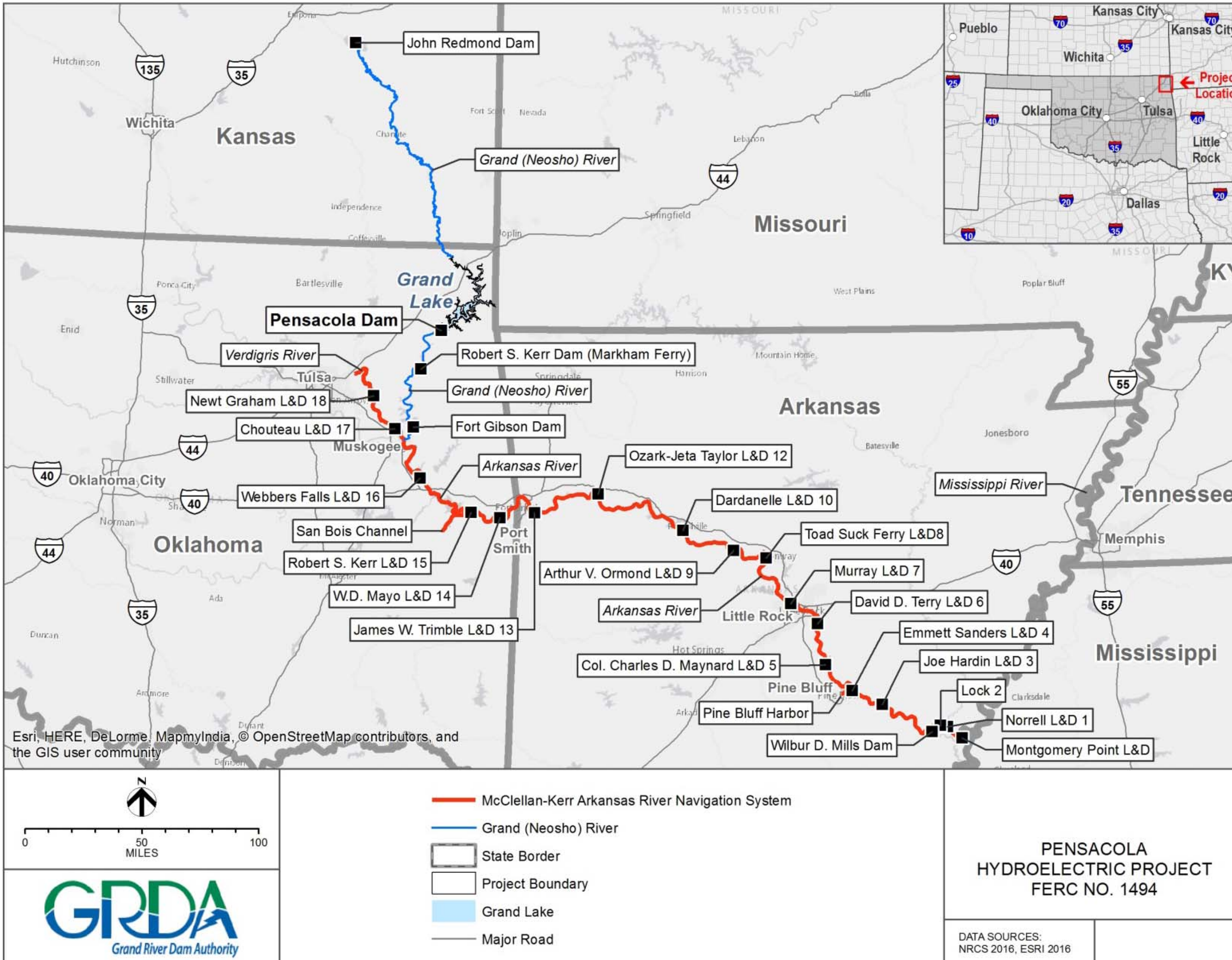
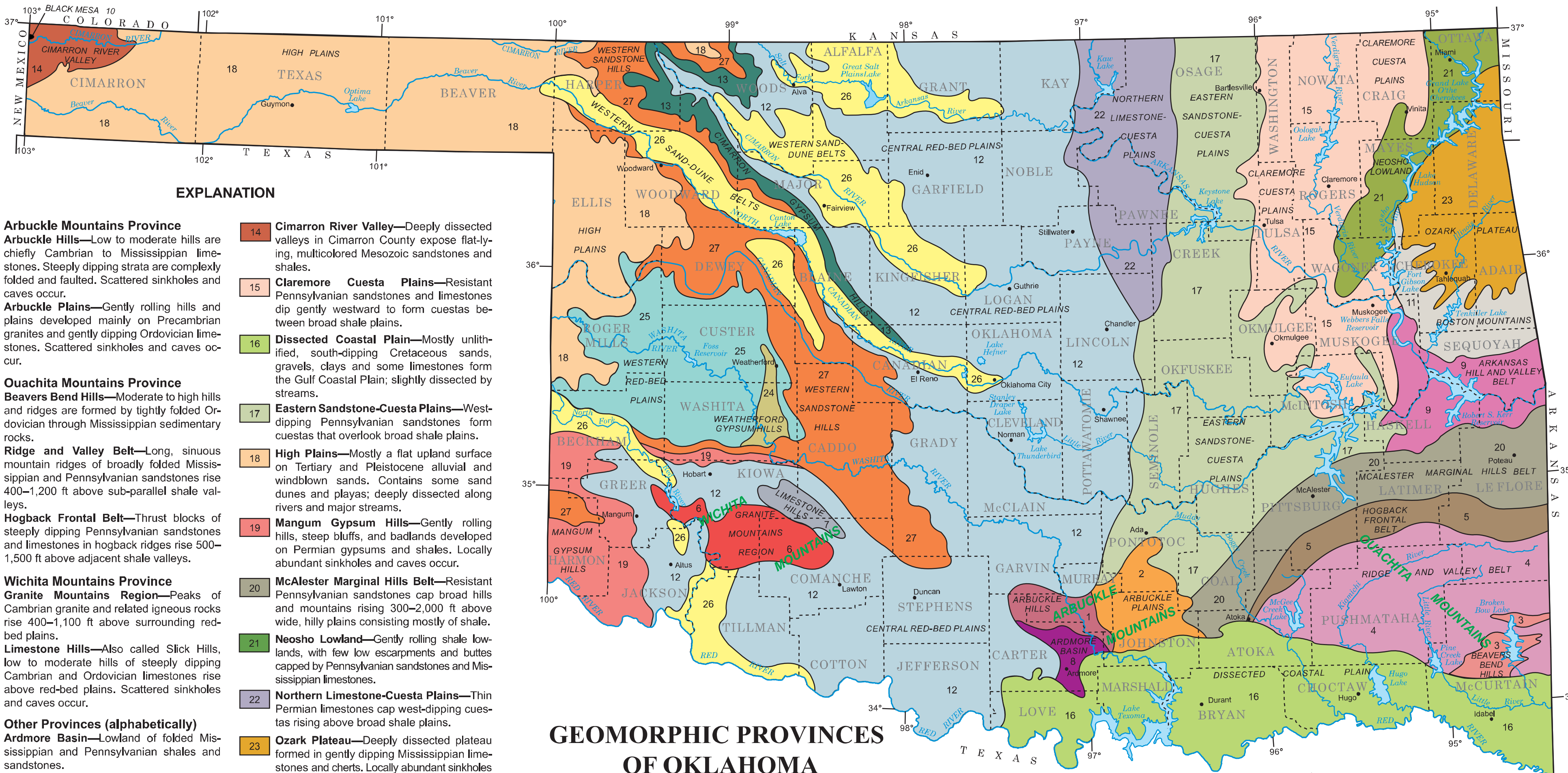
APPENDIX E-1 Dams on the Grand and Arkansas Rivers



PATH: N:\GIS2\PROJECTS\GRAND_RIVER_DAM_AUTHORITY\10027621_GRDA_PENSACOLA_RELICENSING\MAP_DOCS\FINAL\MCCLELLAN_KERR_SYSTEM_STUDY_MAP_PENSACOLA_PROJECT_20180416.MXD - USER: DSOUCIE - DATE: 4/16/2018

APPENDIX E-2 Geomorphic Provinces of Oklahoma



EXPLANATION

Arbuckle Mountains Province

1 — **Arbuckle Hills**—Low to moderate hills are chiefly Cambrian to Mississippian limestones. Steeply dipping strata are complexly folded and faulted. Scattered sinkholes and caves occur.

2 — **Arbuckle Plains**—Gently rolling hills and plains developed mainly on Precambrian granites and gently dipping Ordovician limestones. Scattered sinkholes and caves occur.

Ouachita Mountains Province

3 — **Beavers Bend Hills**—Moderate to high hills and ridges are formed by tightly folded Ordovician through Mississippian sedimentary rocks.

4 — **Ridge and Valley Belt**—Long, sinuous mountain ridges of broadly folded Mississippian and Pennsylvanian sandstones rise 400–1,200 ft above sub-parallel shale valleys.

5 — **Hogback Frontal Belt**—Thrust blocks of steeply dipping Pennsylvanian sandstones and limestones in hogback ridges rise 500–1,500 ft above adjacent shale valleys.

Wichita Mountains Province

6 — **Granite Mountains Region**—Peaks of Cambrian granite and related igneous rocks rise 400–1,100 ft above surrounding red-bed plains.

7 — **Limestone Hills**—Also called Slick Hills, low to moderate hills of steeply dipping Cambrian and Ordovician limestones rise above red-bed plains. Scattered sinkholes and caves occur.

Other Provinces (alphabetically)

8 — **Ardmore Basin**—Lowland of folded Mississippian and Pennsylvanian shales and sandstones.

9 — **Arkansas Hill and Valley Belt**—Broad, gently rolling plains and valleys with scattered hills, 100–300 ft high, are capped by Pennsylvanian sandstones.

10 — **Black Mesa**—Flat-topped erosional remnant of Tertiary basaltic lava flow that was extruded from a volcano in Colorado; the highest point in Oklahoma (elevation, 4,973 ft).

11 — **Boston Mountains**—Deeply dissected plateau is capped by gently dipping Pennsylvanian sandstones.

12 — **Central Red-Bed Plains**—Permian red shales and sandstones form gently rolling hills and broad, flat plains.

13 — **Cimarron Gypsum Hills**—Escarpments and badlands developed on Permian gypsums and shales. Locally abundant sinkholes and caves occur.

14 — **Cimarron River Valley**—Deeply dissected valleys in Cimarron County expose flat-lying, multicolored Mesozoic sandstones and shales.

15 — **Claremore Cuesta Plains**—Resistant Pennsylvanian sandstones and limestones dip gently westward to form cuestas between broad shale plains.

16 — **Dissected Coastal Plain**—Mostly unlithified, south-dipping Cretaceous sands, gravels, clays and some limestones form the Gulf Coastal Plain; slightly dissected by streams.

17 — **Eastern Sandstone-Cuesta Plains**—West-dipping Pennsylvanian sandstones form cuestas that overlook broad shale plains.

18 — **High Plains**—Mostly a flat upland surface on Tertiary and Pleistocene alluvial and windblown sands. Contains some sand dunes and playas; deeply dissected along rivers and major streams.

19 — **Mangum Gypsum Hills**—Gently rolling hills, steep bluffs, and badlands developed on Permian gypsums and shales. Locally abundant sinkholes and caves occur.

20 — **McAlester Marginal Hills Belt**—Resistant Pennsylvanian sandstones cap broad hills and mountains rising 300–2,000 ft above wide, hilly plains consisting mostly of shale.

21 — **Neosho Lowland**—Gently rolling shale lowlands, with few low escarpments and buttes capped by Pennsylvanian sandstones and Mississippian limestones.

22 — **Northern Limestone-Cuesta Plains**—Thin Permian limestones cap west-dipping cuestas rising above broad shale plains.

23 — **Ozark Plateau**—Deeply dissected plateau formed in gently dipping Mississippian limestones and cherts. Locally abundant sinkholes and caves occur.

24 — **Weatherford Gypsum Hills**—Gently rolling hills occur in massive Permian gypsum beds, 100 ft thick. Locally abundant sinkholes and caves occur.

25 — **Western Red-Bed Plains**—Gently rolling hills of nearly flat-lying Permian red sandstones and shales.

26 — **Western Sand-Dune Belts**—Hummocky fields of grass-covered, stabilized sand dunes and some active dunes, occur mainly on north sides of major rivers. Sand is from Quaternary alluvium and terrace deposits.

27 — **Western Sandstone Hills**—Slightly lithified, nearly flat-lying Permian red sandstones form gently rolling hills cut by steep-walled canyons.

GEOMORPHIC PROVINCES OF OKLAHOMA

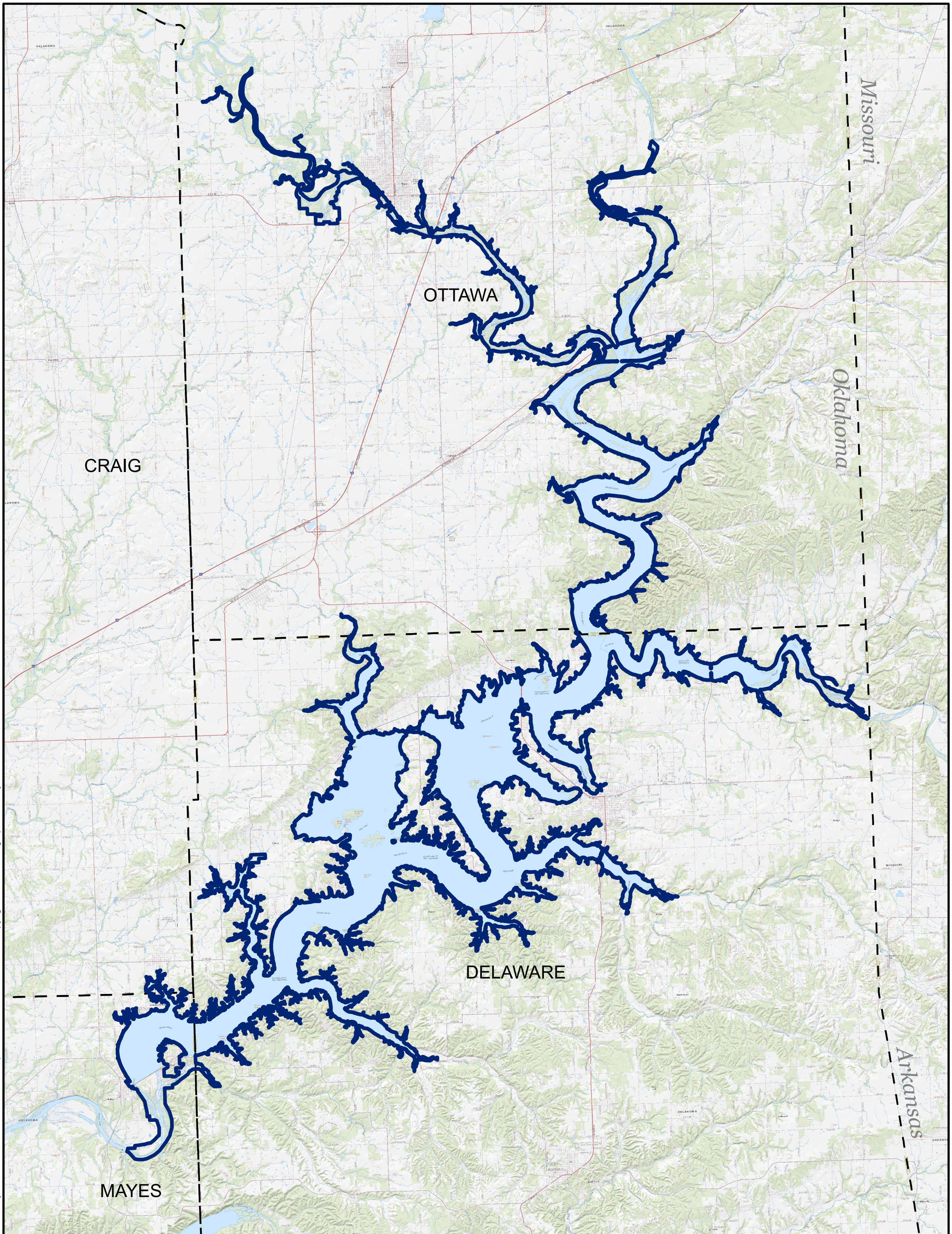
Neville M. Curtis, Jr., William E. Ham, and Kenneth S. Johnson, Oklahoma Geological Survey

A geomorphic province is part of the Earth's surface where a suite of rocks with similar geologic character and structure underwent a similar geologic history, and where the present-day character and landforms differ significantly from adjacent provinces. The term used here is the same as "physiographic province."

Most outcrops in Oklahoma consist of horizontal or gently dipping sandstones, sands, and shales of Pennsylvanian, Permian, Cretaceous, and Tertiary ages (see Geologic Map of Oklahoma on page 6). Some sandstones (mainly in eastern Oklahoma) are well indurated (cemented), but in most other parts of Oklahoma they are not so well indurated and erode easily; therefore, much of Oklahoma is gently rolling hills and broad, flat plains. Elsewhere, erosion-resistant layers of sandstone, limestone, or gypsum form protective caps on buttes, cuestas, escarpments, and high hills.

Among the more impressive geomorphic provinces are several mountain belts and uplifts in southern and northeastern Oklahoma. In the southern third of Oklahoma, well-indurated rocks were folded, faulted, and uplifted forming the Wichita, Arbuckle, and Ouachita Mountains. The mountains and high hills, the resistant rock units, and the complex geology of these three provinces contrast sharply with Oklahoma's typical rolling hills and broad plains. In hilly, wooded areas of the Ozark Plateau and Boston Mountains in northeastern Oklahoma, streams and rivers created sharp relief locally by cutting down into resistant limestones and sandstones.

APPENDIX E-3 Topographic Map of Project Vicinity



Anticipated Project Boundary

Oklahoma County Boundary

0 1 2 4 6 Miles

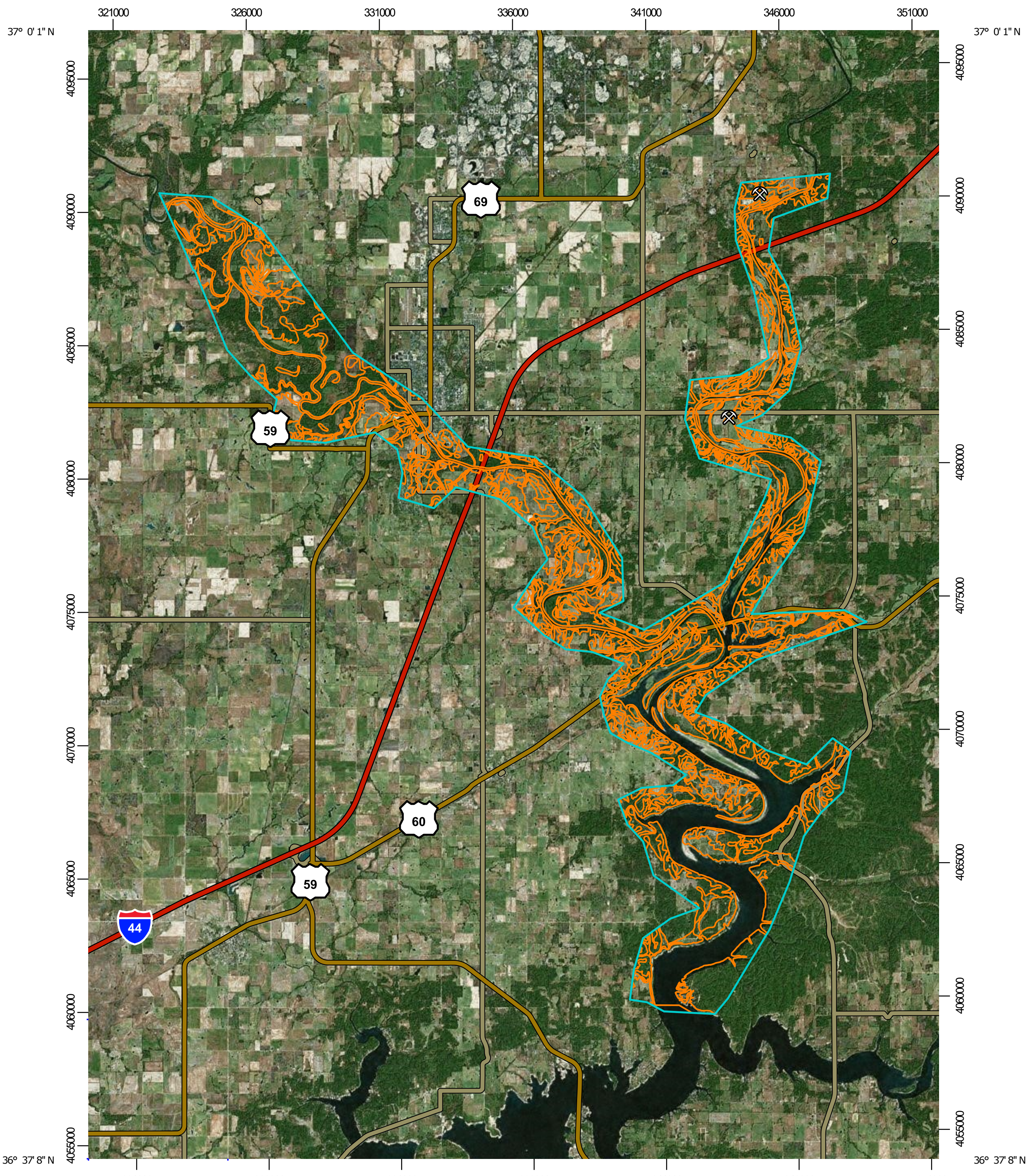
N

Pensacola Hydroelectric Project
Topographic Map

FERC No. 1494

APPENDIX E-4 Pensacola Project Soils Report

Soil Map—Delaware County, Oklahoma, and Ottawa County, Oklahoma
(Pensacola Project Soils-North Part)



Map Scale: 1:206,000 if printed on A portrait (8.5" x 11") sheet.

Meters: 0, 3000, 6000, 12000, 18000

Feet: 0, 10000, 20000, 40000, 60000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 15N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Delaware County, Oklahoma
Survey Area Data: Version 19, Sep 6, 2022

Soil Survey Area: Ottawa County, Oklahoma
Survey Area Data: Version 17, Sep 6, 2022

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jan 1, 1999—Dec 31, 2003

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
CkD	Clarksville very gravelly silt loam, 1 to 8 percent slopes	0.0	0.0%
ClF	Clarksville very gravelly silt loam, 20 to 50 percent slopes, stony	0.7	0.0%
W	Water	62.7	0.1%
Subtotals for Soil Survey Area		**63.4**	**0.1%**
Totals for Area of Interest		**45,359.5**	**100.0%**

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Ad	Osage-Verdigris complex, 0 to 1 percent slopes, frequently flooded	1,245.0	2.7%
BaB	Bates loam, 1 to 3 percent slopes	197.0	0.4%
BaC	Bates loam, 3 to 5 percent slopes	485.8	1.1%
BaC2	Bates loam, 3 to 5 percent slopes, eroded	45.5	0.1%
Bb	Coweta-Bates complex, 1 to 5 percent slopes	67.0	0.1%
BcB	Macedonia silt loam, 1 to 3 percent slopes	161.4	0.4%
BcC	Macedonia silt loam, 3 to 5 percent slopes	47.0	0.1%
BdB	Clarksville gravelly silt loam, 0 to 3 percent slopes	502.8	1.1%
BnD	Clarksville very gravelly silt loam, 1 to 8 percent slopes	3,896.3	8.6%
BoE	Clarksville stony silt loam, 12 to 50 percent slopes	7,050.6	15.5%
Bp	Pits, borrow	61.1	0.1%
Br	Eram-Verdigris complex, 0 to 20 percent slopes	121.8	0.3%
ChA	Choteau silt loam, 0 to 1 percent slopes	487.8	1.1%
ChB	Choteau silt loam, 1 to 3 percent slopes	1,537.0	3.4%
Co	Collinsville stony loam, 3 to 20 percent slopes	122.0	0.3%
CrB	Craig silt loam, 1 to 3 percent slopes	124.9	0.3%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
CrC	Craig silt loam, 3 to 5 percent slopes	137.7	0.3%
DnB	Dennis silt loam, 1 to 3 percent slopes	1,899.2	4.2%
DnC	Dennis silt loam, 3 to 5 percent slopes	171.3	0.4%
DnC2	Dennis silt loam, 3 to 5 percent slopes, eroded	297.3	0.7%
DUM	Dumps	4.8	0.0%
Ed	Eldorado gravelly silt loam, 1 to 8 percent slopes	605.4	1.3%
EhD	Waben gravelly silt loam, 3 to 8 percent slopes	1,271.7	2.8%
EtA	Britwater silt loam, 0 to 3 percent slopes	2,732.5	6.0%
Hg	Razort gravelly silt loam, 0 to 1 percent slopes, frequently flooded	153.8	0.3%
Hu	Healing silt loam, 0 to 1 percent slopes, occasionally flooded	1,204.1	2.7%
Ka	Wynona silty clay loam, 0 to 1 percent slopes, frequently flooded	5.4	0.0%
La	Captina silt loam, 0 to 1 percent slopes	68.7	0.2%
Ln	Lightning silt loam, 0 to 1 percent slopes, occasionally flooded	429.2	0.9%
M-W	Miscellaneous water	17.8	0.0%
Mp	Dumps, mine	1.3	0.0%
NaB	Newtonia silt loam, 1 to 3 percent slopes	516.5	1.1%
NaC	Newtonia silt loam, 3 to 5 percent slopes	2.0	0.0%
Ns	Newtonia-Shidler complex, 1 to 8 percent slopes	94.7	0.2%
Os	Osage silty clay, 0 to 1 percent slopes, occasionally flooded	5,442.6	12.0%
PaA	Parsons silt loam, 0 to 1 percent slopes	1,385.2	3.1%
PaB	Parsons silt loam, 1 to 3 percent slopes	423.8	0.9%
PaB2	Parsons silt loam, 1 to 3 percent slopes, eroded	22.5	0.0%
Prqg	Pits, gravel and quarry	54.9	0.1%
RvC	Riverton gravelly loam, 3 to 5 percent slopes	104.9	0.2%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
SuB	Apperson silty clay loam, 1 to 3 percent slopes	43.6	0.1%
TaA	Taloka silt loam, 0 to 1 percent slopes	889.8	2.0%
Vd	Verdigris silt loam, 0 to 1 percent slopes, occasionally flooded	2,402.4	5.3%
W	Water	8,465.4	18.7%
WoA	Mayes silty clay loam, 0 to 1 percent slopes	221.9	0.5%
WoB	Mayes silty clay loam, 1 to 3 percent slopes	71.1	0.2%
Subtotals for Soil Survey Area		**45,294.8**	**99.9%**
Totals for Area of Interest		**45,359.5**	**100.0%**

RUSLE2 Related Attributes

This report summarizes those soil attributes used by the Revised Universal Soil Loss Equation Version 2 (RUSLE2) for the map units in the selected area. The report includes the map unit symbol, the component name, and the percent of the component in the map unit. Soil property data for each map unit component include the hydrologic soil group, erosion factor Kf for the surface horizon, erosion factor T, and the representative percentage of sand, silt, and clay in the mineral surface horizon. Missing surface data may indicate the presence of an organic layer.

Report—RUSLE2 Related Attributes

Soil properties and interpretations for erosion runoff calculations. The surface mineral horizon properties are displayed or the first mineral horizon below an organic surface horizon. Organic horizons are not displayed.

RUSLE2 Related Attributes–Delaware County, Oklahoma								
Map symbol and soil name	Pct. of map unit	Slope length (ft)	Hydrologic group	Kf	T factor	Representative value		
						% Sand	% Silt	% Clay
CkD—Clarksville very gravelly silt loam, 1 to 8 percent slopes								
Clarksville	85	174	A	.37	5	29.3	53.7	17.0
ClF—Clarksville very gravelly silt loam, 20 to 50 percent slopes, stony								
Clarksville	80	108	B	.32	3	21.2	67.5	11.3

RUSLE2 Related Attributes–Ottawa County, Oklahoma								
Map symbol and soil name	Pct. of map unit	Slope length (ft)	Hydrologic group	Kf	T factor	Representative value		
						% Sand	% Silt	% Clay
Ad—Osage-Verdigris complex, 0 to 1 percent slopes, frequently flooded								
Osage	60	325	D	.20	5	26.1	28.9	45.0
Verdigris	35	325	B	.37	5	11.3	67.7	21.0
BaB—Bates loam, 1 to 3 percent slopes								
Bates	85	298	C	.28	3	42.0	37.0	21.0
BaC—Bates loam, 3 to 5 percent slopes								
Bates	90	223	C	.28	3	42.0	37.0	21.0
BaC2—Bates loam, 3 to 5 percent slopes, eroded								
Bates	85	223	C	.28	3	42.0	37.0	21.0

RUSLE2 Related Attributes–Ottawa County, Oklahoma								
Map symbol and soil name	Pct. of map unit	Slope length (ft)	Hydrologic group	Kf	T factor	Representative value		
						% Sand	% Silt	% Clay
Bb—Coweta-Bates complex, 1 to 5 percent slopes								
Coweta	63	223	D	.28	2	42.0	38.0	20.0
Bates	35	223	C	.28	3	42.0	37.0	21.0
BcB—Macedonia silt loam, 1 to 3 percent slopes								
Macedonia	90	276	B	.43	4	26.5	53.5	20.0
BcC—Macedonia silt loam, 3 to 5 percent slopes								
Macedonia	90	223	B	.43	4	26.5	53.5	20.0
BdB—Clarksville gravelly silt loam, 0 to 3 percent slopes								
Clarksville	90	276	A	.37	2	26.5	53.5	20.0
BnD—Clarksville very gravelly silt loam, 1 to 8 percent slopes								
Clarksville	90	174	A	.37	5	29.3	53.7	17.0
BoE—Clarksville stony silt loam, 12 to 50 percent slopes								
Clarksville	100	108	A	.32	2	26.3	52.7	21.0
Br—Eram-Verdigris complex, 0 to 20 percent slopes								
Eram	55	108	D	.43	3	26.0	52.0	22.0
Verdigris	35	325	B	.37	5	15.0	62.0	23.0
ChA—Choteau silt loam, 0 to 1 percent slopes								
Choteau	95	325	C	.32	5	25.0	53.0	22.0
ChB—Choteau silt loam, 1 to 3 percent slopes								
Choteau	90	276	C	.32	5	25.0	53.0	22.0
Co—Collinsville stony loam, 3 to 20 percent slopes								
Collinsville	90	108	D	.43	1	45.0	42.0	13.0
CrB—Craig silt loam, 1 to 3 percent slopes								
Craig	85	276	C	.43	4	25.0	55.0	20.0
CrC—Craig silt loam, 3 to 5 percent slopes								
Craig	85	223	C	.43	4	25.0	55.0	20.0

RUSLE2 Related Attributes–Ottawa County, Oklahoma								
Map symbol and soil name	Pct. of map unit	Slope length (ft)	Hydrologic group	Kf	T factor	Representative value		
						% Sand	% Silt	% Clay
DnB—Dennis silt loam, 1 to 3 percent slopes								
Dennis	82	298	C/D	.43	5	23.0	58.0	19.0
DnC—Dennis silt loam, 3 to 5 percent slopes								
Dennis	85	223	C/D	.43	5	23.0	58.0	19.0
DnC2—Dennis silt loam, 3 to 5 percent slopes, eroded								
Dennis	82	223	C/D	.43	5	23.0	58.0	19.0
Ed—Eldorado gravelly silt loam, 1 to 8 percent slopes								
Eldorado	85	174	B	.37	3	26.0	52.0	22.0
EhD—Waben gravelly silt loam, 3 to 8 percent slopes								
Waben	90	174	A	.37	5	30.9	56.6	12.5
EtA—Britwater silt loam, 0 to 3 percent slopes								
Britwater	95	298	B	.43	5	27.0	53.0	20.0
Hg—Razort gravelly silt loam, 0 to 1 percent slopes, frequently flooded								
Razort	90	325	B	.37	5	29.1	53.4	17.5
Hu—Healing silt loam, 0 to 1 percent slopes, occasionally flooded								
Healing	90	325	B	.37	4	13.6	68.9	17.5
Ka—Wynona silty clay loam, 0 to 1 percent slopes, frequently flooded								
Wynona	90	325	C	.37	5	6.9	62.1	31.0
La—Captina silt loam, 0 to 1 percent slopes								
Captina	95	98	C/D	.43	3	14.4	76.1	9.5
Ln—Lightning silt loam, 0 to 1 percent slopes, occasionally flooded								
Lightning	90	325	D	.43	5	12.0	68.0	20.0
NaB—Newtonia silt loam, 1 to 3 percent slopes								
Newtonia	90	276	B	.43	5	13.7	69.3	17.0
NaC—Newtonia silt loam, 3 to 5 percent slopes								
Newtonia	84	223	B	.43	5	13.7	69.3	17.0

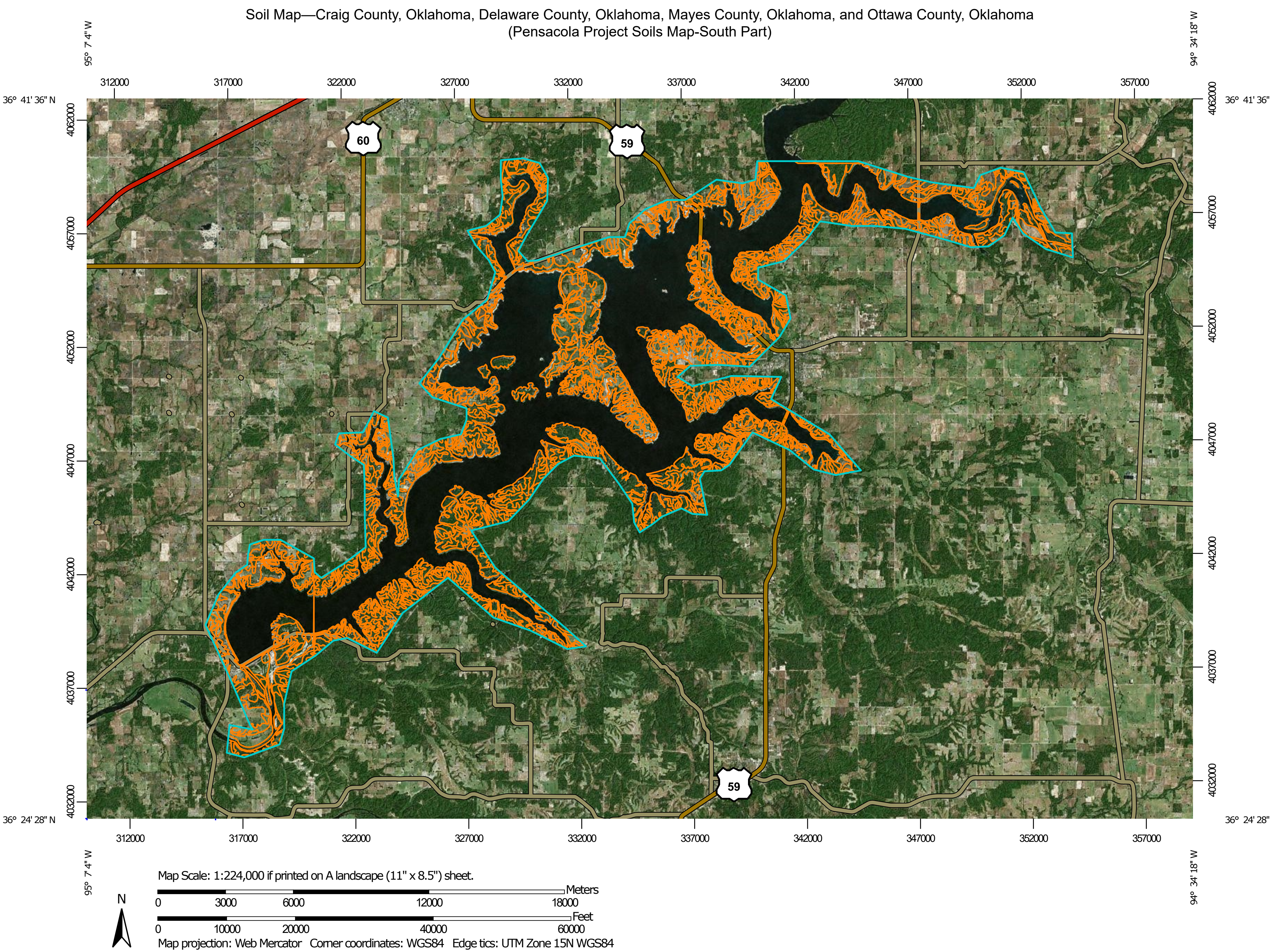
RUSLE2 Related Attributes–Ottawa County, Oklahoma								
Map symbol and soil name	Pct. of map unit	Slope length (ft)	Hydrologic group	Kf	T factor	Representative value		
						% Sand	% Silt	% Clay
Ns—Newtonia-Shidler complex, 1 to 8 percent slopes								
Newtonia	46	174	B	.43	5	13.7	69.3	17.0
Shidler	45	174	D	.43	1	26.0	52.0	22.0
Os—Osage silty clay, 0 to 1 percent slopes, occasionally flooded								
Osage	86	98	D	.20	5	2.0	45.0	53.0
PaA—Parsons silt loam, 0 to 1 percent slopes								
Parsons	85	98	D	.43	3	13.0	67.0	20.0
PaB—Parsons silt loam, 1 to 3 percent slopes								
Parsons	90	298	D	.49	3	13.0	67.0	20.0
PaB2—Parsons silt loam, 1 to 3 percent slopes, eroded								
Parsons	90	298	D	.49	3	13.0	67.0	20.0
RvC—Riverton gravelly loam, 3 to 5 percent slopes								
Riverton	90	223	B	.32	4	40.0	37.0	23.0
SuB—Apperson silty clay loam, 1 to 3 percent slopes								
Apperson	90	298	D	.32	3	11.0	58.0	31.0
TaA—Taloka silt loam, 0 to 1 percent slopes								
Taloka	92	325	D	.43	4	13.0	67.0	20.0
Vd—Verdigris silt loam, 0 to 1 percent slopes, occasionally flooded								
Verdigris	82	197	B	.37	5	15.0	62.0	23.0
WoA—Mayes silty clay loam, 0 to 1 percent slopes								
Mayes	90	325	D	.37	5	20.0	49.0	31.0
WoB—Mayes silty clay loam, 1 to 3 percent slopes								
Mayes	90	276	D	.37	5	20.0	49.0	31.0

Data Source Information

Soil Survey Area: Delaware County, Oklahoma
Survey Area Data: Version 19, Sep 6, 2022

Soil Survey Area: Ottawa County, Oklahoma
Survey Area Data: Version 17, Sep 6, 2022

Soil Map—Craig County, Oklahoma, Delaware County, Oklahoma, Mayes County, Oklahoma, and Ottawa County, Oklahoma
(Pensacola Project Soils Map-South Part)



MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at scales ranging from 1:20,000 to 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Craig County, Oklahoma
Survey Area Data: Version 19, Sep 2, 2022

Soil Survey Area: Delaware County, Oklahoma
Survey Area Data: Version 19, Sep 6, 2022

Soil Survey Area: Mayes County, Oklahoma
Survey Area Data: Version 16, Sep 6, 2022

Soil Survey Area: Ottawa County, Oklahoma
Survey Area Data: Version 17, Sep 6, 2022

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jan 1, 1999—Dec 31, 2003

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
CmE	Clarksville stony silt loam, 5 to 12 percent slopes	84.8	0.1%
CnD	Clarksville very gravelly silt loam, 1 to 8 percent slopes	110.9	0.2%
CrB	Craig silt loam, 1 to 3 percent slopes	90.6	0.1%
ElD	Eldorado stony silt loam, 1 to 8 percent slopes	11.8	0.0%
EoC	Eldorado silt loam, 3 to 5 percent slopes	103.3	0.1%
NcB	Nixa gravelly silt loam, 0 to 3 percent slopes	0.5	0.0%
W	Water	77.0	0.1%
Subtotals for Soil Survey Area		**479.0**	**0.7%**
Totals for Area of Interest		**71,392.4**	**100.0%**

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
BaB	Bates loam, 1 to 3 percent slopes	250.2	0.4%
BcB	Macedonia silt loam, 1 to 3 percent slopes	688.6	1.0%
BhB	Doniphan gravelly silt loam, 1 to 3 percent slopes	389.1	0.5%
BlC	Doniphan-Tonti complex, 3 to 5 percent slopes	36.1	0.1%
CaB	Captina silt loam, 1 to 3 percent slopes	27.5	0.0%
ChA	Choteau silt loam, 0 to 1 percent slopes	133.2	0.2%
ChB	Choteau silt loam, 1 to 3 percent slopes	197.0	0.3%
CkD	Clarksville very gravelly silt loam, 1 to 8 percent slopes	4,047.4	5.7%
ClE	Clarksville very gravelly silt loam, 5 to 20 percent slopes, stony	4,367.5	6.1%
ClF	Clarksville very gravelly silt loam, 20 to 50 percent slopes, stony	7,477.3	10.5%
CoC	Coweta fine sandy loam, 3 to 5 percent slopes, very rocky	199.8	0.3%
DAM	Large dam	16.3	0.0%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
DnB	Dennis silt loam, 1 to 3 percent slopes	681.4	1.0%
EdB	Eldorado silt loam, 1 to 3 percent slopes	2,588.5	3.6%
EdC	Eldorado silt loam, 3 to 5 percent slopes	1,095.2	1.5%
ElD	Eldorado stony silt loam, 3 to 12 percent slopes	3,474.9	4.9%
Es	Elsah very gravelly loam, 0 to 3 percent slopes, frequently flooded	332.0	0.5%
LoB	Tonti gravelly silt loam, 1 to 3 percent slopes	126.4	0.2%
NaA	Newtonia silt loam, 0 to 1 percent slopes	163.2	0.2%
NaB	Newtonia silt loam, 1 to 3 percent slopes	279.1	0.4%
OeA	Okemah silt loam, 0 to 1 percent slopes	85.2	0.1%
OkA	Okemah silty clay loam, 0 to 1 percent slopes	17.9	0.0%
OkB	Okemah silty clay loam, 1 to 3 percent slopes	104.8	0.1%
PaA	Parsons silt loam, 0 to 1 percent slopes	208.1	0.3%
PIT	Pits	15.1	0.0%
SaB	Britwater silt loam, 1 to 3 percent slopes	955.8	1.3%
SgB	Britwater gravelly silt loam, 1 to 3 percent slopes	283.5	0.4%
SgD	Britwater gravelly silt loam, 3 to 8 percent slopes	1,357.8	1.9%
Sm	Healing silt loam, 0 to 1 percent slopes, occasionally flooded	362.9	0.5%
Sn	Razort gravelly loam, 0 to 3 percent slopes, occasionally flooded	544.6	0.8%
SrA	Stigler silt loam, 0 to 1 percent slopes	5.5	0.0%
TkA	Taloka silt loam, 0 to 1 percent slopes	344.4	0.5%
TrD	Shidler-Rock outcrop complex, 2 to 8 percent slopes	280.1	0.4%
Vd	Verdigris silt loam, 0 to 1 percent slopes, occasionally flooded	227.9	0.3%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Vr	Verdigris silt loam, 0 to 1 percent slopes, frequently flooded	106.0	0.1%
W	Water	32,199.0	45.1%
WoA	Mayes silt loam, 0 to 1 percent slopes	301.0	0.4%
Subtotals for Soil Survey Area		**63,970.4**	**89.6%**
Totals for Area of Interest		**71,392.4**	**100.0%**

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Bp	Pits, borrow	0.7	0.0%
Ca	Razort gravelly loam, 0 to 1 percent slopes, occasionally flooded	81.6	0.1%
ChA	Choteau silt loam, 0 to 1 percent slopes	11.5	0.0%
CkD	Clarksville gravelly silt loam, 1 to 8 percent slopes	731.7	1.0%
ClE	Clarksville very gravelly silt loam, 5 to 20 percent slopes, stony	294.4	0.4%
ClF	Clarksville very gravelly silt loam, 20 to 50 percent slopes, stony	620.2	0.9%
CrB	Craig silt loam, 1 to 3 percent slopes	179.5	0.3%
CrC	Craig silt loam, 3 to 5 percent slopes	41.6	0.1%
DAM	Large dam	15.4	0.0%
ElD	Eldorado gravelly silt loam, 1 to 8 percent slopes	67.3	0.1%
Es	Elsah gravelly loam, 0 to 1 percent slopes, frequently flooded	6.8	0.0%
NxB	Nixa gravelly silt loam, 0 to 3 percent slopes	226.5	0.3%
PaA	Parsons silt loam, 0 to 1 percent slopes	165.0	0.2%
Qu	Quarles silt loam, 0 to 1 percent slopes, occasionally flooded	20.9	0.0%
ReB	Riverton loam, 1 to 3 percent slopes	318.8	0.4%
RvC	Riverton gravelly loam, 1 to 5 percent slopes	99.7	0.1%
SaB	Britwater silt loam, 1 to 3 percent slopes	366.5	0.5%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
TaA	Taloka silt loam, 0 to 1 percent slopes	41.3	0.1%
Ve	Verdigris silty clay loam, 0 to 1 percent slopes, occasionally flooded	593.6	0.8%
Vs	Verdigris silty clay loam, 0 to 1 percent slopes, frequently flooded	298.8	0.4%
W	Water	2,693.1	3.8%
Subtotals for Soil Survey Area		**6,874.8**	**9.6%**
Totals for Area of Interest		**71,392.4**	**100.0%**

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
BoE	Clarksville stony silt loam, 12 to 50 percent slopes	45.8	0.1%
EtA	Britwater silt loam, 0 to 3 percent slopes	0.1	0.0%
W	Water	21.6	0.0%
Subtotals for Soil Survey Area		**67.5**	**0.1%**
Totals for Area of Interest		**71,392.4**	**100.0%**

RUSLE2 Related Attributes

This report summarizes those soil attributes used by the Revised Universal Soil Loss Equation Version 2 (RUSLE2) for the map units in the selected area. The report includes the map unit symbol, the component name, and the percent of the component in the map unit. Soil property data for each map unit component include the hydrologic soil group, erosion factor Kf for the surface horizon, erosion factor T, and the representative percentage of sand, silt, and clay in the mineral surface horizon. Missing surface data may indicate the presence of an organic layer.

Report—RUSLE2 Related Attributes

Soil properties and interpretations for erosion runoff calculations. The surface mineral horizon properties are displayed or the first mineral horizon below an organic surface horizon. Organic horizons are not displayed.

RUSLE2 Related Attributes–Craig County, Oklahoma								
Map symbol and soil name	Pct. of map unit	Slope length (ft)	Hydrologic group	Kf	T factor	Representative value		
						% Sand	% Silt	% Clay
CmE—Clarksville stony silt loam, 5 to 12 percent slopes								
Clarksville	85	108	A	.32	5	26.3	52.7	21.0
CnD—Clarksville very gravelly silt loam, 1 to 8 percent slopes								
Clarksville	90	174	A	.37	5	29.3	53.7	17.0
CrB—Craig silt loam, 1 to 3 percent slopes								
Craig	85	276	C	.43	4	25.0	55.0	20.0
EID—Eldorado stony silt loam, 1 to 8 percent slopes								
Eldorado	90	174	B	.37	5	26.0	52.0	22.0
EoC—Eldorado silt loam, 3 to 5 percent slopes								
Eldorado	90	223	B	.37	3	26.0	52.0	22.0
NcB—Nixa gravelly silt loam, 0 to 3 percent slopes								
Nixa	95	298	D	.49	4	14.6	74.4	11.0

RUSLE2 Related Attributes–Delaware County, Oklahoma								
Map symbol and soil name	Pct. of map unit	Slope length (ft)	Hydrologic group	Kf	T factor	Representative value		
						% Sand	% Silt	% Clay
BaB—Bates loam, 1 to 3 percent slopes								
Bates	85	298	C	.28	3	42.0	37.0	21.0
BcB—Macedonia silt loam, 1 to 3 percent slopes								
Macedonia	92	276	B	.43	5	26.5	53.5	20.0
BhB—Doniphan gravelly silt loam, 1 to 3 percent slopes								
Doniphan	90	276	B	.43	5	24.8	52.7	22.5
BlC—Doniphan-Tonti complex, 3 to 5 percent slopes								
Doniphan	58	223	B	.43	5	24.8	52.7	22.5
Tonti	42	223	D	.43	2	29.1	53.4	17.5
CaB—Captina silt loam, 1 to 3 percent slopes								
Captina	90	298	C/D	.43	3	14.4	76.1	9.5
ChA—Choteau silt loam, 0 to 1 percent slopes								
Choteau	95	325	C	.32	5	25.0	53.0	22.0
ChB—Choteau silt loam, 1 to 3 percent slopes								
Choteau	90	276	C	.32	5	25.0	53.0	22.0
CkD—Clarksville very gravelly silt loam, 1 to 8 percent slopes								
Clarksville	85	174	A	.37	5	29.3	53.7	17.0
ClE—Clarksville very gravelly silt loam, 5 to 20 percent slopes, stony								
Clarksville	80	108	B	.32	3	21.2	67.5	11.3
ClF—Clarksville very gravelly silt loam, 20 to 50 percent slopes, stony								
Clarksville	80	108	B	.32	3	21.2	67.5	11.3
CoC—Coweta fine sandy loam, 3 to 5 percent slopes, very rocky								
Coweta	82	223	D	.28	2	60.0	30.0	10.0
DnB—Dennis silt loam, 1 to 3 percent slopes								
Dennis	87	276	C/D	.43	5	27.1	54.4	18.5

RUSLE2 Related Attributes–Delaware County, Oklahoma								
Map symbol and soil name	Pct. of map unit	Slope length (ft)	Hydrologic group	Kf	T factor	Representative value		
						% Sand	% Silt	% Clay
EdB—Eldorado silt loam, 1 to 3 percent slopes								
Eldorado	97	276	B	.37	3	26.0	52.0	22.0
EdC—Eldorado silt loam, 3 to 5 percent slopes								
Eldorado	100	223	C	.37	3	21.0	61.0	18.0
ElD—Eldorado stony silt loam, 3 to 12 percent slopes								
Eldorado	100	108	C	.37	3	21.0	61.0	18.0
Es—Elsah very gravelly loam, 0 to 3 percent slopes, frequently flooded								
Elsah	90	197	B	.32	5	45.4	41.6	13.0
LoB—Tonti gravelly silt loam, 1 to 3 percent slopes								
Tonti	85	276	D	.43	3	20.0	68.0	12.0
NaA—Newtonia silt loam, 0 to 1 percent slopes								
Newtonia	95	325	D	.43	5	13.7	69.3	17.0
NaB—Newtonia silt loam, 1 to 3 percent slopes								
Newtonia	92	298	B	.43	5	13.7	69.3	17.0
OeA—Okemah silt loam, 0 to 1 percent slopes								
Okemah	85	325	C/D	.49	5	20.0	56.0	24.0
OkA—Okemah silty clay loam, 0 to 1 percent slopes								
Okemah	93	325	C/D	.37	5	20.0	49.0	31.0
OkB—Okemah silty clay loam, 1 to 3 percent slopes								
Okemah	93	325	C/D	.37	5	20.0	49.0	31.0
PaA—Parsons silt loam, 0 to 1 percent slopes								
Parsons	95	325	D	.43	3	26.5	53.5	20.0
SaB—Britwater silt loam, 1 to 3 percent slopes								
Britwater	95	298	B	.43	5	27.0	53.0	20.0
SgB—Britwater gravelly silt loam, 1 to 3 percent slopes								
Britwater	95	298	B	.43	5	26.0	54.0	20.0

RUSLE2 Related Attributes–Delaware County, Oklahoma								
Map symbol and soil name	Pct. of map unit	Slope length (ft)	Hydrologic group	Kf	T factor	Representative value		
						% Sand	% Silt	% Clay
SgD—Britwater gravelly silt loam, 3 to 8 percent slopes								
Britwater	95	157	B	.43	5	26.0	54.0	20.0
Sm—Healing silt loam, 0 to 1 percent slopes, occasionally flooded								
Healing	87	325	B	.37	5	13.6	68.9	17.5
Sn—Razort gravelly loam, 0 to 3 percent slopes, occasionally flooded								
Razort	81	325	B	.32	5	43.0	39.5	17.5
SrA—Stigler silt loam, 0 to 1 percent slopes								
Stigler	94	325	D	.43	3	30.1	54.9	15.0
TkA—Taloka silt loam, 0 to 1 percent slopes								
Taloka	89	325	D	.37	4	26.5	53.5	20.0
TrD—Shidler-Rock outcrop complex, 2 to 8 percent slopes								
Shidler	62	174	D	.37	1	20.0	49.0	31.0
Vd—Verdigris silt loam, 0 to 1 percent slopes, occasionally flooded								
Verdigris	95	325	B	.37	5	11.3	67.7	21.0
Vr—Verdigris silt loam, 0 to 1 percent slopes, frequently flooded								
Verdigris	85	197	B	.37	5	11.3	67.7	21.0
WoA—Mayes silt loam, 0 to 1 percent slopes								
Mayes	92	325	D	.49	3	27.0	54.0	19.0

RUSLE2 Related Attributes–Mayes County, Oklahoma								
Map symbol and soil name	Pct. of map unit	Slope length (ft)	Hydrologic group	Kf	T factor	Representative value		
						% Sand	% Silt	% Clay
Ca—Razort gravelly loam, 0 to 1 percent slopes, occasionally flooded								
Razort	90	325	B	.32	5	43.0	39.5	17.5
ChA—Choteau silt loam, 0 to 1 percent slopes								
Choteau	95	325	C	.32	5	25.0	53.0	22.0

RUSLE2 Related Attributes–Mayes County, Oklahoma								
Map symbol and soil name	Pct. of map unit	Slope length (ft)	Hydrologic group	Kf	T factor	Representative value		
						% Sand	% Silt	% Clay
CkD—Clarksville gravelly silt loam, 1 to 8 percent slopes								
Clarksville	90	174	A	.37	5	26.5	53.5	20.0
ClE—Clarksville very gravelly silt loam, 5 to 20 percent slopes, stony								
Clarksville	80	108	B	.32	3	21.2	67.5	11.3
ClF—Clarksville very gravelly silt loam, 20 to 50 percent slopes, stony								
Clarksville	80	108	B	.32	3	21.2	67.5	11.3
CrB—Craig silt loam, 1 to 3 percent slopes								
Craig	85	276	C	.43	4	25.0	55.0	20.0
CrC—Craig silt loam, 3 to 5 percent slopes								
Craig	85	223	C	.43	4	25.0	55.0	20.0
ElD—Eldorado gravelly silt loam, 1 to 8 percent slopes								
Eldorado	85	174	B	.37	3	26.0	52.0	22.0
Es—Elsah gravelly loam, 0 to 1 percent slopes, frequently flooded								
Elsah	90	325	B	.37	5	44.3	40.7	15.0
NxB—Nixa gravelly silt loam, 0 to 3 percent slopes								
Nixa	95	298	D	.49	4	14.6	74.4	11.0
PaA—Parsons silt loam, 0 to 1 percent slopes								
Parsons	85	98	D	.43	3	13.0	67.0	20.0
Qu—Quarles silt loam, 0 to 1 percent slopes, occasionally flooded								
Quarles	90	325	C/D	.37	5	24.5	52.0	23.5
ReB—Riverton loam, 1 to 3 percent slopes								
Riverton	85	276	B	.32	4	40.0	37.0	23.0
RvC—Riverton gravelly loam, 1 to 5 percent slopes								
Riverton	85	223	B	.32	5	39.8	37.7	22.5
SaB—Britwater silt loam, 1 to 3 percent slopes								
Britwater	95	298	B	.43	5	27.0	53.0	20.0

RUSLE2 Related Attributes–Mayes County, Oklahoma								
Map symbol and soil name	Pct. of map unit	Slope length (ft)	Hydrologic group	Kf	T factor	Representative value		
						% Sand	% Silt	% Clay
TaA—Taloka silt loam, 0 to 1 percent slopes								
Taloka	92	325	D	.43	4	13.0	67.0	20.0
Ve—Verdigris silty clay loam, 0 to 1 percent slopes, occasionally flooded								
Verdigris	90	98	C	.32	5	7.0	62.0	31.0
Vs—Verdigris silty clay loam, 0 to 1 percent slopes, frequently flooded								
Verdigris	95	325	C	.32	5	7.0	62.0	31.0

RUSLE2 Related Attributes–Ottawa County, Oklahoma								
Map symbol and soil name	Pct. of map unit	Slope length (ft)	Hydrologic group	Kf	T factor	Representative value		
						% Sand	% Silt	% Clay
BoE—Clarksville stony silt loam, 12 to 50 percent slopes								
Clarksville	100	108	A	.32	2	26.3	52.7	21.0
EtA—Britwater silt loam, 0 to 3 percent slopes								
Britwater	95	298	B	.43	5	27.0	53.0	20.0

Data Source Information

Soil Survey Area: Craig County, Oklahoma
Survey Area Data: Version 19, Sep 2, 2022

Soil Survey Area: Delaware County, Oklahoma
Survey Area Data: Version 19, Sep 6, 2022

Soil Survey Area: Mayes County, Oklahoma
Survey Area Data: Version 16, Sep 6, 2022

Soil Survey Area: Ottawa County, Oklahoma
Survey Area Data: Version 17, Sep 6, 2022

APPENDIX E-5 Grand Lake Bathymetric Map

U.S. Department of the Interior
U.S. Geological Survey

Prepared in cooperation with the
Grand River Dam Authority

Scientific Investigations Map 3467
Sheet 1 of 2

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Abstract

The U.S. Geological Survey (USGS), in cooperation with the Grand River Dam Authority, completed a high-resolution multibeam bathymetric survey to compute a new area and capacity table for Grand Lake O' the Cherokees in northeastern Oklahoma. Area and capacity tables identify the relation between the elevation of the water surface and the volume of water that can be impounded at each water-surface elevation. The area and capacity of Grand Lake O' the Cherokees were computed from a triangular irregular network surface created in Global Mapper Version 21.0.1. The triangular irregular network surface was created from three datasets: (1) a multibeam mapping system bathymetric survey of Grand Lake O' the Cherokees completed during April–July 2019, (2) a previous bathymetric survey of the Neosho, Spring, and Elk Rivers, and (3) a 2010 USGS lidar-derived digital elevation model. The digital elevation model data were used in areas with land-surface elevations greater than 744 feet above the North American Vertical Datum of 1988 where the multibeam sonar data could not be collected. The 2019 multibeam sonar data were the predominant data used to compute the new area and capacity table for Grand Lake O' the Cherokees.

Introduction[1]

In February 2017, the Grand River Dam Authority (GRDA) filed a Pre-Application Document and Notice of Intent for relicensing the Pensacola Hydroelectric Project with the Federal Energy Regulatory Commission (FERC). The predominant feature of the Pensacola Hydroelectric Project (FERC license number 1494; GRDA, 2017) is Pensacola Dam, which impounds Grand Lake O' the Cherokees (known locally and hereinafter referred to as "Grand Lake") in northeastern Oklahoma. Identification of information gaps and assessment of project effects on stakeholders are central aspects of the FERC relicensing process (FERC, 2012). One of the information gaps is that a complete area and capacity table has not been produced since 1940. Area and capacity tables identify the relations between the elevation of the water surface and the volume of water that can be impounded at each water-surface elevation.

In the 80-year history of Grand Lake, only four area and capacity tables have been developed. The first area and capacity table was developed in 1940 by the U.S. Army Corps of Engineers (USACE) when the Pensacola Dam was built, spanning water-surface elevations from 612.33 to 758.33 feet (ft) (values adjusted to feet above the North American Vertical Datum of 1988) (NAVD 88) (Hunter and others, 2020). An updated area and capacity table was published in 1949, spanning water-surface elevations from 714.33 to 754.43 ft above NAVD 88 (Hunter and Labriola, 2019). In 2009, the Oklahoma Water Resources Board (OWRB) calculated a third area and capacity table, spanning water-surface elevations from 613.46 to 746.46 ft above NAVD 88 (OWRB, 2009). The fourth and most recent area and capacity table (Hunter and Labriola, 2019) was produced in 2019 by combining the bathymetric survey of Grand Lake (OWRB, 2009, 2016) and the 2017 U.S. Geological Survey (USGS) bathymetric survey of the Neosho, Spring, and Elk Rivers (Hunter and others, 2017; Smith and others, 2017). The area and capacity table for the 2019 study spanned water-surface elevations from 612 to 759 ft above NAVD 88. Although the Hunter and Labriola (2019) area and capacity table was published in 2019, it was produced by combining data obtained during 2009 and 2017, with most of the bathymetry data collected in 2009. Because the majority of the data used to compute the area and capacity table in Hunter and Labriola (2019) were more than 10 years old, it was determined that an up-to-date area and capacity table was needed and that the best way to achieve this goal was to complete a new bathymetric survey.

Over time, the capacity of reservoirs to store water decreases as the sediment load carried by the impounded river(s) is deposited on the lakebed and as the water-surface elevation associated with a given surface area of the reservoir changes (OWRB, 2009; Hunter and others, 2017). Because of this natural phenomenon, updated area and capacity tables are periodically needed to identify the volume of water that a reservoir can hold at any given elevation. Stakeholders need an updated version of the area and capacity table for Grand Lake to assist in making informed decisions for project operations and floodplain management. The stakeholders in the study area include the GRDA, USACE, and citizens living on property bordering Grand Lake and its tributaries. The data from USGS streamgage 07190000, Lake O' the Cherokees at Langley, Okla. (USGS, 2019), along with the updated area and capacity values presented in this report, can be used by the GRDA and USACE when making decisions about the management of the lake.

Purpose and Scope

This report presents an updated area and capacity table for Grand Lake featuring bathymetric data collected in 2019 and augmented by previously collected data. Descriptions of the equipment and methods that were used are included. The updated area and capacity values are summarized and depicted in the report and are available in complete digital form in an associated data release (Hunter and others, 2020). The results of this bathymetric survey are compared with previous bathymetric surveys of Grand Lake.

Description of the Study Area[1]

Grand Lake spans parts of Craig, Delaware, Mayes, and Ottawa Counties in northeastern Oklahoma and is the third largest reservoir in terms of surface area and capacity in the State (OWRB, 2015). Three major rivers in Oklahoma flow into Grand Lake: the Neosho, Spring, and Elk Rivers (fig. 1). The Neosho River and its tributaries are impounded by Pensacola Dam to form Grand Lake. Pensacola Dam spans 1 mile between the communities of Langley and Disney, Okla. (fig. 1). The hydroelectric energy produced by the lake is distributed to citizens in 75 of the 77 counties in Oklahoma (GRDA, 2015). Elevation data compiled by Grand Lake project engineers are referenced to a local datum established by the USACE for the Pensacola Dam referred to as the "Pensacola Datum" (PD). The PD has been used since the construction of the dam in March 1940 and can be converted to National Geodetic Vertical Datum of 1929 (NGVD 29) by adding 1.07 ft (USACE, 2018a) and to NAVD 88 by adding 1.40 ft (National Geodetic Survey [NGS], National Oceanic and Atmospheric Administration [NOAA], 2018) (fig. 2).

Grand Lake has seasonal conservation pool elevations. Pending environmental conditions, elevations of the top of the conservation pool (referenced to the PD) are as follows:

- May 1–31 (start of the annual season), 742.0 to 744.0 ft;
- June 1–July 31, 744.0 ft;
- August 1–15, 744.0 to 743.0 ft;
- August 16–September 15, 743.0 ft;
- September 16–30, 743.0 to 742.0 ft;
- October 1–April 30 (winter conservation pool elevation), 742.0 ft.

The top of the dam is 757.00 ft above PD or 758.40 ft above NAVD 88 (USACE, 2018b) (fig. 2).

Methods of Bathymetric Survey and Data Analysis

A bathymetric survey of Grand Lake was completed between April 1 and July 31, 2019. The methods and tools used in this study were similar to those described in Richards and others (2019) and Huizinga and others (2019). During data collection, the water-surface elevation of the lake ranged from a minimum elevation of 741.79 ft above PD on April 30, 2019, to a maximum elevation of 755.08 ft above PD on June 24, 2019, which was only 0.19 ft less than the peak of record for the lake (07190000; USGS, 2019). The extreme high-water-surface elevations in Grand Lake culminating with the maximum elevation of 755.08 ft in June 2019 facilitated the collection of a more extensive set of multi-beam bathymetric data than would have been possible if the lake had been at more typical water-surface elevations during the survey.

Bathymetric Data Collection

The multibeam mapping system (MBMS) used for sonar data collection of depths and positions (fig. 3; see sheet 2) consists of several different components that work together to output a high-resolution point-cloud dataset: the multibeam echosounder (MBES), an inertial navigation system (INS), and a data-collection and data-processing computer. The MBES used in this survey was a 400-kilohertz NORBIT iWBMSh mounted on a manned boat (NORBIT, 2014a). The iWBMSh has a curved array that allows data to be collected in a swath out to 210 degrees, meaning from nadir (directly below the MBES) to 105 degrees to either side. During this survey, most data were collected by using a swath of 140 degrees, but shallow areas were surveyed with 150-degree swaths. Even though most data were collected at 140- and 150-degree swaths, the iWBMSh can collect quality data from swaths as large as 160 degrees, although limiting the beam width reduced noise on the outer edges of the swath in some instances. The NORBIT iWBMSh swath also can electronically tilt the curved array allowing the user to accurately survey sloped banks or shallow areas up to the water surface in some instances.

The next component in the MBMS was the INS. The INS used in this survey was the Applanix OceanMaster (Applanix Corporation, 2017). The INS provides the position location of the survey vessel in three-dimensional space. The INS simultaneously measures heave, pitch, roll, and heading of the watercraft during the survey.

The MBES data were collected and stored by using HYPACK/HYSWEEP software (HYPACK, Inc., 2019). The MBES was mounted to a NORBIT Portus Pole made of flex-free carbon fiber (NORBIT, 2014b). The flex-free carbon fiber pole limited expansion and contraction, which provided repeatable offsets between the multibeam head and the global positioning system antennas during the survey.

Real-time navigation was guided by using global navigation satellite systems (GNSS) with two GNSS antennas mounted on the Portus Pole. These data were collected in real time on the boat and then were postprocessed using the POSPac Mobile Mapping Suite (MMS) software (Applanix Corporation, 2020). POSPac MMS is software that identifies and corrects sensor and environmental errors that occur during data collection. POSPac software blended the raw data with values collected by Applanix SmartBase (ASB) postprocessed virtual reference stations through a subroutine known as Applanix PP-RTX (Applanix Corporation, 2019). Once the data were blended, POSPac output a "smoothed best estimate of trajectory," or "SBET" file. This SBET file was then used as the navigation data from each day to provide the best possible trajectory of the boat. The SBET file was coupled with the depth data from the MBES to correctly position the MBES data in three-dimensional space.

In a bathymetric survey, the velocity of sound in water must be known in order to accurately calculate depth based on acoustic wave two-way travel time. For this survey, a series of sound velocity casts were collected by using an AML Oceanographic Base X_2 sound velocity profiler (SVP) (AML Oceanographic, 2020). Casts were collected once an hour at different locations to determine the velocity of sound throughout the water column at various locations. These data were then applied to the MBES data during postprocessing.

The bathymetric survey preparation and data collection were completed using HYPACK/HYSWEEP software (HYPACK, Inc., 2019). Once data collection was completed, data were visualized in HYPACK/HYSWEEP as a point cloud. This point cloud was georeferenced using the SBET file provided by POSPac. After the data were georeferenced, they were further corrected by the removal of extreme outliers (data spikes) and the application of sound velocity and patch test corrections (Huizinga, 2017). The georeferenced data were output to a comma-delimited file (CSV) where the data were filtered and reduced to a 3.28-ft data resolution, which were used for bathymetric surface and contour map creation. The georeferenced data, associated metadata, and shapefiles (Blue Marble Geographics, 2019) are provided in Hunter and others (2020).

Surveying revealed several interesting features on the lakebed, including what appeared to be several sunken boats. During the 1930s, several small communities were evacuated in order to create this lake; the displaced populace left behind homes, businesses, and other structures. The foundations of many of those structures were evident in the MBES data. A notable finding was a large cavity in the lakebed close to the entrance of Duck Creek (fig. 1). This cavity measured about 10 ft wide, 25 ft long, and 90 ft deep. When the lake is at summer conservation pool elevation of 744.00 ft, the total depth over this cavity exceeds 130 ft.

Bathymetric Surface and Contour Map Creation

A bathymetric surface was derived from a triangulated irregular network (TIN) created in Global Mapper Version 21.0.1 (Blue Marble Geographics, 2019) using multibeam sonar data collected during this study, a 4-ft-resolution single-beam sonar elevation raster for the Spring and Neosho Rivers and a 2-ft resolution for the Elk River (Hunter and others, 2017), a 1/9 arc-second light detection and ranging (lidar) digital elevation model (DEM) completed in 2010 near Grand Lake (USGS, 2012), and a lidar dataset in the LASer (LAS) data format used for three-dimensional point lidar cloud data (USGS, 2014; Arms and others, 2020). The LAS dataset was used to supplement points along Pensacola Dam to better define elevations. Centroids from the single-beam sonar rasters and the lidar DEM were extracted and used to supplement the creation of the bathymetric surface. For this survey, the vertical datum was the NAVD 88 using the geoid model GEOID12b (National Geodetic Survey, 2017), and the horizontal datum was the North American Datum of 1983 (NAD 83). The DEM data were used in areas with land-surface elevations above 744 ft above NAVD 88 where the multibeam data could not be collected. With the 2019 multibeam sonar data representing the predominant source of data, the area and capacity data documented by this report reflect lake conditions during 2019 when the multibeam data were collected.

Linear enforcement (Wilson and Richards, 2006) was used to define areas with steep topography, areas with V-shaped stream channels bordering the lake, and areas with gaps between the lidar data and multibeam data. Linear enforcement was primarily used along gaps between the multibeam sonar data and the lidar data to enforce steep topography that would otherwise be interpolated as flat by the TIN algorithm. Linear enforcement entailed generating linear vectors and linearly interpolating points along those vectors. End points of each linear vector were used to extract elevation values from either the multibeam data or lidar data. Elevations were interpolated from the minimum elevation to the maximum elevation. These points were then used to calculate the bathymetric surface.

Contour lines were generated at 2-ft intervals from the bathymetric TIN surface. Contour lines were then filtered to remove small, closed contour lines that did not affect the lake capacity depicted by the contour map and only distracted from the visual appearance of the map. Small, closed contours of less than 1,000 ft in length were removed from the contour lines for the multibeam data below 743 ft. For the lidar data, contour lines above 743 ft in elevation and less than 300 ft in length were also removed. Contours were filtered to improve the visual appearance of contour lines without affecting the lake capacity depicted by the contour map (fig. 3; see sheet 2).

Bathymetric Data-Collection Quality Assurance

The bathymetric data-collection quality was assessed in real time while collecting data. The MBMS chief operator continually monitored the data as it was being collected. The operator monitored the MBES screen as well as the INS screen looking for inconsistencies and alarms that would reveal bad data collection or loss of satellite connection. The overlapping transects were also monitored for inconsistencies. The real-time quality assurance was part of the data screening in addition to collection of beam-angle checks and patch tests to maintain data integrity. Uncertainty estimations were also computed from those data that were collected to help quantify the accuracy of the survey results.

Beam-Angle Check

The beam-angle check is required to verify that the MBES is operating within the USACE-approved standards, particularly in the outer beams (greater than 25 degrees from nadir [vertical]) of the MBES. The beam-angle check was done at the beginning of this project and was completed following guidance set by the USACE; the results were within the recommended performance standards described by the USACE (USACE, 2013).

Patch Tests

For this bathymetric survey, patch tests were conducted on the first and last day of data collection. A patch test is a calibration test that is used to identify and correct for systematic errors that might be created by the mounting angle, timing, or position of the MBES with respect to the INS. After the initial offsets from a patch test are determined, they usually remain consistent, with the exception of an event that would change how the system is mounted, such as striking underwater or floating debris (Huizinga, 2017). The offsets provided by the patch test are used during post processing of the data. Proper calibration will yield consistent bathymetric results despite varying boat orientation, speed, and motion. The patch tests from the beginning and end of this survey were consistent, showing no systematic changes.

Uncertainty Estimations

Uncertainty associated with this bathymetry survey was estimated by computing the total propagated uncertainty (TPU) as described in Huizinga (2010, 2017). The TPU was calculated for each 3.28-ft (1 meter) survey-grid cell by using the Combined Uncertainty and Bathymetry Estimator (CUBE) method (Calder and Mayer, 2003; Richards and Huizinga, 2018). The CUBE method allows all random system component uncertainties and resolution effects to be combined and propagated through the data processing steps, thereby providing a robust estimate of the spatial distribution of possible uncertainty within the survey area. Thus, when all relevant error sources are considered, the TPU of a point is an estimate of the accuracy to be expected for such a point (Czuba and others, 2011; Richards and Huizinga, 2018). More than 95 percent of the TPU values were less than 0.30 ft, which is within the most stringent specifications for an International Hydrographic Organization (IHO) Special Order survey (IHO, 2008). The median TPU value of the data was about 0.07 ft. The largest TPU in this survey was 2.48 ft (fig. 4). The higher uncertainties were located near high relief features or along edges of transects where MBES side-lobe data were collected, which typically are sources of noisier data (Richards and Huizinga, 2018).

The process to create a raster dataset from various inputs with different resolutions requires resampling to incorporate all of the data into a single file with a single resolution. This process will create minor differences between the input and output raster datasets, which typically resulted in reduced resolution (larger cell size) compared to higher resolution (smaller cell size) raster datasets (Lowell and Jaton, 2020). Information provided in the data release associated with this publication helps illustrate some of the resampling differences between the raster dataset in this data release (Hunter and others, 2020) and the raster datasets used as inputs to generate a bathymetric surface along the Neosho, Elk, and Spring Rivers (Hunter and others, 2017).

Bathymetric Surface and Contour Quality Assurance

A quality-assurance (QA) dataset was created from the multibeam dataset generated from random points distributed throughout the survey area. These data were removed from the multibeam dataset and compared to data from the final TIN for QA and accuracy. The QA dataset consisted of about 4.2 percent (about 6.8 million points) of the total multibeam dataset. The QA data points were then used to extract elevation values from the TIN to compare the difference between the QA dataset and the TIN. Calculated error was about 0.47 ft at the 95th-percentile value for the approximately 6.8 million points in the QA dataset (Hyndman and Fan, 1996; Huizinga and others, 2019). A 1-ft buffer was generated around each contour line, and QA multibeam points were extracted from this buffer. The contour elevations were used to compare elevations to the QA dataset. Calculated error was 1.77 ft at the 95th-percentile value for the approximately 6.8-million-point QA dataset (Hyndman and Fan, 1996; Huizinga and others, 2019).

Bathymetry, Surface Area, and Capacity Results

The surface area and capacity data calculated in this study are reported in table 1, and the previous calculated capacities are graphed in figure 5, along with the capacities calculated as part of this study, for comparison. These newly calculated capacities are slightly less than those derived from the previous area and capacity tables (OWRB, 2009; Hunter and Labriola, 2019). At the conservation pool elevation of 743.40 ft above NAVD 88, the area and capacity table from 1940 gives the interpolated capacity of 1,584,600 acre-feet (acre-ft) (Hunter and others, 2020). The more recent hybrid 2009/2017 table gives a capacity of 1,424,400 acre-ft (Hunter and Labriola, 2019), and the calculated capacity table for this study gives a capacity of 1,307,300 acre-ft. At the top of the dam elevation of 758.40 ft above NAVD 88, the capacities were 2,387,400 acre-ft in 1940 (Hunter and others, 2020), 2,183,200 acre-ft in the hybrid 2009/2017 study (Hunter and Labriola, 2019), and 2,067,600 acre-ft for this study.

The capacity in Grand Lake has gradually decreased over time. Total capacity between the hybrid 2009/2017 capacity table that mostly consisted of data collected in 2009 and the capacity table from this study decreased by about 117,100 acre-ft (about −8.2 percent) at the conservation pool elevation of 743.40 ft above NAVD 88 and decreased by about 115,600 acre-ft (about −5.3 percent) at the top of the dam elevation of 758.40 ft above NAVD 88 (fig. 5). The interpolated 1940 capacity is 2,387,400 acre-ft at an elevation of 758.40 ft above NAVD 88, whereas the 2019 capacity is 2,067,600 acre-ft at an elevation of 758.40 ft above NAVD 88. The capacity of Grand Lake at conservation pool elevation has decreased about 277,300 acre-ft since 1940, and the capacity at the top of dam elevation has decreased about 319,800 acre-ft since 1940.

As explained in the Introduction of this report, reservoirs slowly impound sediment carried by the rivers that drain into them, thus losing capacity over time. Although the methods used to collect data in 1940 are unknown (Hunter and Labriola, 2019), the multibeam data collected in the 2019 survey of Grand Lake are likely of much higher resolution and accuracy than previously collected bathymetry data (OWRB, 2009) because of technological advancements in the tools and methods used to collect bathymetric data. In addition, differences in data collection methods among 1940 (unknown), 2009 (single-beam sonar), 2009/2017 hybrid (single-beam sonar), and 2019 (multi-beam sonar) may have contributed to perceived changes in the capacity of Grand Lake. The single-beam sonar data collected in 2009 were collected along transects spaced about 300 ft apart, but the data density of the multi-beam sonar data was far greater in most areas. The multi-beam survey used a POS MV Ocean Master to correct for pitch, roll, and yaw of the survey boat (Applanix 2017). Failure to dynamically correct for these variables during data collection activities in previous surveys would increase calculated depths relative to this survey because any movement of the survey boat will cause the sonar beam to deviate from vertical, increasing the beam travel distance and thus overestimating depth for a surface with relatively flat topography (L-3 Communications SeaBeam Instruments, 2000). The Grand Lake lakebed consists of mostly flat topography (as illustrated by widely spaced contours [fig. 3; see sheet 2]). Previous surveys likely did not correct for boat movement to the same precision as this survey, and some of the reduced capacity could be attributed to this difference in data-collection techniques.

[1]This section is modified from Hunter and Labriola (2019).

References

AML Oceanographic, 2020, AML Base X2 SVP: Victoria, British Columbia, AML Oceanographic web page, accessed February 10, 2020, at https://amloceanographic.com/product/base-x2-svp/.

Applanix Corporation, 2017, POS MV OceanMaster specifications: Richmond Hill, Ontario, Canada, Applanix Corporation web page, 2 p., accessed January 27, 2020, at https://www.applanix.com/downloads/products/specs/posmv/POSMV_OCEANMASTER.pdf.

Applanix Corporation, 2019, Applanix PP-RTX in hydrographic survey: Richmond Hill, Ontario, Canada, Applanix Corporation web page, 2 p., accessed January 27, 2020, at https://www.applanix.com/downloads/case_studies/Applanix_PP-RTX_in_Hydrographic_Survey.pdf.

Applanix Corporation, 2020, POSPac MMS: Richmond Hill, Ontario, Canada, Applanix Corporation website, accessed January 27, 2020, at https://www.applanix.com/.

Arms, C.A., Fleischhauer, C., and Murray, K., 2020, Sustainability of digital formats—Planning for Library of Congress collections: U.S. Library of Congress web page, accessed July 24, 2020, at https://www.loc.gov/preservation/digital/formats/fdd/fdd000418.shtml.

Blue Marble Geographics, 2019, Create contours from TIN areas: Blue Marble Geographics Global Mapper web page, accessed January 27, 2020, at https://www.bluemarblegeo.com/knowledgebase/global-mapper-21-1/Generate_Contours.htm?Highlight=triangulated%20irregular%20network#TIN.

Calder, B.R., and Mayer, L.A., 2003, Automatic processing of high-rate, high-density multibeam echosounder data: Geochemistry, Geophysics, Geosystems, v. 4, no. 6, 22 p., accessed January 27, 2020, at https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2002GC000486.

Czuba, J.A., Best, J.L., Oberg, K.A., Parsons, D.R., Jackson, P.R., Garcia, M.H., and Ashmore, P., 2011, Bed morphology, flow structure, and sediment transport at the outlet of Lake Huron and in the upper St. Clair River: Journal of Great Lakes Research, v. 37, no. 3, p. 480–493, accessed January 27, 2020, at https://doi.org/10.1016/j.jglr.2011.05.011.

Federal Energy Regulatory Commission [FERC], 2012, A guide to understanding and applying the integrated licensing process study criteria: Federal Energy Regulatory Commission, 33 p., accessed May 26, 2017, at https://www.ferc.gov/industries/hydropower/gen-info/guidelines/guide-study-criteria.pdf.

Grand River Dam Authority [GRDA], 2015, The economic impact of the Grand River Dam Authority, accessed September 17, 2020, at http://www.grda.com/wp-content/uploads/2015/04/2015-GRDA-Economic-Impact.pdf.

Grand River Dam Authority [GRDA], 2017, Pensacola Hydroelectric Project—Scoping document 2 for the Pensacola Hydroelectric Project: Grand River Authority, Federal Energy Regulatory Commission report no. 1494–438, 566 p., accessed September 17, 2020, at https://www.grda.com/wp-content/uploads/2019/04/Pensacola-P-1494-NOI-PAD-02-01-17-FINAL.pdf.

Huizinga, R.J., 2010, Bathymetric surveys at highway bridges crossing the Missouri River in Kansas City, Missouri, using a multibeam echo sounder, 2010: U.S. Geological Survey Scientific Investigations Report 2010–5207, 61 p., accessed January 27, 2020, at https://doi.org/10.3133/sir20105207.

Huizinga, R.J., 2017, Bathymetric and velocimetric surveys at highway bridges crossing the Missouri and Mississippi Rivers near St. Louis, Missouri, May 23–27, 2016: U.S. Geological Survey Scientific Investigations Report 2017–5076, 102 p., accessed January 27, 2020, at https://doi.org/10.3133/sir20175076.

Huizinga, R.J., Ellis, J.T., Sharpe, J.B., LeRoy, J.Z., and Richards, J.M., 2019, Bathymetric map and surface area and capacity table for Beaver Lake near Rogers, Arkansas, 2018: U.S. Geological Survey Scientific Investigations Map 3445, 2 sheets, accessed January 27, 2020, at https://doi.org/10.3133/sim3445.

Hunter, S.L., Ashworth, C.E., and Smith, S.J., 2017, Bathymetric surveys of the Neosho River, Spring River, and Elk River, northeastern Oklahoma and southwestern Missouri, 2016–17: U.S. Geological Survey Scientific Investigations Report 2017–5101, 59 p., accessed January 27, 2020, at https://doi.org/10.3133/sir20175101.

Hunter, S.L., and Labriola, L.G., 2019, Area and capacity of Grand Lake O' the Cherokees, northeastern Oklahoma, 2009: U.S. Geological Survey Scientific Investigations Report 2019–5040, 18 p., accessed January 27, 2020, at https://doi.org/10.3133/sir20195040.

Hunter, S.L., Trevisan, A.R., and Villa, J., 2020, Data release of bathymetric map, surface area, and capacity of Grand Lake O' the Cherokees, northeastern Oklahoma, 2019: U.S. Geological Survey data release, https://doi.org/10.5066/P9KA2T3Z.

Hyndman, R.J., and Fan, Y., 1996, Sample quantiles in statistical packages: American Statistician, v. 50, no. 4, p. 361–365, accessed July 28, 2020, at https://doi.org/10.2307/2684934.

HYPACK, Inc., 2019, HYPACK user manual: Middletown, Conn., HYPACK, Inc., 2,556 p., accessed January 23, 2020, at http://www.hypack.com/File%20Library/Resource%20Library/Manuals/2019/2019-HYPACK-User-Manual.pdf.

International Hydrographic Organization [IHO], 2008, IHO standards for hydrographic surveys (5th ed.): International Hydrographic Organization Special Publication no. 44, 28 p., accessed July 24, 2020, at https://iho.int/uploads/user/pubs/standards/s-44/S-44_5E.pdf.

L-3 Communications SeaBeam Instruments, 2000, Multibeam Sonar Theory of Operation, 107 p., accessed October 14, 2020, at https://www3.mbari.org/data/mbsystem/sonarfunction/SeaBeamMultibeamTheoryOperation.pdf.

Lowell, K., and Jaton, A., 2000, Spatial accuracy assessment—Land information uncertainty in natural resources (1st ed.): Boca Raton, Fla., CRC Press, 450 p., accessed September 22, 2020, at https://doi.org/10.1201/9781482279573.

National Geodetic Survey, 2017, GEOID12b: National Oceanic and Atmospheric Administration, National Geodetic Survey web page, accessed July 29, 2020, at https://www.ngs.noaa.gov/GEOID/GEOID12/.

National Geodetic Survey [NGS], National Oceanic and Atmospheric Administration [NOAA], 2018, VERTCON—North American Vertical Datum conversion: National Oceanic and Atmospheric Administration, National Geodetic Survey web page, accessed October 25, 2018, at https://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html.

NORBIT, 2014a, Datasheet: Trondheim, Norway, NORBIT Subsea Accessed September 21, 2020, at https://norbit.com/media/PS-150010-10_iWBMSh_Pn_12007-AACDB4_A4.pdf.

NORBIT, 2014b, NORBIT carbon fibre "Portus" mounting pole: Trondheim, Norway, 1 p., accessed January 27, 2020, at https://norbit.com/media/PS-190002-1_Carbon-Fiber-PORTUS-Pole_A4.pdf.

Oklahoma Water Resources Board [OWRB], 2009, Hydrographic survey of Grand Lake: Oklahoma Water Resources Board, 27 p., accessed January 27, 2017, at https://www.owrb.ok.gov/studies/reports/reports_pdf/GrandLake--hydrologicsurvey.pdf.

Oklahoma Water Resources Board [OWRB], 2015, Lakes of Oklahoma (3d ed.): Oklahoma Water Resources Board web page, accessed December 17, 2018, at http://www.owrb.ok.gov/news/publications/lok/lok.php.

Oklahoma Water Resources Board [OWRB], 2016, Bathymetric lake studies: Oklahoma Water Resources Board web page, accessed January 27, 2020, at http://www.owrb.ok.gov/maps/pmg/owrbdata_Bathy.html.

Richards, J.M., and Huizinga, R.J., 2018, Bathymetric contour map, surface area and capacity table, and bathymetric difference map for Clearwater Lake near Piedmont, Missouri, 2017: U.S. Geological Survey Scientific Investigations Map 3409, 1 sheet, accessed January 27, 2020, at https://doi.org/10.3133/sim3409.

Richards, J.M., Huizinga, R.J., and Ellis, J.T., 2019, Bathymetric contour map, surface area and capacity table, and bathymetric change map for Sugar Creek Lake near Moberly, Missouri, 2018: U.S. Geological Survey Scientific Investigations Map 3431, 1 sheet, accessed January 27, 2020, at https://doi.org/10.3133/sim3431.

Smith, S.J., Ashworth, C.E., and Smith, K.A., 2017, Bathymetry and capacity of Shawnee Reservoir, Oklahoma, 2016: U.S. Geological Survey data release, accessed January 16, 2017, at https://doi.org/10.5066/F72805SC.

U.S. Army Corps of Engineers [USACE], 2013, Engineering and design—Hydrographic surveying: Washington, D.C., U.S. Army Corps of Engineers manual no. EM 1110–2–1003, 560 p., accessed January 27, 2020, at https://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1003.pdf?ver=2014-01-06-155809-307.

U.S. Army Corps of Engineers [USACE], 2018a, Pensacola Lake, monthly lake report, Apr 96: U.S. Army Corps of Engineers web page, accessed October 25, 2018, at http://www.swt-wc.usace.army.mil/chartbin/PENSApr96.html.

U.S. Army Corps of Engineers [USACE], 2018b, PENO2—Pensacola (Grand Lake), OK: U.S. Army Corps of Engineers web page, accessed October 25, 2018, at http://www.swt-wc.usace.army.mil/PENS.lakepage.html.

U.S. Geological Survey [USGS], 2012, National Elevation Dataset (NED) 1/9 arc-second DEM: U.S. Geological Survey database, accessed January 28, 2020, at https://viewer.nationalmap.gov/basic/?basemap=b1&category=ned&q=&zoom=10&bbox=-95.1059,37.0359,-94.5016,36.4268&preview=&avail=DEM%201/9%20arc-second.

U.S. Geological Survey [USGS], 2014, National Elevation Dataset (NED) lidar point cloud (LPC): U.S. Geological Survey database, accessed June 23, 2020, at https://viewer.nationalmap.gov/basic/?basemap=b1&category=nedsrc&q=&zoom=15&bbox=-95.04525661,36.46319398,-94.99749184,36.48990336&preview=&avail=&refpoly=.

U.S. Geological Survey [USGS], 2019, USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed June 1, 2020, at https://doi.org/10.5066/F7P55KJN.

Wilson, G.L., and Richards, J.M., 2006, Procedural documentation and accuracy assessment of bathymetric maps and area/capacity tables for small reservoirs: U.S. Geological Survey Scientific Investigations Report 2006–5208, 24 p., accessed January 27, 2020, at https://doi.org/10.3133/sir20065208.

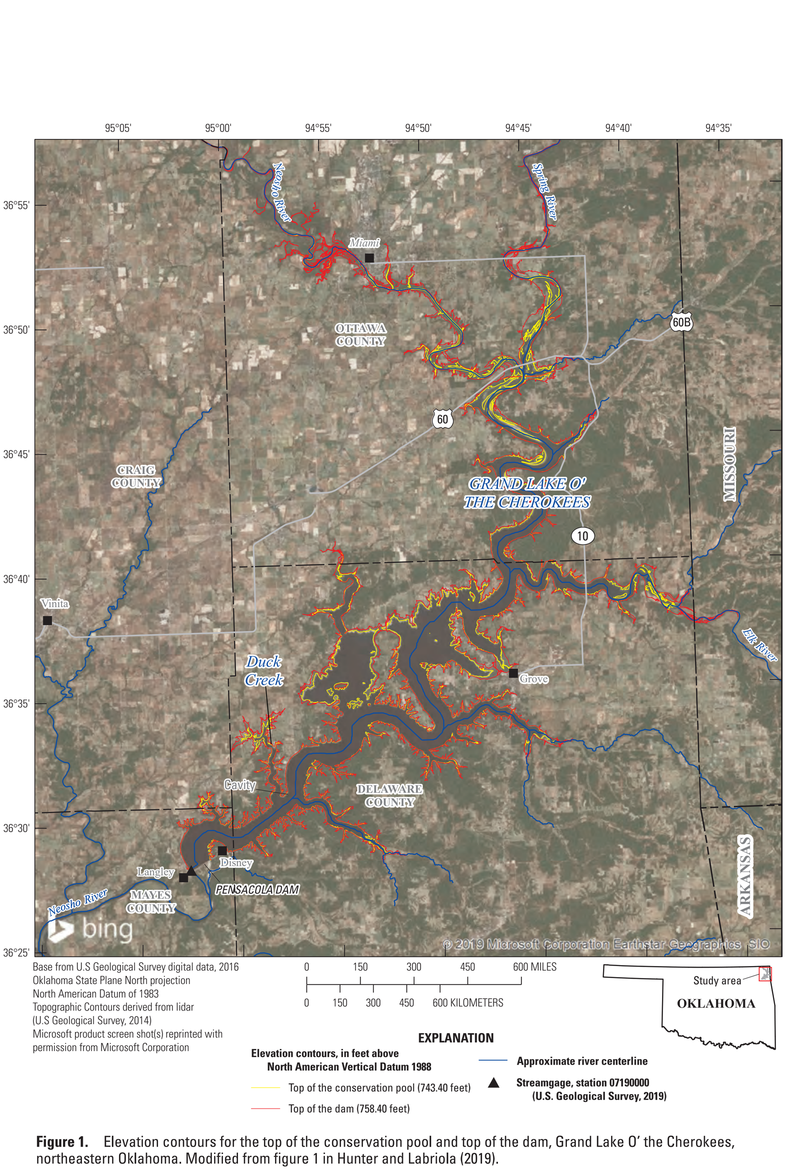


Figure 1. Elevation contours for the top of the conservation pool and top of the dam, Grand Lake O' the Cherokees, northeastern Oklahoma. Modified from figure 1 in Hunter and Labriola (2019).

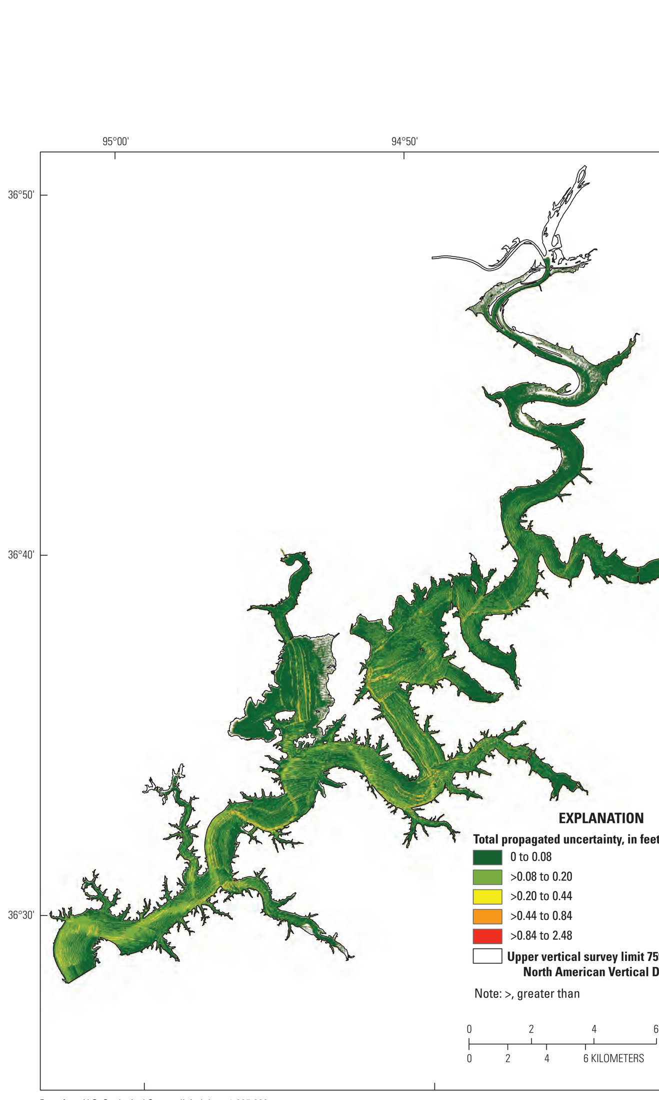
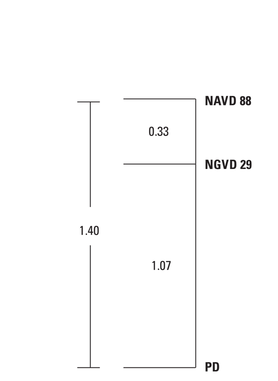


Figure 4. Extent of multibeam bathymetric data collected in 2019 and the total propagated uncertainty pertaining to the collected data, Grand Lake O' the Cherokees, northeastern Oklahoma.



	Elevations, in feet		
	NAVD 88	NGVD 29	PD
Conservation pool	743.40	743.07	742.00
Top of the dam	758.40	758.07	757.00

Figure 2. Datum transformations and conversions for the North American Vertical Datum of 1988 (NAVD 88), National Geodetic Vertical Datum of 1929 (NGVD 29), and Pensacola Datum (PD) used in the computation of area and capacity for Grand Lake O' the Cherokees, northeastern Oklahoma. Reprinted from Hunter and Labriola (2019).

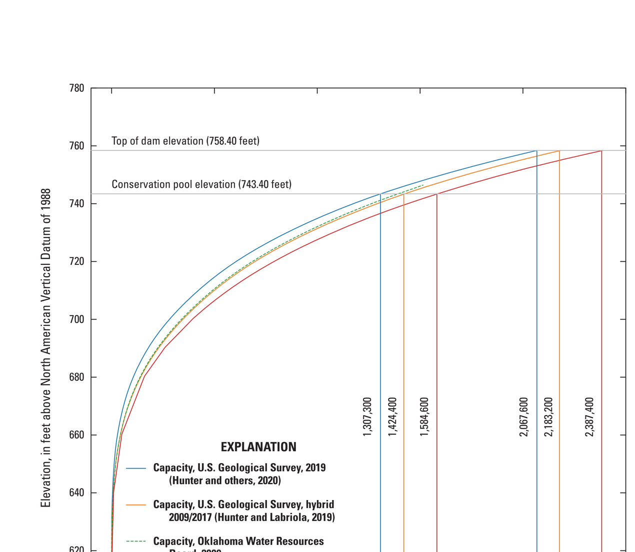


Figure 5. Capacity of Grand Lake O' the Cherokees as calculated with elevation data from 1940, from the Oklahoma Water Resources Board (2009), from the U.S. Geological Survey hybrid 2009/17 study (Hunter and Labriola, 2019), and from bathymetric data collected in 2019 and compiled for this study. Modified from figure 4 in Hunter and Labriola (2019).

Table 1. Surface area and capacity at specified water-surface elevations for Grand Lake O' the Cherokees in northeastern Oklahoma from a bathymetric survey completed during April 1–July 31, 2019, augmented with previously collected single-beam sonar data and lidar point-cloud data.

[ft, feet; NAVD 88, North American Vertical Datum of 1988; winter conservation pool elevation is 742.0 ft above Pensacola Datum, 743.4 ft above NAVD 88, and the top of dam elevation is 757.0 ft above Pensicola Datum, 758.4 ft above NAVD 88]

Water-surface elevation,[1] in ft	Water-surface elevation,[2] in ft	Capacity,[3] in acre-ft	Surface area, in acres	Water-surface elevation,[1] in ft	Water-surface elevation,[2] in ft	Capacity,[3] in acre-ft	Surface area, in acres	Water-surface elevation,[1] in ft	Water-surface elevation,[2] in ft	Capacity,[3] in acre-ft	Surface area, in acres
626.00	624.60	100	60	672.00	670.60	65,400	4,040	718.00	716.60	563,900	19,960
628.00	626.60	300	110	674.00	672.60	73,900	4,470	720.00	718.60	605,100	21,260
630.00	628.60	500	170	676.00	674.60	83,300	4,960	722.00	720.60	649,000	22,660
632.00	630.60	1,000	270	678.00	676.60	93,700	5,420	724.00	722.60	695,700	24,020
634.00	632.60	1,600	360	680.00	678.60	105,100	5,930	726.00	724.60	745,100	25,330
636.00	634.60	2,400	430	682.00	680.60	117,400	6,420	728.00	726.60	797,100	26,730
638.00	636.60	3,300	500	684.00	682.60	130,800	6,950	730.00	728.60	852,100	28,220
640.00	638.60	4,400	580	686.00	684.60	145,200	7,460	732.00	730.60	910,100	29,760
642.00	640.60	5,600	640	688.00	686.60	160,600	7,990	734.00	732.60	971,000	31,260
644.00	642.60	7,000	710	690.00	688.60	177,100	8,570	736.00	734.60	1,035,300	33,010
646.00	644.60	8,500	840	692.00	690.60	195,000	9,300	738.00	736.60	1,103,200	34,900
648.00	646.60	10,300	950	694.00	692.60	214,400	10,050	740.00	738.60	1,174,900	36,860
650.00	648.60	12,300	1,070	696.00	694.60	235,100	10,760	742.00	740.60	1,250,900	39,240
652.00	650.60	14,600	1,210	698.00	696.60	257,400	11,490	**743.40**	**742.00**	**1,307,300**	**41,580**
654.00	652.60	17,200	1,410	700.00	698.60	281,100	12,190	744.00	742.60	1,332,500	42,390
656.00	654.60	20,300	1,690	702.00	700.60	306,200	12,930	746.00	744.60	1,419,400	44,580
658.00	656.60	24,000	1,970	704.00	702.60	332,900	13,710	748.00	746.60	1,510,900	46,850
660.00	658.60	28,200	2,270	706.00	704.60	361,000	14,460	750.00	748.60	1,606,900	49,190
662.00	660.60	33,000	2,530	708.00	706.60	390,600	15,160	752.00	750.60	1,707,800	51,690
664.00	662.60	38,400	2,800	710.00	708.60	421,700	15,910	754.00	752.60	1,813,800	54,390
666.00	664.60	44,200	3,070	712.00	710.60	454,300	16,740	756.00	754.60	1,925,500	57,300
668.00	666.60	50,700	3,360	714.00	712.60	488,800	17,720	758.00	756.60	2,043,300	60,520
670.00	668.60	57,700	3,680	716.00	714.60	525,200	18,750	**758.40**	**757.00**	**2,067,700**	**61,180**

[1]Elevations are referenced to the North American Vertical Datum of 1988.

[2]Elevations are referenced to the Pensacola Datum, a local datum established in 1940 by the U.S. Army Corps of Engineers for the Penscola Dam impounding Grand Lake O' the Cherokees. Pensacola Datum is calculated by subtracting 1.40 ft from NAVD 88.

[3]Capacities were computed from a surface triangulated irregular network that was computed at about 0.47 ft at the 95th-percentile value for the approximately 6.8-million-point quality-assurance dataset. The explanation of the vertical accuracy calculation is in the "Bathymetric Surface and Contour Quality Assurance" section of this report. Capacities have been rounded to the nearest hundred.

Bathymetric Map, Surface Area, and Capacity of Grand Lake O' the Cherokees, Northeastern Oklahoma, 2019

By

Shelby L. Hunter, Adam R. Trevisan, Jennifer Villa, and Kevin A. Smith

2020

For sale by U.S. Geological Survey, Information Services, Box 25286, Federal Center, Denver, CO 80225, 1–888–ASK–USGS

Digital files available at https://doi.org/10.3133/sim3467

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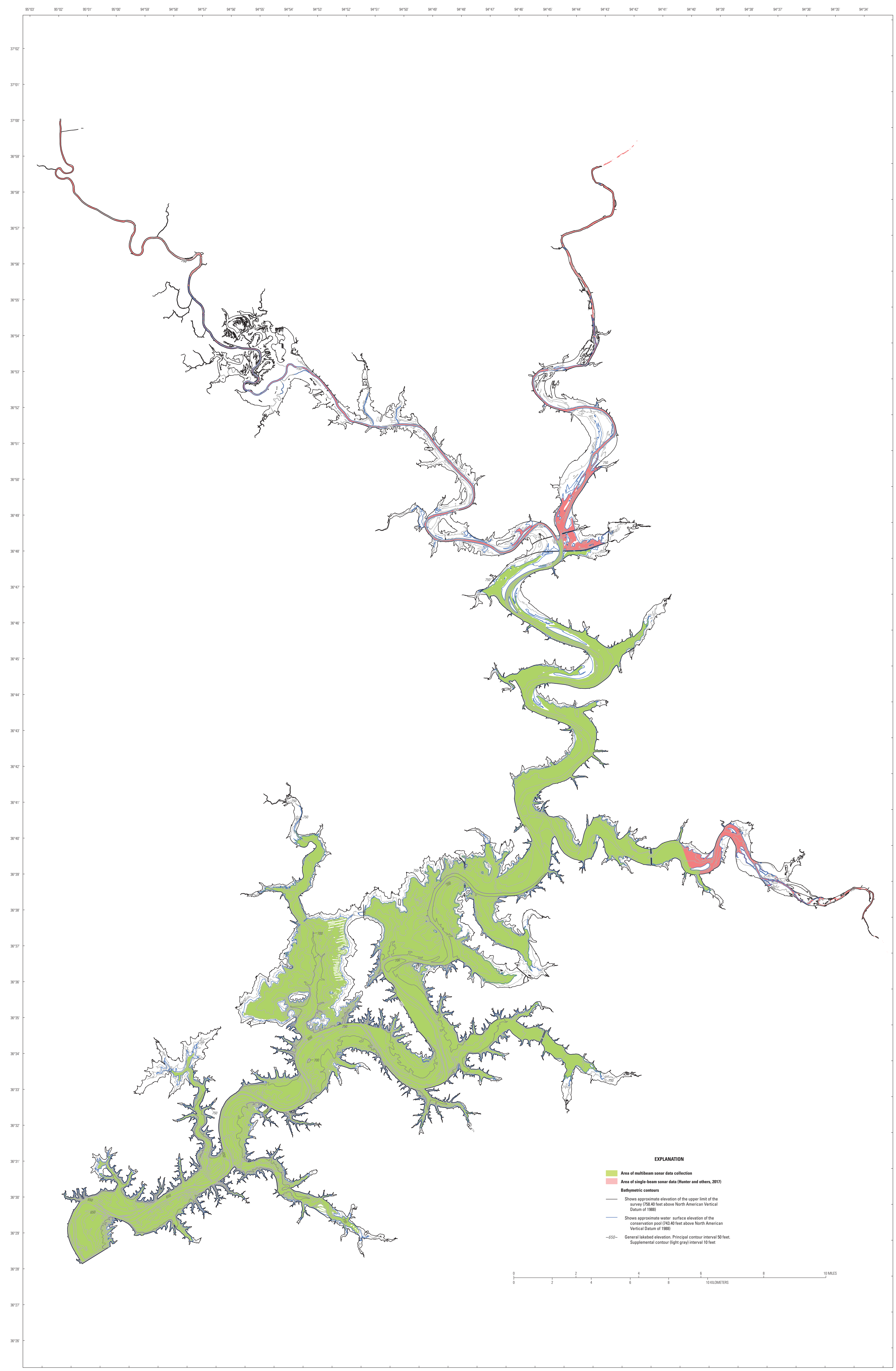
U.S. Geological Survey

Prepared in cooperation with the
Grand River Dam Authority

Scientific Investigations Map 3467
Sheet 2 of 2



Base from U.S. Geological Survey digital data,1:80,000
Oklahoma State Plane North projection
North American Datum of 1983

Figure 3. Bathymetric contours for Grand Lake O’ the Cherokees obtained from the multibeam mapping system survey completed in 2019 and augmented with previously collected single-beam sonar data (Hunter and others, 2017) and lidar point-cloud data (U.S. Geological Survey, 2014).

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APPENDIX E-6 Updated Study Report

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Grand River Dam Authority

September 30, 2022

Via E-Filing

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, DC 20426

Subject: **Pensacola Hydroelectric Project (FERC Project No. 1494-438)**
Updated Study Report and Request for Privileged Treatment of Cultural Resources Information

Dear Secretary Bose:

The Grand River Dam Authority (GRDA) hereby electronically files its Updated Study Report (USR) pursuant to 18 C.F.R. § 5.15(f) for the relicensing of the Pensacola Hydroelectric Project (FERC No. 1494). The purpose of this USR is to describe GRDA's overall progress during the final study season in implementing its relicensing study plan and schedule. The schedule originated in GRDA's Revised Study Plan (RSP) in September 2018 and was approved with Federal Energy Regulatory Commission (Commission) staff-recommended modifications in the Commission's November 8, 2018 study plan determination (SPD) letter.

The enclosed USR builds on the Initial Study Report (ISR), which GRDA filed with the Commission on September 30, 2021. In the ISR, GRDA recommended modifications to the Sedimentation Study and Terrestrial Species of Concern Study. In response to the ISR, relicensing participants recommended modifications to the Hydrologic and Hydraulic Modeling Study, Sedimentation Study, Aquatic Species of Concern Study, Cultural Resources Study, Socioeconomic Study, and Infrastructure Study. In addition, the Relicensing participants also recommended a Contaminated Sediment Transport Study, which Commission staff had previously rejected in its November 2018 SPD.

Commission staff resolved most of these issues in its February 24, 2022 Study Modification Determination (SMD). In the SMD, Commission staff recommended modifications to the Hydrologic and Hydraulic Modeling Study, Aquatic Species of Concern Study, and the Infrastructure Study. Staff's SMD deferred a decision on the Sedimentation Study and did not recommend any modifications to the Terrestrial Species of Concern, Cultural Resources, or Socioeconomics Study. Also in the SMD, Commission staff once again rejected the request for Contaminated Sediment Transport Studies, just as it had in its November 2018 SPD.

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Grand River Dam Authority

On April 27, 2022, GRDA provided the Commission with an updated Sedimentation Study Plan. On May 27, 2022, Commission staff approved the updated Sedimentation Study Plan with several staff-recommended modifications.

The enclosed USR contains a complete and exhaustive reporting of all studies undertaken since last year's ISR and is the culmination of the environmental study phase of this relicensing effort. With the filing of the USR, GRDA has now completed the Commission-approved study plan for the relicensing of the Project, including all elements of staff's November 2018 SPD, February 2022 SMD, and May 2022 determination regarding the Sedimentation Study Plan.

The USR includes reports for all Commission-approved study plans, including Hydrologic and Hydraulic Modeling, Sedimentation, Aquatic Species of Concern, Terrestrial Species of Concern, Wetlands and Riparian Habitat, Recreation, Cultural Resources, Socioeconomics, and Infrastructure.

The Bathymetric Study is considered part of the Hydrologic and Hydraulic Modeling Study because the Commission recommended it be completed in their study determination letter as part of the Hydrologic and Hydraulic Modeling Study. For completeness, this USR includes the final reports for the Recreation and Socioeconomic studies provided in last year's ISR, but these reports remain unchanged, as these studies were completed in the first study season.

GRDA greatly appreciates the engagement of Commission staff, other federal and state resource agencies, Native American tribes, local governmental entities, and all relicensing participants in the development and implementation of the Commission-approved study plan—an effort that has taken nearly four years to complete. This highly collaborative, closely scrutinized, and time-consuming effort has resulted in an administrative record that is robust, scientifically sound, and fully satisfactory of the Commission's obligations under the Federal Power Act, National Environmental Policy Act, and other applicable programs in this relicensing effort.

With the scientific record now complete, GRDA hereby notifies the Commission and relicensing participants of its intent to file a Draft License Application (DLA) in lieu of a preliminary licensing proposal. *See* 18 C.F.R. § 5.16(c). As provided in the Commission's September 9, 2019 order, GRDA plans to file the DLA by January 1, 2023. *See Grand River Dam Auth.*, 168 FERC ¶ 62,145 (2019), *reh'g denied*, 170 FERC ¶ 61,027 (2020).

Prior to preparing the DLA, GRDA looks forward to discussing the USR with Commission staff and relicensing participants. Pursuant to 18 C.F.R. § 5.15(c)(2), GRDA has scheduled the USR meetings for Wednesday, October 12, and Thursday, October 13, 2022, beginning at 9:00 a.m. CDT. The meeting will be held virtually. An informal notification of the meeting location, time, and date was provided to the relicensing participants on record on September 16, 2022. The

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notice and agenda have been updated to include the virtual information. The agenda is enclosed as Appendix 1 of the USR.

Finally, GRDA notes that the enclosed cultural resources studies contain sensitive, non-public information related to the location and character of cultural resources; therefore, pursuant to 18 C.F.R. § 388.112, GRDA requests privileged designation of these reports in their entirety and that the Commission maintain these reports in its non-public file. As required by Commission regulation and guidance, each page of the cultural resources studies has been labeled as privileged and confidential, designated as CUI//PRIV, and marked "DO NOT RELEASE." *See id.* § 388.112(b)(1).

If there are any questions or comments regarding this submittal, please contact me by phone at (918) 981-8472 or by email at Darrell.Townsend@grda.com.

Sincerely,

Darrell Townsend II, Ph.D.
Vice President
Grand River Dam Authority

Enclosure-USR

cc: Distribution list (see attached)

Stakeholder Distribution List
September 2022

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GRAND RIVER DAM AUTHORITY

PENSACOLA HYDROELECTRIC PROJECT

FERC No. 1494

UPDATED STUDY REPORT

September 30, 2022

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List of Abbreviations and Terms

1D	One-Dimensional
ABB	American Burying Beetle
APE	Area of Potential Effect
Commission	Federal Energy Regulatory Commission
CRWG	Cultural Resources Work Group
CHM	Comprehensive Hydraulic Model
DLA	Draft License Application
DHM	Downstream Hydraulic Model
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FRM	Flood Routing Model
GIS	Geographic Information Systems
Grand Lake	Grand Lake O' the Cherokees
GRDA	Grand River Dam Authority
H&H Study	Hydrologic and Hydraulic Modeling Study
HEC	Hydrologic Engineering Center
HPMP	Historic Properties Management Plan
ILP	Integrated Licensing Process
ISR	Initial Study Report
Kerr Dam	Robert S. Kerr Dam (Markham Ferry Hydroelectric Project)
LiDAR	Light Detection and Ranging
MISR	Model Input Status Report
NDAA 2020	National Defense Authorization Act for Fiscal Year 2020
NHPA	National Historic Preservation Act
NOI	Notice of Intent
NRHP	National Register of Historic Places
NWI	National Wetland Inventory
ODWC	Oklahoma Department of Wildlife Conservation
OM	Operations Model
PAD	Pre-Application Document
Pcf	Per Cubic Foot
PD	Pensacola Datum
Project	Pensacola Hydroelectric Project
PSP	Proposed Study Plan
Qals	Quarternary landforms
RAS	River Analysis System
REAS	1998 Real Estate Adequacy Study
RM	River Mile
ROI	Region of Influence
RSP	Revised Study Plan
RWM	USACE'S RiverWare Model
SBP	Sub-bottom Profiler
SHPO	State Historic Preservation Officer
SMD	Study Modification Determination

SPD ... Study Plan Determination
SSC ... Suspended Sediment Concentration
STM ... Sediment Transport Model
TCP ... Traditional Cultural Properties
UHM ... Upstream Hydrologic Model
USACE ... United States Army Corps of Engineers
USFWS ... U.S. Fish and Wildlife Service
USGS ... United States Geological Survey
USR ... Updated Study Report
WSEL ... Water Surface Elevation

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1.0 GENERAL

This document presents Grand River Dam Authority's (GRDA's) Updated Study Report (USR) for the Pensacola Hydroelectric Project (Project), Federal Energy Regulatory Commission (FERC or Commission) Project No. 1494. The USR—the culmination of nearly four years of intensive, highly collaborative, and closely scrutinized environmental study regarding the Project—presents GRDA's progress in implementing and completing the approved study plan and schedule by providing the data collected and summarizing the results of comprehensive reports for both the First Study Season and the Final Study Season. The purpose of the USR is also to provide an explanation of variances from the approved study plans and schedules and modifications to ongoing studies (if any) or new studies proposed by GRDA (if any).

The study plan and schedule first originated in the Revised Study Plan (RSP), which was filed by GRDA in September 2018[1] and approved by the Commission in its November 8, 2018[2] study plan determination (SPD) (FERC 2018) and further clarified in its January 23, 2019, Order on Request for Clarification and Rehearing (FERC 2019).

In September 2021[3], GRDA filed its Initial Study Report (ISR) (GRDA 2021) and recommended modifications to the Sedimentation Study and Terrestrial Species of Concern Study. In response to the ISR, relicensing participants requested modifications to the Hydrologic and Hydraulic Modeling (H&H) Study, Sedimentation Study, Aquatic Species of Concern Study, Cultural Resources Study, Socioeconomic Study, and Infrastructure Study. In addition, the relicensing participants also requested a new study for Contaminated Sediment Transport.

In the Commission's February 2022[4] Study Modification Determination (SMD) (FERC SMD 2022) modifications to the Hydrologic and Hydraulic Modeling Study, Aquatic Species of Concern Study, and the Infrastructure Study were approved. At that time, the Commission deferred a decision on the Sedimentation Study, but its SMD did not accept proposed modifications to the Terrestrial Species of Concern Study, Cultural Resources Study, and Socioeconomics Study. Also, consistent with its November 2018 SPD, the Commission in its SMD did not approve a proposed Contaminated Sediment Transport Study.

In April 2022[5], GRDA provided the Commission with an updated Sedimentation Study Plan (GRDA 2022). In May 2022[6], the Commission approved the updated Sedimentation Study Plan with Commission staff-recommended modifications (FERC Determination 2022).

Variances to the approved study plan and schedule are outlined in Section 3.0.

As documented in this USR, all study plan objectives and methodologies set forth in the Commission-approved study plan—including in the November 2018 SPD, February 2022 SMD, and May 2022 approval of the Sedimentation Study Plan—have been fully met, and all studies are complete. Therefore, no further modifications to the approved studies or new studies are necessary or appropriate for the

[1] GRDA's Revised Study Plan, P-1494-438 (September 24, 2018).
[2] Study Plan Determination, P-1494-438 (November 8, 2018).
[3] GRDA's Initial Study Report, P-1494-438 (September 30, 2021).
[4] FERC's Determination on Requests for Study Modifications and New Studies, P-1494-438 (February 24, 2022).
[5] GRDA's Response Comments on Sedimentation Study and Submission of Updated Study Plan, P-1494-438 (April 27, 2022).
[6] FERC's Determination on Requests for Study Modifications for Pensacola Hydroelectric Project, P-1494-438 (May 27, 2022).

Commission to meet its obligations under the Federal Power Act, National Environmental Policy Act, or any other review requirement in this relicensing effort.

Appendices 2 through 11 of this USR contain the individual reports for the ten studies identified in the RSP. A summary of the studies and the status of each is provided in **Table 1**.

Table 1. Summary of studies included in this USR

Study	Study Consultant(s)	Study Requirements and Status
Hydrologic and Hydraulic Modeling	Mead & Hunt	Develop a Comprehensive Hydraulic Model (CHM) (Section 2 of the Upstream Hydraulic Model (UHM) and Downstream Hydraulic Model (DHM) report) using updated 2019 bathymetry and calibrate the CHM using six historical events (Section 3 of the UHM and Section 2 of the DHM report in Appendix 2)-***Complete***. Validate model results against RiverWare (RWM)[7] output (Section 5 of the Operations Model (OM) report in Appendix 2)-***Complete***. Compare water surface elevations observed at the USGS gage on the upstream side of the dam to simulated stage hydrographs for the December 2015 and October 2009 inflow events (Section 5.3 of the OM report in Appendix 2)-***Complete***. Run a sensitivity analysis on the effect of switching to the most recent (i.e., 2019) bathymetry data in the OM (Section 5.4.4 of the OM report in Appendix 2)-***Complete***. Perform a flood frequency analysis of peak inflow to estimate a 100-year event flow at Pensacola Dam (Section 4 of the UHM report in Appendix 2)-***Complete***. Determine the duration and extent of inundation under the current license (baseline) operations of the Project and anticipated change in these operations that occurs during several measured inflow events starting at elevation 734 Pensacola Datum (PD) up to and including elevation 757 PD (Sections 7 through 10 of the UHM report and Sections 3 through 6 of the DHM report in Appendix 2)-***Complete***. Report the frequency, timing (i.e., seasonality), amplitude (i.e., elevation), and duration for each of the simulated inflow events with starting elevations between 734 feet PD and 757 feet PD for the baseline analysis and under any anticipated change in operations (Sections 8 and 10 of the UHM report and Sections 4 and 6 of the DHM report in Appendix 2)-Complete. Section 11 of the UHM report in Appendix 2 provides the timing (seasonality) information-***Complete***. Provide the model results in a format that can inform other analyses (to be completed separately) of

[7] United States Army Corps of Engineers (USACE) RiverWare Model.

Study	Study Consultant(s)	Study Requirements and Status
		Project effects, if any, in several resource areas including the production of Lentic and Lotic Maps for baseline and anticipated operations, as needed, in the Aquatic Species of Concern, the Terrestrial Species of Concern, and the Wetland and Riparian Study (Section 11 and electronic attachment of the UHM report in Appendix 2)-***Complete***. Provide the means necessary to complete any additional return (flood) frequency analysis that may be deemed necessary following review of the USR (UHM report in Appendix 2 electronic attachment)-***Complete***. Determine the feasibility of implementing anticipated operations scenarios, if applicable, that may be proposed by GRDA as part of the relicensing effort (Section 10 of the UHM report and Section 6 of the DHM report in Appendix 2)-***Complete***.
Bathymetry[8]	U.S. Geological Survey (USGS)	See Appendix 3-***Complete***.
Sedimentation	Anchor QEA and Simons and Associates	Compile Existing Data and review literature on suspended sediments, sediment properties, flow, and water levels (Section 2 of the report in Appendix 4)-***Complete***. Collect additional field measurements and data (Section 2 of the report in Appendix 4)-***Complete***. Collect 10 vibracore samples in the delta feature (Section 2 of the report in Appendix 4)-***Complete***. Conduct a bathymetric change analysis (Section 4 of the report in Appendix 4)-***Complete***. Develop a Sediment Transport Model (STM) using Hydrologic Engineering Center River Analysis System (HEC-RAS) to determine the fate of sediment upstream of river mile (RM) 100 (Section 5 of the report in Appendix 4)-***Complete***. Calibrate the STM to measured bed changes based on the historical surveys (Section 6 of the report in Appendix 4)-***Complete***. Complete a qualitative analysis to understand the general trends in the system and how the stream has evolved over time (Section 4 of the report in Appendix 4)-***Complete***. Complete a quantitative engineering analysis of sediment transport in the study area focusing on the delta feature and downstream of RM 100 (Section 4 of the report in Appendix 4)-***Complete***.

[8] The collection of new bathymetric data in 2019 is not listed as a separate study in the Commission's November 8, 2018 SPD. In the letter, it is incorporated into the H&H Study section. However, in this table only it is listed as a separate study only to illustrate it is being completed by the USGS and a report independent of the H&H Study was provided.

Study	Study Consultant(s)	Study Requirements and Status
		Characterize Sedimentation impacts on upstream water levels over a 50-year period for baseline and anticipated operations (Sections 7 and 8 of the report in Appendix 4)-***Complete***. Analyze the effects of sediment on storage capacity in Grand Lake O' the Cherokees (Grand Lake) using hydraulic outputs from the STM and the United States Army Corps of Engineers (USACE) sediment trapping efficiency calculations downstream of RM 100 (Section 4 of the report in Appendix 4)-***Complete***.
Aquatic Species of Concern	Olsson	Gather existing information and map areas of known areas of paddlefish spawning (Section 4 of the report in Appendix 5)-***Complete***. Review existing information (including density) for Neosho mucket to characterize the physical habitat preferences and spatial and temporal patterns of the species (Section 3 of the report in Appendix 5)-***Complete***. Review existing information (including density) for Neosho madtom to characterize the physical habitat preferences and spatial and temporal patterns of the species (Section 4 of the report in Appendix 5)-***Complete***. Review existing information for Neosho smallmouth bass to characterize the physical habitat preferences and spatial and temporal patterns of the species (Section 4 of the report in Appendix 5)-***Complete***. Review existing information (including density) for rabbitsfoot mussel to characterize the physical habitat preferences and spatial and temporal patterns of the species (Section 4 of the report in Appendix 5)-***Complete***. Review existing information (including density) for winged mapleleaf mussel to characterize the physical habitat preferences and spatial and temporal patterns of the species (Section 4 of the report in Appendix 5)-***Complete***. Conduct targeted field surveys for Neosho mucket in the Spring River between Warren Branch and the confluence with the Neosho River and in the Neosho River between the City of Miami and the confluence with the Spring River), after consultation with the U.S. Fish and Wildlife Service (USFWS), EcoAnalysts, and Tar Creek Trustee Council on the survey design to develop density estimates, availability of spawning habitat during the spawning season, and estimates of the distribution of the species in relevant reaches (Section 4 of the report in Appendix 5)-***Complete***. Conduct targeted field surveys for Neosho madtom to develop density estimates, availability of spawning habitat during the spawning season, and estimates of the distribution of the species in

Study	Study Consultant(s)	Study Requirements and Status
		relevant reaches (Section 4 of the report in Appendix 5)-***Complete***. Assess potential effects of project operation, if any, on the Neosho mucket (Section 4 of the report in Appendix 5)-***Complete***. Assess potential effects of project operation, if any, on the Neosho madtom (Section 4 of the report in Appendix 5)-***Complete***. Assess potential effects of project operation, if any, on the Neosho smallmouth bass (Section 4 of the report in Appendix 5)-***Complete***.
Terrestrial Species of Concern	Horizon Environmental Services	Produce maps that delineate the riverine reaches that would be converted to lentic habitat, over a range of inflow conditions, as the result of water level management associated with Project operations (Section 4 of the report in Appendix 6)-***Complete***. Assess the degree to which anticipated operations would inundate the main entrance to Beaver Dam Cave and compare the frequency of inundation with that associated with baseline operations (Section 4 of the report in Appendix 6)-***Complete***. Determine whether the secondary exit at Beaver Dam Cave suffices to provide an alternative access by gray bats to the cave (during times of inundation) (Sections 3 and 4 of the report in Appendix 6)-***Complete***. Sample for American Burying Beetle (ABB) during the active season in locations that are determined in consultation with the USFWS during the first and final study season (Section 2 of the report in Appendix 6)-***Complete***. If ABB are found within the study area, compare distributions of beetles to inundation maps generated by the CHM for characterizing the effects of Project operations. If areas that support beetles will be inundated as the result of Project operations, coordinate with the USFWS to estimate the level of impact, if any (Section 5 of the report in Appendix 6)-***Complete***.
Wetlands and Riparian Habitat	Horizon Environmental Services	Develop base maps in geographic information systems (GIS), using source data from the National Wetland Inventory (NWI) and potentially other resources of wetland cover types in the Project study area. Cover type maps will be produced from existing resources that will include riparian and wetland vegetation throughout the study area (Attachment A of the report in Appendix 7)-***Complete***. Use the results of the H&H Study to produce maps that depict the change in inundation areas due to anticipated operations versus baseline operations overlayed on the wetland base maps showing the

Study	Study Consultant(s)	Study Requirements and Status
		current Project boundary (Attachment A of the report in Appendix 7)-***Complete***. Assess potential impacts to wetlands and riparian areas by identifying the extent, duration, and seasonality (timing) of inundation occurring in the Project area (Section 2 of the report in Appendix 7)-***Complete***. Verify the accuracy of the base maps through ground-truthing if it is determined anticipated operations are impacting wetlands. Ground-truthing is only required for any major deviations from the preliminary wetland cover-type maps (Section 2 of the report in Appendix 7)-***Complete.***
Recreation Facilities Inventory and Use	Mead & Hunt	Conduct recreation observation surveys at the required recreation facilities (Section 5 of the report in Appendix 8)-***Complete***. Conduct recreation visitor use interviews at the required recreation facilities (Section 5 of the report in Appendix 8)-***Complete***. Conduct facility condition assessments at the required recreation facilities (Section 5 of the report in Appendix 8)-***Complete***. Collect boat launch elevation data (Section 5 of the report in Appendix 8)-***Complete***. Characterize current recreation use and future demand for recreation use at the required recreation facilities (Section 5 of the report in Appendix 8)-***Complete***.
Cultural Resources[9]	Wood E&I Solutions Algonquin Consultants, Inc.	**Wood E&I Solutions** Complete background research and archival review-***Complete***. Complete cultural resource investigations (Section 4 of the report in Appendix 9)-***Complete***. Develop a Historic Properties Management Plan (HPMP)-***Ongoing; updated draft HPMP to be included in the Draft License Application (DLA); final HPMP to be included in the Final License Application***. **Algonquin Consultants, Inc.** Conduct Tribe-specific Traditional Cultural Properties Inventories (Appendix 9)-***Complete***.

[9] Due to the sensitive nature of the cultural resource information, these study reports will not be available to the public, rather, they will be filed with FERC as Privileged. The report will be reviewed by the Cultural Resources Working Group (CRWG).

Study	Study Consultant(s)	Study Requirements and Status
Socioeconomics	Enercon	Describe baseline socioeconomic information and gather/analyze additional economic information (Sections 1 and 2 of the report in Appendix 10)-***Complete***. Assess cumulative socioeconomic impacts (Section 3 of the report in Appendix 10)-***Complete***.
Infrastructure	Mead & Hunt	In consultation with stakeholders, determine a list of infrastructure types to be included in the recommended infrastructure study (Section 4 of the report in Appendix 11)-***Complete***. Analyze the impact of baseline and anticipated operation on the inundation of critical upstream infrastructure by providing maps and tables (Sections 5, 6, and 7 of the report in Appendix 11)-***Complete***.

Each study report is a comprehensive study report that includes information obtained during both the first study season and the final study season. Each study report provides all information specified under FERC's Integrated Licensing Process (ILP) requirements (18 CFR § 5.15) and is generally organized under the following headings:

- Introduction
- Study objectives
- Study area
- Methods
- Results
- Conclusions
- References
- Appendices

2.0 PROCESS AND SCHEDULE OVERVIEW

The current schedule in this ILP began with the Notice of Intent to Relicense (NOI) being filed on February 1, 2017 and is expected to be completed by the time the current license expires on May 31, 2025. The following activities listed in chronological order have dictated the schedule following the filing of the NOI.

2.1 Abeyance Period

On February 15, 2017, Commission staff issued a letter order[10] holding the relicensing process in abeyance until the Commission acted on GRDA's May 6, 2016, request to amend the project's license.[11] The Commission issued an order amending the project license[12] on August 15, 2017, and on August 24,

[10] Letter Order Holding the Pensacola Project's Pre-filing process in Abeyance (February 15, 2017).

[11] GRDA's Application for Non-Capacity Related Amendment of License (May 6, 2016).

[12] Grand River Dam Authority, 160 FERC ¶ 61,001 (2017).

2017, Commission staff issued a letter order[13] (Abeyance Order) that lifted the abeyance and provided an ILP process plan and schedule. As a result, the ILP process resumed on January 12, 2018, and the September 26, 2019, deadline for filing the ISR under 18 CFR § 5.15(c)(1) was established.

2.2 Study Plan Development

According to the Abeyance Order, the deadline for GRDA to file a Proposed Study Plan (PSP) under 18 CFR § 5.11(a) was established as April 27, 2018. On April 27, 2018, GRDA filed its PSP[14] with the Commission and hosted a meeting on the PSP according to 18 CFR § 5.8(b)(3)(viii) on May 30 and 31, 2018. Following the meeting, comments were received on the PSP under 18 CFR § 5.12. GRDA filed its Revised Study Plan (RSP) on September 24, 2018,[15] under 18 CFR § 5.13(a).

2.3 Study Plan Determination

As required under 18 CFR § 5.13(c), on November 8, 2018, within 30 days of the filing of the RSP, the Commission issued its SPD[16] approving the RSP with staff recommended modifications. The SPD made study recommendations outlined in **Table 2**.

Table 2. Summary of Commission Staff Recommendations

Study	Staff Recommendation(s)	Recommended Modification(s)
Hydrologic and Hydraulic Modeling	Approved with modifications	• Increase range of inflow events and starting elevations. • Lotic and lentic mapping for anticipated operations. • Update bathymetry. • Define material difference in Model Input Status Report. • Validate model with RWM. • Use Pensacola Datum. • Provide access to model.
Sedimentation	Approved with modifications	• Update bathymetry. • Create Sediment Transport Model. • Describe observed or predicted effects of sedimentation on the power pool. • Provide access to model.
Aquatic Species of Concern	Approved with modifications	• Estimate proportion of Neosho Smallmouth Bass spawning habitat affected by anticipated operations by literature review in Item 1 and, if necessary, survey under Item 2. • Add Neosho Smallmouth Bass lentic and lotic paddlefish evaluation in Item 3. • Review of existing population density estimates in the Project vicinity for Neosho Mucket, Rabbitsfoot Mussel, Winged Mapleleaf Mussel, and Neosho Madtom.

[13] Letter Order Lifting Abeyance and Providing a Revised ILP Process Plan and Schedule, P-1494-438 (August 24, 2017).
[14] GRDA's Proposed Study Plan, P-1494-438 (April 27, 2018).
[15] GRDA's Revised Study Plan, P-1494-438 (September 24, 2018).
[16] Study Plan Determination, P-1494-438, (November 8, 2018).

Study	Staff Recommendation(s)	Recommended Modification(s)
		• If necessary, survey existing population to estimate density in the Project vicinity for Neosho Mucket, Rabbitsfoot Mussel, Winged Mapleleaf Mussel, and Neosho Madtom.
Terrestrial Species of Concern	Approved	None
Wetlands and Riparian Habitat	Approved	None
Recreation Facilities Inventory and Use	Approved with modifications	• Add Spring River, Council Cove, and Willow Park Survey Sites. • Add Wildlife Viewing as an option in question 10. • Add new question about hunting and wildlife viewing recreation activities participated in near Grand Lake in the past year. • Add rating scale to question 13.
Cultural Resources	Approved with modifications to study plan	• Consult with and request concurrence from the Oklahoma State Historic Preservation Officer (SHPO) and THPOs for tribes with lands within the Project boundary on the final Area of Potential Effect (APE). • Final APE should clearly identify the Project boundary, lands outside the Project boundary that are included in the APE, and the specific locations of any tribal trust lands that GRDA and Bureau of Indian Affairs determine are within the Project boundary. • For the Traditional Cultural Properties (TCP) Inventory, GRDA, to the best of its ability, should prepare a summary of study results to date to be filed with the USR, file individual TCP reports for each tribe upon their completion, and file a final comprehensive TCP report that contains the TCP results for all tribes with the final license application. • Obtain concurrence on survey methods with the SHPO. • Evaluate sites in Section 6.9 of the Pre-Application Document in consultation with the Cultural Resources Working Group. • Include a discussion of any project-related effects to identify TCPs during the TCP Inventory including, but not limited to effects associated with recreation in the cultural resources study report. • File sensitive cultural resources information as “privileged” on the Commission’s website. • Documentation on known sites of cultural property should not be shared with all tribes if the cultural property is traceable to a particular tribe or tribes.
Socioeconomics	Approved with modifications	• Include an appendix in the study report containing electronic copies of documents submitted by

Study	Staff Recommendation(s)	Recommended Modification(s)
		stakeholders and links to publicly accessible web sites containing such documents. • Include within the study report, a summary of the socioeconomic conditions in the four-county study area, but also tabular data on these conditions reported at the county and census tract level, where such data exist. The study report should clearly state which data source was used for each level of aggregation.
Infrastructure	Complete new study requirements	• In consultation with stakeholders, determine a list of infrastructure to be included in the Infrastructure Study. • Using H&H output, determine the range of inflow conditions for which model results show Project operations and other purposes in combination with the USACE’S flood control operations are likely to have an effect on the frequency and depth of flooding. • Provide maps and table identifying the frequency and depth of flooding for each infrastructure item under existing operations and operations for other purposes. • Provide additional maps and tables based on any alternative operating scenarios proposed or developed through consultation.

2.4 Modification of Relicensing Plan and Schedule

On May 20, 2019, GRDA requested a modification of the relicensing plan and schedule. It amended its request on June 17, 2019. The modification was requested because of the unanticipated delays due to the abeyance process, the time required to update the bathymetric data, and the need for the updated bathymetric data before the Hydrologic and Hydraulic Model and the Sedimentation Model could be fully developed. On September 9, 2019, the Commission issued an order extending the license term and modifying the relicensing plan and schedule (Extension Order). The Extension Order waived the one-year requirement under 18 CFR § 5.14(c)(1) and established the deadline for submitting the ISR as September 30, 2021.

2.5 National Defense Authorization Act

On December 20, 2019, Congress enacted the National Defense Authorization Act for Fiscal Year 2020 (NDAA 2020).[17] Importantly, NDAA 2020 includes special legislation applicable only to the Pensacola Project, and it significantly changes the scope of the ongoing relicensing for this Project.

First, NDAA 2020 resolves a long-standing dispute between GRDA and the City of Miami regarding Project lands and lands over which GRDA has a responsibility to obtain title pursuant to Article 5 of its license.[18] In response to the City of Miami’s assertion that GRDA has a license obligation to obtain title to

[17] Pub. L. No. 116-92 (2019).

[18] See, e.g., Formal Complaint of the City of Miami, Oklahoma, Project No. 1494-445 (filed Dec. 26, 2018).

"approximately 13,000 acres of land, including much of the City of Miami" due to periodic flooding,[19] Congress in NDAA 2020 forbids any such requirement in at least three ways:

- First, NDAA 2020 provides that "[t]he licensing jurisdiction of the Commission for the project shall not extend to any land or water outside the project boundary."[20] Thus, NDAA statutorily prohibits the Commission from imposing any license obligation outside of the Project boundary as it existed as of Congress' enactment of NDAA 2020—including any obligation to purchase lands outside the Project boundary.

- Second, NDAA 2020 provides that "[a]ny land, water, or physical infrastructure or other improvement outside the project boundary shall not be considered to be part of the project."[21] This language also confirms that GRDA cannot be required under its license to obtain title to the approximately 13,000 acres identified by the City of Miami.[22] This provision is consistent with the Act of Congress in 1946, which returned the Project to GRDA following World War II, and in doing so retained "all lands or interests therein of the United States above elevation seven hundred and fifty feet mean sea level necessary or desirable for operation of the Grand River Dam project at a pool election of seven hundred and fifty-five feet above mean sea level at the Grand River Dam"—i.e., lands that are needed to support USACE's flood control operations.[23] The savings clauses in NDAA 2020 expressly preserve this provision.[24]

- Third, NDAA 2020 allows FERC to amend the Project boundary "only with the expressed written agreement of" GRDA.[25] If GRDA does not consent to a Project boundary amendment, NDAA 2020 provides that the Commission's responsibilities under the Federal Power Act (FPA) are met without any change to the Project boundary.[26]

Additionally, NDAA 2020 confirms—consistent with the Corps' long-standing jurisdiction under section 7 of the Flood Control Act of 1944[27]—that the Corps has "exclusive jurisdiction and responsibility for management of the flood pool for flood control operations at Grand Lake O' the Cherokees."[28] In addition to confirming the Corps' exclusive jurisdiction for flood control, Congress in NDAA 2020 prohibits the Commission or any other federal or state agency from imposing any license condition related to surface water elevations. NDAA 2020 provides:

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[19] Id. at 2, 37; see also id. at 24–30.
[20] Pub. L. No. 116-92, § 7612(b)(3)(A).
[21] Id. § 7612(b)(3)(B).
[22] See 16 U.S.C. § 796(11) (defining the "project" to include "lands, or interest in lands the use and occupancy of which are necessary or appropriate in the maintenance and operation of" the unit of development); compare Standard Article 5, Form L-3, 54 F.P.C. 1817, 1818–19 (requiring GRDA to acquire lands "necessary or appropriate for the construction, maintenance, and operation of the project").
[23] Pub. L. No. 79-573, § 3, 60 Stat. 743, 744 (1946).
[24] Pub. L. No. 116-92, § 7612(e)(3).
[25] Id. § 7612(b)(3)(C).
[26] Id.
[27] 33 U.S.C. § 709.
[28] Pub. L. No. 116-92, § 7612(c).

> Except as may be required by the Secretary [of the Army] to carry out responsibilities under section 7 of the Flood Control Act of 1944 (33 U.S.C. 709), the Commission or any other Federal or State agency shall not include in any license for the project any condition or other requirement relating to—
>
> (i) surface elevations of the conservation pool; or
>
> (ii) the flood pool (except to the extent it references flood control requirements prescribed by the Secretary).[29]

The only exception to this broad prohibition is a requirement for the Project to "remain subject to the Commission's rules and regulations for project safety and protection of human health."[30]

2.6 Model Input Status Report

As outlined in the RSP, confirmed in the SPD, and clarified in the Commission's Order on Request for Clarification and Rehearing dated January 23, 2020[31], a Model Input Status Report (MISR) was developed and provided to the relicensing participants on March 30, 2021. GRDA held a Technical Conference on April 21, 2021, to summarize the MISR and answer questions.

On June 23, 2021, the City of Miami, OK filed comments on the MISR with the Commission.[32] The City of Miami's comments were addressed in the UHM report contained in **Appendix 2**.

2.7 Initial Study Report

On September 30, 2021, GRDA electronically filed its ISR pursuant to 18 C.F.R. § 5.15(c)(1). In addition to providing a progress report on the completion of the studies, GRDA recommended modifications to the Sedimentation Study and Terrestrial Species of Concern Study.

GRDA also listed variances for the H&H Study, Sedimentation Study, Cultural Resources Study, and Infrastructure Study. For the Sedimentation Study, GRDA requested a schedule variance to provide the calibrated STM by December 31, 2021.

Lastly, the ISR included an agenda for the ISR meeting required to be held within 15 days of the filing of the ISR.

2.8 Initial Study Report Meeting

Consistent with requirements under 18 CFR § 5.15(c)(2), GRDA held a virtual meeting with agencies and other interested parties and Commission staff to discuss the 2021 study results reported in the ISR and plans for completing the study program. The meeting took place on October 12 and 13, 2021.

[29] Id. § 7612(b)(2)(A).

[30] Id. § 7612(b)(2)(B).

[31] Grand River Dam Authority, 170 FERC ¶ 61,027 (2020).

[32] Comments of Tetra Tech on Behalf of the City of Miami, Oklahoma (Corrected) on Mead & Hunt's H&H Modeling Upstream Hydraulic Model Input Status Report on behalf of GRDA, June 23, 2021.

2.9 Initial Study Report Meeting Summary

As required under 18 CFR § 5.15(c)(3), GRDA filed a meeting summary on October 29, 2021, including any proposed modifications to ongoing studies and no new studies were proposed.

2.10 Initial Study Report Comments

Pursuant to 18 CFR § 5.15(c)(4) and in response to the ISR, within 30 days of the filing of the meeting summary, requests for modifications to the H&H Study, Sedimentation Study, Aquatic Species of Concern Study, Cultural Resources Study, Socioeconomic Study, and Infrastructure Study were made by relicensing participants. In addition, a Contaminated Sediment Transport Study was requested as a new study.

2.11 GRDA Response to Comments and Updated Sedimentation Study Report

In accordance with 18 CFR § 5.15(c)(5), and within 30 days of receipt of the request for modifications and new studies, GRDA, on December 29, 2021, filed its responses to comments on the ISR. In addition to the responses to comments, GRDA included an updated Grand Lake Sedimentation Report[33] (Appendix D of the filing), proposed several enhancements and other modifications to the study plans for the final study season including a detailed proposed modified study plan for the Sedimentation Study (Appendix E of the filing) and an invitation for relicensing participants to attend a technical meeting about the proposed modified study plan on January 14, 2022.

Based on comments received from agencies and other relicensing participants, GRDA modified its second season study plans as provided in the subsections that follow.

2.11.1 H&H Study

As stated in the ISR, GRDA proposed the following activities during the final study season for the H&H Study:

- Update OM as described in OM ISR and based upon comments.
- Update Upstream Model based upon comments.
- Update Downstream Model based upon comments.
- Run anticipated operations for upstream and downstream model.
- Provide Lentic and Lotic Maps for current and anticipated operations, as needed, in the Aquatic Species of Concern, the Terrestrial Species of Concern, and the Wetland and Riparian Study.

Based on comments received from resource agencies and other relicensing participants, GRDA proposed the following additional activities for the H&H Study during the final study season:

- In response to comments from Commission staff, the title of Table 1 of the Upstream Hydraulic Modeling Report has been updated to: “Summary of historical event boundary conditions used in Upstream Hydrologic Model (UHM) calibration.” The revised table title more accurately describes the information included in the table. In addition, GRDA has included the following tables in the appendices of the USR:

[33] In the September 30, 2021, ISR, GRDA proposed a schedule variance to provide an updated report including a calibrated STM by December 31, 2021.

  - Tables of maximum water surface elevation (feet, PD) for each simulation.
  - Tables of maximum extent of inundation (feet) for each simulation.[34]
  - Tables of duration of inundation (hours) for each simulation.

- In response to comments from the City of Miami, now that the OM has been validated against RWM output, the Operations Model has been updated to include the 2019 elevation-storage data. Because the OM simulations were updated as part of the USR development, the updated simulation results were used to review the CHM results and the CHM simulations were re-run. The conclusions of the CHM simulations did not change. Therefore, the studies that depended upon the conclusions of the CHM did not change.

- In response to comments from the City of Miami, GRDA simulated the inflow hydrographs from the Federal Emergency Management Agency's (FEMA) 2019 study (including the Neosho River hydrograph with a peak flow of 165,000 cfs at the Commerce gage) despite the methodological flaws in the 2019 FEMA study hydrology. GRDA simulated starting reservoir elevations as low as 734 feet PD and as high as 757 feet PD. Water surface elevation profiles for this set of simulations were included as Appendix B to GRDA's December 29, 2021 response to comments. Despite the methodological flaws in the 2019 FEMA study, the results are very similar to the 100-year event simulation results in the ISR. A starting reservoir elevation difference of 23 feet resulted in no appreciable difference in maximum water surface elevation at the City of Miami. Inflow hydrographs from the 2019 FEMA study and the hydraulic results displayed in Appendix B of the December 29, 2021 filing should not be misconstrued as a replacement of the 100-year event results included in GRDA's UHM Report. GRDA completed this exercise as a courtesy to the City of Miami, following the ISR. The purpose of the work was to show relicensing participants how the modification to the 100-year inflow hydrographs would not change the conclusions of the H&H Study. GRDA did not propose to conduct further analysis of the 2019 FEMA hydrographs in the second study season.

- In response to comments from the City of Miami on the ISR, GRDA performed a sensitivity analysis to determine the impact of the abandoned railway bridge high chord on upstream water surface elevations. Of all the historical inflow events used in the simulation scenarios (see Section 7 of the UHM ISR), only the July 2007 event exceeded the high chord of the bridge in the Neosho River channel. Two geometries were tested in the sensitivity analysis: (1) the original geometry used in the ISR, and (2) a flat deck with the bridge trusses completely removed from the high chord. Water surface elevation profiles from the sensitivity analysis were included as Appendix C of the December 29, 2021 response. The results showed that removing the trusses from the high chord of the bridge resulted in no appreciable difference in maximum water surface elevation upstream of the bridge. The results of the sensitivity analysis displayed in Appendix C of the December 29, 2021 response should not be misconstrued as a replacement of the results included in GRDA's UHM ISR. GRDA completed this exercise as a courtesy to the City of Miami, after receiving the City of Miami's comments on the ISR. The purpose of the work was to show

[34] As discussed in Section 2.13, the Commission staff clarified in its February 24, 2022 determination letter that GRDA should report maximum extent of inundation in acres.

relicensing participants how the simulation results were insensitive to the bridge high chord. GRDA did not propose to change the bridge high cord as set forth in the UHM during the second study season.

2.11.2 Sedimentation Study

As stated in the ISR, GRDA proposed to complete the following activities during the final study season for the Sedimentation Study:

- Update Sediment Transport Model based upon comments;
- Run Sediment Transport Model for current operation;
- Run Sediment Transport Model for anticipated operations; and
- Describe observed or predicted effects of sedimentation on the power pool.

In addition, the ISR included an interim study report for the sedimentation modeling work conducted at the time of the ISR, noting GRDA's expectation that a full report would be completed by December 31, 2021, once calibration of the model was complete. GRDA completed the work and a full Grand Lake Sedimentation Study report was included in Appendix D of GRDA's December 29, 2021 response. Based on GRDA's completed calibration effort, GRDA proposed significant changes to the Commission-approved Sedimentation Study. Because GRDA's calibration efforts were ongoing at the time GRDA completed the ISR, as well as during the ensuing meetings and comment period and only completed the work in late December 2021, GRDA proposed a final-season modification to the Sedimentation Study, which appeared in Appendix E of the December 29, 2021 response.

The revision to the FERC-approved study plan for the Sedimentation Study was warranted for several reasons:

- The information provided by the City of Miami during the PSP and RSP stages of study plan development, alleging that the bed of the river/reservoir system consisted primarily of sand and that cohesive sediment need not be considered, proved to be incorrect. Field data proved that the sediment being transported down the rivers and into the reservoir consists primarily and predominantly of silt and clay which are cohesive in nature. This required collection of core samples and laboratory testing of cohesive sediment using SEDflume.

- SEDflume analysis demonstrated that the cohesive sediment characteristics, including density, critical shear stress and erosion rate, vary widely with depth below the sediment surface (485%, 3000%, and 10,000%, respectively). These characteristics also tend to vary over time as cohesive sediment tends to consolidate and gain strength as time goes on.

- While HEC-RAS in the sediment transport mode allows sediment density to change over time, it only allows one set of parameters for cohesive erosion characteristics which does not vary with depth below the sediment surface and does not change over time. As a result, any selected set of parameters can significantly misrepresent the complexity of cohesive sediment modeling.

- Testing of the STM demonstrated significant inconsistencies with reality which indicate it cannot reasonably be expected to simulate the complexities of cohesive and non-cohesive sediment found in this river and reservoir system with any acceptable degree of confidence.

- Sediment transport (whether cohesive or non-cohesive) is driven by the hydraulic shear stresses exerted by flowing water over the bed of a river or reservoir. Analysis of the distribution of hydraulic shear stresses as they vary over the longitudinal extent of the river/reservoir system can be related to the pattern of sedimentation that occurred over the time period from 2009 to 2019 when cross-section and bathymetry data are available.

Further, the City of Miami cited the “widely-accepted ASCE Manual” in their comments on GRDA’s RSP, stating “where full calibration is not possible, ‘model tests are devised so that engineering judgment can be used to assess the credibility of the calculated results.’” As detailed in the Sedimentation Study Report, tests were performed, and the results were incorrect, leading to the conclusion that the STM was unreliable as a predictive tool for sedimentation.

As a result of the conclusion regarding the unreliable predictive nature of the STM, GRDA planned to convene a technical meeting to present the results of the STM calibration. Since GRDA concluded that the STM recommended by Commission staff in its SPD would not simulate the complexities of cohesive and non-cohesive sediment found in this river and reservoir system with any acceptable degree of confidence, the technical meeting presented an opportunity for relicensing participants to discuss GRDA’s proposed modification to the Sediment Study plan.

The technical meeting was held on January 14, 2022.

Finally, based on comments received from resource agencies and other relicensing participants, in Section 5.1.2.1 of the ISR for the Sedimentation Study appearing in Appendix D to the December 29, 2021 response, GRDA clarified in detail how flow roughness factors were changed to calibrate the model. The section also included explanations for those changes.

2.11.3 Aquatic Species of Concern Study

2.11.3.1 Neosho Mucket

As stated in the ISR, GRDA proposed the following activities during the final study season for the Neosho mucket:

- The study area would consist of the Elk River from the Oklahoma/Missouri State line to the confluence of Buffalo Creek.
- A phased sampling design incorporating both Qualitative and Quantitative methods would be used.
- Qualitative surveys would characterize the substrate, identify potential mussel beds, and potential presence of live mussels within the study area.
- A minimum search time of five person-hours (divided into five one person-hour searches) would be conducted within the delineated search area.
- If no live mussels are encountered after the first three one-person hour searches, surveys within this location would cease and it would be assumed no live mussels are present.

- At the end of each search period, collected mussels would be identified and enumerated.
- If no new species of mussels were collected during the fifth search period, the survey was complete.
- If at least one new mussel species was collected in the fifth search period, additional one person-hour search periods were required until no new species were collected.
- Visual, combined with tactile searching (hand-grubbing into the top 1-4 inches of substrate to increase detection of more-deeply buried mussels) would be used.
- Searchers would select a shoreline and begin searching from downstream to upstream moving back and forth across the stream, ensuring that all the delineated search area was sufficiently covered.
- If listed mussels were detected, initial surveys would immediately cease, and quantitative methods would commence.
- Quantitative surveys would involve sampling on mussel beds identified during qualitative surveys to quantify the mussel populations.
- Quantitative point sampling would be conducted on mussel beds by randomly selecting 0.25 m^2 quadrats plots within each bed.
- Systematic sampling would incorporate three random starts with 2 additional quadrats selected at 1-m intervals (9 quadrats per sample/site).
- Additional, randomly selected quadrat points would be available to replace locations that do not provide mussel habitat (e.g., too close to shore, water depth, poor substrate).
- Quantitative surveys would be performed by visual and tactile searches of randomly placed 0.25 m^2 quadrats placed at random locations as outlined above.
- Substrate within the quadrats would be excavated to a depth of 20 cm and sieved, as this increases the likelihood of detecting juvenile mussels.
- All live individuals would be identified, enumerated, and returned to the approximate location of collection.
- Shell material would also be collected and quantified during sampling from the stream and classified as fresh dead (FD; intact periostracum and lustrous nacre), weathered dead (WD; intact periostracum, weathered and chalky nacre), or subfossil (SF; shell chalky, no periostracum).

2.11.3.2 Rabbitsfoot

As explained in the ISR, GRDA completed all requirements of the FERC-approved study plan relative to the rabbitsfoot mussel in the first study season. Because records received by GRDA indicated that neither the rabbitsfoot nor its host species have been present at sampling events in the Neosho, Spring, and Elk Rivers over the past 18 years, any additional study on this species was unwarranted.

In their comments on the ISR, no relicensing participant recommended any proposal to modify this study during the second study season, nor did any relicensing participant disagree with GRDA's conclusion that no further study on the rabbitsfoot was needed. Accordingly, GRDA maintained its view that any additional study of the rabbitsfoot was unwarranted. However, GRDA agreed to report any occurrences of rabbitsfoot in the survey for the Neosho mucket.

2.11.3.3 Winged Mapleleaf

As explained in the ISR, GRDA completed all requirements of the FERC-approved study plan relative to the winged mapleleaf mussel in the first study season. A 5-year review of the species completed in 2015 indicated the species is considered extirpated from the Neosho River and Spring River in Kansas and no known populations occur within the larger Grand Lake watershed or the Neosho River Basin. For that reason, GRDA concluded that any additional study on this species was unwarranted.

In their comments on the ISR, no relicensing participant recommended any proposal to modify the study during the second study season, nor did any relicensing participant disagree with GRDA's conclusion that no further study on the winged mapleleaf was needed. Accordingly, GRDA maintained its view that any additional study of the winged mapleleaf was unwarranted. However, GRDA would report any occurrences of winged mapleleaf in the survey for the Neosho mucket.

2.11.3.4 Neosho Madtom

As stated in the ISR, GRDA proposed the following activities during the final study season for the Neosho madtom:

- A 20-mile stretch of the river from HWY60 to the county border would be assessed in locations that contain riffles and moderate to low-velocity gravel bar habitats. Fish sampling would be conducted between late summer and early fall at selected sites where riffles and gravel bars are identified via review of aerial imagery that are readily accessible via public roads, bridges, or access points.

- Fish sampling would be conducted by kick-seining (4.6 m x 1.8 m seine with 3.2 mm mesh) by one or two individuals thoroughly disturbing the substrate beginning four meters upstream from a stationary seine and then kicking in a downstream direction to the seine's lead line.

- Kick-seining would start at the downstream end of a habitat and proceeded laterally and then upstream with multiple kick-seine efforts until all habitat less than one meter deep at a site had been sampled.

- All fishes captured would be identified to species, measured for total length to the nearest millimeter, counted, and then returned to the stream.

Both Commission staff and USFWS submitted clarifying comments and questions related to GRDA's proposed study of the Neosho madtom during the final study season. Based on comments received, GRDA proposed the following changes for the Neosho madtom component of the Aquatic Species of Concern study:

- On the Neosho River, instead of surveying downstream to the HWY60 bridge, GRDA agreed to limit the study area to the Interstate 44 bridge. This decision was based on further consideration of the habitat requirements of the Neosho madtom, current information, and knowledge of existent habitat conditions downstream of this point as indicated by other studies in the ISR. The upstream range of the studies would extend to the "Neosho 2" site. Neosho 2 is located near the originally proposed Craig and Ottawa county border.
- Based on comments received on the ISR, GRDA agreed to expand surveys to include the Spring River. On the Spring River, GRDA planned to survey between the Interstate 44 bridge to the HWY 10 Bridge. Methods used for assessment on the Spring River would be identical to the Neosho River.

2.11.3.5 Neosho Smallmouth Bass

As stated in the ISR, GRDA proposed a modification to FERC's SPD to eliminate any future work on the Neosho smallmouth bass. GRDA explained that records show that a smallmouth bass population is present within the drainages surrounding the Project, but that there was no determination that the Neosho subspecies was identified. Because the Neosho smallmouth bass has no state or federal listing, and the cost of the additional work was expected to be approximately $100,000, GRDA did not believe that the results of any study would justify the cost.

Based on comments received from Commission staff and the Oklahoma Department of Wildlife Conservation (ODWC) and based on further consultation with ODWC following the ISR meetings, GRDA maintained its view that any additional study of the Neosho smallmouth bass was unwarranted.

2.11.3.6 Paddlefish

As stated in the ISR, GRDA proposed a modification to FERC's SPD to eliminate any surveys or additional work on paddlefish spawning habitat during the final study season. GRDA explained that the background research completed in the first study season showed the availability of continuous high flows during spawning has a significant effect upon paddlefish spawning success. The H&H Modeling Study demonstrated Project operation has an immaterial impact on upstream water surface elevations and consequently the hydraulic conditions which paddlefish seek at upstream spawning sites during high inflow conditions. Because inflow events—regardless of any future operations of the Project—will continue to dominate hydraulic conditions at upstream spawning sites, and because there is an abundance of paddlefish spawning habitat, additional studies were unwarranted.

In comments filed on the ISR, no relicensing participant recommended any proposal to modify this study during the final study season, nor did any relicensing participant disagree with GRDA's conclusion that no further study on the paddlefish was needed. Accordingly, GRDA maintained its view that any additional study of the paddlefish was unwarranted.

2.11.4 Terrestrial Species of Concern Study

2.11.4.1 American Burying Beetle

As stated in the ISR, GRDA proposed to discontinue the survey for ABB for the final study season. GRDA explained that the results of the H&H Modeling Study demonstrate that future operational changes that may be implemented by GRDA within the conservation pool of Grand Lake will not appreciably influence water levels beyond the current Project boundary. Moreover, GRDA explained that because ABB only uses areas with a soil and/or leaf litter substrate and vegetated cover (as opposed to bare rocky or sandy shorelines), suitable habitat within the Project boundary is limited.

In comments filed on the ISR, no relicensing participant recommended any proposal to modify this study during the second study season, nor did any relicensing participant disagree with GRDA's conclusion that no further study on the ABB was needed. Accordingly, GRDA maintained its view that any additional study of the ABB was unwarranted.

2.11.4.2 Gray Bat

As stated in the ISR, GRDA proposed to continue gray bat surveys during the final study season, as provided in the FERC-approved study plan, with no modifications.

In their comments on the ISR, no relicensing participant recommended any proposal to modify this study during the final study season. Accordingly, GRDA maintained its view that the gray bat surveys should continue during the second study season in accordance with the FERC-approved study plan, with no modifications.

2.11.5 Wetland and Riparian Habitat Study

As stated in the ISR, GRDA proposed the following activities during the final study season for the Neosho mucket:

- Once the lentic and lotic maps were produced by the H&H Study, changes in wetland inundation and riparian habitat due to anticipated operations would be analyzed.

- If it was determined that anticipated operations would be impacting wetlands, the accuracy of the base maps would be verified, as necessary, through ground-truthing.

Based on comments received from resource agencies and other relicensing participants, GRDA proposed the following additional activities for the Wetland and Riparian Habitat Study during the final study season:

- In response to a comment from Commission staff, GRDA would file the GIS data layers for the survey as part of the USR.

2.11.6 Recreation Facilities Inventory and Use Study

As explained in the ISR, GRDA completed all requirements of the FERC-approved study plan relative to the Recreation Facilities Inventory and Use Study. Therefore, GRDA proposed no further activities for this study during the final study season.

In their comments on the ISR, no relicensing participant recommended any proposal to modify this study during the final study season, nor did any relicensing participant disagree with GRDA's conclusion that the Recreation Facilities Inventory and Use Study was complete. Accordingly, GRDA maintained its view that any additional study of recreation resources was unwarranted.

2.11.7 Cultural Resources Study

As explained in the ISR, GRDA made substantial progress in meeting the requirements of the Commission-approved studies for cultural resources in the first study season. Working closely with the CRWG, GRDA completed a cultural historic investigation, archaeological investigations in 2019, 2020, and 2021, and initiated efforts to complete a TCP inventory within the Project's APE.

As noted in the ISR, the following additional work was planned to occur during the final study season:

- Report results of the archaeological reconnaissance on five sites not included in the ISR.
- Determine National Register of Historic Places (NRHP) eligibility on recommended sites in consultation with CRWG.
- Report the results of the surveys on the remaining bluff areas not included in the ISR.
- Complete surveys and report the results of the remaining three (3) areas in the USR.
- Continue with TCP inventory.
- Continue to adjust the testing interval density for quaternary landforms (Qals) based upon in-field conditions as necessary during remaining surveys using the adjusted survey methods for buried archaeological deposits.

In addition, on December 13, 2021, GRDA held its quarterly meeting with the CRWG, in which it presented its proposed fieldwork plan for the final study season. CRWG participants reviewed the plans and GRDA implemented the 2022 fieldwork based on feedback from the CRWG.

Also, based on written comments received from CRWG in response to the ISR, GRDA proposed several activities for the Cultural Resources Study during the final field season.

Most comments on GRDA's Cultural Resources Study from CRWG members highlighted the desire for ongoing fieldwork. GRDA appreciates these comments and committed to completing the work outlined above. GRDA noted that while CRWG members' requests were consistent with GRDA's overall Cultural Resources Study Plan, some of the fieldwork would not be possible in 2022, as GRDA would need to shift its efforts to preparing the HPMP. The work that could not be completed in 2022 would be completed pursuant to the requirements of the HPMP.

2.11.8 Socioeconomic Study

As explained in the ISR, GRDA completed all requirements of the FERC-approved study plan relative to the Socioeconomics Study. Therefore, GRDA proposed no further activities for this study during the final study season.

GRDA received a number of proposed modifications to the Socioeconomics Study—all from the City of Miami. GRDA did not propose to adopt any of the proposed modifications. Rather, GRDA maintained its view that the Socioeconomics Study was complete and that any additional study of socioeconomic resources was unwarranted.

GRDA recognized that, should conclusions of the H&H Modeling Study change during the final study season, GRDA would update the other studies, including the Socioeconomic Study, as needed. Any such changes would appear in the USR.

2.11.9 Infrastructure Study

As explained in the ISR, GRDA completed all requirements of the FERC-approved study plan relative to the Infrastructure Study. Therefore, GRDA proposed no further activities for this study during the final study season.

GRDA received two proposed modifications to the Infrastructure Study—both from the City of Miami. GRDA did not propose to adopt either of the proposed modifications. Rather, GRDA maintained its view that the Infrastructure Study was complete and that any additional study of infrastructure was unwarranted.

GRDA recognized that should conclusions of the H&H Modeling Study change during the final study season, GRDA would update the other studies, including the Infrastructure Study, as needed. Any such changes would appear in the USR.

2.12 Sedimentation Study Technical Meeting

On January 14, 2022, GRDA held a virtual technical meeting for the Sedimentation Study. The purpose of the technical meeting was to review the results of the Sedimentation Study since the ISR and discuss GRDA's proposed modified study plan for the study as described in its December 29, 2021 response.

The list of attendees for the meeting was attached along with the presentation.

2.13 Determination on Requests for Study Modifications and New Studies

On February 24, 2022, pursuant to 18 CFR § 5.15(c)(5), the Commission issued its SMD containing determinations on requests for modifications to the approved study plans. Comments on the ISR had been submitted by the Bureau of Indian Affairs, the ODWC, the City of Miami, USFWS, Oklahoma Archaeological Survey, and the Cherokee Nation. GRDA responded to comments received on the ISR on December 7, 2021 in addition to its December 29, 2021 response outlined in Section 2.11.

Several of the comments on the ISR did not request study modifications, but provided additional information, recommended protection, mitigation, and enhancement measures, discussed ongoing and future consultation, or requested additional information that depends upon future study results. Therefore, those comments were not addressed in the Commission's February 2022 SMD.

According to section 18 CFR § 15(d), requested study modifications must include a showing of good cause and must include demonstration that the approved study was not conducted as provided for in the approved study plan or the study was conducted under anomalous environmental conditions or environmental conditions have changed in a material way. Based on this standard, Commission staff in its SMD recommended modifications for the H&H Study, Aquatic Species of Concern Study, and the Infrastructure Study.

Staff approved the following modifications to the H&H Study:

- Make the OM, model inputs, and model outputs, without commercially-sensitive financial information, available to Commission staff and relicensing participants within 60 days of February 24, 2022.
- Run operating scenarios starting at elevation 734 feet PD and extending up to and including elevation 757 feet PD.
- Provide the following information in the USR in tabular form: (1) maximum water surface elevation (feet); (2) maximum extent of inundation (acres); and (3) duration of inundation (hours).
- Report the frequency, timing (i.e., seasonality)[35], amplitude (i.e., elevation), and duration for each of the simulated inflow events with starting elevations between 734 feet and 757 feet PD.
- Compare water surface elevations observed at USGS gage no. 0719500 (Neosho River near Langley, OK) to the simulated HEC-RAS state hydrographs for the December 2015 and October 2009 inflow events on the upstream side of the dam.
- Provide a graphical comparison of the simulated and observed water surface elevations over a daily time step for the duration of the flood event.

Staff approved the following modifications to the Aquatic Species of Concern Study:

- Conduct a targeted freshwater mussel survey in the Spring River between Warren Branch and the confluence with the Neosho River and in the Neosho River between the City of Miami and the confluence with the Spring River as recommended by the USFWS, after consultation with FWS, EcoAnalysts, and TCTC on the survey design.

[35] The terms "timing" and "seasonality" are interchangeable as stated in Section 2.6.2 of the Wetlands and Riparian Habitat Study RSP submitted to the Commission on September 24, 2018.

Staff approved the following modifications to the Infrastructure Study:

- Depict, on maps, and in tabular format, the change in flood depth and frequency for each affected infrastructure location with the same starting elevations required in the H&H Study.
- Include inundation maps and tabular data for the June 2004 (1-year flood), and October 2009 (3-year flood) in addition to the September 1993, July 2007, and December 2015 events.
- Revise the Infrastructure Study report to present tables and maps that clearly show both the depth and frequency of flooding (i.e., return period) for each modeled event.

All other requested modifications were not approved by Commission staff.

According to Section 18 CFR § 15(e), requests for new studies must include an explanation of any material change in any applicable law or regulation, why the goals and objectives of the approved study could not be met with the approved methodology, why the request was not made earlier, significant new information has become available, and why the new study satisfies the criteria of 18 CFR § 5.9 (b). Based on this standard, Commission staff did not approve the City of Miami's request for a Contaminated Transport Study.

Finally, Commission staff's February 2022 SMD deferred its decision regarding the Sedimentation Study. Instead, staff allowed relicensing participants 30 days to file comments on the first study season report on the Sedimentation Study, followed by a 30-day period for GRDA to respond to comments. Staff's February 2022 SMD indicated that they would issue its decision on the Sedimentation Study following their review of these comments.

2.14 Second Proposed Study Modification for the Sedimentation Study

In response to the Commission's creation of additional opportunities to provide comments on the Sedimentation Study, the City of Miami filed comments on March 28, 2022. GRDA responded to the City of Miami's comments in its April 27, 2022 filing.

In addition to responding to the City of Miami's comments, GRDA proposed a compromise solution, in an effort to resolve the difference of opinion between GRDA and the City of Miami on how best to investigate sedimentation in Grand Lake.[36] The updated study plan proposed by GRDA in its April 27 filing satisfied the goals and objectives established by Commission staff for the Sedimentation Study and proposed a new approach that used the STM using HEC-RAS, but truncated to the upper reach of Grand Lake and the Neosho and Spring Rivers in which the City has expressed its greatest interest. The new approach also considered other methodologies to address the complexities of the silts and clays dominating the system.

[36] The Commission later refers to the Updated Study Plan in its May 27, 2022 determination letter as the second proposed plan modification.

2.15 Operations Model Technical Conference

On April 20, 2022, GRDA held a technical conference to allow relicensing participants to ask questions regarding the Operations Model, discuss planned improvements to the model, and present the results of two historical validation cases recommended by the Commission.

2.16 Determination on Requests for Study Modifications to Sedimentation Study Plan

On May 27, 2022, pursuant to 18 CFR § 5.15 (c)(5) the Commission provided a letter containing determinations on requests for modifications to the approved Sedimentation Study plan.

Commission staff approved the following modifications to the Sedimentation Study:

- Extend the downstream modeling limit for HEC-RAS to the U.S. Route 59 crossing at RM 100.
- Analyze the effects of sediment on storage capacity in Grand Lake using hydraulic outputs and the USACE sediment trapping efficiency calculations downstream of RM 100.
- Run the UHM model with the 2019 geometry to provide a baseline for comparison against predicted geometry results.
- Run the UHM using, at a minimum, starting reservoir elevations of 740, 745, and 750 feet PD to understand the effects of project operation and predicted channel geometry on upstream water levels.
- Run the UHM with the predicted channel geometries and starting reservoir elevations of 740, 745, and 750 feet PD and using, at a minimum, the simulated 100-year inflow event and the historic July 2007 inflow event to determine operational scenarios most-likely to result in significant effects on the upstream water surface elevations.

All other requested modifications were not approved.

2.17 Reporting Timeline through the USR Process

Following submittal of this USR and consistent with requirements under 18 CFR § 5.15(c)(2), GRDA will, (within 15 days following the filing of the USR), hold a meeting with agencies and other interested parties and Commission staff to discuss the 2022 study results reported in the USR. The meeting will take place on October 12 and 13, 2022 beginning at 9:00 a.m. The meeting will be held virtually.

Under 18 CFR § 5.15(c)(3), within 15 days following the USR meeting or by October 30, 2022, GRDA will file a meeting summary. Under 18 CFR § 5.15(c)(4), FERC staff or any agency and other interested party may file a disagreement concerning GRDA's meeting summary within 30 days of its issuance or by November 29, 2022. This filing must set forth the basis of any disagreement with the material content of GRDA's meeting summary and propose any desired alternative modifications to ongoing studies or new studies. Under 18 CFR § 5.15(c)(5), GRDA will then have 30 days to respond to any disagreements by

December 29, 2022. Within 30 days of GRDA's response or by January 28, 2023, under 18 CFR § 5.15(c)(6), any remaining disagreements will be resolved by the Commission, and the study plan will be amended as appropriate.

The proposed timeline for these actions, as modified by the Commission's 2019 license Extension Order, is presented in **Table 3**.

Table 3. Reporting and review opportunities associated with the ISR and USR

Activity or Information Sharing	Commission Deadline
File USR	September 30, 2022
Hold USR meeting (meeting on study results and any proposals to modify study plan)	October 12 and 13, 2022
File USR Meeting Summary	October 30, 2022
File Meeting Summary Disagreements	November 29, 2022
File Responses to Disagreements	December 29, 2022
Commission Resolution of Disagreements	January 28, 2022

3.0 STUDY VARIANCES

Under 18 CFR § 5.15(f), the USR must include "an explanation of any variance from the study plan and schedule." As discussed below, this USR includes only one variance from the FERC-approved study plan.

As noted in **Table 1**, GRDA encountered only one variance from the Commission-approved study plan during the final study year. As described in Section 3.1, this variance occurred in the Sedimentation Study.

3.1 Study Variances

Sedimentation

The Sedimentation Study was completed in accordance with the RSP, as modified by the Commission staff in both the November 8, 2018 SPD, and May 27, 2022 Determination letter except for one variance in the usable dataset.

As outlined in the April 27, 2022 Updated Study Plan (second proposed plan modification), GRDA planned to include the entire 2009 OWRB survey dataset of Grand Lake to calibrate the STM.

However, as stated in Section 2.1.1.5.1 of the updated Sedimentation Study report included as **Appendix 4** of this USR regarding the 2009 OWRB dataset, GRDA explained:

> *"Although it is the best available dataset from this timeframe, it shows significantly more sedimentation than is realistic given incoming sediment loads. The total incoming sediment volume from 1940 to 2019 is approximately 234,974 acre-feet with an incoming sediment load of approximately 327,044,375 tons,*

> *which converts to a sediment density of 63.9 pounds per cubic foot (pcf). The same calculation based on volume change and sediment load from 1940 to 2009 results in a computed sediment density of approximately 115.5 pcf, whereas the 2009 to 2019 calculation results in a sediment density of 10.6 pcf. This disparity of calculated sediment densities between the 1940 to 2009 and 2009 to 2019 data demonstrates the issue with the bathymetric surveys compared to sediment load. The issue with this dataset is not simply that deposition was near the dam because hyperpycnal flows are capable of bringing sediment to the lower reservoir. The issue is the total volume of deposition given the incoming sediment load."*

To explain the total volume disparity, an April 20, 2022 e-mail exchange between GRDA's representative and USGS indicated the USGS had not found any major issues with the 2009 bathymetric dataset. However, the USGS also believed the 2009 dataset tends to show much greater variability in flat areas compared with 2019 data. GRDA suspects that the disparity had to do with correction processes such as GPS and temperature correction issues and boat movements.

The impossibly high deposition in the lower reservoir led GRDA to use only the portion of the 2009 OWRB dataset above RM 100 for calibration purposes. In GRDA's analysis, the reservoir downstream of RM 100 was evaluated using the total change from 1940 to 2019. This preserved a reasonable long-term estimate of total deposition in the conservation pool while not utilizing portions of the 2009 OWRB dataset where USGS noted greater variability in the data and where GRDA's analysis showed more-than-realistic sedimentation, given incoming sedimentation loads.

Because the dataset has documented quality control and there is a known date of data collection, GRDA used the 2009 data for calibration and validation upstream of RM 100. However, as explained above, deposition in the lower reservoir is not realistic given the sediment loading between 1940 and 2009, so the 2019 USGS survey was used for long-term evaluation data below RM 100.

The use of the 2009 OWRB dataset upstream of RM 100 and not downstream of RM 100 is a variance from the approved Sedimentation Study Plan.

As outlined in **Table 4** below, the partial use of the 2009 OWRB dataset is the only variance to any of GRDA's approved Study Plans in development of this USR.

Table 4. Study Variances During Final Study Year

Study	Variance(s)
Hydrologic and Hydraulic Modeling	None
Sedimentation	Partial Use of 2009 OWRB Bathymetric dataset for calibration.
Aquatic Species of Concern	None
Terrestrial Species of Concern	None
Wetland and Riparian Habitat	None
Recreation Facilities Inventory and Use	None

Study	Variance(s)
Cultural Resources	None
Socioeconomics	None
Infrastructure	None

4.0 STUDY SUMMARIES

4.1 Hydrologic and Hydraulic Study

The H&H Study was included as a study in the relicensing process because Project operations influence water levels both upstream and downstream of the Pensacola Dam. The H&H Study was intended to quantify the influences and improve the understanding of the magnitude, duration, and frequency of influences. Also, it identified operational sources of such influences and was intended to assist in analyzing resource-level effects that could be associated with the influences. The H&H Study was also intended to help identify changes in areas that are inundated, if any, that may be associated with any changes to baseline operations that are anticipated by GRDA.

An H&H Study was first proposed by GRDA as part of the Pre-Application Document (PAD).

The Commission staff requested a “Flooding and Sedimentation Study” which became the H&H Study in their Study Request Letter dated March 13, 2018[37]. Staff’s reasoning for requesting the study is best outlined in their stated nexus which was as follows:

> “GRDA does not propose any changes in current operation. However, upstream flooding has been an ongoing issue in the project area. Information gathered through this study would allow stakeholders to develop an understanding of the interactions between project operation and flooding, the specific factors or project elements that can influence flooding, and associated effects on other resources…” The collection of data from this study would provide the basis for potential license requirements pertaining to project operational constraints and/or environmental measures necessary to protect, mitigate for, or enhance aquatic, terrestrial, recreation, and cultural resources around the project. This information would also be important in determining whether the current project boundary is appropriate.”

The RSP states the nexus for H&H Study as the following:

> “Project operation influences water levels of the Grand/Neosho River, as well as some tributaries, both upstream and downstream of Pensacola Dam. The H&H Study will help quantify these influences; improve understanding of the magnitude, duration, and frequency of such influences; identify the operational sources of such influences (e.g., hydroelectric operations or USACE flood control operations); and assist in analyzing resource-level effects that could be associated with these influences. The H&H Study will also help identify changes in areas

[37] Staff Comments on the Pre-Application Document and Study Request for the Pensacola Hydroelectric Project, P-1494-438 (March 13, 2018).

inundated, if any, that may be associated with any changes to current operations that may be proposed by GRDA as part of the relicensing effort."

The study plan was first presented in the PSP and was later modified by Commission staff in its SPD based upon relicensing participant comments for the RSP. Following the ISR, Commission staff again required some refinements to the study plan, as set forth in the February 24, 2022 SMD.

The H&H Study has two main areas:

- Determine the effect of initial water surface elevations (WSELs) on the extent of inundation upstream of Pensacola Dam; and
- Provide lentic and lotic maps for baseline and anticipated operations to be used for the analysis in the Aquatic Species of Concern, the Terrestrial Species of Concern, and the Wetland and Riparian Studies, should GRDA anticipate any changes to Project operations.

The H&H Study is divided into three separate study efforts: the OM, the UHM, and the DHM. The OM provides input to upstream and downstream studies.

4.1.1 Operations Model

USACE's RWM period-of-record model is a tool used by USACE Southwestern Division, Tulsa District to simulate reservoir operations on the Arkansas River system upstream of USGS gage number 07250500 at Van Buren, Arkansas, including the Project. This model uses a daily time step and includes over 30 reservoirs.

A Flood Routing Model (FRM) was developed to replicate, as closely as possible, the Project flow routing decisions in the USACE RWM period-of-record model as an input to the OM required for the upstream and downstream study efforts. The FRM was needed to investigate hypothetical events and operating scenarios that would be difficult and time-consuming to program into the RWM. The FRM includes three reservoirs (Pensacola, Kerr, and Fort Gibson), which operate as a subsystem for flow routing, and uses daily time steps like the RWM.

The OM simulates flow routing, hydropower scheduling, and other constraints on an hourly time step to support the Project relicensing effort. Because electricity prices vary widely within a day, hourly time steps provide improved accuracy for hydropower operations simulation. Output from the FRM – most importantly the average daily total discharge – is used as an input to the OM. The OM seeks to optimize the hydropower generation revenue at each facility while simultaneously satisfying various physical and operational constraints, including the flow routing decisions based on the RWM model as simulated in the FRM. The OM includes Pensacola Dam and Kerr Dam (Markham Ferry Hydroelectric Project), which is downstream of Pensacola Dam. Both Pensacola Dam and Kerr Dam are owned and operated by GRDA, and flow routing decisions at both projects are regulated by USACE under certain conditions.

The FRM and OM have been validated against the RWM using the common metrics of the Coefficient of Determination and the Nash-Sutcliffe Efficiency to evaluate modeled total discharge and elevation. The OM was also validated by comparing the WSEL results to USGS gage data upstream of Pensacola Dam for two historical events recommended by the Commission. Sensitivity of OM results to stage-area-storage table updates were calculated.

The OM was used to simulate the reservoir levels resulting from different combinations of starting elevations, flow events, existing and future stage-storage relationships, and baseline or anticipated operation scenarios. The OM was also used to simulate the effects of changing elevation-storage relationships over time in support of the STM. Lastly, the OM was also used to simulate the effects of anticipated operations on reservoir water levels in support of the aquatic species study, terrestrial species study, wetlands and riparian habitat study, and assessment of recreation navigation impacts.

The UHM and model inputs and outputs have been made available to relicensing participants for download upon request.

The OM Study report is available in **Appendix 2**.

The study report for the updated bathymetry is available in **Appendix 3**.

4.1.2 Upstream Model

The HEC-RAS model, previously developed by the City of Miami's consultant Tetra Tech, was used as the base for the UHM development. A detailed review of Tetra Tech's Model identified ways in which the model should be improved. The Tetra Tech Model was transformed into the UHM by updating the version of HEC-RAS from a beta version to a full release version, modifying the geometry to contain larger flood events and to improve model stability and accuracy, updating bridge geometry, adding the Spring River and the Elk River, replacing the reservoir bathymetry to reflect newly surveyed conditions, and by using computational parameters recommended by the HEC-RAS development team. This resulted in an improved hydraulic model of Grand Lake and the river system upstream of Pensacola Dam.

The UHM was calibrated using measured data, including USGS gage elevations, high water marks, and recorded data from loggers installed by the project team. Six historical events were used to calibrate the model. Manning's n-values were adjusted until simulated water surface elevations reasonably matched measured data. Flow roughness factors were used to fine-tune the model.

A flood frequency analysis was performed for the study area using data from USACE. Data from 1940 (dam construction date) to 2019 (latest available data at time of data delivery from USACE) were used and a graphical frequency analysis of peak inflows was performed. The analysis estimated a 100-year event flow at Pensacola Dam of approximately 300,000 cubic feet per second (cfs). The largest events of recent record did not meet or exceed the 100-year event threshold at Pensacola Dam. The July 2007 event was scaled so the peak flow at Pensacola Dam approximately matched the estimated 100-year event, with a daily inflow volume to Pensacola Dam that approximately matched the results of a statistical analysis of historical inflow volumes.

The calibrated UHM was used to analyze five historical inflow events and one synthetic event with a range of starting pool elevations at Pensacola Dam. Maximum WSEL values and inundation extents were extracted from HEC-RAS and analyzed.

The results of the UHM demonstrate that starting pool elevations at Pensacola Dam within GRDA's anticipated operational range have an immaterial impact on upstream WSELs, inundation, and duration for a range of inflow events. Compared to starting elevations within GRDA's anticipated operational range, only a different natural inflow event caused an appreciable difference in maximum WSEL, maximum inundation extent, or duration. The differences in WSEL, inundation extent, and duration due to the size of the natural inflow event were orders of magnitude greater than the differences in WSEL, inundation extent, and duration due to the initial stage at Pensacola Dam. The maximum impact of nature typically ranged from over 10 times to over 100 or even over 1,000 times the maximum simulated impact of GRDA's anticipated operational range.

Even if extreme, hypothetical starting pool elevations outside GRDA's anticipated operational range are used, the maximum impact of nature is much greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet. The impact of nature typically ranged from 2 times to 10 or even 100 times the impact of the extreme, hypothetical starting stage range.

Comparing anticipated operations to baseline operations for a suite of simulations that spanned the FERC-requested range of starting pool elevations and inflow event magnitudes, the results of the UHM demonstrate that anticipated operations have an immaterial impact on upstream WSELs, inundation, and duration as compared to baseline operations.

All conclusions on potential lentic or lotic conversion areas are discussed in each of the individual biological assessment reports.

The UHM, and model inputs and outputs have been made available to relicensing participants for download upon request.

The UHM Study report is available in **Appendix 2**.

The study report for the updated bathymetry is available in **Appendix 3**.

4.1.3 Downstream Model

The DHM was developed using a one-dimensional (1D) HEC-RAS Model extending from just downstream of Pensacola Dam and through Lake Hudson (also referred to as the Markham Ferry Hydroelectric Project) to the Robert S. Kerr Dam, where flood control operations are also regulated by USACE. The model geometry was developed from the best available topographic and bathymetric data. Bridge structures within the model were represented based on record drawings obtained from various agencies. The model was calibrated to four historical events based on measurements at the USGS stream gage near Langley, OK (USGS Gage No. 07190500) and observed WSEL at Kerr Dam.

The calibrated HEC-RAS model was used to analyze a range of operating conditions at Pensacola Dam utilizing results from the OM. Five historical flow events and one synthetic event were analyzed for a range of starting pool elevations at Pensacola Dam. An additional suite of simulations was computed to analyze an alternate operational scenario anticipated by GRDA for Pensacola Dam. Inflows to Lake Hudson for the synthetic 100-year event were derived from a statistical analysis of historical inflow volumes. Maximum WSEL values and inundation extents were extracted from HEC-RAS and analyzed.

The results of the DHM demonstrate that initial stages at the Project within GRDA's anticipated and extreme, hypothetical operational ranges have an impact on downstream WSELs and out-of-bank inundation. As the analysis shows, downstream WSELs, stages at Kerr Dam, and inundation extents are dependent on the magnitude and volume of releases from the Project, which in turn are dependent on initial stage at the Project. Out-of-bank inundation downstream of the Project is the result of spillway releases which are directed by the USACE. Under authority of Section 7 of the 1944 Flood Control Act, the Tulsa District of the USACE is responsible for prescribing and directing the flood control operations of the Project. The USACE is also responsible for directing spillway releases in accordance with the procedures for system balancing of flood storage outlined in the Arkansas River Basin Water Control Master Manual. This authority is reinforced by Section 7612 (c) of the NDAA 2020 which states that "The Secretary [of the Army] shall have exclusive jurisdiction and responsibility for management of the flood pool for flood control operations at Grand Lake O' the Cherokees."

In comparing anticipated operations to baseline operations for a suite of simulations that spanned the FERC-requested range of starting pool elevations and inflow event magnitudes, the results of the DHM demonstrate that anticipated operations have an immaterial impact on downstream WSELs and inundation as compared to baseline operations.

The DHM model inputs and outputs have been made available to relicensing participants for download upon request.

The DHM Study report is available in **Appendix 2**.

The study report for the updated bathymetry is available in **Appendix 3**.

4.2 Sedimentation Study

The Commission staff originally requested a "Flooding and Sedimentation Study" which became the H&H Study in their Study Request Letter dated March 13, 2018. Their reasoning for requesting the study is best outlined in their stated nexus which was as follows:

> "GRDA does not propose any changes in current operation. However, upstream flooding has been an ongoing issue in the project area. Information gathered through this study would allow stakeholders to develop an understanding of the interactions between project operation and flooding, the specific factors or project elements that can influence flooding, and associated effects on other resources…" The collection of data from this study would provide the basis for potential license requirements pertaining to project operational constraints and/or environmental measures necessary to protect, mitigate for, or enhance aquatic, terrestrial, recreation, and cultural resources around the project. This information would also be important in determining whether the current project boundary is appropriate."

The study plan was proposed in the PSP, modified per relicensing participants' comments for the RSP, modified per Commission staff recommendations provided in the SPD, and again modified per Commission staff recommendations in the May 27, 2022 determination letter.

As part of this study, GRDA developed the STM using the HEC-RAS fluvial modeling software. Data needed for model development ranged from topographic information to stream discharge volumes, WSELs, and sediment parameters both in the lake and streambeds and moving into the system through major tributaries. GRDA evaluated publicly available data sources to compile parameters necessary for model development and to determine where additional field work was required to fill data gaps.

Topographic and bathymetric data are available from a range of sources. Grand Lake itself was surveyed by the OWRB in 2009, then again by the USGS in 2019. Surveys upstream of RM 120.1 on the Neosho River and Spring River, and upstream on the Elk River were performed as part of the 1998 Real Estate Adequacy Study (REAS), and USGS surveyed those reaches again in 2017. Topographic information was available from surveys performed in support of the REAS and Light Detection and Ranging (LiDAR) flights conducted in 2011. Other topographic information was obtained from the USGS National Elevation Dataset one-third, arc-second datasets where LiDAR information was unavailable. Circa-1940 topographic maps were digitized for analysis of conditions at the time of dam construction. Additionally, stage storage curves were available from circa-1940 USACE as-built drawings as well as the more recent Grand Lake bathymetry surveys.

Other data are available from USGS gaging stations located throughout the Grand Lake watershed. WSEL data and stream discharge information are available along the Neosho, Spring, and Elk rivers, as well as on Tar Creek. These stations also provide sediment transport data in the form of suspended sediment concentration (SSC) measurements taken throughout the period of record at each gage.

Data gaps existed within the period of record for the USGS gaging stations within the Grand Lake watershed, and the gaging network lacked spatial density. As a result, the study team developed a field monitoring system to track WSEL throughout the study area and fill data gaps. A set of 16 monitoring locations were selected, and pressure loggers were installed at each site in December 2016. Pressure and temperature were recorded at 30-minute intervals. The record provided a detailed dataset of water levels that were used for model development and calibration.

Other data gaps identified were related to sediment properties. Sediment conditions within the basin were evaluated using grab samples to evaluate grain size distributions. In general, the streambeds consist of gravel with limited sand; the lake is primarily silt and clay. Due to the presence of cohesive material (silt and clay) in the lake, GRDA also collected core samples for SEDflume erosion analysis. The erosion analysis was used to determine parameters for sediment movement as part of model development.

Subsurface investigations included sub-bottom profiler (SBP) surveys and core sampling. SBP surveys and core sampling were used to estimate the thickness of deposited silt and clay material in the region of the delta feature. Core samples were also used to provide sediment grain size information and evaluate approximate date of deposition through cesium-137 analysis. Findings indicated a thick layer of cohesive material that is in continual flux, i.e., not consistently depositional on the delta feature.

Sediment transport rates were the final missing parameters. The aforementioned SSC measurements occur only occasionally, and samples taken during large flow events are limited. Researchers were also unable to find bedload sediment transport measurements at any location in the watershed. GRDA field work included trips to gather additional SSC measurements to help close data gaps in the record. Technicians also sampled bedload sediment transport and found that even under large flows, the bulk of sediment transport occurs as cohesive silt and clay in suspension rather than along the bed.

Hydraulic calibration of the model consisted of tuning roughness parameters to match measured peak WSELs for a range of flow events. Events that occurred between July 2007 and April 2017 were used for hydraulic calibration. Model tuning relied on adjusting hydraulic roughness coefficients and flow roughness factors. Calibration datasets included the USGS gages throughout the model domain, high water marks, and the GRDA monitoring stations. Model results showed good agreement with the gaged locations.

HEC -RAS has limited capabilities to accurately model cohesive sediment. GRDA discussed this at length in the Updated Study Plan submitted in April 2022 and proposed using a quantitative analysis of bathymetric change in addition to an STM focused on the upper regions of the study area.

In issuing their May 27, 2022 determination letter, Commission staff allowed development of the quantitative analysis and also agreed that HEC-RAS could be used to model portions of the study area above river mile 100, and that trapping efficiency and modeled sediment outflows could be used to evaluate sedimentation within the lower portion of the reservoir.

GRDA conducted a qualitative analysis to understand the general trends in the system and how the stream has evolved over time. The qualitative analysis discovered how several physical features affect the geomorphology of the rivers in the study area that either exist naturally or have been constructed. Such features include Pensacola Dam, bridges, and geologic and geomorphic features. Because bridges constrict flow and often encroach on the river floodplain (an extreme case is the railroad bridge downstream of Twin Bridges), they typically cause backwater effects and sediment deposition upstream of the bridge. Reaches of river that are confined by the vertical rock banks, rock valley bottoms, and rock thalweg bottoms from the Ozark Uplift constrict the flow and reduce steepness of the river valley. The reduced steepness (as shown in the 1938 valley bottom profile from RM 108 to RM 115) the reduced steepness), causes upstream backwater effects and sediment deposition.

At the confluence of the Neosho River and Elk River, some of the sediment load from the tributary is deposited. The Ozark Uplift crossing the Neosho River at the confluence, combined with the attendant potential for the formation of a tributary bar, also suggest a natural tendency for sediment deposition at this location.

GRDA used a quantitative analysis of sedimentation to evaluate future deposition within the study area. A relationship between hydraulic bed shear stress as evaluated using a fixed bed HEC-RAS model and measured sediment deposition was developed for this purpose. After evaluation, the results indicated that sediment deposition would occur primarily on the downstream face of the delta feature, which follows typical evolution patterns of such deposits. The delta feature is not expected to grow in height over the coming license period.

Sediment model calibration showed reasonable agreement with measured sediment deposition between the circa-1940 datasets and more modern surveys. Discrepancies are attributable to measurement uncertainties, particularly due to the significant limitations of the circa-1940 survey information.

Predictive 50-year simulations included analyses of High and Low Sedimentation simulations to account for the uncertainties of the available datasets. The calibrated sediment inflows were used to evaluate expected results under both baseline and anticipated operations; the High and Low Sedimentation simulations were used to bound the maximum and minimum sedimentation volumes that could reasonably occur in the upcoming license period under anticipated operations. These analyses showed that the sediment primarily accumulates on the downstream face of the delta feature, as predicted by literature sources. The predicted geometry was then imported to the 1D UHM to evaluate impacts to water levels.

Evaluation with the 1D UHM allowed assessment of changes to water levels based on sedimentation. The 1D UHM was used to evaluate the July 2007 flow event and a synthetic 100-year event on the Neosho River for three separate starting pool elevations.

Model results were compared to determine the relative impacts of 50 years of sediment accumulation under expected loading, High Sedimentation versus Low Sedimentation rates, and baseline operations versus anticipated operations. The results indicated that sediment loading, a natural phenomenon outside GRDA’s control, generally has the largest impact on upstream water levels in the Neosho River, overshadowing any impacts caused by Project operations. The impacts to water levels in the City of Miami for all evaluations are immaterial. Project operations, sediment loading, and future geometry show immaterial changes to water levels in the vicinity of the City of Miami. GRDA does not control the volume of incoming sediment, and the simulations indicate that, much like the findings of the Hydrologic and Hydraulic Study, nature dictates incoming sediment loads and therefore water levels in the study area, not Project operations.

The sedimentation model inputs and outputs have been made available to relicensing participants for download upon request.

The comprehensive Sedimentation Study Report for both study seasons is available in **Appendix 4**.

4.3 Aquatic Species of Concern Study

USFWS originally requested in their letter dated March 12, 2018[38], an "Inundation Study" which became in part the Aquatic Species of Concern Study. Their reasoning for requesting the study is best outlined in their stated goals and objectives, which were as follows:

> "The goals and objectives of this study are to determine the inundation effects of raising the target elevation to 745 feet."

In the March 12 letter, the USFWS also states their resource management goals to which the inundation effects are to be evaluated for. They were stated as follows:

> "*The Service has management goals for maintaining and enhancing habitat for federally-listed species and other trust resources. The Service has been involved in previous management of listed species, fisheries such as paddlefish, and wetlands in the project area and we see great potential for future management-related enhancements."*

The ODWC originally requested a study to quantify the effects of increased water level within the Grand Lake watershed, a study of the impacts of Grand Lake elevation manipulation on headwater river hydrology and paddlefish spawning/recruitment, and an impoundment fluctuation study. The requests were made in their letter dated March 13, 2018, to the Commission and became the Aquatic Species of Concern Study. Their reasonings for the study requests are all centered around identifying the potential effects on aquatic species (Neosho mucket, Neosho madtom, Neosho smallmouth bass, and paddlefish) by raising the target elevation to as high as 745 feet PD.

The study plan was not originally proposed in the PSP, but based upon relicensing participant comments, the proposed study was included in the RSP, modified per Commission staff recommendations provided in the SPD, and again modified by Commission staff recommendations in the February 24, 2022 determination letter.

The Aquatic Species of Concern Study gathered existing information on the potential species of concern and based on that existing information, identifies the species that are proposed for additional investigation needed to assess the effects of the Project, if any. The sensitive species reviewed as part of this study are the Neosho mucket, rabbitsfoot, winged mapleleaf, Neosho madtom, Neosho smallmouth bass, and paddlefish. A summary of the existing information for each species is outlined in the following sections.

4.3.1 Neosho Mucket

The Neosho Mucket (*Lampsilis rafinesqeana*) is a freshwater mussel species endemic to the Arkansas River system with recorded distributions located within the Verdigris, Illinois, and Neosho River basins. Within the Pensacola Project basin, the Neosho, Spring, and Elk River all have documented populations. According to a 5-year status review by the USFWS, the most recent freshwater mussel surveys conducted in 2016-2017 indicate that no live Neosho Mucket specimens were located with the Project

[38] Letter from Jonna E. Polk, Field Supervisor-USFWS to Kimberly Bose, Secretary-FERC, P-1494-438, (March 12, 2018).

boundary or upstream of the area of probable effects on the Spring or Neosho Rivers. These findings are consistent with other mussel surveys completed on the Spring and Neosho Rivers over the past 30 years. Therefore, on the Neosho and Spring Rivers we conclude that the Neosho Mucket is unlikely to occur.

On the Elk River, the current Project boundary overlaps about a one mile stretch of Critical Habitat named NM2 which includes 20.3 rkm (12.6 rmi) of the Elk River from Missouri Highway 59 at Noel, McDonald County, Missouri, to the confluence of Buffalo Creek immediately downstream of the Oklahoma and Missouri State line, Delaware County, Oklahoma. The most recent survey on the Missouri side of the state line as well as other historic surveys indicate that a viable population of Neosho Mucket exists within this stretch of river, however no data could be located with respect to the density or distribution of the mussel on the Oklahoma state line or within Project boundary.

Surveys were conducted during the week of July 18th, 2022. Overall, 188 mussels represented by 12 species were collected from 13 sites during 57 person-hours of total survey effort. Bluefer (Potamilus purpuratus) was the most abundant species, with 108 individuals collected. The next most abundant species was Fragile Papershell (Leptodea fragilis), with 23 individuals collected. Threehorn Wartyback (Obliquaria reflexa) and Pink Papershell (Potamilus ohiensis) were the next most abundant species overall, with 19 and 17 individuals collected, respectively. No Neosho Muckets were collected during this study.

4.3.2 Rabbitsfoot

The Rabbitsfoot (*Quadrula cylindrica cylindrica*) freshwater mussel is a historically widespread species with a range from the Lower Great Lakes to the Lower Mississippi River. Within the Arkansas River Basin, the Neosho and Spring Rivers are considered historical range. Within the study area, the most recent 5-year review indicated that in 2016-2017, surveys on the Neosho River 1.5 RM downstream of Miami to the Kansas State line did not locate any specimens. Similarly, surveys conducted in 2016-2017 on the Spring River from the confluence of the Neosho North did not locate any live specimens from the Oklahoma Portion of the Spring River. No data were located on the status of the Rabbitsfoot from recent or historical sources for the Elk River.

The rabbitsfoot is a freshwater mussel typically found in small-to-medium-sized rivers that have a moderate current and clear, relatively shallow water. It prefers river bottoms that are a mixture of sand and gravel substrates. The rabbitsfoot spawns from May to June. Three species of minnows have been determined to be suitable hosts for the rabbitsfoot larval stage: whitetail shiner, spotfin shiner, and bigeyed chub; however, it’s possible that other cyprinid (species) may be suitable hosts. Records received from the OWRB, show none of the host species have been present at sampling events in the Neosho, Spring, and Elk Rivers draining into the Project area from 2003-2018.

Based on the literature and data available it is not likely that a population would occur within the study area and no further species-specific studies were conducted. However, during the Neosho madtom and Neosho mucket studies, observations were made for the occurrence of this species. No occurrences were identified.

4.3.3 Winged Mapleleaf

The Winged Mapleleaf (*Quadrula fragosa*) has a historic range that spans the greater Mississippi basin. Current known locations for this species include locations in Missouri, Wisconsin, Arkansas, and Oklahoma. A 5-year review of the species completed in 2015 indicates this species is considered extirpated from the Neosho River and Spring River in Kansas and no known populations occur within the larger Grand Lake watershed or the Neosho River Basin. Historical and the most recent mussel surveys conducted on the Spring and Neosho Rivers have no record of this species and the species has not been documented on the Elk River based on our available data. Known host fish for this species include Channel Catfish (*Ictalurus punctatus*) and Blue Catfish (*Ictalurus furcatus*), both of which occur within the Project boundary.

Personal contact with the Sam Nobel Museum, Oklahoma State invertebrate collection department and ODWC indicate that no specimens have been previously found within the Neosho, Spring, and Elk Rivers or surrounding drainages leading up to the reservoir. The only recognized population in Oklahoma is within the Little River which is 175 miles from the study area. It is not likely that there is a population within the study area and no further studies were conducted. However, during the Neosho madtom and Neosho mucket studies, observations were made for the occurrence of this species. No occurrences were identified.

4.3.4 Neosho Madtom

The Neosho madtom is a small catfish commonly 1.75–2.75 inches long; the maximum is about 3 inches long. The density of Neosho madtom populations is much greater in the Neosho system (i.e., the Neosho and Cottonwood Rivers combined) than in the Spring River. Extant Oklahoma populations of the Neosho madtom are restricted to the Neosho River upstream from Grand Lake.

Neosho madtoms have been found in the highest numbers during daylight in riffles in late summer and early fall, after young of the year are estimated to have recruited to the population. Neosho madtoms prefer the interstitial spaces of unconsolidated pebbles and gravel, moderate-to-slow flows, and depths averaging 0.23 meters. Adults hide in the interstices of loose gravel riffles during the day and feed nocturnally on the aquatic insects. Young of the year are said to inhabit slower flowing waters downstream from riffles and use pools and backwaters as nursery areas.

Neosho madtoms have been found in the drainages of the Project area from 1969-2007. The last sampling attempts near the Project area occurred in 2016. The closest collection point within the Project was conducted in 1991.

Targeted surveys for Neosho mucket were completed on the Neosho on Spring Rivers in July and August of 2022. Neosho madtoms were found to be present on the Neosho River, but not found on the Spring River.

Using historical data in the CHM to represent normal events including 1-year flood events, the output of the H&H Study produced a comparison of the mean WSEL under baseline operations versus the mean WSEL under anticipated operations for the May 15 to July 8 period each year. In the area of the Neosho River where the Neosho madtoms were identified during the 2022 survey the lines representing the mean WSEL for baseline operations are coincident with the lines representing mean WSEL for anticipated operations.

The CHM also calculated section-averaged velocities for cross-sections extracted at each Neosho madtom sampling location under both the baseline operations and anticipated operations. The predicted velocities for baseline operations are nearly identical to the predicted velocities for anticipated operations.

4.3.5 Neosho Smallmouth Bass

The Neosho smallmouth bass is a genetically distinct subspecies of smallmouth bass. The Neosho smallmouth bass is found in the western extent of the Ozark Highlands ecoregion and is known to occur in the Spring River, the Elk River, the Neosho River, Spavinaw Creek, Spring Creek, the Illinois River, Baron Fork, Sallisaw Creek, Lee Creek, Clear Creek, the Mulberry River, Big Piney Creek, and the Illinois Bayou.

The Neosho smallmouth bass is found in streams that have watersheds with coarse-textured soils within the Ozark and Boston Mountain ecoregions. Generally, the smallmouth bass is found in clear streams, but the Neosho smallmouth bass can persist in some streams that are often spring fed and have relatively high sediment loads. Though Neosho smallmouth bass are found in pool habitats, larger streams that have various channel units, including runs and riffles, are necessary for abundant populations.

Spawning habitat for the Neosho smallmouth bass consists of low-velocity, nearshore waters that are close to cover. The Neosho smallmouth bass also prefers to construct nests in areas that have fine sediment substrates and avoids areas that have thick layers or silts and clays. In years that have low stream flows, low water velocity at the nest site was found to be important for nest success. In years that have elevated discharge events, nest success was influenced by streamflow, temperature, and distance to shore.

Several records show that a smallmouth bass population is present within the drainages surrounding the Project, but during the sampling there was no determination that the Neosho subspecies was identified. It is likely that all records of smallmouth bass are not of the Neosho strain because the smallmouth bass that may occur within Grand Lake and the stretches of the Neosho, Spring, and Elk Rivers in Oklahoma are likely to be reservoir-strain fish. ODWC sampling efforts, which looked for both the Neosho and reservoir subspecies, did not detect the Neosho subspecies of the smallmouth bass within this Project or surrounding drainages. The latest surveys occurred in 2019.

Maps were generated from the results of the CHM to depict the change in inundation areas due to anticipated operations. Using historical data to represent normal events including 1-year flood events, the output of the H&H Study produced a comparison of the mean WSEL under baseline operations versus the mean WSEL under anticipated operations for the May 15 to July 8 period each year (a critical time for the species). The results show the mean WSEL is higher for anticipated operations than for baseline operations during the critical time period.

The Neosho smallmouth bass has no state or federal listing and there is no need to collect any additional information to determine if there is an adverse effect upon the species.

No additional work on the Neosho smallmouth bass on was required in the final study season.

4.3.6 Paddlefish

Paddlefish are native to large rivers and lakes of the Mississippi River drainage and nearby gulf slope drainages. In Oklahoma, paddlefish were originally present in most large rivers of the Arkansas system (including the Neosho and Grand Rivers), the Little River, and the Red River.

Adult paddlefish inhabit deep slow-moving pools of large rivers and associated lakes and reservoirs. They typically inhabit areas with depths greater than 9.8 ft and current velocities below 1.6 feet per second (ft/s) in reservoirs. Appropriate spawning habitats are more specific and require riverine habitats. Paddlefish spawning occurs in aggregations over hard substrates such as washed cobble within river environments. In Oklahoma, spawning peaks in late March and early April. Spawning appears to be episodic, often initiated by rising water levels and occurring during periods of high flow, and year-class recruitment is often highest in years that have extended high flow conditions during the spring spawning period. Paddlefish spawn demersal eggs that become adhesive upon fertilization and stick to the substrate. Hard substrates such as gravel and cobble are key to spawning success.

Previous research has quantified the amount of hard spawning substrates within the Neosho and Spring Rivers upstream of Grand Lake. This study compiled spawning substrate data and developed maps to evaluate the amount and spatial distribution of paddlefish spawning substrate within the area that may be impacted by Project operation.

At the maximum extent evaluated, a total of over 2,647 acres of potential habitat occurs, of which 1,701 acres (64 percent) consist of hard substrates presumably suitable for paddlefish spawning. Specifically, 997 acres of paddlefish spawning substrates (69 percent of available) were identified within the Neosho River and 704 acres (59 percent of available) were identified in the Spring River. The availability of hard substrates generally increases moving upstream from the river/reservoir interface. Within the Project boundary, 696 acres of paddlefish spawning substrate was identified within the Neosho River and 493 acres of spawning substrate was observed within the Spring River. Therefore, 70 percent of the available spawning substrate within the Neosho River falls within the Project boundary and 55 percent of the available spawning habitat in the Spring River falls within the Project boundary.

In the SPD, Commission staff recommended an assessment of potential effects on anticipated operations on the spawning areas for paddlefish because increasing reservoir elevations would broaden and deepened the Grand Lake tributaries, slow water velocities, and deposition of soft, fine substrates to occur further upstream than currently occurs.

The availability of continuous high flows during spawning has a significant effect upon Paddlefish spawning success. The H&H Study has demonstrated Project operation (initial stage at Pensacola Dam) has an immaterial impact on upstream water surface elevations and consequently the hydraulic conditions which Paddlefish seek at upstream spawning sites during high inflow conditions.

Regardless of the anticipated operation of the Project, the inflow events will continue to dominate the hydraulic conditions at the upstream spawning sites during high inflow events and dominate spawning success. Therefore, based upon the abundance of spawning habitat, the minimal impact of anticipated operations on upstream inundation, and the dominance of inflow events over successful paddlefish spawning, no additional work on Paddlefish was required in the final study season.

The comprehensive Aquatic Species of Concern Study Report for both study seasons is available in **Appendix 5**.

4.4 Terrestrial Species of Concern Study

The USFWS originally requested in their letter dated March 12, 2018, an "Inundation Study" which became the Terrestrial Species of Concern Study. Their reasoning for requesting the study is best outlined in their stated goals and objectives which were as follows:

> "The goals and objectives of this study are to determine the inundation effects of raising the target elevation to 745 feet."

In the March 12, 2018 letter, the USFWS also states their resource management goals, which the inundation effects are to be evaluated for. They were stated as follows:

> "The Service has management goals for maintaining and enhancing habitat for federally-listed species and other trust resources. The Service has been involved in previous management of listed species, fisheries such as paddlefish, and wetlands in the project area and we see great potential for future management-related enhancements."

The study plan was not originally proposed in the PSP, but based upon relicensing participant comments, the proposed study was included in the RSP.

The Terrestrial Species of Concern Study gathered existing information on the potential species of concern and based on that existing information, identified the species for which additional investigation was needed to assess the effects of the Project, if any. The sensitive species reviewed as part of this study are the federally threatened American Burying Beetle (*Nicrophorus americanus*; ABB) and the federally endangered Gray Bat (*Myotis grisescens*). A summary of the existing information and proposed additional investigation for each species is outlined in the following sections.

4.4.1 American Burying Beetle Survey

Two presence/absence surveys for the ABB were conducted in 2021 and 2022 to determine whether the ABB, a federally threatened species, may be present within the study area and may be impacted by Project operations according to the H&H Study. The area of potential impact is the ABB's current range but does not include any conservation priority area as defined by the USFWS.

On July 18, 2021 and June 6, 2022, ABB Specialist Stephanie Rainwater (permit number TE-00284A) placed six (6) traps to cover representative samples of all suitable habitat types within the area of potential impact.

The traps were designed, baited, and checked following the guidelines of the American Burying Beetle Range-wide Presence/Absence Survey Guidance. Trap locations were oriented in Delaware and Ottawa

Counties only, but confirmed with Kevin Stubbs, USFWS National Species Lead as sufficiently representative of the overall four county area.

The six traps were checked daily for a total of five nights with valid weather parameters and yielded no positive ABB findings. The negative survey findings indicate that the ABB is not active within the study area.

The negative results indicate GRDA's change from baseline operations to anticipated operations are not expected to have a negative impact on ABB populations.

4.4.2 Gray Bat Survey

This study was an assessment of species utilization of colonies of the federally endangered Gray Bat in caves DL-2 and DL-91, in Delaware County, Oklahoma. In Oklahoma, Gray Bats represent a contingent in North America that are year-round, obligate cave dwelling species.

Infrared-illuminated entrance and night vision optics were used to conduct non-intrusive exit surveys and population estimates of Gray Bat colonies exiting caves DL-2 and DL-91 in the 2021 summer maternity and post-maternity season. Such surveys are used to document habitation, assist in estimating colony size at the respective caves, and monitor movements of the colony during potential high water and flood events on Grand Lake.

Exit surveys were conducted at cave DL-2 on June 22, 2021 and June 27, 2022. The population was estimated to be 11,800 in 2021 and 13,300 in 2022. On June 24, 2021, July 16, 2021, May 10, 2022, June 22, 2022, and August 4, 2022 cave DL-91 was surveyed. The post-maternity colony population estimate at cave DL-91 during late summer 2021 was 20,440 and within the range of 10,000 to 29,905 bats (average=18,245) over the past decade. The post-maternity colony population estimate at cave DL-91 during late summer 2022 was within the range of 10,000 to 29,905 bats (average=19,877) over the past decade.

Observations from exit surveys support historical evidence that during high water or flood events during the maternity season, a maternity colony of the gray bat vacates cave DL-2 (Beaver Dam Cave) where the original exit lies below the flood pool elevation of Grand Lake. The maternity colony then migrates to an alternative cave.

The persistent threat of cave inundation increases the likelihood of "take" of adult females and young. Complete inundation of the cave passage of DL-2 occurs at about elevation 752 feet PD. When Grand Lake is at about elevation 751 feet PD, only about one foot of flyway exists between the top of the water in the cave and the rock ceiling of the flyway, forcing evacuation of the colony.

In October 2008, a small, high passage within cave DL-2 was identified and minimally excavated and enlarged. Enlarging this passage was suspected to provide an alternative escape route for exiting bats, particularly during high water. Additional excavation and enlargement of this second-high passage was completed in October 2013. The length of the high passage was about 5m and was widened to about 0.40 meters wide by 0.50 meters tall.

An inspection of the passage following flood events since 2011 revealed scattered guano in the enlarged passage indicating use by bats. A post-inundation monitoring visits to the cave following a flood event in 2019 failed to give any indication that take had occurred as a result of inundation, and that the colony had successfully vacated to another location.

Management efforts at cave DL-91 over the past 40 years have improved the security and potential for the colony's persistence. The average post-maternity colony size illustrates relative consistency, ranging from 15,200 to 29,905 bats with an average colony size of 19,288 Gray Bats for the past 10 years.

As a product of the CHM, specific to the Gray bat analysis, percentages of time the reservoir would be above the key reservoir elevations of 746 feet PD, 751 feet PD, and 752 feet PD for both the baseline and anticipated operations during the key season of April 1 to July 31 each year were provided.

The CHM analysis shows under the anticipated operations of the Project, the Grand Lake Reservoir will exceed 746 feet PD, the reservoir elevation at which water flows into the entrance of cave DL-2 (Beaver Dam) is 16.5% under baseline operations and 16.9% under anticipated operations. The anticipated operations will cause this situation to occur 0.4% more frequently.

Evacuation of DL-2 generally does not begin to occur until Grand Lake reaches an elevation of approximately 751 feet PD. According to the CHM analysis, under the anticipated operations of the Project, the Grand Lake Reservoir will exceed 751 feet PD, 2.9% under baseline operations and 2.7% under anticipated operations. The anticipated operations will cause this situation to occur 0.2% less frequently.

A Grand Lake Reservoir elevation of 752 feet PD results in a complete inundation of the cave passage in DL-2 forcing evacuation. According to the CHM analysis, under the anticipated operations of the Project, the Grand Lake Reservoir will exceed 752 feet PD, 1.9% under baseline operations and 1.9% under anticipated operations. The anticipated operations will cause this situation to occur the same percentage of time as the baseline operations.

The CHM analysis shows very little increase (0.4%) in the potential for water to enter the cave opening of DL-2 at an elevation of 746 feet PD and very little decrease in the potential for water to enter the cave to an elevation of 751 feet PD that possibly forces an evacuation of the colony to the alternative cave. Lastly, the CHM results indicate there is no change in the percentage of time the passage in cave DL-2 becomes entirely submerged at an elevation of 752 feet PD under the anticipated operations.

As a result, the findings of the gray bat study indicate the secondary exit suffices to provide an alternative access by gray bats in cave DL-2. Regardless of the efficacy of the alternative access, the entrance to cave DL-2 does not become completely inundated to elevations 751 feet PD and greater (complete inundation is 752 feet PD) any more frequently under the anticipated operations than it becomes inundated under the baseline operations.

The comprehensive Terrestrial Species of Concern Study Report for both study seasons is available in **Appendix 6**.

4.5 Wetland and Riparian Habitat Study

The ODWC originally requested "Impoundment Fluctuation Studies" and "Wetland Documentation." The requests were made in their March 13, 2018 letter to the Commission and became the Wetland and Riparian Habitat Study. Their reasonings for the study requests are all centered around identifying the potential aerial extent of riparian habitat and potential aerial extent and change in type of wetland habitats by raising the target elevation to as high as 745 feet PD.

The study was not originally proposed in the PSP, but based upon relicensing participant comments, the proposed study was included in the RSP.

The purpose of the Wetland and Riparian Habitat Study is to quantify and refine the potential impacts associated with the proposed operations of the Project (a potential raise in target elevation to as high as 745 feet PD or anticipated operations). Base mapping was completed to identify, display, and describe the current composition of wetland communities within and adjacent to the area that may be impacted by anticipated operations.

In the area studied, according to NWI data 54,980.72 acres of wetland habitat types and 4,236.06 acres of riparian habitat types were identified. Once the lentic and lotic maps according to anticipated operations are developed through the H&H Study, the potential impacts of any anticipated operations can be outlined in the USR.

Overall, GRDA's anticipated operations result in water level fluctuations ranging from 742 to 745 feet PD or three feet. Whereas, baseline operations result in water level fluctuations ranging from 741 to 745 feet PD or four feet. As a result, overall impacts to wetlands are expected to be less under the anticipated operations than the baseline operations.

Using historical data to represent normal events including 1-year flood events, the output of the H&H Study produced a comparison of the mean WSEL under baseline operations versus the mean WSEL under anticipated operations for the growing season period (March 30-November 2). The mapped output when overlayed on other sources of data included the NWI data, showed very small differences along shorelines that result in a net increase in wetlands because the anticipated operations have a higher mean elevation during the growing season than do the baseline operations.

The comprehensive Wetland and Riparian Habitat Study Report for both study seasons is available in **Appendix 7**.

4.6 Recreation Facilities Inventory and Use

A recreation inventory and use survey was first proposed by GRDA as part of the PAD. The study was refined based upon relicensing participant comments on the PSP, modified based upon relicensing participant comments for the RSP, and again modified per Commission staff recommendations provided in the SPD.

During the months of May through September of 2020, a total of 30 recreation observation surveys were conducted on 20 separate recreation sites as outlined in the RSP and recommended in the SPD. In addition, bi-monthly surveys were completed along river channel sites below the Pensacola Dam.

The surveys included counting individuals and vehicles at each site, classifying primary and secondary activities, and interviewing people at the sites. Photos were taken at recreation sites, which focused on the water level at boat ramps and typical activities.

During visitor interviews, participants were asked various questions based on their input for sites visited. If additional sites were visited in the Project area, other than the interview site location, the survey requested visitor input for each site visited.

During at least one site visit to the five FERC-approved recreation sites, state parks, and other public access sites, the condition of each recreation facility and its immediate vicinity were assessed, and an inventory of recreation enhancements was made.

Although there is a large amount of recreational use in the Project area, there are numerous non-commercial quality recreation access sites available around the Project shoreline. All but one recreation site has adequate capacity for the near future and this study did not identify a need for any additional access sites to be established as part of the relicensing process. It is recommended recreation use be surveyed every six years during the future license term to assure adequate recreation access is maintained during the term of the future license.

No additional work on this study was required in the final study season. The Recreation Facilities Inventory and Use Study report is available in **Appendix 8**.

4.7 Cultural Resources Study

A cultural resources study was first proposed by GRDA as part of the PAD. The study was refined based upon relicensing participant requests for the PSP, modified based upon relicensing participant comments for the RSP, and again modified per Commission staff recommendations provided in the SPD.

The Cultural Resources Study is composed of the following efforts:

- Cultural Historic Investigation
- Archaeological investigations in 2019 and 2020-Volume I
- Archaeological investigations in 2020 and 2021-Volume II
- Archaeological investigations in 2021 and 2022-Volume III
- Ethnography Study
- Finalize the area of potential effect (APE) based on the results of the H&H Study, other relicensing studies, and information gathered during the first year of the cultural resources study and file the information in the USR.
- Develop a proposed HPMP and file the proposed HPMP in the DLA.

The five study reports are incorporated as **Appendix 9** but have been filed with the Commission as privileged information.

4.7.1 Area of Potential Effect

The APE is currently defined in the RSP and confirmed in the SPD as:

> *"...all lands within the FERC-approved project boundary. The APE also includes lands or properties outside the project boundary where project operations or project-related recreation activities or other enhancements may cause changes in the character or use of historic properties, if any such properties exist."*

APE is consistent with the requirements of Section 106 and the definition of a project's APE provided at 36 CFR 800.16(d), which would encompass project-related effects both within and outside the Project boundary.

GRDA has been completing studies under this standard definition of the APE in the initial study period, recognizing that the APE could fluctuate if the results of other relicensing studies (e.g., the H&H Study) demonstrate potential effects of Project operations outside the Project boundary.

In the RSP and confirmed by Commission staff in SPD, after the initial study period, GRDA should consult with the CRWG to refine the APE, if necessary.

Since the initial establishment of the APE, the H&H Study determined that starting pool elevations at Pensacola Dam within GRDA's anticipated operational range have an immaterial impact on upstream WSELs, inundation, and duration for a range of inflow events. Compared to starting elevations within GRDA's anticipated operational range, only a different inflow event caused an appreciable difference in maximum WSEL, maximum inundation extent, or duration. The differences in WSEL, inundation extent, and duration due to the size of the inflow event were orders of magnitude greater than the differences in WSEL, inundation extent, and duration due to the initial stage at Pensacola Dam. The maximum impact of nature typically ranged from over 10 times to over 100 or even over 1,000 times the maximum simulated impact of GRDA's anticipated operational range.

Comparing anticipated operations to baseline operations for a suite of simulations that spanned the FERC-requested range of starting pool elevations and inflow event magnitudes, the results of the H&H Study demonstrate that anticipated operations have an immaterial impact on upstream WSELs and inundation compared to baseline operations.

Since the APE already encompasses land up to an approximate elevation of 750 feet and any anticipated Project operations authorized by FERC under the license will not exceed 745 feet PD (due to the USACE's exclusive jurisdiction and responsibility for management of the flood pool beginning at 745 feet PD or even less for flood control operations at Grand Lake), the APE does not require modification. It already encompasses all the areas where Project operations under the FERC license potentially have an effect. Therefore, there is no basis for conducting additional cultural resources investigations beyond the APE that has been established for several years, and the current suite of studies fulfills GRDA's obligations under Section 106 of the NHPA.

4.7.2 Cultural Historic Investigation

The investigation was conducted to document and evaluate the potential effects of the operation of the Project on known historic resources, including the Pensacola Dam Historic District and the Splitlog Church. In addition, a resource survey was conducted for unknown above ground historic properties within the APE. The APE consists of areas within the current Project boundary and includes lands or properties outside the Project boundary where Project operations or Project-related recreation activities or other enhancements may cause changes in the character or use of historic properties. The survey was conducted, assessing any associated buildings or structures over 50 years old for their respective eligibility for listing on the NRHP. Identified historic resources were also evaluated for the potential effects from the renewal of the license for the Project.

The Pensacola Dam Historic District was established in 2003 when the Dam and its associated structures were determined eligible for the NRHP and listed at that time. The Splitlog Church was determined eligible for the NRHP and listed in 1972. The investigation has determined the renewal of the license for the Project has no adverse effect on the Pensacola Historic District or the Splitlog Church.

Two bridges, the Stepps Ford Bridge and the Spring River Bridge over State Highway 10, were previously recommended as eligible for listing on the NRHP. However, these two bridges have since been demolished and replaced with modern structures. An additional eighteen historic bridges were also identified within the APE. Of the eighteen bridges, thirteen had been previously surveyed, with the remaining five newly identified. However, all eighteen bridges were deemed not eligible for listing on the NRHP based on a lack of historic significance and/or material integrity, with six of the bridges recently replaced with modern structures. The investigation has determined the renewal of the license for the Project has no adverse effect on the twenty bridges identified.

4.7.3 Archaeological Investigations in 2019 and 2020.

The 2019-2020 field season was divided into two distinct mobilizations with two distinct goals. During the first mobilization between November 5 and December 12, 2019, an archaeological reconnaissance was conducted on 34 previously recorded sites within and immediately adjacent to the Pensacola Project APE that were designated as “high priority” by members of the CRWG. In early 2020, four additional sites were added to the list of high priority sites requested for assessment by the CRWG, for a final priority site total of 38. The goal of the site reconnaissance efforts was to relocate the 38 sites and assess their current condition, integrity, and document ongoing disturbances. During the 2019-2020 field effort, the mapped locations of 37 of the 38 sites, totaling 239.1 acres, were visited. Findings from the reconnaissance investigations varied. Many sites were found to be completely inundated within the body of the reservoir. Some could not be accessed due to landowner restrictions or were found to be mis-plotted, while others necessitated systematic testing to establish condition and integrity. Of the revisited sites, seven sites were considered “potentially threatened” due to their locations, current condition, and/or other mitigating factors. Additional management actions were recommended for the seven sites.

The second mobilization of the 2019-2020 field season was conducted between February 19 and March 10, 2020 and consisted of the systematic archaeological survey of high-archaeological potential Quarternary alluvial landforms (Qals) previously identified in the Pre-Fieldwork Study commissioned by GRDA (Cerimele et al. 2019). The 29 Qals located within the Pensacola Project APE were determined by the CRWG to have high potential to retain intact archaeological deposits. Ten Qals were investigated during the winter 2020 field mobilization. The total acreage of the surveyed landforms was 838 acres (339.1 hectares). Eight previously unrecorded archaeological sites were identified, delineated, and fully documented. Three isolated finds were also recorded. Five of the newly recorded sites are recommended for additional archaeological investigations to determine eligibility to the NRHP. Two sites are also recommended for additional work to fully delineate the site boundaries beyond the Project APE.

4.7.4 Archaeological Investigations in 2020 and 2021

The 2020-2021 field season (November 2020 to March 2021) builds upon the efforts reported in Volume I (Bissett et al. 2020). The total survey area for this project fell within the Pensacola Project APE. The 2020-2021 investigations consisted of relocating and assessing conditions at 11 previously recorded sites, surveying 16 Qals determined to have a high potential for cultural materials (Cerimele et al. 2019), and a visual inspection of exposed bluffs along the lake edge to identify potential rock shelters and caves. Additionally, one site outside of the Project APE was revisited at the request of the CRWG.

Archaeological reconnaissance was conducted on 11 previously recorded sites within and immediately adjacent to the Pensacola Project APE that were not revisited during the 2019-2020 field efforts. The goal of the site reconnaissance efforts was to relocate the sites and, if relocated, to assess their current condition, document ongoing disturbances, and assess integrity if possible. Five sites were not able to be reported on as part of this ISR. One site is a Cherokee cemetery that required a tribal monitor who could not attend due to Cherokee Nation Covid-19 protocols. One site was located within the protective buffer around an active bald eagle nest.

The locations of six of the 11 previously recorded sites investigated during the 2019-2020 season were visited during the current survey, but the sites could not be relocated. The remaining five of the 11 were relocated and assessed. Four are recommended as potentially eligible and require additional work to determine NRHP eligibility.

The second task of the 2020-2021 field season consisted of the systematic archaeological survey of previously identified Qals. Sixteen were surveyed in the 2020-2021 field season. Survey included pedestrian survey and shovel test excavations. Additionally, 13 islands were surveyed. In total, 2,108 acres were encompassed between the 16 Qals and 13 islands surveyed. Eleven new archaeological sites were identified and preliminarily evaluated. Three isolated finds were also recorded. Six of the newly recorded sites are recommended for additional archaeological investigations to determine eligibility to the NRHP.

The bluff face survey was based on the findings of the Pensacola Project Pre-Fieldwork Report that delineated 60.4 linear miles of high potential exposed bluff faces. Bluff areas are visually inspected to identify potential rock shelters or caves that may contain archaeological deposits. Portions of three areas, and an additional 22 full areas, originally could not be reached by boat, but have been completed. The reports for the additional areas will be included in the USR.

4.7.5 Archaeological Investigations in 2021 and 2022

The 2021-2022 field season (November 2021 to March 2022) builds upon the efforts reported in Volumes I and II. The total survey area for this project fell within the Pensacola Project APE. The 2021-2022 investigations consisted of relocating and assessing conditions at five previously recorded sites, surveying three Late Qals determined to have a high potential for cultural materials, survey of an unnamed island, and completion of the visual inspection of exposed bluffs along the lake edge to identify potential rockshelters and caves.

Wood conducted archaeological reconnaissance of five previously recorded sites within and immediately adjacent to the Pensacola Project APE that were not revisited during the previous field efforts. The goal of the site reconnaissance efforts was to relocate the sites and, if relocated, to assess their current condition, document ongoing disturbances, and assess integrity if possible. The last remaining previously recorded site that was mapped within the Project APE that was not revisited was determined to be on a ridgetop 50 to 100 feet above the 745 pool and well outside of any potential Project impact. GRDA does not believe a revisit to the plotted location is warranted.

Of the five previously recorded sites investigated during the 2021-2022 season (sites a, b, c, d, and e)[39], sites a and b revisited in Ottawa County did not reveal evidence of an archaeological presence at either location plotted within the Project APE. Site a was determined to be located on an undisturbed terrace setting outside of the Project APE, and site b was determined to be grossly mis plotted. No evidence of cultural materials was identified at the mapped location and archival documentation places the recorded portion of the site well away from the currently plotted site. GRDA recommends that the locations and boundaries of both sites a and b be adjusted in the Oklahoma Archaeological Survey database to accurately reflect their location. Three sites (sites c, d, and e) were able to be relocated and assessed. Sites c and d are Post-Contact Cherokee priority site locations. While attempts were made at locating site c during the 2020-2021 field effort, it was found that the mapped location of the site was erroneous. Additional archival research revealed the accurate location of site c, and it was visited in January of 2022. While the true location of site c is located well outside of the Project APE and is not subject to any Project related impacts, it was found that no indications remain of site c, and construction/development activities relating to the adjacent RV park have impacted the ground surface. Site d was visited in August of 2021 and appears to be well maintained. This site is positioned outside of the Project APE and does not appear to be prone to any Project related effects. Site e is located on a high bluff below the Pensacola Dam. The site was found to consist of a mixed Pre-Contact and Post-Contact assemblage. Site e is currently being affected by disturbances in the form of all-terrain vehicle trails and traffic and is recommended as potentially eligible with additional work to determine NRHP eligibility.

The second task of the 2021-2022 field season consisted of the completion of the systematic archaeological survey of previously identified Late Qals located within the Pensacola Project APE that have been determined by the CRWG as having high potential to retain intact archaeological deposits. A total of 29 of these Qals have been identified within the APE. GRDA was able to investigate all but three of these landforms during previous field sessions, with only Qals 2, 3, and 7 remaining. Survey methods included pedestrian survey and shovel test excavations. However, portions of several Qals in the northern reaches of the Project APE were determined to have a thick layer of recent alluvial deposits. After consultation with the CRWG in 2020, a modified survey methodology was devised that used auger testing and/or examination of exposed cutbanks to investigate any areas where older, intact soils were too

[39] Generic identifiers are assigned to the sites in this summary to protect potentially sensitive information.

deeply buried beneath recent alluvial deposits to be accessible using standard survey methods (e.g., shovel testing).

The three Qals remaining for survey totaled 259.5 acres in size. One new archaeological site was identified on Qal 3 and preliminarily evaluated. The newly recorded site is recommended for additional archaeological investigations to determine eligibility to the NRHP. In addition to survey of the Qals, a single unnamed island located in the main channel of the Grand River south of the confluence of the Neosho and Spring Rivers was surveyed. The island encompasses approximately 124.3 acres of low-lying landform with little relief that appears to be prone to regular and prolonged periods of inundation. No cultural resources were identified during the island survey.

The defined bluff face survey area was based on the findings of the Pensacola Project Pre-Fieldwork Report that delineated 60.4 linear miles of high potential exposed bluff faces divided into 83 areas of various lengths. During the 2020-2021 field season, GRDA used boats to access and visually inspect 58 of these predetermined bluff areas to identify potential rockshelters or caves that may contain archaeological deposits. During January of 2022, GRDA completed 14 linear miles of the remaining bluff face survey by watercraft during leaf-off conditions to allow for relatively clear views of the bluff faces. Two of the potential bluff areas remain inaccessible and were not inspected during the 2021-2022 field effort, although GRDA does not believe these locations would be viable for bluff shelters.

The results of the 2021-2022 effort are contained in the Volume III report available in **Appendix 9**.

4.7.6 Ethnography Study

To address the need to manage NRHP-eligible TCPs located within the Project APE, GRDA completed an ethnographic study designed to obtain information about the locations, types, and number of TCPs within the Project APE from members of the Native American Tribes represented among the Cultural Stakeholders. This information was collected and compiled from interviews with Tribal members. Information about TCPs within the Project APE is considered privileged and confidential at the explicit request of Native American Tribes, and access to data on the nature and locations of individual TCPs is restricted to the cultural consultant conducting the study, to each respective Tribe, and to GRDA.

4.7.7 Historic Properties Management Plan

As part of the approved Cultural Resources Study plan, GRDA has been developing an HPMP in consultation with the CRWG.

HPMPs are compliance and management plans that integrate the entirety of Federal and State cultural resources program requirements with ongoing practices such as hydropower generating activities, allowing for the identification of potential compliance and preservation actions that may occur over the course of a license period. The intent is to ensure that historic properties, as that term is defined under federal law, that may be affected by the generation of hydropower are appropriately managed for scientific research, education, and cultural, religious, and traditional uses for future generations. This HPMP is designed to comply with the requirements of applicable federal and state laws and regulations, including the NHPA, Native American Graves Protection and Repatriation Act of 1990, Archaeological Resources Protection Act of 1979, and the Commission guidelines for development of the HPMP.

GRDA prepared and circulated a draft HPMP to participants of the CRWG on July 1, 2022. As of the date of this USR, GRDA is reviewing the comments received and will include an updated draft HPMP as part of the DLA to be filed by January 1, 2023. The final HPMP is expected to be filed with the FLA and ultimately approved by FERC when it issues the new license for the Project.

4.8 Socioeconomics Study

The study plan was proposed in the PSP, modified based upon relicensing participant comments on the RSP, and again modified per Commission staff recommendations provided in the SPD.

The Socioeconomic Study presents information including land use patterns, population, and employment of the Project and the State of Oklahoma. The region of influence (ROI) for socioeconomic impacts are defined as Craig, Delaware, Mayes and Ottawa Counties, Oklahoma. Socioeconomic and demographic data establish baseline conditions consist of publicly available information about the ROI and, to provide perspective, the State of Oklahoma.

The population of the State of Oklahoma increased consistently between 2000 and 2020 and is 3,959,353 in the latest decennial census in 2020. The population in the ROI increased between 2000 and 2010 but decreased between 2010 and 2020 and is 123,835 in the latest decennial census in 2020. Oklahoma is expected to see a population increase up to 5,560,007 by 2075, with the population in the ROI expected to reach 198,444 for the same time-period.

GRDA sent letters to various stakeholders, including local tribes, organizations, and businesses, in the ROI to request additional socioeconomic information. GRDA requested additional information on industry trends (e.g., goods and services, agricultural use), trends in land and resource values (e.g., hunting, fishing, ecotourism, outfitting, trapping, recreation, exploration, and mining activities), as well as other socioeconomic information that may be relevant to a socioeconomic analysis. Responses were received from eight stakeholders and are attached in the report.

The presence of the Project provides significant economic benefit to the economy in the ROI. The City of Miami, tribes, and other interested parties have raised the issue of flooding in the area and potential economic impacts on the community. The H&H Study provides information to evaluate any reasonably foreseeable effect that has a reasonably close causal relationship to the Project operations and USACE flood control operations.

The cumulative socioeconomic impact analysis has concluded that the continued operation of the Pensacola Dam will result in continued significant economic benefits for the region.

No additional work on this study was required in the final study season. The Socioeconomic Study report is available in **Appendix 10**.

4.9 Infrastructure Study

The study plan was not originally proposed by GRDA in the PSP or the RSP because GRDA wanted to assure there was a nexus for such a study. If a nexus was determined to exist through work on the H&H Study in the first study period, the study information would be gathered and outlined in the application.

However, based on Commission staff recommendations provided in the SPD, the Infrastructure Study was included in the list of approved studies and again modified by Commission staff recommendations in the February 24, 2022 determination letter.

The Commission recommended an Infrastructure Study to determine a range of inflow conditions for which H&H Model results show Project operations may influence the frequency or depth of flooding. Specifically, the Commission requested maps and tables identifying the frequency and depth of inundation for each item of infrastructure.

The H&H Model of the area upstream of the Project, along with a range of extreme, hypothetical starting pool elevations (ranging from 734 feet PD to 757 feet PD) considerably outside GRDA's anticipated operational range and inflow events representing a range of flood frequencies, were used for the study. Hydraulic results were extracted at infrastructure locations. Infrastructure locations were mapped, and tabular data of inundation depth were developed. The difference in depth between different starting reservoir elevations was also tabulated.

According to analysis results, only 7% of the infrastructure locations studied experience an appreciable increase in maximum inundation depth for different starting reservoir elevations within GRDA's anticipated operational range of 742 feet PD to 745 feet PD. In addition, all appreciable increases in maximum inundation depth occur during high-flow conditions when the USACE controls the flood control operations under the Flood Control Act of 1944 and its other statutory mandates, except when the time of maximum inundation depth is solely a function of inflow event arrival time and not reservoir elevation, meaning the time of maximum depth at the infrastructure location was completely independent of the Project reservoir elevation. The inflow event moved down the river and then arrived at the infrastructure location completely independent of Project operations. Therefore, infrastructure locations are not adversely affected by GRDA's Project operations.

Additionally, except for two parks, a reduction in reservoir operational elevation to 734 feet PD would not decrease the loss of infrastructure use for any of the inflow events studied. The first park, Wolf Creek Park, was designed (and partially funded) by GRDA to avoid being impacted by inflow events, and only a low-lying portion of the park near Grand Lake would experience a difference in inundation for the October 2009 (3-year) inflow event. Therefore, any potential adverse impacts have already been mitigated and enhanced by GRDA through their assistance in designing and funding the recent improvements to the park.

At the second park, Grove Springs Park, low-lying portions of the park would experience a difference in inundation for the October 2009 (3-year) inflow event. Decreasing the low end of the anticipated operation range from 742 to 734 feet PD, a difference of 8 feet in operational elevation, would only change infrastructure adverse impacts slightly at Grove Springs Park.

Because infrastructure such as parks are generally sited in areas that are subject to frequent flooding and are the most-resistant type of infrastructure being reviewed in the Infrastructure Study, the minor potential reduction in impacts to infrastructure identified through operating at an extreme, hypothetical elevation of 734 feet PD do not significantly decrease loss of infrastructure use at the Project.

Extreme, hypothetical operational levels up to and including 757 feet PD were analyzed. If GRDA operated at 757 feet PD, a reservoir elevation that is 12 feet higher than the top of GRDA's anticipated operational range and an elevation equal to the top of dam, infrastructure locations would be inundated by depths similar to or greater than those depths for operational levels within GRDA's anticipated operational range. Practically speaking, increasing the top of the operational range to 757 feet PD is simply not possible.

Infrastructure locations are not adversely affected by GRDA's existing or anticipated operations of the Project, which consist of reservoir levels within an operational range of 742 feet PD to 745 feet PD. Even under the hypothetical and extreme operational level of 734 feet PD, only two parks would experience a minor decrease in the loss of infrastructure use.

The comprehensive Infrastructure Study Report for both study seasons is available in **Appendix 11**.

5.0 FULFILLMENT OF STUDY OBJECTIVES AND REQUIREMENTS

The following descriptions provide in detail how the objectives and requirements of each of the approved study plans have been fulfilled. The descriptions demonstrate no further modifications to any of the approved study plans are required.

5.1 Hydrologic and Hydraulic Study

The objective of the H&H Study is to provide information, through modeling and mapping, to support the determination of the effects, if any, of GRDA's operations under the FERC-issued license for the Project upon several resource areas. Specifically, the H&H Study was intended to: (1) determine the duration and extent of inundation under the current license operations of the Project during several measured inflow events; (2) determine the duration and extent of inundation under any proposed change in these operations that occurs during several measured or synthetic inflow events; (3) provide the model results in a format that can inform other analyses (to be completed separately) of Project effects, if any, in several resource areas; and (4) determine the feasibility of implementing alternative operation scenarios, if applicable, that may be proposed by GRDA as part of the relicensing effort.

More specifically, the H&H Study met the objectives of the study by following the recommendations outlined in the RSP, staff's November 8, 2018 determination letter and its February 24, 2022 determination letter which recommended the following activities to be completed. In the list of activities below all items have been completed and each item identifies where in each study report the activity is discussed:

- Develop a CHM using updated 2019 bathymetry and calibrate the CHM using several historical events.
    - Section 2 of the UHM report in **Appendix 2** explains how the UHM was developed using a HEC-RAS model, previously developed by Tetra Tech, as the base for UHM development. A detailed review of Tetra Tech's model was conducted and identified ways in which the model should be improved. As part of the study, the Tetra Tech model was transformed by updating the version of HEC-RAS from a beta version to a full release version, modifying the geometry to contain larger flood events and to improve

model stability and accuracy, updating bridge geometry, adding the Spring River and the Elk River, replacing the reservoir bathymetry to reflect newly surveyed conditions, and by using computational parameters recommended by the HEC-RAS development team. This resulted in an improved hydraulic model of Grand Lake and the river system upstream of Pensacola Dam.

  - Section 2 of the DHM report in **Appendix 2** explains how the DHM was developed using a 1D HEC-RAS model extending from just downstream of Pensacola Dam and through Lake Hudson to the Robert S. Kerr Dam (also referred to as the Markham Ferry Hydroelectric Project), where flood control operations are also regulated by USACE. The model geometry was developed from the best available topographic and bathymetric data. Bridge structures within the model were represented based on record drawings obtained from various agencies.

  - Section 3 of the UHM report in **Appendix 2** documents how the model was calibrated using measured data, including USGS gage elevations, high water marks, and recorded data from loggers installed by the project team. Six historical events were used to calibrate the model. Manning's n-values were adjusted until simulated water surface elevations reasonably matched measured data. Flow roughness factors were used to fine-tune the model.

  - Section 2 of the DHM report in **Appendix 2** documents how the model was calibrated to four historical events based on measurements at the USGS stream gage near Langley, OK (USGS Gage No. 07190500) and observed WSELs at Kerr Dam.

- Validate model results against RiverWare (RWM) output.
  - Section 5 of the OM report in **Appendix 2** provides an explanation of how the OM was validated against the RWM using the common metrics of the Coefficient of Determination and the Nash-Sutcliffe Efficiency to evaluate modeled total discharge and elevation.

- Compare water surface elevations observed at the USGS gage on the upstream side of the dam to simulated stage hydrographs for the December 2015 and October 2009 inflow events.
  - Section 5.3 of the OM report in **Appendix 2** provides an explanation of how the OM was validated by comparing the water surface elevation WSEL results to USGS gage data upstream of Pensacola Dam for the historical events recommended by the Commission.

- Run a sensitivity analysis on the effect of switching to the most recent (i.e., 2019) bathymetry data in the OM.
  - Section 5.4.4 of the OM report in **Appendix 2** provides an explanation of how sensitivity of OM results to stage-area-storage table updates were calculated and summarizes the results.

- Perform a flood frequency analysis of peak inflow to estimate a 100-year event flow at Pensacola Dam.

  - Section 4 of the UHM report in **Appendix 2** clarifies how a flood frequency analysis was performed for the study area using data from USACE. Data from 1940 (dam construction date) to 2019 (latest available data at time of data delivery from USACE) were used and a graphical frequency analysis of peak inflows was performed. The analysis estimated a 100-year event flow at Pensacola Dam of approximately 300,000 cubic feet per second. The largest events of recent record did not meet or exceed the 100-year event threshold at Pensacola Dam. The July 2007 event was scaled so the peak flow at Pensacola Dam approximately matched the estimated 100-year event, with a daily inflow volume to Pensacola Dam that approximately matched the results of a statistical analysis of historical inflow volumes.

- Determine the duration and extent of inundation under the current license (baseline) operations of the Project and anticipated change in these operations that occurs during several measured inflow events starting at elevation 734 Pensacola Datum (PD) up to and including elevation 757 PD.
  - Sections 7 through 10 of the UHM report demonstrate how the calibrated UHM was used to analyze five historical inflow events and one synthetic event with a range of starting pool elevations at Pensacola Dam. Maximum WSEL values and inundation extents were extracted from HEC-RAS and analyzed.

  - Sections 3 through 6 of the DHM report in **Appendix 2** demonstrate how the calibrated HEC-RAS model was used to analyze a range of operating conditions at Pensacola Dam utilizing results from the OM. Five historical flow events and one synthetic event were analyzed for a range of starting pool elevations at Pensacola Dam. An additional suite of simulations was computed to analyze an alternate operational scenario anticipated by GRDA for Pensacola Dam. Inflows to Lake Hudson for the synthetic 100-year event were derived from a statistical analysis of historical inflow volumes. Maximum WSEL values and inundation extents were extracted from HEC-RAS and analyzed.

- Report the frequency, timing (i.e., seasonality), amplitude (i.e., elevation), and duration for each of the simulated inflow events with starting elevations between 734 feet PD and 757 feet PD for the baseline analysis and under any anticipated change in operations.
  - Section 8 of the UHM report in **Appendix 2** demonstrates that starting pool elevations at Pensacola Dam within GRDA’s anticipated operational range have an immaterial impact on upstream WSELs, inundation, and duration for a range of inflow events. Compared to starting elevations within GRDA’s anticipated operational range, only a different natural inflow event caused an appreciable difference in maximum WSEL, maximum inundation extent, or duration. The differences in WSEL, inundation extent, and duration due to the size of the natural inflow event were orders of magnitude greater than the differences in WSEL, inundation extent, and duration due to the initial stage at Pensacola Dam. The maximum impact of nature typically ranged from over 10 times to over 100 or even over 1,000 times the maximum simulated impact of GRDA’s anticipated operational range.

  - Even if extreme, hypothetical starting pool elevations outside GRDA’s anticipated operational range are used, the maximum impact of nature is much greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet. The impact of nature typically ranged from 2 times to 10 or even 100 times the impact of the extreme, hypothetical starting stage range.

  - Section 10 of the UHM report in **Appendix 2** demonstrates that, compared to baseline operations, anticipated operations have an immaterial impact on maximum WSELs, maximum inundation extent, and duration.

  - Section 4 of the DHM report in **Appendix 2** demonstrates that initial stages at the Project within GRDA's anticipated and extreme, hypothetical operational ranges have an impact on downstream WSELs and out-of-bank inundation. As the analysis shows, downstream WSELs, stages at Kerr Dam, and inundation extents are dependent on the magnitude and volume of releases from the Project, which in turn are dependent on initial stage at the Project. Out-of-bank inundation downstream of the Project is the result of spillway releases which are directed by the USACE. Under authority of Section 7 of the 1944 Flood Control Act, the Tulsa District of the USACE is responsible for prescribing and directing the flood control operations of the Project. The USACE is also responsible for directing spillway releases in accordance with the procedures for system balancing of flood storage outlined in the Arkansas River Basin Water Control Master Manual. This authority is reinforced by NDAA 2020 which states that "The Secretary [of the Army] shall have exclusive jurisdiction and responsibility for management of the flood pool for flood control operations at Grand Lake O' the Cherokees".

  - Section 6 of the DHM report in **Appendix 2** demonstrates that, compared to baseline operations, anticipated operations have an immaterial impact on maximum WSELs, maximum inundation extent, and duration.

  - Section 11 of the UHM report in **Appendix 2** explains the analysis for the timing (seasonality) information requested to inform other analyses of Project effects.

- Provide the model results in a format that can inform other analyses (to be completed separately) of Project effects, if any, in several resource areas including the production of Lentic and Lotic Maps for baseline and anticipated operations, as needed, in the Aquatic Species of Concern, the Terrestrial Species of Concern, and the Wetland and Riparian Study
  - Section 11 of the UHM report in **Appendix 2** explains the simulations that were run to inform other analyses to assess changes in Project effects from changing from the baseline operations to anticipated operations.

- Provide the means necessary to complete any additional return (flood) frequency analysis that may be deemed necessary following review of the USR.
  - As outlined in the UHM report in **Appendix 2**, GRDA has included the return frequency analysis (i.e., flood frequency analysis) as an electronic attachment to the USR.

- Determine the feasibility of implementing anticipated operations scenarios, if applicable, that may be proposed by GRDA as part of the relicensing effort.
    - Section 10 of the UHM report in **Appendix 2** compares anticipated operations to baseline operations for a suite of simulations that spanned the FERC-requested range of starting pool elevations and inflow event magnitudes. The results of the UHM demonstrate that anticipated operations have an immaterial impact on upstream WSELs, inundation, and duration as compared to baseline operations.

    - Section 6 of the DHM report in **Appendix 2** compares anticipated operations to baseline operations for a suite of simulations that spanned the FERC-requested range of starting pool elevations and inflow event magnitudes. The results of the DHM demonstrate that anticipated operations have an immaterial impact on downstream WSELs, inundation, and duration as compared to baseline operations.

The Hydrologic and Hydraulic Study is complete, and no additional work is planned.

5.2 Sedimentation Study

Since sediment transport processes in the Project area were relatively unknown, and as such, the linkages between Project operations, bed changes, and potential upstream flooding were not clearly understood, the primary objective of the Sedimentation Study was to determine the potential effect of Project operations on sediment transport, erosion, and deposition in the lower reaches of tributaries to Grand Lake upstream of Pensacola Dam. Additionally, the Sedimentation Study is designed to provide an understanding of the sediment transport processes and patterns upstream of Grand Lake on the Neosho, Spring, and Elk rivers and Tar Creek. The Sedimentation Study complements GRDA's H&H Study in determining the impact of Project operations, if any, on bathymetric changes and upstream inundation levels.

The objective of the Sedimentation Study is also to investigate the overall trends and impact of sedimentation within the Project boundary. Specifically, this study will analyze the amount of sedimentation that has occurred in the reservoir; evaluate sediment transport, erosion, and deposition in Grand Lake and its tributaries; and characterize the impact that sedimentation may have on flood extents and duration throughout the study area under potential future operation scenarios.

More specifically, the Sedimentation Study meets the objectives of the study by following the recommendations outlined in the RSP, the November 8, 2018 SPD, and the May 27, 2022 determination letter which recommended the following activities to be completed:

- Compile existing data and review literature on suspended sediments, sediment properties, flow, and water levels.
    - Section 2 of the Sedimentation Study report in **Appendix 4** explains the efforts to compile existing data on suspended sediments, sediment properties, flow and water levels.

- Collect additional field measurements and data.

  - Section 2 of the Sedimentation Study report in **Appendix 4** also outlines efforts in collecting additional field measurements and data resulting in a major change in available information that the sediment moving through the study area was dominated by cohesive material rather than sand and gravel.

- Collect sediment core samples at ten locations in the delta feature.
  - Section 2.2.5 of the Sedimentation Study describes the subsurface investigations completed in the delta feature.

- Conduct a bathymetric change analysis.
  - Section 4.5 of the Sedimentation Study report in **Appendix 4** outlines how the quantitative analysis of sediment transport consists of using the basic data and quantitative tools to analyze the hydrology, hydraulics, and resulting effect on sedimentation in Grand Lake.

  - The analysis uses the historical bathymetric data combined with the hydraulic analysis of historical flows and reservoir operation to develop a relationship between hydraulic shear stress and sedimentation pattern. Hydraulic shear stress is the driving force behind the transport and deposition of sediment. Hydraulic shear stress is the basic variable used in many sediment transport equations for both cohesive and non-cohesive sediments to determine whether sediment is eroded or deposited, and the rate at which sediment is transported.

- Develop a Sediment Transport Model (STM) using HEC-RAS to determine the fate of sediment upstream of RM 100.
  - Section 5 of the Sedimentation Study report in **Appendix 4** explains how the STM was developed using HEC-RAS v. 6.2 as available from USACE. The software is one of the leading fluvial system modeling packages and is frequently used for flood evaluations, hydrologic and hydraulic studies, and sediment transport estimates. The original version of the STM as submitted in December 2021 was built in HEC-RAS v. 5.0.7. This decision to use the newer software was made to take advantage of more robust sediment transport code that was included with the software updates.

  - The STM directly models the system above RM 100. Truncating the STM at RM 100 allows more accurate modeling of sediment deposition patterns by focusing primarily on the non-cohesive portion of sediment loading (and cohesive sedimentation not defined by density currents) and its impacts on water levels, which HEC-RAS was developed to evaluate. HEC-RAS is less well-suited to model the cohesive sediment that is found lower in the reservoir.

  - The results of the STM were exported to a 1D UHM for hydraulic evaluation. The 1D UHM was based on the STM and was developed in HEC-RAS v. 6.2 to maintain consistency with the STM. The 1D UHM is distinct from the UHM and STM. It was run in fully unsteady hydraulic-only mode.

- Calibrate the STM to measured bed changes based on the historical surveys.
  - Section 6 of the Sedimentation Study report in **Appendix 4** describes how the STM calibration was performed in two components. As with any model calibration procedure, it is easiest to start with the simplest format available, ensure accuracy, then increase complexity. For the STM, that meant beginning with hydraulic calibration and neglecting sediment movement, erosion, and deposition. Once the hydraulics were well-calibrated, sediment transport was added to the STM, and the sediment model parameters were finalized.
  - Sediment calibration and validation simulations ran from 1942 to 2019. Results were then compared against measured data from REAS surveys, the 2009 OWRB survey, and USGS surveys performed in 2017 and 2019.
  - The overall goal of this step was to create a baseline geometry using the 2019 terrain dataset that could be used to predict future sediment transport, erosion, and deposition patterns.
- Complete a qualitative analysis to understand the general trends in the system and how the stream has evolved over time.
  - Section 3 of the Sedimentation Study report in **Appendix 4** outlines in the qualitative analysis how several physical features affect the geomorphology of the rivers in the study area that either exist naturally or have been constructed. Such features include Pensacola Dam, bridges, and geologic and geomorphic features.
  - The analysis shows that sediment forming the delta feature is transported a considerable distance downstream into the reservoir. Because sands and gravels tend to drop out of the water column sooner, if a significant portion of the sediment load consisted of bed material load (sand and gravel), the delta feature would have begun forming much farther upstream near the head of the reservoir. Therefore, the delta feature location further supports what field sampling showed: the feature consists primarily of fine sediment.
  - Because bridges constrict flow, the analysis shows they typically cause backwater effects upstream of the bridge. The backwater effects include increased WSELs and reductions in velocity. At the bridges themselves, the reduced flow areas result in increased velocities. Bridges also potentially trap debris such as floating logs, which further constricts the flow and increases the backwater effect. The effects of hydraulic constrictions at bridges potentially cause sediment deposition upstream of the structure due to the reduced velocities. An extreme example of bridge encroachment on the river and floodplain is the railroad bridge just downstream of the Twin Bridges area below the

confluence of the Neosho and Spring rivers. At the bridge, flow is constricted to just 20% of the river width upstream of the railroad embankment, creating significant backwater at this location.

- Vertical rock banks are evident in various reaches along the Neosho River. Reaches of river that are confined by vertical rock banks disconnect the floodplain and confine the flow to a relatively narrow cross section, which constricts the flow, potentially causing upstream backwater effects and sediment deposition.

- Separate from the geologic features, there are also flood protection levees upstream that disconnect the river from the floodplain and confine the flow to a relatively narrow cross section, which constricts the flow, potentially causing upstream backwater effects and sediment deposition.

- Submerged ridges in the now-submerged valley can act as stable points. Many of these ridges are perpendicular to downstream flow in the valley and can also cause sediment to deposit between and amongst the submerged ridges. These stable points are also capable of contributing to the creation and evolution of the delta feature that is shown in the 2019 USGS profile and the 2009 OWRB profile from RM 100 upstream to RM 122. The Ozark Uplift causes the narrowing and stable points (grade control) in the now-submerged valley. Dendritic drainage patterns from the surrounding uplands entering the submerged valley impede the transport of sediment downstream into the lower reaches of the reservoir and cause aggradation of sediment in these sections of submerged river valley. Additional evidence of ridges composed of limestone and chert within the now-submerged valley can be observed in the grade changes of the 1938 bank line elevation profile (the other profile lines display submerged thalweg elevations not submerged valley elevations). The bank line grade change begins at RM 108 and extends upstream to approximately RM 115.

- At a confluence of a tributary, some of the sediment load from the tributary is frequently deposited, forming a tributary bar within the river. Tributary bars form because the slope of the tributary is typically steeper than the river into which it flows, so some portion of the sediment load cannot be readily transported downstream resulting in sediment deposition. This process also occurs when the tributary transports a high sediment load or a coarser sediment load than the main river. The Ozark Uplift crosses the Neosho River at the confluence of the Elk River. This feature, combined with the steeper slope of the Elk River and the attendant potential for the formation of a tributary bar, suggest a natural tendency for sediment deposition at this location. Although these geomorphic features affect potential sedimentation patterns at this location, it is not possible to quantify these effects on the overall sedimentation pattern.

- Complete a quantitative engineering analysis of sediment transport in the study area focusing on the delta feature and downstream of RM 100.

- Section 4 of the Sedimentation Study report in **Appendix 4** describes the quantitative analysis and how it developed a relationship between hydraulic shear stress and the pattern of sedimentation specifically in terms of the percent of sediment passing each cross section based on the change in historical bathymetry using historical flows and operation.

- The quantitative analysis of the future 50 years of hydrology and operation shows no significant sediment deposition on top of the delta feature that would adversely affect existing hydraulic control in upstream reaches. Most of the sediment delivered to the reservoir is transported past the top of the delta feature, farther downstream to the downstream face of the feature. Approximately 98% to 99% of the incoming sediment load is transported past RM 110. The future flows with baseline operations cause slightly reduced deposition on the downstream face of the delta feature and shift the deposition slightly downstream compared to the anticipated operation. This comparison of computed sediment deposition pattern demonstrates the very small effect of Project operations on sedimentation rates and patterns.

- In addition, after evaluation, the results indicated that sediment deposition would occur primarily on the downstream face of the delta feature, which follows typical evolution patterns of such deposits. The delta feature is not expected to grow in height over the next 50 years.

- Characterize Sedimentation impacts on upstream water levels over a 50-year period for baseline and anticipated operations.
  - Section 7 of the Sedimentation Study report in **Appendix 4** shows after model calibration, predictive simulations were performed to evaluate future conditions within the study area and evaluate the impact of sedimentation on upstream water levels.

  - The results indicate that the impacts of sedimentation on WSEL are immaterial in urbanized areas, regardless of loading rates, Project operations, or future versus current geometry. This finding further confirms the fact that Project operations are not a major contributor to increased upstream water levels in the City of Miami or other urbanized portions of the study area. Downstream of Miami, sediment loading, a natural phenomenon outside GRDA’s control, has the biggest impact on WSEL.

- Analyze the effects of sediment on storage capacity in Grand Lake using hydraulic outputs from the STM and the USACE sediment trapping efficiency calculations downstream of RM 100.
  - Section 4 of the Sedimentation Study report in **Appendix 4** explains, based on the quantity of sediment computed using the sediment transport rating curves over the 50-year future scenario, approximately 109 million tons of sediment are delivered to Grand Lake. This converts to a volume of 71,587 acre-feet at 70 per cubic foot (pcf) and 86,398 acre-feet at 58 pcf (assuming a 100% trapping efficiency). This volume of sediment (storage loss from the reservoir) would be distributed according to the results of the

hydraulic shear stress analysis for the anticipated (or baseline) operations. The analysis shows that virtually no sediment is deposited upstream of RM 116, approximately 10% of the sediment is deposited between RM 116 and RM 105 (Elk River confluence), approximately 22% is deposited between RM 105 and RM 100, and the remaining 68% is deposited between RM 100 and the dam.

The Sedimentation Study is complete, and no additional work is planned.

5.3 Aquatic Species of Concern Study

The objective of the Aquatic Species of Concern Study is to gather existing and additional information on certain species of concern to assess the effects of the Project, if any, on those species. The sensitive species reviewed as part of this study are the Neosho mucket, rabbitsfoot, winged mapleleaf, Neosho madtom, Neosho smallmouth bass, and paddlefish.

More specifically, the Aquatic Species of Concern Study meets the objectives of the study by following the recommendations outlined in the RSP, the November 8, 2018 determination letter and the February 24, 2022 determination letter, which recommended the following activities to be completed. In the list of activities below, all items have been completed and each item identifies where in each study report the activity is discussed:

- Gather existing information and map areas of known areas of paddlefish spawning.
    - Known areas of paddlefish spawning were identified and outlined in Figures 4 through 6 of the Aquatic Species of Concern Study report in **Appendix 5**.

- Review existing information (including density) for Neosho mucket to characterize the physical habitat preferences and spatial and temporal patterns of the species.
    - Existing information for Neosho mucket was identified and outlined in Section 3 of the Aquatic Species of Concern Study report in **Appendix 5** and was utilized to determine parameters for additional field studies on the species.

- Review existing information (including density) for Neosho madtom to characterize the physical habitat preferences and spatial and temporal patterns of the species.
    - Existing information for Neosho madtom was identified and outlined in Section 4 of the Aquatic Species of Concern Study report in **Appendix 5** and was utilized to determine parameters for additional field studies on the species and it has been repeated in the USR.

- Review existing information for Neosho smallmouth bass to characterize the physical habitat preferences and spatial and temporal patterns of the species.
    - Existing information for Neosho madtom was identified and outlined in Section 4 of the Aquatic Species of Concern Study report in **Appendix 5**.

- Review existing information (including density) for rabbitsfoot mussel to characterize the physical habitat preferences and spatial and temporal patterns of the species.
    - Existing information for rabbitsfoot mussel was identified and outlined in Section 4 of the Aquatic Species of Concern Study report in **Appendix 5**.

- Review existing information (including density) for winged mapleleaf mussel to characterize the physical habitat preferences and spatial and temporal patterns of the species.
    - Existing information for winged mapleleaf mussel was identified and outlined in Section 4 of the Aquatic Species of Concern Study report in **Appendix 5**.

- Section 3 of the Aquatic Species of Concern Study report in **Appendix 5** explains how targeted field surveys for Neosho mucket were conducted in the Spring River between Warren Branch and the confluence with the Neosho River and in the Neosho River between the City of Miami and the confluence with the Spring River, after consultation with the USFWS, EcoAnalysts, and Tar Creek Trustee Council on the survey design to develop density estimates, availability of spawning habitat during the spawning season, and estimates of the distribution of the species in relevant reaches.
    - Targeted surveys for Neosho mucket were completed during the week of July 28, 2022 at thirteen sites.

    - Twelve species were collected. Bluefer (Potamilus purpuratus) was the most abundant species. The next most abundant species was Fragile Papershell (Leptodea fragilis). Threehorn Wartyback (Obliquaria reflexa) and Pink Papershell (Potamilus ohiensis) were the next most abundant species overall. No Neosho Muckets were collected during this study.

- Section 3 of the Aquatic Species of Concern Study report in **Appendix 5** documents targeted field surveys for Neosho madtom to develop density estimates, availability of spawning habitat during the spawning season, and estimates of the distribution of the species in relevant reaches.
    - Targeted surveys for Neosho mucket were completed on the Neosho on Spring Rivers in July and August of 2022. Neosho madtoms were found to be present on the Neosho River, but not found on the Spring River.

- Included in Sections 3 and 4 of the Aquatic Species of Concern Study report in **Appendix 5** respectively, GRDA assesses potential effects of Project operation, if any, on the Neosho mucket and Neosho madtom.
    - As described in Section 11 of the H&H Study UHM report contained in **Appendix 2**, maps were generated from the results of the CHM to depict the change in inundation areas due to anticipated operations. The shape file information from the maps was used to overlay aerial photography to evaluate the impacts to aquatic habitat in the area where the species were identified during the surveys. Specifically, using historical data to represent normal events including 1-year flood events, the output of the H&H Study produced a comparison of the mean WSEL under baseline operations versus the mean WSEL under anticipated operations for the May 15 to July 8 each year.

    - The UHM also calculated section-averaged velocities for cross-sections extracted at each Neosho madtom sampling location under both the baseline and anticipated operations.

- Included in Section 4 of the Aquatic Species of Concern Study report in **Appendix 5**, GRDA assesses potential effects of Project operation, if any, on the Neosho smallmouth bass.
    - As described in Section 11 of the H&H Study UHM report contained in **Appendix 2**, maps were generated from the results of the CHM to depict the change in inundation areas due to anticipated operations. The shape file information from the maps was used to overlay aerial photography to evaluate the impacts to aquatic habitat in the area where the species were identified during the surveys. Specifically, using historical data to represent normal events including 1-year flood events, the output of the H&H Study produced a comparison of the mean WSEL under baseline operations versus the mean WSEL under anticipated operations for the May 15 to July 8 period each year (a critical time for the species).

The Aquatic Species of Concern Study is complete, and no additional work is planned.

5.4 Terrestrial Species of Concern Study

The objective of the Terrestrial Species of Concern Study is to gather existing and additional information on certain species of concern and assess the effects of the Project, if any. The sensitive species reviewed as part of this study are the ABB and gray bat.

More specifically, the Terrestrial Species of Concern Study meets the objectives of the study by following the requirements of the RSP. In the list of requirements below all items have been completed and each item identifies where in each study report the activity is discussed:

- Section 4 of the Terrestrial Species of Concern report in **Appendix 6** discusses how maps were produced that delineate the riverine reaches that would be converted to lentic habitat, over a range of inflow conditions, as the result of water level management associated with Project operations.
    - As described in Section 11 of the H&H Study UHM report contained in **Appendix 2**, maps were generated from the results of the CHM to delineate areas that would be converted to lentic habitat under the anticipated operations. The shape file information from the maps can be used to determine if areas that support ABB are impacted under the anticipated operations more than the baseline operations.

- Section 4 of the Terrestrial Species of Concern report in **Appendix 6** assess the degree to which anticipated Project operations would inundate the main entrance to Beaver Dam Cave and compare the frequency of inundation with that associated with baseline operations.
    - The CHM analysis shows under the anticipated operations of the Project, the Grand Lake Reservoir will exceed 746 feet PD, the reservoir elevation at which water flows into the entrance of cave DL-2 (Beaver Dam), is 16.5% under baseline operations and 16.9% under anticipated operations. The anticipated operations will cause this situation to occur 0.4% more frequently.

    - Evacuation of DL-2 generally does not begin to occur until Grand Lake reaches an elevation of approximately 751 feet PD. According to the CHM analysis, under the anticipated operations of the Project, the Grand Lake Reservoir will exceed 751 feet PD, 2.9% under baseline operations and 2.7% under anticipated operations. The anticipated operations will cause this situation to occur 0.2% less frequently.

  - A Grand Lake Reservoir elevation of 752 feet PD results in a complete inundation of the cave passage in DL-2 forcing evacuation. According to the CHM analysis, under the anticipated operations of the Project, the Grand Lake Reservoir will exceed 752 feet PD, 1.9% under baseline operations and 1.9% under anticipated operations. The anticipated operations will cause this situation to occur the same percentage of time as the baseline operations.

- Sections 3 and 4 of the Terrestrial Species of Concern report in **Appendix 6** determined whether the secondary exit at Beaver Dam Cave suffices to provide an alternative access by gray bats to the cave (during times of inundation).
  - The average post-maternity colony size illustrates relative consistency, ranging from 15,200 to 29,905 bats with an average colony size of 19,877 gray bats for the past 10 years. Efforts should be concentrated on maintaining strong ties with the landowner of the access to cave DL-2, so that similar security efforts can continue there for the long-term. In sum, the gray bat colony sharing caves DL-2 and DL-91 each summer appears to maintain a stable population size.

  - The findings of the gray bat study indicate the secondary exit suffices to provide an alternative access by gray bats in cave DL-2. Regardless of the efficacy of the alternative access, the entrance to cave DL-2 does not become completely inundated to elevations 751 feet PD and greater (complete inundation is 752 feet PD) any more frequently under the anticipated operations than it becomes inundated under the baseline Project operations.

- Section 3 of the Terrestrial Species of Concern report in **Appendix 6** outlines the sampling for American Burying Beetle (ABB) during the active season in locations that are determined in consultation with the USFWS during the first study and final study season.
  - Sampling for ABB in consultation with the USFWS on trap locations was completed 2021 and 2022. Six traps were set on July 18, 2021 and six traps were set on June 9, 2022.

- Section 3 of the Terrestrial Species of Concern report in **Appendix 6** explains the ABB survey results. If ABB were found within the study area, GRDA would compare distributions of beetles to inundation maps generated by the CHM for characterizing the effects of Project operations. If areas that support beetles would be inundated as the result of Project operations, GRDA would coordinate with the USFWS to estimate the level of impact, if any.
  - As outlined in the Terrestrial Species of Concern report, ABB surveys were completed in 2021 and 2022 in consultation with the USFWS on the locations to place traps. No ABBs were collected during the 2021 and 2022 surveys. Therefore, it is unnecessary to characterize the effects of anticipated operations on the distribution of beetles.

The Terrestrial Species of Concern Study is complete, and no additional work is planned.

5.5 Wetland and Riparian Habitat Study

The objective of the Wetland and Riparian Habitat Study is to gather existing and additional information to assist in the evaluation of potential Project effects to wetlands and riparian habitat.

More specifically, the Wetland and Riparian Habitat Study meets the objectives of the study by following the requirements of the RSP. In the list of requirements below all items have been completed and each item identifies where in each study report the activity is discussed:

- Develop base maps in GIS, using source data from the NWI and potentially other resources, of wetland cover types in the Project study area. Cover type maps will be produced from existing resources that will include riparian and wetland vegetation throughout the study area.
    - Wetland and riparian habitat maps from the NWI were developed and included in the ISR.

- Use the results of the H&H Study to produce maps that depict the change in inundation areas due to anticipated operations versus baseline operations overlayed on the wetland base maps showing the current Project boundary.
    - As described in Section 11 of the H&H Study UHM report contained in **Appendix 2**, maps were generated from the results of the CHM to depict the change in inundation areas due to anticipated operations. The shape file information from the maps is being used to overlay wetland base maps to evaluate the impacts to wetlands are greater under the anticipated operations more than the baseline operations.

    - As described in Section 2 of the Wetland and Riparian Habitat Study report, overall, GRDAs anticipated operations result in water level fluctuations ranging from 742 to 745 feet PD or three feet. Whereas, baseline operations result in water level fluctuations ranging from 741 to 745 feet PD or four feet. As a result, overall impacts to wetlands are expected to be less under the anticipated operations than the baseline operations.

- Assess potential impacts to wetlands and riparian areas by identifying the extent, duration, and seasonality (timing) of inundation occurring in the Project area.
    - As outlined in Section 2 of the Wetland and Riparian Habitat Study report, using historical data to represent normal events including 1-year flood events, the output of the H&H Study produced a comparison of the mean WSEL under baseline operations versus the mean WSEL under anticipated operations for the growing season period (March 30-November 2). The mapped output when overlayed on other sources of data included the NWI data, showed very small differences along shorelines that result in a net increase in wetlands because the anticipated operations have a higher mean elevation during the growing season than do the baseline operations.

- Verify the accuracy of the base maps through ground-truthing if it is determined anticipated operations are impacting wetlands. Ground-truthing is only required for any major deviations from the preliminary wetland cover-type maps.
    - As discussed in Section 2 of the Wetland and Riparian Habitat Study report, no major deviations from the preliminary wetland cover-type maps that could not be resolved using

other accurate desktop methods such as aerial photography were identified that required ground-truthing.

The Wetland and Riparian Habitat Study is complete, and no additional work is planned.

5.6 Recreation Facilities Inventory and Use Study

The goals of the Recreation Facilities Inventory and Use Study are to gather information regarding current recreational use and identify recreation resources and activities that may be affected by the continued operation of the Project. Consistent with FERC's study request, the specific objectives of the study are to:

- Characterize current recreational use of the Project area,
- Estimate future demand for public recreation use at the Project,
- Gather information on the condition of GRDA's FERC-approved recreation facilities,
- Identify any need for improvement, and
- Evaluate the potential effects of continued operation of the Project on recreation resources and public access in the Project area.

More specifically, the Recreation Facilities Inventory and Use Study meets the objectives of the study by following the recommendations outlined in the RSP and the November 8, 2018 determination letter which recommended the following activities to be completed. In the list of activities below all items have been completed and each item identifies where in each study report the activity is discussed:

- Conduct recreation observation surveys at the required recreation facilities.
  - Section 5 of the Recreation Facilities Inventory and Use Study report in **Appendix 8** contains the data gathered as part of the recreation observation surveys. Surveyed recreation sites range in size, usage, facilities, and accessibility. Survey results indicate the most popular sites include three state parks (Bernice, Honey Creek, Little Blue) and one FERC-approved site (Wolf Creek). Most of these sites are relatively large, easily accessible, and have diverse facilities. Little Blue State Park has one of the highest number of visitors even though it is a smaller site. This site cannot be expanded due to topography. Little Blue State Park provides a scenic setting and the high volume of visitors can be attributed to its seasonal access point to the river channels and water below the easternmost spillway of the Pensacola Dam system. It is a popular destination for swimming and shoreline fishing, as well as other activities.

  - The most popular recreational activities at the surveyed sites include camping, shoreline fishing, boat fishing, boating, and picnicking. Visitors and vehicles that visited the sites during the 30 survey dates were counted. The counts are approximate and were tallied at each site over the course of the 30 one-hour visits.

- Conduct recreation visitor use interviews at the required recreation facilities.
  - Section 5 of the Recreation Facilities Inventory and Use Study report in **Appendix 8** explains the visitor use interview. Visitor interviews were conducted at sites between May and September 2020, except for Big Hollow and Willow Park. The observed use at Big Hollow is minimal; no visitors were observed during survey times and therefore no visitors could be interviewed. Willow Park is a boat launch facility, and although visitors were observed, they generally were not available for interviews as they were on the water.

  - A total of 163 visitor interviews were conducted, with the majority (23) conducted at Bernice State Park. The number of interviews at each site reflects the availability of visitors at that recreation site. Sites with a greater number of campsites had more visitors to interview, while sites with high boating usage had fewer visitors to interview, as they were typically on the water. Repeat and regular site visitors were not interviewed more than once. Most repeat visitors utilized smaller sites such as Spring River, Connors Bridge, Riverview Park, Seaplane Base, and Council Cove. First time visitors were more likely to visit larger sites such as Bernice State Park and Honey Creek State Park. Regular visitors traveled an average of 48.8 miles to recreate in the vicinity of Grand Lake. By comparison, first time visitors traveled an average of 177.06 miles. On survey days with excessive amounts of rain and/or high water, no visitors were available for interviews.

- Conduct facility condition assessments at the required recreation facilities.
  - Section 5 of the Recreation Facilities Inventory and Use Study report in **Appendix 8** outlines the process and results of the facility condition assessment. Both a recreation facility inventory and site condition assessment were completed at each of the five FERC-approved recreation sites on either September 22 or 23, 2020. Each site condition assessment is explained and any subsequent recommendations are made.

- Collect boat launch elevation data.
  - Section 5 of the Recreation Facilities Inventory and Use Study report in **Appendix 8** explains boat launch elevations were photo-documented at all recreation sites with a boat launch. Photos are provided showing high water and low water elevations at these sites are provided. Twin Bridges Upper State Park, Little Blue State Park, Cherokee Main State Park, and river channel sites do not have a boat launch. The top of the reservoir conservation pool is 745.00 feet PD. Over the course of the survey dates, Grand Lake elevation fluctuated between 742.20 and 748.29 feet PD. All survey dates and the corresponding reservoir elevation acquired from USACE are listed. The highest reservoir elevation was recorded on May 30, 2020, and the lowest on September 26, 2020 (last survey day). Inundation occurred at various sites on May 27 and May 30, 2020. GRDA assessed boat launch elevations to evaluate the reservoir surface elevation range at which the boat ramps are accessible. At the lowest recorded water elevation during the survey of 742.2 feet PD all boat launches appeared to be accessible. At the highest and second highest recorded water elevations during the survey of 748.29 or 747.83 feet PD nine of the sixteen boat launch sites are accessible.

- Characterize current recreation use and future demand for recreation use at the required recreation facilities.
    - Section 6 of the Recreation Facilities Inventory and Use Study report in **Appendix 8** explains the most popular sites include three state parks (Bernice, Honey Creek, Little Blue) and one FERC-approved site (Wolf Creek). Most of these sites are relatively large, easily accessible, and have diverse facilities. Little Blue State Park has one of the highest number of visitors because it provides a unique recreational experience.

    - The most popular recreational activities at the surveyed sites include camping, shoreline fishing, boat fishing, boating, and picnicking.

    - A comparison of projected population data for Ottawa, Craig, Delaware, and Mayes Counties shows that between the years 2010 and 2020, these counties had a population growth of (4.9%), (6.1%), 2.6%, and (5.4%) respectively. If the projected population growth experienced from 2010 to 2020 continues at this rate for the region, the public can further utilize any of the surveyed recreation sites that have unused capacity, which would absorb the needs of the growing population. It is generally not feasible to expand the highly-used sites due to physical and/or geographical barriers, seasonal high water events, and private property surrounding most sites. Very few visitor comments referenced overcrowding at recreation sites. Data indicates additional recreation sites or addition of camping sites to existing state parks is not necessary.

The Recreation Facilities Inventory and Use Study is complete, and no additional work is planned.

5.7 Cultural Resources Study

The objectives of the Cultural Resources Study are: (1) to identify historic properties within the Project's APE that are being adversely affected by Project operations (if any), including properties of traditional religious and cultural importance; and (2) to develop a HPMP in consultation with the SHPO, Oklahoma Archaeological Survey, and Native American Tribes that provides for the long-term management of historic properties within the APE over the term of the new license.

More specifically, the Cultural Resources Study meets the objectives of the study by following the recommendations outlined in the RSP and the November 8, 2018 determination letter which recommended the following activities to be completed. In the list of activities below all items have been completed and each item identifies where in each study report the activity is discussed:

- Complete background research and archival review.
    - In preparation for the Cultural Historic Investigations and any archaeological investigations and as outlined in Volume I, II, and III of the reports, background and archival research was completed as a precursor to any field investigations such that the requirements of Section 106 of the NHPA are fulfilled.

- Complete cultural resource investigations.

- Section 4 of the Cultural Resources Study report in **Appendix 9** explains how Volume III of the report contained in **Appendix 9** builds upon the results contained in Volume I and Volume II of the report previously submitted with the Commission as sensitive information, pursuant to 18 CFR § 388.112(b) and 388.113(c)(1) and have special treatment of the reports in their entirety as Privileged material by maintaining these reports in the Commission's non-public file.

- The total survey area for this project fell within the Pensacola Project APE. The 2021-2022 investigations consisted of relocating and assessing conditions at five previously recorded sites, surveying three Late Qals determined to have a high potential for cultural materials, survey of an unnamed island, and completion of the visual inspection of exposed bluffs along the lake edge to identify potential rockshelters and caves.

- Develop a HPMP.
  - As part of the approved Cultural Resources Study plan, GRDA has been developing an HPMP in consultation with the CRWG.

  - The HPMP is a compliance and management plan that integrate the entirety of Federal and State cultural resources program requirements with ongoing practices such as hydropower generating activities, allowing for the identification of potential compliance and preservation actions that may occur over the course of a license period. The intent is to ensure that historic properties, as that term is defined under federal law, that may be affected by the generation of hydropower are appropriately managed for scientific research, education, and cultural, religious, and traditional uses for future generations. This HPMP is designed to comply with the requirements of applicable federal and state laws and regulations, including the NHPA, Native American Graves Protection and Repatriation Act of 1990, Archaeological Resources Protection Act of 1979, and the Commission guidelines for development of the HPMP.

  - The HPMP will be included in the DLA and the final HPMP is expected to be included as a requirement of FERC's new license, which will become effective following expiration of the existing license.

- Conduct Tribe-specific Traditional Cultural Properties Inventories.
  - GRDA completed an ethnographic study designed to obtain information about the locations, types, and number of TCPs within the Project APE from members of the Native American Tribes represented among the Cultural Stakeholders. This information was collected and compiled from interviews with Tribal members. Information about TCPs within the Project APE is considered privileged and confidential at the explicit request of Native American Tribes, and access to data on the nature and locations of individual TCPs is restricted to the cultural consultant conducting the study, to each respective Tribe, and to GRDA.

With the exception of development of a final HPMP, which GRDA expects to include in the Final License Application, the Cultural Resources Study Phase I work is complete, and no additional work is planned. Based on the results of the Phase I study, the final HPMP will address the recommended Phase II field work.

5.8 Socioeconomics Study

The goal of the Socioeconomics Study is to gather, synthesize, and report on existing information necessary to qualitatively evaluate the socioeconomic effects of the Pensacola Project in the study area.

More specifically, the Socioeconomic meets the objectives of the study by following the requirements of the RSP and the recommendations outlined in the November 8, 2018 determination letter which recommended the following activities to be completed. In the list of activities below all items have been completed and each item identifies where in each study report the activity is discussed:

- Describe baseline economic conditions in the Project study area.
    - Section 1 of the Socioeconomic Study Report in **Appendix 10** presents information on the socioeconomics, including land use patterns, population, and employment, of the Project and the State of Oklahoma. The region of influence ROI for socioeconomic impacts are defined as Craig, Delaware, Mayes and Ottawa County, Oklahoma, where the project impacts is located. Socioeconomic and demographic data establish baseline conditions that consist of publicly available information about the ROI and, to provide perspective, the state of Oklahoma.

- Broadly assess the cumulative socioeconomic impacts of the Project within the study area.
    - Section 3 of the Socioeconomic Study Report in **Appendix 10** presents information on a cumulative impacts analysis that involves determining if there is an overlapping or compounding of the anticipated impacts of the continued operation of the Pensacola Dam during the proposed operating term with past, present, and reasonably foreseeable future actions, regardless of what agency (federal or non-federal) or person undertakes such actions.

- Identify the socioeconomic contribution of the Project within the study area.
    - Sections 1 and 3 of the Socioeconomic Study Report in **Appendix 10** explains the economic activity of GRDA continues to contribute a large portion of the GDP in the ROI as well as a measurable contribution to the state. Job opportunities, low electricity rates, recreational opportunities, and quality of life will continue to attract individuals to Oklahoma and are expected to continue into the foreseeable future. As such, GRDA has a large beneficial impact to the local economy and, to a lesser extent, to the entire State of Oklahoma. Economic impacts due to additional local economic stimulation are expected to contribute to the large beneficial reasonably foreseeable effect that has a reasonably close causal relationship associated with the continued operation of the Pensacola Dam.

The Socioeconomic Study is complete, and no additional work is planned.

5.9 Infrastructure Study

The objective of the Infrastructure Study is to determine a range of inflow conditions for which H&H Model results show Project operations may influence the frequency or depth of flooding. Specifically, the Commission requested maps and tables identifying the frequency and depth of inundation for each item of infrastructure.

More specifically, the Infrastructure Study meets the objectives of the study by following the recommendations outlined in the November 8, 2018 determination letter and the February 24, 2002 determination letter which recommended the following activities to be completed. In the list of activities below all items have been completed and each item identifies where in each study report the activity is discussed:

- In consultation with stakeholders, determine a list of infrastructure types to be included in the recommended infrastructure study.
    - Section 4 of the Infrastructure Study report in **Appendix 11** explains how GRDA compiled infrastructure locations from available data sources. The primary data source for GIS features and location information was Oklahoma Digital Data Online. Features obtained from this source were supplemented with data obtained from the USGS Geographic Names Information System, EPA's Facility Registry Service, Federal Aviation Administration, and Homeland Infrastructure Foundation Level Database.

    - GRDA also refined and supplemented the list of infrastructure, local emergency management agencies were contacted and given the opportunity to provide information on and/or the location of infrastructure features of concern to their jurisdictions. These contacts included county, city, and tribal emergency management entities, as well as the State of Oklahoma and USACE, Tulsa District Office.

    - Additional infrastructure locations identified through coordination with emergency management entities were added to the facilities GIS data layer.

- Analyze the impact of baseline and anticipated operation on the inundation of critical upstream infrastructure by providing maps and tables.
    - Sections 5, 6, and 7 of the Infrastructure Study report in **Appendix 11** explains According to analysis results, only 7% of the infrastructure locations studied experience an appreciable increase in maximum inundation depth for different starting reservoir elevations within GRDA's anticipated operational range of 742 feet PD to 745 feet PD. In addition, all appreciable increases in maximum inundation depth occur during high-flow conditions when the USACE controls the flood control operations under the Flood Control Act of 1944 and its other statutory mandates, except when the time of maximum inundation depth is solely a function of inflow event arrival time and not reservoir elevation, meaning the time of maximum depth at the infrastructure location was completely independent of the Project reservoir elevation. The inflow event moved down the river and then arrived at the infrastructure location completely independent of Project operations. Therefore, infrastructure locations are not adversely affected by GRDA's Project operations.

- Additionally, except for two parks, a reduction in reservoir operational elevation to 734 feet PD would not decrease the loss of infrastructure use for any of the inflow events studied. The first park, Wolf Creek Park, was designed (and partially funded) by GRDA to avoid being impacted by inflow events, and only a low-lying portion of the park near Grand Lake would experience a difference in inundation for the October 2009 (3 year) inflow event. Therefore, any potential adverse impacts have already been mitigated by GRDA through their assistance in designing and funding the recent improvements to the park.

- At the second park, Grove Springs Park, low-lying portions of the park would experience a difference in inundation for the October 2009 (3 year) inflow event. Decreasing the low end of the anticipated operation range from 742 to 734 feet PD, a difference of 8 feet in operational elevation, would only change infrastructure adverse impacts slightly at Grove Springs Park.

- Because infrastructure such as parks are generally sited in areas that are subject to frequent flooding and are the most-resistant type of infrastructure being reviewed in this Study, the minor potential reduction in impacts to infrastructure identified through operating at an extreme, hypothetical elevation of 734 feet PD do not significantly decrease loss of infrastructure use at the Project.

- Extreme, hypothetical operational levels up to and including 757 feet PD were analyzed. If GRDA operated at 757 feet PD, a reservoir elevation that is 12 feet higher than the top of GRDA's anticipated operational range and an elevation equal to the top of dam, infrastructure locations would be inundated by depths similar to or greater than those depths for operational levels within GRDA's anticipated operational range. Practically speaking, increasing the top of the operational range to 757 feet PD is simply not possible.

- In summary, infrastructure locations are not adversely affected by GRDA's existing or anticipated operations of the Project, which consist of reservoir levels within an operational range of 742 feet PD to 745 feet PD. Even under the hypothetical and extreme operational level of 734 feet PD, only two parks would experience a minor decrease in the loss of infrastructure.

The Infrastructure Study is complete, and no additional work is planned.

6.0 REQUESTED STUDY MODIFICATIONS AND REQUESTED NEW STUDIES

At the USR stage of the ILP, any proposal to modify an approved study must show good cause and demonstrate that: (1) the approved study was not conducted as described in the approved RSP or (2) that it was conducted under anomalous environmental conditions, or that environmental conditions have changed in a material way since the study plan's approval. 18 C.F.R. §§ 5.15(f) (referencing the criteria in § 5.15(d)).

With regard to proposed new studies at the USR stage, any such proposal must "demonstrate extraordinary circumstances warranting approval. 18 C.F.R. § 5.15(f), moreover, any new study proposal at the USR stage must include an appropriate statement explaining: (1) any material changes in the law or regulations applicable to the information request, (2) why the study's goals and objectives cannot be met via the approved study's methodology, (3) why the request was not made earlier, (4) significant changes in the proposal or significant new information has become available that affects the study, and (5) why the study request meets the criteria of 18 CFR 5.9(b).

6.1 Proposed Study Modifications

Based upon the results of the studies conducted in both study seasons described herein, all study plan objectives have been met, therefore, as shown in Table 5, GRDA does not propose any modifications to the approved studies as part of this USR. As detailed in Section **5**, all study plan objectives have been met.

Table 5. Proposed Study Modifications

Study	Proposed Modification(s)
Hydrologic and Hydraulic Modeling	None
Sedimentation	None
Aquatic Species of Concern	None
Terrestrial Species of Concern	None
Wetland and Riparian Habitat	None
Recreation Facilities Inventory and Use	None
Cultural Resources	None
Socioeconomics	None
Infrastructure	None

6.2 Requested New Studies

Based upon the study results of the studies conducted in the first study season and the final study season, all study objectives have been met and GRDA does not propose any new studies as part of this USR.

7.0 STATEMENT OF LICENSE APPLICATION

The relicensing studies addressed in the USR will provide the information necessary for determining and characterizing Project impacts and identifying appropriate protection, mitigation, and enhancement measures relevant to those impacts. As provided in 18 CFR § 5.16(c), GRDA has elected to prepare a Draft License Application (DLA) in lieu of a preliminary licensing proposal. The DLA will conform to the contents required by 18 CFR § 5.18. The DLA will be filed with FERC no later than January 1, 2023.[40]

Following the 90-day comment period on the DLA, as provided in 18 CFR § 5.16(e), GRDA will prepare and file the Final License Application no later than May 31, 2023.[41]

[40] Due no later than 150 days prior to deadline for filing of License Application (18 CFR §5.16(a)).

[41] Due no later than 2 years prior to license expiration (18 CFR § 5.17(a)).

8.0 REFERENCES

City of Miami, OK. 2021. Comments of Tetra Tech on Behalf of the City of Miami, Oklahoma (Corrected) on Mead & Hunt's H&H Modeling Upstream Hydraulic Model Input Status Report on behalf of GRDA. eFiled June 23, 2021.

Cerimele, Nicole, Karl Kibler, Sandra Shannon, Marcus Huerta, Lolita Guarin, Ann Keen, Haley Rush, Christy Stewart, Delaney Cooley, Hannah Pottage, Scotty Moore, Heather Stettler, and Chris Dayton. 2019. Pensacola Hydroelectric Relicensing Project Pre-Fieldwork Report, FERC No. 1494, Craig, Delaware, Mayes, and Ottawa Counties, Oklahoma. Cox | McLain Environmental Consulting, Inc. Tulsa, Oklahoma.

FERC (Federal Energy Regulatory Commission). 2018 Staff Comments on the Pre-Application Document and Study Request for the Pensacola Hydroelectric Project, Letter dated March 13, 2018.

FERC (Federal Energy Regulatory Commission). 2020. Order on Request for Clarification and Rehearing. Order dated January 23, 2020.

FERC (Federal Energy Regulatory Commission). 2019. Order Extending License Term, Modifying Relicensing Process Plan and Schedule, Granting Extensions of Time, and Amending Storm Adaptive Management Plan. Order dated September 9, 2019.

FERC (Federal Energy Regulatory Commission). 2019. Order on Request for Clarification and Rehearing. Order dated January 23, 2019.

FERC (Federal Energy Regulatory Commission). 2018. Study Plan Determination for the Pensacola Hydroelectric Project. Letter dated November 8, 2018.

FERC (Federal Energy Regulatory Commission). 2022. Study Plan Determination for the Pensacola Hydroelectric Project. Letter dated February 24, 2022.

FERC (Federal Energy Regulatory Commission). 2022. Determination on Requests for Study Modifications for the Pensacola Hydroelectric Project. Letter dated May 27, 2022.

GRDA (Grand River Dam Authority). 2022. Response Comments on Sedimentation Study and Submission of Updated Study Plan for Approval. eFiled April 27, 2022.

GRDA (Grand River Dam Authority). 2021. Initial Study Report (ISR) for the Pensacola Project. eFiled September 30, 2021.

GRDA (Grand River Dam Authority). 2022. Sediment Study Technical Meeting for the Pensacola Project. eFiled January 20, 2021.

GRDA (Grand River Dam Authority). 2021. Response to Comments on Initial Study Report, Notice of Technical Meeting, and Request for Privileged Treatment of Cultural Resources Information for the Pensacola Project. eFiled December 29, 2021.

GRDA (Grand River Dam Authority). 2021. Technical Conference Details for the Six-Month Model Input Status Report for the Hydrologic and Hydraulic (H&H) Modeling Study associated with the Pensacola Project. eFiled March 30, 2021.

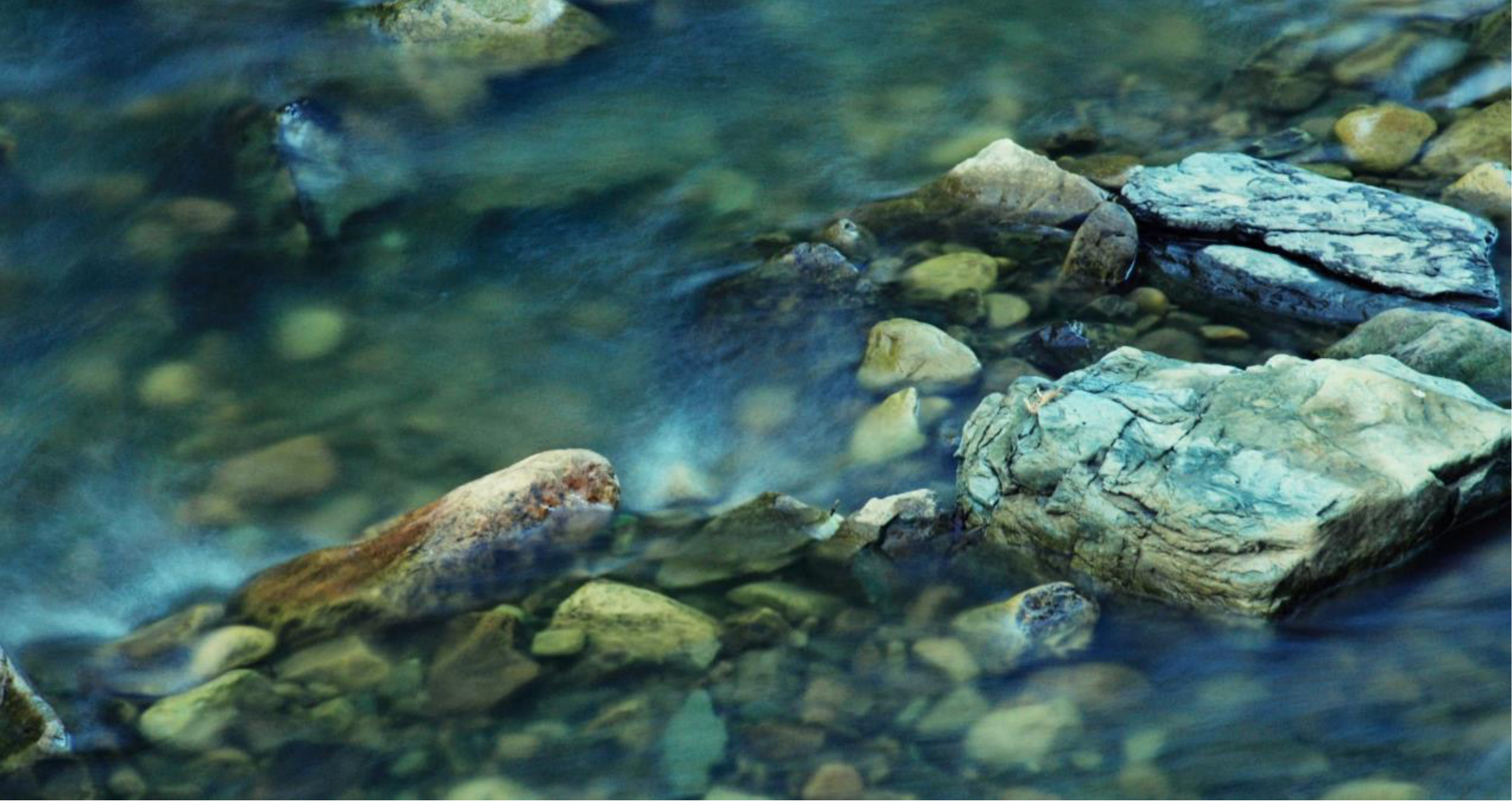
GRDA (Grand River Dam Authority). 2018. Revised Study Plan for the Pensacola Hydroelectric Project. eFiled on September 24, 2018.

ODWC (Oklahoma Department of Wildlife Conservation). 2018. Comment on Water Control Manual and Water Control Agreement for Pensacola Dam and Reservoir. Letter dated March 13, 2018.

USFWS (U.S. Fish and Wildlife Service). 2018. Letter from Jonna E. Polk, Field Supervisor-USFWS to Ms. Kimberly Bose, Secretary-FERC. Letter dated March 12, 2018.

ALL USR APPENDICES HAVE BEEN PREVIOUSLY FILED WITH THE COMMISSION AND HAVE NOT BEEN DUPLICATED HERE TO MINIMIZE DOCUMENT SIZE

APPENDIX E-7 Sedimentation Study Report



September 2022
Grand Lake Sedimentation Study

Updated Study Report

Prepared for

Grand River Dam Authority

September 2022
Grand Lake Sedimentation Study

Updated Study Report

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LIST OF ABBREVIATIONS AND TERMS

µm	micrometer
1D	one-dimensional
2D	two-dimensional
3D	three-dimensional
AASHTO	American Association of State Highway and Transportation Officials
ADCP	acoustic Doppler current profiler
BC	boundary condition
cfs	cubic feet per second
cm	centimeter
cm/s	centimeters per second
FERC	Federal Energy Regulatory Commission
ft^2	square feet
ft^3	cubic feet
ft/ft	vertical feet per horizontal foot
g/cm^3	grams per cubic centimeter
GIS	Geographic Information System
GPS	Global Positioning System
Grand Lake	Grand Lake O' the Cherokees
GRDA	Grand River Dam Authority
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HEC-SSP	Hydrologic Engineering Center Statistical Software Package
H&H	hydrology and hydraulics
ISR	Initial Study Report
ITR	Independent Technical Review
lb/ft^2	pounds per square foot
$lb/ft^2/hr$	pounds per square foot per hour
LiDAR	Light Detection and Ranging
mm	millimeter
N/A	not applicable
NED	National Elevation Dataset
NGVD29	National Geodetic Vertical Datum of 1929
NSE	Nash-Sutcliffe Efficiency
OM	Operations Model
Ops	operations
OWRB	Oklahoma Water Resources Board
Pa	Pascal

PBIAS	Percent Bias
pcf	pounds per cubic foot
PD	Pensacola Datum
Project	Pensacola Hydroelectric Project
REAS	Real Estate Adequacy Study
RM	river mile
RMSE	root-mean-square deviation
RSR	RMSE-Observations Standard Deviation Ratio
RTK	Real-Time Kinematic
SBP	Sub-Bottom Profiler
SMD	Study Modification Determination
SPD	Study Plan Determination
SSC	suspended sediment concentration
STM	sediment transport model
TPU	total propagated uncertainty
UHM	Upstream Hydraulic Model
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USP	Updated Study Plan
USR	Updated Study Report
USSD	U.S. Society on Dams
UWSFL	University of Wisconsin Soil and Forage Laboratory
WEST	WEST Consultants, Inc.
WSE	water surface elevation
WSLH	Wisconsin State Laboratory of Hygiene

Executive Summary

Anchor QEA, LLC (formerly FreshWater Engineering), and Simons & Associates were retained to support the Grand River Dam Authority (GRDA) as subconsultants to Mead & Hunt for the Federal Energy Regulatory Commission (FERC) relicensing of the Pensacola Hydroelectric Project (Project). Anchor QEA's and Simons & Associates' role, with Mead & Hunt's support, is to perform a Sedimentation Study to determine the rates and locations of sedimentation throughout the Grand Lake O' the Cherokees (Grand Lake) watershed and associated tributaries.

This task culminated in the development of a sediment transport model (STM) using the Hydrologic Engineering Center's River Analysis System (HEC-RAS) fluvial modeling software. Data needed for model development range from topographic information to stream discharge volumes, water surface elevations (WSEs), and sediment parameters both in the lake and streambeds and moving into the system through major tributaries. Anchor QEA evaluated publicly available data sources to compile parameters necessary for model development and to determine where additional field work was required to fill data gaps.

WEST Consultants, Inc. (WEST), provided assistance in the Sedimentation Study. Initially, WEST completed an Independent Technical Review (ITR) of the STM and Initial Study Report. The ITR comments and recommendations are documented in a technical memorandum completed in April 2022 (WEST 2022). WEST provided technical support in the development and calibration of the STM for the Updated Study Report (USR). This effort included providing recommendations to improve model calibration and statistical methods to measure how the model is performing and developing a script to adjust the HEC-RAS geometry to account for consolidation of the future sediment deposits within the reservoir. WEST provided quality assurance reviews of the STM developed for the USR.

Topographic and bathymetric data are available from a range of sources. Grand Lake itself was surveyed by the Oklahoma Water Resources Board in 2009, then again by the U.S. Geological Survey (USGS) in 2019. Upstream surveys of the Neosho River, Spring River, and Elk River were performed as part of the 1998 Real Estate Adequacy Study (REAS), and USGS surveyed those reaches again in 2017. Topographic information was available from surveys performed in support of the 1998 REAS and Light Detection and Ranging (LiDAR) flights conducted in 2011. Other topographic information was obtained from the USGS National Elevation Dataset one-third, arc-second datasets where LiDAR information was unavailable. Circa-1940 topographic maps were digitized for analysis of conditions at the time of dam construction. Additionally, stage-storage curves were available from circa-1940 U.S. Army Corps of Engineers as-built drawings as well as the more recent Grand Lake bathymetry surveys.

Other data are available from USGS gaging stations located throughout the Grand Lake watershed. WSE data and stream discharge information are available along the Neosho, Spring, and Elk rivers, as well as on Tar Creek. These stations also provide sediment transport data in the form of suspended sediment concentration (SSC) measurements taken throughout the period of record at each gage.

Data gaps existed within the period of record for the USGS gaging stations within the Grand Lake watershed, and the gaging network lacked spatial density. As a result, the study team developed a field monitoring system to track WSE throughout the study area and fill data gaps. A set of 16 monitoring locations were selected, and HOBO pressure loggers were installed at each site in December 2016. Over the last 4.5 years, pressure and temperature were recorded at 30-minute intervals. The record provided a detailed dataset of water levels that were used for model development and calibration.

Other data gaps identified were related to sediment properties. Sediment conditions within the basin were evaluated using grab samples to evaluate grain size distributions. In general, the streambeds consist of gravel with limited sand; the lake is primarily silt and clay. Due to the presence of cohesive material (silt and clay) in the lake, Anchor QEA also collected core samples for SEDflume erosion analysis. The erosion analysis was used to determine parameters for sediment movement as part of model development.

Subsurface investigations included sub-bottom profiler (SBP) surveys and core sampling. SBP surveys and core sampling were used to estimate the thickness of deposited silt and clay material in the region of the delta feature. Core samples were also used to provide sediment grain size information and evaluate approximate date of deposition through cesium-137 analysis. Findings indicated a thick layer of cohesive material that is in continual flux, i.e., **not consistently depositional on the delta feature.**

Sediment transport rates were the final missing parameters. The aforementioned SSC measurements occur only occasionally, and samples taken during large flow events are limited. Researchers were also unable to find bedload sediment transport measurements at any location in the watershed. Anchor QEA field work included trips to gather additional SSC measurements to help close data gaps in the record. Technicians also sampled bedload sediment transport and found that even under large flows, the **bulk of sediment transport occurs as cohesive silt and clay in suspension rather thn along the bed**.

Hydraulic calibration of the model consisted of tuning roughness parameters to match measured peak WSEs for a range of flow events. Events that occurred between July 2007 and April 2017 were used for hydraulic calibration. Model tuning relied on adjusting hydraulic roughness coefficients and flow roughness factors. Calibration datasets included the USGS gages throughout the model domain, high water marks, and the Anchor QEA monitoring stations. Model results showed good agreement with the gaged locations.

HEC-RAS has limited capabilities to accurately model cohesive sediment. GRDA discussed this at length in the Updated Study Plan submitted in April 2022 and proposed using a quantitative analysis of bathymetric change in addition to an STM focused on the upper regions of the study area.

In issuing their Determination on Request for Study Modifications (FERC 2022), FERC allowed development of the quantitative analysis and also agreed that HEC-RAS could be used to model portions of the study area above river mile 100, and that trapping efficiency and modeled sediment outflows could be used to evaluate sedimentation within the lower portion of the reservoir.

GRDA used a quantitative analysis of sedimentation to evaluate future deposition within the study area. A relationship between hydraulic bed shear stress as evaluated using a fixed bed HEC-RAS model and measured sediment deposition was developed for this purpose. After evaluation, the results indicated that sediment deposition would occur primarily on the downstream face of the delta feature, which follows typical evolution patterns of such deposits. The end result is that the delta feature is not expected to grow in height over the coming license period.

Sediment model calibration showed reasonable agreement with measured sediment deposition between the circa-1940 datasets and more modern surveys. Discrepancies are attributable to measurement uncertainties, particularly due to the significant limitations of the circa-1940 survey information.

Predictive 50-year simulations included analyses of *High* and *Low Sedimentation* simulations to account for the uncertainties of the available datasets. The calibrated sediment inflows were used to evaluate expected results under both *Baseline* and *Anticipated Operations*; the *High* and *Low Sedimentation* simulations were used to bound the maximum and minimum sedimentation volumes that could reasonably occur in the upcoming license period under anticipated Project operations. These analyses showed that the sediment primarily accumulates on the downstream face of the delta feature, as predicted by literature sources such as Vanoni (2006). The predicted geometry was then imported to the one-dimensional (1D) Upstream Hydraulic Model (UHM) to evaluate impacts to water levels.

Evaluation with the 1D UHM allowed assessment of changes to water levels based on sedimentation. The 1D UHM was used to evaluate the July 2007 flow event and a synthetic 100-year event on the Neosho River for three separate starting pool elevations.

Model results were compared to determine the relative impacts of 50 years of sediment accumulation under expected loading, *High Sedimentation* versus *Low Sedimentation* rates, and *Baseline* versus *Anticipated Operations*. The results indicated that **sediment loading, a natural**

phenomenon outside GRDA's control, generally has the largest impact on upstream water levels in the Neosho River, overshadowing any impacts caused by Project operations. The impacts to water levels in the City of Miami for all evaluations are immaterial. Project operations, sediment loading, and future geometry show immaterial changes to water levels in the vicinity of the City. GRDA does not control the volume of incoming sediment, and the simulations indicate that, much like the findings of the Hydrologic and Hydraulic Study, nature dictates incoming sediment loads and therefore water levels in the study area, *not* Project operations.

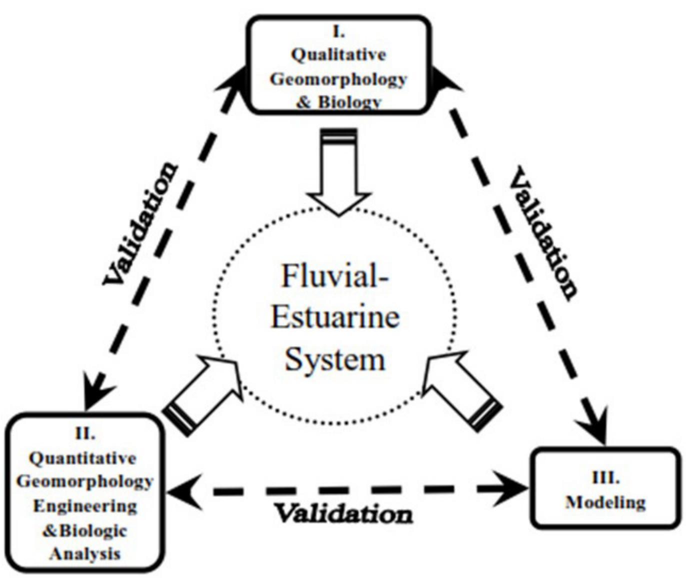
The sedimentation model inputs and outputs have been made available to relicensing participants for download upon request.

1 Introduction

The Sedimentation Study has been divided into three main stages—data collection, model development, and sedimentation predictions. During the initial stage, the study team collected data that were publicly available, analyzed data gaps, and created and executed plans to gather additional information. Model development used the field data to develop and calibrate the sediment transport model (STM). Sedimentation predictions will use the calibrated model to estimate the future deposition and erosion patterns within the study area to help evaluate future flood risks in the basin.

As discussed in the *Updated Study Plan Sedimentation Study* (USP; Anchor QEA et al. 2022), a three-level approach was implemented in conducting the Sedimentation Study. This approach includes qualitative geomorphic analysis, quantitative engineering and geomorphic analysis, and computer modeling (Figure 1). Qualitative geomorphic analysis considers the general trends in the system and how the stream has evolved over time. The quantitative engineering and geomorphic analysis uses measured data and hydraulic shear stress model results to determine the amount of sediment deposited or eroded in the study area, and computer modeling uses Hydrologic Engineering Center's River Analysis System (HEC-RAS) sediment transport features to evaluate sedimentation within the study area. Each individual component of this approach is intended to provide validation to the other components to ensure reasonable and reliable results are obtained.

Figure 1
A Conceptual Schematic of the Three-Level Approach for Analyzing Geomorphology, Sediment Transport, and Sedimentation Processes



Note: Validation must occur between all three levels to ensure that reasonable results have been achieved.

1.1 Study Goals and Objectives

The primary goal of the Sedimentation Study is to determine the potential effect of the Pensacola Hydroelectric Project (Project) operations on sediment transport, erosion, and deposition in the lower reaches of tributaries to Grand Lake upstream of Pensacola Dam. Additionally, the Sedimentation Study is designed to provide an understanding of the sediment transport processes and patterns upstream of Grand Lake on the Neosho, Spring, and Elk rivers, as well as on Tar Creek. An STM will provide estimates of overall sedimentation trends and impacts of sedimentation in the project boundary.

1.2 Study Area

The Pensacola Dam is located near Langley, Oklahoma. It impounds the Neosho River, forming the Grand Lake reservoir (often referred to as Grand Lake O' the Cherokees). The Grand Lake reservoir is split between four counties, including Craig, Ottawa, Delaware, and Mayes in northeastern Oklahoma. The main tributaries that flow into the reservoir are the Neosho, Spring, and Elk rivers. Honey, Drowning, Duck, and Horse creeks also flow into the lake. Additional minor tributaries include Sycamore and Tar creeks.

1.3 Study Plan Proposals and Determinations

Grand River Dam Authority (GRDA) is currently relicensing the Project. A timeline of study plan proposals and determinations is as follows:

1. On April 27, 2018, GRDA filed its Proposed Study Plan (PSP) to address sedimentation modeling in support of its intent to relicense the Project.
2. On September 24, 2018, GRDA filed its Revised Study Plan (RSP).
3. On November 8, 2018, the Federal Energy Regulatory Commission (FERC) issued its Study Plan Determination (SPD) for the Project.
4. On January 23, 2020, FERC issued an Order on the Request for Clarification and Rehearing, which clarified the timeline for certain milestones applicable to the relicensing study plan.
5. On September 30, 2021, GRDA filed its Initial Study Report (ISR).
6. On December 29, 2021, GRDA filed its response comments on the ISR. This document included the following two attachments relevant to the Sedimentation Study:
    a. Appendix D – Sedimentation ISR (updated)
    b. Appendix E – Proposed Modified Study Plan for Sedimentation Study
7. On January 14, 2022, GRDA held a technical meeting for the Sedimentation Study. A summary of the technical meeting was filed with FERC on January 20, 2022.
8. On April 27, 2022, GRDA filed Response Comments on Sedimentation Study and Submission of USP for Approval with FERC. The document included the following three attachments:
    a. Attachment 1 – GRDA Response Comments on Sedimentation Study Plan

    b. Attachment 2 – Independent Technical Review (ITR) of HEC-RAS STM
    c. Attachment 3 – USP
9. On May 27, 2022, FERC issued its Determination on Request for Study Modifications for the Pensacola Hydroelectric Project. This Study Modification Determination (SMD) focused on the Sedimentation Study.
10. On September 30, 2022, GRDA filed this report, the Updated Study Report (USR).

FERC's May 27, 2022 SMD approved GRDA's USP (also referred to by FERC as the second proposed plan modification) with the following modifications:

1. Extend the proposed downstream modeling limit for HEC-RAS to the U.S. Route 59 crossing at river mile (RM) 100.
2. Analyze the effects of sediment on storage capacity in Grand Lake using hydraulic outputs from the Upstream Hydraulic Model (UHM) and the U.S. Army Corps of Engineers (USACE) sediment trapping efficiency calculations downstream of RM 100.
3. Run the UHM using starting reservoir elevations of 740 feet, 745 feet, and 750 feet Pensacola Datum (PD).
4. Run the UHM with the predicted channel geometries and starting reservoir elevations using the simulated 100-year inflow event and the historical July 2007 inflow event.

As documented in this USR, GRDA has completed FERC's requested modifications to GRDA's approved USP.

2 Description of Data

2.1 Existing Data

A significant amount of the necessary data was available to the study team at the beginning of the project. Sources included USACE, the U.S. Geological Survey (USGS), past studies in Grand Lake, and surveys performed by the Oklahoma Water Resources Board (OWRB).

2.1.1 Terrain Information

Multiple datasets were available for potential use in this analysis. The earliest data are survey information from circa 1940. The most recent dataset was collected in 2019. All datasets considered for the study are discussed in chronological order in the following subsections.

Sedimentation deposition and erosion rates are key to the Sedimentation Study. Having reliable survey data collected at a ***known date*** is crucial to develop a useful STM. Without accurate information about the time interval between surveys, it is impossible to estimate a rate of change to calibrate a model. During calibration, model parameters are adjusted to reflect measured changes. For example, if those changes occur over a period of 10 years, the resulting parameters would be significantly different than if the same measured changes occurred over 70 years. Therefore, GRDA has documented the available data and assessed both: 1) the reliability of the data; and 2) whether a ***known date*** of data collection can be established.

2.1.1.1 Circa-1940 Data

The circa-1940 dataset comprises the following three available data sources:

1. 1938 USACE topographic maps with 5-foot contours (USACE 1938)
2. 1941 USACE Pensacola reservoir envelope curve computation folder (USACE 1941)
3. 1942 USACE Pensacola reservoir revised envelope curve computation folder (USACE 1942)

The 1938 USACE maps were used in the 1941 and 1942 USACE computations. The 1941 information does not include cross sections in plotted or tabular format. Rather, the data are presented as elevation/area and elevation/width relationships. The 1942 information includes plotted cross sections, but no data are available below the Neosho River/Spring River confluence.

Because the ***known date*** of the data collection can be established, these three data sources were used to create a single circa-1940 representation of Pensacola Reservoir and the upstream area. The information is imprecise and has significant limitations. Nevertheless, GRDA recognizes that this dataset represents the best available data for conditions at the time of dam construction and used it as the basis for model development in this study.

2.1.1.2 1969 USACE Data

During the Sedimentation Study Technical Meeting, the 1988 Flood Insurance Study was mentioned as a potential source for historical bathymetric information. GRDA reviewed the Flood Insurance Study and found that the bathymetry came from a 1969 USACE study (USACE 1969). GRDA analyzed the data. Even though the ***known date*** of the data collection can be established, unfortunately the data only extend from RM 134.6 upstream to RM 136.9. This 2.3-mile segment of historical bathymetric data is too short for use in STM calibration and validation. Thus, GRDA did not use the 1969 USACE data in STM calibration and validation.

2.1.1.3 1996 Expert Report

The 1998 Real Estate Adequacy Study (REAS; USACE 1998) states that modeling data (i.e., bathymetry) from Pensacola Dam to Twin Bridges State Park were taken from the Rule 26 Expert Report for the Grand (Neosho) River Upstream of Pensacola Dam (see Section VII, Subsection D of the Hydraulic Analysis section of the 1998 REAS). GRDA obtained the 1996 Expert Report (DeVries 1996) from USACE. The following three presentations of bathymetric data were in the 1996 Report:

1. River thalweg elevation profiles
2. Cross-section plots
3. HEC-2 printouts of cross-section data

The report does not state the source of the bathymetric data presented. Therefore, the ***known date*** of the data cannot be established. GRDA compared these data sources against each other. Multiple thalweg elevation profiles were presented in the report. One thalweg profile did not match the other profiles. The other profiles matched each other, matched the inverts of the cross-section plots, and matched the inverts in the HEC-2 printouts. Therefore, the one outlying thalweg profile was disregarded.

Next, the 1996 Expert Report data were compared to the 1998 REAS data. Results of the comparison are displayed in Figure 2. The 1998 REAS claims that data below Twin Bridges were taken from the 1996 Expert Report. However, the two datasets are significantly different. The 1998 REAS data clearly did not come from the 1996 Expert Report dataset.

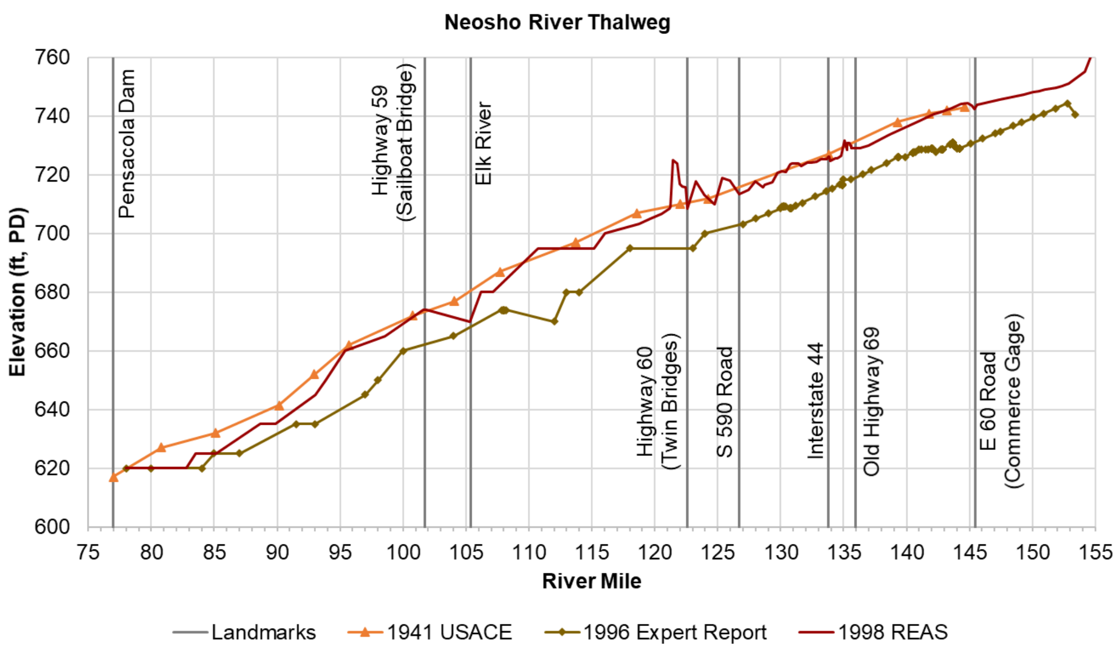
The 1996 Expert Report profile was also compared to the 1941 envelope curve profile to see if the 1996 data originated from the 1941 data. The 1941 profile is also displayed in Figure 2. The 1996 and 1941 data are significantly different from each other. Furthermore, the 1996 Expert Report thalweg is significantly lower than the 1941 thalweg. GRDA considered whether a misreported datum could be the issue, but the differences are on the order of 10 feet or more. This significant decrease in elevation from the 1941 thalweg to the thalweg reported in the 1996 report could only be the result of significant erosion in the lower portion of the reservoir, which is entirely unrealistic.

Summary

1. The ***known date*** of collection for data presented in the 1996 Expert Report cannot be established.
2. The 1996 report data do not match the 1998 REAS data, invalidating the claim that the 1998 REAS data downstream of Twin Bridges came from the 1996 report data.
3. The 1996 report data do not match the 1941 data; the 1996 report data could not have been sourced from the 1941 data.
4. Regardless of the collection date of the 1996 report data, significant and unrealistic erosion would have had to occur after 1941 for the dataset to be valid.

For these reasons, GRDA discarded the 1996 Expert Report data.

Figure 2
1996 Expert Report Thalweg Comparison



2.1.1.4 1998 Real Estate Adequacy Study Data

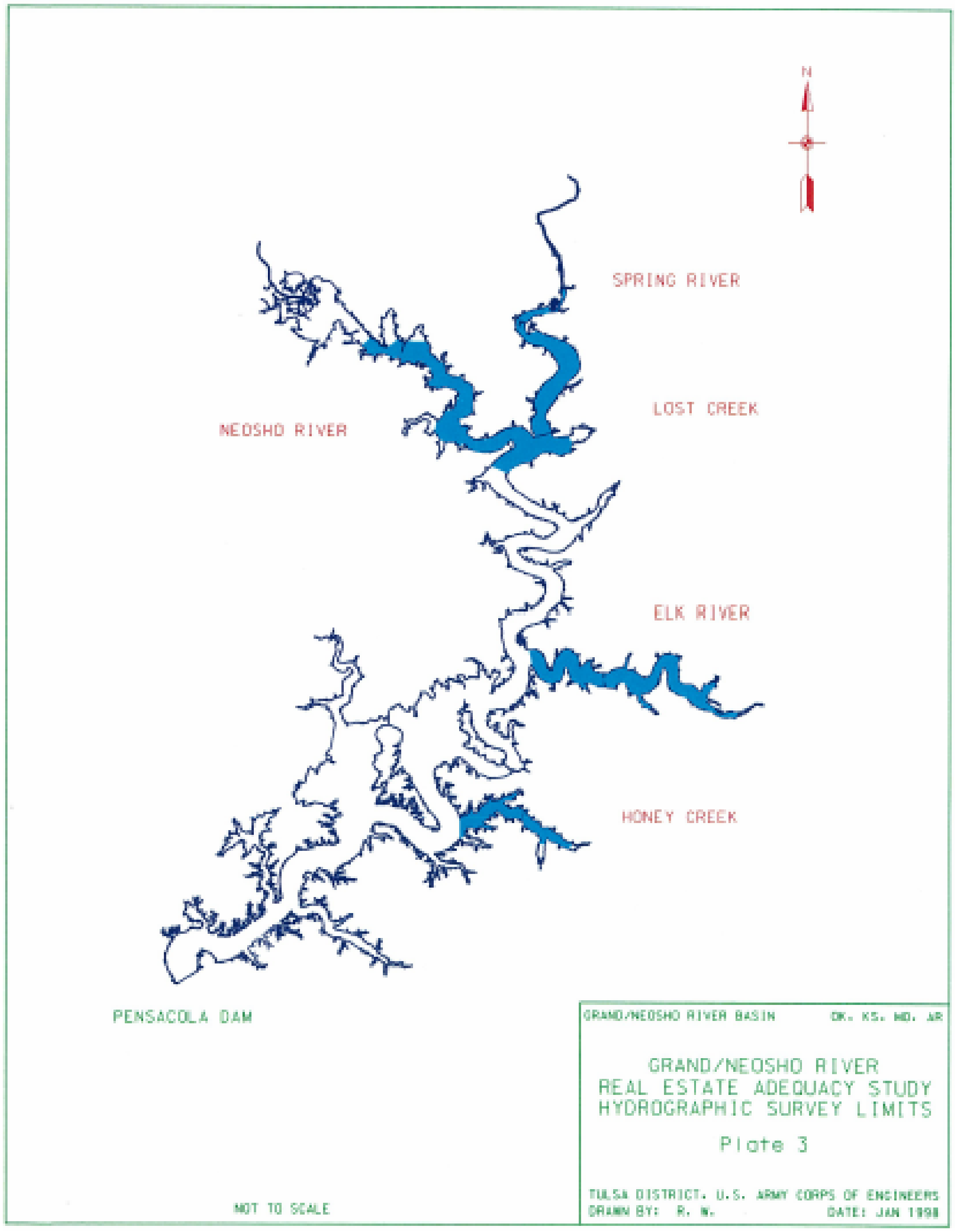
Multiple datasets were presented in the 1998 REAS and are discussed individually in the following subsections.

2.1.1.4.1 Grand and Neosho Downstream Data

The REAS hydrographic survey limits extend downstream to RM 120.1 (approximately 2 miles downstream of the Spring River confluence) along the Neosho River. Data below RM 120.1 were not surveyed as part of the REAS study but were included in the study's analysis. Plate 3 from the 1998

REAS, which documents REAS survey extents, is presented as Figure 3. The solid blue sections represent the area surveyed as part of the REAS.

Figure 3
Hydrographic Survey Limits for REAS



Source: USACE (1998)

As discussed in Section 2.1.1.3, the 1998 REAS states that the 1996 Expert Report downstream data have been invalidated by comparing the two datasets. This fact calls the validity of the REAS downstream data into question. Furthermore, that means the ***known date*** of the data collection cannot be established.

GRDA compared the downstream REAS data to the 1941 envelope curve data in hopes that they would match. This would indicate that the REAS data were from 1941 and would assign a date to the dataset, making it usable for STM calibration and validation. Unfortunately, the downstream data presented in the REAS do not match the 1941 data. Thus, the survey date of the REAS data below RM 120.1 remains unknown. Furthermore, the REAS thalweg is lower than the 1941 thalweg in multiple locations within the downstream reach. Assuming that the REAS data were collected after 1941, that would require erosion in the lower portion of the reservoir, which is extremely unlikely given that low flow velocities and shear stress typically result in sediment depositions within reservoirs.

Summary

1. The REAS directly states that the downstream data were not collected as part of the 1998 study effort.
2. The REAS states that the downstream data came from the 1996 Expert Report. This claim has been invalidated by a comparison of the two datasets.
3. The ***known date*** of collection for the downstream REAS data cannot be established.
4. Unrealistic erosion would have had to occur for the downstream REAS data to be valid.
5. The downstream REAS data do not match any other available datasets. If the data matched, the collection date could be established.

For these reasons, GRDA discarded the downstream portion of the REAS data.

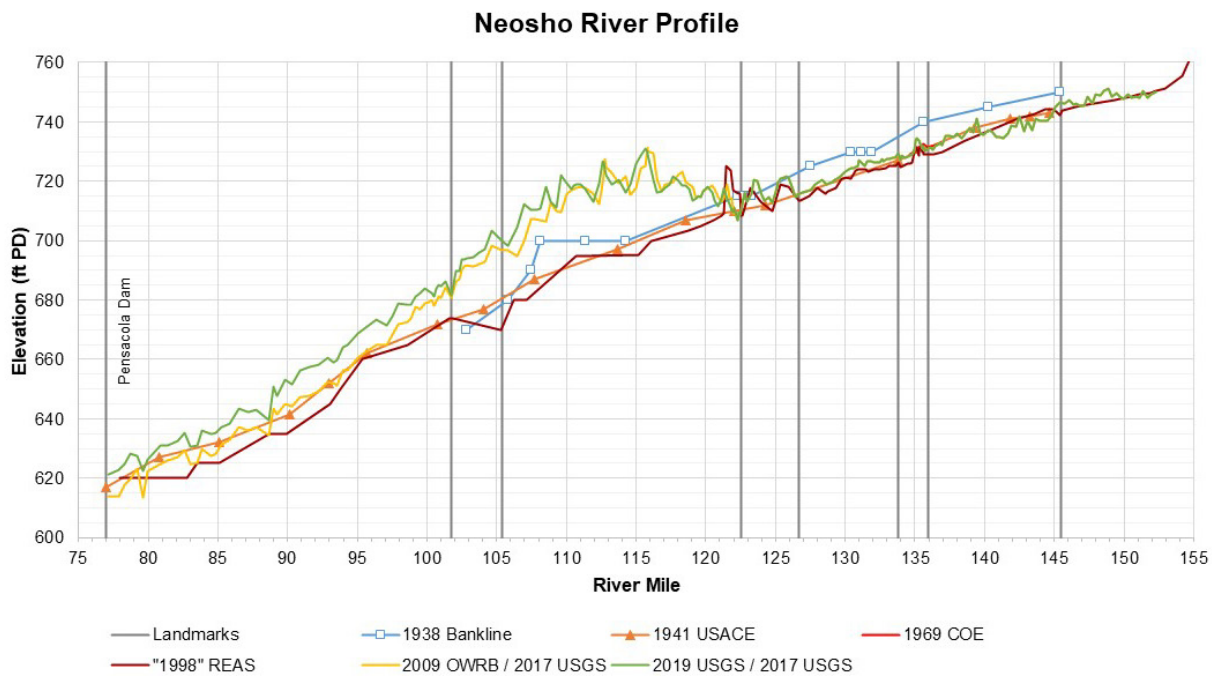
2.1.1.4.1.1 The City's Claims Regarding the Downstream Data

The City of Miami has used the downstream portion of the REAS data to make unsubstantiated claims regarding sedimentation rates and patterns of deposition in the study area. The City claimed that "comparison of the pre-dam river profile with recent bathymetric surveys indicates significant sediment deposition near the head of Grand Lake," and then jumped to the conclusion that sediment deposition in Grand Lake "increases upstream flooding along the Neosho and Spring Rivers."

The foundation of the City's claims is a presumed 1998 date of the downstream REAS data, which cover Grand Lake and extend upstream to RM 120.1. As discussed in Section 2.1.1.4.1, the REAS explicitly states that the downstream data are not from 1998 and were not surveyed as part of the REAS data collection. Regardless, GRDA investigated the City's claims regarding sediment deposition in the study area.

Figure 4 displays multiple thalweg profiles. Even assuming that the "1998" REAS profile was surveyed in 1998 (which it was not), comparison of the datasets would suggest that sediment deposition patterns have changed significantly in ways that cannot be explained solely by the construction of the dam or Project operations.

Figure 4
Historical Neosho River Thalweg Comparison



Note: This plot covers the Neosho River from RM 152.2 at the upstream end to the Pensacola Dam at RM 77.12 on the downstream end.

As shown in Figure 4, the City's claims regarding sediment deposition and erosion patterns would require significant and unrealistic changes since completion of the dam. For a moment, assume that despite the USACE REAS documentation clearly stating otherwise, the City's assumption that the downstream REAS data are from 1998 is correct. If the City is correct, that would mean the following:

1. From 1940 to 1998, sediment eroded in the delta feature region and near the dam.
2. From 1998 to 2009, the sedimentation pattern reversed, and 20 to 30 feet of sediment accumulated at the delta feature in only approximately 11 years.
3. From 2009 to 2019, sedimentation patterns changed again, with virtually no sediment depositing on the top of the delta feature.

This thought experiment reveals how the City's assumptions, which contradict USACE documentation, are flawed.

To further show how the City's assumptions are flawed, GRDA evaluated sediment loading to the reservoir (also referred to as sediment inflow to the reservoir) since completion of the dam in 1940. Using the sediment rating curves developed with USGS data and the field data collected by GRDA, the portion of sediment that entered the study area from 1940 to 1998, 1998 to 2009, and 2009 to 2019 is calculated, assuming that the downstream REAS data were collected in 1998. Sediment loading calculations are presented in Table 1.

Table 1
Relative Sediment Delivery and Measured Deposition Thickness at the Delta Feature by Specified Time Period (if the "1998" REAS Data Are to be Believed)

Time Period	Number of Years	Percentage of Total Sediment Loading	Apparent Deposition in Region of the Delta Feature
1940–"1998"	58	68%	~0 feet
"1998"–2009	11	14%	20–30 feet
2009–2019	10	13%	~0 feet on the top, ~2–3 feet on the downstream face

Most of the deposition (68%) should have occurred between 1940 and "1998"—a period of 58 years—based on historical sediment loading rates. However, the thalweg comparison shows virtually no deposition in the region of the delta feature for this period. Then in the 11 years between "1998" and 2009 with no change in the regulated operations of the reservoir, when only 14% of the deposition should have occurred, there was 20 or 30 feet of deposition at some specific locations within the region of the delta feature. Then in the 10 years between 2009 and 2019, when 13% of the deposition should have occurred, there was 2 to 3 feet of deposition on the downstream face of the delta feature. The City offers no scientific explanation for the complete disconnection between sediment loading and deposition.

Summary

1. The City of Miami has made unsubstantiated claims about sedimentation rates and patterns in the study area.
2. The foundation of the City's claims is based on a presumed (but demonstrably erroneous) 1998 date of the downstream REAS data, which cover Grand Lake and extend up to RM 120.1.
3. The REAS explicitly states that the downstream data are not from 1998.
4. A comparison of the thalweg profiles shows the flaws in the City's assumptions.
5. A comparison of sediment loading to deposition depths shows the flaws in the City's assumptions.
6. The City has offered no scientific data to substantiate their assumptions.

For these reasons and the reasons stated in the previous section, GRDA cannot accept the City's claim that the downstream portion of the REAS data is from 1998.

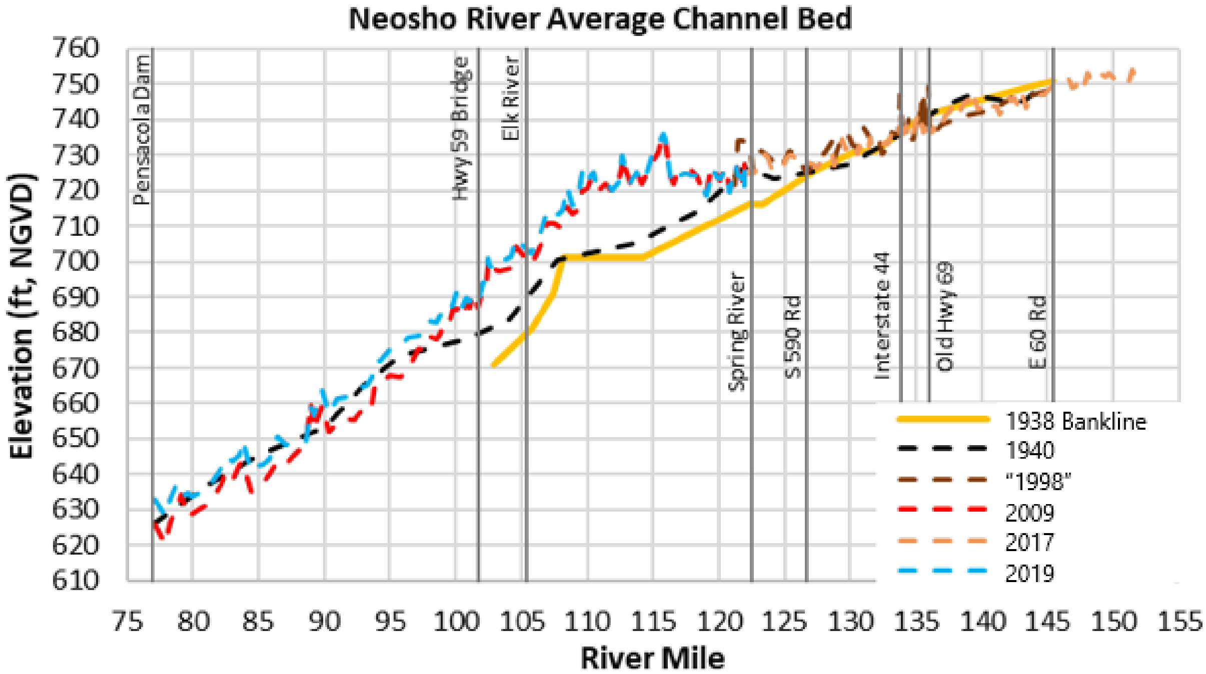
2.1.1.4.2 Neosho and Spring Upstream Data

As displayed in Figure 3, the REAS hydrographic survey limits extend downstream to RM 120.1 along the Neosho River. The Spring River is also included within the upstream REAS survey limits.

In their ITR, WEST Consultants, Inc. (WEST), used the average channel bed profile to compare several datasets against each other, including the REAS geometry (Figure 5). This method of analysis is more representative of overall channel geometries than the simple thalweg profile, because it accounts for portions of the channel that are outside of the thalweg. WEST concluded that the portion of the REAS dataset above RM 120.1 can be used for this study. GRDA agreed that this portion of the REAS dataset can be used in STM development as a calibration dataset. However, there is no quality control documentation in the REAS for this data (see Section 2.1.1.4.4) and the data were obtained using less accurate techniques compared to the more recent datasets. Thus, there is a significant amount of uncertainty regarding this dataset, which influenced the accuracy of the STM calibration and validation.

Determining the rate of sediment accumulation in the study area is critical, and surveyed data with a known collection date is required to calculate rates of sediment accumulation. Although the upstream REAS dataset met the threshold for usability in the STM, the lack of quality control documentation in the REAS casts doubt on the accuracy of the dataset. Nevertheless, because the ***known date*** of the data collection has been established, GRDA recognizes that this dataset represents a usable, comprehensive historical dataset and used the upstream REAS data for STM calibration and validation.

Figure 5
Historical Neosho River Average Channel Bed Comparison



Source: WEST's ITR technical memorandum (WEST 2022)

2.1.1.4.2.1 The City's Recommendations Regarding the Upstream Data

Regarding the upstream REAS data, the City states the following:

> The Neosho River upstream of the City has changed very little since 1940. It may be appropriate to replace the 1998 survey data with the 2019 [sic – the survey is from 2017] survey data for the reach upstream of the City. (City of Miami 2022).

The City proposed to discard the upstream REAS data, which are at least documented in some form, while keeping the least reliable, incorrectly documented data within the REAS—the downstream data that cover Grand Lake. ***The City proposed discarding the only section of the REAS dataset that is based on surveys completed during the 1998 study***. Furthermore, discarding the upstream 1998 REAS data would have prevented GRDA from performing calibration and validation of the STM in the upstream reach. Implementing the City's proposal would have resulted in an STM with less predictive capability.

Therefore, GRDA rejected the City's proposal to discard the documented upstream portion of the REAS dataset.

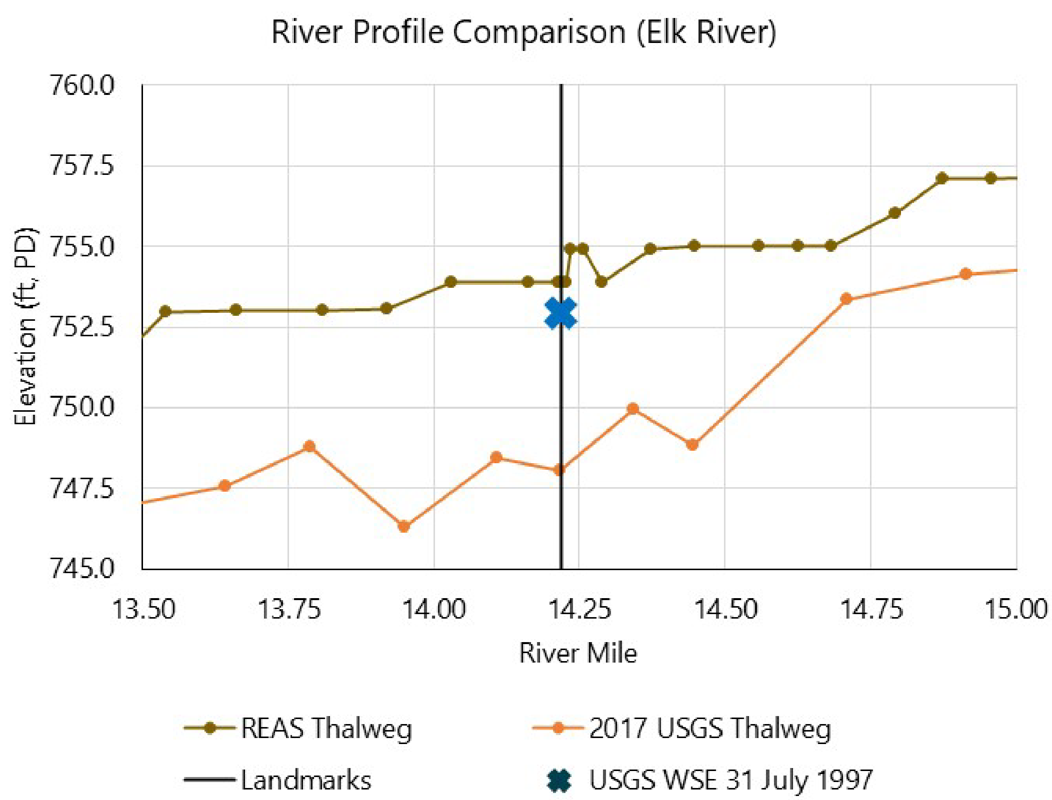
2.1.1.4.3 *Elk River Data*

As displayed in Figure 3, bathymetry on the Elk River was collected as part of the REAS hydrographic survey. However, there was an obvious issue with the collected data.

A USGS gaging station (07189000 Elk River near Tiff City; USGS 2021a) on the Elk River is located at RM 14.22 on the Highway 43 Bridge. In the REAS dataset, the channel invert at that location is 753.90 feet PD. This is implausible, because that invert elevation is higher than water surface elevations (WSEs) recorded by USGS. REAS documentation states that the survey was performed in July 1997. The USGS reported WSEs were less than 753.90 feet PD at the site for all but 3 days in July 1997, with a low WSE of 752.94 feet PD reported on July 31, 1997 (Figure 6). This is clearly an impossible result, because it suggests the water surface was below ground. As a result, no HEC-RAS model can ever predict the correct WSE at the site during low flow events.

Although the ***known date*** of the data collection has been established, the data are not reliable. For this reason, GRDA did not use the Elk River REAS data in the STM.

Figure 6
Elk River Thalweg Comparison and WSE Measurement



2.1.1.4.4 USACE Stance on Reliability

Given the concerns with the REAS dataset below RM 120.1, GRDA contacted USACE to discuss the REAS data. David Williams, PhD, PE, CFPM, D.WRE, of the Tulsa District stated the following in an email dated January 26, 2022:

> I do have concerns about the applicability of the cross-sectional survey that was used in the 1998 study (for the reasons that have been described), and I have no issue w/ sharing these concerns.

His stated reasons were as follows:

> I did speak with an engineer who previously worked for the Tulsa District, and he pointed out that the survey wasn't subjected to a rigorous QA/QC process.

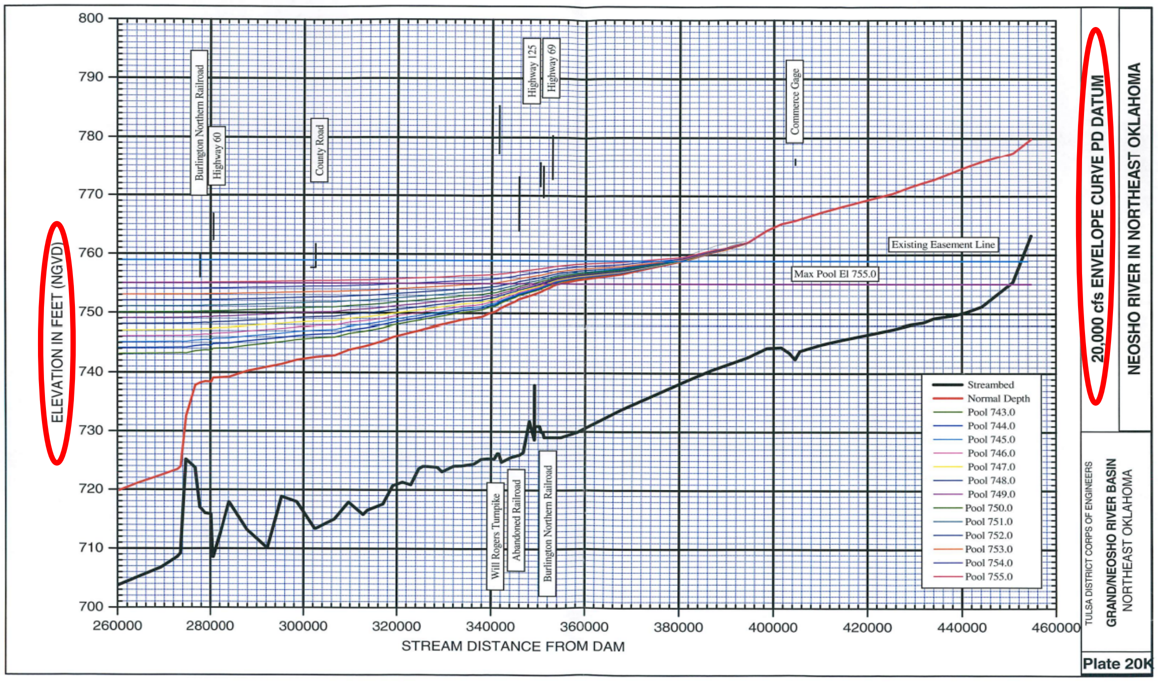
The City itself acknowledged there are problems with the data, suggesting that the datum shift may have been incorrectly applied. In their March 2022 comment submission (City of Miami 2022), the City wrote the following:

> Tetra Tech's review of the REAS dataset indicates that it is about 2 feet higher than other surveys, raising the possibility that the REAS dataset was incorrectly adjusted from Pensacola Datum (PD) to NGVD29.

The City then stated that if that issue is resolved, "the REAS dataset probably may be reliable." The City provided no technical arguments for why the data are reliable or why the datum issue does not call the reliability of the data into question.

GRDA agreed that a datum shift is likely one problem with the data, as evidenced by a plot provided by USACE (Figure 7). In the figure, the vertical axis (on the left) is "Elevation in Feet (NGVD)," but the chart title at right is "20,000 cfs Envelope Curve PD Datum." GRDA compared the streambed in the figure to the channel invert in the REAS data and determined that the vertical datum of the displayed data is PD. This type of error (listing two datums in the same figure) confirms inadequate quality control of the data and contradicts the City's argument that the full REAS dataset "probably may be reliable" (a heavily caveated assertion that itself demonstrates the City's lack of confidence in its own assertion).

Figure 7
USACE Figure Showing Mislabeled Vertical Datum



Note: Figure provided by USACE showing thalweg profile of the Neosho River in the vicinity of Miami, Oklahoma; red outlines added to highlight conflicting vertical datum labels.

The City's argument for inclusion of the full REAS dataset did not rely on technical criteria. The City cited use of the REAS in litigation as a reason to use the full REAS dataset as a basis for STM development. The fact that the REAS was used in litigation proceedings in the past has no bearing on whether the dataset is reliable or useful for the purposes of this study. The City claimed the delta feature was formed in an 11-year span between 1998 and 2009 but, as discussed in Section 2.1.1.4.1, the "1998" data are not actually from 1998. This fact undermines the City's claims regarding delta feature formation. The City's consultant could have easily performed a sediment loading analysis, which would have revealed the City's error. The City asserted that REAS data in the reservoir should be treated as representative of 1998 conditions, ignoring the USACE documentation in the REAS report. Any objective evaluation of the data shows that the REAS data below RM 120.1 cannot reasonably be used for this study.

Summary

1. USACE informed GRDA that the REAS was completed without proper quality control processes, and as a result, the data may not be reliable.
2. The City acknowledged that there are issues with the REAS yet provided no technical arguments for why those issues do not call the reliability of the data into question.

3. The City's claim that the delta feature was formed in an 11-year span between 1998 and 2009 relies on an undated dataset and thus is invalid.

Based on the information presented in Section 2.1.1.4.1 and the information in this section, GRDA discarded the downstream portion of the REAS data.

2.1.1.4.5 Conclusion on 1998 Real Estate Adequacy Study Data Reliability

Portions of the "1998" REAS dataset are usable while other portions are unusable, as summarized in the following:

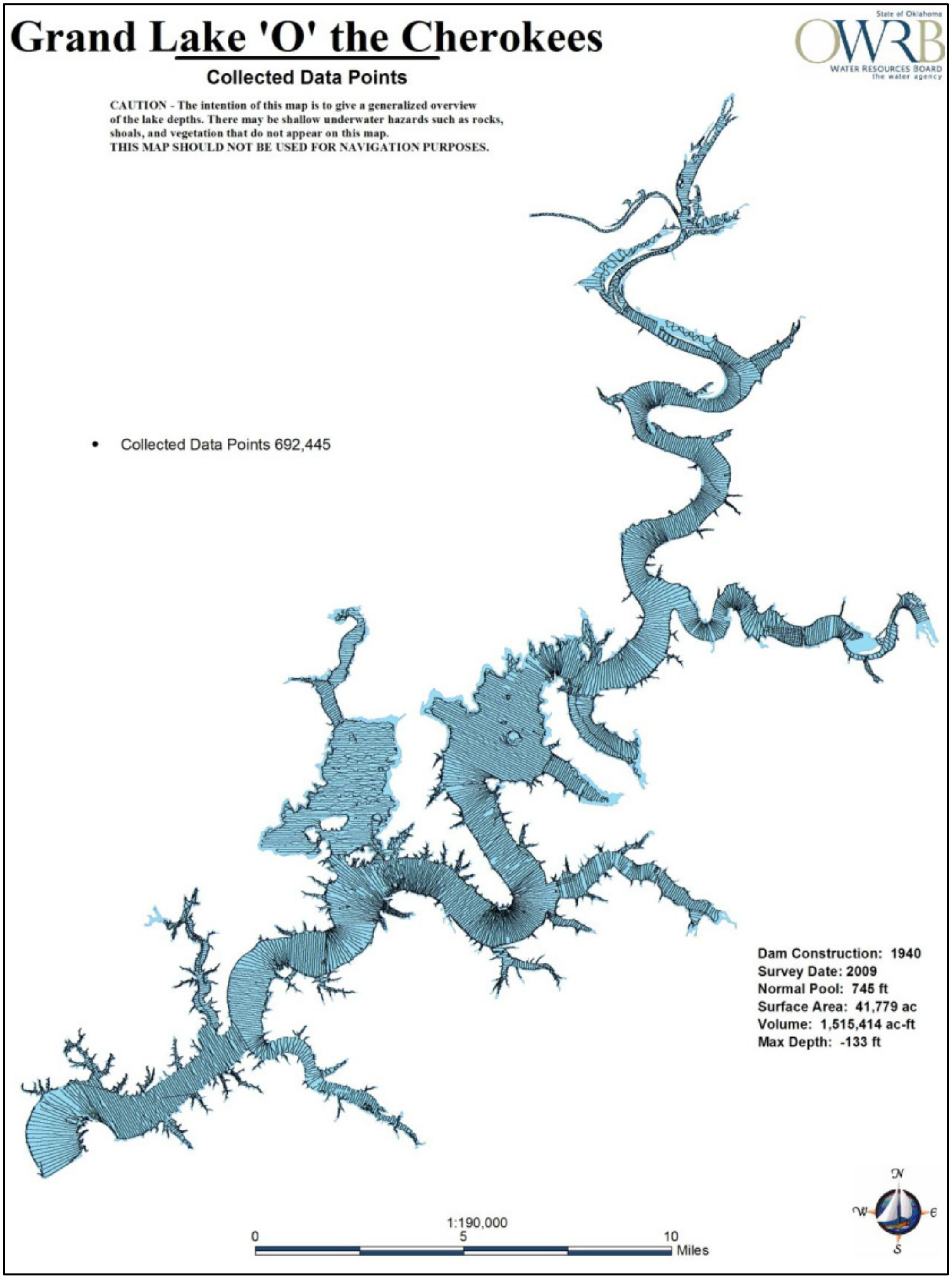
1. The downstream data, which cover Grand Lake below RM 120.1, are not usable and were discarded for the purposes of this study.
2. The upstream data, which cover the Neosho River above RM 120.1 and the Spring River, are usable for this study.
3. The Elk River data are not usable and were discarded for the purposes of this study.

There is a significant amount of uncertainty regarding the usable data. The upstream REAS data meet the threshold of usability in the STM, but the lack of quality control documentation in the REAS casts doubt on the accuracy of the dataset and increases the level of uncertainty in the data. Nevertheless, because the ***known date*** of the upstream REAS data has been established, GRDA recognizes that this dataset represents a usable, comprehensive historical dataset and used the upstream REAS data for STM calibration and validation.

2.1.1.5 2009 Oklahoma Water Resources Board Survey

The 2009 Grand Lake bathymetry data were collected by OWRB using a single-beam echosounder. The coverage of the lake was extensive, with data collected along 1,680 virtual transects (OWRB 2009). The finalized dataset includes nearly 700,000 points. The 2009 OWRB report shows survey track lines; this figure is presented as Figure 8. The 2009 OWRB report includes a section devoted to the discussion of quality control/quality assurance. Intersecting transect lines and channel track lines were compared to assess the estimated accuracy of the survey measurements. OWRB documented that the data quality met or exceeded USACE's performance standards (USACE 2002), with a reported depth accuracy at the 95% confidence level of ±1.3 feet and a bias of 0.5 foot.

Figure 8
Data Density and Survey Track Lines Provided by OWRB in 2009 Grand Lake Survey Report



A review of typical reservoir deposition and siltation patterns shows that fine sediments can be transported far into a reservoir. van Rijn (n.d.) states that inflowing, sediment-laden water may travel under the relatively clear reservoir water as a plume (density or turbidity currents), bringing sediment far closer to the dam than would be allowed through shear stress alone. Zavala (2020) confirms this in a discussion of hyperpycnal flows, or density-driven flows, in which he states that incoming flows can transfer large volumes of sediment even without steep bed slopes. Hyperpycnal flows occur when a relatively denser gravity flow of sediment-laden water enters a marine or lacustrine body of water and the density of the moving water is greater than the density of the standing water, causing the denser, sediment-laden water to flow along the bed, as an underflow below the standing water.

2.1.1.5.1 Quality Concerns

The 2009 OWRB survey was not without problems. Although it is the best available dataset from this timeframe, it shows significantly more sedimentation than is realistic given incoming sediment loads. The total incoming sediment volume from 1940 to 2019 is approximately 234,974 acre-feet with an incoming sediment load of approximately 327,044,375 tons, which converts to a sediment density of 63.9 pounds per cubic foot (pcf). The same calculation based on volume change and sediment load from 1940 to 2009 results in a computed sediment density of approximately 115.5 pcf, whereas the 2009 to 2019 calculation results in a sediment density of 10.6 pcf. This disparity of calculated sediment densities between the 1940 to 2009 and 2009 to 2019 data demonstrates the issue with the bathymetric surveys compared to sediment load. The issue with this dataset is not simply that deposition was near the dam because hyperpycnal flows are capable of bringing sediment to the lower reservoir. The issue is the total volume of deposition given the incoming sediment load.

In an e-mail exchange with USGS, Jason Lewis (2022) indicated they had not found any major issues with the 2009 bathymetric dataset. He also stated the following:

> The 2009 dataset tends to show much greater variability in flat areas compared with 2019 data, so I suspect a lot of that has to do with correction processes such as GPS correction, temperature correction issues, and other issues such as boat movement.

The impossibly high deposition in the lower reservoir led GRDA to use only the portion above RM 100 for calibration purposes. The reservoir downstream of RM 100 was evaluated using only total change from 1940 to 2019 in analysis. This preserves a reasonable long-term estimate of total deposition where impacts are to the conservation pool while not discarding the entire 2009 dataset because it is the best available dataset.

Because the dataset has documented quality control and there is a ***known date*** of data collection, GRDA used the 2009 data for calibration and validation upstream of RM 100. However, as explained above, deposition in the lower reservoir is not realistic given the sediment loading between 1940 and 2009, so the 2019 USGS survey was used for long-term evaluation below RM 100.

2.1.1.6 2017 USGS Upstream Survey

The 2017 USGS upstream survey data cover the Neosho, Spring, and Elk rivers. The 2017 USGS upstream survey data went through a thorough quality control process and, as a result, are considered a reliable data source. USGS calculated quality assurance statistics at the intersection of primary and control transects. The root-mean-square-error (RMSE) of the quality assurance data was less than 0.5 foot for all data collection methods on all rivers (Smith et al. 2017).

Because the dataset has documented quality control and there is a ***known date*** of data collection, GRDA can use the 2017 USGS data for STM calibration and validation.

2.1.1.7 2019 USGS Grand Lake Survey

As part of the FERC SPD, the 2019 USGS Grand Lake bathymetry data were collected by USGS using a multi-beam echosounder. The 2019 USGS survey data went through the highest levels of quality assurance and, as a result, are considered a reliable data source. USGS used literature-based methodologies for quality assurance. Quality assurance measures included beam-angle checks (required to verify that the multi-beam system is operating within USACE-approved standards), patch tests (used to identify and correct systematic errors), and uncertainty estimations (using total propagated uncertainty, or TPU). USGS reported that more than 95% of the TPU values were less than 0.30 foot, which is within the most stringent specifications for an International Hydrographic Organization Special Order survey (IHO 2008).

Yet the City found issue with the 2019 USGS dataset despite the rigorous quality assurance documented by USGS (2020). The City compared thalweg elevations between the 2009 and 2019 datasets and claimed that the aggradation rates were unrealistic (City of Miami 2022).

The City argued that seeing deposition near the dam is unreasonable and indicates there is no explanation for sediment moving that far into the reservoir. The literature is clear that density currents, and other transport mechanisms, operate in reservoirs and carry sediment far into impoundments (Lumborg and Vested 2008; van Rijn n.d.; Zavala 2020).

The City’s comments do not cast doubt on the accuracy of the entire 2009 and 2019 datasets. Rather, the disregard for documented reservoir sediment transport phenomena demonstrate that the City’s consultant misunderstands basic principles of sediment transport in reservoirs.

Because the dataset has documented quality control and there is a ***known date*** of data collection, GRDA used the 2019 USGS data for STM calibration and validation.

2.1.1.8 Topographic Surveys

Two primary data sources exist for overbank analyses. The first is topographic survey information gathered during the 1998 REAS (USACE 1998). The extents of this survey reach the Oklahoma and Kansas border along both the Neosho and Spring rivers and approximately 5 miles upstream of the Highway 43 Bridge on the Elk River. The second major overbank data source is Light Detection and Ranging (LiDAR) data from a mission flown in 2011 (Dewberry 2011). Where additional data were needed for overbank areas, they were obtained from the USGS National Elevation Dataset (NED) one-third, arc-second dataset (USGS 2017). These combined datasets covered the entire overbank portion of the study area.

2.1.1.9 Terrain Datasets

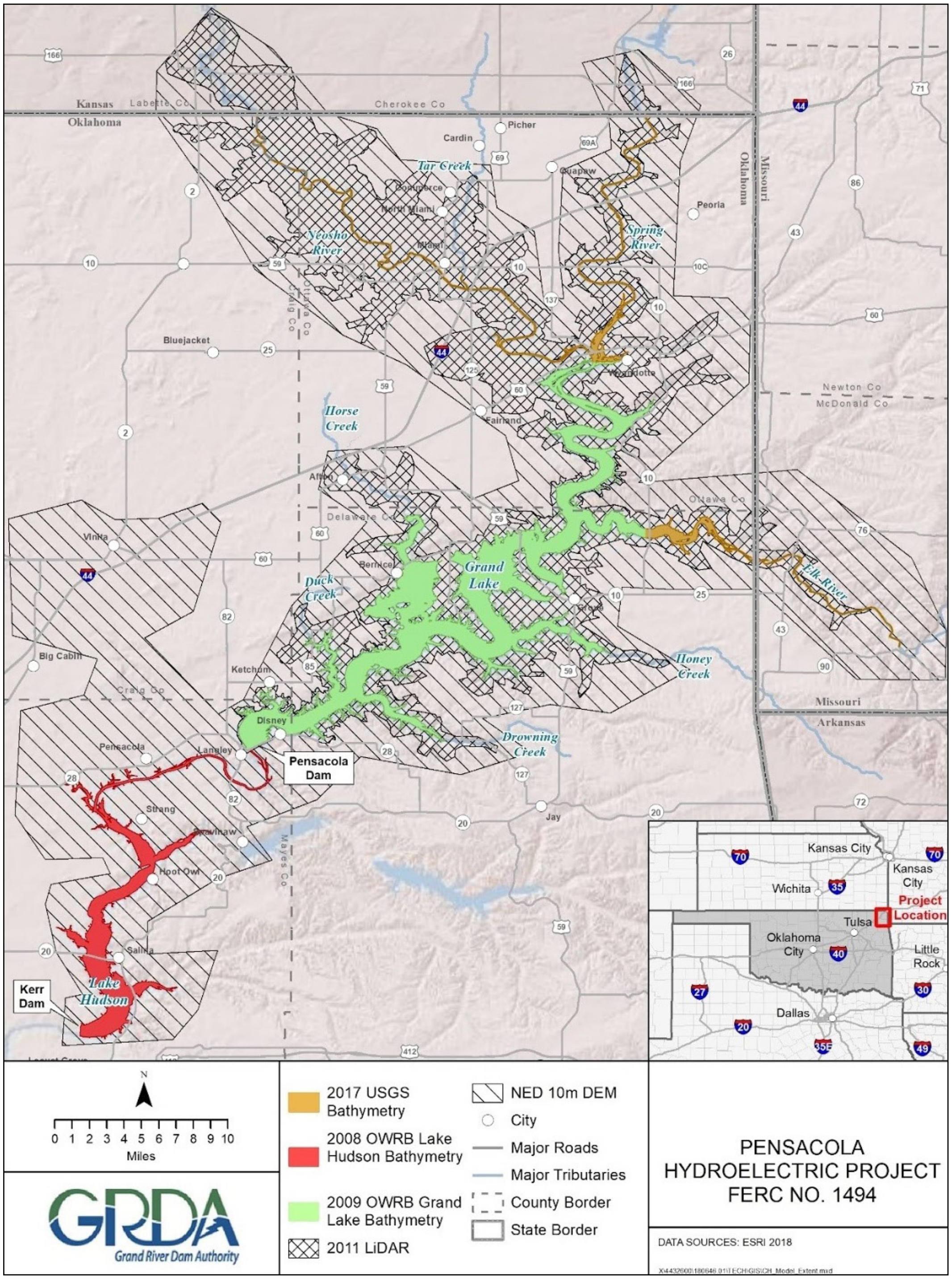
The information gathered from the above-referenced sources was compiled to make three terrain datasets. The datasets served as the basis for all STM geometry development. Although data for each were created from a patchwork of sources measured at different times, for simplicity of naming them, they will be referred to in this report by the year of the relevant Grand Lake survey. Upland topography is stable enough over time that it can be combined with bathymetry data taken at a different point in time. Terrain files contain both bathymetric and topographic information. Table 2 details the terrain names and relevant source materials.

Table 2
Summary of Datasets Used to Create the Three Primary Terrain Files Used in the Sediment Study

Terrain Name	Grand Lake Survey	Upstream Survey	Overbank Survey
"1998" Terrain	Unspecified Circa-1940 Data	1998 REAS	1998 REAS/2011 LiDAR/2017 NED
2009 Terrain	2009 OWRB	2017 USGS	2011 LiDAR/2017 NED
2019 Terrain	2019 USGS	2017 USGS	2011 LiDAR/2017 NED

Figure 9 shows the survey areas for each of the above-referenced surveys, except the 2019 USGS bathymetric survey of Grand Lake and the 1998 REAS survey. The extents of the 2019 Grand Lake survey are approximately the same as those of the 2009 OWRB survey.

Figure 9
Survey Extents of Various Data Sources for Sediment Transport Model Development



2.1.1.10 Stage-Storage Curves

Grand Lake stage-storage curves were available dating back to 1940. USACE created a capacity curve from as-built dimensions and surveys at that time. The 2009 OWRB survey of Grand Lake and the 2019 USGS survey of Grand Lake provide additional stage-storage curves. These were used to estimate the annual volume of sediment deposition within the Grand Lake reservoir as a ground-truthing measure.

2.1.1.11 ADCP Bathymetric Profile Comparison

USGS periodically performs discharge profile measurements near gage stations using an acoustic Doppler current profiler (ADCP), and data are available on request. Although the primary function of the ADCP sampling events is to generate current profiles, the ADCP also measures water depth along the sampling transect. Using the river stage at the time of the event, water depth can be converted to bed elevation. Comparing the multiple profiles taken at a similar location over several years can reveal sediment transport trends.

For each gage, ADCP profile locations vary from event to event. The data were projected onto a single profile line for comparison. The profile lines were placed to represent as many ADCP transects as possible. Given that the transects are not taken at exactly the same location, elevations near the banks are likely unreliable.

2.1.1.11.1 Neosho River near Commerce

Figure 10 displays the ADCP transects taken at the Neosho River near the Commerce USGS station. Only the 2017, 2018, and 2019 data are near enough spatially to be compared. The 2018 and 2019 transects in Figure 11 show a stair-stepping effect, which is likely due to poor Global Positioning System (GPS) signal and reporting. Change in volume cannot be analyzed due to the data gaps in the 2018 and 2019 transects.

Figure 10
Neosho River near Commerce USGS ADCP Transects

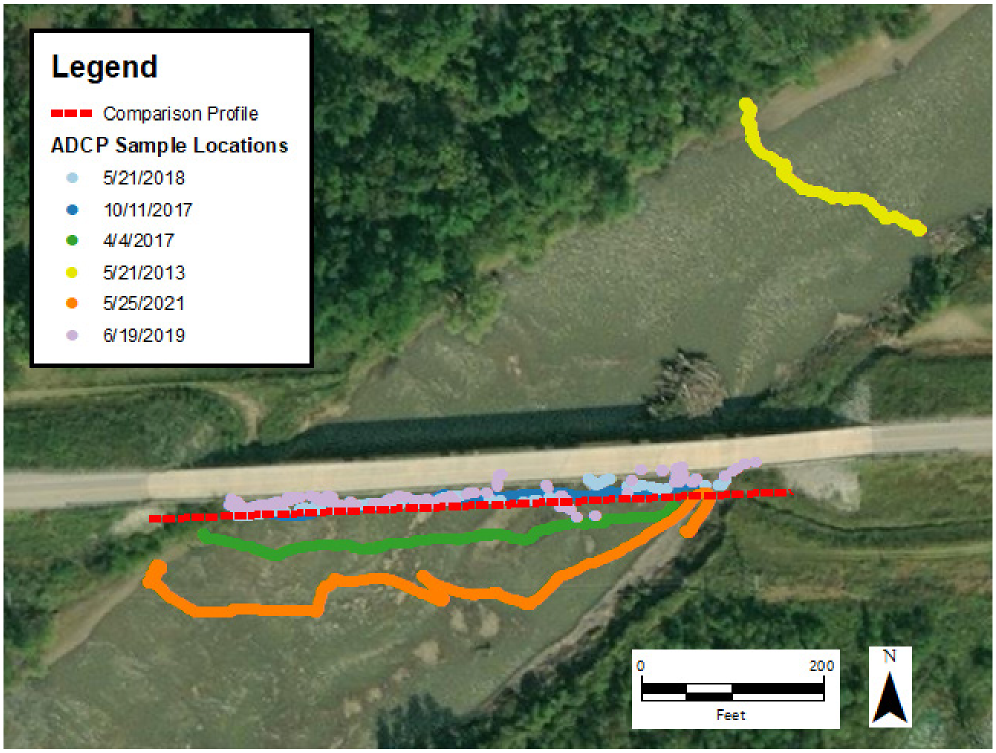
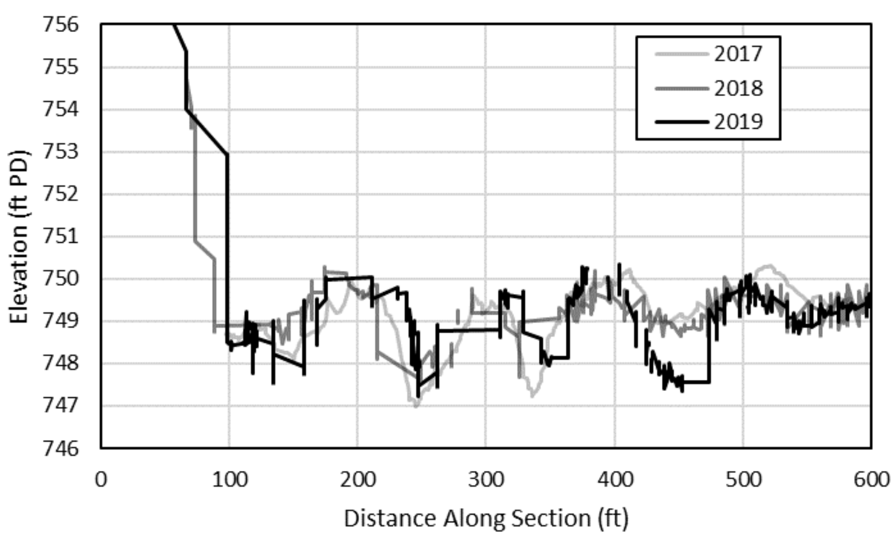


Figure 11
Neosho River near Commerce USGS ADCP Sections



2.1.1.11.2 Neosho River at Miami

The Neosho River at Miami station has data from six sampling events spanning 2017 to 2021. The transects are spaced along approximately 50 feet of river as seen in Figure 12. Three high-quality transects equally spaced in time are displayed in Figure 13. There is almost no change in channel depth from 2017 to 2021.

Figure 12
Neosho River at Miami USGS ADCP Transects

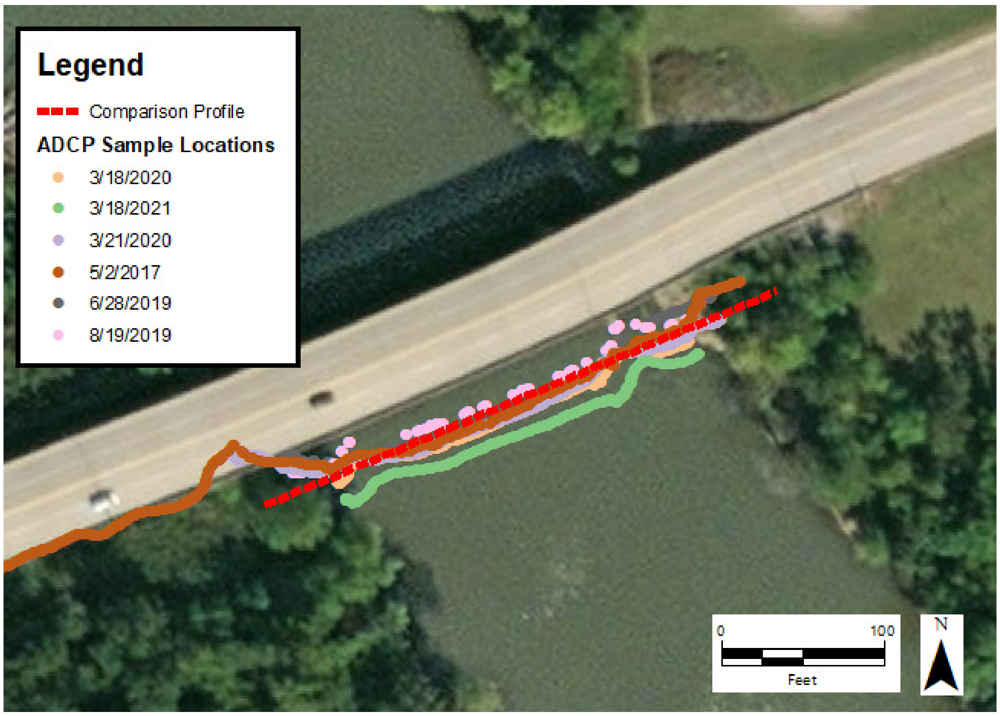
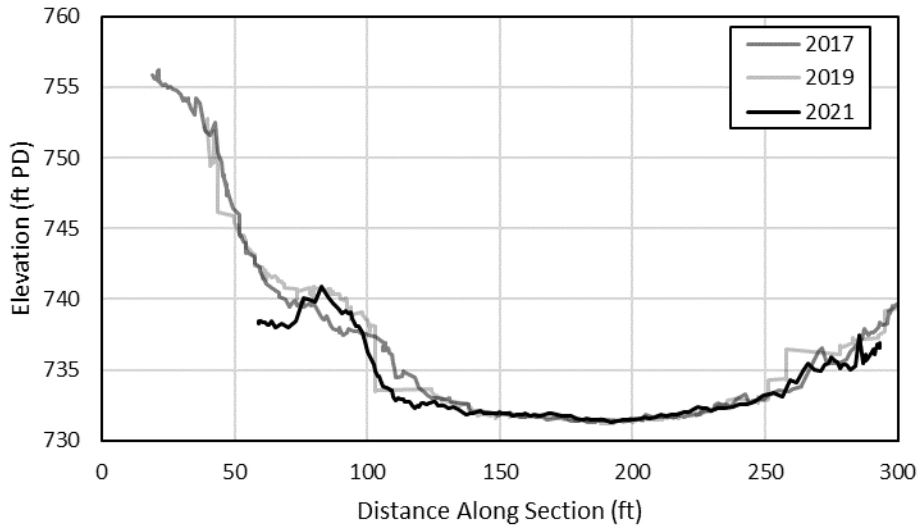


Figure 13
Neosho River at Miami USGS ADCP Sections



2.1.1.11.3 Tar Creek near Commerce

The Tar Creek near Commerce station has data available from four events ranging from 2004 to 2019, taken within 20 feet of each other as seen in Figure 14. The 2019 sample was removed due to data gaps. Figure 15 shows the transects from 2008, 2014, and 2017. Although the 2009 overbank topography is higher than 2014 and 2017, the three sections show a slightly increasing channel elevation, approximately 1 foot from 2008 to 2017.

Figure 14
Tar Creek near Commerce USGS ADCP Transects

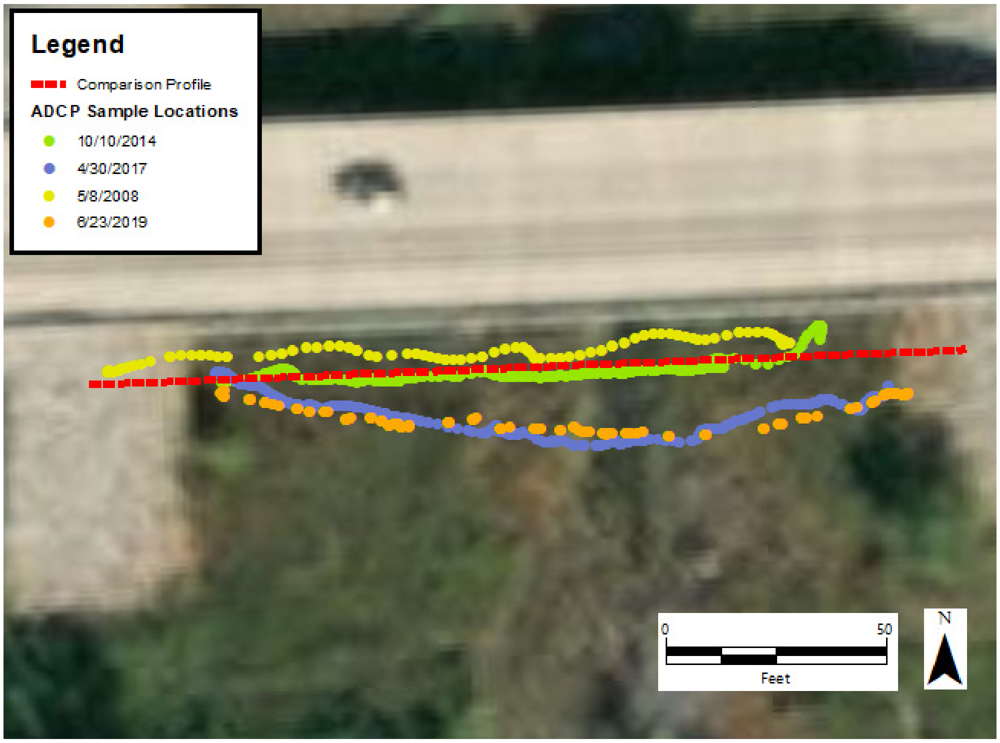
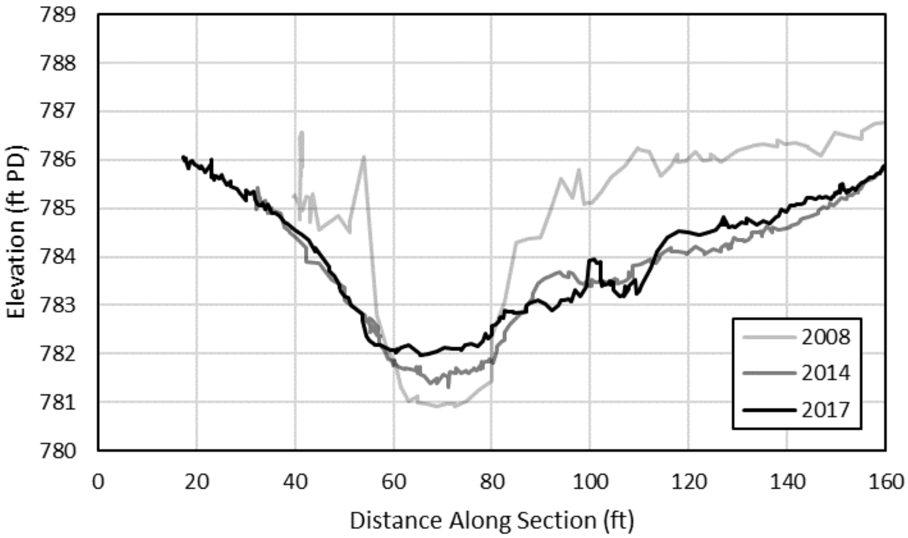


Figure 15
Tar Creek near Commerce USGS ADCP Sections



2.1.1.11.4 Tar Creek at 22nd Street Bridge

Two ADCP sample events were available from Tar Creek at 22nd Street Bridge, taken in 2013 and 2016, spaced approximately 10 feet apart as seen in Figure 16. The data showed no significant change in channel elevation from 2013 to 2016 (Figure 17).

Figure 16
Tar Creek at 22nd Street Bridge USGS ADCP Transects

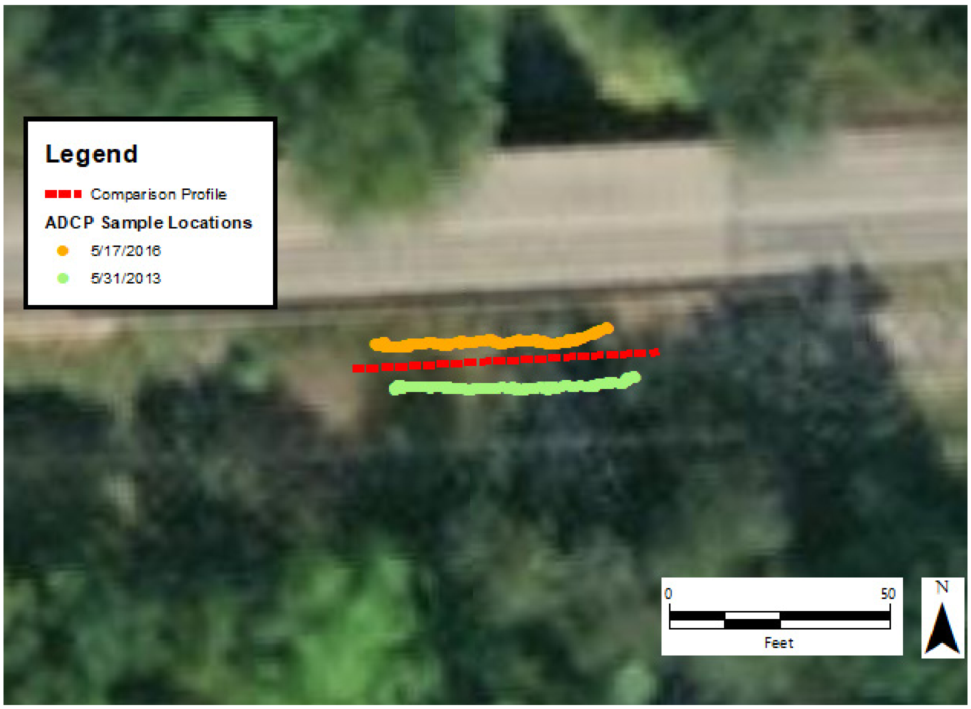
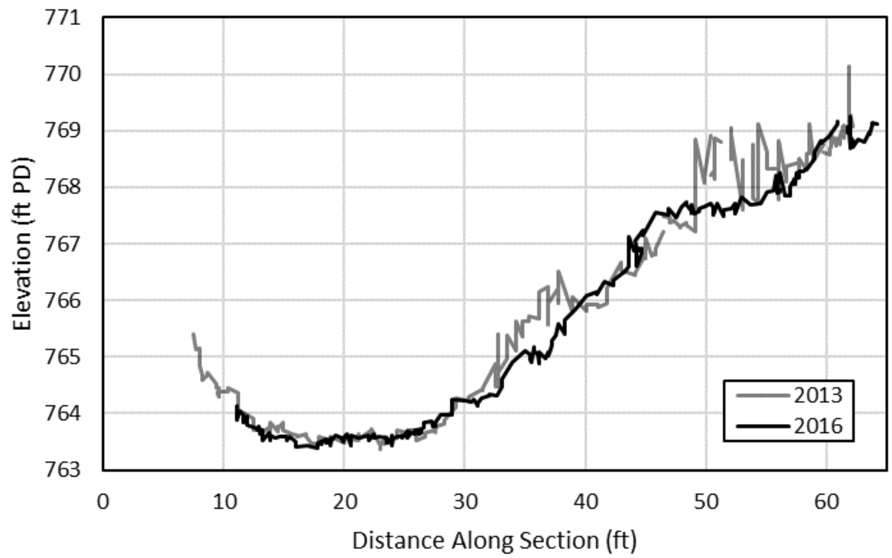


Figure 17
Tar Creek at 22nd Street Bridge USGS ADCP Sections



2.1.1.11.5 Spring River near Quapaw

The USGS has made ADCP data available from seven sampling events at Spring River near Quapaw station, taken from 2009 to 2015, spaced across approximately 60 feet of river as shown in Figure 18. The data from events taken from 2009 to 2015 show a different profile than those taken from 2016 to 2020. Figure 19 shows no change in channel elevation from 2009 to 2015, and Figure 20 shows an increasing channel elevation from 2016 to 2020. The distance between the transects accounts for some of the variation.

Figure 18
Spring River near Quapaw USGS ADCP Transects

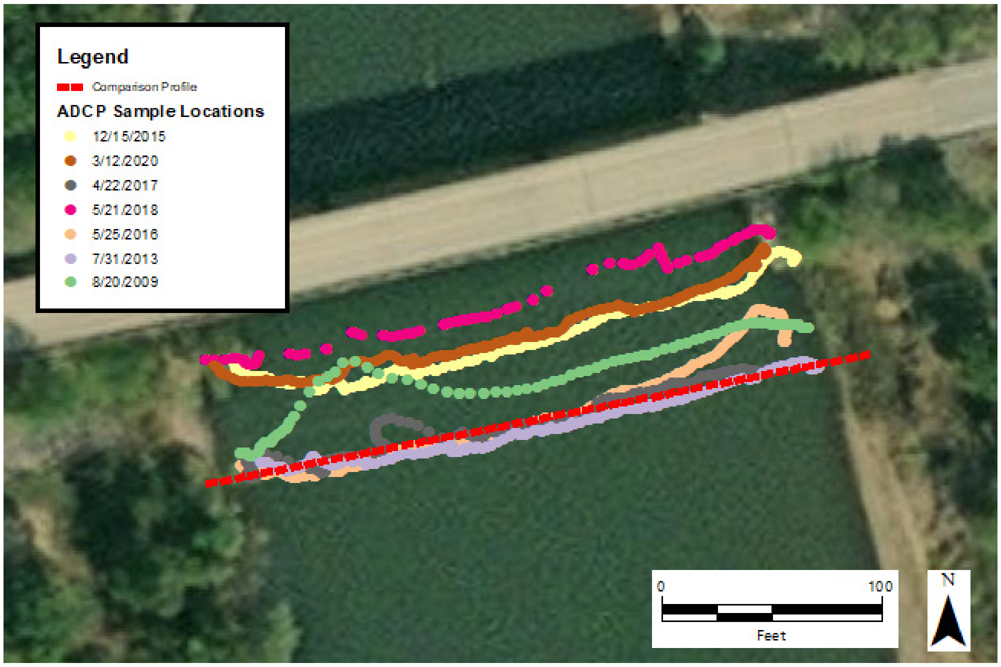


Figure 19
Spring River near Quapaw USGS ADCP Sections

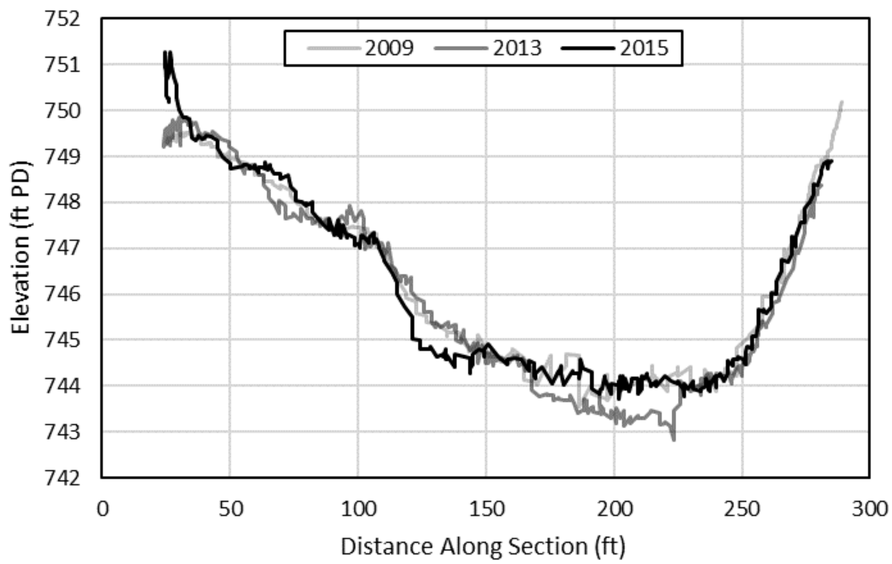
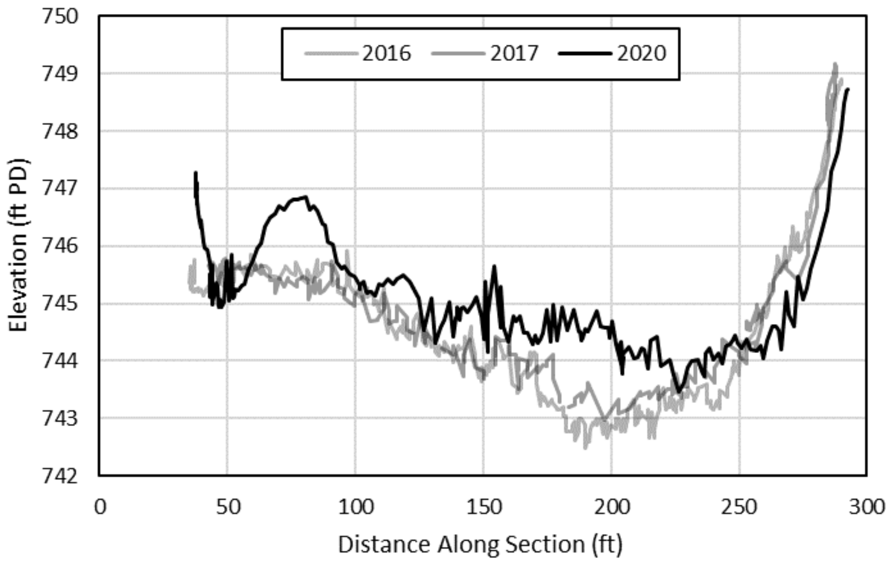


Figure 20
Spring River near Quapaw USGS ADCP Sections



2.1.1.11.6 Elk River near Tiff City

Figure 21 shows USGS ADCP data from six sampling events at Elk River near the Tiff City USGS station. The transects are spaced approximately 50 feet apart, and span 2011 to 2022. High-quality datasets in close proximity to the comparison profile are shown in Figure 22. The sections show some movement in the existing sand bar between the sampling events, and an overall trend toward higher channel elevation.

Figure 21
Elk River near Tiff City USGS ADCP Transects

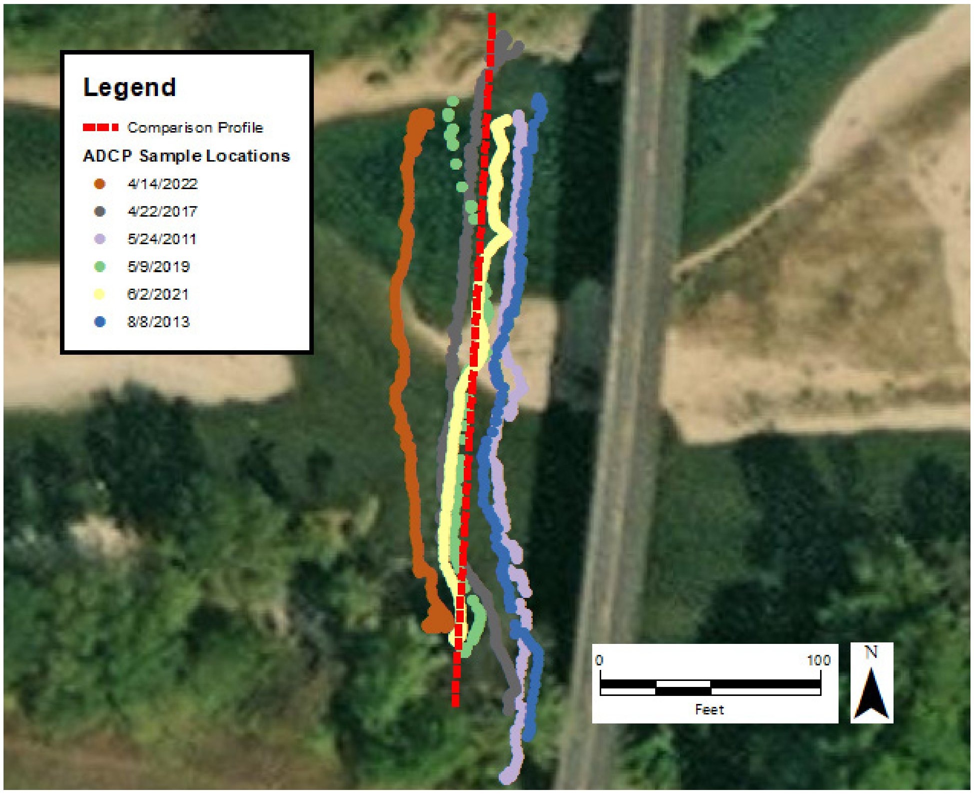
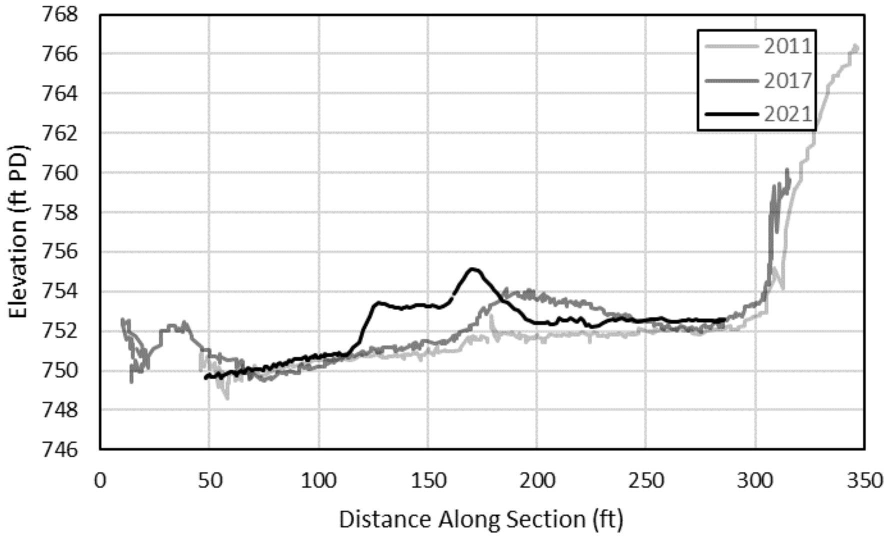


Figure 22
Elk River near Tiff City USGS ADCP Sections



2.1.2 Water Surface Elevation, Discharge, and Flow Velocity

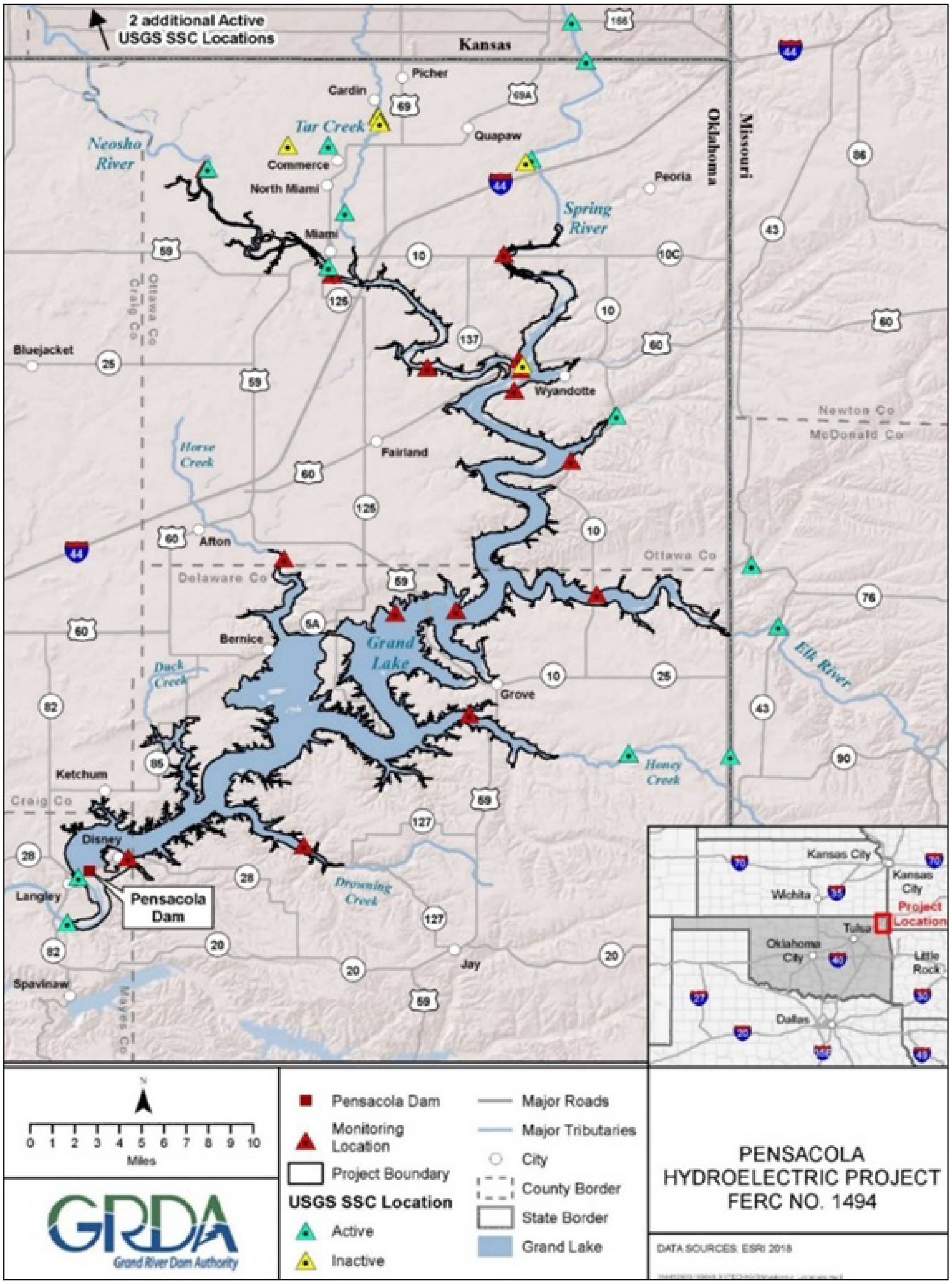
USGS provides monitoring gages in several locations within the study area watershed. These locations are shown in Figure 23, and station information is provided in Table 3. Each station provides WSE information at regular intervals; most also list discharge volumes. These gage readings are available to the public through USGS websites (USGS 2021a, 2021b, 2021c, 2021d, 2021e, 2021f, 2021g).

Table 3
USGS Gages Present in the Grand Lake Watershed and Periods of Record for Parameters Relevant to the Study

USGS Station ID	Site Name	Period of Record		
		Discharge (Continuous Record)	WSE (Continuous Record)	SSC (Intermittent Record)
07185000	Neosho River near Commerce, Oklahoma	1990–Present	2007–Present	1944–2016
07185080	Neosho River at Miami, Oklahoma	N/A	2007–Present	N/A
07185090	Tar Creek near Commerce, Oklahoma	2007–Present	2007–Present	2004–2016
07185095	Tar Creek at 22nd Street Bridge at Miami, Oklahoma	1989–Present	2007–Present	1988–2006
07188000	Spring River near Quapaw, Oklahoma	1989–Present	2007–Present	1944–Present
07189000	Elk River near Tiff City, Missouri	1990–Present	2007–Present	1993–2009
07190000	Lake O' the Cherokees at Langley, Oklahoma	N/A	2007–Present	N/A

Note:
N/A indicates that the specific data type was not recorded at these locations.

Figure 23
Map of the Study Area Showing Locations of USGS Gaging Stations and Water Surface Elevation Monitoring Sites



USGS also performs periodic discharge profile measurements at the gage stations. These typically use an ADCP. Table 4 provides a summary of the available ADCP data.

Table 4
Acoustic Doppler Current Profiler Data Available from USGS Measurements

USGS Station ID	Site Name	Period of Record	Range of Flows (cubic feet per second)
07185000	Neosho River near Commerce, Oklahoma	2006–Present	931–129,000
07185080	Neosho River at Miami, Oklahoma	2013–2017	172–57,100
07185090	Tar Creek near Commerce, Oklahoma	2008–2017	402–4,930
07185095	Tar Creek at 22nd Street Bridge at Miami, Oklahoma	2012–2016	398–2,400
07188000	Spring River near Quapaw, Oklahoma	2004–Present	639–62,600
07189000	Elk River near Tiff City, Missouri	2008–2017	2,340–24,800

2.1.3 Sediment Information

There are two primary components of sediment information needed for this study. The first is analysis of the bed sediments in the rivers and lake; the second is evaluation of sediment volumes moving into the study area from upstream sources.

2.1.3.1 Bed Sediments

Understanding and analysis of sediment transport through the rivers flowing into Grand Lake require knowledge of the sediment forming the bed of these streams. Only limited information was available regarding bed material of these streams. Several studies investigated sediment in the channel and upland areas within Grand Lake (e.g., Pope 2005; Andrews et al. 2009; Ingersoll et al. 2009; Juracek and Becker 2009; Smith 2016). Although the studies have produced a great deal of sediment analysis, they do not contain information that can be used to determine properties necessary for the proposed study such as critical shear stress or detailed grain size distributions.

Mussetter, in a 1998 report entitled *Evaluation of the Roughness Characteristics of the Neosho River in the Vicinity of Miami, Oklahoma*, photographically documented characteristics of the bed material forming the Neosho River and described the sediment as sand and gravel.

Mussetter (1998) observed the following regarding the bed material of the Neosho River (see):

> Based on field observations and sediment samples taken from bank-attached bars and from the bed of the river, the bed material in the reach upstream from approximately the I-44 Bridge (RM 142) is composed primarily of gravel and sand. Downstream from I-44, the surface bed material at the time of the sampling in late 1996, which was performed when the discharge in the river was relatively low, was primarily silt and clay (Mussetter 1997). There are no obvious factors other than reduced flow velocities caused by backwater from Pensacola Dam that would cause the observed change in character of the river bed in the reach downstream from Miami. Prior to construction of the dam, the bed of the river downstream from Miami was most likely gravel and sand, similar to that found upstream.

Figure 24
Typical Sand and Gravel Material on a Point Bar Along the Left (North) Side of the Neosho River at Approximately RM 147

Source: Mussetter (1998)

In the conclusions of his report, Mussetter continues his observations and speculation regarding the bed of the Neosho River:

> The bed of the Neosho River through and upstream from Miami consists of a mixture of sand and gravel. In contrast, the bed is composed of finer-grained material in the reaches downstream from Miami due to the effects of backwater from Grand Lake. Samples taken from the bed surface at low flow in late 1996 consisted primarily of silt- and clay-sized material. Based on the characteristics of the upstream bed material, it is probable that the silt and clay is entrained and carried farther downstream into the reservoir during higher flows, and that the bed is composed primarily of sand.
> (Mussetter 1998)

The concept that the bed consists primarily of sand was apparently reinforced by the analysis of resistance to flow. In discussing the Manning's *n* values, which quantify resistance to flow in hydraulic modeling, Mussetter states the following:

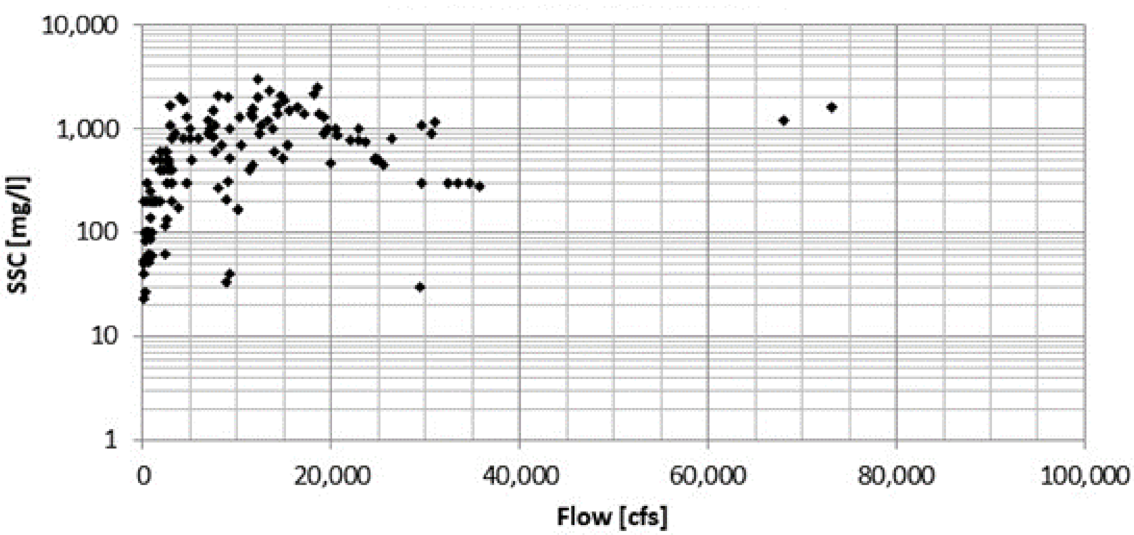
> These values are consistent with observed values in other sand bed streams having dune bedforms. This result indicates that dunes, and therefore relatively high Manning's n values, must be present in the reach downstream from Miami during high flows under with-reservoir conditions.
> (Mussetter 1998)

As demonstrated in subsequent sections of this report, there are a number of factors that contribute to the observed change in character of the bed material from non-cohesive sand and gravel to cohesive silt and clay. Mussetter (1998) focuses only on the presence of Pensacola Dam, but there are other factors influencing those findings. These factors include backwater from bridges, geologic and geomorphic features, and the fact that the river is transporting almost exclusively cohesive silt- and clay-sized material with very little bedload transport of non-cohesive material. In addition, on the recession limb of hydrographs, some sediment being transported by the river may temporarily deposit before being flushed farther downstream during subsequent higher flows resulting in the transition of the bed surface from coarser material to finer and back to coarser again.

2.1.3.2 Sediment Transport

The second sediment analysis required is measurement of sediment volumes flowing into the system. Approximate sediment transport rates can be determined from USGS measurements of suspended sediment concentrations (SSCs; Figure 25). SSC provides a measurement of sediment loading, typically in milligrams per liter, of streamflow. That information can then be multiplied by discharge volumes to determine transport rates within the water column. Table 3 provides a summary of the available period of record for SSC information. However, the datasets are small with samples collected on rare occasions; they do not represent continuous records like the discharge and WSE measurements.

Figure 25
Suspended Sediment Concentration Samples and Stream Discharges During Sampling on the Neosho River Near Commerce (USGS Gage 07185000)



Note: Only two samples were collected at discharges above 40,000 cfs.

SSC measurements focus only on fine materials suspended in the water column. This typically includes silts and clays, with limited sand possible depending on turbulence at the sampling site. It does not, however, measure transport rates along the streambed. Bedload transport is generally dominated by sands, gravels, and cobbles that "roll" downstream along the streambed. This information is critical to understand the full sediment transport regimes of a watershed. Recorded sediment transport rates are limited to SSC calculations because bedload transport has not been reported within the Grand Lake watershed.

2.1.3.3 Contaminated Sediment

City of Miami, Miami Tribe, Eastern Shawnee Tribe, Ottawa Tribe, Seneca Cayuga Nation, Wyandotte Nation, and N. Larry Bork (counsel for the City of Miami citizens) provided a list of existing information to be used in their requested contaminated sediment transport study. The toxicity of the sediments is not within the scope of this study. However, existing data and information available from studies conducted of the Superfund site within the Tar Creek watershed were reviewed and incorporated in the study as appropriate.

2.2 Field Data Collection

Due to information gaps relevant to the study, field data collection was deemed necessary. This consisted primarily of WSE monitoring and sediment and water sampling to provide calibration information for eventual model development.

2.2.1 Water Surface Elevation Monitoring

Anchor QEA collected WSE data throughout the Project site (Figure 23). Sixteen monitoring locations were selected, and HOBO pressure loggers (Figure 26) were installed at each site in December 2016. The loggers record raw pressures and water temperatures at 30-minute intervals to provide a continuous WSE record throughout the basin. Data are stored in onboard memory; with 30-minute recording intervals, the memory capacity is approximately 1.2 years.

Figure 26
Photograph of HOBO Pressure Loggers and Mounting Chamber

Loggers were placed in a mounting chamber and attached to rebar driven into the bed at each location shown in Figure 23. The mounting chamber was constructed of PVC with threaded caps painted black to limit visibility and deter theft or vandalism. Rebar was driven into the bed to a sufficient depth to prevent the loggers from washing away during high flow events.

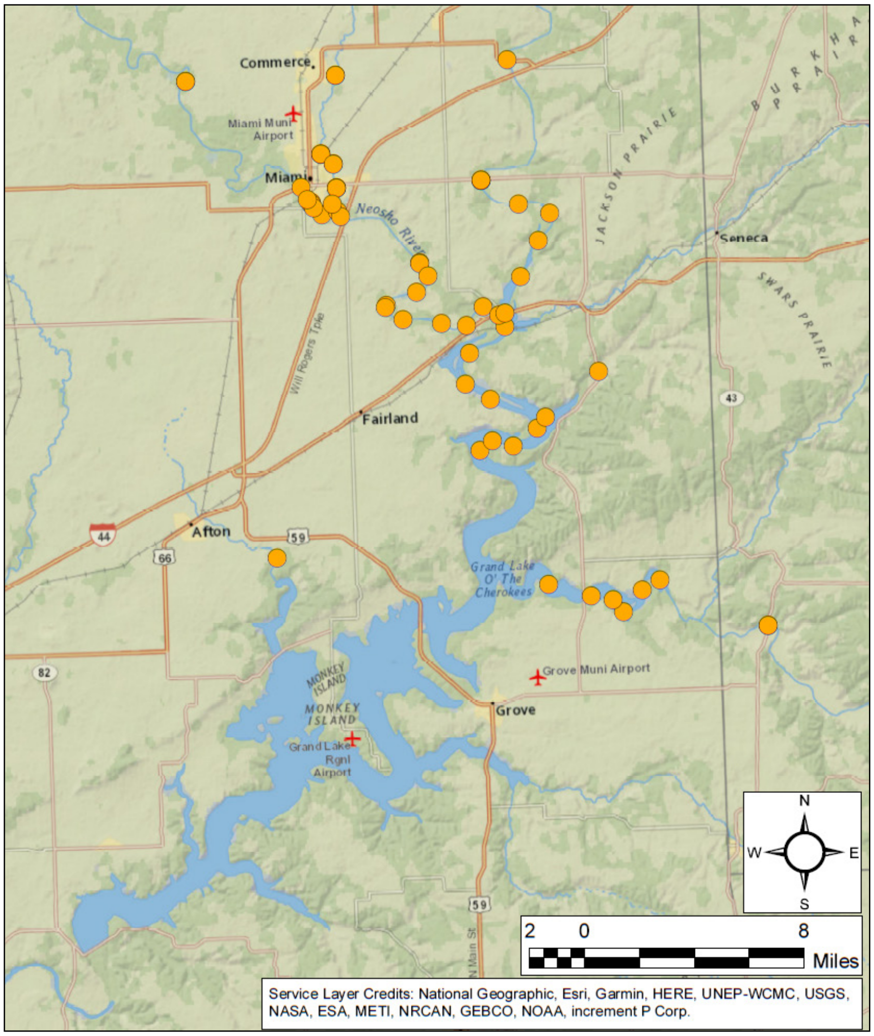
2.2.2 Sediment Grab Samples

The study team first collected surface samples of stream sediment throughout the watershed. A total of 62 samples were collected during a visit in December 2019 (Table 5). Figure 27 shows the locations of the sediment samples. Appendix B provides the plots of the gradations of the sediment grab samples.

Table 5
Surface Sediment Grab Sampling Locations by River and Reach

Stream	Samples Collected
Neosho River North of Spring River	20
Neosho River South of Spring River	9
Tar Creek	13
Spring River	10
Elk River	8
Sycamore Creek	1
Horse Creek	1

Figure 27
Location of Sediment Grab Sampling Efforts within the Grand Lake Watershed



Samples were collected both in the overbank and in-channel areas. Overbank samples were gathered with shovels and in-channel samples were taken with either a PVC push-core sampler, a shovel, or an Ekman dredge (Figure 28). Once collected, the samples were placed into containers for analysis at the University of Wisconsin Soil and Forage Laboratory (UWSFL) in Marshfield, Wisconsin.

2.2.3 SEDflume Core Sampling

Cohesive sediment cores were collected during the study for erosion testing using SEDflume (see Appendix C). Despite initial reports indicating that Grand Lake watershed sediment transport was dominated by sands (Tetra Tech 2018), field information showed that cohesive sediments were prevalent throughout the basin and comprised the majority of sediment moving through the study area. As a result, plans were adapted to account for the presence of silts and clays, which are not eroded or transported in the same way as non-cohesive sediments such as sand and gravel.

Figure 28
Ekman Dredge Used for In-Channel Sediment Sampling

Sediment transport is generally dictated by bed shear stress. Bed shear is a function of bed slope and water depth. It is essentially a measure of frictional drag on the streambed. At low shear stress, sediment is held in place by gravitational forces. At the point of incipient motion, shear and gravitational forces are essentially balanced; the shear stress in this condition is known as the critical shear stress. Above critical shear, the bed sediment becomes mobile and can be transported. Below critical shear, sediment does not move and can settle out of the water column. Depending on sediment properties, critical shear stress can vary widely, with boulders having high critical shear values and fine sand exhibiting low critical shear stresses.

Non-cohesive sediments such as sand, gravel, and cobbles (Figure 29, top photograph) tend to have easily predictable critical shear stress. It is typically proportional to sediment density and grain size and is relatively constant through the entire sediment layer. Generally, grains move relatively independently of each other. As a result, these sediments are comparatively simple to evaluate and model.

Figure 29
Visual Comparison of Different Sediment Types

Note: Top—non-cohesive sand, gravel, and cobbles; bottom—cohesive silt and clay.

Modeling cohesive sediments is far more complex. Critical shear stress is determined primarily by the cohesive forces between silt and clay particles rather than individual grain sizes. This is complicated by the process of consolidation; as sediment is deposited in an area, it applies force to the underlying layers, compressing them and increasing the cohesion, making them less susceptible to erosion. The amount of time spent on the bed also affects consolidation and critical shear stress. Furthermore, erosion typically occurs as clumps break free of the surrounding sediment. Due to the changing resistance to erosion based on depth and the nature of cohesive sediment transport, it is considerably more difficult to accurately model and requires additional information.

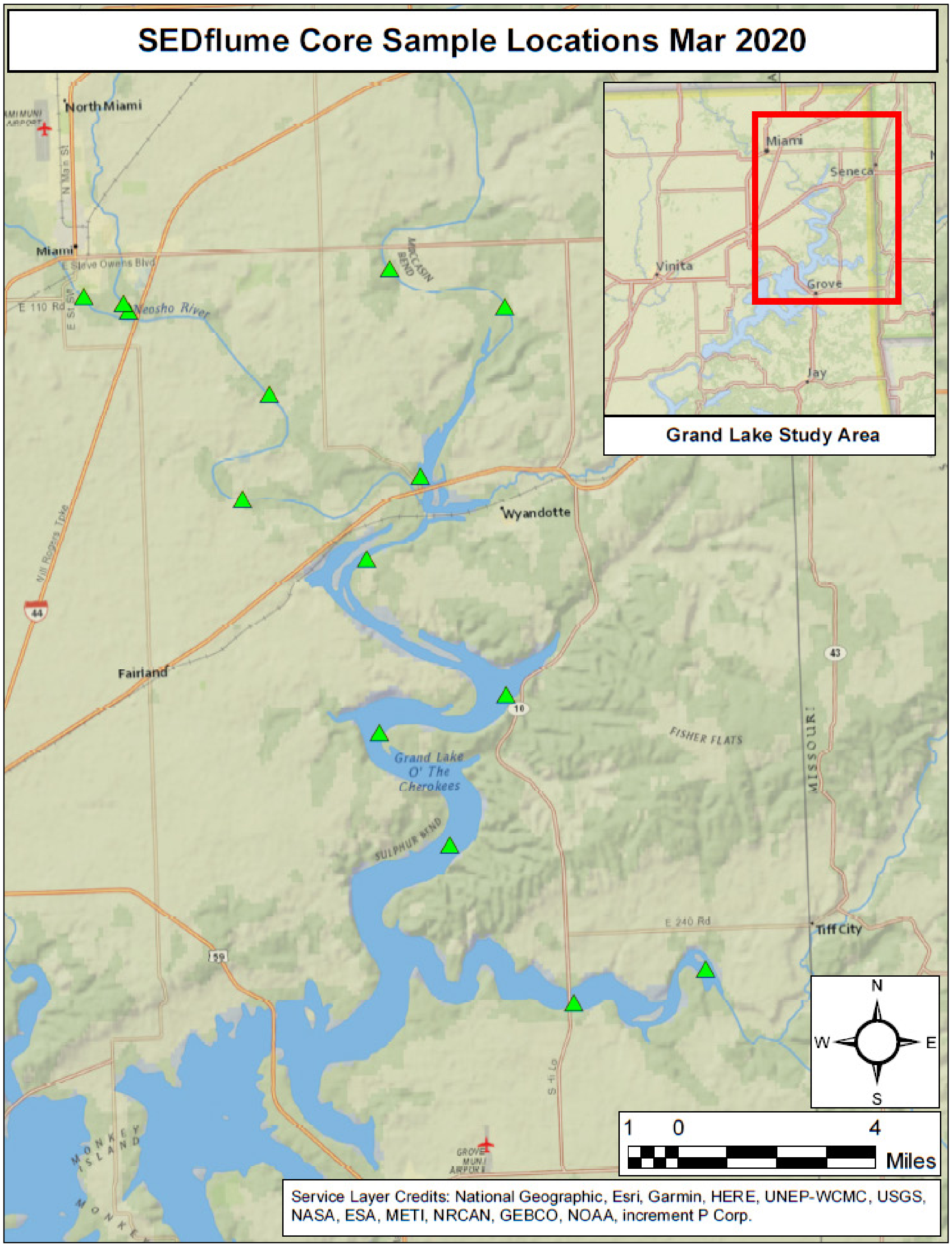
Accurate collection of sediment information can be accomplished through erosion testing on SEDflume (Borrowman et al. 2006; McNeil et al. 1996). The SEDflume testing facility consists of an enclosed flume with a hole in the bed. An undisturbed sediment core sample is placed under the hole, and the surface of the core is raised to be flush with the flume bed. Water is pumped across the sample surface at a known shear stress; as the core erodes, a jack lifts it to keep the surface flush with the flume bed. The rate of erosion is the distance the jack moved per unit time of the test. Bed shear stress can then be increased to evaluate rates at a range of shear values. This test provides information about critical shear stress throughout the sediment core, allowing engineers to evaluate critical shear as a function of depth.

The study team collected core samples for SEDflume analysis in March 2020 (Figure 30). A total of 14 core samples were collected using a box push-core system (Figure 31). The box core was a clear plastic sleeve, which was pressed into the sediment bed. A pressure relief valve at the top of the core allowed air and water to escape as the core sank into the streambed. The resulting suction pressure kept the sample inside the sleeve as it was raised back to the water surface. The sample was then measured, sealed, and transported to the test laboratory for analysis.

Figure 30
SEDflume Core Sampling

Note: Left—technician pulling box core rig out of the bed; center—box core showing sediment fill and measuring depth of sample; right—several collected samples before shipment to the test facility.

Figure 31
Locations of SEDflume Core Samples Collected During the Sediment Investigation



SEDflume analysis also provided particle size analysis. During testing, Integral Consulting used a Beckman Coulter LS particle size analyzer over a range of depths below the surface of the core for each sample.

2.2.4 Sediment Transport Measurements

Sediment transport measurements were also included in the sediment study. These consisted primarily of two forms of data: SSC and bedload transport quantification. Bedload samples were collected immediately following SSC sampling at each site. Dates of sampling efforts and discharges are provided in Table 6.

Table 6
Sampling Dates and Discharge Measurements, per USGS Gaging Station Records

Date	Discharge (cubic feet per second)			
	USGS 07185000 Neosho River at E 60 Rd	**USGS 07185090 Tar Creek at Hwy 69**	**USGS 07188000 Spring River at E 57 Rd**	**USGS 07189000 Elk River at Hwy 43**
August 2019	15,500	10.0	1,240	537
May 2020	37,500	*	8,040	4,940
July 2020	2,930	5.29	3,480	*
April 2021	2,330	*	2,250	*
May 2021	18,900	750	16,500 23,400**	*
July 2021	41,600	500	14,700	*

Notes:
*Samples not taken at this location.
**Spring River was sampled twice during the May 2021 site visit.

2.2.4.1 Suspended Sediment Concentration

A D-74 depth-integrating water sampler was used to collect SSC samples (Figure 32). This sampler features a finned body with a nozzle pointing upstream and a vent pointing downstream. As it is lowered into the water, flow is allowed through the nozzle and into a sampling bottle. The sampler is lowered into the stream until it reaches the bed, then is raised; this is all done at a constant speed. Based on flow conditions at the site, researchers have an array of nozzle sizes and travel speeds to choose to ensure valid data (USGS 2006).

Figure 32
Sampling Equipment Used During Suspended Sediment Concentration Sampling Efforts

Notes: The D-74 water sampler is attached to the crane, and the SonTek M9 ADCP used to measure stream flows is in the lower right. Samples are placed in the carrier at left after collection.

Anchor QEA followed standard USGS protocols for equal width interval water sampling (USGS 2006). The field technicians used a SonTek M9 ADCP or timed a floating object moving a known distance to measure current profiles at each site before sampling began. Based on flow velocities and patterns, they selected appropriate nozzle sizes and descent and ascent velocities for the D-74 sampler following USGS standard procedures (USGS 2006). Following nozzle installation, a calibrated winch lowered the sampler to the stream and raised it at the specified rates. Samples were then capped and sent to the Wisconsin State Laboratory of Hygiene (WSLH) for SSC analysis.

Field notes and a detailed description of the process followed were provided in April 2022 as attachments to GRDA's response comment.

2.2.4.2 Bedload Transport

Anchor QEA used a Helley-Smith bedload sampler (Figure 33) to collect bedload transportation measurements. Sampling sites were the same as those used for SSC measurements to ensure capture of all sediment (SSC and bedload) moving through the system under given flow conditions. The Helley-Smith sampler sits on the streambed with a rectangular opening pointed upstream. Saltating, sliding, and rolling sediment is transported at the bed surface into the opening and trapped in a mesh bag. USGS documentation provides guidelines for the use of this equipment; Anchor QEA followed USGS procedures (Edwards and Glysson 1999) to collect bedload sediment during site visits (Table 6).

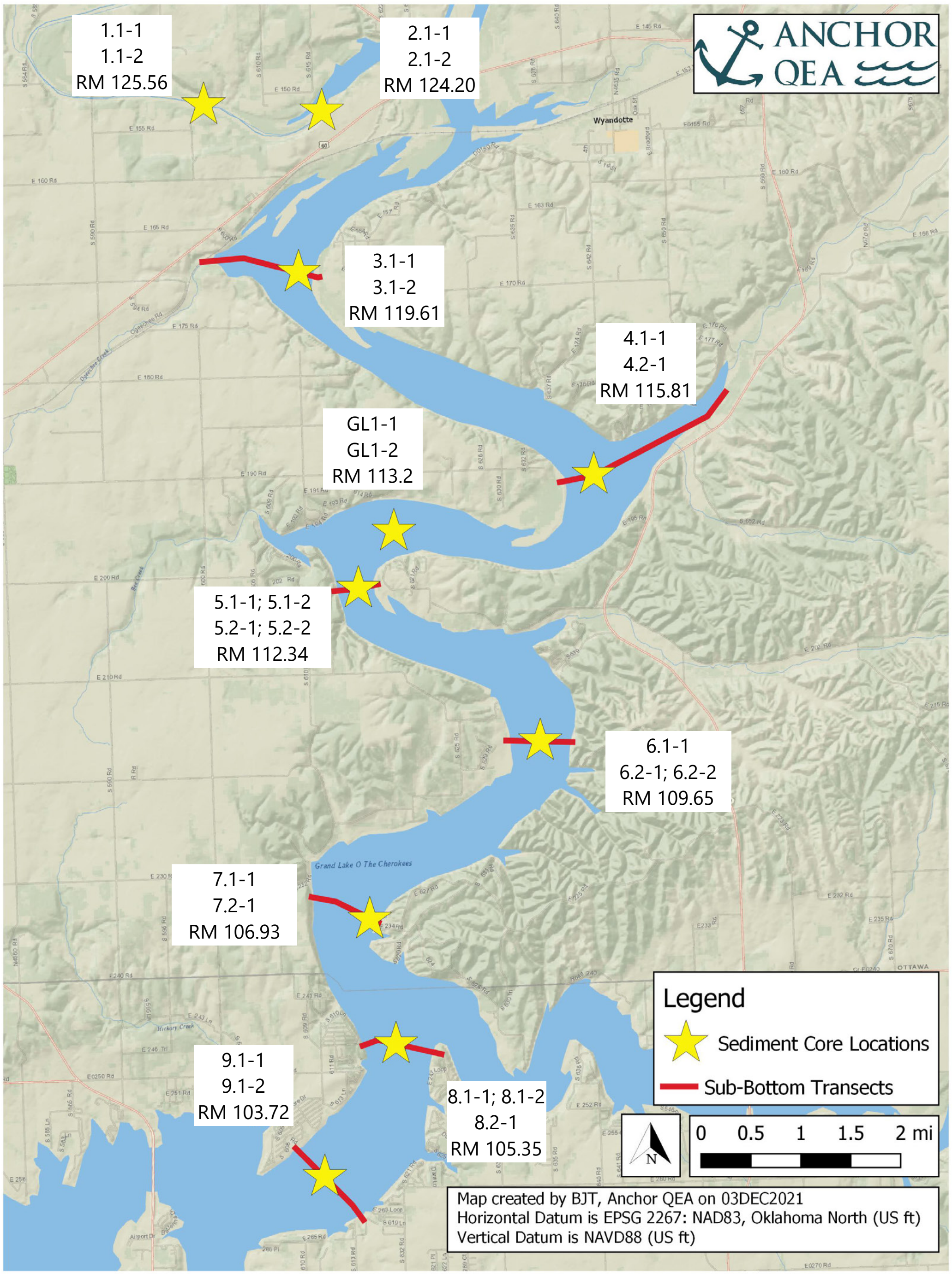
Figure 33
Bedload Transport Measurements Collected Using the Helley-Smith Sampler

Field notes and a full description of the process followed were provided in April 2022 as attachments to GRDA's response comment (GRDA 2022).

2.2.5 Subsurface Investigations

GRDA also performed subsurface investigations of the delta feature. These included two primary components: sub-bottom profiler (SBP) surveying and vibracore sampling. The SBP survey covered nine transects of the Neosho River and was completed in January 2022 (Figure 34). Vibracore sampling included multiple samples at each SBP transect and was completed in February 2022.

Figure 34
Locations of SBP Transects and Sediment Cores Collected by GRDA



An SBP uses sonar pulses to determine depth of a waterbody. There is an emitter and a receiver on the SBP head unit, and by measuring the amount of time necessary for the emitted pulse to reach an object and return to the receiver, the SBP is able to measure the distance the pulse traveled. This allows the SBP to measure bathymetry, but the pulse is also powerful enough to penetrate a soft sediment bed, such as clay, silt, and sand before reaching a harder layer. Using the same principles, the SBP can then estimate the thickness of a soft sediment layer above gravel or bedrock.

Vibracoring uses a motorized head unit to press core tubes into the stream or lakebed. The combined weight and vibration of the head unit allows for deeper penetration than simply pressing the core tube into the bed or relying on gravity coring methods. Once collected, grain size analyses and other testing can be used to determine sediment properties as a function of depth in the sediment layers. The cores were used for two purposes: 1) to confirm SBP survey information and evaluate sediment composition; and 2) an attempt to determine approximate dates of deposition through the use of cesium-137 (Cs-137) analysis.

Cs-137 is an isotope that does not occur in nature. It is created by nuclear fission, which humans began developing in the 1940s. As nuclear weapons testing accelerated, atmospheric Cs-137 increased until a 1963 nuclear test ban treaty. The Cs-137 levels then dropped significantly. Atmospheric Cs-137 concentrations are well-correlated with Cs-137 concentrations in soil, showing the same pattern of increase from the 1940s to 1963, then a marked decrease.

Measurement of relative Cs-137 activity in sediment allows researchers to estimate deposition dates for sediment layers. In areas of continual deposition, Cs-137 analysis will find a pattern of increasing Cs-137 activity moving deeper in the column until reaching the 1963 layer. Below that layer, concentrations drop to zero by the 1940s. In disturbed areas or places with non-continuous deposition, there is usually no clear Cs-137 peak. The combination of SBP, vibracore samples, and Cs-137 provides insight into the volume, rate, and timeline of sediment deposition in the Neosho River.

2.3 Field Results

2.3.1 Water Surface Records

Anchor QEA has visited the site several times to collect and redeploy pressure loggers. Trips to collect WSE monitoring data were performed according to Table 7.

Table 7
WSE Monitoring Site Visit Dates and Logger Retrieval Rates

Date	Loggers Recovered
December 2016	16 Deployed
August 2017	13 of 16
March 2018	2 of 16
April 2019	12 of 16
December 2020	13 of 16

Anchor QEA retrieved the loggers on an approximately annual basis. Upon arrival at each monitoring station, Anchor QEA staff collected Real-Time Kinematic (RTK) GPS measurements of the WSE and surveyed any nearby benchmarks. The loggers were collected, and data were read from them using an optic USB interface. They were then relaunched and placed back in the field; staff measured depth to the loggers and depth to bed before leaving the site. After all loggers were retrieved, the data were processed to produce WSE readings from the pressure data.

The loggers recorded raw pressure measurements that had to be converted to water depths and then WSE. Because pressure readings include both water pressure and atmospheric pressure, it was first necessary to subtract ambient air pressure from the measurements. Records from the Grove Municipal Airport provided atmospheric pressure readings for processing. Python programs were used to subtract the raw readings to water pressure measurements; water density was then used to estimate the depth of the sensors according to Equation 1.

Equation 1

$$h = \frac{P}{\rho g}$$

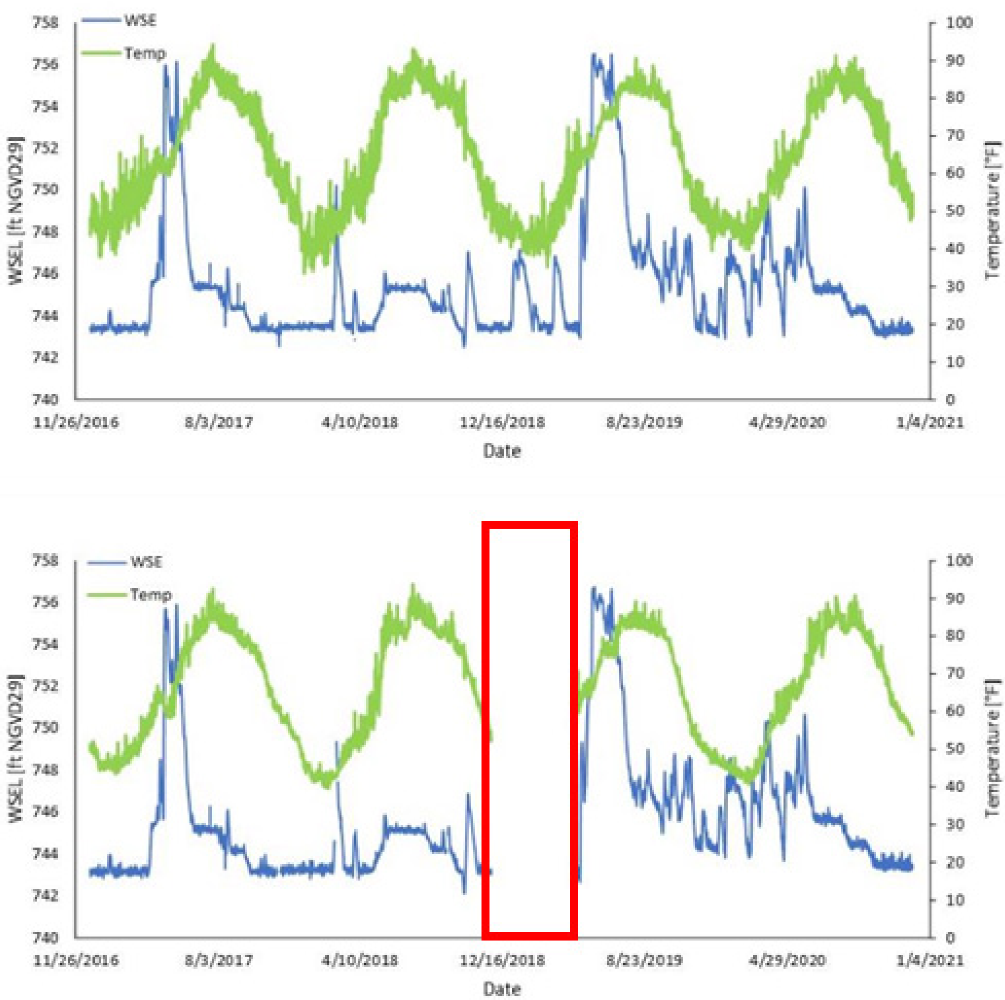
where:

h	=	water depth
P	=	pressure
ρ	=	water density
g	=	acceleration due to gravity

Once water depths were established at the time of retrieval, logger elevation was set based on the measured WSE and recorded depth; data throughout the period of record were thus converted from the raw pressure recordings to WSE measurements (Figure 35). The calculated WSE readings were adjusted to match the RTK GPS measurements taken while on site.

Several loggers had data gaps in the record. At various sites, the loggers were washed away or vandalized, which prevented recovery. One additional data gap was due to an unforeseen high-water event that prevented recovery until after internal storage had been filled. Full datasets are available in Appendix A.

Figure 35
Sample Series

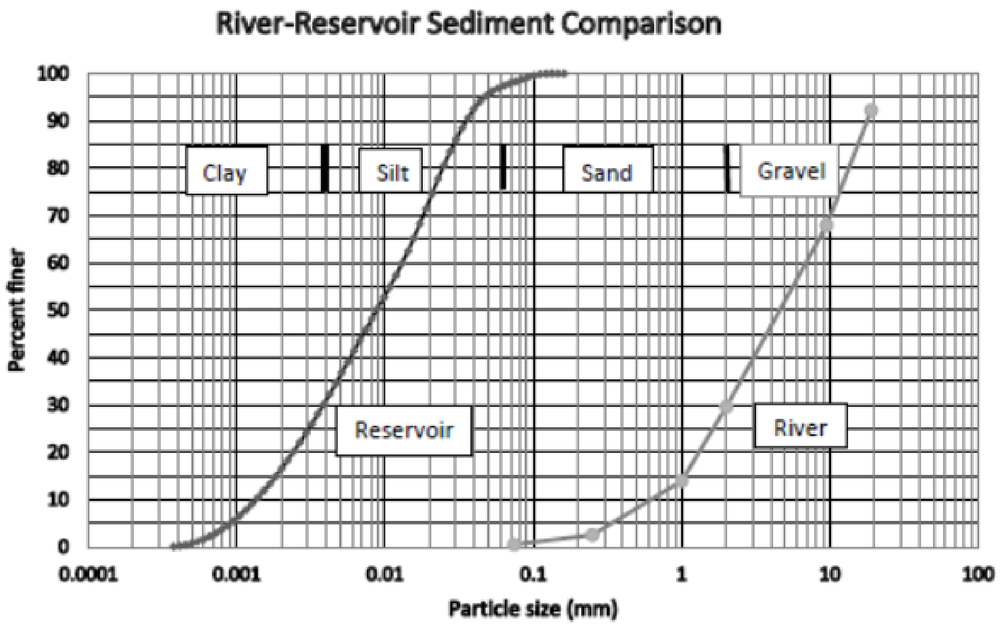


Note: Top: complete dataset; bottom: gap in record.

2.3.2 Sediment Grain Size Analysis

Following the December 2019 sediment grab sample collection, Anchor QEA sent 62 sediment samples to UWSFL for grain size analysis. The results of the analysis indicated a bi-modal size distribution, with a majority of streambed sediments consisting of gravels and coarse sediments and a majority of lakebed sediments composed of silt and clay. The results showed limited volumes of sand in either stream or lake sediments, with most of the lakebed being finer than sand and most of the riverbed being coarser than sand (Figure 36).

Figure 36
Particle Size Distributions within the Grand Lake Study Area



As shown in Figure 37, the beds of these streams consist primarily of gravel, with some sand. The surface of the streambeds appears to be armored by gravel and (in the case of areas of Tar Creek) larger particles. Hydraulic and sediment transport analyses, based on particle size distributions, will determine the extent to which these particles are transported downstream into the reservoir.

Figure 37
Sample Photographs Showing the Sediment in the Spring River, Tar Creek, Elk River, and Neosho River

Note: Clockwise from top left, the Spring River, Tar Creek, Elk River, and Neosho River.

Farther downstream, as the tributaries transition into lacustrine conditions, the character of the bed material changes dramatically. Samples collected from the reservoir bed appear to consist primarily of silt and clay (Figure 38).

Figure 38
Sediment Grab Samples Collected from the Reservoir Bed in Grand Lake

Full results for each sample are presented in Appendix B. These results show the significant variability in particle size distributions from reach to reach within streams and even significant differences between samples taken in close proximity.

2.3.3 SEDflume Test Results

SEDflume samples were tested by Integral Consulting at their Santa Cruz, California laboratory. Testing was performed according to the procedures described by McNeil et al. (1996) and Borrowman et al. (2006). The laboratory analysis of the samples included evaluation of erosion parameters, grain size distributions, and bulk density of the samples.

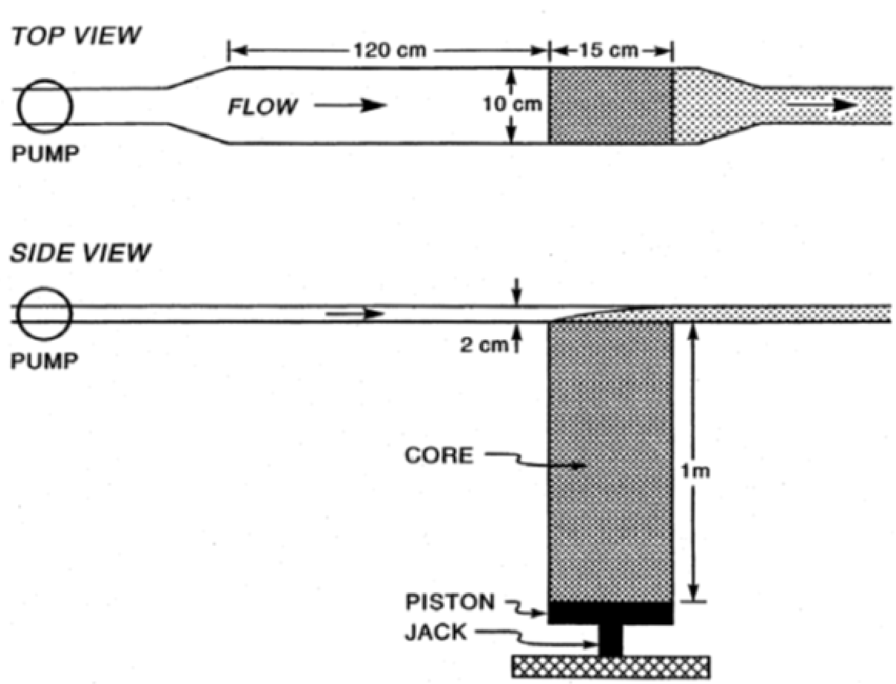
2.3.3.1 Erosion Parameter Analysis

Erosion of cohesive sediment is quantified by two key parameters: critical shear stress at which erosion begins, and the rate of erosion as a function of increasing shear stress greater than critical shear. A standard technology, SEDflume, has been developed to measure these parameters. The SEDflume is described as follows:

> A SEDflume is essentially a straight flume with an open bottom section through which a rectangular, cross-sectional core barrel containing sediment can be inserted [Figure 39]. The main components of the flume are the water tank, pump, inlet flow converter (which establishes uniform, fully developed, turbulent flow), the main duct, test section, hydraulic jack, and the core barrel containing sediment [Figure 40]. The core barrel, test section, flow inlet

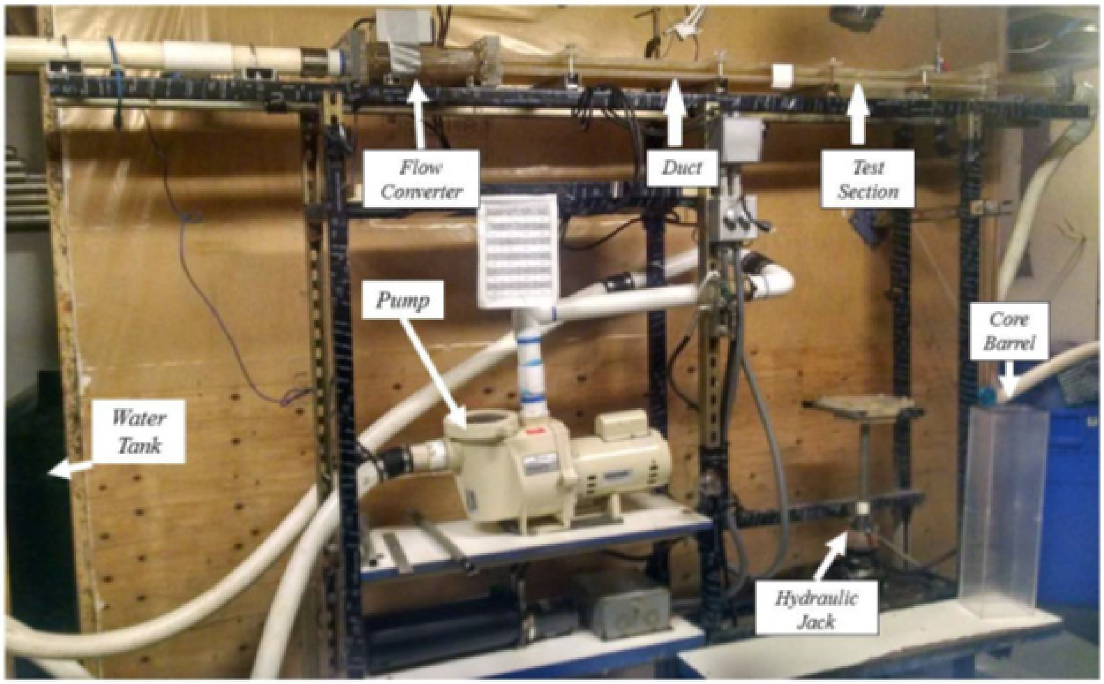
section, and flow exit section are made of transparent acrylic so that the sediment–water interactions can be observed visually. The core barrel has a rectangular cross section, 10 by 15 cm, and a length of 60 cm. (Integral Consulting 2020)

Figure 39
SEDflume Schematic Showing Top and Side Views



Source: Integral Consulting (2020)

Figure 40
Photograph of SEDflume Test System



Source: Integral Consulting (2020)

In its report, Integral Consulting describes the process of conducting the laboratory testing with SEDflume, as follows:

> At the start of each test, a core barrel and the sediment it contains are inserted into the bottom of the test section. The sediment surface is aligned with the bottom of the SEDflume channel. When fully enclosed, water is forced through the duct and test section over the surface of the sediment. The shear stress produced by the flow and imparted on the particles causes sediment erosion. As the sediment on the surface of the core erodes, the remaining sediment in the core barrel is slowly moved upward so that the sediment–water interface remains level with the bottom of the flume. (Integral Consulting 2020)

Integral Consulting then describes the process of taking measurements to develop critical shear and erosion rate data:

> At the start of each core analysis, an initial reference measurement is made of the starting core length. The flume is then operated at a specific flow rate

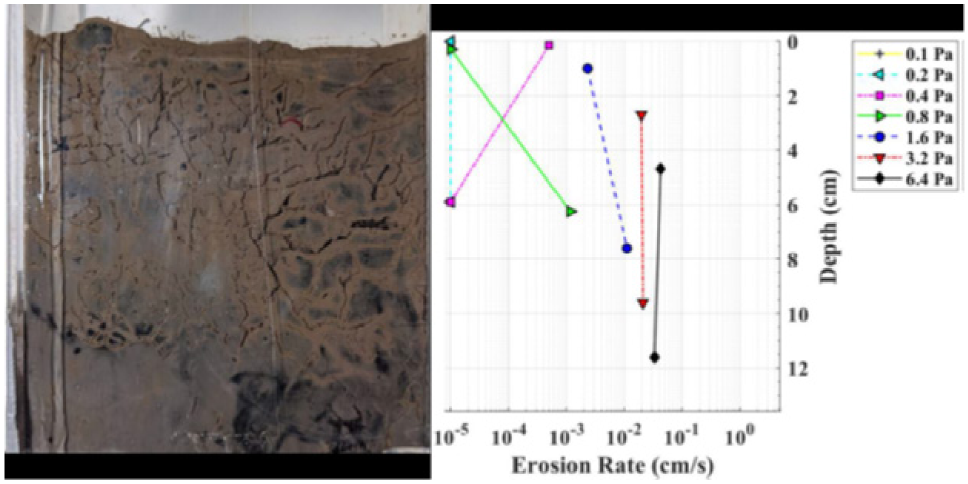
corresponding to a particular shear stress, and sediment is eroded (McNeil et al. 1996; Jepsen et al. 1997). As erosion proceeds, the core is raised if needed to keep the core's surface level with the bottom of the flume. This process is continued until either 10 minutes has elapsed or the core has been raised roughly 2 cm. (Integral Consulting 2020)

As the flow rate is increased through the flume and as sediment begins to erode from the surface of the core determines the critical shear value above which erosion occurs and below which no erosion occurs. Once the critical shear value is determined for that layer of sediment, the flow rate through the flume is increased and erosion measured over a range of flow or shear stresses. This process is repeated at different levels of the core sample below the surface to develop the critical shear and erosion rates through the depth of the sample. Tabulated results for each of the streams showing the critical shear erosion parameters determined using SEDflume can be seen in Table 8 through Table 11 and Figure 41 through Figure 44 show the erosion rates at the various applied shear stresses over the depth of the core sample for the associated streams.

Table 8
Physical Properties and Derived Critical Shear Stresses of SEDflume Sample NR-130 (Neosho River)

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm³)	Dry Bulk Density (g/cm³)	Loss on Ignition (%)	τ_{no} (Pa)	τ_1 (Pa)	τ_c Linear (Pa)	τ_c Power (Pa)	Final Critical Shear (Pa)
0.0	8.34	1.49	0.84	3.7	0.2	0.4	0.84	0.33	0.33
5.9	5.20	1.56	1.01	6.8	0.4	0.8	0.44	0.29	0.40
8.6	7.01	1.64	1.10	5.0	---	---	---	---	---
Mean	**6.85**	**1.56**	**0.98**	**5.2**	**0.3**	**0.6**	**0.64**	**0.31**	**0.37**

Figure 41
Photograph of Core NR-130 (Neosho River) Aligned with Applied Shear Stresses and Associated Erosion Rates

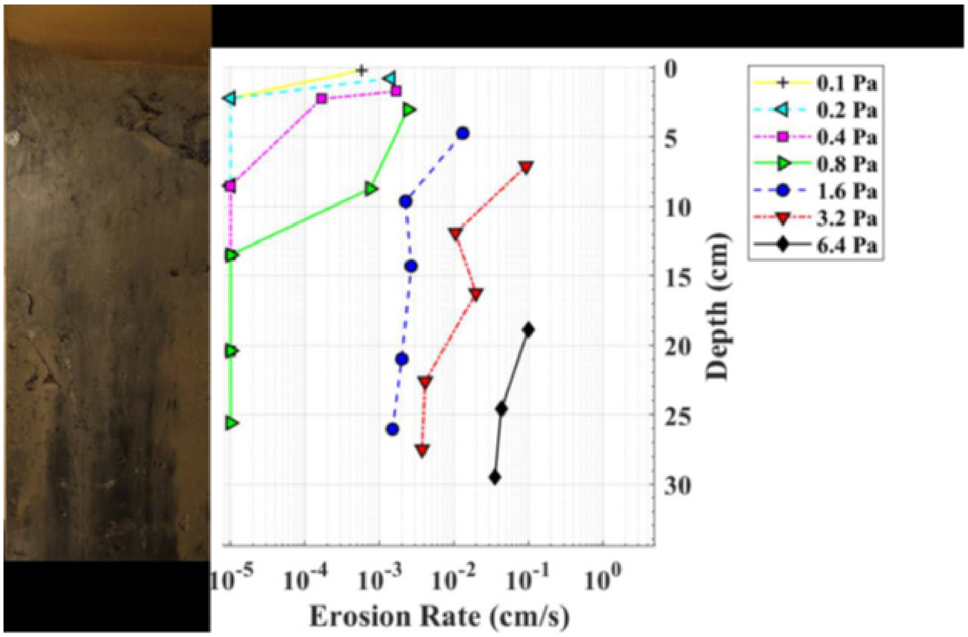


Source: Integral Consulting (2020)

Table 9
Physical Properties and Derived Critical Shear Stresses of SEDflume Sample TC-DS (Tar Creek)

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm^3)	Dry Bulk Density (g/cm^3)	Loss on Ignition (%)	τ_{no} (Pa)	τ_1 (Pa)	τ_c Linear (Pa)	τ_c Power (Pa)	Final Critical Shear (Pa)
0.0	7.99	1.15	0.34	8.0	0.05	0.1	0.06	0.04	0.05
2.2	9.76	1.27	0.53	7.7	0.2	0.4	0.32	0.32	0.32
8.5	8.72	1.20	0.43	8.7	0.4	0.8	0.46	0.40	0.40
13.5	10.64	1.40	0.72	5.8	0.8	1.6	0.83	0.71	0.80
20.4	9.37	1.41	0.74	5.8	0.8	1.6	0.84	0.73	0.80
25.6	7.91	1.47	0.84	5.3	0.8	1.6	0.86	0.76	0.80
Mean	**9.07**	**1.32**	**0.60**	**6.9**	**0.5**	**1.0**	**0.56**	**0.49**	**0.53**

Figure 42
Photograph of Core TC-DS (Tar Creek) Aligned with Applied Shear Stresses and Associated Erosion Rates

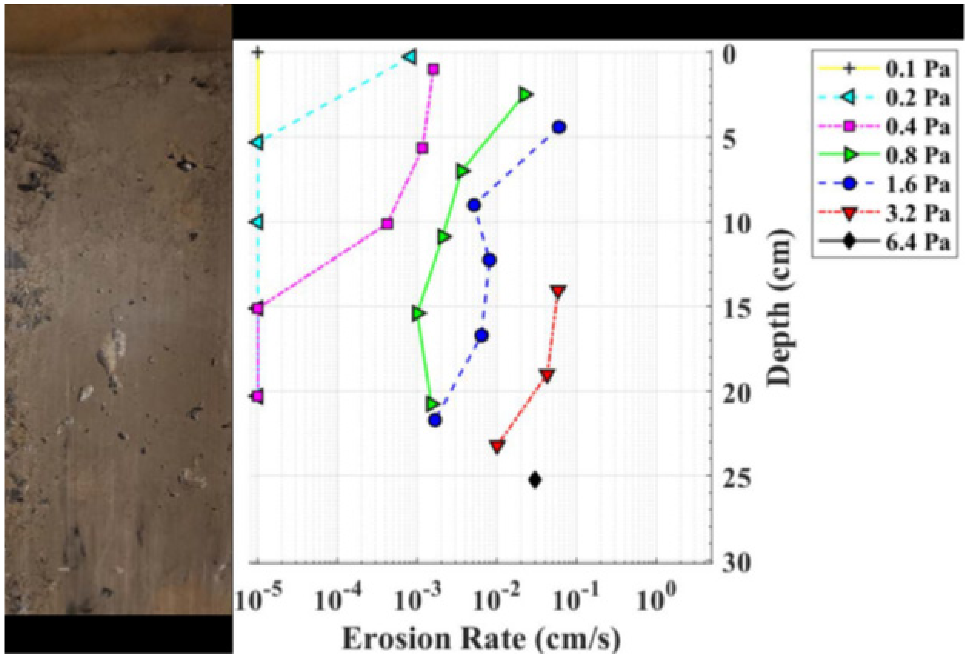


Source: Integral Consulting (2020)

Table 10
Physical Properties and Derived Critical Shear Stresses of SEDflume Sample SR-100 (Spring River)

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm³)	Dry Bulk Density (g/cm³)	Loss on Ignition (%)	τ_{no} (Pa)	τ_1 (Pa)	τ_c Linear (Pa)	τ_c Power (Pa)	Final Critical Shear (Pa)
0.0	13.20	1.13	0.34	11.6	0.1	0.2	0.12	0.11	0.11
5.3	112.80	1.26	0.57	12.1	0.2	0.4	0.22	0.16	0.20
10	6.22	1.38	0.70	6.8	0.2	0.4	0.25	0.24	0.24
15.1	13.00	1.34	0.65	8.1	0.4	0.8	0.45	0.41	0.41
20.3	9.37	1.35	0.68	8.2	0.4	0.8	0.43	0.32	0.40
Mean	**30.92**	**1.29**	**0.59**	**9.4**	**0.3**	**0.5**	**0.29**	**0.25**	**0.27**

Figure 43
Photograph of Core SR-100 (Spring River) Aligned with Applied Shear Stresses and Associated Erosion Rates

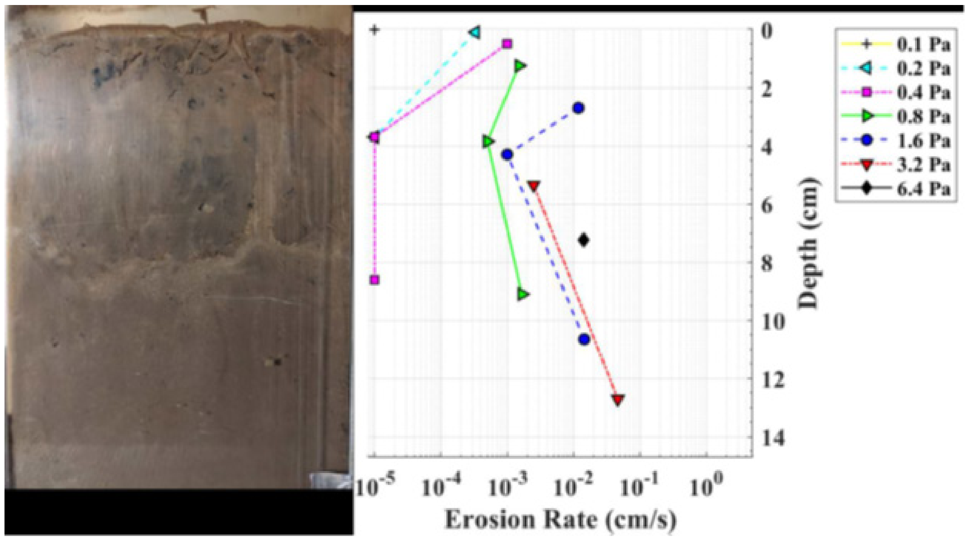


Source: Integral Consulting (2020)

Table 11
Physical Properties and Derived Critical Shear Stresses of SEDflume Sample ER-680 (Elk River)

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm^3)	Dry Bulk Density (g/cm^3)	Loss on Ignition (%)	τ_{no} (Pa)	τ_1 (Pa)	τ_c Linear (Pa)	τ_c Power (Pa)	Final Critical Shear (Pa)
0.0	18.95	1.39	0.68	3.4	0.1	0.2	0.13	0.12	0.12
3.7	32.96	1.70	1.16	2.9	0.4	0.8	0.48	0.42	0.42
8.6	16.32	1.66	1.11	3.0	0.4	0.8	0.43	0.37	0.40
13.7	23.18	1.54	0.94	4.2	---	---	---	---	---
Mean	**22.85**	**1.57**	**0.97**	**3.4**	**0.3**	**0.6**	**0.35**	**0.30**	**0.31**

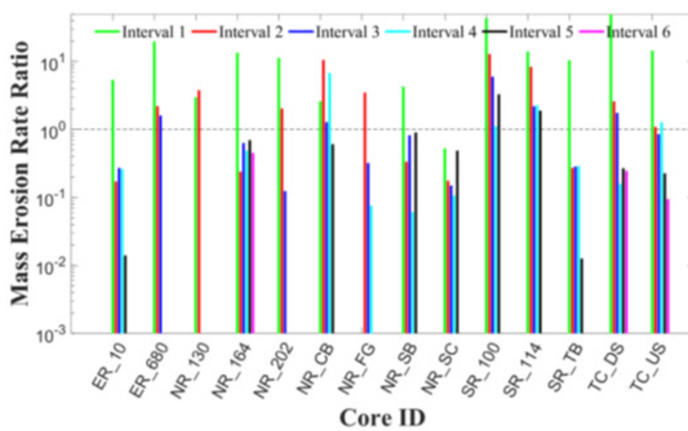
Figure 44
Photograph of Core ER-680 (Elk River) Aligned with Applied Shear Stresses and Associated Erosion Rates



Source: Integral Consulting (2020)

A summary of erosion rates ratios developed by Integral Consulting (Figure 45) shows that erosion rates generally are significantly lower at deeper locations in the sediment columns than at the surface. Interval 1 refers to the top layer of the sediment cores, with each subsequent interval representing a deeper layer of material. Exact interval thicknesses vary, though most are 5 centimeters (cm) or less.

Figure 45
Intracore Erosion Rate by Interval for Each SEDflume Core Sample

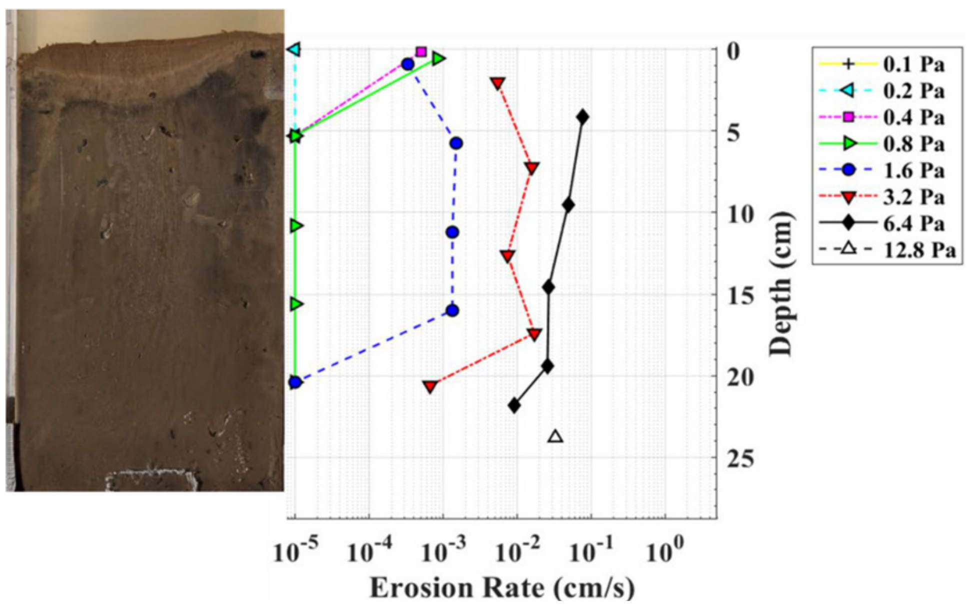


Source: Integral Consulting (2020)

The results of the tests showed expected critical shear patterns. Sediment near the top of the column is more recently deposited and therefore has had less time to consolidate; in general, it is more easily eroded. Lower in the sediment column, the particles have consolidated over time and under higher pressures due to the overlying material; critical shear stress is generally higher as one moves deeper into the core sample.

It is important to understand the high degree of variability of erosion rates as a function of depth below the sediment surface by looking at an example. A sample of the data is shown in Figure 46. The photograph on the left allows visual inspection of the core sample before erosion; the chart on the right provides erosion rate as a function of depth and applied shear stress. It indicates more resistance to erosion at deeper levels of the soil column. For example, at 0.4 pascal (Pa) of shear stress, the surface material eroded at a rate of approximately 4×10^{-3} centimeters per second (cm/s), but at 5 cm of depth, erosion was significantly lower (approximately 10^{-5} cm/s) for the same shear stress.

Figure 46
Example SEDflume Analysis Results



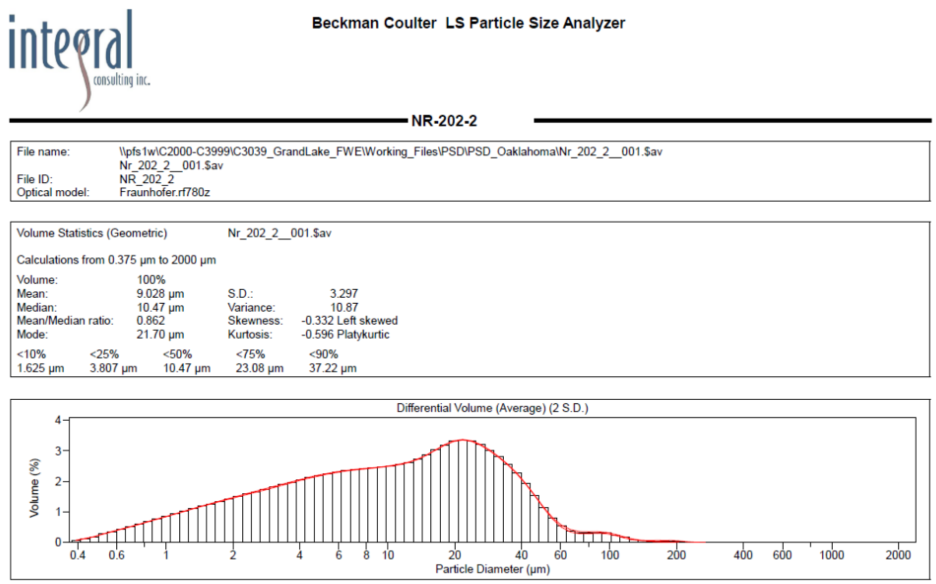
Note: Left: image of sediment core before erosion testing; right: graphical dataset showing erosion rates as a function of bed shear stress and depth in sediment column.
Source: Integral Consulting (2020)

This example and the previous summary of intracore erosion rates show a variation of several orders of magnitude over the depth of samples. This extreme variability affects the development of reasonable erosion parameters to be used in the STM.

2.3.3.2 Sediment Particle Size Analysis

During erosion of the samples, the testing facility used a Beckman Coulter LS particle size analysis system to collect sediment grain size information (Integral Consulting 2020). An example of the output is provided in Figure 47.

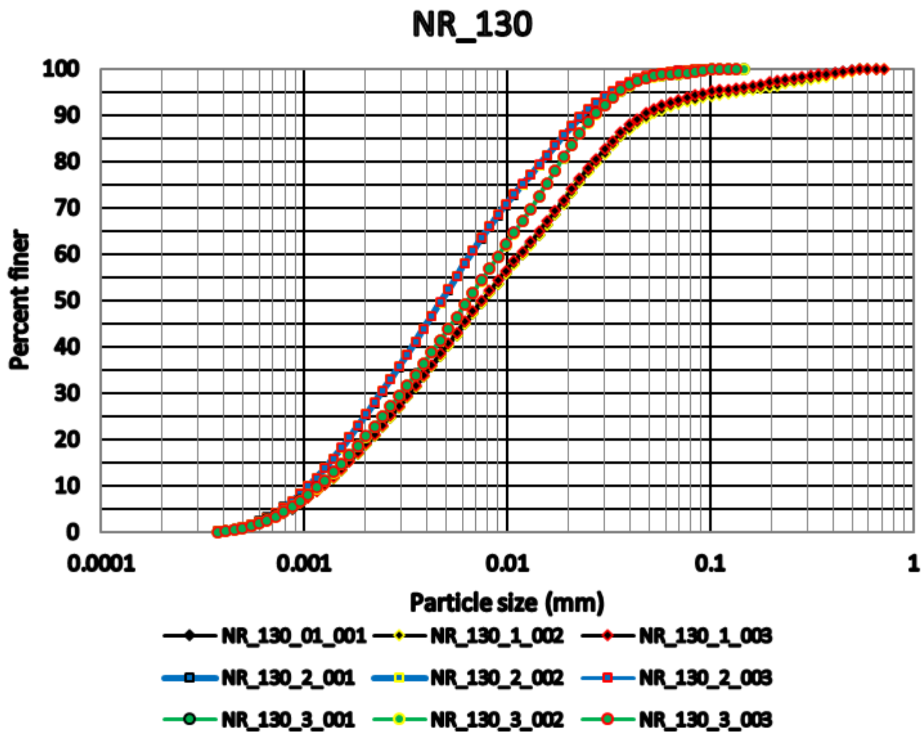
Figure 47
Sample Particle Size Analysis Output from SEDflume Analysis



Source: Integral Consulting (2020)

The particle count analysis shows that most of these samples consist of silt- and clay-sized particles. These data were developed into particle size distribution curves relating sediment size to the percentage of the sample finer than the individual sizes to cover the entire range of sediment sizes in the sample. Figure 48 presents an example of this type of graph. A complete set of particle size distribution graphs for the samples is found in Appendix C.

Figure 48
Sample Particle Size Analysis Output from SEDflume Analysis Showing Cumulative Percent Finer Values for Core NR-130 (Neosho River)



2.3.3.3 Sediment Deposit Bulk Density Analysis

A key factor in understanding silt and clay deposits is the density of sediment and how it varies vertically in the sediment column. Density, along with erodibility and the particle size distribution, are critical parameters for evaluating fluvial transport of this type of sediment.

Although density of sand and gravel deposits fits into a relatively narrow band and does not vary significantly over time, sediment deposits of silt and clay generally settle out of the water column at a low density and then gradually increase in density over time as water is compressed out of the sediment column. As more sediment deposits over the original layers, density of lower layers increases; the consolidation process continues over time until a maximum value is reached. In some situations, this can result in the formation of sedimentary rock such as claystone or shale.

As discussed above, this process also affects the strength or erodibility of sediment. The deeper, more consolidated layers tend to exhibit higher critical shear stress values than the more recently deposited layers near the bed surface.

Density is also the link between sediment transport and deposition. Incoming sediment load is quantified in weight (i.e., tons per day as the unit of sediment transport), whereas sediment deposition as measured by survey is defined in terms of volume. In the case of reservoir sediment deposits, the deposited volume can vary considerably over time and with the depth of the sediment layer.

Sediment density of the upper layer of the sediment deposit was determined in the analysis of sediment cores. Table 12 summarizes the range of sediment density values for the core samples.

Table 12
Density Results from Top Layer Testing of SEDflume Samples

Sediment Core	Minimum Dry Density		Maximum Dry Density		Mean Dry Density (pcf)
	pcf	% of Mean	pcf	% of Mean	
SED-ER-10	28.7	66.7	48.7	113.0	43.1
SED-ER-680	42.5	70.1	72.4	119.6	60.6
SED-NR-130	52.4	85.7	68.7	112.2	61.2
SED-NR-164	76.2	81.9	103.0	110.7	93.0
SED-NR-202	27.5	63.8	53.1	123.2	43.1
SED-NR-CB	37.5	74.1	64.9	128.4	50.6
SED-NR-FG	73.0	90.0	85.5	105.4	81.2
SED-NR-SB	30.6	62.8	62.4	128.2	48.7
SED-NR-SC	48.7	88.6	61.2	111.4	54.9
SED-SR-100	21.2	57.6	43.7	118.6	36.8
SED-SR-114	32.5	69.3	54.9	117.3	46.8
SED-SR-TB	29.3	73.4	46.2	115.6	40.0
SED-TC-DS	21.2	56.7	52.4	140.0	37.5
SED-TC-US	30.0	75.0	46.2	115.6	40.0
Minimum	**21.2**	**56.7**	**43.7**	**105.4**	**36.8**
Mean	**39.4**	**72.6**	**61.7**	**118.5**	**52.7**
Maximum	**76.2**	**90.0**	**103.0**	**140.0**	**93.0**

The summary table shows a significant degree of variability for the dry density values for the sediment cores. For example, the minimum dry density ranges from 21.2 to 76.2 pcf, and the maximum dry density ranges from 43.7 to 103 pcf. For reference, the bulk density of water is 62.4 pcf and solid rock at a specific gravity of 2.65 is 165.4 pcf. Laboratory results for each individual sample analysis are found in Appendix C. Assessment of the data does not reveal any readily apparent spatial trends in sediment density.

Sediment density may be correlated with depth below the surface of the sediment deposit due to the consolidation process as fine sediment deposits generally compress over time. Table 13 through Table 16 display the sediment density from the SEDflume samples in relation to sample depth for each of the streams. Corresponding graphs (Figure 49 through Figure 52) of sediment density with depth below the sediment surface for each stream show this general trend (noting that 1 gram per cubic centimeter [g/cm^3] is equivalent to 62.4 pcf—the density of water). Also shown in the graphs are D_{10}, D_{50}, and D_{90} (the sediment grain diameters that are larger than 10%, 50%, and 90% of the total sample, respectively) to give some perspective on sediment sizes found in the samples.

Table 13
Physical Properties of SEDflume Sample NR-130 (Neosho River)

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm^3)	Dry Bulk Density (g/cm^3)	Loss on Ignition (%)
0.0	8.34	1.49	0.84	3.7
5.9	5.20	1.56	1.01	6.8
8.6	7.01	1.64	1.10	5.0
Mean	**6.85**	**1.56**	**0.98**	**5.2**

Figure 49
Physical Properties of SEDflume Sample NR-130 (Neosho River) with Depth

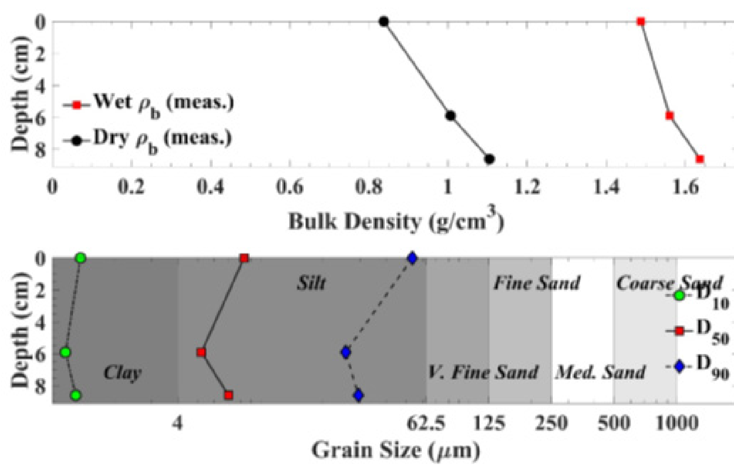


Table 14
Physical Properties of SEDflume Sample SR-100 (Spring River)

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm^3)	Dry Bulk Density (g/cm^3)	Loss on Ignition (%)
0.0	13.20	1.13	0.34	11.6
5.3	112.80	1.26	0.57	12.1
10.0	6.22	1.38	0.70	6.8
15.1	13.00	1.34	0.65	8.1
20.3	9.37	1.35	0.68	8.2
Mean	**30.92**	**1.29**	**0.59**	**9.4**

Figure 50
Physical Properties of SEDflume Sample SR-100 (Spring River) with Depth

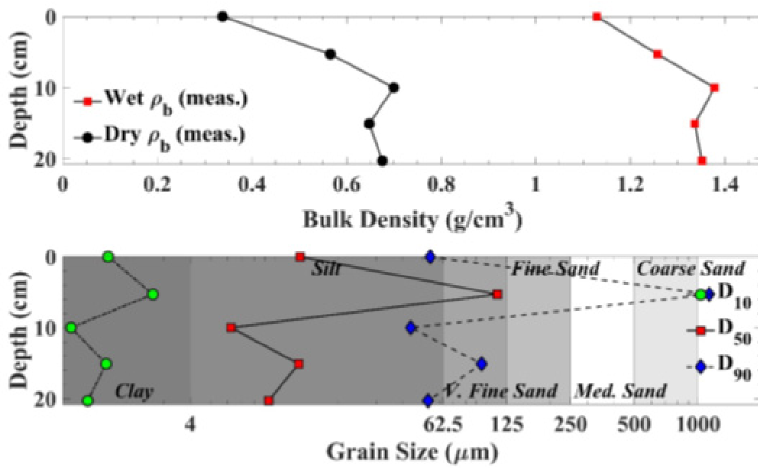


Table 15
Physical Properties of SEDflume Sample TC-DS (Tar Creek)

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm^3)	Dry Bulk Density (g/cm^3)	Loss on Ignition (%)
0.0	7.99	1.15	0.34	8.0
2.2	9.76	1.27	0.53	7.7
8.5	8.72	1.20	0.43	8.7
13.5	10.64	1.40	0.72	5.8
20.4	9.37	1.41	0.74	5.8
25.6	7.91	1.47	0.84	5.3
Mean	**9.07**	**1.32**	**0.60**	**6.9**

Figure 51
Physical Properties of SEDflume Sample TC-DS (Tar Creek) with Depth

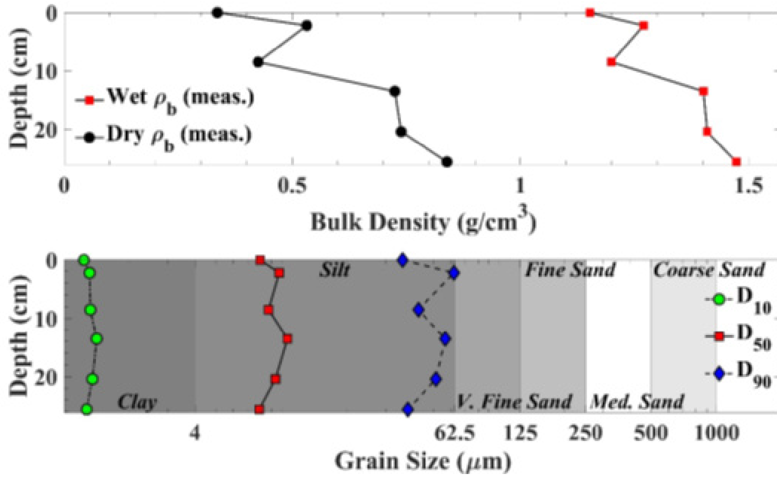
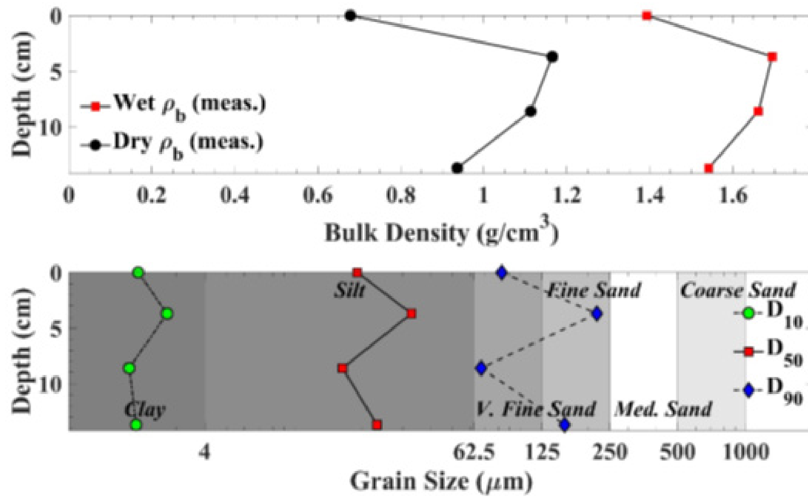


Table 16
Physical Properties of SEDflume Sample ER-680 (Elk River)

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm³)	Dry Bulk Density (g/cm³)	Loss on Ignition (%)
0.0	18.95	1.39	0.68	3.4
3.7	32.96	1.70	1.16	2.9
8.6	16.32	1.66	1.11	3.0
13.7	23.18	1.54	0.94	4.2
Mean	**22.85**	**1.57**	**0.97**	**3.4**

Figure 52
Physical Properties of SEDflume Sample ER-680 (Elk River) with Depth



2.3.4 *Sediment Transport Measurements*

Sediment transport samples were collected during several site visits and delivered to appropriate laboratories for analysis.

2.3.4.1 Suspended Transport Results

SSC samples were processed by the WSLH. Sample analysis evaluated both total sediment concentration and concentration of sediment with grain sizes less than 63 micrometers (µm; upper limit of silt-sized particles) to assess the percentage of cohesive sediments moving through the system in suspension.

Several samples produced erroneous results due to laboratory processing errors, with cohesive sediment concentrations higher than total sediment concentrations. These results were discarded. Across all samples, particles smaller than 63 µm accounted for 82% of all suspended sediment.

Full reports of SSC sample analysis can be found in Appendix D.

2.3.4.2 Bedload Transport Results

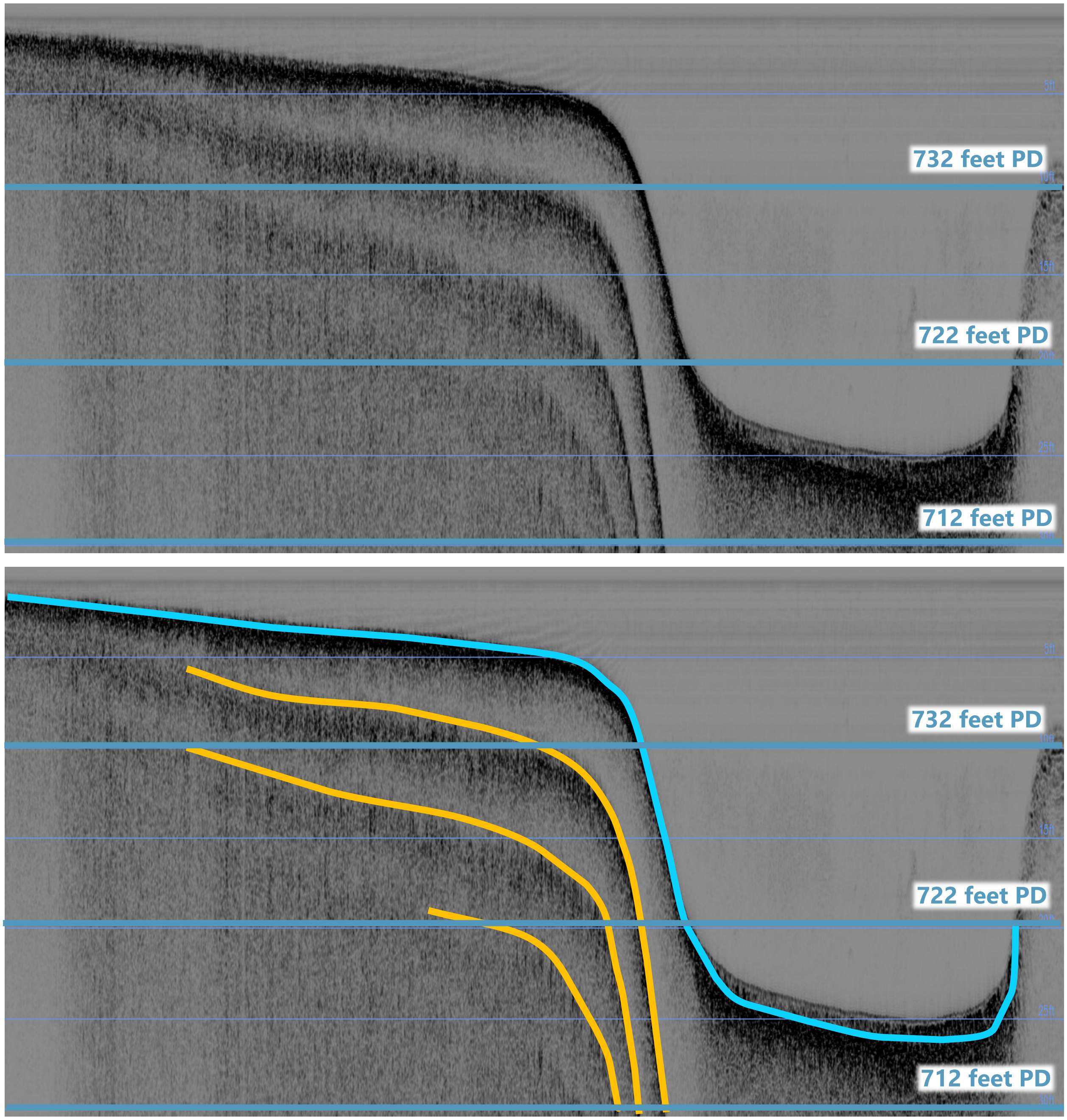
During each SSC sampling trip, Anchor QEA collected bedload transportation measurements as well. At no point did the Helley-Smith sampler bag collect any sediment particles. Flow rates during sampling efforts are shown in Table 6. Data collected to date indicate that for the vast majority of flow conditions experienced on these rivers, very little bedload transport occurs. Bed material particle size distributions, coupled with shear stress calculations over a wider range of flows and standard STM parameters for non-cohesive sediment sizes, will be used in the model to develop a more complete understanding of the relative contribution of bedload transport. Initial indications are that bedload transport does not represent a significant contribution to the overall sediment transport into Grand Lake.

2.3.5 Subsurface Findings

The SBP survey and vibracore sampling results provided information on deposition thicknesses in the area of the delta feature. The SBP survey was the initial field measurement, but it was also important to verify those results with vibracore samples.

The SBP will produce a visual output referred to as a "waterfall" that indicates the distances to different objects. The most powerful return signal is often the lakebed or streambed, and subsequent layers are somewhat weaker signals that are still visible in the data. Another type of signal is referred to as a "multiple," which is produced by pulses bouncing between the SBP sonar head and the bed, several times, resulting in a series of nearly parallel lines. An example image collected during the SBP survey at RM 112.34 showing this is provided in Figure 53.

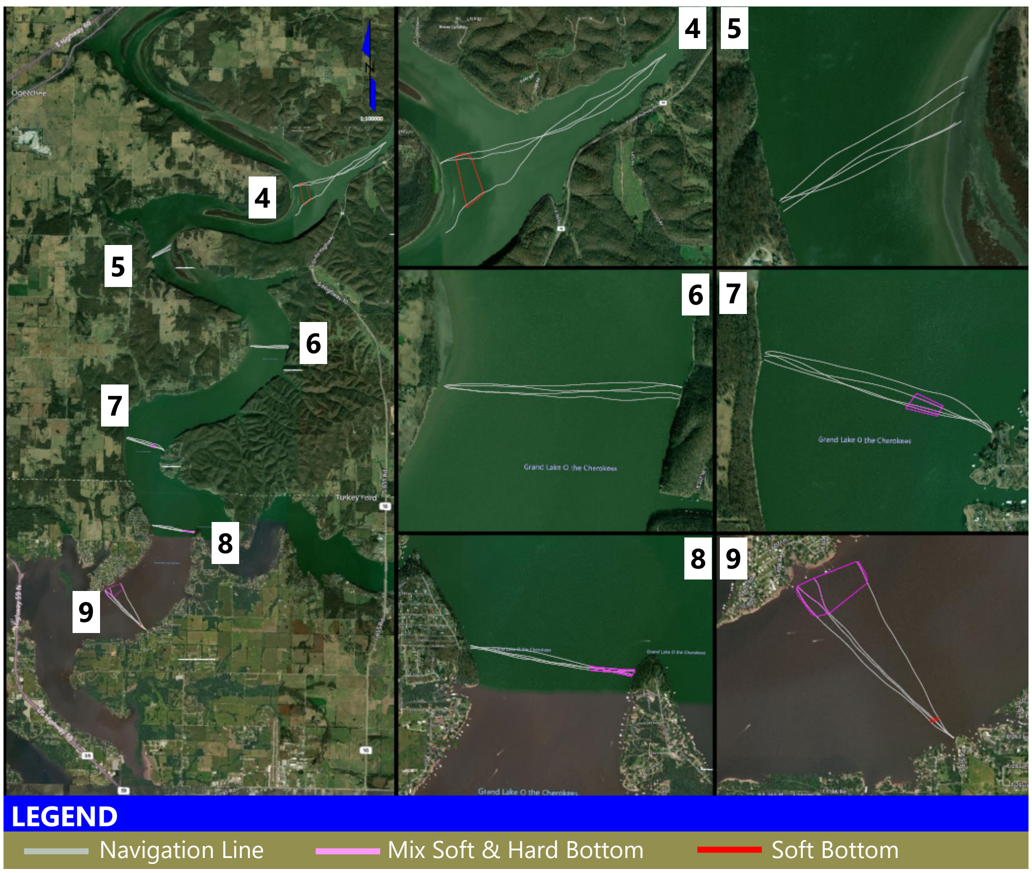
Figure 53
Example SBP Waterfalls showing Layer Transitions and "Multiples"



Notes: Waterfall images taken from SBP survey at RM 112.34 (approximately 1.5 miles upstream of Council Hollow)
Lower image is identical to upper, but locations of layer transitions and multiples are highlighted.
Teal line is the layer transition between soft and hard sediments
Orange lines are "multiples" or secondary reflections

The waterfalls produced during the Neosho River SBP survey showed layer transitions at approximately 2 to 3 feet below the bed surface. This indicated a thin layer of soft material over firmer sediments throughout much of the survey area. The interpretation was confirmed by an SBP expert, and the representative stated that a majority of the areas surveyed were not characterized by soft sediment beds (Figure 54).

Figure 54
Interpretation of SBP Survey Results at Stations 4 through 9

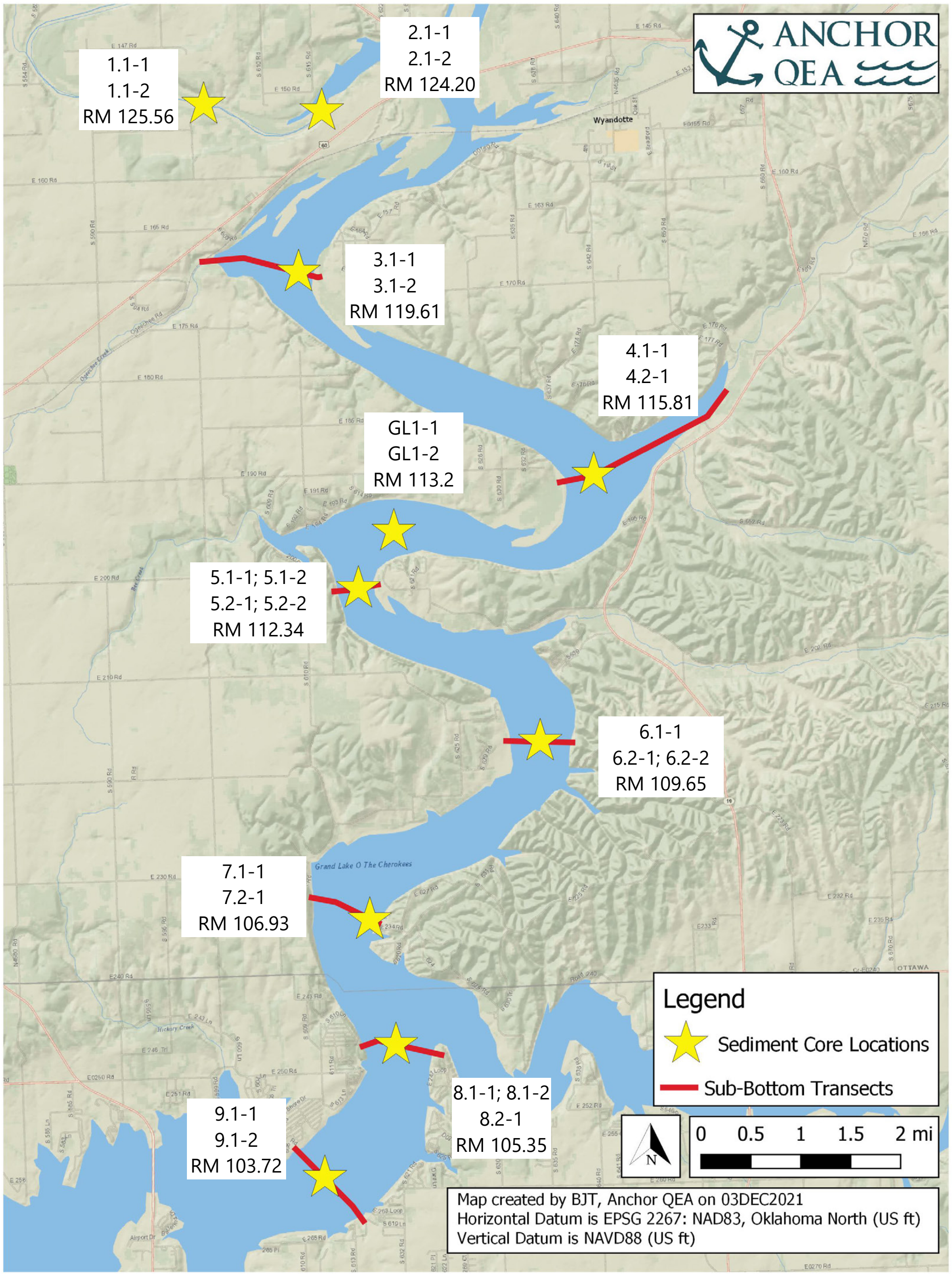


Source: Interpretation of SBP readings; station numbers adjusted from OARS original to reflect GRDA numbers.

Figure 54 shows the navigation lines from the field SBP survey. Where a mixture of soft and hard beds was noted by the SBP expert (for example at transect 9, bottom right), pink outlines were drawn. Red outlines indicate soft bottom materials (transect 4, top center). Areas not colored were interpreted to consist of hard bottom sediments. The vibracore sampling was performed to validate SBP survey results, and they indicated generally thicker layers of deposition than were reported by the SBP.

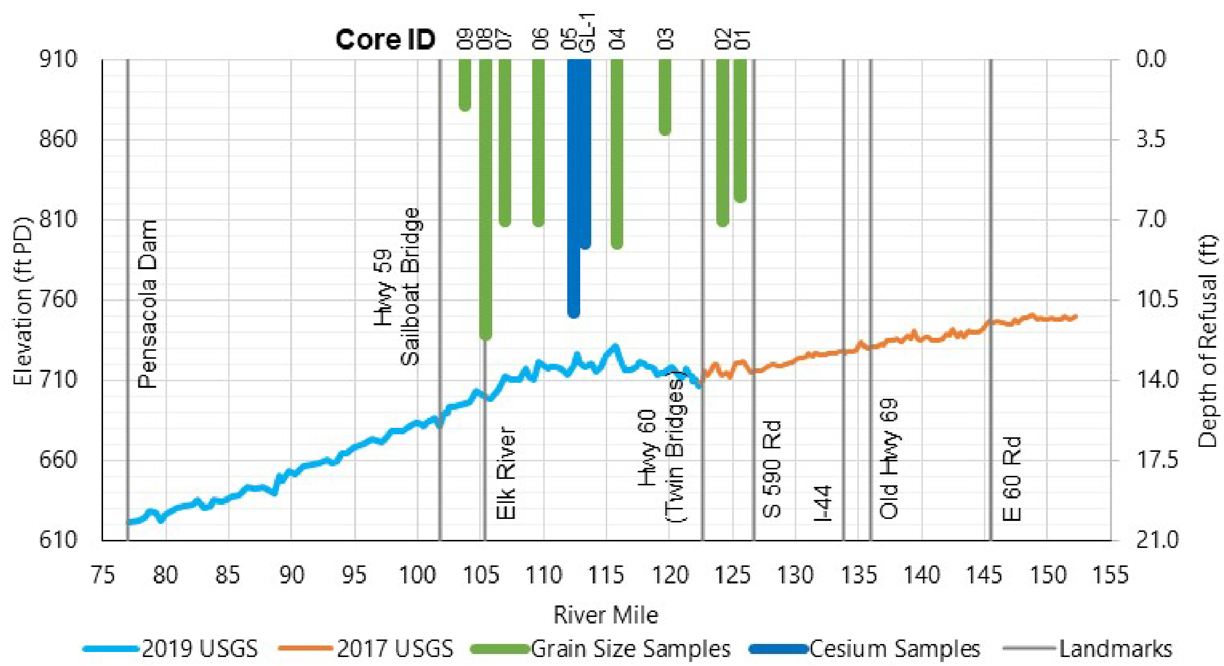
The vibracore pushed core tubes into the riverbed at the locations shown in Figure 55 using 16-foot coring tubes. These were chosen to align with the SBP survey discussed in Section 4.1 as a means of confirming interpretation of the results. SBP survey transects are shown in red with their relationship to the vibracore sample locations.

Figure 55
Locations of Sediment Cores Collected by GRDA



The vibracoring efforts produced 24 core samples for analysis. The cores were pushed to refusal, which ranged from 1.5 to 11 feet in the reach above the Elk River (Figure 56). In the lower reservoir, one core penetrated approximately 12 feet of sediment before refusal. Two cores over 10 feet in length taken in the delta feature (RM 112.34) were evaluated for Cs-137 activity. Cores shorter than 10 feet or taken from the lower reservoir were analyzed only for grain size distribution (see Section 3.3). Figure 56 shows the maximum vibracore penetration depths at each site shown in Figure 55.

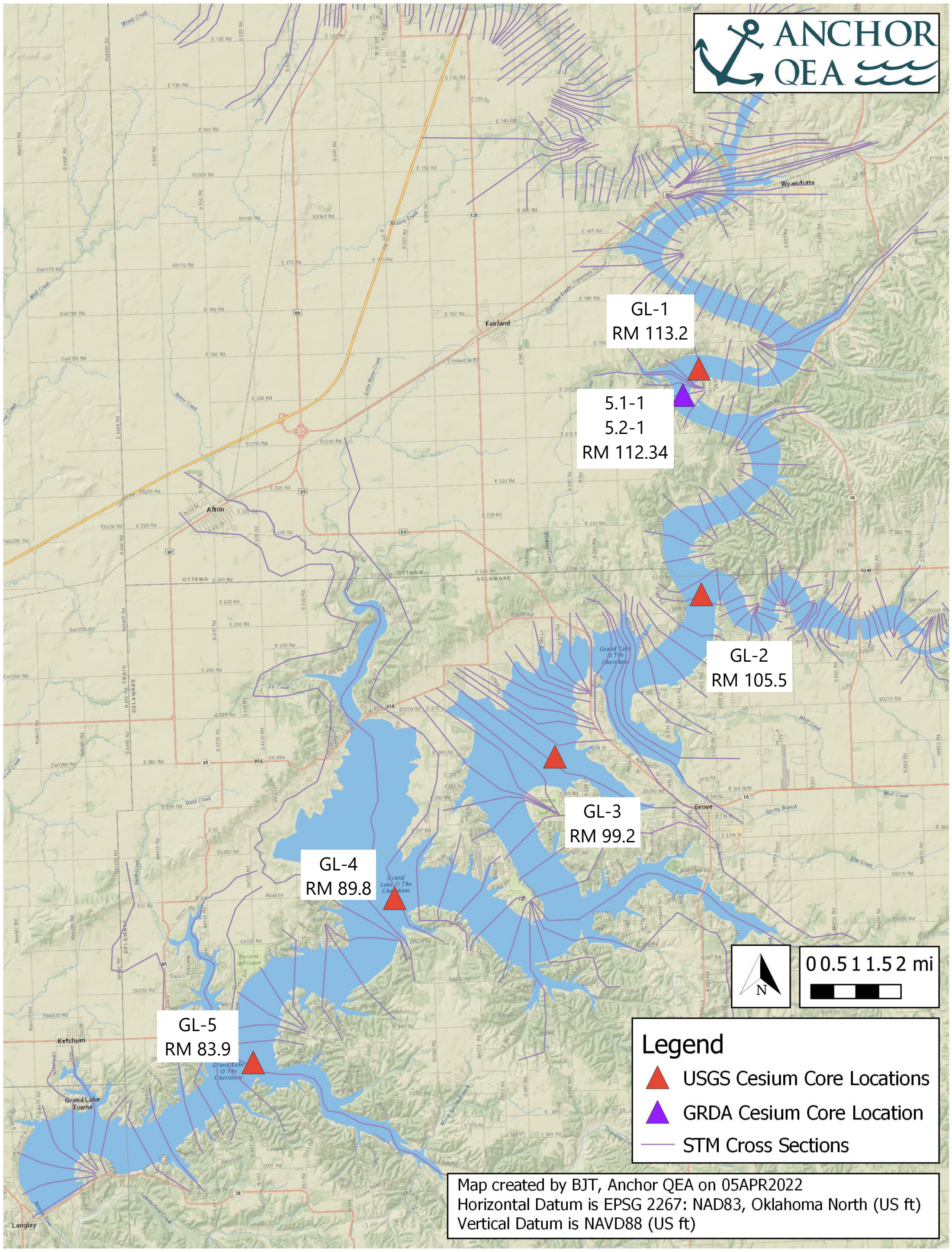
Figure 56
Maximum Vibracore Sample Penetration on Neosho River



Note: GL-1 sample tested for cesium activity by USGS (Juracek and Becker 2009)

The USGS (Juracek and Becker 2009) analyzed sediment Cs-137 levels to determine the approximate age of sediment in various locations within Grand Lake. The 2008 study collected samples from five sites, with one located in the region of the delta feature, one near the confluence with the Elk River, and three others located further downstream in the reservoir (Figure 57). Where USGS data showed a clear, defined Cs-137 peak, the findings were considered settled.

Figure 57
Locations of Sediment Cores Collected for Cesium Analysis



Note: Locations of USGS cores taken from Juracek and Becker (2009).

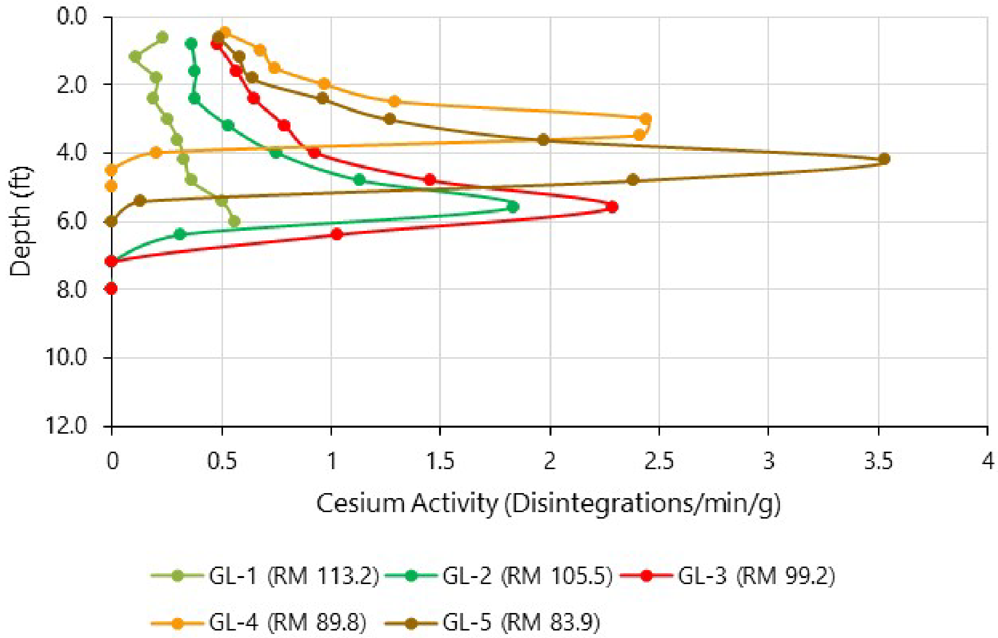
A major goal of sampling was to collect a significantly deeper sample near USGS site GL-1. The USGS sample was approximately 6 feet, and it was decided that a vibracore sample of approximately 10 feet would be sufficient to trigger re-evaluation and Cs-137 analysis. Shorter cores would not likely produce different results from the USGS study (Juracek and Becker 2009). Cores lower in the basin were not analyzed as the USGS dataset was sufficiently robust and were not of interest for delta feature analysis. The cores that met this criterion were 5.1-1 and 5.2-1 as shown in Figure 57.

The vibracore samples show a thicker sediment deposit, which suggests the SBP was not reliably capturing sediment layer thicknesses. Most likely, the penetration of the SBP signal was limited by a layer of biotic activity within the surface of the sediment; several core samples had air bubbles in the top few feet produced by decomposition or other biological activity. This produces readings indicating a softer, air-filled layer above the firmer silt and clay sediment that would register as a separate layer during SBP surveying (Aqua Survey 2004; Science Applications International 2001). As a result, further analyses relied on vibracore sampling rather than SBP results.

Vibracore sampling showed thicker layers of soft sediment deposition, and also provided opportunity to evaluate Cs-137 trends measured by a USGS study (Juracek and Becker 2009).

USGS analysis showed that Cs-137 peaks were located approximately 3 to 6 feet below the bed surface (Figure 58). Those peaks represent sediment that was deposited in approximately 1963, indicating that just 3 to 6 feet of sediment had deposited since 1963 at sites GL-2, -3, -4, and -5 (Figure 57).

Figure 58
Comparisons of Relative Cesium Activity within the USGS Core Samples



Notes: The peak cesium activity indicates the soil layer associated with deposition in approximately 1963. All material above that layer is assumed to have deposited since the nuclear testing ban.

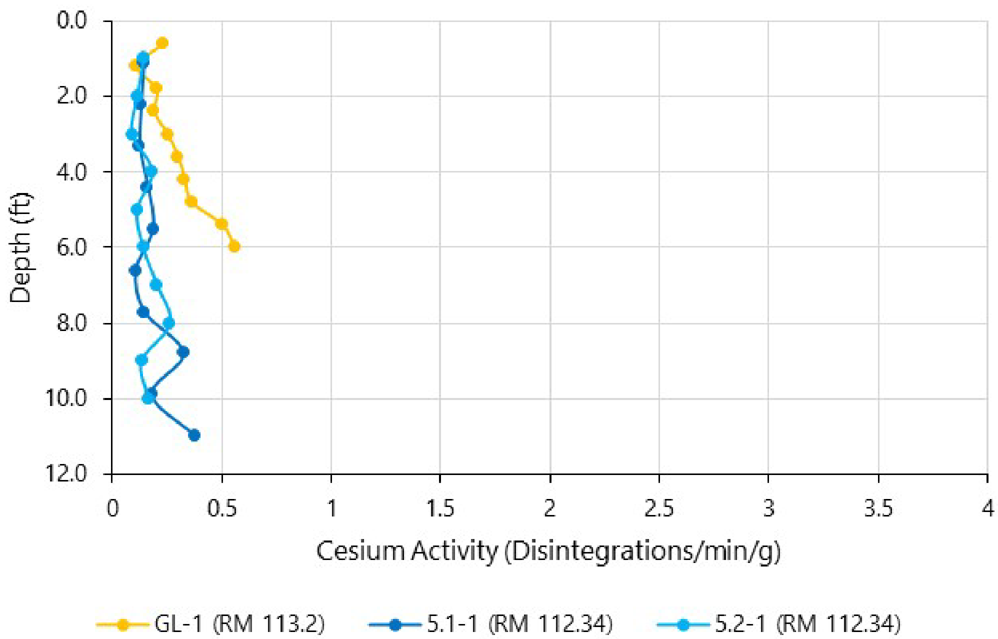
Source: Figure adapted from Juracek and Becker (2009).

The sample in the delta feature (GL-1) showed no spike in Cs-137. Juracek and Becker (2009) concluded the sediment they collected was all deposited post-1963. The USGS interpreted this to indicate that the area was not continually depositional but washes away due to wave action or large flow events before new sediment redeposits. This follows typical reservoir delta feature evolution, with surface sediments at the top of the delta feature washing downstream and extending the delta feature further into the reservoir rather than increasing the top elevation.

During GRDA's vibracore sampling, they repeated the USGS efforts to obtain longer (deeper) cores and see if a longer sample would capture a characteristic Cs-137 spike that denotes a 1963 sediment layer. GRDA collected approximately 11-foot cores near site GL-1 (cores 5.1-1 and 5.2-1) and processed them for Cs-137 analysis. The location of cores 5.1-1 and 5.2-1 are displayed in Figure 57.

GRDA sent 10 samples at equally spaced intervals within each core for Cs-137 evaluation. The results show a similar pattern to those of the USGS study, with no apparent Cs-137 peak (Figure 59).

Figure 59
Comparisons of Relative Cesium Activity Between USGS Core Sample GL-1 and GRDA Samples 5.1-1 and 5.2-1



Notes: GL-1 activity levels taken from Juracek and Becker (2009)
The lack of a defined cesium activity peak indicates that all sediment collected in the core was deposited after 1963.

This further suggests that deposition in the top 10 feet of the soil column is all post-1963 and that the site is not continuously depositional, instead indicating regular mixing of the materials at the top of the delta feature. These results agree with the USGS (Juracek and Becker 2009) findings that this location sees regular disturbance and is not continually depositional and is consistent with typical delta feature evolution patterns (Vanoni 2006).

2.4 Discussion

The field campaign provided valuable insights for the sediment study. Initial understanding of the reservoir indicated the system was dominated by sand and gravel sediments (Mussetter 1998; Tetra Tech 2018). Although that appears to be the case in the riverine components of the overall system, field work results have found cohesive silts and clays play a far more important role than initially anticipated.

The relative dearth of bedload sediment transport and comparatively high concentrations of fines moving in suspension through the watershed have indicated a need to focus extra resources on silt- and clay-sized sediment modeling. Because silt and clay deposits typically exhibit cohesive characteristics, along with several other complicating factors, the complexity of the overall sediment study and associated modeling tasks increases. *Modeling Sediment Movement in Reservoirs*, prepared by the U.S. Society on Dams (USSD) Committee on Hydraulics of Dams, Subcommittee on Reservoir Sedimentation (USSD 2015), presents a discussion of the issues associated with cohesive sediments. Some of the challenges are related to changing density over time through the process of consolidation; others are related to the fact that cohesive sediment particle motion is determined primarily by electrochemical surface forces rather than gravity forces, which dominate sand and gravel motion. Further complicating the development of appropriate input data and parameters is the fact that the data show a wide degree of variability from sample to sample and location to location.

To develop the necessary information, additional efforts for sediment core sampling were required beyond what was originally planned in the Sediment Study Plan. The study team selected locations for and performed sampling of the reservoir bed. The material was then subjected to erosion testing for model parameterization. SEDflume testing provided multiple valuable data points for sediment within the Grand Lake reservoir.

Critical shear stress is perhaps the most important of the SEDflume outputs. The gradual consolidation of fine, cohesive material and its effect on erosion resistance as a function of depth within the sediment column are crucial for accurately modeling sediment transport and deposition within the basin. Its use in developing the STM will allow HEC-RAS to determine whether sediment will erode from the bed or remain in place during a variety of flow conditions, and particle size and density parameters will allow the model to determine whether deposition will occur.

2.4.1 Sediment Transport

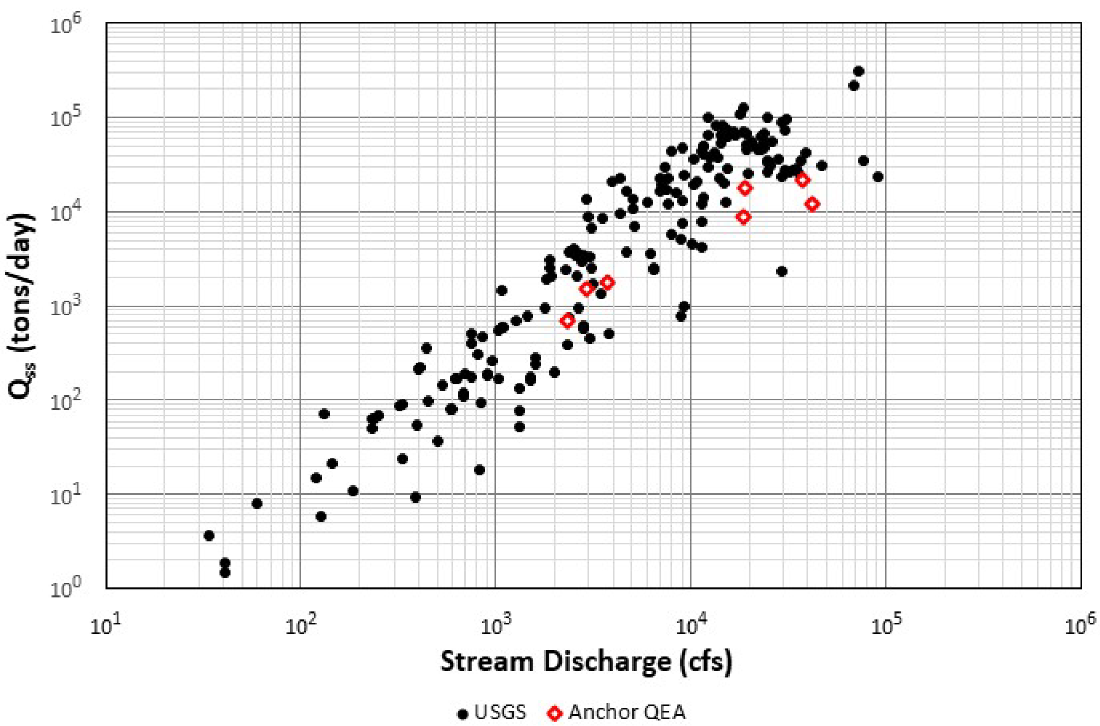
2.4.1.1 Suspended Sediment Transport

Sediment transport data, in the form of suspended sediment sampling, were collected at various USGS stations on the primary rivers of interest flowing into Grand Lake. In addition to the USGS data, suspended sediment samples were collected by Anchor QEA at these same stations. At each station, regression analyses were conducted to develop a numerical relationship between suspended sediment transport (in tons per day) and flow that forms a rating curve between sediment transport and flow. The data used for the development of the suspended sediment transport rating curves include all available data from the USGS through July 8, 2021, and the Anchor QEA data collected through July 1, 2021.

A preliminary assessment of the two sets of data reveals that they both lie within the bounds of variability typically seen in sets of suspended sediment data. The Anchor QEA data, however, generally lie in the middle to lower end of the range of the available data. It is possible that because these data were collected in recent years and the USGS data cover the entire period of record, which dates several decades back in time, there may be a trend toward lower sediment transport from these rivers over time.

Sediment transport data are only collected occasionally so no continuous, or even daily, record of sediment transport exists. With a sediment transport rating curve, the regression equation can be applied to the daily flow data to develop an estimate of the long-term historical quantity of sediment flowing past given stations on these rivers and hence sediment transport into the reservoir. Figure 60 presents an example of the available suspended sediment transport data on the Neosho River near Commerce.

Figure 60
Suspended Sediment Transport Rates and Fluvial Discharge Measured on the Neosho River near Commerce, Oklahoma



Analysis of the particle size distribution of the suspended sediment samples collected by Anchor QEA are shown in Figure 61 through Figure 64. These data show that suspended sediment is predominantly finer than 0.0625 millimeter (mm), which is the break point between sand and silt. Consistent with the bed material in the reservoir, most of the suspended sediment consists of silt and clay-sized sediment, which is being transported into the reservoir.

Figure 61
Fine Sediment as Fraction of Total Suspended Sediment Sampled on the Neosho River near Commerce, Oklahoma

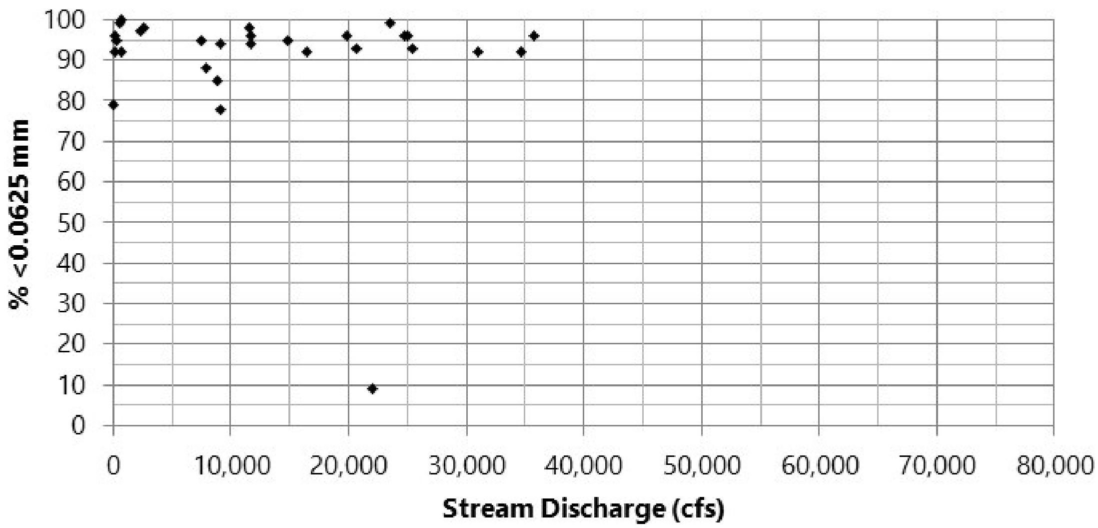


Figure 62
Fine Sediment as Fraction of Total Suspended Sediment Sampled on Tar Creek near Commerce, Oklahoma

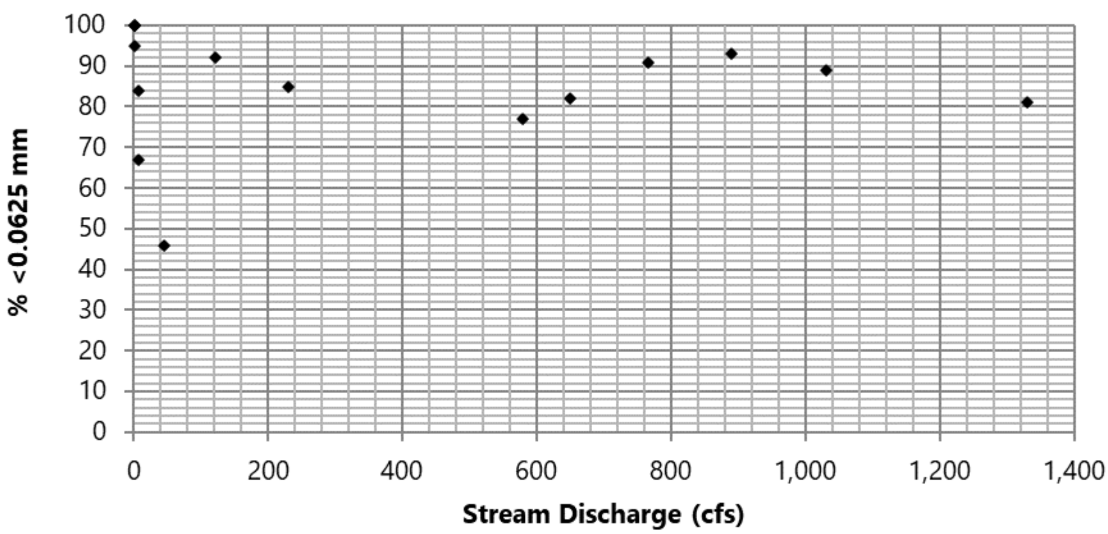


Figure 63
Fine Sediment as Fraction of Total Suspended Sediment Sampled on the Spring River near Quapaw, Oklahoma

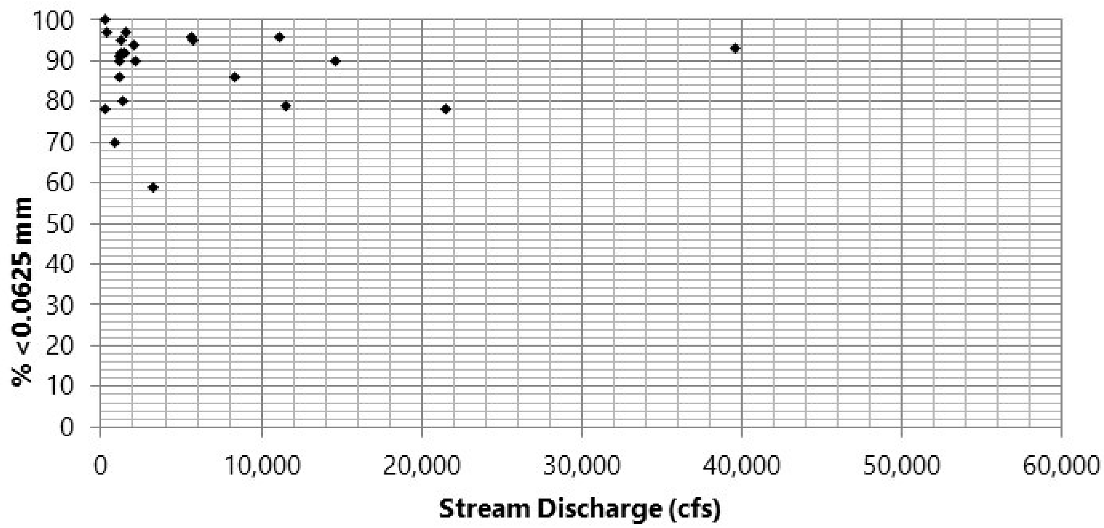
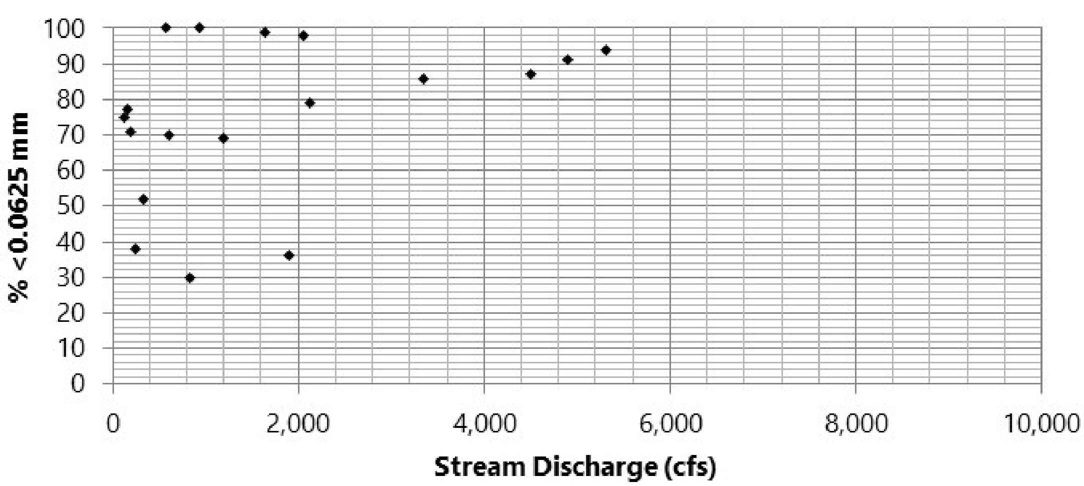


Figure 64
Fine Sediment as Fraction of Total Suspended Sediment Sampled on the Elk River near Tiff City, Missouri



2.4.1.2 Bedload Sediment Transport

Although bedload sediment transport data have been collected, these data indicate virtually no bedload transport. This is likely because shear stresses induced by the velocity of the flowing water have not been sufficient to mobilize, erode, and transport the coarse sediment sizes (primarily gravel) in the upstream river reaches where bedload sampling was conducted. This will be further evaluated in the STM using critical shear criteria for non-cohesive sediments.

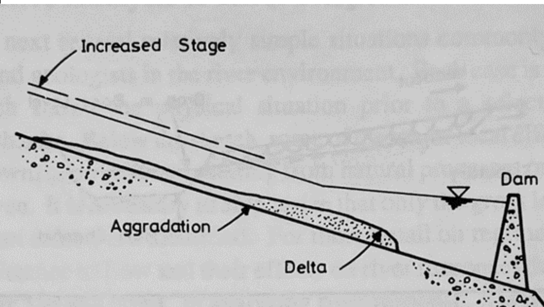
3 Qualitative Geomorphic Analysis

Several physical features affect the geomorphology of the rivers in the study area that either exist naturally or have been constructed. Such features include Pensacola Dam, bridges, and geologic and geomorphic features.

3.1 Pensacola Dam

Pensacola Dam is located at RM 77. With any impounded stream, water velocities decrease near the head of the reservoir, resulting in some amount of sediment deposition. This phenomenon is the expected geomorphic response as found in the scientific literature for virtually any reservoir on an alluvial river (Figure 57; Simons and Senturk 1992). Deltas are also discussed by USACE (1995), U.S. Bureau of Reclamation (Huang et al. 2006), Fan and Morris (1992), and Vanoni (2006).

Figure 65
Typical Geomorphic Response to Dam Construction



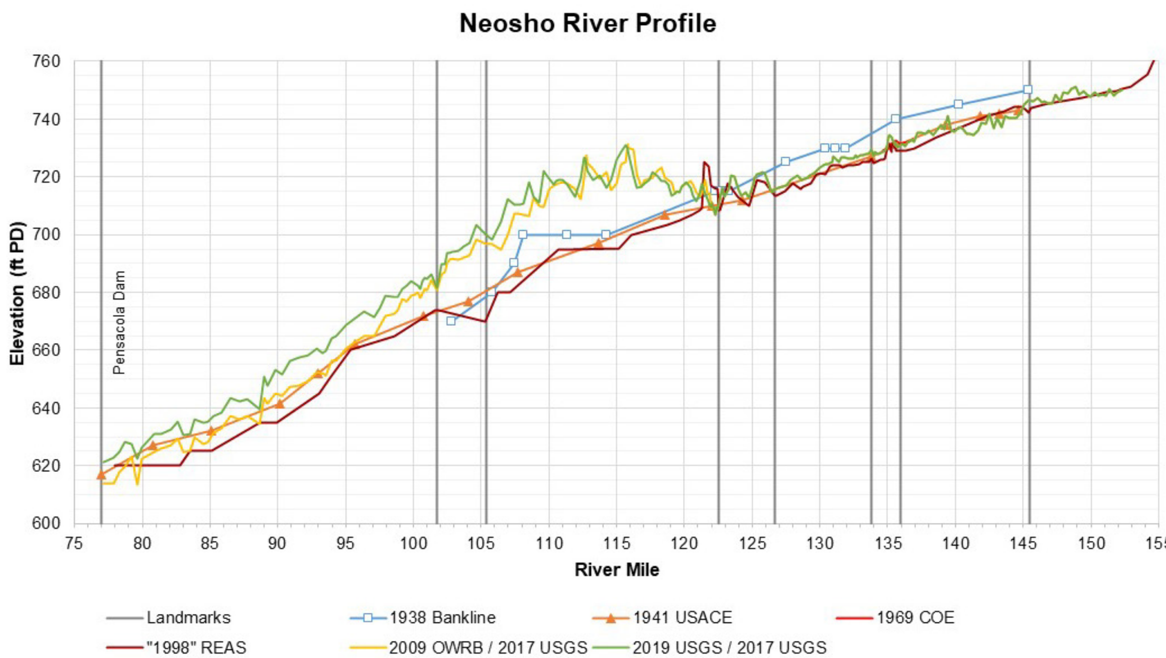
Local Effects	Upstream Effects	Downstream Effects
Aggradation of bed	See local effects	See downstream effects, Fig. 2.18
Loss of waterway capacity	Change in base level for tributaries	
Change in river geometry	Deposition in tributaries near confluences	
Increased flood stage	Aggradation causing a perched river channel to develop a change in the alignment of the main channel	

Source: Simons and Senturk (1992)

The impacts of Project pool elevations are addressed in the hydrology and hydraulics (H&H) study USR, filed concurrently with this report.

Figure 66 shows the Neosho River profile over time. Note that the upstream head of the deltaic feature starts at approximately RM 122 (near the Burlington Northern railroad bridge), which is more than 20 miles downstream of where the WSE of 745 feet PD at the top of the conservation pool intersects the river thalweg approximately 0.5 mile downstream of the USGS Commerce gage at RM 145.4 (East 60th Road Bridge). The bathymetric survey data show that sediment deposition forming the delta feature does not occur until sediment has traveled more than 20 miles downstream into the reservoir.

Figure 66
Historical Neosho River Thalweg Comparison

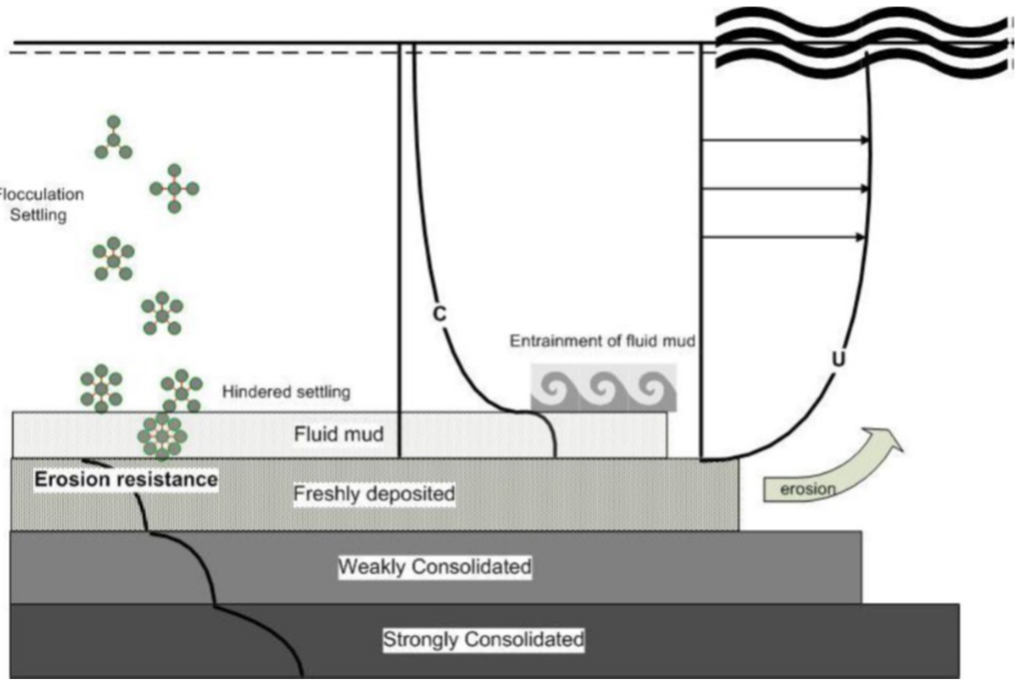


Note: This plot covers the Neosho River from RM 152.2 at the upstream end to the Pensacola Dam at RM 77.12 on the downstream end.

This clearly shows that sediment forming the delta feature is transported a considerable distance downstream into the conservation pool. Because sands and gravels tend to drop out of the water column sooner, if a significant portion of the sediment load consisted of bed material load (sand and gravel), the delta feature would have begun forming much farther upstream near the head of the reservoir. Therefore, the delta feature location further supports what field sampling showed: the feature consists primarily of fine sediment.

Figure 67 from *Modelling of Cohesive Sediment Dynamics* (Lumborg and Vested 2008) shows the various stages and characteristics of sediment as it deposits on the bed of the reservoir. Although this article focuses on coastal deltas, similar processes also occur on reservoir deltas.

Figure 67
Typical Reservoir Sedimentation Processes



Source: Lumborg and Vested (2008)

Suspended sediment forms flocs that deposit at the bed. With increasing currents, the fluid mud layer is re-entrained. Bed shear stresses can be enhanced by short surface waves, and during spring tides or storms the lower sediment layers erode (Lumborg and Vested 2008).

Lumborg and Vested (2008) explain the various stages and characteristics of suspended sediment deposition as follows:

> Fluid mud / hyper concentrated suspensions: The concentration of suspended sediment in the water column increases towards the bed. When the flocs begin to touch each other and interact hydrodynamically the settling velocity is reduced. This phenomenon is known as hindered settling and may lead to high concentration suspensions or fluid mud layers. Fluid mud is a concentration of fine-grained material in which settling is substantially hindered. It forms when the rate of settling exceeds the capacity of dewatering. The process forms a very concentrated suspension that acts neither as a Newtonian fluid nor as a sediment bed. The lower concentration limit of naturally occurring fluid mud layers is often given as about 10 kg m^3. This concentration can often be recognized as a lutocline and it is around this concentration that the suspension transits to become framework supported and much less mobile than the suspension. Fluid mud layers are thus layers with extreme concentrations of

sediment. The layer is moveable but moves as a gel rather than as a Newtonian fluid. Fluid mud layers accomplish a significant challenge for fine-grained sediment modelling.

When the box core samples were collected for the SEDflume testing, those individuals collecting the samples observed the following (Integral Consulting 2020): "In general, sediment consisted of silt and clay with a surface layer of unconsolidated, relatively mobile sediment." They describe a layer of "fluff" of "unconsolidated sediment" on top of the sediment surface and describe the surface material eroding "in clouds" of sediment. The description of an unconsolidated layer of fluff is consistent with the layer of fluid mud as previously described in the scientific literature. These sediment samples were collected in March 2020, months after the last significant runoff (with associated high sediment loading from 2019) and prior to any significant runoff in 2020. This would tend to result in a minimal layer of fluid mud that would result from the recession limb of a high flow event at the time when samples were collected. A more prominent layer of fluid mud would likely be found during or on the recession limb of the inflow hydrograph when sediment loading would be more significant, and this fluid mud layer would likely be a seasonal or temporary feature of the bed. This layer of unconsolidated sediment or fluid mud continues flowing farther downstream into the deeper portions of the reservoir as far as the dam.

As Lumborg and Vested (2008) stated, "The combination of hydrodynamic, sediment and biological processes make it difficult to predict cohesive sediment dynamics." Given that most of the inflowing sediment consists of fine material (silt and clay), and although some of these materials are deposited in the delta feature, significant portions of the sediment load can flow into deeper portions of the reservoir toward the dam. This is indicated by the 2009 and 2019 bathymetry data, which are consistent with the Lumborg and Vested (2008) discussions in the scientific literature.

3.2 Bridges

Several bridges span the rivers of interest and the reservoir. Bridges typically constrict river flow as bridge supports and embankments encroach on the flow area. Bridges also tend to be located at relatively narrow sections of the river to minimize cost of construction.

Because bridges constrict flow, they typically cause backwater effects upstream of the bridge. The backwater effects include increased WSEs and reduction in velocity. At the bridges themselves, the reduced flow areas result in increased velocities. Bridges also potentially trap debris such as floating logs, which further constricts the flow and increases the backwater effect. The effects of hydraulic constrictions at bridges potentially cause sediment deposition upstream of the structure due to the reduced velocities.

An extreme example of bridge encroachment on the river and floodplain is the railroad bridge just downstream of the Twin Bridge area below the confluence of the Neosho and Spring rivers. Figure 68 and Figure 69 present aerial views of this area.

Figure 68
Confluence of Neosho and Spring Rivers at Twin Bridges and the Railroad Bridge

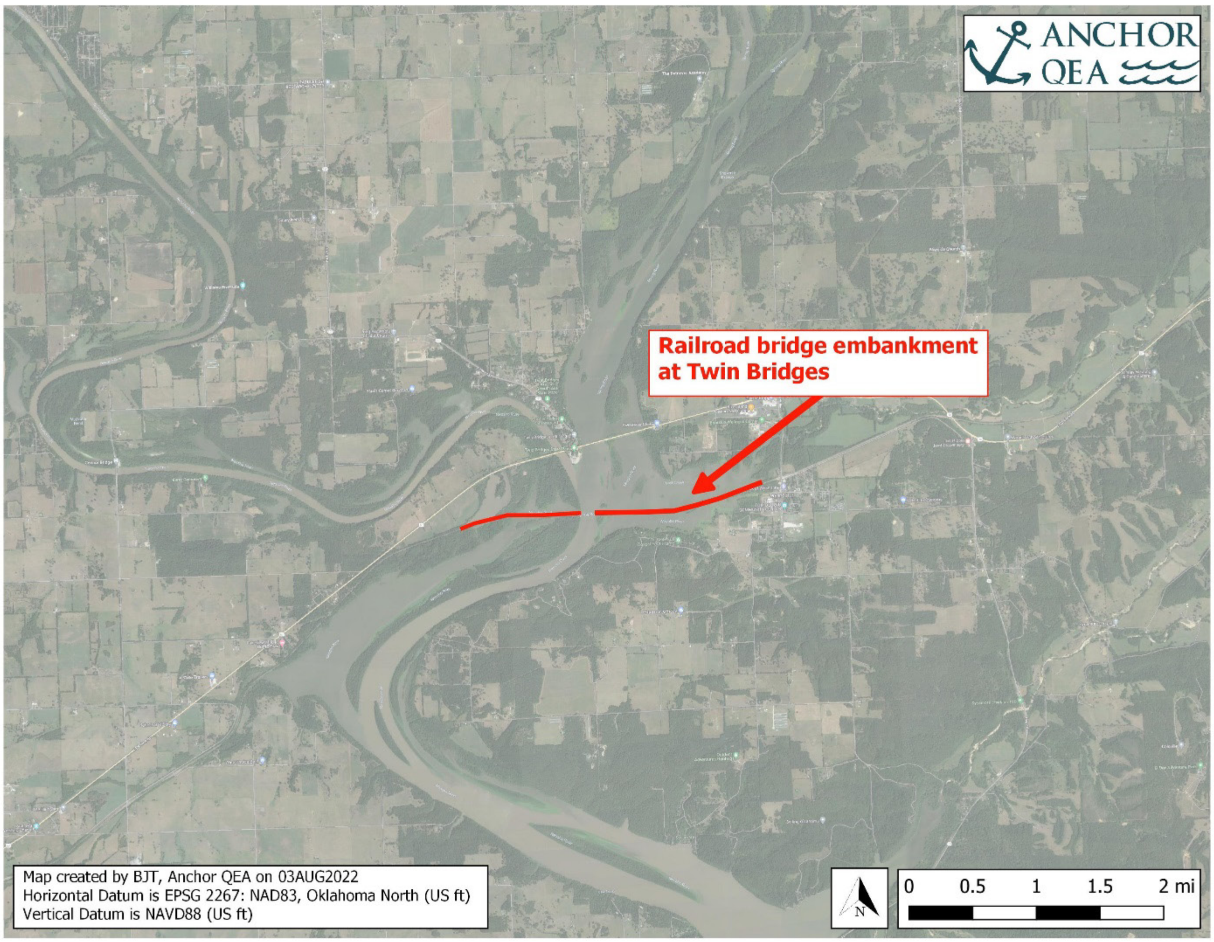
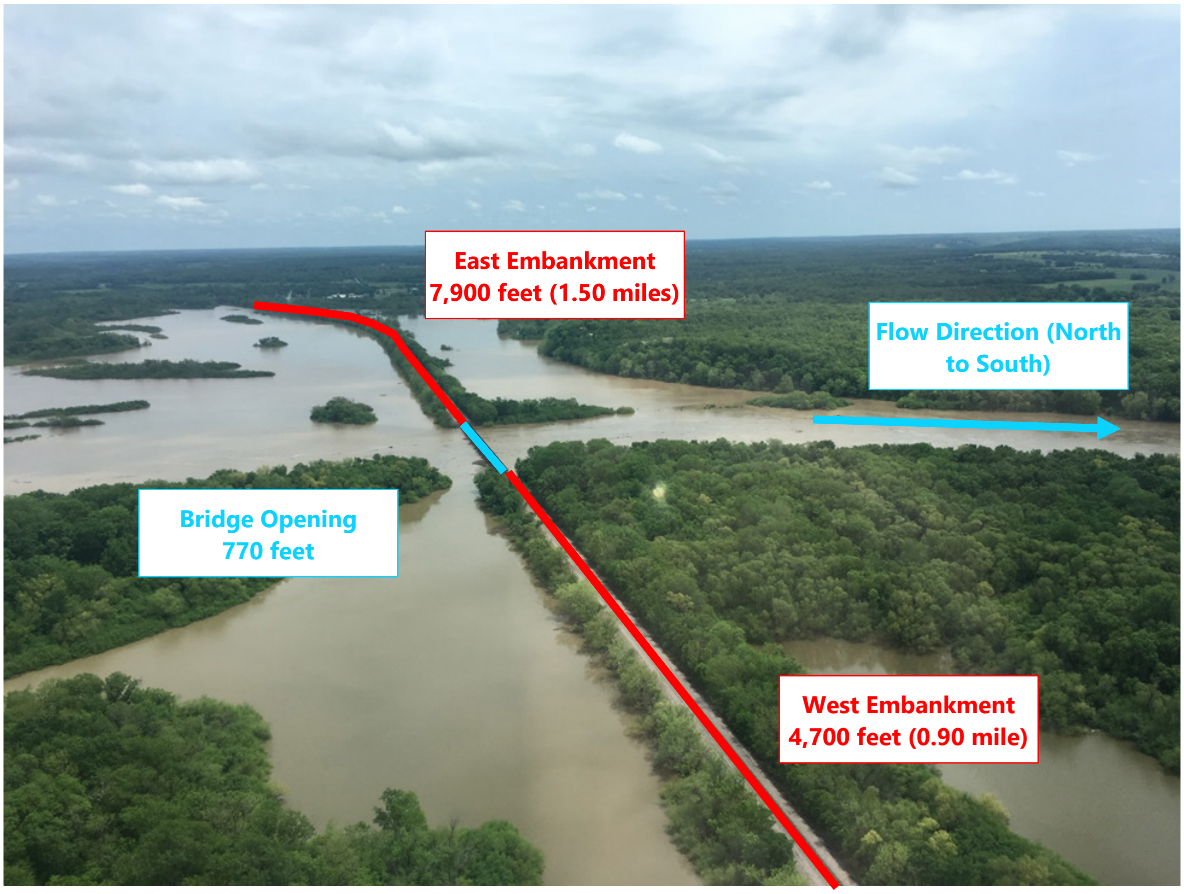


Figure 69
Burlington Northern Railroad Bridge and Embankment near Twin Bridges Photograph Looking East



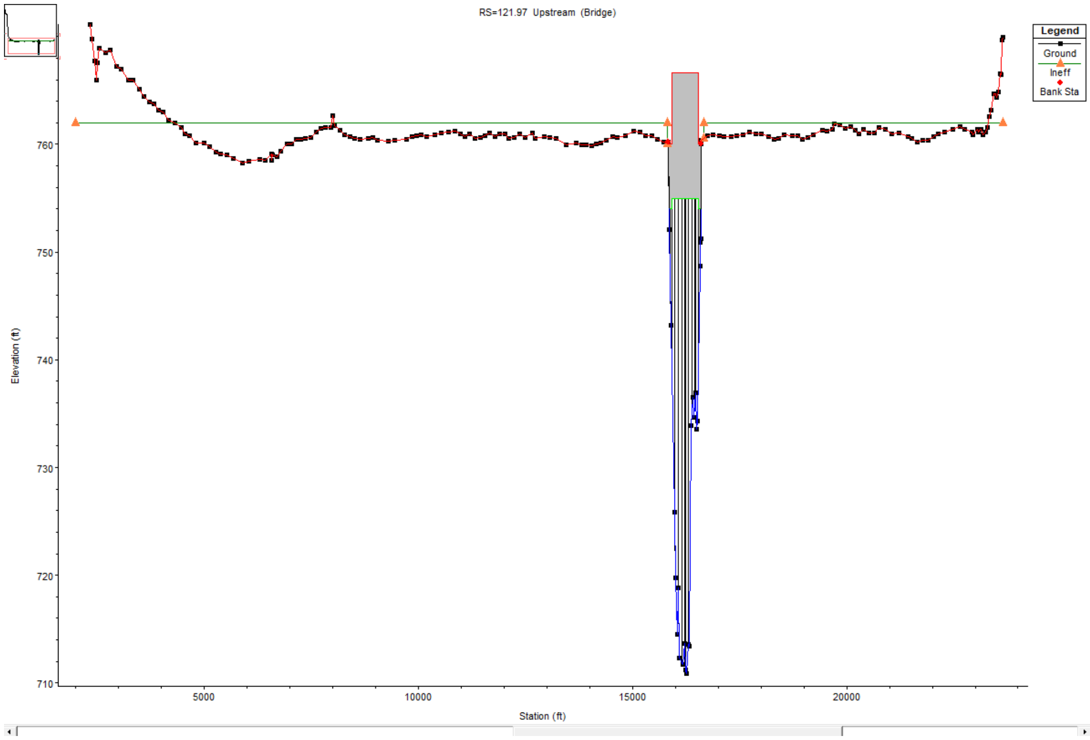
Notes: Photograph taken on May 2, 2019; USGS reported daily discharges were as follows:

- Neosho River near Commerce: 37,700 cfs (USGS 2021a)
- Tar Creek near Commerce: 192 cfs (USGS 2021c)
- Spring River near Quapaw: 48,500 cfs (USGS 2021e)

Flow direction is from left to right, and discharge must pass through the 770-foot bridge constriction.

The cross section at the Burlington Northern Railroad bridge (Figure 70) shows that the top of the embankment across the floodplain is at an average elevation of approximately 758 feet PD (note that the figure is from HEC-RAS and thus has a vertical datum of NGVD29). The width of the bridge opening is approximately 770 feet and the total embankment length is approximately 12,600 feet (2.4 miles).

Figure 70
Burlington Northern Railroad Bridge Cross Section



The aerial image (Figure 68) shows that the flow upstream of the railroad bridge is approximately 11,700 feet (2.22 miles) wide, whereas the width of the Neosho and Spring rivers upstream of Twin Bridges is approximately 2,250 feet wide (Neosho River is approximately 350 feet wide and Spring River is approximately 1,900 feet wide). The significant increase in water width by a factor of approximately five times shows the effect of the bridge in causing a backwater effect and blockage of the floodplain by the embankments.

Bridge piers frequently trap debris because moderate to high flow events carry floating trees and other materials. The following images show debris trapped on bridge piers during the flow event that occurred late in April through May 2019. Peak daily flow on the Neosho River was 90,100 cubic feet per second (cfs) on May 24, 2019; however, the photographs of debris were taken in early May before the flood peak (Figure 71).

Figure 71
May 2019 Photographs of Debris Trapped on Bridge Piers

Additional photographs were taken in December 2019, months after the peak flow in May 2019. The photographs show evidence of debris trapped on bridges, with some debris up on the bridge deck itself (Figure 72).

Figure 72
December 2019 Photographs of Debris Trapped on Bridge Piers

Notes: Top photographs show the abandoned railroad bridge at RM 134.60, approximately 0.6 mile upstream of the Tar Creek confluence.
Bottom photograph is from the East 60th Road Bridge (USGS Neosho River near Commerce gage) at RM 145.4.

3.3 Geologic Features

Vertical rock banks are evident in various reaches along the Neosho River. Examples of vertical rock banks are shown in Figure 73.

Figure 73
Photographs of Vertical Rocky Banks Along the Neosho River

Notes: Top photograph was taken near RM 129.07 on the Neosho River, approximately 2.4 miles upstream of Connors Bridge.
Bottom photograph was taken near RM 127.47 on the Neosho River, approximately 0.75 mile upstream of Connors Bridge.

Locations of the examples of rocky banks are shown in Figure 74, Figure 75, and Figure 77.

Reaches of river that are confined by vertical rock banks eliminate the floodplain and confine the flow to a relatively narrow cross section, which constricts the flow, potentially causing upstream backwater effects and sediment deposition.

Figure 74
Locations of Vertical Rocky Banks on Aerial Imagery

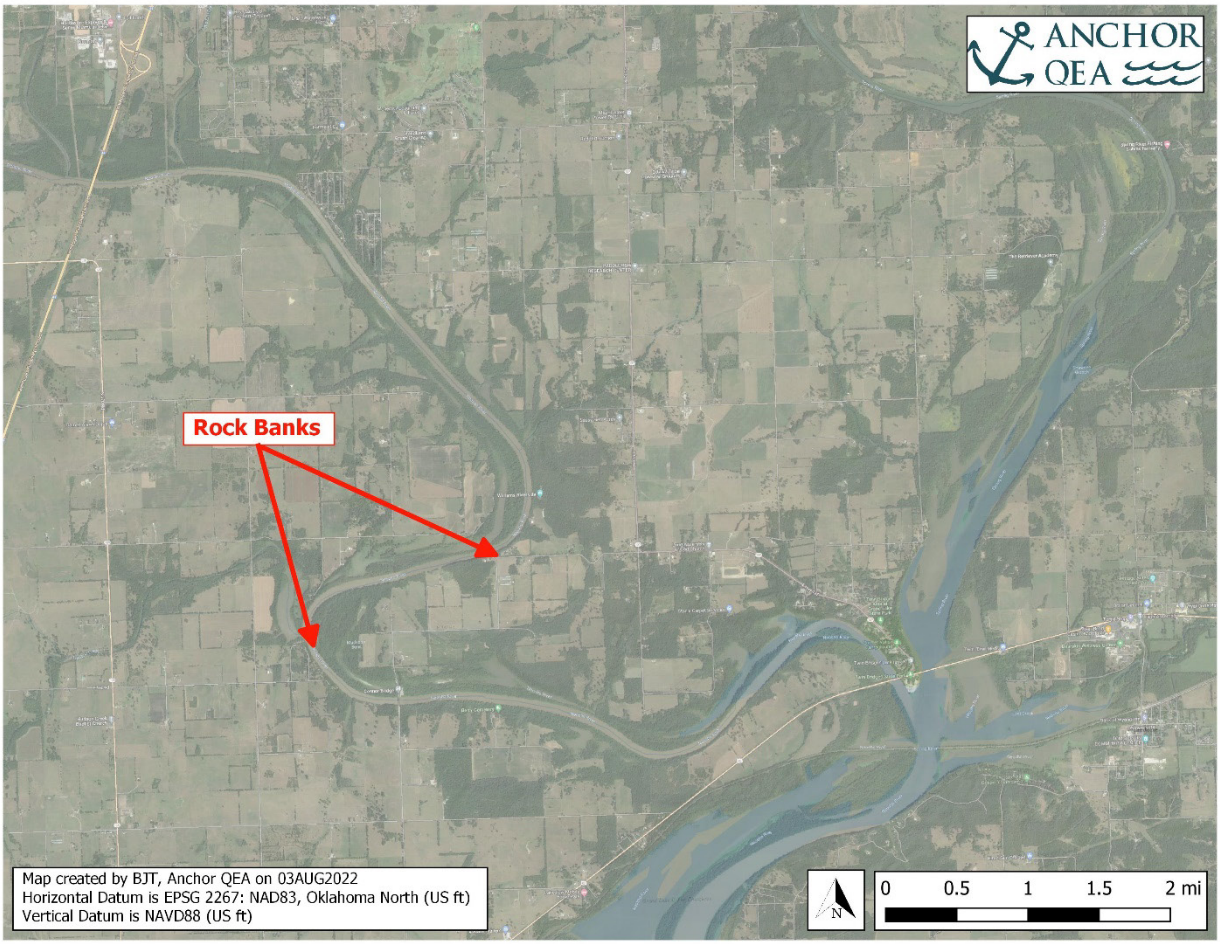
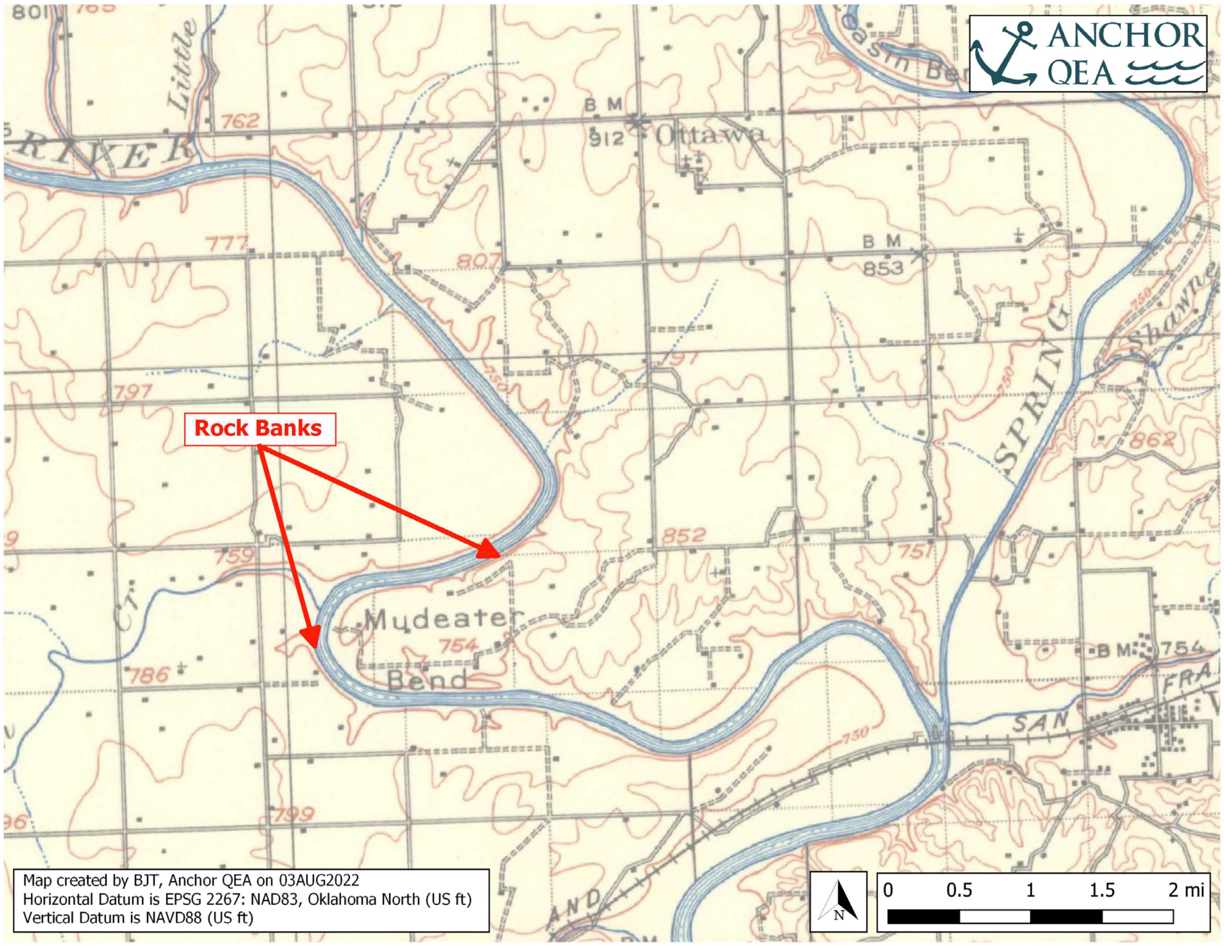


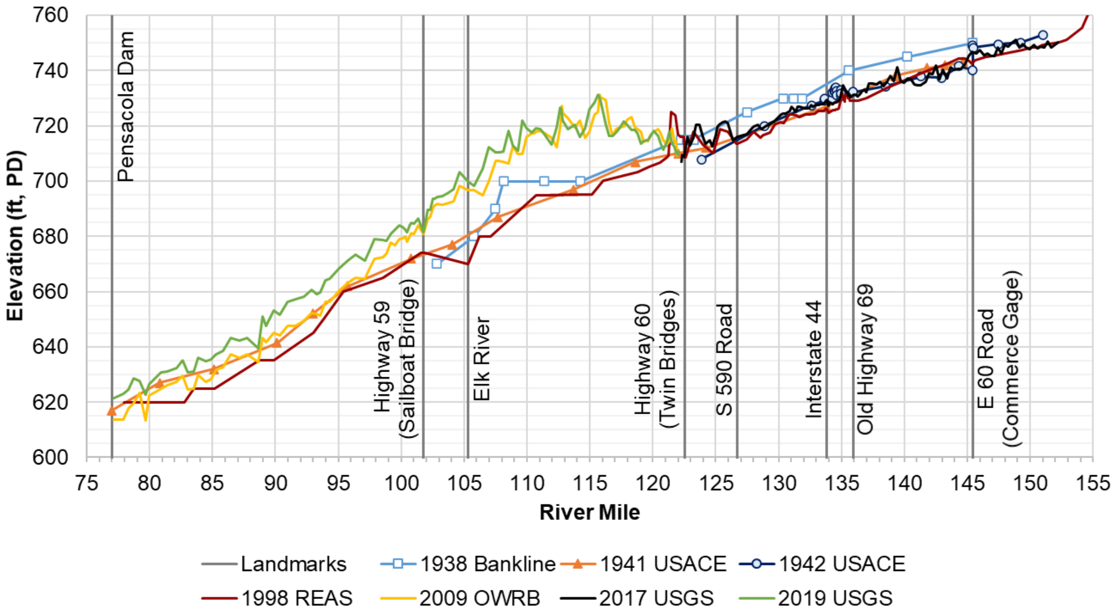
Figure 75
Locations of Vertical Rocky Banks on Topographic Map



Source: Wyandotte, USGS (1907)

A now-submerged bioherm (ridge) composed of erosion-resistant limestone and chert was discussed by McKnight and Fischer (1970) and is located at RM 108. Such structures could also be submerged terraces or talus piles and are part of the southern flank of the exposed and eroding Ozark Uplift often referred to as the Ozark Plateau or Ozark Highlands, but more specifically the Springfield Plateau. They are composed of the Mississippi Boone formation (GRDA 2017) and cause narrowing in the now-submerged valley. Dendritic drainage patterns from the surrounding uplands entering the submerged valley impede the transport of sediment downstream into the lower reaches of the reservoir and cause aggradation of sediment in these sections of submerged river valley. Additional evidence of ridges composed of limestone and chert within the now-submerged valley can be observed in the grade changes of the 1938 bank line elevation profile (Figure 76). The bank line grade change begins at RM 108 and extends upstream to approximately RM 115. Note that the other profile lines in Figure 76 display thalweg elevations. The 1938 profile is the only representation in Figure 76 of the now-submerged valley elevation.

Figure 76
Historical Neosho River Thalweg Comparison



Note: This plot covers the Neosho River from RM 152.2 at the upstream end to the Pensacola Dam at RM 77.12 on the downstream end.

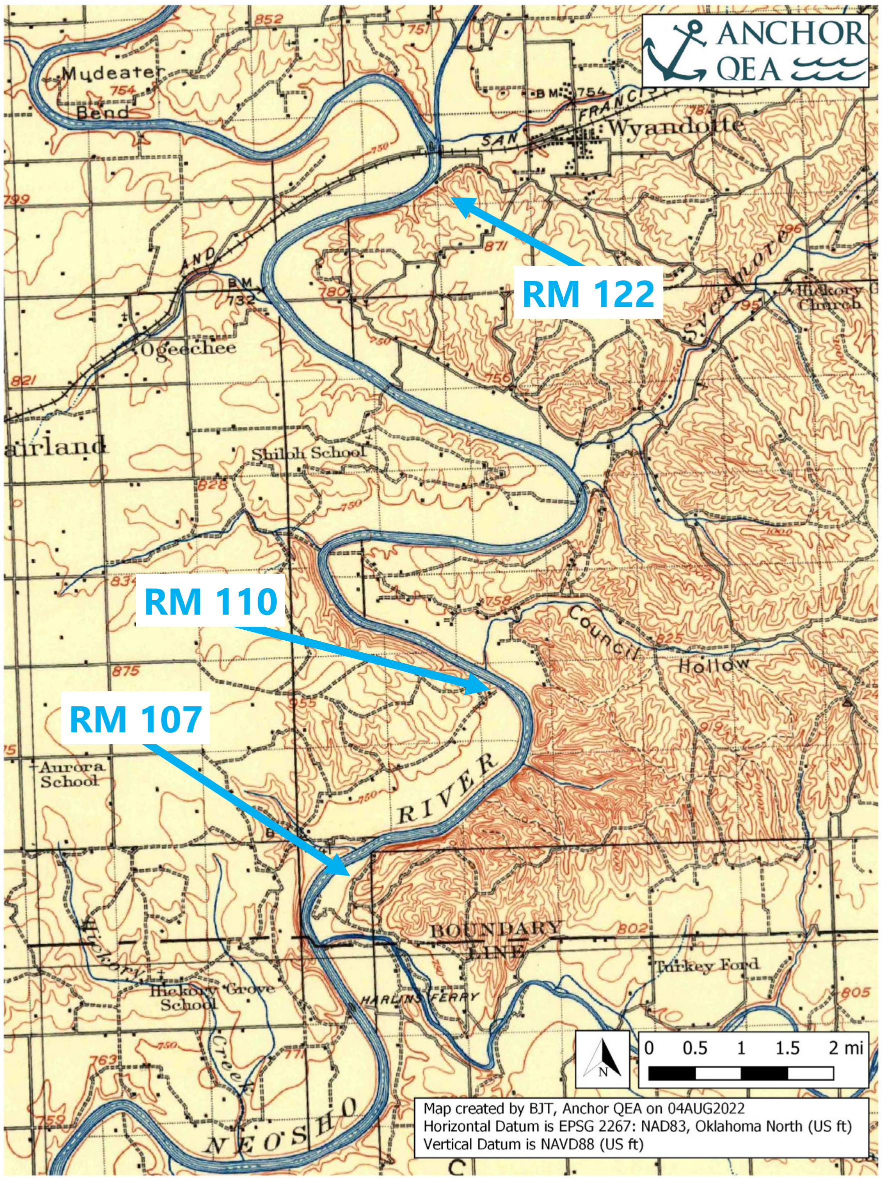
Submerged ridges in the now-submerged valley can act as stable points. Many of these ridges are perpendicular to downstream flow in the valley and can cause sediment to deposit between and amongst the submerged ridges. These stable points are capable of forming the delta feature that is shown in the 2019 USGS profile and the 2009 OWRB profile from RM 100 upstream to RM 122 (Figure 76).

Because McKnight and Fischer (1970) is not a complete catalogue of all erosion-resistant, submerged ridges in the original river valley, it is likely that there are other such ridges in the submerged valley where the delta feature has formed at the edge of the Ozark Uplift.

Evidence of the Ozark Uplift can also be observed on the 1907 topographic map with 50-foot contours shown in Figure 77 (USGS 1907). The entire original river valley from RM 107 to RM 122 displays convoluted and closely spaced contour lines east of the original river channel from RM 107 to RM 120 and on both the east and west sides from RM 107 to RM 110. Therefore, it can be reasonably concluded other ridges submerged in the original river valley that are part of the Ozark

Uplift impede the transport of sediment downstream into the deeper portions of the reservoir and cause the delta feature to form in this location.

Figure 77
Geologic Constrictions along Neosho River in the Region of the Delta Feature



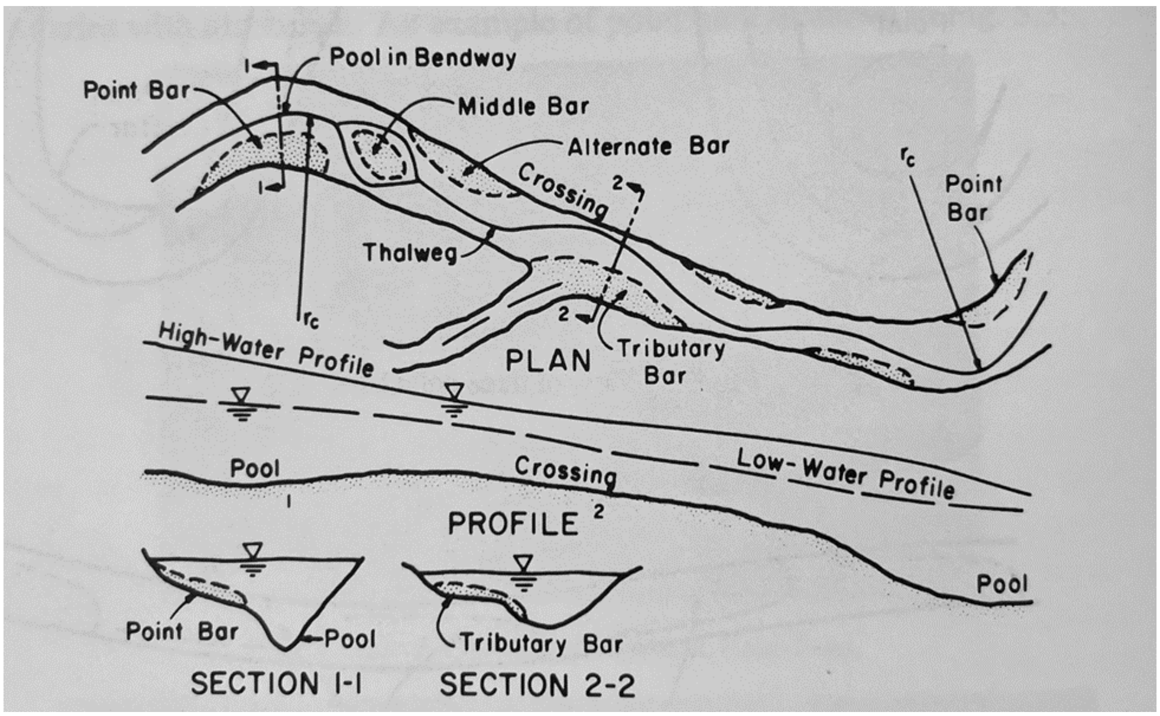
Even in areas without submerged ridges, talus piles, or terraces, the presence of the Ozark Uplift in the vicinity of the delta feature indicates the original channel bottom is likely composed of limestone and chert from the Ozark Uplift that has eroded over time.

The presence of the Ozark Uplift limestone in the area of the delta feature has likely played one of the more significant roles in forming the delta feature to its current size instead of continuous downstream transport of sediment to the location of the dam.

3.4 Riverine Features

At a confluence of a tributary, some of the sediment load from the tributary is frequently deposited, forming a tributary bar within the river (Figure 78).

Figure 78
Illustration of Types of Bars that Occur in Alluvial Channels



Source: Simons and Senturk (1992)

Tributary bars form because the slope of the tributary is typically steeper than the river into which it flows, so some portion of the sediment load cannot be readily transported downstream resulting in sediment deposition. This process also occurs when the tributary transports a high sediment load or a coarser sediment load than the main river.

The slope of the Neosho River bed in the vicinity of the Elk River confluence based on the 1941 USACE data is approximately 2.06 feet per mile. The slope of the Elk River bed upstream of the confluence based on the 2019 data is approximately 3.21 feet per mile, which is approximately 56% steeper than the Neosho River. This difference in riverbed slopes would tend to result in sedimentation in the form of a tributary bar at the confluence. The slope of the Spring River bed is approximately 2.21 feet per mile, which is approximately 7% steeper than the Neosho River.

As stated previously, the Ozark Uplift composed of Mississippi Boone limestone and chert crosses the Neosho River at the confluence of the Elk River. This feature, combined with the steeper slope of the Elk River and the attendant potential for the formation of a tributary bar, suggest a natural tendency for sediment deposition at this location. Although these geomorphic features affect potential sedimentation patterns at this location, it is not possible to quantify these effects on the overall sedimentation pattern.

In addition to the geologic features of the area, there are also flood protection levees upstream that disconnect the river from the floodplains. By building up the streambanks, water is confined to the channel during large flow events, which results in increased water levels because the increased discharge cannot spread to the flat, open areas of the historical floodplains. This can increase flood risk to areas not protected by levees or protected by shorter levees.

4 Quantitative Analysis

The second level of analysis in the three-level approach is quantitative analysis of sedimentation. Beyond the original rationale for the development and application of the three-level approach, additional discussion regarding the quantitative analysis was presented in the USP.

4.1 Quantitative Sediment Transport Evaluation

In addition to the STM, GRDA used a quantitative engineering analysis of sediment transport in the study area. This fulfills the second part of the three-level approach discussed in previous proposals and will focus on the delta feature and the lower reservoir, where the deposition of cohesive materials has the largest potential impacts on the power pool. GRDA used this analysis as a means of validating the model outputs and providing additional confidence in STM results. Recent evaluations of computer modeling by the USSD Committee on Hydraulics of Dams, Subcommittee on Reservoir Sedimentation (2015) suggest that the results of a HEC-RAS model evaluating cohesive sediments may not be reliable. Regarding reservoir sedimentation models, the committee states the following:

> Sediment transport models incorporate a certain degree of simplification to be computationally feasible. Simplified models run into the risk of not obtaining a reliable solution, whereas increasing the model complexity can complicate the problem formulation and incur more input data preparation, calibration, and verification costs. Most of the commonly used numerical sediment transport models were originally developed for the analysis of movable bed rivers having coarse sediments and employ sediment transport equations developed from flume and river data where the effect of fine or wash load on fall velocity, viscosity, and relative density can be ignored. In contrast, reservoir problems may involve the analysis of grain sizes ranging from cobbles in the upstream delta area to clays near the dam. The silts and clays which normally behave as wash load in most rivers, and which are ignored in many river sedimentation models often constitute the majority of the total sediment load in a reservoir. Most 1D sediment transport models, and transport functions, are designed for noncohesive sediment transport. Models often include the addition of simple cohesive sediment computational procedures to enhance model capability. (USSD 2015)

Such is the case with HEC-RAS, where simple cohesive sediment computational procedures were added to a model developed primarily for use in analyzing non-cohesive sediment transport. Specifically, relationships of critical shear and erosion rate developed by Krone (1962) and Partheniades (1962) are the relationships used in HEC-RAS for cohesive sediment.

The USSD (2015) findings also state the following:

> In summary, the sediment transport conditions associated with reservoirs are extremely complex. Detailed analysis of many of these problems lies beyond present knowledge, and only qualitative or rough quantitative estimates can be provided. Caution should be used in the application of numerical techniques in either hand calculations or computer models.

As discussed above, the cohesive sediment modeling routines used in HEC-RAS are limited. It is necessary to have a second analysis to ensure those limitations do not produce erroneous sedimentation predictions. Density currents, mud flows, and other phenomena associated with transported sediment (Lumborg and Vested 2008; van Rijn n.d.; Zavala 2020) are almost certainly active in this system and the routines used in HEC-RAS do not account for those processes. It is expected that this will primarily be of concern lower in the reservoir, hence the decision to directly use the STM only above RM 100 and use a different technique to evaluate sedimentation in the lower reservoir.

For these reasons, GRDA also performed a quantitative engineering analysis of sediment transport within the study area. This approach relied on measured field data including sediment transport, erodibility, and grain size distributions; bathymetric surveys; and overbank topographic information.

Sediment transport equations in the STM for both non-cohesive and cohesive sediments use hydraulic shear stress as the driving force causing erosion and transport of sediment. The quantitative analysis focuses on the relationship between hydraulic shear stress caused by flowing water and the pattern of sediment movement or sedimentation as documented by the change in bathymetric surveys over time.

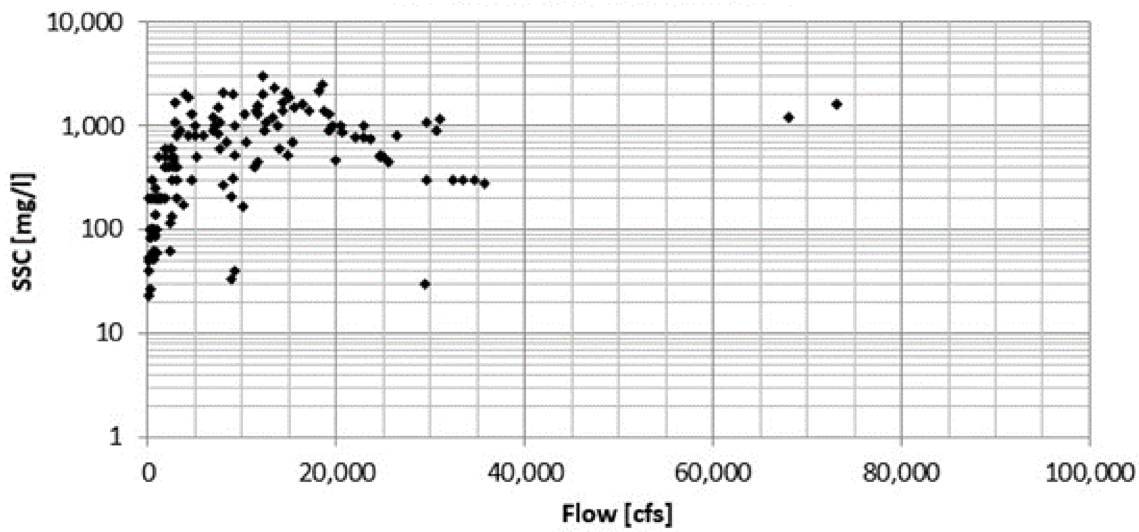
Some supportive analyses of the sediment transport and bathymetric data are necessary to relate the pattern of sedimentation to hydraulic shear stress. These include development of sediment rating curves and sediment density. The sediment rating curves relate sediment transport (in units of tons per day) to the flow of water. The sediment rating curves are applied to the flow data to compute the quantity of sediment being transported down the various rivers and into the reservoir. The density, or specific weight of sediment, in units of pounds per cubic foot, is utilized to convert the tonnage of sediment being transported or deposited to the volume of sediment being deposited.

4.2 Development of Sediment Transport Rating Curves for Quantitative Analysis

Initial development of sediment rating curves was conducted in the ISR. These sediment rating curves have been updated for this quantitative analysis. Significant sets of sediment transport data are available from USGS and collected specifically for this Project by Anchor QEA as discussed in

Section 2. Figure 79 shows the set of suspended sediment transport data for the Neosho River with sediment transport plotted against flow. This graph is plotted on a log-log scale, typically used in showing the relationship between sediment transport and flow. As observed, there is considerable scatter in the data, which is again typical in observations of sediment transport and flow.

Figure 79
Suspended Sediment Concentration Samples and Stream Discharges During Sampling on the Neosho River Near Commerce (USGS Gage 07185000)



Note: Only two samples were collected at discharges above 40,000 cfs.

In analyzing sediment transport whether using a computer model or other quantitative analyses techniques, a sediment rating curve is developed from the data to quantify sediment transport as a function of flow. Typically, a power relationship is utilized because this type of relationship generally fits these data.

To aid in the development of these relationships between sediment transport and flow, a tool has been included in HEC-RAS 6.2 called the "Sediment Rating Curve Analysis Tool" (USACE 2022). Within this tool are two components: bias correction and stationarity to improve the quality of the sediment rating curve. Bias correction rectifies "bias implicit to the log-transform regression used to develop sediment rating curves." Stationarity explores "how sediment data change over time and fit rating curves to temporal sub-sets of the observations."

The following is from the HEC-RAS explanation of the Sediment Rating Curve Analysis Tool:

> Log-transforming the regression makes it relatively easy to fit a power function to log-distributed data. However, it also introduces a bias when the data are untransformed. For example, the observations in the figure below have equal and opposite residuals in the

logarithmic transformation (0.7). However, when these residuals untransform, the positive residual is larger than the negative residual. Therefore, the log-transformed linear regression ends up with larger positive residuals than negative, making the fit power function systematically low. This rating curve will under-predict sediment load for a given flow.

Applying the bias correction decreases the likelihood that the resulting regression will underpredict the sediment load when using the standard power function for the sediment transport rating curves.

The stationarity concept simply considers the extent to which trends in sediment transport may be occurring over time. This concept is explained in the Sediment Rating Curve Analysis Tool documentation (USACE 2022).

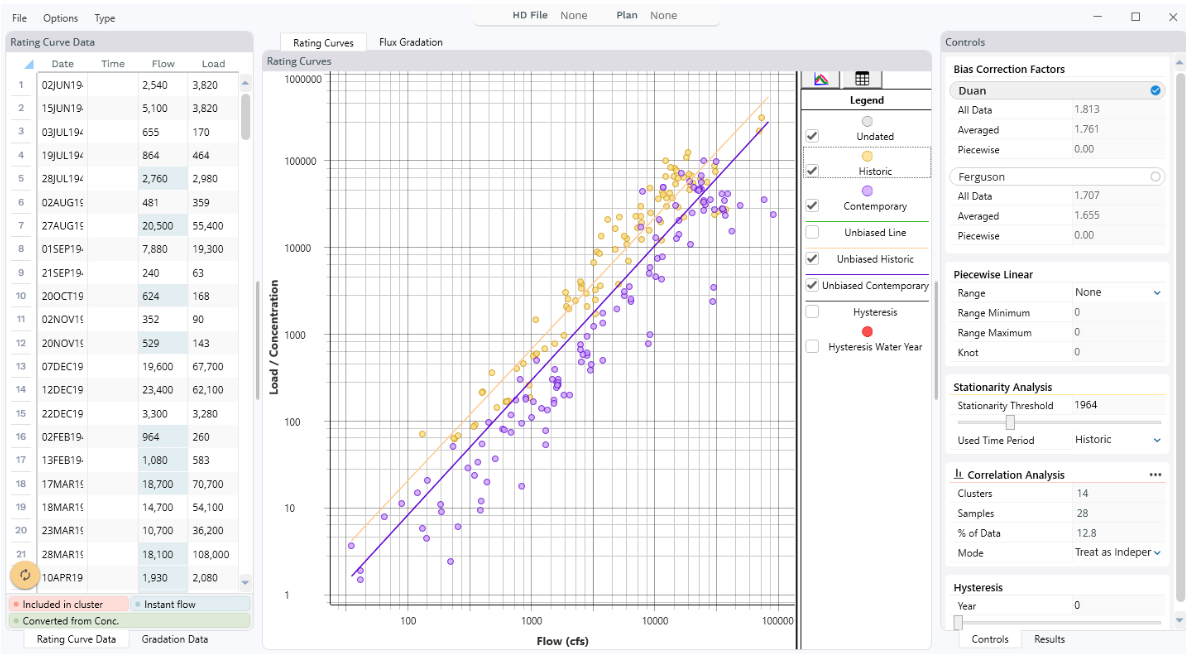
4.2.1 Stationarity Analysis

Sediment load changes over time. Agricultural impacts, land use changes, fires, mass wasting events, dam removals, and eruptions can increase sediment loads, whereas dams, pavement, and improved agricultural practices can decrease sediment loads (Walling and Fang 2003).

Because sediment load data are often scarce, modelers want to make use of all the data available. But it is important to test the load stationarity. The assumption of stationarity is simply that sediment loads do not change over time. Therefore, sediment assessments require analysts to plot and evaluate the data in time blocks, particularly before and after known system changes like a dam or gravel mining policies. If there is a big shift in the rating curve over time, consider using the most recent data to develop the future conditions rating curve.

Figure 80 is an example of a stationarity analysis of a USGS gage (USGS 2021b) as shown in the HEC-RAS stationarity analysis. This particular evaluation compares sediment loading before and after construction of the John Redmond Dam in 1964, and it shows that flows from before its completion carried more sediment than more recent flows. This indicates that the upstream reservoir is trapping sediment and decreasing the loading rates at Grand Lake.

Figure 80
Stationarity Evaluation Example from HEC-RAS



Note: HEC-RAS Sediment Rating Curve Analysis Tool showing stationarity evaluation of USGS Gage 07185000 (Neosho River near Commerce, Oklahoma) with pre-1964 samples in gold and post-1964 samples in purple. This analysis illustrates the decreasing trend in sediment loading over time.

The relationship between flow and load can change systematically over time. If you cannot assume that the relationship between flow and load is "stationary" (constant over time), it may not be appropriate to use all the data for an analysis or model. For example, when calibrating a model in a system with non-stationary sediment data, it is appropriate to use the historical rating curve that reflects the data over the calibration period. Alternately, when forecasting, it is appropriate to use a rating curve based on the most recent relationship. Scientists and modelers should always, at a minimum, evaluate their data stationarity. But if sediment data are non-stationary, they must partition their data to develop a rating curve appropriate for the time period under consideration.

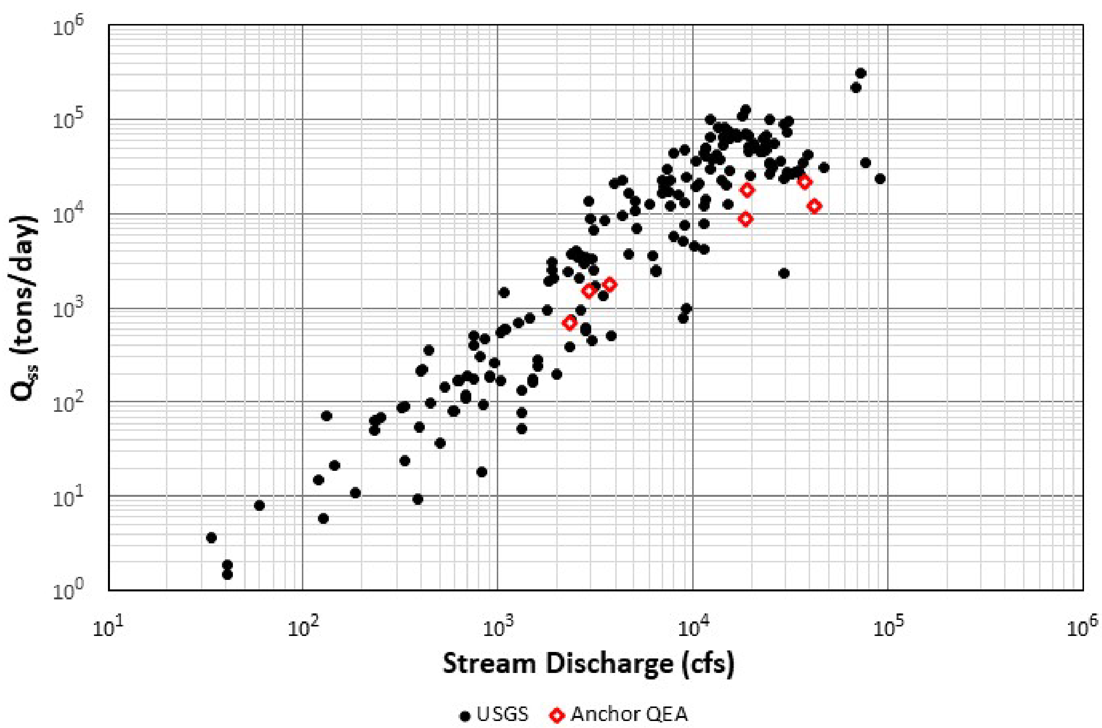
Sediment loading changes over time due to a variety of factors. These include changes in agricultural practices such as the introduction of no-till methods and the use of cover crops, both of which are supported by the Natural Resources Conservation Service (NRCS). Land use changes also affect sediment loading, as forests reduce soil erosion in areas that were previously dominated by agriculture. Furthermore, recent improvements in erosion control and sediment loading practices such as natural stream borders and stormwater retention practices help remove soils from stormwater runoff, reducing sediment loads. In the case of Grand Lake and the Neosho River, the presence of the John Redmond Dam traps significant volumes of sediment and prevents it from reaching the study area.

This study used the Sediment Rating Curve Analysis Tool to correct for bias and the concept of stationarity to account for the reduction in sediment transport over time that exists in the data.

4.3 Suspended Sediment Regression Analyses

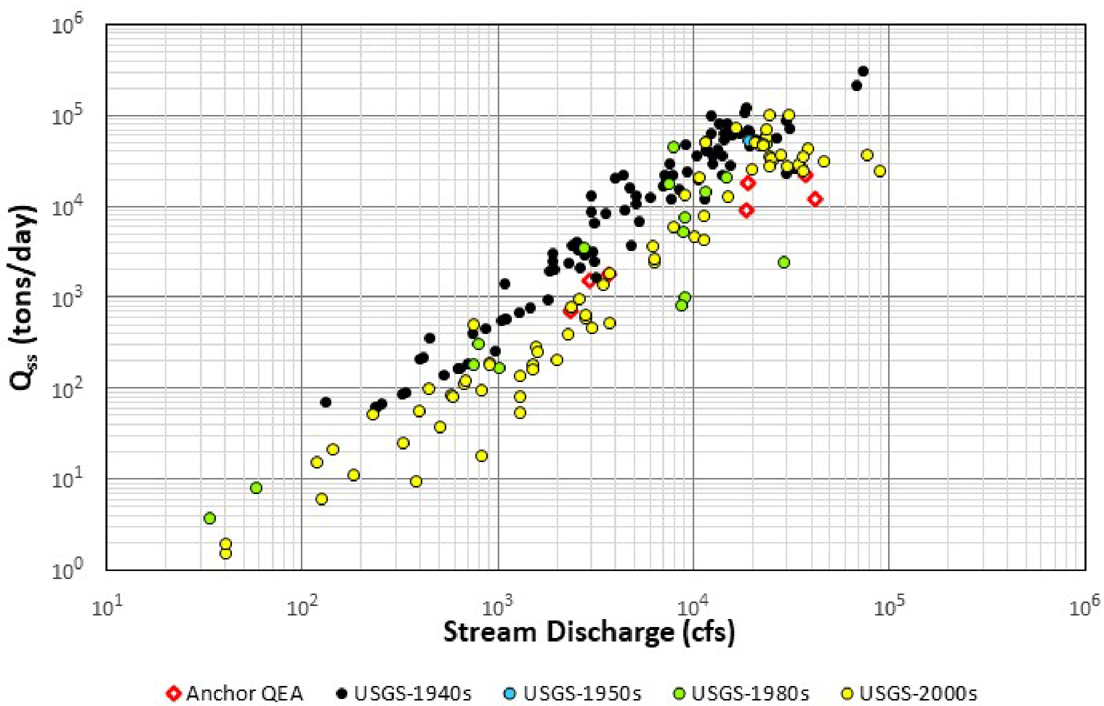
Suspended sediment transport data in tons per day is plotted as a function of flow in Figure 81 for all available data, segregating the USGS data and Anchor QEA data. It must be noted that sediment transport data are typically plotted on a log-log graph. The reason for this is that there is considerable scatter in the data. For example, at a flow of approximately 9,000 cfs, the sediment transport data range from 991 to 48,600 tons per day, which covers a large range, with the higher data point being 49 times greater than the lower data point at the same flow. The uncertainty in fitting a single curve to measured sediment loading data is a significant challenge for sediment transport modeling.

Figure 81
Suspended Sediment Transport: Neosho River Near Commerce



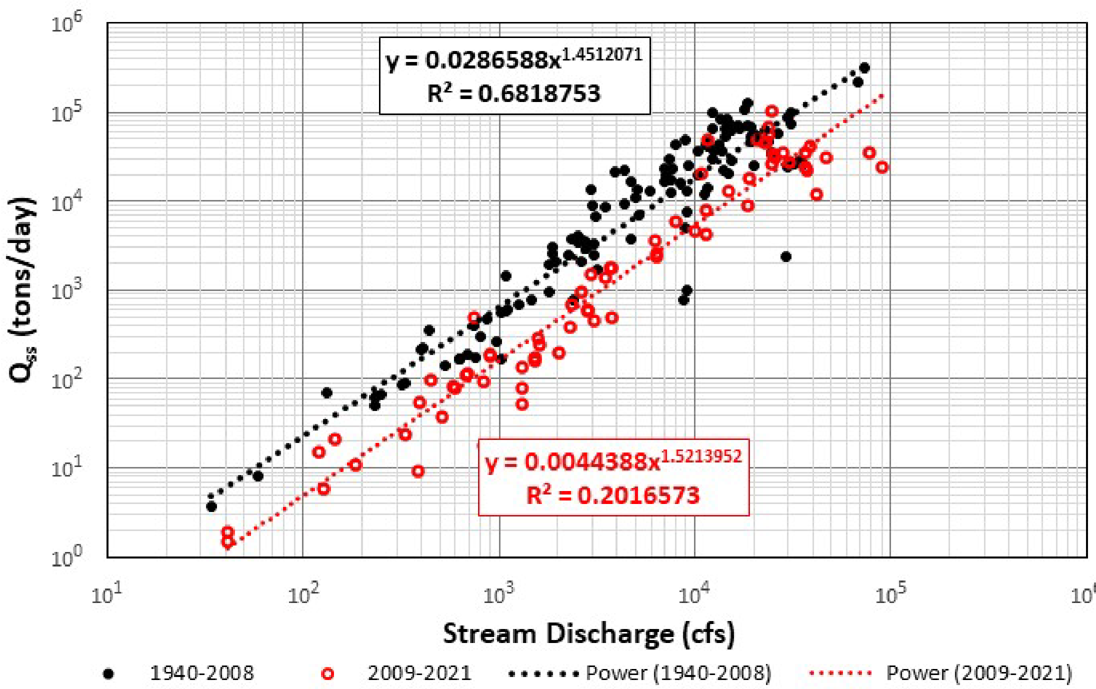
The Anchor QEA data, which were collected in recent years from 2019 to 2021, tended to be on the lower range of the scatter plot typically found in plotting sediment transport data. This prompted an evaluation of whether there were any trends in the relationship between sediment transport and flow as indicated by the data. The Neosho River sediment transport data were collected from 1944 through the present (data for this report extend through summer 2021). Figure 82 presents the same data segregated into various time periods or sets of data over time. As can be seen in the stationarity evaluation, the data show a temporal trend of generally reduced sediment loads with the highest sediment loads occurring in earlier decades and lower sediment loads occurring in recent decades.

Figure 82
Suspended Sediment Transport (Segregated Over Time): Neosho River Near Commerce



Regression analyses were conducted on the data segregated into two sets: 1940 through 2008 and 2009 to 2021 (Figure 83), corresponding to the availability of bathymetric data.

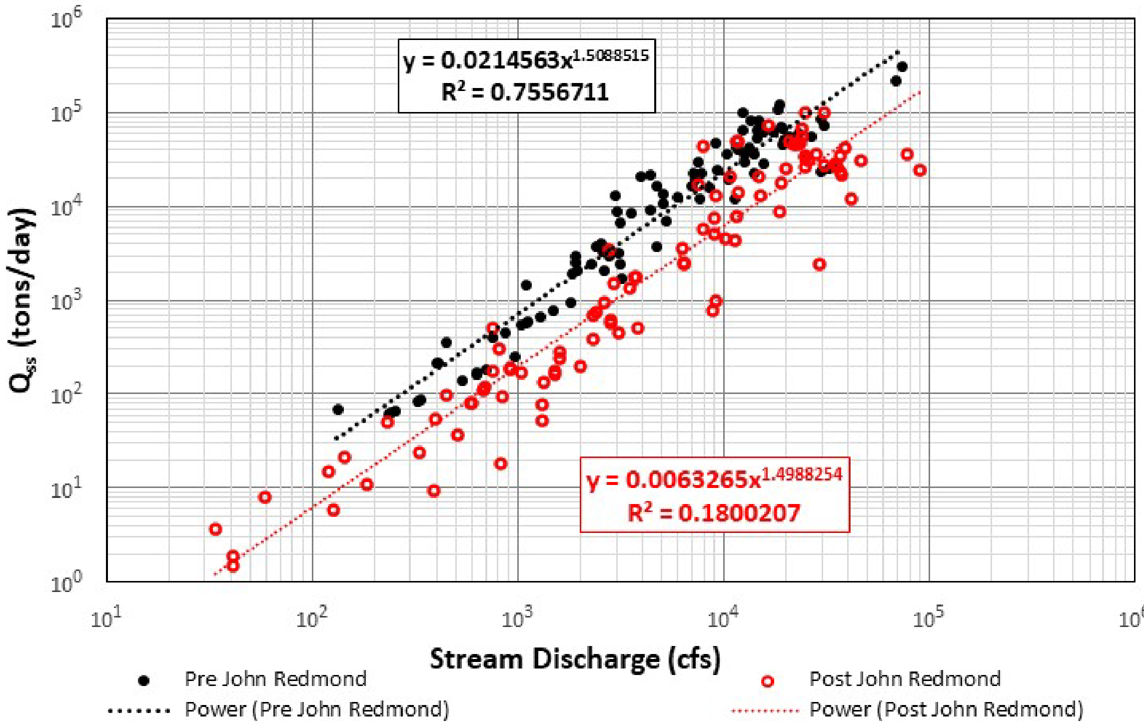
Figure 83
Suspended Sediment Transport Regression Analyses (1940–2008 and 2009–2021): Neosho River Near Commerce



The regression analyses show two distinct relationships with the 1940 to 2008 curve being significantly higher than the 2009 to 2021 curve (again noting that the data and regressions are plotted on a log-log graph). Based on these regression analyses, the suspended sediment transport ranges from approximately 4 times greater at lower flows to approximately 2.9 times greater at higher flows, comparing the 1940 to 2008 curve to the 2009 to 2021 curve. In other words, the data indicate that suspended sediment transport was between approximately 3 to 4 times greater for the earlier time period than the most recent time period. This is a significant decrease in sediment supply over time to consider in the analysis and modeling of sediment transport. One reason there has been a decrease in suspended sediment transport in the Neosho River is the fact that the John Redmond Reservoir on the Neosho River has been trapping sediment since its completion in 1964. Other factors may also have contributed to the trend in decreasing sediment loads over time such as erosion-reduction measures along upstream river channels, land-use changes, and changes in vegetation along the key tributaries; but the effect of sediment trapping in John Redmond Reservoir is a known and significant factor.

Regression analysis was also conducted for the pre- and post-John Redmond Reservoir era as shown in Figure 84. This analysis shows similar results to the pre- and post-2009 because most of the data collected prior to 2009 were collected prior to 1964.

Figure 84
Neosho River Pre- and Post-John Redmond Reservoir Suspended Sediment Relationships with Flow



The final sediment rating curves for the quantitative analysis used the unbiased approach from HEC-RAS and pre- and post-2009 for all rivers. The 2009 break point was chosen because the OWRB survey was completed at that time, making it convenient for comparison of pre- and post-survey sediment loading. The Neosho River was an exception; it uses 1964 as the break point, which coincides with completion of the John Redmond Reservoir and the subsequent reduction in sediment loading to Grand Lake. These rating curves are shown in Figure 85 through Figure 92.

Figure 85 shows the pre-1964 data on the Neosho River in red (along with the associated regression curve and equation), and the equation using output from the unbiased sediment rating curve analysis is shown in black (along with the associated equation). The unbiased equations are the sediment rating curves used in the quantitative analysis for each respective time period.

Figure 85
Neosho River Comparisons of Pre-1964 Biased and Unbiased Sediment Curves

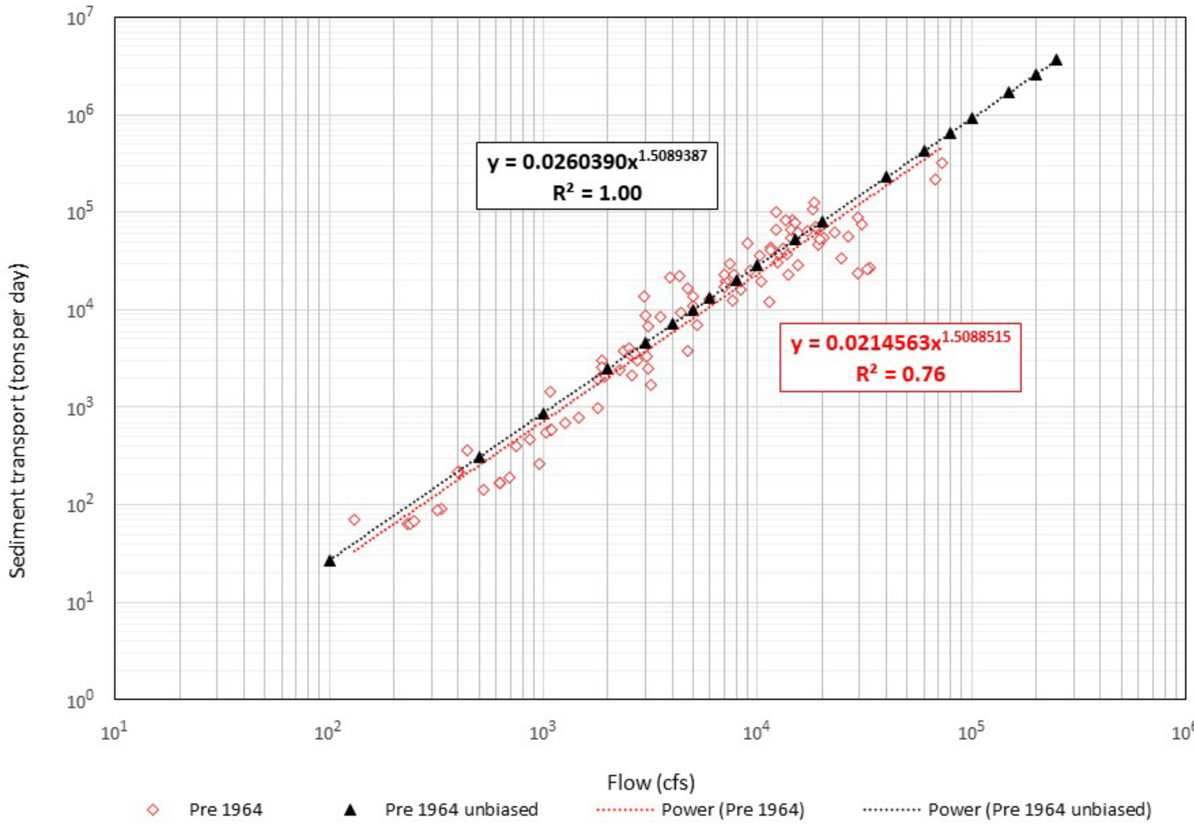


Figure 86 presents the same information for the post-1964 time period, again with the data points shown in red and the unbiased equation shown in black.

Figure 86
Neosho River Comparisons of Post-1964 Biased and Unbiased Sediment Curves

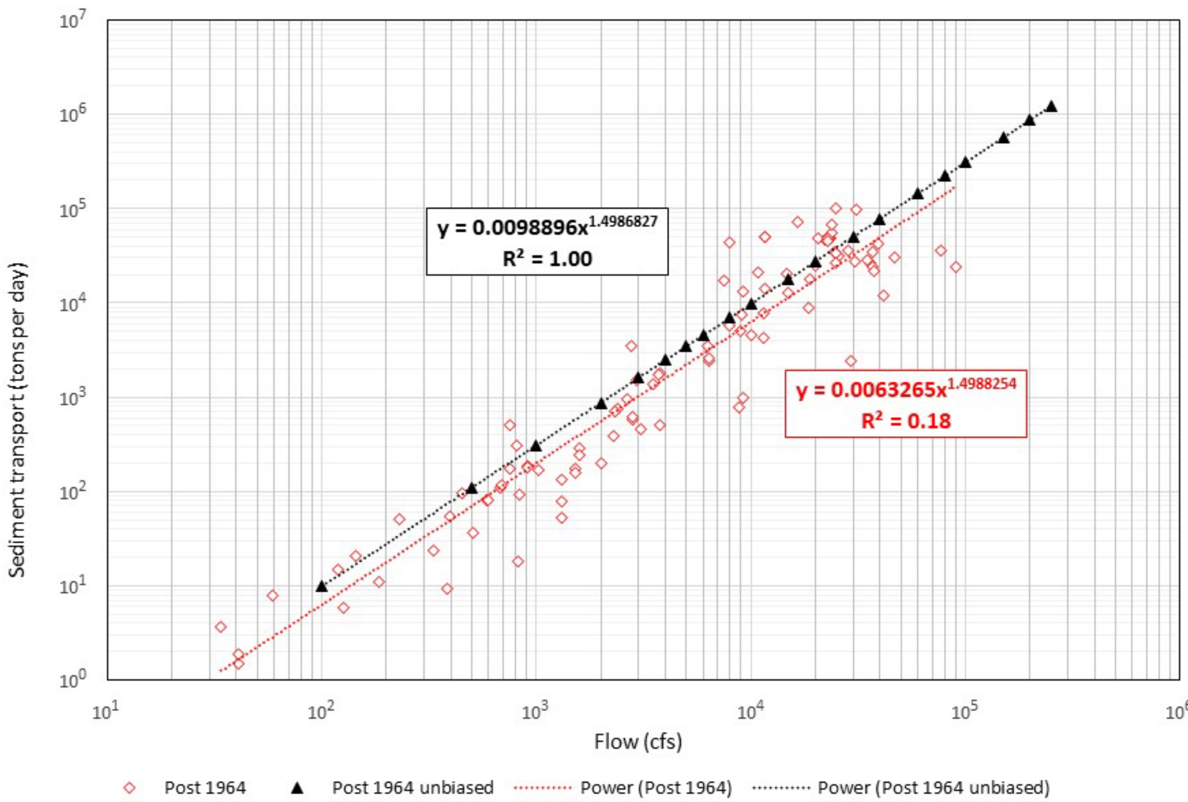


Figure 87 and Figure 88 present the datasets for pre- and post-2009 time periods on the Spring River with the unbiased regressions from the unbiased analysis from HEC-RAS shown in black.

Figure 87
Spring River Comparisons of Pre-2009 Biased and Unbiased Sediment Curves

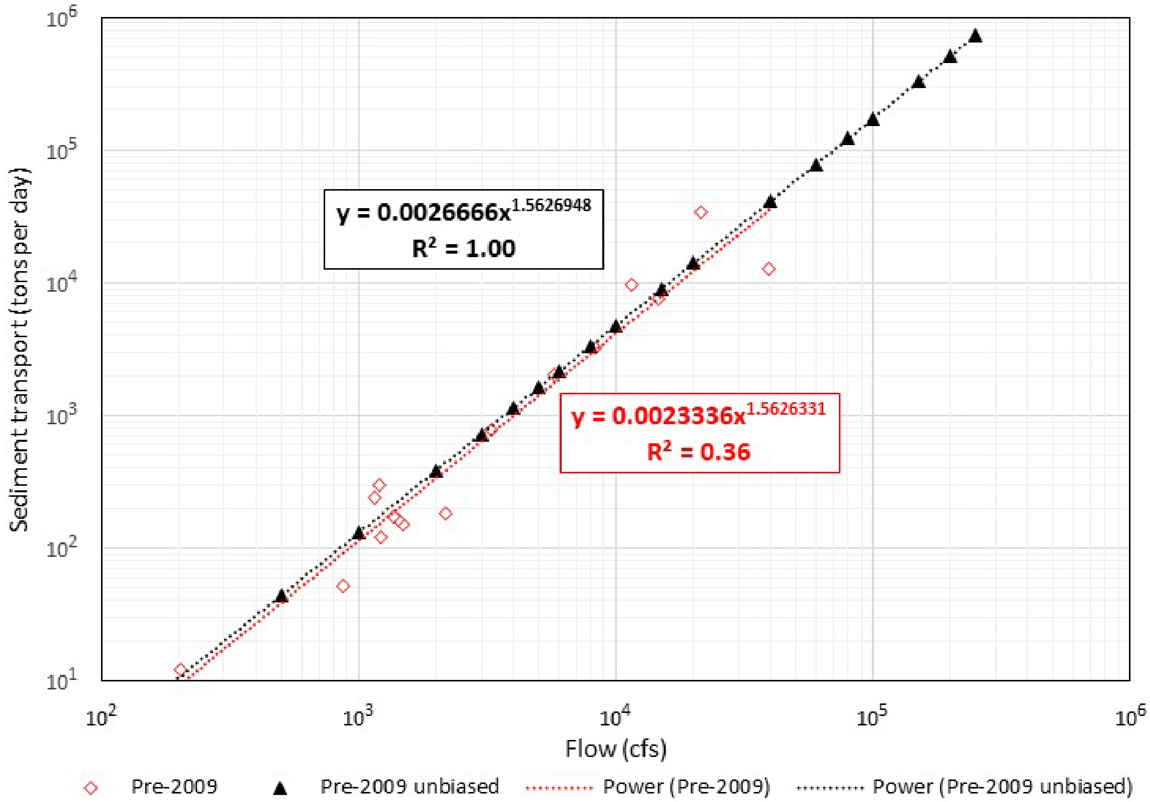


Figure 88
Spring River Comparisons of Post-2009 Biased and Unbiased Sediment Curves

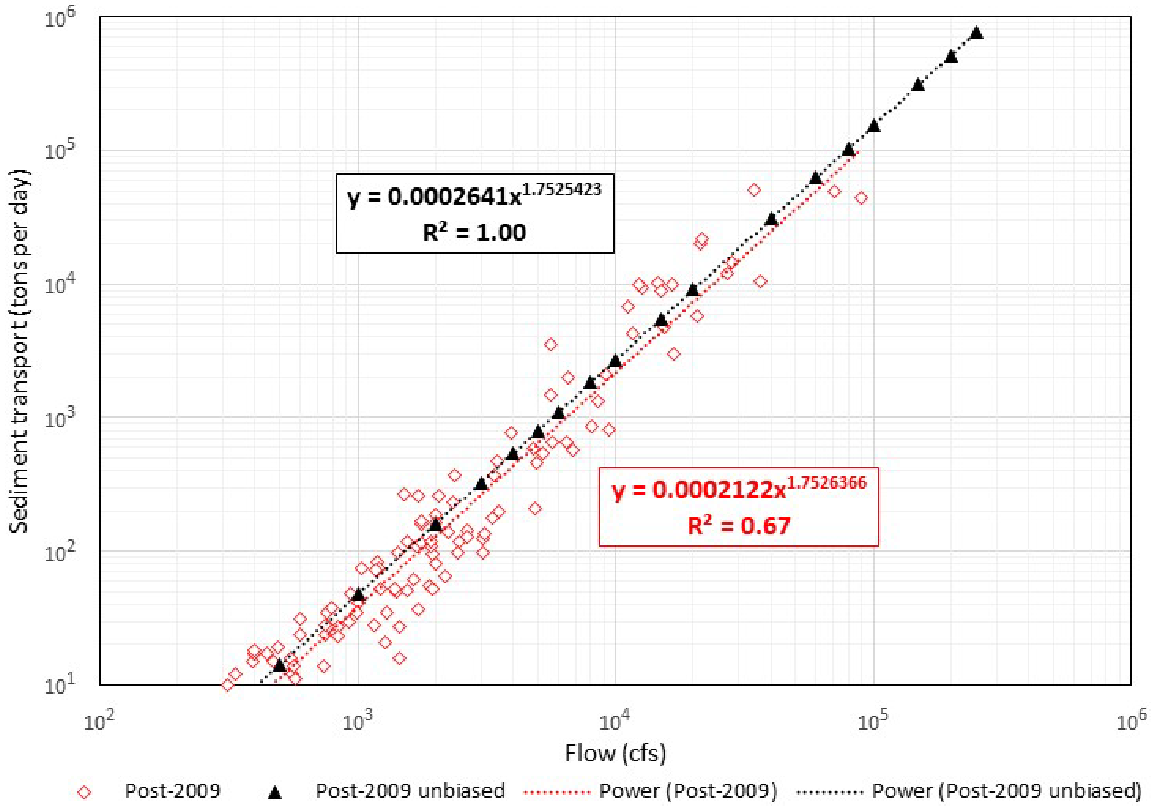


Figure 89 and Figure 90 present the Elk River data for pre- and post-2009 time periods in red and the corresponding unbiased equations for the respective time periods in black.

Figure 89
Elk River Comparisons of Pre-2009 Biased and Unbiased Sediment Curves

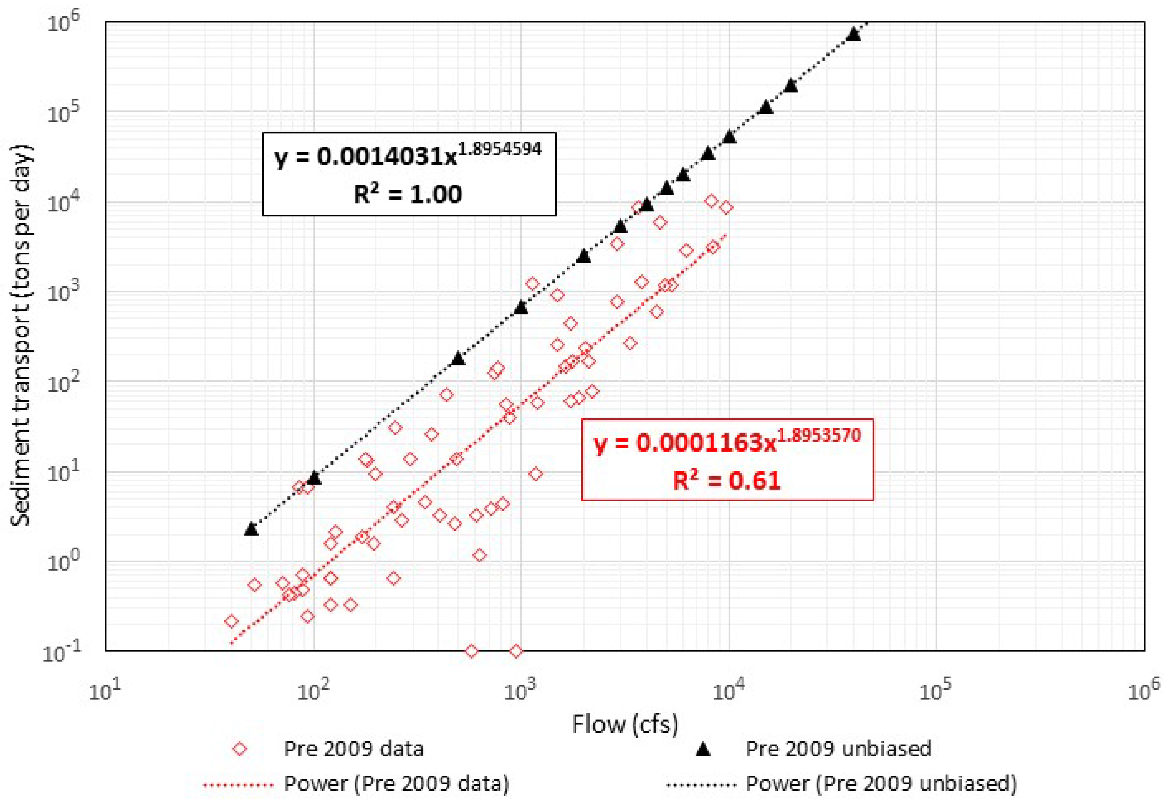


Figure 90
Elk River Comparisons of Post-2009 Biased and Unbiased Sediment Curves

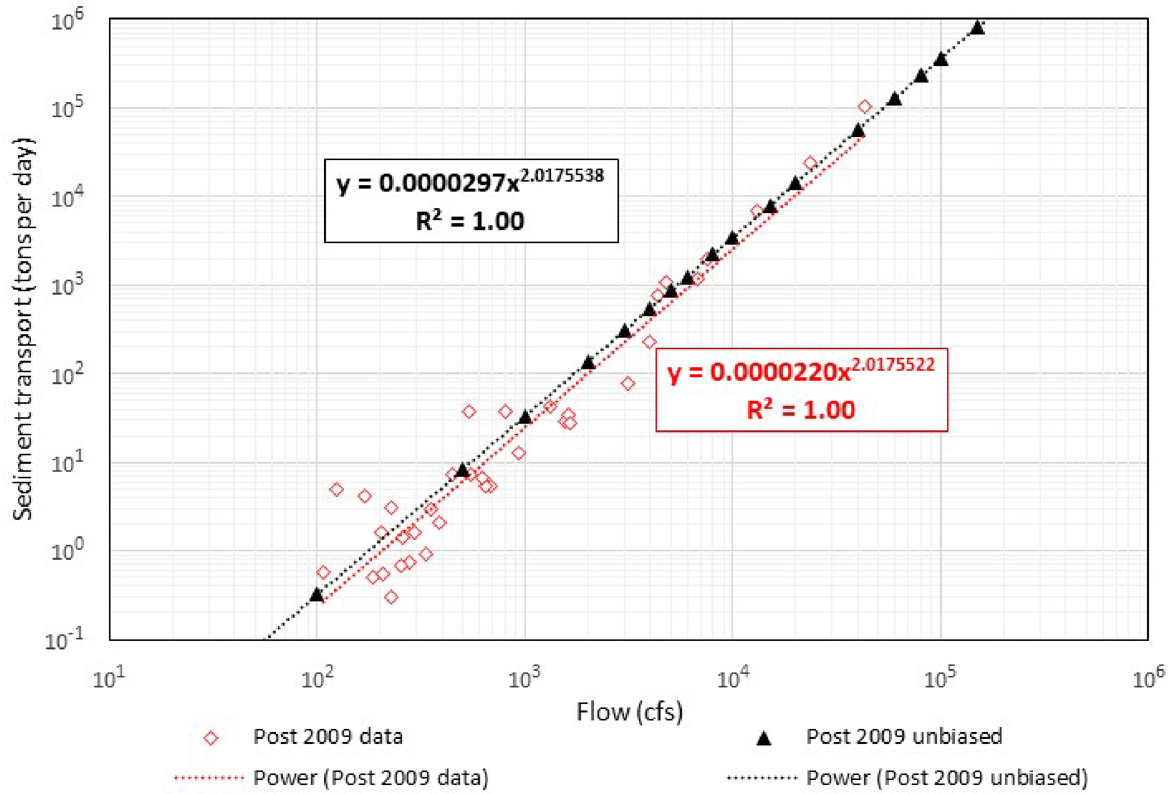


Figure 91 and Figure 92 present the Tar Creek data for pre- and post-2009 time periods in red and the corresponding unbiased equations for the respective time periods in black.

Figure 91
Tar Creek Comparisons of Pre-2009 Biased and Unbiased Sediment Curves

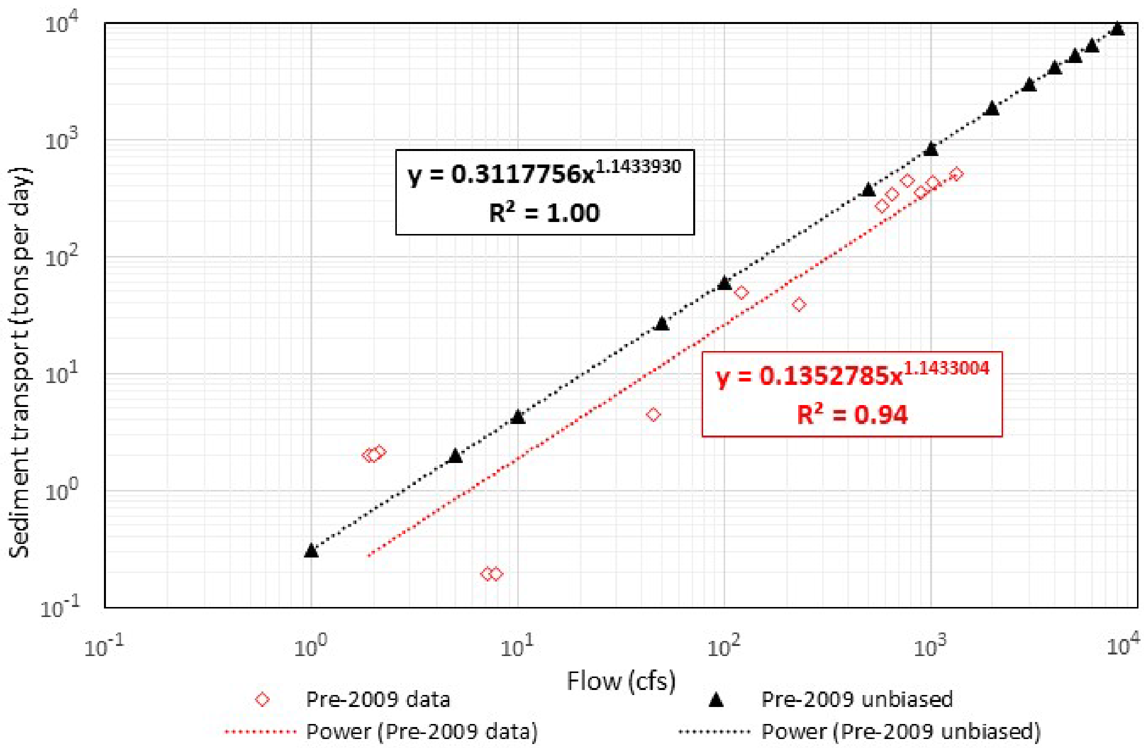
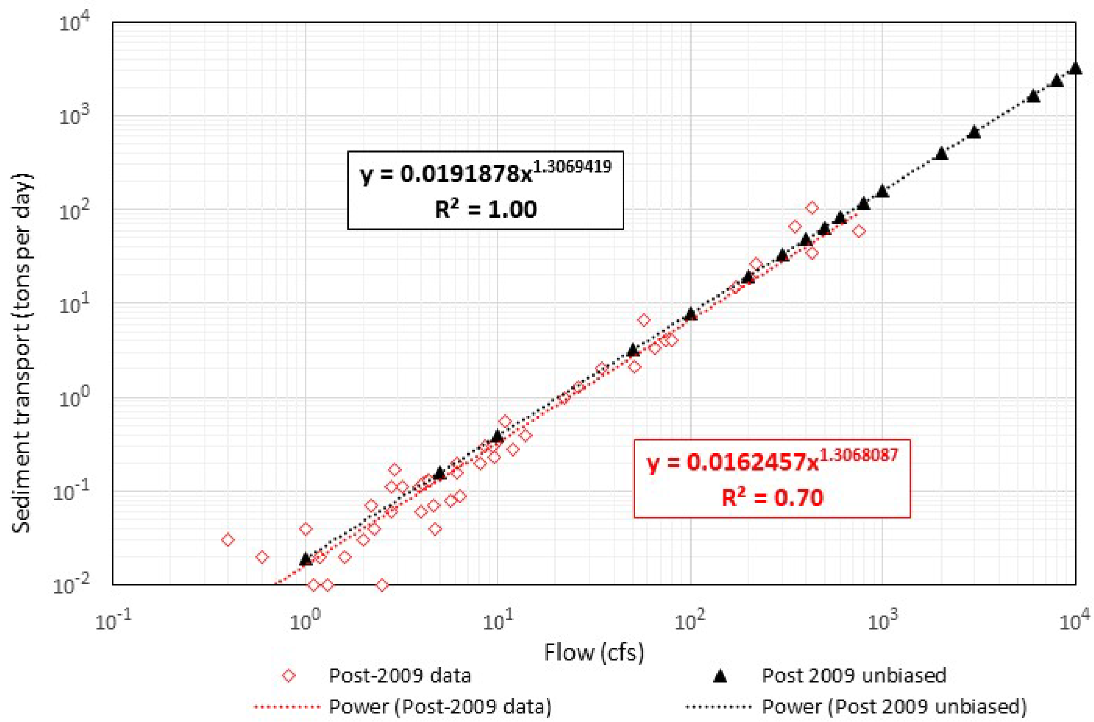


Figure 92
Tar Creek Comparisons of Post-2009 Biased and Unbiased Sediment Curves



A summary of the sediment rating curves is presented in Table 17.

Table 17
Sediment Transport Rating Curve Equations (Unbiased, Considering Stationarity)

River	Pre-2009	Post-2009
Neosho*	Q_{ss} = 0.0260390 $Q^{1.5089387}$	Q_{ss} = 0.0098896 $Q^{1.4986827}$
Tar	Q_{ss} = 0.3117756 $Q^{1.1433930}$	Q_{ss} = 0.0191878 $Q^{1.3069419}$
Spring	Q_{ss} = 0.0026666 $Q^{1.5626948}$	Q_{ss} = 0.0002641 $Q^{1.7525423}$
Elk	Q_{ss} = 0.0014031 $Q^{1.8954594}$	Q_{ss} = 0.0000297 $Q^{2.0175538}$

Note: *Neosho values are pre- and post-1964.

These sediment rating curves were applied to the historical flow data to compute the tonnage of sediment flowing down the rivers and into Grand Lake. They were also applied to the future hydrology to compute the tonnage of sediment for the future scenario.

Summaries of basic flow and water level statistics have been developed, along with corresponding quantities of sediment transported for various time periods of interest using the bias-corrected rating curves considering stationarity. These time periods include 1940 to the beginning of 2009, 2009 through 2019, and future scenarios from 2020 through 2069. For the future scenarios (2020 through 2069), flow and water levels are presented for both anticipated operations and baseline operations (see Section 7 for discussion of anticipated/baseline operations). These summaries provide perspective and comparisons of these key variables between the various time periods.

A summary of flow and WSE averages is presented in Table 18.

Table 18
Summary of Flow and Water Levels

Tributary	1940–2009	2009–2019	2020–2069 Anticipated Operation	2020–2069 Baseline Operation
Neosho River (cfs)	3,818	4,312	4,183	4,183
Tar Creek (cfs)	48	40	55	55
Spring River (cfs)	2,212	2,664	2,526	2,526
Elk River (cfs)	822	953	887	887
Grand Lake Average WSE (feet)	740.95	743.49	742.57	741.65

The tonnage of sediment transported during these various time periods was also computed using the unbiased sediment rating curves and either historical or projected hydrology (Table 19).

Table 19
Summary of Sediment Transport

Tributary	Total Sediment Transport (tons) 1940–2009	Total Sediment Transport (tons) 2009–2019	Total Sediment Transport (tons) 2020–2069
Neosho River	214,264,051	21,144,118	89,616,776
Tar Creek	864,297	19,702	122,593
Spring River	27,464,343	4,088,037	15,866,424
Elk River	57,766,979	1,432,848	3,535,827
Total	**300,359,670**	**26,684,705**	**109,141,619**
No. of years	**69**	**11**	**50**

Table 20 summarizes basic information comparing annual sediment transport for the various time periods of interest.

Table 20
Summary of Annual Sediment Transport

Tributary	Annual Sediment Load (tons/year) 1940–2009	Annual Sediment Load (tons/year) 2009–2019	Annual Sediment Load (tons/year) 2020–2069
Neosho River	3,105,276	1,922,076	1,792,336
Tar Creek	12,526	1,791	2,452
Spring River	398,034	371,640	317,328
Elk River	837,203	1,302,259	70,717
Total	**4,353,039**	**2,425,882**	**2,182,832**

Pursuant to federal law, including the Flood Control Act of 1944 and Section 7612 of the National Defense Authorization Act for 2020, flood control operations at the Project are regulated exclusively by USACE when the reservoir elevation is above 745 feet PD or expected to rise beyond that level.

An analysis of historical data from October 1, 1942 (the first time reservoir elevation data are available), through December 31, 2019, shows that Grand Lake reaches or exceeds elevation 745 feet PD 19.8% of the time. Historical flow data for these periods with a reservoir elevation at or greater than 745 feet PD were segregated, and the sediment rating curves (unbiased, pre/post 1964 for the Neosho River and pre/post 2009 for the Spring River, Elk River, and Tar Creek) were applied to these segregated flow data. The resulting tonnage of sediment delivered to the reservoir when the reservoir was at or above 745 feet PD was compared to the total tonnage of sediment delivered for the entire time period. Table 21 presents the results of this analysis for each stream and for the overall total sediment percentage.

Table 21
Percentage of Sediment Delivered to Grand Lake: Above and Below Water Level 745 feet PD

River	Percentage of sediment delivered >745 feet PD	Percentage of sediment delivered < 745 feet PD
Neosho River	75.1	24.9
Tar Creek	63.2	36.8
Spring River	80.0	20.0
Elk River	75.4	24.6
Total	75.6	24.4

When the reservoir elevation is greater than 745 feet, which only occurs 19.8% of the time, 75.6% of the sediment load is delivered to the reservoir. Under normal operating conditions, which occurs 80.2% of the time, 24.4% of the total sediment load is delivered to the reservoir.

4.4 Sediment Density

Generally, the density of sediment is lower for fine material such as silt and clay and higher for the coarser sand and gravel. In Lane and Koelzer (1943), data were presented regarding the density of sediment deposits in reservoirs. Vanoni (2006) also discusses reservoir sediment density. This study compiled data from a wide variety of sources in the United States as well as Europe and Asia. For reservoirs in Texas, the data showed that for finer silt at the head of reservoirs, the density averaged 82 pcf. In the middle reach of reservoirs, the density was 55 pcf, and for finer material farther downstream that was continually submerged the density was 31 pcf. Deposited sediment in the Missouri River basin ranged from 25.2 to 116 pcf, with a corresponding sand content ranging from 4.9% to 93.5%. The sediment density in a European reservoir ranged from 21.6 to 87.2 pcf, depending on the depth of the sample, which ranged from 1 to 20 meters. Sediment traps in this reservoir showed surface layer deposits ranged from 13.7 to 29.4 pcf. The Soil Conservation Service reported 318 samples of sediment density with a sediment density range of 20.1 to 101.7 pcf. The average density for submerged deposits of fine material for 210 samples was 44 pcf. Vanoni (2006) states the following:

> A determination of unit weight which should be used for reservoir sediment in any case is a complicated problem involving a number of variables. Among them are the manner in which the reservoir will be operated, the size of the sediment particles, the rate of compaction of the sediment, and perhaps other factors.

Lane and Koelzer (1943) presents a figure relating the unit weight of sediment to the percent of sand in the deposit (Figure 93).

Figure 93
Relation of Unit Weight of Deposited Sediments to Percent of Sand

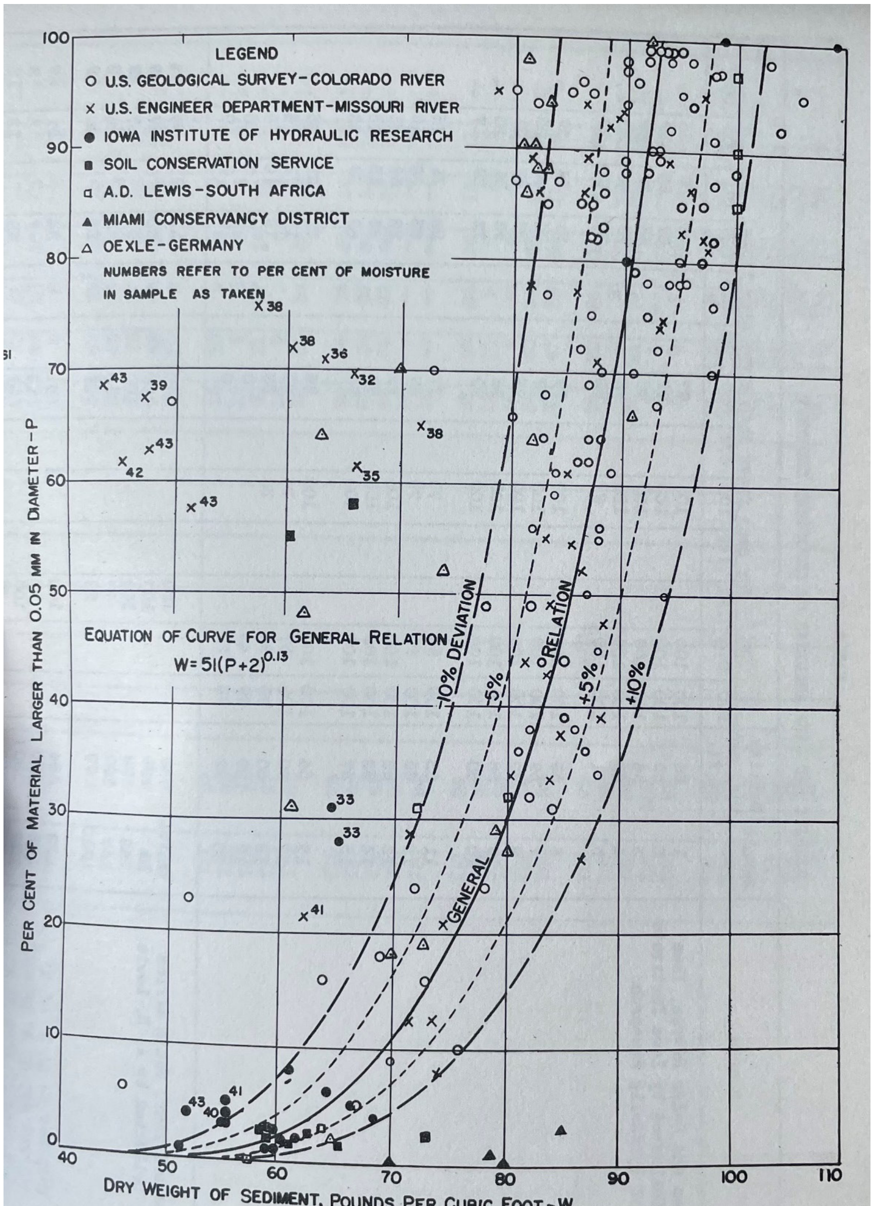


FIG. 2 - RELATION OF UNIT WEIGHT OF DEPOSITED SEDIMENTS TO PER CENT OF SAND

Source: Lane and Koelzer (1943)

The particle size distribution data from the recent core samples collected in 2022 are summarized in Appendix F.

The laboratory that conducted the particle size distribution analysis uses the U.S. Department of Agriculture (USDA) soil classification and size classification. The size breakdown between clay, silt, and sand is shown in Figure 94 from the *Engineering Field Manual* (USDA 1990).

Figure 94
Relationship between Particle Size and the USDA Textural Soil Classes, the Unified Soil Classification System, and the AASHTO Soil Classes

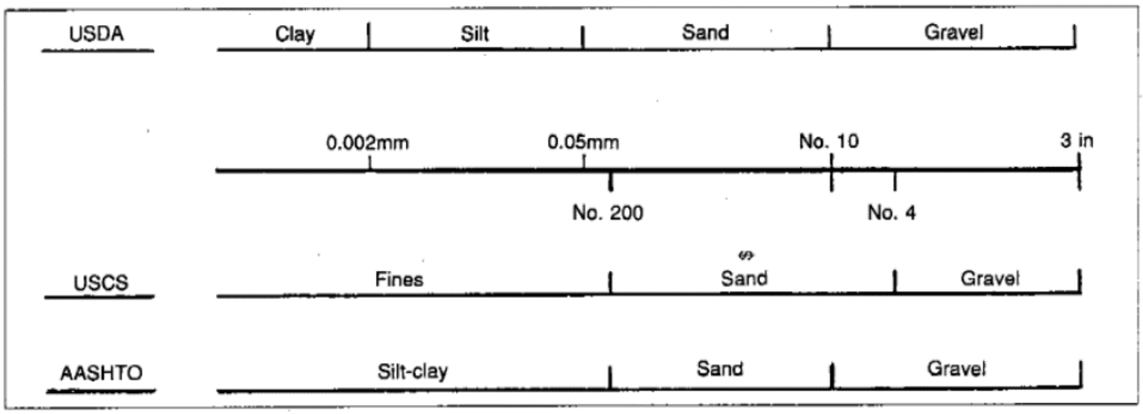


Table 22 presents the breakdown between clay, silt, and sand based on USDA classification.

Table 22
Sediment Type and Size Range

Sediment Type	Sediment Size (mm)
Clay	<0.002
Silt	0.002–0.05
Sand	0.05–2

4.5 Quantitative Analysis of Bathymetric Change Related to Hydraulic Shear Stress

The quantitative analysis of sediment transport consists of using the basic data and quantitative tools to analyze the hydrology, hydraulics, and resulting effect on sedimentation in Grand Lake. This analysis uses the historical bathymetric data combined with the hydraulic analysis of historical flows and reservoir operation to develop a relationship between hydraulic shear stress and sedimentation pattern. Hydraulic shear stress is the driving force behind the transport and deposition of sediment. Hydraulic shear stress is the basic variable used in many sediment transport equations for both cohesive and non-cohesive sediments to determine whether sediment is eroded or deposited, and the rate at which sediment is transported.

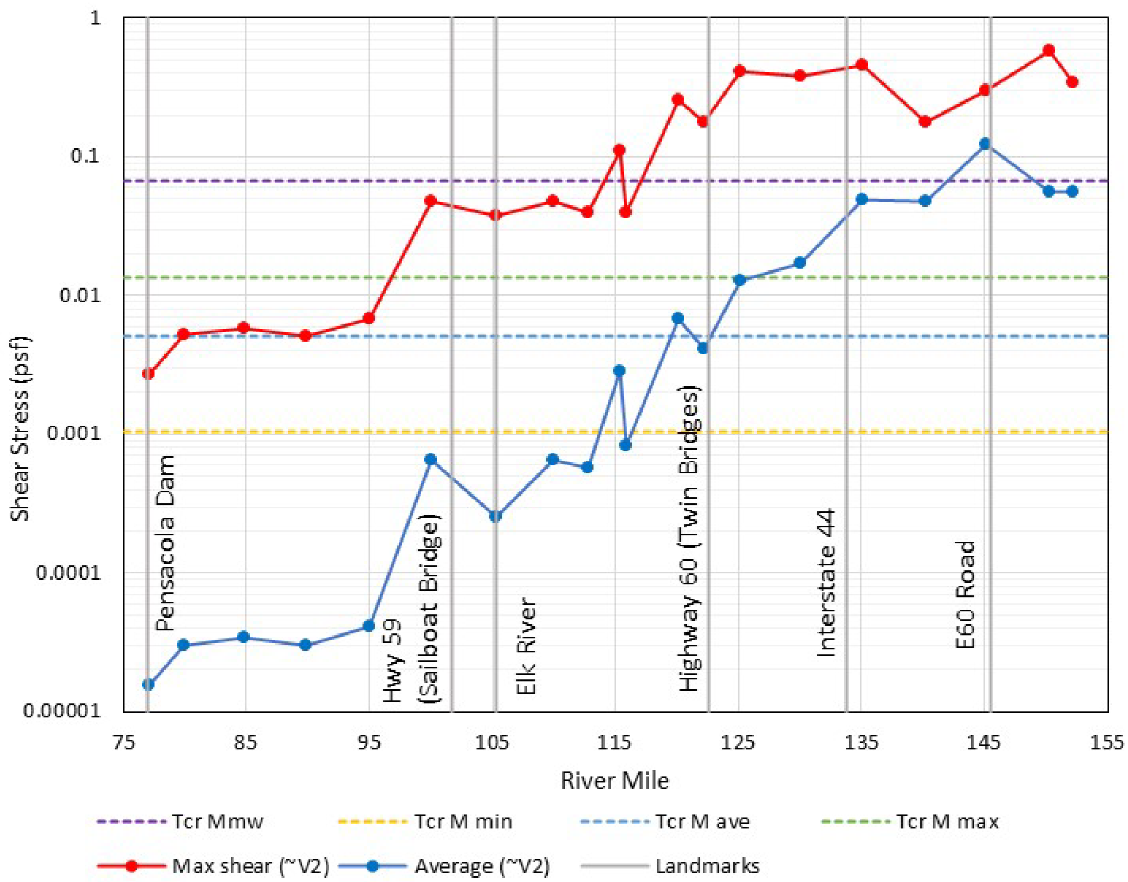
There are two steps in developing a relationship between sediment transport (and associated sedimentation patterns) and hydraulic shear stress. The first step is to run HEC-RAS to calculate hydraulic shear stresses. This step uses the hydraulically calibrated HEC-RAS model over the historical periods of available channel geometry/bathymetric data and hydrologic data of streamflow and historical water levels in the reservoir. The geometry remains fixed based on the surveyed geometry over the time periods utilized. The second step is to determine the pattern of sedimentation based on historical bathymetric surveys. The actual sets of data utilized to compute volume change and pattern of sedimentation are the HEC-RAS input data in the same hydraulic model for the available surveys. Using these two sets of information, the relationship between hydraulic shear stress and sedimentation can then be developed.

It should be noted that the STM itself uses the same data but attempts to simulate the interaction between hydrology, hydraulics, and sedimentation by using upstream sediment input (based on regression analyses of suspended sediment transport data and associated sediment rating curves), bed material particle size distribution data, a standard sediment transport equation (for non-cohesive sediment) available in HEC-RAS, and erosion characteristics of the cohesive sediment (which is the dominant sediment being transported to Grand Lake through the tributaries). The model is run for a given time period starting with the circa-1940 geometry to calibrate parameters in the model such that the computed channel geometry and bathymetry reasonably match the surveyed channel geometry and bathymetry in 2009 at the end of the calibration period. The model is then extended to evaluate whether the results reasonably reproduce the 2019 geometry as a validation process. If the model can be reasonably calibrated and validated, then it can be utilized to predict the future sedimentation patterns for a range of operation and hydrologic scenarios. As noted in the ISR, this is an extremely complicated process given the complex relationship between hydraulic shear stress and the wide variations (five orders of magnitude) in erosion parameters and considerable variability of sediment density, both of which vary with depth below the surface of the sediment column and with time because cohesive sediments consolidate and strengthen with time.

An advantage of the quantitative analysis is that the approach directly utilizes the change in bathymetric data as input to develop relationships between hydraulic shear and sedimentation pattern. In contrast, the STM calibration/verification process attempts to simulate the sedimentation pattern by judicious selection of erosion and related sedimentation parameters in the model (i.e., engineering judgment), with the objective of reasonably matching the change in bathymetric data. In other words, the quantitative analysis process uses the change in bathymetric data as input and the hydraulic shear stresses computed from the fixed-bed model, whereas the STM uses a range of parameters to attempt to match the change in bathymetric data using the hydraulic shear stresses computed from the movable bed model. If the STM could perfectly simulate the complex interaction between erosion parameters and hydraulic shear, it would achieve essentially the same results as the quantitative analysis approach. This is because successful calibration of the STM means that the model reasonably matches the change in bathymetry. The quantitative analysis directly uses this change in bathymetry to develop a relationship between hydraulic shear and sedimentation.

The first step in the quantitative analysis is to determine the hydraulic shear stresses through hydraulic modeling. The STM was modified for the quantitative analysis by setting pass-through nodes (which pass sediment through each cross section without allowing any sediment deposition) at all cross sections as well as not allowing any erosion of the bed, thereby keeping the 2009 channel geometry the same through the entire run to compute the hydraulic conditions from 2009 to 2019. As described in Section 2.6 of the USP, at a number of cross sections (spaced approximately 5 miles apart except more closely spaced over the delta feature), the hydraulic results were analyzed statistically and summarized. These data (maximum and average hydraulic shear stress) were plotted (Figure 95) as a function of longitudinal location (RM).

Figure 95
Hydraulic Shear Stress Profile of Neosho River, 2009 Geometry, 2009–2019 Historical Flows and Operation



Notes:

Tcr Mmw	Critical shear stress for mass wasting
Tcr M min	Minimum critical shear stress for particle erosion across all samples
Tcr M ave	Average critical shear stress for particle erosion across all samples
Tcr M max	Maximum critical shear stress for particle erosion across all samples
Max shear (~V2)	Maximum modeled bed shear stress, proportional to velocity^2
Average (~V2)	Average modeled bed shear stress, proportional to velocity^2

HEC-RAS (USACE 2016) utilizes a default relationship to compute shear stress for the sediment transport equations as shown in Equation 2.

Equation 2

$$\tau = \gamma dS$$

where:

τ	=	bed shear stress
γ	=	specific weight of water
d	=	water depth
S	=	energy grade slope

Where depths are large, such as in the case of a reservoir, this can overestimate shear stress. Another way of computing shear stress is shown in Equation 3:

Equation 3

$$\tau = \frac{1}{8}\rho f V^2$$

where:

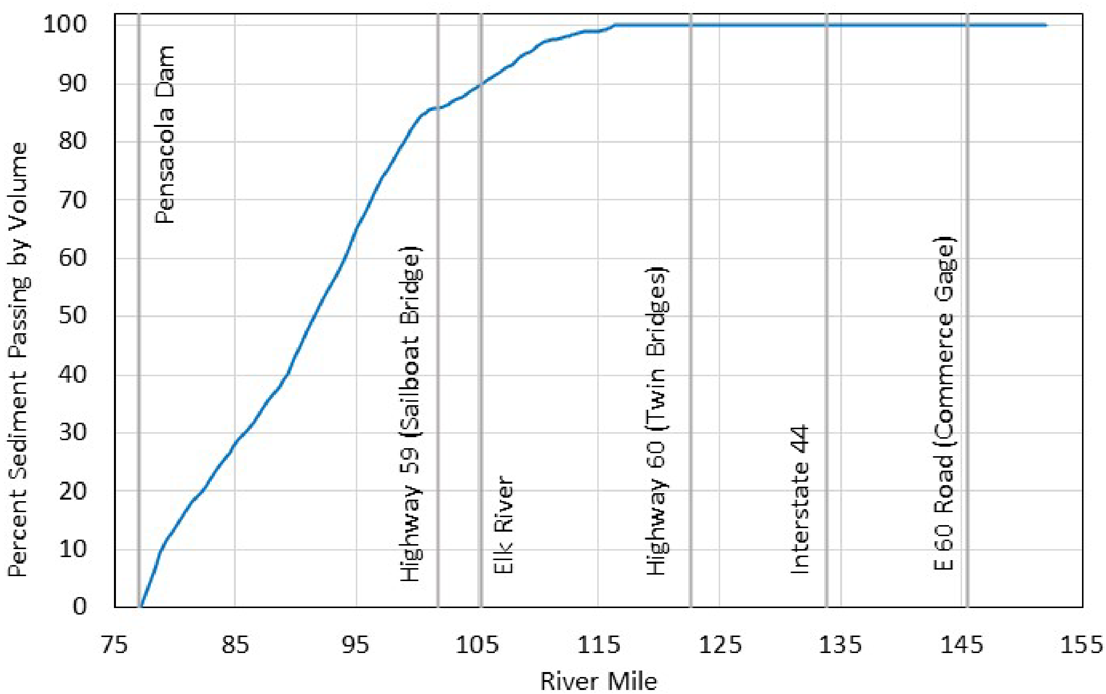
τ	=	bed shear stress
ϱ	=	specific weight of water/acceleration of gravity
f	=	Darcy-Weisbach friction factor
V	=	water velocity

The shear stress computed by Y d S was compared to 1/8 ϱ f V^2. This analysis showed that in the lower part of the reservoir, the shear stress using Y d S is significantly different than shear stress using 1/8 ϱ f V^2. For purposes of this analysis, the approach for computing hydraulic shear stress is the velocity method.

The shear stress generally decreases in the downstream direction as depths and cross-sectional area of the flow increases as it flows into the reservoir. As a point of reference (although not used in this component of the analysis), Figure 95 includes the values of critical shear stress at the surface of the sediment column developed from the SEDflume data and laboratory analysis.

The next component of the analysis is to use the sedimentation pattern that historically occurred based on the change in bathymetric data. Figure 96 presents the percentage of sediment by volume passing each cross section. The volumes were computed directly from the HEC-RAS geometry data using the average end area method from one cross section to the next and the distance by RM between sections.

Figure 96
Cumulative Percentage Sediment Passing by Volume 2009–2019



Note that the location where the percentage of sediment passing begins to drop below 100% is at approximately RM 116. At this location, the average hydraulic shear stress is approximately equal to the minimum critical shear stress for the surface layer of cohesive sediment from the SEDflume laboratory analysis.

These two sets of information were then combined to develop a relationship between hydraulic shear stress and the percentage of sediment passing downstream with the 2009 geometry (Figure-97).

Figure 97
Percentage of Volume Passing vs. Shear Stress on Neosho River, 2009 Geometry

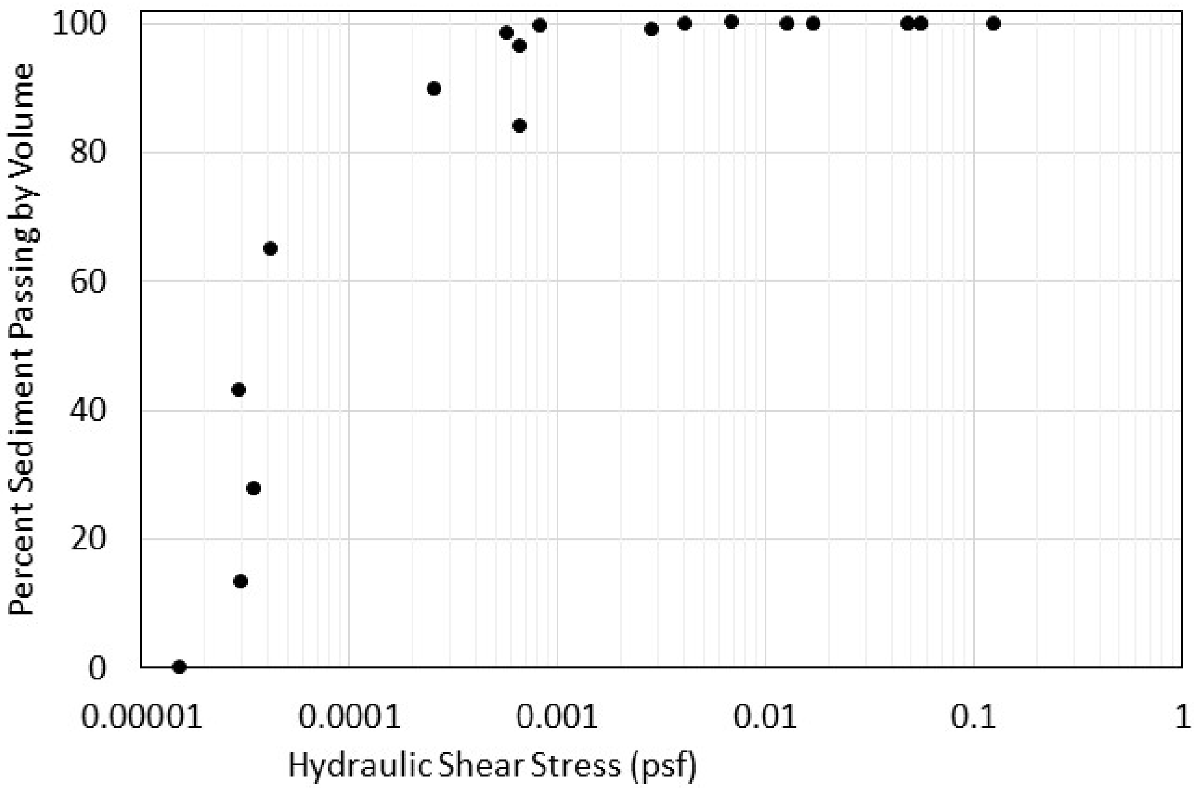
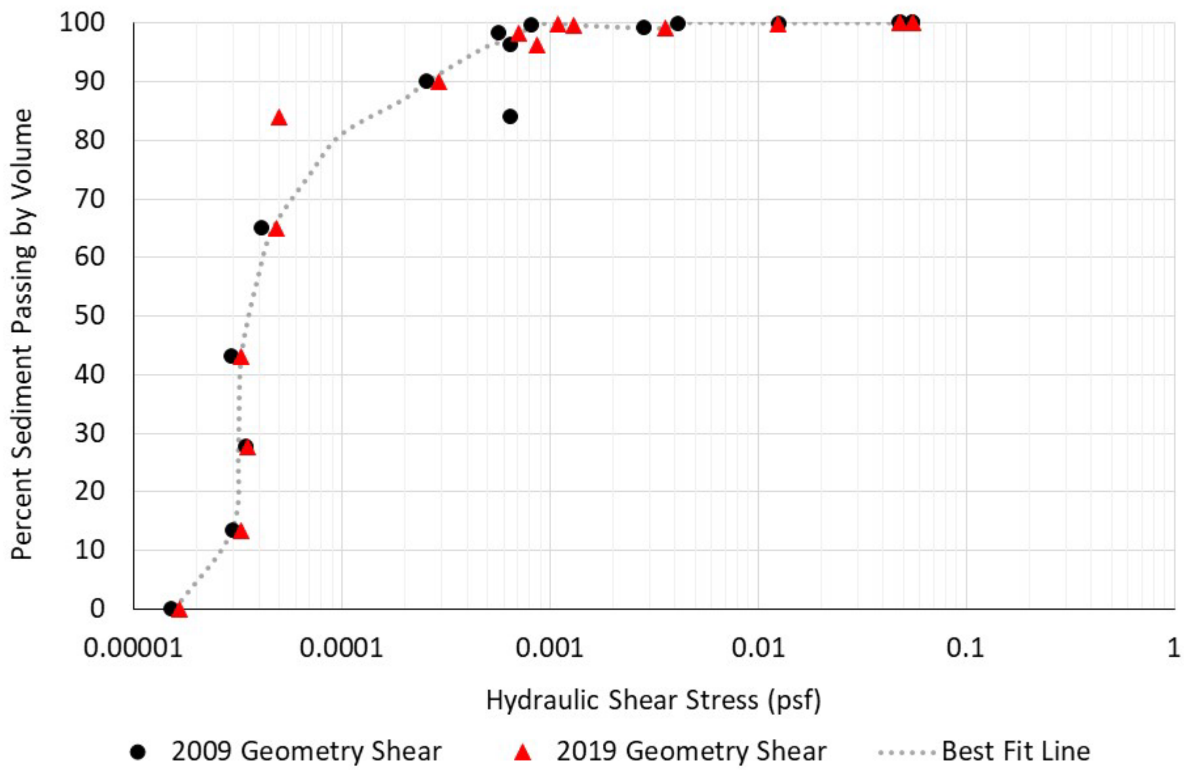


Figure 97 clearly demonstrates that there is a relationship between hydraulic shear stress and sedimentation pattern. To bracket this relationship developed between hydraulic shear stress and sedimentation that occurred between 2009 and 2019, the same information was developed based on applying HEC-RAS using 2019 geometry and the sedimentation that occurred during this time period (Figure 98).

Figure 98
Percentage of Volume Passing vs. Shear Stress on Neosho River, Comparison of 2009 Geometry and 2019 Geometry



The best fit line above correlates to the values shown in Table 23.

Table 23
Relationship between Shear Stress and Percent Sediment Passing by Volume

Shear Stress (lb/ft^2)	Percent Volume Passing (%)
1.59E-05	1.64E-06
2.99E-05	13.48
3.20E-05	27.71
3.30E-05	43.00
4.00E-05	57.00
4.70E-05	65.03
7.00E-05	74.00
1.00E-04	81.00

Shear Stress (lb/ft^2)	Percent Volume Passing (%)
2.00E-04	87.00
2.56E-04	89.93
5.00E-04	96.00
6.54E-04	97.00
8.22E-04	99.50
1.10E-03	99.96
1.31E-03	99.61
2.84E-03	99.12
3.58E-03	99.12
4.14E-03	99.96
6.63E-03	100.04
6.87E-03	100.04
1.24E-02	99.96
1.67E-02	100.00
4.88E-02	100.00
5.55E-02	100.00
5.56E-02	100.00

Using the 2009 or 2019 hydraulics that bracket the 2009 to 2019 change in sedimentation pattern produces essentially the same resulting relationship between hydraulic shear and sedimentation. This lends some confidence in using this relationship to predict future patterns of sedimentation, based on different scenarios of flow and reservoir operations by computing the hydraulics through fixed-bed HEC-RAS simulation for alternative scenarios and then applying the relationship to develop alternative future sedimentation patterns. This is similar to considering the reservoir as a full-scale physical model and developing relationships from the data and analysis to make predictions.

With this relationship based on data and hydraulic analysis (using the hydraulically calibrated HEC-RAS model), the fixed-bed HEC-RAS model was then run using the anticipated reservoir operation and future flow scenario (see Section 7). HEC-RAS produces the longitudinal hydraulic shear distribution under the anticipated operation and future flow scenario. This hydraulic shear distribution is then applied to the above relationship between hydraulic shear and the percentage of sediment passing. From this, the percentage of sediment passing based on hydraulic shear is then related back to location along the profile because the locations where the various hydraulic shear stresses are known are from the output of HEC-RAS.

4.5.1 *Future Scenarios*

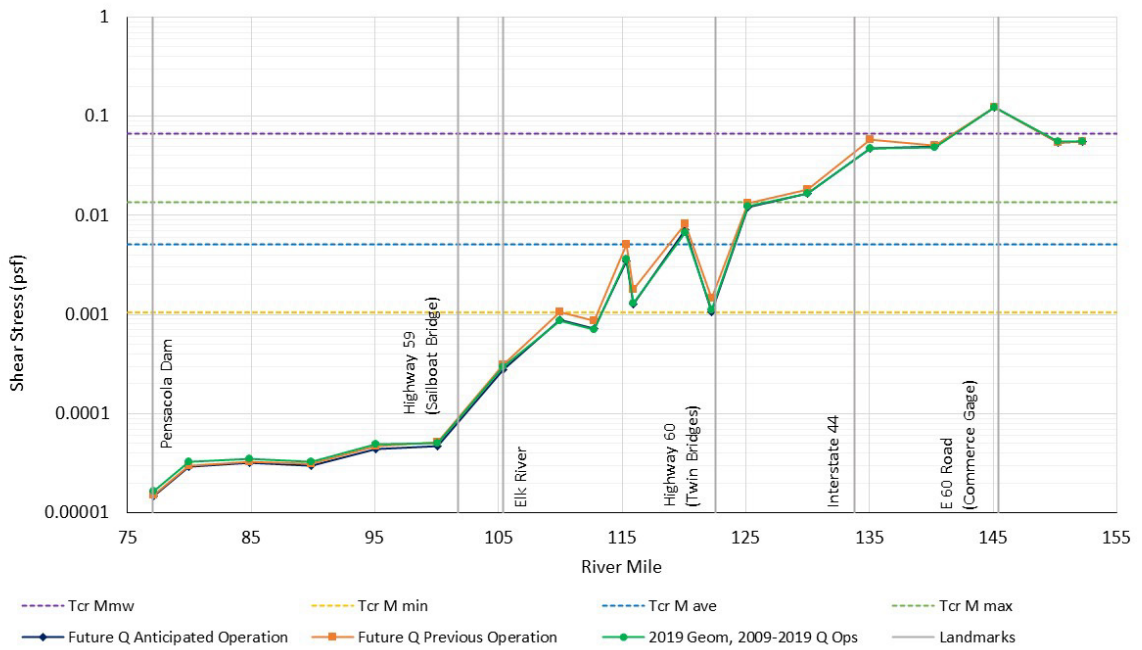
To quantify the effect of future flow and operation scenarios on sedimentation, the hydraulic shear stresses were calculated using the fixed-bed HEC-RAS model for anticipated and baseline operation scenarios using a 50-year period of flow as described in Section 7.1.1. The basic statistics of average flow and water level for these flow and operation scenarios are summarized in Table 24, along with the 1940 to 2009 and 2009 to 2019 historical data for comparison.

Table 24
Average Discharge and WSE at Pensacola Dam for Future Scenario

Tributary	1940–2009	2009–2019	2020–2069 Anticipated	2020–2069 Baseline
Neosho River (cfs)	3818	4312	4183	4183
Tar Creek (cfs)	48	40	55	55
Spring River (cfs)	2212	2664	2526	2526
Elk River (cfs)	822	953	887	887
WSE (feet PD)	740.95	743.49	742.57	741.65

The average hydraulic shear stress for the anticipated operation and baseline operation 50-year scenarios is shown in Figure 99 (also compared to the run using 2019 geometry and 2009 to 2019 historical flows and operation). Note that all three scenarios produce similar results with the future flows, with "baseline operation" resulting in slightly higher shear stresses (by 13%) than the "anticipated operation" due to the lower average water level.

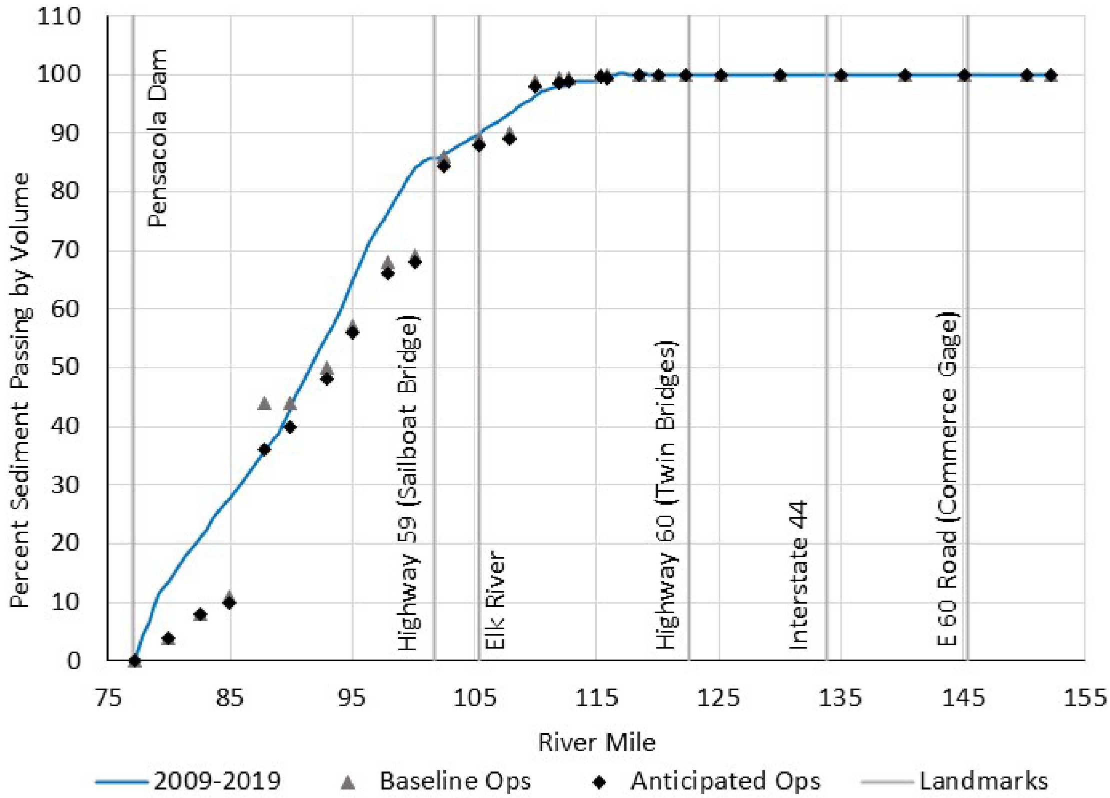
Figure 99
Average Hydraulic Shear Stress Profile on Neosho River during Future Scenario



Notes:	Tcr Mmw	Critical shear stress for mass wasting
	Tcr M min	Minimum critical shear stress for particle erosion across all samples
	Tcr M ave	Average critical shear stress for particle erosion across all samples
	Tcr M max	Maximum critical shear stress for particle erosion across all samples
	Future Q Anticipated Operation	Future flows under *Anticipated Operations*
	Future Q Baseline Operation	Future flows under *Baseline Operations*
	2019 Geom, 2009-2019 Q Ops	2009-2019 historical flows and reservoir operations

The hydraulic shear stress from the 2020 to 2069 hydrology with the anticipated and baseline operations were then utilized to develop the percent sediment passing graph. These values were then correlated back to the location along the river profile. This results in the graph shown in Figure 100 (with the previously developed relationship based on change in bathymetric data for comparison).

Figure 100
Cumulative Percentage of Sediment Passing by Volume for Future Scenario



Based on these computed points of percent passing along the profile through the reservoir and the surface area between the cross sections, coupled with the density of sediment, the corresponding vertical deposition of sediment was estimated for the future 50-year scenarios.

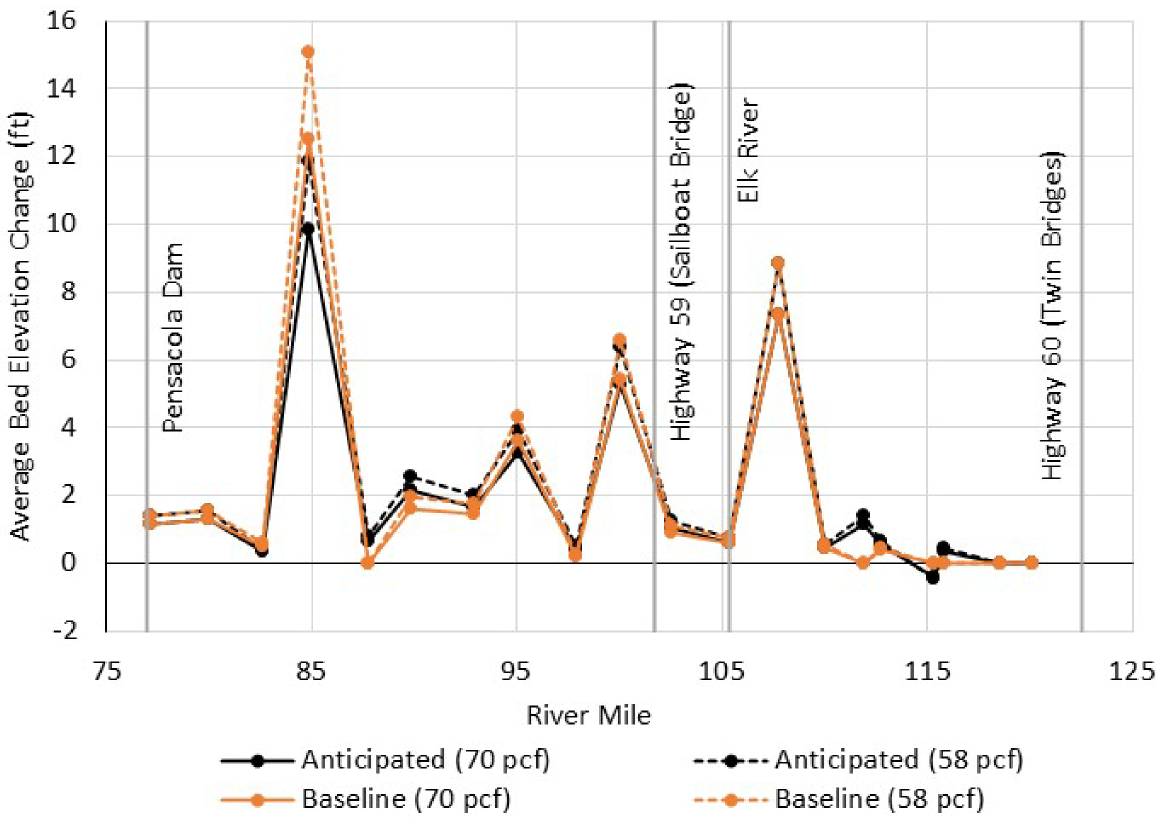
Based on the longitudinal distribution of the percentage of sediment passing cross sections along the river/reservoir profile, the average change in bed elevation due to sediment deposition was calculated along this profile. The tonnage of the incoming sediment load was calculated using the 2020 to 2069 hydrology and the sediment rating curves (unbiased post-1964 for the Neosho River and unbiased post-2009 for the Spring and Elk rivers and Tar Creek). To compute the depth of deposition requires conversion of the tonnage of sediment to volume and then to depth of sediment deposition. Sediment tonnage was then converted to volume using the density or specific weight of the sediment deposit as discussed in the next paragraph. The depth of sediment deposition was then computed by dividing the volume by the surface area over which the sediment is deposited.

Some specific weight data were collected in the upper layers of the sediment deposit as part of the SEDflume data collection program. These data showed that the upper layer (approximately 1 foot) of the sediment deposit ranged from 21.2 to 103 pcf and averaged 52.7 pcf. Although no actual data exist to quantify the specific weight below the surface layer, sediment size distribution data from the core sample dataset show that the sediment deposition in the delta feature region consists primarily of silt and clay (89%) and an average of 11% sand (using the USDA definition of sand being <0.05 mm). This information, combined with the relationship developed by Lane and Koelzer (1943), results in a range of specific weights ranging from 63 to 78 pcf and averaging 70 pcf. The specific weight utilized in the STM (Section 6.2.2) was 58 pcf. Both values are plausible and generally fit within the range of values either found in the sampling of Grand Lake (see Section 2.3.3) or from the analysis of other reservoirs as shown by Lane and Koelzer (1943).

The first level of analysis is to use the tonnage of sediment coming into the reservoir based on the 2020 to 2069 hydrology and sediment rating curves spread uniformly over the surface area of the reservoir (45,000 acres) at an average density of 70 pcf. This results in an average depth of sediment deposition of 1.59 feet over this 50-year time period. Although this basic calculation provides some perspective on the quantity of sediment in terms of depth of deposition, the next step is to distribute this sediment based on the information generated from the longitudinal distribution of hydraulic shear for this 50-year time period and the relationship between hydraulic shear and percentage of sediment passing cross sections along the river/reservoir. Results of this analysis using the percentage passing each location and the surface area of the reservoir, coupled with average density of 70 (58) pcf, and incoming sediment load over the 50-year time period of 109,141,619 tons were plotted along the longitudinal profile from RM 122.25 to RM 77.12 for both future scenarios (Figure 101) showing average bed elevation change and Figure 102 showing volume change). The analysis assumes sediment from the various tributaries comes into the Neosho River rather than subtracting the Elk River component and only including this sediment at the confluence. This compensates to some degree for the fact that approximately 10% of the drainage area is not accounted for in terms of flow and sediment input which, in turn, is counteracted by the fact that the sediment trapping efficiency is somewhat less than 100%. These relatively small percent differences being on the order of 10% or less is well within the scatter exhibited by the sediment transport data and the measurement errors in the flow data.

The quantitative analysis shows very little sediment deposition, with even some scour, down to approximately RM 115. The analysis shows approximately 2 feet (2.6 feet at 58 pcf) of deposition between RM 115 and RM 112.75. This is in an area of relatively lower bed profile between the two higher points at RM 115 and RM 112.75 shown on the thalweg profile. Between RM 112.75 and RM 110, the analysis shows some scour. The quantitative analysis shows no significant rise of the existing high point of the delta as indicated in the 2009 and 2019 bathymetric surveys. Downstream of RM 110, more significant sediment deposition occurs, but the analysis shows some oscillations between sedimentation and scour. This analysis shows minimal sedimentation on the top surface of the delta feature (with some deposition being indicated in the low area between the two existing high points on the thalweg profile). The bulk of the sediment delivered to the reservoir deposits on the lower face of the delta downstream of RM 110. This is consistent with the progression of delta formation in the scientific literature (Figure 103 and Figure 104), where the downstream face of the delta progressively builds in the downstream direction on the foreset slope.

Figure 101
Average Bed Elevation Change 2020–2069 (70 pcf Sediment Density)



Notes: RM 85 is approximately 1.1 miles upstream of the Drowning Creek confluence.

Figure 102
Average Bed Volume Change 2020–2069

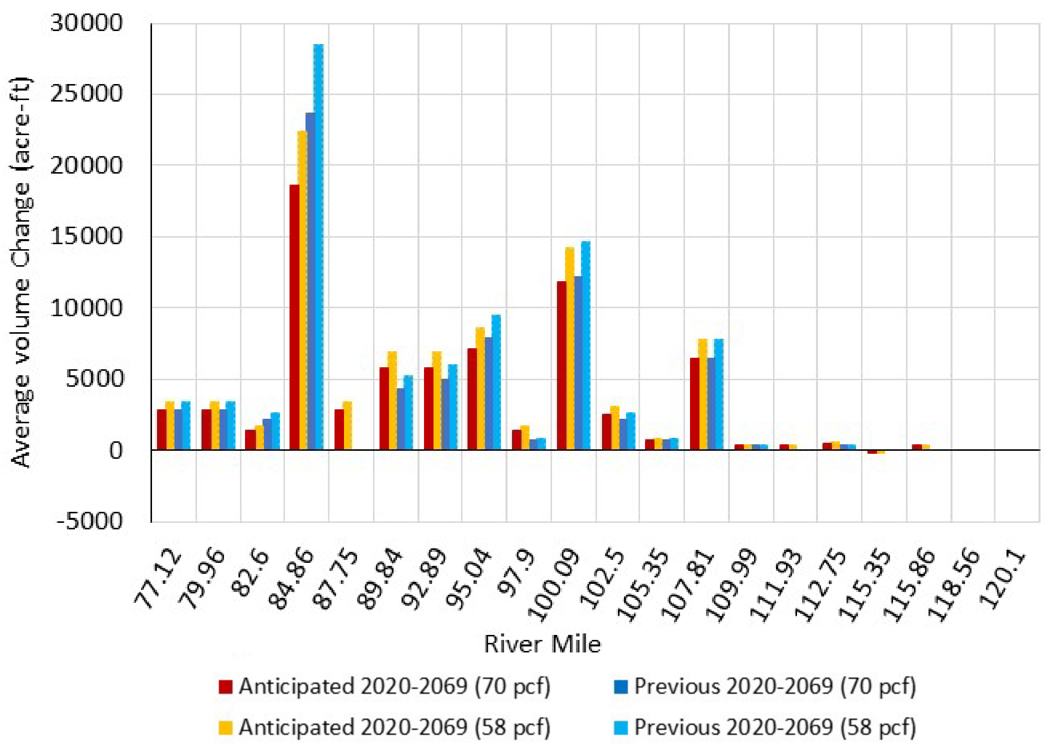
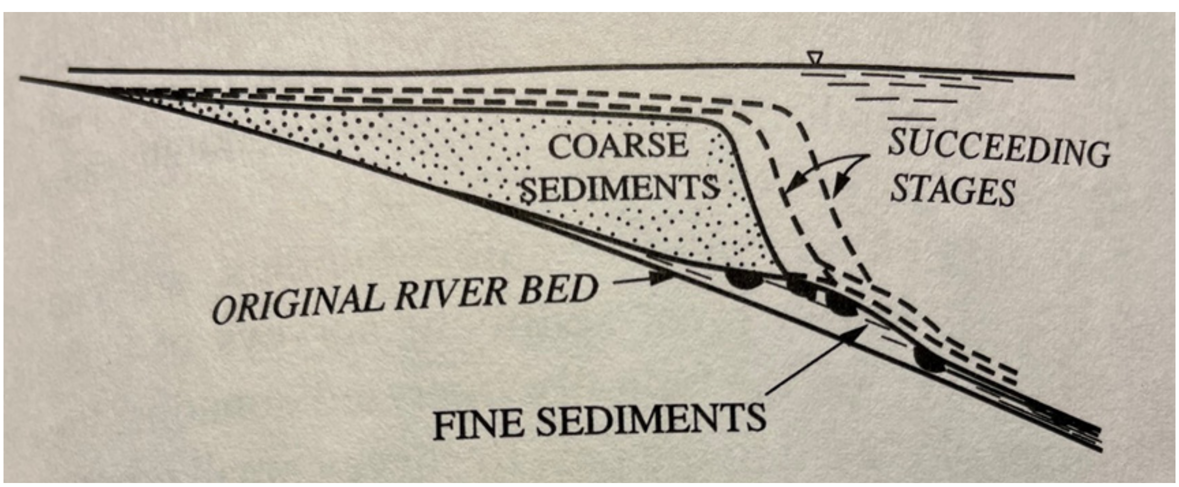
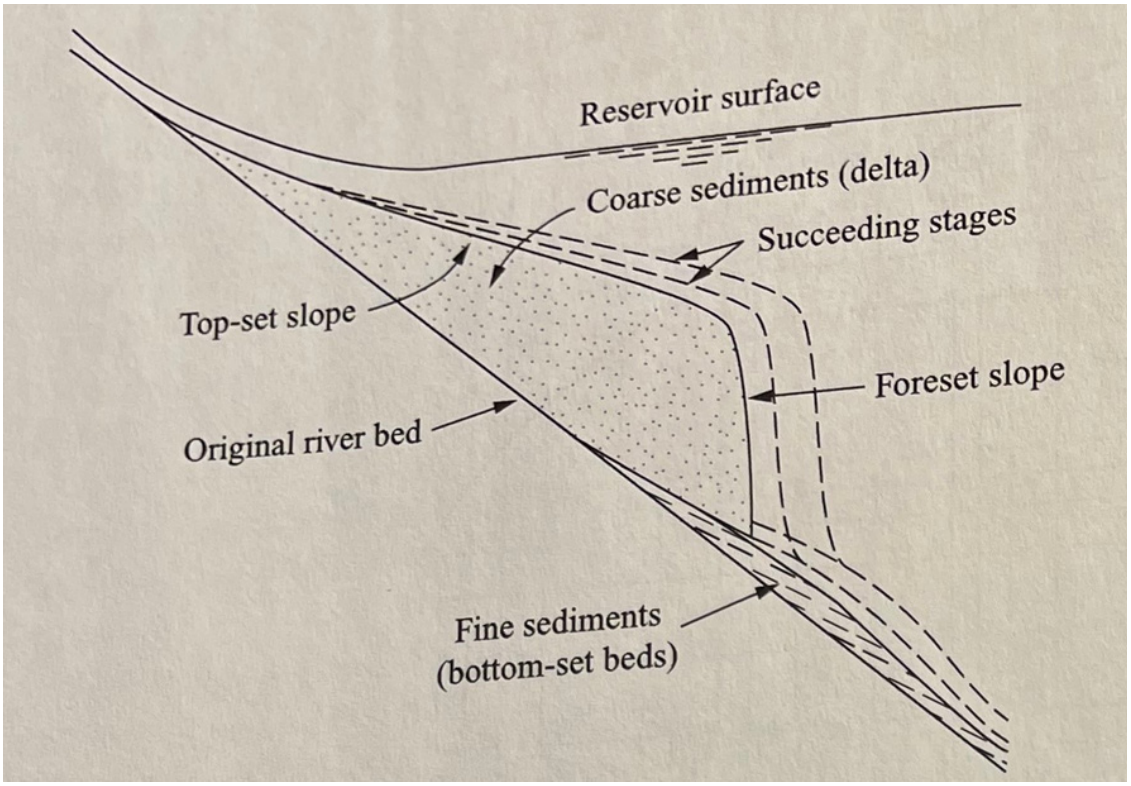


Figure 103
Profile of Typical Reservoir Delta



Source: Figure 3.30, Vanoni (2006)

Figure 104
Reservoir Delta Form



Source: Figure 5.44, Vanoni (2006)

Again, one of the key conclusions is that because the vast majority of the sediment being transported down these rivers and into the reservoir consists of silt- and clay-sized materials (with very little sand or coarser material), this sediment is primarily depositing 35 miles downstream from the upper end of the reservoir (most sedimentation in the future flow and operation scenarios is quantified to be occurring downstream of RM 110).

As discussed in Section 3, there are multiple factors contributing to the delta feature and its location within the study area. The Ozark Uplift formation, confluence of the Spring River, and the confined upstream channels all play a role in the location and elevation of the delta feature.

Furthermore, the delta feature is currently in dynamic equilibrium, with all available evidence suggesting that deposition on the crest during low flows is washed further downstream during high flows. Dynamic equilibrium, in engineering terms regarding sedimentation, occurs when the bed experiences relatively minor fluctuations about a mean bed elevation with no significant long-term trend.

The long-term growth of the feature is expected to be on the downstream face, where it will affect storage volume. Its presence and predicted future evolution do not provide evidence that future upstream water levels will significantly increase due to sedimentation.

Regardless of that fact, it is also relevant to note that the USACE dictates Project operations whenever WSE at the dam is above 745 feet PD or expected to rise above that level. GRDA has no control over the incoming streamflow, nor do they even control dam operations during the largest events. As shown in the analysis of sediment inflow at or above 745 feet PD, which only occurs 19.8% of the time, delivers 75.6% of the incoming sediment load to the reservoir. This sediment inflow is a result of upstream erosion and sediment transport over which the Project has no control and most of the sediment is delivered to the reservoir when USACE is in operational control of Grand Lake.

4.6 Trapping Efficiency

Several methods have been developed to estimate the sediment trapping efficiency, which are typically based on such factors as the inflow rate compared to storage capacity and residence time of water in the reservoir. These relationships were developed based on data from several reservoirs for which such data exist.

A significant set of data exists on sediment trapping efficiency of a major reservoir on the Neosho River, the John Redmond Reservoir located upstream of Grand Lake. Data have been collected for a considerable time that include the volume of sediment deposited as well as the incoming sediment load and release of sediment downstream of the dam. This set of data is more extensive and complete than most datasets used in the development of the typical sediment trapping efficiency relationship. It is also noteworthy that these data were collected on the river with the greatest sediment load (Neosho River) that contributes to Grand Lake.

John Redmond Reservoir is primarily a flood control reservoir with a relatively small conservation pool and a large flood control pool above the conservation pool. The conservation pool provides 50,501 acre-feet of storage and the flood control pool provides 524,417 acre-feet of storage (Engineering-Environmental Management, Inc. 2013).

The top of the conservation pool is at elevation 1,039 feet above the National Geodetic Vertical Datum of 1929 (NGVD29) and the top of the flood control pool is at elevation 1,068 feet NGVD29. The reservoir covers 29,800 acres and the length of the reservoir is approximately 4.5 miles from where water enters the reservoir to the dam. A source of information on the studies of reservoir sedimentation in John Redmond Reservoir is found in a 2021 USGS report (Kramer et al. 2021). The following information is summarized from this report.

The drainage area contributing to John Redmond Reservoir is 3,015 square miles and has a storage capacity of 816,795 acre-feet.

During years with a complete data record at Neosho Rapids and Burlington (2010, 2014 to 2019), the trapping efficiency of the reservoir ranged from 82% to 94% (mean: 89%).

Different reservoir outflow management strategies, including operating near normal capacity as opposed to higher flood pool levels, could reduce the total reservoir storage lost by 3% (approximately 261 acre-feet).

Grand Lake is significantly larger than John Redmond Reservoir. Grand Lake is approximately 68 miles long and the storage capacity is approximately 1.44 million acre-feet (at elevation 745 feet PD). Being significantly longer and with a larger storage capacity, it is likely that the sediment trapping efficiency of Grand Lake is greater than that of John Redmond Reservoir. Because the sediment trapping efficiency of John Redmond Reservoir averages 89% (with a range of 82% to 94% over recent years), the sediment trapping efficiency of Grand Lake is well into the 90%-plus range, if not approaching the high 90% range. A review of aerial images shows some clear water released from Pensacola Dam at relatively high flows (with quite turbid water flowing into the reservoir), but on other images some turbid water is being released through the dam. This suggests that under some circumstances the sediment trapping efficiency is not 100%. Based on the comparison with John Redmond Reservoir, which recently averaged 89%, again it is likely that the sediment trapping efficiency of Grand Lake is in the high 90% range based on these comparisons and observations.

Regarding the effect of operations on flushing sediment through John Redmond Reservoir, the USGS study found that operating John Redmond Reservoir at an elevation of 1,039 feet NGVD29 (which is the top of the conservation pool) was 3% more effective in reducing storage loss than operating the reservoir "to higher flood pool" levels (top of flood pool is 1,068 feet NGVD29). So, a reduction in water level of up to 29 feet only produced a 3% reduction in sediment trapping. This was determined by continuous water quality monitoring coupled with a two-dimensional (2D) hydrodynamic model (CE-QUAL-W2) to evaluate sediment trapping reduction by altering reservoir operations. The specific study (Lee and Foster 2013) as summarized in Kramer et al. (2021) concluded that "The idealized alternative outflow management scenario was projected to reduce sediment trapping in the reservoir by about 3 percent."

Given that Grand Lake is significantly larger and operates the conservation pool at a range of 3 feet, lowering the water level only a few feet will not produce significant benefits in terms of sediment trapping.

Based on the quantity of sediment computed using the sediment transport rating curves over the 50-year future scenario, approximately 109 million tons of sediment are delivered to Grand Lake. This converts to a volume of 71,587 acre-feet at 70 pcf and 86,398 acre-feet at 58 pcf (assuming a 100% sediment trapping efficiency). This volume of sediment resulting in storage loss to the reservoir would be distributed according to the results of the hydraulic shear stress analysis for the anticipated (or baseline) operations as shown in Figure 93. This figure shows that no sediment is deposited upstream of RM 116, approximately 10% of the sediment is deposited between RM 116 and RM 105 (Elk River confluence), approximately 22% is deposited between RM 105 and RM 100, and the remaining 68% is deposited between RM 100 and the dam.

4.7 Summary and Conclusions of Quantitative Analysis

The quantitative analysis developed a relationship between hydraulic shear stress and the pattern of sedimentation specifically in terms of the percent of sediment passing each cross section based on the change in historical bathymetry using historical flows and operation.

The quantitative analysis of the future 50 years of hydrology and operation shows no significant sediment deposition on top of the delta feature that would adversely affect existing hydraulic control in upstream reaches. Most of the sediment delivered to the reservoir is transported past the top of the delta feature, farther downstream to the downstream face of the feature. Approximately 98% to 99% of the incoming sediment load is transported past RM 110. The future flows with baseline operations cause slightly reduced deposition on the downstream face of the delta feature and shift the deposition slightly downstream compared to the anticipated operation. This comparison of computed sediment deposition pattern demonstrates the very small effect on sedimentation of operating the reservoir according to baseline operations.

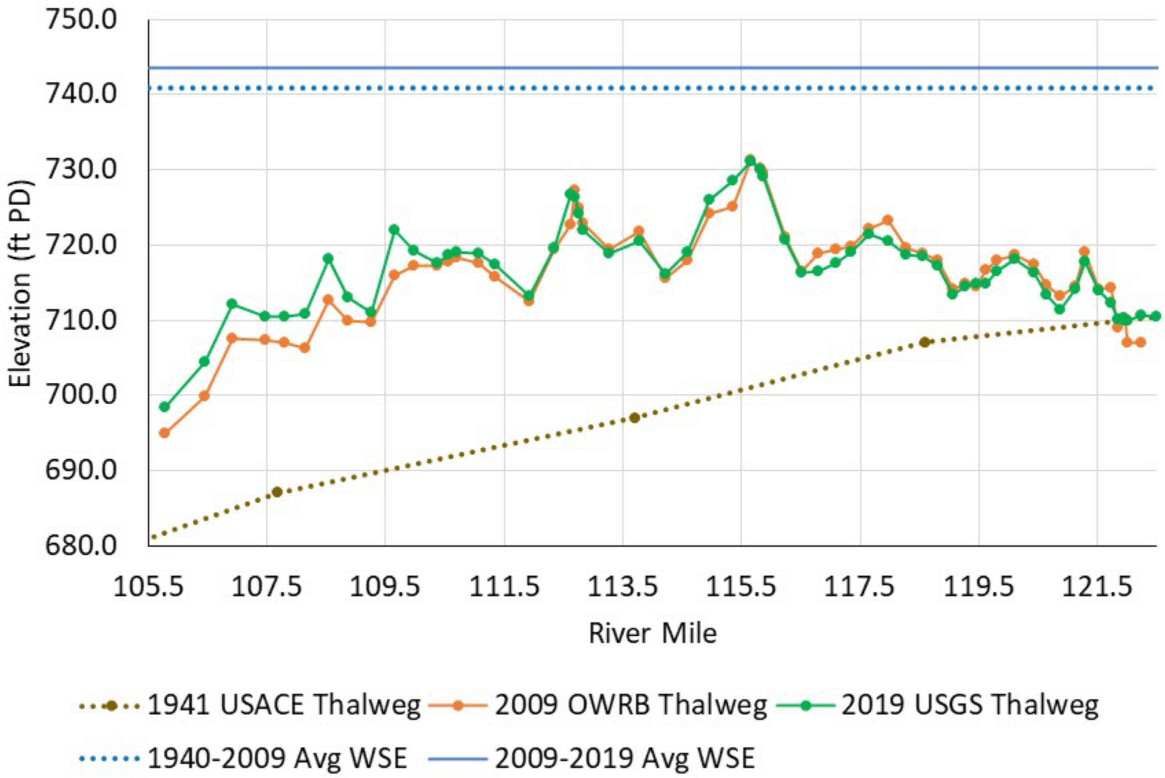
The average hydraulic shear stress for future flow conditions remains greater than the minimum critical shear stress determined by the SEDFlume analysis down to approximately RM 110. Sedimentation downstream of RM 110 is in the reach of the reservoir that is several feet below the highest elevation of the delta feature, which occurs farther upstream at approximately RM 116. For example, the predicted elevation of the delta feature with an average of 3 to 4 feet of deposition after 50 years reaches an elevation of approximately 724 feet PD. The highest elevation in the delta feature based on the 2019 data, which occurs at approximately RM 116 (approximately elevation 729 feet PD), remains without significant aggradation at that location after 50 years. The quantitative analysis demonstrates that the top surface of the delta feature is in a state of dynamic equilibrium. This state of dynamic equilibrium is consistent with the fact that the average shear stress over the top of the delta feature is generally equal to or greater than the minimum critical shear from the SEDflume analysis. In addition, considering that much of the sediment passing through this area continues farther downstream being in a state of fluid mud, rather than actual stationary deposition as discussed in the scientific literature, this further suggests a state of dynamic equilibrium of the top of the delta feature.

With this pattern of predicted sediment deposition, located downstream of the high point on the delta feature and at an elevation several feet below this high point, it cannot reasonably be expected to adversely affect upstream hydraulics and flooding. Based on the relatively small change in effectiveness of moving sediment downstream with the comparison between the future flows with anticipated operation and baseline operation, as well as the USGS analysis of the effect of significant changes in water level resulting in very limited changes in sediment storage in John Redmond Reservoir, there is no basis to conclude that there would be any significant benefit in continuing to operate Grand Lake as it has been under baseline conditions or at lower levels.

Bathymetric data from 1940 to 2009 show the development of the delta feature. Again, as discussed in Section 3, there are multiple factors contributing to the location and size of the delta feature. It is located on the Ozark Uplift, which slows water and increases deposition. The steeper Spring River contributes additional sediment loading that is likely to deposit near the confluence as flow velocities decrease. Additionally, the rocky cliffs and levees confining the Neosho River channel upstream of the confluence result in raised velocities and sediment carrying capacity. As flow reaches the site of the delta feature, flows can spread, velocities and corresponding bed shear stresses decrease, and sediment drops out of the water column.

The average water level at Pensacola Dam between 1942 (at the start of the earliest reliable records) and 2009 was 740.95 feet PD. From 2009 to 2019, there was no significant rise of the top of the delta surface on what is called the top-set slope, yet the average water level was 743.49 feet PD. The data show delta formation and growth on the top-set slope from 1940 to 2009 when the average water level was 2.49 feet lower than the 2009 to 2019 time period when virtually no upward growth on top of the top-set slope occurred. Figure 105 shows the delta feature evolution. As discussed previously, there is no indication that the crest elevation of the delta feature is expected to increase over the next 50 years either in literature (Vanoni 2006) or in this analysis. The data contradict the theory that operating at a lower level would keep the level of the top of the top-set slope lower. Although this could be considered contradictory to the approach suggested by the City to keep the delta surface low, it emphasizes the complexities of interaction between flow, sediment transport, critical shear, and water level to eventuate equilibrium.

Figure 105
Comparison of Historical Thalweg Profiles on the Neosho River



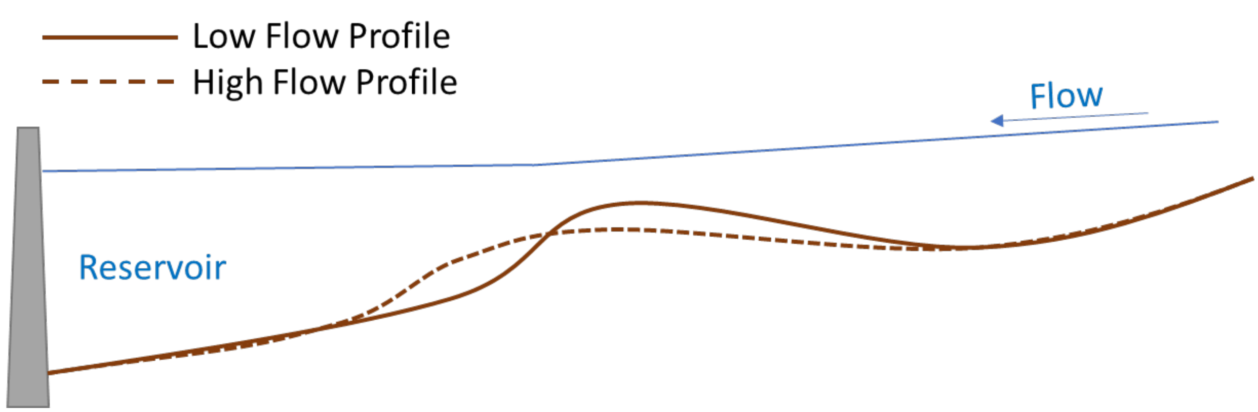
Note that the delta feature accumulation occurred primarily during the lower water levels from 1940 to 2009, and vertical growth was essentially stopped from 2009 to 2019 when average water levels were higher despite the City's claims that increased water levels will create a higher delta feature. By 2019, further deposition is only expected to occur on the downstream face of the delta feature rather than on the crest as predicted by scientific literature (Vanoni 2006).

Once the top of the top-set slope reached the level where the hydraulic shear equals or exceeds the critical shear of the sediment surface over a sufficient portion of time, then no significant sediment deposition occurs on this key portion of the delta feature, and a state of dynamic equilibrium has developed. This is consistent with the findings of the studies on John Redmond Reservoir, where operating the reservoir at a significantly lower water level only improved sediment transport through the reservoir by 3%.

Based on the quantity of sediment computed using the sediment transport rating curves over the 50-year future scenario, approximately 109 million tons of sediment are delivered to Grand Lake. This converts to a volume of 71,587 acre-feet at 70 pcf and 86,398 acre-feet at 58 pcf (assuming a 100% trapping efficiency). This volume of sediment (storage loss from the reservoir) would be distributed according to the results of the hydraulic shear stress analysis for the anticipated (or baseline) operations. The analysis shows that virtually no sediment is deposited upstream of RM 116, approximately 10% of the sediment is deposited between RM 116 and RM 105 (Elk River confluence), approximately 22% is deposited between RM 105 and RM 100, and the remaining 68% is deposited between RM 100 and the *dam*.

It is logical to conclude the delta feature is currently in dynamic equilibrium because the quantitative analysis relating shear to percentage of sediment being transported farther downstream indicates no significant sediment deposition on the top surface of the delta feature (topset slope). A riverine-like system such as the upper reservoir, which includes the delta feature, moves sediment according to the shear stress created by inflows. As inflows increase, shear stress increases proportionately. In other words, the upper reservoir's ability to move sediment increases proportionally with inflow. Therefore, if there is a significant inflow event, rather than creating a significant backwater effect, the finer sediments composing the delta feature will be moved farther downstream and out of the way because they will not have the ability to hold back the water and create a backwater effect (Figure 106). As shown by the hydraulic analysis, the average shear stress is generally greater than the critical shear stress on the topset portion of the delta feature. The quantitative analysis shows that most of the sediment deposition occurs downstream of the topset slope where hydraulic shears progressively decrease below critical shear for the cohesive sediment. To believe the delta feature has the ability to hold back a significant inflow event and create a backwater effect when it is composed primarily of fine sediments as the City asserts is contradictory to the fundamental scientific principles of shear stress and dynamic equilibrium.

Figure 106
Conceptual Delta Formation under Low and High Flow Conditions



It is important to remember that Grand Lake is under operational control of USACE when the water level approaches or exceeds elevation 745 feet PD and that under these conditions, which only occur 19.8% of the time, delivers 75.6% of the incoming sediment load to the reservoir. Neither the upstream sediment load nor operational control of Grand Lake is controlled by GRDA at that time.

5 Sediment Transport Model Development

Following the data-gathering phase of the project, the team developed the STM. Terrain files, USGS gaging station records, sediment transport rates, and sediment sampling information were used as inputs for the model.

The STM was developed using HEC-RAS v. 6.2 as available from USACE. The software is one of the leading fluvial system modeling packages and is frequently used for flood evaluations, hydrologic and hydraulic studies, and sediment transport estimates. The original version of the STM as submitted in December 2021 was built in HEC-RAS v. 5.0.7. This decision to use the newer software was made to take advantage of more robust sediment transport code that was included with the software updates.

The STM directly models the system above RM 100 as requested in FERC's May 27, 2022 SMD (page B-6). This modification to the original plan allows more accurate modeling of sediment deposition patterns by focusing primarily on the non-cohesive portion of sediment loading (and cohesive sedimentation not defined by density currents) and its impacts on water levels, which HEC-RAS was developed to evaluate. HEC-RAS is less well-suited to model the cohesive sediment that is found lower in the reservoir.

As discussed in the USP and subsequent SMD, the results of the STM were exported to a one-dimensional (1D) UHM for hydraulic evaluation. The 1D UHM was based on the STM and was developed in HEC-RAS v. 6.2 to maintain consistency with the STM. The 1D UHM is distinct from the STM and was run in fully unsteady hydraulic-only mode. More detailed discussion of this model is included in Section 7.4 of this report.

5.1 Terrain Information

Terrain files were developed to provide input geometries for the STM. These files were compilations from a range of surveys performed between approximately 1940 and 2019. A full description of the available datasets can be found in Section 2.1.1 of this report. All elevations are reported in reference to the PD unless otherwise noted.

5.1.1 Circa-1940 Terrain

The circa-1940 terrain was built from digitized 1938 USACE topographic maps and surveyed channel information from 1941 and 1942. Topographic maps were georeferenced using Geographic Information System (GIS) software and contour lines were traced and assigned elevations.

These topographic data came from several sets of contour maps. One was a relatively high-resolution set of 1:10,000 maps with labeled contours. Another was a 1:31,680 maps that did not contain legible contours. Where the 1:10,000 maps were available, they were used to develop the topographic surface; the 1:31,680 maps were only used where the others could not be used (Figure 107).

Figure 107
Graphic Showing Map Coverage of the Study Area

Publish Date: 2022/08/05, 9:38 AM | User: epipkin
Filepath: Q:\Jobs\Mead_and_Hunt_2451\Sedimentation_Study_GRDA\Maps\Topography Sources.mxd

Note: The maps on white background are the 1:10,000 scale contour maps with legible, labeled contour elevations; maps with a brown background are the 1:31,680 scale with no legible contour elevation labels.
Source: USACE (1938)

Once all contours had been compiled, GIS software was used to create a three-dimensional (3D) surface, which provided a basis for the overbank portions of the system.

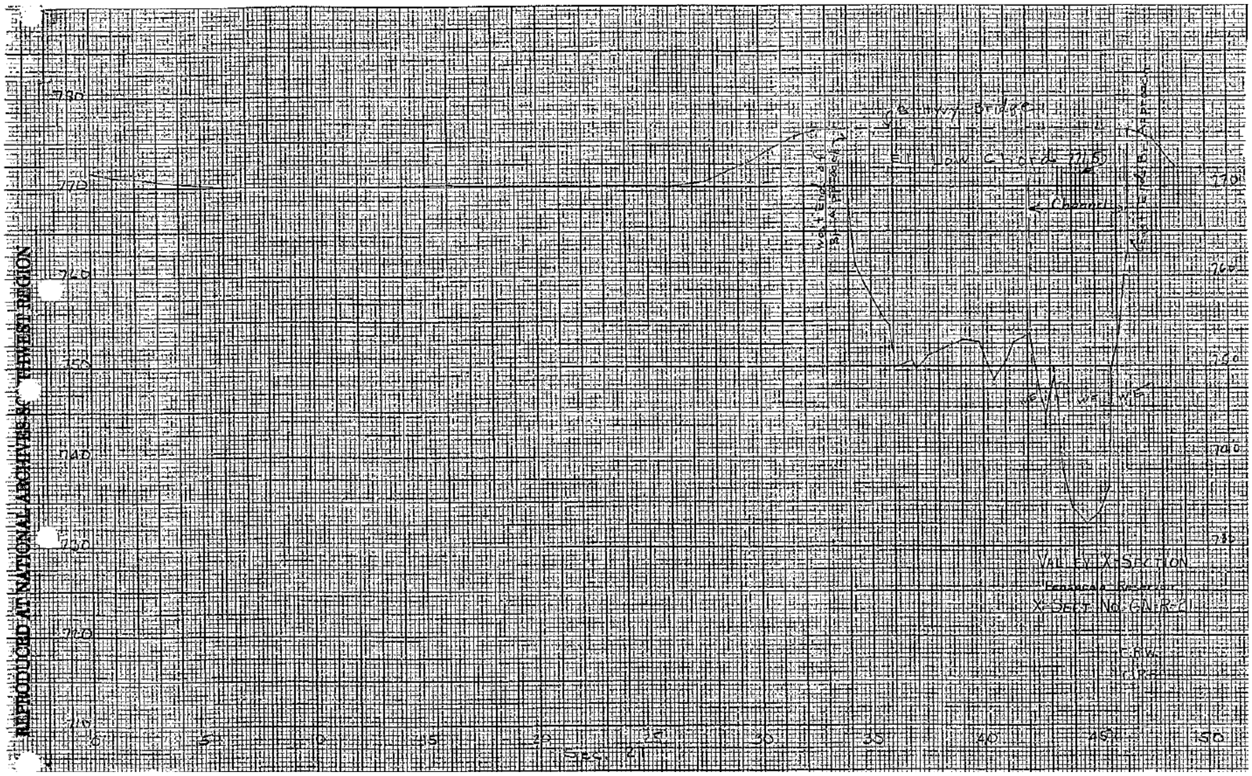
Channel surveys completed by USACE in 1941 and 1942 were then used to cut stream channels into the topography. As discussed in Section 2.1.1.1 of this report, there were no station/elevation data available for the Neosho River below the Neosho River/Spring River confluence. Instead, that data were estimated from elevation/area and elevation/width relationships.

The USACE reports mention plates that present the geographic location of surveyed cross sections, but the plates were not included in the files retrieved from USACE archives. Therefore, exact locations of surveyed cross sections were unknown. The USACE reports did include downstream reach lengths between cross sections. Given the changing stream meanders, uncertainty of circa-1940 survey measurements, and imprecise definition of reference points provided in the 1941 and 1942 USACE reports, there is uncertainty in the georeferenced location of many of these cross sections.

To address this shortcoming, known landmarks such as bridges were used to estimate the geographic location of surveyed cross sections. Between these landmarks, cross sections were placed according to documented downstream reach lengths. Linear scaling factors were applied to downstream reach lengths when the sum of documented reach lengths between landmarks did not match the physical distance between landmarks. This process was effective for portions of the Neosho River near the City of Miami where multiple, closely spaced bridges could be used as landmarks but was less effective along the Elk River where bridge locations were not documented in the circa-1940 cross-sectional surveys.

Several of the cross-section surveys included bridge geometries, which allowed for accurate placement of those cross sections. One example is shown in Figure 108, which is taken from the USACE (1942) revised envelope curve document and shows cross section GN-R-21 at the U.S. Highway 66 Bridge near Miami. Between known reference points, the distances were adjusted with a linear scaling factor to place cross sections more accurately.

Figure 108
Published Cross-Section Information for GN-R-21 Showing U.S. Highway 66 Bridge



Source: USACE (1942)

This figure is a typical image of the cross-sectional surveys and was chosen to illustrate the difficulty of using the circa-1940 survey data; it is difficult to read, horizontal scales are not explicitly stated, and hand-written notes are occasionally illegible. Regardless, this also represents the most complete dataset of site conditions at the time of Project construction.

On the Elk River, no bridges were included in the surveys (USACE 1941). Downstream reach lengths listed in the report were initially used to locate the surveyed cross sections. However, using these initial locations, the cross sections were approximately 20 feet above the topographic data. To better locate these cross sections, bank elevations were extracted from the reported surveys compared to streambank elevations in the 1938 USACE topographic maps. Correlation between surveyed cross-section bank elevations and topographic bank elevations were used to georeference the cross sections. The documented downstream reach lengths between the surveyed cross sections were maintained in the georeferenced set of cross sections to maintain the surveyed bed slope.

Once the locations of the channel cross-section surveys were defined, the channels were cut into the topographic surface along the stream thalwegs to produce a full circa-1940 terrain file. This was imported to HEC-RAS and model cross sections were cut from the terrain.

Model quality is sensitive to the quality of data available for model development. The terrain data represent one of the largest sources of uncertainty in this study. Data from circa 1940 is limited by the resolution of digital maps, lateral accuracy of original measurements, vertical accuracy of the available equipment, and legibility of contour labels on the available maps. There is also uncertainty regarding the georeferencing of the contour mapping and the exact locations of many of the surveyed cross sections, and there are no longer records available of the station-elevation data from many of the circa-1940 surveys.

These are imperfect datasets, but they also represent the *best available data for this time period*. These shortcomings in data quality were discussed in detail in both the USP submitted by GRDA in April 2022 and in Section 2.1.1 of this report. To address this, the STM was used to simulate bounding scenarios of high and low sedimentation as a means of accounting for the potential range of outcomes as discussed in Section 7.1.2 of this report.

5.1.1.1 Manning's n Values

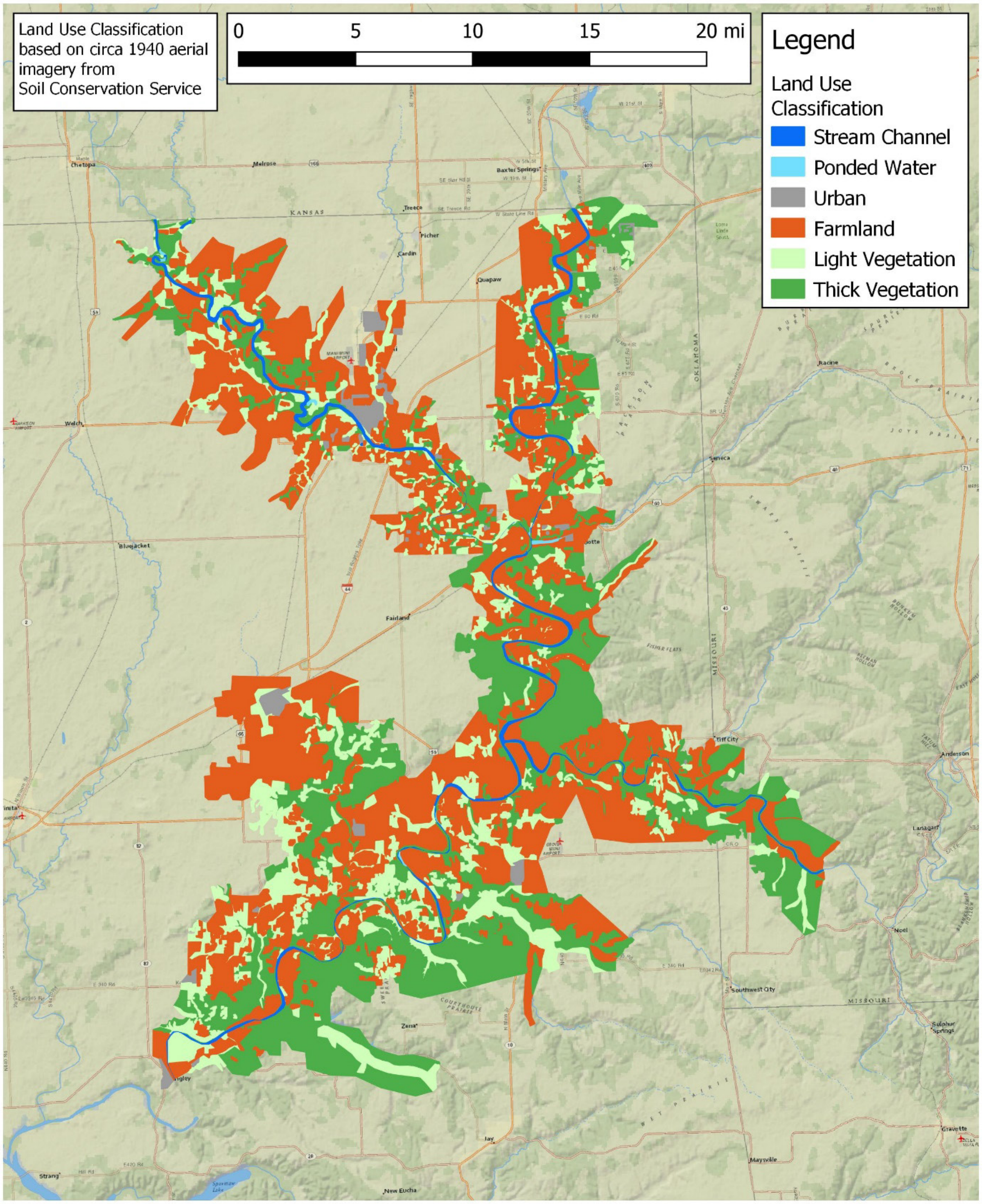
Manning's *n* values were assigned based on aerial imagery collected by the USDA (USDA 1938, 1939a, 1939b, 1940). The land use was visually identified and roughness parameters were developed according to Arcement and Schneider (1989). The parameters were assigned based on the composite roughness values shown in Table 25 and Figure 109.

Table 25
Composite Manning's *n* Values for Circa-1940 Land Use

Land Use Classification	Composite Manning's *n*
Stream Channel[1]	0.03
Ponded Water	0.04
Urban	0.07
Farmland	0.08
Light Vegetation	0.10
Thick Vegetation	0.15

Notes:
Composite values based on Arcement and Schneider (1989).
1. Stream channel roughness assigned based on typical bed channels.

Figure 109
Land Use Classifications of the Grand Lake Study Area as Determined from Circa-1940 Soil Conservation Service Aerial Imagery



5.1.2 *Modern Terrain*

The UHM's 2D flow areas were converted to 1D cross sections. These were cut from the relevant model terrain using built-in features of the HEC-RAS geometry editor. Cross-section stations were then filtered to limit station-elevation points at each cross section to a maximum of 500 individual values in accordance with HEC-RAS modeling requirements. Filtering was also performed using standard HEC-RAS features; data were filtered using the program's "Minimize Area Change" option.

Land use patterns were used to determine the base Manning's *n* values for the model. Where cross sections were copied from the UHM to the STM, these were left unchanged. Where 2D flow areas had been converted to 1D cross sections, river stations were used to define the Manning's *n* values to match the UHM values at those locations.

Bridge geometry information was gathered from the Oklahoma Department of Transportation, Missouri Department of Transportation, local and county road commissions, and measurements provided by GRDA. Bridge geometries in HEC-RAS typically are input as separate structures, with bridge deck geometry, support piles, and abutments entered into the program along with widths and cross sections immediately upstream and downstream of the structure.

5.2 Streams

The STM consisted of four streams: the Neosho, Spring, and Elk rivers, as well as Tar Creek.

5.2.1 *Neosho River*

The Neosho River was modeled from RM 152.25 to RM 99.82, approximately 22 miles upstream of Pensacola Dam (USGS gage 07190000). It was divided into three reaches with junctions at the confluence with the Spring and Elk rivers (upstream of RM 122.25 and 105.35, respectively).

5.2.2 *Spring River*

The Spring River was modeled from RM 21 to its confluence with the Neosho River at RM 0.

5.2.3 *Elk River*

The Elk River was modeled from RM 19.59 to the confluence with the Neosho River and Grand Lake at RM 0.

5.2.4 *Tar Creek*

Tar Creek was modeled from RM 7.6 to the confluence with the Neosho River. The downstream end of Tar Creek was modeled with normal depth, as discussed in Section 5.3. Geometry of the lateral structure was cut from the terrain and filtered to 500 data points to comply with model requirements. The STM therefore does not contain cross sections below Tar Creek RM 1.6; the rest of the creek was included in the lateral extent of Neosho River cross sections.

5.3 Boundary Conditions

Boundary conditions (BCs) define parameters at the model limits. HEC-RAS offers several options for BC types, including WSE, discharge, and normal depths. WSE and discharge can be set as a specified time series, and normal depths can be calculated based on the friction slope. For the STM, upstream BCs (at the upstream extents of the Neosho, Spring, and Elk rivers, as well as Tar Creek) were defined by USGS discharge measurements stepped at intervals ranging from 15 to 60 minutes. The downstream BC was set as normal depth with a friction slope of 0.0033 vertical feet per horizontal feet [ft/ft] (for Tar Creek) and recorded WSE at Pensacola Dam (Neosho River). WSE measurements taken at Pensacola Dam were used to set the downstream water levels in the model. These data points are provided at 1-hour intervals. These inputs were used to run the model in Quasi-Unsteady Mode.

Water temperature can also be defined in *Quasi-Unsteady* models and is an important component of STMs. Water viscosity is related to temperature, with higher temperatures producing lower viscosity values. The decreased viscosity reduces sediment transport capacity and is therefore a necessary input parameter. Because this affects sedimentation, it was included in the sensitivity analysis discussed in Section 7.4.2.2 of this document.

5.4 Sediment Data

Input data for the STM includes the sediment supply for the upstream boundary for each stream, the sediment characterizing the bed of each stream through the various reaches, and the erosion parameters defining the cohesive sediment where it is found in the river or lake beds. Data from field work was adapted to create the inputs. Specific parameters are described in the following subsections.

5.4.1 Upstream Sediment Supply

The upstream sediment supply applies the suspended sediment regression curves to develop a sediment rating curve (table of suspended sediment transport rate in tons per day with flow). This table is input into the HEC-RAS model for each stream: Neosho River, Tar Creek, Spring River, and Elk River. These tables can be seen as input files for the STM. The model then computes suspended sediment inflow at the upstream boundary of each stream for each time step of the model using the flow data for the calibration time period (1942 through 2019). The upstream sediment supply for these rivers and creek are tabulated versions of the regression equations developed in Section 4.3.

5.4.2 *Bed Material*

For each cross section and for each stream, a bed material size distribution was developed as input into the STM. These data are based on the particle size distributions for the bed material and core sampling analysis and can be seen as input tables of the particle size distribution for each cross section.

As previously shown (see Section 2.3.2), the bed of these streams and the reservoir consist of a wide range of sediment sizes resulting in a bi-modal distribution of sediment, one of which is fine, cohesive material (primarily silt and clay), and the other distribution being non-cohesive material (primarily gravel with some sand and finer material as well as cobble-sized material). Further complicating the bi-modal distributions, samples of primarily non-cohesive gravel exist near samples of predominantly cohesive silt and clay. In addition, samples do not show any clear longitudinal trend of sediment characteristics where an upstream sample may be fine, cohesive sediment and the next sample farther downstream may be coarse, non-cohesive sediment. This range of longitudinal distributions of sediment in close proximity complicates development of input data that describe the characteristics of the bed of these streams. The following examples demonstrate this complexity.

Figure 110 and Figure 111 show the wide range of bed material sizes along the Neosho River. Locations of the sediment samples are included in Appendix B.

Figure 110
Neosho River Sediment Size Gradation Results Comparison

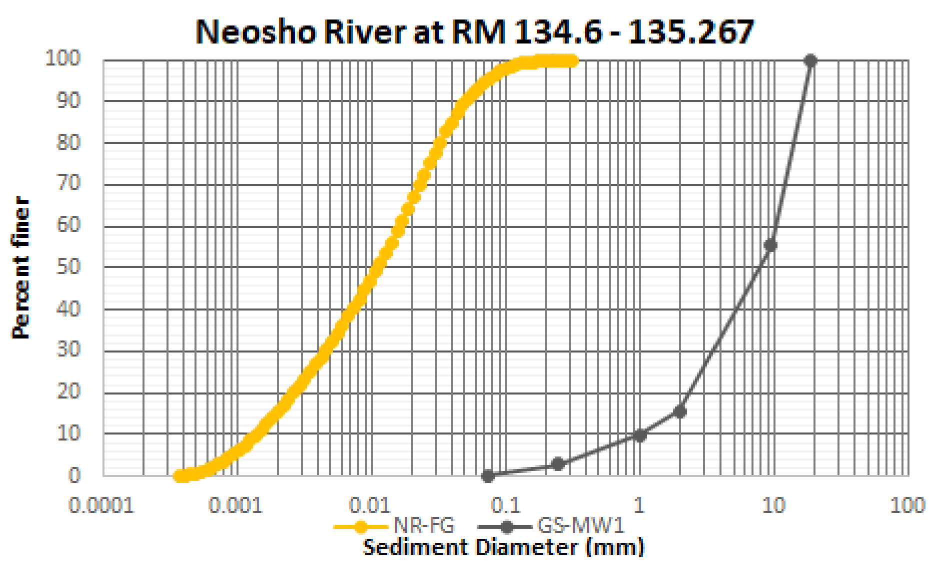
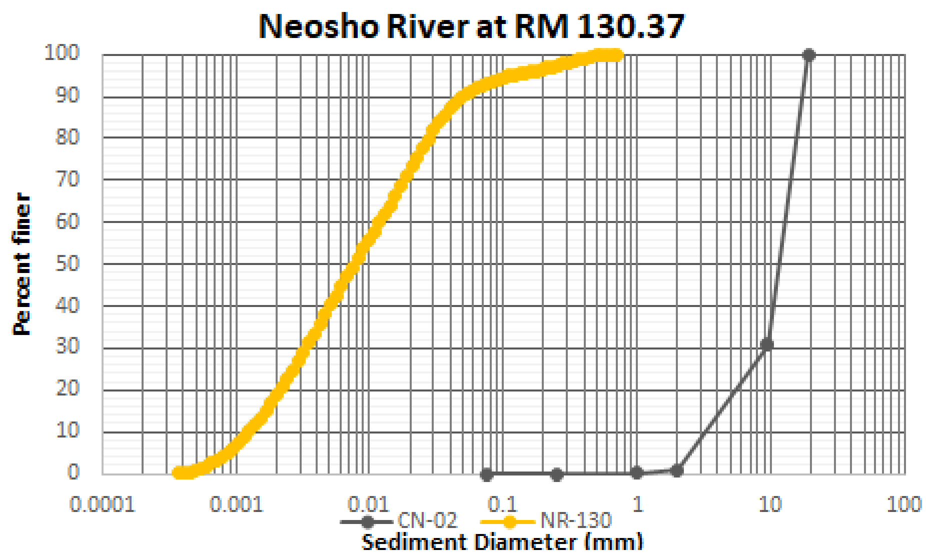


Figure 111
Neosho River Sediment Size Gradation Results Comparison



Farther downstream in the upper reservoir, this same wide range in bed material size distributions continue in close proximity to these separate samples (Figure 112 and Figure 113).

Figure 112
Upper Grand Lake Sediment Size Gradation Results Comparison

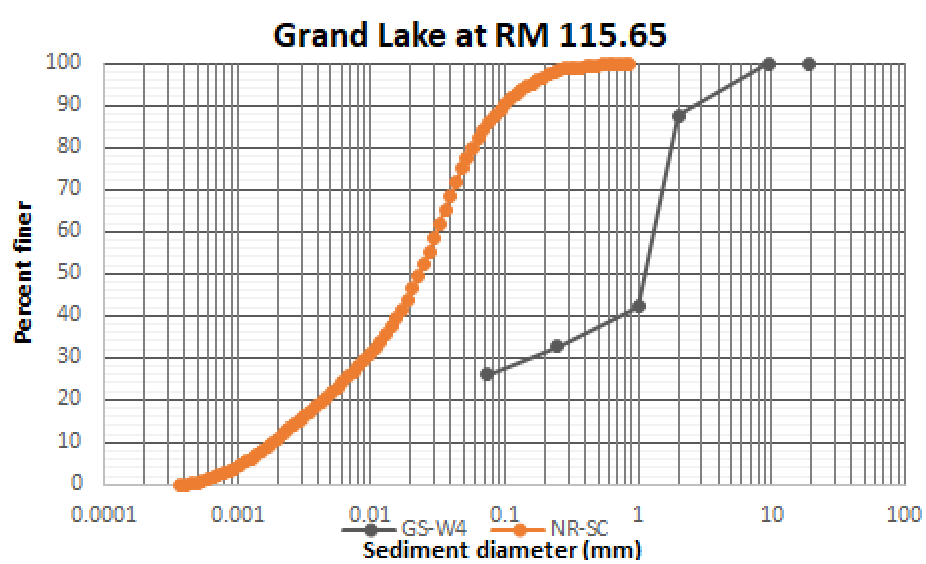
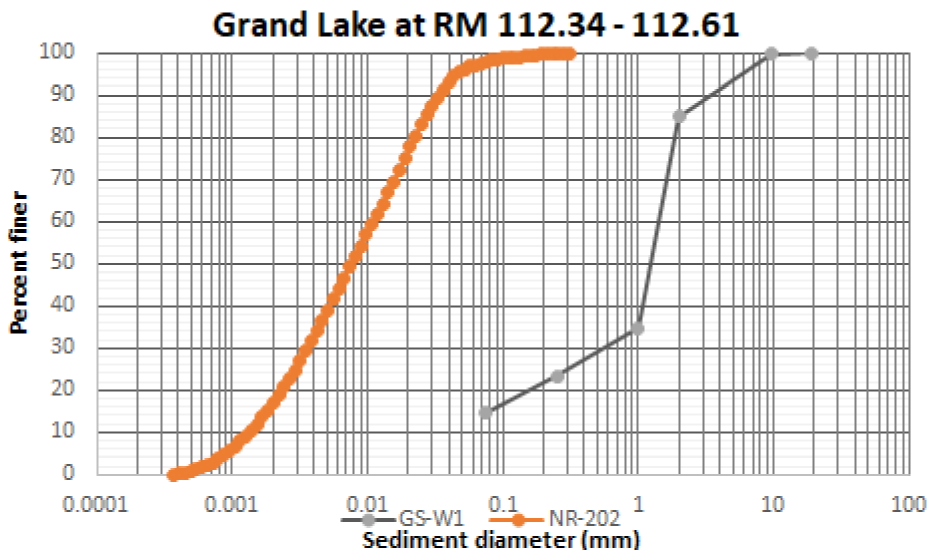


Figure 113
Upper Grand Lake Sediment Size Gradation Results Comparison



This same disparity in adjacent samples continues on the tributaries as well (Figure 114 through Figure 119).

Figure 114
Tar Creek Sediment Size Gradation Results Comparison

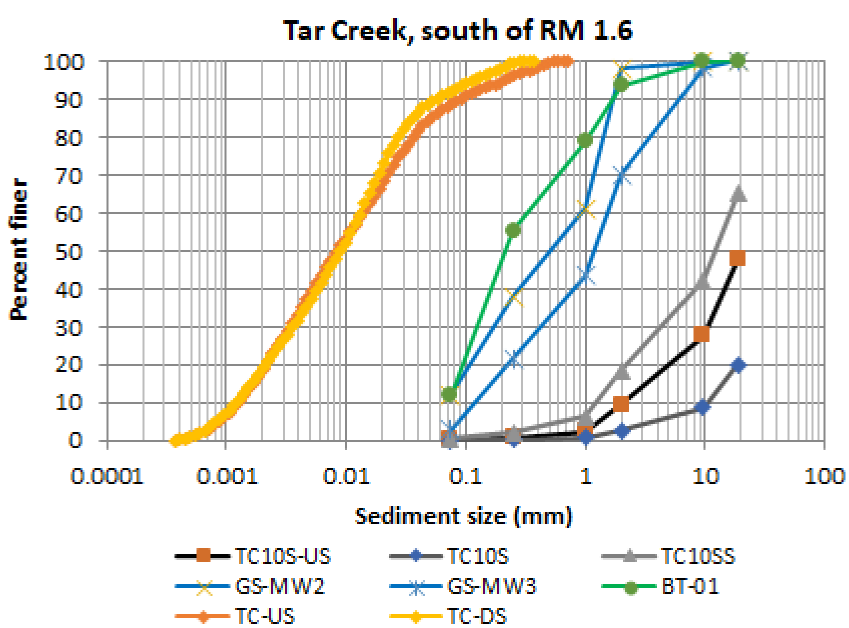


Figure 115
Spring River Sediment Size Gradation Results Comparison

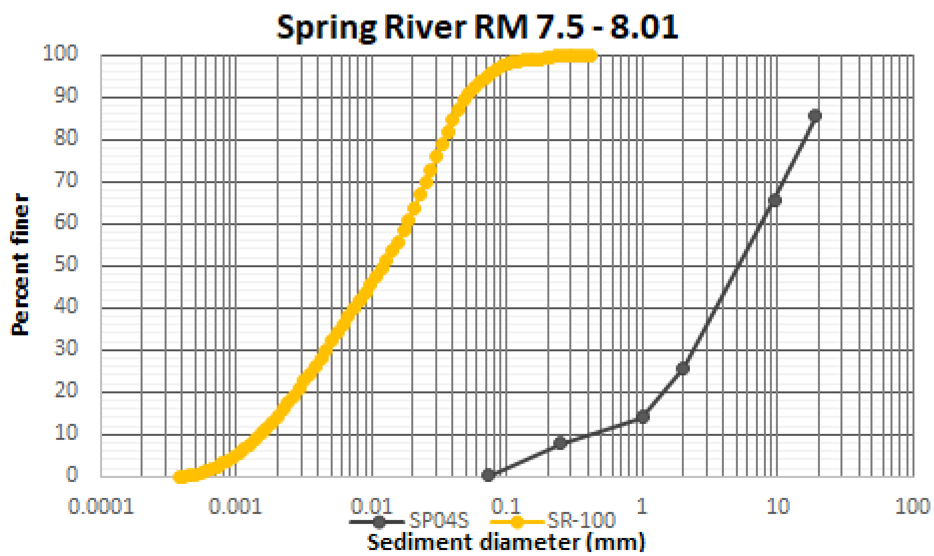


Figure 116
Spring River Sediment Size Gradation Results Comparison

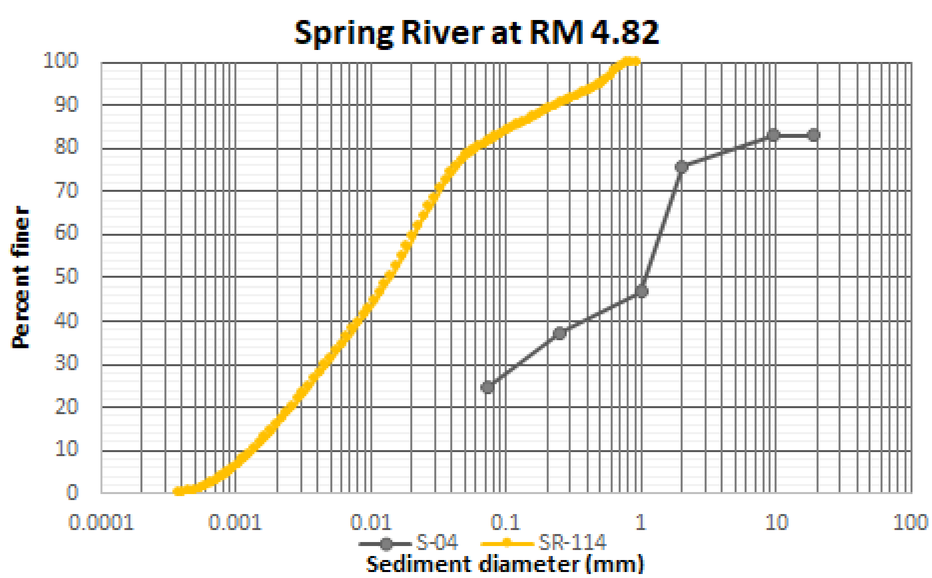


Figure 117
Spring River Sediment Size Gradation Results Comparison

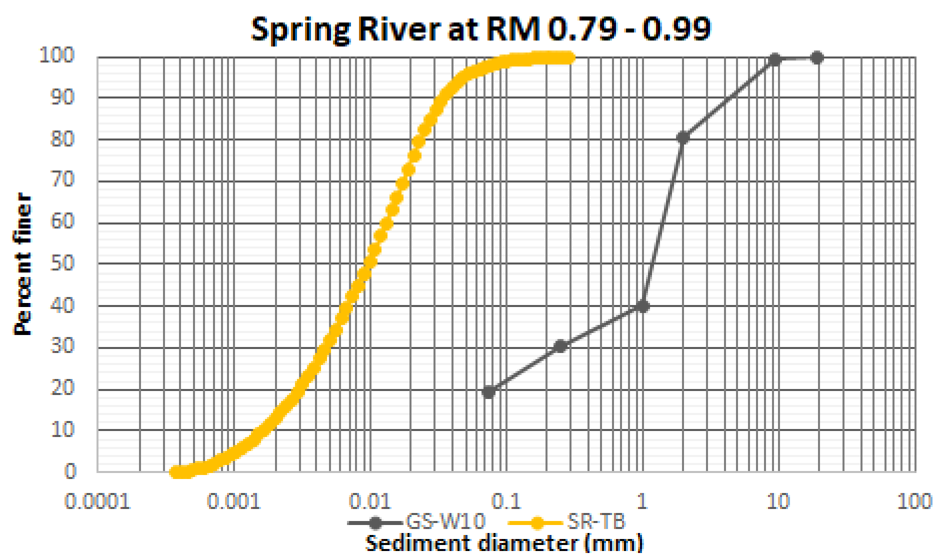


Figure 118
Elk River Sediment Size Gradation Results Comparison

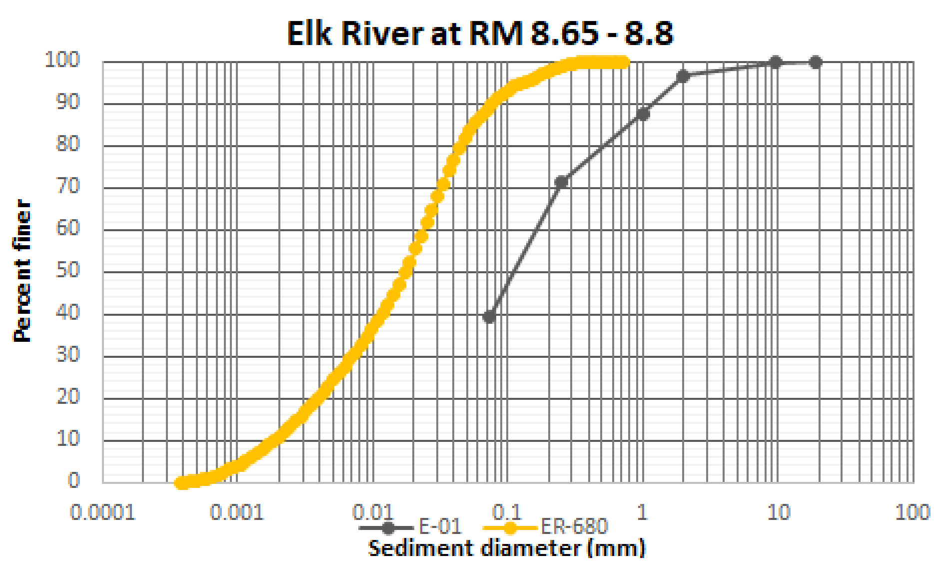
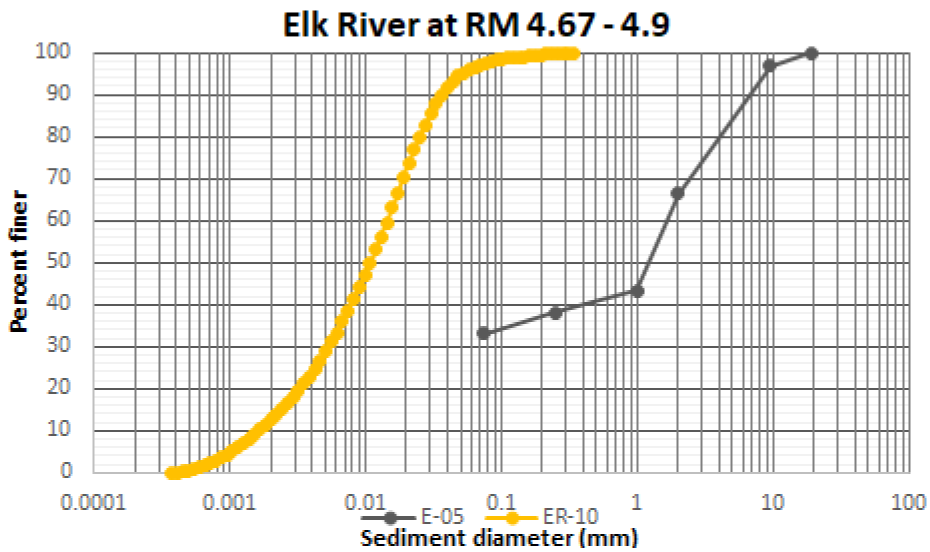


Figure 119
Elk River Sediment Size Gradation Results Comparison



The above plots show that samples taken along the Neosho, Spring, and Elk rivers, as well as Tar Creek, include both fine cohesive sediment (primarily silt and clay) near non-cohesive sediment (primarily gravel along with some finer sediment and coarser sediment). These bi-modal distributions cover six log cycles of sediment size in samples collected in relatively close proximity (but different times: December 2019 and March 2020). This wide range of sediment types and sizes is due to fine sediment being transported down river and deposited in the reservoir during certain events or seasons and then flushed farther downstream under other flow and reservoir conditions.

As discussed in Section 2.1.3.1, under some conditions, the bed consists of fine-sized sediment (silt and clay), and under other conditions, in close proximity to the fine samples, the bed consists primarily of coarser, non-cohesive sediment (gravel and sand). The data and observations indicate that the fine sediment transported down river into the upstream reaches of the reservoir as suspended load tends to deposit temporarily under some hydrologic and hydraulic conditions and then is flushed farther downstream under other hydrologic and hydraulic conditions as suggested previously by Mussetter (1998).

Tetra Tech's discussion from both the 2015 and 2016 reports, *Hydraulic Analysis to Evaluate the Impacts of the Rule Curve Change at Pensacola Dam on Neosho River Flooding in the Vicinity of Miami, Oklahoma* (Tetra Tech 2015, 2016), make comparisons between 1940, 1998, and 2015 survey data and basic hydraulic and sediment transport concepts to conclude that:

> Because the amount of sediment that can be carried by the river is controlled by the local hydraulic energy, and the required amount of energy increases with increasing particle size, the coarser-grained portion of the sediment load (i.e., sands and gravels) will typically deposit on the river bed near the head of the reservoir and the finer grained sediment will be carried progressively farther downstream into the reservoir. (Tetra Tech 2016)

And regarding the quantities of deposition:

> Based on the bank elevations, there has been approximately 15 feet of overbank deposition in the vicinity of Twin Bridges between 1940 and 2015.
>
> Comparison of the thalweg (i.e., minimum bed elevation) profiles from the 2015 bathymetry with thalweg elevations measured in 1940 indicates that the bed has aggraded by an average of about 5 feet, with over 10 feet of aggradation in some locations in the 6- to 7-mile reach upstream from Twin Bridges/U.S. Highway 60. (Tetra Tech 2016)

Although Tetra Tech presents a logical position that the coarser-grained portion of the sediment load (sands and gravels) would tend to deposit in the upper reach of the reservoir, recent collection of bedload transport data showed virtually no transport of those grain sizes in the rivers. The sediment team used equipment specifically designed to capture sands and gravels and found no evidence of coarse material transport even at the highest flows sampled in 2019 and 2020, which represents more than 90% of the recorded flow regime. It is difficult to conclude significant deposition of these sizes of sediment is occurring on the bed when no movement of such materials has been measured.

Sediment transport sampling shows that virtually all sediment transport consists of fine silts and clays, and that bed samples at a given location alternate between stationary coarse materials and more mobile fines. Therefore, it is clear the earlier observation of Mussetter and current observations of the transitory nature of fine sediment deposition are valid and most of the fine sediment load is eventually moved farther down into the reservoir without permanent or ongoing deposition in the more riverine sections of the river. These are the complexities of the sediment transport analysis, which were addressed through the data collection, analysis, and modeling process. Any previous quantification and conclusions regarding the sediment transport and deposition process must be evaluated considering these complexities, significantly increased data, and further analysis including the modeling process.

Several factors contribute to a complicated analysis and model development effort, as follows:

- Sediment sizes and types are quite different, even when collected near other samples representing entirely different sediments.
- There is a wide range in sediment density from sample to sample and depth below sediment surface.
- Non-cohesive sediments are expected to follow standard transport equations and parameters and are found in certain bed samples but not in the bulk of the incoming sediment load.
- Incoming sediment load consists primarily of fine sediment that will deposit under some conditions and exhibit a wide range of erosion and transport parameters that vary location to location and depth below sediment surface.

Further complicating the physical characteristics of the diversity of sediment types, sizes, and characteristics is the fact that the bulk of data collected to develop the sediment characteristics were collected in 2019 and 2020, whereas the model calibration period starts in 2009. If these types of data were collected in 2009, they were collected before this study began and the findings have not been available to the STM development team. As a result, although channel and reservoir geometry were surveyed in 2009, the river and lakebed sediment characteristics for 2009 are based on data collected a decade later, which may or may not represent conditions at the beginning of the calibration period. STM setup and calibration present a very complicated and challenging task.

6 Sediment Transport Model Calibration

STM calibration was performed in two components. As with any model calibration procedure, it is easiest to start with the simplest format available, ensure accuracy, then increase complexity. For the STM, that meant beginning with hydraulic calibration and neglecting sediment movement, erosion, and deposition. Once the hydraulics were well-calibrated, sediment transport was added to the STM, and the sediment model parameters were finalized.

Sediment calibration and validation simulations ran from 1942 to 2019. Results were then compared against measured data from 1998 REAS surveys, the 2009 OWRB survey, and USGS surveys performed in 2017 and 2019 as discussed in Section 6.2.2.

The overall goal of this step was to create a baseline geometry using the 2019 terrain dataset that could be used to predict future sediment transport, erosion, and deposition patterns.

6.1 Hydraulic Calibration

6.1.1 Circa-1940 Geometry

Hydraulic data for calibrating the circa-1940 model is not available in the upper reaches of the study area. WSE data are not available for the circa-1940 model, so calibration was performed by assigning Manning's *n* roughness parameters based on land use as described in Section 5.1.1.1.

6.1.2 Modern Geometry

Hydraulic calibration for the modern geometry focused on matching peak WSE records. WSE information was provided by a collection of USGS gages, WSE monitoring stations placed by the project team, and high water mark information provided by Tetra Tech.

6.1.2.1 Model Inputs

Model input parameters were developed specifically for the hydraulic calibration components. Sediment modeling was not included in this part of the calibration procedure.

6.1.2.1.1 Sediment Information

The process started with hydraulic calibration. To remove any sediment influence, an empty sediment dataset was created for the entire model domain. This dataset included an arbitrary bed gradation and set maximum erodible depths to 0 feet throughout the model. The BCs were set to clear water inflow conditions, and all cross sections were defined as pass-through nodes (meaning sediment would not deposit and instead be transported downstream).

6.1.2.1.2 *Modeled Events*

Hydraulic calibration involved using known parameters from USGS data. BCs were defined as described in Section 5.3 for several flow events. The modeling team selected six events for calibration; these were also used for UHM calibration procedures. The timing of specific events and peak stream discharges used for hydraulic calibration are listed in Table 26.

Table 26
Modeled Flow Events and Stream Discharges

	Peak Stream Discharge (cfs)			
Event Date	Elk River at Highway 43	Neosho River at East 60th Road	Tar Creek at East 50th Road	Spring River at East 57th Road
July 2007	4,830	141,000	2,490	105,000
October 2009	39,300	46,100	5,150	66,200
December 2015	107,000	45,400	3,320	151,000
January 2017	1,140	10,200	672	15,900
April 2017	107,000	58,200	2,980	114,000
May 2019	66,500	91,400	6,410	109,000

The downstream WSE at Pensacola Dam was defined by USGS gage records, and the downstream BC for Tar Creek at its confluence with the Neosho River was set at normal depth with a friction slope of 0.0033 ft/ft.

6.1.2.2 Roughness Parameters

Calibration of hydraulic models in HEC-RAS relies primarily on hydraulic roughness parameters. These are typically reported as Manning's *n* values and are usually defined within a set range by land cover type (Table 27). The STM values were based on UHM roughness parameters throughout the model domain. Generally, higher *n* values produce slower flows and raise WSE, whereas lower *n* values decrease WSE.

Table 27
Typical Overland Manning's *n* Values by Land Cover

Land Cover	*n* Value
Field crops	0.040
Pasture	0.080
Urban	0.070
Urban, dense	0.090
Water	0.040

Land Cover	*n* Value
Woody vegetation	0.100
Woody vegetation, dense	0.150

In-channel Manning's *n* values were adjusted iteratively until simulated WSE results showed reasonable agreement with recorded measurements. Table 28 lists in-channel roughness values developed during the calibration process.

Table 28
Base Manning's *n* Roughness Parameters for Streams in the Sediment Transport Model

Reach	*n* Value
Grand Lake (reservoir, up to RM 121.29)	0.020
Neosho River (RM 121.51 up to RM 122.33)	0.025
Neosho River (RM 122.46 up to RM 130.87)	0.024
Neosho River (RM 131.01 up to RM 133.99)	0.035
Neosho River (RM 134.09 up to RM 135.37)	0.015
Neosho River (RM 135.46 up to RM 152.2)	0.030
Elk River	0.015–0.053
Spring River (full reach)	0.0332
Tar Creek	0.027–0.100

These base roughness values were then modified based on changes in stream discharge values. River bedforms have a significant influence on hydraulic roughness. As stated by Mussetter (1998), the bedforms are affected by flow volumes, generating different bed roughness values as a function of total discharge. In HEC-RAS, "Flow Roughness Factors" were used to tune the model to account for changes in bed roughness at higher or lower flow rates. These parameters are shown in Table 29 and Table 30.

Table 29
Flow Roughness Parameters for Elk and Spring Rivers and Tar Creek in the Sediment Transport Model

Elk River		Spring River		Tar Creek	
Discharge (cfs)	Flow Roughness	Discharge (cfs)	Flow Roughness	Discharge (cfs)	Flow Roughness
0	1.30	0	0.90	0	0.80
40,000	1.25	50,000	1.00	4,600	0.95
66,500	0.85	110,000	1.00	4,700	0.90

Elk River		Spring River		Tar Creek	
Discharge (cfs)	**Flow Roughness**	**Discharge (cfs)**	**Flow Roughness**	**Discharge (cfs)**	**Flow Roughness**
75,000	0.80	120,000	1.20	4,800	1.00
105,000	0.80	151,000	1.20	5,500	1.00
110,000	1.00	152,000	1.00	6,400	0.90
				6,500	1.00

Table 30
Flow Roughness Parameters for the Neosho River in the Sediment Transport Model

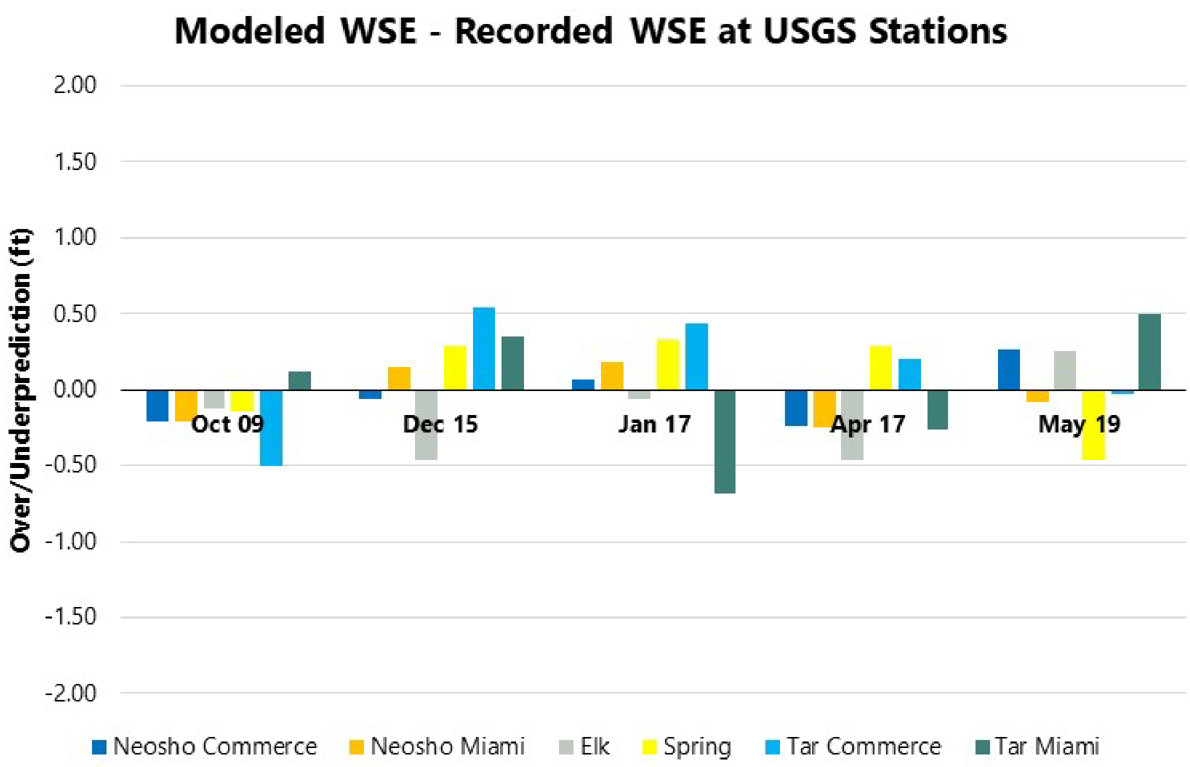
RM 130.54–135.267		RM 135.37–152.25	
Discharge (cfs)	**Flow Roughness**	**Discharge (cfs)**	**Flow Roughness**
0	0.80	0	0.80
45,000	0.80	45,000	1.10
60,000	1.30	60,000	1.20
65,000	1.30	91,000	1.10
91,000	1.30	92,000	1.00
92,000	1.00		

6.1.2.3 Results

Model calibration results showed good agreement with measured WSEs, as discussed herein.

Model calibration results as compared to USGS gages are shown in Figure 120. The average difference between simulated maximum WSE and measured maximum USGS gage WSEs is 0.06 foot; the model slightly overpredicts WSE at the USGS gages for the calibration events.

Figure 120
Overprediction and Underprediction of Simulated WSE at USGS Gages



STM calibration results were also compared to high water marks as compiled by Tetra Tech (2016). Model results from the July 2007, October 2009, and December 2015 calibration run are shown in Figure 121 through Figure 123. Average model difference is 0.29 feet for July 2007, -0.59 feet for October 2009, and -0.66 feet for December 2015; the model overpredicted WSEs during the July 2007 event and underpredicted for the October 2009 and December 2015 events when compared to measured high water marks.

Quasi-unsteady modeling presents difficulties when evaluating WSE measurements downstream of tributaries. WSE is heavily influenced by the arrival times of peak flow pulses from contributing streams. Because quasi-unsteady models change the relative arrival times downstream of confluences, it is difficult to accurately model maximum WSE at those locations. For STMs, it is impractical to model with fully unsteady flows; for WSE evaluations, the UHM is a more fitting tool.

Figure 121
Comparison of STM WSE Results and Measured High Water Marks during the July 2007 Event

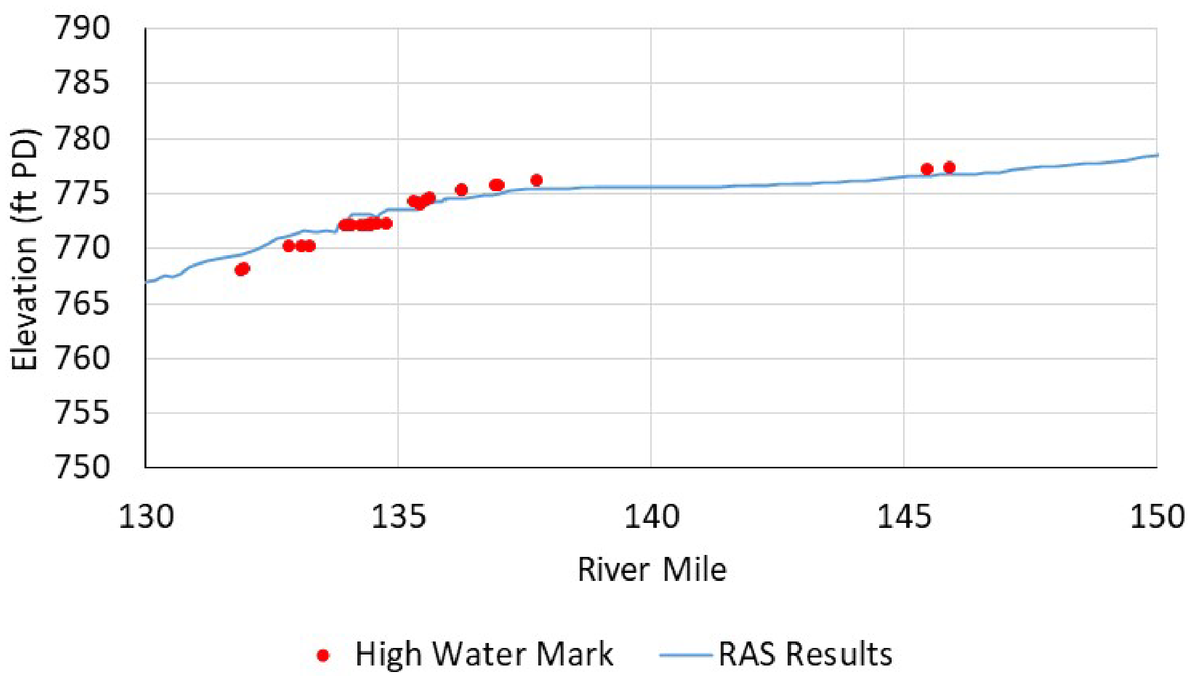


Figure 122
Comparison of STM WSE Results and Measured High Water Marks during the October 2009 Event

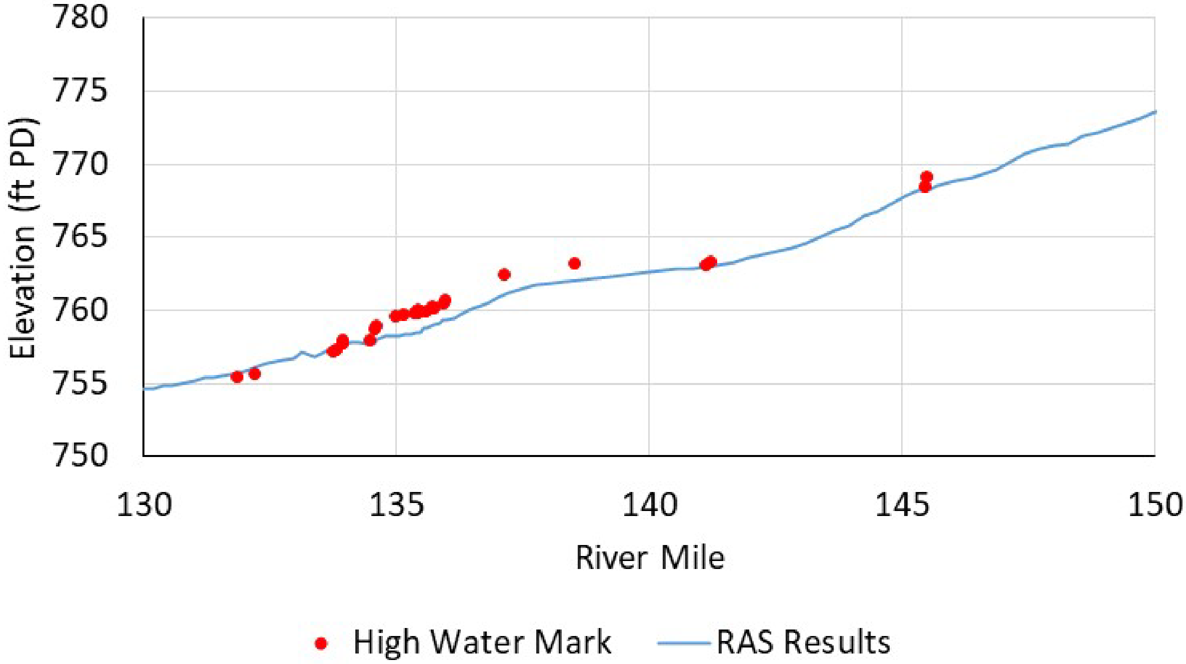
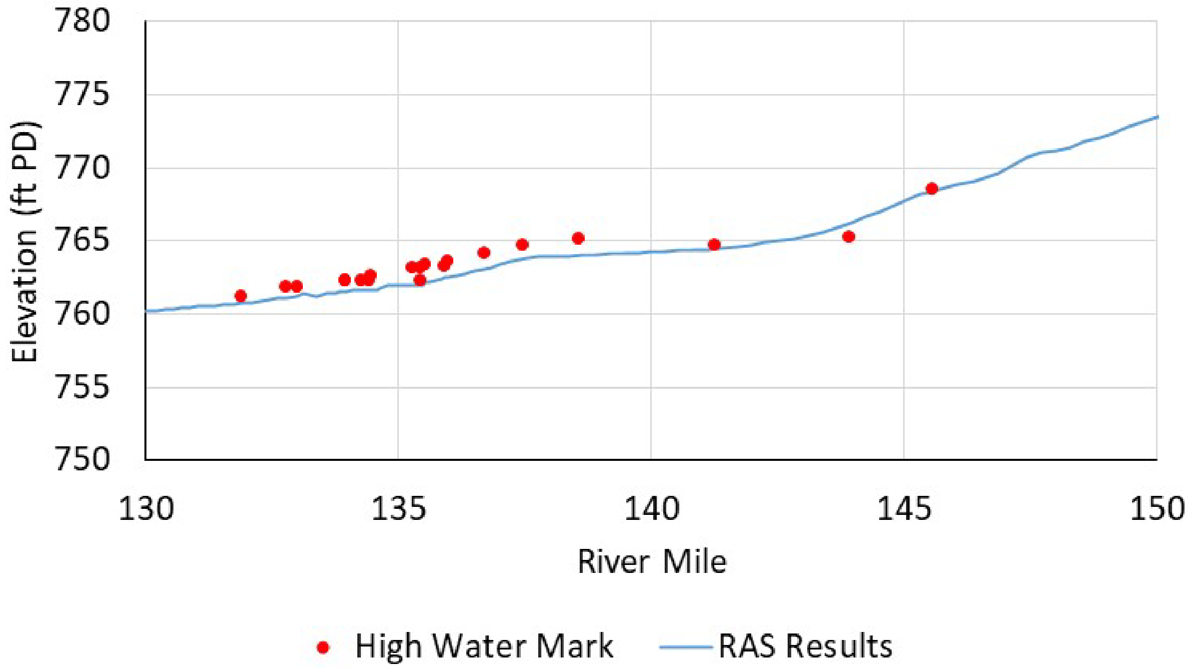
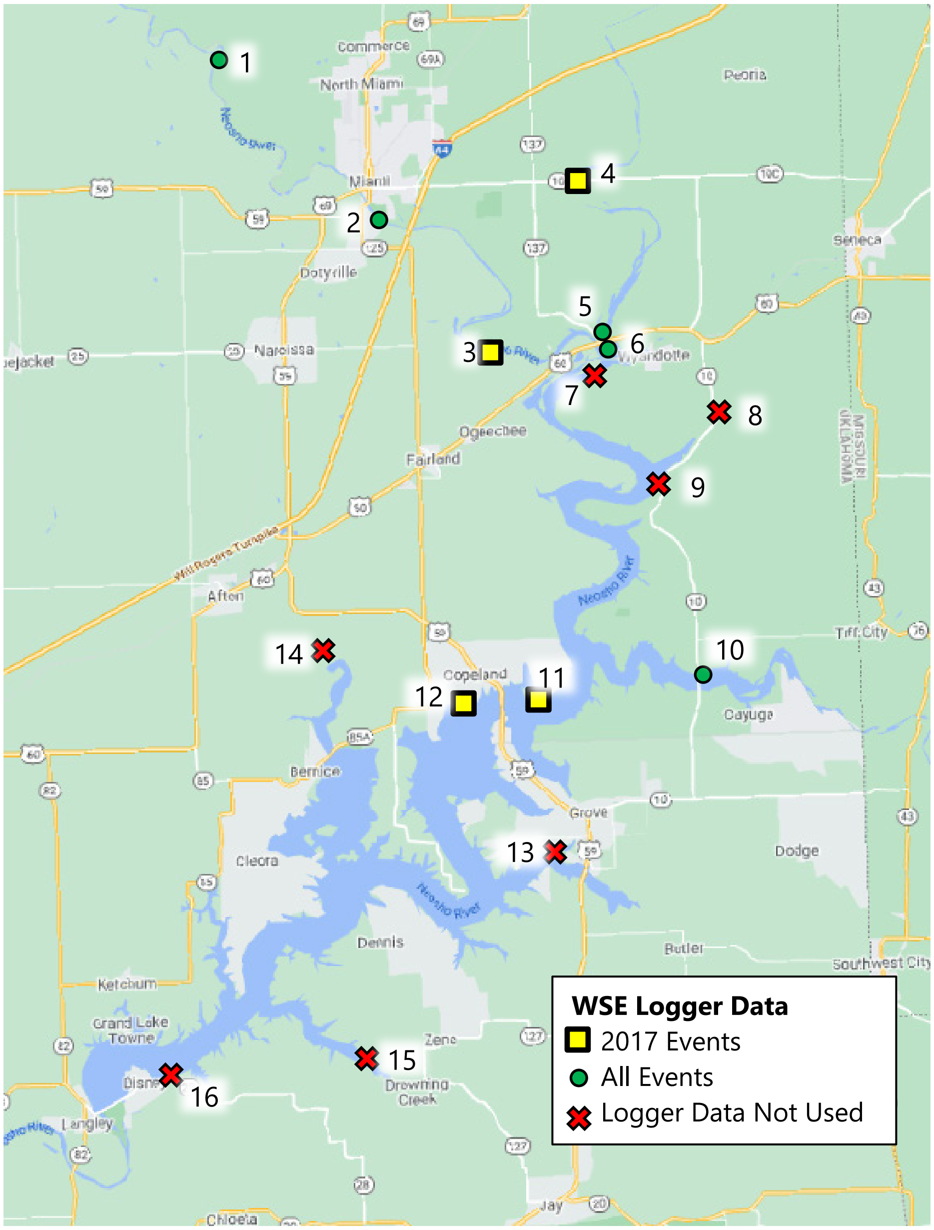


Figure 123
Comparison of STM WSE Results and Measured High Water Marks during the December 2015 Event



A third source of calibration WSEs was the field monitoring data collected during the study. The WSE loggers were in place for three of the calibration events: January 2017, April 2017, and May 2019. Not all logger locations have data for a given event; some were washed away or vandalized when attempts were made to retrieve data. Logger 9 was missing for both events, and data from loggers 7 and 8 were not included in calibration because they were located in areas where incoming, ungaged streams affected WSE reporting. These were initially placed before model parameters had been fully defined. Loggers 13, 14, 15, and 16 were located downstream of model extents. Figure 124 shows the location of loggers used in the calibration process.

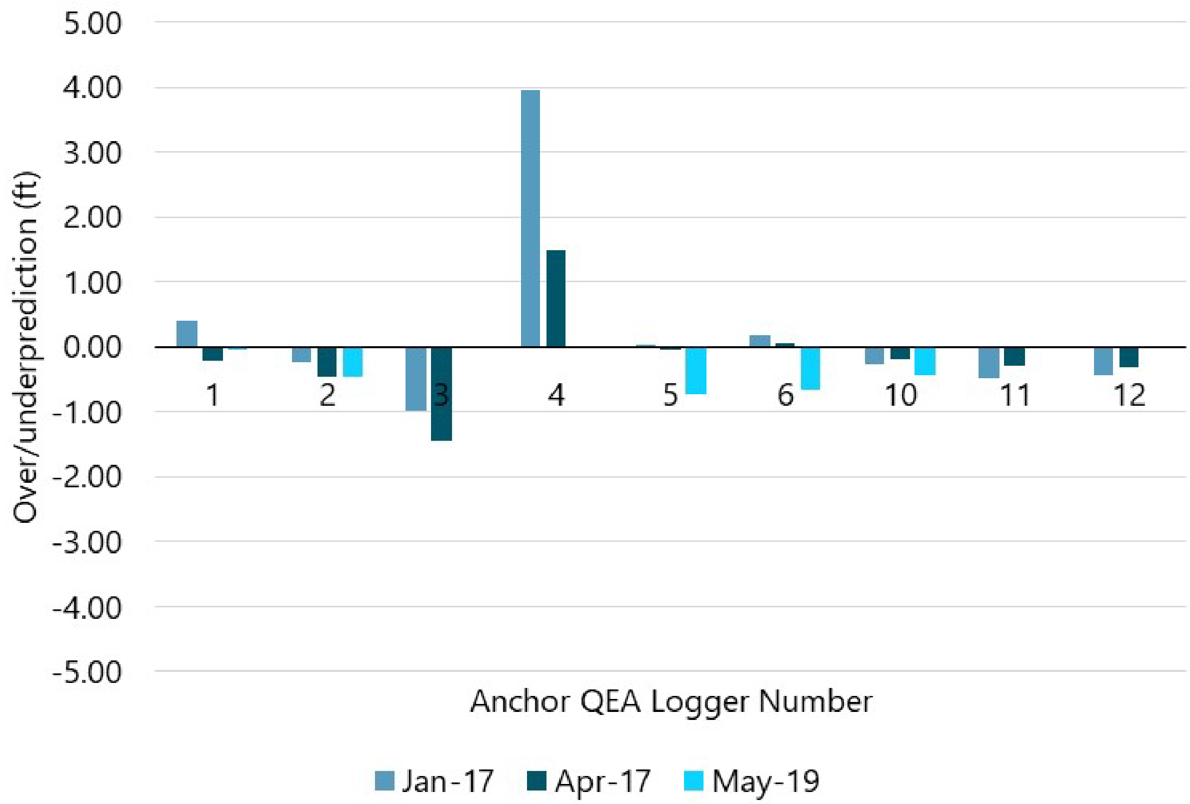
Figure 124
Locations of Anchor QEA Loggers



Note: Data from loggers 7, 8, 9, 13, 14, 15, and 16 were not used in the analysis as discussed above.

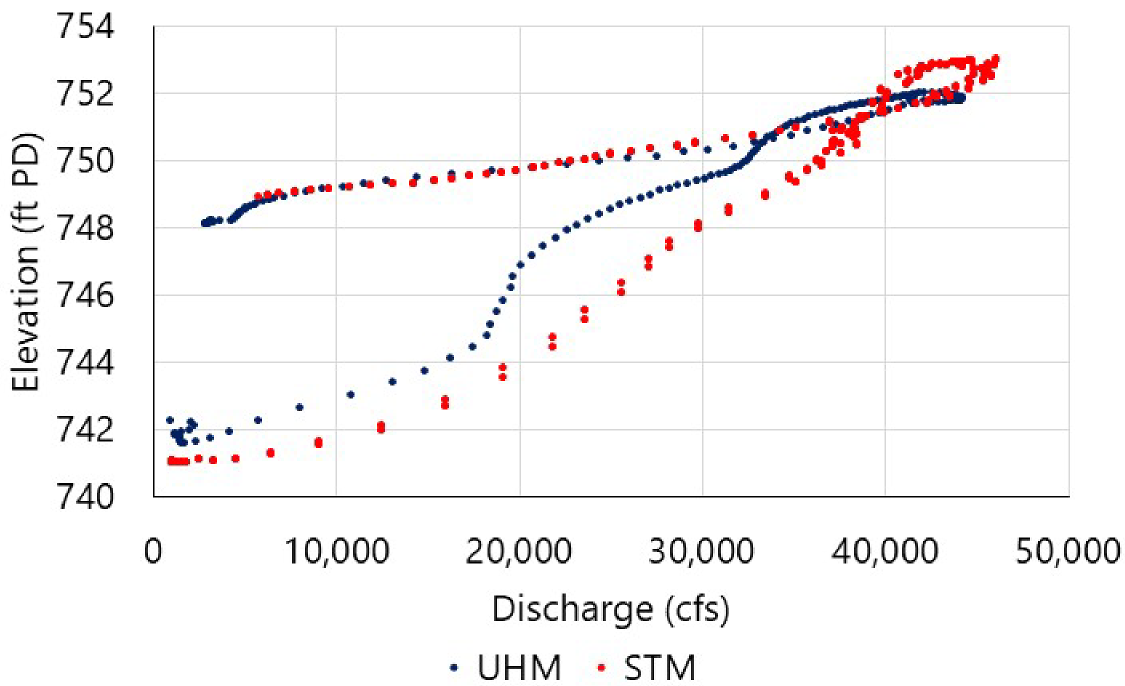
Figure 125 shows the overprediction and underprediction of peak WSE at the logger locations for those loggers used as calibration points. During the January 2017 event, the model averaged an overprediction of WSE by 0.23 foot. During the April 2017 event, the model averaged an underprediction of 0.15 foot. For the May 2019 event, the model averaged an underprediction of 0.47 foot.

Figure 125
Comparison of STM WSE Results and Measured Values from Anchor QEA Loggers



The STM hydraulic results were also compared to UHM simulations. The comparisons shown in the WEST ITR (2022) indicated significant differences between the models. By using the HEC-RAS bridge routines instead of lidded cross sections, the STM showed improved agreement with the UHM as presented in Figure 126 and Figure 127.

Figure 126
Neosho River WSE at RM 122.75, Upstream of Highway 60 near Twin Bridges State Park with STM Bridge Routines



Similar results were found at RM 122, which is between the Highway 60 and Burlington Northern railroad bridges.

Figure 127
Neosho River WSE at RM 122, Between US-60 and Burlington Northern Railroad Bridges near Twin Bridges State Park with STM Bridge Routines

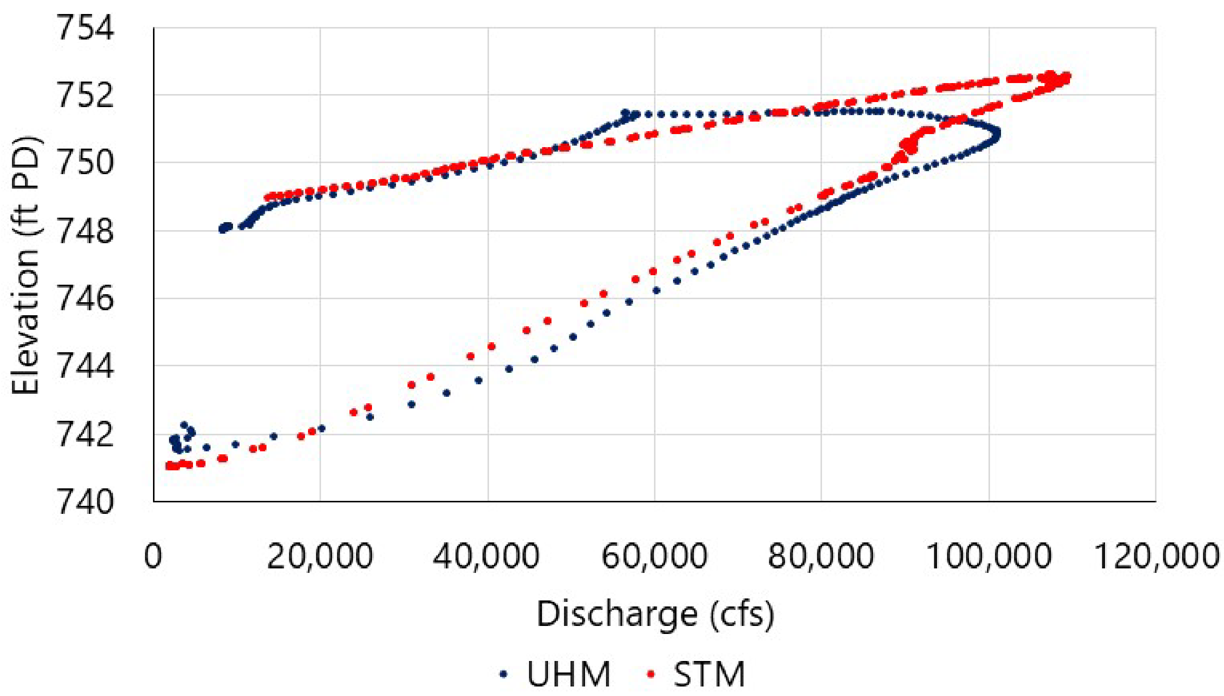


Figure 128 shows the Burlington Northern Railroad bridge and embankment backing up high flows in May 2019.

Figure 128
Burlington Northern Railroad Bridge and Embankment Viewed from Twin Bridges Boat Launch in May 2019

Source: GRDA, May 2019

6.2 Sediment Calibration

6.2.1 Model Inputs

6.2.1.1 Hydraulic Parameters

Sediment transport calibration was performed between 1942 and 2019. This was a function of available hydraulic information; continuous USGS (2021g) reservoir storage records at Pensacola Dam date to October 1942. The original WSE data are unavailable, but the USGS provided the historical stage-storage curves and dates of use (Strong 2022). Storage volumes were converted to elevations with those curves and used to set downstream WSEs in the calibration runs.

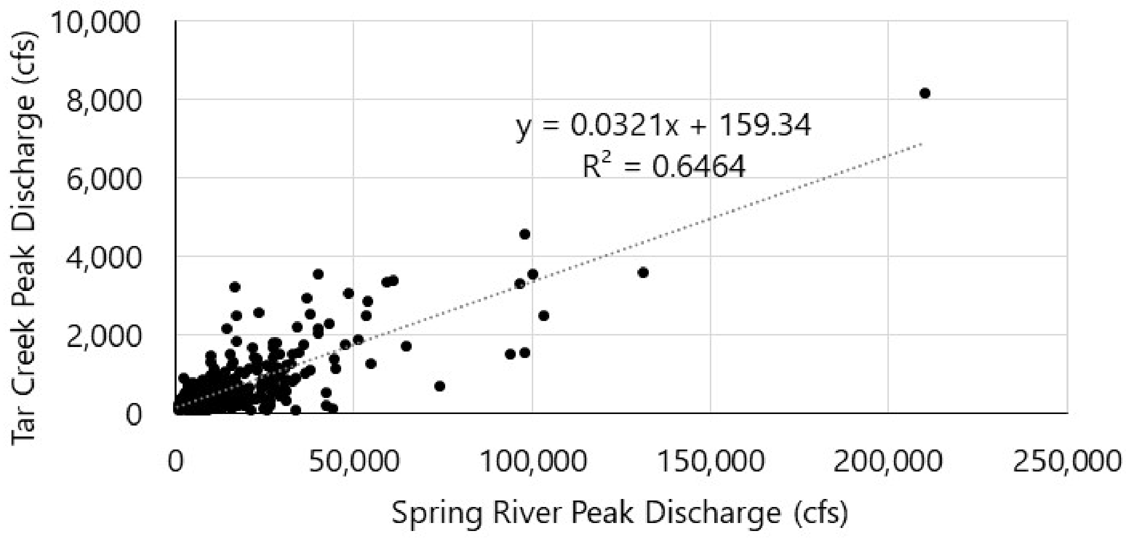
Historical flow data available from USGS gages (USGS 2021a, 2021b, 2021f) provided inflow volumes dating back to 1940 on the Neosho, Elk, and Spring rivers. Inflow volumes were recorded from 1984 to 1990 and 2004 to present on Tar Creek (USGS 2021e).

Due to the lack of available data for Tar Creek from 1940 to 1984, a synthetic hydrograph was generated using the Spring River as a reference hydrograph. The available flow data for Tar Creek (1984 to 2022) were compared to the same date range for Spring River. Spring River was chosen based on similarities in location and geographical extent of the watershed, despite the fact that Spring River is a significantly larger system than Tar Creek.

Linear regression comparing all peak daily discharges of Spring River and Tar Creek for the available data record resulted in a relatively poor correlation (R^2 = 0.29). Visual comparison of typical event hydrographs showed Tar Creek to recede more quickly to baseflow after precipitation events as would be expected of a smaller watershed. To account for this, relative peaks in the daily discharge were used for the comparison between the two watersheds. Relative peaks above the 10% daily exceedance flow for Tar Creek (110 cfs) were identified using Hydrologic Engineering Center Statistical Software Package (HEC-SSP) data filtering. The timing of Tar Creek peaks was compared to relative peaks of the Spring River daily discharge data and found that a Spring River daily discharge peak occurred within ±2 days of the Tar Creek peak discharge for 87% of the events. The linear relationship between these two peaks was much higher than when using all flows (R^2 = 0.65, Figure 129), and this linear relationship was used to determine Tar Creek peak flows during the missing period of record (1940 to 1984).

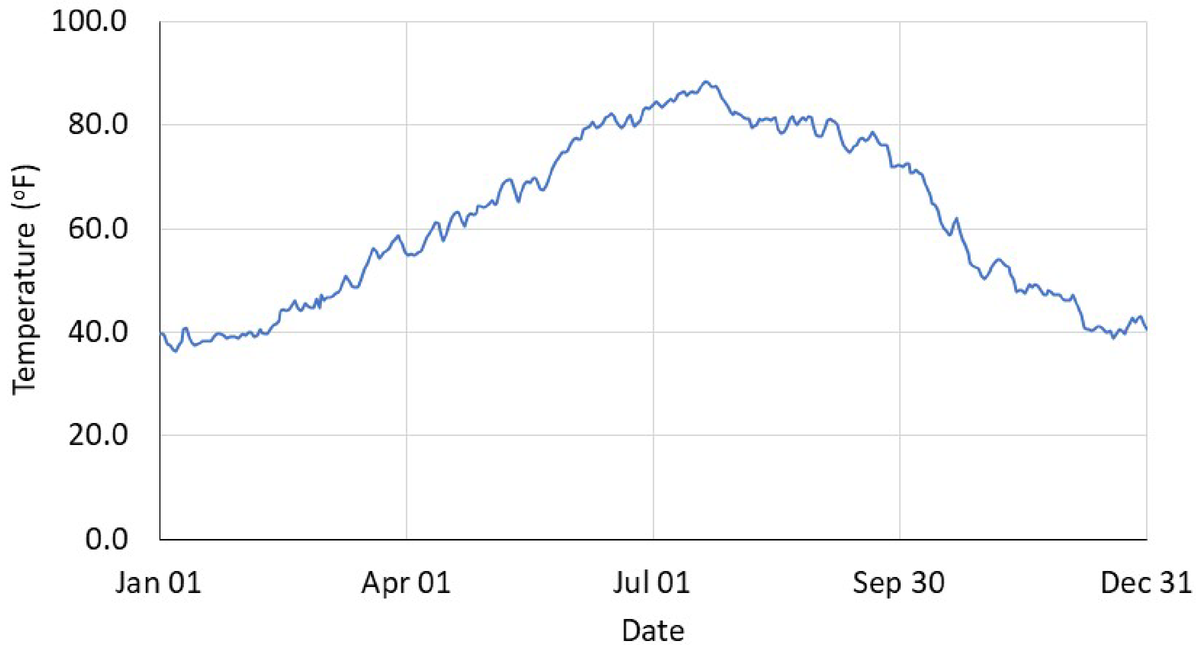
The majority of Tar Creek peak flows occurred 1 day before the peak flow of Spring River, and therefore the estimated peaks for Tar Creek throughout the missing period of record were assumed to occur 1 day before the Spring River peaks of that same time period. Based on visual examination, Tar Creek event hydrographs typically rose to the peak in a single day and then receded to pre-event levels in 2 to 3 days. Therefore, in the synthetic hydrograph for Tar Creek, event discharges were reduced to 50% of the peak for the following day, and to 25% of the peak the second day following the event. For all other daily flows in the synthetic hydrograph, the daily percent exceedance flow of Spring River was matched to the daily percent exceedance flow of Tar Creek to develop the background flow data. The same relationship was used to fill the data gap in Tar Creek daily discharge between 1994 and 2004.

Figure 129
Comparison of Tar Creek and Spring Creek Peak Events Over the 10% Daily Exceedance Flow (1984–2022)



Another important part of the hydraulic inputs for STMs is the water temperature in the system. These data were derived from water level logger measurements collected from December 2016. Daily average temperatures of the Neosho River from East 60th Road were used as an approximation of temperatures throughout the year and applied for the period of evaluation (Figure 130).

Figure 130
Temperature Time Series for 1 Year of STM Simulation



Note: Temperature data were repeated for each year throughout the duration of each simulation

6.2.1.2 Sediment Parameters

6.2.1.2.1 Bed Sediment

There are no known sediment data from pre-Project conditions in the modeled tributaries. Sediment properties were therefore assumed to have been similar to present-day sediment at the upstream extents of the reaches. Sediment grab samples collected during this study were used to define starting bed sediments as shown in Table 31 and their locations are highlighted in Figure 131.

Mobile bed limits were set to bank stations with a maximum erodible depth of 5 feet, and the Rubey falling velocity was used.

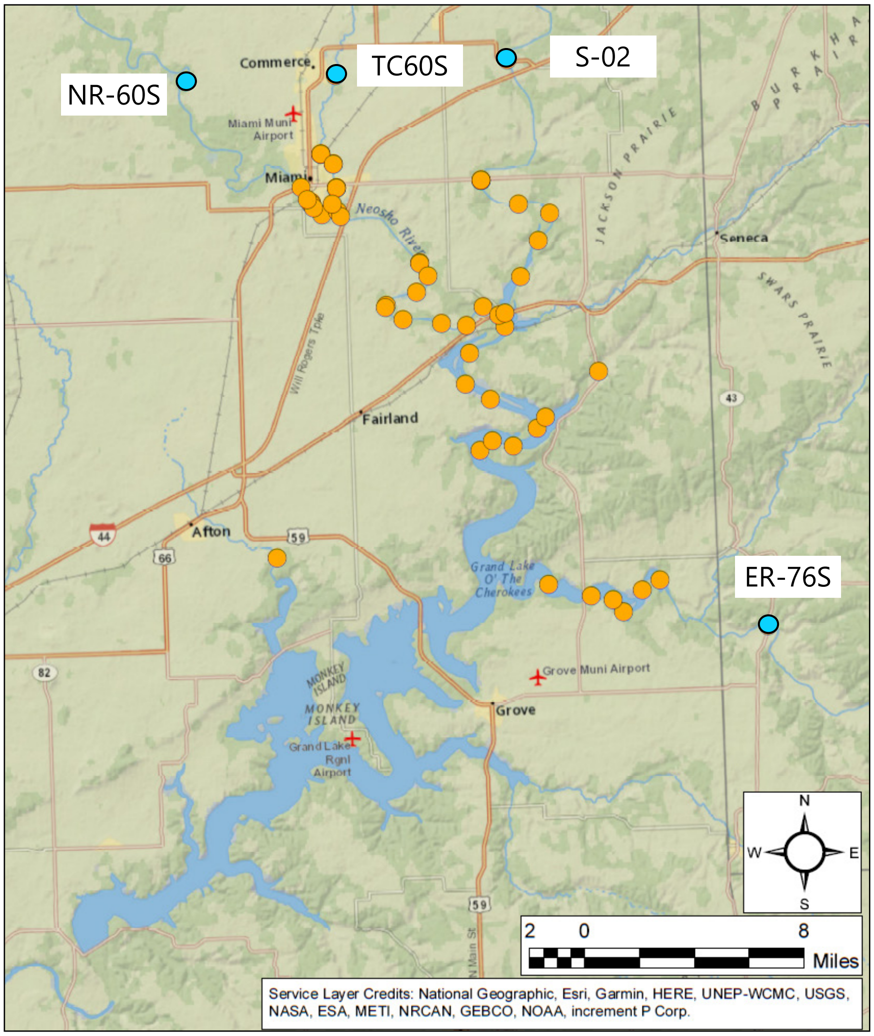
Table 31
Sediment Samples Used to Define Circa-1940 Bed Material

Stream	Sample	Cohesive Sediment Parameters			
Stream	Sample	Critical Shear Stress (lb/ft^2)	Erosion Rate, M (lb/ft^2/hr)	Critical Mass Wasting Shear Stress (lb/ft^2)	Mass Wasting Erosion Rate, M_{MW} (lb/ft^2/hr)
Neosho River	NR-60S	0.008352	0.00062	0.066816	0.08700
Spring River	S-02	0.002297	0.05053	0.066816	34.75437
Elk River	ER-76S	0.002506	0.06772	0.066816	9.04153
Tar Creek	TC60S	0.003550	0.03483	0.006816	22.70010

Note:
Detailed sediment information is included in Appendix B of this report.

The cohesive parameters of the samples were also used for model development and played an important role in determining the erosive characteristics of the bed sediments. HEC-RAS uses the Krone-Partheniades relationship to parameterize the sediments (USACE 2016). The SEDflume (Integral Consulting 2020) results informed selection of the parameters presented in Table 31.

Figure 131
Location of Sediment Grab Sampling Efforts within the Grand Lake Watershed



Notes:
Samples shown in teal (NR-60S, TC60S, S-02, and ER-76S) mark the most upstream locations of grab samples collected during this phase of the study. They were used to define circa-1940 bed conditions.
Samples shown in orange were used to define the bed conditions for future-looking sediment simulation runs.

6.2.1.2.2 Sediment Inflows

Sediment inflow information is sparse during the period of record as discussed in Section 2.1.3.2. The data were supplemented with measurements collected during this study (see Section 2.2.4).

The sediment inflow rating curves were developed from USGS measurements and supplemented with those discussed in Section 2.2.4. The Sediment Rating Curve Analysis Tool in HEC-RAS v. 6.2 was used to develop sediment rating curves for upstream boundaries of the model. This tool downloads

SSC information from user-selected USGS gages and allows importation of user data to create rating curves.

Sediment rating curves are often presented in the form of Equation 4.

Equation 4

$$Q_{ss} = aQ^b$$

where:

Q_{ss} = sediment load
a and b = constants
Q = stream discharge

When fitting this power function, most systems use the Least Mean Squares Error method, introducing implicit bias and resulting in an underprediction of incoming sediment loads. It is important to correct this bias when developing sediment rating curves for models. A more detailed discussion of this issue is presented in the HEC-RAS User's Manual (USACE 2016).

The Sediment Rating Curve Analysis Tool has built-in methods to remove that bias and present a more accurate sediment rating curve as explained in Section 1 of this report.

The rating curves shown in Table 32 were selected for this study.

Table 32
Sediment Rating Curves for STM Inflow Boundaries

Stream	Equation
Neosho River	$2.6039 \cdot 10^{-2} Q^{1.5089387}$
Spring River	$8.239 \cdot 10^{-3} Q^{1.5043}$
Elk River	$1.4031 \cdot 10^{-3} Q^{1.895494}$
Tar Creek	$3.117756 \cdot 10^{-1} Q^{1.143393}$

Note:
Rating curve equations were developed from a combination of data collected as part of this study and USGS gaging station information. Equations were then developed using the Duan method (Duan 1983) in the HEC-RAS Sediment Rating Curve Analysis Tool.

The sediment gradation data were taken from the measurements performed as part of this study. The information in Table 33 shows the distribution of grain sizes selected for incoming flow data.

Table 33
Grain Size Distributions of the Incoming Sediment Load

Stream	% Clay (< 0.004 mm)	% Very Fine Silt (0.004–0.008 mm)	% Fine Silt (0.008–0.016 mm)	% Medium Silt (0.016–0.032 mm)	% Coarse Silt (0.032–0.0625 mm)	% Very Fine Sand (0.0625–0.125 mm)
Neosho River	50	11	12	12	13	2
Spring River	40	10	11	15	20	4
Elk River	50	10	11	11	10	8
Tar Creek	50	10	11	11	10	8

Inflowing sediment erosive parameters are shown in Table 34. This was based on evaluation of sediment in the system and was also used for calibration parameters during model development.

Table 34
Incoming Sediment Erosive Parameters

Critical Shear Stress (lb/ft^2)	Erosion Rate, M (lb/ft^2/hr)	Critical Mass Wasting Shear Stress (lb/ft^2)	Mass Wasting Erosion Rate, M_{MW} (lb/ft^2/hr)
0.002506	0.06772	0.066816	9.04153

6.2.2 Calibration Evaluation

The primary metric used for model evaluation was sediment deposition volumes. This information was extracted from model runs by comparing the mass of sediment deposited between the start of the simulation and the next available bathymetry survey according to Figure 132 and Table 35.

Figure 132
Modeled Reaches Used for Calibration and Validation by Available Survey Data (All Starting Geometry was Based on Circa-1940 Data)

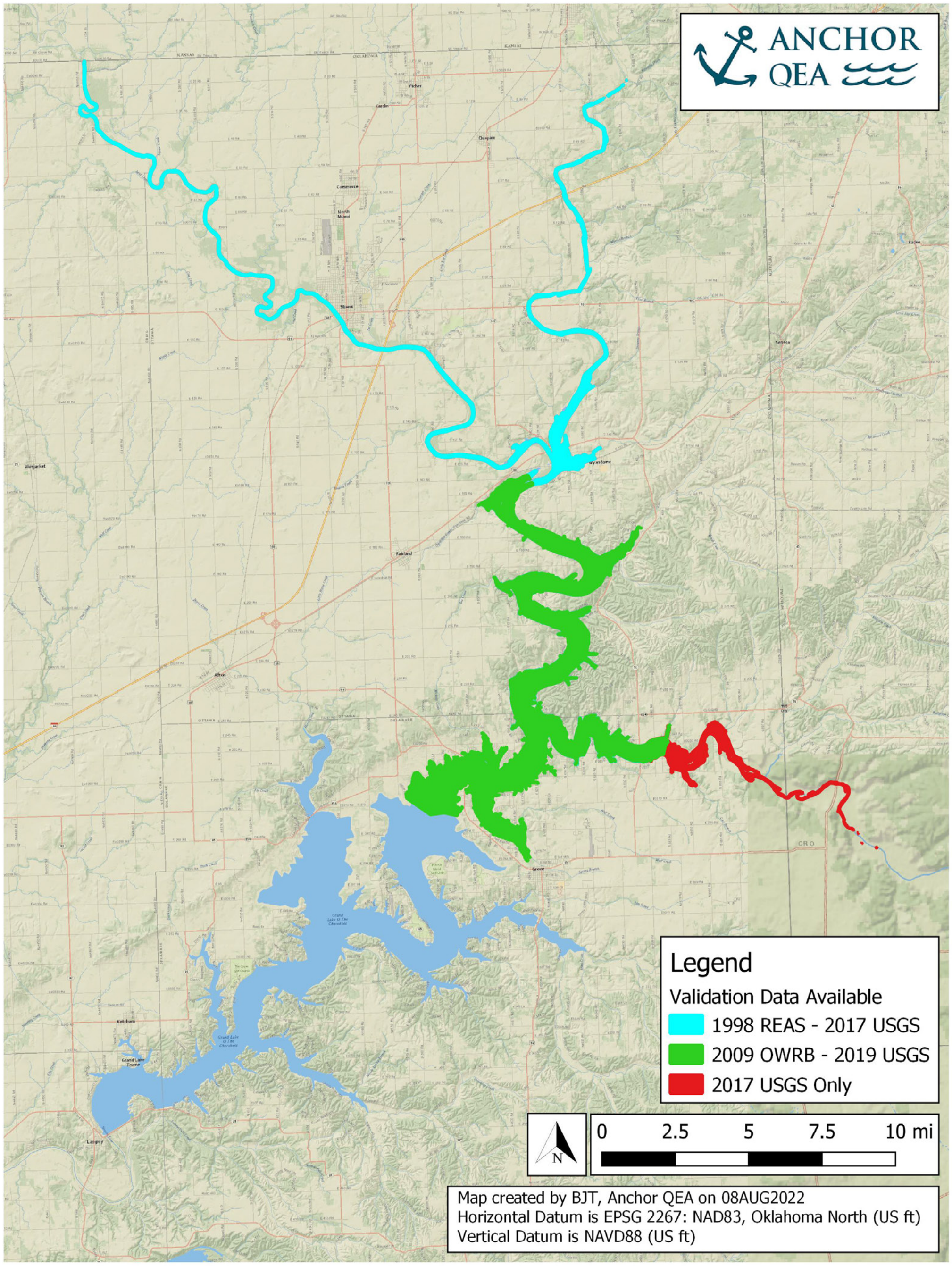


Table 35
Model Reaches and Available Survey Data for STM Development

Reach	Starting Survey	Calibration Survey	Validation Survey
Upper (Above RM 120.1)	Circa-1940 USACE	Circa-1998 REAS	2017 USGS
Lower (RM 120.1–RM 100)	Circa-1940 USACE	2009 OWRB	2019 USGS
Elk River (Above RM 5.47)	Circa-1940 USACE	2017 USGS	N/A
Reservoir (Below RM 100)	Circa-1940 USACE	2009 OWRB*	2019 USGS

Note:
*2009 OWRB data were not used for long-term analysis downstream of RM 100 (Section 2.1.1.5.1). Sedimentation rates from 1940 to 2009 were implausibly different than 2009 to 2019, so an assessment of deposition from 1940 to 2019 was used instead.

Sediment calibration runs simulated flow from October 1942 through October 2019. Evaluation of the results was based on the available survey information for the Neosho River, Spring River, and Elk River. Cross-sectional data from 1941 were digitized from survey data obtained from USACE surveys (1941). For the Neosho River below the Spring River and the Elk River, the current dataset was obtained from the 2019 bathymetric survey data. For the Spring River and the Neosho River upstream of the Spring River, the 2017 bathymetric survey data were used since the 2019 data extents did not include these areas.

River mile stations of the cross sections from the 1941 data were used to identify the most comparable cross sections in the contemporary datasets. Not all the 1941 cross sections had an exact river mile station match in the current data, so the nearest possible cross section was used—with most comparisons being within 0.05 river mile. The river mile stations of each river are shown in Table 36 through Table 39. Horizontal stationing differed between 1941 and 2017/2019 due to a lack of precise geographical information on where the 1941 cross sections are located. To match the horizontal position of 1941 and 2017/2019 cross sections, the horizontal stationing for the 1941 data were shifted based on visual comparison with the contemporary datasets.

Cross-sectional channel area was calculated based on a reference elevation set at the approximate high water level for each cross section, with the same elevation being used between each set of 1941 cross sections and 2017/2019 cross sections. The area under this elevation and above the cross-section elevation was considered the cross-sectional area and these were differenced to find the cross-sectional change in channel capacity. Figure 133 through Figure 136 provide examples for each river, showing the 1941 cross sections, 2017/2019 cross sections, and the reference elevation. Finally, the volume change was calculated using the same approach used by HEC-RAS in defining the representative bed sediment volume for a cross section, which multiplies cross-sectional change in area by the average of upstream and downstream reach lengths. Table 36 through Table 39 show the reference elevation, cross-section areas for 2017 and 2019, change in cross-sectional areas, and the volumetric change in channel cross sections in millions of cubic feet for each river.

Table 36
Elk River 1941 to 2017 Cross-Section Comparison

1941 Cross Section (RM)	2017 Cross Section (RM)	Reference Elevation (feet PD)	1941 Area (ft^2)	2017 Area (ft^2)	Change In Area (ft^2)	Change In Volume ($ft^3 \times 10^6$)
0.76	0.8	758.93	118,092	105,556	12,536	107
3.22	2.96	758.93	132,363	114,771	17,592	220
5.50	5.18	758.93	98,125	77,321	20,804	218
7.20	6.44	758.93	109,768	77,994	31,773	318
9.28	8.41	763.93	118,092	110,807	7,285	74
11.03	10.08	763.93	55,118	44,891	10,227	91
12.64	11.68	763.93	22,140	18,833	3,308	34
13.77	12.8	763.93	18,459	19,849	-1,390	-4
					Reach Total	**617**

Figure 133
Example Elk River Cross Section RM 9.28

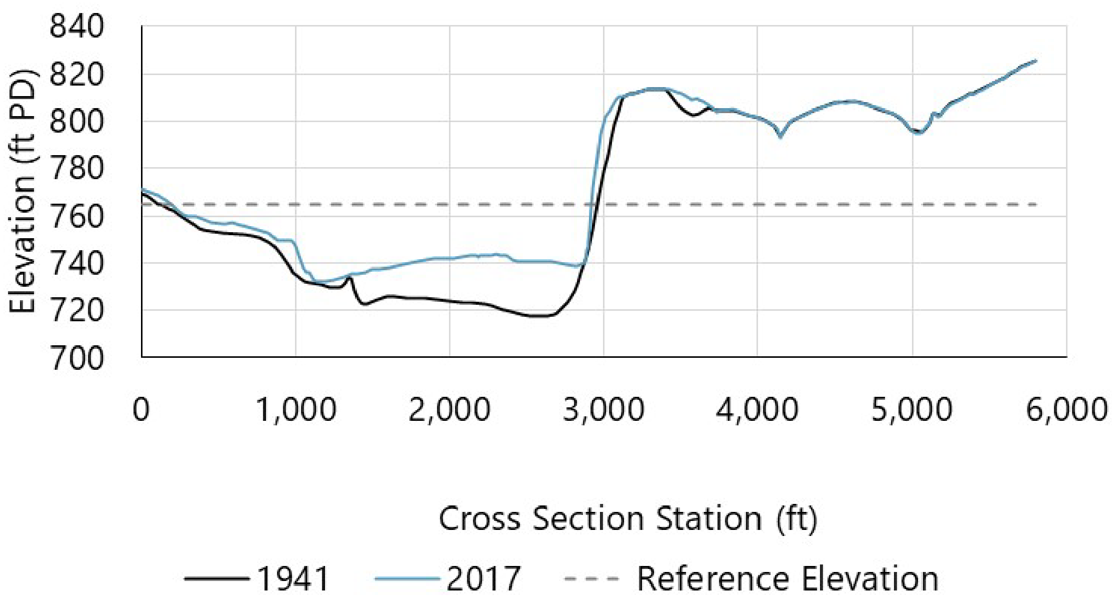


Table 37
Neosho – Below Spring River 1941 to 2019 Cross-Section Comparison

1941 Cross Section (RM)	2019 Cross Section (RM)	Reference Elevation (feet PD)	1941 Area (ft²)	2019 Area (ft²)	Change In Area (ft²)	Change In Volume (ft³ x 10⁶)
100.78	100.82	758.93	347,839	308,627	39,212	555
104.07	104.18	758.93	260,683	212,408	48,275	874
107.68	107.81	758.93	156,905	109,099	47,806	1,000
113.70	113.79	758.93	97,942	61,154	36,788	1,060
118.60	118.56	758.93	72,891	52,126	20,765	268
					Reach Total	**3,757**

Figure 134
Example Neosho River – Below Spring River Cross Section RM 118.60

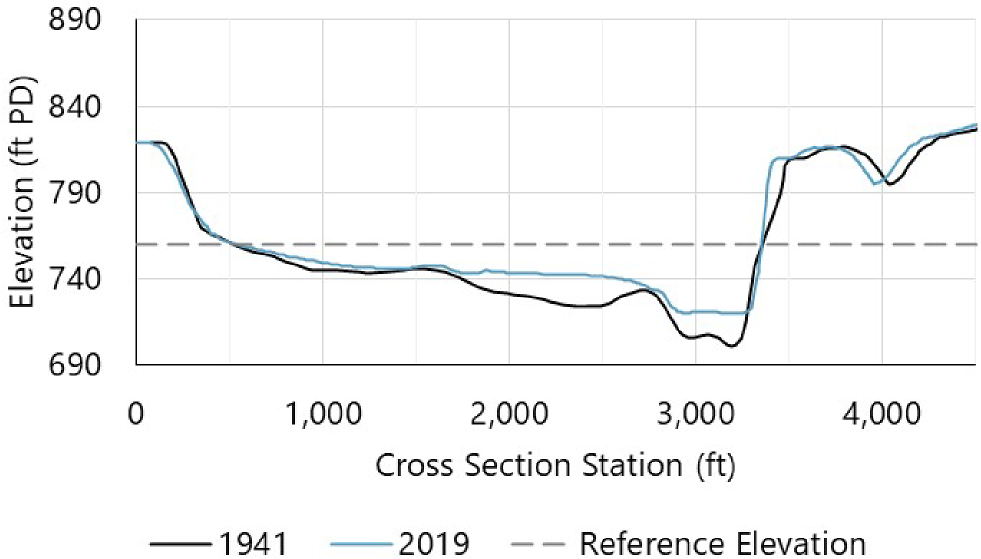


Table 38
Neosho – Above Spring River 1941 to 2017 Cross-Section Comparison

1941 Cross Section (RM)	2017 Cross Section (RM)	Reference Elevation (feet PD)	1941 Area (ft²)	2017 Area (ft²)	Change In Area (ft²)	Change In Volume (ft³ x 10⁶)
124.25	124.20	748.93	16,177	12,082	4,095	70
129.98	130.01	753.93	41,877	26,911	14,967	377
133.79	133.80	753.93	13,037	8,500	4,537	85

1941 Cross Section (RM)	2017 Cross Section (RM)	Reference Elevation (feet PD)	1941 Area (ft^2)	2017 Area (ft^2)	Change In Area (ft^2)	Change In Volume (ft^3 x 10^6)
137.07	136.98	753.93	7,849	6,655	1,193	17
139.26	139.19	758.93	8,807	7,902	905	11
141.80	141.67	763.93	17,090	12,737	4,353	46
143.23	143.38	763.93	7,442	6,520	922	10
144.64	144.52	763.93	6,865	5,340	1,526	70
					Reach Total	**617**

Figure 135
Example Neosho River – Above Spring River Cross Section RM 124.25

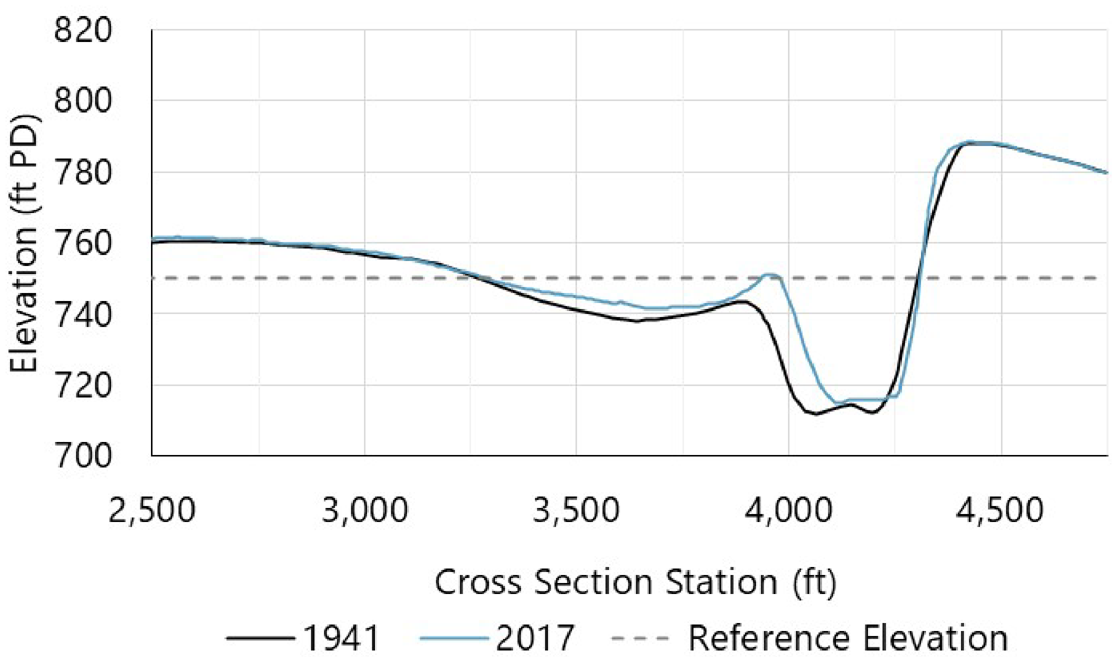
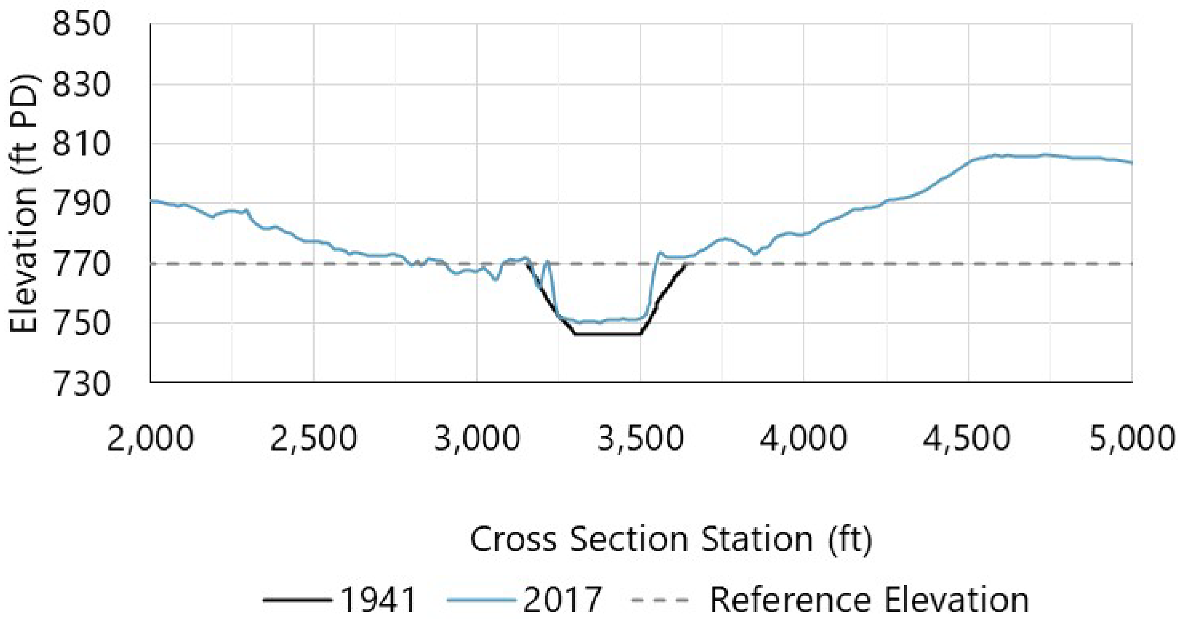


Table 39
Spring River 1941 to 2017 Cross-Section Comparison

1941 Cross Section (RM)	2017 Cross Section (RM)	Reference Elevation (feet PD)	1941 Area (ft^2)	2017 Area (ft^2)	Change In Area (ft^2)	Change In Volume (ft^3 x 10^6)
0.78	0.79	748.93	24,892	19,476	5,415	74
5.19	5.1	748.93	9,721	6,945	2,776	43
6.63	6.64	753.93	8,897	8,388	508	7

1941 Cross Section (RM)	2017 Cross Section (RM)	Reference Elevation (feet PD)	1941 Area (ft^2)	2017 Area (ft^2)	Change In Area (ft^2)	Change In Volume ($ft^3 \times 10^6$)
10.49	10.51	753.93	7,846	4,440	3,406	51
12.35	12.43	768.93	11,400	12,884	-1,484	-21
15.89	15.93	768.93	8,187	6,074	2,113	25
16.84	16.88	768.93	9,240	4,784	4,456	11
					Reach Total	**191**

Figure 136
Example Spring River Cross Section RM 15.89



The simulation data were then compared to measured data using metrics defined by Moriasi et al. (2007). Specifically, the Nash-Sutcliffe Efficiency (NSE), which evaluates the ratio of noise to measured data variance (Nash and Sutcliffe 1970) as defined in Equation 5.

Equation 5

$$NSE = 1 - \left[\frac{\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{sim}\right)^2}{\sum_{i=1}^{n}\left(Y_i^{obs} - Y^{mean}\right)^2}\right]$$

where:

Y_i^{obs} = the *i*th observation for the constituent being evaluated

Y_i^{sim} = the *i*th simulated value for said constituent

Y^{mean} = the mean of observed data

n = the total number of observations

Another metric used was the Percent Bias (PBIAS) as defined by Gupta et al. (1999). This is used as a measure of the tendency for the simulation to overpredict or underpredict the constituent of interest and is defined in Equation 6.

Equation 6

$$PBIAS = \left[\frac{\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{sim}\right) \cdot (100)}{\sum_{i=1}^{n}\left(Y_i^{obs}\right)}\right]$$

where:

$PBIAS$ = percent bias

Where *PBIAS* is expressed as a percentage, and it is consistent with percent difference in volume.

The third metric from Moriasi et al. (2007) used in this study was the RMSE-Observations Standard Deviation Ratio (RSR) as defined by Singh et al. (2004). This measure is a reformulation of the RMSE that normalizes results so an ideal model will produce an RSR of 0. It is defined as shown in Equation 7.

Equation 7

$$RSR = \frac{RMSE}{STDEV_{obs}} = \frac{\left[\sqrt{\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{sim}\right)^2}\right]}{\left[\sqrt{\sum_{i=1}^{n}\left(Y_i^{obs} - Y^{mean}\right)^2}\right]}$$

where:

RMSE = root mean square error

$STDEV_{obs}$ = standard deviation of the observed values

C = the sum of A and B

Table 40 shows typical criteria adopted by Moriasi et al. (2007) for sediment modeling.

Table 40
Statistical Criteria for Sediment Model Performance

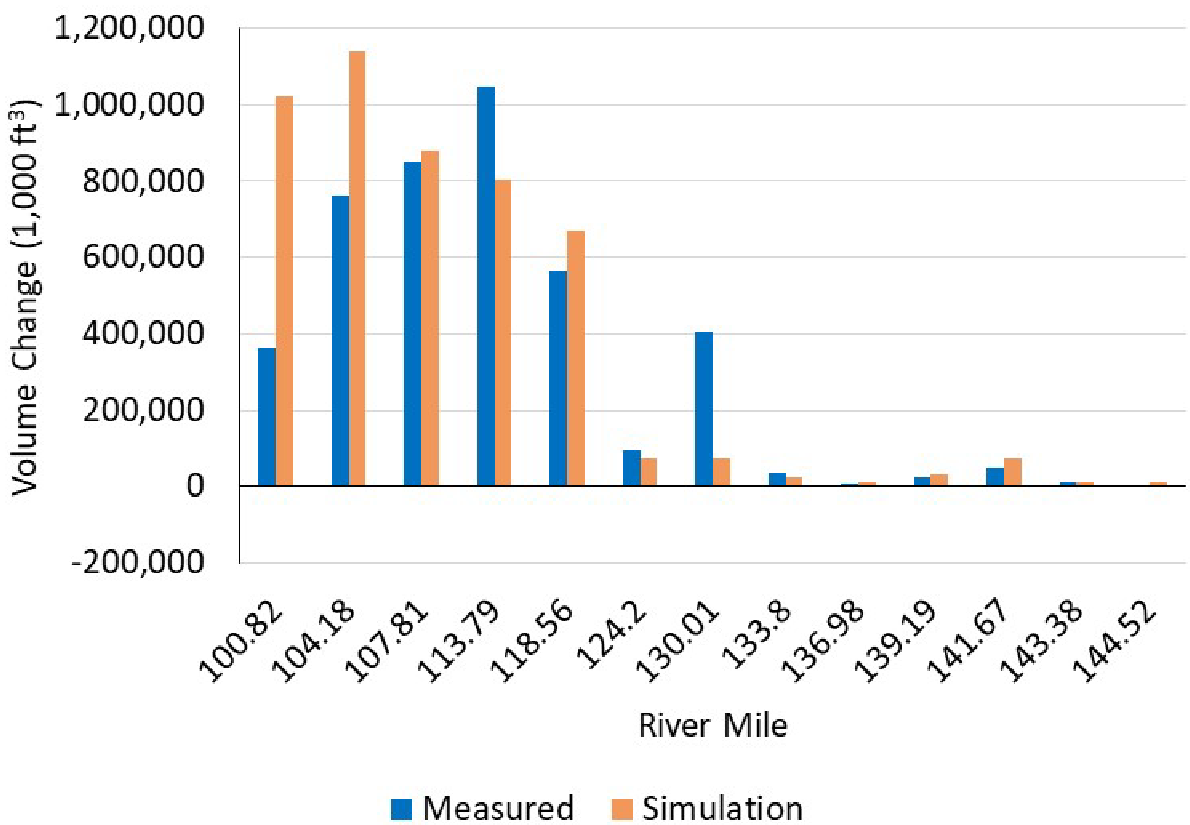
Model Performance	NSE	PBIAS	RSR
Very Good	0.75 < NSE ≤ 1.00	|PBIAS| < 15	0.00 ≤ NSE ≤ 0.50
Good	0.65 < NSE ≤ 0.75	15 ≤ |PBIAS| < 30	0.50 ≤ NSE ≤ 0.60
Satisfactory	0.50 < NSE ≤ 0.65	30 ≤ |PBIAS| < 55	0.60 ≤ NSE ≤ 0.70
Unsatisfactory	NSE ≤ 0.50	|PBIAS| ≥ 55	RSR > 0.70

Note: Adapted from Moriasi et al. (2007)

6.2.2.1 Results

The model performed well in most areas of the Neosho River (Figure 137). The model agrees with measured data in most of the reach upstream of RM 120.1, with the exception of RM 130.01, and it also agrees on the upstream face of the delta feature (RM 120.1 to RM 105), where GRDA asserted in the April 2022 USP the model was able to reasonably predict sediment deposition. Below that point, lacustrine dynamics and the prevalence of cohesive sediments decrease HEC-RAS's suitability for modeling deposition.

Figure 137
Neosho River Volume Change from Circa 1940



Notes: Model results above RM 120.1 are compared to 1998 REAS data.
Model results below RM 120.1 are compared to 2009 OWRB data.

There are two locations where the modeled results match poorly with the measured datasets. It underpredicts deposition on the Neosho River near RM 130.01 and overpredicts deposition on the downstream face of the delta feature (RM 104.18 and 100.82). Removing those locations from the analysis result in a much-improved calibration. The statistical analysis of calibration results with and without those cross sections are shown in Table 41.

Table 41
Statistical Calibration Evaluation Parameters of STM on the Neosho River

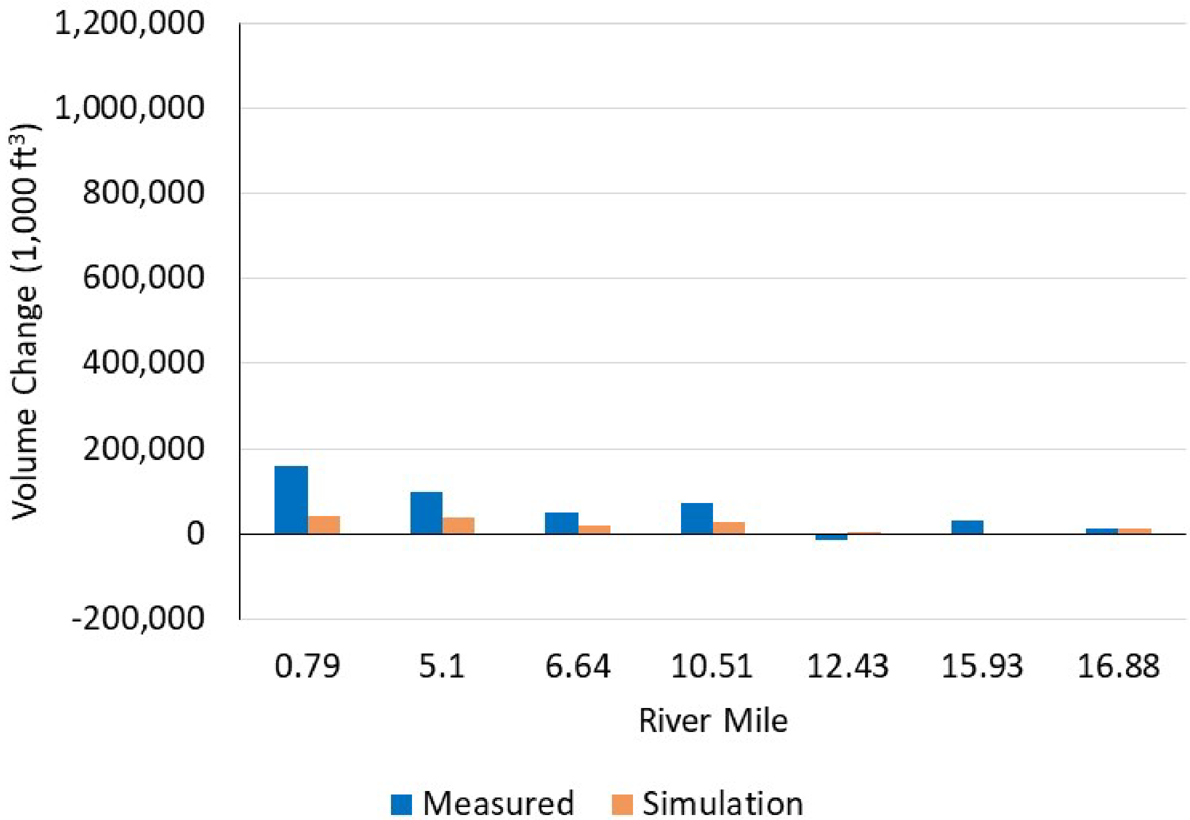
Reach	NSE (Target: > 0.5)	PBIAS (|Target|: < 0.55)	RSR (Target: < 0.70)
All Locations	-0.94	0.19	0.69
Excluding RM 130.01, 104.18, 100.82	0.95	0.01	0.22

Note:
Calibration of the model showed significant underprediction at RM 130.01 and overprediction on the downstream face of the delta feature (RM 104.18, 100.82).

Results on the Spring and Elk rivers were less accurate due to poor historical data quality. As discussed in Sections 2.1.1 and 6.1.1 of this report, the limitations of the data reduce the ability to perfectly simulate sediment transport. As discussed previously, the exact locations of the circa-1940 cross-sectional surveys were estimated based on reported stream distances (USACE 1941, 1942) and placed on the 1938 topographic maps (USACE 1938). Uncertainty of the placement of the cross-section survey data contributes to reduced model calibration results.

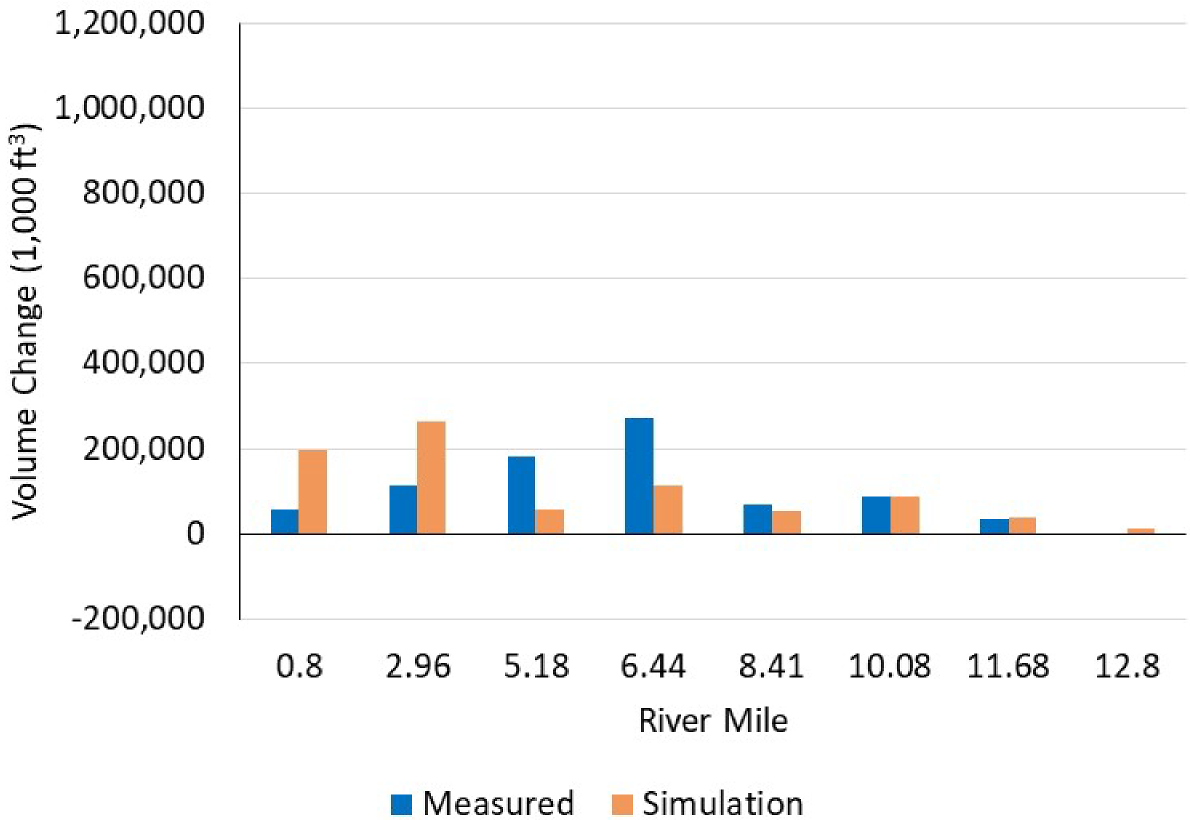
Spring River results are presented in Figure 138 and Elk River results are shown in Figure 139.

Figure 138
Spring River Volume Change from Circa 1940



Note: Model results are compared to 1998 REAS data.

Figure 139
Elk River Volume Change from Circa 1940



Notes: Model results above RM 5.47 are compared to 2017 USGS data.
Model results below RM 5.47 are compared to 2009 OWRB data.

The statistical analysis of the Spring and Elk river model results is presented in Table 42.

Table 42
Statistical Calibration Evaluation Parameters of STM on the Spring and Elk Rivers

Reach	NSE (Target: > 0.5)	PBIAS (|Target|: < 0.55)	RSR (Target: < 0.70)
Spring River	0.04	-0.62	0.98
Elk River	-0.55	0.03	1.24

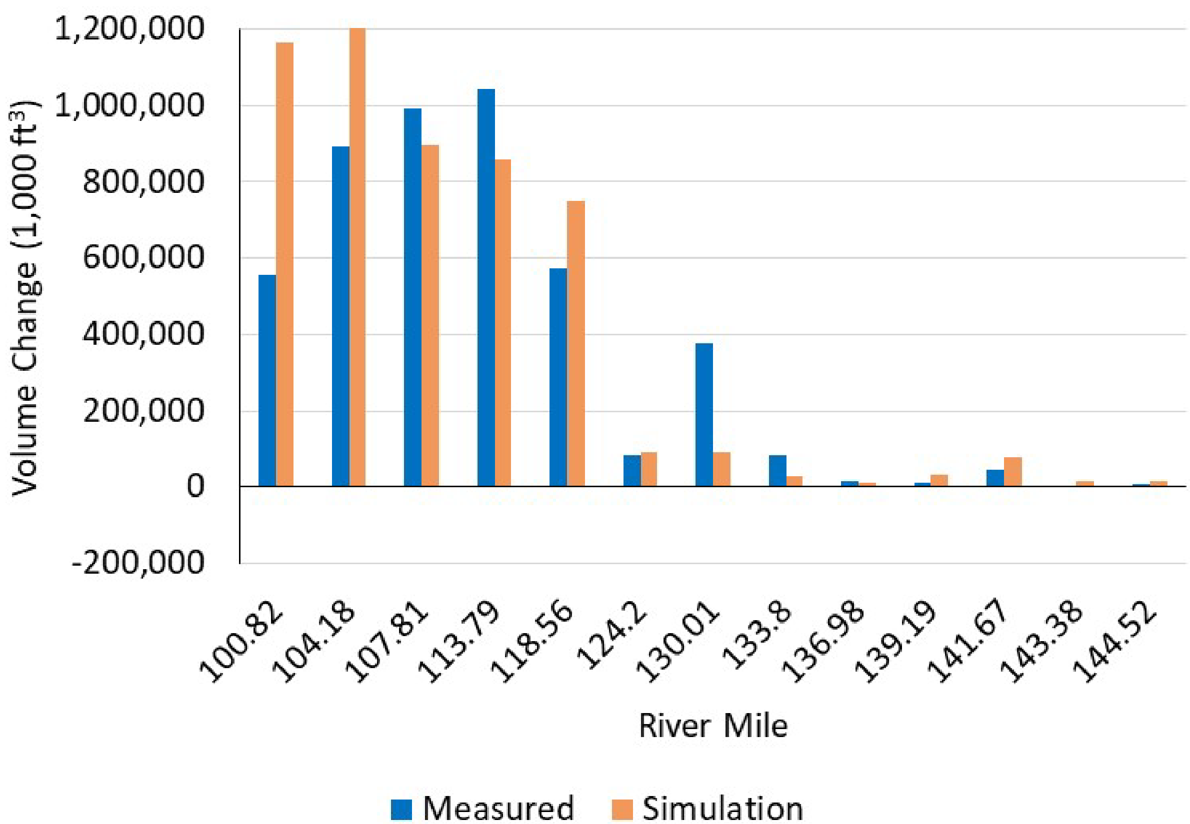
The model tends to underpredict sediment deposition on the Spring River and overpredict deposition on the Elk River. These rivers have the least reliable cross-sectional survey placements, with no bridges to reference for cross-section locations.

Another method of comparing the model results to measured data is to compare predicted and measured geometry. Two of the more useful means of evaluating channel evolution with HEC-RAS models are average channel and average section elevations. These metrics contain far more geometry information than a simple thalweg plot; a thalweg plot looks only at the lowest point of the cross section, whereas the other metrics incorporate the trends across the entire stream channel and submerged portion of the model. These are more closely related to hydraulic flow areas and are in many cases a better means of condensing channel geometry into a simple profile.

6.2.2.2 Calibration Validation

After calibration, the model performance was compared to the latest available modern surveys as shown in Figure 140. The results are presented below.

Figure 140
Neosho River Volume Change Validation



Notes: Model results above RM 120.1 are compared to 2017 USGS data.
Model results below RM 120.1 are compared to 2019 USGS data.

The validation results on the Neosho River showed similar patterns to those in the calibration; deposition was significantly overpredicted on the downstream face of the delta feature (below RM 105) and underpredicted near RM 130.01. Statistical evaluations are shown in Table 43.

Table 43
Statistical Validation Evaluation Parameters of STM on the Neosho River

Reach	NSE (Target: > 0.5)	PBIAS (|Target|: < 0.55)	RSR (Target: < 0.70)
All Locations	-0.64	0.25	0.69
Excluding RM 130.01, 104.18, 100.82	0.80	0.13	0.44

Notes:
Calibration of the model showed significant underprediction at RM 130.01 and overprediction on the downstream face of the delta feature (RM 104.18, 100.82)

Validation on the Elk and Spring rivers was less precise than on the Neosho River, similar to the calibration results (Figure 141 and Figure 142).

Figure 141
Spring River Volume Change Validation

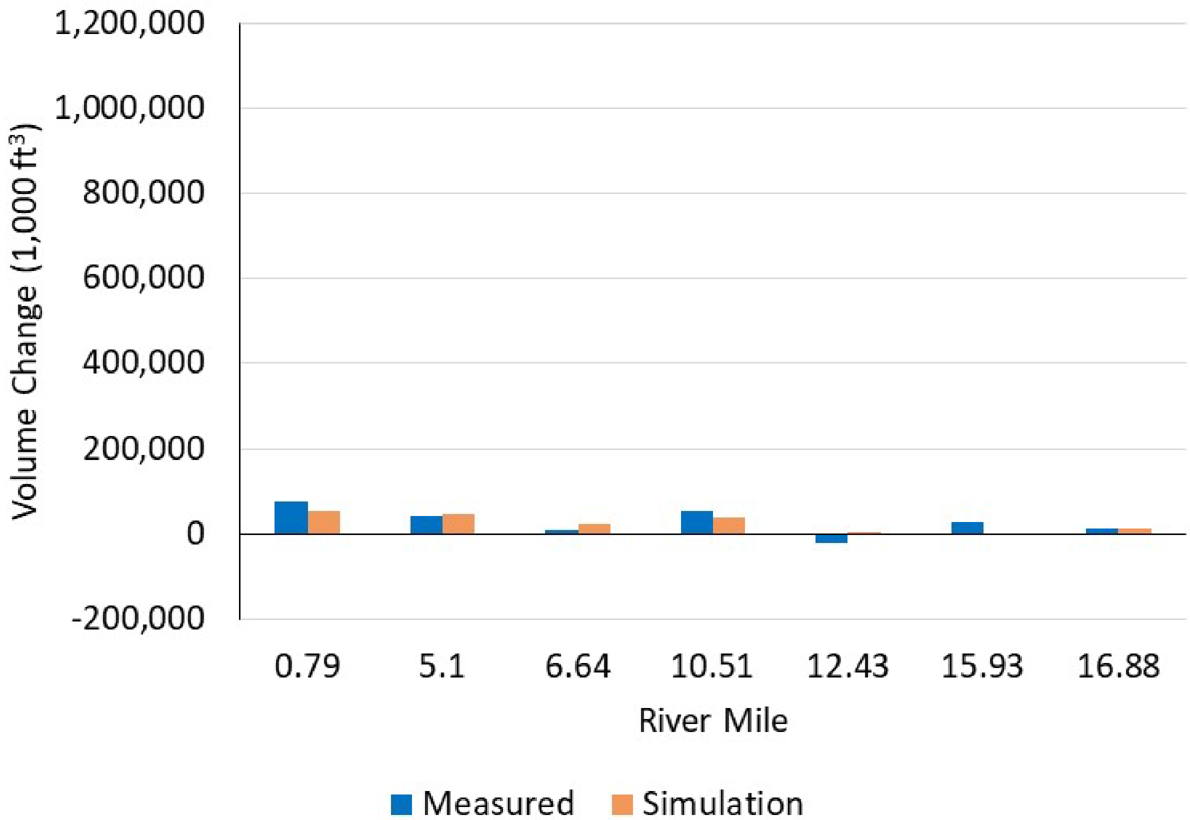
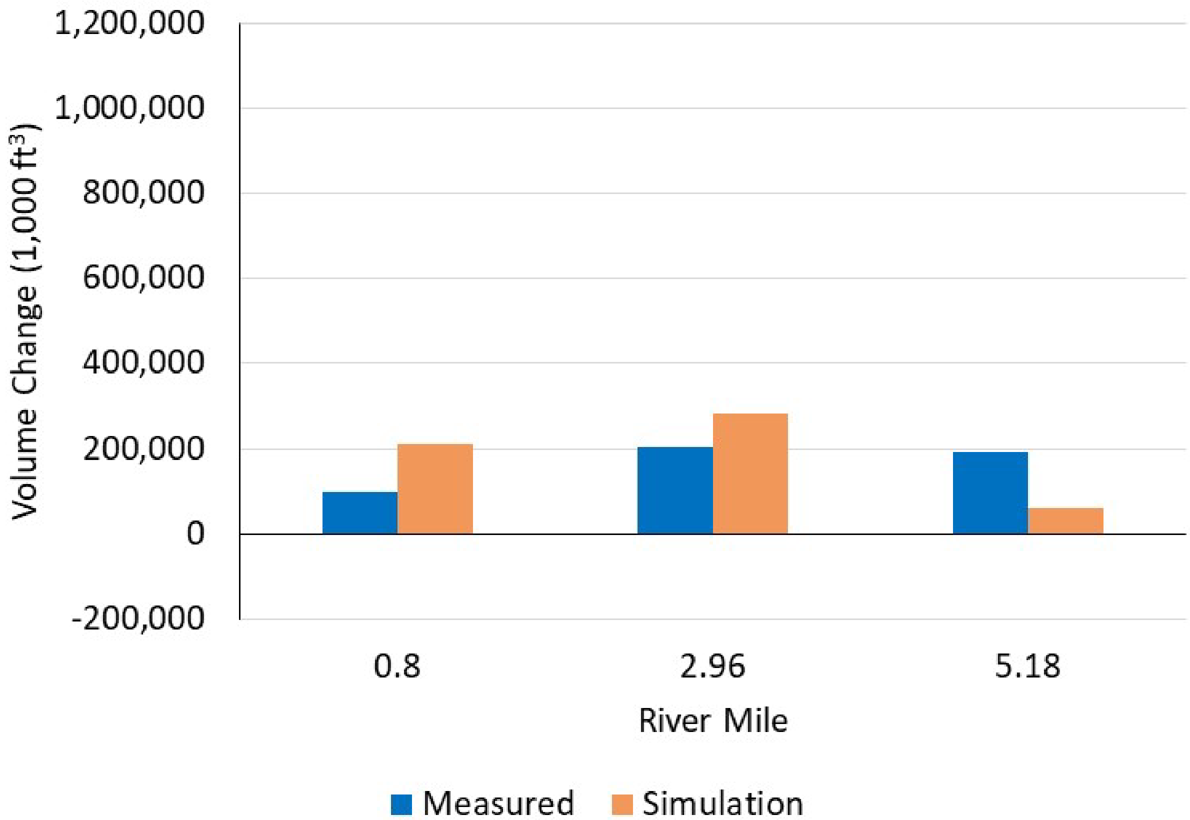


Figure 142
Elk River Volume Change Validation



Note: There is no available validation data on the Elk River above RM 5.46 as shown in Table 35.

The statistical analysis of the validation fits for the Elk River and Spring River is shown in Table 44.

Table 44
Statistical Validation Evaluation Parameters of STM on the Spring and Elk Rivers

Reach	NSE (Target: > 0.5)	PBIAS (|Target|: < 0.55)	RSR (Target: < 0.70)
Spring River	0.62	-0.09	0.62
Elk River	0.08	-0.04	0.98

As during calibration, the model performance in validation runs is limited by the quality of available datasets. This was a known issue during model development and was discussed in the USP. To address this issue, the model was run using several input conditions for sedimentation as a means of bounding the expected sediment deposition and transport within the study area.

Another method to evaluate STMs is comparing average channel and average section profiles. This was discussed by WEST in their ITR (2022) in detail, but a brief summary of the measurement is provided here. The average channel and average section profiles are a more effective means of showing stream geometry than a simple thalweg profile. The thalweg *only* uses one point per cross section to show a stream profile; average section and average channel take the entire channel or entire cross section into consideration, condensing for more information into the profile plot. This also provides a more representative method of evaluating hydraulic characteristics, because it accounts for the cross-section geometry as well as the thalweg.

The Neosho River average channel and average section profiles are shown in Figure 143 and . Mean error in channel elevation on the river compared to measured modern geometry data is -1.1 feet, meaning the model underpredicts bed elevations as compared to measured values. Mean error in average section elevations was -1.8 feet.

Figure 143
Neosho River Comparison of Measured and Modeled Average Channel Profiles

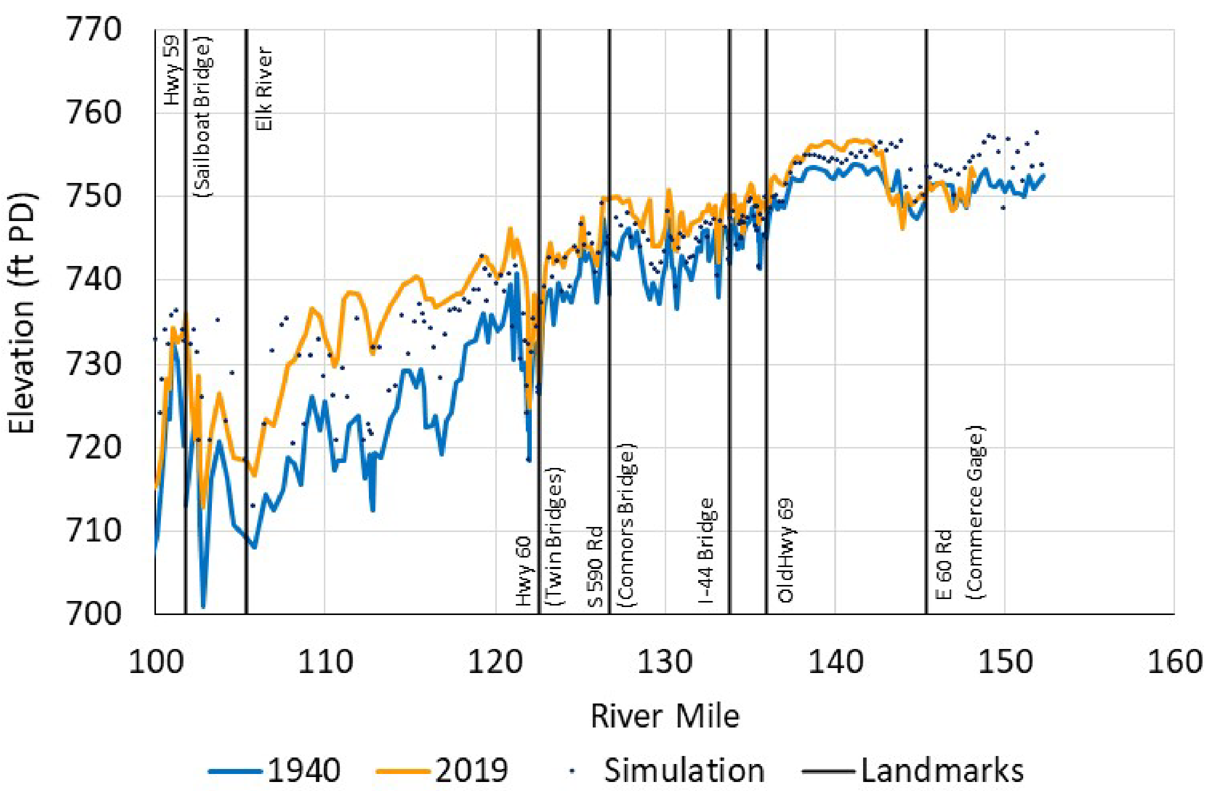
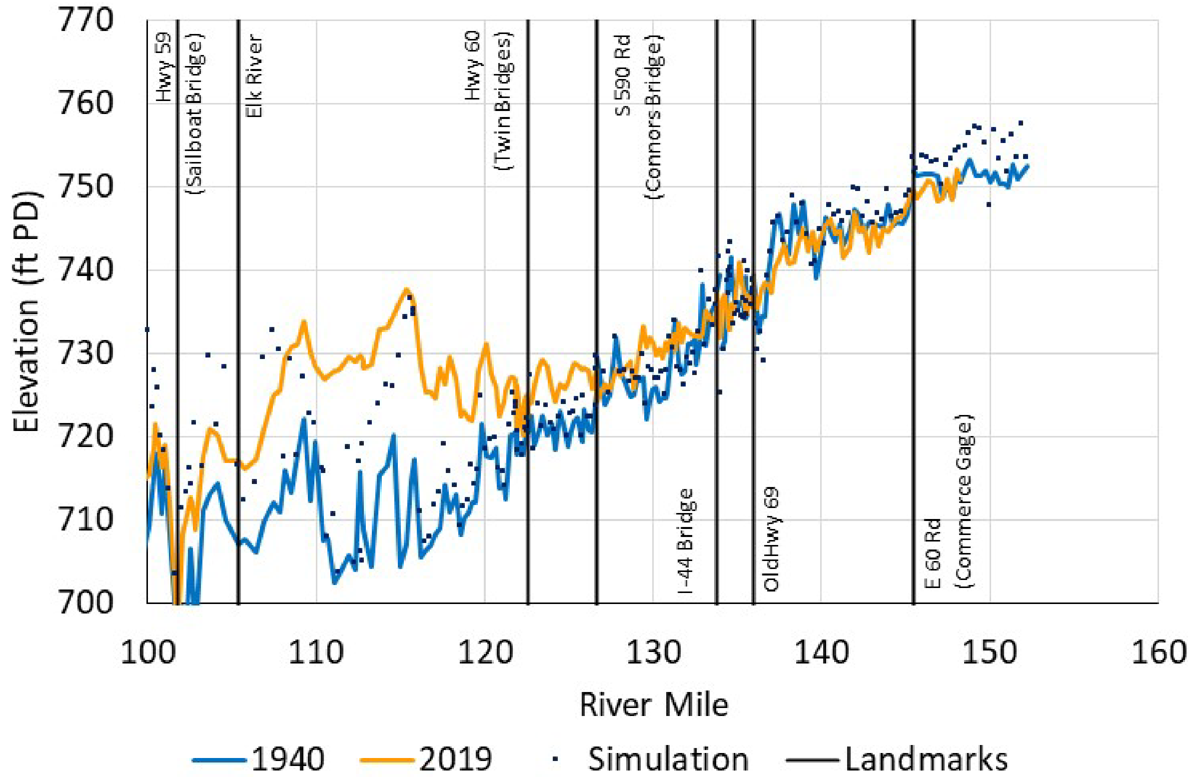


Figure 144
Neosho River Comparison of Measured and Modeled Average Section Profiles



The differences in average channel and average section are largely explained by the poor quality of the circa-1940 geometry. The circa-1940 geometry relies on far fewer measured cross sections that were then interpolated to produce the circa-1940 geometry. Overbank areas are based on poorly scanned topographic maps, resulting in uncertainty when digitizing contour lines. These resulted in several areas of relatively wide channels between measured cross sections.

In contrast, the 2019 geometry is based on high-resolution data. The channels are far narrower in this geometry. As a result, the circa 1940 channel is often wider than its 2019 counterpart and would require significantly more deposition to match total volume changes between measured portions of the river.

HEC-RAS provides outputs showing cumulative volume in a river reach. This calculation finds the volume at every cross section in the model. For the reach between RM 145.4 (East 60th Road, USGS Commerce gage) and the confluence with the Spring River, HEC-RAS reports a volume difference of

53,700 acre-feet between the digitized and interpolated 1940 geometry and the measured 2019 geometry.

Where historical channel cross-section information is available, the model shows good correlation with sediment deposition volumes as shown in the above results. Using only the measured cross sections as shown above results in expected deposition of just 18,500 acre-feet. This matches well with the reported model deposition of approximately 15,300 acre-feet.

In contrast, the large change reported by HEC-RAS cumulative volume outputs from 1940 to 2019 reinforces the conclusion that unsurveyed, interpolated, circa 1940 cross sections are too wide. By including all model cross sections instead of only using those with known survey data, the amount of deposition needed to match the 2019 terrain is approximately three times what is shown when using *only* surveyed locations. This significant discrepancy could only occur if the unsurveyed portions of the circa 1940 terrain had much wider channels than existed in reality. Because the data for these unsurveyed sections are based on poorly scanned contour maps, they are far less reliable than the more accurate survey information used in the above analyses.

7 Predictive Simulations

After model calibration, predictive simulations were performed to evaluate future conditions within the study area and evaluate the impact of sedimentation on upstream water levels and the power pool.

7.1 Model Inputs

Model inputs for the predictive simulations included synthetic hydrographs, bed characteristics recorded from field measurements, and sediment rating curves.

There were four separate predictive simulations to address the uncertainties associated with the available terrain information discussed earlier in this report. These included expected loading simulations under both *Baseline* and *Anticipated* operations, a *High Sedimentation* simulation with adjusted parameters to increase sediment deposition in the study area, and a *Low Sedimentation* scenario with adjusted parameters to place a lower bound on the predicted sedimentation. These will be discussed in more detail in the following sections.

7.1.1 Hydraulic Parameters

To run future sediment simulations, synthetic future hydrographs for the 50-year period of January 1, 2020, to December 31, 2069 (2020 to 2070), were generated for each of the USGS gage locations (USGS 2021a, 2021c, 2021e, 2021f) and the corresponding synthetic Tar Creek hydrograph discussed in Section 5.2.1.1 of this report. Peak annual maximum flows were examined for each of the hydrographs to identity any trends in the peak flows. No significant trends were observed at any of the locations and introduction of a scaling factor to artificially increase or decrease the severity or duration of inflow events was not warranted. Therefore, the yearly hydrographs for 2020 to 2070 were assumed to approximately repeat the set of flows from January 1, 1970, to December 31, 2019 (1970 to 2020). To create some variability in the data, the order in which the flow years occurred was randomized when applied to the future hydrographs. This created a set of randomized hydrographs that would preserve the subannual patterns of individual water years and keep the statistical peak flow events the same between past and future hydrographs. Water years were separated into leap years and non-leap years and a separate randomization was applied, such that historical leap years would only be transposed to future predicted leap years. Because there are more leap years in the projected period of record, one non-leap year was projected to a future leap year and the February 28 flow data were projected to February 29. The same generated randomization of years was applied to each gage location so that peak flows would match between locations.

Downstream WSE BCs were set based on Operations Model (OM) outputs. The OM results were then imported to the STM for future simulations.

7.1.1.1 Stream Temperature

Sediment transport is affected by water temperatures. Water temperature is related to water viscosity, which can increase or decrease the potential for sediment entrainment and transport or deposition.

To bound the potential sediment deposition range, temperature was adjusted for the various future scenarios. In the *Baseline* and *Anticipated* scenarios, temperatures were set to match the measured values as discussed in Section 6.2.1.1 of this report. The *High Sedimentation* and *Low Sedimentation* scenarios (bounding scenarios) used water temperatures increased by 5°F and decreased by 5°F, respectively.

7.1.2 Sediment Parameters

7.1.2.1 Bed Sediment

Bed sediment conditions were selected based on the measured grain size distributions and bed shear stresses measured in the field as part of this study. The properties were assigned to the corresponding locations on the relevant tributaries, and HEC-RAS interpolation functions were used to gradually transition bed materials between locations.

7.1.2.2 Sediment Inflows

Rating curves were adjusted for bounding scenarios, but no changes were made to incoming sediment gradations. The *Anticipated* and *Baseline* operations scenarios used the same incoming sediment rating curves as the calibration run. The *High Sedimentation* scenario increased sediment discharge by 20%, and the *Low Sedimentation* scenario decreased sediment discharge by 20%. This was applied by a simple multiplication factor applied to the rating curves and imported into the HEC-RAS sediment input file.

7.1.2.3 Fall Velocity Method

The other parameter adjusted for the bounding scenarios was the fall velocity method. The *Baseline* and *Anticipated* scenarios used the Rubey method. Analysis of the various methods available in HEC-RAS indicated that van Rijn would increase fall velocity and thus deposition, so it was used in the *High Sedimentation* run, and Dietrich was used for the *Low Sedimentation* simulation.

7.2 Data Processing

The predictive STM simulation required an iterative process to account for potential changes in OM due to future reservoir sedimentation. To evaluate predictive STM simulations, it was necessary to iteratively adjust stage-storage curves within the study area. This iterative process is described as follows:

1. The initial stage-storage curve was extracted from the 2019 HEC-RAS terrain.

2. This initial curve with the synthetic hydrographs was run in the OM to determine the downstream WSE hydrograph. The STM was then run with the downstream WSE boundary computed by the OM.
3. Upon completion of the HEC-RAS sediment simulation, the resulting geometry was processed and stage-storage upstream of RM 100 was extracted from the model. This method does not provide information about the impacts on storage downstream of the model domain. Adjustments to account for the loss of storage below RM 100 are provided below.
4. The OM was re-run with a dynamic stage-storage curve, based on a temporal linear interpolation between the starting 2019 curve and the curve output from Step 3.
5. The STM was then re-run with the downstream WSE boundary computed by the second storage-interpolated iteration of the OM. The stage-storage output from this second STM run was compared to the initial output to determine if storage values changed significantly, which would indicate the need for another iteration.

To estimate stage-storage impacts on the downstream portion of the study area, the measured historical vertical accumulation rate at the dam was projected forward in time to estimate the minimum storage elevation at the dam. Table 45 provides the estimated minimum storage elevation at the dam and total change in storage estimated from measured stage-storage curves (USACE 1941; USGS 2020) for the various future conditions.

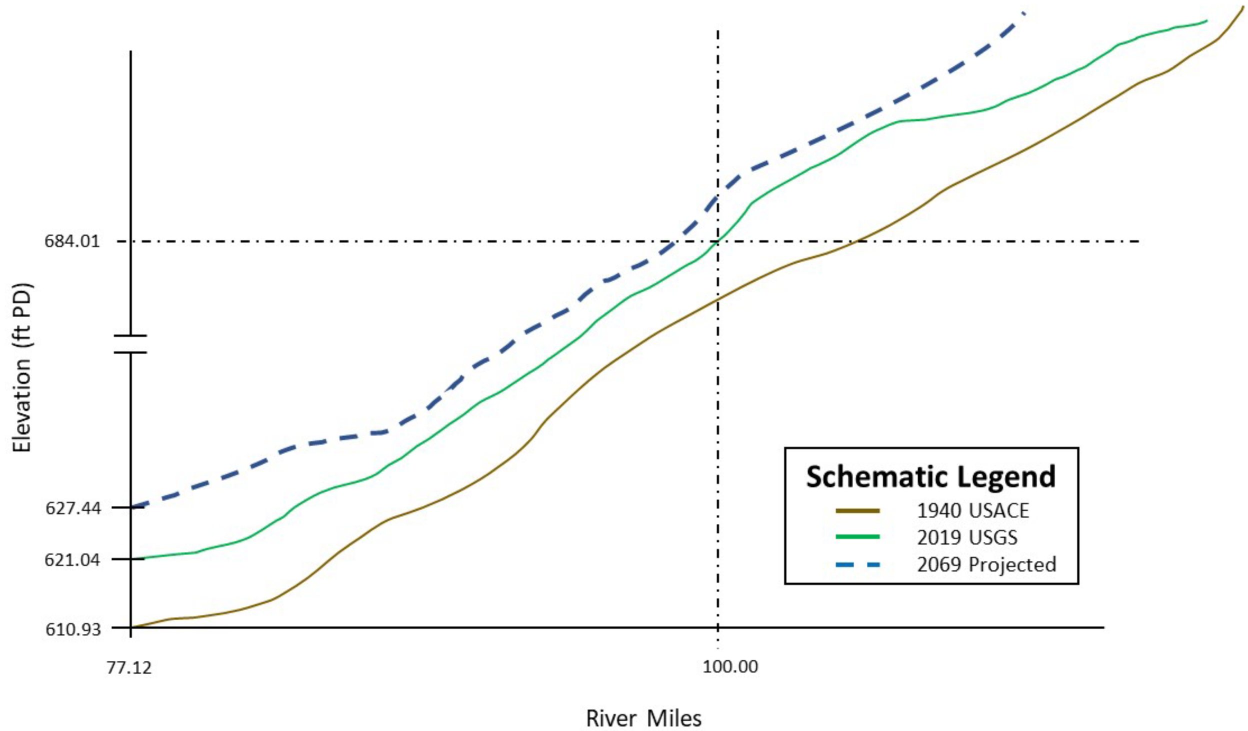
Table 45
Historical Stage-Storage Information Used to Develop Future Stage-Storage Curves Downstream of RM 100

Stage-Storage Curve	Lowest Storage Elevation (feet PD)	Total Change in Storage (acre-feet)
1940 USACE	610.93	--
2019 USGS	621.04	319,473
2069 (Baseline Ops)	627.44	224,332
2069 (Anticipated Ops)	627.44	224,332
2069 (High Sedimentation)	627.44	269,258
2069 (Low Sedimentation)	627.44	179,505

Based on the change in storage between 1940 and 2019, the long-term sediment deposition at the base of Pensacola Dam is approximately 0.13 foot per year. Projecting that rate into the future provides an estimated low point of approximately 627.44 feet. Because dam operations depend on storage changes, but not the specific location of sediment deposition near the dam, the low point is relatively unimportant to overall storage volume change and was therefore held constant for all predictive simulations.

To determine approximate storage volume change downstream of RM 100, the thalweg elevation at RM 100 was used as a reference point (Figure 145). This elevation was 684.01 feet at the time of the 2019 USGS survey.

Figure 145
Schematic Representation of Neosho River Thalweg for Illustration Purposes



All material deposited below an elevation of 684.01 feet was therefore necessarily deposited downstream of RM 100. Material deposited upstream of RM 100 is modeled directly in the STM simulations. The remaining volume was accounted for through the use of trap efficiencies and relative sediment loading.

The volume of sediment entering, depositing in, and leaving the model domain in each simulation is summarized in Table 46.

Table 46
Modeled Sediment Loading

Simulation	Modeled Incoming Load (acre-feet)	Modeled Outgoing Load (acre-feet)	Deposited in Modeled Reach (acre-feet)	Deposited Below RM 100 (acre-feet)	Total Storage Volume Change (acre-feet)
1942–2019	402,733	236,242	166,491	152,982	319,473 (measured)
2020–2069 (Baseline Ops)	280,481	173,978	106,503	117,882	224,385
2020–2069 (Anticipated Ops)	280,481	166,282	114,200	110,185	224,385
2020–2069 (High Sediment)	336,573	202,377	134,196	135,062	269,258
2020–2069 (Low Sediment)	224,382	127,682	96,700	82,806	179,506

Note: *Values are approximated by converting to volume using a sediment density of 58 pcf.

Total change in storage within the reservoir between 1940 and 2019 can be evaluated based on published stage-storage curves from USACE and USGS. For this period, the total sediment inflow as modeled was approximately 402,733 acre-feet, and total measured storage volume change was approximately 319,473 acre-feet. This corresponds to a trap efficiency of approximately 0.8.

Trap efficiency of the entire system is not expected to change drastically from one simulation to the next, so the same study-area-wide trap efficiency of 0.8 was used for all analyses. It should be noted that this may differ from trap efficiencies calculated by other methods; it relies on measured data and model results to ensure consistency through the analysis. It is not the trap efficiency for the unmodeled area alone; it includes deposition and erosion upstream of RM 100.

For the *Baseline Operations* and *Anticipated Operations* simulations, the total inflow volume of sediment was identical, and the expected trapping efficiency is the same. Therefore, the total expected change in storage volume is also expected to match (Table 46).

Relative sediment loading rates were used to calculate the storage volume change in the lower left quadrant of the schematic in Figure 145. The volume lost in that quadrant between 1940 and 2019 was measured to be 69,926 acre-feet. Storage volume change was assumed to scale with inflow volumes and adjusted accordingly (Table 47).

Table 47
Sediment Loading Compared to Storage Volume Change Below Elevation 684.01 feet PD and Storage Total Volume Change Downstream of RM 100

Simulation	Modeled Incoming Load (acre-feet)	Total Storage Change Below 684.01 feet PD (acre-feet)	Total Storage Change Downstream of RM 100 (acre-feet)
1942–2019	402,733	69,926 (measured)	--
2020–2069 (Baseline Ops)	280,481	48,668	132,450
2020–2069 (Anticipated Ops)	280,481	48,668	123,926
2020–2069 (High Sediment)	336,573	58,038	141,973
2020–2069 (Low Sediment)	224,382	38,949	87,389

Note: *Loss downstream of RM includes both the upper and lower quadrants of Figure 145 and cannot be precisely determined through available rating curves.

This storage volume change was applied to elevations below 684.01 feet at a rate proportional to the additional storage volume increment at each elevation step.

Accounting for additional storage changes in the upper left quadrant of Figure 145 used a similar approach. The difference between modeled deposition and calculated by the method above was assumed to have been in the upper left quadrant. It was assumed to also apply at a rate proportional to the incremental change in storage volume at each elevation step.

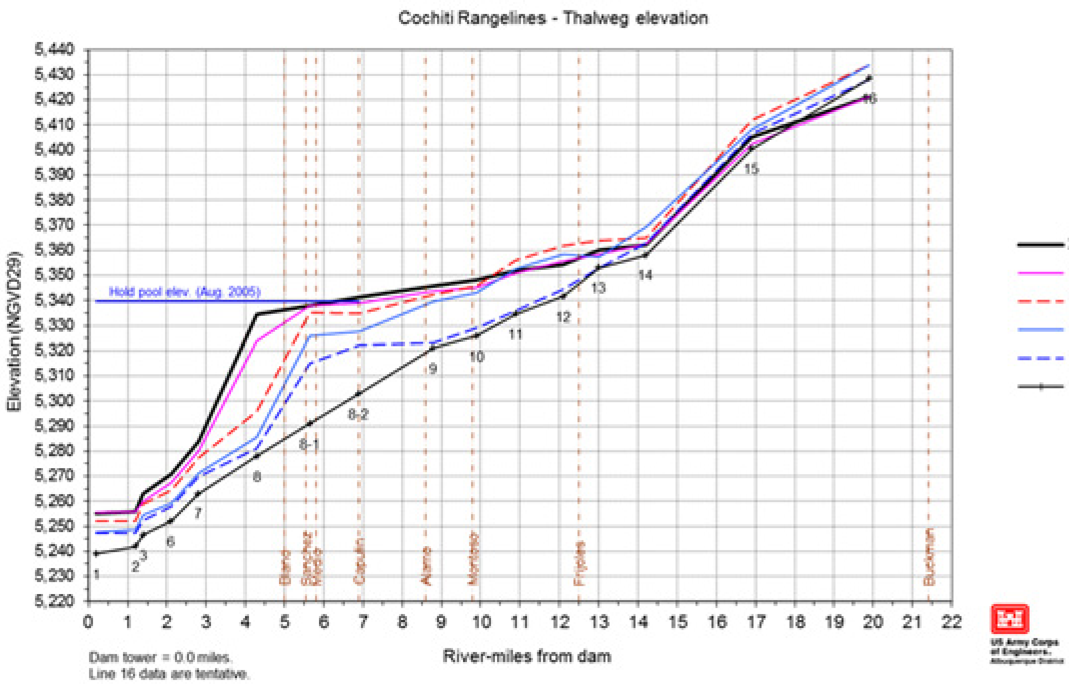
The change in total storage below 684.01 feet PD was assumed to be identical under *Baseline Operations* and *Anticipated Operations* scenarios. There is no information to determine the exact location of deposition downstream of RM 99.82, but the expected total change in volume is identical between the scenarios as discussed above. No changes were made to storage change below 684.01 feet PD, but the expected storage change was accounted for when calculating deposition in the upper left quadrant of Figure 145.

This resulted in the stage-storage curves for projected future bathymetry discussed below.

7.3 Deposition Patterns

Typical sediment deposition patterns in reservoirs follow a standard process (Vanoni 2006) illustrated in Figure 146. Sediment being carried by streamflow moves to the reservoir headwaters. As it reaches the headwaters and flow velocities decrease, sediment drops out of suspension and deposits, gradually forming a delta. Inflowing tributaries, stream geometry, bridges, and other features can also influence this process.

Figure 146
Typical Reservoir Delta Formation and Evolution—Progressive Bathymetric Surveys of the Cochiti Reservoir Delta, Rio Grande River, New Mexico



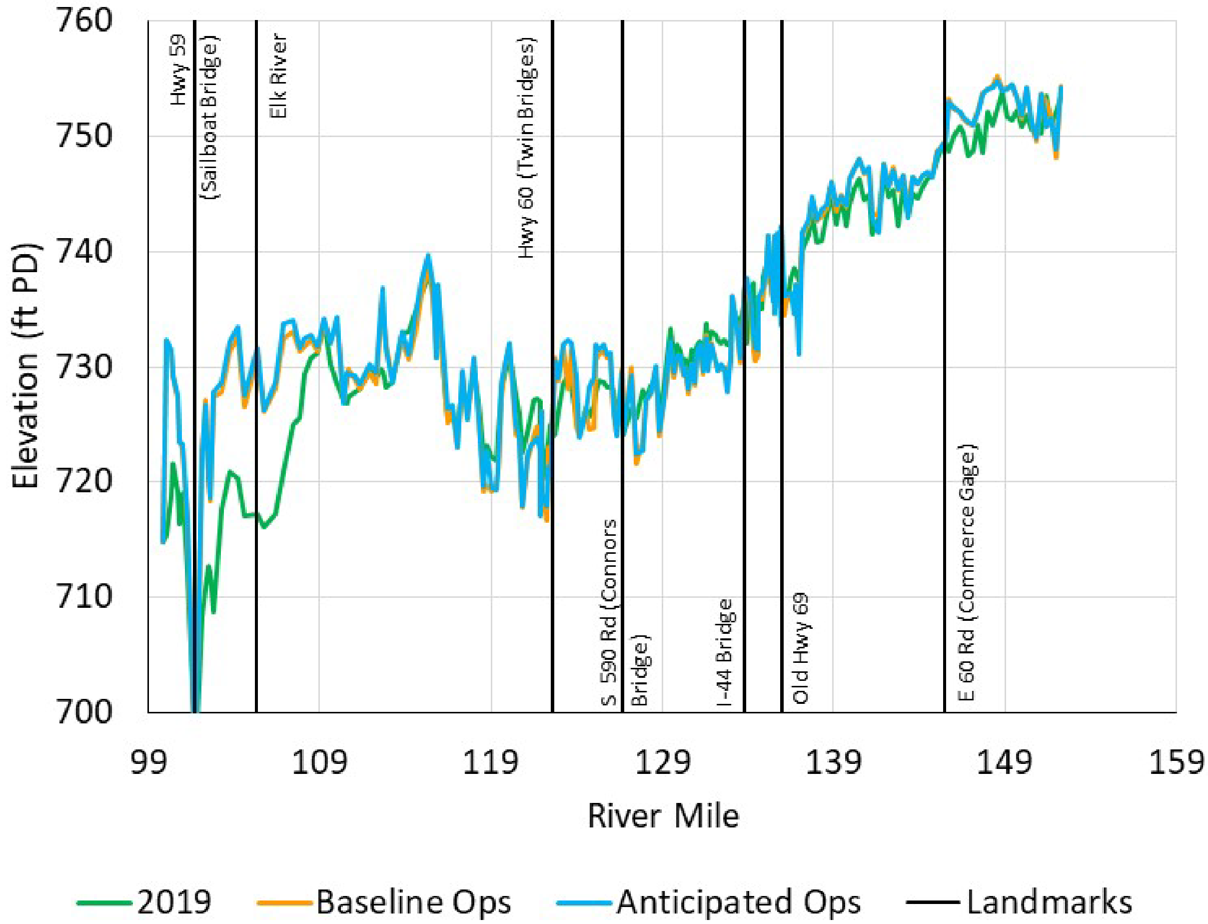
Source: WEST (2012)

Over time, the delta feature grows in height and decreases flow area within the channel. This results in raised stream velocities and associated bed shear stresses, which are the hydraulic drag forces on bed sediment. As the bed shear increases, it eventually reaches a dynamic equilibrium with the sediment critical shear stress (the bed shear stress at which sediment begins moving). The peak elevation of the delta feature stays relatively constant, gradually growing during normal and low flow events and eroding during large flow events.

As additional sediment moves into the system, it deposits further into the reservoir, adding to the downstream face of the delta feature (Vanoni 2006). Reviewing the results of the STM for future conditions shows that this typical pattern is followed in the Grand Lake reservoir.

As discussed in Section 6.2.2.1 of this document, the average channel profile provides a summary review of the final geometry that incorporates significantly more information than a simple thalweg profile. The results from the future simulations on the Neosho River are presented in Figure 147 and Figure 148.

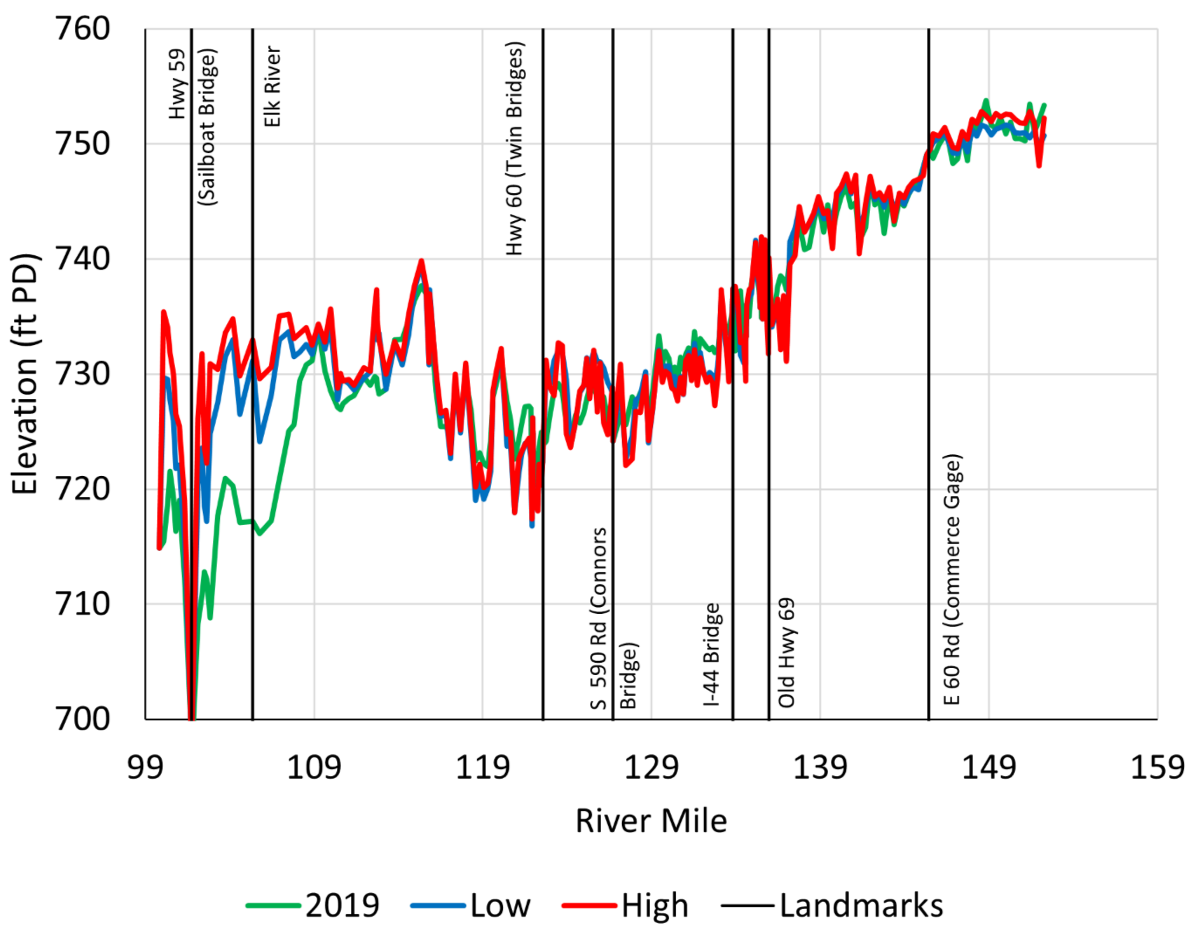
Figure 147
Neosho River Average Channel Showing Predicted Effects of Operations



As shown above, project operations have a limited impact on sediment deposition patterns. Most of the sediment is expected to deposit on the downstream face of the delta feature (below approximately RM 109) and wash further into the reservoir.

The mean difference is just 0.24 foot of increased bed elevation under the *Anticipated* operations as compared to *Baseline* operations, and the mean absolute difference is 0.49 foot.

Figure 148
Neosho River Average Channel Showing Predicted Effects of Sediment Loading



The differences between the bounding scenarios for potential sediment loading conditions are more significant than between operations parameters as shown in Table 48. The table shows a global change in average channel elevations as well as changes covering the entire delta feature and changes on the downstream face of the delta feature.

Table 48
Comparison of Average Channel Changes between Sediment Loading and Operations Scenarios

Comparison	Mean Change in Average Channel (feet)	Mean Change in Average Channel Below RM 122 (feet)	Mean Change in Average Channel Below RM 115.35 (feet)
High Sediment – Low Sediment	0.47	1.45	2.09
Anticipated Ops – Baseline Ops	0.24	0.38	0.45

As shown above, the sediment loading would account for approximately 2.54 times the deposition depth on the delta feature and 3.76 times the deposition depth on the downstream face of the feature as compared to the Project operational scenarios. Project operations, therefore, do not drive the majority of future sediment deposition within the reservoir.

Model results indicate that sediment loading to the system plays a larger role than Project operations. This is an important point to note because future sediment loading is projected to be lower than the long-term historical dataset indicates. This is attributable to a range of factors including the presence and operation of John Redmond Dam, which serves as a sediment barrier upstream of Grand Lake. Other changes include land use patterns, which show increased vegetation density since Project construction and a change from agriculture to woodland as well as changes to agricultural practices including no-till and cover crop programs that are incentivized by the NRCS. This change also decreases the amount of sediment entering the system from stormwater runoff, lowering future sediment deposition volumes. The model was run using the historical sediment inflow rating curves, which means predicted deposition is *higher* than anticipated future sediment deposition, and therefore represents a conservative estimate of future sedimentation and its impacts.

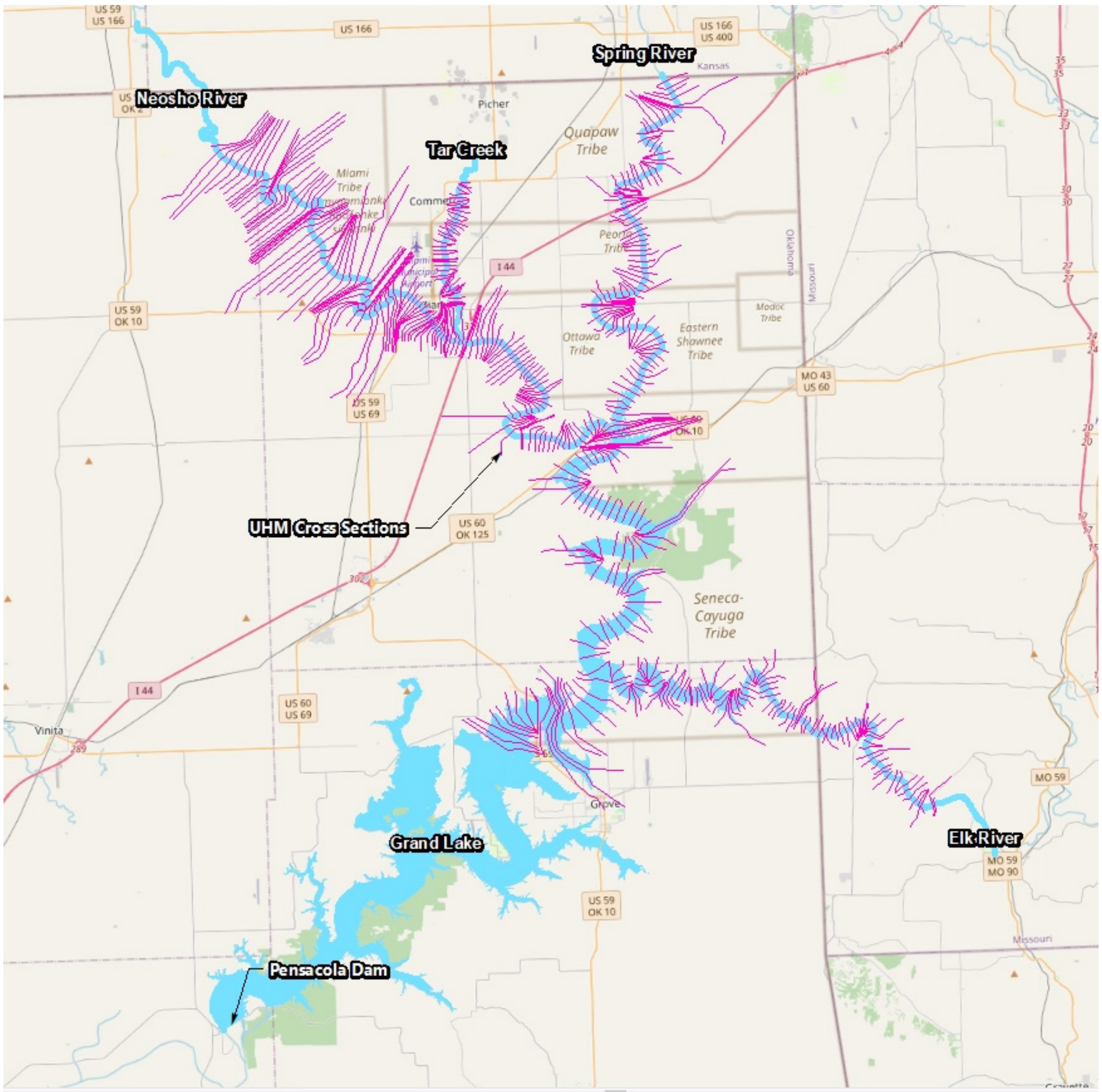
For all modeled scenarios, the sediment deposition follows typical reservoir deposition patterns, with sedimentation largely occurring downstream of the existing delta feature rather than continuing to increase the delta elevation. To evaluate the impacts of sediment deposition on upstream water levels, the final model geometries were used to create 1D UHMs.

7.4 1D Upstream Hydraulic Model Simulations

7.4.1 Background

The geometry files from the long-term STM simulations were imported to the 1D UHM for hydraulic analysis. Mead & Hunt developed the UHM to analyze the flooding impacts of modeled sedimentation. The 1D UHM was based on the STM and was developed in HEC-RAS v. 6.2 to maintain consistency with the STM. This model is distinct from the STM because it is run in hydraulic-only simulations using the fully unsteady mode. It is also distinct from the 1D/2D UHM discussed in the H&H study report. Figure 149 displays the 1D UHM model cross sections and extent.

Figure 149
1D UHM Model Cross Sections and Extent



The calibrated 1D UHM was used to assess the hydraulic impact of sediment transport from 2019 to 2069 as estimated by the STM. Mead & Hunt performed hydraulic simulations of the 2069 geometry using a variety of sedimentation scenarios and dam operations in combination with the starting pool elevations and inflow events specified by FERC in its May 27, 2022 SMD (Table 49).

Table 49
1D UHM Simulation Runs Completed

Inflow Event and Starting WSE (feet PD)	Existing Stage-Storage	Future Stage-Storage			
		Anticipated Ops			***Baseline Ops***
	Sediment Rate N/A	**Expected Sediment**	**Low Sediment**	**High Sediment**	**Expected Sediment**
July 2007, 740	✔	✔	✔	✔	✔
July 2007, 745	✔	✔	✔	✔	✔
July 2007, 750	✔	✔	✔	✔	✔
100-Year, 740	✔	✔	✔	✔	✔
100-Year, 745	✔	✔	✔	✔	✔
100-Year, 750	✔	✔	✔	✔	✔

As shown in the table, the evaluations considered three starting WSEs, three sediment loading rates, and two operational scenarios and compared them against existing conditions.

The 2069 STM geometry represents the predicted topo-bathymetric surface after 50 years of simulated sediment transport. The impact of dam operations on sediment transport diminishes with distance from the dam. Sediment transport is a natural process and significant geomorphic changes would occur in the study area regardless of the dam operation. The changes in WSE shown in the 1D UHM results are based on changes in bathymetry.

With any model results, boundary effects can skew data at the edges of the domain. This is apparent in the STM where coarser sediments dropped out of suspension near the upstream ends; based on measured changes in these portions of the river, it is clear that this is a numerical artifact rather than a real result. Therefore, the analyses have considered *only* the portions of the model not impacted by these BCs. The following analyses cover the river reaches shown in Table 50.

Table 50
River Reaches Considered in WSE Analyses

Stream	Analyzed Region
Neosho River	99.82–145.40
Tar Creek	1.60–7.00
Spring River	0.00–17.00
Elk River	0.00–15.00

7.4.2 Results and Discussion

The results demonstrate that future sediment inflow volumes play the primary role in determining upstream water levels during large flow events. Project operations are less important than the total volume of sediment entering the system. The following sections detail the findings on the Neosho River. Spring River, Elk River, and Tar Creek figures and tables are presented in Appendix F.

7.4.2.1 Future Anticipated Operations versus Existing Conditions

The first comparisons were made between the STM-generated 2069 geometry and existing 2019 geometry. Both sets of simulations were performed using anticipated operations, so differences shown in Table 51 are purely the result of the different geometries.

Table 51
WSE Changes from Future Geometry Compared to Existing Conditions under *Anticipated Operations* during Two Flow Events

Starting Stage (feet PD)	July 2007 (4-Year) Event				100-Year Event			
	Neosho River	Spring River	Elk River	Tar Creek	Neosho River	Spring River	Elk River	Tar Creek
Maximum Increase in WSE								
740	1.28	0.36	1.13	-0.03	1.24	0.60	1.29	0.07
745	1.19	0.21	1.08	-0.03	1.25	0.61	1.29	0.07
750	0.57	0.09	1.04	-0.04	1.25	0.64	1.29	0.07
Max	**1.28**	**0.36**	**1.13**	**-0.03**	**1.25**	**0.64**	**1.29**	**0.07**
Maximum Decrease in WSE								
740	-0.07	-2.19	-0.39	-0.94	-0.01	-1.79	-0.67	-0.70
745	-0.07	-2.18	-0.22	-0.94	-0.01	-1.78	-0.67	-0.70
750	-0.68	-2.18	-0.35	-0.94	-0.01	-1.77	-0.67	-0.70
Min	**-0.68**	**-2.19**	**-0.39**	**-0.94**	**-0.01**	**-1.79**	**-0.67**	**-0.70**
Average Change in WSE (feet)								
740	0.27	-0.26	0.15	-0.36	0.40	-0.09	0.13	-0.13
745	0.23	-0.29	0.08	-0.36	0.40	-0.09	0.16	-0.13
750	-0.04	-0.55	-0.07	-0.37	0.41	-0.07	0.13	-0.13

Notes: Positive values indicate increased WSE under 2069 geometry as compared to 2019 geometry.
"Max" provides the largest increase in WSE across all starting pool elevations and locations within a stream.
"Min" provides the largest decrease (or smallest increase) in WSE across all starting pool elevations and locations within a stream.

The level of impact increases as starting pool elevation decreases for the July 2007 event and increases as starting pool elevation increases for the 100-year event.

Figure 150 shows the changes in WSE from RM 130 to RM 140 on the Neosho River for the July 2007 event. It indicates that the changes in WSE near the City of Miami are generally negligible during the July 2007 event simulation, meaning future geometry under *Anticipated Operations* predicts a *similar* WSE to existing conditions. The largest positive change between RM 133 and RM 137 occurs with starting pool elevations of 740 feet PD and 745 feet PD; the future geometry resulted in water levels 0.11 foot higher at RM 134.28 upstream of the Tar Creek confluence for both starting pool elevations.

Figure 150
Changes in July 2007 Event WSE Due to 50 Years of Expected Sedimentation under *Anticipated Operations* Compared to Existing Conditions from RM 130 to RM 140

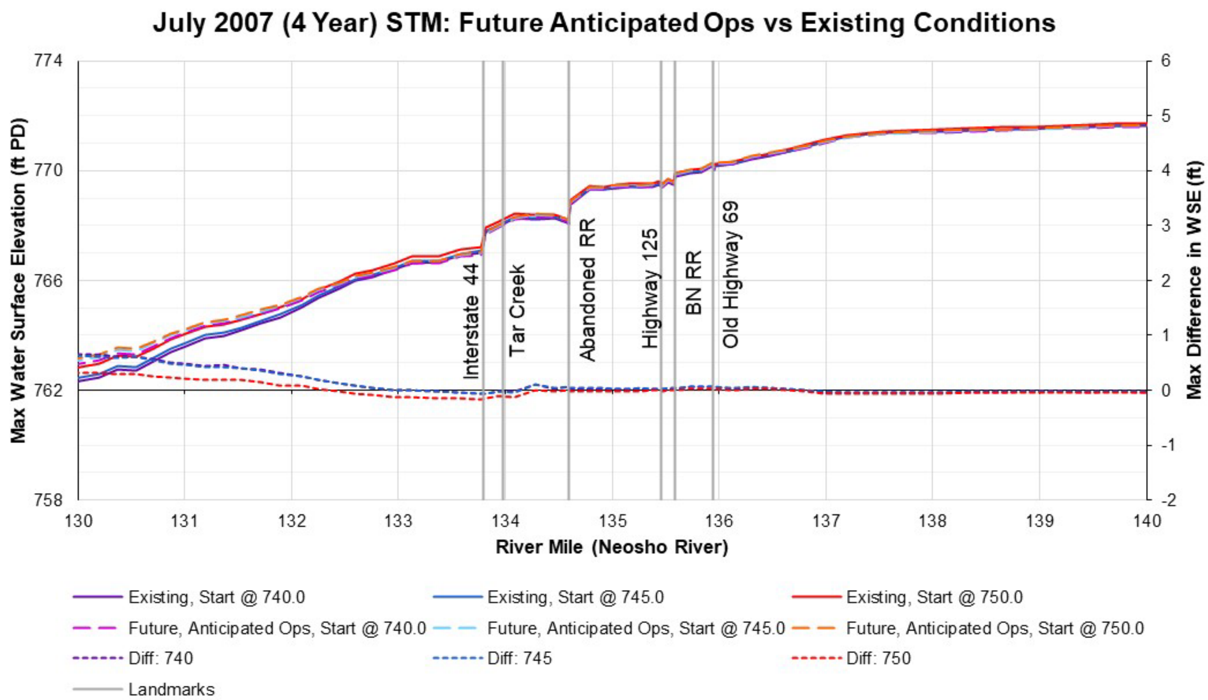
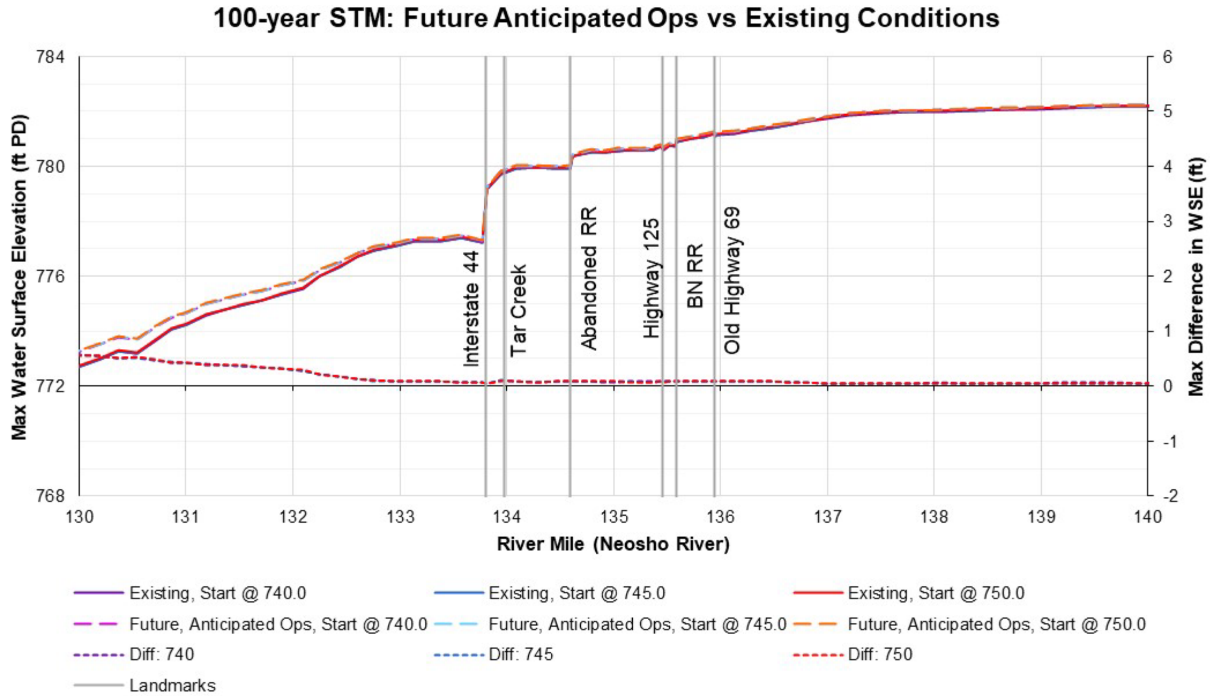


Figure 151 shows the changes in WSE from RM 130 to RM 140 on the Neosho River for the 100-year event. It indicates that the changes in WSE near the City of Miami are generally negligible during the 100-year event simulation, meaning future geometry under *Anticipated Operations* predicts a *similar* WSE to existing conditions. The largest positive change between RM 133 and RM 137 occurs with starting pool elevations of 740 feet and 745 feet PD; the future geometry resulted in water levels 0.11 foot higher at RM 133.94 near the confluence with Tar Creek.

Figure 151
Changes in 100-Year Event WSE Due to 50 Years of Expected Sedimentation under *Anticipated Operations* Compared to Existing Conditions from RM 130 to RM 140



These results indicate that under both the July 2007 and 100-year flow events, water levels near Miami are expected to remain virtually unchanged despite 50 years of future sediment deposition under the anticipated operations.

Figure 152 shows the changes in WSE farther downstream, from RM 120 to RM 130 on the Neosho River for the July 2007 event. It indicates that the changes in WSE during the July 2007 event simulation are largest downstream of Miami, peaking near South 590 Road (Connors Bridge). The largest positive change between RM 120 and RM 130 occurs with a starting pool elevation of 740 feet PD; the future geometry resulted in water levels 1.28 feet higher at RM 126.39, with an average WSE impact of less than 0.30 foot.

Figure 152
Changes in July 2007 Event WSE Due to 50 Years of Expected Sedimentation under *Anticipated Operations* Compared to Existing Conditions from RM 120 to RM 130

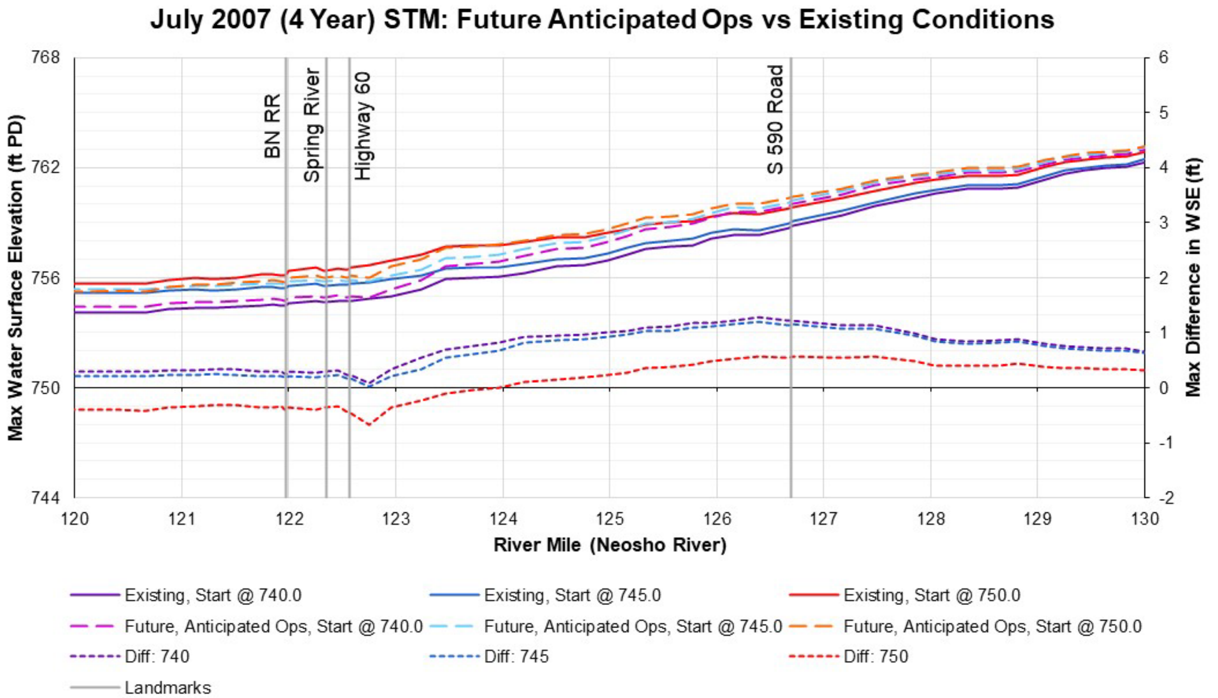
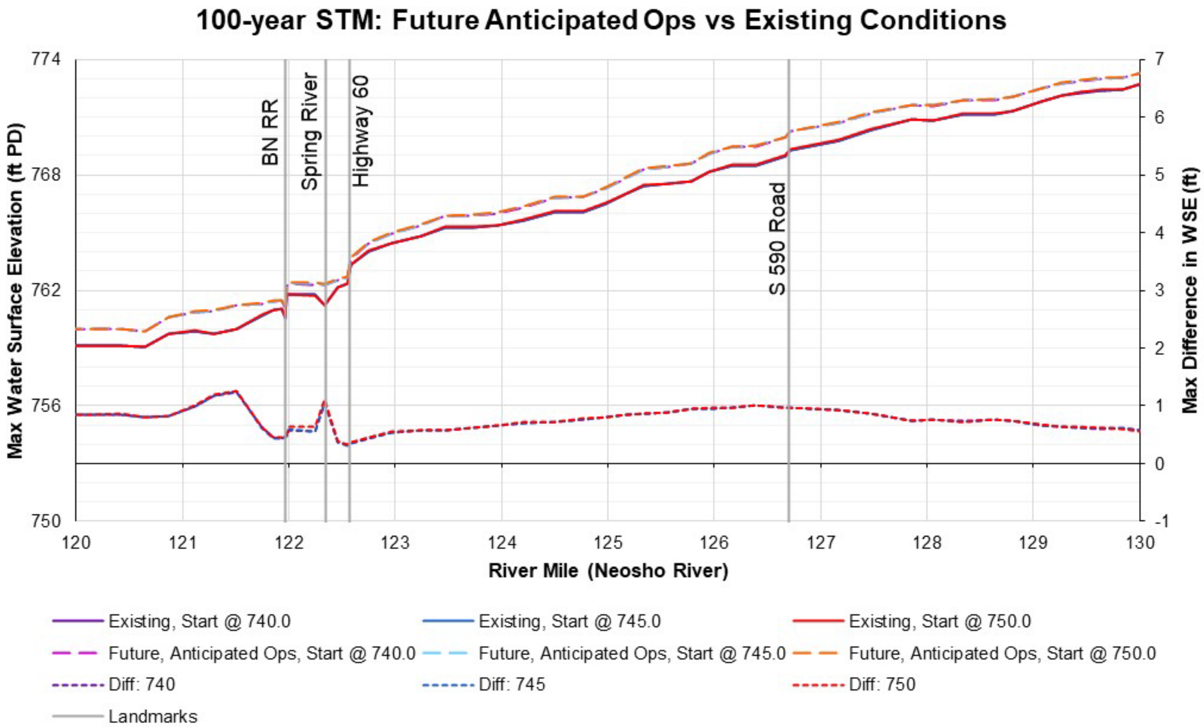


Figure 153 shows the changes in WSE from RM 120 to RM 130 on the Neosho River for the 100-year event. It indicates that the changes in WSE during the 100-year event simulation are largest downstream of Miami, peaking below Twin Bridges. The largest positive change between RM 120 and RM 130 occurs with a starting pool elevation of 750 feet PD; the future geometry resulted in water levels 1.06 feet higher at RM 121.29, with an average WSE impact of 0.30 foot or less.

Figure 153
Changes in 100-Year Event WSE Due to 50 Years of Expected Sedimentation under *Anticipated Operations* Compared to Existing Conditions from RM 120 to RM 130



These results indicate that under both the July 2007 and 100-year flow events, water levels on the Neosho River are expected to remain similar despite 50 years of future sediment deposition under the anticipated operations. The largest impacts to WSE occur downstream of the urbanized area of Miami and are no more than 1.25 feet anywhere on the Neosho River. There is no indication that the expected future sedimentation will significantly impact inundation near heavily populated areas of Miami.

7.4.2.2 Sedimentation Rate Sensitivity

The next comparisons were performed to evaluate the impact of sediment loading on upstream WSEs. The following figures compare simulated WSE profiles for *High Sedimentation* rates and *Low Sedimentation* rates. These simulations used anticipated operations and results are shown in Table 52.

Table 52
WSE Changes between *High Sedimentation* and *Low Sedimentation* Scenarios during Two Flow Events

Starting Stage (feet PD)	July 2007 (4-Year) Event				100-Year Event			
	Neosho River	Spring River	Elk River	Tar Creek	Neosho River	Spring River	Elk River	Tar Creek
Maximum Increase in WSE								
740	0.41	0.33	0.24	0.12	1.21	0.46	0.28	0.09
745	1.38	1.13	0.20	0.12	1.21	0.46	0.28	0.09
750	0.26	0.26	0.20	0.12	0.80	0.52	0.28	0.09
Max	**1.38**	**1.13**	**0.24**	**0.12**	**1.21**	**0.52**	**0.28**	**0.09**
Maximum Decrease in WSE								
740	-0.34	0.05	0.01	-0.06	-0.03	-0.01	-0.05	-0.02
745	-0.30	0.10	0.01	-0.03	-0.03	-0.01	-0.05	-0.02
750	-0.38	0.10	0.00	-0.08	-0.02	0.00	-0.05	-0.02
Min	**-0.38**	**0.05**	**0.00**	**-0.08**	**-0.03**	**-0.01**	**-0.05**	**-0.02**
Average Change in WSE (feet)								
740	0.06	0.19	0.15	0.01	0.22	0.24	0.13	0.01
745	0.30	0.59	0.14	0.02	0.22	0.24	0.14	0.01
750	0.02	0.18	0.02	0.00	0.20	0.27	0.15	0.01

Notes: Positive values indicate increased WSE under *High Sedimentation* loads compared to *Low Sedimentation* loads.
"Max" provides the largest increase in WSE across all starting pool elevations and locations within a stream.
"Min" provides the largest decrease (or smallest increase) in WSE across all starting pool elevations and locations within a stream.

Figure 154 shows the changes in WSE from RM 130 to RM 140 on the Neosho River for the July 2007 event. It indicates that the changes in WSE near the City of Miami are 0.06 foot or less during the July 2007 event simulation, meaning future geometry under high sediment loading predicts slightly higher WSE as compared to low sediment loading under anticipated operations. The largest positive change between RM 133 and RM 137 occurs with a starting pool elevation of 745 feet PD; the *High Sedimentation* geometry resulted in water levels 0.06 foot higher at RM 134.585 near the abandoned railroad bridge.

Figure 154
Changes in July 2007 Event WSE Due to 50 Years of Sedimentation under *High* and *Low Sedimentation* Conditions from RM 130 to RM 140

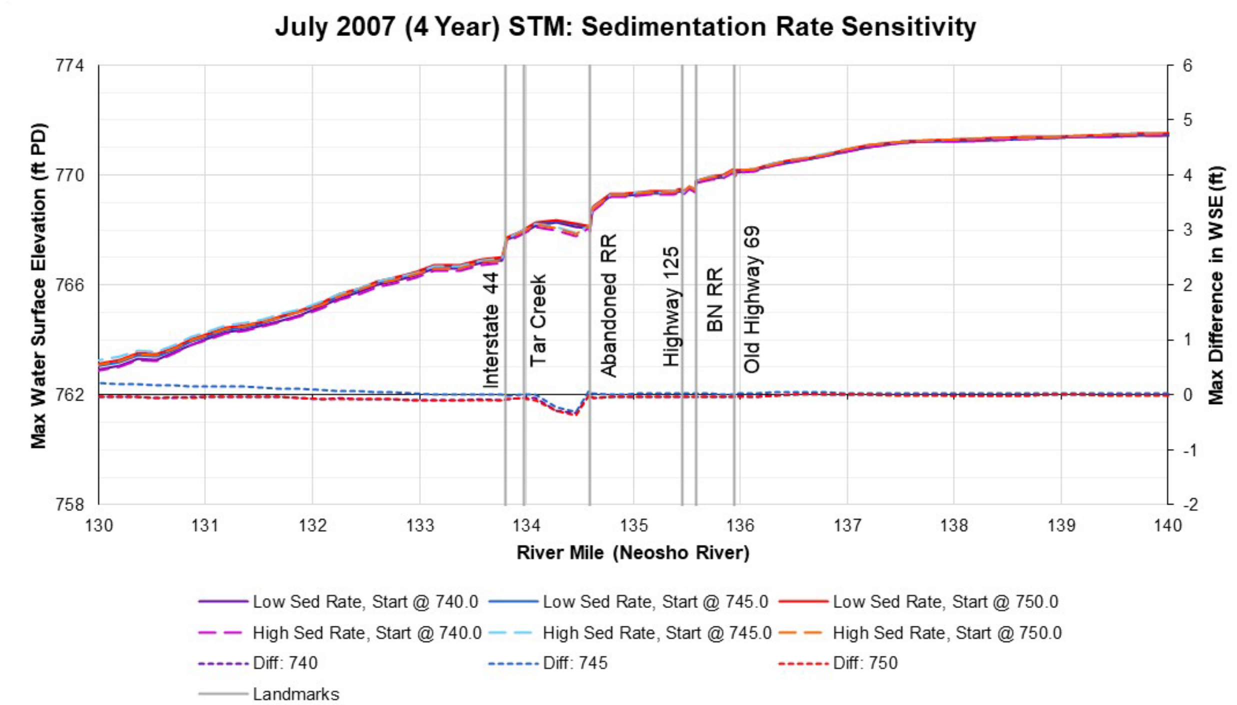
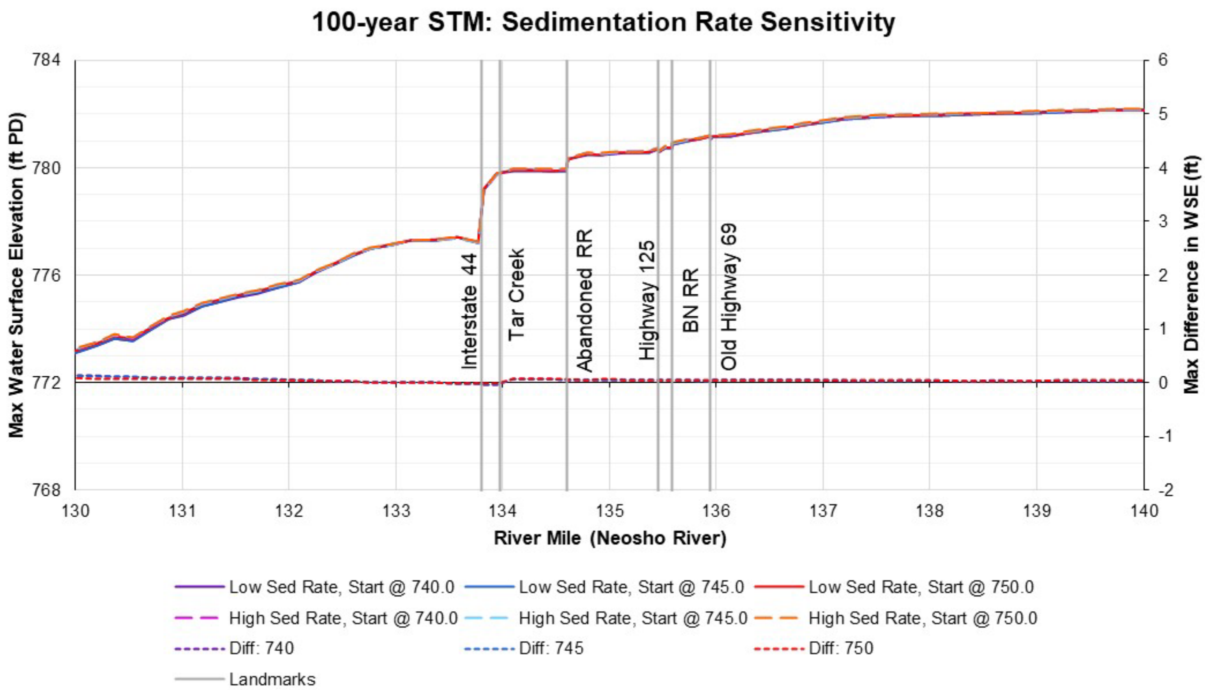


Figure 155 shows the changes in WSE from RM 130 to RM 140 on the Neosho River for the 100-year event. It indicates that the changes in WSE near the City of Miami are generally 0.04 foot or less during the 100-year event simulation, meaning future geometry under high sediment loading predicts similar WSE as compared to low sediment loading under anticipated operations. The largest positive change between RM 133 and RM 137 occurs with a starting pool elevation of 750 feet PD; the *High Sedimentation* geometry resulted in water levels 0.07 foot higher at RM 134.46 near the confluence with Tar Creek.

Figure 155
Changes in 100-Year Event WSE Due to 50 Years of Sedimentation under *High* and *Low Sedimentation* Conditions from RM 130 to RM 140



These results indicate that under both the July 2007 and 100-year flow events, water levels near Miami are expected to remain nearly constant regardless of sediment loading to the study area despite 50 years of future sediment deposition under the anticipated operations.

Figure 156 shows the changes in WSE from RM 120 to RM 130 on the Neosho River for the July 2007 event. It indicates that the changes in WSE during the July 2007 event simulation are largest downstream of Miami, peaking approximately 0.5 mile upstream of Twin Bridges. The largest positive change between RM 120 and RM 130 occurs with a starting pool elevation of 745 feet PD; the future geometry resulted in water levels 1.38 feet higher at RM 123.24 upstream of Twin Bridges.

Figure 156
Changes in July 2007 Event WSE Due to 50 Years of Sedimentation under *High* and *Low Sedimentation* Conditions from RM 120 to RM 130

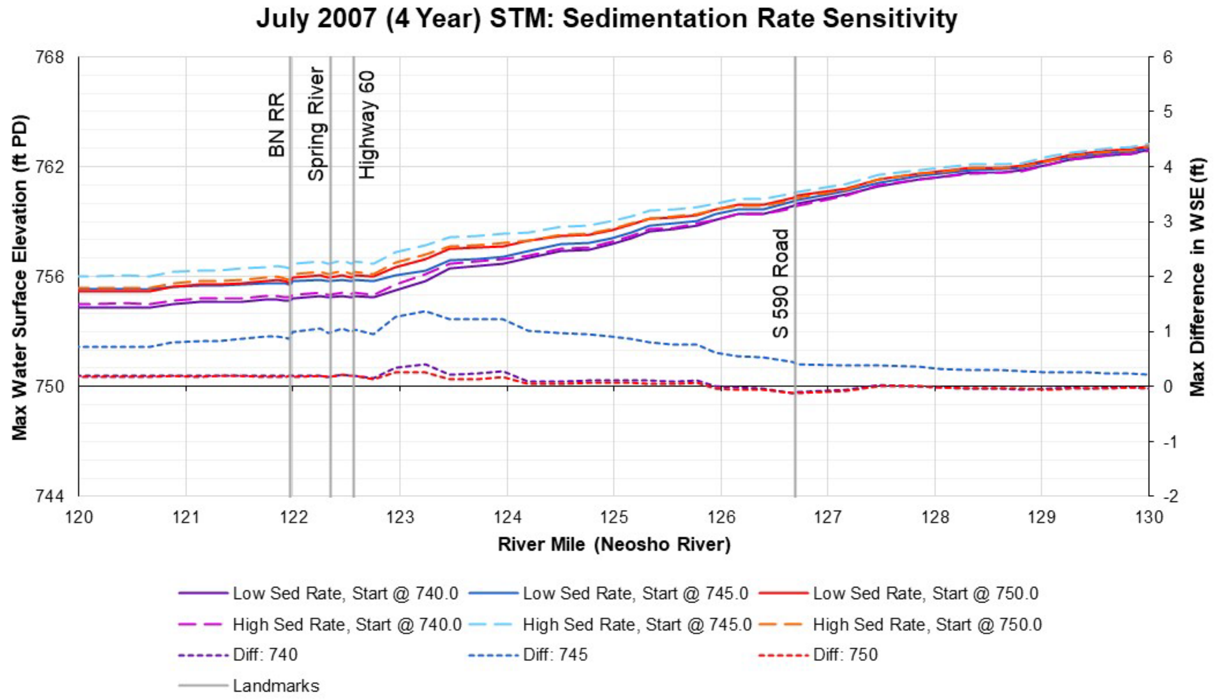
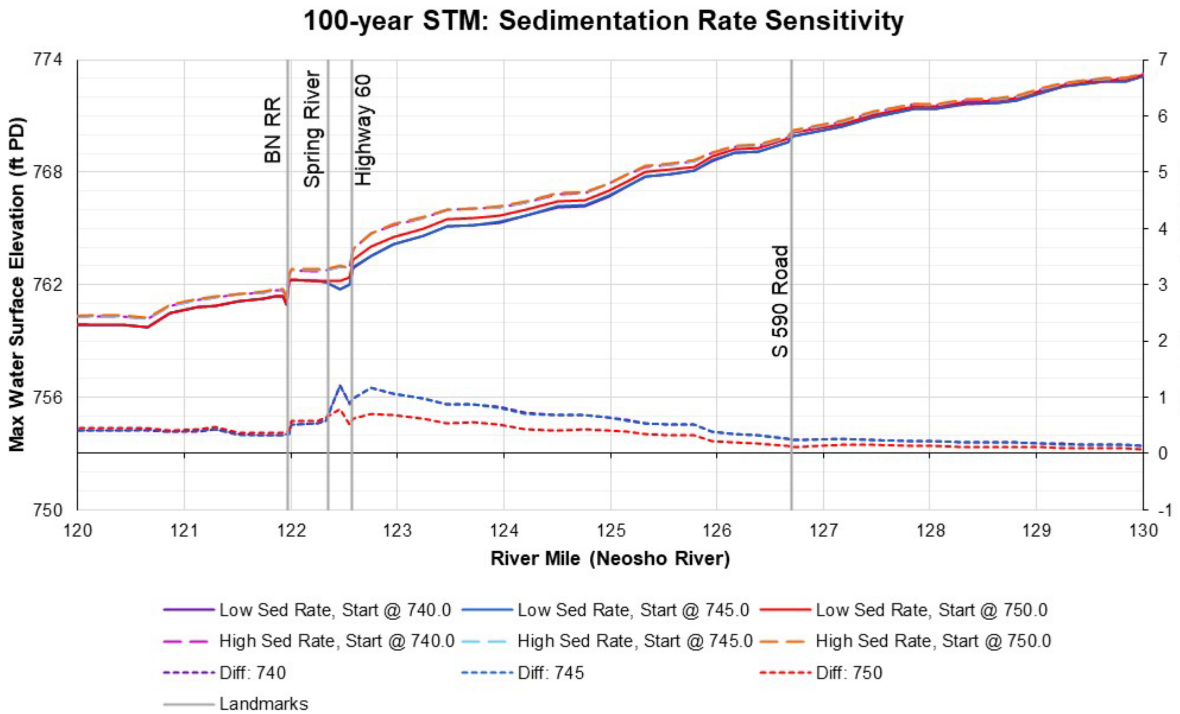


Figure 157 shows the changes in WSE from RM 120 to RM 130 on the Neosho River for the 100-year event. It indicates that the changes in WSE during the 100-year event simulation are largest downstream of Miami, peaking near the Spring River confluence. The largest positive change between RM 120 and RM 130 occurs with a starting pool elevation of 745 feet PD; the future geometry resulted in water levels 1.21 feet higher at RM 122.46 near Twin Bridges.

Figure 157
Changes in 100-Year Event WSE Due to 50 Years of Sedimentation under *High* and *Low Sedimentation* Conditions from RM 120 to RM 130



These results indicate that under both the July 2007 and 100-year flow events, water levels on the Neosho River are expected to change by as much as 1.38 feet due to the variability of sediment loading. The largest impacts to WSE occur downstream of the urbanized area of Miami near Twin Bridges. There is no indication that the future sedimentation will significantly impact inundation near heavily populated areas of Miami.

The impacts of sediment loading rates on upstream water levels are similar to those found between current and future conditions. Further, the impacts occur primarily downstream of the City of Miami. The results show that the predicted range of inflowing sediment quantity, which is not controlled by GRDA, is similar to the expected changes between 2019 and 2069 under anticipated operations.

7.4.2.3 Operations Sensitivity

The third comparison was performed to evaluate the impact of Project operations on upstream water levels. The following section compares WSE impacts between 50 years of simulated *Baseline Operations* and 50 years of simulated *Anticipated Operations*. Sediment loading was identical for these simulations. Both simulations represent a future (2069) bed condition. The only difference was Project operation. The findings are summarized in Table 53.

Table 53
WSE Changes between *Anticipated Operations* and *Baseline Operations* Scenarios during Two Flow Events

Starting Stage (feet PD)	July 2007 (4-Year) Event				100-Year Event			
	Neosho River	Spring River	Elk River	Tar Creek	Neosho River	Spring River	Elk River	Tar Creek
Maximum Increase in WSE								
740	0.09	0.07	-0.09	0.09	1.09	0.27	0.06	0.17
745	0.03	0.07	0.00	0.09	1.11	0.26	0.06	0.17
750	0.26	0.06	0.02	0.09	1.14	0.29	0.06	0.17
Max	**0.26**	**0.07**	**0.02**	**0.09**	**1.14**	**0.29**	**0.06**	**0.17**
Maximum Decrease in WSE								
740	-1.39	-1.30	-0.89	-0.11	0.00	-0.02	-0.13	-0.05
745	-1.07	-0.87	-0.14	-0.13	0.00	-0.02	-0.13	-0.05
750	-0.17	-0.29	-0.21	-0.13	0.00	-0.03	-0.13	-0.05
Min	**-1.39**	**-1.30**	**-0.89**	**-0.13**	**0.00**	**-0.03**	**-0.13**	**-0.05**
Average Change in WSE (feet)								
740	-0.48	-0.51	-0.81	-0.02	0.22	0.13	0.03	0.01
745	-0.19	-0.36	-0.07	-0.02	0.22	0.14	0.02	0.01
750	-0.03	-0.03	-0.04	-0.02	0.22	0.14	0.02	0.02

Notes: Positive values indicate increased WSE under *Anticipated Operations* compared to *Baseline Operations.*
"Max" provides the largest increase in WSE across all starting pool elevations and locations within a stream.
"Min" provides the largest decrease (or smallest increase) in WSE across all starting pool elevations and locations within a stream.

Figure 158 shows the changes in WSE from RM 130 to RM 140 on the Neosho River for the July 2007 event. It indicates that the changes in WSE near the City of Miami are generally negative during the July 2007 event simulation, meaning future geometry under *Anticipated Operations* predicts *lower* WSE as compared to future geometry under *Baseline Operations*. The largest positive change between RM 133 and RM 137 occurs with a starting pool elevation of 740 feet PD; the *Anticipated Operations* geometry resulted in water levels 0.03 foot higher at RM 135.96 near the Old Highway 69 Bridge.

Figure 158
Changes in July 2007 Event WSE Due to 50 Years of Expected Sedimentation under *Anticipated* and *Baseline Operations* Conditions from RM 130 to RM 140

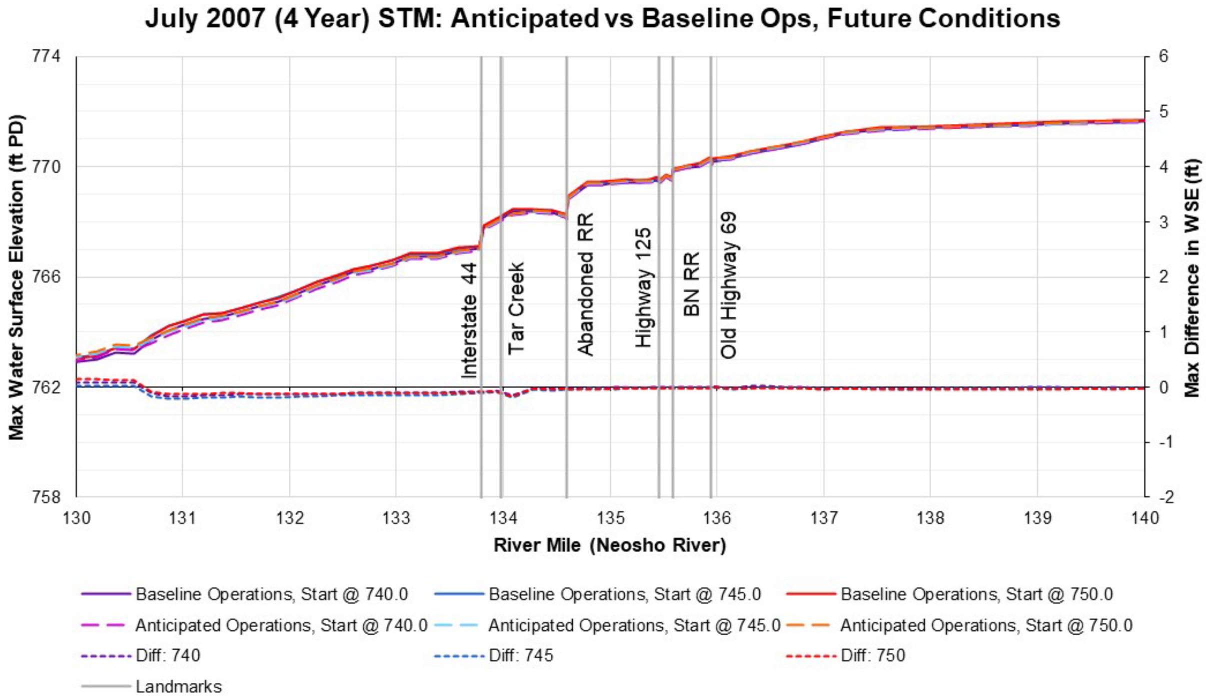
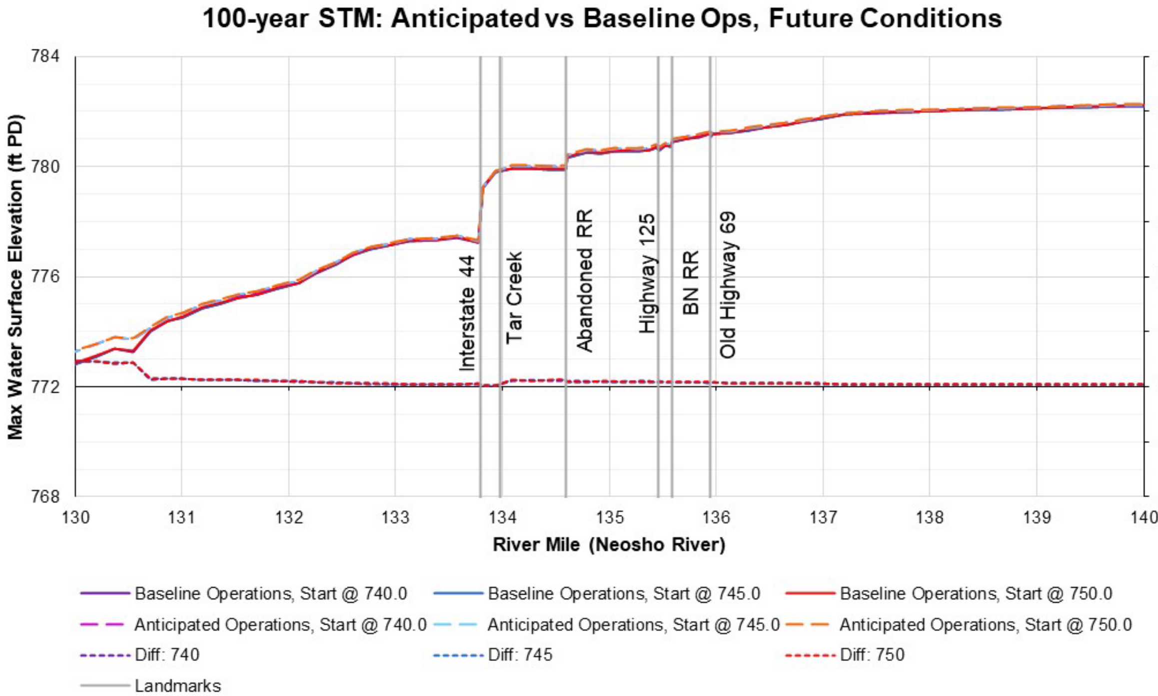


Figure 159 shows the changes in WSE from RM 130 to RM 140 on the Neosho River for the 100-year event. It indicates that average changes in WSE near the City of Miami are 0.05 foot during the 100-year event simulation, meaning future geometry under *Anticipated Operations* predicts similar WSE as compared to future geometry under *Baseline Operations*. The largest positive change between RM 133 and RM 137 occurs with a starting pool elevation of 750 feet PD; the *Anticipated Operations* geometry resulted in water levels 0.12 foot higher near RM 134.46 upstream of Tar Creek.

Figure 159
Changes in 100-Year Event WSE Due to 50 Years of Expected Sedimentation under *Anticipated* and *Baseline Operations* Conditions from RM 130 to RM 140



These results indicate that under both the July 2007 and 100-year flow events, water levels near Miami are expected to remain similar regardless of Project operations despite 50 years of future sediment deposition. In the smaller, more frequent July 2007 event, *Anticipated Operations* resulted in decreased average water levels near the urbanized areas of Miami.

Figure 160 shows the changes in WSE from RM 120 to RM 130 on the Neosho River for the July 2007 event. It indicates that the increases in WSE during the July 2007 event simulation are largest downstream of Miami, peaking between South 590 Road (Connors Bridge) and Twin Bridges. The largest positive change between RM 120 and RM 130 occurs with a starting pool elevation of 750 feet PD; the *Anticipated Operations* geometry resulted in water levels 0.26 foot higher at RM 125.78 downstream of Connors Bridge. It also indicates that water levels are typically *lower* under *Anticipated Operations* as compared to *Baseline Operations* with a maximum *decrease* of 1.39 feet at RM 122.96 upstream of Twin Bridges with a starting pool elevation of 740 feet PD.

Figure 160
Changes in July 2007 Event WSE Due to 50 Years of Expected Sedimentation under *Anticipated* and *Baseline Operations* Conditions from RM 120 to RM 130

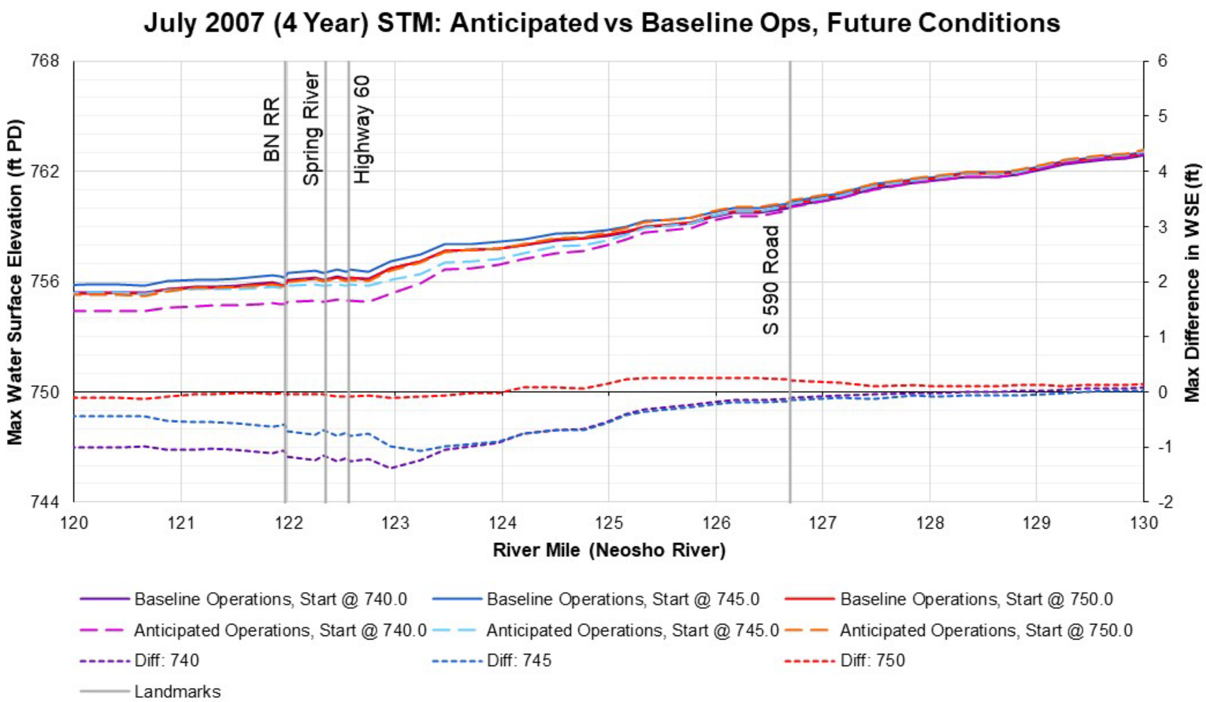
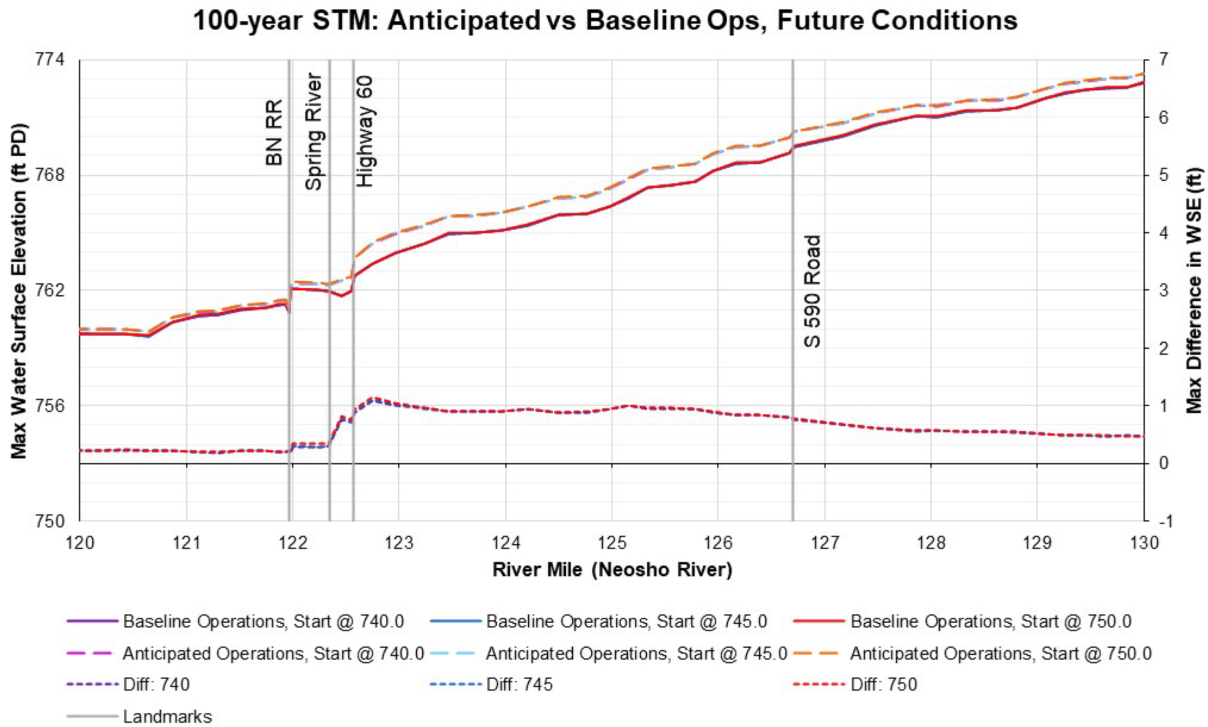


Figure 161 shows the changes in WSE from RM 120 to RM 130 on the Neosho River for the 100-year event. It indicates that the changes in WSE during the 100-year event simulation are largest downstream of Miami, peaking upstream of Twin Bridges. The largest positive change between RM 120 and RM 130 occurs with a starting pool elevation of 750 feet PD; the *Anticipated Operations* geometry resulted in water levels 1.14 feet higher at RM 122.75, upstream of the Highway 60 Bridge.

Figure 161
Changes in 100-Year Event WSE Due to 50 Years of Expected Sedimentation under *Anticipated* and *Baseline Operations* Conditions from RM 120 to RM 130



These results indicate that under the July 2007 event, average water levels on the Neosho River are expected to decrease by 0.35 foot, with a maximum decrease of 1.39 feet under *Anticipated Operations*. During 100-year flow events, average water levels on the Neosho River are expected to increase 0.22 foot under *Anticipated Operations*. There is no indication that the future Project operations will significantly impact inundation near heavily populated areas of Miami.

The impacts of Project operations on upstream water levels are limited and occur primarily downstream of the City of Miami. The results show that during the more typical 4-year flows such as the July 2007 event, *Anticipated Operations* will result in *lower* average water levels, and the changes in WSE near Miami are immaterial.

7.4.3 1D UHM Summary

The results show that potential impacts to WSE due to sedimentation are primarily the result of future sediment loading to the study area (Table 54).

Table 54
Maximum WSE Increases on the Entire Neosho River during Simulated Events

Compared Scenarios	Maximum WSE Increase, July 2007 (feet)	Average WSE Increase, July 2007 (feet)	Maximum WSE Increase, 100-Year (feet)	Average WSE Increase, 100-Year (feet)
Future Geometry vs. Current Geometry	1.28	0.27	1.25	0.41
High Sedimentation vs. *Low Sedimentation*	1.38	0.30	1.21	0.22
Anticipated Operations vs. *Baseline Operations*	0.26	-0.03	1.14	0.22

The simulations show that sediment loading has the biggest impact on upstream water levels, particularly for the historical July 2007 event. Results indicate that the impact of sedimentation loading is more than 5 times the impact of Project operations during the July 2007 event and approximately 1.1 times as large during the 100-year event.

In all evaluations, the average impacts to WSE on the Neosho River during large flow events are expected to be 0.41 foot or less. The maximum impacts are related to differences in sediment loading under the July 2007 event. This fact is unsurprising and is again related to sediment moving into the reservoir; GRDA has no ability to prevent sediment from flowing downstream, and the simulation results do not suggest Project operations are the driving contributor to water level impacts.

These results are similar to the findings of the H&H study, which quantified how *nature* plays the defining role in upstream water levels rather than Project operations. GRDA exerts no more control over incoming sediment than it does over incoming water, and the quantity of incoming sediment is the biggest driver of increases in upstream WSE over the 50-year license period.

Further, all scenarios indicated the impacts to WSE in the City of Miami due to sedimentation or Project operations are immaterial (Table 55). For the evaluations shown, "Vicinity of Miami, OK" was defined as the reach of the Neosho River from RM 133 to RM 137.

Table 55
Maximum WSE Increases on the Neosho River in the Vicinity of Miami, Oklahoma, during Simulated Events

Compared Scenarios	Maximum WSE Increase, July 2007 (feet)	Average WSE Increase, July 2007 (feet)	Maximum WSE Increase, 100-Year (feet)	Average WSE Increase, 100-Year (feet)
Future Geometry vs. Current Geometry	0.11	0.03	0.11	0.08
High Sedimentation vs. *Low Sedimentation*	0.06	0.00	0.07	0.04
Anticipated Operations vs. *Baseline Operations*	0.03	-0.03	0.12	0.08

Notes: Vicinity of Miami is defined as between RM 133 and RM 137.

The results indicate that the impacts of sedimentation on WSE are immaterial in urbanized areas, regardless of loading rates, Project operations, or future versus current geometry. This finding further confirms the fact that Project operations are not a major contributor to increased upstream water levels in the City of Miami or other urbanized portions of the study area. Downstream of Miami, sediment loading, a natural phenomenon outside GRDA's control, has the biggest impact on WSE.

8 Conclusions

The Sedimentation Study produced several significant findings. The first major change in available information was that the sediment moving through the study area was dominated by cohesive material rather than sand and gravel as claimed by the City (2018). A second significant finding is that the delta feature apparent in the 2009 OWRB survey but not visible in bathymetry claimed by the City's consultant to be surveyed circa 1998 did *not* in fact form over a period of 11 years. The third major finding is that sedimentation is primarily driven by the amount of sediment conveyed into the system and *not* by Project operations.

The City argued in their 2018 response to GRDA's preliminary study plan that "The cohesive sediment is carried as wash load well downstream into the reservoir, and deposition and re-entrainment of that material has very little, if any effect, on upstream channel capacity and flooding." This statement implied that cohesive material was unimportant to understanding sediment transport within the study area, and that the only material of interest was the non-cohesive sands and gravels. Multiple sampling efforts of bedload and suspended sediment load by GRDA revealed virtually no coarse material moving through the system.

The importance of cohesive material complicated STM development. HEC-RAS is an excellent tool for evaluating hydraulics and non-cohesive sediment transport but is more limited in its ability to simulate cohesive sediment transport. As a result, it was necessary to model only the upper portions of the system rather than extending the model to Pensacola Dam where cohesive materials reduce the reliability of predictive HEC-RAS models. Calibration required more comprehensive inputs to evaluate critical shear stress, erosion rates, and mobility parameters with the cohesive sediments.

This increased relevance of cohesive materials also introduced uncertainty to the model. Spatial variations in erosive parameters are present in all sedimentation studies, but cohesive material introduces significant temporal variability as well. As cohesive material accumulates, it compresses and consolidates, increasing density and critical shear stress.

The second major discovery of the Sedimentation Study was that the terrain information initially proposed for use in the study was unreliable. This is covered in significant detail in Section 2.1.1, but the key takeaways are as follows:

- The 1998 REAS dataset did *not* extend downstream of RM 120.1 and the data below that point are from an unknown time period, likely circa 1940, despite the City's arguments that GRDA should be required to use the REAS terrain for the entire system (City 2022).
- There is limited information available from circa 1940 including topographic maps of varying quality and cross-sectional survey information within the study area.

As detailed above, the reliable portions of the available datasets were used for STM development. However, although the data used represent the best available information, they are imperfect and introduce uncertainty to any measurements, particularly the circa-1940 data.

These datasets were flawed but nonetheless are also the most complete available for the relevant time periods. The data were used to evaluate sedimentation and future impacts through two separate approaches as part of the three-level process: the quantitative analysis and the STM. The objective of the three-level approach is to ensure that reasonable and reliable results are obtained. This is achieved if there is consistency between the results of the quantitative analysis and the STM.

The quantitative analysis approach utilized the hydraulic component of HEC-RAS to compute hydraulic shear stresses for historical flows and operation and future scenarios. The historical change in bathymetry was then related to hydraulic shear stresses for historical flows and operation to develop a relationship between hydraulic shear stress and the sedimentation pattern. The HEC-RAS hydraulic component was then run for future flow and operation scenarios to compute the hydraulic shear stresses under these future conditions. The resulting shear stresses were then used in the relationship between hydraulic shear and sedimentation pattern to compute sedimentation for the future scenarios. The quantitative analysis (Section 4) concluded the following:

> The quantitative analysis of the future 50 years of hydrology and operation shows no significant sediment deposition on top of the delta feature that would adversely affect existing hydraulic control in upstream reaches. Most of the sediment delivered to the reservoir is transported past the top of the delta feature, farther downstream to the downstream face of the feature. Approximately 98 to 99 percent of the incoming sediment load is transported past RM 110.
>
> The quantitative analysis demonstrates that the top surface of the delta feature is in a state of dynamic equilibrium. This state of dynamic equilibrium is consistent with the fact that the average shear stress over the top of the delta feature is generally equal to or greater than the minimum critical shear from the SEDFlume analysis.
>
> This pattern of predicted sediment deposition, located downstream of the high point on the delta feature and at an elevation several feet below this high point, cannot reasonably be expected to adversely affect upstream hydraulics and flooding. Based on the relatively small change in effectiveness of moving sediment downstream with the comparison between the future flows with anticipated operation and baseline operation, as well as the USGS analysis of the effect of significant changes in water level resulting in very limited changes in sediment storage in John Redmond Reservoir; there is no basis to conclude that there would be any significant benefit in operating Grand Lake at a lower level.

> It is important to remember that Grand Lake is under operational control of USACE when the water level approaches or exceeds elevation 745 feet PD and that under these conditions, which only occur 19.8% of the time, delivers 75.6% of the incoming sediment load to the reservoir. Neither the upstream sediment load nor operational control of Grand Lake is controlled by GRDA at that time.

The STM utilized the HEC-RAS model with available bathymetric data to describe the channel/reservoir geometry, analysis of sediment sampling to describe the physical characteristics of the sediment (including particle size distributions, erosion parameters, and sediment density), and inflow hydrology along with sediment inflow rates using sediment rating curves based on sediment transport and flow data. This was an extremely complex process due to the nature of the dominance of cohesive sediment (silt and clay) for which densities, critical shear, and erosion rates vary widely.

The uncertainties associated with both the sediment properties and the available topographic and bathymetric data contributed to difficulties in model calibration and validation. The Neosho River was captured with reasonable accuracy, but modeled changes on the Elk and Spring rivers were somewhat less reliable.

To manage the uncertainties associated with both the cohesive sediment and terrain information, the model evaluated *High Sedimentation* and *Low Sedimentation* scenarios in addition to the *Baseline Operations* and *Anticipated Operations* simulations. The *High* and *Low Sedimentation* scenarios provided bounding possibilities for future sediment deposition. Differences between those scenarios in terms of sediment deposition depths were larger than the differences between modeled Project operations. This also holds true for storage volume changes over time, with the operational scenarios showing relatively little difference and sediment loading playing a larger role.

Each of these scenarios used a high sediment loading condition based on older, higher sediment rating curves. This was the same loading used for calibration and validation, and it is considered a conservative evaluation. As discussed in Section 4.2.1 of this report, changes in land use, increased use of no-till, and cover crop agricultural practices, and the presence of John Redmond Dam, have all contributed to a *decrease* in total sediment loading to the system. It is almost certain that future sedimentation impacts will be *smaller* than those reported here.

The City has implied that the delta feature is solely attributable to Project operations and changes in those operations would remove it. However, there are a range of factors that influence the exact location of sediment deposition in this area. The presence of the Ozark Uplift changes the bed slope and increases the likelihood of deposition at that location, which coincides with the current delta feature. Sediment carried by the steeper Spring River empties into the Neosho River just upstream of the delta feature; the decreased sediment carrying capacity of the Neosho River below this point results in increased sedimentation downstream of that confluence. The fact that the stream is more well-connected to the floodplain at this location means flows are able to spread laterally, decreasing stream velocity and allowing for deposition; upstream of this area, rocky cliffs prevent this lateral flow expansion and keep fine material in suspension until lower in the system.

The City claimed that ongoing sedimentation would increase the height of the delta feature. The STM showed that is not the case, with simulations showing deposition on the downstream face of the delta feature rather than on the crest, which is typical of such formations as documented by Vanoni (2006) and others in scientific literature. This finding confirmed that the delta feature is not growing appreciably in height, and that neither Project operations nor incoming sediment is expected to have a significant impact on delta feature crest elevations.

The City's claims also neglect the role of bridges and associated embankments on flood risks. The Burlington Northern railroad bridge features an extensive embankment that constricts the flow from a width of 1.80 miles (9,500 feet) upstream of the bridge to just 770 feet at the bridge opening. Multiple bridges in the area also show large masses of debris trapped on piles. This debris reduces flow capacity at those bridges and creates backwater effects that increase water levels upstream. Disregarding these contributing factors and instead placing all blame for high water levels on Project operations is disingenuous and ignores basic hydraulic flow characteristics.

Results of the STM and 1D UHM demonstrate that **sedimentation rates in Grand Lake and the associated tributaries are dictated primarily by the future incoming sediment load rather than Project operations**. The differences in deposition rates and patterns for the *Baseline Operations* and *Anticipated Operations* scenarios are smaller than the differences between the *High Sedimentation* and *Low Sedimentation* scenarios. Furthermore, for all modeled scenarios, the sediment deposition follows typical reservoir deposition patterns, with sedimentation largely occurring downstream of the existing delta feature rather than continuing to increase the delta feature crest elevation.

The City claimed Project operations would increase the delta feature size, thereby raising water levels in Miami. To assess the impact of Project operations on the delta feature size and upstream water levels, geometry from the predicted future sedimentation pattern was imported to the 1D UHM to evaluate flooding events and the effect on flooding in upstream reaches of the Neosho River through the City of Miami. The findings did not support the City's claims. Sediment loading rates, not GRDA's operations, produced the largest impacts to both storage volume change and upstream water levels. Furthermore, the STM showed a majority of incoming material depositing on the downstream face of the delta feature as expected and the 1D UHM results showed immaterial impacts to upstream water levels in the City of Miami.

In the City of Miami, **impacts to water levels due to Project operations are immaterial**. Neither operations nor sedimentation rates produce an appreciable difference in WSE between RM 133 and RM 137. Over a 50-year time period, there is virtually no increase to water levels in the City of Miami due to Project operations, and average water levels were shown to decrease during the July 2007 flow event under anticipated operations. Further, in the vicinity of Miami, the impacts due to sediment loading, Project operations, and expected future deposition produce only immaterial changes to water levels. Any meaningful increase in water levels due to sedimentation is further downstream and is primarily driven by the incoming sediment load.

Sedimentation and associated impacts to water levels are not driven by Project operations. This finding is similar to that of the H&H study, which showed that Project operations have limited ability to dictate WSE upstream of Pensacola Dam. GRDA has no control over the incoming sediment loads, and adjusting Project operations does not have a meaningful impact to sediment depositional patterns. Impacts of future sedimentation are the result of incoming material, and *not* Project operations.

The Sedimentation Study has shown that the sediment moving through the system is fine, cohesive material. It has also evaluated a range of datasets for stream bathymetry and overland topography in the study area and concluded that significant portions of the 1998 REAS data are unreliable and that the circa-1940 data are limited. To bound the uncertainties of the available datasets, multiple sediment transport simulations were performed, and the study showed that nature, not Project operations, dictates the rate of sedimentation in Grand Lake. Any material impacts to upstream WSE during large flow events are the result of sediment loading, which GRDA does not control. Furthermore, when the water level in Grand Lake is above 745 feet PD or expected to rise beyond that level, USACE dictates operation of the reservoir to mitigate downstream flooding, and under these conditions most of the sediment (75.6%) is delivered to the reservoir.

9 References

Anchor QEA, LLC, Simons & Associates, and Mead & Hunt, 2022. *Updated Study Plan Sedimentation Study.* Prepared for Grand River Dam Authority. April 2022.

Andrews, W.J., M.F. Becker, S.L. Mashburn, and S.J. Smith, 2009. *Selected Metals in Sediments and Streams in the Oklahoma Part of the Tri-State Mining District, 2000–2006*. U.S. Geological Survey Scientific Investigations Report SIR 2009-5032. July 2009.

Aqua Survey, 2004. *Technical Report Environmental Dredging and Sediment Decontamination Technology Demonstration Pilot Study Lower Passaic River Restoration Project Magnetometer and Sub-Bottom Profiler Debris Survey*. December 3, 2004.

Arcement, G.K., and V.R. Schneider, 1989. *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Floodplains*. U.S. Geological Survey Water Supply Paper 2339.

Borrowman, T.D., E.R. Smith, J.Z. Gailani, and L. Caviness, 2006. *Erodibility Study of Passaic River Sediments Using USACE SEDflume*. Dredging Operations and Environmental Research Program. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi Environmental Laboratory. September 2006.

City of Miami, 2018. Letter to: Kimberly D. Bose. Regarding: Comments of the City of Miami, Oklahoma on GRDA's Revised Study Plan Pensacola Hydroelectric Project, Project No. 1494-438. October 24, 2018.

City of Miami, 2022. Letter to: Kimberly D. Bose. Regarding: Pensacola Hydroelectric Project, FERC Project No. 1494-438; Supplemental Comments on GRDA's Untimely Request to Modify Sedimentation Study and Requests for Study Modifications to Conform with Approved Study Plan. March 28, 2022.

DeVries, R.N., 1996. *Rule 26 Expert Report: An Evaluation of the Water Surface Elevations of the Grand (Neosho) River Upstream of the Pensacola Dam*. March 14, 1996.

Dewberry, 2011. *USGS Grand Lake, OK LiDAR Project.* Prepared for the U.S. Geological Survey.

Duan, N., 1983. "Smearing estimate: A nonparametric retransformation method." *Journal of the American Statistical Association* 78(383):605–610.

Edwards, T.K., and G.D. Glysson, 1999. "Field Methods for Measurement of Fluvial Sediment." *Technique of Water-Resources Investigations of the U.S. Geological Survey*. Book 3, Chapter C2. Denver, Colorado: U.S. Geological Survey.

Engineering-Environmental Management, Inc., 2013. *Final Supplement to the Final Environmental Statement Volume 1*. Prepared for Storage Reallocation John Redmond Dam and Reservoir, Kansas.

Fan, J., and G.L. Morris, 1992. "Reservoir sedimentation I. Delta and density current deposits." *Journal of Hydraulic Engineering* 118(3):354–69.

FERC (Federal Energy Regulatory Commission), 2022. *Determination on Request for Study Modifications for Project No. 1494-438*.

GRDA (Grand River Dam Authority), 2017. *Pensacola Hydroelectric Project, FERC No. 1494 Pre-Application Document*.

GRDA, 2018. Letter to: Kimberly D. Bose. Regarding: Pensacola Hydroelectric Project (FERC No. 1494-438); Filing of Revised Study Plan. September 24, 2018.

GRDA, 2022. GRDA Response Comments on Sedimentation Study Plan: Pensacola Hydroelectric Project No. 1494 FERC Relicensing.

Gupta, H.V., S. Sorooshian, and P.O. Yap, 1999. "Status of automatic calibration for hydrologic models: Comparison with multilevel expert calibration." *Journal of Hydrologic Engineering* 4(2) 135–143.

Huang, J., R.C. Hilldate, and B.P. Greiman, 2006. *Erosion and Sedimentation Manual*. US Department of the Interior. United States Bureau of Reclamation.

IHO (International Hydrographic Organization), 2008. *IHO standards for hydrographic surveys (5th ed.): International Hydrographic Organization Special Publication no. 44*, 28 p. Accessed April 20, 2022. Available at: https://iho.int/uploads/user/pubs/standards/s-44/S-44_5E.pdf.

Ingersoll, C.G., C.D. Ivey, W.G. Brumbaugh, J.M. Besser, N.E. Kemble, and S. Dudding, 2009. *Toxicity Assessment of Sediments from the Grand Lake O' the Cherokees with the Amphipod* Hyalella azteca*.* U.S. Geological Survey Administrative Report CERC-8335-FY09-20-01.

Integral Consulting, 2020. *Grand Lake Waterways SEDflume Analysis: Grand Lake o' the Cherokees, Oklahoma*. SEDflume Study, Grand Lake o' the Cherokees. Santa Cruz, California.

Juracek, K.E., and M.F. Becker, 2009. *Occurrence and Trends of Selected Chemical Constituents in Bottom Sediment, Grand Lake O' the Cherokees, Northeast Oklahoma, 1940-2008*. U.S. Geological Survey Scientific Investigations Report 2009-5258, 28 p.

Kramer, A.R., C.L. Peterman-Phipps, M.D. Mahoney, and B.S. Lukasz, 2021. *Sediment Concentrations and Loads Upstream from and through John Redmond Reservoir, East-Central Kansas, 2010–19*. Scientific Investigations Report 2021–5037. U.S. Geological Survey.

Krone R.B., 1962. "Flume studies of the transport of sediment in estuarial shoaling processes." Hydrologic Engineering Laboratory, University of California at Berkely.

Lane, E.W., and V.A. Koelzer, 1943. *Density of sediments deposited in reservoirs, a case study of methods used in measurement and analysis of sediment loads in streams*. Report No. 9, Interagency Committee on Water Resources.

Lee, C., and G. Foster, 2013. "Assessing the potential of reservoir outflow management to reduce sedimentation using continuous turbidity monitoring and reservoir modelling." *Hydrological Processes* v. 27, No. 10, p. 1426–1439.

Lewis, J., 2022. Regarding [EXTERNAL] 2009 OWRB Survey of Grand Lake O' the Cherokees. Email to: Brent Teske (Anchor QEA). April 20, 2022.

Lumborg, U., and H. Vested, 2008. *Modelling of Cohesive Sediment Dynamics* (Chapter 6).

McKnight, E.T., and R.P. Fischer, 1970. *Geology and Ore Deposits of the Picher Field Oklahoma and Kansas*. Geological Survey Professional Paper 588. U.S. Department of Interior.

McNeil, J., C. Taylor, and W. Lick, 1996. "Measurements of Erosion of Undisturbed Bottom Sediments with Depth." *Journal of Hydraulic Engineering* 122(6):316–324.

Moriasi, D.N., J.G. Arnold, M.W. Van Liew, R.L. Bingner, R.D. Harmel, and T.L. Veith, 2007. "Model Evaluation Guidelines for Systematic Quantification of Accuracy in Watershed Simulations." *Transactions of the American Society of Agricultural and Biological Engineers* 50(3): 885–900.

Mussetter, B., 1997. *Analysis of Backwater Conditions Caused by Pensacola Dam on the Neosho River in the Vicinity of Miami, Oklahoma*. Fort Collins, Colorado.

Mussetter, B., 1998. *Evaluation of the Roughness Characteristics of the Neosho River in the Vicinity of Miami, Oklahoma*. Fort Collins, Colorado.

Nash, J.E., and J.V. Sutcliffe, 1970. "River flow forecasting through conceptual models: Part 1. A discussion of principles." *Journal of Hydrology* 10(3): 282–290.

OWRB (Oklahoma Water Resources Board), 2009. *Hydrographic Survey of Grand Lake*.

Partheniades, E., 1962. "A study of erosion of cohesive soils in salt water." University of California at Berkely PhD Dissertation.

Pope, L.M., 2005. *Assessment of Contaminated Streambed Sediment in the Kansas Part of the Historic Tri-State Lead and Zinc Mining District, Cherokee County, 2004.* No. 2005-5251.

Science Applications International Corporation, 2001. *Results of the March 2001 Sub-Bottom Profiling and Sediment Profile Imaging of the Outer Gloucester Harbor*. SAIC Report 541. June 2001.

Simons, D.B., and F. Senturk, 1992. *Sediment Transport Technology Water and Sediment Dynamics*. Water Resource Publications.

Singh, J., H.V. Knapp, and M. Demissie, 2004. *Hydrologic modeling of the Iroquois River watershed using HSPF and SWAT*. ISCW CR 2004-08. Champaign, Ill.: Illinois State Water Survey.

Smith, D.C., 2016. *Occurrence, Distribution, and Volume of Metals-Contaminated Sediment of Selected Streams Draining the Tri-State Mining District, Missouri, Oklahoma, and Kansas, 2011*-12. U.S. Geological Survey Scientific Investigations Report 2016-5144, 86 p., Available at: http://dx.doi.org/10.3133/sir20165144.

Smith, S., S. Hunter, and C. Ashworth, 2017. *Bathymetric Surveys of the Neosho River, Spring River, and Elk River, Northeastern Oklahoma and Southwestern Missouri, 2016-2017.* Denver, Colorado: U.S. Geological Survey.

Strong, S., 2022. Regarding Lake O' the Cherokees (Grand Lake) gage questions. Email to: Jesse Piotrowski, Ryan Greif (Mead & Hunt); Jason Lewis (USGS). March 22, 2022.

Tetra Tech, 2015. *Hydraulic Analysis of the Effects of Pensacola Dam on Neosho River in the Vicinity of Miami, Oklahoma*. Prepared for City of Miami. December 9, 2015.

Tetra Tech, 2016. *Hydraulic Analysis to Evaluate the Impacts of the Rule Curve Change at Pensacola Dam on Neosho River Flooding in the Vicinity of Miami, Oklahoma*. Prepared for City of Miami. February 3, 2016.

Tetra Tech, 2018. *Pensacola hydropower project FERC Project No. 1494-438: Sedimentation Study Plan*. Fort Collins, Colorado: Tetra Tech, Inc.

USACE (U.S. Army Corps of Engineers), 1938. *Photostatic Copies of Plane Table Sheets of the Pensacola Reservoir Area Survey.*

USACE, 1941. *Pensacola Reservoir Computation Folder for Envelope Curve of Water Surface in Reservoir*.

USACE, 1942. *Pensacola Reservoir Computation Folder for Revised Envelope Curve of Water Surface in Reservoir*.

USACE, 1969. *Flood Plain Information, Neosho River and Tar Creek, Miami Oklahoma*. Tulsa, Oklahoma: USACE Tulsa District.

USACE, 1995. *Engineering Manual 1110-2-4000: Engineering and Design – Sedimentation Investigations of Rivers and Reservoirs*.

USACE, 1996. *Rule 26 Expert Report: An Evaluation of the Water Surface Elevations of the Grand (Neosho) River Upstream of the Pensacola Dam*. Prepared by Richard N. DeVries. March 14, 1996.

USACE, 1998. *Grand Lake, Oklahoma Real Estate Adequacy Study*.

USACE, 2002. *Engineering Manual 1110-2-1003: Engineering and Design – Hydrographic Surveying Version 3*.

USACE, 2016. *HEC-RAS River Analysis System User's Manual.* Davis: Hydrologic Engineering Center.

USACE, 2022. "Sediment Rating Curve Analysis Tool." Available at: Sediment Rating Curve Analysis Tool (army.mil).

USDA (U.S. Department of Agriculture), 1938. Aerial photography of McDonald County, MO. Aerial Photography Field Office, Washington, D.C.

USDA, 1939a. Aerial photography of Delaware County, OK. Aerial Photography Field Office, Washington, D.C.

USDA, 1939b. Aerial photography of Ottawa County, OK. Aerial Photography Field Office, Washington, D.C.

USDA, 1940. Aerial photography of Mayes County, OK. Aerial Photography Field Office, Washington, D.C.

USDA, 1990. *Engineering Field Manual, Chapter 4. Elementary Soil Engineering.* U.S. Department of Agriculture, Soil Conservation Service.

USGS (U.S. Geological Survey), 1907. *Wyandotte, OK-MO-KS Historical Map 125000-Scale*.

USGS, 2006. Collection of Water Samples (ver. 2.0). *U.S. Geological Survey Techniques of Water-Resources Investigations,* Book 9.

USGS, 2017. "National Geospatial Program." *The National Map Viewer*. Available at: https://www.usgs.gov/core-science-systems/national-geospatial-program/national-map.

USGS, 2020. *Bathymetric Map, Surface Area, and Capacity of Grand Lake O' the Cherokees, Northeastern Oklahoma, 2019*. Available at: https://pubs.er.usgs.gov/publication/sim3467.

USGS, 2021a. "USGS 07189000 Elk River near Tiff City, Mo." *National Water Information System*. Accessed February 5, 2021. Available at: https://waterdata.usgs.gov/mo/nwis/uv?site_no=07189000.

USGS, 2021b. "USGS 07185000 Neosho River near Commerce, OK." *National Water Information System*. Accessed February 5, 2021. Available at: https://waterdata.usgs.gov/nwis/uv?site_no=07185000.

USGS, 2021c. "USGS 07185080 Neosho River at Miami, OK." *National Water Information System*. Accessed February 5, 2021. Available at: https://waterdata.usgs.gov/ok/nwis/uv?site_no=07185080.

USGS, 2021d. "USGS 07185095 Tar Creek near Commerce, OK." *National Water Information System*. Accessed February 5, 2021. Available at: https://waterdata.usgs.gov/nwis/uv?site_no=07185090.

USGS, 2021e. "USGS 07185095 Tar Creek at 22nd Street Bridge at Miami, OK." *National Water Information System*. Accessed February 5, 2021. Available at: https://waterdata.usgs.gov/nwis/uv?site_no=07185095.

USGS, 2021f. "USGS 07188000 Spring River near Quapaw, OK." *National Water Information System*. Accessed February 5, 2021. Available at: https://waterdata.usgs.gov/nwis/uv?site_no=07188000.

USGS, 2021g. "USGS 07190000 Lake O' the Cherokees at Langley, OK." *National Water Information System*. Accessed February 5, 2021. Available at: https://waterdata.usgs.gov/ok/nwis/uv?site_no=07190000.

USSD (U.S. Society on Dams), 2015. *Modeling Sediment Movement in Reservoirs.* Prepared by the U.S. Society on Dams Committee on Hydraulics of Dams, Subcommittee on Reservoir Sedimentation, June 2015.

van Rijn, L.C., (n.d.). *Sedimentation of Sand and Mud in Reservoirs in Rivers*. Accessed April 11, 2022. Available at: https://www.leovanrijn-sediment.com/.

Vanoni, V.A. ed., 2006. *Sedimentation engineering*. American Society of Civil Engineers. March 2006.

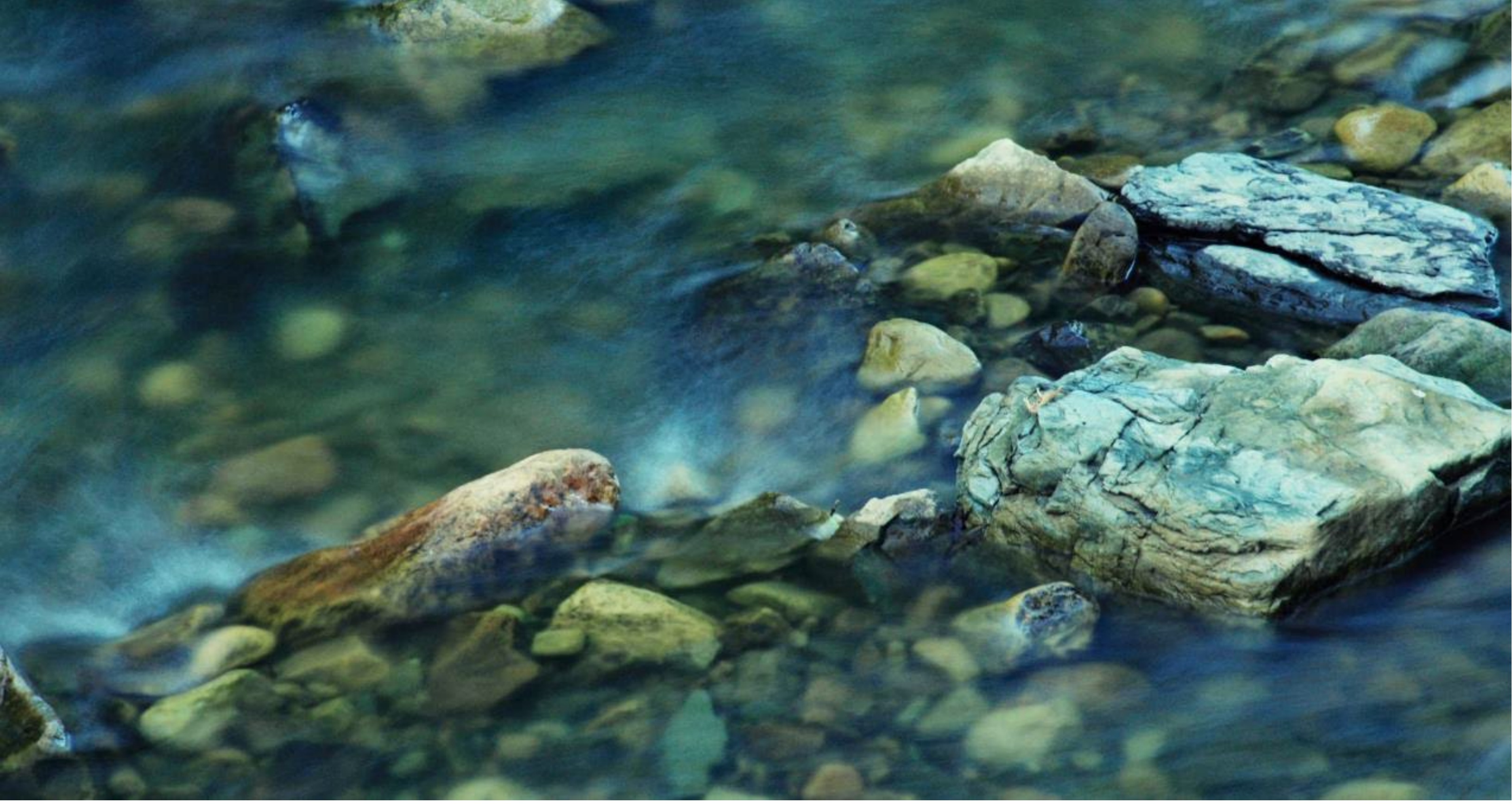
Walling D.E., and D. Fang, 2003. "Recent trends in the suspended sediment loads of the world's rivers." *Global and Planetary Change* 39:111–126.

WEST (WEST Consultants), 2012. *Hydraulic and Sedimentation Modeling in HEC-RAS – Cochiti Baseline Study: Sediment Transport Modeling.* Prepared for the Pueblo de Cochiti and the U.S. Army Corps of Engineers, ABQ District.

WEST, 2022. Independent Technical Review of HEC-RAS Sediment Transport Model.

Zavala, C., 2020. "Hyperpycnal (over density) flows and deposits." *Journal of Palaeogeography 9*(1):1–21.

Appendix A
Water Surface Elevation Monitoring



March 2022
Sedimentation Study

ANCHOR QEA

2021 Grand River Water Level Monitoring

Prepared for Grand River Dam Authority

March 2022
Sedimentation Study

2022 Grand River Water Level Monitoring

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Executive Summary

At the request of council, this report presents the findings of the first 60 months of a multi-year water level monitoring study in the Grand Lake watershed. Anchor QEA is conducting the study as part of the Grand River Dam Authority project team for the Pensacola Dam relicensing project. The objective of the water level monitoring project is to collect high-quality water level data in the Grand Lake reservoir and upstream tributaries to assist hydraulic modeling and any potential sediment transport study efforts of the relicensing project.

Anchor QEA installed 16 HOBO water level loggers in the study area in late December 2016 at locations selected to maximize insights into the watershed response to varying hydrologic conditions or flow events. The loggers are deployed throughout the Grand Lake reservoir, near bridge crossings, at upstream locations in the Neosho and Spring Rivers, and in Horse Creek and Sycamore Creek. The loggers are set to record data at 30-minute increments. Water level data at these locations will provide information on the characteristics of floods which can be used to calibrate and validate hydraulic models of the watershed.

HOBO loggers directly measure pressure, which can be converted to a water depth using atmospheric pressure measurements and the unit weight of water. A reference elevation of the logger must be known to tie in water depth measurements to a datum and make measurements useful for modeling and analysis. Site visits to the loggers included a precise GPS survey of the logger elevation in addition to data retrieval and logger re-installation. Hand measurements prior to logger removal and after re-installation provided a reference to estimate logger measurement errors. A site visit in August 2017 retrieved data from 13 of 16 loggers while a visit in March 2018 was less successful due to an unforeseen minor flood event, and only 2 of 16 loggers were accessible. Due to unusually high water levels throughout the fall and winter of 2018-19, a trip to collect water level data was not possible again until April 2019. As a result, some loggers filled their available data storage capacity and stopped logging, though 12 pressure sensors were recovered and re-deployed at that time. Data loggers were again recovered and re-deployed in December 2020, with 13 of 16 collected. In December 2021 and February 2022, the remaining 12 loggers were permanently removed. The loss of data loggers due to washouts and/or tampering has limited records at several locations.

Water level monitoring in 2017 captured uneventful ‘base’ winter conditions, several small flood events, and a large late spring flood which featured sustained water levels over 10 feet higher than low-water conditions. Monitoring has also captured the large flood events in spring, most notably those in the spring of 2017 and the spring/summer of 2019. Errors compared to hand measurements and nearby USGS gages were small, generally less than 0.06 feet. The data provides insight into the

flood hydrology of the reservoir, but its real value was its use in hydraulic modeling to assess the effects of hydraulic structures, operational changes, or sedimentation in the watershed.

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1 Introduction

Anchor QEA was retained by Mead & Hunt to assist the Grand River Dam Authority (GRDA) in the Pensacola Dam relicensing project. The Pensacola Dam relicensing project is a large-scale, multi-year effort mandated by the Federal Energy Regulatory Commission (FERC). Specifically, Anchor QEA's role in the project was to collect water level data for a 12-month period beginning in December 2016, with the option of continuing monitoring after that period. Anchor QEA collected water level data through February 2022. The water level monitoring study was conducted to provide data with necessary spatial and temporal resolution to assist in the creation of a hydraulic model for the reservoir and upstream reaches, and to provide data for any potential sediment transport study in the watershed.

Water level is a critical piece of information necessary for analysis of any fluvial environment, including rivers and reservoirs. The depth of water in a river is related to the quantity of water flowing in a river and the speed at which the water is moving; the variation of which, in space and time, is essential to modeling and understanding hydraulic systems. This understanding can help researchers understand how structures impact flooding, how flashy the riverine environment is, how sediment is transported through the watershed, and the fate of transported materials, as well as many other aspects of the fluvial system.

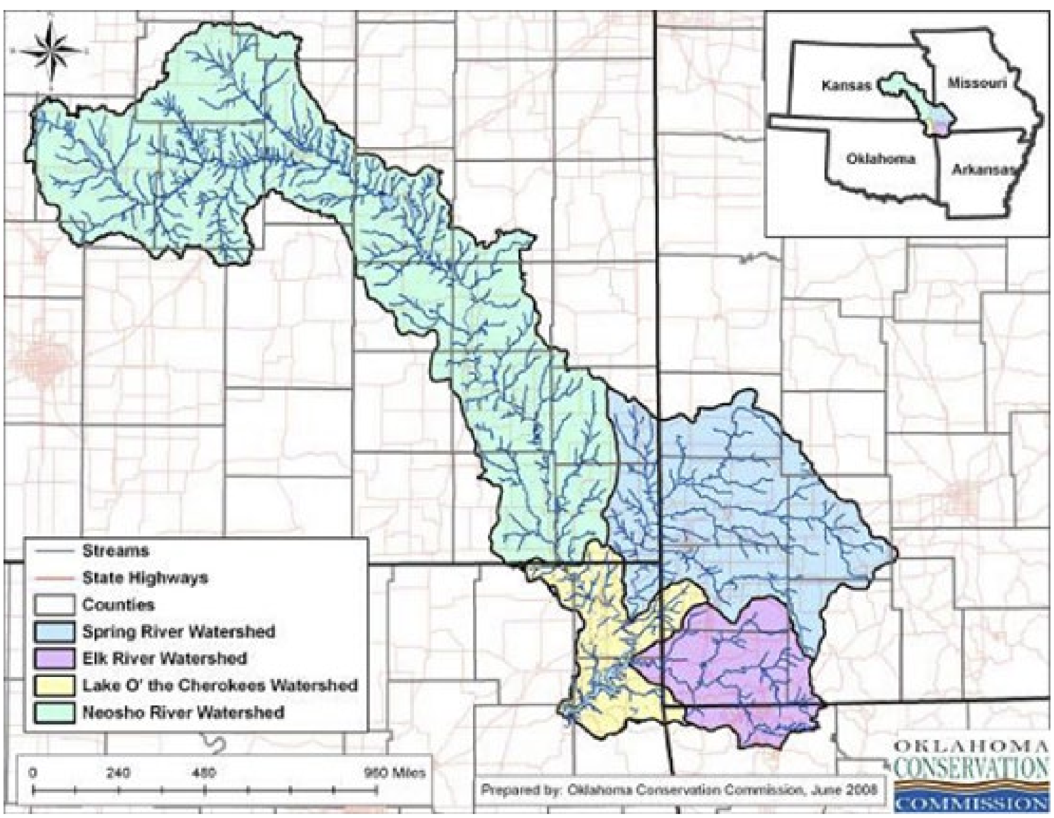
The purpose of this water level study is to provide continuous water level data for a time period of five years at locations distributed through the Grand Lake watershed. This water level data will be used to calibrate and validate hydraulic models of the watershed, understand the nature of flooding in the watershed, and provide data useful for future investigations in the area. At a basic level, the data collected in this phase of the project provides a foundation for other scientific studies of the watershed. This report presents the methodology and preliminary findings of 5 years of the water level monitoring study.

2 Study Area

Pensacola Dam is located at the downstream end of the Grand Lake O' the Cherokees (Grand Lake) reservoir. The reservoir is located downstream of the watersheds of the Spring, Elk, and Neosho Rivers, in addition to the Grand Lake watershed (Figure 1). The drainage area to the Pensacola Dam includes parts of Oklahoma, Missouri, Kansas, and Arkansas. In addition to Pensacola Dam, several large bridges cross the reservoir and tributaries. Highway and railroad bridges are often built with embankments constricting large portions of the river, which may exacerbate flooding.

The watershed is located in a region that typically experiences hot, humid summers with intense rainstorms that can lead to flooding. Floods in the watershed can cause serious damage to homes, businesses, and infrastructure. Recently, focus has turned to the effects of hydraulic structures on flooding. Previous investigations of flooding in the Grand Lake watershed have differed in determining the impacts Pensacola Dam and other structures have on upstream flooding. Nevertheless, high quality field data is missing with regards to the impacts of Pensacola Dam and other structures under current operational scenarios.

Figure 1
Map of Grand Lake watershed



3 Methods

Water levels in the Grand Lake watershed were measured using HOBO water level loggers. HOBO loggers contain a pressure transducer that responds to the weight of overlying water and atmospheric pressure, a thermometer, and an internal data logger which stores over a year of data. Figure 2 shows a HOBO logger prior to installation. HOBO loggers were installed in approximately 18 inches of water during a period of low water levels to ensure that the loggers were always submerged. Loggers are programmed to record pressure and temperature data every 30 minutes.

Figure 2
HOBO water level logger prior to deployment

Loggers were deployed at 16 locations throughout the watershed in December 2016, as shown in Figure 3. Locations of logger deployment were selected to span the length of the area of interest in the watershed, on important tributaries, and upstream and downstream of major constrictions. Loggers at stations 1 and 16 are located near USGS gaging stations on the Neosho River and at Pensacola Dam, respectively.

Raw logger data contains absolute pressure readings, which must be converted to a water depth or water surface elevation. To convert pressure data to a water depth, a reference elevation of the logger and atmospheric pressure must be known. A Real-Time Kinematic (RTK) GPS was used at logger installation and all follow-up visits to measure the water surface elevation and temporary and established benchmarks. A measuring stick was also used to measure the water depth to the logger, establishing the reference elevation of the logger. Pressure data was post-processed by subtracting atmospheric pressure data recorded at the nearby Grove, OK airport from the recorded data, then converting the hydrostatic pressure to a water depth.

Water level records begin in late December 2016, when the loggers were installed. A follow-up site visit in August 2017 downloaded data from 13 of the 16 water level loggers (Table 1). Another follow-up visit in March 2018 was able to only download data from 2 loggers because of a flood event that occurred during the visit. The remaining loggers continued to record data and most were retrieved during a visit in April 2019. Another visit occurred in December 2019, during which 11 loggers were retrieved. Data loggers were again recovered and re-deployed in December 2020, with 13 of 16 collected. In December 2021 and February 2022, the 12 remaining loggers were permanently removed.

Figure 3
Location of HOBO loggers in the study area.

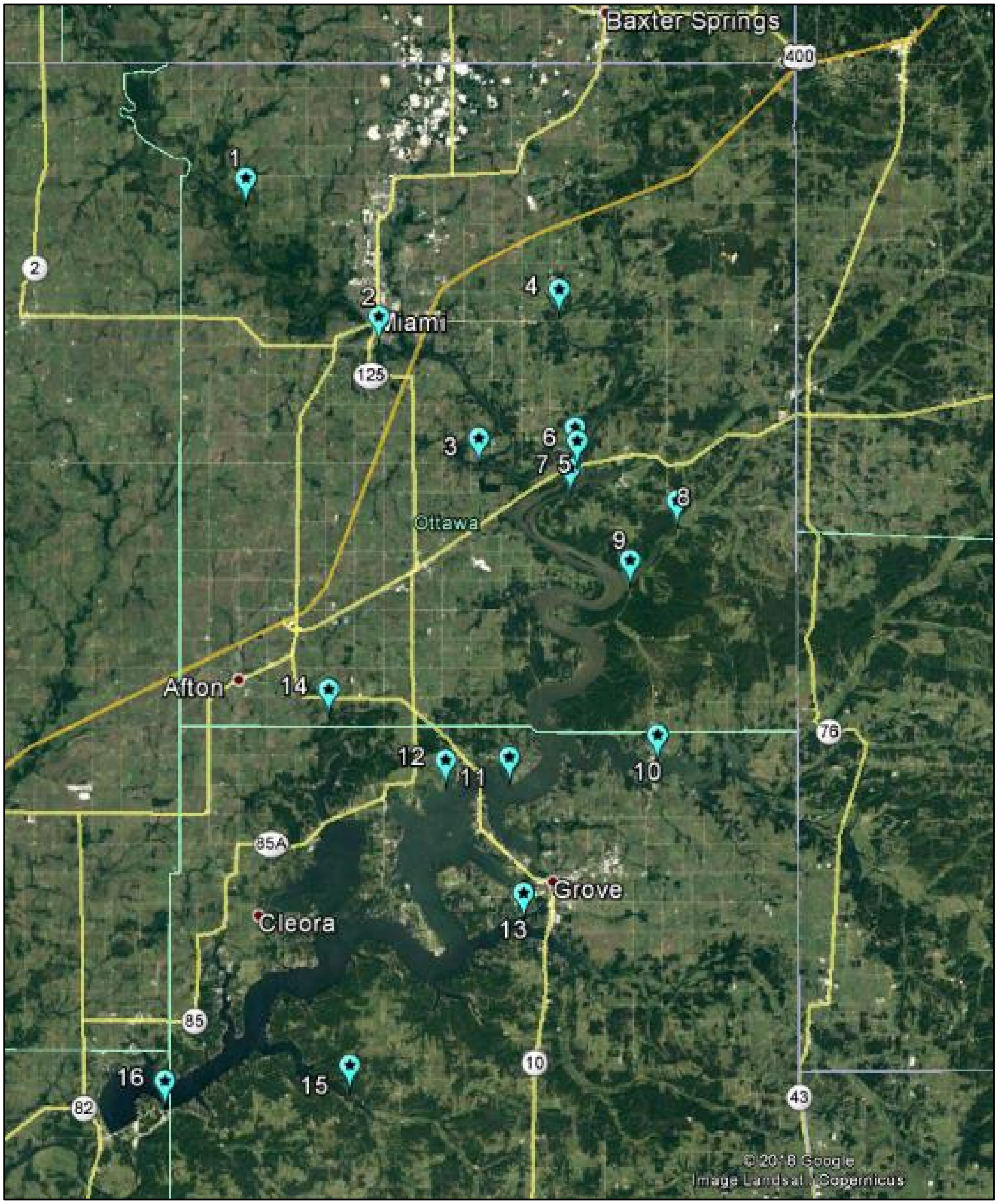


Table 1
Location of HOBO data loggers in the Grand Lake watershed

Sta.	Lat.	Long.	Location	Duration of Data
1	36°55'41.35"N	94°57'32.22"W	Neosho River at E 64 Rd near Commerce, OK	Dec 2016-Dec 2020
2	36°51'34.36"N	94°52'35.20"W	Neosho River at Riverview Park, Miami, OK	Dec 2016-Aug 2017 Apr 2019-Dec 2021
3	36°47'57.17"N	94°48'52.36"W	Neosho River near Connors Bridge on S 590 Rd.	Dec 2016-Mar 2018 Dec 2019-Feb 2022
4	36°52'22.42"N	94°45'53.19"W	Spring River upstream of Hwy 10 Bridge	Dec 2016-Nov 2018 Dec 2019-Dec 2021
5	36°48'16.24"N	94°45'18.05"W	Spring River at Twin Bridges Area at Grand Lake State Park boat launch	Dec 2016-Nov 2018 Apr 2019- Feb 2022
6	36°47'52.17"N	94°45'13.37"W	Confluence of Spring and Neosho at Twin Bridges Area at Grand Lake State Park	Dec 2016-Nov 2018 Apr 2019- Feb 2022
7	36°47'4.21"N	94°45'28.75"W	Neosho River off E157 Rd downstream of railroad bridge	Dec 2016- Feb 2022
8	36°46'5.58"N	94°41'31.88"W	Sycamore Creek at Hwy 10 bridge	Dec 2016-Aug 2017 Dec 2020 - Dec 2021
9	36°44'19.69"N	94°43'16.46"W	Neosho River downstream of roadside park off Hwy 10	Never recovered
10	36°39'8.19"N	94°42'16.21"W	Grand Lake/Elk River US of Hwy 10 bridge north of Grove, OK	Dec 2016-Aug 2017 Apr 2019-Dec 2020
11	36°38'29.32"N	94°47'45.57"W	Grand Lake at Hickory Point, US of Hwy 59 bridge	Dec 2016-Nov 2018 Apr 2019- Feb 2022
12	36°38'24.09"N	94°50'7.12"W	Grand Lake at public access point off S. 580 Rd, DS of Hwy 59 bridge	Dec 2016-Aug 2017 Re-installed Dec 2020
13	36°34'27.15"N	94°47'14.41"W	Grand Lake at Honey Creek State Park	Dec 2016-Nov 2018 Apr 2019-Dec 2021
14	36°40'30.13"N	94°54'26.81"W	Horse Creek off E 240 Rd	Dec 2016-Nov 2018 Apr 2019-Dec 2020
15	36°29'20.45"N	94°53'40.87"W	Grand Lake near Woods Spring Branch off S 560 & E 360 Rd.	Dec 2016-Dec 2020
16	36°28'51.72"N	95° 0'31.36"W	Grand Lake at Cherokee State Park Boat Ramp, Disney, OK	Dec 2016-Nov 2018 Apr 2019-Dec 2021

3.1 Existing Data Sources

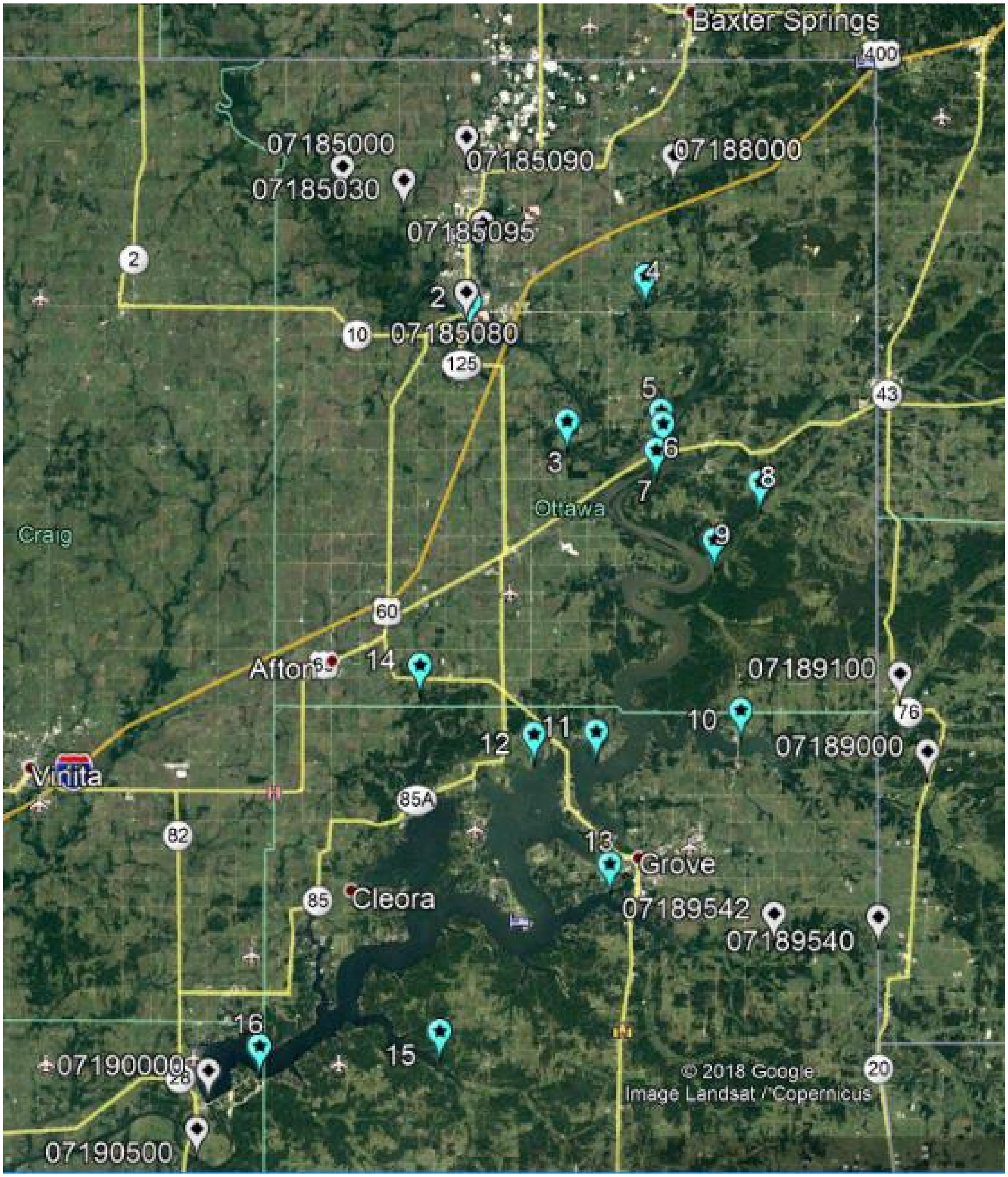
Grand Lake has been extensively studied and has several existing data sources. USGS gages are present throughout the watershed and are located near HOBO loggers at locations 1 and 16 (Table 2). Those USGS gages were used to verify water level measurements from the HOBO loggers. Station 1 is located on a bridge pier adjacent to USGS Gage 07185000 (Neosho River near Commerce, OK), and readings from the two instruments show generally good agreement. Station 16 is located near the emergency spillway of Pensacola Dam, about 2 miles upstream of USGS Gage 07190000, but because the reservoir surface was nearly always horizontal at this downstream location, the data is useful for validation of the HOBO measurements.

Table 2
USGS gaging stations located near HOBO loggers in the study area

USGS Station ID	Location	Lat.	Long.	Datum
7185000	Neosho River near Commerce, OK	36° 55' 43" N	94° 57' 26" W	NGVD29
7190000	Lake O' the Cherokees (Grand Lake) at Langley, OK	36° 28' 07" N	95° 02' 28" W	Pensacola Datum

The Grand Lake watershed has a total of 13 USGS stations on the Grand/Neosho, Spring, and Elk Rivers as well as several tributaries such as Tar and Sycamore Creeks. The USGS stations (shown with gray markers in Figure 4) are actively recording water levels and other environmental data. When combined with the data from the HOBO loggers, the entire dataset provides a total of 29 locations recording water levels, creating a robust data set in the watershed. The study area is sufficiently monitored with water level data to aid in analysis of the system.

Figure 4
Location of HOBO loggers and USGS gaging stations within the study area



Benchmarks established by the USGS are present at several locations throughout the watershed and are used as validation points for the accuracy of the RTK-GPS used for surveying. Table 3 shows the locations and elevations of the benchmarks in addition to the surveyed elevations. Surveyed benchmark elevations are 1-minute averages of elevation measurements taken once a second with a Fixed RTK-GPS signal. USGS benchmark elevations are provided as the average of 2 to 15 individual measurements.

Table 3
Benchmarks surveyed during field visits.

Benchmark	Location	Lat. (Dec. Deg.)	Long. (Dec. Deg.)	BM Elevation (ft, NAVD88)	Surveyed Elevation (ft, NAVD88)
RM-G	Concrete anchor bolt at boat ramp at Oklahoma State Highway 10 bridge near Grove, Oklahoma	36.652419	-94.707825	754.295	754.2
RM-C	Concrete anchor bolt at boat ramp near S 590 Road (Connors) bridge near Fairland, Oklahoma	36.799278	-94.818872	752.376	752.413

4 Results

4.1 Water Level Data

Hydrographs showing time series of water surface elevation and temperature for the HOBO loggers accessible during site visits are provided in Appendix I. Water surface elevation data is also available in spreadsheet form in a separate file. Taken together, these hydrographs provide a rich dataset that can be used with hydraulic models to better understand the behavior of the Grand Lake watershed.

HOBO loggers at Stations 1 and 16 showed generally good agreement with the USGS gauging stations (Appendix II). Station 1 has one period of significant deviation from USGS water level records from April to August 2018. The presence of a mass of debris may have affected water level readings by directing flow away from the pier and producing artificially lower WSE readings. It appears to have been removed or washed away sometime around 15 August 2018. Station 16 data matches very well until 5:30 PM on 7 May 2018, when there is a shift of 0.3 feet. The sensor may have been moved by an unknown individual or hit by a boat, driftwood, or other debris, causing it to record the offset WSEs. The offset is consistent throughout the rest of the period of record.

At one point during the period of record, approximately one year elapsed between site visits, during which only a handful of sensors were retrievable. Due to the large length of time between site visits, several of the loggers reached their internal storage capacity and stopped recording. There is therefore a data gap between November 2018 and April 2019 at many of the stations as shown in Table 1, above. The field team was delayed by repeated high water levels, which prevent logger retrieval. Following a site visit in April 2019, all loggers were retrieved and data recording was restarted. Recording continued through site visits to retrieve loggers and data in December 2020 and again in December 2021.

Loggers deployed over a large portion of the Grand Lake watershed since December 2016 have recorded a wide range of hydrologic events, including rule curve changes, long periods of 'baseline' behavior, small flood events, and large sustained flood events. The two most notable flood events captured in the data record occurred between late April and late June 2017 and from May to August 2019. Loggers located at upstream locations show a series of sharp peaks in water surface elevation, indicative of high flows due to storms over the watershed. Downstream loggers in Grand Lake recorded a broad peak as floodwaters collected in the reservoir before being released.

Water level records differ significantly in character depending on location in the watershed. During a flood event, upstream areas display a sharp rise and fall in water levels, referred to as a 'rising limb' and 'falling limb' of a hydrograph, respectively. At locations further downstream, the rising limb of a flood hydrograph typically becomes lower and more gradually sloped than upstream areas, while the falling limb will display a more gradual lowering of water levels. This effect is especially prominent in dammed reservoirs, where operational procedures often have significant influence on hydrographs. Land use and topography also play large roles in hydrograph character, in addition to watershed position.

An example of the differences of hydrographs at logger locations is shown in Figure 5 for a series of three floods between August 4th and August 21st, 2017. The hydrographs at Stations 1 and 2 are on upstream reaches of the Neosho River, Station 6 is at the confluence of the Neosho and Spring Rivers, and Stations 12 and 16 are located 22 and 1.5 miles above Pensacola Dam, respectively. Each hydrograph is adjusted so that 0 ft in elevation is the pre-flooding water level at each station.

The hydrographs shown in Figure 5 provide an example of a typical flooding scenario in the Grand Lake watershed. A large pulse of water in the upstream reaches of the Neosho River results in a water level rise of 8-14 feet, and a falling limb of the hydrograph that is slightly less steep than the rising limb. Areas downstream show progressively lower peaks in the flood hydrograph, with a peak rise of only 1.61 feet at Station 16 at Pensacola Dam (Table 4). There is a delay in peak water level at downstream locations and the falling limb of the hydrograph is much more gradual than the rising limb at these locations. These phenomena are typical of floods in the Grand Lake watershed and can be observed for large and small events throughout the period of water level monitoring.

Figure 5
Flood hydrographs of a series of three floods in August 2017. Selected HOBO logging stations are shown to display differences in hydrograph character throughout the watershed.

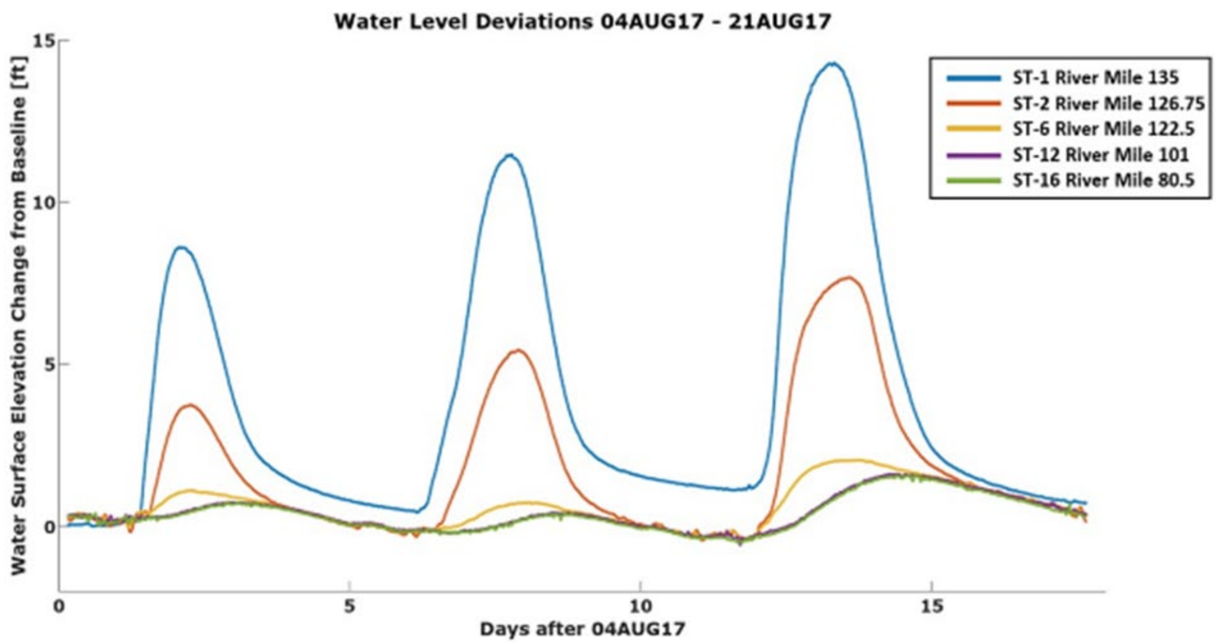


Table 4
Key parameters of the August 2017 floods shown in Figure 5

Station, River Mile	Peak Level Above Pre-Flood (ft)	Date and Time of Flood Peak	Date and Time of Return to Low Stage
Station 1, RM 135	14.3	August 14, 04:30	August 26, 22:30
Station 2, RM 126.75	7.69	August 14, 11:00	August 27, 13:30
Station 6, RM 122.5	2.05	August 14, 14:30	August 27, 21:00
Station 16, RM 80.5	1.61	August 15, 13:30	August 28, 01:30

4.2 Temperature Data

HOBO loggers recorded water temperature in addition to pressure data. Temperature timeseries are provided in Appendix I and in accompanying spreadsheet files. While hydraulic modeling studies typically do not need to consider temperature of the water, this data could potentially be useful for ecological studies or pollutant/contaminant transport studies in the watershed.

4.3 Measurement Error and Uncertainty

Recorded data error was calculated by comparing data records with water depths measured during site visits ('measure-down'). Table 5 shows average errors at each site. Measurement error is less than 0.16 feet at all sites and are typically less than 0.08 ft. Potential sources of error and uncertainty in pressure measurements include instrument drift, synoptic errors, atmospheric pressure changes, waves, and slight differences in water density. 'Measure-down' uncertainty is estimated to be 0.25 inches (0.021 ft).

Table 5
Mean error between HOBO loggers and water depth measurements.

Station	Root Mean Squared Error (ft)
1	0.1528
2	0.0632
3	0.0709
4	0.0707
5	0.0767
6	0.0543
7	0.0712
8	0.0024
9	N/A
10	0.0473
11	0.0854
12	0.054
13	0.0432
14	0.0584
15	0.0519
16	0.0962

HOBO loggers were located near USGS gages at stations 1 and 16. Comparisons between USGS gage data and collected HOBO data show that differences between the two are small compared to the magnitude of water level fluctuations, though HOBO loggers tended to record lower water surface elevations during flood peaks (Table 6 and Appendix II). Sources of differences between HOBO water level data and USGS gage data include mean water surface elevation differences at the two nearby locations, measurement technique and instrument errors, and differences in timing. Larger differences in the data records during peaks in flood events may be due to local hydraulic effects caused by blockages in the river or differences in the timing of measurements, given the rapid nature of flood peaks in upstream areas. Station 1 in particular has had large blockages affecting the data.

Figure 6
Photo of blockage taken in August 2019. Debris pile remains in place and has grown since photo was taken.

Table 6
RMS error between HOBO water level loggers and nearby USGS gaging stations.

Station/USGS gage	RMSE (ft)
Station 1/USGS 07185000	1.128 (excluding May-Aug 2018)
Station 16/USGS 07190000	0.49

4.4 RTK-GPS Measurement Adjustments

Initial logger deployment was done without the aid of RTK-GPS instrumentation. As a result, exact elevations were unknown, and logger elevations were measured in reference to a set benchmark. The benchmarks were later measured with RTK-GPS equipment to define logger elevations. In some locations, RTK-GPS signals are limited, and the elevations were based on the best available data at the time.

Since initial deployment, field technicians have been able to fix elevations with RTK-GPS measurements. Sites 4 (Spring River) and 15 (Drowning Creek) are two such sites where significant adjustments have been made to WSE measurements. In both cases, processing involved evaluating vertical offsets between HOBO measurements validated by RTK-GPS recorded between April 2019 and February 2022 and USGS WSE records during the same time period. HOBO data from before the April 2019 WSE measurements was then adjusted so the offsets before April 2019 match the more recent values.

5 Discussion and Conclusions

Water level data has been collected in the Grand Lake watershed to gain a better understanding of flood hydrology in the area. HOBO loggers installed near streambanks have collected water level data every 30 minutes from December 2016 to February 2022 with one gap from November 2018 to April 2019 at several locations. The water level timeseries collected will serve multiple purposes in the Pensacola Dam relicensing project, including as a high-quality dataset for hydraulic model calibration and verification; as an important dataset for a proposed sediment transport study; and as information that can be used to support other activities on the reservoir, including infrastructure, planning, and research projects.

Water levels are the foundation of hydrologic and hydraulic investigations. This investigation provides more than 60 months of half-hourly records at 16 locations in the watershed. Alone, water level data provides insight into flood impacts, hydraulic characteristics of the river, and the effects of structures in the watershed. When combined with other information such as the composition and slope of the river bottom and flow in the river, one can determine the impacts of future storms, understand the impacts dam regulation plays on water surface elevations, and predict how sediment and particles move through the watershed.

The findings of the water level monitoring captured several small flood events and two large flood events. The spring 2017 flood caused significant damage within the watershed as water levels rose over 10 feet higher than the low-pool elevation. For the second large flood event in spring 2019, flooding was similar in magnitude in the Grand Lake reservoir but had higher peaks upstream and a longer duration than the spring 2017 event. The hydrographs presented in Appendix I show that flooding persists the longest in Grand Lake with lower peaks, while areas further upstream experience sharper peaks of flooding that pass more quickly. The data is shown to be high quality, as error analysis shows differences between HOBO loggers and nearby USGS gages were small compared to fluctuations in the water levels, as were differences between the loggers and 'measure-down' records.

Unfortunately, due to multiple flood events in the basin, some of the loggers were not retrievable between August 2017 and April 2019. The internal data storage is only sufficient for a period of approximately 14 months, so some of the monitoring data was lost. Several loggers were washed away by flood events, debris, or boat traffic, resulting in further lost data.

The water level monitoring work described in this document provides important information that will be used in several other aspects of the Pensacola Dam relicensing project. Please see Appendices I and II for collected data described in this report.

Appendix I
Water Level Monitoring Data

Figure A1
Station 1: Neosho River near Commerce, OK

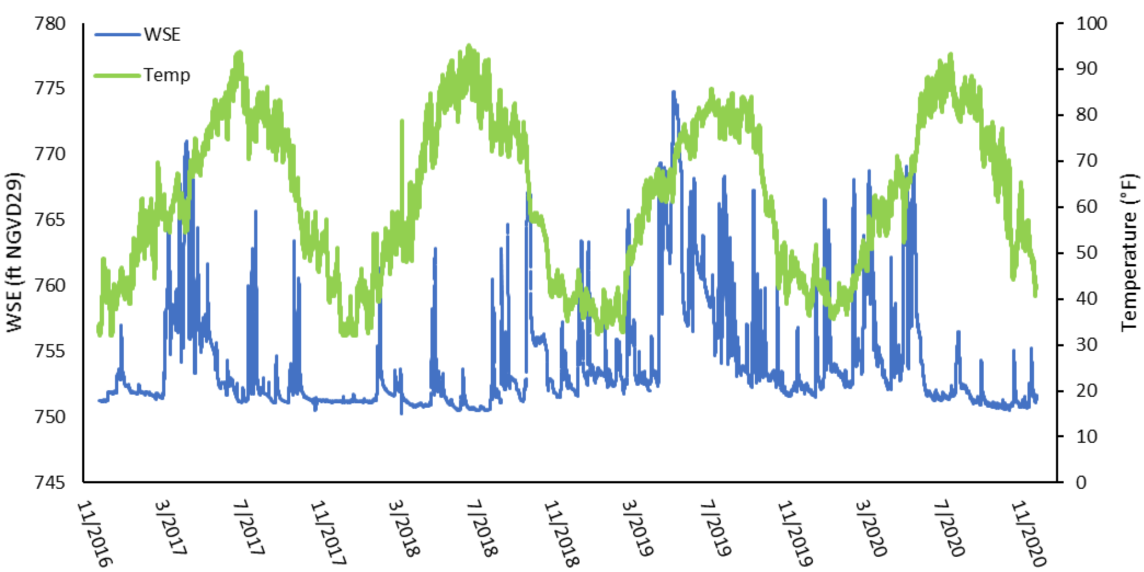


Figure A2
Station 2: Neosho River at Riverview Park, Miami, OK

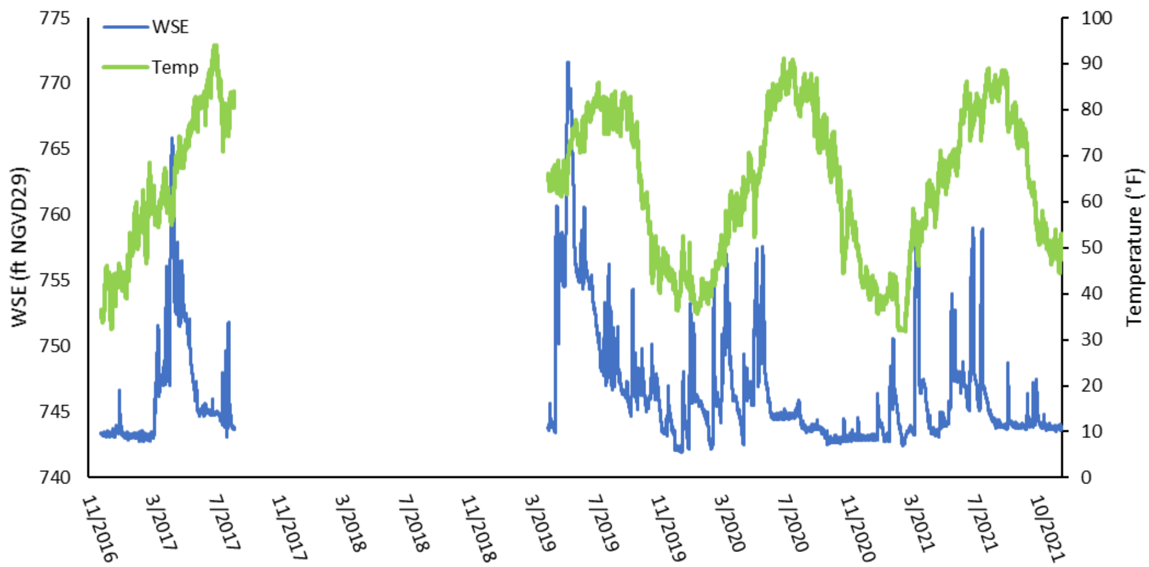


Figure A3
Station 3: Neosho River at Connors Bridge at S 590 Rd.

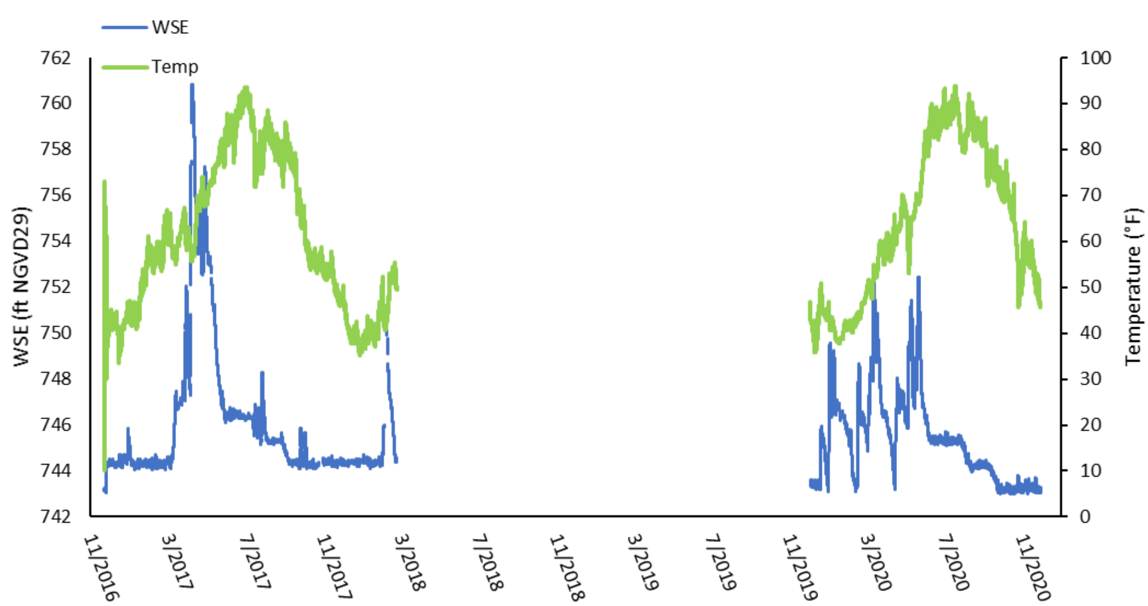


Figure A4
Station 4: Spring River upstream of Hwy 10 bridge

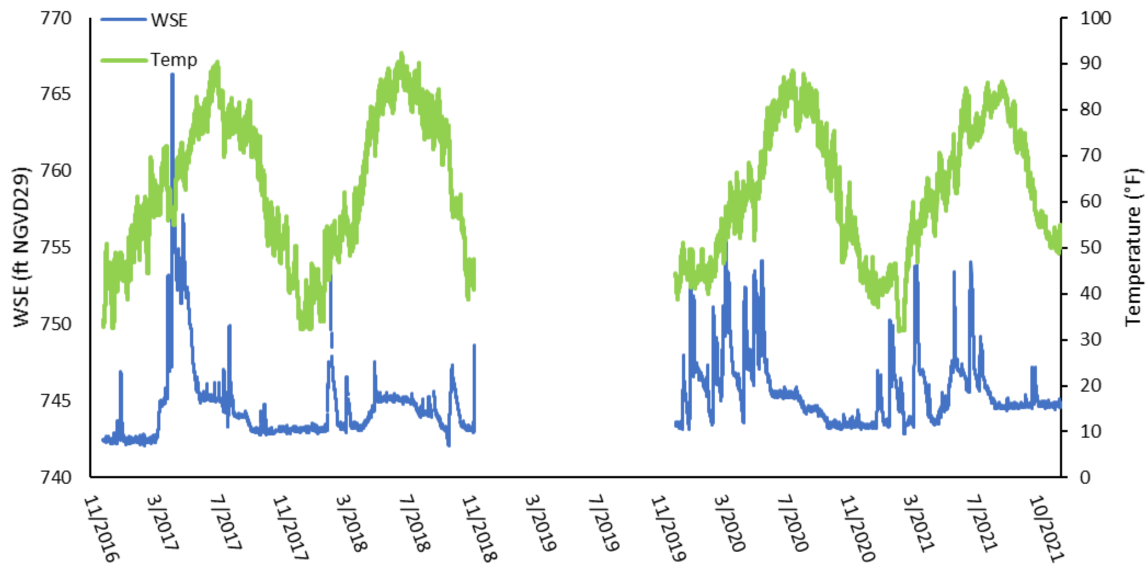


Figure A5
Station 5: Spring River at Twin Bridges Area at Grand Lake State Park boat launch

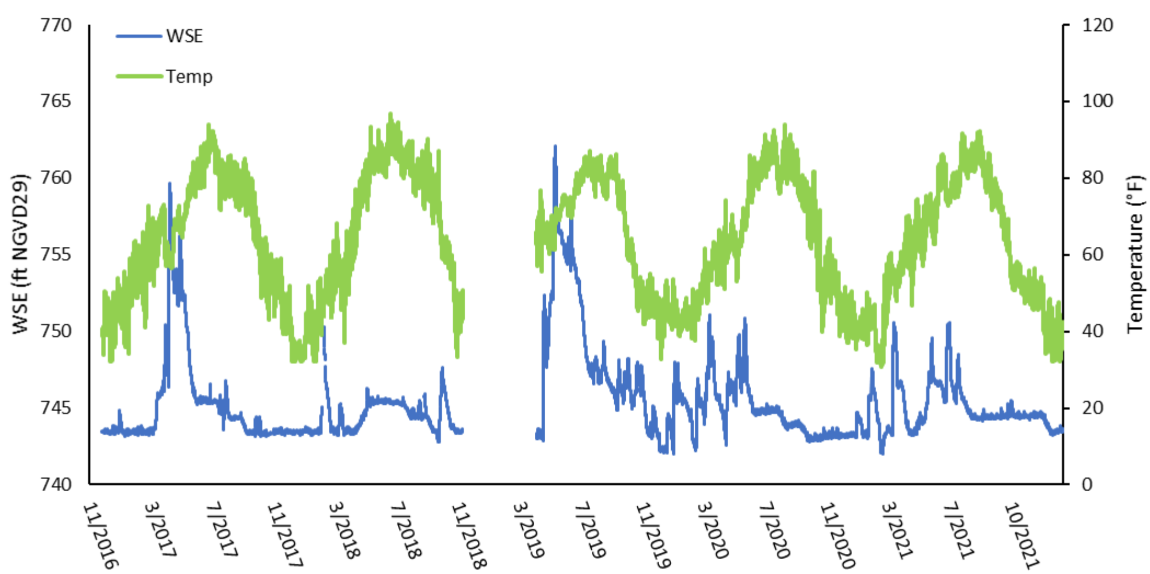


Figure A6
Station 6: Confluence of Neosho and Spring Rivers at Twin Bridges Area at Grand Lake State Park

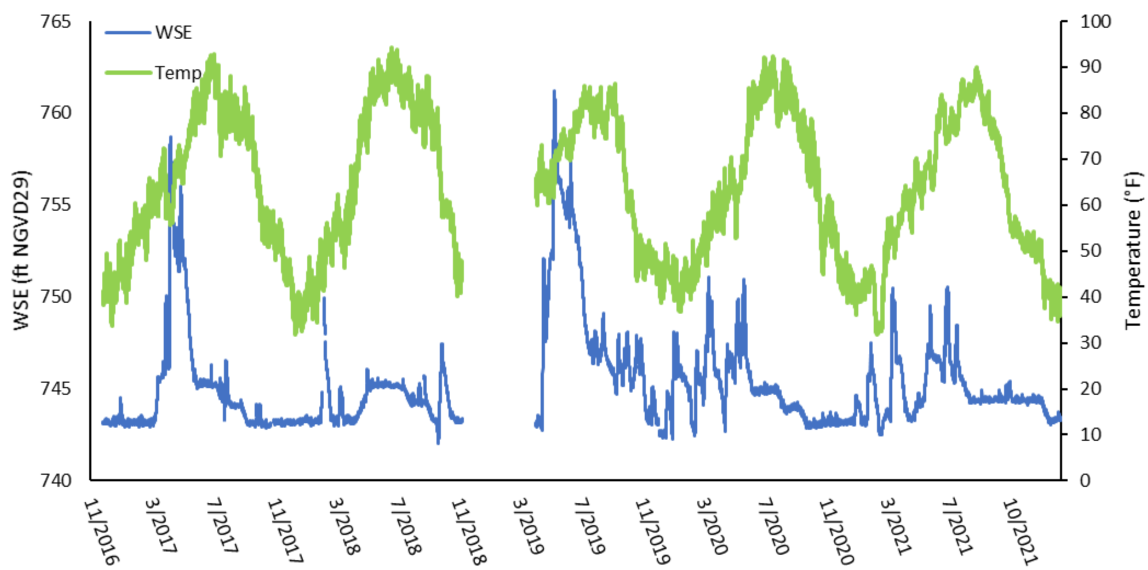


Figure A7
Station 7: Neosho River off E157 Road downstream of railroad bridge

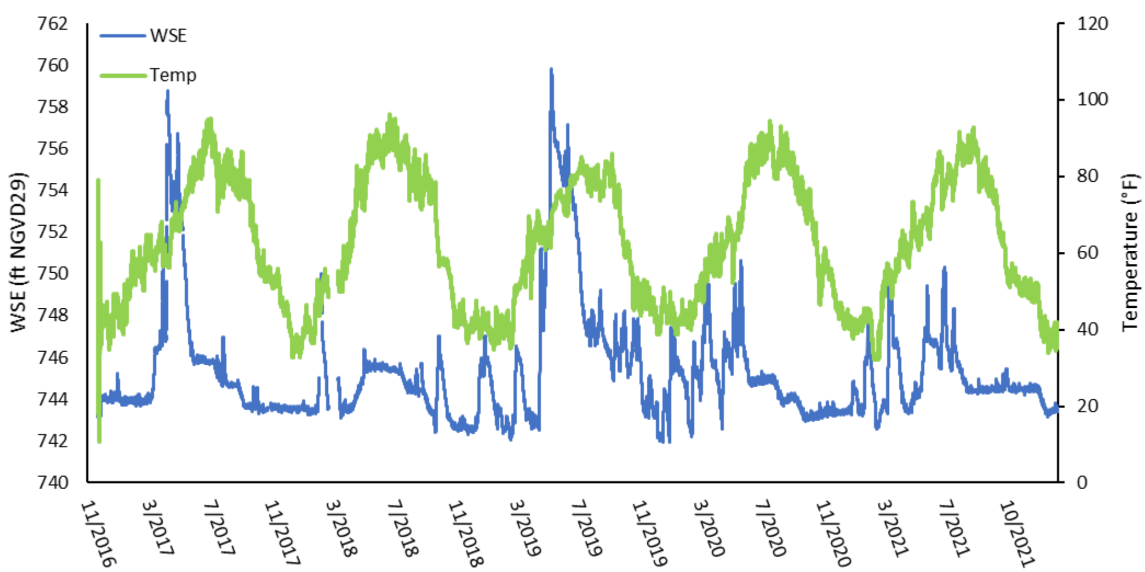


Figure A8
Station 8: Sycamore Creek at Hwy 10 bridge

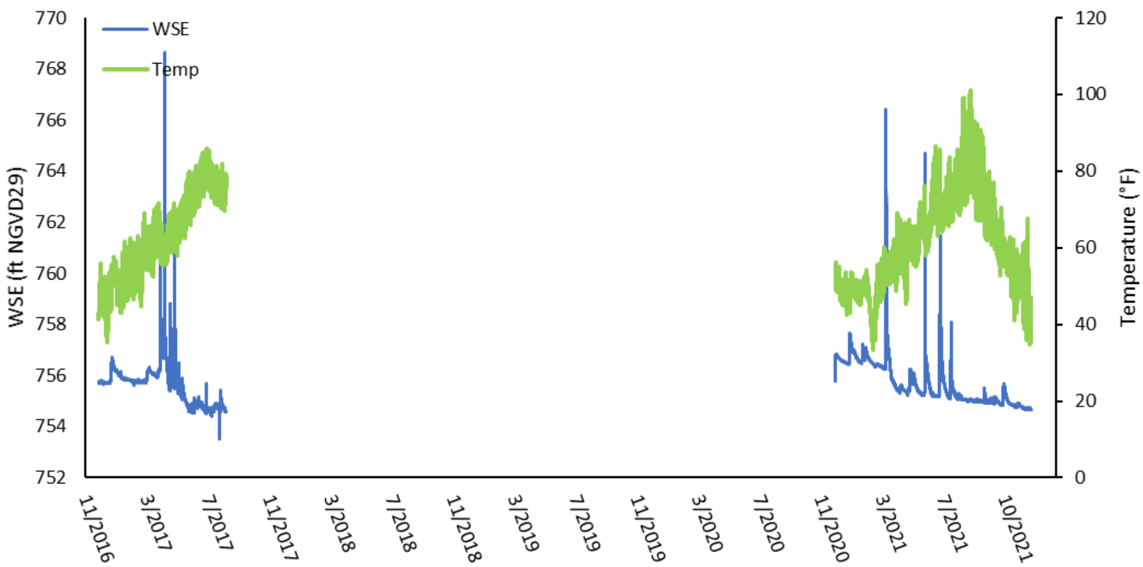


Figure A9
Station 10: Grand Lake/Elk River upstream of Hwy 10 bridge north of Grove, OK

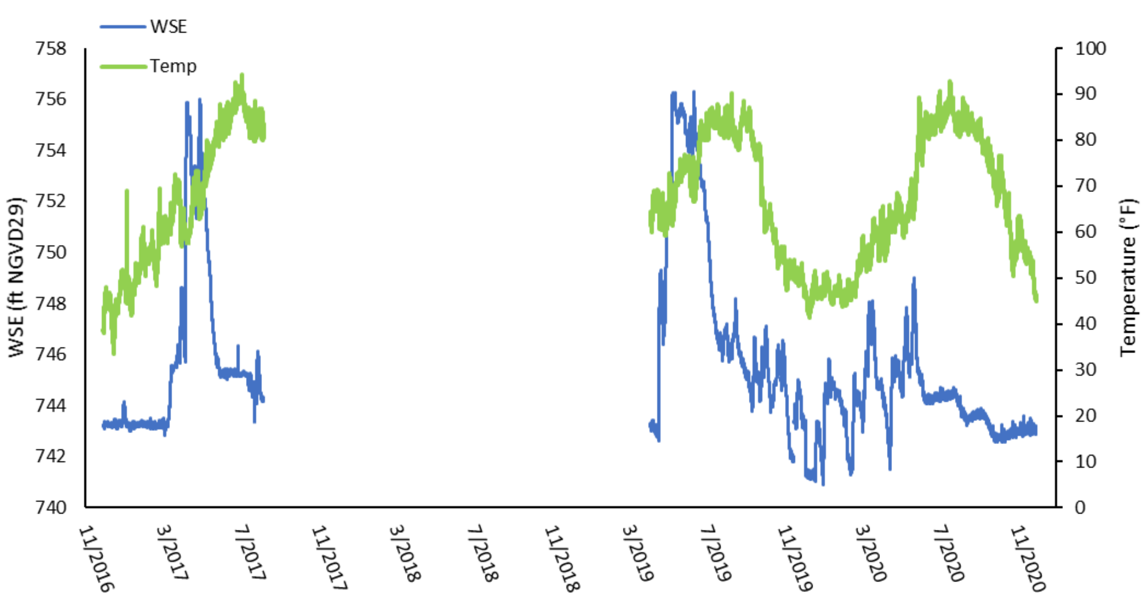


Figure A10
Station 11: Grand Lake at Hickory Point, upstream of Hwy 59 bridge

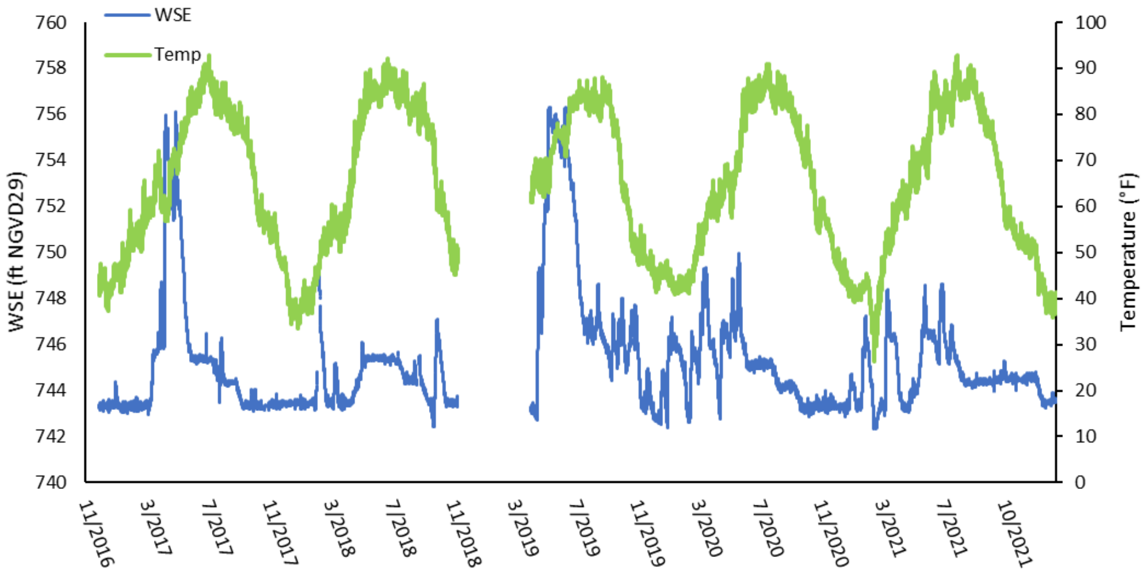


Figure A11
Station 12: Grand Lake at public access off S. 580 Rd, downstream of Hwy 59 bridge

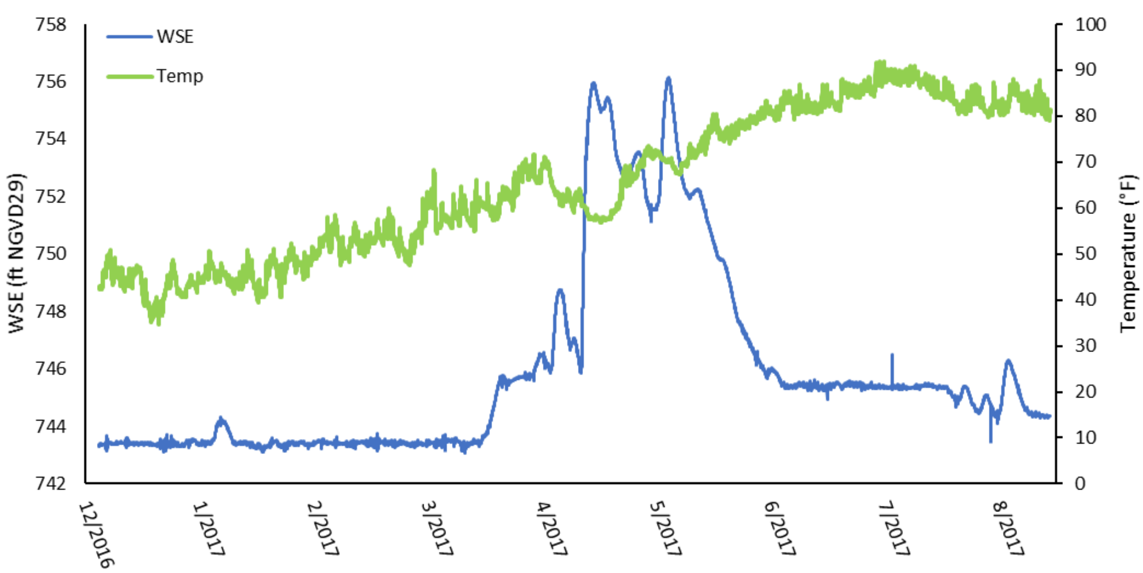


Figure A12
Station 13: Grand Lake at Honey Creek State Park

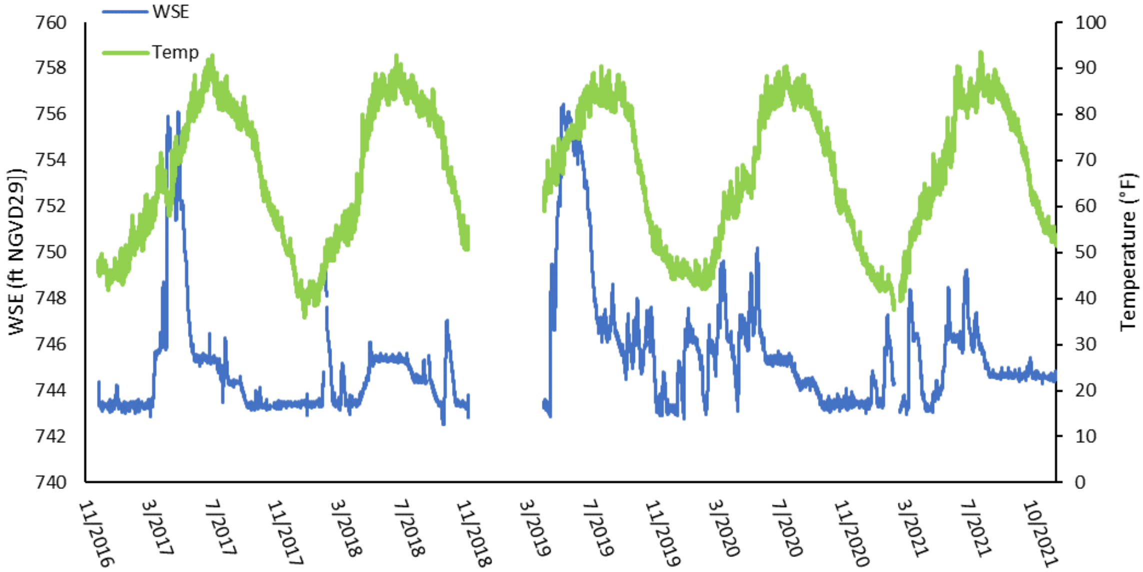


Figure A13
Station 14: Horse Creek off E 249 Rd

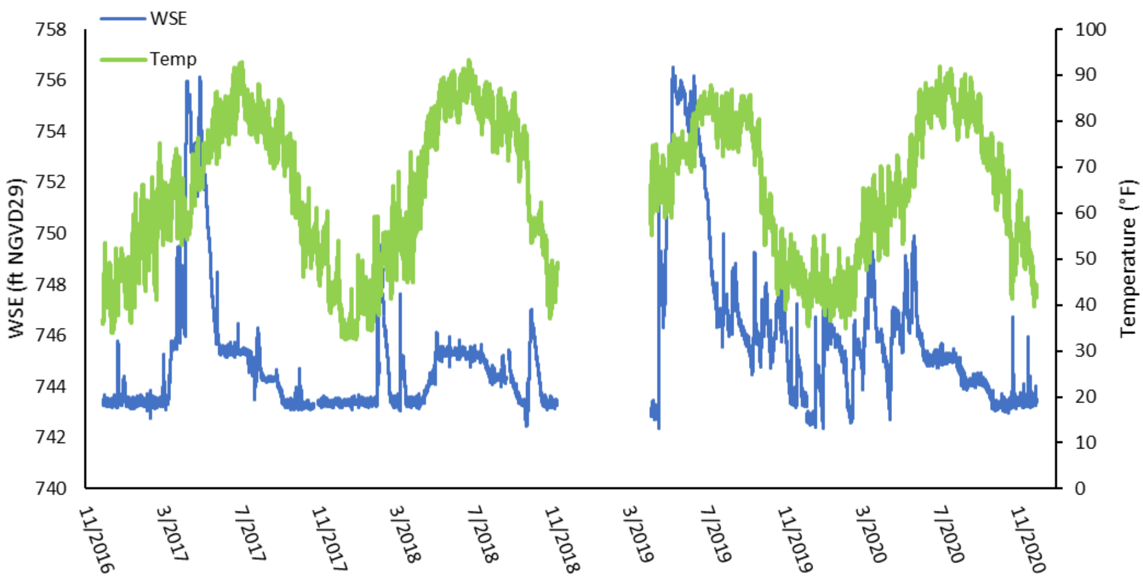


Figure A14
Station 15: Grand Lake near Woods Spring Branch off S 560 Rd & E 360 Rd

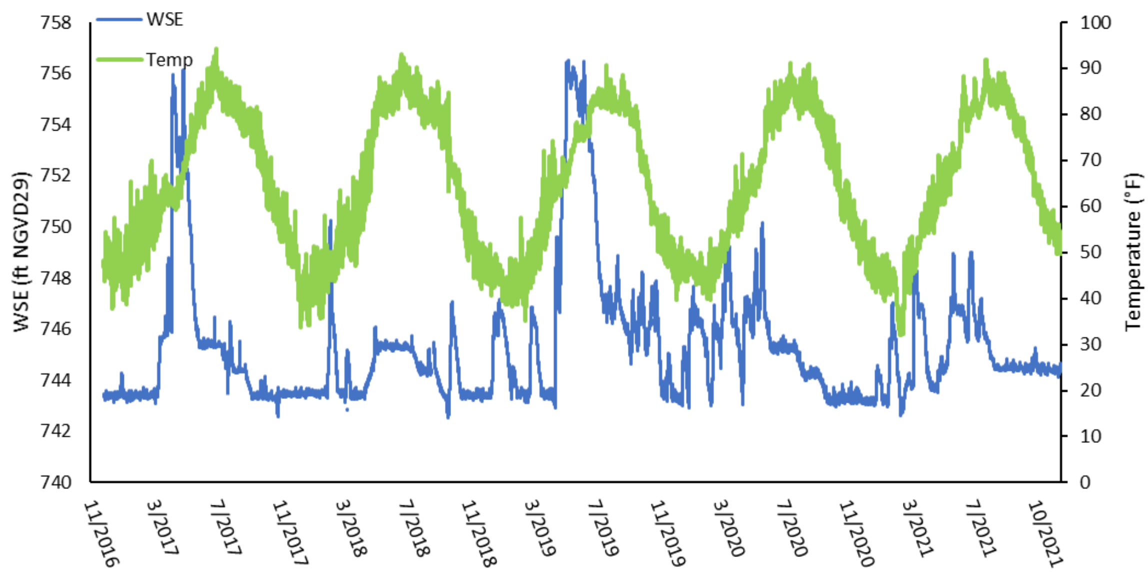
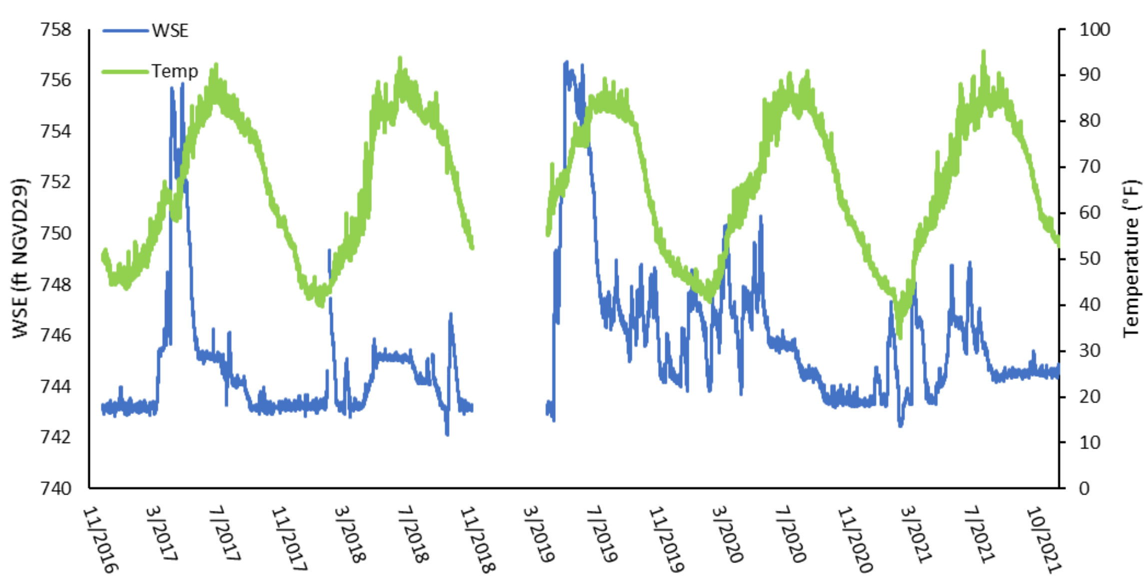
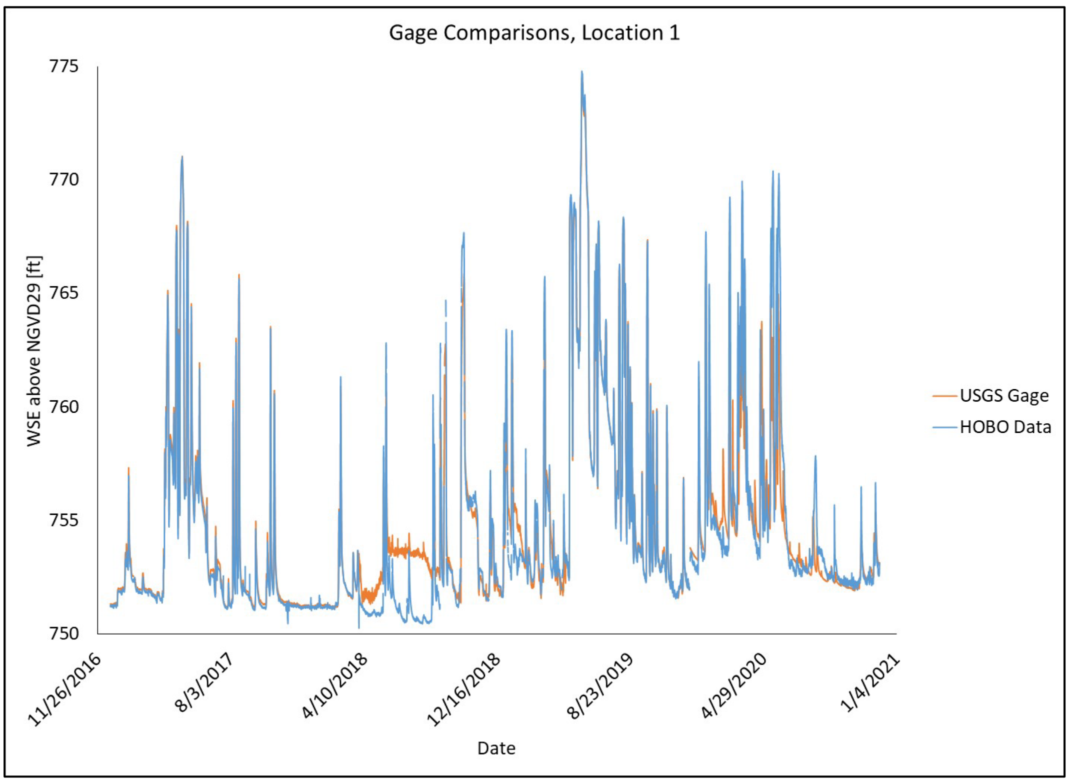


Figure A15
Station 16: Grand Lake at Cherokee State Park Boat Ramp, Disney, OK



Appendix II Comparison of HOBO Logger Data and USGS Gage Data

Figure A16
Station 1 compared to USGS Gage 07185000 (Neosho River near Commerce, OK).



Data shows generally good agreement between USGS gaging station and HOBO logger, with some deviations during later part of record (see detail below).

Figure A17
Station 1 2020 data compared to USGS Gage 07185000 (Neosho River near Commerce, OK).

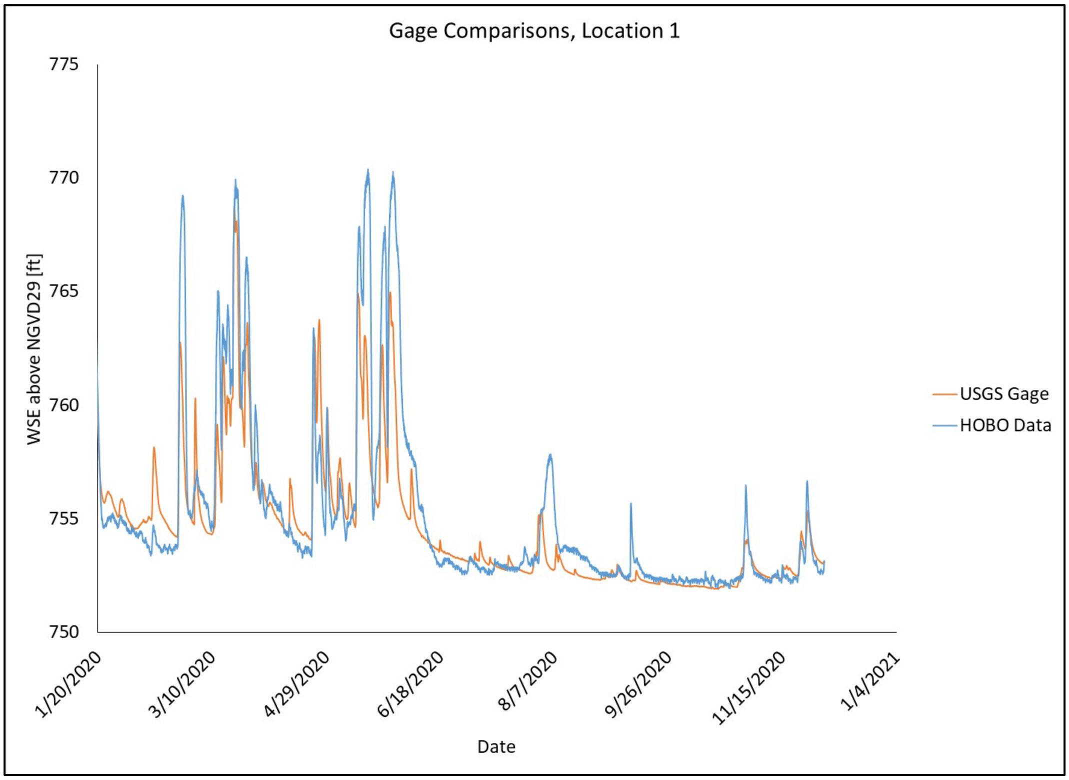
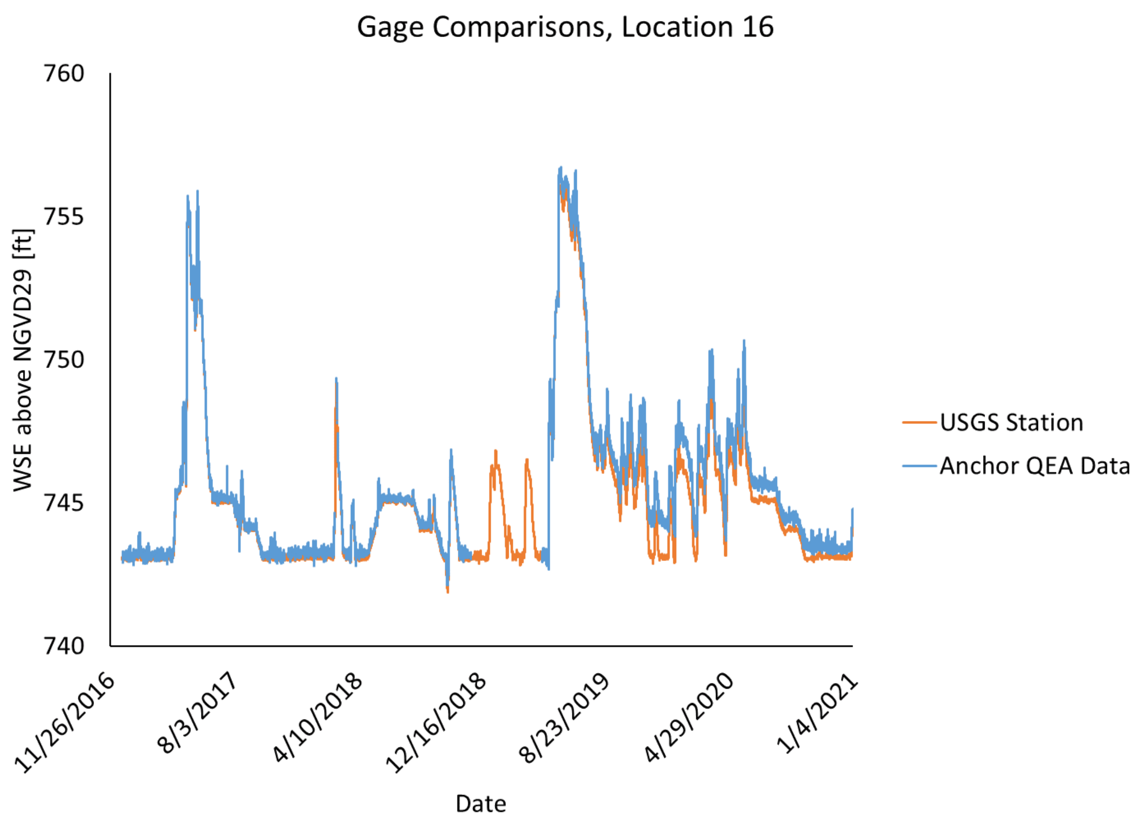


Figure A18
Station 16 compared to USGS Gage 07190000 (Lake O' the Cherokees at Langley, OK).



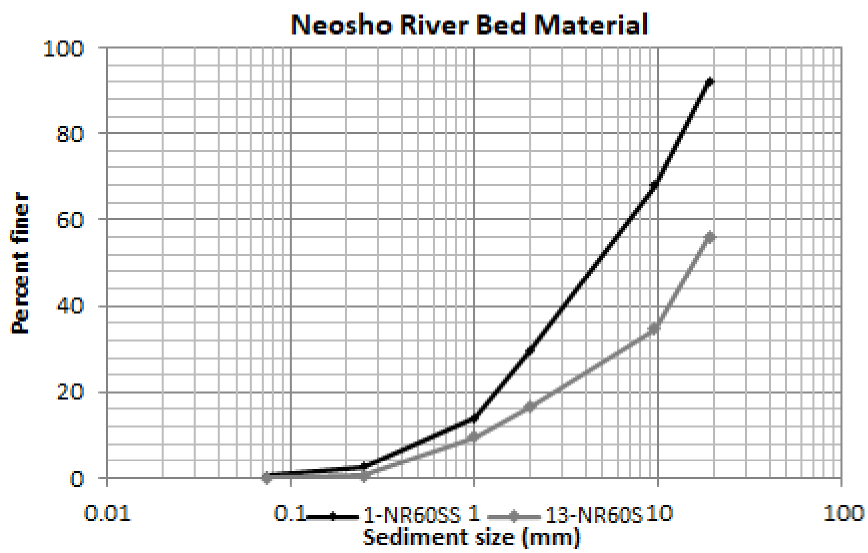
Appendix B
Sediment Grab Sampling

Particle Size Distribution Results

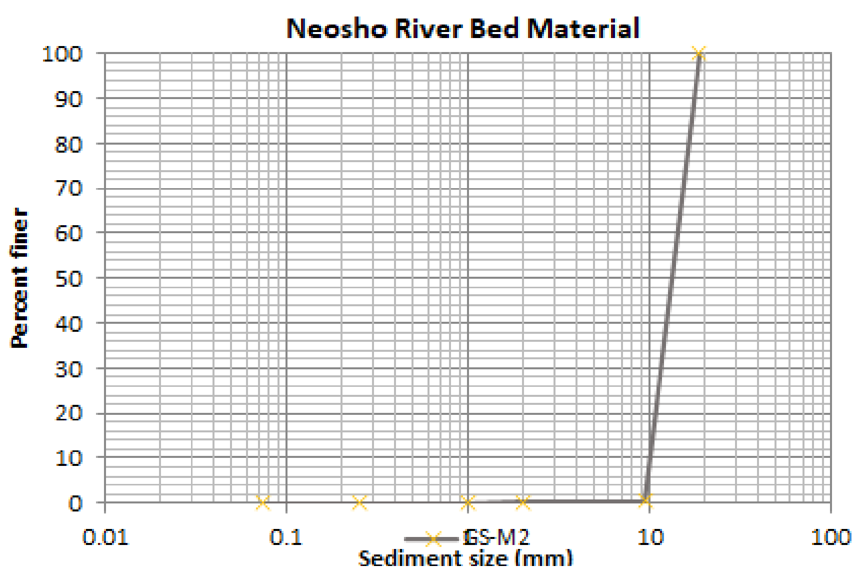
Note: Graphs are provided for each stream in an upstream to downstream direction showing HEC-RAS River Mile for each sample. Core sample particle size distributions are also included with other samples to provide context and completeness. Unless otherwise noted, samples are from the riverbed.

Neosho River above Tar Creek

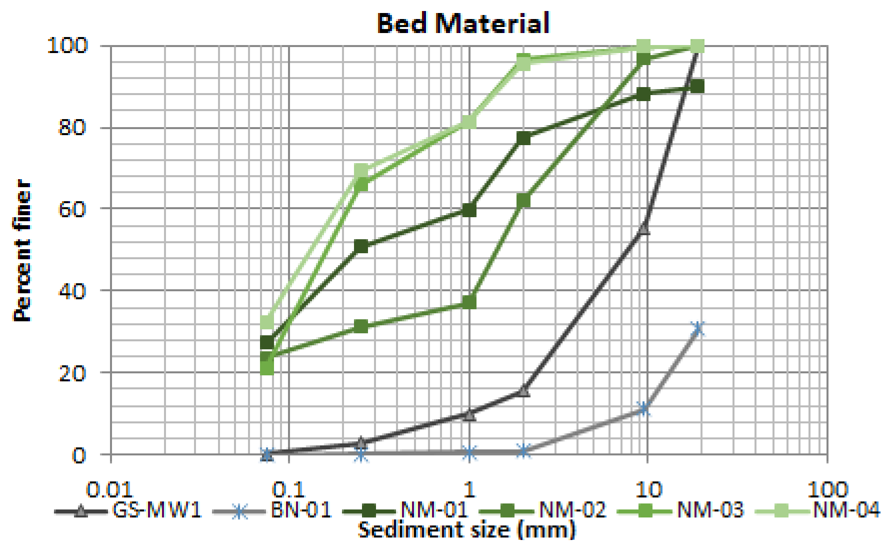
River Mile 145.5



River Mile 135.95

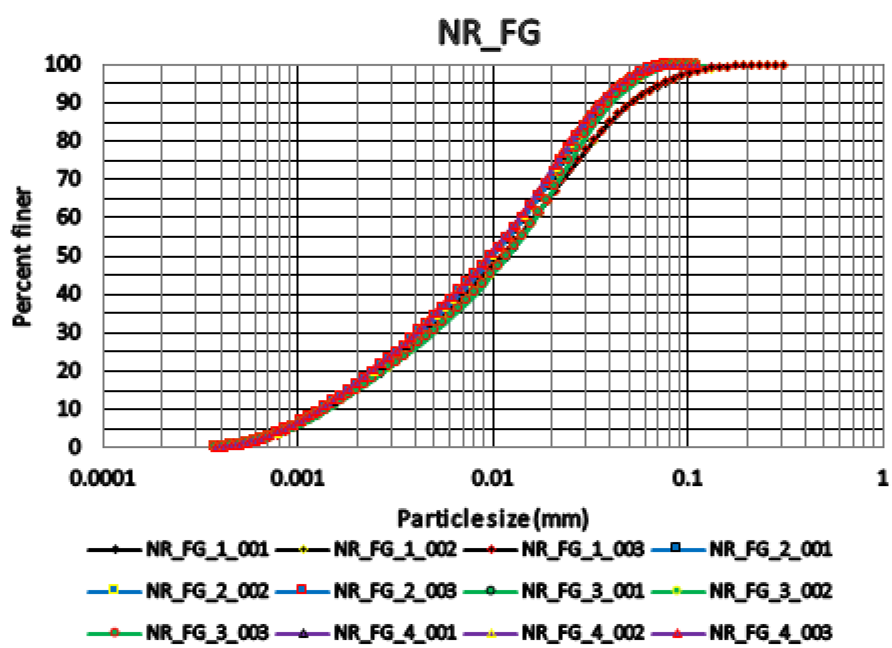


River Mile 134.6–135.46

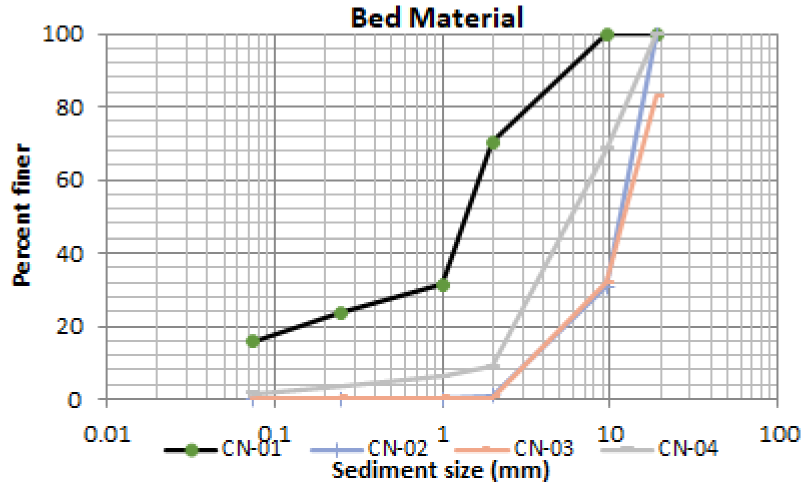


Note: NM-01 – left bank surface, NM-02 – floodplain surface, NM-04 – right bank surface

River Mile 135.04

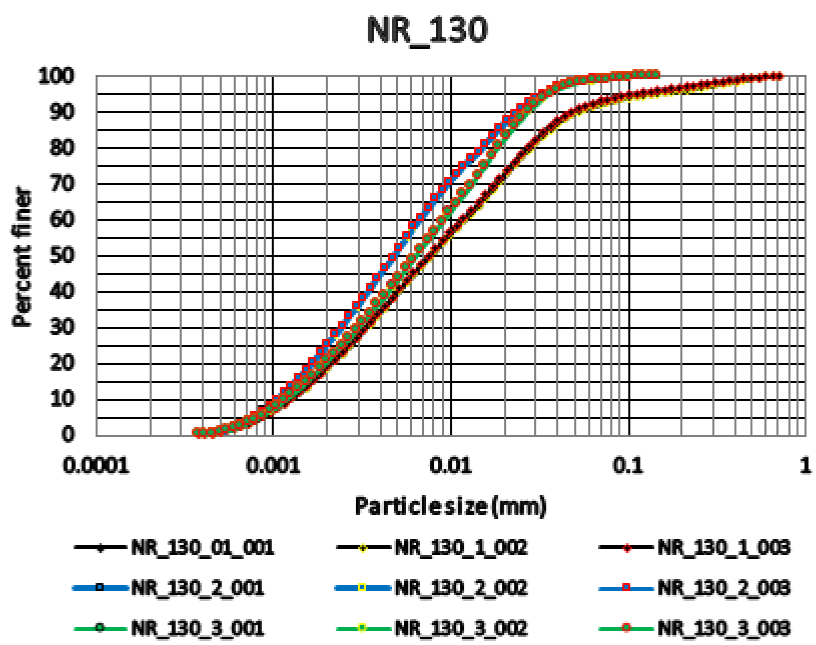


River Mile 128.81–130.37

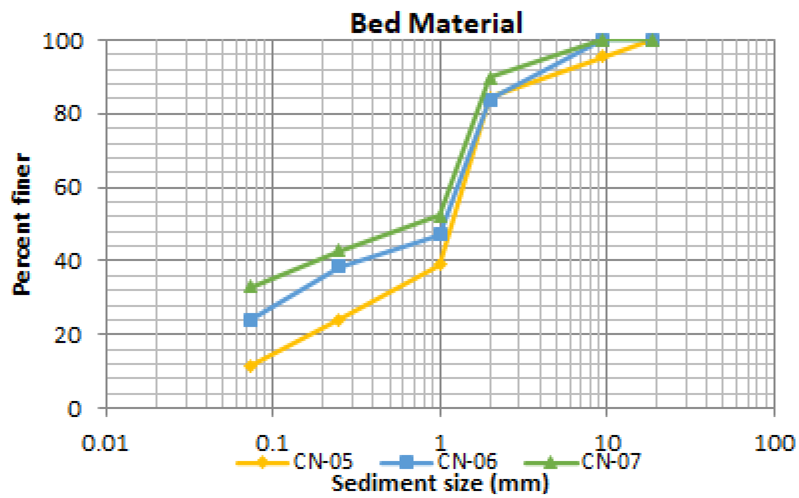


Note: CN-01 – bank

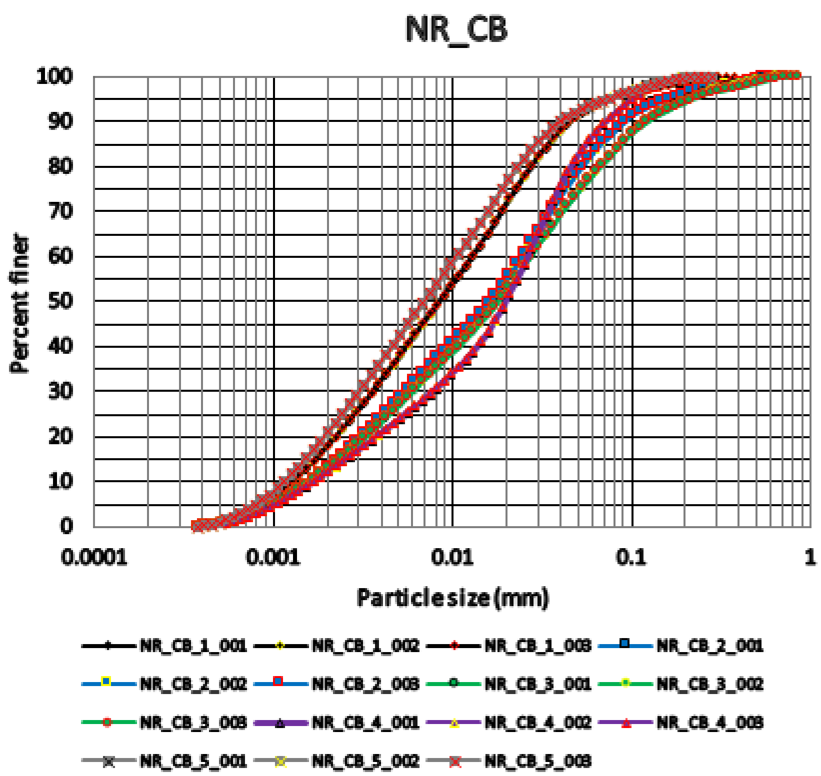
River Mile 130.37



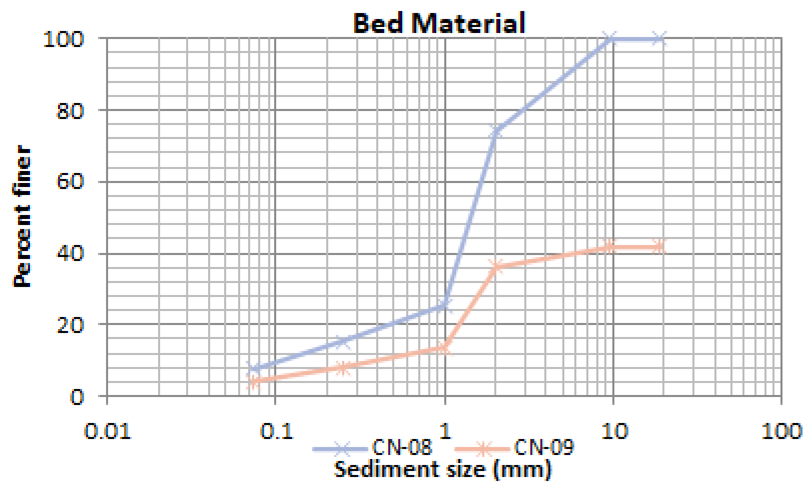
River Mile 126.69–127.85



River Mile 126.69

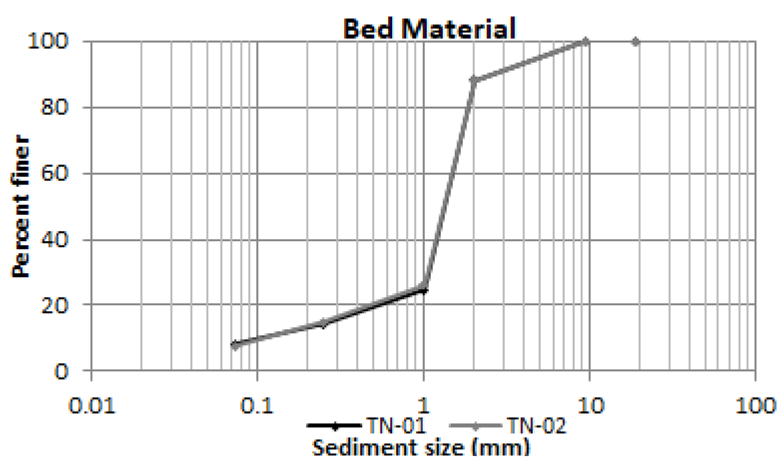


River Mile 124.2–125.33



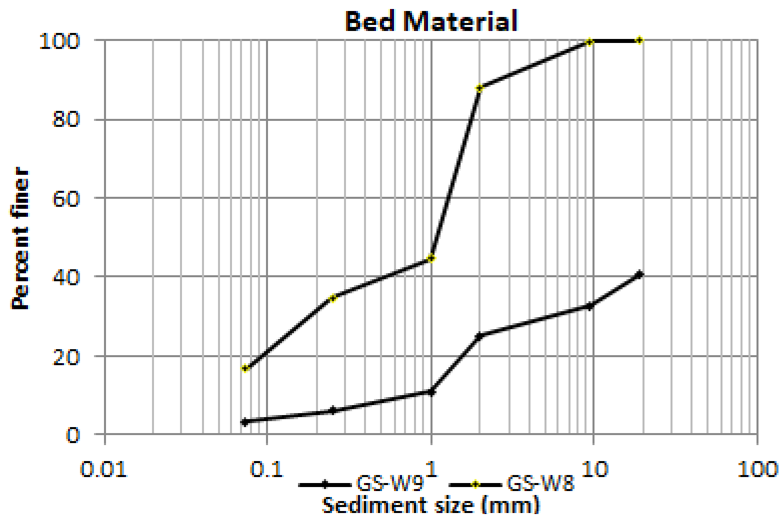
Note: CN-08 – left bank

River Mile 122.57–123.24

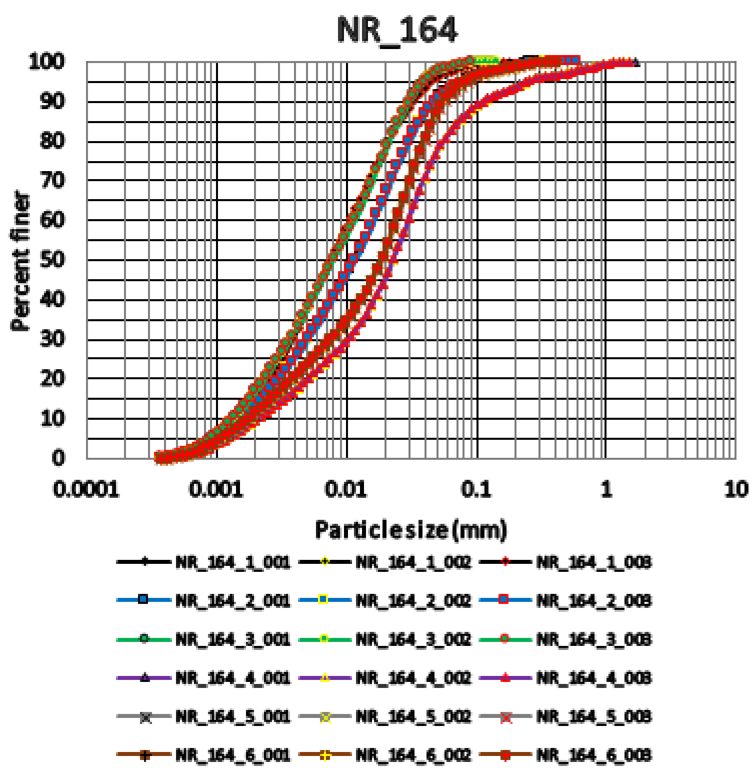


Neosho River – Grand Lake

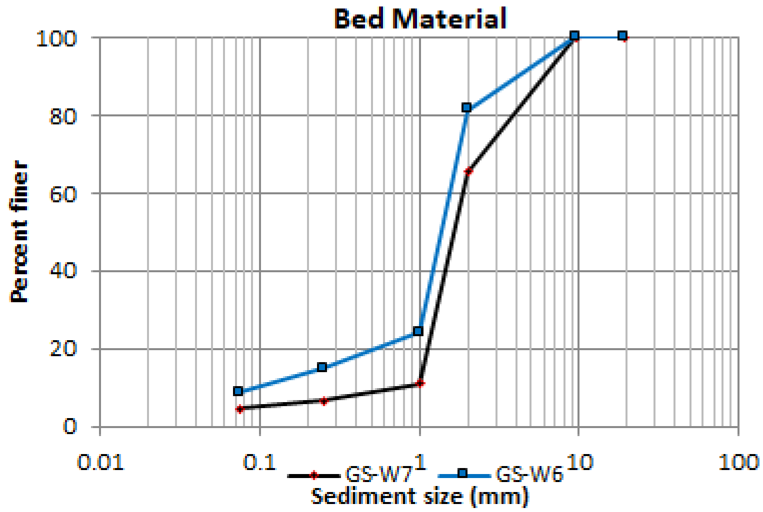
River Mile 120.1–122.25



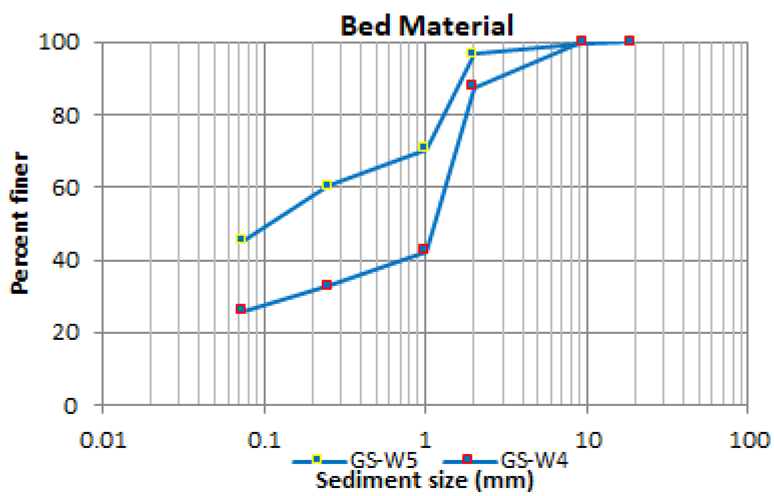
River Mile 120.1–120.43



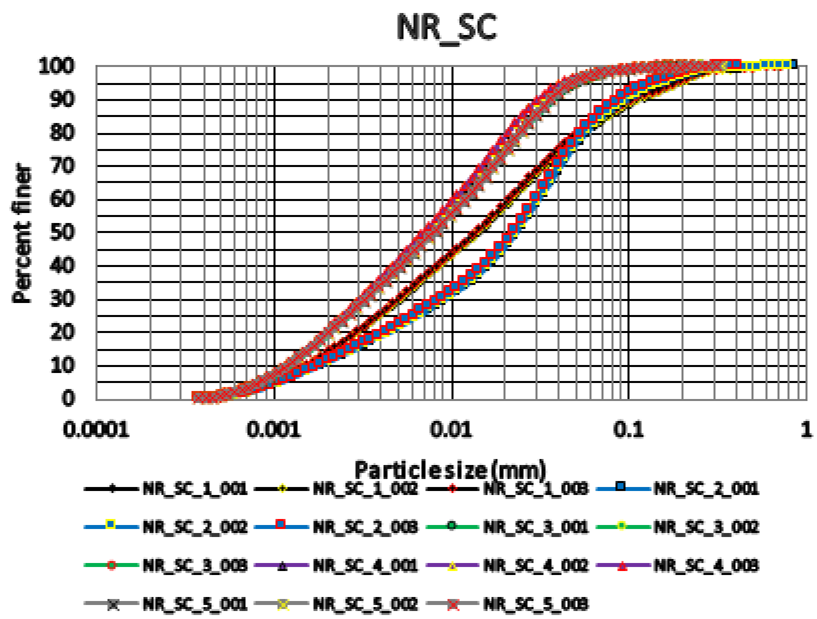
River Mile 117.66–119.06



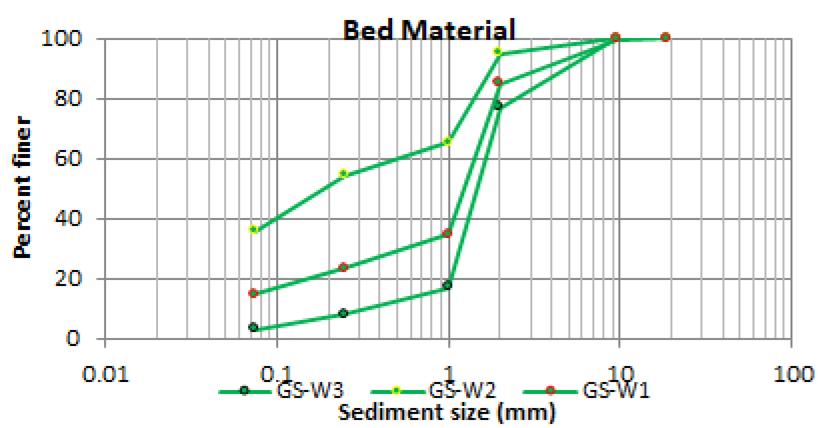
River Station 115.65–115.86



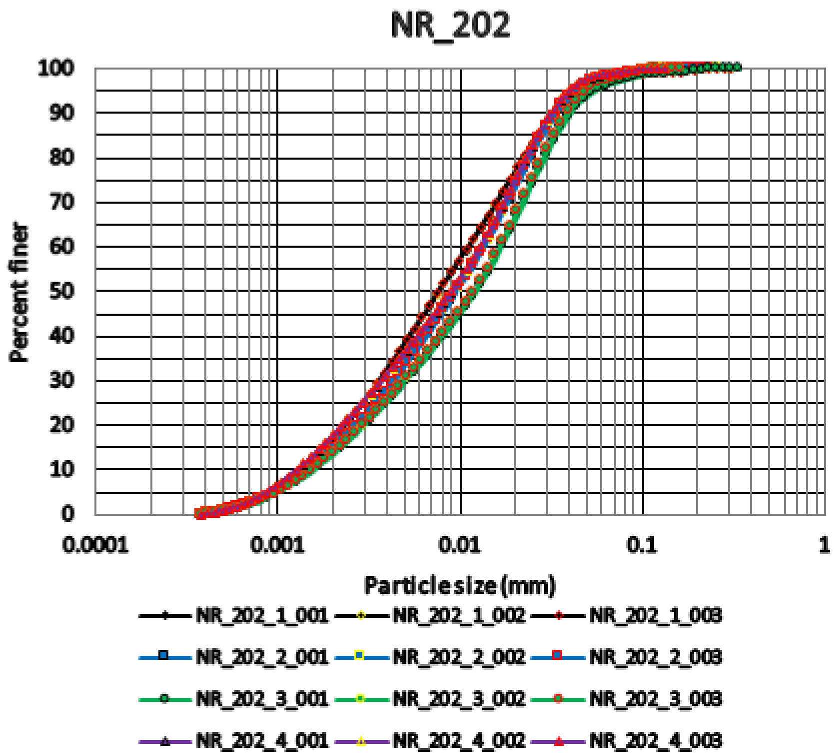
River Station 115.65–115.86



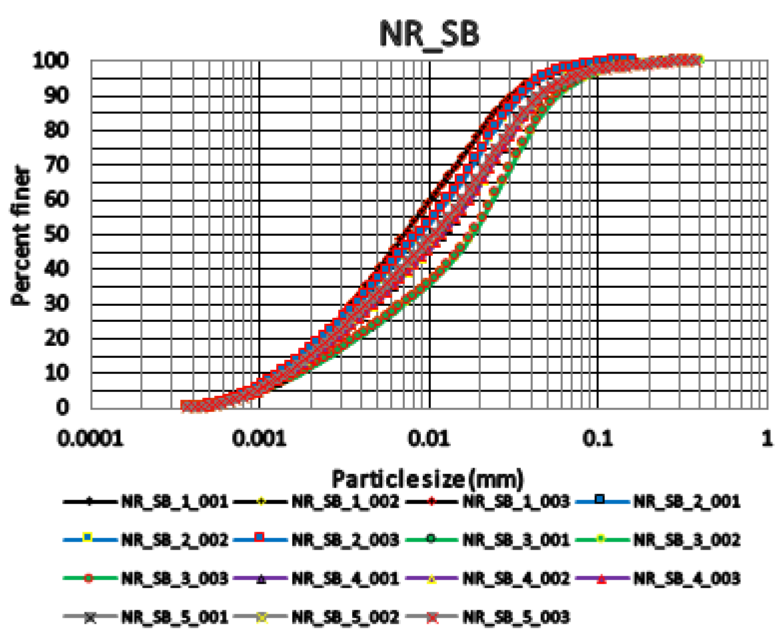
River Mile 112.34–114.21



River Mile 112.34–112.61

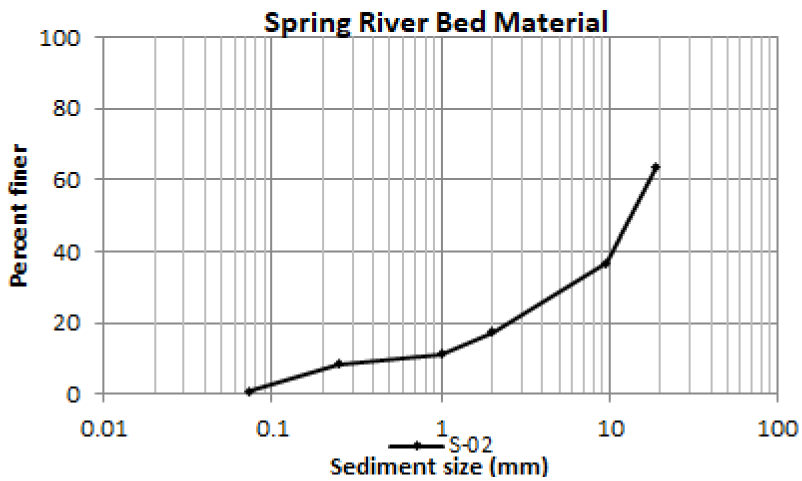


River Mile 108.87–109.25

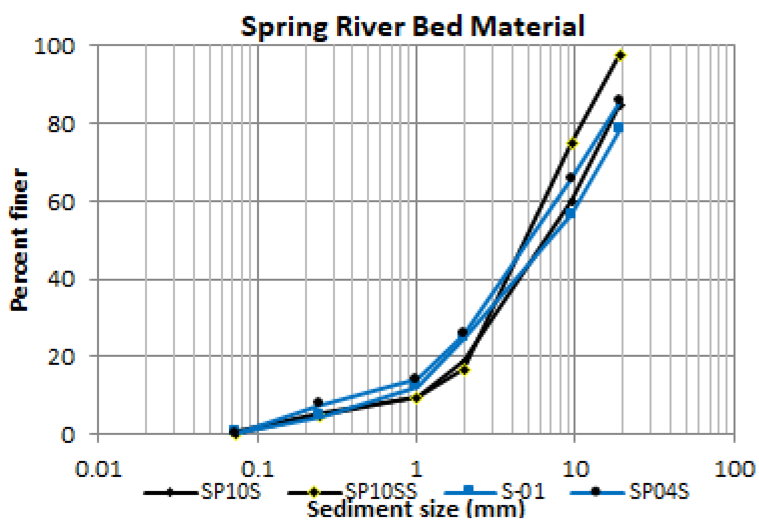


Spring River

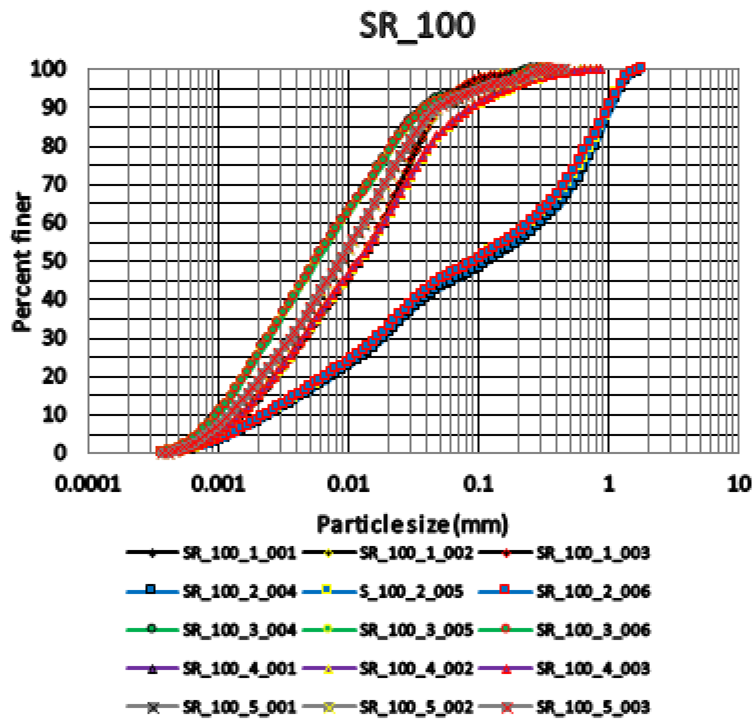
River Mile 14.16



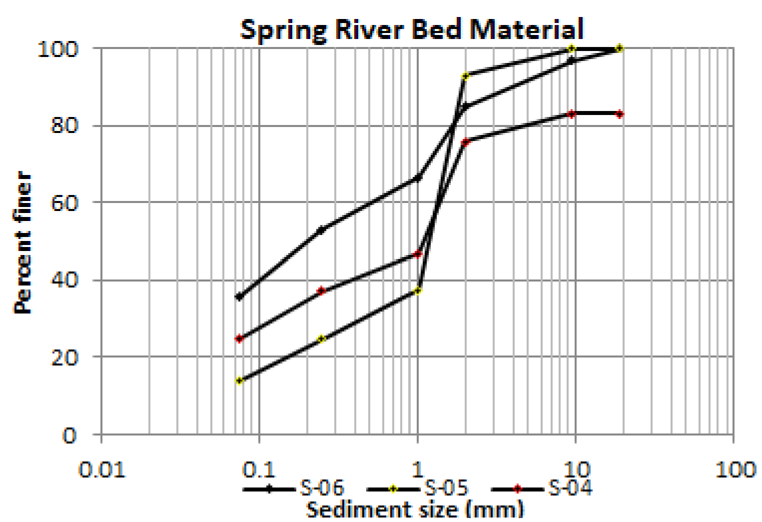
River Mile 8.01



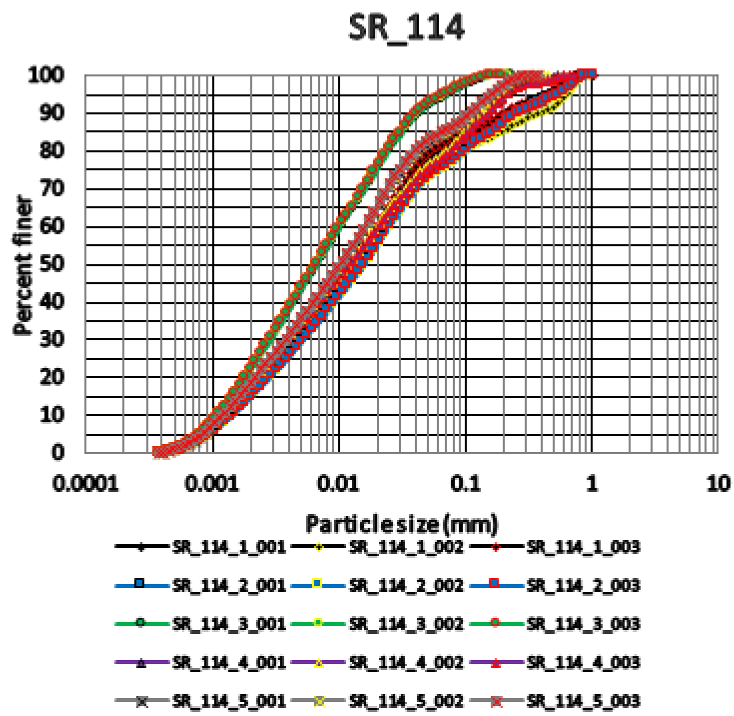
River Mile 7.5



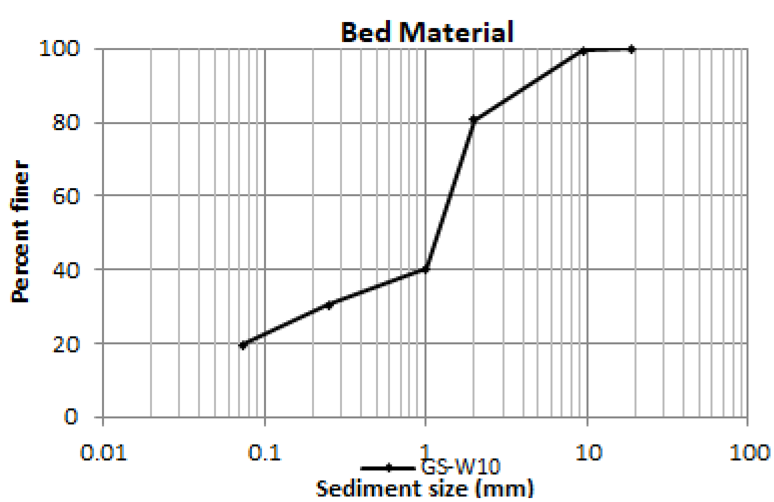
River Mile 2.26–5.1



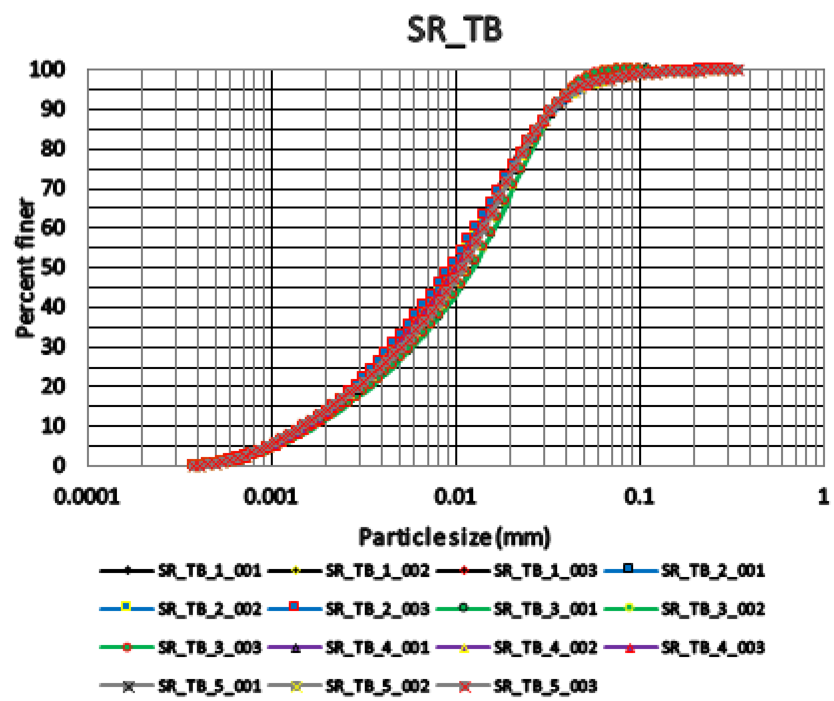
River Mile 4.82



River Mile 0.57–0.69

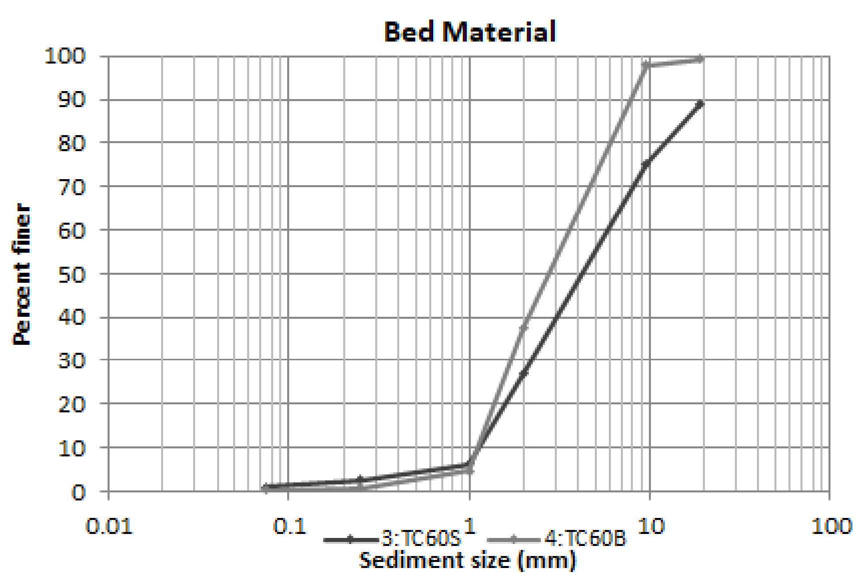


River Mile 0.79–0.99

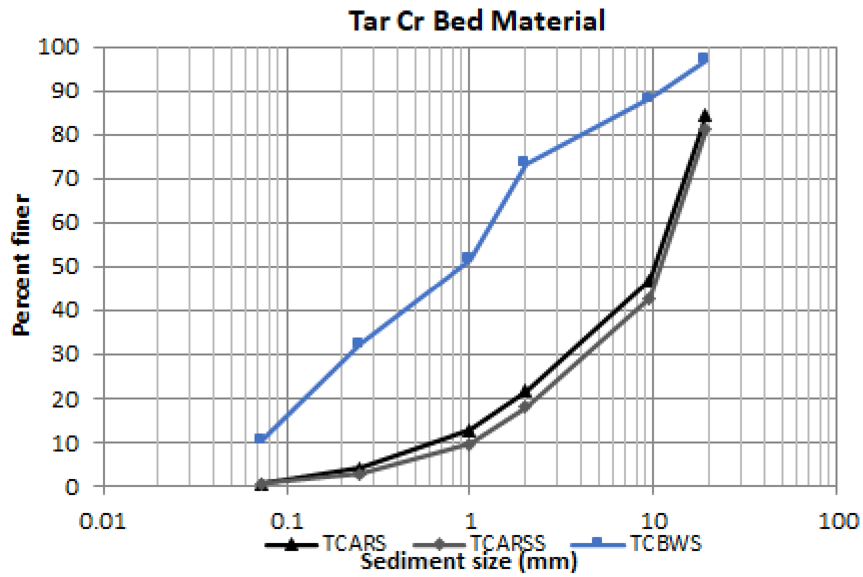


Tar Creek

River Mile 6.33

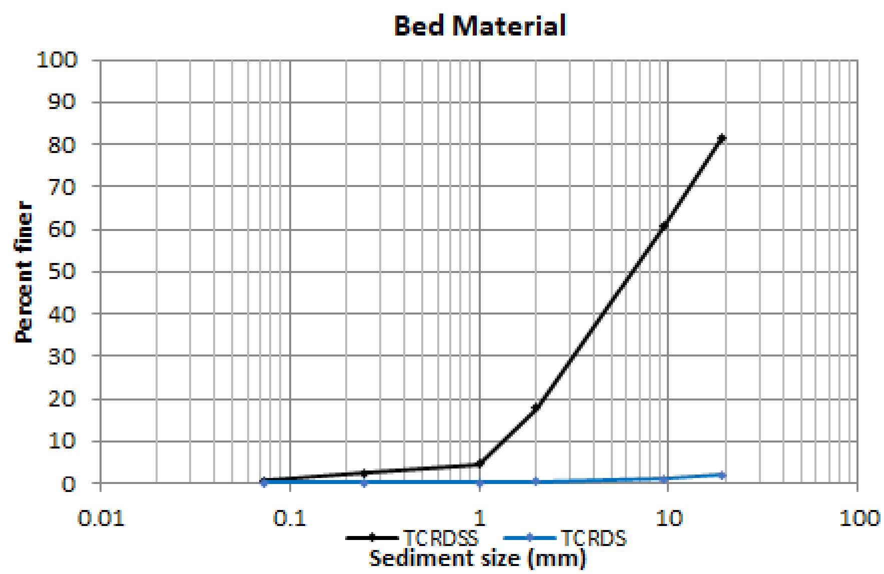


River Mile 2.74–2.98

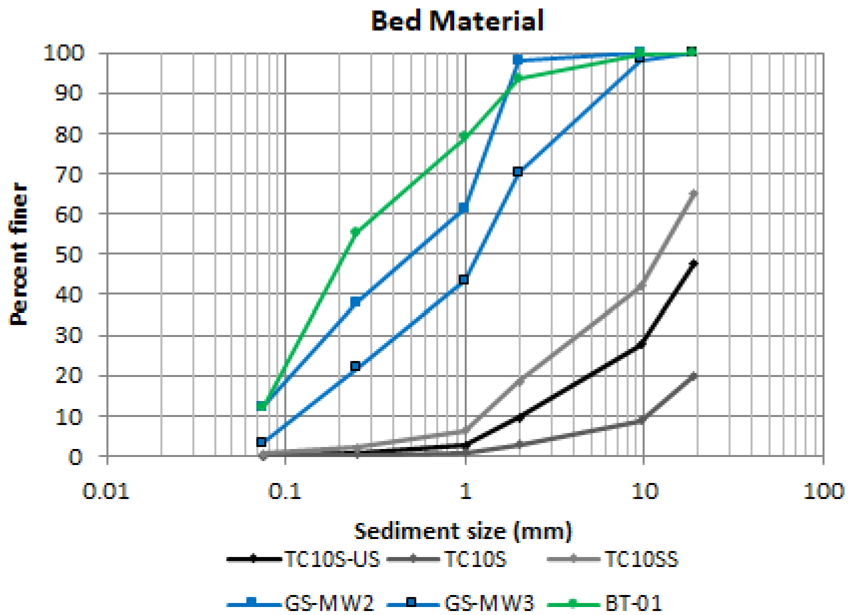


Note: BW: backwater

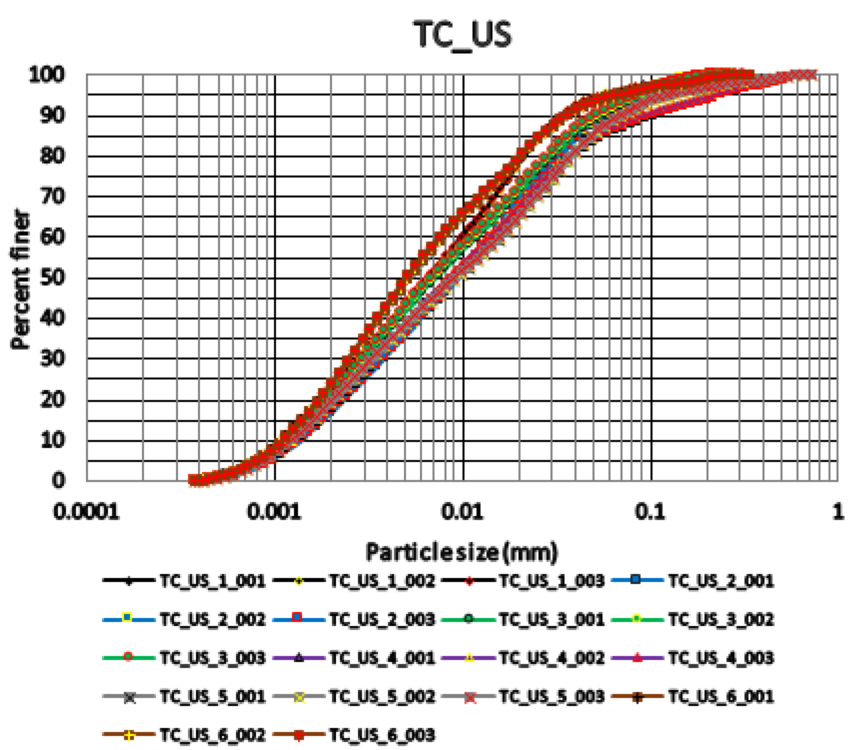
River Mile 2.23



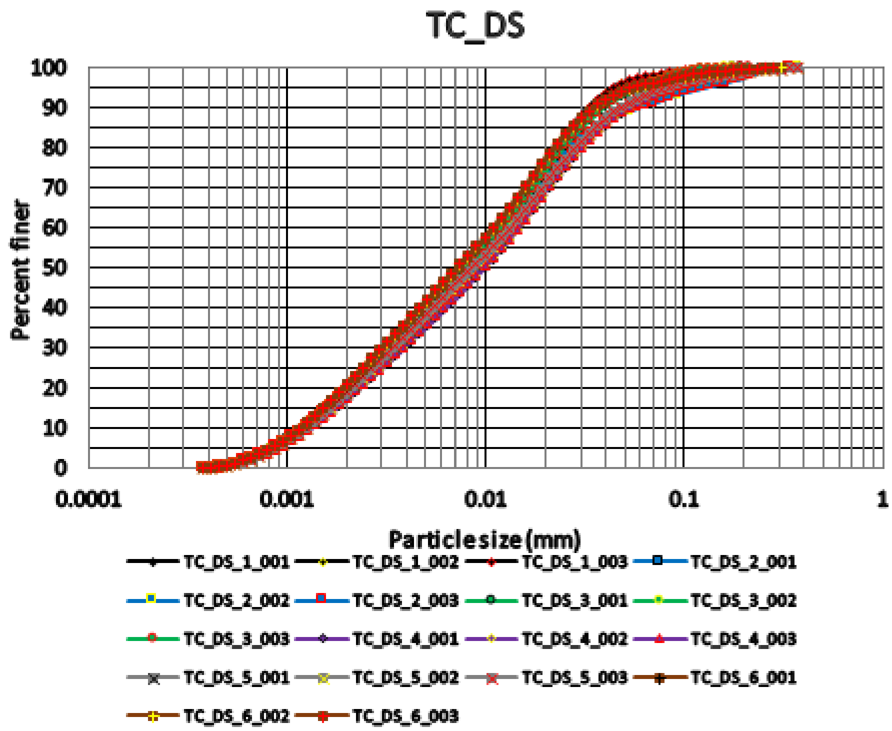
River Mile 1.6



River Mile 1.6

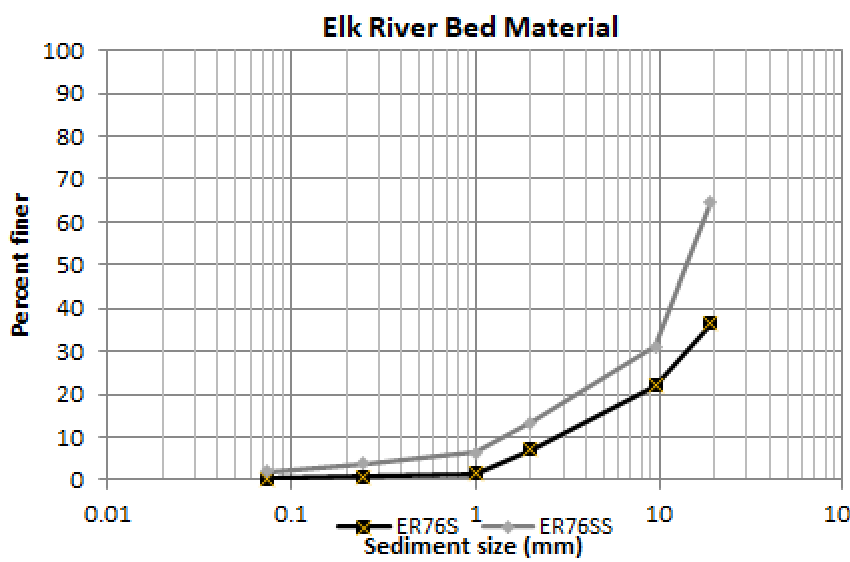


River Mile 1.6

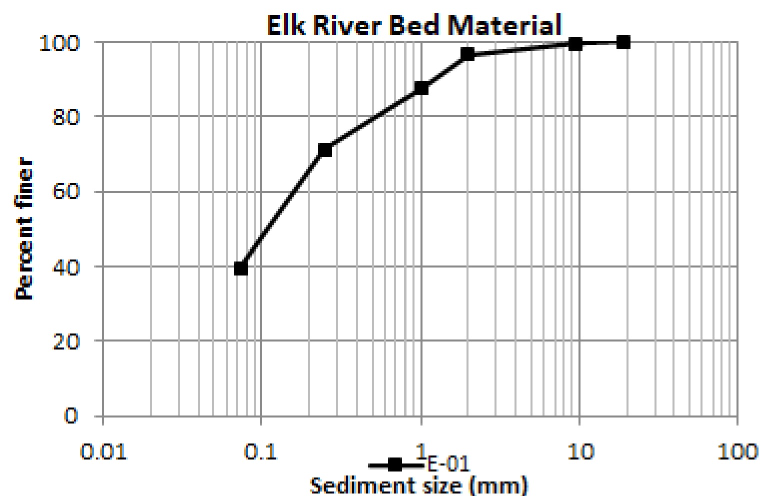


Elk River

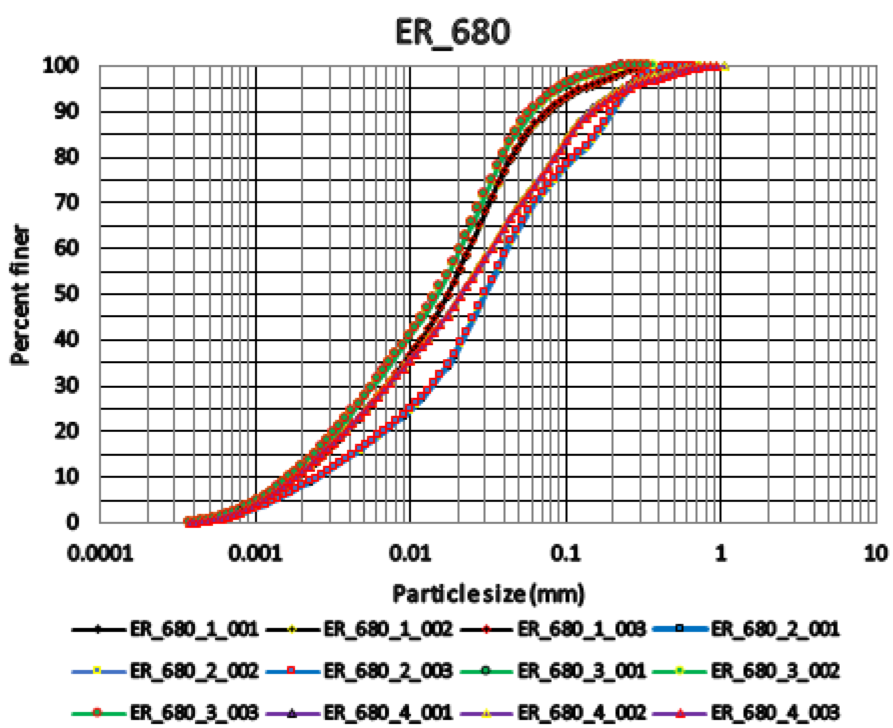
River Mile 14.22



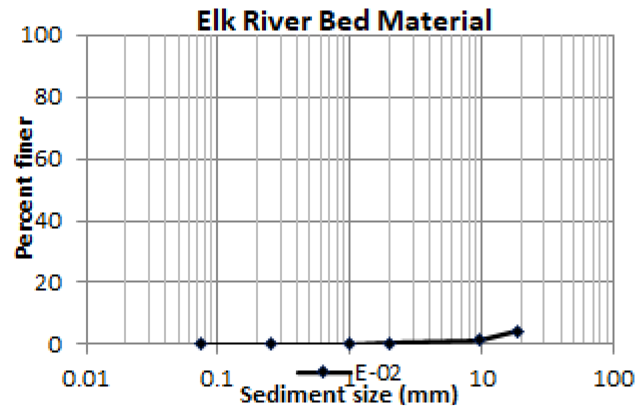
River Mile 8.8



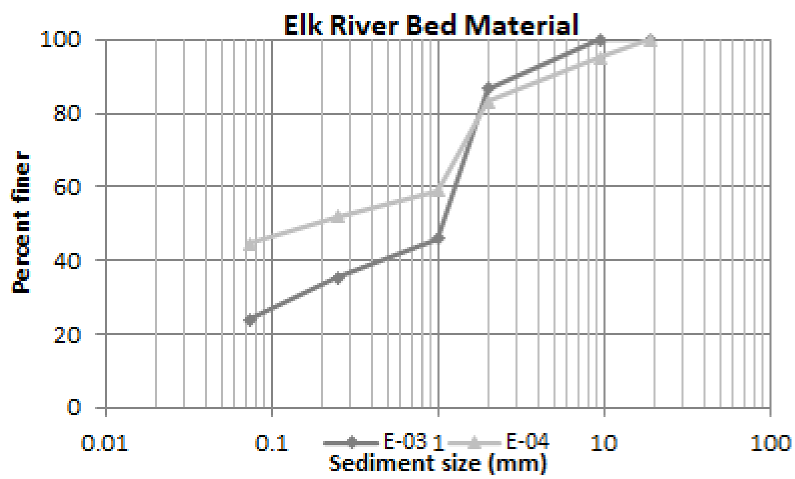
River Mile 8.8



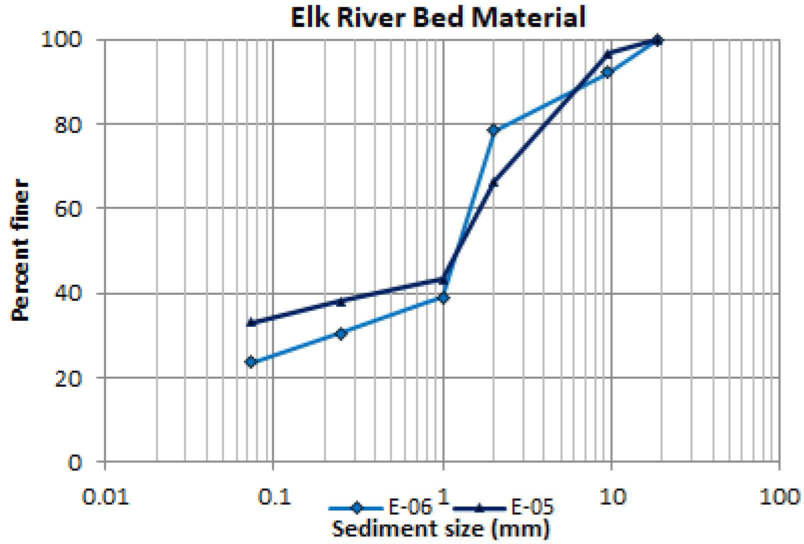
River Mile 7.5-7.79



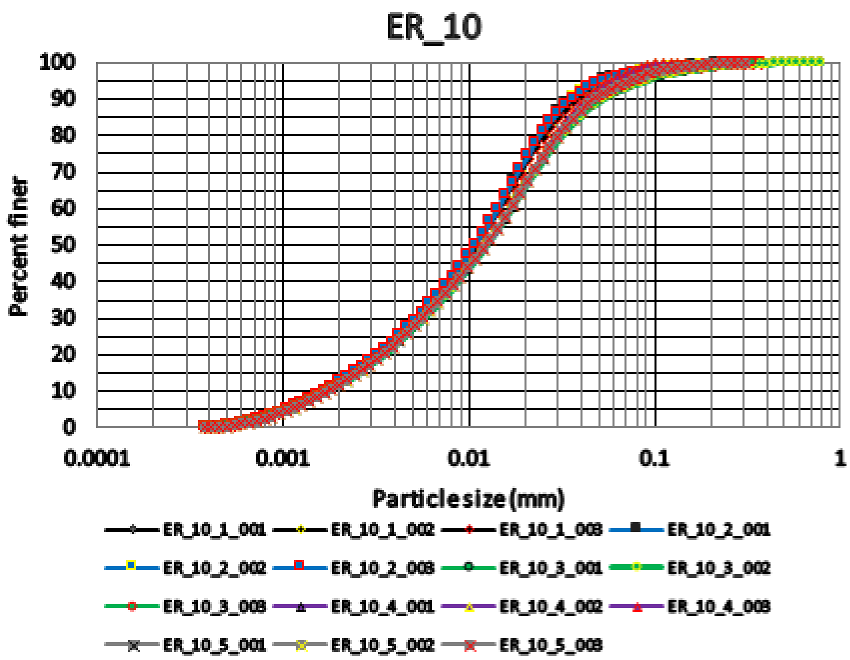
River Mile 5.86–6.57



River Mile 4.67–4.9 (E-05 and ER_10)



River Mile 3.2–3.43 E-06



Sediment Grab Sampling

FreshWater Engineering

Date: 12 DEC 2019

Staff: RS, TK

Weather: 27F, windy

Stream Name: Neosho (North of Tar & Spring)

Station No: BN-01

Site Description and Flow Observations:

Surface sample from streambed

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 692,411

Easting: 2,881,745

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 12 DEC 2019

Staff: TK, RS

Weather: 25F, windy

Stream Name: Tar Creek

Station No: BT-01

Site Description and Flow Observations:

Taken from bed surface

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 690,921

Easting: 2,886,846

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

FRESHWATER ENGINEERING

Date: 12 DEC 2019

Staff: RS, TK

Weather: 27F, windy

Stream Name: Neosho (North of Tar & Spring)

Station No: GS-M2

Site Description and Flow Observations:

Surface sample from streambed

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 695,578

Easting: 2,879,827

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 12 DEC 2019

Staff: RS, TK

Weather: 27F, windy

Stream Name: Neosho (North of Tar & Spring)

Station No: GS-MW1

Site Description and Flow Observations:

Surface sample from streambed

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 690,281

Easting: 2,883,797

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 12 DEC 2019

Staff: TK, RS

Weather: 26F, windy

Stream Name: Tar Creek

Station No: GS-MW2

Site Description and Flow Observations:

Taken from bed surface off boat

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Core

Northing: 690,059

Easting: 2,887,392

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 12 DEC 2019

Staff: TK, RS

Weather: 26F, windy

Stream Name: Tar Creek

Station No: GS-MW3

Site Description and Flow Observations:

Taken from bed surface off boat

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Core

Northing: 692,363

Easting: 2,885,869

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 13 DEC 2019

Staff: TK, RS

Weather: 29F, windy

Stream Name: Neosho North of Spring

Station No: CN-01

Site Description and Flow Observations:

Taken near bank

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 681,389

Easting: 2,902,395

Datum: OK N (USft)

Total Number of Samples Collected: 1

FreshWater Engineering

Sediment Grab Sampling

Date: 13 DEC 2019

Staff: TK, RS

Weather: 30F Clouds/windy

Stream Name: Neosho River North of Spring

Station No: CN-02

Site Description and Flow Observations:

Taken from middle of channel
Few pieces of gravel, sand

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 681,261

Easting: 2,902,343

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 13 DEC 2019

Staff: TK, RS

Weather: 30F, windy

Stream Name: Neosho North of Spring

Station No: CN-03

Site Description and Flow Observations:

Taken from middle of channel, mostly gravel

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 678,308

Easting: 2,904,418

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 13 DEC 2019

Staff: TK, RS

Weather: 30F, windy

Stream Name: Neosho North of Spring

Station No: CN-04

Site Description and Flow Observations:

Taken from middle of channel, mostly gravel

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 675,328

Easting: 2,902,125

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 13 DEC 2019

Staff: TK, RS

Weather: 30F, windy

Stream Name: Neosho North of Spring

Station No: CN-05

Site Description and Flow Observations:

Taken from middle of channel

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 672,798

Easting: 2,896,344

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 13 DEC 2019

Staff: TK, RS

Weather: 30F, windy

Stream Name: Neosho North of Spring

Station No: CN-06

Site Description and Flow Observations:

Taken from bed surface

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 672,469

Easting: 2,896,019

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

FreshWater Engineering

Date: 13 DEC 2019

Staff: TK, RS

Weather: 31F, windy

Stream Name: Neosho North of Spring

Station No: CN-07

Site Description and Flow Observations:

Taken from bed surface

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 670,065

Easting: 2,899,504

Datum: OK N (USft)

Total Number of Samples Collected: 1

FreshWater Engineering

Sediment Grab Sampling

Date: 13 DEC 2019

Staff: TK, RS

Weather: 31F, windy

Stream Name: Neosho North of Spring

Station No: CN-08

Site Description and Flow Observations:

Taken from bed surface

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 669,361

Easting: 2,906,967

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 13 DEC 2019

Staff: TK, RS

Weather: 30F, windy

Stream Name: Neosho North of Spring

Station No: CN-09

Site Description and Flow Observations:

Taken from bed surface

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 668,979

Easting: 2,911,669

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 14 DEC 2019

Staff: TK, RS

Weather: 27F, windy

Stream Name: Neosho South of Spring

Station No: GS-W1

Site Description and Flow Observations:

Taken from bed surface in shallow area

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 644,851

Easting: 2,914,163

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 14 DEC 2019

Staff: TK, RS

Weather: 27F, windy

Stream Name: Neosho South of Spring

Station No: GS-W2

Site Description and Flow Observations:

Taken from bed surface

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 646,875

Easting: 2,916,794

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

FreshWater Engineering

Date: 14 DEC 2019

Staff: TK, RS

Weather: 27F, windy

Stream Name: Neosho South of Spring

Station No: GS-W3

Site Description and Flow Observations:

Taken from bed surface

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 645,759

Easting: 2,920,602

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 14 DEC 2019

Staff: TK, RS

Weather: 27F, windy

Stream Name: Neosho South of Spring

Station No: GS-W4

Site Description and Flow Observations:

Taken from bed surface

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 649,504

Easting: 2,925,265

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 14 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Neosho South of Spring

Station No: GS-W5

Site Description and Flow Observations:

Taken from bed surface in shallow area

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 651,197

Easting: 2,926,663

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 14 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Neosho South of Spring

Station No: GS-W6

Site Description and Flow Observations:

Taken from bed surface

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 654,346

Easting: 2,916,738

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 14 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Neosho South of Spring

Station No: GS-W7

Site Description and Flow Observations:

Taken from bed surface

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 657,497

Easting: 2,911,603

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 14 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Neosho South of Spring

Station No: GS-W8

Site Description and Flow Observations:

Taken from bed surface

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 663,866

Easting: 2,912,784

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 14 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Neosho South of Spring

Station No: GS-W9

Site Description and Flow Observations:

Taken from bed surface between bridges

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 668,841

Easting: 2,919,164

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

FRESHWATER ENGINEERING

Date: 14 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Spring River, North of Twin Bridges

Station No: GS-W10

Site Description and Flow Observations:

Taken from channel bed surface

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 671,462

Easting: 2,919,130

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 14 DEC 2019

Staff: TK, RS

Weather: 26F, windy

Stream Name: Neosho North of Spring

Station No: TN-01

Site Description and Flow Observations:

Taken from middle of channel

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 672,542

Easting: 2,914,879

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 14 DEC 2019

Staff: TK, RS

Weather: 26F, windy

Stream Name: Neosho North of Spring

Station No: TN-02

Site Description and Flow Observations:

Taken from middle of channel

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 671,019

Easting: 2,917,954

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 15 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Elk River

Station No: E-01

Site Description and Flow Observations:

Taken from surface of streambed

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 619,855

Easting: 2,949,007

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 15 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Elk River

Station No: E-02

Site Description and Flow Observations:

Taken from surface of streambed

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 617,795

Easting: 2,945,419

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 15 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Elk River

Station No: E-03

Site Description and Flow Observations:

Taken from surface of streambed

Bed Sediment Sampling

Sampling Platform: ☐ Wading ☐ Cable ☐ Ice ☑ Boat ☐ Bridge

Type of Sampler Used: Ekman

Northing: 613,838

Easting: 2,941,958

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 15 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Elk River

Station No: E-04

Site Description and Flow Observations:

Taken from surface of streambed

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 616,342

Easting: 2,940,034

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 15 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Elk River

Station No: E-05

Site Description and Flow Observations:

Taken from surface of streambed

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 616,836

Easting: 2,935,568

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 15 DEC 2019

Staff: TK, RS

Weather: 29F, windy

Stream Name: Elk River

Station No: E-06

Site Description and Flow Observations:

Taken from surface of streambed

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 618,739

Easting: 2,927,992

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 15 DEC 2019

Staff: BT, BD

Weather: 28F, breezy

Stream Name: Horse Creek

Station No: HC14S

Site Description and Flow Observations:

Taken from edge of channel near access point on S 540 Rd/E 240 Rd (near WSE monitoring site 14)

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 624,204

Easting: 2,875,288

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

FRESHWATER ENGINEERING

Date: 15 DEC 2019

Staff: TK, RS

Weather: 27F, windy

Stream Name: Spring River

Station No: S-01

Site Description and Flow Observations:

Taken from gravel bar near HWY 10 bridge

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 696,874

Easting: 2,914,550

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 15 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Spring River

Station No: S-02

Site Description and Flow Observations:

Taken from gravel bar near E 57 Rd bridge

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 720,124

Easting: 2,919,626

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 15 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Spring River

Station No: S-03

Site Description and Flow Observations:

Taken from middle of channel

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 692,379

Easting: 2,921,645

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 15 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Spring River

Station No: S-04

Site Description and Flow Observations:

Taken from middle of stream channel

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 690,680

Easting: 2,927,648

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 15 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Spring River

Station No: S-05

Site Description and Flow Observations:

Taken from bed surface

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 685,207

Easting: 2,925,403

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 15 DEC 2019

Staff: TK, RS

Weather: 28F, windy

Stream Name: Spring River

Station No: S-06

Site Description and Flow Observations:

Taken from middle of channel

Bed Sediment Sampling

Sampling Platform: ☐Wading ☐Cable ☐Ice ☑Boat ☐Bridge

Type of Sampler Used: Ekman

Northing: 677,999

Easting: 2,921,911

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 15 DEC 2019

Staff: BT, BD

Weather: 28F, breezy

Stream Name: Sycamore Creek

Station No: SC08S

Site Description and Flow Observations:

Taken from natural surface armor of streambed near HWY 10 bridge (WSE monitoring site 8)

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 660,189

Easting: 2,937,225

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 15 DEC 2019

Staff: BT, BD

Weather: 30F, calm

Stream Name: Spring River North of Neosho

Station No: SP04S

Site Description and Flow Observations:

Bank edge surface (armor) sample near boat launch and Hwy 10 bridge piers
Near WSE monitoring site 4

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 696,932

Easting: 2,914,549

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: RS

Weather: 27F, windy

Stream Name: Elk River

Station No: ER76S

Site Description and Flow Observations:

Surface sample (natural armor layer) upstream of bridge

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 611,473

Easting: 2,969,867

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: RS

Weather: 30F, cloudy/windy

Stream Name: Elk River

Station No: ER76SS

Site Description and Flow Observations:

Sample was taken from the subsurface (below natural armoring) upstream of bridge

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 611,473

Easting: 2,969,867

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: TK, BT, BD

Weather: 29F, breezy, cloudy

Stream Name: Neosho (North of Tar & Spring)

Station No: NM-01

Site Description and Flow Observations:

Taken from left bank downstream of logjam; some silt deposits immediately downstream, this taken from ~30' beyond logs

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 692,354

Easting: 2,882,005

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: TK, BT, BD

Weather: 29F, cloudy, breezy

Stream Name: Neosho (North of Spring & Tar)

Station No: NM-02

FRESHWATER ENGINEERING

Site Description and Flow Observations:

Taken from parking lot scrape pile (left after high water)

Bed Sediment Sampling

Sampling Platform: ▯Wading ▯Cable ▯Ice ▯Boat ▯Bridge

Type of Sampler Used: Shovel

Northing: 692,620

Easting: 2,882,018

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: TK, BT, BD

Weather: 29F, breezy, cloudy

Stream Name: Neosho (North of Tar & Spring)

Station No: NM-03

Site Description and Flow Observations:

Taken from right edge of stream very near WSE monitoring station 2 (Miami fairgrounds)

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 691,689

Easting: 2,882,196

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: TK, BT, BD

Weather: 29F, breezy, cloudy

Stream Name: Neosho (North of Tar & Spring)

Station No: NM-04

Site Description and Flow Observations:

Taken at boat launch by fairgrounds under bridge (right bank); site is sheltered from direct flows by riprap-armored banks

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 693,153

Easting: 2,881,134

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: RS

Weather: 30F clouds & wind

Stream Name: Neosho River North of Spring & Tar

Station No: NR60S

Site Description and Flow Observations:

Sample was taken from surface layer (natural armor) of Neosho River upstream of E 60 Rd bridge

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 716,021

Easting: 2,857,805

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

FRESHWATER ENGINEERING

Date: 16 DEC 2019

Staff: RS

Weather: 30F, windy, cloudy

Stream Name: Neosho (North of Spring & Tar)

Station No: NR60SS

Site Description and Flow Observations:

Sub-surface (taken from under natural armoring layer) upstream of E 60 Rd bridge

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 716,021

Easting: 2,857,805

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

FRESHWATER ENGINEERING

Date: 16 DEC 2019

Staff: RS

Weather: 28F, cloudy, windy

Stream Name: Spring River

Station No: SP10S

Site Description and Flow Observations:

Taken from riverbed, natural armor layer, near bridge

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 696,942

Easting: 2,914,547

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: RS

Weather: 30F, cloudy/windy

Stream Name: Spring River

Station No: SP10SS

Site Description and Flow Observations:

Sample was taken from the subsurface (below natural armoring) downstream of Hwy 10 Bridge

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 696,942

Easting: 2,914,547

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: RS

Weather: 29F, cloudy, windy

Stream Name: Tar Creek

Station No: TC10S

Site Description and Flow Observations:

Taken from surface of riverbed downstream of bridge

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 695,518

Easting: 2,886,708

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: RS

Weather: 30F, clouds/wind

Stream Name: Tar Creek

Station No: TC10SS

Site Description and Flow Observations:

Sample was taken from the subsurface (below natural armoring) downstream of HWY 10 bridge

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 695,518

Easting: 2,886,708

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: RS

Weather: 29F, cloudy, windy

Stream Name: Tar Creek

Station No: TC10S-US

Site Description and Flow Observations:

Sample was taken from surface layer (natural armor) of Tar Creek upstream of Hwy 10 bridge

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 695,518

Easting: 2,886,708

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: RS

Weather: 30F, clouds, wind

Stream Name: Tar Creek

Station No: TC60B

Site Description and Flow Observations:

Sample was taken from gravel bar in stream at E 60 Rd bridge

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 717,081

Easting: 2,886,495

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: RS

Weather: 28F

Stream Name: Tar Creek

Station No: TC60S

Site Description and Flow Observations:

Taken from surface of riverbed

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 717,081

Easting: 2,886,495

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: TK, BT, BD

Weather: 30F windy, cloudy

Stream Name: Tar Creek

Station No: TCARS

Site Description and Flow Observations:

Sample from right (west) bank of stream surface sample of natural armoring
Near dirt access road

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 701,914

Easting: 2,883,699

Datum: OK N (USft)

Total Number of Samples Collected: 1

FRESHWATER ENGINEERING

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: TK, BT, BD

Weather: 30F windy, cloudy

Stream Name: Tar Creek

Station No: TCARSS

Site Description and Flow Observations:

Sample from right (west) streambank subsurface (below natural armoring)
Near dirt access road

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 701,914

Easting: 2,883,699

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: TK, BT, BD

Weather: 30F cloudy, windy

Stream Name: Tar Creek

Station No: TCBWS

FreshWater Engineering

Site Description and Flow Observations:

Sample was taken from the edge of a backwater area protected by a spit-like bar
Near dirt access road

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 701,914

Easting: 2,883,699

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: RS

Weather: 30F clouds/wind

Stream Name: Tar Creek

Station No: TCRDS

Site Description and Flow Observations:

Sample was taken from natural armoring layer of the bed

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 700,055

Easting: 2,886,160

Datum: OK N (USft)

Total Number of Samples Collected: 1

Sediment Grab Sampling

Date: 16 DEC 2019

Staff: RS

Weather: 30F, cloudy/windy

Stream Name: Tar Creek

Station No: TCRDSS

Site Description and Flow Observations:

Sample was taken from the subsurface (below natural armoring) downstream of Rockdale Road bridge

Bed Sediment Sampling

Sampling Platform: ☑Wading ☐Cable ☐Ice ☐Boat ☐Bridge

Type of Sampler Used: Shovel

Northing: 700,055

Easting: 2,886,160

Datum: OK N (USft)

Total Number of Samples Collected: 1

Please see the following file for grab sample locations:

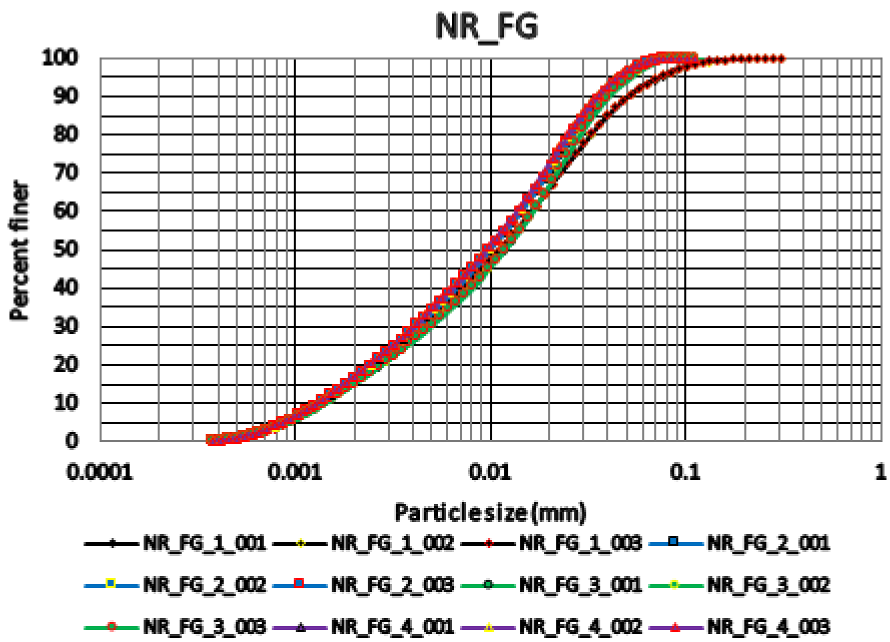
- GrabSampleLocations.csv

Appendix C
SEDflume Core Sampling

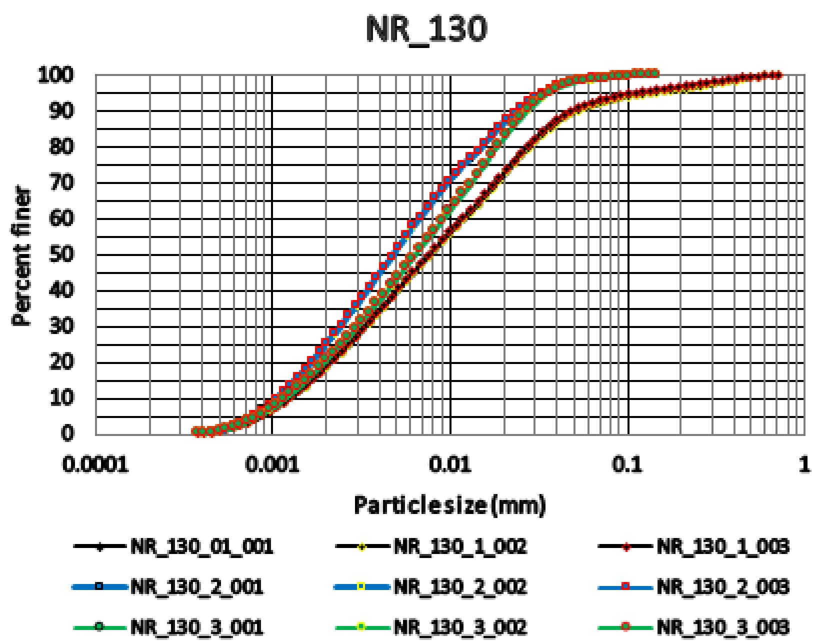
Particle Size Distribution Results

Neosho River above Tar Creek

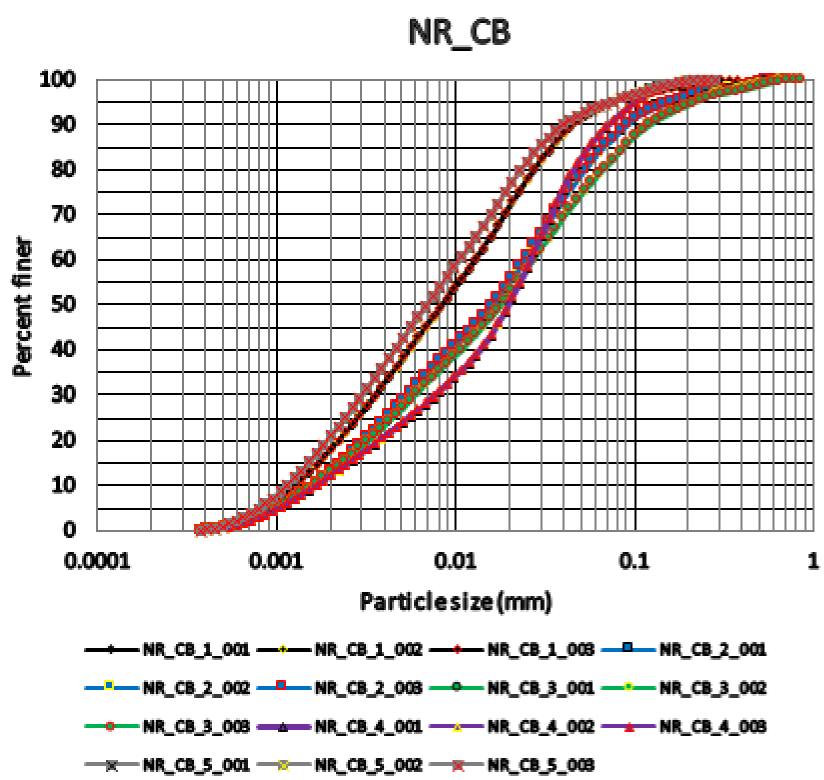
River Mile 135.15



River Mile 130.54

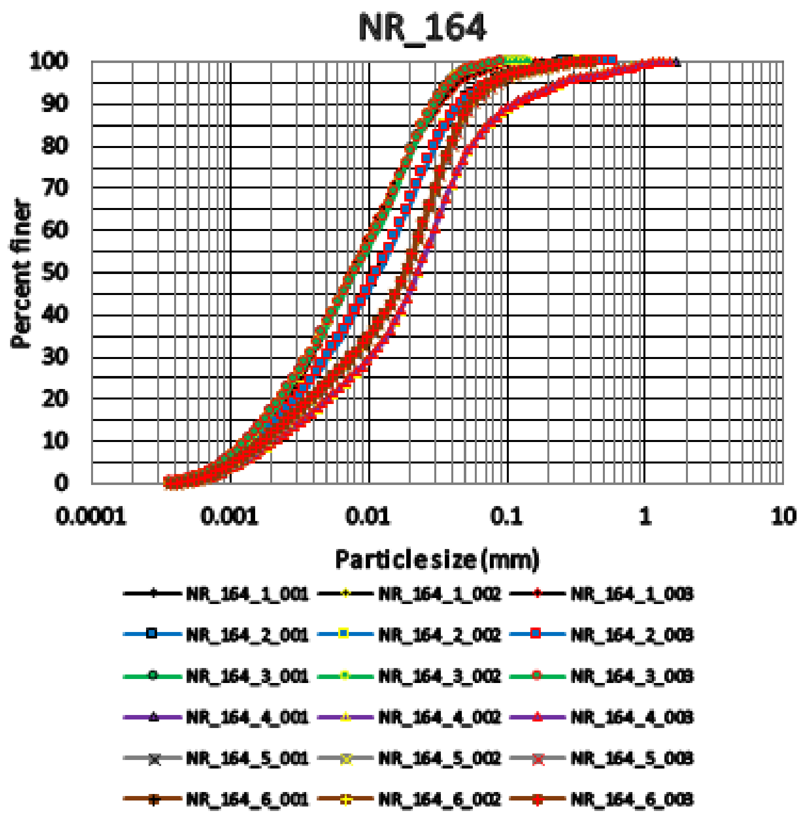


River Mile 126.69

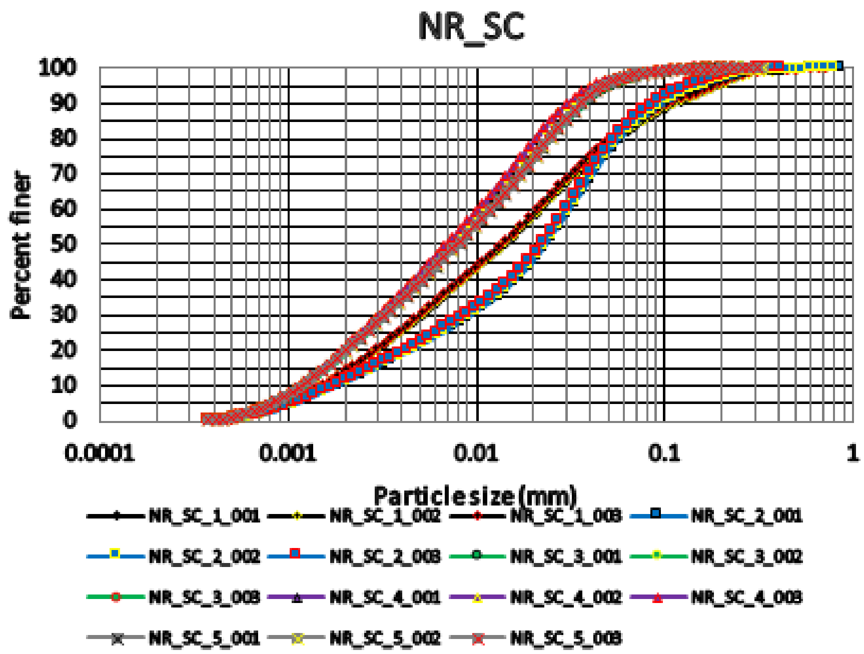


Neosho River – Grand Lake

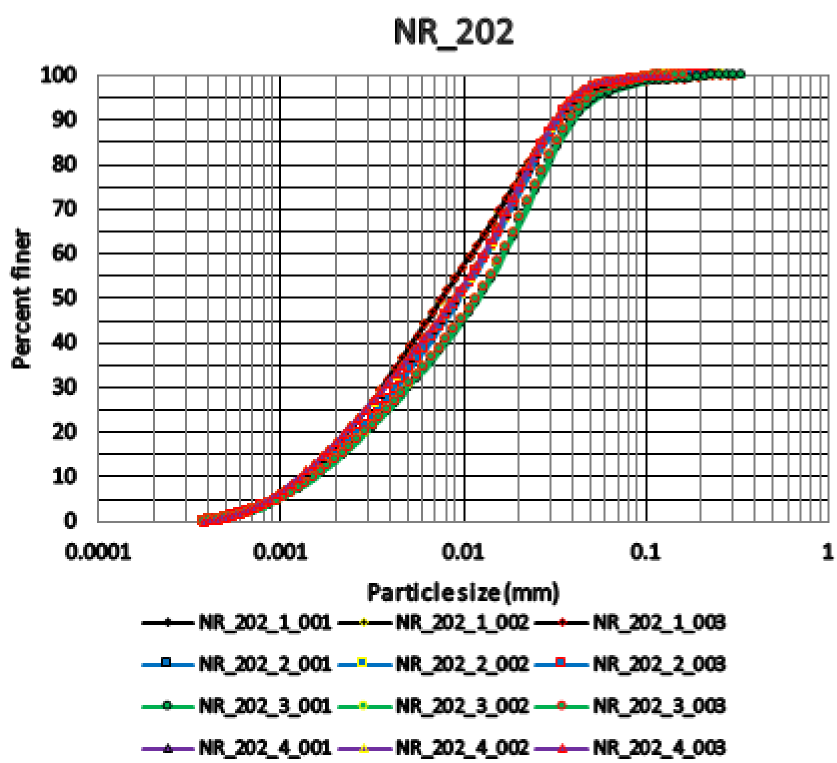
River Mile 120.43



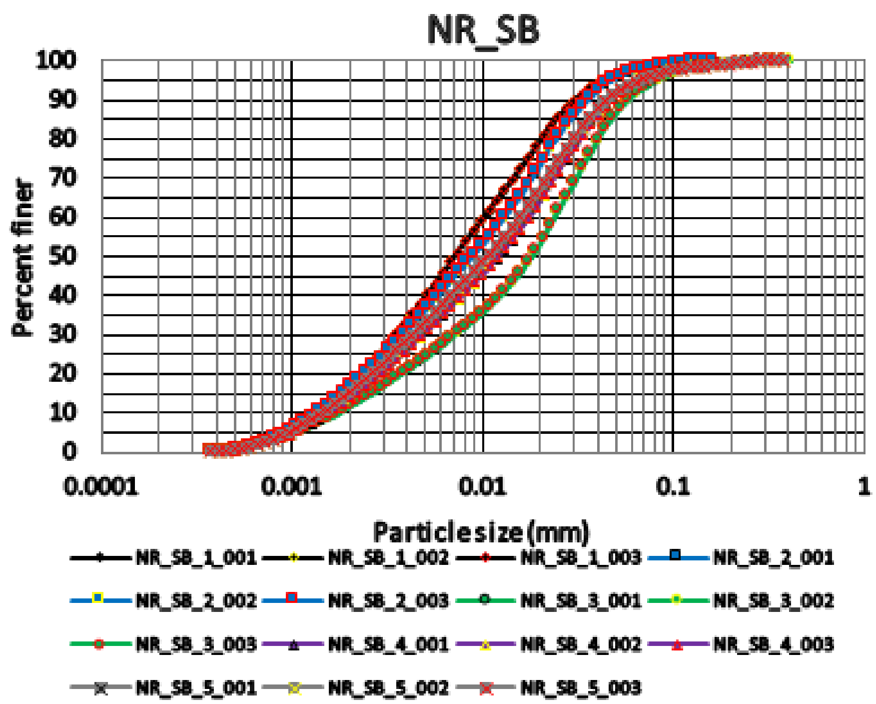
River Mile 115.81



River Mile 112.69

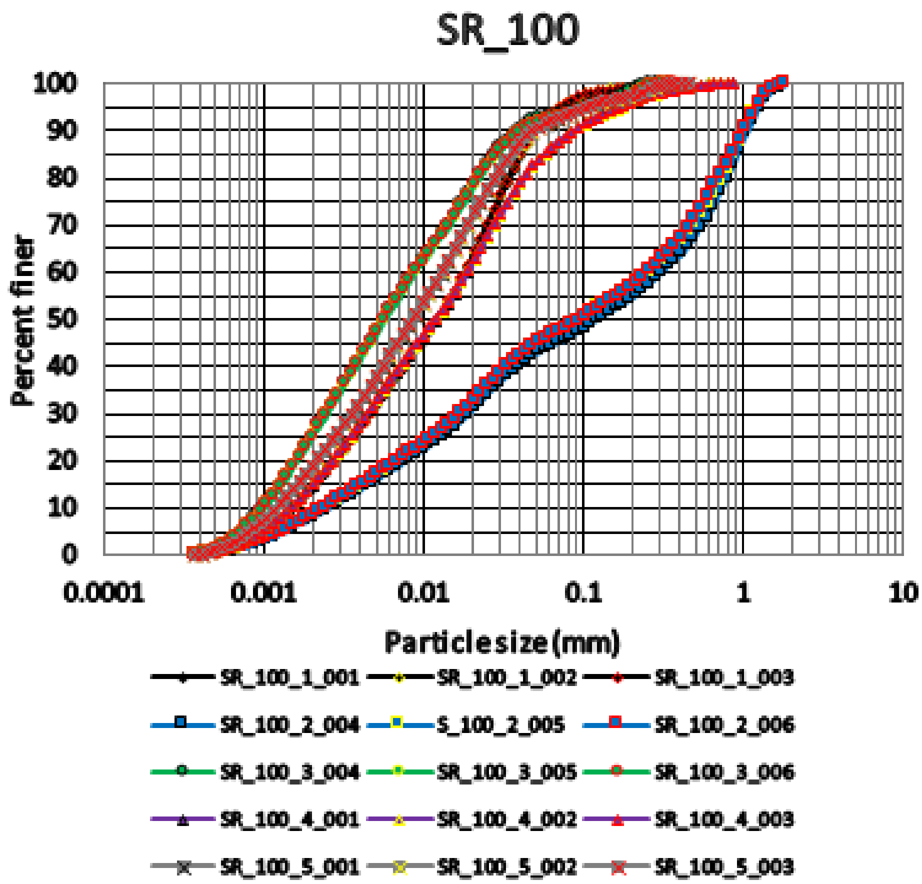


River Station 109.65

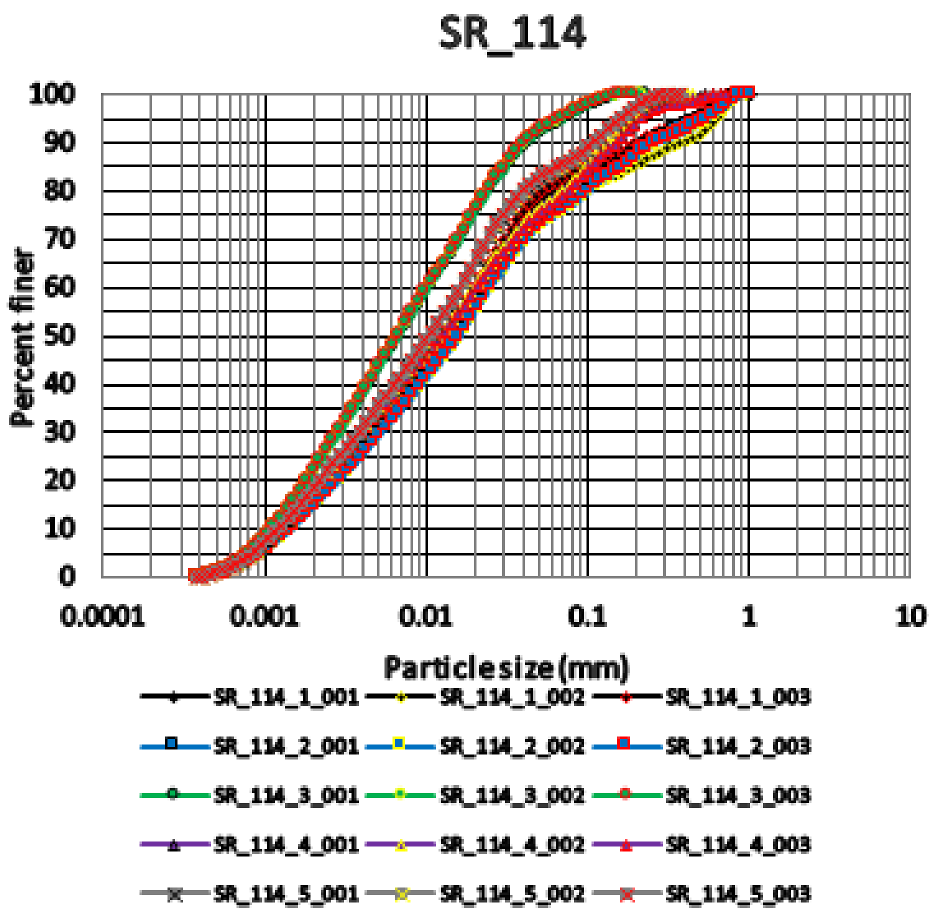


Spring River

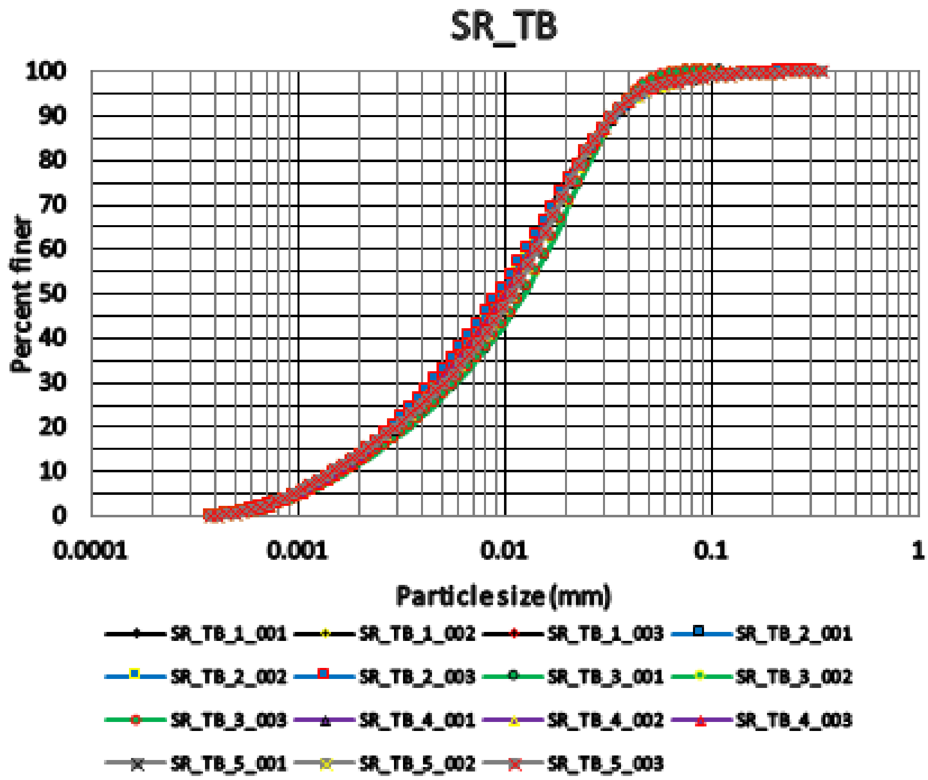
River Mile 7.5



River Mile 4.82

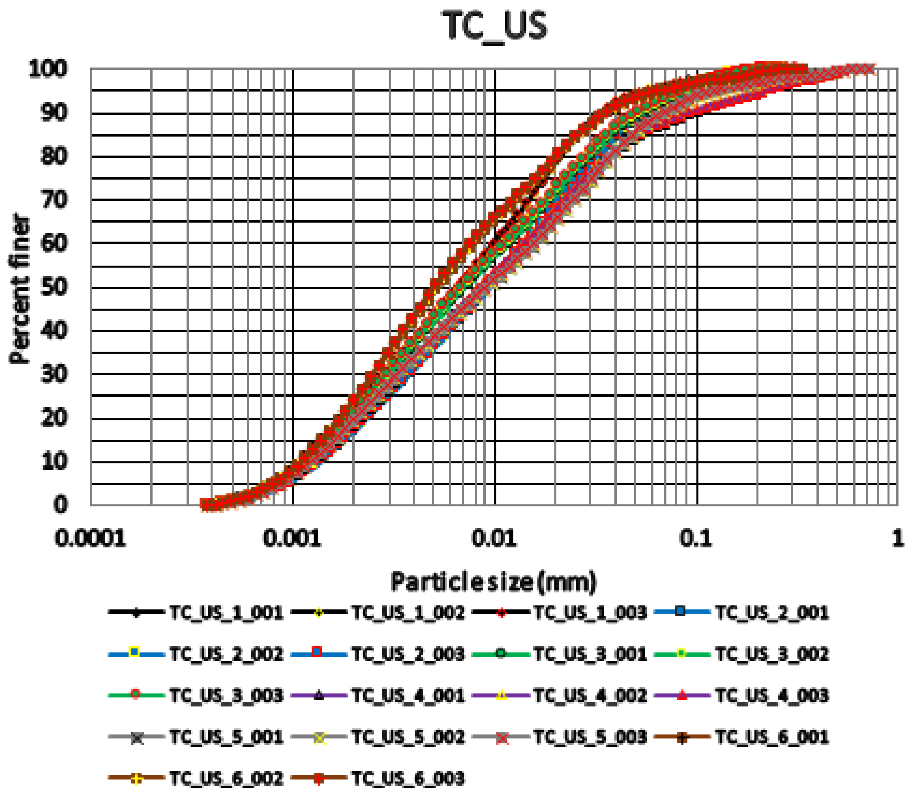


River Mile 0.79

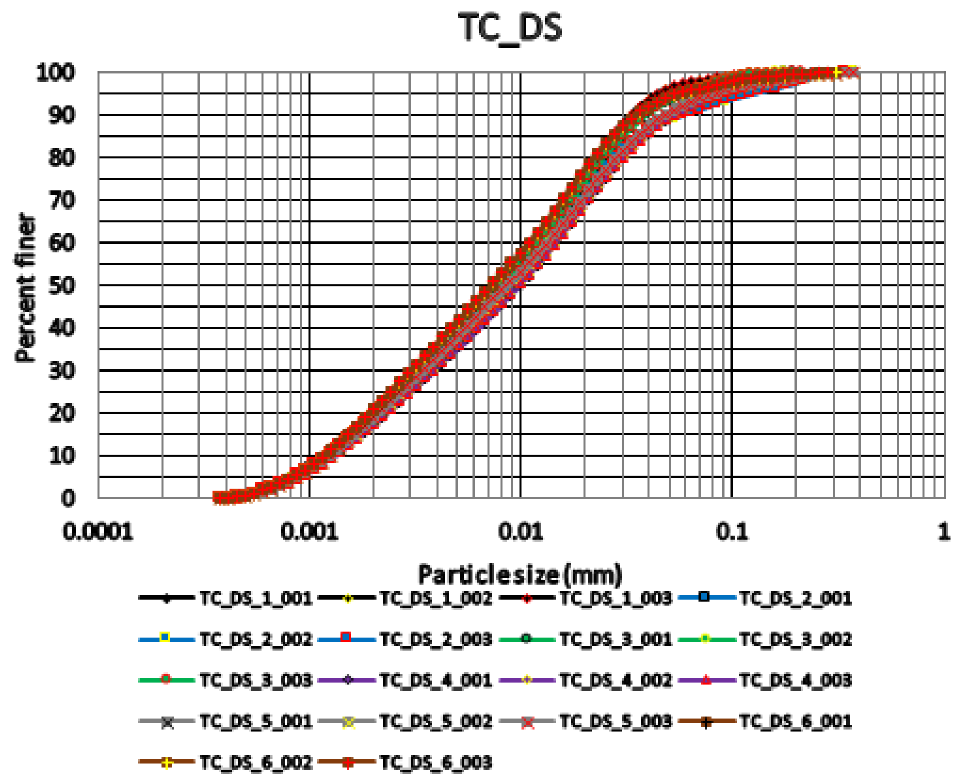


Tar Creek

Downstream of River Mile 1.6

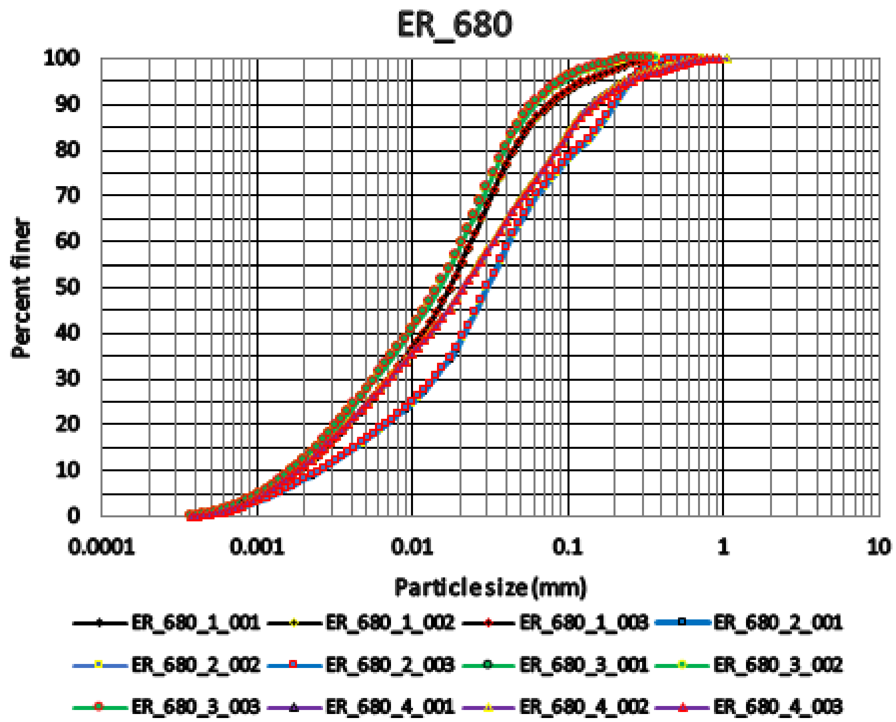


Downstream of River Mile 1.6

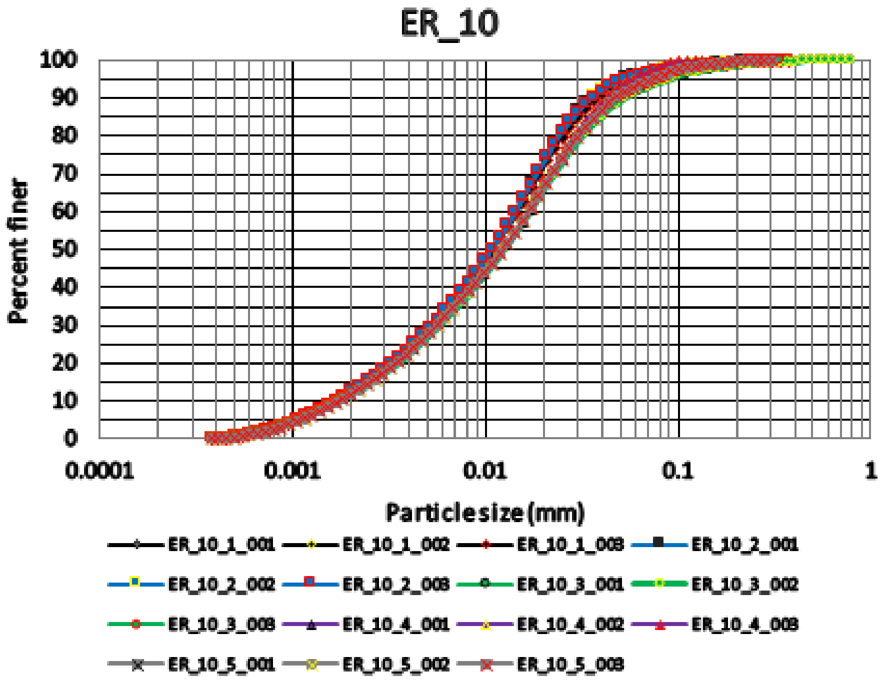


Elk River

River Mile 8.41



River Mile 4.67



GRAND LAKE WATERWAYS SEDFLUME ANALYSIS

Grand Lake o' the Cherokees, OK

Prepared for

FreshWater Engineering

Prepared by

integral consulting inc.

200 Washington Street
Suite 201
Santa Cruz, CA 95060

May 2020

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ACRONYMS AND ABBREVIATIONS

Grand Lake	Grand Lake o' the Cherokees
Integral	Integral Consulting Inc.
LISST	laser *in situ* scattering and transmissometry
SEDflume	sediment-erosion-at-depth flume

EXECUTIVE SUMMARY

The complex and dynamically linked relationships between biological activity, hydrodynamic forcing, and sediment properties can regulate morphological bed changes in aquatic systems. The ongoing investigation of sediment mobility within the tributaries and waterways of the Grand Lake o' the Cherokees (Grand Lake) calls for the development of a site-specific sediment transport model. Quantification of the erosional and physical characteristics of a sediment bed can help define ranges of values to bound uncertainty in sediment transport models. Integral Consulting Inc. collected and conducted a sediment-erosion at depth flume (SEDflume) analysis on 14 sediment cores representing a range of bed types and areas within the system. SEDflume analysis produced erosion rate data, determined critical bed shear stresses, and measured particle size distribution and bulk density across multiple sediment types and depths within the sediment bed.

This report provides a summary of the SEDflume analysis for each SEDflume core collected during field sampling efforts. Laboratory measurements of erosion rates at applied shear stresses, ranging from 0.1 to 12.8 Pa, were used to determine the critical shear stress for erosion at multiple depth intervals within each sediment core. The critical shear stress for erosion governs the threshold at which sediment may become suspended. Coefficients relating shear stress and erosion rate based on a power law fit are provided. Supplemental data of grain size distributions via laser diffraction and bulk density measurements at each depth interval are also provided to characterize the physical characteristics of the sediment bed.

In general, sediment consisted of silt and clay with a surface layer of unconsolidated, relatively mobile sediment. Below the surface layer, sediment became more consolidated resulting in larger computed critical shear stresses. Prominent biotic activity, such as invertebrate burrows, extended up to 10 cm from the surface, resulting in a range of erosion conditions. Leaves and root structures present within some samples also modified the erosional properties of the surrounding sediment. Measured and computed parameters varied between different water bodies. It is advised that SEDflume results be analyzed in conjunction with other system characteristics, such as hydrodynamic forcing, to assess overall site stability and sediment transport trends.

1 INTRODUCTION TO SEDFLUME

Analysis of sediment erosion properties using SEDflume can provide quantitative information on sediment bed characteristics. The sediment bed is governed by a complex and dynamically linked relationship between biologic activity, hydrodynamic forcing, and the physical and chemical makeup of the bed. SEDflume provides measurements of erosion rates to inform how the bedded sediment responds to controlled, measurable hydrodynamic flow. The following section outlines collection efforts of 16 cores within the Grand Lake connected waters. An overview of SEDflume setup and processing procedures, as well as methods used for determining the critical shear stresses for erosion. Supplemental information regarding physical characteristic analyses including particle size distribution and bulk density is also provided.

1.1 SAMPLE COLLECTION

Sample collection occurred between March 9 and March 12, 2020. Samples were collected via a box-core collection system by staff from Integral Consulting Inc. (Integral) and FreshWater Engineering. A summary of samples collected and their locations is provided in Table 1. Of the 16 proposed sampling sites, 14 were successfully collected. Alterations to originally proposed locations were determined based on viability of collection on site. The presence of tree limbs and gravel at some sites necessitated the field team to move to more conducive sampling areas. Soft, sediment-rich banks of the river were targeted rather than deeper center channels where gravel and cobble are present.

Samples were collected using a push coring system to penetrate clear acrylic box cores into the sediment bed. When pushing by hand did not result in sufficient penetration, blows from a post-hole hammer were applied. At some sites, such as ER-680, multiple attempts to collect a sufficient sample were performed. Further description of sampling efforts is provided on a core-by-core basis in Sections 2.1 through 2.16.

Table 1. Summary of SEDflume samples

Sample ID	Date	Time	Water depth (ft)	Length (cm)	Latitude	Longitude
SED-ER-10	3/12/2020	3:30:00 PM	8	30	36.64759	-94.704862
SED-ER-640	3/12/2020	----	----	----	36.65529	-94.728458
SED-ER-680	3/9/2020	5:30:00 PM	5	22	36.65639	-94.656731
SED-NR-130	3/11/2020	4:00:00 PM	1	17	36.82961	-94.808654
SED-NR-164	3/10/2020	6:00:00 PM	5	41	36.7801	-94.774844
SED-NR-202	3/10/2020	4:35:00 PM	5	23	36.72824	-94.772617

Sample ID	Date	Time	Water depth (ft)	Length (cm)	Latitude	Longitude
SED-NR-CB	3/11/2020	5:02:00 PM	1	32	36.79897	-94.819643
SED-NR-FG	3/11/2020	11:00:00 AM	1	23	36.85977	-94.875079
SED-NR-HP	3/12/2020	---	---	---	36.64564	-94.779563
SED-NR-SB	3/10/2020	2:00:00 PM	6	37	36.69502	-94.748474
SED-NR-SC	3/10/2020	5:10:00 PM	6	27	36.73894	-94.726088
SED-SR-100	3/10/2020	11:40:00 AM	5	43	36.86481	-94.762871
SED-SR-114	3/10/2020	12:30:00 PM	5	41	36.85253	-94.721566
SED-SR-TB	3/10/2020	11:10:00 AM	4	32	36.8039	-94.754402
SED-TC-DS	3/11/2020	2:30:00 PM	8	44	36.85475	-94.858931
SED-TC-US	3/11/2020	2:00:00 PM	6	44	36.85717	-94.860699

1.2 EXPERIMENTAL PROCEDURES

Detailed descriptions of SEDflume analysis and its application are given in McNeil et al. (1996), Jepsen et al. (1997), and Roberts et al. (1998). The following sections supplement those reports with a general description of the SEDflume analysis procedures used in this study. Supplemental analyses of grain size distribution using laser diffraction (ISO Standard 13-320), water content (ASTM Method D2216-05), and bulk density (ASTM Method D2216-10; Håkanson and Jansson 1983), and loss on ignition (ASTM Method D7348-13) were also implemented at the beginning of each interval to quantify physical sediment characteristics.

1.2.1 SEDflume Setup

A SEDflume is essentially a straight flume with an open bottom section through which a rectangular, cross-sectional core barrel containing sediment can be inserted (Figure 1). The main components of the flume are the water tank, pump, inlet flow converter (which establishes uniform, fully developed, turbulent flow), the main duct, test section, hydraulic jack, and the core barrel containing sediment (Figure 2). The core barrel, test section, flow inlet section, and flow exit section are made of transparent acrylic so that the sediment–water interactions can be observed visually. The core barrel has a rectangular cross section, 10 by 15 cm, and a length of 60 cm.

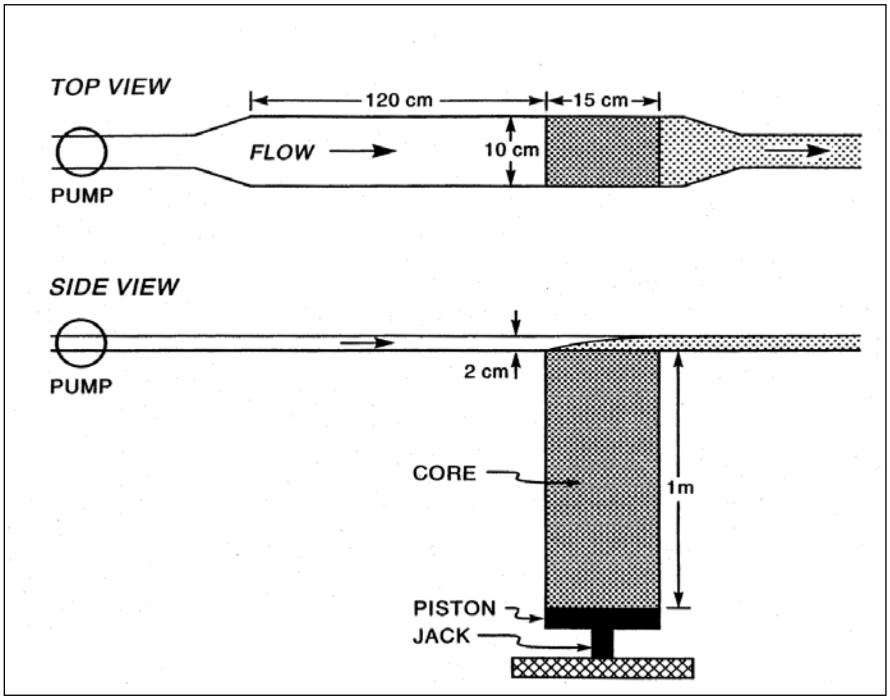

Figure 1. Schematic of SEDflume setup showing top and side views

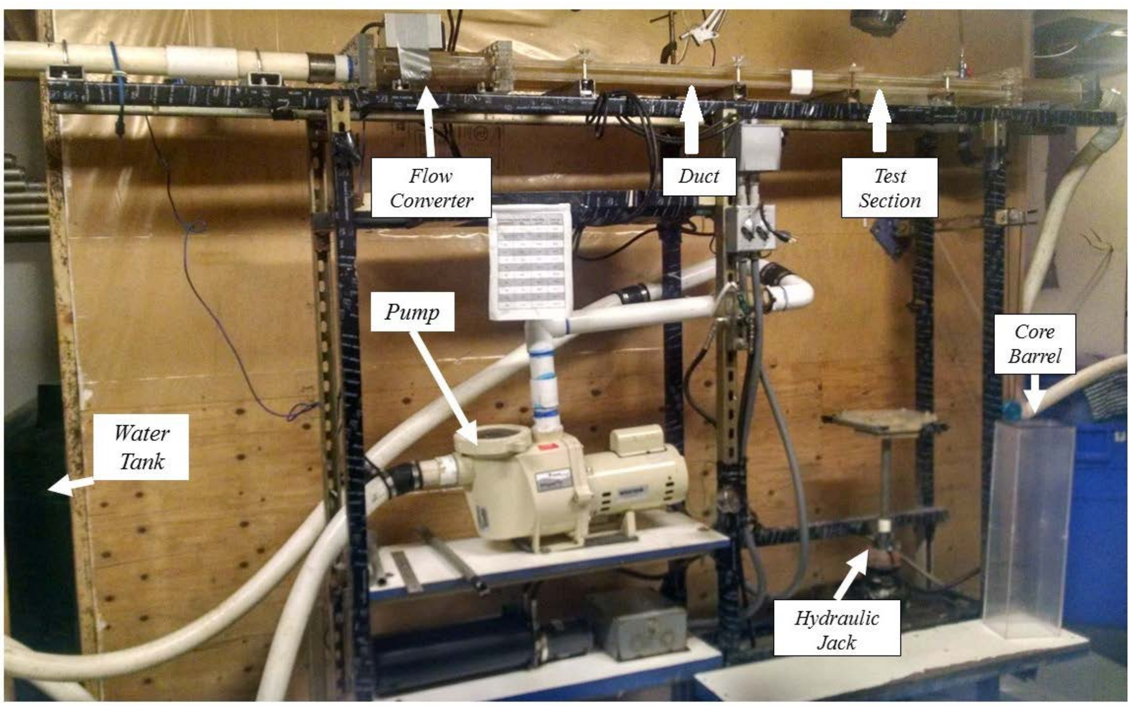

Figure 2. SEDflume in Integral's laboratory, Santa Cruz, California

Water is pumped from a 300-gallon storage tank into a 5-cm-diameter pipe and then through the flow converter into the main duct. The duct is rectangular, 2 cm in height, 10 cm in width, and 120 cm in length; it connects to the test section, which has the same cross-sectional area (2 by 10 cm) and is 15 cm long. The flow converter changes the shape of the cross section from circular to rectangular while maintaining a constant cross-sectional area. A ball valve regulates the amount of water entering the flume so that the flow rates can be carefully controlled. The flume also has a small valve immediately downstream from the test section that opens to the atmosphere, preventing a pressure vacuum from forming and enhancing erosion.

At the start of each test, a core barrel and the sediment it contains are inserted into the bottom of the test section. The sediment surface is aligned with the bottom of the SEDflume channel. When fully enclosed, water is forced through the duct and test section over the surface of the sediment. The shear stress produced by the flow and imparted on the particles causes sediment erosion. As the sediment on the surface of the core erodes, the remaining sediment in the core barrel is slowly moved upward so that the sediment–water interface remains level with the bottom of the flume.

An operator moves the sediment upward using a hydraulically controlled piston that is inside the core barrel. The jack is driven by a release of pressure that is regulated with a switch and valve system. In this manner, the sediment can be raised and made level with the bottom of the test section. The movement of the hydraulic jack can be controlled for measurable increments as small as 0.5 mm.

1.2.2 Measurements of Sediment Erosion Rate

At the start of each core analysis, an initial reference measurement is made of the starting core length. The flume is then operated at a specific flow rate corresponding to a particular shear stress, and sediment is eroded (McNeil et al. 1996; Jepsen et al. 1997). As erosion proceeds, the core is raised if needed to keep the core's surface level with the bottom of the flume. This process is continued until either 10 minutes has elapsed or the core has been raised roughly 2 cm. The erosion rate for the applied shear stress is then calculated as:

$$E = \frac{\Delta z}{T} \quad [1]$$

Where:

E = erosion rate

Δz = distance that sediment is raised during a particular measurement period

T = measurement time interval

Because material is eroded and the core structure is broken down, repetitive erosion measurements at a given depth are not possible. The following procedures were performed for all Grand Lake waterway cores to best determine the erosion rate at several different shear stresses and depths using only one core:

1. The core was inserted into the bottom of the SEDflume test section.
2. The total length of sediment in the core barrel was measured and recorded.
3. Two 5 g (approximately) subsamples of sediment from the core surface were collected using a clean spoon. Sediment sampling was constrained to the downstream (relative to the SEDflume flow direction) end of the sediment surface, to minimize potential scour effects.
4. Shear stresses (from low to high) were applied to the core's surface, and sediment erosion was measured (if it occurred; 0.5 mm of erosion in 10 minutes was considered quantifiable). Applied shear stresses started at 0.1 Pa and were sequentially doubled until a given shear stress caused approximately 2 cm of erosion in 20 seconds, or a maximum of 5 cm was eroded in a given interval (defined as a continuous succession of increasing shear stress cycles where erosion is measured). Each shear stress cycle was applied for a minimum of 20 seconds and a maximum of 10 minutes. To the extent possible, no more than 2 cm of sediment was allowed to erode at a single shear stress.
5. Once the threshold—2 cm of erosion in 20 seconds, or a maximum of 5 cm of erosion in a single interval—was met, a new depth interval was started. Steps 3 and 4 were repeated.[1] Also, if the sediment composition changed noticeably in appearance or erosion properties, the depth interval was stopped, sediment subsamples were collected, and a new depth interval was started (Step 4).
6. Where practicable, at least three and up to five depth intervals were tested per core.

1.2.2.1 Determination of Critical Shear Stress

The critical shear stress of a sediment bed, τ_{cr}, is the applied shear stress at which sediment motion is initiated. In this study, it is operationally defined as the shear stress required to produce 0.001 mm of erosion in 1 second. This represents an erosion rate of 10^{-4} cm/s, or roughly 1 mm of erosion in 15 minutes.[2]

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[1] If a particular shear stress did not cause any observable erosion over a 10-minute period for consecutive depth intervals (e.g., less than 0.5 mm eroded in 10 minutes), that shear stress was removed from subsequent testing cycles; higher shear stresses were added, as appropriate, to attempt to measure at least three erosion rates.

[2] Though other definitions of critical shear stress erosion rate thresholds can be argued (and considered valid), the value of 10^{-4} cm/s threshold is used here for consistency with previous SEDflume efforts and to keep testing times to a practical duration.

Because it is difficult to measure τ_{cr} exactly at the 10^{-4} cm/s threshold, erosion was instead measured over a range of shear stresses designed to bracket the initiation of erosion threshold. The highest applied shear stress where erosion *did not occur* is defined by τ_{no}, and τ_{first} is the lowest applied shear stress where erosion *did occur*.

Using the measured erosion rate data in each depth interval, a power law regression analysis (described below) was employed to determine the shear stress (τ_{power}) required to cause 10^{-4} cm/s of erosion. Assimilating the bracketed shear stress values (τ_0 and τ_1) and τ_{power}, the critical shear stress of each interval was then chosen according to the following criteria (where τ_{no} and τ_{first} are determined directly from the SEDflume measurements):

- If $\tau_{no} \leq \tau_{power} \leq \tau_{first}$, then τ_{power} was the selected critical shear stress, τ_{cr}, for the interval.
- If $\tau_{no} \geq \tau_{power}$, then τ_{no} was the selected critical shear stress for the interval.
- If $\tau_{power} \geq \tau_{first}$, then τ_{first} was the selected critical shear stress for the interval.
- If $r^2 < r^2_{thresh}$, then τ_{linear} was selected as the critical shear stress for the interval.

The τ_{cr} criteria allowed for selection of critical shear stresses using the power law results where the regression analysis was in agreement with measured erosion rate data.

1.2.2.2 Power Law Regression

Following the methods of Roberts et al. (1998), the erosion rates for sediment can be approximated by the power law regression:

$$E = A\tau^n \rho^m \quad [2]$$

Where:

E	=	erosion rate (cm/s)
τ	=	bed shear stress (Pa)
ρ	=	sediment bulk density (g/cm^3)
A, n, and m	=	constants that depend on sediment characteristics

The equation used in the present analysis is an abbreviated variation of Equation 2:

$$E = A\tau^n \quad [3]$$

where the constant A is a function of the sediment bulk density and other difficult properties to measure, such as sediment geochemistry and biological influences. The variation of erosion rate with density typically cannot be determined for field sediment because of natural variation in other sediment properties (e.g., mineralogy, particle size, and electrochemical forces). Therefore, the density term from the equation above, for a particular interval of approximately constant density, is incorporated into the constant *A*.

For each depth interval, the measured erosion rates (*E*) and applied shear stresses (τ) were used to determine the *A* and *n* constants that provide a best-fit power law curve to the data for that interval. Good regression fits of these parameters, where they existed, were then used to estimate the critical shear stress for the respective intervals. A coefficient of determination (r^2) of 0.70 was used as a threshold criterion for acceptance.[3]

1.2.3 Measurement of Sediment Bulk Properties

In addition to the measurement of erosion rates during the analysis, sediment subsamples were periodically collected at depth to determine the water content, particle size distribution, and loss on ignition of the sediment in each core. Water content and loss on ignition values are incorporated into the determination of wet and dry bulk densities. Subsamples were collected from the undisturbed core surface (prior to analysis) as well as the sediment surface at the beginning of each subsequent depth interval. Samples were weighed, dried, and reweighed to determine the mass of water. Samples were then subjected to sufficient heat to ignite the organic material to determine loss on ignition.

Wet bulk density was determined by first measuring the wet and dry weight of the collected sample to determine the water content (*W)* as described in Håkanson and Jansson (1983):

$$W = \frac{M_w - M_d}{M_w} * 100\% \qquad [4]$$

Where:

W = water content
M_w = wet weight of sample
M_d = dry weight of sample

For the determination of wet bulk density, water content in this formulation have value from 0 to 1. Wet bulk densities were then determined using the method described by Håkanson and Jansson (1983):

[3]The coefficient of determination, r^2, is a function of Pearson's *r*, which is a measure of the linear dependence (correlation) between two variables. Pearson's *r* can be positive or negative, and is a value between –1 and +1. The more common usage of the correlation coefficient is to square Pearson's *r*, r^2, and report that value.

$$\rho_{wet} = \frac{(100 * \rho_s)}{100 + (W + IG)(\rho_s - 1)} \quad [5]$$

Where

ρ_w	=	density of water (assumed 1 g/cm^3)
ρ_s	=	density of sediment particle (assumed 2.65 g/cm^3)
IG	=	% loss on ignition based on wet weight (ASTM Method D7348-13)

Dry bulk densities are based on the moisture content (*MC*) defined by ASTM D2216-05 as

$$MC = \frac{M_w - M_d}{M_d} \quad [6]$$

This formulation represents the ratio of water to solids. Using the moisture content value, dry bulk densities were calculated using the following relationship:

$$\rho_{dry} = \frac{\rho_{wet}}{1 + MC} \quad [7]$$

Particle size distributions were determined using laser diffraction analysis at Integral's laboratory in Santa Cruz, California. Sediment samples were screened with a 2,000-µm sieve to remove large pieces of organic material, dispersed in water, and inserted into a Beckman Coulter LS 13-320 laser diffraction analyzer. Each sample was analyzed in three 1-minute intervals, and the results of the three analyses were averaged automatically by the instrument. The Beckman Coulter LS 13-320 measures volumetric distribution of particles from 0.4 to 2,000 µm. Caution should be taken when comparing directly to more narrowly ranged instruments such as a laser *in situ* scattering and transmissometry (LISST) instrument or traditional mass-based sieve and hydrometer studies. A LISST measures aggregated particles in the natural environment and has detection ranges different from that of the desktop instrument. Use of the Beckman Coulter involves the disaggregation of particles so any direct comparison must consider these factors.

The relationships used to determine sediment bulk properties are summarized in Table 2.

Table 2. Parameters measured and computed during the SEDflume analysis

Measurement	Definition	Units	Detection Limit	Internal Consistency
Water Content	$W = \frac{M_w - M_d}{M_w}$	Dimensionless	0.001 g in sample weight ranging from 1 to 50 g	0 < W < 1
Moisture Content	$MC = \frac{M_w - M_d}{M_d}$	Dimensionless	0.001 g in sample weight ranging from 1 to 50 g	
Wet Bulk Density	$\rho_{wet} = \frac{(100 * \rho_s)}{100 + (W + IG)(\rho_s - 1)}$	g/cm³	0.001 g in sample weight ranging from 1 to 50 g	$\rho_w < \rho_{wet} < 2.6\ \rho_w$
Dry Bulk Density	$\rho_{dry} = \frac{\rho_{wet}}{1 + MC}$	g/cm³	0.001 g in sample weight ranging from 1 to 50 g	$\rho_w<\rho_{dry}<\rho_{wet}$
Particle size distribution below 2,000 µm	Distribution of particle sizes by volume percentage using laser diffraction	µm	Method specific	1 µm < grain size < 2,000 µm

Notes:
M_w = wet weight of sample
M_d = dry weight of sample
ρw = density of water (assumed 1 g/cm³)
ρs = density of sediment particle (assumed 2.65 g/cm³)

1.2.4 Intra- and Intercore Comparisons

A potentially useful method of comparing sediment characteristics at a specific site is to compute intracore and intercore erosion rates. This method provides a means to quantify the erosion rates within each core (intracore) as well as the general erosion rates of the cores across the site (intercore).

1.2.4.1 Intracore Erosion Rate Ratios

Once the power law regression *A* and *n* coefficients for each depth interval within an individual core were known, the *interval-average* erosion rate for the core was determined using Equation 3 and the logarithmic average of the range of shear stresses tested in the SEDflume analysis.[4] C*ore-average* erosion rates were then computed by:

1. Log-averaging the *A* coefficient values from each depth interval within a core to arrive at an average *A* coefficient for the entire core
2. Arithmetically averaging the *n* coefficient values from each depth interval within a core to arrive at an average *n* coefficient for the entire core
3. Solving for the core-average erosion rate following Equation 3 and using the log-average of the range of shear stresses applied to the depth interval (1.13 Pa).

An intracore erosion-rate-ratio was then defined by dividing the interval-average erosion rate by the core-average erosion rate, providing a quantitative estimation of the relative erosion susceptibility of each depth interval. This method highlights the core intervals that are more or less susceptible to erosion within a particular core, and may indicate layering within a core.

1.2.4.2 Intercore Erosion Rate Ratios

Two additional ratios were computed to evaluate large-scale spatial erosion susceptibility. An intercore erosion rate ratio was computed by comparing the individual core-average erosion rate with a site-wide average erosion rate. The site-wide average erosion rate was computed by:

1. Log-averaging the core-average *A* coefficient values from each core to arrive at an average *A* coefficient for the entire site
2. Arithmetically averaging the core-average *n* coefficient values in each core to arrive at an average *n* coefficient for the entire site
3. Solving for the site-wide average erosion rate following Equation 3 and using the log-average of the range of shear stresses (1.13 Pa).

The intercore erosion rate ratio computed in this manner provided a qualitative estimate of the erosion susceptibility of each core (as a whole) relative to other cores in the site, potentially indicating spatial locations that are more or less susceptible to erosion than other locations.

[4]The shear stress values averaged were 0.1, 0.2, 0.4, 0.8, 1.6, 3.2, 6.4, and 12.8 Pa. The logarithmic average of these, used to compute erosion rate ratios, was 1.13 Pa.

2 RESULTS

This section of the report contains both qualitative and quantitative findings from the SEDflume analysis. Results are presented on a core-by-core basis. Appendix A contains additional grain size statistics and distribution plots for each interval in each core. Raw data from the grain size analysis can be provided upon request.

Results are presented both graphically and in tabular form. Erosion rates at applied shear stresses are presented with depths adjacent to an image of the core. The indication of no erosion measured refers to the thin dotted line at 10^{-5} cm/s. As described in the previous sections, values of 10^{-4} cm/s are defined as the erosion rate related to minimum measurable critical shear stress. Tables of the derived constants A and n are provided with the r^2 value. Mean values are also presented over the entire core. The coefficient A is log-averaged because of the order of magnitude variations that can occur within its values, while n is arithmetically averaged because its range is narrow. Values of n typically range from 1 to 4, and values outside of this range may also indicate a spurious data fit.

A table of particle sizes, wet and dry bulk densities, loss on ignition, greatest applied shear with no erosion measured, first applied shear with erosion measured, and power law derived critical shear is also presented. The power law-derived critical shear was determined using the A and n values from tables also provided for each sample. A column labeled "Final Critical Shear" provides the recommended value based on the criteria outlined in Section 1.2.2.1.

Qualitative descriptions of the type of erosion are included when necessary to highlight changing processes. Erosion of the core surface generally occurs via individual particles becoming suspended, aggregated clumps of sediment (clump erosion) breaking off causing an uneven surface, or sheets of material peeling off the sediment bed. Noncohesive materials such as sands, in the absence of any organic matter acting as a "glue," will erode as individual particles. Fine-grained sediment such as silts and clays can bind together and will move together under an applied shear. Cracks and uneven sedimentation may cause these bonded sediments to move together as clumps. Sediment deposited cyclically may deposit in uniform layers and can erode as thin sheets.

Cores were processed according to the procedures in Section 1.2.2. Cores were processed until at least five intervals were completed or processing came within 5 cm from the end of the core.

2.1 SED-ER-10

Core ER-10 was collected on March 12, 2020, at 3:30 p.m. in 8 ft of water. The 30 cm length of core was collected east of the Highway 10 Bridge using a combination of hand pressure and post-hammer blows. Collected sediment consisted of olive, brown silty material with a uniform fine texture throughout with a lighter oxidized layer extending up to 3 cm from the surface. Worm tubes and possible feeding voids 0.25 to 0.5 cm in diameter were observed up to 15 cm below the surface. Sediment below the biotic influenced zone was uniform in olive color and silty texture. Leaves and stems were uncovered 25 cm below the surface but were not observed prior to that depth.

A photograph of the recovered sediment aligned with applied shear stresses and resulting erosion rates is presented in Figure 3. Shear stresses ranging from 0.1 to 12.8 Pa were applied during five shear stress intervals. Not all shear stresses were included in each interval as described in Section 1.2.2. The surface was more erodible than underlying sediment. Intervals 2, 3, and 4 exhibited uniform erosion rates and erodibility while interval 5 encompassed the least erodible sediment analyzed in ER-10 (Figure 4). In interval 1 extending 5.3 cm from the surface, sediment eroded evenly across the bed as individual grains or pieces of the surface were suspended. As depth and shear stress increased, erosion occurred when pieces or larger clumps of the surface broke free. Pieces ranged in size relative to applied shear stress and the surface eroded unevenly.

Sediment properties were relatively uniform throughout the core with the exception of low-density sediment at the surface (Figure 5, Table 3). The low-density material is associated with the lowest critical shear stresses determined from the measured erosion rates. Table 3 provides a summary of shear stress measurement as well the final critical shear stress based on the criteria outlined in Section 1.2.2.1. Derived critical shear stresses ranged from 0.25 to 1.73 Pa. Power law fit parameters relating the erosion rate to applied shear stress are presented in Table 4.

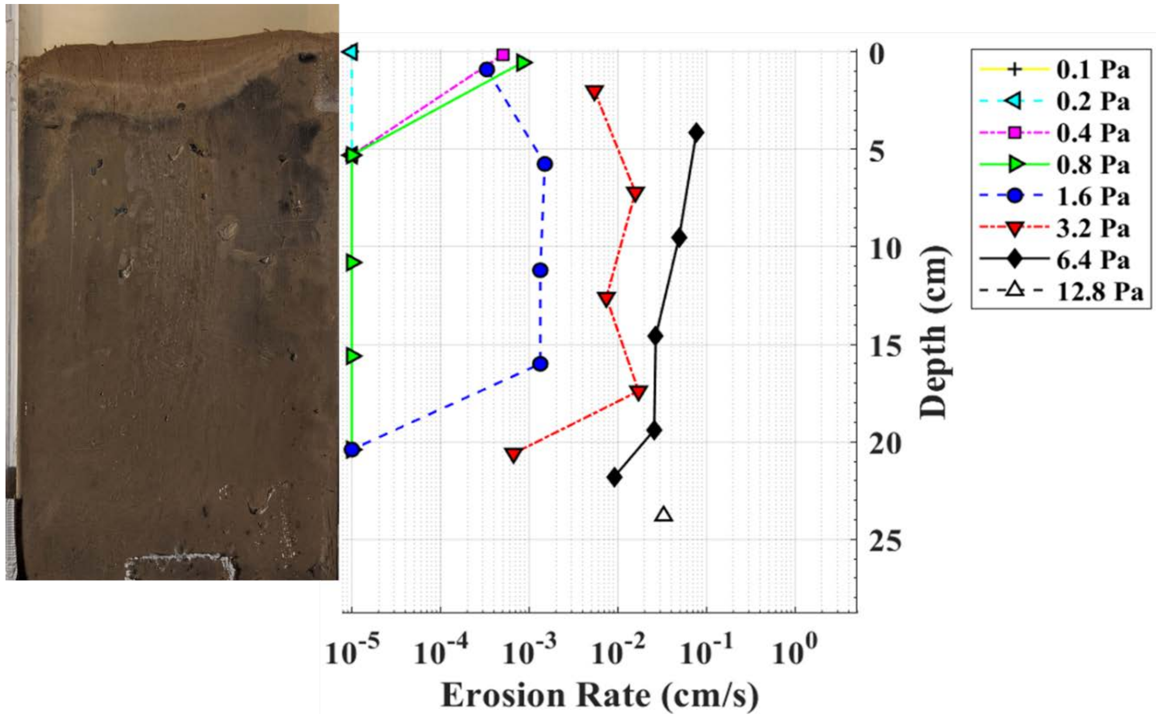


Figure 3. Photograph of Core ER-10 aligned with applied shear stresses and associated erosion rates

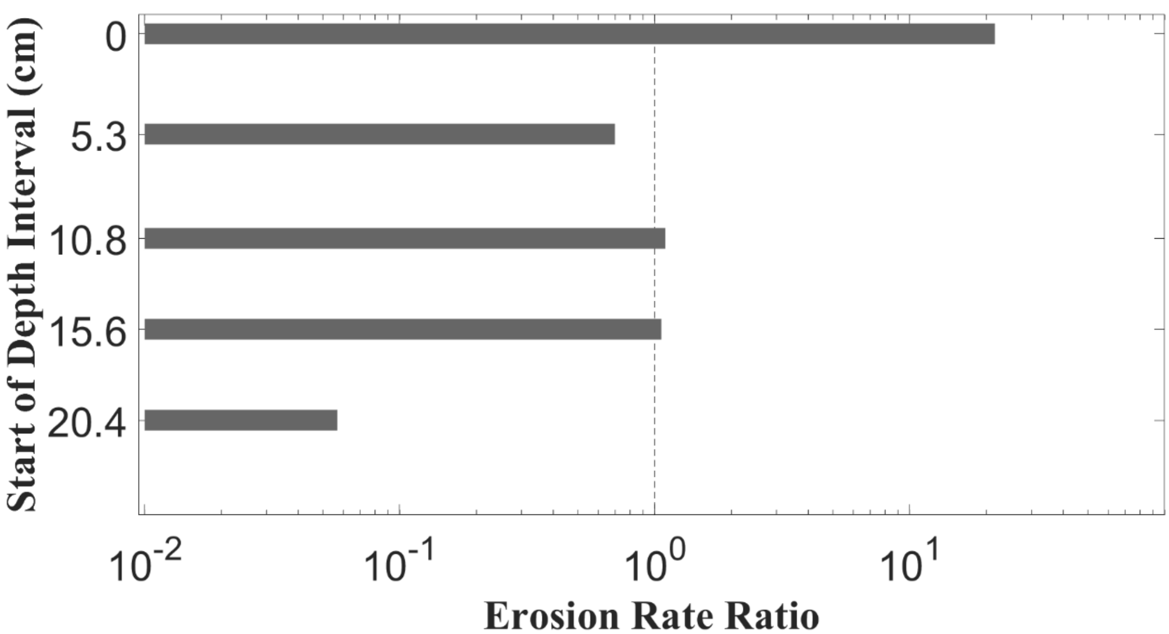


Figure 4. Intracore erosion rates of ER-10

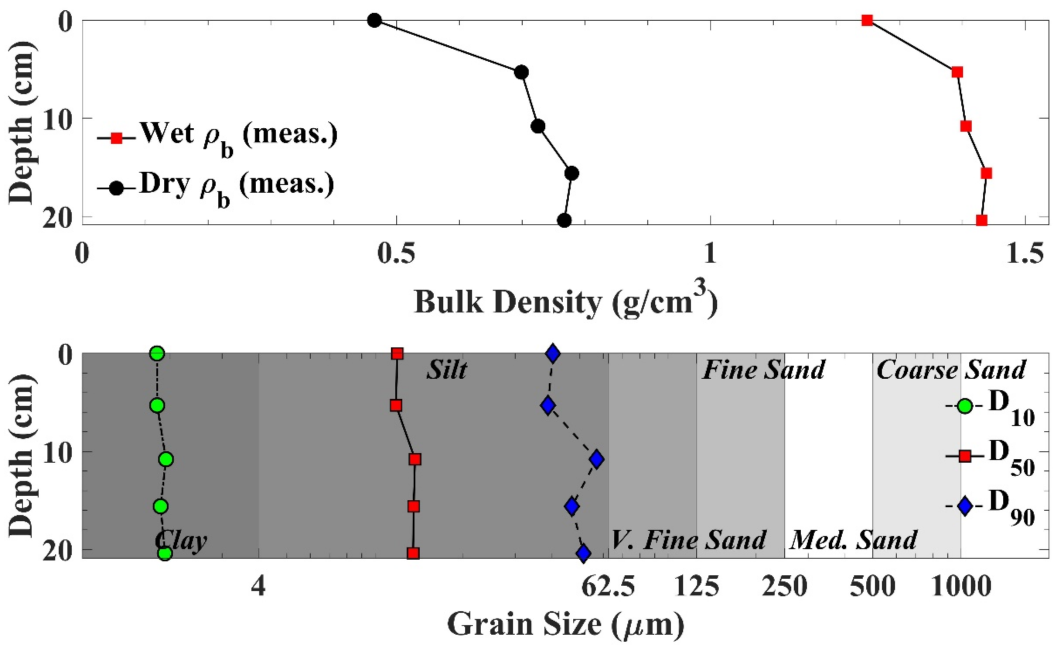


Figure 5. Physical properties of ER-10 with depth

Table 3. Physical properties and derived critical shear stresses of ER-10

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm³)	Dry Bulk Density (g/cm³)	Loss on Ignition (%)	Tau_no (Pa)	Tau_first (Pa)	Tau Crit Linear (Pa)	Tau Crit Power (Pa)	Final Critical Shear (Pa)
0.0	11.89	1.25	0.46	5.2%	0.2	0.4	0.24	0.25	0.25
5.3	11.78	1.39	0.7	5.0%	0.8	1.6	0.86	0.75	0.8
10.8	13.68	1.41	0.73	5.2%	0.8	1.6	0.86	0.74	0.8
15.6	13.54	1.44	0.78	5.2%	0.8	1.6	0.86	0.72	0.8
20.4	13.47	1.43	0.77	5.3%	1.6	3.2	1.84	1.73	1.73
Mean	12.87	1.38	0.69	5.2%	0.84	1.68	0.93	0.84	0.88

Table 4. Power law fit parameters for SED-ER-10

Interval	Depth Start (cm)	Depth Finish (cm)	A	n	r^2
1	0.0	5.3	2.1E-05	1.69	0.79
2	5.3	10.8	1.93E-07	3.1	0.96
3	10.8	15.6	4.21E-07	2.74	0.97
4	15.6	20.4	3.71E-07	2.84	0.92
5	20.4	24.8	1.64E-08	3.06	0.98

2.2 SED-ER-680

Core ER-680 was collected on March 9, 2020, at 5:30 p.m. in 5 ft of water and is the easternmost sample in the Elk River. This was the first core collected during the study and required multiple attempts and the use of a post-hammer to achieve adequate penetration resulting in 22 cm of sediment collected. The sample contained evidence of biotic activity at the surface in the upper 10 cm of the sample in form of tubes and possible feeding voids. Below a 1–3 cm surface layer of lighter sediment, an olive gray mixture of silt and sand extended throughout the sample. On the surface, the sediment was unconsolidated, yellow-tan material with some biotic mounds present. A translucent fish approximately 2 cm in length was also observed in the overlying water and burrowed into the sand when disturbed.

A photograph of the recovered sediment aligned with applied shear stress and associated erosion rates is presented in Figure 6. Shear stresses of 0.1 to 6.4 Pa were applied in three intervals utilizing 13.7 cm of material. The unconsolidated surface material eroded more easily than the underlying material possibly due to bioturbation (Figure 7). Sediment eroded in streams of individual grains as the loose sandy material eroded from the surface. Below the surface interval, sediment eroded as individual grains giving way to larger pieces of the surface 1–3 mm in diameter breaking away. Pockets of interspersed sandy material eroded as individual grains causing the exposed sediment level to erode unevenly. Critical shear stresses ranged from 0.12 to 0.4 Pa from the first to third interval (Table 5). Intervals 2 and 3 had similar properties resulting in an average critical shear stress of 0.3 Pa. Power law fit parameters governing the relationship between shear stress and erosion rate are provided in Table 6. The r^2 values show an excellent fit relating the two variables.

Four subsamples of material were collected for density and particle size distribution testing. The first three correlate to the beginning of each shear stress interval and the fourth corresponds to the end of the third interval. The low-density surface material comprised sand, silt, and clay

(Figure 8, Table 5). Below, sediment had a larger density and the proportions of sand, silt, and clay varied.

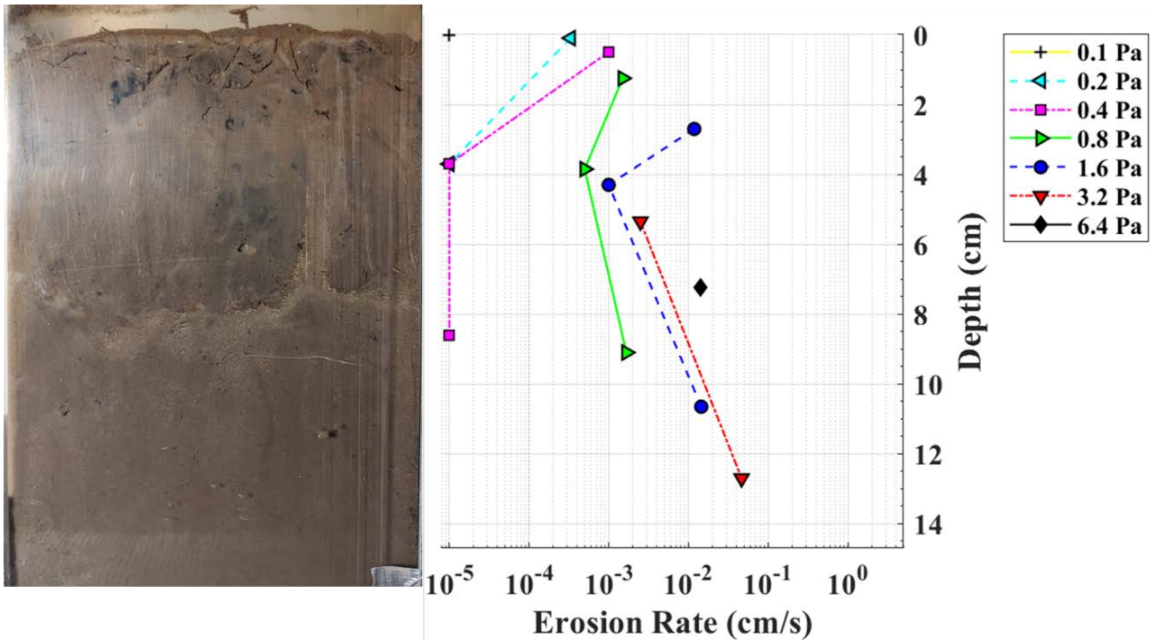


Figure 6. Photograph of Core ER-680 aligned with applied shear stresses and associated erosion rates

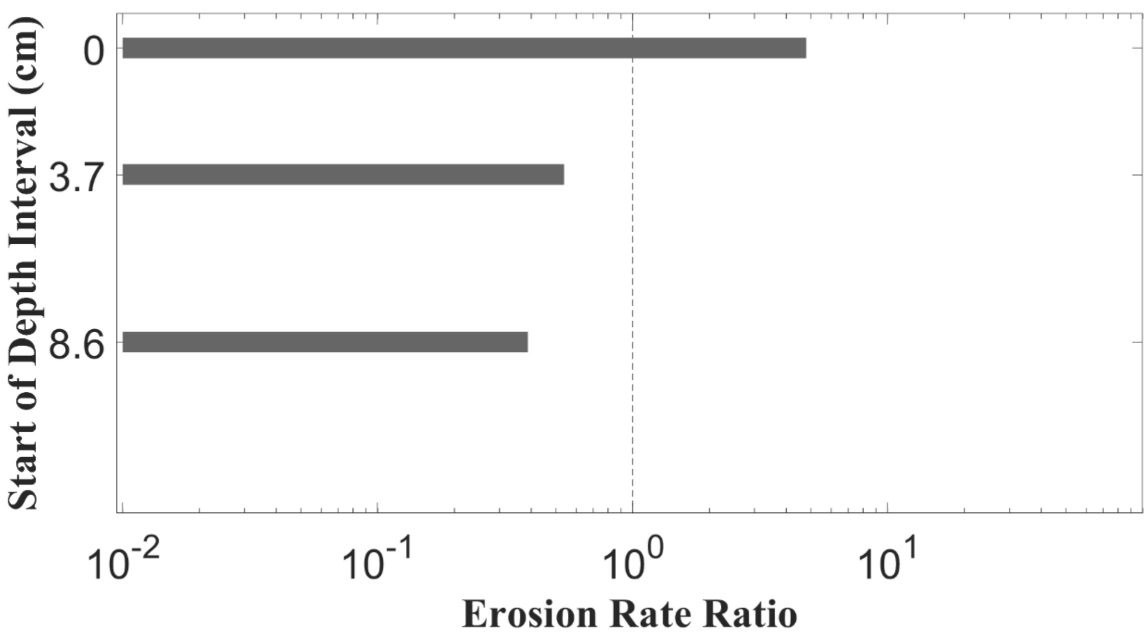


Figure 7. Intracore erosion rates in ER-680

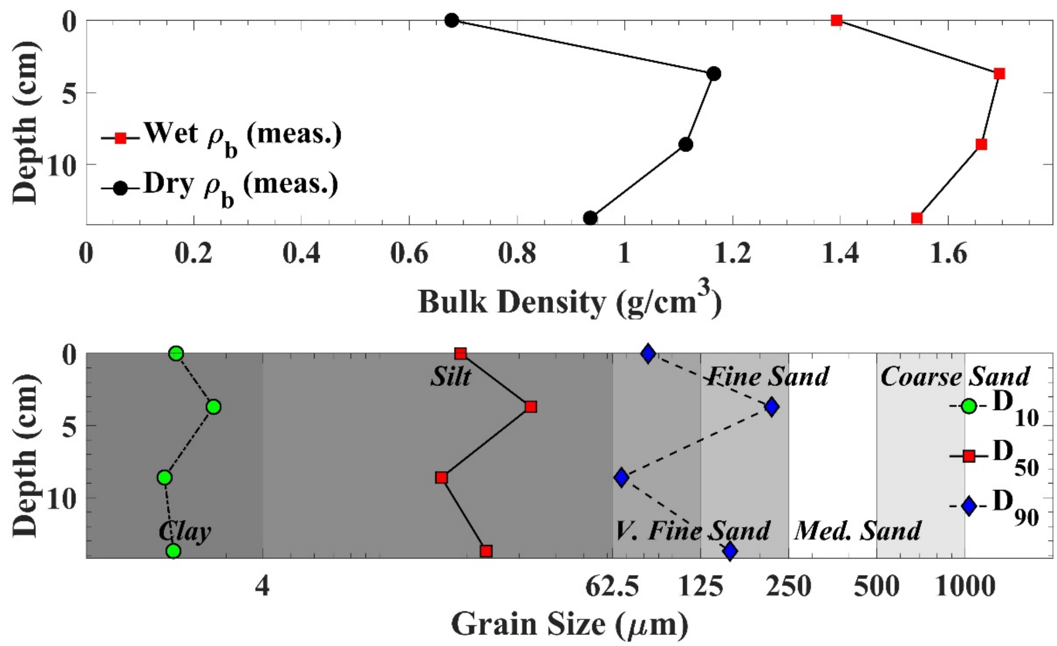


Figure 8. Physical properties of ER-680 with depth

Table 5. Physical properties and derived critical shear stresses of ER-680

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm^3)	Dry Bulk Density (g/cm^3)	Loss on Ignition (%)	Tau_no (Pa)	Tau_first (Pa)	Tau Crit Linear (Pa)	Tau Crit Power (Pa)	Final Critical Shear (Pa)
0	18.95	1.39	0.68	3.4%	0.1	0.2	0.13	0.12	0.12
3.7	32.96	1.7	1.16	2.9%	0.4	0.8	0.48	0.42	0.42
8.6	16.32	1.66	1.11	3.0%	0.4	0.8	0.43	0.37	0.4
13.7	23.18	1.54	0.94	4.2%	---	---	---	---	---
Mean	22.85	1.57	0.97	3.4%	0.3	0.6	0.35	0.30	0.31

Table 6. Power law fit parameters of ER-680

Interval	Depth Start (cm)	Depth Finish (cm)	A	n	r^2
1	0.0	3.7	7.64E-05	1.71	0.95
2	3.7	8.4	8.35E-06	1.74	0.97
3	8.6	13.7	1.88E-06	3.05	0.96

2.3 SED-NR-130

Core NR-130 was collected on March 11, 2020, at 4:00 p.m. on the east bank of the Neosho River. The sample was collected along the bank due to the flow of the river. The core recovery length was 17 cm, and a post-hammer was required to achieve penetration through the sediment. Shown in Figure 9, the collected sediment contained invertebrate burrows and tubes that extended and criss-crossed throughout the sample. An example of the worm observed in this core as well as other collected samples and presumably responsible for these burrows is shown in Figure 10. Patches of oxic sediment associated with the presence of worm tubes extended 10−12 cm below the surface. Darker patches of olive silt were present in the absence of worm tubes.

A photograph of the collected sediment core and applied shear stresses is provided in Figure 9. Due to the limited material collected at NR-130, shear stresses ranging from 0.1 to 6.4 Pa were applied to only two intervals of the sediment. Both intervals exhibited similar erosive (Figure 11) and physical properties as summarized in Table 7 and visualized in Figure 12. Critical shear stresses ranged from 0.33 to 0.4 Pa and fit parameters suggest good agreement with a power law relationship relating shear stress and erosion rate (Table 8). Grain sizes were consistent down-core, and densities increased with depth.

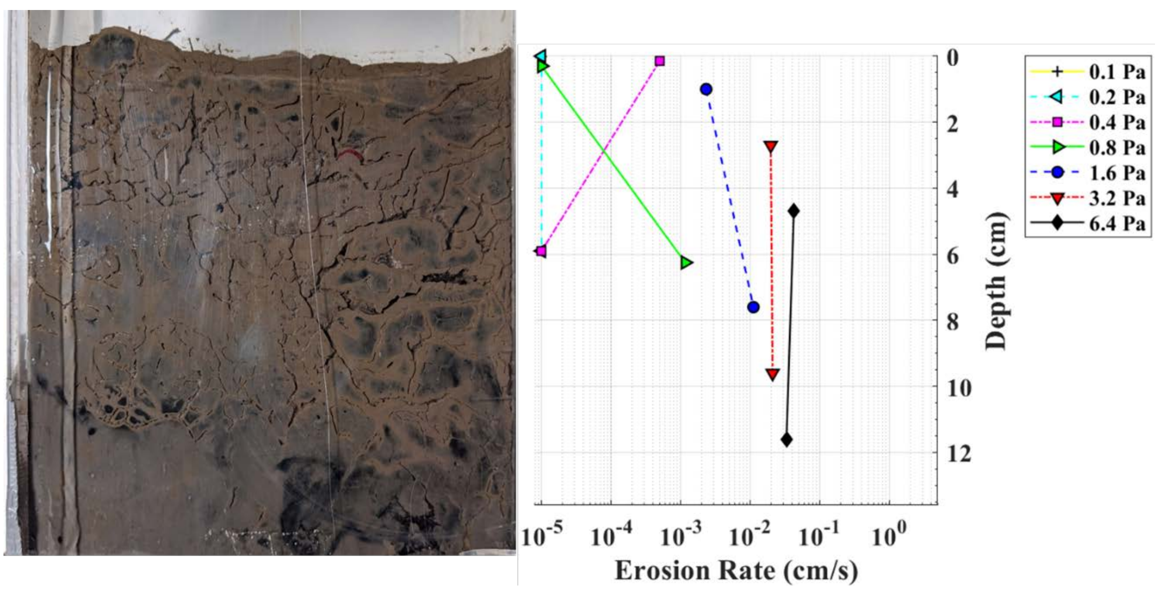


Figure 9. Photograph of Core NR-130 aligned with applied shear stresses and associated erosion rates

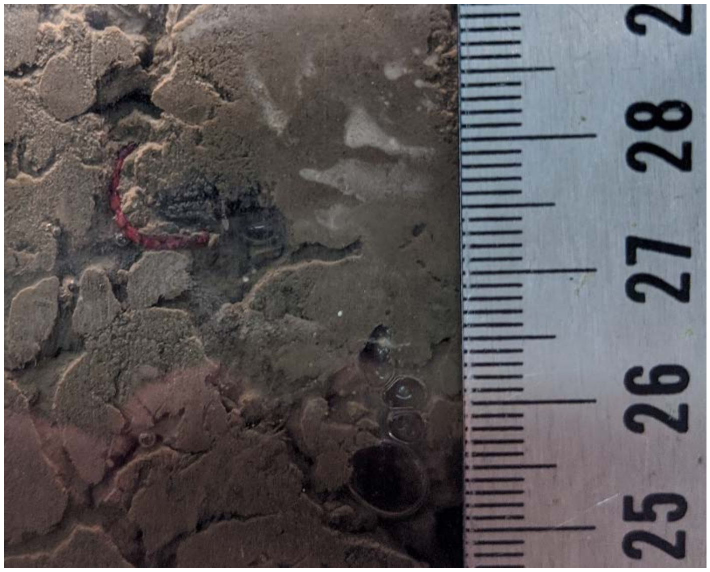


Figure 10. Invertebrate in burrow in NR-130

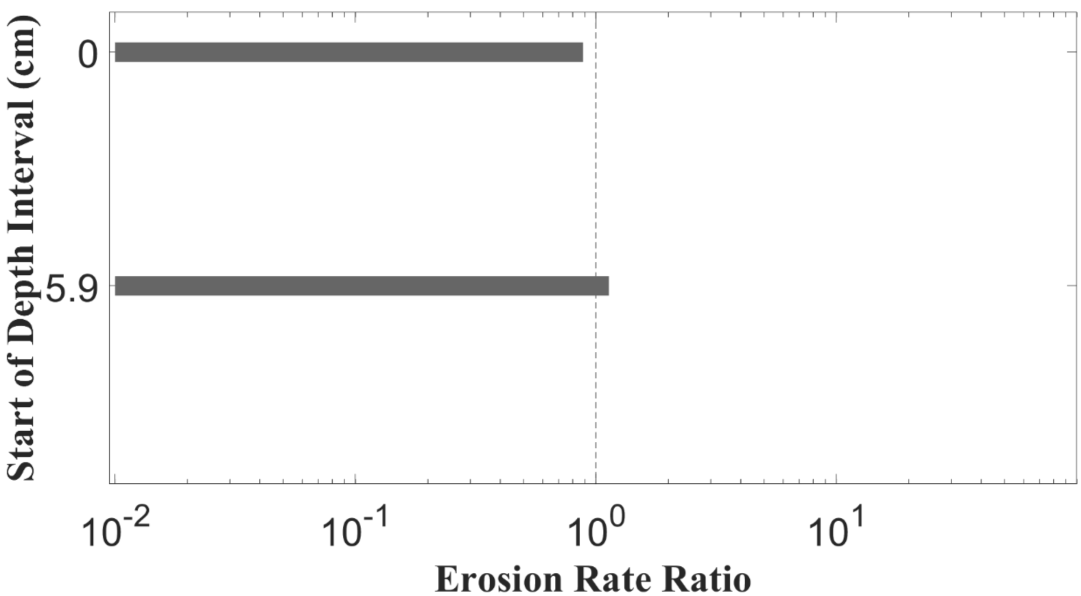


Figure 11. Intracore erosion rates in NR-130

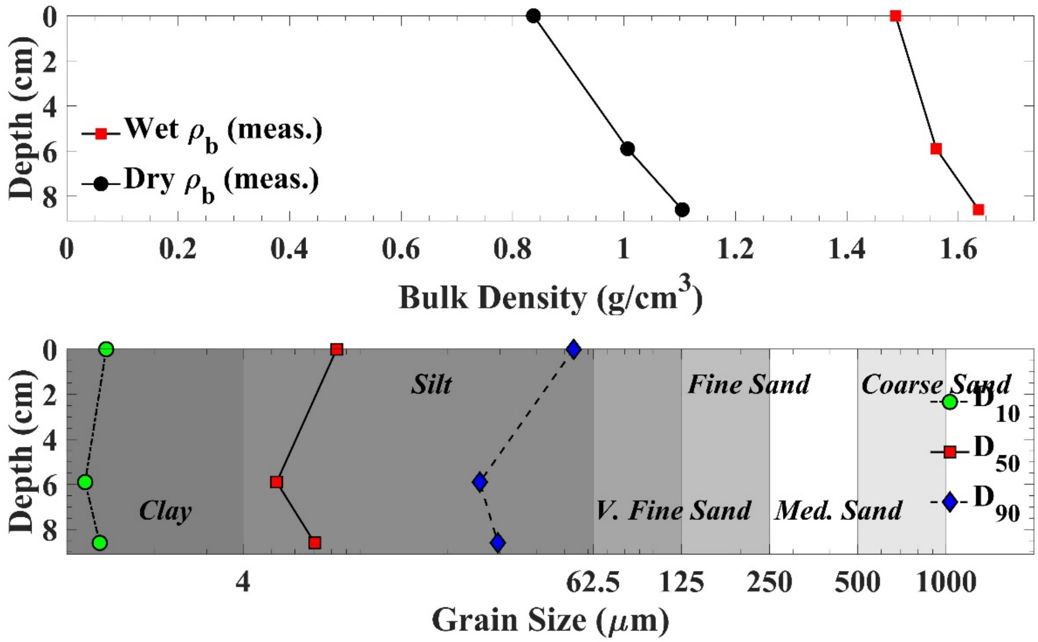


Figure 12. Physical properties of NR-130 with depth

Table 7. Physical properties and derived critical shear stresses of NR-130

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm³)	Dry Bulk Density (g/cm³)	Loss on Ignition (%)	Tau_no (Pa)	Tau_first (Pa)	Tau Crit Linear (Pa)	Tau Crit Power (Pa)	Final Critical Shear (Pa)
0.0	8.34	1.49	0.84	3.7%	0.2	0.4	0.84	0.33	0.33
5.9	5.2	1.56	1.01	6.8%	0.4	0.8	0.44	0.29	0.4
8.6	7.01	1.64	1.1	5.0%	---	---	---	---	---
Mean	6.85	1.56	0.98	5.2%	0.30	0.60	0.64	0.31	0.37

Table 8. Power law fit parameters for NR-130

Interval	Depth Start (cm)	Depth Finish (cm)	A	n	r^2
1	0.0	5.7	8.57E-06	2.04	0.78
2	5.9	12.6	1.01E-05	2.13	0.88

2.4 SED-NR-164

Core NR-164 was collected on the eastern bank of the Neosho River downstream of the confluence of the Neosho and Spring rivers. Sampling required light blows from the post-hammer and resulted in the recovery of 41 cm of sediment. Recovered material appeared dark brown or olive in color with a lighter oxidized layer 1–2 cm on the surface. Sediment less than 10 cm from the surface showed signs of biotic activity and contained leaves and twigs.

A photograph of the recovered sediment aligned with applied shear stresses and resulting erosion rates is presented in Figure 13. Shear stresses ranging from 0.1 to 12.8 Pa were applied to six intervals of sediment in the upper 25 cm of sample. The first interval extended 1.8 cm from the original surface and ended when the unconsolidated material was eroded away leaving a much firmer looking, gray material. In subsequent intervals, bedded material did not respond to applied shear stresses less than 1.6 Pa. The material contained worms (Figure 14) and their structures and eroded in pieces or in some instances larger episodes of multiple millimeters of sediment peeled away. The sediment in intervals 2 through 6 behaved in a similar way to the applied shear stresses (Figure 15).

Low-density surface material gave way to generally denser material down-core. Sediment grain size distributions varied with some sand present intermittently around 10 cm below the recovered surface (Figure 16, Table 9). Derived critical shear stresses ranged from 0.12 at the surface to a uniform 0.8 Pa at deeper intervals. The 0.8 value was determined using the criteria in Section 1.2.2.1 because the critical shear stress derived using the power law fell below the *tau_no* value. Power law fit parameters indicate that despite the critical shear stress values being lower than the *tau_no*, there is still generally good agreement with the erosion rates and shear stresses (Table 10).

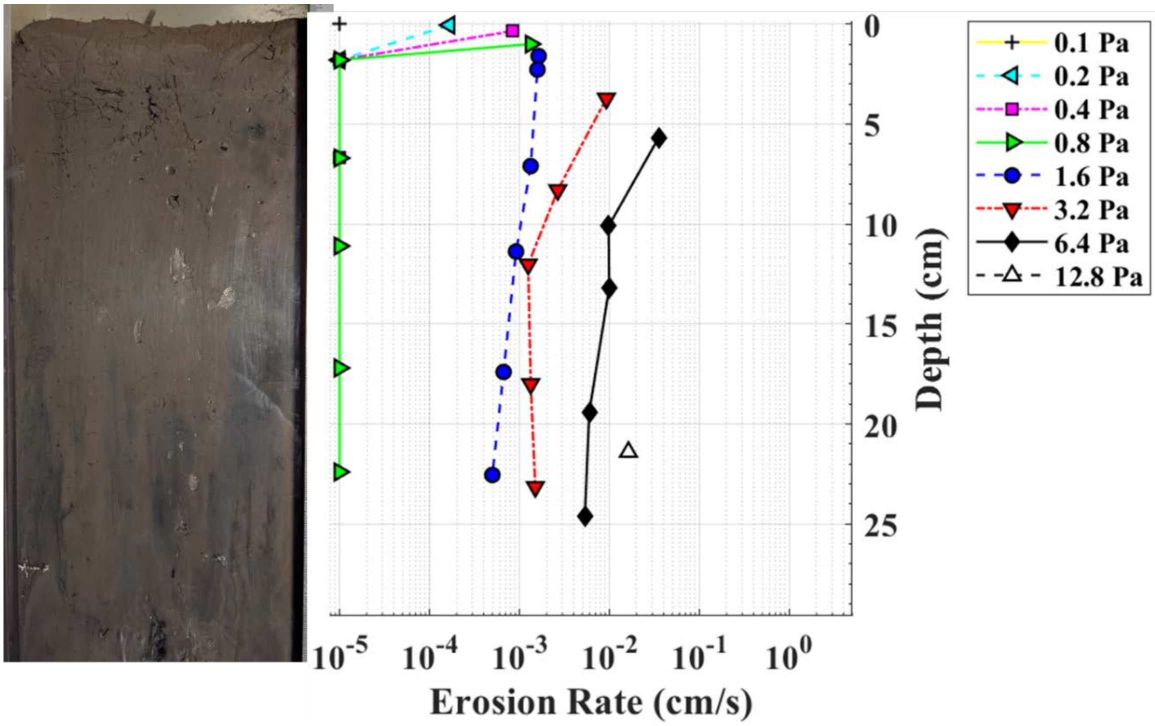


Figure 13. Photograph of Core NR-164 aligned with applied shear stresses and associated erosion rates

Figure 14. Grouping of invertebrates in NR-164

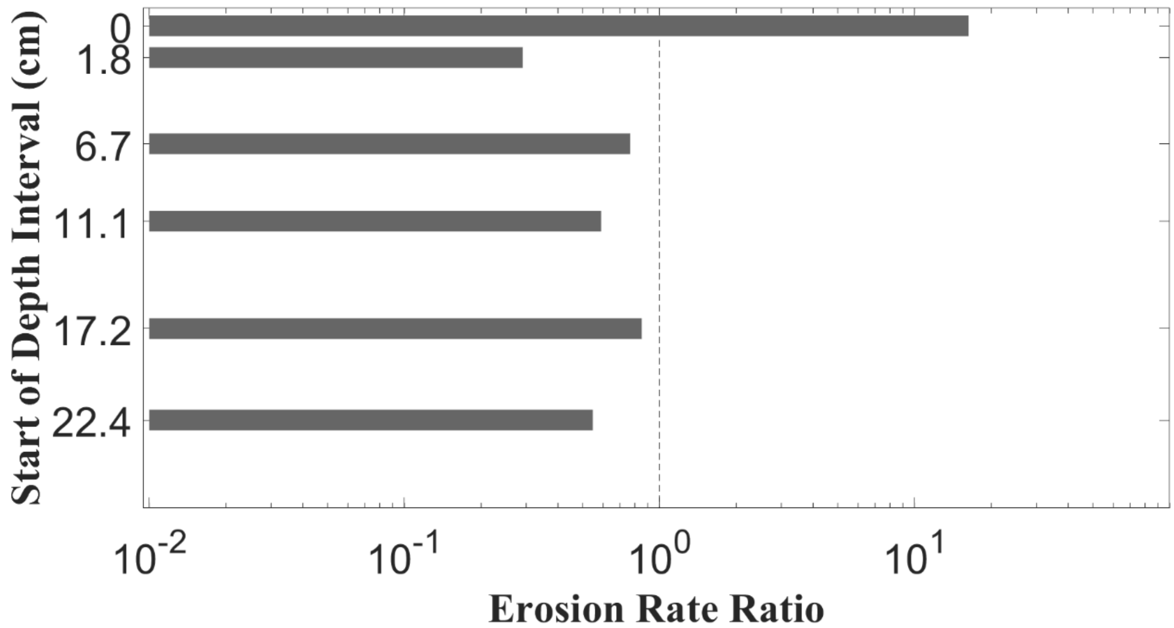


Figure 15. Intracore erosion rates in NR-164

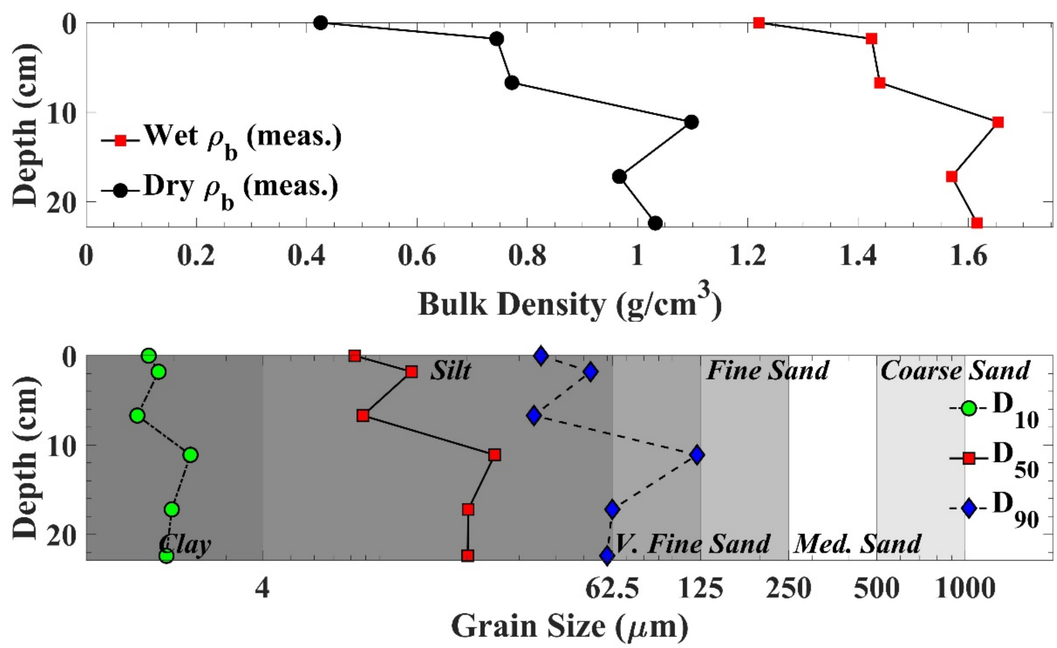


Figure 16. Physical properties of NR-164 with depth

Table 9. Physical properties and derived critical shear stresses of NR-164

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm³)	Dry Bulk Density (g/cm³)	Loss on Ignition (%)	Tau_no (Pa)	Tau_first (Pa)	Tau Crit Linear (Pa)	Tau Crit Power (Pa)	Final Critical Shear (Pa)
0.0	8.25	1.22	0.43	5.9%	0.1	0.2	0.16	0.12	0.12
1.8	12.89	1.42	0.74	4.4%	0.8	1.6	0.86	0.73	0.8
6.7	8.8	1.44	0.77	4.6%	0.8	1.6	0.86	0.68	0.8
11.1	24.8	1.65	1.1	2.9%	0.8	1.6	0.89	0.77	0.8
17.2	20.15	1.57	0.97	3.3%	0.8	1.6	0.92	0.75	0.8
22.4	20.05	1.62	1.03	2.7%	0.8	1.6	0.96	0.85	0.85
Mean	15.82	1.49	0.84	4.0%	0.68	1.37	0.78	0.65	0.70

Table 10. Power law fit parameters in NR-164

Interval	Depth Start (cm)	Depth Finish (cm)	A	n	r^2
1	0.0	1.8	7.93E-05	1.24	0.88
2	1.8	6.7	3.32E-07	2.87	0.96
3	6.7	11.1	1.68E-06	2.14	0.92
4	11.1	14	1.31E-06	2.12	0.93
5	17.2	22.4	2.41E-06	1.85	0.97
6	22.4	25.6	1.33E-06	2.02	0.98

2.5 SED-NR-202

Core NR-202 was collected on March 10, 2020, at 4:35 p.m. in 5 ft of water. The sediment bed resisted penetration and required multiple blows from a post-hammer to achieve a core recovery length of 23 cm from the eastern bank along the inside bend of the Neosho River. A 3.5 cm layer of oxidized, unconsolidated sediment covered dark, anoxic silty material. The presence of visible worm tubes in the upper 7 cm of sediment suggests that observations on the undisturbed surface are the result of bioturbation and biotic mounds.

A photograph of NR-202 aligned with applied shear stresses and resulting shear stresses highlights the reduction in erodibility with depth (Figure 17). The surface sediment eroded at lower shear stresses and more easily than the material below (Figure 15). The reduction in erodibility correlates with the increase in density with depth (Figure 16, Table 11). Critical shear stresses ranges from 0.15 to 1.14 and fit parameters indicate excellent agreement in measurements and the use of a power law relationship (Table 12). When erosion occurred, sediment suspended in the form of cloud erosion at the surface and individual grains and pieces of the bed as depth increased.

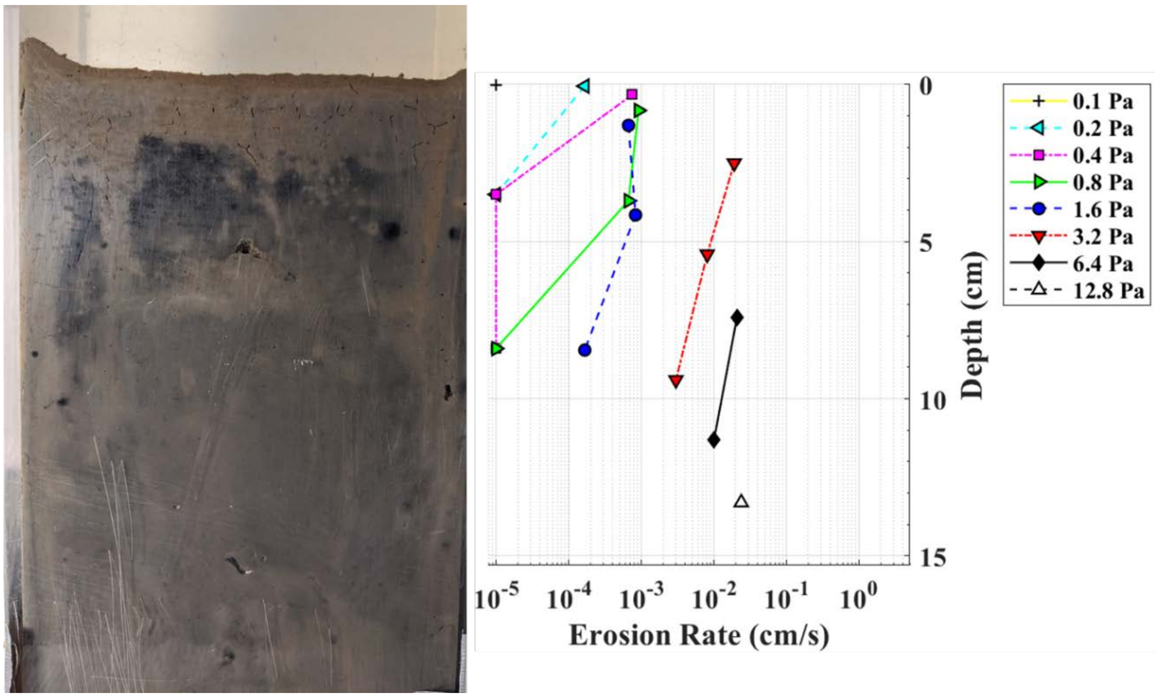


Figure 17. Photograph of Core NR-202 aligned with applied shear stresses and associated erosion rates

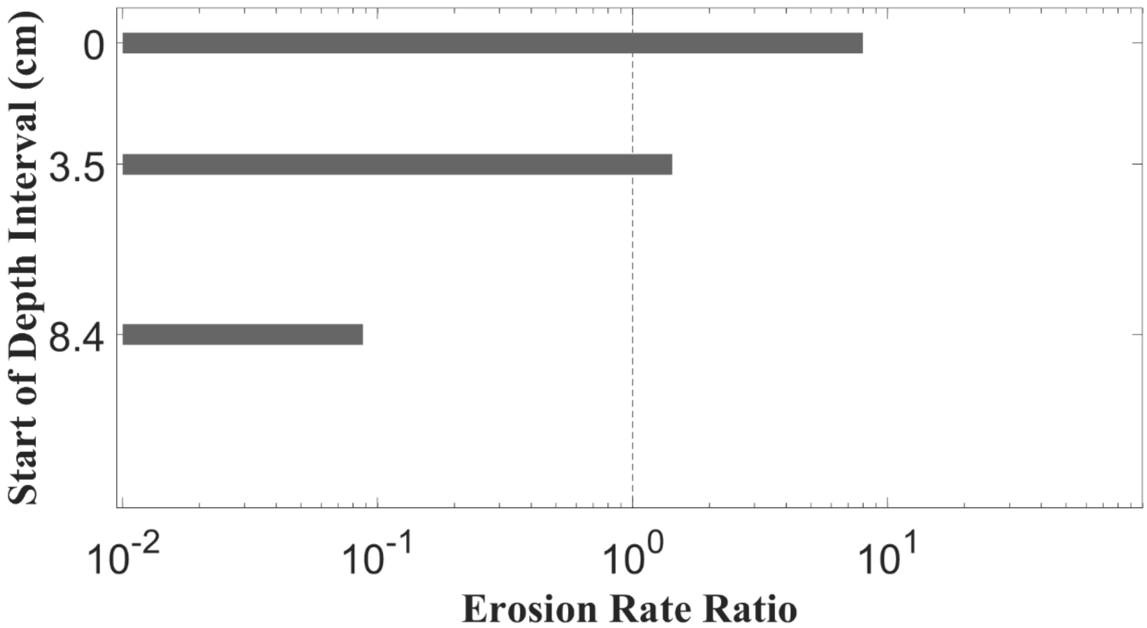


Figure 18. Intracore erosion rates in NR-202

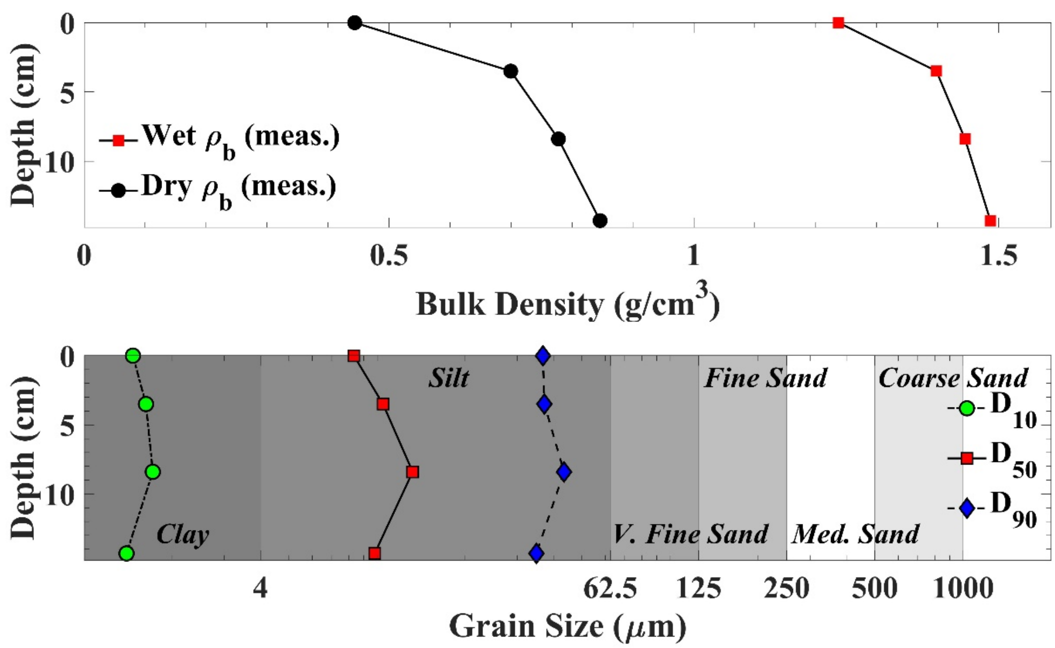


Figure 19. Physical properties of NR-202 with depth

Table 11. Physical properties and derived critical shear stresses of NR-202

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm^3)	Dry Bulk Density (g/cm^3)	Loss on Ignition (%)	Tau_no (Pa)	Tau_first (Pa)	Tau Crit Linear (Pa)	Tau Crit Power (Pa)	Final Critical Shear (Pa)
0.0	8.33	1.24	0.44	5.1%	0.1	0.2	0.16	0.15	0.15
3.5	10.47	1.4	0.7	4.3%	0.4	0.8	0.46	0.41	0.41
8.4	13.22	1.44	0.78	4.4%	0.8	1.6	1.28	1.14	1.14
14.3	9.81	1.49	0.85	4.4%	---	---	---	---	---
Mean	10.46	1.39	0.69	4.6%	0.43	0.87	0.63	0.57	0.57

Table 12. Power law fit parameters for NR-202

Interval	Depth Start (cm)	Depth Finish (cm)	A	n	r^2
1	0.0	3.5	5.85E-05	1.39	0.8
2	3.5	8.4	6.22E-06	1.97	0.95
3	8.4	14.3	2.43E-07	2.48	0.95

2.6 SED-NR-CB

Core NR-CB was collected on the Neosho River north of Connors Bridge at 5:02 p.m. on March 11, 2020. Sampling occurred on the bank of the river away from the known gravel and rocky substrate in the center of the river. The steep slope of the bank resulted in multiple attempts to collect a sample. Samples were pushed by hand in the upper 10 cm but required post-hammer blows to recover 32 cm of sediment.

A photograph of NR-CB aligned with applied shear stresses and resulting erosion rates is presented in Figure 20. Light gray sediment at the surface contained evidence of biotic activity that extended up to 12 cm into the sediment bed. Below the surface layer, sediment was silty in texture and transitioned from olive to dark gray material approximately 15 cm below the surface. Resulting erosion rates varied with the most erodible sediment occurring in the second interval (Figure 21). This may be due to the effects of wetting and drying associated with the shallow bank where the core was collected.

Variations in density mimic trends in erodibility but median grain sizes generally increased throughout the sample (Figure 22, Table 13). Critical shear stresses also varied in a similar manner to density ranging from 0.2 in interval 2 to 0.8 Pa at interval 5. Fit parameters indicate good and excellent fits relating shear stress to erosion rate (Table 14).

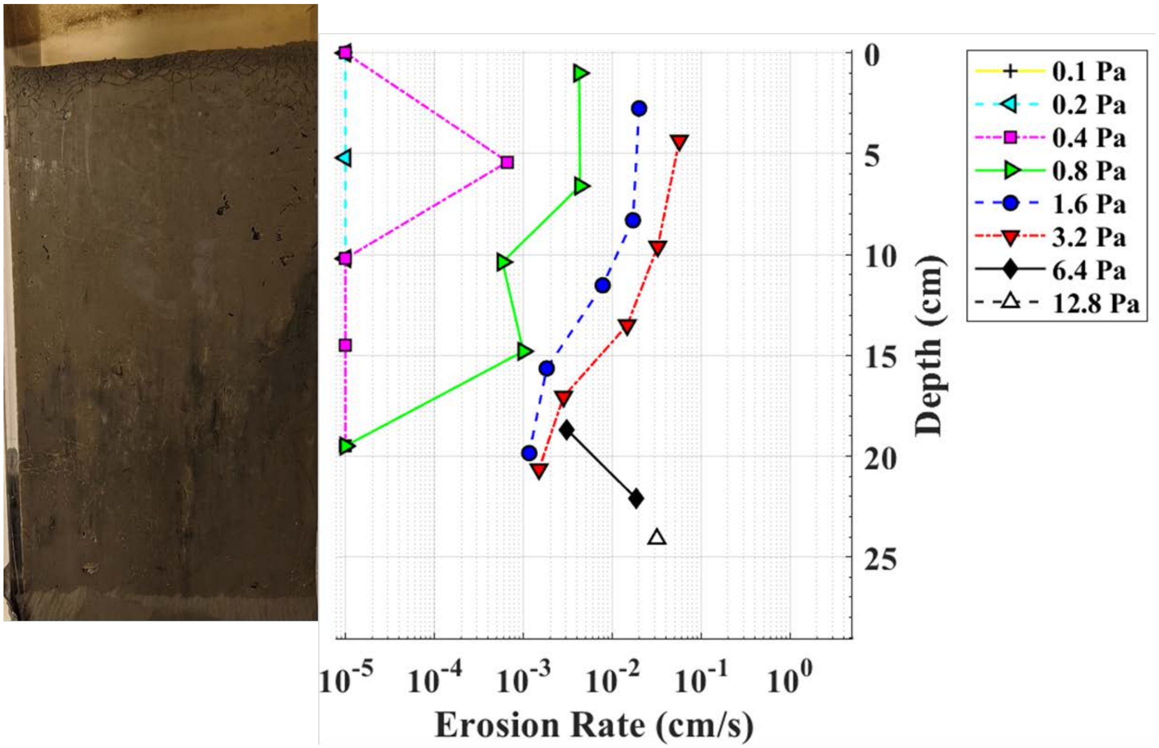


Figure 20. Photograph of Core NR-CB aligned with applied shear stresses and associated erosion rates

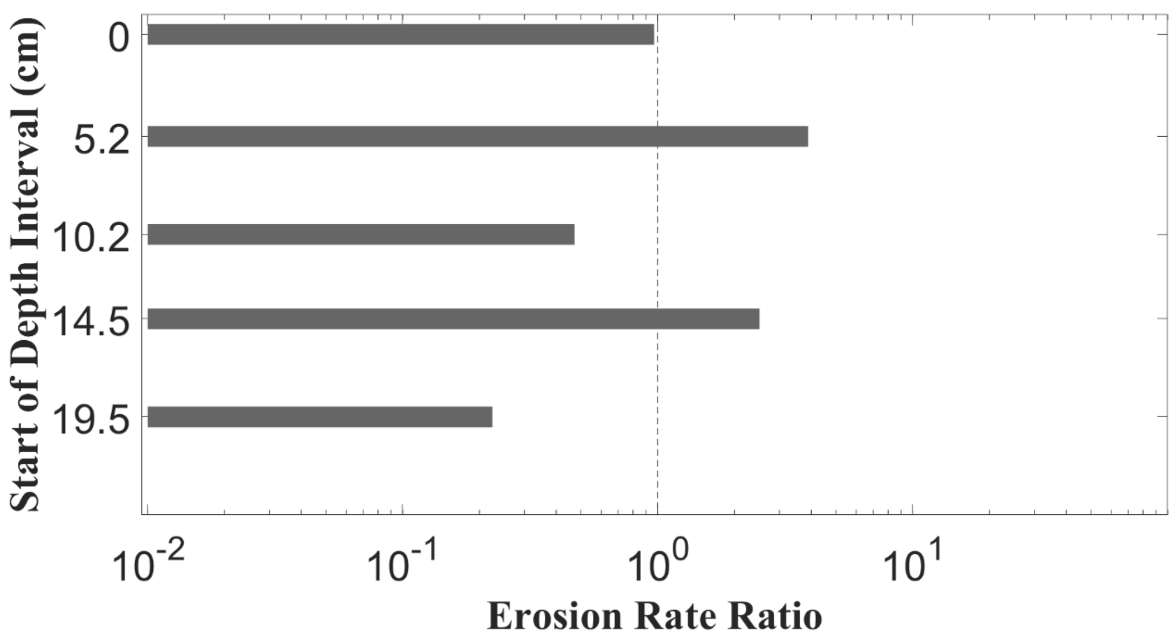


Figure 21. Intracore erosion rates in NR-CB

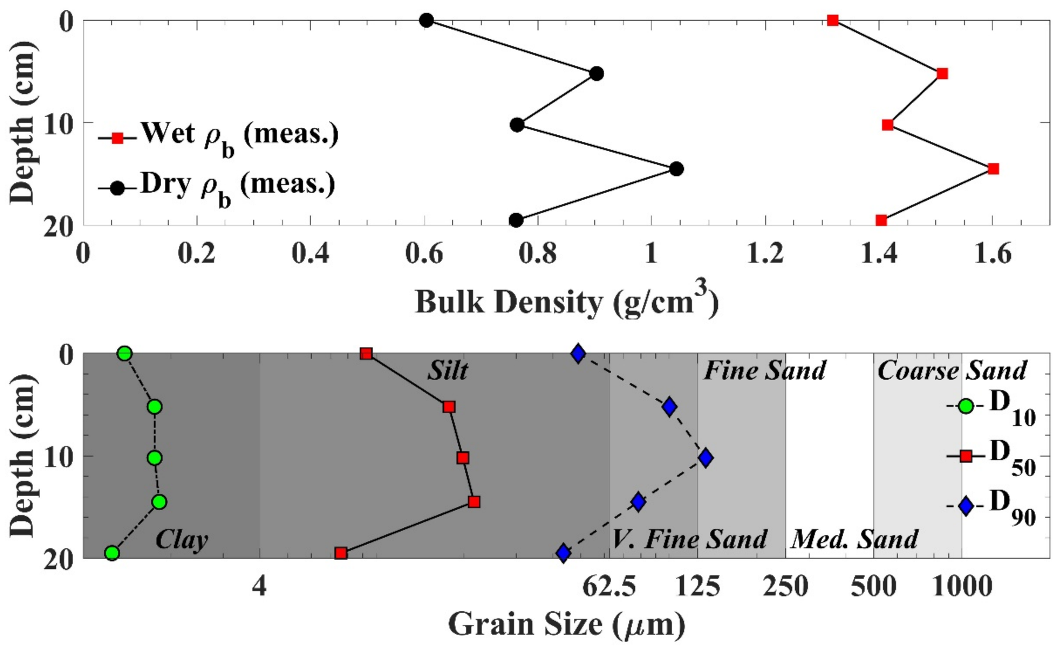


Figure 22. Physical properties of NR-CB with depth

Table 13. Physical properties and derived critical shear stresses of NR-CB

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm³)	Dry Bulk Density (g/cm³)	Loss on Ignition (%)	Tau_no (Pa)	Tau_first (Pa)	Tau Crit Linear (Pa)	Tau Crit Power (Pa)	Final Critical Shear (Pa)
0.0	9.23	1.32	0.6	7.0%	0.4	0.8	0.41	0.31	0.4
5.2	17.73	1.51	0.9	5.4%	0.2	0.4	0.23	0.18	0.2
10.2	19.76	1.42	0.76	6.8%	0.4	0.8	0.47	0.42	0.42
14.5	21.58	1.6	1.04	4.9%	0.4	0.8	0.45	0.21	0.4
19.5	7.58	1.4	0.76	8.0%	0.8	1.6	0.87	0.7	0.8
Mean	15.18	1.45	0.81	6.4%	0.44	0.88	0.49	0.36	0.44

Table 14. Power law fit parameters in NR-CB

Interval	Depth Start (cm)	Depth Finish (cm)	A	n	r^2
1	0.0	5.2	3.24E-06	2.99	0.91
2	5.2	10.2	2.62E-05	2.21	0.96
3	10.2	14.5	2.05E-06	2.7	0.94
4	14.5	19.5	4.31E-05	1.16	0.75
5	19.5	25.1	1.66E-06	2.1	0.94

2.7 SED-NR-FG

Core NR-FG was collected near the Miami fairgrounds on March 11, 2020, at 11:00 a.m. The 23 cm length of core was collected from the east bank of the river. The area was noted to be seasonally wet and dry by the FreshWater Engineering team members. The surface was covered in clumps of sediment and resisted penetration from the coring system due to the presence of stiff sediment. Sediment at NR-FG was light gray or tan with evidence of anoxic patches as depth increased.

A photograph of NR-FG with applied shear stresses and resulting erosion rates is presented in Figure 23. Shear stress was applied successfully to three intervals of the sample. The loose surface material that formed broken clumps was tested for grain size distribution and density but was not considered for critical shear stress determination. To reduce anthropogenic disturbance, the clumpy material was subjected to a 1.6 Pa flow that removed the clumps from the surface. After their removal, processing took place as normal. Sediment properties remained relatively constant with depth but erodibility (and subsequently critical shear stress) declined as depth increased (Figure 24, Figure 25).

Critical shear stresses increased an order of magnitude from 0.4 Pa at interval 1 to 2.46 Pa in interval 3 located 10 cm below the surface (Table 15). Sediment eroded unevenly across the surface and sporadically during the application of shear stresses. The sediment appeared to be crumbly and eroded by pieces breaking away often resulting in a subsequent event occurring where more particles or pieces eroded. Power law fit parameters provided in Table 16 were used to determine the critical shear stresses for each successful interval.

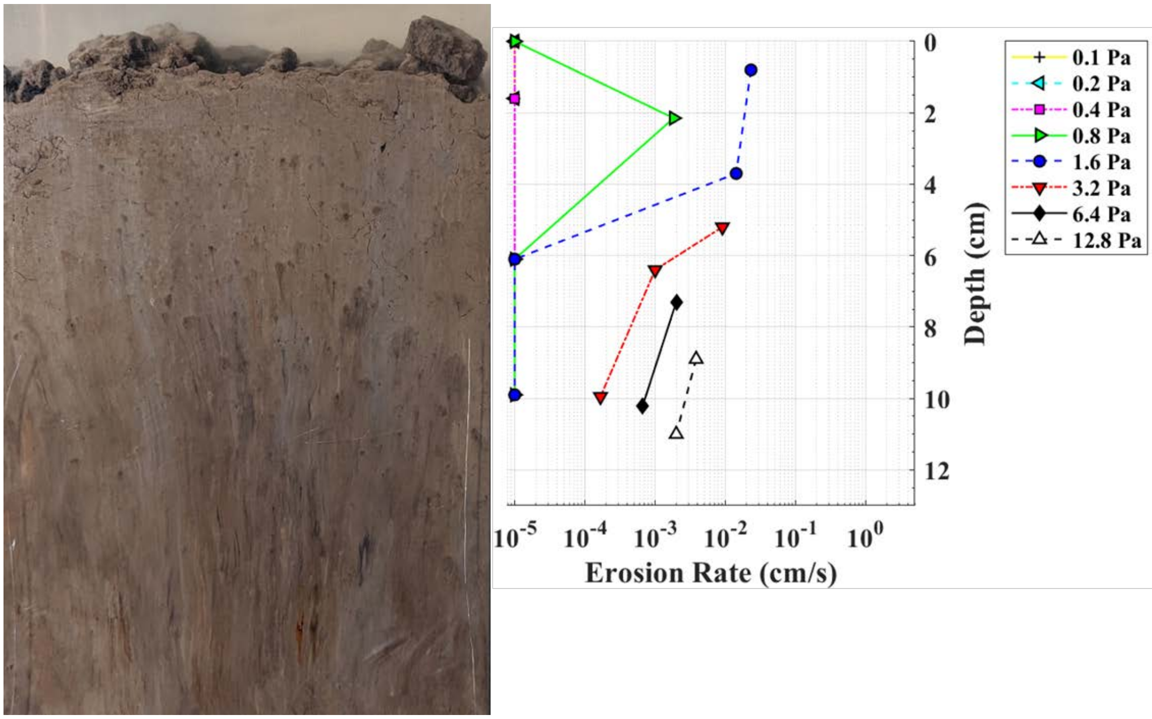


Figure 23. Photograph of Core NR-FG aligned with applied shear stresses and associated erosion rates

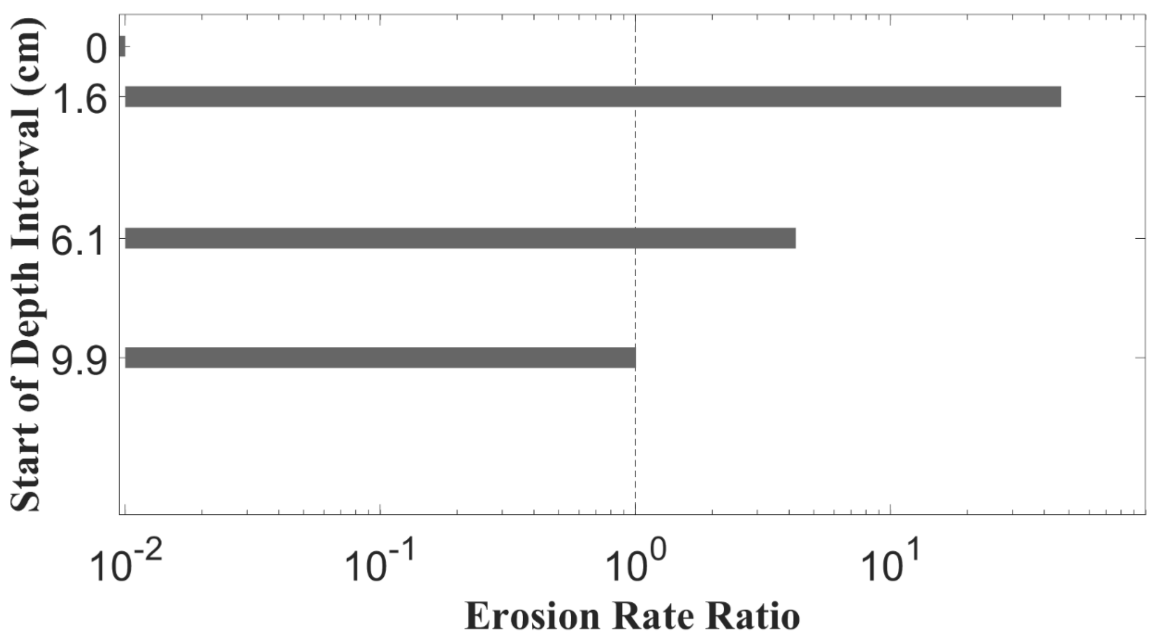


Figure 24. Intracore erosion rates in NR-FG

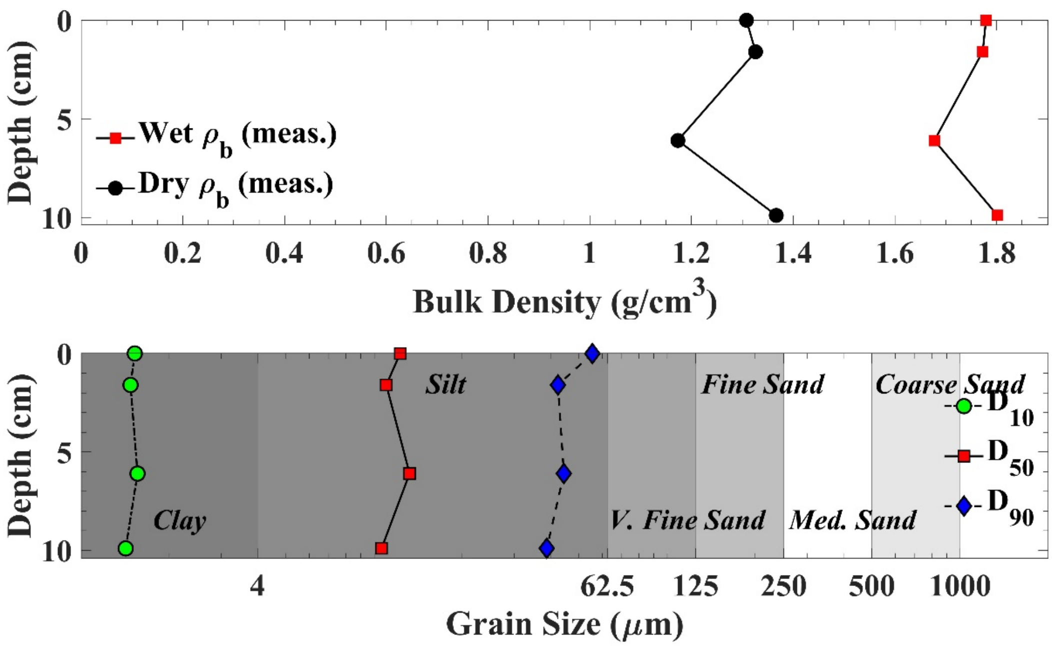


Figure 25. Physical properties of NR-FG with depth

Table 15. Physical properties and derived critical shear stresses of NR-FG

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm³)	Dry Bulk Density (g/cm³)	Loss on Ignition (%)	Tau_no (Pa)	Tau_first (Pa)	Tau Crit Linear (Pa)	Tau Crit Power (Pa)	Final Critical Shear (Pa)
0.0	12.27	1.78	1.31	3.2%	---	---	---	---	---
1.6	11	1.77	1.33	4.8%	0.4	0.8	0.43	0.3	0.4
6.1	13.21	1.68	1.17	5.1%	1.6	3.2	1.77	1.27	1.6
9.9	10.6	1.8	1.37	4.4%	1.6	3.2	2.56	2.46	2.46
Mean	11.77	1.76	1.30	4.4%	1.1	2.2	1.39	1.21	1.32

Table 16. Power law fit parameters in NR-FG

Interval	Depth Start (cm)	Depth Finish (cm)	A	n	r^2
1	---	---	---	---	---
2	1.6	5.7	8.1E-06	2.29	0.79
3	6.1	9.9	1.22E-06	1.73	0.87
4	9.9	11.6	2.57E-07	1.86	1.0

2.8 SED-NR-SB

Core NR-SB was collected in the Neosho River on March 10, 2020, at 2:00 p.m. On the second collection attempt, a 37 cm length of sediment core was collected in 6 ft of water from the center of the river. The sample contained silty, gray sediment with a 2- to 3-cm oxic surface layer and evidence of biotic activity in the upper 10 cm.

Shear stresses ranging from 0.1 to 12.8 Pa were applied to the upper 24.6 cm of collected sediment (Figure 26). The unconsolidated surface layer was easily eroded relative to the rest of the sample. Properties such as erodibility varied with depth (Figure 27). During testing, erosion processes varied from individual grains producing even erosion across the surface to clumps of sediment breaking away leaving an uneven surface. The change in behavior was attributed to variations in grain size within the sediment bed (Figure 28, Table 17). Density increased with depth up to 20 cm below the surface.

Critical shear stresses ranged from 0.27 to 1.6 Pa and generally increased with depth.
Core NR-SB exhibits properties consistent with others from the site by having an erodible, unconsolidated surface layer and more uniform properties in the firmer sediments below. Parameters relating to erosion rate and shear stress suggest good agreement between measurements using a power law fit (Table 18).

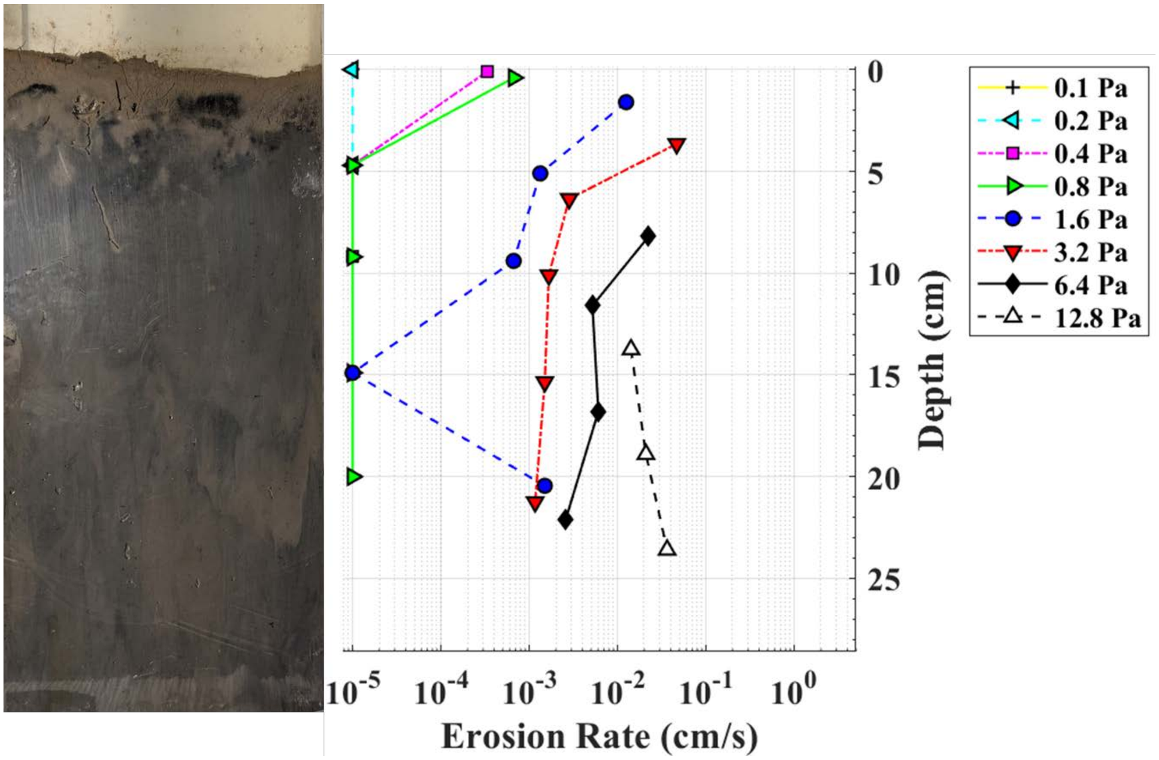


Figure 26. Photograph of Core NR-SB aligned with applied shear stresses and associated erosion rates

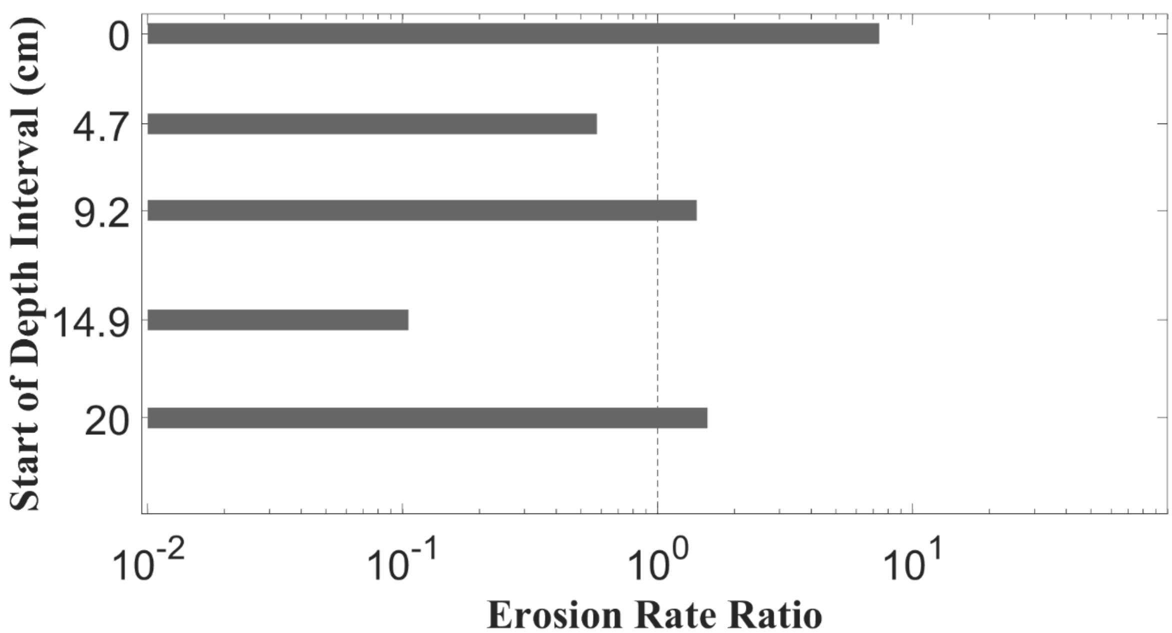


Figure 27. Intracore erosion rates for NR-SB

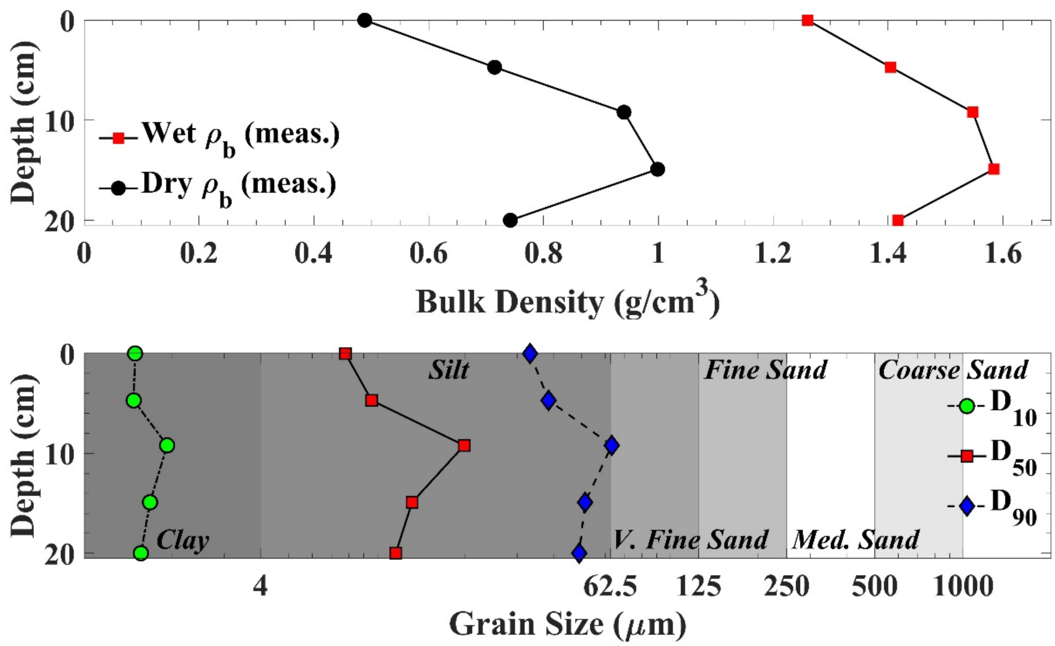


Figure 28. Physical properties of NR-SB with depth

Table 17. Physical properties and derived critical shear stresses of NR-SB

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm³)	Dry Bulk Density (g/cm³)	Loss on Ignition (%)	Tau_no (Pa)	Tau_first (Pa)	Tau Crit Linear (Pa)	Tau Crit Power (Pa)	Final Critical Shear (Pa)
0.0	7.79	1.26	0.49	5.6%	0.2	0.4	0.26	0.27	0.27
4.7	9.57	1.4	0.71	4.6%	0.8	1.6	0.86	0.75	0.8
9.2	19.82	1.55	0.94	3.9%	0.8	1.6	0.92	0.72	0.8
14.9	13.16	1.58	1.00	3.8%	1.6	3.2	1.71	1.41	1.6
20.0	11.57	1.42	0.74	5.1%	0.8	1.6	0.86	0.67	0.8
Mean	12.38	1.44	0.78	4.6%	0.84	1.68	0.92	0.76	0.85

Table 18. Power law fit parameters of NR-SB

Interval	Depth Start (cm)	Depth Finish (cm)	A	n	r^2
1	0.0	4.7	8.24E-06	2.49	0.97
2	4.7	9.2	6.28E-07	2.52	0.95
3	9.2	14.9	2.98E-06	1.79	0.97
4	14.9	20	1.09E-07	2.58	0.95
5	20	24.6	3.21E-06	1.81	0.85

2.9 SED-NR-SC

Core NR-SC was collected on the Neosho River on March 10, 2020, at 5:10 p.m. Located on the outer portion of a bend in the river, collection efforts in 6 ft of water resulted in a core recovery length of 27 cm. Unlike other samples from the Neosho River, NR-SC did not present evidence of biotic activity such as worm tubes, but upon processing, worms and their pathways were intermittently uncovered. In the upper 10 cm, sandier material was mixed with olive silty material (Figure 29).

Applied shear stresses ranged from 0.1 to 12.8 Pa in five intervals. Erosion rates at a given shear stress did not exhibit a consistent trend (Figure 29). The first and fifth intervals are shown to be most erodible but critical shear stresses across the sample ranged from 0.65 Pa, peaking in interval 3 at 1.6 Pa and then decreasing again to 0.8 (Figure 30, Table 19). The changes to critical shear stresses did not follow an obvious pattern with physical properties (Figure 31). Coefficients and fit parameters linking erosion rate and shear stress suggest an excellent power law relationship between the two variables (Table 20).

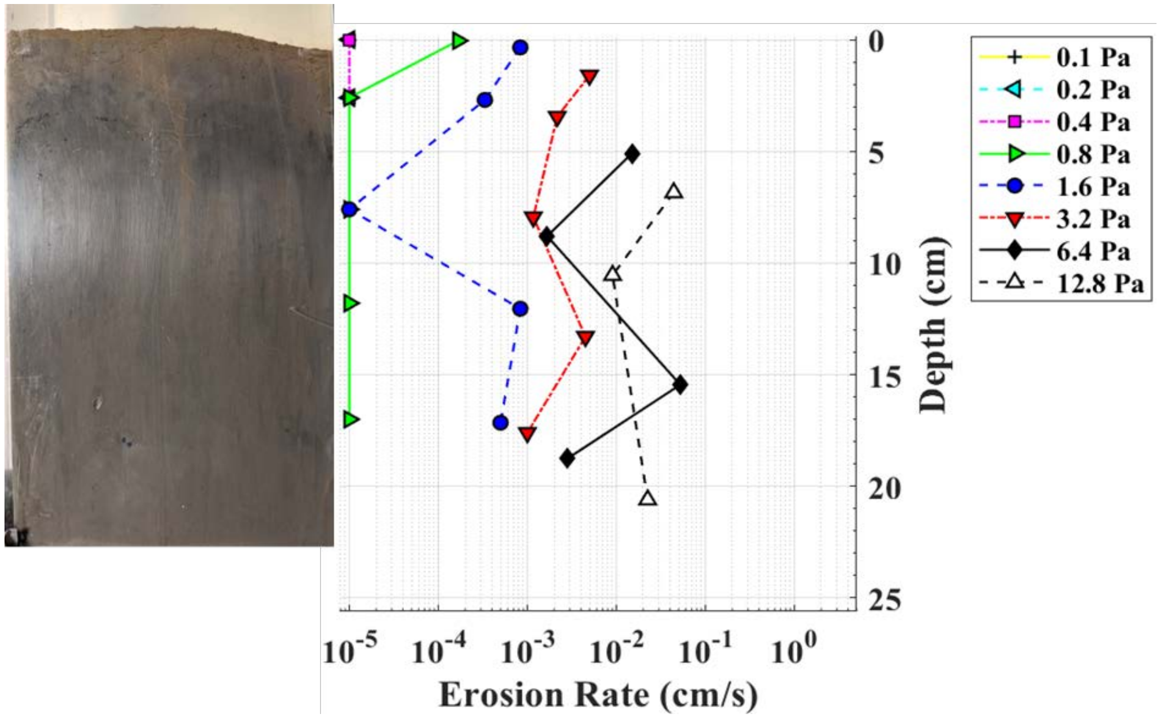


Figure 29. Photograph of Core NR-SC aligned with applied shear stresses and associated erosion rates

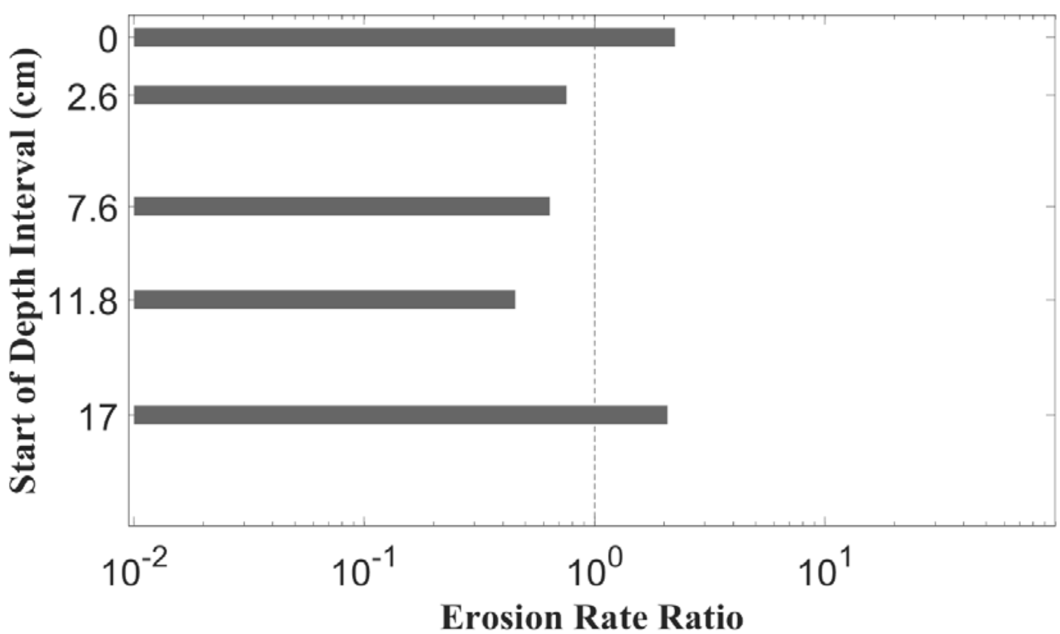


Figure 30. Intracore erosion rates of NR-SC

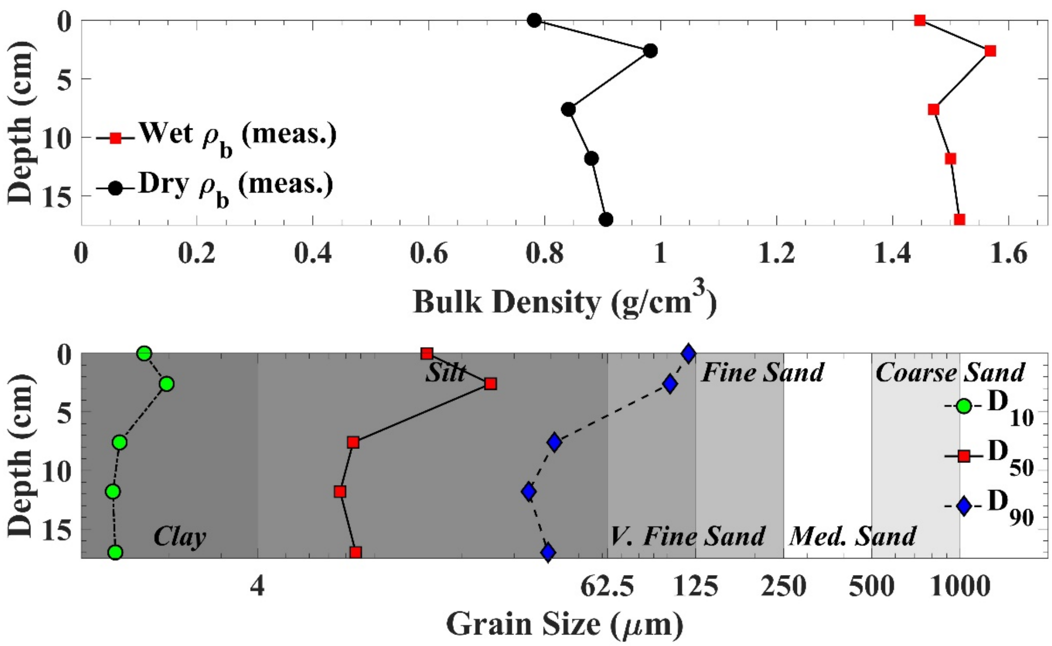


Figure 31. Physical properties of NR-SC with depth

Table 19. Physical properties and derived critical shear stresses of NR-SC

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm³)	Dry Bulk Density (g/cm³)	Loss on Ignition (%)	Tau_no (Pa)	Tau_first (Pa)	Tau Crit Linear (Pa)	Tau Crit Power (Pa)	Final Critical Shear (Pa)
0.0	15.14	1.45	0.78	4.4%	0.4	0.8	0.64	0.65	0.65
2.6	24.98	1.57	0.98	4.4%	0.8	1.6	1.04	0.98	0.98
7.6	8.48	1.47	0.84	5.8%	1.6	3.2	1.74	1.41	1.6
11.8	7.65	1.5	0.88	5.1%	0.8	1.6	0.9	0.87	0.87
17.0	8.65	1.52	0.91	5.1%	0.8	1.6	0.96	0.88	0.88
Mean	12.98	1.50	0.88	5.0%	0.88	1.76	1.06	0.96	1.00

Table 20. Power law fit parameters of NR-SC

Interval	Depth Start (cm)	Depth Finish (cm)	A	n	r^2
1	0.0	2.6	1.08E-06	2.42	1.0
2	2.6	7.6	3.45E-07	2.49	0.99
3	7.6	11.8	4.26E-07	2.06	0.92
4	11.8	16.6	1.19E-07	3.11	0.99
5	17.0	21.6	1.59E-06	1.91	0.97

2.10 SED-SR-100

Core SR-100 was collected in 5 ft of water on March 10, 2020, at 11:40 a.m. SR-100 is located on the Spring River and is the northernmost sample collected. Sampling took place on the eastern bank to avoid the steep slope and rocky bed on the western bank and resulted in the collection of 43 cm of sediment. Soft, brown sediment with pockets of sand and leafy debris extended throughout the sample (Figure 32). The surface contained evidence of invertebrate activity but evidence down-core was difficult to ascertain due to the presence of leaves and plant matter. Pockets present in the photograph may be attributed to biotic activity or gas pockets of decaying matter.

Applied shear stresses ranging from 0.1 to 6.4 Pa were applied to SR-100 over 26.2 cm of the recovered sample (Figure 33). Erosion rates at a specified shear stress generally decreased with depth (Figure 36). Because of the sandy material present, sediment eroded in individual grains in bedload and "clouds" as shear stress increased. Leaves and plant matter affected the sediment by alternatively sheltering sediment below and then eroding in events as the leaves broke away from the surface. The concentration of leafy material increased with depth.

Physical properties varied with depth with density increasing and grain size changing depending on the quantity of sand present (Figure 37, Table 21). Critical shear stresses increased with depth and ranged from 0.11 to 0.41 Pa. Each interval spanned approximately 5 cm of sediment and fit parameters suggest an excellent relationship using a power law relationship between erosion rate and critical shear stress (Table 22).

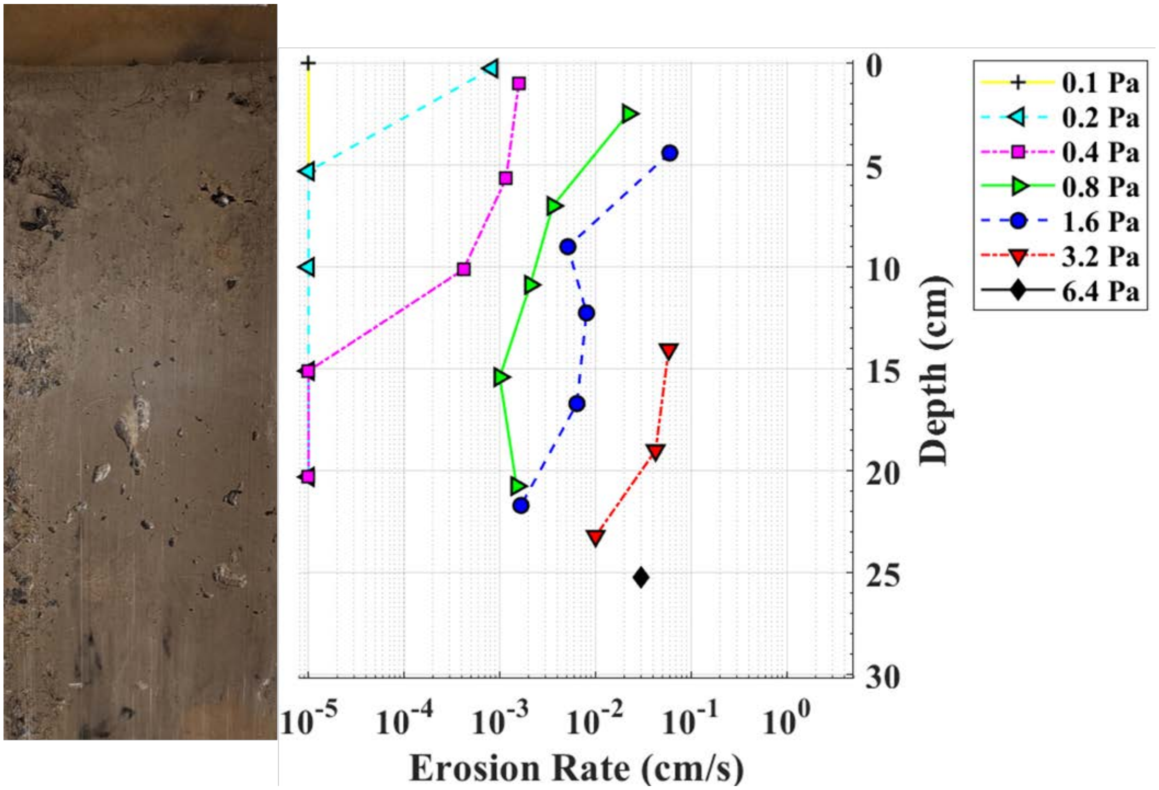


Figure 32. Photograph of Core SR-100 aligned with applied shear stresses and associated erosion rates

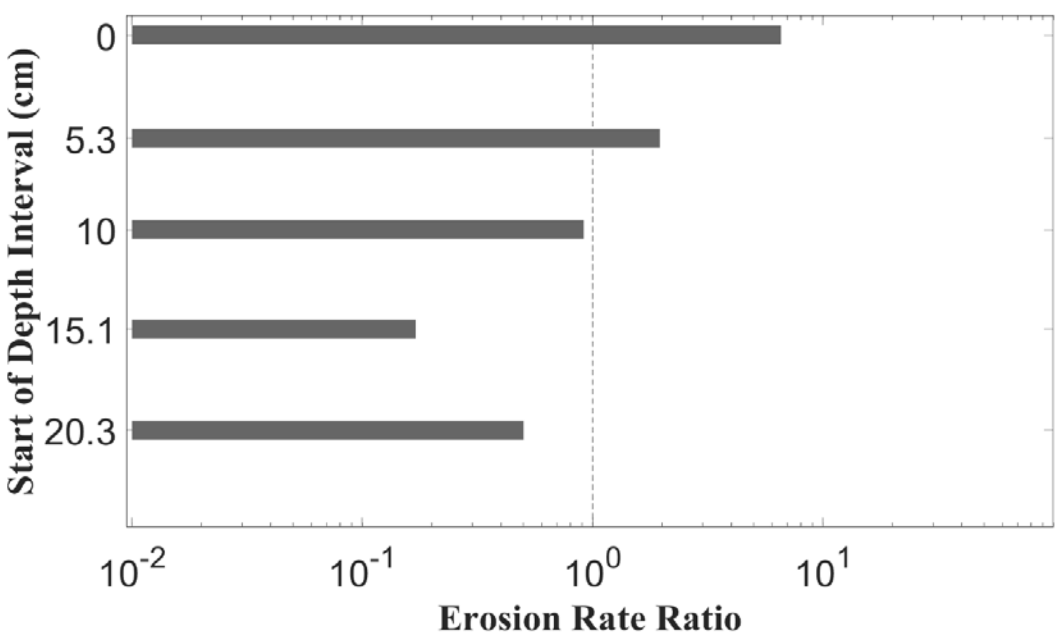


Figure 33. Intracore erosion rates for SR-100

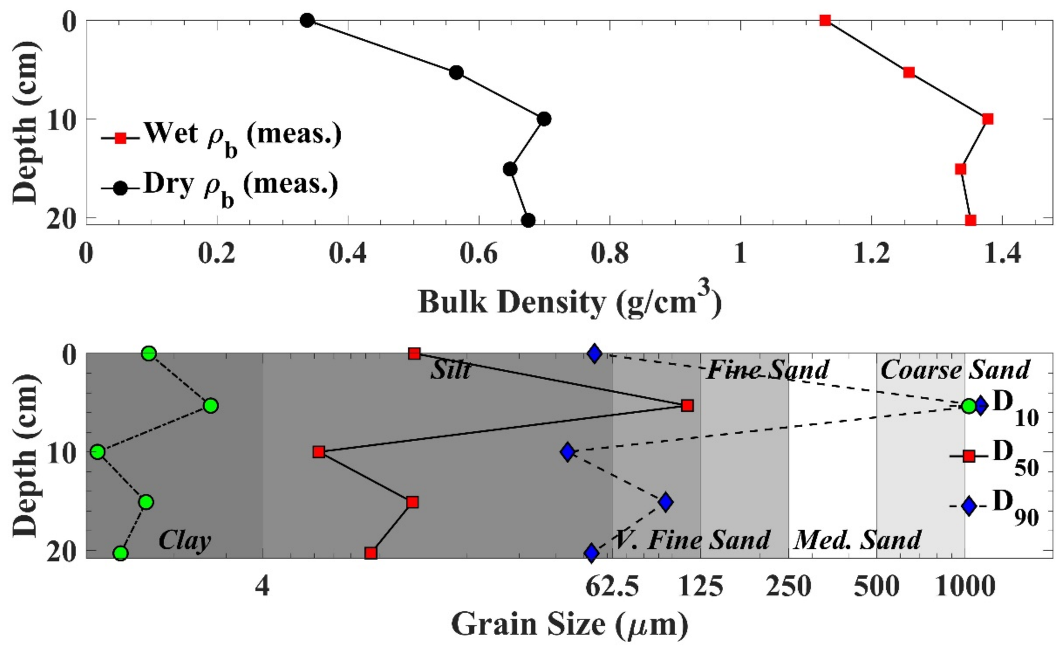


Figure 34. Physical properties of SR-100 with depth

Table 21. Physical properties and derived critical shear stresses of SR-100

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm³)	Dry Bulk Density (g/cm³)	Loss on Ignition (%)	Tau_no (Pa)	Tau_first (Pa)	Tau Crit Linear (Pa)	Tau Crit Power (Pa)	Final Critical Shear (Pa)
0.0	13.2	1.13	0.34	11.6%	0.1	0.2	0.12	0.11	0.11
5.3	112.8	1.26	0.57	12.1%	0.2	0.4	0.22	0.16	0.2
10	6.22	1.38	0.7	6.8%	0.2	0.4	0.25	0.24	0.24
15.1	13	1.34	0.65	8.1%	0.4	0.8	0.45	0.41	0.41
20.3	9.37	1.35	0.68	8.2%	0.4	0.8	0.43	0.32	0.4
Mean	30.92	1.29	0.59	9.4%	0.26	0.52	0.29	0.25	0.27

Table 22. Power law fit parameters of SR-100

Interval	Depth Start (cm)	Depth Finish (cm)	A	n	r^2
1	0.0	5.3	8.79E-05	2.43	0.97
2	5.3	10.0	4.14E-05	1.92	0.86
3	10.0	15.1	1.24E-05	2.41	1.0
4	15.1	20.3	1.34E-06	3.03	0.99
5	20.3	26.2	1.03E-05	1.95	0.93

2.11 SED-SR-114

Core SR-114 was collected on the Spring River on March 10, 2020, at 12:30 p.m. Located on the western bank in 5 ft of water, the bed allowed easy penetration and only one attempt was needed to recover 41 cm of sediment. The sample contained a variable mixture of organic matter, biotic activity, and sandy regions amid the predominantly silty material. A thin surface layer less than 1 cm of lighter, unconsolidated sediment was present over the olive colored mixture of silt, sand, and clay.

Applied shear stresses aligned with the core SR-114 ranged from 0.1 to 3.2 Pa in five intervals (Figure 35). Responses to individual shear stresses did not follow a consistent pattern relative to depth but overall erodibility decreased with depth (Figure 35, Figure 36). Resulting critical shear stresses determined from the power law fit and *tau_no* values ranged from 0.2 to 0.4 Pa. The under-prediction of critical shear stress by the power law fit method is attributed to the volume of organic matter in the core that can alter erosion mechanisms. The organic matter at times shielded the bed from erosion until giving way in larger events, slowing the rate of erosion measured in the 10-minute period of applied shear stress. An example of the woody debris found in the core is shown in Figure 38. However, the fit parameters still suggest that a power law relationship provides a good relationship overall for erosion rate and applied shear stress once the critical shear stress has been met (Table 24). The sandy sediment eroded in individual grains and streams of grains around the organic matter and left uneven surfaces of the firmer silt and clay mixtures. Erodibility trends correlated with the increase in density and grain size distributions. The noted trends were potentially modulated by the amount of sandy material in the interval (Figure 37, Table 23).

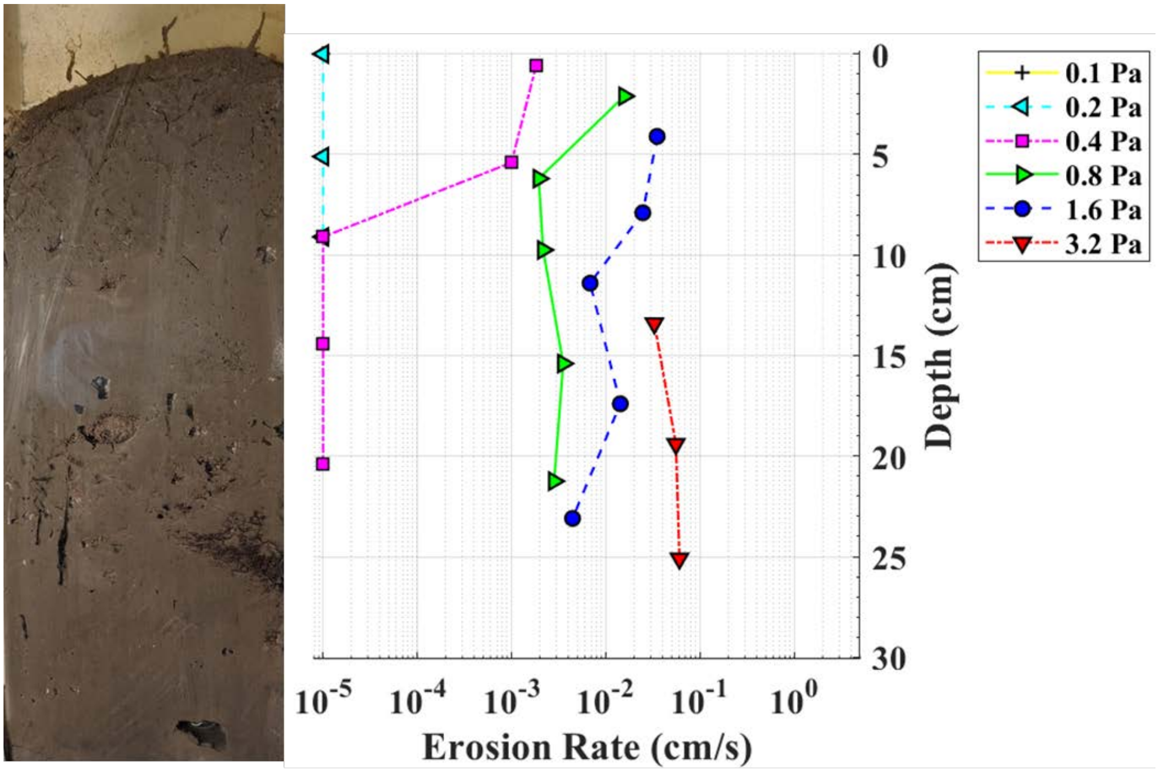


Figure 35. Photograph of Core SR-114 aligned with applied shear stresses and associated erosion rates

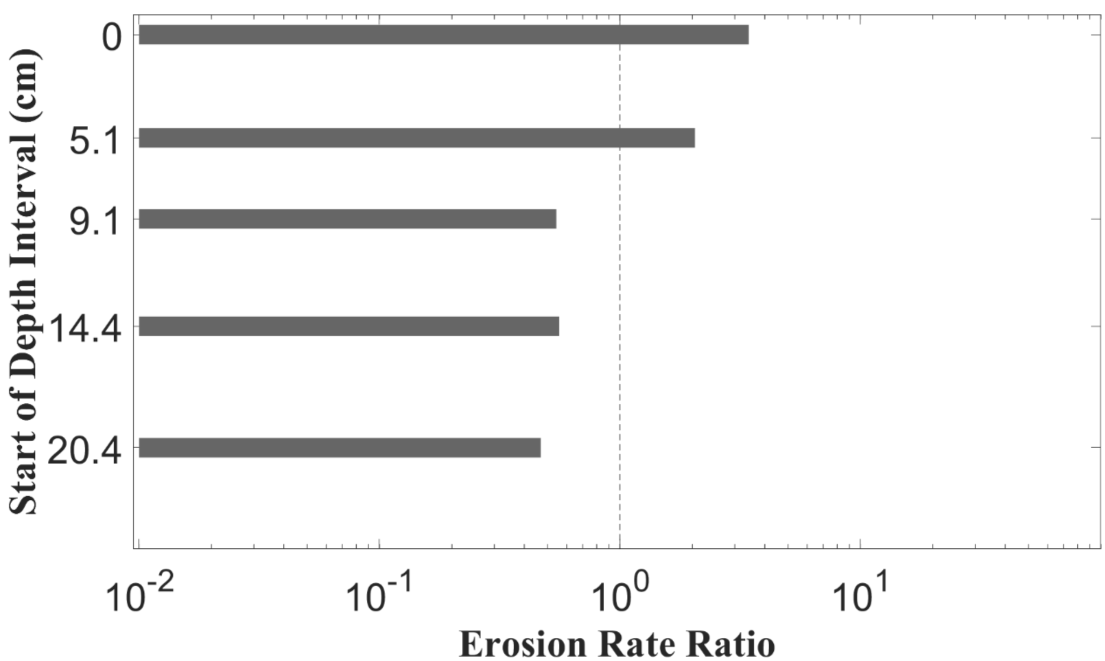


Figure 36. Intracore erosion rates of SR-114

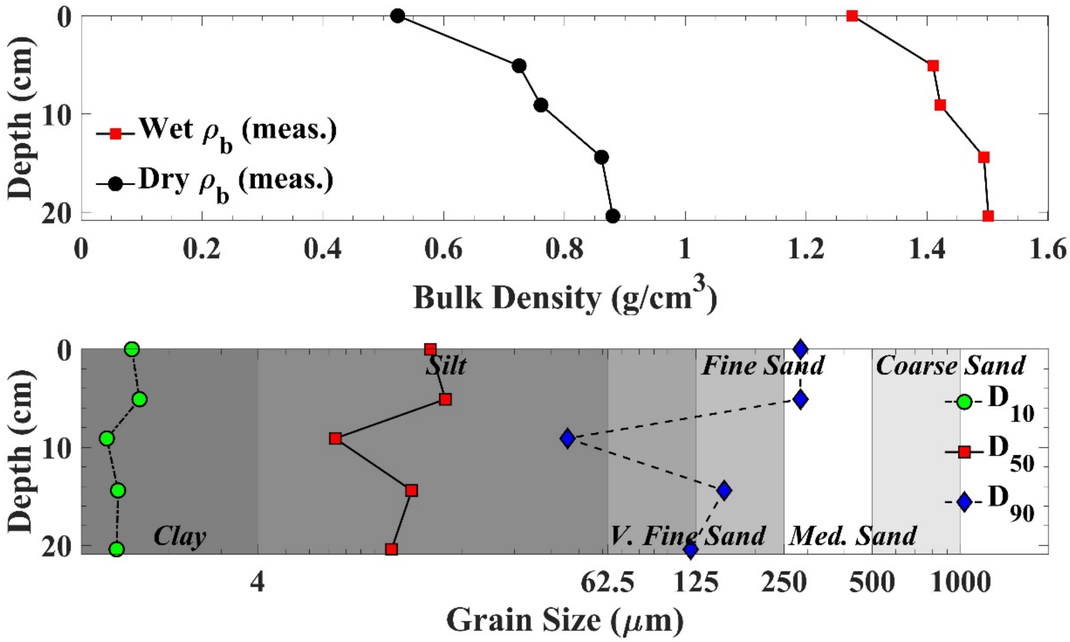


Figure 37. Physical properties of SR-114 with depth

Figure 38. Wood chips found in SR-114

Table 23. Physical properties and derived critical shear stresses of SR-114

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm^3)	Dry Bulk Density (g/cm^3)	Loss on Ignition (%)	Tau_no (Pa)	Tau_first (Pa)	Tau Crit Linear (Pa)	Tau Crit Power (Pa)	Final Critical Shear (Pa)
0.0	15.53	1.28	0.52	6.2%	0.2	0.4	0.22	0.18	0.2
5.1	17.47	1.41	0.72	4.7%	0.2	0.4	0.23	0.21	0.21
9.1	7.36	1.42	0.76	5.8%	0.4	0.8	0.42	0.34	0.4
14.4	13.42	1.49	0.86	4.5%	0.4	0.8	0.42	0.33	0.4
20.4	11.45	1.5	0.88	4.9%	0.4	0.8	0.42	0.35	0.4
Mean	13.05	1.42	0.75	5.2%	0.32	0.64	0.34	0.28	0.32

Table 24. Power law fit parameters of SR-114

Interval	Depth Start (cm)	Depth Finish (cm)	A	n	r^2
1	0.0	5.1	1.8E-05	2.94	0.93
2	5.1	9.1	1.43E-05	2.63	0.95
3	9.1	14.4	3.49E-06	2.72	0.95
4	14.4	20.4	2.83E-06	2.99	0.93
5	20.4	26.1	2.58E-06	2.89	0.93

2.12 SED-SR-TB

Core SR-TB was collected on March 10, 2020, at 11:10 a.m. in an area north of Highway 60 in the Spring River. The 32 cm long sample was collected on the second attempt after stiff material resisted initial efforts to produce a sufficient recovery length. Recovered sediment contained an unconsolidated surface layer with evidence of biotic activity such as excavation mounds seen in Figure 39. Sediment appeared to have a homogenous, fine texture, with varied color ranging from light gray to olive gray, and contained scattered gas or feeding voids.

Shear stresses applied to SR-TB produced erosion rates that decreased with depth for each shear value (Figure 40). The resulting computed critical shear stresses increased with depth, ranging from 0.2 to 1.73 Pa and correlated to an increase in sediment density (Table 25, Figure 45). While density varied with depth, the particle size distributions remained constant throughout the core (Figure 42).

The surface eroded in clouds and streams of individual grains and small (<0.5 mm) pieces of the surface. During the first interval, an event occurred at the application of 1.6 Pa resulting in a 0.7 cm layer of sediment eroding in less than 10 seconds. After the first interval, sediment eroded sporadically in fractured pieces of the surface initialized around invertebrate structures and intermittent leafy debris. Parameters relating shear stress and erosion rates suggest a good correlation using a power law fit between the two variables (Table 26).

Figure 39. Evidence of biotic activity on surface of SR-TB

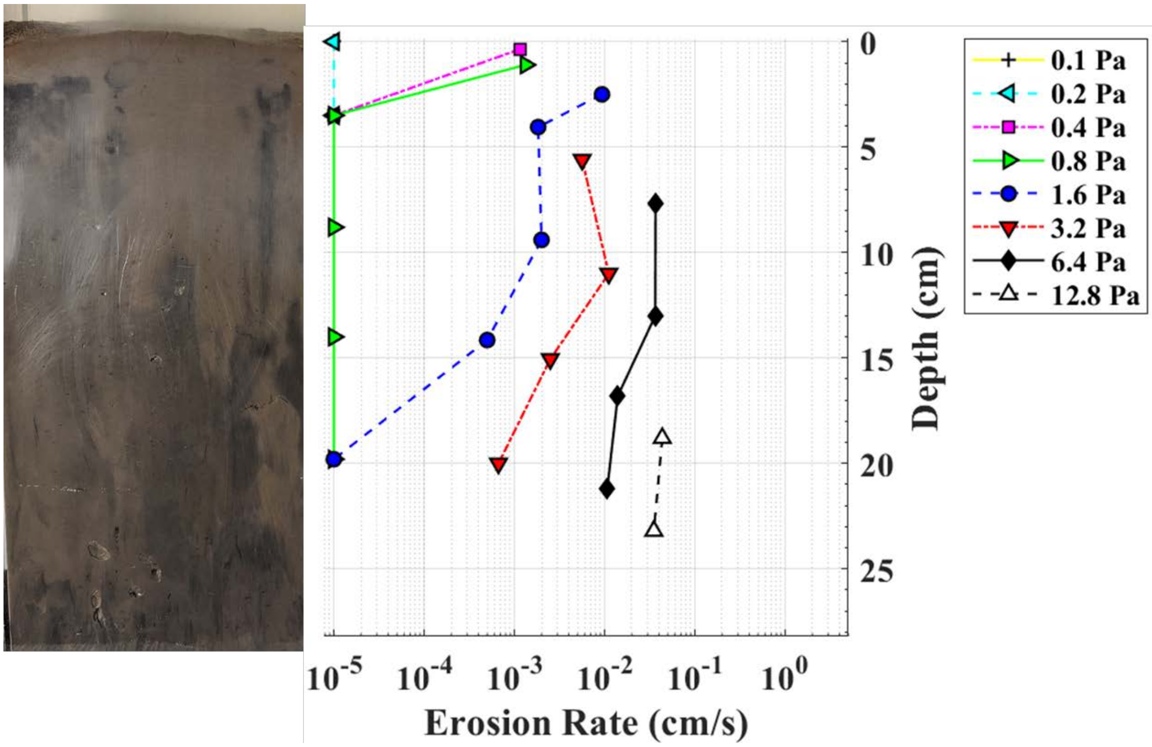


Figure 40. Photograph of Core SR-TB aligned with applied shear stresses and associated erosion rates

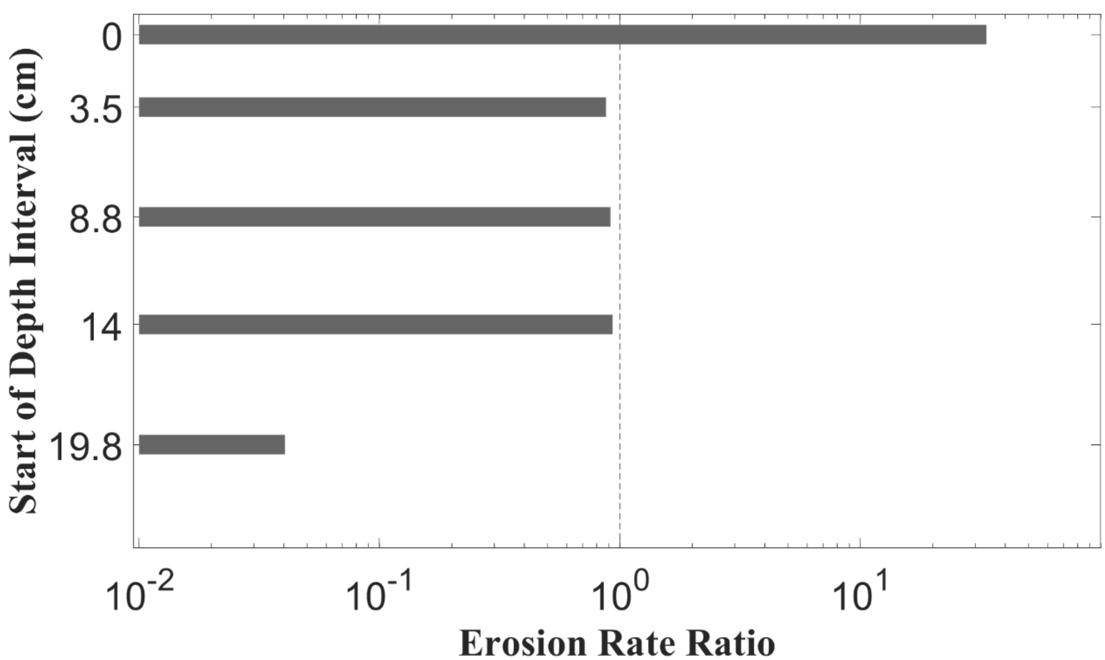


Figure 41. Intracore erosion rate of SR-TB

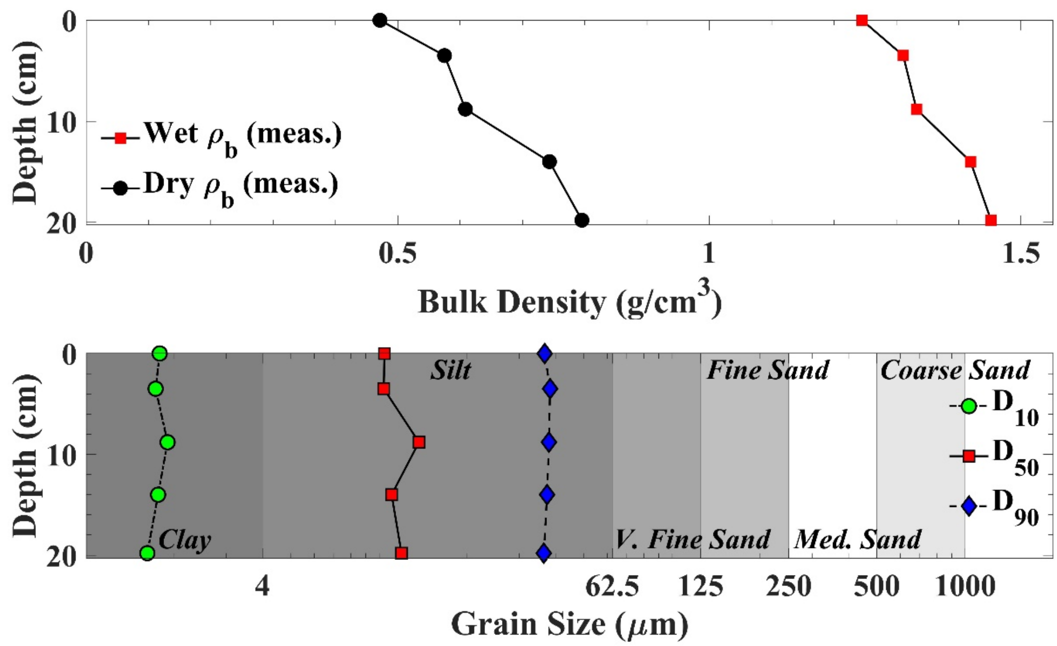


Figure 42. Physical properties of SR-TB with depth

Table 25. Physical properties and derived critical shear stresses of SR-TB

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm³)	Dry Bulk Density (g/cm³)	Loss on Ignition (%)	Tau_no (Pa)	Tau_first (Pa)	Tau Crit Linear (Pa)	Tau Crit Power (Pa)	Final Critical Shear (Pa)
0.0	10.42	1.24	0.47	6.3%	0.2	0.4	0.22	0.18	0.2
3.5	10.37	1.31	0.58	5.8%	0.8	1.6	0.85	0.72	0.8
8.8	13.67	1.33	0.61	5.6%	0.8	1.6	0.84	0.69	0.8
14	11.03	1.42	0.74	5.0%	0.8	1.6	0.96	0.86	0.86
19.8	11.92	1.45	0.8	4.8%	1.6	3.2	1.84	1.73	1.73
Mean	11.48	1.35	0.64	5.5%	0.84	1.68	0.94	0.84	0.88

Table 26. Power law fit parameters of SR-TB

Interval	Depth Start (cm)	Depth Finish (cm)	A	n	r^2
1	0.0	3.5	2.99E-05	2.05	0.9
2	3.5	8.8	4.09E-07	2.78	0.96
3	8.8	14	4.01E-07	2.85	0.95
4	14	19.8	6.4E-07	2.35	0.99
5	19.8	24.2	1.4E-08	3.11	0.97

2.13 SED-TC-DS

Core TC-DS was collected on March 11, 2020, at 2:30 p.m. from Tar Creek. Relative to TC-US, TC-DS is downstream closer to the Neosho River. TC-DS was collected in 8 ft of water in the center of the channel. Soft, easy to penetrate material containing leaves and twigs was collected resulting in a recovery length of 44 cm. Recovered sediment consisted of dark gray silt with pockets of leaves throughout and voids in the upper 10 cm.

Shear stresses ranging from 0.1 to 0.64 Pa were applied to the sediment core shown in Figure 43. Erosion rates were greatest at the surface, decreasing with depth but stabilizing below 20 cm (Figure 43, Figure 44). The surface responded to the lowest applied shear (0.1 Pa), which resulted in a critical shear stress determination of 0.05 Pa. The material at the surface was very soft, unconsolidated silt. Further down-core, density increased while particle size distributions stayed relatively constant (Figure 48, Table 27). Erosion in the first two intervals occurred evenly and consistently as loose particles were suspended. As depth increased, erosion was affected by the presence of leafy debris and changes in density resulting in more sporadic erosion events. A power law relationship between erosion rate and shear stress is applicable as shown by the high r^2 values and coefficients that fall into ranges typical of cohesive sediment (Table 28).

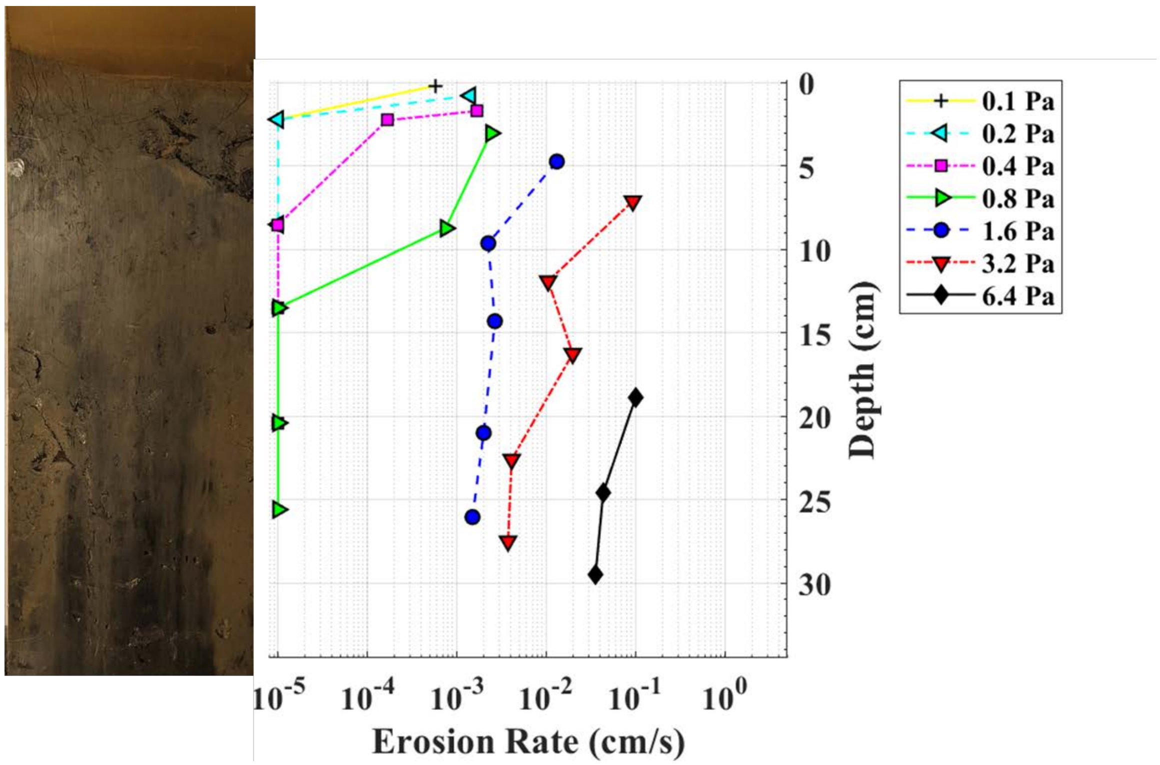


Figure 43. Photograph of Core TC-DS aligned with applied shear stresses and associated erosion rates

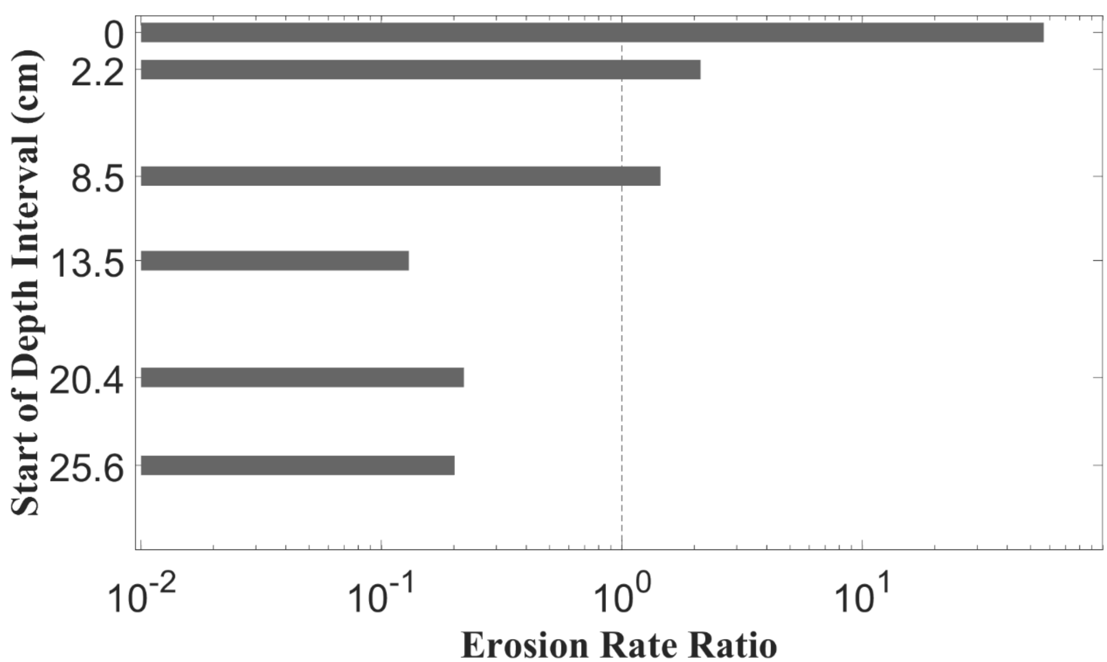


Figure 44. Intracore erosion rates of TC-DS

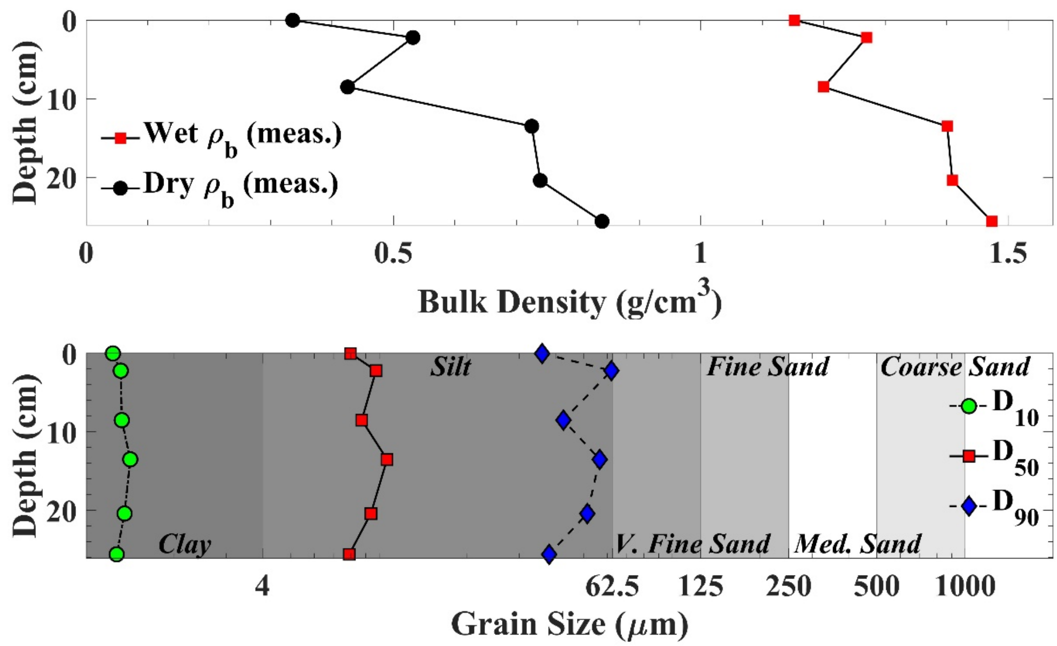


Figure 45. Physical properties of TC-DS with depth

Table 27. Physical properties and derived critical shear stresses of TC-DS

Sample Depth (cm)	Median Grain Size (μm)	Wet Bulk Density (g/cm³)	Dry Bulk Density (g/cm³)	Loss on Ignition (%)	Tau_no (Pa)	Tau_first (Pa)	Tau Crit Linear (Pa)	Tau Crit Power (Pa)	Final Critical Shear (Pa)
0.0	7.99	1.15	0.34	8.0%	0.05	0.1	0.06	0.04	0.05
2.2	9.76	1.27	0.53	7.7%	0.2	0.4	0.32	0.32	0.32
8.5	8.72	1.2	0.43	8.7%	0.4	0.8	0.46	0.4	0.4
13.5	10.64	1.4	0.72	5.8%	0.8	1.6	0.83	0.71	0.8
20.4	9.37	1.41	0.74	5.8%	0.8	1.6	0.84	0.73	0.8
25.6	7.91	1.47	0.84	5.3%	0.8	1.6	0.86	0.76	0.8
Mean	9.07	1.32	0.60	6.9%	0.51	1.02	0.56	0.49	0.53

Table 28. Power law fit parameters of TC-DS

Interval	Depth Start (cm)	Depth Finish (cm)	A	n	r^2
1	0.0	2.2	3.49E-04	1.42	0.82
2	2.2	8.5	3.17E-06	3.01	0.99
3	8.5	13.5	4.07E-06	2.3	0.97
4	13.5	20.4	1.46E-07	3.32	0.97
5	20.4	25.6	4.0E-07	2.78	0.95
6	25.6	30.5	3.77E-07	2.75	0.96

2.14 SED-TC-US

Core TC-US was collected on March 11, 2020, at 2:00 p.m. TC-US is located upstream of TC-DS in Tar Creek. Sampling efforts produced 44 cm of sediment without the need for added force via use of a post-hammer. Root structures along the bank necessitated multiple attempts before successful collection was achieved. A 2 cm layer of unconsolidated, light colored, oxidized silt blanketed darker sediment containing voids, leaves, and sticks.

Shear stresses, ranging from 0.1 to 6.4 Pa were applied to TC-US over six intervals (Figure 46). The unconsolidated surface layer was shown to be the most erodible, consistent with many other cores processed in this study (Figure 47). As depth increased, erodibility relative to the core average varied as did grain size and density (Figure 47, Figure 48, Table 29). The unconsolidated and sandier sections of the core eroded in streams of particles or clouds of suspended sediment depending on shear stress magnitude. Finer sediment regimes tended to erode in larger pieces or clumps unevenly across the surface.

Derived critical shear stresses varied from 0.17 to 0.8 Pa from the first to the sixth interval. Parameters defining the relationship between erosion rate and shear stress indicate a good power law relationship between the two variables (Table 30).

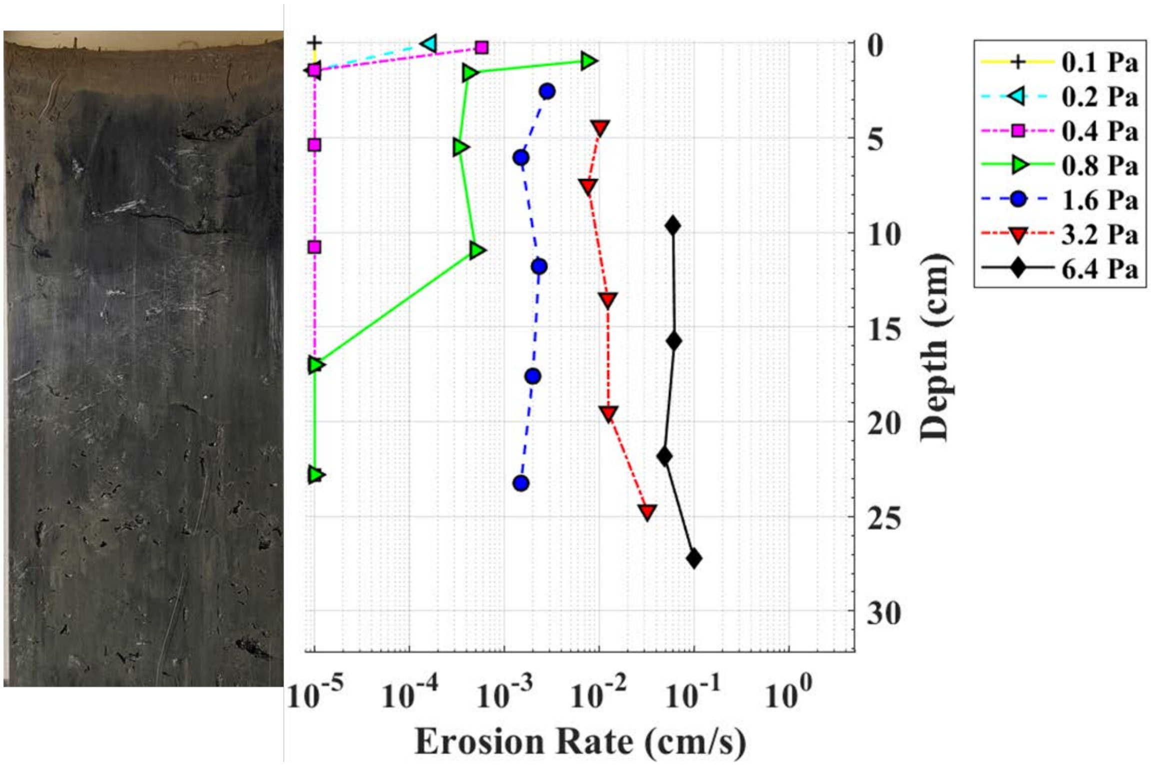


Figure 46. Photograph of Core TC-US aligned with applied shear stresses and associated erosion rates

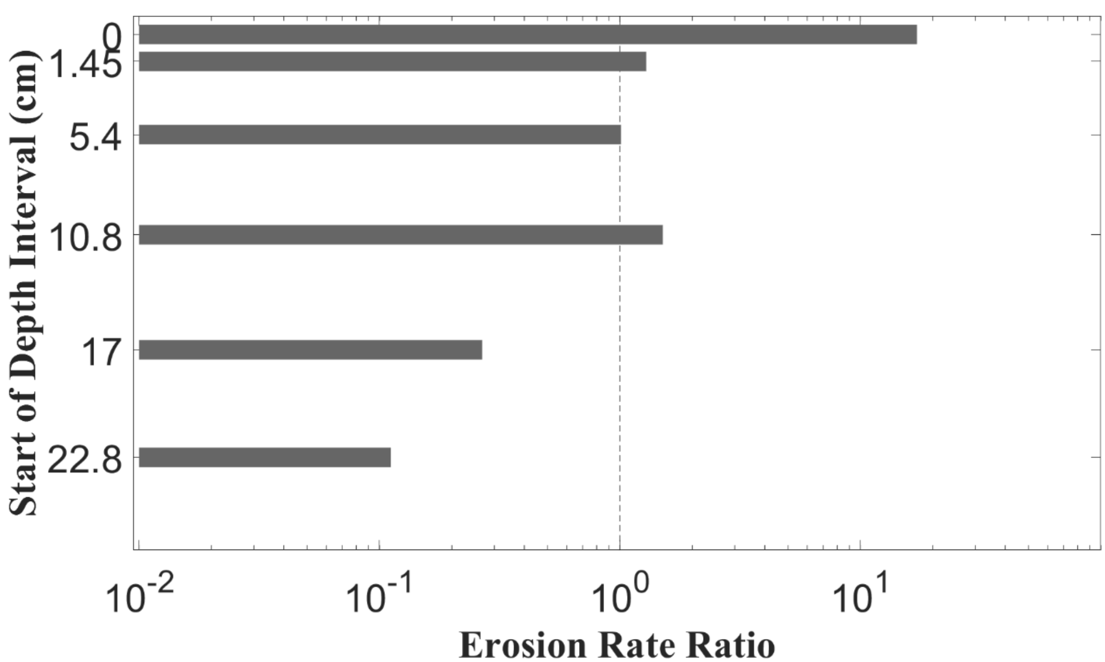


Figure 47. Intracore erosion rates for TC-US

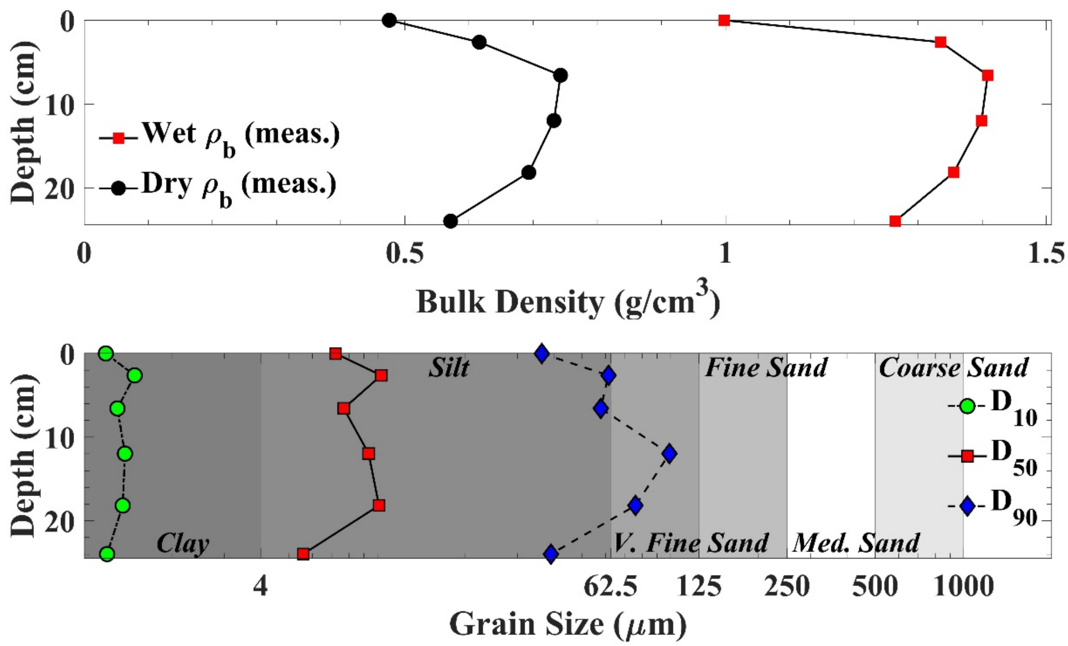


Figure 48. Physical properties of TC-US with depth

Table 29. Physical properties and derived critical shear stresses of TC-US

Sample Depth (cm)	Median Grain Size (µm)	Wet Bulk Density (g/cm³)	Dry Bulk Density (g/cm³)	Loss on Ignition (%)	Tau_no (Pa)	Tau_first (Pa)	Tau Crit Linear (Pa)	Tau Crit Power (Pa)	Final Critical Shear (Pa)
0.0	7.2	1	0.48	48.1%	0.1	0.2	0.16	0.17	0.17
1.45	10.31	1.34	0.62	5.8%	0.4	0.8	0.5	0.47	0.47
5.4	7.68	1.41	0.74	6.1%	0.4	0.8	0.52	0.52	0.52
10.8	9.34	1.4	0.73	6.5%	0.4	0.8	0.48	0.45	0.45
17.0	10.13	1.36	0.69	9.0%	0.8	1.6	0.84	0.71	0.8
22.8	5.58	1.26	0.57	11.6%	0.8	1.6	0.86	0.78	0.8
Mean	8.37	1.30	0.64	14.5%	0.48	0.97	0.56	0.52	0.54

Table 30. Power law fit parameters of TC-US

Interval	Depth Start (cm)	Depth Finish (cm)	A	n	r^2
1	0.0	1.45	2.55E-05	2.61	0.97
2	1.45	5.4	2.08E-06	2.51	0.99
3	5.4	10.8	1.66E-06	2.49	1.0
4	10.8	17.0	2.58E-06	2.44	1.0
5	17.0	22.8	2.79E-07	3.0	0.96
6	22.8	28.7	7.23E-08	3.53	0.96

2.15 SED-ER-640

No sample was recovered at ER-640, located west of the Highway 10 Bridge. The sediment bed near ER-640 was known to contain substantial portions of gravel and rock that would limit the effectiveness of collecting a sample.

2.16 SED-NR-HB

No sample was collected at ER-640. Multiple attempts were made to collect a sample, but no viable sample was produced. Despite ample penetration, recovered material was either not intact or absent in recovery of the core barrel. Unfavorable weather conditions of high winds and waves resulted in the field team aborting further attempts.

3 SUMMARY

Integral conducted a SEDflume analysis on 14 sediment cores collected from waterways connected to Grand Lake o' the Cherokees in northeast Oklahoma. The goal of this work was to characterize the erosion rates, critical shear stresses for erosion, and physical properties of the bedded sediment within the Elk River, Neosho River, Spring River, and Tar Creek. The SEDflume study results provide a baseline for the development of site-specific sediment parameters to support transport studies and bolster the conceptual understanding of dynamics within the system.

The cores were subjected to shear stresses ranging from 0.1 to 12.8 Pa to determine erosion rates as a function of shear stress and depth. In addition, cores were subsampled during the analysis to determine sediment bulk density, loss on ignition, and particle size distributions related to each shear stress interval. Critical shear stresses were calculated from the measured erosion rate data and ranged from less than 0.1 Pa in surface sediment to 2.46 Pa in deeper bedded sediment.

To better visualize the relative erodibility of the sediment throughout the system, the ratio of the mean erosion rate of each core (core vertically averaged erosion rate) to the average mean erosion rate of all cores at the site was calculated and plotted in Figure 49. The dashed line denotes a site-wide average erosion rate ratio of 1.0 Pa. A value above this line generally means that the core is more susceptible to erosion than those cores below. A similar figure to compare individual intervals between cores is also provided in Figure 50.

A few trends of note were observed. Surface intervals were the most erosive due to the presence of an unconsolidated layer up to 3 cm thick (see green bars in Figure 50). Below the "fluff" layer, sediment was pitted and pockmarked from the invertebrates present, and the sediment tended to erode in clumps nucleated by the biotic structures. The presence of leaves, twigs, stems, and worm burrows also influenced the sediment erosion by breaking away and drawing material away from the surface. Similar properties were observed in some cores collected from the same waterway. This was most obvious in the Tar Creek samples, TC-US and TC-DS. However, samples from the Neosho River exhibited a wider range of erodibility and sediment properties. Samples such as NR-FG, taken near the fairgrounds and in an area known to have wet and dry cycles, were less erosive than samples from further downriver such as NR-CB or NR-202. While predominantly silt, the presence of some fine sand in cores such as NR-CB and the Spring River samples may influence erodibility as it moves through the system.

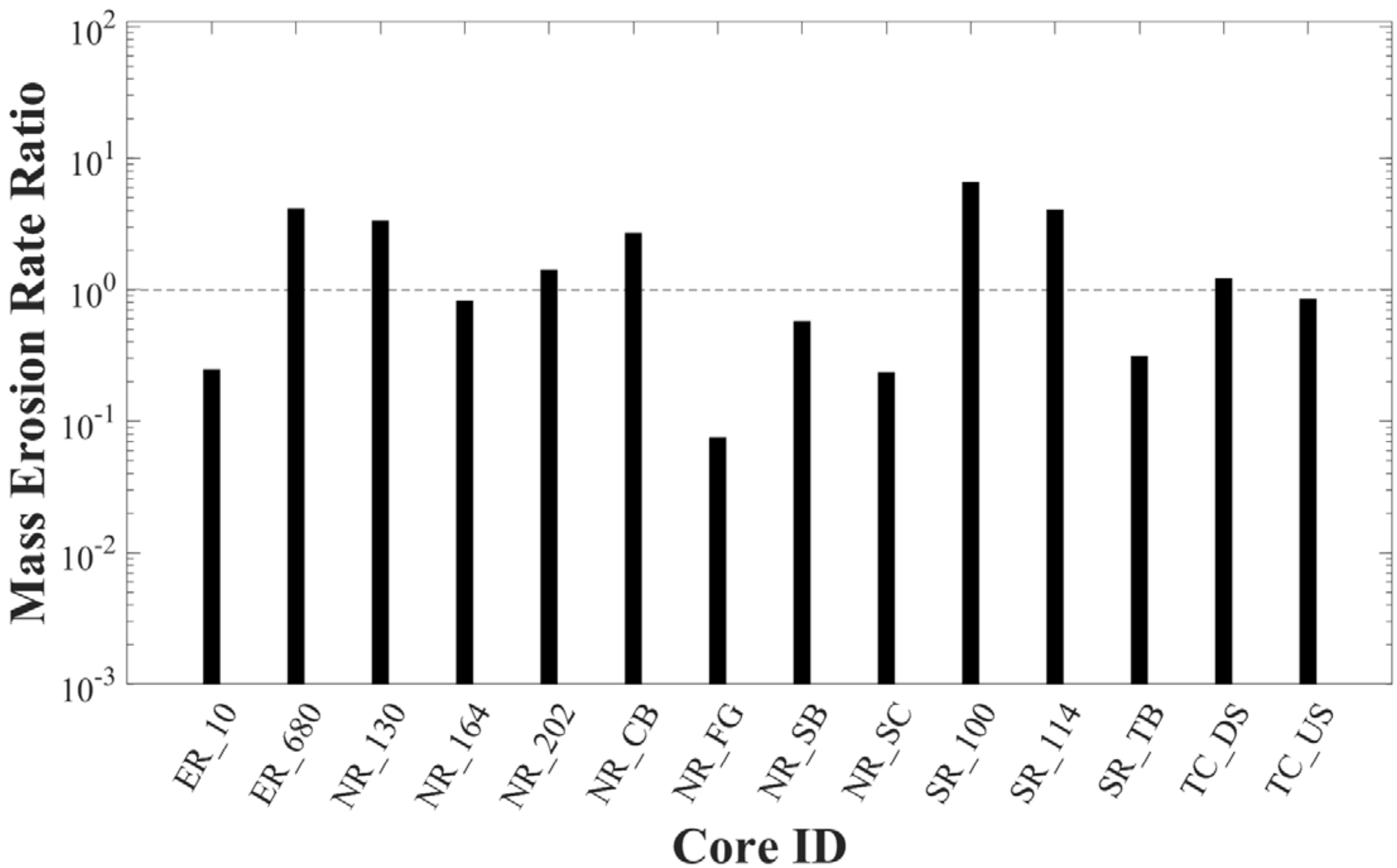


Figure 49. Intercore erosion rate ratios: Depth-averaged core erosion rates compared to the site-wide average erosion rates.

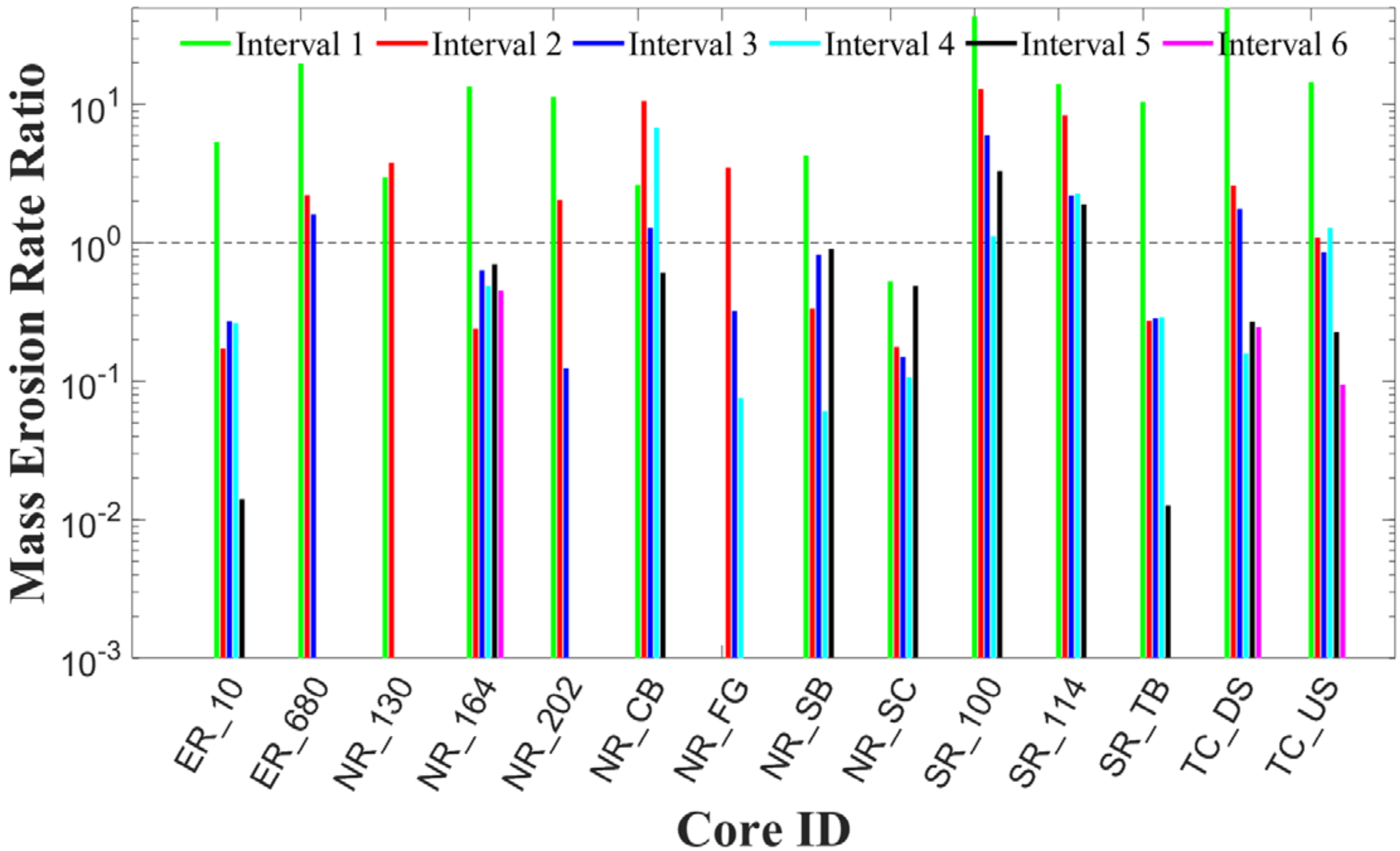


Figure 50. Intracore erosion rate by interval for each core.

4 REFERENCES

ASTM. 2007. *Annual book of ASTM standards.* Vol. 04.08, Soil and Rock (I): D420–D5611. ASTM International, West Conshohocken, PA. pp. 314–315.

Håkanson, L., and M. Jansson. 1983. *Principles of Lake Sedimentology*. 320 pp. Berlin–New York: Springer-Verlag. ISBN 3–540 (Berlin) 0–387 (New York)–12645–7. DM 98, *Int. Revue ges. Hydrobiol.*

Jepsen, R., J. Roberts, and W. Lick. 1997. Effects of bulk density on sediment erosion rates. *Water Air Soil Pollut.* 99:21–31.

McNeil, J., C. Taylor, and W. Lick. 1996. Measurements of erosion of undisturbed bottom sediments with depth. *J. Hydr. Engr.* 122(6):316–324.

Roberts, J., R. Jepsen, D. Gotthard, and W. Lick. 1998. Effects of particle size and bulk density on erosion of quartz particles. *J. Hydr. Engr.* 124(12):1261–1267.

Appendix D
Suspended Sediment Concentration Measurements

SSC/Bedload Sampling

FRESHWATER ENGINEERING

Site: Neosho @ Commerce

Staff: TJK, BJT, LLR   Date: 8/14/2019   Time: 10:57

Weather: Sunny, clear, still   Stream Width: 550'

Stream Name: Neosho River   Gage Reading: 12.8'   Discharge: 15,500 CFS

USGS Station: 07185000   Mean Flow Vel: 3 FPS   WSE: 761.9'

Max Water Depth: 15'   Datum: NAVD88   Stage ☐ Rising ☑ Falling ☐ Steady ☐ Peak

Temperature: Air: 87   Water: ______

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
15:06	24.3A,24.3B	24.3
15:23	72.9A,72.9B	72.9
15:31	121.5A,121.5B	121.5
15:39	170.1A,170.1B	170.1
15:51	218.7A,218.7B	218.7
16:05	267.3A,267.3B	267.3
16:17	315.9A,315.9B	315.9
16:28	364.5A,364.5B	364.5
16:48	413.1A,413.1B	413.1
16:48	461.7A,461.7B	461.7
17:03	520.3A,520.3B	520.3

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 1/4"

Transit Rate: 1.2 fps

No. of SSC Samples Collected: 22

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith   Time: 10:57   No. Samples: 48

Stations: 14, 42, 70*, 98, 126, 154, 182, 210*,   Bridge   ~10 feet below gage

238, 266, 294, 322, 350*, 378, 406, 434, 462, 490*, 518, 546

Notes: (SEWI, *=MEWI x 5)

Sample times 1-10 min; Collected few grains of sand, occasional gravel; not measurable

General Remarks:

SSC/Bedload Sampling

FRESHWATER ENGINEERING

Site: Elk River at Hwy 43

Staff: TJK, BJT, LLR | Date: 8/15/2019 | Time: 09:18

Weather: Sunny, still | Stream Width: 300'

Stream Name: Elk River | Gage Reading: 4.04' | Discharge: 537 CFS

USGS Station: 07189000 | Mean Flow Vel: 3.9 FPS | WSE: 764.65'

Max Water Depth: 6' | Datum: NGVD29 | Stage: ☐ Rising ☑ Falling ☐ Steady ☐ Peak

Temperature: Air: 80 Water:

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
09:45	12A,12B	12
09:51	36A,36B	36
09:57	60A,60B	60
10:03	84A,84B	84
10:10	108A,108B	108
10:20	132A,132B	132
10:28	156A,156B	156
10:40	180A,180B	180
10:50	262A,262B	262
10:57	282A,282B	282

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 1/8"

Transit Rate: 0.20 fps

No. of SSC Samples Collected: 20

Notes:

Gravel bar from 220-250

Bedload Sediment Transport Sampling

Sampler: Helley-Smith | Time: 09:18 | No. Samples: 45

Stations: 8, 23, 38*, 53, 68, 83, 98, 113*, 128, 143, 158, 173, 188*, 203, 218, 250, 260, 270*, 280, 290

Bridge ~10 feet below gage

Notes:

(SEWI, *=MEWI x 5) - Gravel bar from 220-250

Sample times 1-10 min; no sediment in bag after sampling

General Remarks:

Gravel bar in channel was dry, did not sample on bar

SSC/Bedload Sampling

FRESHWATER ENGINEERING

Site: Spring at E 57 Rd

Staff: TJK, BJT, LLR   Date: 8/15/2019   Time: 13:25

Weather: Clear, light wind   Stream Width: 263'

Stream Name: Spring River   Gage Reading: 7.26'   Discharge: 1240 CFS

USGS Station: 07188000   Mean Flow Vel: 1.1 FPS   WSE: 753.54'

Max Water Depth: 10.1'   Datum: NAVD88   Stage: ☐ Rising ☑ Falling ☐ Steady ☐ Peak

Temperature: Air: 86   Water: ______

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
14:48	13A,13B	13
14:57	39A,39B	39
15:04	65A,65B	65
15:12	91A,91B	91
15:24	117A,117B	117
15:34	143A,143B	143
15:43	169A,169B	169
15:48	195A,195B	195
15:55	221A,221B	221
16:02	247A,247B	247

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 1/4"

Transit Rate: 0.28 FPS

No. of SSC Samples Collected: 20

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith   Time: 13:25   No. Samples: 45

Stations: 7, 20, 33*, 46, 59, 72, 85, 98*, 111, 124,   Bridge   ~10 feet below gage

137, 150, 163*, 176, 189, 202, 215, 228*, 241, 254

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; Collected few grains of sand; not measurable

General Remarks:

SSC/Bedload Sampling

FreshWater Engineering

Site: Tar Creek @ HWY 69

Staff: TJK, BJT, LLR Date: 8/16/2019 Time: 14:28

Weather: Cloudy, light rain, light wind Stream Width: 18'

Stream Name: Tar Creek Gage Reading: 8.55' Discharge: 10 CFS

USGS Station: 07185090 Mean Flow Vel: 1 FPS WSE: 783.71'

Max Water Depth: 1' Datum: NAVD88 Stage: ☑ Rising ☐ Falling ☐ Steady ☐ Peak

Temperature: Air: 75 Water:

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
14:50	A,B	0.9
14:57	A,B	2.7
15:05	A,B	4.5
15:13	A,B	6.3
15:48	A,B	8.1
15:56	A,B	9.9
16:02	A,B	11.7
16:12	A,B	13.5
16:18	A,B	15.3
16:31	A,B	17.1

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 1/4"

Transit Rate: 0.02 fps

No. of SSC Samples Collected: 20

Notes:

Samples combined

Bedload Sediment Transport Sampling

Sampler: Helley-Smith Time: 14:28 No. Samples: 42

Stations: 1, 2, 3*, 4, 5, 6, 7*, 8, 9, 10, 11, 12*, 13, Bridge ~10 feet below gage

14, 15, 16*, 17, 18

Notes:

(SEWI, *=MEWI x 5) - Narrow stream, so only 18 sample locations

Sample times 1-10 min; No sample in bag

General Remarks:

SSC/Bedload Sampling

Site: Elk River at Hwy 43

Staff: TJK, BLD, LLR, EAF Date: 5/17/2020 Time: 16:15

Weather: Cloudy, mod. winds Stream Width: 340'

Stream Name: Elk River Gage Reading: 8.13' Discharge: 4,940 CFS

USGS Station: 07189000 Mean Flow Vel: 5.9 FPS WSE: 758.74'

Max Water Depth: 6.6' Datum: NGVD29 Stage: ☐ Rising ☑ Falling ☐ Steady ☐ Peak

Temperature: Air: 65 Water: ______

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
17:02	40A,40B	40
17:16	70A,70B	70
17:25	100A,100B	100
17:39	130A,130B	130
17:46	160A,160B	160
17:51	190A,190B	190
18:00	220A,220B	220
18:09	250A,250B	250
18:19	280A,280B	280
18:28	310A,310B	310

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 3/16"

Transit Rate: 0.6 FPS

No. of SSC Samples Collected: 20

Notes:

Single transit for SSC measurements

Bedload Sediment Transport Sampling

Sampler: Helley-Smith Time: 16:15 No. Samples: 42

Stations: 9, 26, 43*, 60, 77, 94, 111, 128*, 145, Bridge ~10 feet below gage

162, 179, 196, 213*, 230, 247, 264, 281, 298*, 315, 332

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; No sediment collected in bag

General Remarks:

SSC/Bedload Sampling

FRESHWATER ENGINEERING

Site: Neosho River at Commerce

Staff: TJK, BLD, LLR, EAF   Date: 5/17/2020   Time: 11:00

Weather: Cloudy, mod winds   Stream Width: 600'

Stream Name: Neosho   Gage Reading: 19.78'   Discharge: 37,500 CFS

USGS Station: 07185000   Mean Flow Vel: 4.5 FPS   WSE: 768.88'

Max Water Depth: 21.4'   Datum: NAVD88   Stage: ☐ Rising ☐ Falling ☑ Steady ☐ Peak

Temperature: Air: 64   Water: ____

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
11:34	30A,30B	30
12:12	90A,90B	90
12:28	150A,150B	150
12:44	210A,210B	210
13:00	270A,270B	270
13:14	330A,330B	330
13:30	430A,430B	430
13:44	450A,450B	450
14:14	520A,520B	520
14:25	570A,570B	570

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 1/4"

Transit Rate: 1.8 FPS

No. of SSC Samples Collected: 20

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith   Time: 11:00   No. Samples: 42

Stations: 15, 45, 75*, 105, 135, 165, 195, 225*,   Bridge   ~10 feet below gage

255, 285, 315, 345, 375*, 405, 435, 465, 495, 525*, 555, 585

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; Collected few grains of sand, one gravel; not measurable

General Remarks:

SSC/Bedload Sampling

FRESHWATER ENGINEERING

Site: Spring River at E 57Rd

Staff: TJK, BLD, LLR, EAF   Date: 5/18/2020   Time: 10:15

Weather: Cloudy, windy   Stream Width: 280'

Stream Name: Spring   Gage Reading: 10.87'   Discharge: 8,040 CFS

USGS Station: 07188000   Mean Flow Vel: 2.8 FPS   WSE: 757.15'

Max Water Depth: 13.7'   Datum: NAVD88   Stage: ☐ Rising ☑ Falling ☐ Steady ☐ Peak

Temperature: Air: 60   Water: ______

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
10:30	14A,14B	14
10:40	42A,42B	42
10:48	70A,70B	70
10:55	98A,98B	98
11:04	126A,126B	126
11:13	154A,154B	154
11:21	182A,182B	182
11:28	210A,210B	210
11:35	238A,238B	238
11:44	266A,266B	266

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 3/16"

Transit Rate: 0.5 FPS

No. of SSC Samples Collected: 20

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith   Time: ______   No. Samples: 42

Stations: 7, 21, 35*, 49, 63, 77, 91, 105*, 119, 133,   Bridge   ~10 feet below gage

147, 161, 175*, 189, 203, 217, 231, 245*, 259, 273

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; No sediment collected in bag

General Remarks:

SSC/Bedload Sampling

FRESHWATER ENGINEERING

Site: Neosho at Commerce

Staff: TJK, BLD Date: 7/31/2020 Time: 17:00

Weather: Cloudy, windy Stream Width: 530'

Stream Name: Neosho Gage Reading: 4.16' Discharge: 2,930 CFS

USGS Station: 07185000 Mean Flow Vel: 3.6 FPS WSE: 753.25'

Max Water Depth: 5.8' Datum: NAVD88 Stage: ☑ Rising ☐ Falling ☐ Steady ☐ Peak

Temperature: Air: 76 Water:

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
17:15	10A,10B	10
17:30	63A,63B	63
17:39	116A,116B	116
17:52	169A,169B	169
18:05	222A,222B	222
18:23	275A,275B	275
18:34	313A,313B	313
18:47	381A,381B	381
18:56	424A,424B	424
19:10	519A,519B	519

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 3/16"

Transit Rate: 0.47

No. of SSC Samples Collected: 20

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith Time: 17:00 No. Samples: 42

Stations: 13, 40, 67*, 94, 121, 148, 175, 202*, Bridge ~10 feet below gage

229, 256, 283, 310, 337*, 364, 391, 418, 445, 472*, 499, 526

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; Collected few grains of sand, organic debris; not measurable

General Remarks:

SSC/Bedload Sampling

Site: Spring River at E 57 Rd

Staff: TJK, BLD Date: 7/31/2020 Time: 10:30

Weather: Cloudy, windy Stream Width: 260'

Stream Name: Spring River Gage Reading: 8.63' Discharge: 3,480 CFS

USGS Station: 07188000 Mean Flow Vel: 1.8 FPS WSE: 754.91'

Max Water Depth: 11.5' Datum: NAVD88 Stage: ☐ Rising ☑ Falling ☐ Steady ☐ Peak

Temperature: Air: 76 Water:

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
11:45	10A,10B	10
12:05	28A,28B	28
12:18	56A,56B	56
12:28	84A,84B	84
12:40	112A,112B	112
13:28	140A,140B	140
13:42	168A,168B	168
13:49	196A,196B	196
14:00	224A,224B	224
14:15	252A,252B	252

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 1/4"

Transit Rate: 0.55

No. of SSC Samples Collected: 20

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith Time: 10:30 No. Samples: 42

Stations: 7, 20, 33*, 46, 59, 72, 85, 98*, 111, 124, Bridge ~10 feet below gage

137, 150, 163*, 176, 189, 202, 215, 228*, 241, 254

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; Collected few grains of sand, organic debris; not measurable

General Remarks:

SSC/Bedload Sampling

Site: Tar Creek at HWY 69

Staff: TJK, BLD Date: 7/31/2020 Time: 15:00

Weather: Cloudy, windy Stream Width: 20'

Stream Name: Tar Creek Gage Reading: 8.25' Discharge: 5.29 CFS

USGS Station: 07185090 Mean Flow Vel: 1 FPS WSE: 783.41'

Max Water Depth: 0.7' Datum: NAVD88 Stage: ☐ Rising ☐ Falling ☑ Steady ☐ Peak

Temperature: Air: 75 Water: ______

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
15:20	9A,9B	9

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 1/8"

Transit Rate: 0.2 FPS

No. of SSC Samples Collected: 2

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith Time: 15:00 No. Samples: 42

Stations: 1, 2, 3*, 4, 5, 6, 7, 8*, 9, 10, 11, 12, 13*, Bridge ~10 feet below gage

14, 15, 16, 17, 18*, 19, 20

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; No sediment collected in mesh bag; not measurable

General Remarks:

SSC/Bedload Sampling

Site: Neosho River @ E 60 Rd

Staff: TJK, BLD Date: 4/30/2021 Time: 15:30

Weather: Warm, overcast Stream Width: 500'

Stream Name: Neosho River Gage Reading: 4.10' Discharge: 2,330 CFS

USGS Station: 07185000 Mean Flow Vel: 3.5 FPS WSE: 753.20'

Max Water Depth: 5.7' Datum: NAVD88 Stage: ☑ Rising ☐ Falling ☐ Steady ☐ Peak

Temperature: Air: 76 Water: ______

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
15:45	0A, 0B	25
15:55	50A, 50B	75
16:00	100A, 100B	125
16:10	150A, 150B	175
16:17	200A, 200B	225
16:25	250A, 250B	275
16:35	300A, 300B	325
16:49	350A, 350B	375
16:58	400A, 400B	425
17:06	450A, 450B	475

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 3/16"

Transit Rate: 0.3 FPS

No. of SSC Samples Collected: 20

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith Time: 15:30 No. Samples: 42

Stations: 13, 38, 63*, 88, 113, 138, 163, 188*, 213, 238, 263, 288, 313*, 338, 363, 388, 413, 438*, 463, 488 Bridge ~10 feet below gage

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; Collected few grains of sand, organics; not measurable

General Remarks:

SSC/Bedload Sampling

FreshWater Engineering

Site: Spring River @ E 57 Rd

Staff: TJK, BLD   Date: 4/30/2021   Time: 10:30

Weather: Warm, overcast   Stream Width: 270'

Stream Name: Spring River   Gage Reading: 7.75'   Discharge: 2,250 CFS

USGS Station: 07188000   Mean Flow Vel: 1.1 FPS   WSE: 754.03'

Max Water Depth: 10.6'   Datum: NAVD88   Stage: ☑ Rising ☐ Falling ☐ Steady ☐ Peak

Temperature: Air: 74   Water: ____

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
12:00	14A, 14B	14
12:14	41A, 41B	41
12:23	68A, 68B	68
12:32	95A, 95B	95
12:40	122A, 122B	122
12:46	149A, 149B	149
12:55	176A, 176B	176
13:02	203A, 203B	203
13:12	230A, 230B	230
13:21	257A, 257B	257

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 1/4"

Transit Rate: 0.28 FPS

No. of SSC Samples Collected: 20

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith   Time: 10:30   No. Samples: 42

Stations: 7, 20, 33*, 46, 59, 72, 85, 98*, 111, 124,   Bridge   ~10 feet below gage

137, 150, 163*, 176, 189, 202, 215, 228*, 241, 254

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; Collected few grains of sand, organics; not measurable

General Remarks:

SSC/Bedload Sampling

FreshWater Engineering

Site: Neosho River @ E 60 Rd

Staff: TJK, BLD Date: 5/28/2021 Time: 17:10

Weather: Warm, overcast Stream Width: 640'

Stream Name: Neosho River Gage Reading: 13.36' Discharge: 18,900 CFS

USGS Station: 07185000 Mean Flow Vel: 3.6 FPS WSE: 762.46'

Max Water Depth: 15.0' Datum: NAVD88 Stage: ☐ Rising ☑ Falling ☐ Steady ☐ Peak

Temperature: Air: 76 Water: ______

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
18:32	58A, 58B	58
18:40	116A, 116B	116
19:03	174A, 174B	174
19:09	232A, 232B	232
19:16	290A, 290B	290
19:21	348A, 348B	348
19:26	406A, 406B	406
19:32	464A, 464B	464
19:37	522A, 522B	522
19:43	580A, 580B	580

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 3/16"

Transit Rate: 44 seconds in water

No. of SSC Samples Collected: 20

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith Time: 17:10 No. Samples: 42

Stations: 16, 48, 80*, 112, 144, 176, 208, 240*, Bridge ~10 feet below gage

272, 304, 336, 368, 400*, 432, 464, 496, 528, 560*, 592, 624

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; Collected grains of sand, three gravel, debris; no measurable sample

General Remarks:

SSC/Bedload Sampling

FRESHWATER ENGINEERING

Site: Spring River @ E 57 Rd

Staff: TJK, BLD Date: 5/28/2021 Time: 9:28

Weather: Warm, overcast Stream Width: 270'

Stream Name: Spring River Gage Reading: 14.41' Discharge: 16,500 CFS

USGS Station: 07188000 Mean Flow Vel: 4.3 FPS WSE: 760.69'

Max Water Depth: 17.3' Datum: NAVD88 Stage: ☐ Rising ☑ Falling ☐ Steady ☐ Peak

Temperature: Air: 63 Water:

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
10:03	14A, 14B	14
10:12	25A, 25B	25
10:23	68A, 68B	68
10:28	95A, 95B	95
10:36	122A, 122B	122
10:42	149A, 149B	149
10:49	176A, 176B	176
10:56	203A, 203B	203
11:06	230A, 230B	230
11:20	257A, 257B	257

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 3/16"

Transit Rate: 0.94 FPS

No. of SSC Samples Collected: 20

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith Time: 9:28 No. Samples: 42

Stations: 7, 21, 35*, 49, 63, 77, 91, 105*, 119, 133, 147, 161, 175*, 189, 203, 217, 231, 245*, 259, 268 Bridge ~10 feet below gage

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; Collected grains of sand, organic material, leaves, stick; no measurable sediment

General Remarks:

SSC/Bedload Sampling

FreshWater Engineering

Site: Tar Creek @ HWY 69

Staff: TJK, BLD Date: 5/28/2021 Time: 12:01

Weather: Warm, overcast Stream Width: 172'

Stream Name: Tar Creek Gage Reading: 13.12' Discharge: 750 CFS

USGS Station: 07185090 Mean Flow Vel: 1.2 FPS WSE: 788.28'

Max Water Depth: 5.6' Datum: NAVD88 Stage: ☐ Rising ☑ Falling ☐ Steady ☐ Peak

Temperature: Air: 65 Water: ______

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
12:37	22A, 22B	22
12:39	29A, 29B	29
12:44	44A,44B	44
12:49	59A, 59B	59
12:53	74A, 74B	74
12:58	89A, 89B	89
13:03	104A, 104B	104
13:09	119A, 119B	119
13:18	134A, 134B	134
13:22	149A, 149B	149

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 1/4"

Transit Rate: 0.15 FPS

No. of SSC Samples Collected: 20

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith Time: 12:01 No. Samples: 42

Stations: 4, 12, 20*, 28, 36, 44, 52, 60*, 68, 76, 84, 92, 100*, 108, 116, 124, 132, 140*, 148, 156

Bridge ~10 feet below gage

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; No measurable sample, nothing collected in bag

General Remarks:

SSC/Bedload Sampling

FreshWater Engineering

Site: Spring River @ E 57 Rd

Staff: TJK, BLD Date: 5/29/2021 Time: 8:58

Weather: Warm, overcast Stream Width: 303'

Stream Name: Spring River Gage Reading: 16.82' Discharge: 23,400 CFS

USGS Station: 07188000 Mean Flow Vel: 5.2 FPS WSE: 763.10'

Max Water Depth: 19.7' Datum: NAVD88 Stage: ☐Rising ☑Falling ☐Steady ☐Peak

Temperature: Air: 62 Water: ______

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
9:29	25A, 25B	25
9:37	50A, 50B	50
9:50	100A, 100B	100
9:58	125A, 125B	125
10:10	150A, 150B	150
10:45	175A, 175B	175
10:56	200A, 200B	200
11:06	225A, 225B	225
11:17	250A, 250B	250
11:31	275A, 275B	275

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 3/16"

Transit Rate: 1.1 FPS

No. of SSC Samples Collected: 20

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith Time: 8:58 No. Samples: 42

Stations: 8, 23, 38*, 53, 68, 83, 98, 113*, 128, 143, 158, 173, 188*, 203, 218, 233, 248, 263*, 278, 293 Bridge ~10 feet below gage

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; Collected few grains of sand; no measurable quantity

General Remarks:

SSC/Bedload Sampling

FRESHWATER ENGINEERING

Site: Neosho River @ E 60 Rd

Staff: TJK, BLD   Date: 7/1/2021   Time: 14:30

Weather: Warm, overcast   Stream Width: 604'

Stream Name: Neosho River   Gage Reading: 20.34'   Discharge: 41,600 CFS

USGS Station: 07185000   Mean Flow Vel: 4.8 FPS   WSE: 769.44'

Max Water Depth: 21.9'   Datum: NAVD88   Stage: ☐ Rising ☐ Falling ☑ Steady ☐ Peak

Temperature: Air: 80   Water: ______

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
16:54	32A, 32B	32
17:01	95.5A, 95.5B	95.5
17:07	159A, 159B	159
17:14	222.5A, 222.5B	222.5
17:18	286A, 286B	286
17:27	349.5A, 349.5B	349.5
17:34	413A, 413B	413
17:43	476.5A, 476.5B	476.5
17:48	540A, 540B	540
17:55	572A, 572B	572

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 1/8"

Transit Rate: 0.47 FPS

No. of SSC Samples Collected: 20

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith   Time: 14:30   No. Samples: 42

Stations: 15, 45, 75*, 105, 135, 165, 195, 225*,   Bridge   ~10 feet below gage

255, 285, 315, 345, 375*, 405, 435, 465, 495, 525*, 555, 585

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; Collected grains of sand, debris; not measurable

General Remarks:

SSC/Bedload Sampling

FRESHWATER ENGINEERING

Site: Spring River @ E 57 Rd

Staff: TJK, BLD Date: 7/1/2021 Time: 19:00

Weather: Warm, overcast Stream Width: 280'

Stream Name: Spring River Gage Reading: 13.75' Discharge: 14,700 CFS

USGS Station: 07188000 Mean Flow Vel: 4.0 FPS WSE: 760.03'

Max Water Depth: 16.6' Datum: NAVD88 Stage: ☑ Rising ☐ Falling ☐ Steady ☐ Peak

Temperature: Air: 78 Water: ______

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
19:26	14A, 14B	14
19:36	42A, 42B	42
19:42	70A, 70B	70
19:46	98A, 98B	98
19:52	126A, 126B	126
19:57	154A, 154B	154
20:04	182A, 182B	182
20:07	210A, 210B	210
20:12	238A, 238B	238
20:18	266A, 266B	266

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 3/16"

Transit Rate: 0.88 FPS

No. of SSC Samples Collected: 20

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith Time: 19:00 No. Samples: 42

Stations: 7, 21, 35*, 49, 63, 77, 91, 105*, 119, 133, 147, 161, 175*, 189, 203, 217, 231, 245*, 259, 273

Bridge ~10 feet below gage

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; Collected grains of sand, debris; not measurable

General Remarks:

SSC/Bedload Sampling

FRESHWATER ENGINEERING

Site: Tar Creek @ HWY 69

Staff: TJK, BLD Date: 7/1/2021 Time: 10:30

Weather: Warm, overcast Stream Width: 70'

Stream Name: Tar Creek Gage Reading: 11.72' Discharge: 500 CFS

USGS Station: 07185090 Mean Flow Vel: 1.1 FPS WSE: 786.79'

Max Water Depth: 4.2' Datum: NAVD88 Stage: ☐ Rising ☑ Falling ☐ Steady ☐ Peak

Temperature: Air: 76 Water: ______

Suspended Sediment Sampling

Time	*Sample No.*	*Station*
12:11	23A, 23B	23"
12:22	68.5A, 68.5B	68.5"
12:29	114A, 114B	114"
12:35	159.5A, 159.5B	159.5"
12:40	205A, 205B	205"
12:46	250.5A, 250.5B	250.5"
12:51	296A, 296B	296"
12:56	341.5A, 341.5B	341.5"
13:02	387A, 387B	387"
13:07	410A, 410B	410"

Method: Cable and crane off bridge

Type of Sampler Used: D-74

Nozzle Size: 1/4"

Transit Rate: 0.15

No. of SSC Samples Collected: 20

Notes:

Bedload Sediment Transport Sampling

Sampler: Helley-Smith Time: 10:30 No. Samples: 42

Stations: 2, 5.5, 9*, 12.5, 16, 19.5, 23, 26.5*, 30, Bridge ~10 feet below gage

33.5, 37, 40.5, 44*, 47.5, 51, 54.5, 58, 61.5*, 65, 68.5

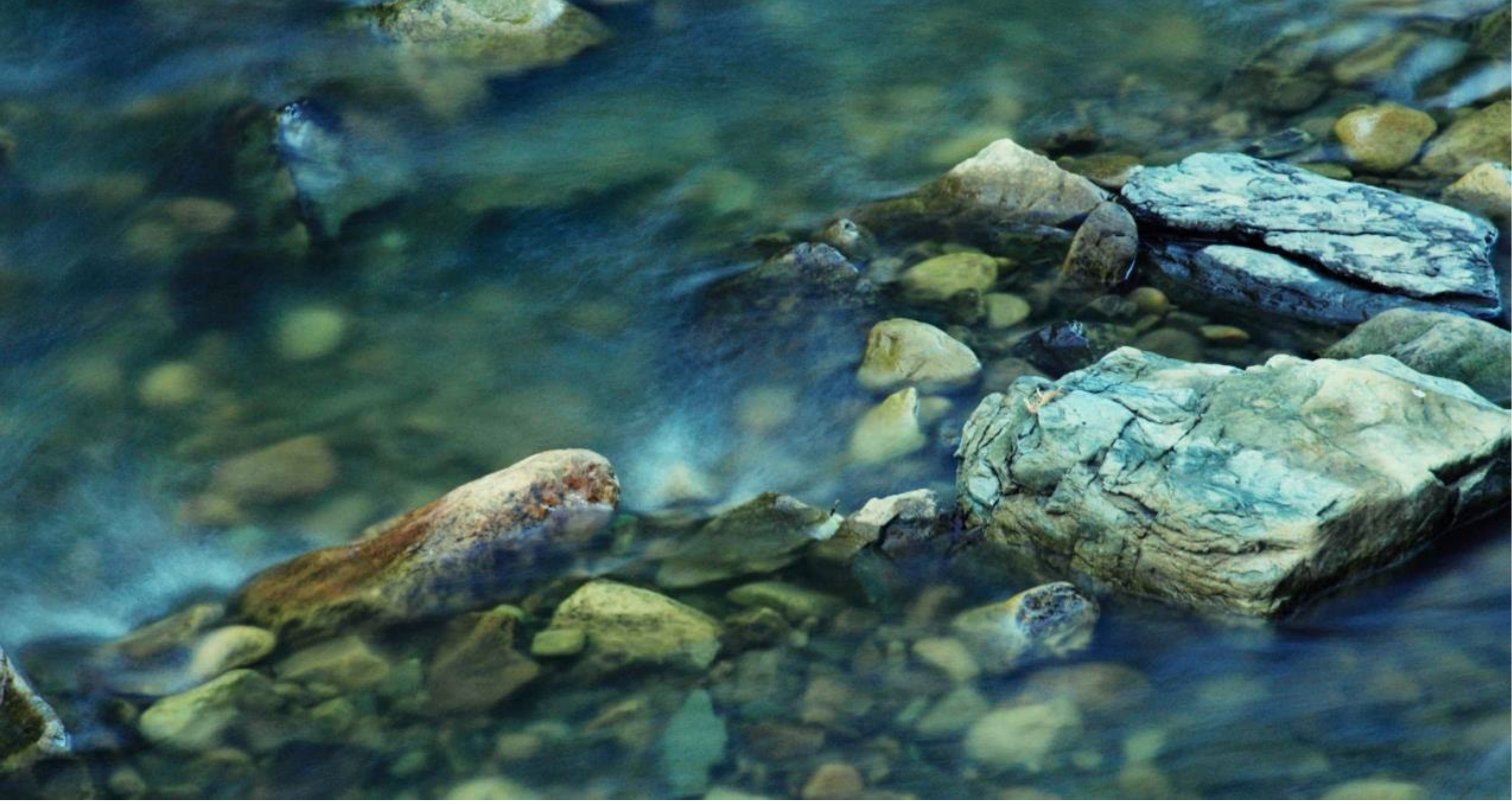
Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; No measurable sample material

General Remarks:

Appendix E
Subsurface Investigation



August 2022
Oklahoma Dam Relicensing

Grand Lake Subsurface Investigation Field Report

Prepared for Grand River Dam Authority

August 2022
Oklahoma Dam Relicensing

Grand Lake Subsurface Investigation Field Report

Prepared for
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P.O. Box 409
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Madison, Wisconsin 53715

Project Number: ###########
https://anchorqea-my.sharepoint.com/personal/bteske_anchorqea_com/Documents/Documents/Anchor QEA/00 Projects/GRDA/08 Deliverables/USR/SharedFolder/Appendix E - Subsurface Investigation/SourceFiles/220815_SBP-Report.docx

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FIGURES

APPENDICES

1 Introduction

GRDA performed an investigation of sediment deposition on the Neosho River at multiple locations to estimate bottom sediment layer thicknesses. The goal of the survey was to determine the volume of sediment deposited in these areas since the construction of the Pensacola Dam. Historical records indicate that a delta feature had accumulated in this reach of the system, and GRDA used a sub-bottom profiler (SBP) to assess deposition thicknesses.

Two methods were used to investigate the sediment accumulation. The first was an SBP survey, and the second was vibracoring for sediment samples. The SBP survey covered nine transects of the Neosho River and was completed in January 2022. The vibracore sampling was completed in February 2022 and included multiple samples at each SBP transect.

An SBP uses sonar pulses to determine depth of a water body. There is an emitter and a receiver on the SBP head unit, and by measuring the amount of time necessary for the emitted pulse to reach an object and return to the receiver, the SBP is able to measure the distance the pulse traveled. This allows the SBP to measure bathymetry, but the pulse is also powerful enough to penetrate a soft sediment bed, such as clay, silt, and sand before reaching a harder layer. Using the same principles, the SBP can then estimate the thickness of a soft sediment layer above gravel or bedrock.

Vibracoring uses a motorized head unit to press core tubes into the stream- or lakebed. The combined weight and vibration of the head unit allows for deeper penetration than simply pressing the core tube into the bed or relying on gravity coring methods. Once collected, grain size analyses and other testing can be used to determine sediment properties as a function of depth in the sediment layers. The cores were used for two purposes: one was to confirm SBP survey information and evaluate sediment composition; the other was an attempt to determine approximate dates of deposition through the use of cesium-137 (Cs-137) analysis.

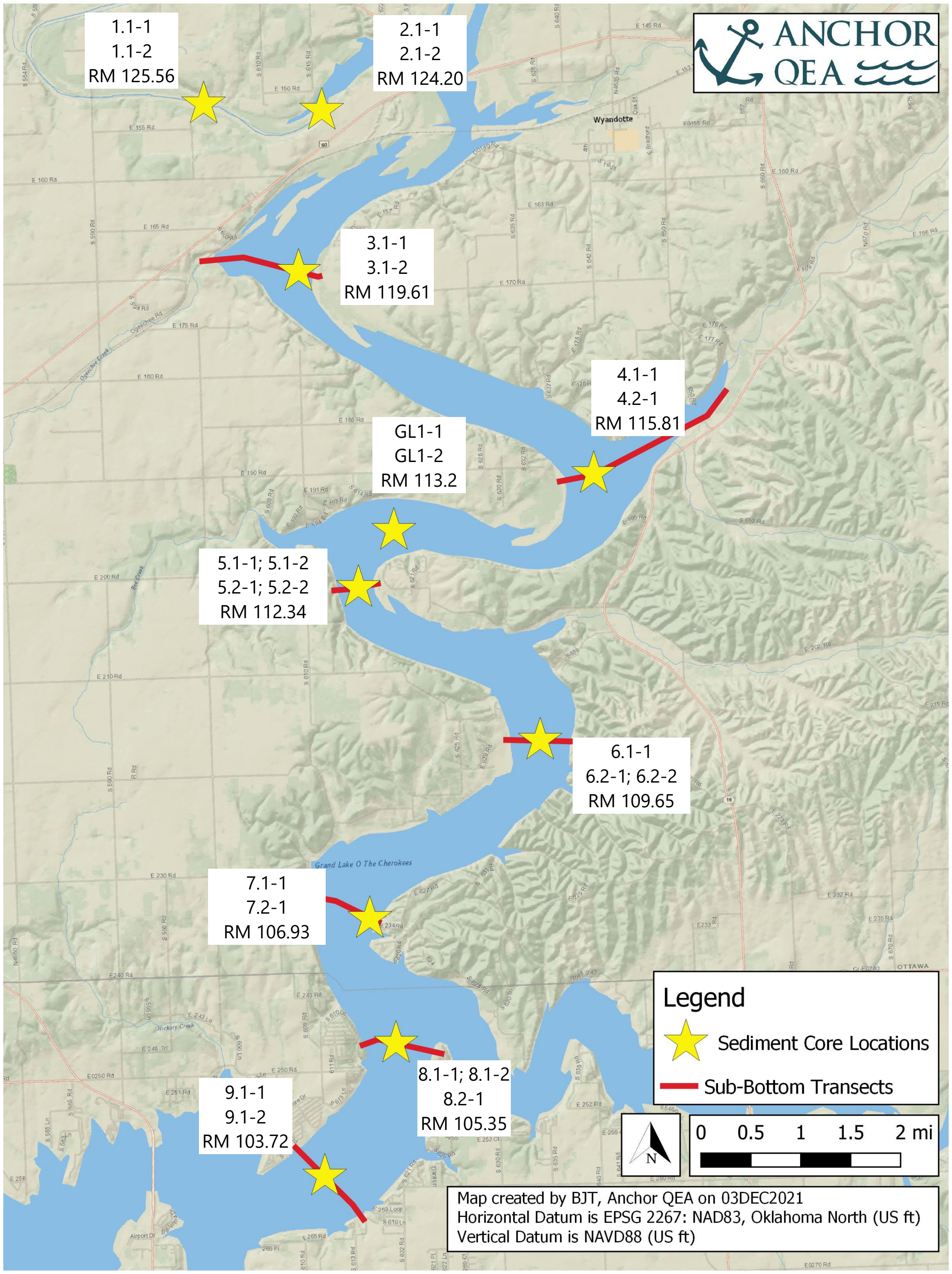
Cs-137 is an isotope that does not occur in nature. It is created by nuclear fission, which humans began developing in the 1940s. As nuclear weapons testing accelerated, atmospheric Cs-137 increased until a 1963 nuclear test ban treaty. The Cs-137 levels then dropped significantly. Atmospheric Cs-137 concentrations are well-correlated with Cs-137 concentrations in soil, showing the same pattern of increase from the 1940s to 1963, then a marked decrease.

Measurement of relative Cs-137 activity in sediment allows researchers to estimate deposition dates for sediment layers. In areas of continual deposition, Cs-137 analysis will find a pattern of increasing Cs-137 activity moving deeper in the column until reaching the 1963 layer. Below that layer, concentrations drop to zero by the 1940s. In disturbed areas or places with non-continuous deposition, there is usually no clear Cs-137 peak. The combination of SBP, vibracore samples, and Cs-137 provides insight into the volume, rate, and timeline of sediment deposition in the Neosho River.

2 Study Area

The study area for this survey was the Neosho River between river mile (RM) 125.56 approximately one mile downstream of Connors Bridge and RM 103.72 approximately two miles below the Elk River confluence. The survey team collected SBP transects at 9 locations to determine sediment layer thicknesses (Figure 1). At least two vibracore samples were collected at each transect. In addition, two additional samples at RM 113.2 for Cs-137 assessment to replicate an earlier USGS (Juracek and Becker 2009) effort.

Figure 1
Locations of SBP Transects and Sediment Cores Collected by GRDA



3 Equipment

3.1 Sub-Bottom Profiler

The survey team used a 19-ft vessel to tow an EdgeTech SB-424 towfish (Figure 2). The towfish was pulled across each of the nine transects on the Neosho River to collect SBP data. The system was processed onboard using the EdgeTech 3100-P portable sub-bottom topside electronics and Discover software that displayed and stored data. The reported SB-424 specifications are shown in Table 1.

Figure 2
EdgeTech 424 Sub-Bottom Profiler Towfish

Note: The EdgeTech SB-424 is a tow vehicle that was pulled across the measured transects. The topside 3100-P portable sub-bottom profiling system with Discover software is not shown in this image.

Table 1
EdgeTech SB-424 Specifications

EdgeTech SB-424 Characteristics	Text
Frequency Range	4-24 kHz
Pulses (user selected)	4-24 kHz, 4-20 kHz, 4-16 kHz
Vertical Resolution	4 cm / 4-24 kHz 6 cm / 4-20 kHz 8 cm / 4-16 kHz
Penetration (typical)	In coarse calcareous sand – 2 m In clay – 40 m
Beam Width (depends on center frequency)	16° / 4-24 kHz 19° / 2-20 kHz 23° / 2-16 kHz
Size (cm)	L – 77 W – 50 H – 34

EdgeTech SB-424 Characteristics	Text
Weight (kg)	45
Optimum Tow height	3-5 m above bed
Tow Speed	3-4 knots optimal, 7 knots maximum safe

The data was geolocated using a Differential GPS (DPGS) antenna. Track lines were set to follow cross sections aligned with the HEC-RAS computer model of the river system as shown in Figure 1.

3.2 Vibracore

The vibracore used for this effort was a Rossfelder P-3 system. The head clamped onto 16-ft clear ceramic tubes and was lowered to the bed with an electric winch from a vessel-mounted tripod system (Figure 3). Location data was collected with an RTK-GPS unit onboard the sampling boat.

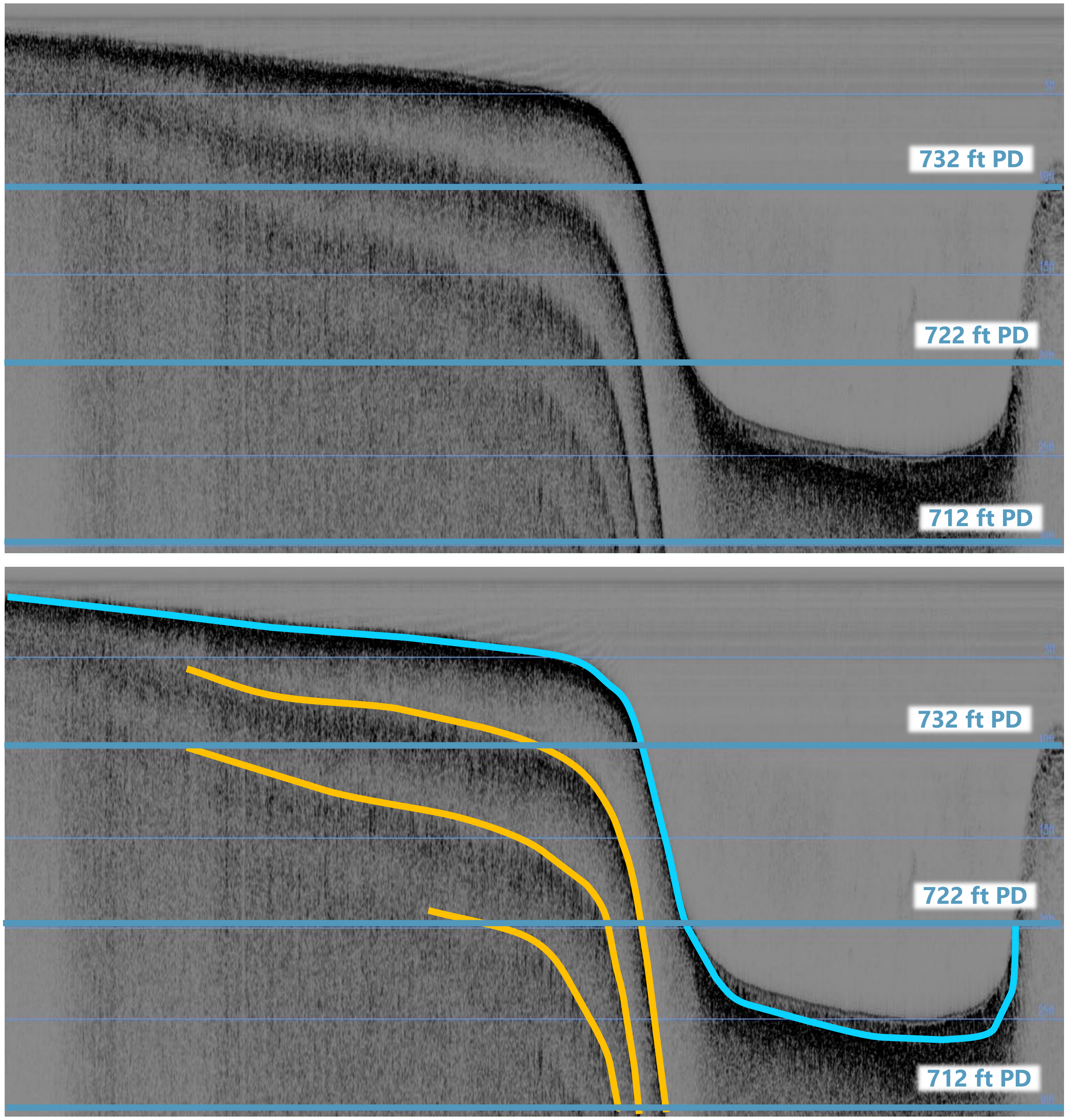
Figure 3
Vibracore System Used during February 2022 Sample Collection

4 Results

4.1 Sub-Bottom Survey Outputs

The SBP will produce a visual output referred to as a “waterfall” that indicates the distances to different objects. The most powerful return signal is often the lakebed or streambed, and subsequent layers are somewhat weaker signals that are still visible in the data. Another type of signal is referred to as a “multiple,” which is produced by pulses bouncing between the SBP sonar head and the bed, several times, resulting in a series of nearly parallel lines. An example image collected during the SBP survey at RM 112.34 showing this is provided in Figure 4. Full images are included in Appendix I.

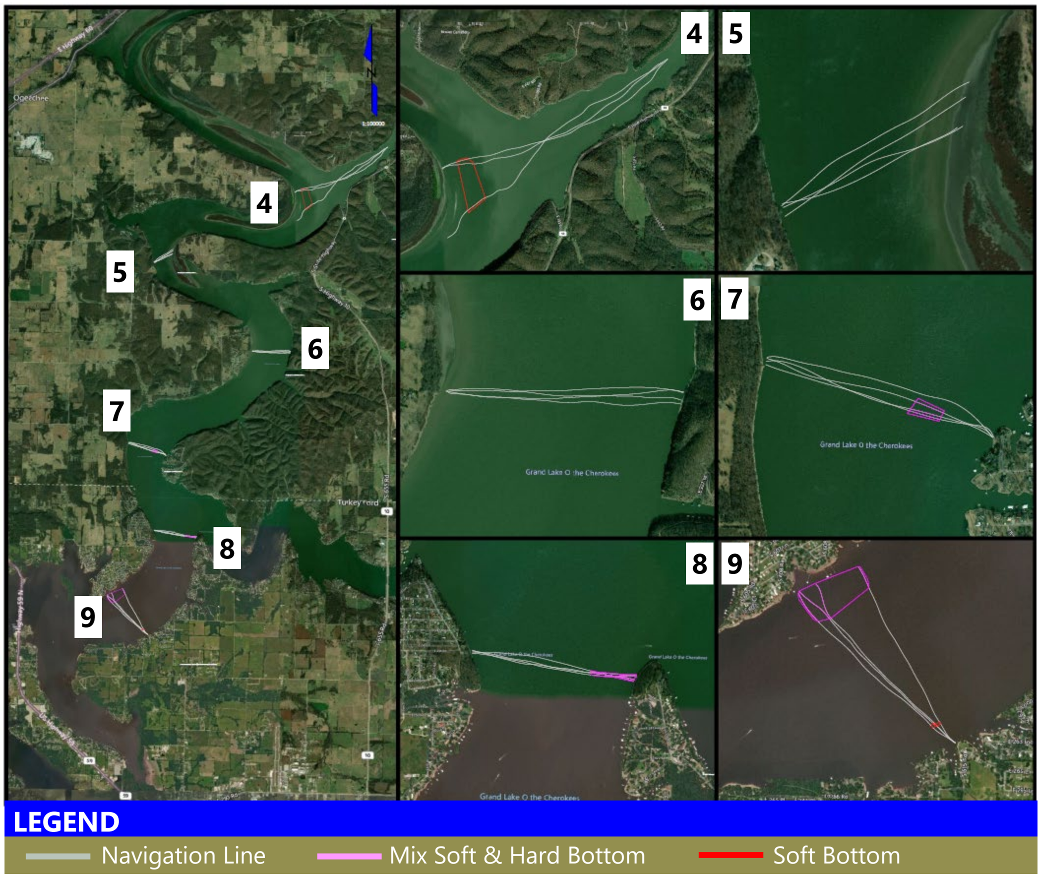
Figure 4
Example SBP Waterfalls showing Layer Transitions and "Multiples"



Notes: Waterfall images taken from SBP survey at RM 112.34 (approximately 1.5 miles upstream of Council Hollow)
Lower image is identical to upper, but locations of layer transitions and multiples are highlighted.
Teal line is the layer transition between soft and hard sediments
Orange lines are "multiples" or secondary reflections

The waterfalls produced during the Neosho River SBP survey showed layer transitions at approximately 2-3 ft below the bed surface. This indicated a thin layer of soft material over firmer sediments throughout much of the survey area. The interpretation was confirmed by an SBP expert, and the representative stated that a majority of the areas surveyed were not characterized by soft sediment beds (Figure 5).

Figure 5
Interpretation of SBP Survey Results at Stations 4 through 9



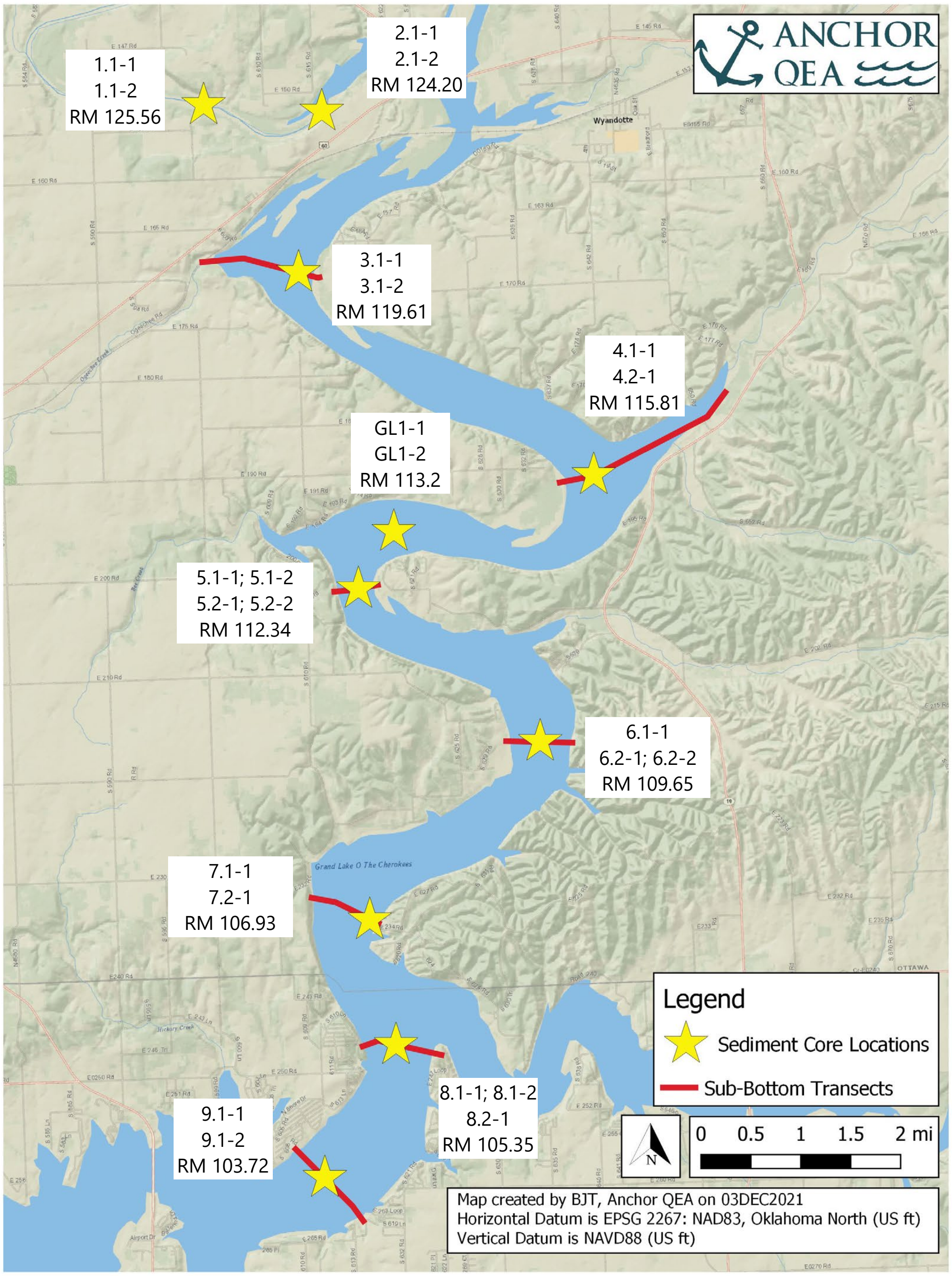
Source: Interpretation of SBP readings; station numbers adjusted from OARS original to reflect GRDA numbers

Figure 5 shows the navigation lines from the field SBP survey. Where a mixture of soft and hard beds were noted by the SBP expert (for example at transect 9, bottom right), pink outlines were drawn. Red outlines indicate soft bottom materials (transect 4, top center). Areas not colored were interpreted to consist of hard bottom sediments.

4.2 Vibracore Analysis

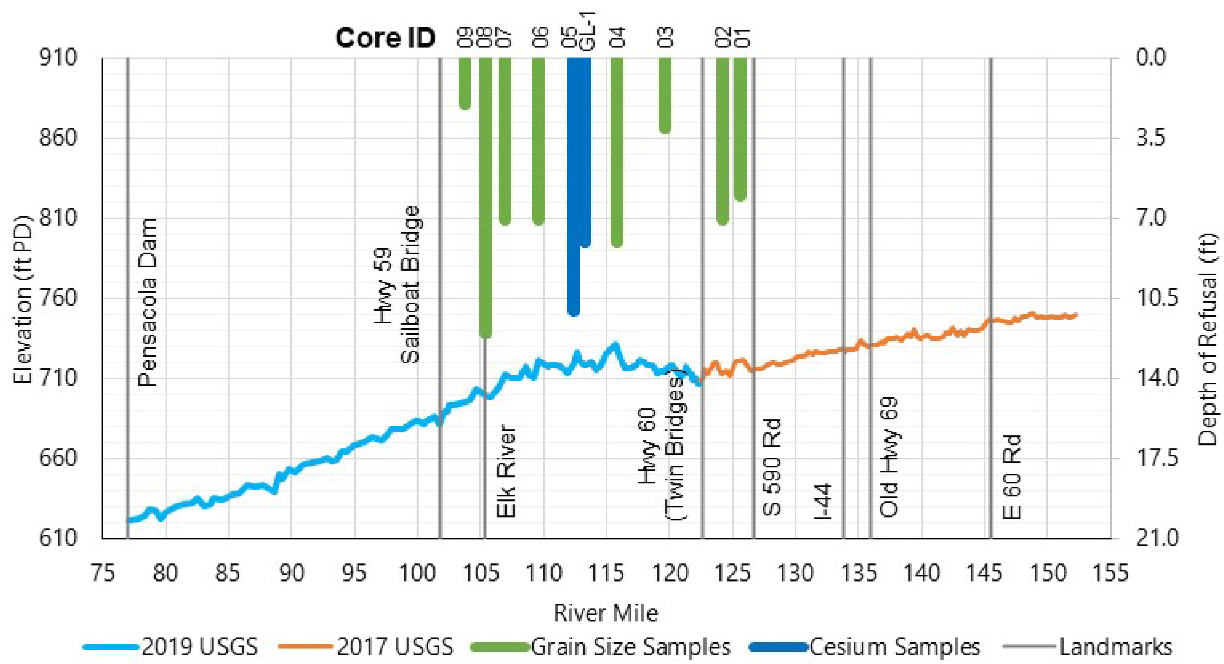
The vibracore pushed core tubes into the riverbed at the locations shown in Figure 6 using 16-foot coring tubes. These were chosen to align with the SBP survey discussed in Section 4.1 as a means of confirming interpretation of the results. SBP survey transects are shown in red with their relationship to the vibracore sample locations.

Figure 6
Locations of Sediment Cores Collected by GRDA



The vibracoring efforts produced 24 core samples for analysis. The cores were pushed to refusal, which ranged from 1.5 to 11 feet in the reach above the Elk River (Figure 7). In the lower reservoir, one core penetrated approximately 12 feet of sediment before refusal. Two cores over 10 feet in length taken in the delta feature (RM 112.34) were evaluated for Cesium-137 (Cs-137) activity. Cores shorter than 10 feet or taken from the lower reservoir were analyzed only for grain size distribution (see Section 3.3). Figure 7 shows the maximum vibracore penetration depths at each site shown in Figure 6.

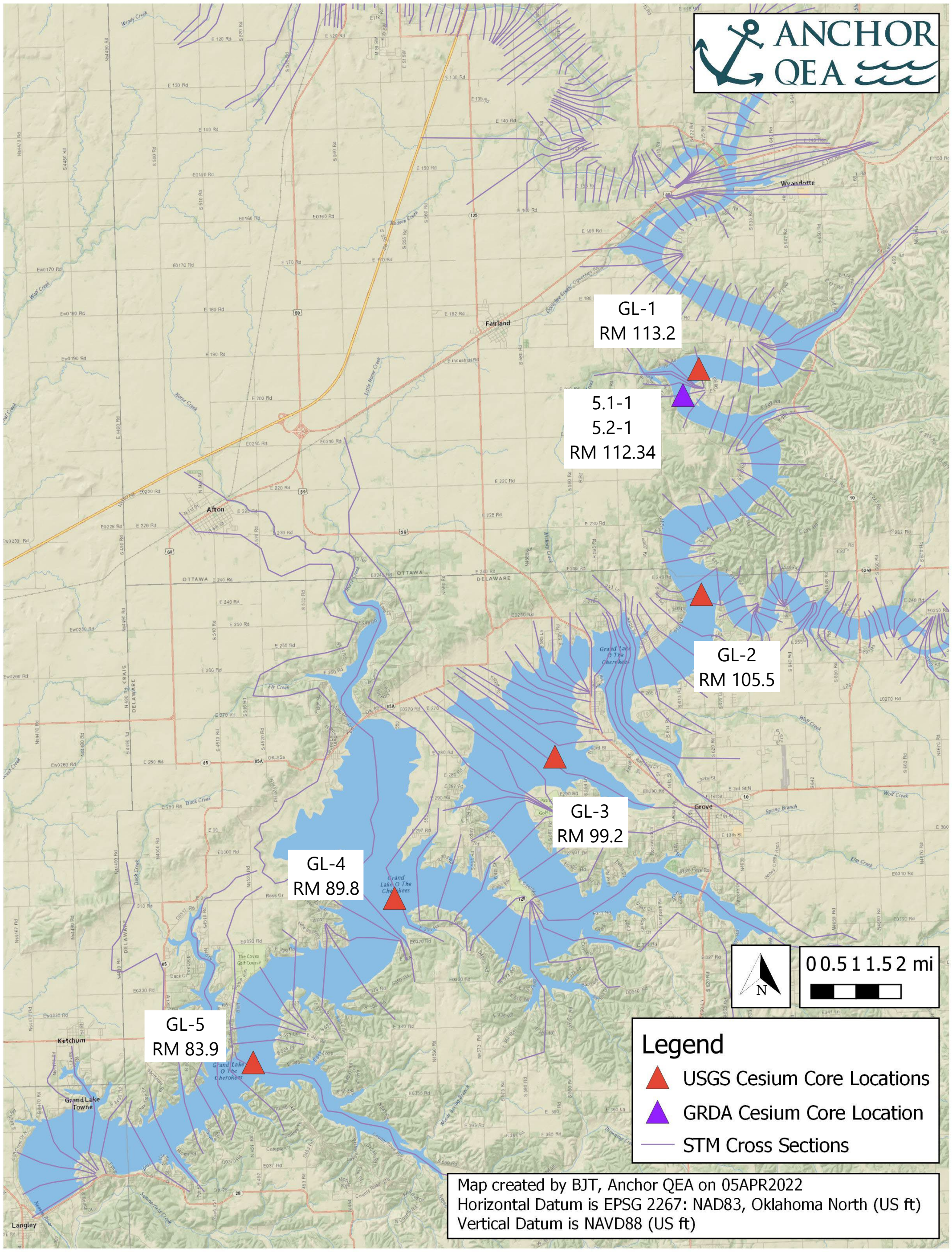
Figure 7
Maximum Vibracore Sample Penetration on Neosho River



Note: GL-1 sample tested for cesium activity by USGS (Juracek and Becker 2009)

The USGS (Juracek and Becker 2009) analyzed sediment Cs-137 levels to determine the approximate age of sediment in various locations within Grand Lake. The 2008 study collected samples from five sites, with one located in the region of the delta feature, one near the confluence with the Elk River, and three others located further downstream in the reservoir (Figure 8). Where USGS data showed a clear, defined Cs-137 peak, the findings were considered settled.

Figure 8
Locations of Sediment Cores Collected for Cesium Analysis



Note: Locations of USGS cores taken from Juracek and Becker (2009)

A major goal of sampling was to collect a significantly deeper sample near USGS site GL-1. The USGS sample was approximately 6 ft, and it was decided that a vibracore sample of approximately 10 ft would be sufficient to trigger re-evaluation and Cs-137 analysis. Shorter cores would not likely produce different results from the USGS (2009) study. Cores lower in the basin were not analyzed as the USGS dataset was sufficiently robust and were not of interest for delta feature analysis. The cores that met this criteria were 5.1-1 and 5.2-1 as shown in Figure 8.

Sediment cores were subdivided by cutting along the length of the core tube using an electric shear. Total recovered length was measured and recorded (Figure 9). Plastic spoons were used to mark the divisions between samples. Cores sent for grain size analyses were divided into 1-ft segments, and Cs-137 samples into 4-cm increments for laboratory assessment by Teledyne Brown Engineering. The spoons were then used to scoop samples into a clean container while avoiding the outer 1.5 cm of the core sample to prevent mixing of material smeared along the sample tube itself. Once used, the spoons were discarded to avoid contamination of any other samples. Sample containers were labeled, sealed, and packaged for transport. Because these were for grain size and Cs-137 analysis, there was no need for preservatives or cooling.

Figure 9
Image of Core 5.1-2 during Processing

Grain size results showed primarily silts and clays throughout each core. Full results are presented in Appendix II. Cs-137 analysis showed no obvious trend in the activity levels. See Appendix III for the laboratory report.

5 Discussion

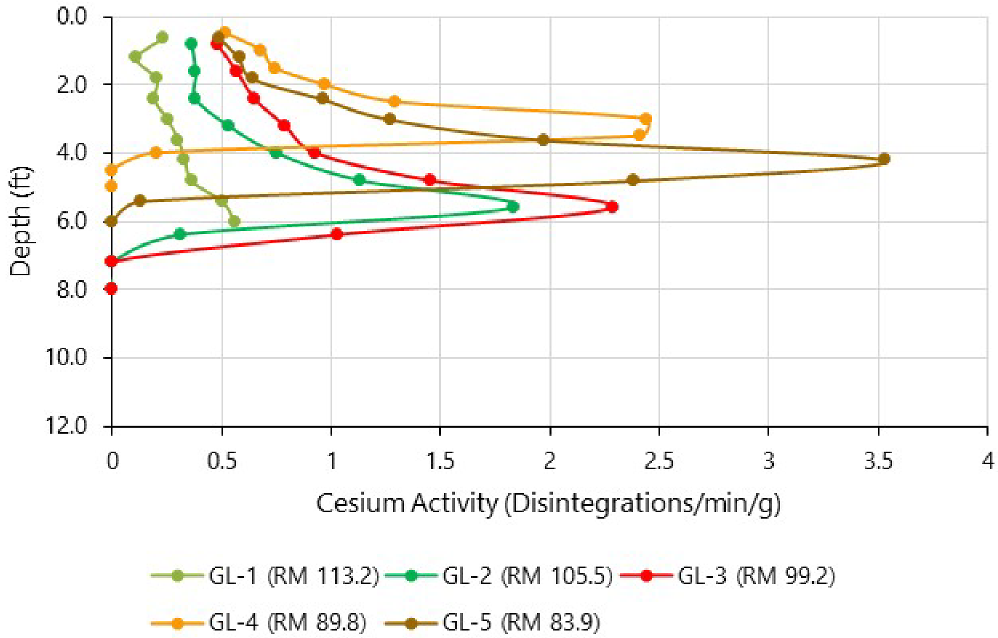
SBP results indicate a primarily firm bed with limited deposition of softer silts and clays. This suggests relatively limited deposition of soft cohesive material. However, these results are contingent upon field sampling to confirm the readings.

The vibracore samples show a thicker sediment deposit which suggests the SBP was not reliably capturing sediment layer thicknesses. Most likely, the penetration of the SBP signal was limited by a layer of biotic activity within the surface of the sediment; several core samples had air bubbles in the top few feet produced by decomposition or other biological activity. This produces readings indicating a softer, air-filled layer above the firmer silt and clay sediment that would register as a separate layer during SBP surveying (Aqua Survey 2004, Science Applications International 2001). As a result, further analyses relied on vibracore sampling rather than SBP results.

Vibracore sampling showed thicker layers of soft sediment deposition, and also provided opportunity to evaluate Cs-137 trends measured by a USGS study (Juracek and Becker 2009).

USGS analysis showed that Cs-137 peaks were located approximately 3 to 6 feet below the bed surface (Figure 10). Those peaks represent sediment that was deposited in approximately 1963, indicating that just 3 to 6 feet of sediment had deposited since 1963 at sites GL-2, -3, -4, and -5 (Figure 8).

Figure 10
Comparisons of Relative Cesium Activity within the USGS Core Samples



Notes: The peak cesium activity indicates the soil layer associated with deposition in approximately 1963. All material above that layer is assumed to have deposited since the nuclear testing ban.

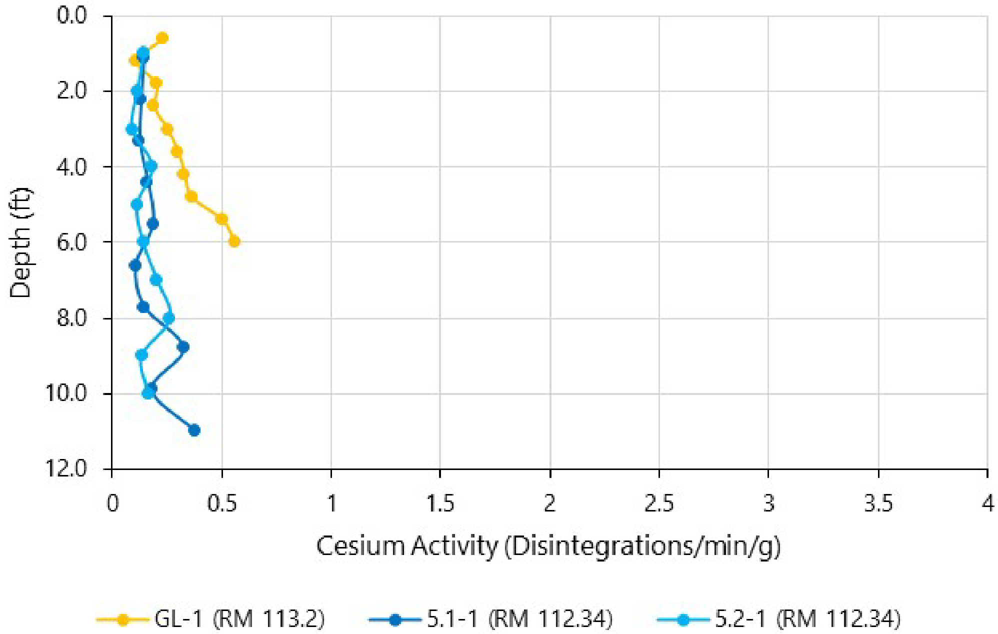
Source: Figure adapted from Juracek and Becker (2009).

The sample in the delta feature (GL-1) showed no spike in Cs-137. Juracek and Becker (2009) concluded the sediment they collected was all deposited post-1963. The USGS interpreted this to indicate that the area was not continually depositional but washes away due to wave action or large flow events before new sediment redeposits. This follows typical reservoir delta feature evolution, with surface sediments at the top of the delta feature washing downstream and extending the delta feature further into the reservoir rather than increasing the top elevation.

During GRDA's vibracore sampling, they repeated the USGS efforts to obtain longer (deeper) cores and see if a longer sample would capture a characteristic Cs-137 spike that denotes a 1963 sediment layer. GRDA collected approximately 11-foot cores near site GL-1 (cores 5.1-1 and 5.2-1) and processed them for Cs-137 analysis. The location of cores 5.1-1 and 5.2-1 are displayed in Figure 8.

GRDA sent 10 samples at equally spaced intervals within each core for Cs-137 evaluation. The results show a similar pattern to those of the USGS study, with no apparent Cs-137 peak (Figure 11).

Figure 11
Comparisons of Relative Cesium Activity Between USGS Core Sample GL-1 and GRDA Samples 5.1-1 and 5.2-1



Notes: GL-1 activity levels taken from Juracek and Becker (2009)
The lack of a defined cesium activity peak indicates that all sediment collected in the core was deposited after 1963.

This further suggests that deposition in the top 10 feet of the soil column is all post-1963 and that the site is not continuously depositional, instead indicating regular mixing of the materials at the top of the delta feature. These results agree with the USGS (Juracek and Becker 2009) findings that this location sees regular disturbance and is not continually depositional.

6 References

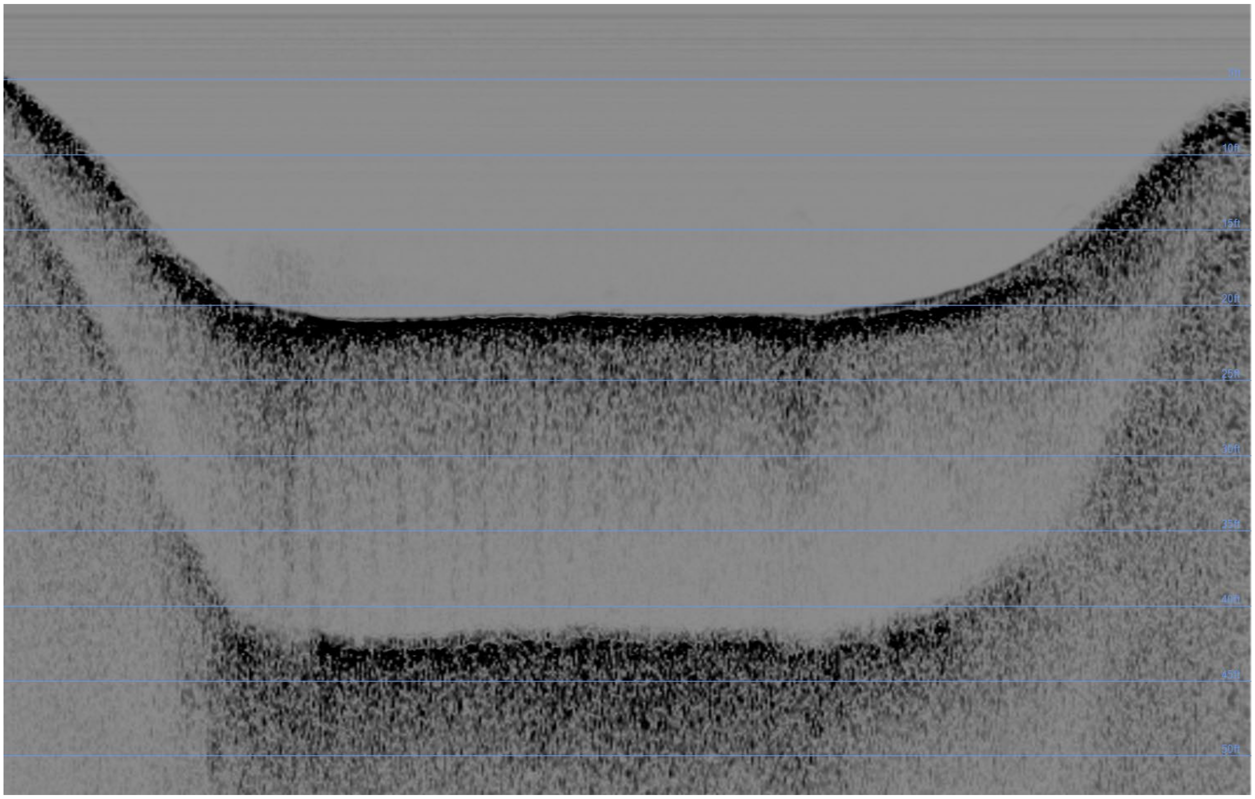
Aqua Survey, 2004. *Technical Report Environmental Dredging and Sediment Decontamination Technology Demonstration Pilot Study Lower Passaic River Restoration Project Magnetometer and Sub-Bottom Profiler Debris Survey*. December 3, 2004.

Juracek, K.E. and M.F. Becker, 2009. *Occurrence and Trends of Selected Chemical Constituents in Bottom Sediment, Grand Lake O' the Cherokees, Northeast Oklahoma, 1940–2008*. U.S. Geological Survey Scientific Investigations Report 2009–5258, 28 p.

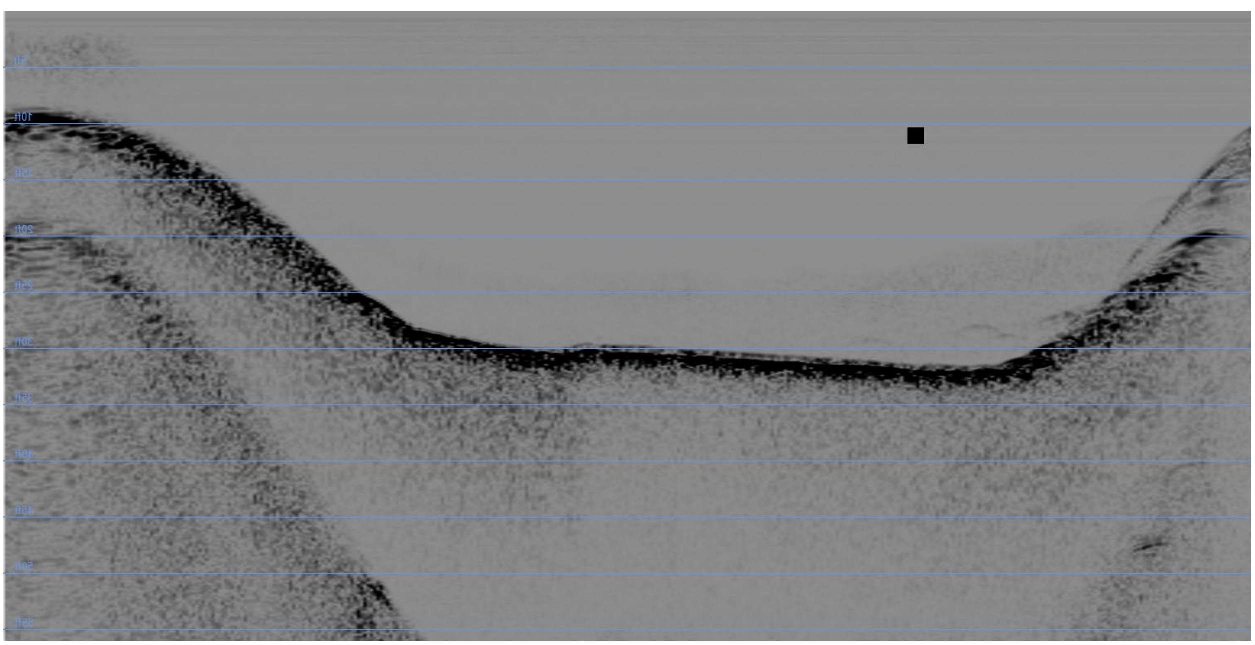
Science Applications International Corporation, 2001. *Results of the March 2001 Sub-Bottom Profiling and Sediment Profile Imaging of the Outer Gloucester Harbor*. SAIC Report 541. June 2001.

Appendix I
Waterfall Images from Sub-Bottom Survey

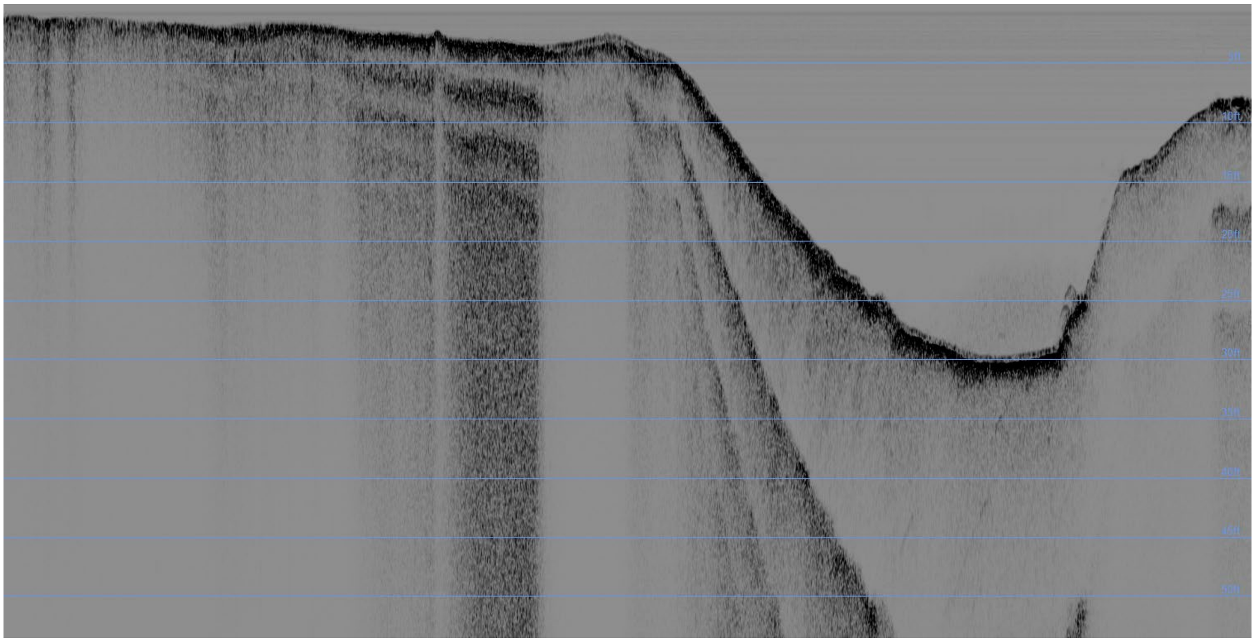
AI.1 Transect 1



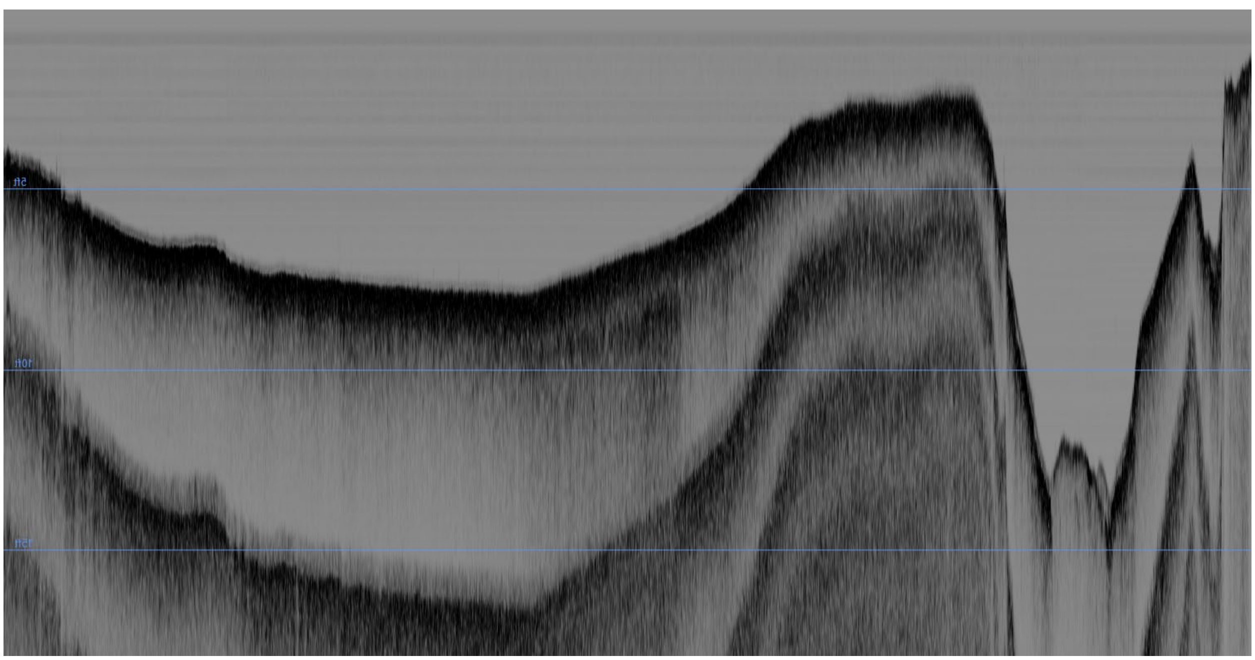
AI.2 Transect 2



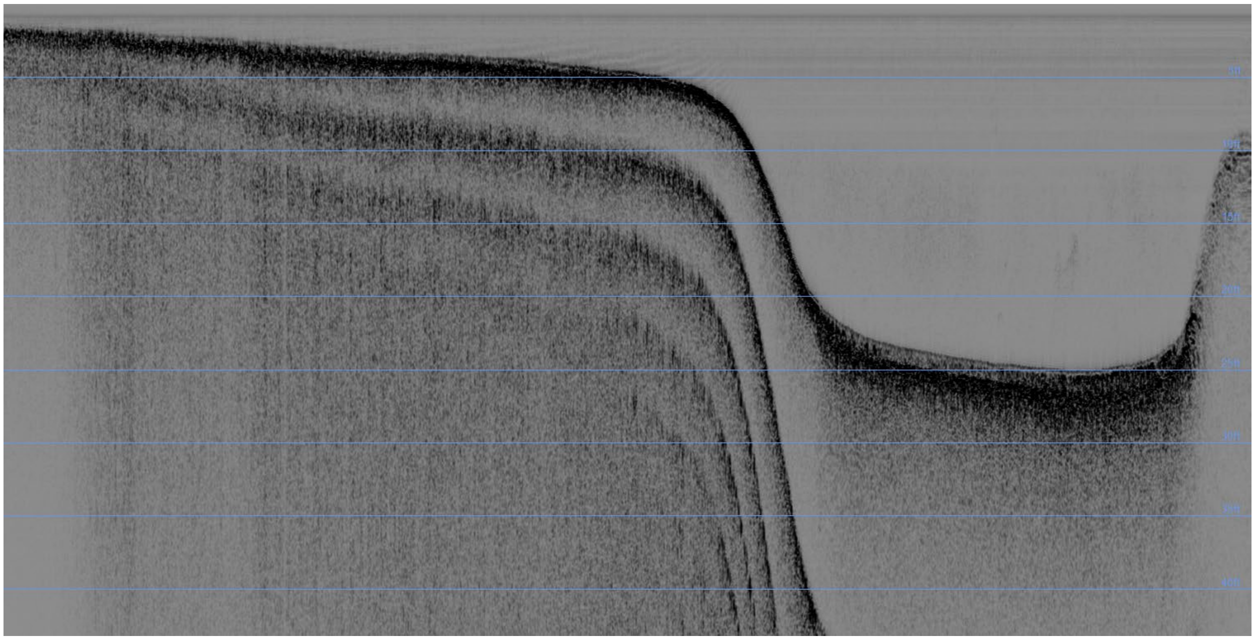
AI.3 Transect 3



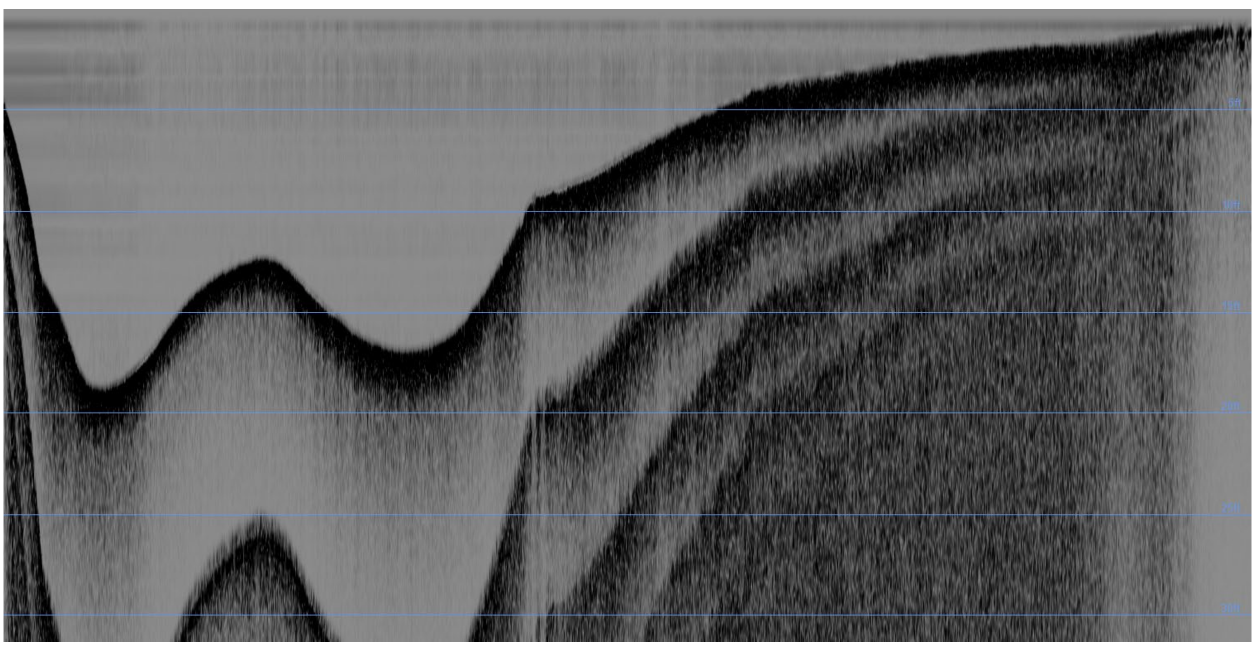
AI.4 Transect 4



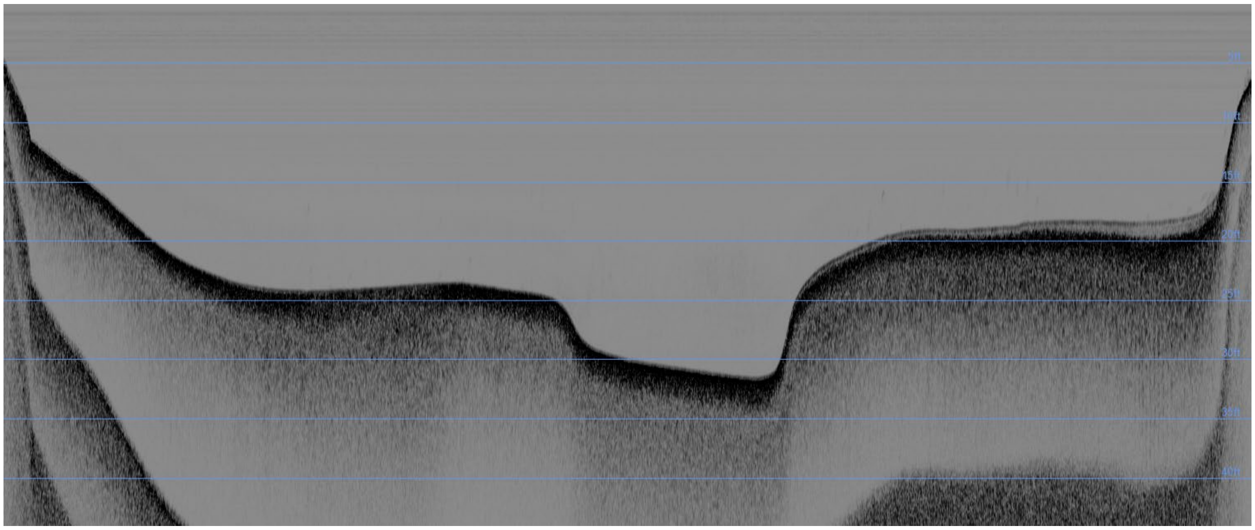
AI.5 Transect 5



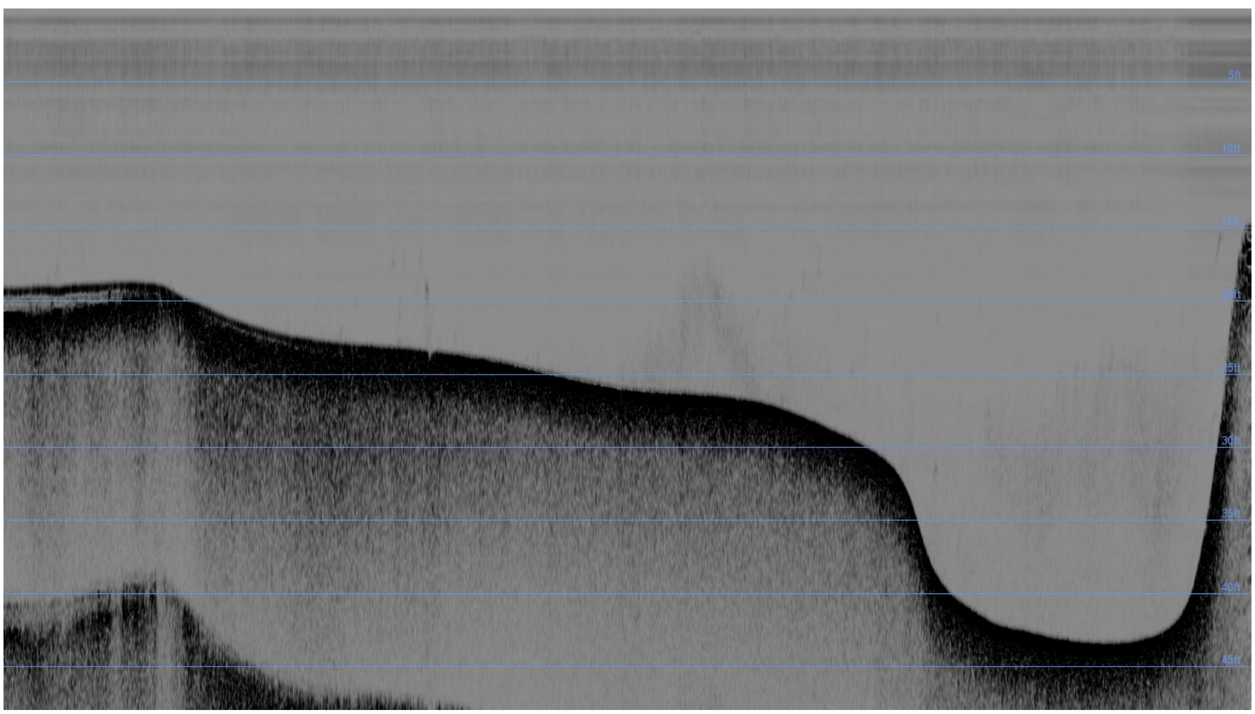
AI.6 Transect 6



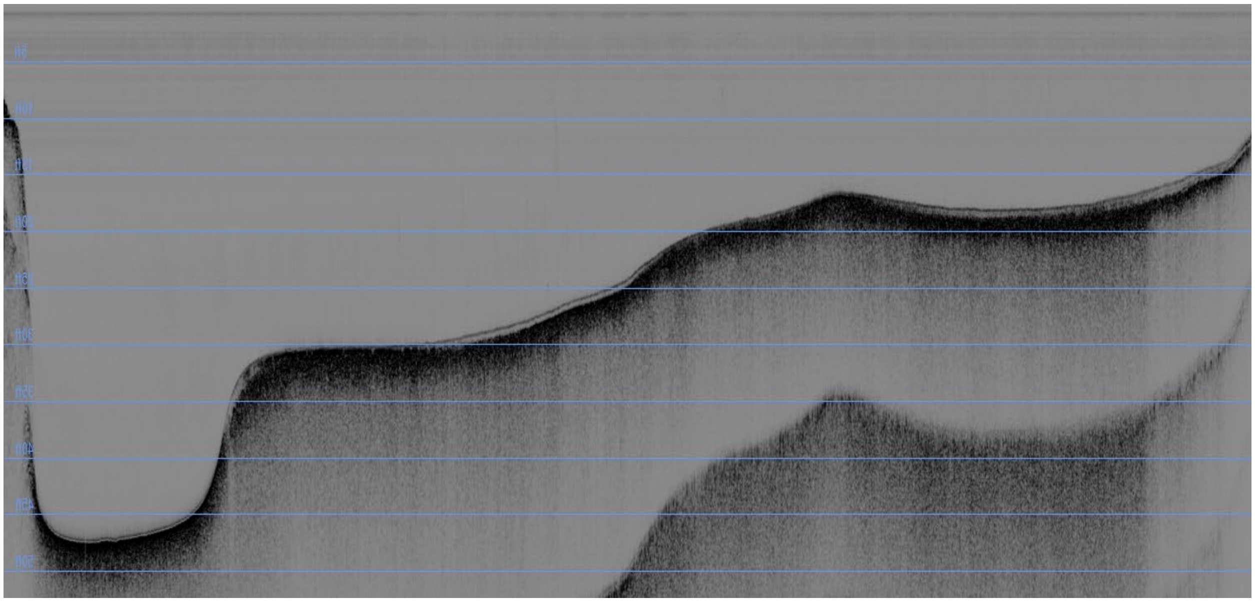
AI.7 Transect 7



AI.8 Transect 8



AI.9 Transect 9



Appendix II
Grain Size Analysis

Soil and Forage Analysis Lab
WISCONSIN STATE LABORATORY OF HYGIENE
UNIVERSITY OF WISCONSIN-MADISON

4702 University Ave
Madison, WI 53705
(608) 262-4364
http://uwlab.soils.wisc.edu

Date 4/18/2022
Acct # 559106
Report # 1228

Anchor QEA, LLC
30 W Mifflin St, Ste 801
Madison, WI 53713

Comments

Soil Texture Analysis

Sample Number	Sample Name Core	Depth (in)	SAND %	SILT %	Clay %	Soil Type
1	01.1-1	0-12	9.0	57.0	34	Silty Clay Loam
2		12 to 24	9.0	47.0	44	Silty Clay
3		24-36	17.0	41.0	42	Silty Clay.
4		36-48	17.0	39.0	44	Clay
5	01.1-2	0-12	5.0	59.0	36	Silty Clay Loam
6		12 to 24	9.0	37.0	54	Clay
7		24-36	9.0	49.0	42	Silty Clay
8		36-48	17.0	43.0	40	Silty Clay
9		48-60	8.0	44.0	48	Silty Clay
10		60-63	2.0	44.0	54	Silty Clay
11	02.1-1	0-12	16.0	52.0	32	Silty Clay Loam
12		12 to 24	12.0	50.0	38	Silty Clay Loam
13		24 to 36	14.0	42.0	44	Silty Clay
14		36 - 48	5.0	50.0	42	Silty Clay
15		48 - 60	14.0	42.0	44	Silty Clay
16		60 - 63	20.0	42.0	38	Silty Clay Loam
17	02.1-2	0 - 12	14.0	48.0	38	Silty Clay Loam
18		12 to 24	16.0	42.0	42	Silty Clay
19		24 to 36	18.0	42.0	40	Silty Clay
20		36 - 48	14.0	44.0	42	Silty Clay
21		48 - 60	32.0	30.0	38	Silty Clay Loam
22		60 - 72	18.0	44.0	38	Silty Clay Loam
23	03.1-1	0 - 12	30.0	34.0	36	Silty Clay Loam
24		12 to 24	14.0	48.0	38	Silty Clay Loam
25		12 to 24	18.0	42.0	40	Silty Clay
26		24 - 33	30.0	40.0	30	Clay Loam
27	03.1-2	0 - 12	14.0	52.0	34	Silty Clay Loam
28		24 - 36	16.0	44.0	40	Silty Clay
29	04.1-1	0 - 12	12.0	52.0	36	Silty Clay Loam
30		12 to 24	8.0	56.0	36	Silty Clay Loam
31		24 - 36	6.0	56.0	38	Silty Clay Loam
32		36 - 43	6.0	50.0	44	Silty Clay Loam
33		0 - 12	26.0	54.0	20	Silt Loam

Soil and Forage Analysis Lab
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Date 4/18/2022
Acct # 559106
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30 W Mifflin St, Ste 801
Madison, WI 53713

Comments

Soil Texture Analysis

Sample Number	Sample Name Core	Depth (in)	SAND %	SILT %	Clay %	Soil Type
34	04.2-1	12 to 24	16.0	56.0	28	Silty Clay Loam
35		24 - 36	16.0	52.0	32	Silty Clay Loam
36		36 - 48	12.0	54.0	34	Silty Clay Loam
37		48 - 60	12.0	54.0	34	Silty Clay Loam
38		60 - 72	14.0	50.0	36	Silty Clay Loam
39		72 - 84	8.0	54.0	38	Silty Clay Loam
40		84 - 92	8.0	52.0	40	Silty Clay
41	05.1-2	0 - 12	8.0	58.0	34	Silty Clay Loam
42		12 to 24	8.0	56.0	36	Silty Clay Loam
43		24 - 36	12.0	54.0	34	Silty Clay Loam
44		36 - 48	8.0	58.0	34	Silty Clay Loam
45		48 - 60	9.0	52.0	39	Silty Clay Loam
46		60 - 72	9.0	50.0	41	Silty Clay
47		72 - 84	7.0	50.0	43	Silty Clay
48		84 - 96	13.0	48.0	39	Silty Clay Loam
49		96 - 102	18.8	48.0	33	Silty Clay Loam
50	05.2-2	0 - 12	12.8	50.0	37	Silty Clay Loam
51		12 to 24	28.8	44.0	27	Clay Loam
52		24 - 36	16.8	52.0	31	Silty Clay Loam
53		36 - 48	18.8	50.0	31	Silty Clay Loam
54		48 - 60	10.8	48.0	41	Silty Clay
55		60 - 72	8.8	52.0	39	Silty Clay Loam
56		72 - 84	10.8	56.0	33	Silty Clay Loam
57		84 - 96	12.8	50.0	37	Silty Clay Loam
58		96 - 102	10.8	54.0	35	Silty Clay Loam
59	06.1-1	0 - 12	10.8	52.0	37	Silty Clay Loam
60	06.2-1	0 - 12	14.8	52.0	33	Silty Clay Loam
61		12 to 24	8.8	54.0	37	Silty Clay Loam
62		24 - 36	6.8	56.0	37	Silty Clay Loam
63		36 - 48	4.8	58.0	37	Silty Clay Loam
64		48 - 60	4.8	56.0	39	Silty Clay Loam
65		60 - 72	4.8	52.0	43	Silty Clay Loam
66	06.2-2	0 - 12	6.8	58.0	35	Silty Clay Loam
67		12 to 24	4.8	58.0	37	Silty Clay Loam
68		24 - 36	8.8	56.0	35	Silty Clay Loam
69		36 - 48	6.8	58.0	35	Silty Clay Loam
70		48 - 60	4.8	56.0	39	Silty Clay Loam
71		60 - 72	2.8	58.0	39	Silty Clay Loam

Soil and Forage Analysis Lab
WISCONSIN STATE LABORATORY OF HYGIENE
UNIVERSITY OF WISCONSIN-MADISON

4702 University Ave
Madison, WI 53705
(608) 262-4364
http://uwlab.soils.wisc.edu

Date 4/18/2022
Acct # 559106
Report # 1228

Anchor QEA, LLC
30 W Mifflin St, Ste 801
Madison, WI 53713

Comments

Soil Texture Analysis

Sample Number	Sample Name Core	Depth (in)	SAND %	SILT %	Clay %	Soil Type
72		72 - 81	0.8	58.0	41	Silty Clay
73	07.1-1	0 - 12	0.8	56.0	43	Silty Clay
74		12 to 24	0.8	60.0	39	Silty Clay Loam
75		24 - 36	2.8	58.0	39	Silty Clay Loam
76		36 - 48	2.8	54.0	43	Silty Clay
77		48 - 53	18.8	42.0	39	Silty Clay Loam
78	07.2-1	0 - 12	0.8	60.0	39	Silty Clay Loam
79		12 to 24	0.8	58.0	41	Silty Clay
80		24 - 36	0.8	56.0	43	Silty Clay
81		36 - 48	6.8	50.0	43	Silty Clay
82		48 - 60	6.8	48.0	45	Silty Clay
83		60 -72	2.8	46.0	51	Silty Clay
84		72 - 79	2.8	44.0	53	Silty Clay
85	08.1-1	0 - 12	4.8	52.0	43	Silty Clay
86		81 - 93	2.8	40.0	57	Silty Clay
87	08.1-2	0 - 12	10.8	52.0	37	Silty Clay Loam
88		117 - 129	2.8	34.0	63	Clay Loam
89	08.2-1	0 - 12	4.8	44.0	51	Silty Clay
90		12 to 24	6.8	42.0	51	Silty Clay
91	09.1-1	0 - 6	12.8	48.0	39	Silty Clay Loam
92		6 to 18	40.8	40.0	19	Silty Clay
93	09.1-2	0 - 12	42.8	36.0	21	Silty Clay
94	GL1-1	0 - 12	20.8	50.0	29	Clay Loam
95		12 to 24	10.8	54.0	35	Silty Clay Loam
96		24 - 36	8.8	54.0	37	Silty Clay Loam
97		36-48	7.0	52.0	41	Silty Clay
98		48-60	9.0	50.0	41	Silty Clay
99		60-72	8.0	52.0	40	Silty Clay
100		72-84	4.0	50.0	46	Silty Clay
101	GL1-2	0-12	16.0	52.0	32	Silty Clay Loam
102		12 to 24	8.0	56.0	36	Silty Clay Loam
103		24-36	10.0	56.0	34	Silty Clay Loam
104		36-48	8.0	52.0	40	Silty Clay
105		48-60	10.0	50.0	40	Silty Clay
106		60-72	4.0	48.0	48	Silty Clay
107		72-84	6.0	42.0	52	Silty Clay
108		84-90	6.0	38.0	56	Clay

Appendix III
Cesium-137 Analysis Results

TELEDYNE
BROWN ENGINEERING, INC.
A Teledyne Technologies Company
2508 Quality Lane
Knoxville, TN 37931-3133
865-690-6819

Work Order #: L95403

ANCHOR QEA

March 23, 2022

Table of Contents

TELEDYNE
BROWN ENGINEERING, INC.
A Teledyne Technologies Company
2508 Quality Lane
Knoxville, TN 37931-3133

Brent Teske
1201 3rd Ave, Suite 2600
Seattle WA 98101

Case Narrative - L95403
AN003-3EREGBTESKE-22

03/23/2022 14:01

Sample Receipt

The following sample(s) were received on March 10, 2022 in good condition, unless otherwise noted.

Cross Reference Table

Client ID	Laboratory ID	Station ID(if applicable)
1; 5.2-1	L95403-1	0-4 CM
8; 5.2-1	L95403-2	28-32 CM
15; 5.2-1	L95403-3	56-60 CM
22; 5.2-1	L95403-4	84-88 CM
29; 5.2-1	L95403-5	112-116 CM
36; 5.2-1	L95403-6	140-144 CM
43; 5.2-1	L95403-7	168-172 CM
50; 5.2-1	L95403-8	196-200 CM
57; 5.2-1	L95403-9	224-228 CM
63; 5.2-1	L95403-10	248-252 CM
64; 5.1-1	L95403-11	0-4 CM
72; 5.1-1	L95403-12	32-36 CM
80; 5.1-1	L95403-13	64-68 CM
88; 5.1-1	L95403-14	96-100 CM
96; 5.1-1	L95403-15	128-132 CM
104; 5.1-1	L95403-16	160-164 CM
112; 5.1-1	L95403-17	192-196 CM
120; 5.1-1	L95403-18	224-228 CM
128; 5.1-1	L95403-19	256-260 CM
137; 5.1-1	L95403-20	292-296 CM

Sample Analysis

Instrument(s) used for all analyses were in calibration.
Standard solution(s) used in analyses were National Institute of Standards and Technology (NIST) traceable.

Analytical Method Cross Reference Table

Radiological Parameter	TBE Knoxville Method	Reference Method
Gamma Spectrometry	TBE-2007	EPA 901.1

TELEDYNE
BROWN ENGINEERING, INC.
A Teledyne Technologies Company
2508 Quality Lane
Knoxville, TN 37931-3133

Case Narrative - L95403
AN003-3EREGBTESKE-22

03/23/2022 14:01

Special Considerations

Gamma Spectroscopy

Quality Control

Quality control sample(s) analyzed as WG38781, WG38795.

Duplicate Sample

All duplicate result(s) were within acceptance limits, unless otherwise noted. Duplicate(s) were analyzed for the following sample(s).

Client ID	Laboratory ID	QC Sample #
JORDAN COVE W	L95387-1	WG38781-1
SA-GAM-13E3	L95392-1	WG38795-1

Certification

This is to certify that Teledyne Brown Engineering - Environmental Services, located at 2508 Quality Lane, Knoxville, Tennessee, 37931, has analyzed, tested and documented samples as specified in the applicable purchase order.

This also certifies that requirements of applicable codes, standards and specifications have been fully met and that any quality assurance documentation which verified conformance to the purchase order is on file and may be examined upon request.

I hereby certify that the above statements are true and correct.

Keith Jeter
Operations Manager

ANALYTICAL RESULTS

Brent Teske

AN003-3EREGBTESKE-22

Sample ID:	**1; 5.2-1**	Collect Start:	02/13/2022 13:34	Matrix:	Sediment/Silt (SS)
Station:	0-4 CM	Collect Stop:	02/13/2022 13:40	Volume:	
Description:		Receive Date:	03/10/2022	% Moisture:	35.53
LIMS Number:	L95403-1				

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	1.81E-02	3.95E-02	**6.62E-02**	pCi/g Dry		21.4	g dry	02/13/22 13:40	03/17/22	62071	Sec	U		No

Sample ID:	**8; 5.2-1**	Collect Start:	02/13/2022 13:34	Matrix:	Sediment/Silt (SS)
Station:	28-32 CM	Collect Stop:	02/13/2022 13:40	Volume:	
Description:		Receive Date:	03/10/2022	% Moisture:	33.49
LIMS Number:	L95403-2				

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	3.63E-02	3.00E-02	**5.25E-02**	pCi/g Dry		32.3	g dry	02/13/22 13:40	03/18/22	64800	Sec	U		No

Sample ID:	**15; 5.2-1**	Collect Start:	02/13/2022 13:34	Matrix:	Sediment/Silt (SS)
Station:	56-60 CM	Collect Stop:	02/13/2022 13:40	Volume:	
Description:		Receive Date:	03/10/2022	% Moisture:	35.8
LIMS Number:	L95403-3				

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	4.54E-02	3.94E-02	**4.20E-02**	pCi/g Dry		35.7	g dry	02/13/22 13:40	03/18/22	64800	Sec	U		Yes

Sample ID:	**22; 5.2-1**	Collect Start:	02/13/2022 13:34	Matrix:	Sediment/Silt (SS)
Station:	84-88 CM	Collect Stop:	02/13/2022 13:40	Volume:	
Description:		Receive Date:	03/10/2022	% Moisture:	36.82
LIMS Number:	L95403-4				

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	3.26E-02	4.89E-02	**8.32E-02**	pCi/g Dry		26.7	g dry	02/13/22 13:40	03/17/22	62056	Sec	U		No

Flag Values
U = Compound/Analyte not detected (< MDC) or less than 3 sigma
+ = Activity concentration exceeds MDC and 3 sigma; peak identified(gamma only)
U* = Compound/Analyte not detected. Peak not identified, but forced activity concentration exceeds MDC and 3 sigma
High = Activity concentration exceeds customer reporting value
Spec = MDC exceeds customer technical specification
L = Low recovery
H = High recovery

Bolded text indicates reportable value.

TBE-ROA013

No = Peak not identified in gamma spectrum
Yes = Peak identified in gamma spectrum

**** Unless otherwise noted, the analytical results reported are related only to the samples tested in the condition they are received by the laboratory.

MDC - Minimum Detectable Concentration

L95403

TELEDYNE BROWN ENGINEERING, INC.
A Teledyne Technologies Company

Brent Teske

AN003-3EREGBTESKE-22

Sample ID: **29; 5.2-1**	Collect Start: 02/13/2022 13:34	Matrix: Sediment/Silt	(SS)
Station: 112-116 CM	Collect Stop: 02/13/2022 13:40	Volume:	
Description:	Receive Date: 03/10/2022	% Moisture: 30.69	
LIMS Number: L95403-5			

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	2.74E-02	3.08E-02	**5.19E-02**	pCi/g Dry		30.4	g dry	02/13/22 13:40	03/18/22	64800	Sec	U		No

Sample ID: **36; 5.2-1**	Collect Start: 02/13/2022 13:34	Matrix: Sediment/Silt	(SS)
Station: 140-144 CM	Collect Stop: 02/13/2022 13:40	Volume:	
Description:	Receive Date: 03/10/2022	% Moisture: 41.21	
LIMS Number: L95403-6			

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	4.68E-02	3.65E-02	**6.43E-02**	pCi/g Dry		24.6	g dry	02/13/22 13:40	03/17/22	62086	Sec	U		No

Sample ID: **43; 5.2-1**	Collect Start: 02/13/2022 13:34	Matrix: Sediment/Silt	(SS)
Station: 168-172 CM	Collect Stop: 02/13/2022 13:40	Volume:	
Description:	Receive Date: 03/10/2022	% Moisture: 40.14	
LIMS Number: L95403-7			

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	**9.32E-02**	3.46E-02	4.29E-02	pCi/g Dry		27.4	g dry	02/13/22 13:40	03/18/22	64800	Sec	+		Yes

Sample ID: **50; 5.2-1**	Collect Start: 02/13/2022 13:34	Matrix: Sediment/Silt	(SS)
Station: 196-200 CM	Collect Stop: 02/13/2022 13:40	Volume:	
Description:	Receive Date: 03/10/2022	% Moisture: 34.07	
LIMS Number: L95403-8			

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	**1.19E-01**	5.25E-02	6.65E-02	pCi/g Dry		45.9	g dry	02/13/22 13:40	03/18/22	64800	Sec	+		Yes

Flag Values
U = Compound/Analyte not detected (< MDC) or less than 3 sigma
\+ = Activity concentration exceeds MDC and 3 sigma; peak identified(gamma only)
U* = Compound/Analyte not detected. Peak not identified, but forced activity concentration exceeds MDC and 3 sigma
High = Activity concentration exceeds customer reporting value
Spec = MDC exceeds customer technical specification
L = Low recovery
H = High recovery

Bolded text indicates reportable value.

No = Peak not identified in gamma spectrum
Yes = Peak identified in gamma spectrum

**** Unless otherwise noted, the analytical results reported are related only to the samples tested in the condition they are received by the laboratory.

MDC - Minimum Detectable Concentration

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Report of Analysis

03/23/22 14:01

L95403

TELEDYNE BROWN ENGINEERING, INC.
A Teledyne Technologies Company

Brent Teske

AN003-3EREGBTESKE-22

Sample ID: **57; 5.2-1**	Collect Start: 02/13/2022 13:34	Matrix: Sediment/Silt	(SS)
Station: 224-228 CM	Collect Stop: 02/13/2022 13:40	Volume:	
Description:	Receive Date: 03/10/2022	% Moisture: 27.7	
LIMS Number: L95403-9			

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	4.68E-02	3.56E-02	**6.08E-02**	pCi/g Dry		31.1	g dry	02/13/22 13:40	03/18/22	64800	Sec	U		No

Sample ID: **63; 5.2-1**	Collect Start: 02/13/2022 13:34	Matrix: Sediment/Silt	(SS)
Station: 248-252 CM	Collect Stop: 02/13/2022 13:40	Volume:	
Description:	Receive Date: 03/10/2022	% Moisture: 34.86	
LIMS Number: L95403-10			

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	3.53E-02	4.48E-02	**7.55E-02**	pCi/g Dry		24.8	g dry	02/13/22 13:40	03/17/22	62078	Sec	U		No

Sample ID: **64; 5.1-1**	Collect Start: 02/13/2022 12:52	Matrix: Sediment/Silt	(SS)
Station: 0-4 CM	Collect Stop: 02/13/2022 13:00	Volume:	
Description:	Receive Date: 03/10/2022	% Moisture: 36.13	
LIMS Number: L95403-11			

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	2.68E-02	3.92E-02	**6.46E-02**	pCi/g Dry		25.5	g dry	02/13/22 13:00	03/17/22	62093	Sec	U		No

Sample ID: **72; 5.1-1**	Collect Start: 02/13/2022 12:52	Matrix: Sediment/Silt	(SS)
Station: 32-36 CM	Collect Stop: 02/13/2022 13:00	Volume:	
Description:	Receive Date: 03/10/2022	% Moisture: 40.9	
LIMS Number: L95403-12			

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	-1.16E-02	3.62E-02	**5.91E-02**	pCi/g Dry		26.9	g dry	02/13/22 13:00	03/17/22	62081	Sec	U		No

Flag Values
U = Compound/Analyte not detected (< MDC) or less than 3 sigma
\+ = Activity concentration exceeds MDC and 3 sigma; peak identified(gamma only)
U* = Compound/Analyte not detected. Peak not identified, but forced activity concentration exceeds MDC and 3 sigma
High = Activity concentration exceeds customer reporting value
Spec = MDC exceeds customer technical specification
L = Low recovery
H = High recovery

Bolded text indicates reportable value.

No = Peak not identified in gamma spectrum
Yes = Peak identified in gamma spectrum

**** Unless otherwise noted, the analytical results reported are related only to the samples tested in the condition they are received by the laboratory.

MDC - Minimum Detectable Concentration

TBE-ROA013

Report of Analysis

03/23/22 14:01

L95403

TELEDYNE BROWN ENGINEERING, INC.
A Teledyne Technologies Company

Brent Teske

AN003-3EREGBTESKE-22

Sample ID: **80; 5.1-1** | Collect Start: 02/13/2022 12:52 | Matrix: Sediment/Silt (SS)
Station: 64-68 CM | Collect Stop: 02/13/2022 13:00 | Volume:
Description: | Receive Date: 03/10/2022 | % Moisture: 29.79
LIMS Number: L95403-13

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	3.94E-02	3.16E-02	**5.59E-02**	pCi/g Dry		21.4	g dry	02/13/22 13:00	03/17/22	62106	Sec	U		No

Sample ID: **88; 5.1-1** | Collect Start: 02/13/2022 12:52 | Matrix: Sediment/Silt (SS)
Station: 96-100 CM | Collect Stop: 02/13/2022 13:00 | Volume:
Description: | Receive Date: 03/10/2022 | % Moisture: 35.63
LIMS Number: L95403-14

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	1.83E-02	4.36E-02	**7.35E-02**	pCi/g Dry		41.7	g dry	02/13/22 13:00	03/18/22	64800	Sec	U		No

Sample ID: **96; 5.1-1** | Collect Start: 02/13/2022 12:52 | Matrix: Sediment/Silt (SS)
Station: 128-132 CM | Collect Stop: 02/13/2022 13:00 | Volume:
Description: | Receive Date: 03/10/2022 | % Moisture: 35.73
LIMS Number: L95403-15

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	7.64E-02	4.74E-02	**8.37E-02**	pCi/g Dry		27.3	g dry	02/13/22 13:00	03/17/22	62114	Sec	U		No

Sample ID: **104; 5.1-1** | Collect Start: 02/13/2022 12:52 | Matrix: Sediment/Silt (SS)
Station: 160-164 CM | Collect Stop: 02/13/2022 13:00 | Volume:
Description: | Receive Date: 03/10/2022 | % Moisture: 33.69
LIMS Number: L95403-16

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values		
CS-137	2007	5.08E-02	3.81E-02	**4.70E-02**	pCi/g Dry		30	g dry	02/13/22 13:00	03/18/22	64800	Sec	U		Yes

Flag Values
U = Compound/Analyte not detected (< MDC) or less than 3 sigma
+ = Activity concentration exceeds MDC and 3 sigma; peak identified(gamma only)
U* = Compound/Analyte not detected. Peak not identified, but forced activity concentration exceeds MDC and 3 sigma
High = Activity concentration exceeds customer reporting value
Spec = MDC exceeds customer technical specification
L = Low recovery
H = High recovery

Bolded text indicates reportable value.

No = Peak not identified in gamma spectrum
Yes = Peak identified in gamma spectrum

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MDC - Minimum Detectable Concentration

TBE-ROA013

Report of Analysis

03/23/22 14:01

TELEDYNE BROWN ENGINEERING, INC.
A Teledyne Technologies Company

L95403

Brent Teske

AN003-3EREGBTESKE-22

Sample ID: **112; 5.1-1**
Station: 192-196 CM
Description:
LIMS Number: L95403-17

Collect Start: 02/13/2022 12:52
Collect Stop: 02/13/2022 13:00
Receive Date: 03/10/2022

Matrix: Sediment/Silt (SS)
Volume:
% Moisture: 34.13

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values	
CS-137	2007	6.14E-02	3.75E-02	**6.51E-02**	pCi/g Dry		44.1	g dry	02/13/22 13:00	03/18/22	64800	Sec	U	No

Sample ID: **120; 5.1-1**
Station: 224-228 CM
Description:
LIMS Number: L95403-18

Collect Start: 02/13/2022 12:52
Collect Stop: 02/13/2022 13:00
Receive Date: 03/10/2022

Matrix: Sediment/Silt (SS)
Volume:
% Moisture: 34.26

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values	
CS-137	2007	**1.48E-01**	5.30E-02	6.01E-02	pCi/g Dry		23.6	g dry	02/13/22 13:00	03/17/22	62133	Sec	+	Yes

Sample ID: **128; 5.1-1**
Station: 256-260 CM
Description:
LIMS Number: L95403-19

Collect Start: 02/13/2022 12:52
Collect Stop: 02/13/2022 13:00
Receive Date: 03/10/2022

Matrix: Sediment/Silt (SS)
Volume:
% Moisture: 31.74

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values	
CS-137	2007	**8.09E-02**	5.28E-02	5.56E-02	pCi/g Dry		49.1	g dry	02/13/22 13:00	03/21/22	63387	Sec	+	Yes

Sample ID: **137; 5.1-1**
Station: 292-296 CM
Description:
LIMS Number: L95403-20

Collect Start: 02/13/2022 13:00
Collect Stop: 02/13/2022 13:00
Receive Date: 03/10/2022

Matrix: Sediment/Silt (SS)
Volume:
% Moisture: 33.22

Radionuclide	SOP#	Activity Conc	Uncertainty 2 Sigma	MDC	Units	Run #	Aliquot Volume	Aliquot Units	Reference Date	Count Date	Count Time	Count Units	Flag Values	
CS-137	2007	**1.73E-01**	5.35E-02	6.11E-02	pCi/g Dry		53.6	g dry	02/13/22 13:00	03/21/22	63423	Sec	+	Yes

Flag Values
U = Compound/Analyte not detected (< MDC) or less than 3 sigma
+ = Activity concentration exceeds MDC and 3 sigma; peak identified(gamma only)
U* = Compound/Analyte not detected. Peak not identified, but forced activity concentration exceeds MDC and 3 sigma
High = Activity concentration exceeds customer reporting value
Spec = MDC exceeds customer technical specification
L = Low recovery
H = High recovery

Bolded text indicates reportable value.

No = Peak not identified in gamma spectrum
Yes = Peak identified in gamma spectrum

**** Unless otherwise noted, the analytical results reported are related only to the samples tested in the condition they are received by the laboratory.

MDC - Minimum Detectable Concentration

TBE-ROA013

QC RESULTS

QC Summary Report for L95403
AN003-3EREGBTESKE-22

03/23/2022 14:01

TELEDYNE BROWN ENGINEERING Everywhereyoulook™

GAMMA
Duplicate Summary

TBE Sample ID	Radionuclide	Matrix	Count Date/Time	Original Result	DUP Result	Units	RPD	Range	Qualifier	P/F
WG38781-1 L95387-1	K-40	VA	03/10/2022 12:48	6.561E+00	5.754E+00	pCi/g Wet	13.1	<50	+	P
WG38795-1 L95392-1	K-40	AN	03/11/2022 11:21	3.007E+03	3.013E+03	pCi/kg Wet	0.2	<50	+	P

GAMMA

Associated Samples for WG38781

Sample #	Client ID
L95403-1	1; 5.2-1
L95403-2	8; 5.2-1
L95403-3	15; 5.2-1
L95403-4	22; 5.2-1
L95403-5	29; 5.2-1
L95403-6	36; 5.2-1
L95403-7	43; 5.2-1
L95403-8	50; 5.2-1
L95403-9	57; 5.2-1
L95403-10	63; 5.2-1

+	Positive Result
U	Compound/analyte was analyzed, peak not identified and/or not detected above MDC
*	< 5 times the MDC are not evaluated
**	Nuclide not detected
***	Spiking level < 5 times activity
P	Pass
F	Fail
NE	Not evaluated

QC Summary Report for L95403

AN003-3EREGBTESKE-22

03/23/2022 14:01

TELEDYNE BROWN ENGINEERING
Everywhereyoulook™

GAMMA

GAMMA

Associated Samples for **WG38795**

Sample #	Client ID
L95403-11	64; 5.1-1
L95403-12	72; 5.1-1
L95403-13	80; 5.1-1
L95403-14	88; 5.1-1
L95403-15	96; 5.1-1
L95403-16	104; 5.1-1
L95403-17	112; 5.1-1
L95403-18	120; 5.1-1
L95403-19	128; 5.1-1
L95403-20	137; 5.1-1

+	Positive Result
U	Compound/analyte was analyzed, peak not identified and/or not detected above MDC
*	< 5 times the MDC are not evaluated
**	Nuclide not detected
***	Spiking level < 5 times activity
P	Pass
F	Fail
NE	Not evaluated

SAMPLE RECEIPT

TELEDYNE BROWN ENGINEERING
A Teledyne Technologies Company

Analysis Request
Chain of Custody

E - Environmental: E
P - 10CFR61, 10CFR50, Other high level:
Turn-around-time 14 days
Purchase order:

Lims# L95403
(for lab use)

Client name: Anchor QEA
Client address: 1201 3rd Ave, Suite 2600
Seattle, WA 98101
Phone Number 608-616-9450
Cell number:
email; bteske@Anchorqea.com
Contact: Brent Teske

T.I. Number (for lab use)	Client Sample ID	Description	Station	Collection Date/Time Start		Stop		Volume	Units	Matrix or type	Analysis Request
	1; 5.2-1	0-4 cm		2/13/2022	13:34	2/13/2022	13:40			SS	GELI, Sample Prep
	8; 5.2-1	28-32 cm		2/13/2022	13:34	2/13/2022	13:40			SS	GELI, Sample Prep
	15; 5.2-1	56-60 cm		2/13/2022	13:34	2/13/2022	13:40			SS	GELI, Sample Prep
	22; 5.2-1	84-88 cm		2/13/2022	13:34	2/13/2022	13:40			SS	GELI, Sample Prep
	29; 5.2-1	112-116 cm		2/13/2022	13:34	2/13/2022	13:40			SS	GELI, Sample Prep
	36; 5.2-1	140-144 cm		2/13/2022	13:34	2/13/2022	13:40			SS	GELI, Sample Prep
	43; 5.2-1	168-172 cm		2/13/2022	13:34	2/13/2022	13:40			SS	GELI, Sample Prep
	50; 5.2-1	196-200 cm		2/13/2022	13:34	2/13/2022	13:40			SS	GELI, Sample Prep
	57; 5.2-1	224-228 cm		2/13/2022	13:34	2/13/2022	13:40			SS	GELI, Sample Prep
	63; 5.2-1	248-252 cm		2/13/2022	13:34	2/13/2022	13:40			SS	GELI, Sample Prep
	64; 5.1-1	0-4 cm		2/13/2022	12:52	2/13/2022	13:00			SS	GELI, Sample Prep
	72; 5.1-1	32-36 cm		2/13/2022	12:52	2/13/2022	13:00			SS	GELI, Sample Prep
	80; 5.1-1	64-68 cm		2/13/2022	12:52	2/13/2022	13:00			SS	GELI, Sample Prep
	88; 5.1-1	96-100 cm		2/13/2022	12:52	2/13/2022	13:00			SS	GELI, Sample Prep
	96; 5.1-1	128-132 cm		2/13/2022	12:52	2/13/2022	13:00			SS	GELI, Sample Prep
	104; 5.1-1	160-164 cm		2/13/2022	12:52	2/13/2022	13:00			SS	GELI, Sample Prep
	112; 5.1-1	192-196 cm		2/13/2022	12:52	2/13/2022	13:00			SS	GELI, Sample Prep
	120; 5.1-1	224-228 cm		2/13/2022	12:52	2/13/2022	13:00			SS	GELI, Sample Prep
	128; 5.1-1	256-260 cm		2/13/2022	12:52	2/13/2022	13:00			SS	GELI, Sample Prep
	137; 5.1-1	292-296 cm		2/13/2022	13:00	2/13/2022	13:00			SS	GELI, Sample Prep

Special Instructions:

Relinquished by:	Date:	Relinquished by:	Date:	Relinquished by:	Date:
Received by: [signature]	Date: 5-10-22	Received by:	Date:	Received by:	Date:

TELEDYNE
BROWN ENGINEERING, INC.
A Teledyne Technologies Company
2508 Quality Lane
Knoxville, TN 37931-3133
865-690-6819

General Information

Quote#: Q685
Quote Date: 02/10/2022
Description: 120 Soil Core samples for Cs-137 dating.
Client: Anchor QEA
Address: 1201 3rd Ave, Suite 2600
Seattle, WA 98101

Contact: Brent Teske
Phone #: (608)616-9450 **Ext.**
Fax #:
Email: bteske@Anchorqea.com

Project Manager: Karli Arterburn
Email: Karli.Arterburn@Teledyne.com
Phone: (865)934-0371
Fax:

Ship samples to:
Teledyne Brown Engineering
2508 Quality Lane
Knoxville, TN 37931
Attention: Sample Receiving

Project Requirements

Data Deliverable: Level 4 - Full 3Sigma
Electronic Deliverable: EQuis,AQ_EZEDD,EDI Anchor QEA
Regulatory Agency:

Estimated Start Date:
Quote Expiration: 12/31/2022
Terms: Net 30

Comments: Standard turn around time may be extended depending on how many sample are sent to be analyzed due the additional step of drying and grinding.

Price per Sample

Matrix	Product Code	30 Day TAT
Sediment/Silt	Gamma *Cs-137 0.1 pCi/g (extended count)*	$126.00
Sediment/Silt	~~Lead 210~~ ~~*Pb-210 0.1 pCi/g*~~	~~$84.00~~
Sediment/Silt	Sample Prep *Drying, grinding, and sieving samples.*	$25.00

Special Considerations

Unless otherwise instructed, batch Laboratory QC will be used and is included in pricing.

Disclaimer

Receipt of samples from the above referenced project shall constitute acceptance of TBE payments terms of and acceptance of the Laboratory Terms and Conditions.

Batch QC is included in pricing.
Client specific QC will be billed at the above rate.

03/23/22 14:09

SR #: SR73957

Client: Anchor QEA, LLC

Teledyne Brown Engineering
Sample Receipt Verification/Variance Report

Project #: AN003-3EREGBTESKE-22 LIMS #L95403

Initiated By: KNOXLAB
Init Date: 03/10/22 Receive Date: 03/10/22

Notification of Variance

Person Notified: Contacted By:
Notify Date:
Notify Method:
Notify Comment:

Client Response

Person Responding:
Response Date:
Response Method:
Response Comment:

Criteria		Yes No NA	Comment
1	Shipping container custody seals present and intact.	NA	
2	Sample container custody seals present and intact.	NA	
3	Sample containers received in good condition.	Y	
4	Chain of custody received with samples.	Y	
5	All samples listed on chain of custody received.	Y	
6	Sample container labels present and legible.	Y	
7	Information on container labels correspond with chain of custody.	Y	
8	Sample(s) properly preserved.	Y	
9	Sample(s) appropriate container(s).	Y	
10	Other. (Describe)	NA	
For Hazardous Materials Only:			
11	Paperwork shows TBE and shippers name, address and phone number.	NA	
12	Paperwork shows sample quantity information.	NA	

INTERNAL CHAIN OF CUSTODY

Internal Chain of Custody

****
Sample # L95403-1 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****
Sample # L95403-2 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****
Sample # L95403-3 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****
Sample # L95403-4 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****
Sample # L95403-5 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****
Sample # L95403-6 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****
Sample # L95403-7 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****

****

Sample # L95403-8 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****

Sample # L95403-9 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****

Sample # L95403-10 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****

Sample # L95403-11 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****

Sample # L95403-12 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****

Sample # L95403-13 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****

Sample # L95403-14 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****

****
Sample # L95403-15 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****
Sample # L95403-16 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****
Sample # L95403-17 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****
Sample # L95403-18 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****
Sample # L95403-19 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

****
Sample # L95403-20 Containernum 1

Prod Analyst
GELI DH

SAMPLE PREP

Relinquish Date Relinquish By Received By
03/10/2022 00:00 099999 Sample Custodian

Internal Chain of Custody
Supplemental Sheet

L95403

****

L95403-1 SS 1; 5.2-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/17/22

****

L95403-2 SS 8; 5.2-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/18/22

****

L95403-3 SS 15; 5.2-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/18/22

****

L95403-4 SS 22; 5.2-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/17/22

****

L95403-5 SS 29; 5.2-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/18/22

****

L95403-6 SS 36; 5.2-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/17/22

Internal Chain of Custody
Supplemental Sheet

L95403

****

L95403-7 SS 43; 5.2-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/18/22

****

L95403-8 SS 50; 5.2-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/18/22

****

L95403-9 SS 57; 5.2-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/18/22

****

L95403-10 SS 63; 5.2-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/17/22

****

L95403-11 SS 64; 5.1-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/17/22

****

L95403-12 SS 72; 5.1-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/17/22

Internal Chain of Custody
Supplemental Sheet

L95403

****

L95403-13 SS 80; 5.1-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/17/22

****

L95403-14 SS 88; 5.1-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/18/22

****

L95403-15 SS 96; 5.1-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/17/22

****

L95403-16 SS 104; 5.1-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/18/22

****

L95403-17 SS 112; 5.1-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/18/22

****

L95403-18 SS 120; 5.1-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/17/22

Teledyne Brown Engineering
Internal Chain of Custody
Supplemental Sheet

L95403

****

L95403-19 SS 128; 5.1-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/21/22

****

L95403-20 SS 137; 5.1-1

Process step	Prod	Analyst	Date
Login		KARTERBURN	03/10/22
%Moisture		DH	03/10/22
Aliquot	GELI	DH	03/16/22
Aliquot	SAMPLE PREP		
Count Room	GELI	SMC	03/21/22

GAMMA SPECTROSCOPY

Gamma Spectroscopy

Background

Analyst:

==
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 7-MAR-2022 09:20:18.81
TBE01 33-TP20784A HpGe ******* Aquisition Date/Time: 4-MAR-2022 12:08:17.00

LIMS No., Customer Name, Client ID: BKG

Sample ID : 01BG030422MT
Sample Type : PCI
Quantity : 1.00000E+00 TOTAL
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 5.00000
MDA Multiple : 1.30890ELibrary Used: LIBD
Peak Evaluation - Identified and Unidentified

Smple Date: 4-MAR-2022 00:00:00.0
Geometry : 01FT082219
BKGFILE : NOBKG
Real Time : 2 12:00:21.41
Live time : 2 12:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	Fit
1	1	63.13	415	3905	1.04	126.70	124	7	1.92E-03	25.2	4.09E+00
2	2	72.70	722	3223	0.95	145.82	136	18	3.34E-03	13.0	3.42E+00
3	2	74.95	1455	3213	0.94	150.30	136	18	6.73E-03	6.8	
4	1	84.62	1018	3868	1.28	169.62	166	8	4.71E-03	11.0	2.47E+00
5	1	87.37	324	2763	1.20	175.11	174	6	1.50E-03	26.2	1.23E+00
6	1	92.63	1891	3426	1.16	185.62	182	8	8.75E-03	5.8	8.00E-01
7	1	139.75	325	2702	1.00	279.71	277	7	1.50E-03	27.1	1.80E+00
8	1	143.61	430	3003	1.36	287.41	284	8	1.99E-03	22.6	8.91E-01
9	1	185.76	1485	3390	1.01	371.59	367	9	6.88E-03	7.5	8.30E-01
10	1	198.23	404	2434	1.05	396.50	393	7	1.87E-03	20.8	3.48E+00
11	1	238.72	696	2898	1.13	477.36	473	9	3.22E-03	14.4	1.40E+00
12	1	295.20	323	2212	1.22	590.15	587	9	1.50E-03	26.8	2.69E+00
13	1	352.17	748	2455	1.62	703.93	698	13	3.46E-03	14.2	3.66E+00
14	1	511.16	5839	2717	2.72	1021.45	1014	18	2.70E-02	2.5	1.65E+00
15	1	569.91	211	1175	1.61	1138.81	1134	10	9.75E-04	31.2	9.53E-01
16	1	583.42	348	1227	1.42	1165.79	1161	11	1.61E-03	20.2	4.58E-01
17	1	609.49	657	1206	1.75	1217.87	1213	10	3.04E-03	10.7	7.81E-01
18	1	803.17	210	635	1.82	1604.75	1600	10	9.71E-04	23.7	1.08E+00
19	1	847.08	640	1123	2.31	1692.46	1683	17	2.96E-03	12.7	2.65E+00
20	1	911.71	212	589	1.84	1821.56	1816	11	9.79E-04	23.3	8.40E-01
21	1	969.33	91	467	1.88	1936.67	1933	9	4.23E-04	44.3	1.61E+00
22	1	1001.51	188	508	2.59	2000.96	1996	11	8.69E-04	24.4	5.49E-01
23	1	1120.56	165	486	2.13	2238.80	2233	12	7.63E-04	28.0	2.45E+00
24	1	1238.84	160	345	2.21	2475.13	2470	11	7.39E-04	24.1	1.24E+00
25	1	1461.58	853	360	2.54	2920.19	2913	16	3.95E-03	6.1	2.07E+00
26	1	1764.95	183	279	2.26	3526.47	3519	17	8.47E-04	22.3	2.01E+00

Analyst:

===

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 7-MAR-2022 09:20:27.96
TBE02 51-TP42214B HpGe ******* Aquisition Date/Time: 4-MAR-2022 12:08:17.80

LIMS No., Customer Name, Client ID: BKG

Sample ID : 02BG030422MT
Sample Type : PCI
Quantity : 1.00000E+00 TOTAL
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 5.00000
MDA Multiple : 1.30890ELibrary Used: LIBD
Peak Evaluation - Identified and Unidentified

Smple Date: 4-MAR-2022 00:00:00.0
Geometry : 02FT082119
BKGFILE : NOBKG
Real Time : 2 12:00:27.07
Live time : 2 12:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	Fit
1	3	63.39	658	3038	0.96	111.51	108	13	3.05E-03	13.9	1.86E+00
2	3	66.35	478	3064	1.06	117.47	108	13	2.21E-03	18.9	
3	2	72.91	1228	3413	0.98	130.66	126	16	5.69E-03	8.1	3.87E+00
4	2	74.96	2423	2773	0.88	134.80	126	16	1.12E-02	3.9	
5	2	77.05	365	2156	0.70	139.00	126	16	1.69E-03	18.9	
6	0	84.72	1248	3807	1.31	154.43	151	7	5.78E-03	8.7	
7	0	87.14	400	3166	0.85	159.30	158	6	1.85E-03	22.9	
8	0	92.65	1789	4082	1.09	170.39	167	8	8.28E-03	6.6	
9	0	139.99	341	4092	1.16	265.63	262	8	1.58E-03	32.9	
10	0	143.91	278	3628	0.87	273.54	271	7	1.29E-03	36.4	
11	0	185.90	1384	3956	1.05	358.03	354	9	6.41E-03	8.6	
12	0	238.64	740	2649	0.93	464.15	461	7	3.43E-03	12.1	
13	0	241.42	172	2614	1.57	469.73	468	7	7.97E-04	49.9	
14	0	295.32	459	2381	1.18	578.20	574	9	2.13E-03	19.7	
15	0	338.08	137	1857	0.87	664.24	661	8	6.35E-04	55.1	
16	0	351.98	1012	2014	1.24	692.22	688	10	4.69E-03	8.9	
17	0	511.01	5511	2426	2.55	1012.24	1004	20	2.55E-02	2.6	
18	0	583.44	331	923	1.11	1158.00	1153	9	1.53E-03	17.5	
19	0	609.38	790	1192	1.40	1210.21	1205	11	3.66E-03	9.2	
20	0	802.76	238	533	2.20	1599.40	1595	10	1.10E-03	19.2	
21	0	846.77	508	823	1.67	1687.98	1681	14	2.35E-03	12.8	
22	0	911.27	243	662	1.89	1817.80	1812	13	1.13E-03	22.8	
23	0	1001.15	99	422	1.23	1998.71	1994	10	4.57E-04	40.2	
24	0	1120.55	222	415	1.50	2239.04	2233	11	1.03E-03	19.1	
25	0	1460.60	979	340	2.25	2923.55	2913	19	4.53E-03	5.5	
26	0	1764.71	276	197	2.10	3535.80	3529	16	1.28E-03	13.0	

Analyst:

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 7-MAR-2022 09:20:47.60
TBE06 33-TP10933A HpGe ******* Aquisition Date/Time: 4-MAR-2022 12:08:18.51

LIMS No., Customer Name, Client ID: BKG

Sample ID : 06BG030422MT
Sample Type : PCI
Quantity : 1.00000E+00 TOTAL
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 5.00000
MDA Multiple : 1.30890ELibrary Used: LIBD
Peak Evaluation - Identified and Unidentified

Smple Date: 4-MAR-2022 00:00:00.0
Geometry : 06FT012721
BKGFILE : NOBKG
Real Time : 2 12:00:35.23
Live time : 2 12:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	Fit
1	0	75.01	742	3487	0.94	150.49	148	6	3.44E-03	13.1	
2	0	84.60	629	3875	1.11	169.64	166	8	2.91E-03	17.6	
3	0	92.64	708	3734	1.10	185.69	182	8	3.28E-03	15.4	
4	0	140.03	319	3416	0.94	280.30	277	8	1.48E-03	32.2	
5	0	185.73	1003	3681	1.14	371.52	368	9	4.64E-03	11.3	
6	0	198.35	359	3248	1.43	396.72	393	8	1.66E-03	28.0	
7	0	238.64	795	2857	1.16	477.14	473	8	3.68E-03	12.2	
8	0	295.36	363	2507	1.12	590.37	587	9	1.68E-03	25.4	
9	0	352.12	660	2282	1.12	703.67	699	10	3.06E-03	14.1	
10	0	511.00	5491	2729	2.52	1020.80	1013	17	2.54E-02	2.6	
11	0	569.88	237	1277	1.26	1138.33	1134	10	1.10E-03	28.9	
12	0	583.40	453	1178	1.21	1165.31	1161	10	2.10E-03	14.9	
13	0	609.48	607	1354	1.48	1217.38	1213	10	2.81E-03	12.1	
14	0	727.50	108	515	1.49	1452.92	1450	6	5.00E-04	34.6	
15	0	803.18	206	757	1.76	1603.96	1600	10	9.55E-04	25.9	
16	0	847.01	236	940	1.97	1691.43	1686	11	1.09E-03	26.0	
17	0	911.29	479	646	1.83	1819.72	1814	12	2.22E-03	11.6	
18	0	969.52	126	648	1.16	1935.93	1930	10	5.82E-04	39.0	
19	0	1120.47	261	555	1.16	2237.17	2233	11	1.21E-03	18.5	
20	0	1238.80	90	395	0.84	2473.29	2469	9	4.15E-04	41.5	
21	0	1461.07	1626	449	1.88	2916.79	2909	17	7.53E-03	3.9	
22	0	1764.87	295	263	2.01	3522.92	3517	13	1.37E-03	12.7	

Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 7-MAR-2022 09:21:11.85
TBE07 31-TP10768B HpGe ******* Aquisition Date/Time: 4-MAR-2022 12:08:19.02

LIMS No., Customer Name, Client ID: BKG

Sample ID : 07BG030422MT
Sample Type : PCI
Quantity : 1.00000E+00 TOTAL
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 5.00000
MDA Multiple : 1.30890ELibrary Used: LIBD
Peak Evaluation - Identified and Unidentified

Smple Date: 4-MAR-2022 00:00:00.0
Geometry : 07FT082119
BKGFILE : NOBKG
Real Time : 2 12:00:23.56
Live time : 2 12:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	Fit
1	3	63.42	482	3069	1.22	126.63	123	14	2.23E-03	19.7	1.49E+00
2	3	66.33	574	3670	1.31	132.45	123	14	2.66E-03	18.6	
3	3	72.80	1584	4219	1.38	145.41	141	18	7.34E-03	7.5	5.84E-01
4	3	74.99	3129	3945	1.31	149.79	141	18	1.45E-02	4.0	
5	3	77.17	455	2809	1.07	154.15	141	18	2.11E-03	20.4	
6	3	84.78	1794	4024	1.57	169.37	162	16	8.30E-03	6.8	5.80E-01
7	3	87.34	530	3003	1.15	174.49	162	16	2.45E-03	18.3	
8	1	92.67	1647	3871	1.30	185.15	181	9	7.63E-03	7.2	2.86E+00
9	1	139.75	329	3405	1.31	279.34	276	8	1.53E-03	31.1	1.11E-01
10	1	143.62	268	3466	1.41	287.09	284	8	1.24E-03	38.5	3.29E-01
11	1	185.74	1207	4104	1.56	371.35	367	10	5.59E-03	10.3	2.41E-01
12	1	198.33	479	3212	1.47	396.54	393	8	2.22E-03	21.0	7.29E-01
13	1	238.49	1156	3370	1.27	476.89	473	9	5.35E-03	9.5	2.50E+00
14	1	295.12	437	2428	0.89	590.18	586	8	2.03E-03	20.1	1.01E+00
15	1	338.75	487	2283	2.14	677.47	673	9	2.25E-03	18.1	5.58E+00
16	1	351.73	935	2937	1.59	703.43	698	12	4.33E-03	12.0	5.71E-01
17	1	510.78	7517	3512	2.98	1021.59	1012	22	3.48E-02	2.3	2.96E+00
18	1	569.60	201	1457	1.81	1139.25	1134	10	9.33E-04	36.0	4.73E-01
19	1	582.98	749	1371	2.31	1166.03	1160	11	3.47E-03	10.2	1.83E+00
20	1	609.23	994	2116	1.84	1218.52	1213	13	4.60E-03	10.1	7.69E-01
21	1	802.54	398	1559	2.94	1605.18	1595	20	1.84E-03	24.9	7.44E-01
22	1	846.38	581	1449	2.08	1692.87	1685	16	2.69E-03	15.2	8.73E-01
23	1	910.84	409	889	2.05	1821.79	1816	12	1.89E-03	15.4	6.34E-01
24	1	968.99	273	699	1.99	1938.08	1933	11	1.27E-03	19.8	5.26E-01
25	1	1120.01	263	613	2.15	2240.11	2235	11	1.22E-03	19.2	7.10E-01
26	1	1460.25	2023	627	2.44	2920.48	2909	22	9.36E-03	3.9	8.75E-01
27	1	1727.69	112	531	6.96	3455.19	3445	27	5.19E-04	57.8	1.77E+00
28	1	1763.58	426	460	3.11	3526.94	3515	24	1.97E-03	14.3	1.26E+00

Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 7-MAR-2022 09:21:29.94
TBE08 31-TP20610B HpGe ******** Aquisition Date/Time: 4-MAR-2022 12:08:18.05

LIMS No., Customer Name, Client ID: BKG

Sample ID : 08BG030422MT
Sample Type : PCI
Quantity : 1.00000E+00 TOTAL
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 5.00000
MDA Multiple : 1.30890ELibrary Used: LIBD
Peak Evaluation - Identified and Unidentified

Smple Date: 4-MAR-2022 00:00:00.0
Geometry : 08FT082019
BKGFILE : NOBKG
Real Time : 2 12:01:26.92
Live time : 2 12:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	Fit
1	1	67.04	394	3094	1.09	140.22	138	6	1.83E-03	22.9	1.60E+00
2	1	75.63	1335	4718	0.82	157.37	154	7	6.18E-03	8.9	2.85E+00
3	1	85.35	1032	3996	1.41	176.76	173	8	4.78E-03	11.0	2.53E+00
4	1	93.30	971	4116	1.21	192.62	188	9	4.49E-03	12.3	5.06E-01
5	1	186.46	914	3785	1.19	378.42	375	9	4.23E-03	12.6	4.12E-01
6	1	199.36	291	3110	1.36	404.13	401	8	1.35E-03	33.8	6.84E-01
7	1	239.27	1199	2908	1.21	483.72	480	8	5.55E-03	8.3	9.13E-01
8	1	242.86	339	2714	1.35	490.89	487	8	1.57E-03	27.3	2.71E+00
9	1	296.01	402	2760	1.75	596.87	592	10	1.86E-03	25.0	4.46E-01
10	1	338.90	201	1980	1.30	682.39	679	8	9.32E-04	38.8	9.19E-01
11	1	352.64	1082	2838	2.21	709.79	704	13	5.01E-03	10.5	6.54E+00
12	1	511.45	5343	2541	2.85	1026.40	1018	17	2.47E-02	2.6	2.10E+00
13	1	583.64	501	1354	1.63	1170.29	1165	11	2.32E-03	14.9	8.17E-01
14	1	609.79	749	1392	1.64	1222.41	1217	11	3.47E-03	10.3	5.03E-01
15	1	846.97	353	1029	1.78	1695.08	1689	14	1.63E-03	20.1	1.77E+00
16	1	911.34	492	820	1.91	1823.34	1817	14	2.28E-03	13.2	9.14E-01
17	1	969.21	198	650	1.48	1938.64	1932	11	9.18E-04	25.8	1.91E+00
18	1	1120.50	205	476	1.73	2240.00	2235	10	9.50E-04	21.1	1.21E+00
19	1	1237.89	170	459	2.47	2473.81	2468	12	7.87E-04	26.5	1.48E+00
20	1	1377.76	84	239	1.64	2752.32	2749	9	3.91E-04	34.7	6.54E-01
21	1	1460.96	1492	435	1.99	2917.97	2910	16	6.91E-03	4.1	7.37E-01
22	1	1764.53	338	237	2.98	3522.24	3515	18	1.57E-03	12.0	1.53E+00

Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 7-MAR-2022 09:21:39.23
TBE11 59-TN51806A HpGe ******* Aquisition Date/Time: 4-MAR-2022 12:08:19.72

LIMS No., Customer Name, Client ID: BKG

Sample ID : 11BG030422MT
Sample Type : PCI
Quantity : 1.00000E+00 TOTAL
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 4.00000
MDA Multiple : 1.30890ELibrary Used: LIBD
Peak Evaluation - Identified and Unidentified

Smple Date: 4-MAR-2022 00:00:00.0
Geometry : 11FT112019
BKGFILE : NOBKG
Real Time : 2 12:01:41.91
Live time : 2 12:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	Fit
1	0	46.61	2817	4750	1.13	91.85	87	10	1.30E-02	5.0	
2	0	53.39	277	2723	1.50	105.39	103	6	1.28E-03	30.4	
3	3	63.30	2213	3526	1.19	125.22	121	15	1.02E-02	5.0	1.62E+00
4	3	66.07	426	4705	1.50	130.75	121	15	1.97E-03	30.0	
5	7	71.27	718	5839	2.21	141.15	136	22	3.33E-03	22.4	2.22E+00
6	7	72.95	3478	3686	1.18	144.51	136	22	1.61E-02	3.5	
7	7	75.05	6480	3615	1.21	148.71	136	22	3.00E-02	2.1	
8	7	77.11	484	3044	0.99	152.82	136	22	2.24E-03	20.3	
9	3	84.85	3034	4253	1.45	168.30	163	15	1.40E-02	4.3	1.27E+00
10	3	87.36	769	2885	0.98	173.33	163	15	3.56E-03	11.9	
11	0	92.82	3115	5019	1.35	184.24	179	11	1.44E-02	4.8	
12	0	139.86	254	3096	1.58	278.28	276	7	1.18E-03	36.8	
13	0	143.85	421	3568	1.42	286.26	283	8	1.95E-03	25.1	
14	0	185.97	1331	4281	1.29	370.47	366	10	6.16E-03	9.6	
15	0	198.46	324	3229	1.33	395.45	392	8	1.50E-03	30.8	
16	0	238.88	674	3441	1.36	476.26	472	9	3.12E-03	16.2	
17	0	295.53	340	2219	1.11	589.53	586	8	1.57E-03	24.6	
18	0	352.20	531	2069	1.39	702.83	699	9	2.46E-03	16.1	
19	0	511.41	7452	3541	2.84	1021.15	1012	24	3.45E-02	2.4	
20	0	570.00	175	1182	2.75	1138.30	1135	9	8.11E-04	36.1	
21	0	583.45	491	1513	1.42	1165.20	1159	12	2.27E-03	16.5	
22	0	609.63	736	2046	1.59	1217.54	1210	14	3.41E-03	13.6	
23	0	796.03	82	788	0.93	1590.22	1585	10	3.78E-04	65.5	
24	0	803.26	183	864	1.23	1604.70	1601	10	8.49E-04	30.8	
25	0	846.93	633	1109	1.64	1692.00	1686	13	2.93E-03	11.5	
26	0	911.30	399	827	1.37	1820.71	1814	14	1.84E-03	16.1	
27	0	969.73	122	588	2.06	1937.53	1932	10	5.63E-04	38.5	
28	0	1120.36	249	710	2.33	2238.72	2232	15	1.15E-03	24.2	
29	0	1238.79	183	611	1.21	2475.50	2468	15	8.47E-04	30.4	
30	0	1246.46	103	551	5.67	2490.85	2483	15	4.79E-04	50.5	
31	0	1461.19	1228	659	2.41	2920.19	2910	22	5.68E-03	6.0	
32	0	1556.32	8	232	3.23	3110.41	3107	11	3.73E-05	366.8	
33	0	1765.22	188	338	1.79	3528.09	3519	15	8.71E-04	22.5	

Analyst:

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report:  7-MAR-2022 09:21:20.77
TBE13 31-TP10727B HpGe ******* Aquisition Date/Time:  4-MAR-2022 12:08:20.32
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LIMS No., Customer Name, Client ID: BKG

Sample ID       : 13BG030422MT                  Smple Date: 4-MAR-2022 00:00:00.0
Sample Type     : PCI                           Geometry  : 13FT012021
Quantity        : 1.00000E+00 TOTAL             BKGFILE   : NOBKG
Start Channel   : 80       Energy Tol   : 2.00000   Real Time : 2 12:00:44.85
End Channel     : 4090     Pk Srch Sens: 5.00000    Live time : 2 12:00:00.00
MDA Multiple    : 1.30890ELibrary Used: LIBD
Peak Evaluation - Identified and Unidentfied
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Pk	It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	Fit
1	1	63.16	313	2283	0.84	126.28	124	6	1.45E-03	24.6	1.48E+00
2	1	66.52	161	2266	0.86	132.98	131	6	7.46E-04	47.4	1.89E+00
3	10	69.87	548	2728	1.64	139.67	136	22	2.54E-03	17.4	6.33E+00
4	10	72.70	1226	2436	1.13	145.31	136	22	5.68E-03	7.4	
5	10	74.79	1922	2135	0.93	149.48	136	22	8.90E-03	4.5	
6	10	76.92	583	2529	1.22	153.73	136	22	2.70E-03	15.6	
7	6	84.59	998	2498	1.14	169.03	165	13	4.62E-03	8.9	1.33E+00
8	6	87.15	458	2063	1.01	174.14	165	13	2.12E-03	16.6	
9	1	92.51	910	2961	1.05	184.84	181	8	4.22E-03	10.8	6.23E+00
10	1	139.94	340	2893	1.15	279.47	276	8	1.57E-03	27.9	2.33E+00
11	1	185.47	880	2796	1.00	370.33	367	8	4.07E-03	10.9	2.12E+00
12	1	198.09	312	2689	0.91	395.51	392	8	1.44E-03	29.3	3.21E-01
13	1	238.43	1067	2975	0.96	476.02	471	10	4.94E-03	10.0	1.82E+00
14	1	294.93	383	1786	1.04	588.78	585	8	1.78E-03	19.7	6.09E-01
15	1	338.34	323	1716	1.52	675.42	671	9	1.50E-03	23.7	1.39E+00
16	1	351.68	827	1763	1.41	702.05	697	10	3.83E-03	10.1	2.45E+00
17	7	510.54	4009	1876	2.45	1019.21	1012	22	1.86E-02	3.0	5.74E+00
18	7	511.58	1345	1338	1.84	1021.29	1012	22	6.23E-03	7.5	
19	1	582.92	438	1003	1.65	1163.75	1158	11	2.03E-03	14.8	7.51E-01
20	1	609.06	592	1054	1.34	1215.95	1211	10	2.74E-03	11.1	7.23E-01
21	1	726.98	106	566	1.07	1451.49	1449	8	4.93E-04	39.5	8.30E-01
22	1	802.69	188	518	1.59	1602.74	1599	9	8.71E-04	22.9	6.26E-01
23	1	846.28	507	899	2.20	1689.85	1681	15	2.35E-03	13.6	3.67E+00
24	1	911.00	374	590	1.71	1819.16	1813	13	1.73E-03	14.4	1.58E+00
25	1	968.60	122	368	1.24	1934.27	1930	8	5.66E-04	28.8	7.85E-01
26	1	1120.42	215	481	2.02	2237.75	2231	14	9.96E-04	22.9	1.84E+00
27	1	1238.59	94	366	2.04	2474.01	2470	10	4.37E-04	39.2	9.19E-01
28	1	1460.58	1176	365	1.99	2918.02	2909	19	5.44E-03	4.9	7.92E-01
29	1	1764.25	230	193	2.91	3525.67	3518	16	1.07E-03	14.9	9.62E-01

Analyst:

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 7-MAR-2022 09:20:56.91
TBE14 54-TP42603C HpGe ******* Aquisition Date/Time: 4-MAR-2022 12:08:18.70

LIMS No., Customer Name, Client ID: BKG

Sample ID : 14BG030422MT
Sample Type : PCI
Quantity : 1.00000E+00 TOTAL
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 5.00000
MDA Multiple : 1.30890ELibrary Used: LIBD
Peak Evaluation - Identified and Unidentified

Smple Date: 4-MAR-2022 00:00:00.0
Geometry : 14FT082119
BKGFILE : NOBKG
Real Time : 2 12:00:34.29
Live time : 2 12:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	Fit
1	1	46.72	247	3283	0.96	90.52	88	7	1.14E-03	39.0	1.96E-01
2	1	63.35	215	2126	0.82	123.83	122	5	9.93E-04	32.9	9.28E-01
3	1	66.31	419	2855	1.20	129.75	127	7	1.94E-03	21.7	4.07E+00
4	2	72.83	749	2222	0.80	142.80	139	13	3.47E-03	10.1	5.25E-01
5	2	74.97	1531	2192	0.76	147.09	139	13	7.09E-03	5.3	
6	4	84.75	1162	2462	1.25	166.68	161	15	5.38E-03	7.7	2.18E+00
7	4	87.42	438	2760	1.25	172.01	161	15	2.03E-03	21.7	
8	1	92.60	787	3197	0.92	182.38	178	9	3.64E-03	13.5	5.64E-01
9	1	139.72	252	2685	1.34	276.73	273	8	1.17E-03	36.1	1.04E+00
10	1	185.77	856	3051	1.32	368.94	364	10	3.96E-03	12.6	8.93E-01
11	1	198.29	217	1497	0.75	394.01	392	5	1.01E-03	27.5	4.94E-01
12	1	238.54	485	2733	1.09	474.58	470	10	2.24E-03	20.6	9.76E-01
13	1	294.99	302	1396	1.58	587.63	584	7	1.40E-03	21.2	3.42E+00
14	1	351.84	493	1267	1.15	701.46	698	8	2.28E-03	13.3	4.31E-01
15	1	510.87	4330	2104	2.74	1019.91	1012	20	2.00E-02	3.0	1.17E+00
16	1	583.34	220	904	1.73	1165.05	1160	10	1.02E-03	26.4	1.63E+00
17	1	609.22	365	976	1.39	1216.87	1212	10	1.69E-03	16.9	6.38E-01
18	1	802.48	105	645	2.52	1603.95	1599	12	4.88E-04	49.4	2.41E+00
19	1	846.63	413	669	1.85	1692.37	1688	13	1.91E-03	13.9	1.74E+00
20	1	910.82	173	397	1.61	1820.95	1817	9	8.00E-04	22.2	1.12E+00
21	1	968.82	107	426	1.97	1937.13	1932	11	4.95E-04	39.3	2.43E+00
22	1	1120.02	125	375	1.83	2240.02	2233	12	5.76E-04	32.3	4.53E-01
23	1	1460.25	805	345	2.11	2921.67	2912	18	3.72E-03	6.5	2.23E+00
24	1	1764.07	129	251	2.78	3530.51	3522	16	5.96E-04	28.9	2.53E+00

Analyst:

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 7-MAR-2022 09:20:36.66
TBE23 11410 HpGe ********** Aquisition Date/Time: 4-MAR-2022 12:08:18.26

LIMS No., Customer Name, Client ID: BKG

Sample ID : 23BG030422MT
Sample Type : PCI
Quantity : 1.00000E+00 TOTAL
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 5.00000
MDA Multiple : 1.30890ELibrary Used: LIBD
Peak Evaluation - Identified and Unidentified

Smple Date: 4-MAR-2022 00:00:00.0
Geometry : 23FT121020
BKGFILE : NOBKG
Real Time : 2 12:00:24.00
Live time : 2 12:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	Fit
1	0	46.45	1509	4082	0.96	92.95	88	10	6.99E-03	8.3	
2	8	63.36	1691	2598	1.12	126.74	122	15	7.83E-03	5.5	8.72E+00
3	8	66.36	566	3281	1.44	132.72	122	15	2.62E-03	19.0	
4	2	74.89	1011	2466	1.04	149.77	144	15	4.68E-03	8.3	2.73E+00
5	2	77.19	1451	2312	0.99	154.36	144	15	6.72E-03	6.0	
6	0	84.27	511	3045	0.99	168.52	165	8	2.37E-03	19.2	
7	0	87.30	357	2736	1.04	174.57	172	7	1.65E-03	24.9	
8	0	92.83	2476	3220	1.09	185.61	181	8	1.15E-02	4.5	
9	0	112.74	221	2048	0.75	225.39	223	6	1.02E-03	33.1	
10	0	139.66	419	2600	1.08	279.19	276	8	1.94E-03	21.6	
11	0	143.70	405	2282	1.04	287.26	284	7	1.87E-03	20.2	
12	0	185.77	1407	2849	1.00	371.33	367	9	6.51E-03	7.3	
13	0	198.31	339	2603	0.92	396.39	393	8	1.57E-03	26.6	
14	0	204.96	152	1767	0.93	409.67	408	6	7.03E-04	44.5	
15	1	238.67	3300	1597	0.97	477.05	473	13	1.53E-02	2.6	1.62E+00
16	1	241.07	320	1835	1.16	481.84	473	13	1.48E-03	24.9	
17	0	295.40	183	1410	1.30	590.42	587	7	8.49E-04	34.8	
18	0	299.64	256	2322	1.01	598.91	594	11	1.18E-03	37.0	
19	0	351.95	402	1199	1.24	703.48	700	7	1.86E-03	15.1	
20	0	511.02	5670	2073	2.57	1021.51	1014	17	2.63E-02	2.3	
21	0	569.98	468	1161	1.48	1139.42	1134	12	2.17E-03	15.3	
22	0	583.29	958	1054	1.39	1166.04	1161	11	4.44E-03	7.3	
23	0	609.19	324	1147	1.04	1217.83	1214	9	1.50E-03	19.6	
24	0	669.42	101	593	1.34	1338.32	1336	8	4.68E-04	42.8	
25	0	727.59	147	744	1.19	1454.69	1450	10	6.80E-04	35.7	
26	0	803.22	189	653	1.55	1605.99	1601	10	8.73E-04	26.4	
27	0	860.60	145	546	1.43	1720.81	1717	9	6.69E-04	30.3	
28	0	911.19	213	487	1.94	1822.05	1817	11	9.84E-04	21.2	
29	0	962.03	105	634	1.16	1923.80	1917	12	4.84E-04	49.1	
30	0	1001.27	156	437	2.21	2002.34	1997	11	7.21E-04	27.3	
31	0	1063.71	276	486	1.45	2127.34	2121	13	1.28E-03	17.5	
32	0	1120.25	63	403	1.29	2240.55	2237	9	2.92E-04	58.6	
33	0	1460.89	621	258	2.08	2922.81	2915	13	2.87E-03	6.7	
34	0	1764.78	103	219	1.20	3531.86	3524	12	4.77E-04	30.4	

GAMMA SPECTROSCOPY

Initial Calibration

E & Z 2088-10-1 Mixed Gamma
6/1/19 12:00 PM

S25 Bottle

		Orig. Wt	5.1617	Volume	50				
		Wt Used	4.4184	Aliquot	5.0000	Certificate	Aliquoted	Actual	Percent
	Half-Life	Energy(KeV)	ate G/s/	%err	%abn	Bq/Tot	G/S	Bq/Tot	Diff
Cd-109	462.9d	88.0	84.75		3.72%	1006.61	37.45	1006.0	-0.06%
Co-57	271.8d	122.1	77.25		85.51%	39.92	34.13	40.0	0.14%
Ce-139	137.64d	165.9	92.68		80.35%	50.96	40.95	51.1	0.34%
Hg-203	46.6d	279.2	273		77.30%	156.04	120.62	143.9	-7.78%
Sn-113	115.09d	391.7	280		64.90%	190.62	123.72	192.6	1.04%
Sr-85	64.849	514.0	547.9		98.40%	246.02	242.08	242.2	-1.55%
Cs-137	30.17y	661.6	330.6		85.12%	171.61	146.07	175.4	2.21%
Y-88	106.65d	898.0	858.7		93.40%	406.22	379.41	393.8	-3.06%
Co-60	5.27y	1173.2	460.4		100.00%	203.42	203.42	202.8	-0.31%
Co-60	5.27y	1332.5	460.9		100.00%	203.64	203.64	207.4	1.84%
Y-88	106.65d	1836.0	908		99.38%	403.69	401.19	401.6	-0.52%

Eff. Name: **01S25121819**

Analyst: KOJ

Analyst:

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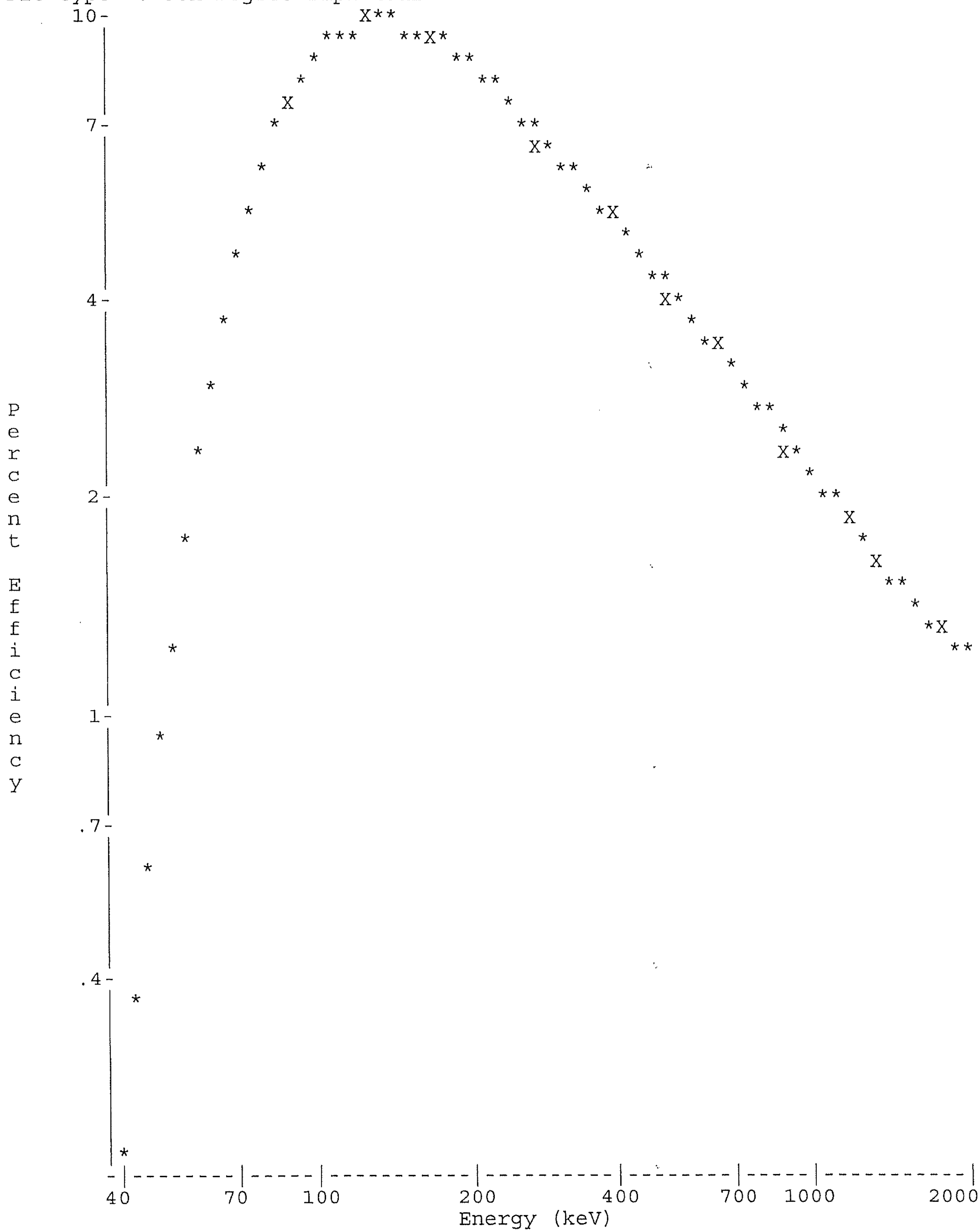
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 12:04:39.66
TBE01 33-TP20784A HpGe ******* Aquisition Date/Time: 18-DEC-2019 12:47:40.18

LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID : 01S25121819 Smple Date: 1-JUN-2019 12:00:00.0
Sample Type : STD Geometry : 01S25121819
Quantity : 1.00000E+00 TOTAL BKGFILE : 01BG112719MT
Start Channel : 80 Energy Tol : 2.00000 Real Time : 0 02:06:53.02
End Channel : 4090 Pk Srch Sens: 7.00000 Live time : 0 02:06:29.39
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	46.45	873	3808	1.00	93.40	7.53E-01	1.15E-01	12.2	3.75E+00
2	1	88.03	16295	6174	0.91	176.45	7.74E+00	2.15E+00	1.2	9.74E-01
3	1	122.06	15462	5708	0.93	244.42	9.95E+00	2.04E+00	1.3	1.85E+00
4	1	136.46	1848	3995	0.93	273.18	1.00E+01	2.44E-01	6.6	4.08E-01
5	1	165.87	10934	4511	0.98	331.91	9.60E+00	1.44E+00	1.5	2.21E+00
6	1	255.13	773	3303	1.28	510.20	7.43E+00	1.02E-01	13.8	1.74E+00
7	1	279.18	3150	3109	1.14	558.24	6.94E+00	4.15E-01	3.6	2.14E+00
8	1	391.74	14953	3343	1.21	783.06	5.26E+00	1.97E+00	1.1	1.41E+00
9	1	513.99	8925	3061	1.24	1027.27	4.15E+00	1.18E+00	1.6	5.91E-01
10	1	661.59	36880	2841	1.41	1322.13	3.30E+00	4.86E+00	0.6	7.72E-01
11	1	813.93	273	1389	1.86	1626.49	2.71E+00	3.60E-02	26.0	2.58E+00
12	1	898.00	18696	2476	1.63	1794.47	2.46E+00	2.46E+00	0.9	1.34E+00
13	1	1173.24	27075	1426	1.85	2344.43	1.89E+00	3.57E+00	0.7	4.76E+00
14	1	1324.88	289	668	2.56	2647.44	1.68E+00	3.81E-02	19.9	7.84E-01
15	1	1332.54	24528	764	1.96	2662.75	1.67E+00	3.23E+00	0.7	2.70E+00
16	1	1835.98	10624	255	2.33	3668.96	1.29E+00	1.40E+00	1.0	4.72E+00

Spectrum : MCA0:[NDSCOUNT]TBE01$1
Calib Date: 26-DEC-2019 12:04
Detector :   Geometry   : 01S25121819
Fit type : 5th Degree Empirical



Analyst:

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 12:05:42.41
TBE01 33-TP20784A HpGe ******* Aquisition Date/Time: 18-DEC-2019 12:47:40.18
-----------------------------------------------------------------------------
LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID      : 01S25121819                   Smple Date: 1-JUN-2019 12:00:00.0
Sample Type    : STD                           Geometry  : 01S25121819
Quantity       : 1.00000E+00 TOTAL             BKGFILE   : 01BG112719MT
Start Channel  : 80     Energy Tol   : 2.00000 Real Time : 0 02:06:53.02
End Channel    : 4090   Pk Srch Sens: 7.00000  Live time : 0 02:06:29.39
MDA Multiple   : 4.6600  Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified
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Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	46.45	873	3808	1.00	93.40	7.53E-01	1.15E-01	12.2	3.75E+00
2	1	88.03	16295	6174	0.91	176.45	7.74E+00	2.15E+00	1.2	9.74E-01
3	1	122.06	15462	5708	0.93	244.42	9.95E+00	2.04E+00	1.3	1.85E+00
4	1	136.46	1848	3995	0.93	273.18	1.00E+01	2.44E-01	6.6	4.08E-01
5	1	165.87	10934	4511	0.98	331.91	9.60E+00	1.44E+00	1.5	2.21E+00
6	1	255.13	773	3303	1.28	510.20	7.43E+00	1.02E-01	13.8	1.74E+00
7	1	279.18	3150	3109	1.14	558.24	6.94E+00	4.15E-01	3.6	2.14E+00
8	1	391.74	14953	3343	1.21	783.06	5.26E+00	1.97E+00	1.1	1.41E+00
9	1	513.99	8925	3061	1.24	1027.27	4.15E+00	1.18E+00	1.6	5.91E-01
10	1	661.59	36880	2841	1.41	1322.13	3.30E+00	4.86E+00	0.6	7.72E-01
11	1	813.93	273	1389	1.86	1626.49	2.71E+00	3.60E-02	26.0	2.58E+00
12	1	898.00	18696	2476	1.63	1794.47	2.46E+00	2.46E+00	0.9	1.34E+00
13	1	1173.24	27075	1426	1.85	2344.43	1.89E+00	3.57E+00	0.7	4.76E+00
14	1	1324.88	289	668	2.56	2647.44	1.68E+00	3.81E-02	19.9	7.84E-01
15	1	1332.54	24528	764	1.96	2662.75	1.67E+00	3.23E+00	0.7	2.70E+00
16	1	1835.98	10624	255	2.33	3668.96	1.29E+00	1.40E+00	1.0	4.72E+00

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	2-Sigma %Error
02-CD109	88.03	16295	3.72*	7.738E+00	7.459E+02	1.006E+03	2.45
03-CO57	122.06	15462	85.51*	9.946E+00	2.395E+01	3.997E+01	2.54
04-CE139	165.85	10934	80.35*	9.601E+00	1.867E+01	5.114E+01	3.07
05-HG203	279.20	3150	81.46*	6.936E+00	7.346E+00	1.439E+02	7.30
06-SN113	391.69	14953	64.90*	5.260E+00	5.771E+01	1.926E+02	2.29
07-SR85	513.99	8925	99.27*	4.152E+00	2.853E+01	2.422E+02	3.28
08-CS137	661.65	36880	85.12*	3.296E+00	1.732E+02	1.754E+02	1.22
09-Y88	898.02	18696	93.40*	2.458E+00	1.073E+02	3.938E+02	1.89
10-CO60	1173.22	27075	100.00	1.891E+00	1.887E+02	2.028E+02	1.38
	1332.49	24528	100.00*	1.674E+00	1.930E+02	2.074E+02	1.39
12-Y88	1836.01	10624	99.38*	1.287E+00	1.094E+02	4.016E+02	2.08

Flag: "*" = Keyline

Total number of lines in spectrum	16	
Number of unidentified lines	5	
Number of lines tentatively identified by NID	11	68.75%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.459E+02	1.006E+03	0.025E+03	2.45	
03-CO57	270.90D	1.67	2.395E+01	3.997E+01	0.101E+01	2.54	
04-CE139	137.66D	2.74	1.867E+01	5.114E+01	0.157E+01	3.07	
05-HG203	46.61D	19.6	7.346E+00	1.439E+02	0.105E+02	7.30	
06-SN113	115.10D	3.34	5.771E+01	1.926E+02	0.044E+02	2.29	
07-SR85	64.84D	8.49	2.853E+01	2.422E+02	0.079E+02	3.28	
08-CS137	30.17Y	1.01	1.732E+02	1.754E+02	0.021E+02	1.22	
09-Y88	106.65D	3.67	1.073E+02	3.938E+02	0.074E+02	1.89	
10-CO60	5.27Y	1.07	1.930E+02	2.074E+02	0.029E+02	1.39	
12-Y88	106.65D	3.67	1.094E+02	4.016E+02	0.084E+02	2.08	
			---------	---------			
	Total Activity :		1.465E+03	2.855E+03			
	Grand Total Activity :		1.465E+03	2.855E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Sample ID : 01S25121819 Acquisition date : 18-DEC-2019 12:47:40

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
1	46.45	873	3808	1.00	93.40	90	7	1.15E-01	24.3	7.53E-01	
1	136.46	1848	3995	0.93	273.18	269	9	2.44E-01	13.2	1.00E+01	
1	255.13	773	3303	1.28	510.20	506	9	1.02E-01	27.7	7.43E+00	
1	813.93	273	1389	1.86	1626.49	1622	10	3.60E-02	52.1	2.71E+00	
1	1324.88	289	668	2.56	2647.44	2641	14	3.81E-02	39.7	1.68E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	16	
Number of unidentified lines	5	
Number of lines tentatively identified by NID	11	68.75%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected BQ/TOTAL	Wtd Mean Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.459E+02	1.006E+03	0.025E+03	2.45	
03-CO57	270.90D	1.67	2.395E+01	3.997E+01	0.101E+01	2.54	
04-CE139	137.66D	2.74	1.867E+01	5.114E+01	0.157E+01	3.07	
05-HG203	46.61D	19.6	7.346E+00	1.439E+02	0.105E+02	7.30	
06-SN113	115.10D	3.34	5.771E+01	1.926E+02	0.044E+02	2.29	
07-SR85	64.84D	8.49	2.853E+01	2.422E+02	0.079E+02	3.28	
08-CS137	30.17Y	1.01	1.732E+02	1.754E+02	0.021E+02	1.22	
09-Y88	106.65D	3.67	1.073E+02	3.938E+02	0.074E+02	1.89	
10-CO60	5.27Y	1.07	1.908E+02	2.051E+02	0.020E+02	0.98	
12-Y88	106.65D	3.67	1.094E+02	4.016E+02	0.084E+02	2.08	
			---------	---------			
	Total Activity :		1.463E+03	2.852E+03			
	Grand Total Activity :		1.463E+03	2.852E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (BQ/TOTAL)	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
02-CD109	1.006E+03	2.464E+01	1.546E+01	0.000E+00	65.101
03-CO57	3.997E+01	1.014E+00	6.132E-01	0.000E+00	65.179
04-CE139	5.114E+01	1.570E+00	1.070E+00	0.000E+00	47.778
05-HG203	1.439E+02	1.051E+01	1.033E+01	0.000E+00	13.933
06-SN113	1.926E+02	4.407E+00	2.722E+00	0.000E+00	70.732

07-SR85	2.422E+02	7.940E+00	5.671E+00	0.000E+00	42.717
08-CS137	1.754E+02	2.138E+00	8.972E-01	0.000E+00	195.463
09-Y88	3.938E+02	7.444E+00	3.952E+00	0.000E+00	99.670
10-CO60	2.051E+02	2.007E+00	8.230E-01	0.000E+00	249.140
12-Y88	4.016E+02	8.365E+00	2.259E+00	0.000E+00	177.763

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (BQ/TOTAL)	K.L. Ided	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
01-AM241	-5.914E-01		1.827E+00	2.908E+00	0.000E+00	-0.203

```
A,01S25121819      ,12/26/2019 12:05,06/01/2019 12:00,   1.000E+00,S25 5ML MIXED
B,01S25121819      ,CALIBRATION         ,12/26/2019 12:04,01S25121819
C,02-CD109,YES,   1.006E+03,   2.464E+01,   1.546E+01,,   65.101
C,03-CO57 ,YES,   3.997E+01,   1.014E+00,   6.132E-01,,   65.179
C,04-CE139,YES,   5.114E+01,   1.570E+00,   1.070E+00,,   47.778
C,05-HG203,YES,   1.439E+02,   1.051E+01,   1.033E+01,,   13.933
C,06-SN113,YES,   1.926E+02,   4.407E+00,   2.722E+00,,   70.732
C,07-SR85 ,YES,   2.422E+02,   7.940E+00,   5.671E+00,,   42.717
C,08-CS137,YES,   1.754E+02,   2.138E+00,   8.972E-01,,  195.463
C,09-Y88  ,YES,   3.938E+02,   7.444E+00,   3.952E+00,,   99.670
C,10-CO60 ,YES,   2.051E+02,   2.007E+00,   8.230E-01,,  249.140
C,12-Y88  ,YES,   4.016E+02,   8.365E+00,   2.259E+00,,  177.763
C,01-AM241,NO ,  -5.914E-01,   1.827E+00,   2.908E+00,,   -0.203
```

E & Z 2088-10-1 Mixed Gamma
6/1/19 12:00 PM

S25 Bottle

		Orig. Wt	5.1617	Volume	50				
		Wt Used	4.4184	Aliquot	5.0000	Certificate	Aliquoted	Actual	Percent
	Half-Life	Energy(KeV)	ate G/s	%err	%abn	Bq/Tot	G/S	Bq/Tot	Diff
Cd-109	462.9d	88.0	84.75		3.72%	1006.61	37.45	1003.0	-0.36%
Co-57	271.8d	122.1	77.25		85.51%	39.92	34.13	40.5	1.56%
Ce-139	137.64d	165.9	92.68		80.35%	50.96	40.95	50.0	-1.83%
Hg-203	46.6d	279.2	273		77.30%	156.04	120.62	149.2	-4.39%
Sn-113	115.09d	391.7	280		64.90%	190.62	123.72	192.7	1.09%
Sr-85	64.849	514.0	547.9		98.40%	246.02	242.08	239.1	-2.81%
Cs-137	30.17y	661.6	330.6		85.12%	171.61	146.07	175.3	2.15%
Y-88	106.65d	898.0	858.7		93.40%	406.22	379.41	395.1	-2.74%
Co-60	5.27y	1173.2	460.4		100.00%	203.42	203.42	206.2	1.37%
Co-60	5.27y	1332.5	460.9		100.00%	203.64	203.64	204.0	0.17%
Y-88	106.65d	1836.0	908		99.38%	403.69	401.19	402.5	-0.30%

Eff. Name: **02S25121819**

Analyst: KOJ

Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 15:31:26.63
TBE02 51-TP42214B HpGe ******* Aquisition Date/Time: 18-DEC-2019 18:27:24.76

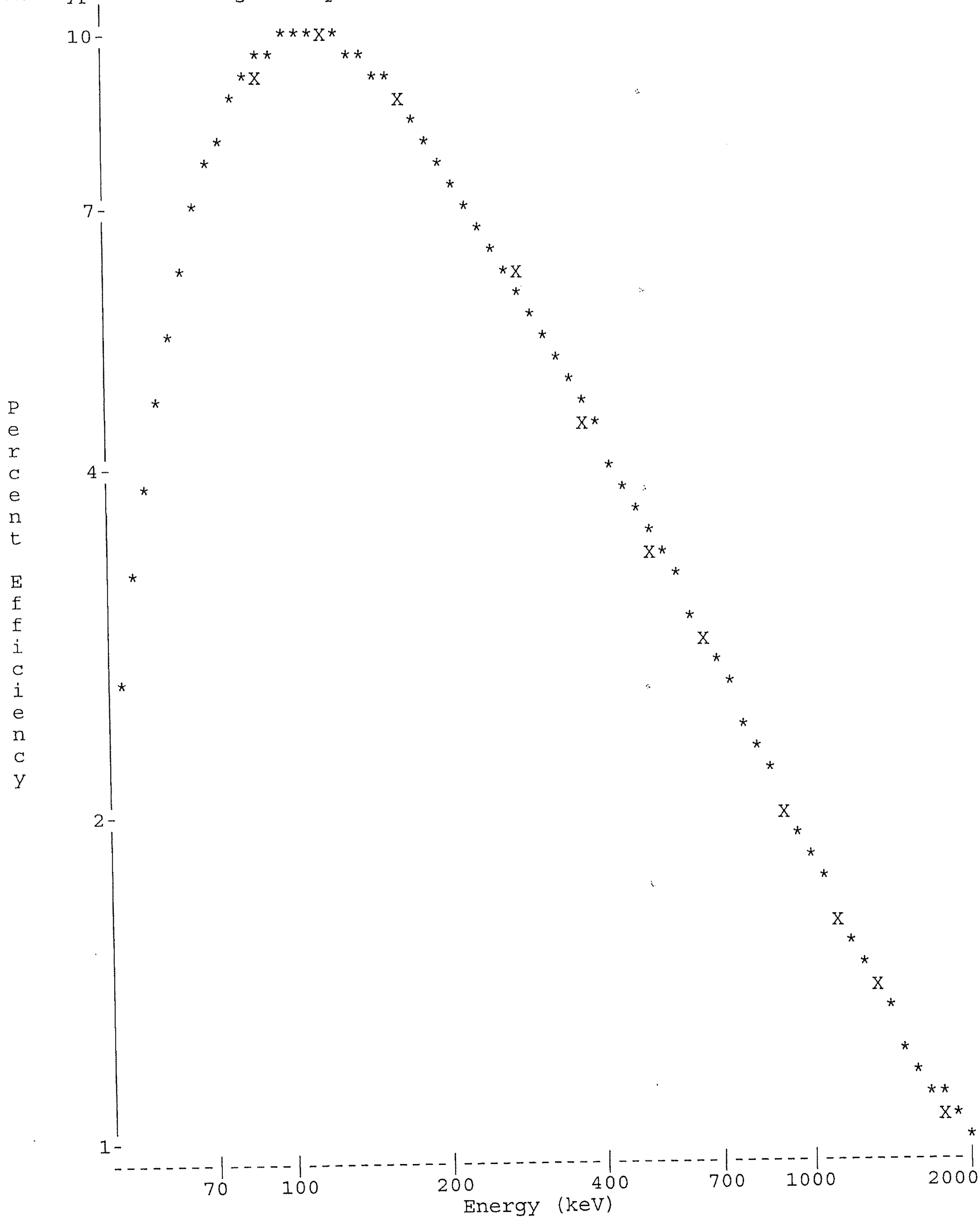
LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID : 02S25121819
Sample Type : STD
Quantity : 1.00000E+00 TOTAL
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Smple Date: 1-JUN-2019 12:00:00.0
Geometry : 02S25121819
BKGFILE : 02BG112719MT
Real Time : 0 04:00:55.90
Live time : 0 04:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	88.00	37891	11475	0.91	160.79	9.51E+00	2.63E+00	0.8	
2	0	122.02	30362	9762	0.98	229.23	1.02E+01	2.11E+00	0.9	
3	0	136.42	3890	6454	1.03	258.18	9.85E+00	2.70E-01	4.1	
4	0	165.86	18919	7972	1.06	317.42	8.96E+00	1.31E+00	1.2	
5	0	255.18	1383	5277	1.23	497.07	6.55E+00	9.60E-02	9.9	
6	0	279.23	5403	5694	1.14	545.46	6.07E+00	3.75E-01	3.0	
7	0	391.70	24333	5851	1.20	771.69	4.52E+00	1.69E+00	0.9	
8	0	514.06	14116	4868	1.28	1017.85	3.52E+00	9.80E-01	1.3	
9	0	661.65	58552	5074	1.46	1314.80	2.76E+00	4.07E+00	0.5	
10	0	814.01	328	2126	1.39	1621.33	2.25E+00	2.28E-02	25.9	
11	0	898.02	29394	4236	1.63	1790.38	2.03E+00	2.04E+00	0.8	
12	0	1173.19	42934	2084	1.83	2344.08	1.55E+00	2.98E+00	0.5	
13	0	1332.45	37534	1525	1.96	2664.60	1.37E+00	2.61E+00	0.6	
14	0	1836.03	16498	472	2.27	3678.18	1.05E+00	1.15E+00	0.9	

Spectrum   : MCA0:[NDSCOUNT]TBE02$1
Calib Date: 26-DEC-2019 15:31
Detector   :   Geometry   : 02S25121819
Fit type   : 5th Degree Empirical



Analyst:

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================================================================================
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 15:32:31.22
TBE02 51-TP42214B HpGe ******* Aquisition Date/Time: 18-DEC-2019 18:27:24.76
--------------------------------------------------------------------------------
LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID      : 02S25121819                         Smple Date: 1-JUN-2019 12:00:00.0
Sample Type    : STD                                 Geometry  : 02S25121819
Quantity       : 1.00000E+00 TOTAL                   BKGFILE   : 02BG112719MT
Start Channel  : 80       Energy Tol    : 2.00000   Real Time : 0 04:00:55.90
End Channel    : 4090     Pk Srch Sens: 9.00000     Live time : 0 04:00:00.00
MDA Multiple   : 4.6600   Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified
```

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	88.00*	37869	11475	0.91	160.79	9.51E+00	2.63E+00	0.8	
2	0	122.02	30362	9762	0.98	229.23	1.02E+01	2.11E+00	0.9	
3	0	136.42	3890	6454	1.03	258.18	9.85E+00	2.70E-01	4.1	
4	0	165.86	18919	7972	1.06	317.42	8.96E+00	1.31E+00	1.2	
5	0	255.18	1383	5277	1.23	497.07	6.55E+00	9.60E-02	9.9	
6	0	279.23	5403	5694	1.14	545.46	6.07E+00	3.75E-01	3.0	
7	0	391.70	24333	5851	1.20	771.69	4.52E+00	1.69E+00	0.9	
8	0	514.06	14116	4868	1.28	1017.85	3.52E+00	9.80E-01	1.3	
9	0	661.65	58552	5074	1.46	1314.80	2.76E+00	4.07E+00	0.5	
10	0	814.01	328	2126	1.39	1621.33	2.25E+00	2.28E-02	25.9	
11	0	898.02	29394	4236	1.63	1790.38	2.03E+00	2.04E+00	0.8	
12	0	1173.19	42934	2084	1.83	2344.08	1.55E+00	2.98E+00	0.5	
13	0	1332.45	37534	1525	1.96	2664.60	1.37E+00	2.61E+00	0.6	
14	0	1836.03	16498	472	2.27	3678.18	1.05E+00	1.15E+00	0.9	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	2-Sigma %Error
02-CD109	88.03	37869	3.72*	9.511E+00	7.433E+02	1.003E+03	1.51
03-CO57	122.06	30362	85.51*	1.015E+01	2.428E+01	4.054E+01	1.74
04-CE139	165.85	18919	80.35*	8.962E+00	1.824E+01	5.003E+01	2.34
05-HG203	279.20	5403	81.46*	6.074E+00	7.583E+00	1.492E+02	5.90
06-SN113	391.69	24333	64.90*	4.516E+00	5.766E+01	1.927E+02	1.82
07-SR85	513.99	14116	99.27*	3.516E+00	2.809E+01	2.391E+02	2.63
08-CS137	661.65	58552	85.12*	2.760E+00	1.731E+02	1.753E+02	0.99
09-Y88	898.02	29394	93.40*	2.034E+00	1.074E+02	3.951E+02	1.53
10-CO60	1173.22	42934	100.00	1.554E+00	1.919E+02	2.062E+02	1.08
	1332.49	37534	100.00*	1.374E+00	1.898E+02	2.040E+02	1.14
12-Y88	1836.01	16498	99.38*	1.053E+00	1.095E+02	4.025E+02	1.70

Flag: "*" = Keyline

Total number of lines in spectrum	14	
Number of unidentified lines	3	
Number of lines tentatively identified by NID	11	78.57%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.433E+02	1.003E+03	0.015E+03	1.51	
03-CO57	270.90D	1.67	2.428E+01	4.054E+01	0.070E+01	1.74	
04-CE139	137.66D	2.74	1.824E+01	5.003E+01	0.117E+01	2.34	
05-HG203	46.61D	19.7	7.583E+00	1.492E+02	0.088E+02	5.90	
06-SN113	115.10D	3.34	5.766E+01	1.927E+02	0.035E+02	1.82	
07-SR85	64.84D	8.51	2.809E+01	2.391E+02	0.063E+02	2.63	
08-CS137	30.17Y	1.01	1.731E+02	1.753E+02	0.017E+02	0.99	
09-Y88	106.65D	3.68	1.074E+02	3.951E+02	0.060E+02	1.53	
10-CO60	5.27Y	1.07	1.898E+02	2.040E+02	0.023E+02	1.14	
12-Y88	106.65D	3.68	1.095E+02	4.025E+02	0.069E+02	1.70	
			---------	---------			
	Total Activity :		1.459E+03	2.852E+03			
	Grand Total Activity :		1.459E+03	2.852E+03			

Flags: "K" = Keyline not found
"E" = Manually edited
"M" = Manually accepted
"A" = Nuclide specific abn. limit

Unidentified Energy Lines
Sample ID : 02S25121819

Acquisition date : 18-DEC-2019 18:27:24

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
0	136.42	3890	6454	1.03	258.18	254	9	2.70E-01	8.1	9.85E+00	
0	255.18	1383	5277	1.23	497.07	493	9	9.60E-02	19.7	6.55E+00	
0	814.01	328	2126	1.39	1621.33	1618	9	2.28E-02	51.8	2.25E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	14	
Number of unidentified lines	3	
Number of lines tentatively identified by NID	11	78.57%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected BQ/TOTAL	Wtd Mean Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.433E+02	1.003E+03	0.015E+03	1.51	
03-CO57	270.90D	1.67	2.428E+01	4.054E+01	0.070E+01	1.74	
04-CE139	137.66D	2.74	1.824E+01	5.003E+01	0.117E+01	2.34	
05-HG203	46.61D	19.7	7.583E+00	1.492E+02	0.088E+02	5.90	
06-SN113	115.10D	3.34	5.766E+01	1.927E+02	0.035E+02	1.82	
07-SR85	64.84D	8.51	2.809E+01	2.391E+02	0.063E+02	2.63	
08-CS137	30.17Y	1.01	1.731E+02	1.753E+02	0.017E+02	0.99	
09-Y88	106.65D	3.68	1.074E+02	3.951E+02	0.060E+02	1.53	
10-CO60	5.27Y	1.07	1.909E+02	2.051E+02	0.016E+02	0.78	
12-Y88	106.65D	3.68	1.095E+02	4.025E+02	0.069E+02	1.70	
			---------	---------			
	Total Activity :		1.460E+03	2.853E+03			

Grand Total Activity : 1.460E+03 2.853E+03

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (BQ/TOTAL)	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
02-CD109	1.003E+03	1.518E+01	9.288E+00	0.000E+00	108.029
03-CO57	4.054E+01	7.037E-01	4.185E-01	0.000E+00	96.891
04-CE139	5.003E+01	1.169E+00	8.113E-01	0.000E+00	61.669
05-HG203	1.492E+02	8.804E+00	8.128E+00	0.000E+00	18.357
06-SN113	1.927E+02	3.513E+00	2.198E+00	0.000E+00	87.654
07-SR85	2.391E+02	6.279E+00	4.569E+00	0.000E+00	52.341
08-CS137	1.753E+02	1.735E+00	7.369E-01	0.000E+00	237.891

09-Y88	3.951E+02	6.045E+00	3.245E+00	0.000E+00	121.744
10-CO60	2.051E+02	1.607E+00	8.533E-01	0.000E+00	240.402
12-Y88	4.025E+02	6.851E+00	1.857E+00	0.000E+00	216.801

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (BQ/TOTAL)	K.L. Ided	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
01-AM241	-5.736E-01		7.199E-01	1.117E+00	0.000E+00	-0.513

```
A,02S25121819      ,12/26/2019 15:32,06/01/2019 12:00,   1.000E+00,S25 5ML MIXED
B,02S25121819      ,CALIBRATION          ,12/26/2019 15:31,02S25121819
C,02-CD109,YES,   1.003E+03,   1.518E+01,   9.288E+00,,  108.029
C,03-CO57 ,YES,   4.054E+01,   7.037E-01,   4.185E-01,,   96.891
C,04-CE139,YES,   5.003E+01,   1.169E+00,   8.113E-01,,   61.669
C,05-HG203,YES,   1.492E+02,   8.804E+00,   8.128E+00,,   18.357
C,06-SN113,YES,   1.927E+02,   3.513E+00,   2.198E+00,,   87.654
C,07-SR85 ,YES,   2.391E+02,   6.279E+00,   4.569E+00,,   52.341
C,08-CS137,YES,   1.753E+02,   1.735E+00,   7.369E-01,,  237.891
C,09-Y88  ,YES,   3.951E+02,   6.045E+00,   3.245E+00,,  121.744
C,10-CO60 ,YES,   2.051E+02,   1.607E+00,   8.533E-01,,  240.402
C,12-Y88  ,YES,   4.025E+02,   6.851E+00,   1.857E+00,,  216.801
C,01-AM241,NO ,  -5.736E-01,   7.199E-01,   1.117E+00,,   -0.513
```

E & Z 2088-10-1 Mixed Gamma
6/1/19 12:00 PM

S25 Bottle

		Orig. Wt	5.1617	Volume	50				
		Wt Used	4.4184	Aliquot	5.0000	Certificate	Aliquoted	Actual	Percent
	Half-Life	Energy(KeV)	.ate G/s/	%err	%abn	Bq/Tot	G/S	Bq/Tot	Diff
Pb-210	22.26Y	46.6	72.1		4.18%	762.12	31.86		
Cd-109	462.9d	88.0	84.75		3.72%	1006.61	37.45	1009.0	0.24%
Co-57	271.8d	122.1	77.25		85.51%	39.92	34.13	40.0	0.29%
Ce-139	137.64d	165.9	92.68		80.35%	50.96	40.95	50.8	-0.32%
Hg-203	46.6d	279.2	273		77.30%	156.04	120.62		
Sn-113	115.09d	391.7	280		64.90%	190.62	123.72	190.1	-0.28%
Sr-85	64.849	514.0	547.9		98.40%	246.02	242.08		
Cs-137	30.17y	661.6	330.6		85.12%	171.61	146.07	173.6	1.16%
Y-88	106.65d	898.0	858.7		93.40%	406.22	379.41	396.4	-2.42%
Co-60	5.27y	1173.2	460.4		100.00%	203.42	203.42	203.4	-0.01%
Co-60	5.27y	1332.5	460.9		100.00%	203.64	203.64	205.4	0.86%
Y-88	106.65d	1836.0	908		99.38%	403.69	401.19	401.9	-0.44%

Eff. Name: **06S25031921**

Analyst: KOJ

Analyst:

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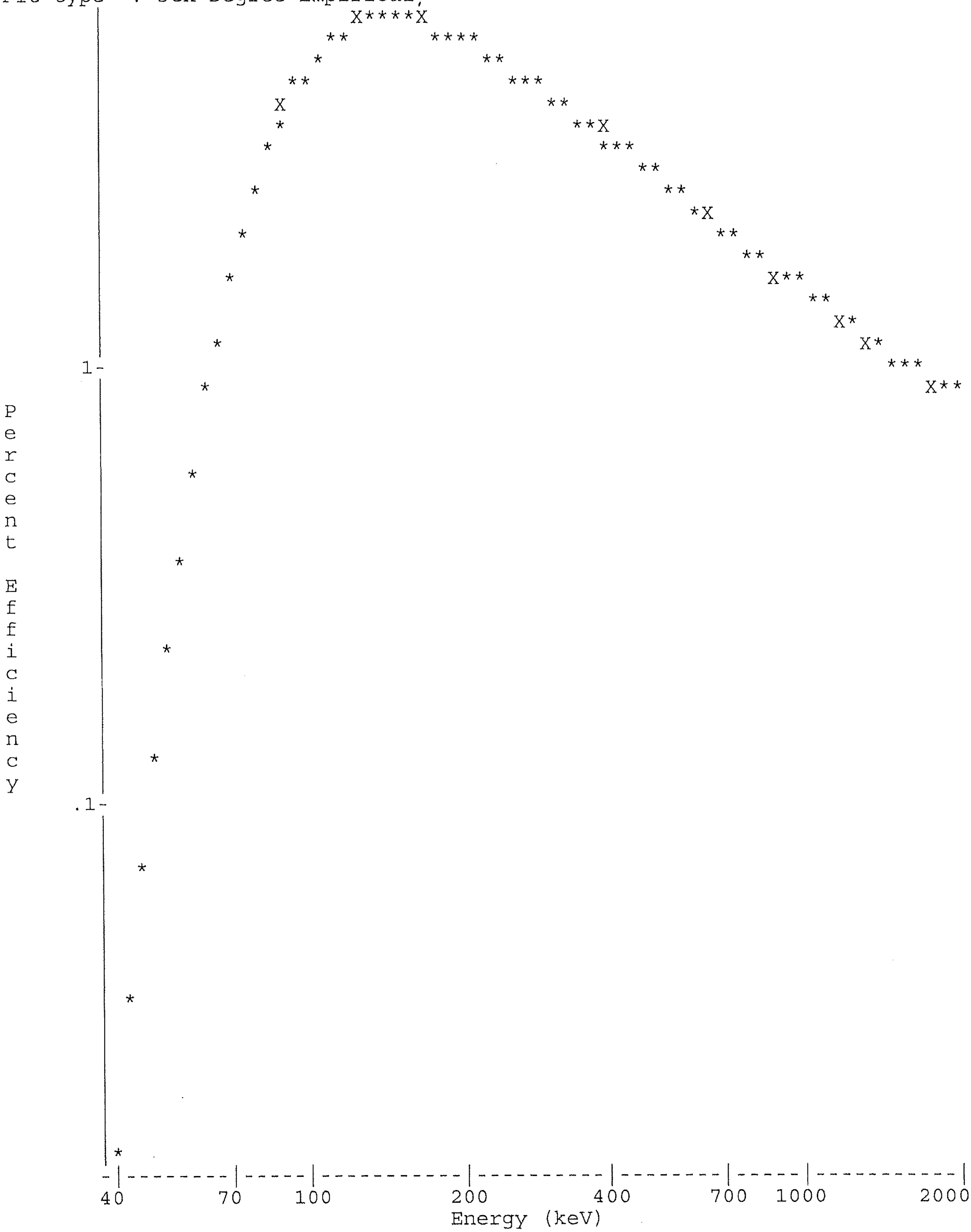
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 22-MAR-2021 07:40:38.83
TBE06 33-TP10933A HpGe ******* Aquisition Date/Time: 19-MAR-2021 14:45:58.43

LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID : 06S25031921 Smple Date: 1-JUN-2019 12:00:00.0
Sample Type : STD Geometry : 06S25031921
Quantity : 1.00000E+00 TOTAL BKGFILE : NOBKG
Start Channel : 80 Energy Tol : 2.00000 Real Time : 2 16:43:37.11
End Channel : 4090 Pk Srch Sens: 9.00000 Live time : 2 16:39:12.77
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.49	1952	34584	0.92	93.80	9.94E-02	8.39E-03	14.5	
2	0	74.78	1441	47490	0.94	150.37	2.39E+00	6.19E-03	25.2	
3	0	88.01	128267	68527	0.97	176.82	3.94E+00	5.51E-01	0.5	
4	0	122.05	92059	59957	0.99	244.90	6.23E+00	3.96E-01	0.6	
5	0	136.44	11811	51850	1.00	273.67	6.50E+00	5.07E-02	3.6	
6	0	165.86	22108	55027	1.10	332.52	6.41E+00	9.50E-02	2.1	
7	0	391.75	19042	41769	1.19	784.24	3.50E+00	8.18E-02	2.1	
8	0	510.77	4028	39854	2.05	1022.23	2.78E+00	1.73E-02	9.7	
9	0	609.07	1127	19831	1.79	1218.80	2.38E+00	4.84E-03	21.8	
10	0	661.61	730914	38504	1.41	1323.85	2.21E+00	3.14E+00	0.1	
11	0	898.04	19946	33401	1.55	1796.59	1.67E+00	8.57E-02	2.0	
12	0	1173.20	485697	20164	1.69	2346.73	1.30E+00	2.09E+00	0.2	
13	0	1332.49	437484	6704	1.77	2665.19	1.16E+00	1.88E+00	0.2	
14	0	1460.73	1780	2060	2.03	2921.57	1.07E+00	7.65E-03	5.8	
15	0	1836.01	11866	1676	2.05	3671.75	9.22E-01	5.10E-02	1.2	

Spectrum : MCA0:[NDSCOUNT]TBE06$1
Calib Date: 22-MAR-2021 07:40
Detector : Geometry : 06S25031921
Fit type : 5th Degree Empirical,



Analyst:

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 22-MAR-2021 07:41:45.73
TBE06 33-TP10933A HpGe ******* Aquisition Date/Time: 19-MAR-2021 14:45:58.43

LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID : 06S25031921		Smple Date: 1-JUN-2019 12:00:00.0	
Sample Type : STD		Geometry : 06S25031921	
Quantity : 1.00000E+00 TOTAL		BKGFILE : NOBKG	
Start Channel : 80	Energy Tol : 2.00000	Real Time : 2 16:43:37.11	
End Channel : 4090	Pk Srch Sens: 9.00000	Live time : 2 16:39:12.77	
MDA Multiple : 4.6600	Library Used: CALIBRATION		

Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.49	1952	34584	0.92	93.80	9.94E-02	8.39E-03	14.5	
2	0	74.78	1441	47490	0.94	150.37	2.39E+00	6.19E-03	25.2	
3	0	88.01	128267	68527	0.97	176.82	3.94E+00	5.51E-01	0.5	
4	0	122.05	92059	59957	0.99	244.90	6.23E+00	3.96E-01	0.6	
5	0	136.44	11811	51850	1.00	273.67	6.50E+00	5.07E-02	3.6	
6	0	165.86	22108	55027	1.10	332.52	6.41E+00	9.50E-02	2.1	
7	0	391.75	19042	41769	1.19	784.24	3.50E+00	8.18E-02	2.1	
8	0	510.77	4028	39854	2.05	1022.23	2.78E+00	1.73E-02	9.7	
9	0	609.07	1127	19831	1.79	1218.80	2.38E+00	4.84E-03	21.8	
10	0	661.61	730914	38504	1.41	1323.85	2.21E+00	3.14E+00	0.1	
11	0	898.04	19946	33401	1.55	1796.59	1.67E+00	8.57E-02	2.0	
12	0	1173.20	485697	20164	1.69	2346.73	1.30E+00	2.09E+00	0.2	
13	0	1332.49	437484	6704	1.77	2665.19	1.16E+00	1.88E+00	0.2	
14	0	1460.73	1780	2060	2.03	2921.57	1.07E+00	7.65E-03	5.8	
15	0	1836.01	11866	1676	2.05	3671.75	9.22E-01	5.10E-02	1.2	

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	2-Sigma %Error
02-CD109	88.03	128267	3.72*	3.936E+00	3.764E+02	1.009E+03	0.95
03-CO57	122.06	92059	85.51*	6.230E+00	7.425E+00	4.003E+01	1.19
04-CE139	165.85	22108	80.35*	6.407E+00	1.845E+00	5.080E+01	4.19
06-SN113	391.69	19042	64.90*	3.498E+00	3.604E+00	1.901E+02	4.13
08-CS137	661.65	730914	85.12*	2.215E+00	1.666E+02	1.736E+02	0.26
09-Y88	898.02	19946	93.40*	1.671E+00	5.490E+00	3.964E+02	3.93
10-CO60	1173.22	485697	100.00	1.301E+00	1.604E+02	2.034E+02	0.32
	1332.49	437484	100.00*	1.160E+00	1.620E+02	2.054E+02	0.31
12-Y88	1836.01	11866	99.38*	9.216E-01	5.566E+00	4.019E+02	2.47

Flag: "*" = Keyline

Sample ID : 06S25031921 Acquisition date : 19-MAR-2021 14:45:58

Total number of lines in spectrum	15	
Number of unidentified lines	6	
Number of lines tentatively identified by NID	9	60.00%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	2.68	3.764E+02	1.009E+03	0.001E+04	0.95	
03-CO57	270.90D	5.39	7.425E+00	4.003E+01	0.048E+01	1.19	
04-CE139	137.66D	27.5	1.845E+00	5.080E+01	0.213E+01	4.19	
06-SN113	115.10D	52.7	3.604E+00	1.901E+02	0.079E+02	4.13	
08-CS137	30.17Y	1.04	1.666E+02	1.736E+02	0.005E+02	0.26	
09-Y88	106.65D	72.2	5.490E+00	3.964E+02	0.156E+02	3.93	
10-CO60	5.27Y	1.27	1.620E+02	2.054E+02	0.006E+02	0.31	
12-Y88	106.65D	72.2	5.566E+00	4.019E+02	0.099E+02	2.47	
			---------	---------			
	Total Activity :		7.289E+02	2.467E+03			
	Grand Total Activity :		7.289E+02	2.467E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
0	46.49	1952	34584	0.92	93.80	92	5	8.39E-03	29.0	9.94E-02	
0	74.78	1441	47490	0.94	150.37	148	7	6.19E-03	50.4	2.39E+00	
0	136.44	11811	51850	1.00	273.67	270	9	5.07E-02	7.2	6.50E+00	
0	510.77	4028	39854	2.05	1022.23	1017	11	1.73E-02	19.4	2.78E+00	
0	609.07	1127	19831	1.79	1218.80	1216	8	4.84E-03	43.6	2.38E+00	
0	1460.73	1780	2060	2.03	2921.57	2915	13	7.65E-03	11.5	1.07E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum 15
Number of unidentified lines 6
Number of lines tentatively identified by NID 9 60.00%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected BQ/TOTAL	Wtd Mean Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	2.68	3.764E+02	1.009E+03	0.001E+04	0.95	
03-CO57	270.90D	5.39	7.425E+00	4.003E+01	0.048E+01	1.19	
04-CE139	137.66D	27.5	1.845E+00	5.080E+01	0.213E+01	4.19	
06-SN113	115.10D	52.7	3.604E+00	1.901E+02	0.079E+02	4.13	
08-CS137	30.17Y	1.04	1.666E+02	1.736E+02	0.005E+02	0.26	
09-Y88	106.65D	72.2	5.490E+00	3.964E+02	0.156E+02	3.93	
10-CO60	5.27Y	1.27	1.620E+02	2.054E+02	0.006E+02	0.31	
12-Y88	106.65D	72.2	5.566E+00	4.019E+02	0.099E+02	2.47	
			---------	---------			
Total Activity :			7.289E+02	2.467E+03			
Grand Total Activity :			7.289E+02	2.467E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (BQ/TOTAL)	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
02-CD109	1.009E+03	9.567E+00	7.229E+00	0.000E+00	139.569
03-CO57	4.003E+01	4.783E-01	3.829E-01	0.000E+00	104.556
04-CE139	5.080E+01	2.131E+00	1.982E+00	0.000E+00	25.632
06-SN113	1.901E+02	7.858E+00	8.714E+00	0.000E+00	21.813
08-CS137	1.736E+02	4.566E-01	1.586E-01	0.000E+00	1094.419
09-Y88	3.964E+02	1.558E+01	1.503E+01	0.000E+00	26.383

10-CO60	2.054E+02	6.469E-01	1.376E-01	0.000E+00	1492.376
12-Y88	4.019E+02	9.945E+00	5.425E+00	0.000E+00	74.088

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (BQ/TOTAL)	K.L. Ided	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
01-AM241	7.460E-02		7.931E-01	1.344E+00	0.000E+00	0.056
05-HG203	2.768E+02		1.141E+03	1.805E+03	0.000E+00	0.153
07-SR85	4.560E+02		9.668E+01	1.427E+02	0.000E+00	3.195

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A,06S25031921      ,03/22/2021 07:41,06/01/2019 12:00,   1.000E+00,S25 5ML MIXED
B,06S25031921      ,CALIBRATION         ,03/22/2021 07:40,06S25031921
C,02-CD109,YES,   1.009E+03,   9.567E+00,   7.229E+00,,  139.569
C,03-CO57 ,YES,   4.003E+01,   4.783E-01,   3.829E-01,,  104.556
C,04-CE139,YES,   5.080E+01,   2.131E+00,   1.982E+00,,   25.632
C,06-SN113,YES,   1.901E+02,   7.858E+00,   8.714E+00,,   21.813
C,08-CS137,YES,   1.736E+02,   4.566E-01,   1.586E-01,, 1094.419
C,09-Y88  ,YES,   3.964E+02,   1.558E+01,   1.503E+01,,   26.383
C,10-CO60 ,YES,   2.054E+02,   6.469E-01,   1.376E-01,, 1492.376
C,12-Y88  ,YES,   4.019E+02,   9.945E+00,   5.425E+00,,   74.088
C,01-AM241,NO ,   7.460E-02,   7.931E-01,   1.344E+00,,    0.056
C,05-HG203,NO ,   2.768E+02,   1.141E+03,   1.805E+03,,    0.153
C,07-SR85 ,NO ,   4.560E+02,   9.668E+01,   1.427E+02,,    3.195
```

E & Z 2088-10-1 Mixed Gamma
6/1/19 12:00 PM

S50 Bottle

		Orig. Wt	5.1617	Volume	50				
		Wt Used	4.4184	Aliquot	5.0000	Certificate	Aliquoted	Actual	Percent
	Half-Life	Energy(KeV)	ate G/s	%err	%abn	Bq/Tot	G/S	Bq/Tot	Diff
Pb-210	22.26Y	46.6	72.1		4.18%	762.12	31.86		
Cd-109	462.9d	88.0	84.75		3.72%	1006.61	37.45	1008.0	0.14%
Co-57	271.8d	122.1	77.25		85.51%	39.92	34.13	39.9	0.01%
Ce-139	137.64d	165.9	92.68		80.35%	50.96	40.95	51.0	0.15%
Hg-203	46.6d	279.2	273		77.30%	156.04	120.62		
Sn-113	115.09d	391.7	280		64.90%	190.62	123.72	188.9	-0.90%
Sr-85	64.849	514.0	547.9		98.40%	246.02	242.08		
Cs-137	30.17y	661.6	330.6		85.12%	171.61	146.07	174.9	1.92%
Y-88	106.65d	898.0	858.7		93.40%	406.22	379.41	391.6	-3.60%
Co-60	5.27y	1173.2	460.4		100.00%	203.42	203.42	204.2	0.38%
Co-60	5.27y	1332.5	460.9		100.00%	203.64	203.64	205.1	0.71%
Y-88	106.65d	1836.0	908		99.38%	403.69	401.19	401.9	-0.44%

Eff. Name: **06S50031621**

Analyst: KOJ

Analyst:

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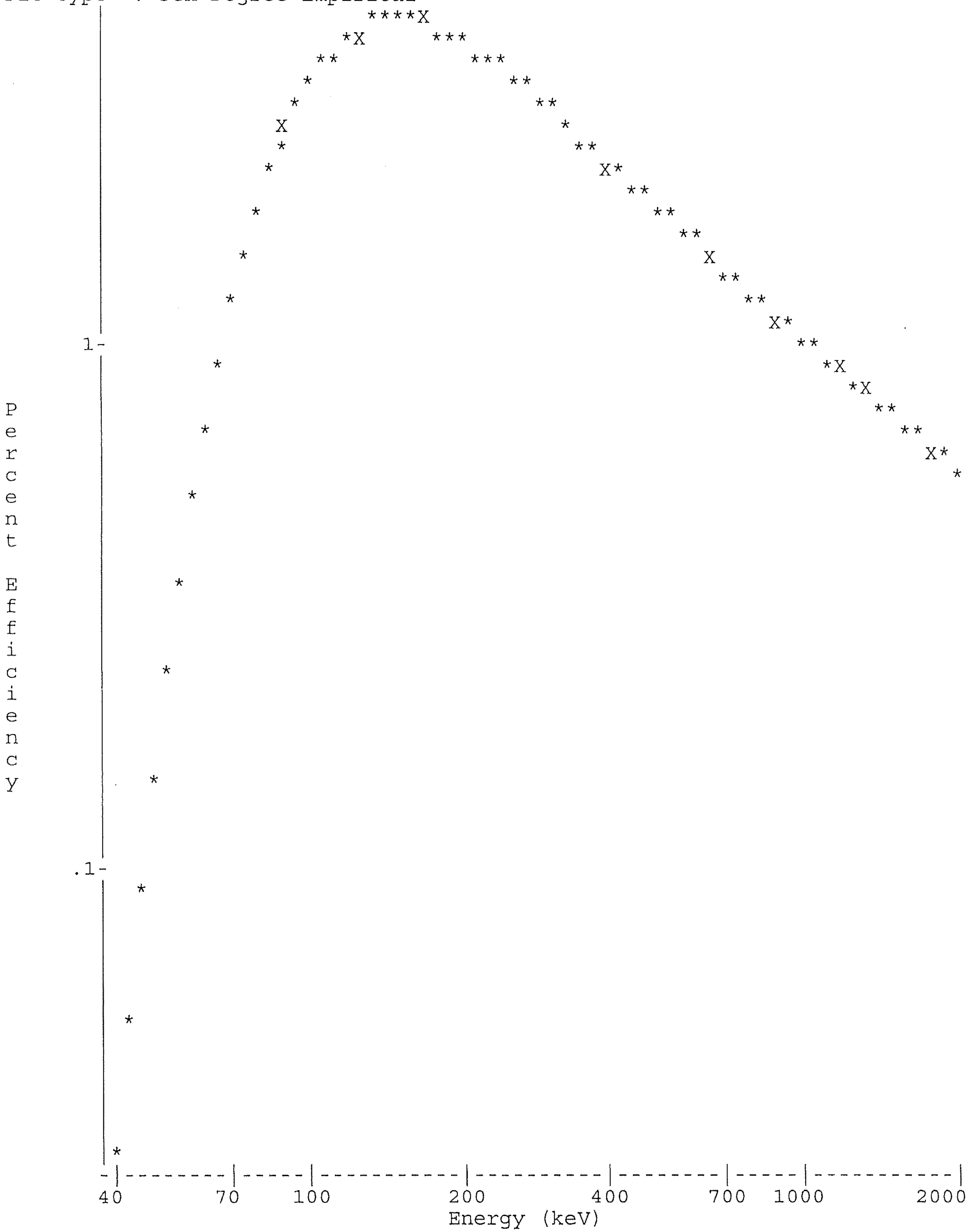
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 22-MAR-2021 09:44:01.72
TBE06 33-TP10933A HpGe ******* Aquisition Date/Time: 16-MAR-2021 08:49:41.57

LIMS No., Customer Name, Client ID: S50 5ML MIXED GAMMA CALIBRATION

Sample ID : 06S50031621 Smple Date: 1-JUN-2019 12:00:00.0
Sample Type : STD Geometry : 06S50031621
Quantity : 1.00000E+00 TOTAL BKGFILE : NOBKG
Start Channel : 80 Energy Tol : 2.00000 Real Time : 3 07:08:03.15
End Channel : 4090 Pk Srch Sens: 9.00000 Live time : 3 07:04:03.86
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.48	1992	42775	1.15	93.77	1.26E-01	7.00E-03	17.4	
2	0	74.90	1912	30566	1.00	150.61	1.68E+00	6.72E-03	13.9	
3	10	85.40	6727	89463	2.43	171.60	2.42E+00	2.36E-02	10.8	1.56E+01
4	10	88.01	103303	34137	0.96	176.82	2.58E+00	3.63E-01	0.4	
5	0	122.04	72172	54617	0.98	244.87	3.97E+00	2.54E-01	0.7	
6	0	136.46	9186	41242	1.06	273.70	4.17E+00	3.23E-02	4.0	
7	0	165.87	17944	44649	1.12	332.51	4.17E+00	6.30E-02	2.3	
8	0	185.73	1831	37630	1.36	372.23	4.02E+00	6.43E-03	17.7	
9	0	391.74	15588	36578	1.25	784.15	2.31E+00	5.48E-02	2.4	
10	0	510.95	5205	35452	2.11	1022.50	1.83E+00	1.83E-02	7.1	
11	0	661.63	594880	31745	1.41	1323.77	1.46E+00	2.09E+00	0.1	
12	0	898.00	16557	26885	1.57	1796.35	1.13E+00	5.82E-02	2.1	
13	0	1173.22	412497	19014	1.73	2346.57	8.99E-01	1.45E+00	0.2	
14	0	1332.51	372411	5543	1.78	2665.00	8.08E-01	1.31E+00	0.2	
15	0	1460.90	2381	1616	2.06	2921.67	7.48E-01	8.37E-03	4.0	
16	0	1764.40	424	1111	1.61	3528.32	6.43E-01	1.49E-03	17.4	
17	0	1836.00	10002	1215	2.07	3671.44	6.23E-01	3.51E-02	1.3	

Spectrum : MCA0:[NDSCOUNT]TBE06$1
Calib Date: 22-MAR-2021 09:44
Detector : Geometry : 06S50031621
Fit type : 5th Degree Empirical



Analyst:

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 22-MAR-2021 09:48:13.84
TBE06 33-TP10933A HpGe ******* Aquisition Date/Time: 16-MAR-2021 08:49:41.57

LIMS No., Customer Name, Client ID: S50 5ML MIXED GAMMA CALIBRATION

Sample ID : 06S50031621 Smple Date: 1-JUN-2019 12:00:00.0
Sample Type : STD Geometry : 06S50031621
Quantity : 1.00000E+00 TOTAL BKGFILE : NOBKG
Start Channel : 80 Energy Tol : 2.00000 Real Time : 3 07:08:03.15
End Channel : 4090 Pk Srch Sens: 9.00000 Live time : 3 07:04:03.86
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.48	1992	42775	1.15	93.77	1.26E-01	7.00E-03	17.4	
2	0	74.90	1912	30566	1.00	150.61	1.68E+00	6.72E-03	13.9	
3	10	85.40	6727	89463	2.43	171.60	2.42E+00	2.36E-02	10.8	1.56E+01
4	10	88.01	103303	34137	0.96	176.82	2.58E+00	3.63E-01	0.4	
5	0	122.04	72172	54617	0.98	244.87	3.97E+00	2.54E-01	0.7	
6	0	136.46	9186	41242	1.06	273.70	4.17E+00	3.23E-02	4.0	
7	0	165.87	17944	44649	1.12	332.51	4.17E+00	6.30E-02	2.3	
8	0	185.73	1831	37630	1.36	372.23	4.02E+00	6.43E-03	17.7	
9	0	391.74	15588	36578	1.25	784.15	2.31E+00	5.48E-02	2.4	
10	0	510.95	5205	35452	2.11	1022.50	1.83E+00	1.83E-02	7.1	
11	0	661.63	594880	31745	1.41	1323.77	1.46E+00	2.09E+00	0.1	
12	0	898.00	16557	26885	1.57	1796.35	1.13E+00	5.82E-02	2.1	
13	0	1173.22	412497	19014	1.73	2346.57	8.99E-01	1.45E+00	0.2	
14	0	1332.51	372411	5543	1.78	2665.00	8.08E-01	1.31E+00	0.2	
15	0	1460.90	2381	1616	2.06	2921.67	7.48E-01	8.37E-03	4.0	
16	0	1764.40	424	1111	1.61	3528.32	6.43E-01	1.49E-03	17.4	
17	0	1836.00	10002	1215	2.07	3671.44	6.23E-01	3.51E-02	1.3	

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	2-Sigma %Error
02-CD109	88.03	103303	3.72*	2.584E+00	3.775E+02	1.008E+03	0.85
03-CO57	122.06	72172	85.51*	3.975E+00	7.460E+00	3.992E+01	1.42
04-CE139	165.85	17944	80.35*	4.170E+00	1.881E+00	5.104E+01	4.50
06-SN113	391.69	15588	64.90*	2.315E+00	3.646E+00	1.889E+02	4.71
08-CS137	661.65	594880	85.12*	1.463E+00	1.679E+02	1.749E+02	0.29
09-Y88	898.02	16557	93.40*	1.127E+00	5.528E+00	3.916E+02	4.14
10-CO60	1173.22	412497	100.00	8.986E-01	1.613E+02	2.042E+02	0.35
	1332.49	372411	100.00*	8.076E-01	1.620E+02	2.051E+02	0.34
12-Y88	1836.01	10002	99.38*	6.232E-01	5.674E+00	4.019E+02	2.54

Flag: "*" = Keyline

Sample ID : 06S50031621   Acquisition date : 16-MAR-2021 08:49:41

Total number of lines in spectrum	17	
Number of unidentified lines	8	
Number of lines tentatively identified by NID	9	52.94%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	2.67	3.775E+02	1.008E+03	0.009E+03	0.85	
03-CO57	270.90D	5.35	7.460E+00	3.992E+01	0.057E+01	1.42	
04-CE139	137.66D	27.1	1.881E+00	5.104E+01	0.230E+01	4.50	
06-SN113	115.10D	51.8	3.646E+00	1.889E+02	0.089E+02	4.71	
08-CS137	30.17Y	1.04	1.679E+02	1.749E+02	0.005E+02	0.29	
09-Y88	106.65D	70.8	5.528E+00	3.916E+02	0.162E+02	4.14	
10-CO60	5.27Y	1.27	1.620E+02	2.051E+02	0.007E+02	0.34	
12-Y88	106.65D	70.8	5.674E+00	4.019E+02	0.102E+02	2.54	
	Total Activity :		7.316E+02	2.461E+03			
	Grand Total Activity :		7.316E+02	2.461E+03			

Flags: "K" = Keyline not found   "M" = Manually accepted
       "E" = Manually edited   "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
0	46.48	1992	42775	1.15	93.77	91	7	7.00E-03	34.7	1.26E-01	
0	74.90	1912	30566	1.00	150.61	149	5	6.72E-03	27.8	1.68E+00	
10	85.40	6727	89463	2.43	171.60	164	18	2.36E-02	21.6	2.42E+00	
0	136.46	9186	41242	1.06	273.70	270	8	3.23E-02	7.9	4.17E+00	
0	185.73	1831	37630	1.36	372.23	370	7	6.43E-03	35.4	4.02E+00	
0	510.95	5205	35452	2.11	1022.50	1017	11	1.83E-02	14.3	1.83E+00	
0	1460.90	2381	1616	2.06	2921.67	2915	13	8.37E-03	8.1	7.48E-01	
0	1764.40	424	1111	1.61	3528.32	3522	14	1.49E-03	34.7	6.43E-01	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	17	
Number of unidentified lines	8	
Number of lines tentatively identified by NID	9	52.94%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected BQ/TOTAL	Wtd Mean Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	2.67	3.775E+02	1.008E+03	0.009E+03	0.85	
03-CO57	270.90D	5.35	7.460E+00	3.992E+01	0.057E+01	1.42	
04-CE139	137.66D	27.1	1.881E+00	5.104E+01	0.230E+01	4.50	
06-SN113	115.10D	51.8	3.646E+00	1.889E+02	0.089E+02	4.71	
08-CS137	30.17Y	1.04	1.679E+02	1.749E+02	0.005E+02	0.29	
09-Y88	106.65D	70.8	5.528E+00	3.916E+02	0.162E+02	4.14	
10-CO60	5.27Y	1.27	1.616E+02	2.047E+02	0.005E+02	0.24	
12-Y88	106.65D	70.8	5.674E+00	4.019E+02	0.102E+02	2.54	
			---------	---------			
	Total Activity :		7.312E+02	2.460E+03			
	Grand Total Activity :		7.312E+02	2.460E+03			

Flags: "K" = Keyline not found   "M" = Manually accepted
"E" = Manually edited   "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (BQ/TOTAL)	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
02-CD109	1.008E+03	8.546E+00	8.191E+00	0.000E+00	123.002
03-CO57	3.992E+01	5.681E-01	4.654E-01	0.000E+00	85.778
04-CE139	5.104E+01	2.299E+00	2.363E+00	0.000E+00	21.597
06-SN113	1.889E+02	8.890E+00	9.893E+00	0.000E+00	19.094

08-CS137	1.749E+02	5.077E-01	1.849E-01	0.000E+00	946.222
09-Y88	3.916E+02	1.620E+01	1.675E+01	0.000E+00	23.380
10-CO60	2.047E+02	5.012E-01	1.475E-01	0.000E+00	1387.846
12-Y88	4.019E+02	1.019E+01	5.711E+00	0.000E+00	70.369

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (BQ/TOTAL)	K.L. Ided	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
01-AM241	-4.434E-01		7.290E-01	1.230E+00	0.000E+00	-0.360
05-HG203	6.524E+02		1.179E+03	2.003E+03	0.000E+00	0.326
07-SR85	5.684E+02		1.104E+02	1.632E+02	0.000E+00	3.483

```
A,06S50031621      ,03/22/2021 09:48,06/01/2019 12:00,   1.000E+00,S50 5ML MIXED
B,06S50031621      ,CALIBRATION         ,03/22/2021 09:44,06S50031621
C,02-CD109,YES,   1.008E+03,   8.546E+00,   8.191E+00,,  123.002
C,03-CO57 ,YES,   3.992E+01,   5.681E-01,   4.654E-01,,   85.778
C,04-CE139,YES,   5.104E+01,   2.299E+00,   2.363E+00,,   21.597
C,06-SN113,YES,   1.889E+02,   8.890E+00,   9.893E+00,,   19.094
C,08-CS137,YES,   1.749E+02,   5.077E-01,   1.849E-01,,  946.222
C,09-Y88  ,YES,   3.916E+02,   1.620E+01,   1.675E+01,,   23.380
C,10-CO60 ,YES,   2.047E+02,   5.012E-01,   1.475E-01,, 1387.846
C,12-Y88  ,YES,   4.019E+02,   1.019E+01,   5.711E+00,,   70.369
C,01-AM241,NO ,  -4.434E-01,   7.290E-01,   1.230E+00,,   -0.360
C,05-HG203,NO ,   6.524E+02,   1.179E+03,   2.003E+03,,    0.326
C,07-SR85 ,NO ,   5.684E+02,   1.104E+02,   1.632E+02,,    3.483
```

E & Z 2088-10-1 Mixed Gamma
6/1/19 12:00 PM

S25 Bottle

		Orig. Wt	5.1617	Volume	50				
		Wt Used	4.4184	Aliquot	5.0000	Certificate	Aliquoted	Actual	Percent
	Half-Life	Energy(KeV)	ate G/s/	%err	%abn	Bq/Tot	G/S	Bq/Tot	Diff
Cd-109	462.9d	88.0	84.75		3.72%	1006.61	37.45	1005.0	-0.16%
Co-57	271.8d	122.1	77.25		85.51%	39.92	34.13	40.0	0.14%
Ce-139	137.64d	165.9	92.68		80.35%	50.96	40.95	50.9	-0.05%
Hg-203	46.6d	279.2	273		77.30%	156.04	120.62	143.3	-8.17%
Sn-113	115.09d	391.7	280		64.90%	190.62	123.72	191.3	0.35%
Sr-85	64.849	514.0	547.9		98.40%	246.02	242.08	247.8	0.72%
Cs-137	30.17y	661.6	330.6		85.12%	171.61	146.07	173.9	1.34%
Y-88	106.65d	898.0	858.7		93.40%	406.22	379.41	390.3	-3.92%
Co-60	5.27y	1173.2	460.4		100.00%	203.42	203.42	204.9	0.73%
Co-60	5.27y	1332.5	460.9		100.00%	203.64	203.64	207.6	1.94%
Y-88	106.65d	1836.0	908		99.38%	403.69	401.19	401.3	-0.59%

Eff. Name: **07S25121819**

Analyst: KOJ

Analyst:

==

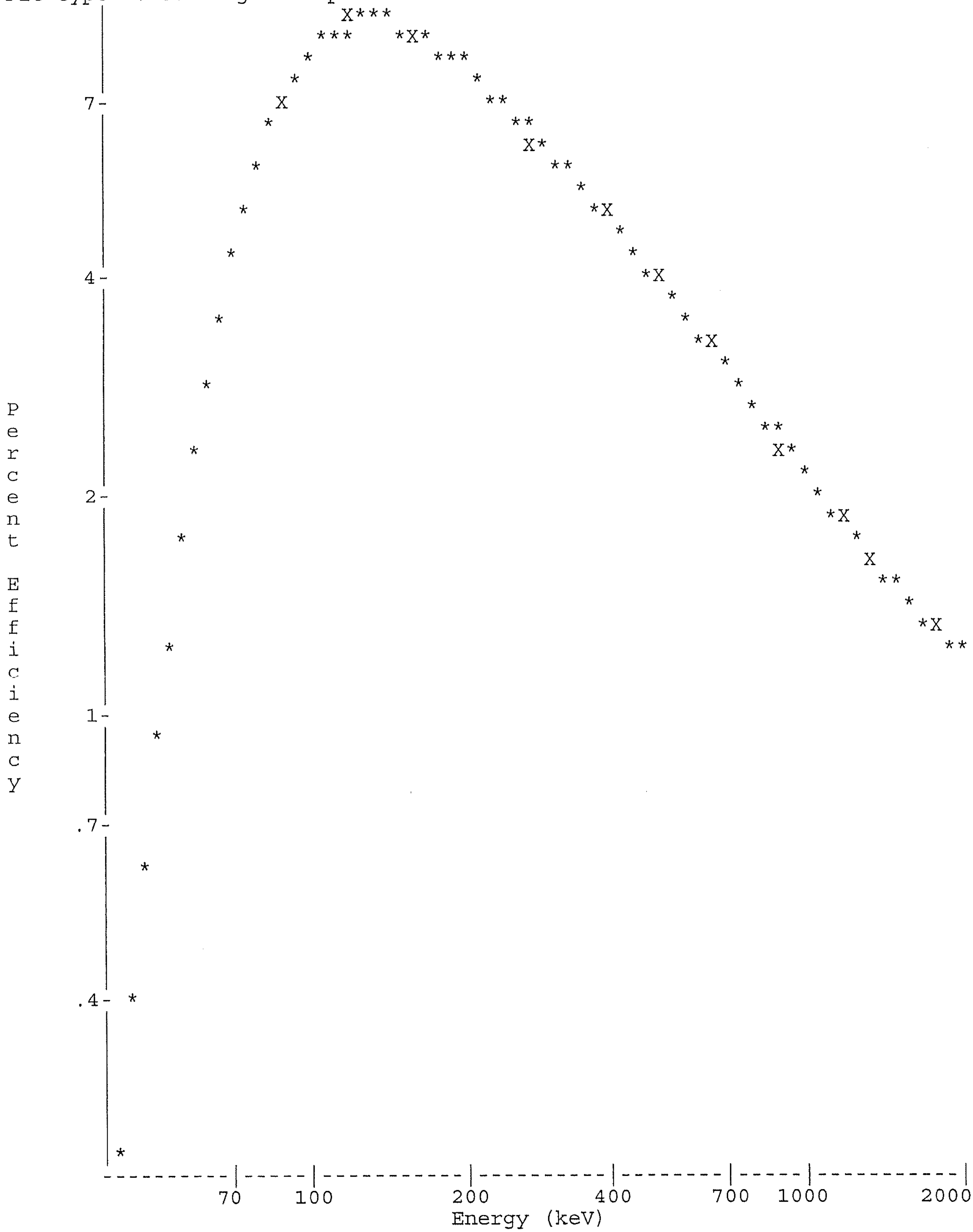
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 10:27:43.64
TBE07 31-TP10768B HpGe ******* Aquisition Date/Time: 18-DEC-2019 14:56:31.96

LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID : 07S25121819 Smple Date: 1-JUN-2019 12:00:00.0
Sample Type : STD Geometry : 07S25121819
Quantity : 1.00000E+00 TOTAL BKGFILE : 07BG112719MT
Start Channel : 80 Energy Tol : 2.00000 Real Time : 0 02:17:08.44
End Channel : 4090 Pk Srch Sens: 9.00000 Live time : 0 02:16:43.01
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	46.64	773	4715	1.33	92.73	7.18E-01	9.43E-02	16.4	7.52E-01
2	1	88.05	15405	5939	1.26	175.52	6.78E+00	1.88E+00	1.3	5.87E-01
3	1	122.07	14618	4613	1.29	243.53	8.70E+00	1.78E+00	1.2	6.83E-01
4	1	136.44	2070	4130	1.47	272.27	8.80E+00	2.52E-01	6.2	4.05E+00
5	1	165.84	10361	5634	1.38	331.06	8.46E+00	1.26E+00	1.8	1.03E+00
6	1	255.21	771	3174	1.55	509.71	6.63E+00	9.39E-02	13.6	2.09E+00
7	1	279.18	3032	3952	1.44	557.65	6.21E+00	3.70E-01	4.5	4.54E-01
8	1	391.68	14556	3443	1.54	782.53	4.77E+00	1.77E+00	1.2	1.82E+00
9	1	514.00	9029	3517	1.66	1027.05	3.80E+00	1.10E+00	1.8	4.47E+00
10	1	661.65	36547	2915	1.77	1322.19	3.05E+00	4.46E+00	0.6	4.17E+00
11	1	898.04	18756	2766	2.00	1794.67	2.30E+00	2.29E+00	1.0	6.67E+00
12	1	1173.22	28118	1516	2.24	2344.63	1.80E+00	3.43E+00	0.7	5.22E+00
13	1	1332.48	25432	837	2.41	2662.88	1.60E+00	3.10E+00	0.7	1.02E+01
14	1	1836.00	11248	356	2.94	3668.97	1.26E+00	1.37E+00	1.0	1.21E+01

Spectrum   : MCA0:[NDSCOUNT]TBE07$1
Calib Date: 26-DEC-2019 10:27
Detector   :   Geometry   : 07S25121819
Fit type   : 5th Degree Empirical



Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 10:29:22.88
TBE07 31-TP10768B HpGe ******* Aquisition Date/Time: 18-DEC-2019 14:56:31.96

LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID : 07S25121819 Smple Date: 1-JUN-2019 12:00:00.0
Sample Type : STD Geometry : 07S25121819
Quantity : 1.00000E+00 TOTAL BKGFILE : 07BG112719MT
Start Channel : 80 Energy Tol : 2.00000 Real Time : 0 02:17:08.44
End Channel : 4090 Pk Srch Sens: 9.00000 Live time : 0 02:16:43.01
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	46.64	773	4715	1.33	92.73	7.18E-01	9.43E-02	16.4	7.52E-01
2	1	88.05	15405	5939	1.26	175.52	6.78E+00	1.88E+00	1.3	5.87E-01
3	1	122.07	14618	4613	1.29	243.53	8.70E+00	1.78E+00	1.2	6.83E-01
4	1	136.44	2070	4130	1.47	272.27	8.80E+00	2.52E-01	6.2	4.05E+00
5	1	165.84	10361	5634	1.38	331.06	8.46E+00	1.26E+00	1.8	1.03E+00
6	1	255.21	771	3174	1.55	509.71	6.63E+00	9.39E-02	13.6	2.09E+00
7	1	279.18	3032	3952	1.44	557.65	6.21E+00	3.70E-01	4.5	4.54E-01
8	1	391.68	14556	3443	1.54	782.53	4.77E+00	1.77E+00	1.2	1.82E+00
9	1	514.00	9029	3517	1.66	1027.05	3.80E+00	1.10E+00	1.8	4.47E+00
10	1	661.65	36547	2915	1.77	1322.19	3.05E+00	4.46E+00	0.6	4.17E+00
11	1	898.04	18756	2766	2.00	1794.67	2.30E+00	2.29E+00	1.0	6.67E+00
12	1	1173.22	28118	1516	2.24	2344.63	1.80E+00	3.43E+00	0.7	5.22E+00
13	1	1332.48	25432	837	2.41	2662.88	1.60E+00	3.10E+00	0.7	1.02E+01
14	1	1836.00	11248	356	2.94	3668.97	1.26E+00	1.37E+00	1.0	1.21E+01

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	2-Sigma %Error
02-CD109	88.03	15405	3.72*	6.778E+00	7.448E+02	1.005E+03	2.55
03-CO57	122.06	14618	85.51*	8.701E+00	2.395E+01	3.997E+01	2.41
04-CE139	165.85	10361	80.35*	8.456E+00	1.859E+01	5.094E+01	3.65
05-HG203	279.20	3032	81.46*	6.215E+00	7.301E+00	1.433E+02	9.06
06-SN113	391.69	14556	64.90*	4.771E+00	5.731E+01	1.913E+02	2.31
07-SR85	513.99	9029	99.27*	3.802E+00	2.916E+01	2.478E+02	3.62
08-CS137	661.65	36547	85.12*	3.048E+00	1.717E+02	1.739E+02	1.24
09-Y88	898.02	18756	93.40*	2.304E+00	1.063E+02	3.903E+02	1.95
10-CO60	1173.22	28118	100.00	1.798E+00	1.907E+02	2.049E+02	1.37
	1332.49	25432	100.00*	1.605E+00	1.932E+02	2.076E+02	1.39
12-Y88	1836.01	11248	99.38*	1.263E+00	1.093E+02	4.013E+02	2.07

Flag: "*" = Keyline

Sample ID : 07S25121819 Acquisition date : 18-DEC-2019 14:56:31

Total number of lines in spectrum 14
Number of unidentified lines 3
Number of lines tentatively identified by NID 11 78.57%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.448E+02	1.005E+03	0.026E+03	2.55	
03-CO57	270.90D	1.67	2.395E+01	3.997E+01	0.096E+01	2.41	
04-CE139	137.66D	2.74	1.859E+01	5.094E+01	0.186E+01	3.65	
05-HG203	46.61D	19.6	7.301E+00	1.433E+02	0.130E+02	9.06	
06-SN113	115.10D	3.34	5.731E+01	1.913E+02	0.044E+02	2.31	
07-SR85	64.84D	8.50	2.916E+01	2.478E+02	0.090E+02	3.62	
08-CS137	30.17Y	1.01	1.717E+02	1.739E+02	0.022E+02	1.24	
09-Y88	106.65D	3.67	1.063E+02	3.903E+02	0.076E+02	1.95	
10-CO60	5.27Y	1.07	1.932E+02	2.076E+02	0.029E+02	1.39	
12-Y88	106.65D	3.67	1.093E+02	4.013E+02	0.083E+02	2.07	
			---------	---------			
	Total Activity :		1.462E+03	2.852E+03			
	Grand Total Activity :		1.462E+03	2.852E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Unidentified Energy Lines
Sample ID : 07S25121819
Acquisition date : 18-DEC-2019 14:56:31

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
1	46.64	773	4715	1.33	92.73	89	9	9.43E-02	32.9	7.18E-01	
1	136.44	2070	4130	1.47	272.27	267	10	2.52E-01	12.4	8.80E+00	
1	255.21	771	3174	1.55	509.71	506	9	9.39E-02	27.3	6.63E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	14	
Number of unidentified lines	3	
Number of lines tentatively identified by NID	11	78.57%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected BQ/TOTAL	Wtd Mean Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.448E+02	1.005E+03	0.026E+03	2.55	
03-CO57	270.90D	1.67	2.395E+01	3.997E+01	0.096E+01	2.41	
04-CE139	137.66D	2.74	1.859E+01	5.094E+01	0.186E+01	3.65	
05-HG203	46.61D	19.6	7.301E+00	1.433E+02	0.130E+02	9.06	
06-SN113	115.10D	3.34	5.731E+01	1.913E+02	0.044E+02	2.31	
07-SR85	64.84D	8.50	2.916E+01	2.478E+02	0.090E+02	3.62	
08-CS137	30.17Y	1.01	1.717E+02	1.739E+02	0.022E+02	1.24	
09-Y88	106.65D	3.67	1.063E+02	3.903E+02	0.076E+02	1.95	
10-CO60	5.27Y	1.07	1.919E+02	2.062E+02	0.020E+02	0.97	
12-Y88	106.65D	3.67	1.093E+02	4.013E+02	0.083E+02	2.07	
			---------	---------			
	Total Activity :		1.460E+03	2.850E+03			

Grand Total Activity : 1.460E+03 2.850E+03

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (BQ/TOTAL)	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
02-CD109	1.005E+03	2.559E+01	1.912E+01	0.000E+00	52.567
03-CO57	3.997E+01	9.624E-01	7.562E-01	0.000E+00	52.860
04-CE139	5.094E+01	1.861E+00	1.275E+00	0.000E+00	39.947
05-HG203	1.433E+02	1.298E+01	1.199E+01	0.000E+00	11.946
06-SN113	1.913E+02	4.427E+00	3.216E+00	0.000E+00	59.495
07-SR85	2.478E+02	8.982E+00	6.105E+00	0.000E+00	40.592
08-CS137	1.739E+02	2.157E+00	1.016E+00	0.000E+00	171.218

09-Y88	3.903E+02	7.605E+00	4.371E+00	0.000E+00	89.291
10-CO60	2.062E+02	2.009E+00	1.090E+00	0.000E+00	189.159
12-Y88	4.013E+02	8.294E+00	2.498E+00	0.000E+00	160.653

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (BQ/TOTAL)	K.L. Ided	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
01-AM241	4.223E-01		2.177E+00	3.537E+00	0.000E+00	0.119

```
A,07S25121819      ,12/26/2019 10:29,06/01/2019 12:00,   1.000E+00,S25 5ML MIXED
B,07S25121819      ,CALIBRATION          ,12/26/2019 10:27,07S25121819
C,02-CD109,YES,    1.005E+03,   2.559E+01,   1.912E+01,,   52.567
C,03-CO57 ,YES,    3.997E+01,   9.624E-01,   7.562E-01,,   52.860
C,04-CE139,YES,    5.094E+01,   1.861E+00,   1.275E+00,,   39.947
C,05-HG203,YES,    1.433E+02,   1.298E+01,   1.199E+01,,   11.946
C,06-SN113,YES,    1.913E+02,   4.427E+00,   3.216E+00,,   59.495
C,07-SR85 ,YES,    2.478E+02,   8.982E+00,   6.105E+00,,   40.592
C,08-CS137,YES,    1.739E+02,   2.157E+00,   1.016E+00,,  171.218
C,09-Y88  ,YES,    3.903E+02,   7.605E+00,   4.371E+00,,   89.291
C,10-CO60 ,YES,    2.062E+02,   2.009E+00,   1.090E+00,,  189.159
C,12-Y88  ,YES,    4.013E+02,   8.294E+00,   2.498E+00,,  160.653
C,01-AM241,NO ,    4.223E-01,   2.177E+00,   3.537E+00,,    0.119
```

E & Z 2088-10-1 Mixed Gamma
6/1/19 12:00 PM

S25 Bottle

		Orig. Wt	5.1617	Volume	50				
		Wt Used	4.4184	Aliquot	5.0000	Certificate	Aliquoted	Actual	Percent
	Half-Life	Energy(KeV)	ate G/s/	%err	%abn	Bq/Tot	G/S	Bq/Tot	Diff
Cd-109	462.9d	88.0	84.75		3.72%	1006.61	37.45	1008.0	0.14%
Co-57	271.8d	122.1	77.25		85.51%	39.92	34.13	40.1	0.49%
Ce-139	137.64d	165.9	92.68		80.35%	50.96	40.95	50.8	-0.38%
Hg-203	46.6d	279.2	273		77.30%	156.04	120.62	146.5	-6.12%
Sn-113	115.09d	391.7	280		64.90%	190.62	123.72	192.2	0.83%
Sr-85	64.849	514.0	547.9		98.40%	246.02	242.08	240.0	-2.45%
Cs-137	30.17y	661.6	330.6		85.12%	171.61	146.07	175.4	2.21%
Y-88	106.65d	898.0	858.7		93.40%	406.22	379.41	396.8	-2.32%
Co-60	5.27y	1173.2	460.4		100.00%	203.42	203.42	202.8	-0.31%
Co-60	5.27y	1332.5	460.9		100.00%	203.64	203.64	206.4	1.35%
Y-88	106.65d	1836.0	908		99.38%	403.69	401.19	402.2	-0.37%

Eff. Name: **08S25121919**

Analyst: KOJ

Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 11:55:49.52
TBE08 31-TP20610B HpGe ******** Aquisition Date/Time: 19-DEC-2019 09:30:14.76

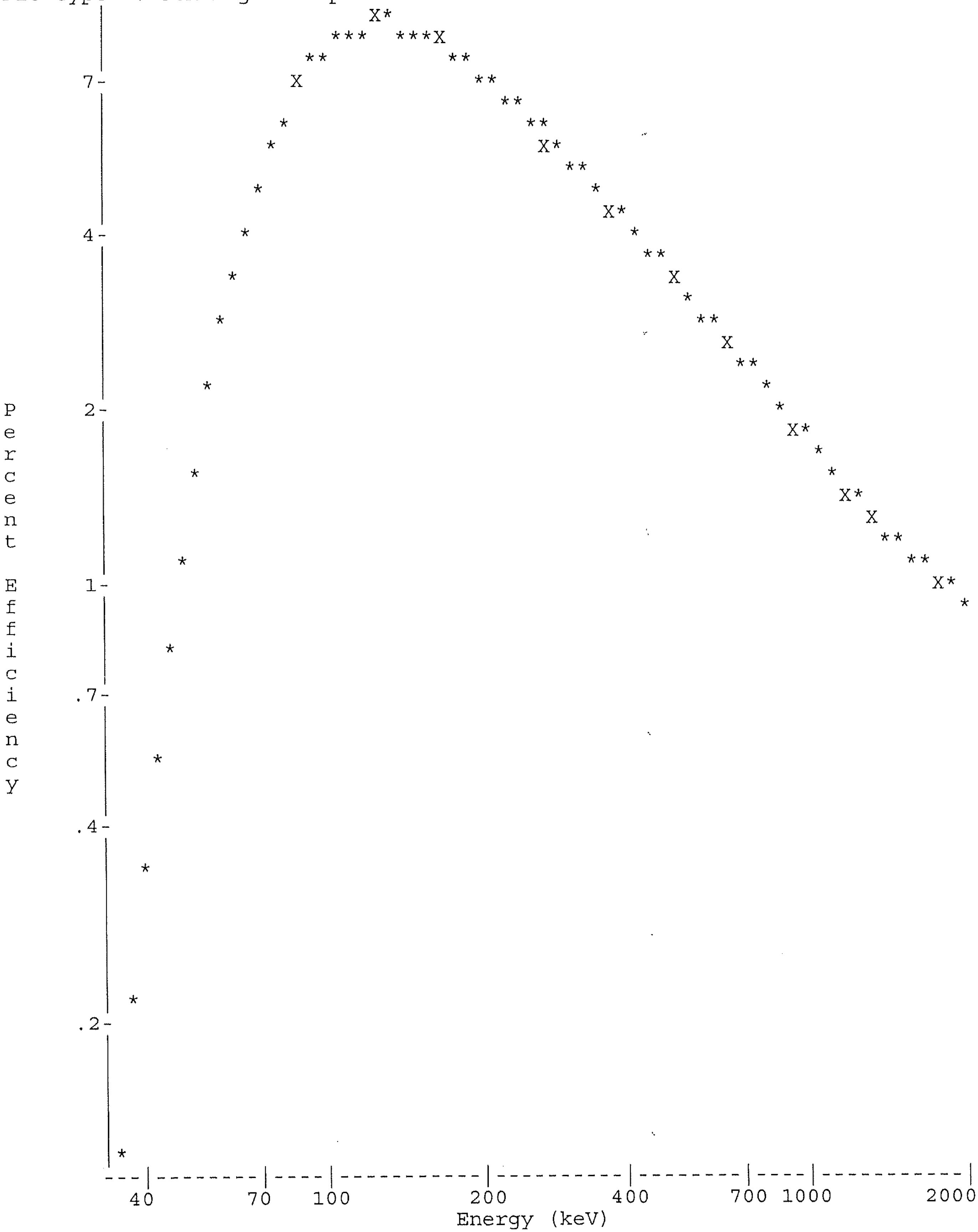
LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID : 08S25121919
Sample Type : STD
Quantity : 1.00000E+00 TOTAL
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Smple Date: 1-JUN-2019 12:00:00.0
Geometry : 08S25121919
BKGFILE : 08BG112719MT
Real Time : 0 02:22:09.14
Live time : 0 02:21:40.56

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	46.22	968	4222	1.09	100.32	7.97E-01	1.14E-01	12.1	7.72E-01
2	1	87.92	16445	5243	1.23	183.54	6.97E+00	1.93E+00	1.1	2.31E+00
3	1	122.05	15075	5614	1.26	251.65	8.65E+00	1.77E+00	1.3	7.88E-01
4	1	136.49	2140	4042	1.49	280.46	8.65E+00	2.52E-01	6.0	1.70E+00
5	1	165.89	10292	4634	1.34	339.14	8.16E+00	1.21E+00	1.7	9.22E-01
6	1	255.24	566	3634	1.33	517.46	6.16E+00	6.66E-02	20.3	1.29E+00
7	1	279.23	2924	3581	1.40	565.32	5.72E+00	3.44E-01	4.4	1.10E+00
8	1	391.76	13449	3344	1.46	789.87	4.25E+00	1.58E+00	1.2	2.30E+00
9	1	514.04	7815	3136	1.53	1033.88	3.31E+00	9.19E-01	1.9	8.36E-01
10	1	661.65	32506	2608	1.64	1328.41	2.59E+00	3.82E+00	0.7	1.21E+00
11	1	898.01	16369	2548	1.78	1800.01	1.92E+00	1.93E+00	1.0	8.30E-01
12	1	1173.18	23661	1206	1.92	2348.99	1.48E+00	2.78E+00	0.7	5.31E-01
13	1	1332.45	21386	633	2.00	2666.73	1.31E+00	2.52E+00	0.7	6.28E-01
14	1	1836.03	9422	225	2.27	3671.21	1.02E+00	1.11E+00	1.1	1.35E+00

Spectrum : MCA0:[NDSCOUNT]TBE08$1
Calib Date: 26-DEC-2019 11:55
Detector : Geometry : 08S25121919
Fit type : 5th Degree Empirical



Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 11:57:03.65
TBE08 31-TP20610B HpGe ******** Aquisition Date/Time: 19-DEC-2019 09:30:14.76

LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID : 08S25121919 Smple Date: 1-JUN-2019 12:00:00.0
Sample Type : STD Geometry : 08S25121919
Quantity : 1.00000E+00 TOTAL BKGFILE : 08BG112719MT
Start Channel : 80 Energy Tol : 2.00000 Real Time : 0 02:22:09.14
End Channel : 4090 Pk Srch Sens: 9.00000 Live time : 0 02:21:40.56
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	46.22	968	4222	1.09	100.32	7.97E-01	1.14E-01	12.1	7.72E-01
2	1	87.92	16445	5243	1.23	183.54	6.97E+00	1.93E+00	1.1	2.31E+00
3	1	122.05	15075	5614	1.26	251.65	8.65E+00	1.77E+00	1.3	7.88E-01
4	1	136.49	2140	4042	1.49	280.46	8.65E+00	2.52E-01	6.0	1.70E+00
5	1	165.89	10292	4634	1.34	339.14	8.16E+00	1.21E+00	1.7	9.22E-01
6	1	255.24	566	3634	1.33	517.46	6.16E+00	6.66E-02	20.3	1.29E+00
7	1	279.23	2924	3581	1.40	565.32	5.72E+00	3.44E-01	4.4	1.10E+00
8	1	391.76	13449	3344	1.46	789.87	4.25E+00	1.58E+00	1.2	2.30E+00
9	1	514.04	7815	3136	1.53	1033.88	3.31E+00	9.19E-01	1.9	8.36E-01
10	1	661.65	32506	2608	1.64	1328.41	2.59E+00	3.82E+00	0.7	1.21E+00
11	1	898.01	16369	2548	1.78	1800.01	1.92E+00	1.93E+00	1.0	8.30E-01
12	1	1173.18	23661	1206	1.92	2348.99	1.48E+00	2.78E+00	0.7	5.31E-01
13	1	1332.45	21386	633	2.00	2666.73	1.31E+00	2.52E+00	0.7	6.28E-01
14	1	1836.03	9422	225	2.27	3671.21	1.02E+00	1.11E+00	1.1	1.35E+00

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	2-Sigma %Error
02-CD109	88.03	16445	3.72*	6.973E+00	7.457E+02	1.008E+03	2.29
03-CO57	122.06	15075	85.51*	8.646E+00	2.399E+01	4.011E+01	2.57
04-CE139	165.85	10292	80.35*	8.164E+00	1.846E+01	5.077E+01	3.30
05-HG203	279.20	2924	81.46*	5.722E+00	7.379E+00	1.465E+02	8.76
06-SN113	391.69	13449	64.90*	4.254E+00	5.731E+01	1.922E+02	2.48
07-SR85	513.99	7815	99.27*	3.306E+00	2.801E+01	2.400E+02	3.83
08-CS137	661.65	32506	85.12*	2.594E+00	1.732E+02	1.754E+02	1.31
09-Y88	898.02	16369	93.40*	1.918E+00	1.075E+02	3.968E+02	2.09
10-CO60	1173.22	23661	100.00	1.475E+00	1.887E+02	2.028E+02	1.47
	1332.49	21386	100.00*	1.311E+00	1.920E+02	2.064E+02	1.47
12-Y88	1836.01	9422	99.38*	1.024E+00	1.090E+02	4.022E+02	2.23

Flag: "*" = Keyline

Sample ID : 08S25121919 Acquisition date : 19-DEC-2019 09:30:14

Total number of lines in spectrum	14	
Number of unidentified lines	3	
Number of lines tentatively identified by NID	11	78.57%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.457E+02	1.008E+03	0.023E+03	2.29	
03-CO57	270.90D	1.67	2.399E+01	4.011E+01	0.103E+01	2.57	
04-CE139	137.66D	2.75	1.846E+01	5.077E+01	0.168E+01	3.30	
05-HG203	46.61D	19.8	7.379E+00	1.465E+02	0.128E+02	8.76	
06-SN113	115.10D	3.35	5.731E+01	1.922E+02	0.048E+02	2.48	
07-SR85	64.84D	8.57	2.801E+01	2.400E+02	0.092E+02	3.83	
08-CS137	30.17Y	1.01	1.732E+02	1.754E+02	0.023E+02	1.31	
09-Y88	106.65D	3.69	1.075E+02	3.968E+02	0.083E+02	2.09	
10-CO60	5.27Y	1.08	1.920E+02	2.064E+02	0.030E+02	1.47	
12-Y88	106.65D	3.69	1.090E+02	4.022E+02	0.089E+02	2.23	
		Total Activity :	1.462E+03	2.858E+03			

Grand Total Activity : 1.462E+03 2.858E+03

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Sample ID : 08S25121919 Acquisition date : 19-DEC-2019 09:30:14

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
1	46.22	968	4222	1.09	100.32	97	8	1.14E-01	24.2	7.97E-01	
1	136.49	2140	4042	1.49	280.46	276	10	2.52E-01	11.9	8.65E+00	
1	255.24	566	3634	1.33	517.46	512	10	6.66E-02	40.6	6.16E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum 14
Number of unidentified lines 3
Number of lines tentatively identified by NID 11 78.57%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected BQ/TOTAL	Wtd Mean Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.457E+02	1.008E+03	0.023E+03	2.29	
03-CO57	270.90D	1.67	2.399E+01	4.011E+01	0.103E+01	2.57	
04-CE139	137.66D	2.75	1.846E+01	5.077E+01	0.168E+01	3.30	
05-HG203	46.61D	19.8	7.379E+00	1.465E+02	0.128E+02	8.76	
06-SN113	115.10D	3.35	5.731E+01	1.922E+02	0.048E+02	2.48	
07-SR85	64.84D	8.57	2.801E+01	2.400E+02	0.092E+02	3.83	
08-CS137	30.17Y	1.01	1.732E+02	1.754E+02	0.023E+02	1.31	
09-Y88	106.65D	3.69	1.075E+02	3.968E+02	0.083E+02	2.09	
10-CO60	5.27Y	1.08	1.903E+02	2.046E+02	0.021E+02	1.04	
12-Y88	106.65D	3.69	1.090E+02	4.022E+02	0.089E+02	2.23	
			---------	---------			
	Total Activity :		1.461E+03	2.856E+03			

Grand Total Activity : 1.461E+03 2.856E+03

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (BQ/TOTAL)	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
02-CD109	1.008E+03	2.311E+01	1.822E+01	0.000E+00	55.299
03-CO57	4.011E+01	1.031E+00	7.340E-01	0.000E+00	54.648
04-CE139	5.077E+01	1.678E+00	1.305E+00	0.000E+00	38.902
05-HG203	1.465E+02	1.282E+01	1.242E+01	0.000E+00	11.794
06-SN113	1.922E+02	4.763E+00	3.294E+00	0.000E+00	58.358
07-SR85	2.400E+02	9.188E+00	6.549E+00	0.000E+00	36.647
08-CS137	1.754E+02	2.292E+00	1.071E+00	0.000E+00	163.721

09-Y88	3.968E+02	8.278E+00	4.619E+00	0.000E+00	85.910
10-CO60	2.046E+02	2.127E+00	1.090E+00	0.000E+00	187.592
12-Y88	4.022E+02	8.950E+00	2.374E+00	0.000E+00	169.424

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (BQ/TOTAL)	K.L. Ided	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
01-AM241	6.813E-02		2.018E+00	3.218E+00	0.000E+00	0.021

```
A,08S25121919      ,12/26/2019 11:57,06/01/2019 12:00,   1.000E+00,S25 5ML MIXED
B,08S25121919      ,CALIBRATION         ,12/26/2019 11:55,08S25121919
C,02-CD109,YES,   1.008E+03,   2.311E+01,   1.822E+01,,   55.299
C,03-CO57 ,YES,   4.011E+01,   1.031E+00,   7.340E-01,,   54.648
C,04-CE139,YES,   5.077E+01,   1.678E+00,   1.305E+00,,   38.902
C,05-HG203,YES,   1.465E+02,   1.282E+01,   1.242E+01,,   11.794
C,06-SN113,YES,   1.922E+02,   4.763E+00,   3.294E+00,,   58.358
C,07-SR85 ,YES,   2.400E+02,   9.188E+00,   6.549E+00,,   36.647
C,08-CS137,YES,   1.754E+02,   2.292E+00,   1.071E+00,,  163.721
C,09-Y88  ,YES,   3.968E+02,   8.278E+00,   4.619E+00,,   85.910
C,10-CO60 ,YES,   2.046E+02,   2.127E+00,   1.090E+00,,  187.592
C,12-Y88  ,YES,   4.022E+02,   8.950E+00,   2.374E+00,,  169.424
C,01-AM241,NO ,   6.813E-02,   2.018E+00,   3.218E+00,,    0.021
```

E & Z 2088-10-1 Mixed Gamma
6/1/19 12:00 PM

S50 Bottle

		Orig. Wt	5.1617	Volume	50				
		Wt Used	4.4184	Aliquot	5.0000	Certificate	Aliquoted	Actual	Percent
	Half-Life	Energy(KeV)	ate G/s/	%err	%abn	Bq/Tot	G/S	Bq/Tot	Diff
Cd-109	462.9d	88.0	84.75		3.72%	1006.61	37.45	1011.0	0.44%
Co-57	271.8d	122.1	77.25		85.51%	39.92	34.13	39.7	-0.47%
Ce-139	137.64d	165.9	92.68		80.35%	50.96	40.95	51.7	1.35%
Hg-203	46.6d	279.2	273		77.30%	156.04	120.62	145.0	-7.08%
Sn-113	115.09d	391.7	280		64.90%	190.62	123.72	188.9	-0.90%
Sr-85	64.849	514.0	547.9		98.40%	246.02	242.08	246.5	0.19%
Cs-137	30.17y	661.6	330.6		85.12%	171.61	146.07	174.8	1.86%
Y-88	106.65d	898.0	858.7		93.40%	406.22	379.41	395.5	-2.64%
Co-60	5.27y	1173.2	460.4		100.00%	203.42	203.42	203.2	-0.11%
Co-60	5.27y	1332.5	460.9		100.00%	203.64	203.64	206.2	1.26%
Y-88	106.65d	1836.0	908		99.38%	403.69	401.19	402.3	-0.35%

Eff. Name: **08S50121919**

Analyst: KOJ [signature]

Analyst:

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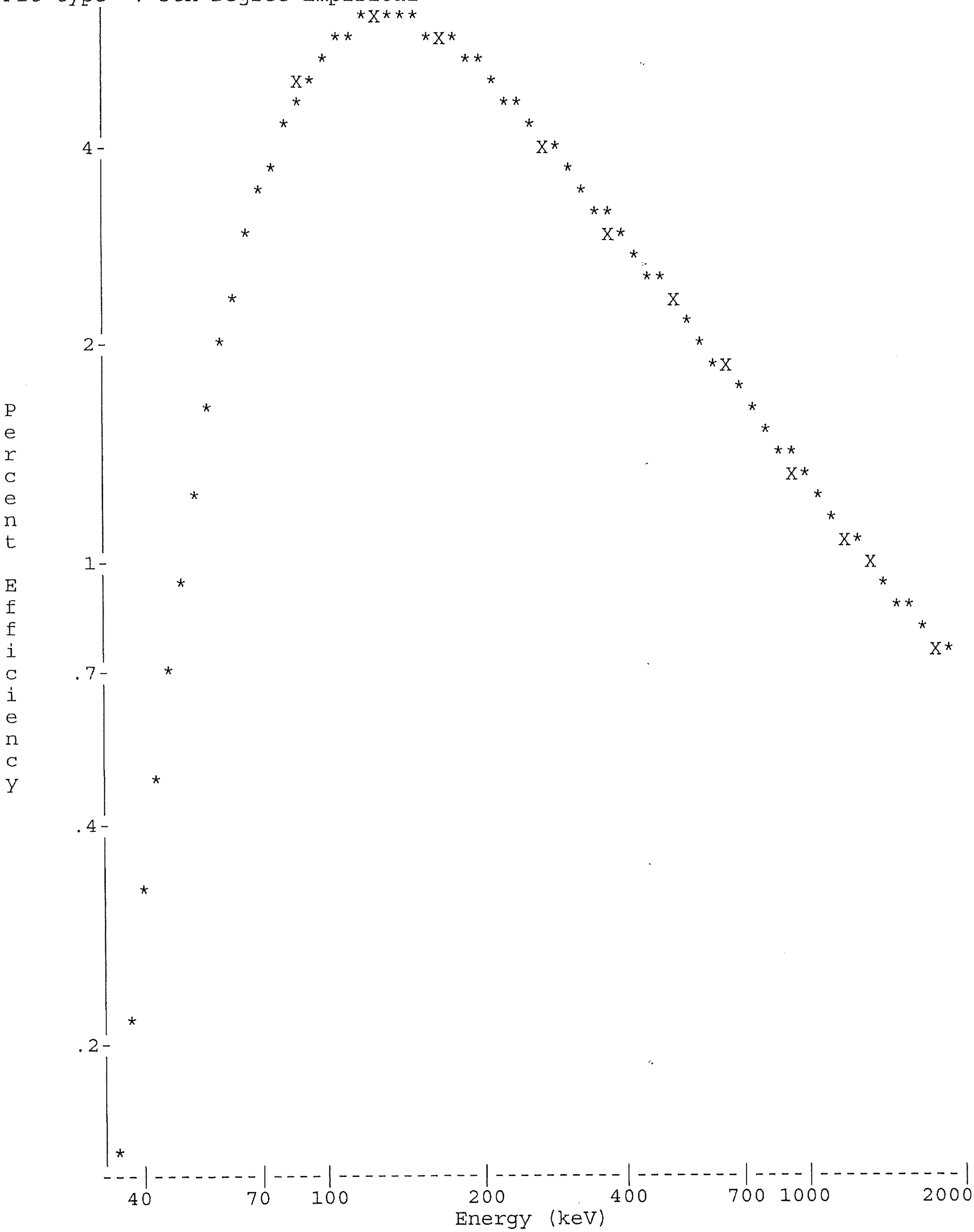
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 11:59:44.02
TBE08 31-TP20610B HpGe ******** Aquisition Date/Time: 19-DEC-2019 14:24:25.59

LIMS No., Customer Name, Client ID: S50 5ML MIXED GAMMA CALIBRATION

Sample ID : 08S50121919
Smple Date: 1-JUN-2019 12:00:00.0
Sample Type : STD
Geometry : 08S50121919
Quantity : 1.00000E+00 TOTAL
BKGFILE : 08BG112719MT
Start Channel : 80
Energy Tol : 2.00000
Real Time : 0 03:30:31.74
End Channel : 4090
Pk Srch Sens: 9.00000
Live time : 0 03:30:00.00
MDA Multiple : 4.6600
Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	46.22	1277	5281	1.50	100.46	7.01E-01	1.01E-01	10.6	1.75E+00
2	1	87.92	16596	6858	1.24	183.66	4.74E+00	1.32E+00	1.2	2.05E-01
3	1	122.05	15088	5409	1.26	251.78	5.90E+00	1.20E+00	1.2	5.56E-01
4	1	136.46	2057	5308	1.46	280.53	5.94E+00	1.63E-01	7.2	6.20E-01
5	1	165.90	10778	5471	1.35	339.29	5.68E+00	8.55E-01	1.7	7.49E-01
6	1	255.16	647	3704	1.43	517.41	4.35E+00	5.13E-02	17.4	3.53E-01
7	1	279.24	3024	4125	1.37	565.47	4.05E+00	2.40E-01	4.5	9.44E-01
8	1	391.75	13827	4116	1.45	789.97	3.01E+00	1.10E+00	1.3	2.11E+00
9	1	514.02	8393	4272	1.57	1033.96	2.34E+00	6.66E-01	2.1	4.31E+00
10	1	661.65	34173	2764	1.64	1328.51	1.85E+00	2.71E+00	0.6	1.83E+00
11	1	814.11	316	1342	1.40	1632.71	1.52E+00	2.51E-02	21.5	1.13E+00
12	1	898.01	17482	2500	1.78	1800.10	1.39E+00	1.39E+00	1.0	7.35E-01
13	1	1173.18	25897	1364	1.89	2349.07	1.09E+00	2.06E+00	0.7	1.16E+00
14	1	1332.46	23483	689	2.00	2666.79	9.72E-01	1.86E+00	0.7	1.07E+00
15	1	1836.03	10194	166	2.26	3671.21	7.48E-01	8.09E-01	1.0	6.49E-01

Spectrum   : MCA0:[NDSCOUNT]TBE08$1
Calib Date: 26-DEC-2019 11:59
Detector :   Geometry   : 08S50121919
Fit type : 5th Degree Empirical



Analyst:

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 12:02:28.82
TBE08 31-TP20610B HpGe ******** Aquisition Date/Time: 19-DEC-2019 14:24:25.59

LIMS No., Customer Name, Client ID: S50 5ML MIXED GAMMA CALIBRATION

Sample ID : 08S50121919
Sample Type : STD
Quantity : 1.00000E+00 TOTAL
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Smple Date: 1-JUN-2019 12:00:00.0
Geometry : 08S50121919
BKGFILE : 08BG112719MT
Real Time : 0 03:30:31.74
Live time : 0 03:30:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	46.22	1277	5281	1.50	100.46	7.01E-01	1.01E-01	10.6	1.75E+00
2	1	87.92	16596	6858	1.24	183.66	4.74E+00	1.32E+00	1.2	2.05E-01
3	1	122.05	15088	5409	1.26	251.78	5.90E+00	1.20E+00	1.2	5.56E-01
4	1	136.46	2057	5308	1.46	280.53	5.94E+00	1.63E-01	7.2	6.20E-01
5	1	165.90	10778	5471	1.35	339.29	5.68E+00	8.55E-01	1.7	7.49E-01
6	1	255.16	647	3704	1.43	517.41	4.35E+00	5.13E-02	17.4	3.53E-01
7	1	279.24	3024	4125	1.37	565.47	4.05E+00	2.40E-01	4.5	9.44E-01
8	1	391.75	13827	4116	1.45	789.97	3.01E+00	1.10E+00	1.3	2.11E+00
9	1	514.02	8393	4272	1.57	1033.96	2.34E+00	6.66E-01	2.1	4.31E+00
10	1	661.65	34173	2764	1.64	1328.51	1.85E+00	2.71E+00	0.6	1.83E+00
11	1	814.11	316	1342	1.40	1632.71	1.52E+00	2.51E-02	21.5	1.13E+00
12	1	898.01	17482	2500	1.78	1800.10	1.39E+00	1.39E+00	1.0	7.35E-01
13	1	1173.18	25897	1364	1.89	2349.07	1.09E+00	2.06E+00	0.7	1.16E+00
14	1	1332.46	23483	689	2.00	2666.79	9.72E-01	1.86E+00	0.7	1.07E+00
15	1	1836.03	10194	166	2.26	3671.21	7.48E-01	8.09E-01	1.0	6.49E-01

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	2-Sigma %Error
02-CD109	88.03	16596	3.72*	4.736E+00	7.477E+02	1.011E+03	2.49
03-CO57	122.06	15088	85.51*	5.897E+00	2.374E+01	3.973E+01	2.45
04-CE139	165.85	10778	80.35*	5.676E+00	1.876E+01	5.165E+01	3.36
05-HG203	279.20	3024	81.46*	4.047E+00	7.281E+00	1.450E+02	8.99
06-SN113	391.69	13827	64.90*	3.007E+00	5.623E+01	1.889E+02	2.56
07-SR85	513.99	8393	99.27*	2.338E+00	2.869E+01	2.465E+02	4.28
08-CS137	661.65	34173	85.12*	1.846E+00	1.726E+02	1.748E+02	1.28
09-Y88	898.02	17482	93.40*	1.389E+00	1.070E+02	3.955E+02	1.96
10-CO60	1173.22	25897	100.00	1.088E+00	1.890E+02	2.032E+02	1.41
	1332.49	23483	100.00*	9.718E-01	1.918E+02	2.062E+02	1.41
12-Y88	1836.01	10194	99.38*	7.480E-01	1.088E+02	4.023E+02	2.08

Flag: "*" = Keyline

Sample ID : 08S50121919 Acquisition date : 19-DEC-2019 14:24:25

Total number of lines in spectrum	15	
Number of unidentified lines	4	
Number of lines tentatively identified by NID	11	73.33%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.477E+02	1.011E+03	0.025E+03	2.49	
03-CO57	270.90D	1.67	2.374E+01	3.973E+01	0.097E+01	2.45	
04-CE139	137.66D	2.75	1.876E+01	5.165E+01	0.174E+01	3.36	
05-HG203	46.61D	19.9	7.281E+00	1.450E+02	0.130E+02	8.99	
06-SN113	115.10D	3.36	5.623E+01	1.889E+02	0.048E+02	2.56	
07-SR85	64.84D	8.59	2.869E+01	2.465E+02	0.106E+02	4.28	
08-CS137	30.17Y	1.01	1.726E+02	1.748E+02	0.022E+02	1.28	
09-Y88	106.65D	3.70	1.070E+02	3.955E+02	0.078E+02	1.96	
10-CO60	5.27Y	1.08	1.918E+02	2.062E+02	0.029E+02	1.41	
12-Y88	106.65D	3.70	1.088E+02	4.023E+02	0.084E+02	2.08	
		Total Activity :	1.463E+03	2.861E+03			
		Grand Total Activity :	1.463E+03	2.861E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Sample ID : 08S50121919 Acquisition date : 19-DEC-2019 14:24:25

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
1	46.22	1277	5281	1.50	100.46	96	9	1.01E-01	21.3	7.01E-01	
1	136.46	2057	5308	1.46	280.53	275	11	1.63E-01	14.4	5.94E+00	
1	255.16	647	3704	1.43	517.41	514	9	5.13E-02	34.9	4.35E+00	
1	814.11	316	1342	1.40	1632.71	1628	9	2.51E-02	43.1	1.52E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum 15
Number of unidentified lines 4
Number of lines tentatively identified by NID 11 73.33%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected BQ/TOTAL	Wtd Mean Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.477E+02	1.011E+03	0.025E+03	2.49	
03-CO57	270.90D	1.67	2.374E+01	3.973E+01	0.097E+01	2.45	
04-CE139	137.66D	2.75	1.876E+01	5.165E+01	0.174E+01	3.36	
05-HG203	46.61D	19.9	7.281E+00	1.450E+02	0.130E+02	8.99	
06-SN113	115.10D	3.36	5.623E+01	1.889E+02	0.048E+02	2.56	
07-SR85	64.84D	8.59	2.869E+01	2.465E+02	0.106E+02	4.28	
08-CS137	30.17Y	1.01	1.726E+02	1.748E+02	0.022E+02	1.28	
09-Y88	106.65D	3.70	1.070E+02	3.955E+02	0.078E+02	1.96	
10-CO60	5.27Y	1.08	1.904E+02	2.047E+02	0.020E+02	1.00	
12-Y88	106.65D	3.70	1.088E+02	4.023E+02	0.084E+02	2.08	
			---------	---------			
	Total Activity :		1.461E+03	2.859E+03			

Grand Total Activity : 1.461E+03 2.859E+03

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (BQ/TOTAL)	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
02-CD109	1.011E+03	2.512E+01	1.884E+01	0.000E+00	53.628
03-CO57	3.973E+01	9.733E-01	7.871E-01	0.000E+00	50.475
04-CE139	5.165E+01	1.737E+00	1.332E+00	0.000E+00	38.790
05-HG203	1.450E+02	1.303E+01	1.248E+01	0.000E+00	11.620
06-SN113	1.889E+02	4.831E+00	3.407E+00	0.000E+00	55.431
07-SR85	2.465E+02	1.055E+01	6.386E+00	0.000E+00	38.593

08-CS137	1.748E+02	2.230E+00	1.062E+00	0.000E+00	164.526
09-Y88	3.955E+02	7.764E+00	4.579E+00	0.000E+00	86.362
10-CO60	2.047E+02	2.041E+00	1.007E+00	0.000E+00	203.154
12-Y88	4.023E+02	8.355E+00	2.125E+00	0.000E+00	189.307

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (BQ/TOTAL)	K.L. Ided	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
01-AM241	-1.459E+00		1.968E+00	3.106E+00	0.000E+00	-0.470

```
A,08S50121919       ,12/26/2019 12:02,06/01/2019 12:00,   1.000E+00,S50 5ML MIXED
B,08S50121919       ,CALIBRATION         ,12/26/2019 11:59,08S50121919
C,02-CD109,YES,   1.011E+03,  2.512E+01,  1.884E+01,,   53.628
C,03-CO57 ,YES,   3.973E+01,  9.733E-01,  7.871E-01,,   50.475
C,04-CE139,YES,   5.165E+01,  1.737E+00,  1.332E+00,,   38.790
C,05-HG203,YES,   1.450E+02,  1.303E+01,  1.248E+01,,   11.620
C,06-SN113,YES,   1.889E+02,  4.831E+00,  3.407E+00,,   55.431
C,07-SR85 ,YES,   2.465E+02,  1.055E+01,  6.386E+00,,   38.593
C,08-CS137,YES,   1.748E+02,  2.230E+00,  1.062E+00,,  164.526
C,09-Y88  ,YES,   3.955E+02,  7.764E+00,  4.579E+00,,   86.362
C,10-CO60 ,YES,   2.047E+02,  2.041E+00,  1.007E+00,,  203.154
C,12-Y88  ,YES,   4.023E+02,  8.355E+00,  2.125E+00,,  189.307
C,01-AM241,NO ,  -1.459E+00,  1.968E+00,  3.106E+00,,   -0.470
```

E & Z 2088-10-1 Mixed Gamma
6/1/19 12:00 PM

S25 Bottle

		Orig. Wt	5.1617	Volume	50				
		Wt Used	4.4184	Aliquot	5.0000	Certificate	Aliquoted	Actual	Percent
	Half-Life	Energy(KeV)	ate G/s/	%err	%abn	Bq/Tot	G/S	Bq/Tot	Diff
Cd-109	462.9d	88.0	84.75		3.72%	1006.61	37.45	993.6	-1.29%
Co-57	271.8d	122.1	77.25		85.51%	39.92	34.13	42.1	5.37%
Ce-139	137.64d	165.9	92.68		80.35%	50.96	40.95	47.8	-6.25%
Hg-203	46.6d	279.2	273		77.30%	156.04	120.62	156.1	0.04%
Sn-113	115.09d	391.7	280		64.90%	190.62	123.72	191.6	0.51%
Sr-85	64.849	514.0	547.9		98.40%	246.02	242.08	246.5	0.19%
Cs-137	30.17y	661.6	330.6		85.12%	171.61	146.07	172.8	0.69%
Y-88	106.65d	898.0	858.7		93.40%	406.22	379.41	386.9	-4.76%
Co-60	5.27y	1173.2	460.4		100.00%	203.42	203.42	204.0	0.28%
Co-60	5.27y	1332.5	460.9		100.00%	203.64	203.64	207.4	1.84%
Y-88	106.65d	1836.0	908		99.38%	403.69	401.19	400.1	-0.89%

Eff. Name: **11S25121819**

Analyst: KOJ [signature]

Analyst:

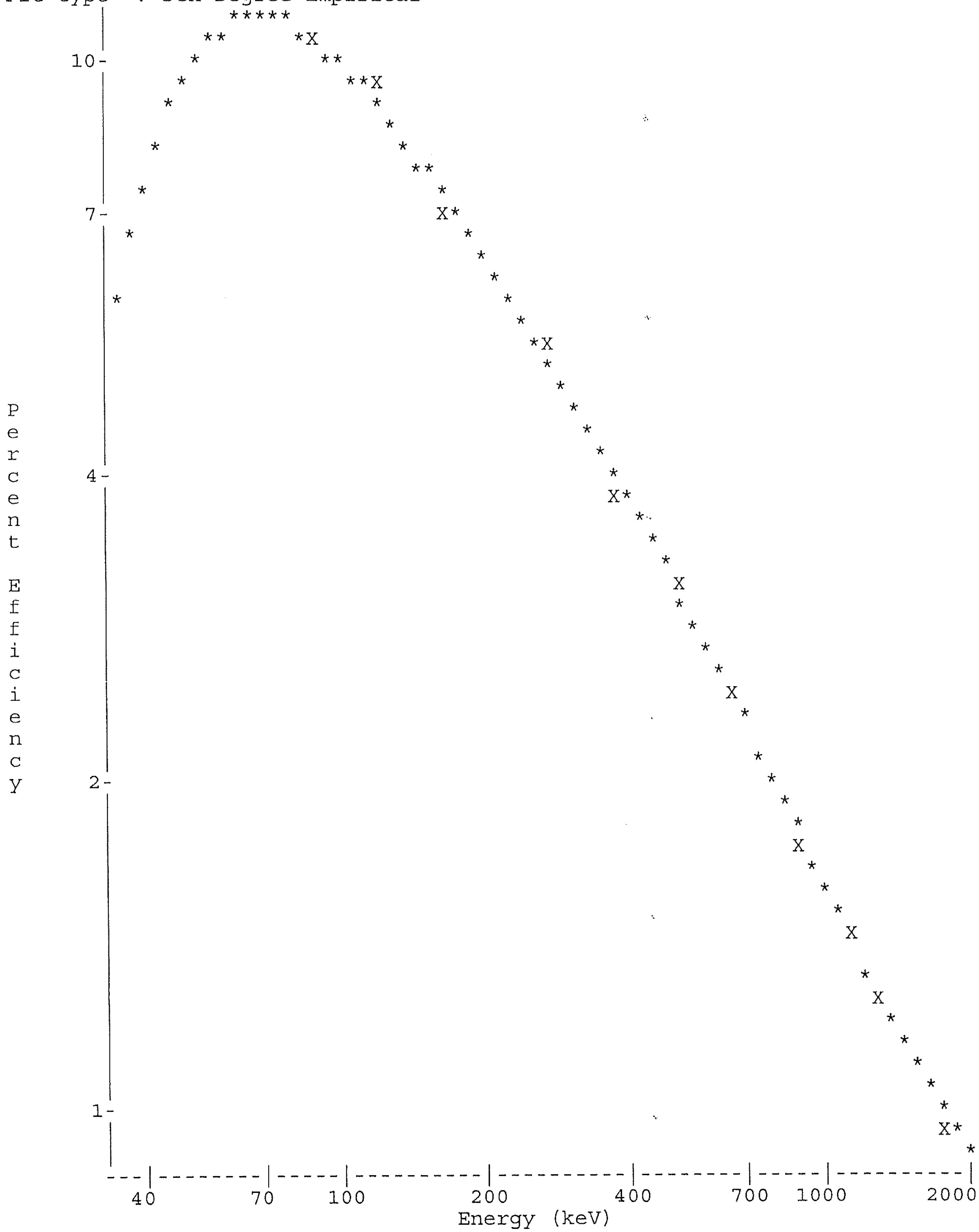
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 12:23:32.17
TBE11 59-TN51806A HpGe ******* Aquisition Date/Time: 18-DEC-2019 09:33:11.11

LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID : 11S25121819 Smple Date: 1-JUN-2019 12:00:00.0
Sample Type : STD Geometry : 11S25121819
Quantity : 1.00000E+00 TOTAL BKGFILE : 11BG112719MT
Start Channel : 70 Energy Tol : 2.00000 Real Time : 0 03:11:53.14
End Channel : 4090 Pk Srch Sens: 9.00000 Live time : 0 03:11:03.28
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.47	35805	13059	1.40	91.92	9.09E+00	3.12E+00	0.9	
2	0	88.02	33122	7436	1.42	175.07	1.05E+01	2.89E+00	0.8	
3	0	122.04	22326	7271	1.51	243.14	9.03E+00	1.95E+00	1.1	
4	0	136.43	2706	4424	1.36	271.93	8.44E+00	2.36E-01	5.0	
5	0	165.87	11911	5271	1.51	330.83	7.41E+00	1.04E+00	1.5	
6	0	199.04	676	4281	1.71	397.18	6.51E+00	5.90E-02	17.9	
7	0	255.21	882	3762	1.57	509.58	5.41E+00	7.69E-02	13.5	
8	0	279.20	3759	5069	1.56	557.57	5.05E+00	3.28E-01	4.3	
9	0	391.75	16494	4392	1.66	782.76	3.86E+00	1.44E+00	1.2	
10	0	513.92	10151	3822	1.80	1027.19	3.07E+00	8.86E-01	1.7	
11	0	661.66	40746	3429	1.88	1322.79	2.45E+00	3.55E+00	0.6	
12	0	898.01	20678	3829	2.05	1795.69	1.83E+00	1.80E+00	1.0	
13	0	1173.22	31189	1914	2.27	2346.36	1.41E+00	2.72E+00	0.7	
14	0	1332.52	27709	1290	2.33	2665.10	1.25E+00	2.42E+00	0.7	
15	0	1835.99	11913	387	2.75	3672.54	9.59E-01	1.04E+00	1.0	

Spectrum : MCA0:[NDSCOUNT]TBE11$1
Calib Date: 26-DEC-2019 12:23
Detector : Geometry : 11S25121819
Fit type : 5th Degree Empirical



Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 12:24:28.73
TBE11 59-TN51806A HpGe ******* Aquisition Date/Time: 18-DEC-2019 09:33:11.11

LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID : 11S25121819
Sample Type : STD
Quantity : 1.00000E+00 TOTAL
Start Channel : 70 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: CALIBRATION
Smple Date: 1-JUN-2019 12:00:00.0
Geometry : 11S25121819
BKGFILE : 11BG112719MT
Real Time : 0 03:11:53.14
Live time : 0 03:11:03.28
Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.47*	35629	13059	1.40	91.92	9.09E+00	3.11E+00	0.9	
2	0	88.02*	33070	7436	1.42	175.07	1.05E+01	2.88E+00	0.8	
3	0	122.04	22326	7271	1.51	243.14	9.03E+00	1.95E+00	1.1	
4	0	136.43	2706	4424	1.36	271.93	8.44E+00	2.36E-01	5.0	
5	0	165.87	11911	5271	1.51	330.83	7.41E+00	1.04E+00	1.5	
6	0	199.04	676	4281	1.71	397.18	6.51E+00	5.90E-02	17.9	
7	0	255.21	882	3762	1.57	509.58	5.41E+00	7.69E-02	13.5	
8	0	279.20	3759	5069	1.56	557.57	5.05E+00	3.28E-01	4.3	
9	0	391.75	16494	4392	1.66	782.76	3.86E+00	1.44E+00	1.2	
10	0	513.92	10151	3822	1.80	1027.19	3.07E+00	8.86E-01	1.7	
11	0	661.66	40746	3429	1.88	1322.79	2.45E+00	3.55E+00	0.6	
12	0	898.01	20678	3829	2.05	1795.69	1.83E+00	1.80E+00	1.0	
13	0	1173.22	31189	1914	2.27	2346.36	1.41E+00	2.72E+00	0.7	
14	0	1332.52	27709	1290	2.33	2665.10	1.25E+00	2.42E+00	0.7	
15	0	1835.99	11913	387	2.75	3672.54	9.59E-01	1.04E+00	1.0	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	2-Sigma %Error
02-CD109	88.03	33070	3.72*	1.053E+01	7.365E+02	9.936E+02	1.51
03-CO57	122.06	22326	85.51*	9.032E+00	2.522E+01	4.206E+01	2.13
04-CE139	165.85	11911	80.35*	7.407E+00	1.746E+01	4.778E+01	3.05
05-HG203	279.20	3759	81.46*	5.046E+00	7.978E+00	1.561E+02	8.67
06-SN113	391.69	16494	64.90*	3.858E+00	5.747E+01	1.916E+02	2.34
07-SR85	513.99	10151	99.27*	3.069E+00	2.907E+01	2.465E+02	3.37
08-CS137	661.65	40746	85.12*	2.447E+00	1.707E+02	1.728E+02	1.19
09-Y88	898.02	20678	93.40*	1.831E+00	1.055E+02	3.869E+02	2.02
10-CO60	1173.22	31189	100.00	1.413E+00	1.926E+02	2.070E+02	1.35
	1332.49	27709	100.00*	1.253E+00	1.930E+02	2.074E+02	1.36
12-Y88	1836.01	11913	99.38*	9.586E-01	1.091E+02	4.001E+02	2.07

Flag: "*" = Keyline

Total number of lines in spectrum 15
Number of unidentified lines 4
Number of lines tentatively identified by NID 11 73.33%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected BQ/TOTAL	Decay Corr. BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.365E+02	9.936E+02	0.150E+02	1.51	
03-CO57	270.90D	1.67	2.522E+01	4.206E+01	0.090E+01	2.13	
04-CE139	137.66D	2.74	1.746E+01	4.778E+01	0.146E+01	3.05	
05-HG203	46.61D	19.6	7.978E+00	1.561E+02	0.135E+02	8.67	
06-SN113	115.10D	3.33	5.747E+01	1.916E+02	0.045E+02	2.34	
07-SR85	64.84D	8.48	2.907E+01	2.465E+02	0.083E+02	3.37	
08-CS137	30.17Y	1.01	1.707E+02	1.728E+02	0.021E+02	1.19	
09-Y88	106.65D	3.67	1.055E+02	3.869E+02	0.078E+02	2.02	
10-CO60	5.27Y	1.07	1.930E+02	2.074E+02	0.028E+02	1.36	
12-Y88	106.65D	3.67	1.091E+02	4.001E+02	0.083E+02	2.07	
			---------	---------			
	Total Activity :		1.452E+03	2.845E+03			

Grand Total Activity : 1.452E+03 2.845E+03

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
0	46.47	35629	13059	1.40	91.92	84	16	3.11E+00	1.8	9.09E+00	
0	136.43	2706	4424	1.36	271.93	267	10	2.36E-01	10.0	8.44E+00	
0	199.04	676	4281	1.71	397.18	393	9	5.90E-02	35.8	6.51E+00	
0	255.21	882	3762	1.57	509.58	505	10	7.69E-02	26.9	5.41E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum 15
Number of unidentified lines 4
Number of lines tentatively identified by NID 11 73.33%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected BQ/TOTAL	Wtd Mean Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.365E+02	9.936E+02	0.150E+02	1.51	
03-CO57	270.90D	1.67	2.522E+01	4.206E+01	0.090E+01	2.13	
04-CE139	137.66D	2.74	1.746E+01	4.778E+01	0.146E+01	3.05	
05-HG203	46.61D	19.6	7.978E+00	1.561E+02	0.135E+02	8.67	
06-SN113	115.10D	3.33	5.747E+01	1.916E+02	0.045E+02	2.34	
07-SR85	64.84D	8.48	2.907E+01	2.465E+02	0.083E+02	3.37	
08-CS137	30.17Y	1.01	1.707E+02	1.728E+02	0.021E+02	1.19	
09-Y88	106.65D	3.67	1.055E+02	3.869E+02	0.078E+02	2.02	
10-CO60	5.27Y	1.07	1.928E+02	2.072E+02	0.020E+02	0.96	
12-Y88	106.65D	3.67	1.091E+02	4.001E+02	0.083E+02	2.07	
			---------	---------			
	Total Activity :		1.452E+03	2.845E+03			
	Grand Total Activity :		1.452E+03	2.845E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (BQ/TOTAL)	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
02-CD109	9.936E+02	1.498E+01	1.082E+01	0.000E+00	91.870
03-CO57	4.206E+01	8.978E-01	5.806E-01	0.000E+00	72.446
04-CE139	4.778E+01	1.458E+00	1.184E+00	0.000E+00	40.361
05-HG203	1.561E+02	1.354E+01	1.154E+01	0.000E+00	13.519
06-SN113	1.916E+02	4.489E+00	3.055E+00	0.000E+00	62.714
07-SR85	2.465E+02	8.295E+00	5.803E+00	0.000E+00	42.472

08-CS137	1.728E+02	2.055E+00	9.699E-01	0.000E+00	178.192
09-Y88	3.869E+02	7.819E+00	4.238E+00	0.000E+00	91.296
10-CO60	2.072E+02	1.985E+00	1.064E+00	0.000E+00	194.716
12-Y88	4.001E+02	8.273E+00	2.392E+00	0.000E+00	167.287

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (BQ/TOTAL)	K.L. Ided	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
01-AM241	3.178E-01		4.178E-01	7.052E-01	0.000E+00	0.451

```
A,11S25121819       ,12/26/2019 12:24,06/01/2019 12:00,   1.000E+00,S25 5ML MIXED
B,11S25121819       ,CALIBRATION         ,12/26/2019 12:23,11S25121819
C,02-CD109,YES,   9.936E+02,   1.498E+01,   1.082E+01,,   91.870
C,03-CO57 ,YES,   4.206E+01,   8.978E-01,   5.806E-01,,   72.446
C,04-CE139,YES,   4.778E+01,   1.458E+00,   1.184E+00,,   40.361
C,05-HG203,YES,   1.561E+02,   1.354E+01,   1.154E+01,,   13.519
C,06-SN113,YES,   1.916E+02,   4.489E+00,   3.055E+00,,   62.714
C,07-SR85 ,YES,   2.465E+02,   8.295E+00,   5.803E+00,,   42.472
C,08-CS137,YES,   1.728E+02,   2.055E+00,   9.699E-01,,  178.192
C,09-Y88  ,YES,   3.869E+02,   7.819E+00,   4.238E+00,,   91.296
C,10-CO60 ,YES,   2.072E+02,   1.985E+00,   1.064E+00,,  194.716
C,12-Y88  ,YES,   4.001E+02,   8.273E+00,   2.392E+00,,  167.287
C,01-AM241,NO ,   3.178E-01,   4.178E-01,   7.052E-01,,    0.451
```

E & Z 2088-10-1 Mixed Gamma
6/1/19 12:00 PM

S50 Bottle

		Orig. Wt	5.1617	Volume	50				
		Wt Used	4.4184	Aliquot	5.0000	Certificate	Aliquoted	Actual	Percent
	Half-Life	Energy(KeV)	ate G/s/	%err	%abn	Bq/Tot	G/S	Bq/Tot	Diff
Cd-109	462.9d	88.0	84.75		3.72%	1006.61	37.45	1006.0	-0.06%
Co-57	271.8d	122.1	77.25		85.51%	39.92	34.13	41.5	3.92%
Ce-139	137.64d	165.9	92.68		80.35%	50.96	40.95	48.2	-5.44%
Hg-203	46.6d	279.2	273		77.30%	156.04	120.62	161.2	3.30%
Sn-113	115.09d	391.7	280		64.90%	190.62	123.72	195.4	2.51%
Sr-85	64.849	514.0	547.9		98.40%	246.02	242.08	237.4	-3.50%
Cs-137	30.17y	661.6	330.6		85.12%	171.61	146.07	177.2	3.26%
Y-88	106.65d	898.0	858.7		93.40%	406.22	379.41	401.1	-1.26%
Co-60	5.27y	1173.2	460.4		100.00%	203.42	203.42	205.2	0.87%
Co-60	5.27y	1332.5	460.9		100.00%	203.64	203.64	203.0	-0.32%
Y-88	106.65d	1836.0	908		99.38%	403.69	401.19	403.2	-0.12%

Eff. Name: **11S50121819**

Analyst: KOJ [signature]

Analyst:

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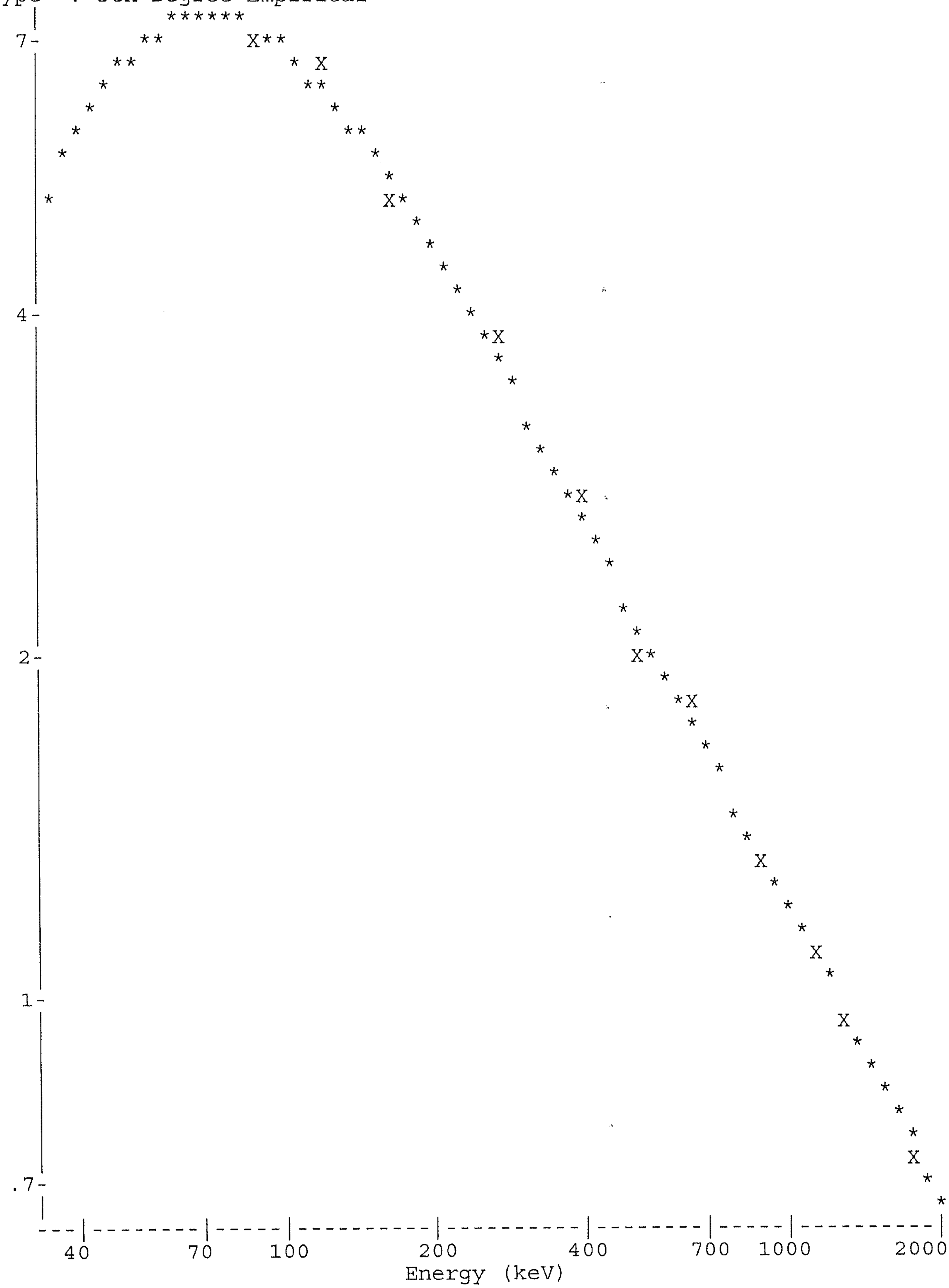
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 12:13:14.79
TBE11 59-TN51806A HpGe ******* Aquisition Date/Time: 18-DEC-2019 12:47:43.02

LIMS No., Customer Name, Client ID: S50 5ML MIXED GAMMA CALIBRATION

Sample ID : 11S50121819 Smple Date: 1-JUN-2019 12:00:00.0
Sample Type : STD Geometry : 11S50121819
Quantity : 1.00000E+00 TOTAL BKGFILE : 11BG112719MT
Start Channel : 70 Energy Tol : 2.00000 Real Time : 0 03:46:41.61
End Channel : 4090 Pk Srch Sens: 9.00000 Live time : 0 03:45:57.97
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.49	28911	9660	1.40	92.06	6.56E+00	2.13E+00	0.9	
2	0	75.22	520	6287	0.90	149.55	7.43E+00	3.84E-02	27.0	
3	0	88.03	27395	7771	1.41	175.20	7.27E+00	2.02E+00	0.9	
4	0	122.05	18602	6243	1.46	243.27	6.46E+00	1.37E+00	1.1	
5	0	136.49	2351	4406	1.44	272.17	6.08E+00	1.73E-01	5.7	
6	0	165.86	10336	4773	1.52	330.94	5.39E+00	7.62E-01	1.6	
7	0	199.23	418	3693	1.51	397.70	4.74E+00	3.09E-02	25.6	
8	0	255.31	472	3399	1.11	509.93	3.91E+00	3.48E-02	22.7	
9	0	279.10	3299	4526	1.55	557.54	3.63E+00	2.43E-01	4.7	
10	0	391.72	14071	4008	1.68	782.88	2.73E+00	1.04E+00	1.3	
11	0	514.04	8152	3688	1.71	1027.64	2.17E+00	6.01E-01	2.0	
12	0	661.64	35340	3260	1.87	1322.97	1.75E+00	2.61E+00	0.6	
13	0	898.01	18766	3059	2.00	1795.90	1.36E+00	1.38E+00	1.0	
14	0	1173.19	28107	1699	2.23	2346.47	1.09E+00	2.07E+00	0.7	
15	0	1332.49	24977	1153	2.36	2665.17	9.75E-01	1.84E+00	0.7	
16	0	1836.01	10864	297	2.57	3672.49	7.34E-01	8.01E-01	1.0	

Spectrum : MCA0:[NDSCOUNT]TBE11$1
Calib Date: 26-DEC-2019 12:13
Detector :   Geometry   : 11S50121819
Fit type : 5th Degree Empirical



Analyst:

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 12:14:19.85
TBE11 59-TN51806A HpGe ******* Aquisition Date/Time: 18-DEC-2019 12:47:43.02

LIMS No., Customer Name, Client ID: S50 5ML MIXED GAMMA CALIBRATION

Sample ID : 11S50121819 Smple Date: 1-JUN-2019 12:00:00.0
Sample Type : STD Geometry : 11S50121819
Quantity : 1.00000E+00 TOTAL BKGFILE : 11BG112719MT
Start Channel : 70 Energy Tol : 2.00000 Real Time : 0 03:46:41.61
End Channel : 4090 Pk Srch Sens: 9.00000 Live time : 0 03:45:57.97
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.49*	28703	9660	1.40	92.06	6.56E+00	2.12E+00	0.9	
2	0	75.22*	72	6287	0.90	149.55	7.43E+00	5.31E-03	196.1	
3	0	88.03*	27332	7771	1.41	175.20	7.27E+00	2.02E+00	0.9	
4	0	122.05	18602	6243	1.46	243.27	6.46E+00	1.37E+00	1.1	
5	0	136.49	2351	4406	1.44	272.17	6.08E+00	1.73E-01	5.7	
6	0	165.86	10336	4773	1.52	330.94	5.39E+00	7.62E-01	1.6	
7	0	199.23	418	3693	1.51	397.70	4.74E+00	3.09E-02	25.6	
8	0	255.31	472	3399	1.11	509.93	3.91E+00	3.48E-02	22.7	
9	0	279.10	3299	4526	1.55	557.54	3.63E+00	2.43E-01	4.7	
10	0	391.72	14071	4008	1.68	782.88	2.73E+00	1.04E+00	1.3	
11	0	514.04	8152	3688	1.71	1027.64	2.17E+00	6.01E-01	2.0	
12	0	661.64	35340	3260	1.87	1322.97	1.75E+00	2.61E+00	0.6	
13	0	898.01	18766	3059	2.00	1795.90	1.36E+00	1.38E+00	1.0	
14	0	1173.19	28107	1699	2.23	2346.47	1.09E+00	2.07E+00	0.7	
15	0	1332.49	24977	1153	2.36	2665.17	9.75E-01	1.84E+00	0.7	
16	0	1836.01	10864	297	2.57	3672.49	7.34E-01	8.01E-01	1.0	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	2-Sigma %Error
02-CD109	88.03	27332	3.72*	7.270E+00	7.455E+02	1.006E+03	1.80
03-CO57	122.06	18602	85.51*	6.455E+00	2.486E+01	4.148E+01	2.29
04-CE139	165.85	10336	80.35*	5.393E+00	1.759E+01	4.819E+01	3.25
05-HG203	279.20	3299	81.46*	3.633E+00	8.224E+00	1.612E+02	9.32
06-SN113	391.69	14071	64.90*	2.731E+00	5.855E+01	1.954E+02	2.55
07-SR85	513.99	8152	99.27*	2.166E+00	2.796E+01	2.374E+02	3.92
08-CS137	661.65	35340	85.12*	1.750E+00	1.750E+02	1.772E+02	1.30
09-Y88	898.02	18766	93.40*	1.357E+00	1.092E+02	4.011E+02	2.03
10-CO60	1173.22	28107	100.00	1.086E+00	1.909E+02	2.052E+02	1.42
	1332.49	24977	100.00*	9.751E-01	1.889E+02	2.030E+02	1.42
12-Y88	1836.01	10864	99.38*	7.343E-01	1.098E+02	4.032E+02	2.09

Flag: "*" = Keyline

Sample ID : 11S50121819 Acquisition date : 18-DEC-2019 12:47:43

Total number of lines in spectrum 16
Number of unidentified lines 5
Number of lines tentatively identified by NID 11 68.75%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.455E+02	1.006E+03	0.018E+03	1.80	
03-CO57	270.90D	1.67	2.486E+01	4.148E+01	0.095E+01	2.29	
04-CE139	137.66D	2.74	1.759E+01	4.819E+01	0.157E+01	3.25	
05-HG203	46.61D	19.6	8.224E+00	1.612E+02	0.150E+02	9.32	
06-SN113	115.10D	3.34	5.855E+01	1.954E+02	0.050E+02	2.55	
07-SR85	64.84D	8.49	2.796E+01	2.374E+02	0.093E+02	3.92	
08-CS137	30.17Y	1.01	1.750E+02	1.772E+02	0.023E+02	1.30	
09-Y88	106.65D	3.67	1.092E+02	4.011E+02	0.081E+02	2.03	
10-CO60	5.27Y	1.07	1.889E+02	2.030E+02	0.029E+02	1.42	
12-Y88	106.65D	3.67	1.098E+02	4.032E+02	0.084E+02	2.09	
			---------	---------			
	Total Activity :		1.466E+03	2.874E+03			
	Grand Total Activity :		1.466E+03	2.874E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
0	46.49	28703	9660	1.40	92.06	86	13	2.12E+00	1.9	6.56E+00	
0	75.22	72	6287	0.90	149.55	146	8	5.31E-03	****	7.43E+00	
0	136.49	2351	4406	1.44	272.17	267	10	1.73E-01	11.3	6.08E+00	
0	199.23	418	3693	1.51	397.70	395	8	3.09E-02	51.3	4.74E+00	
0	255.31	472	3399	1.11	509.93	506	9	3.48E-02	45.5	3.91E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum 16
Number of unidentified lines 5
Number of lines tentatively identified by NID 11 68.75%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected BQ/TOTAL	Wtd Mean Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.455E+02	1.006E+03	0.018E+03	1.80	
03-CO57	270.90D	1.67	2.486E+01	4.148E+01	0.095E+01	2.29	
04-CE139	137.66D	2.74	1.759E+01	4.819E+01	0.157E+01	3.25	
05-HG203	46.61D	19.6	8.224E+00	1.612E+02	0.150E+02	9.32	
06-SN113	115.10D	3.34	5.855E+01	1.954E+02	0.050E+02	2.55	
07-SR85	64.84D	8.49	2.796E+01	2.374E+02	0.093E+02	3.92	
08-CS137	30.17Y	1.01	1.750E+02	1.772E+02	0.023E+02	1.30	
09-Y88	106.65D	3.67	1.092E+02	4.011E+02	0.081E+02	2.03	
10-CO60	5.27Y	1.07	1.899E+02	2.041E+02	0.020E+02	1.00	
12-Y88	106.65D	3.67	1.098E+02	4.032E+02	0.084E+02	2.09	
			---------	---------			
	Total Activity :		1.467E+03	2.875E+03			

Grand Total Activity : 1.467E+03 2.875E+03

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (BQ/TOTAL)	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
02-CD109	1.006E+03	1.807E+01	1.322E+01	0.000E+00	76.080
03-CO57	4.148E+01	9.485E-01	6.726E-01	0.000E+00	61.665
04-CE139	4.819E+01	1.566E+00	1.358E+00	0.000E+00	35.490
05-HG203	1.612E+02	1.503E+01	1.309E+01	0.000E+00	12.319
06-SN113	1.954E+02	4.977E+00	3.498E+00	0.000E+00	55.856

07-SR85	2.374E+02	9.307E+00	7.023E+00	0.000E+00	33.813
08-CS137	1.772E+02	2.297E+00	1.100E+00	0.000E+00	161.086
09-Y88	4.011E+02	8.140E+00	4.509E+00	0.000E+00	88.957
10-CO60	2.041E+02	2.049E+00	1.112E+00	0.000E+00	183.540
12-Y88	4.032E+02	8.438E+00	2.376E+00	0.000E+00	169.648

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (BQ/TOTAL)	K.L. Ided	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
01-AM241	-4.500E-01		5.041E-01	8.374E-01	0.000E+00	-0.537

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A,11S50121819      ,12/26/2019 12:14,06/01/2019 12:00,   1.000E+00,S50 5ML MIXED
B,11S50121819      ,CALIBRATION          ,12/26/2019 12:13,11S50121819
C,02-CD109,YES,   1.006E+03,   1.807E+01,   1.322E+01,,   76.080
C,03-CO57 ,YES,   4.148E+01,   9.485E-01,   6.726E-01,,   61.665
C,04-CE139,YES,   4.819E+01,   1.566E+00,   1.358E+00,,   35.490
C,05-HG203,YES,   1.612E+02,   1.503E+01,   1.309E+01,,   12.319
C,06-SN113,YES,   1.954E+02,   4.977E+00,   3.498E+00,,   55.856
C,07-SR85 ,YES,   2.374E+02,   9.307E+00,   7.023E+00,,   33.813
C,08-CS137,YES,   1.772E+02,   2.297E+00,   1.100E+00,,  161.086
C,09-Y88  ,YES,   4.011E+02,   8.140E+00,   4.509E+00,,   88.957
C,10-CO60 ,YES,   2.041E+02,   2.049E+00,   1.112E+00,,  183.540
C,12-Y88  ,YES,   4.032E+02,   8.438E+00,   2.376E+00,,  169.648
C,01-AM241,NO ,  -4.500E-01,   5.041E-01,   8.374E-01,,   -0.537
```

E & Z 2088-10-1 Mixed Gamma
6/1/19 12:00 PM

S25 Bottle

		Orig. Wt	5.1617	Volume	50				
		Wt Used	4.4184	Aliquot	5.0000	Certificate	Aliquoted	Actual	Percent
	Half-Life	Energy(KeV)	ate G/s	%err	%abn	Bq/Tot	G/S	Bq/Tot	Diff
Pb-210	22.26Y	46.6	72.1		4.18%	762.12	31.86		
Cd-109	462.9d	88.0	84.75		3.72%	1006.61	37.45	1006.0	-0.06%
Co-57	271.8d	122.1	77.25		85.51%	39.92	34.13	40.2	0.76%
Ce-139	137.64d	165.9	92.68		80.35%	50.96	40.95	50.5	-0.89%
Hg-203	46.6d	279.2	273		77.30%	156.04	120.62		
Sn-113	115.09d	391.7	280		64.90%	190.62	123.72	190.5	-0.07%
Sr-85	64.849	514.0	547.9		98.40%	246.02	242.08	245.0	-0.41%
Cs-137	30.17y	661.6	330.6		85.12%	171.61	146.07	174.3	1.57%
Y-88	106.65d	898.0	858.7		93.40%	406.22	379.41	392.8	-3.30%
Co-60	5.27y	1173.2	460.4		100.00%	203.42	203.42	203.4	-0.01%
Co-60	5.27y	1332.5	460.9		100.00%	203.64	203.64	206.5	1.40%
Y-88	106.65d	1836.0	908		99.38%	403.69	401.19	401.3	-0.59%

Eff. Name: **13S25030421**

Analyst: KOJ

Analyst:

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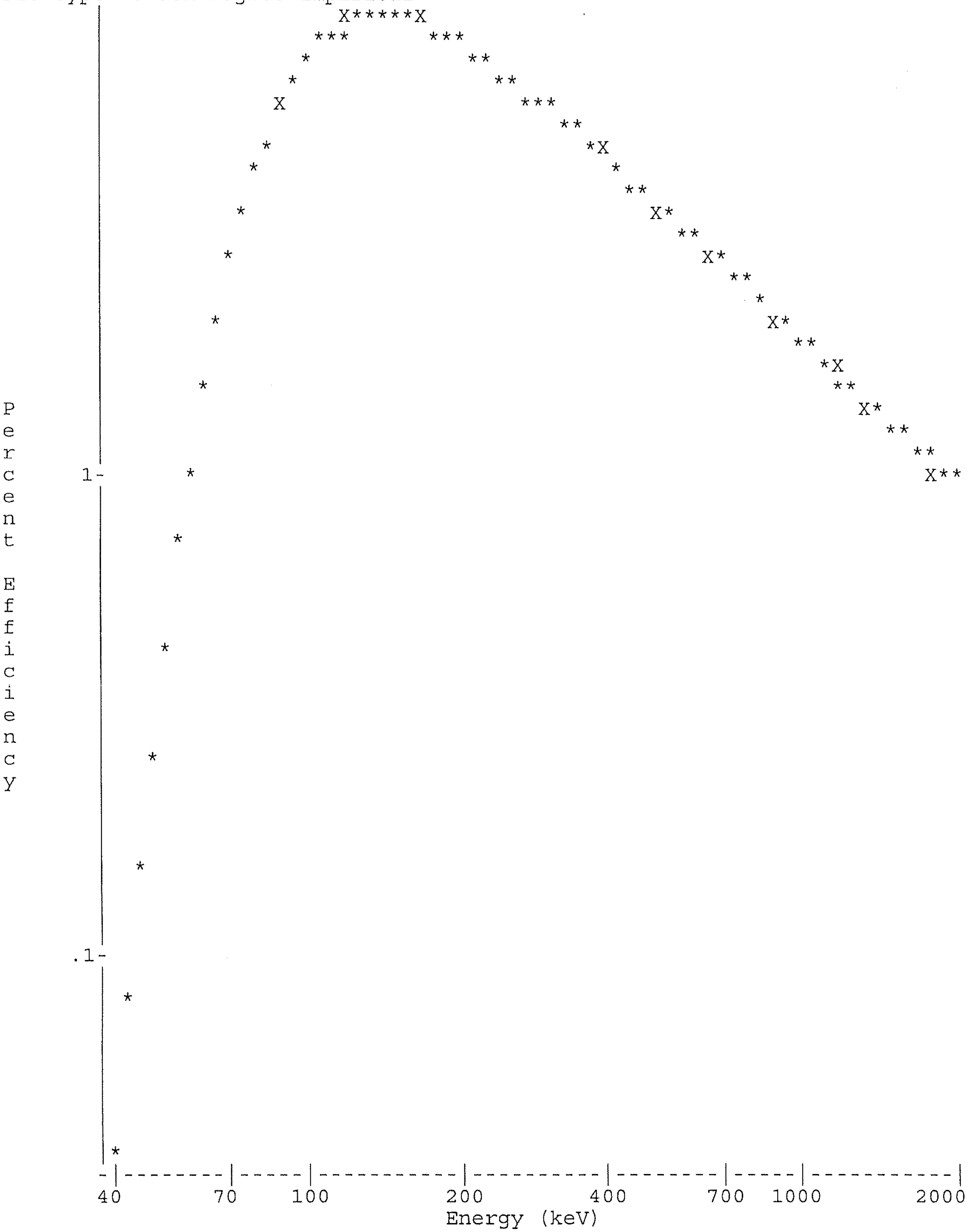
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 10-MAR-2021 08:32:24.00
TBE13 31-TP10727B HpGe ******* Aquisition Date/Time: 4-MAR-2021 08:26:35.99

LIMS No., Customer Name, Client ID: S25 BOTTLE 5ML MIXED GAMMA CALIBRATION

Sample ID : 13S25030421 Smple Date: 1-JUN-2019 12:00:00.0
Sample Type : PCI Geometry : 13S25030421
Quantity : 1.00000E+00 TOTAL BKGFILE : NOBKG
Start Channel : 80 Energy Tol : 2.00000 Real Time : 2 07:44:10.81
End Channel : 4090 Pk Srch Sens: 9.00000 Live time : 2 07:39:05.39
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentfied

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	46.58	4989	51226	0.71	93.19	2.06E-01	2.49E-02	7.7	1.43E+00
2	1	74.96	2858	35428	0.67	149.83	3.49E+00	1.43E-02	10.1	2.59E+00
3	10	85.57	4415	72939	1.67	171.01	5.06E+00	2.20E-02	12.1	3.44E+01
4	10	88.07	154794	33915	0.76	176.01	5.39E+00	7.73E-01	0.3	
5	1	122.09	105952	56401	0.79	243.91	7.97E+00	5.29E-01	0.5	2.91E+00
6	1	136.48	13314	45983	0.78	272.65	8.21E+00	6.65E-02	2.9	4.73E-01
7	1	165.86	25526	49624	0.83	331.30	8.00E+00	1.27E-01	1.7	6.24E-01
8	1	310.50	1311	28512	0.92	620.13	5.27E+00	6.54E-03	20.6	2.48E+00
9	1	391.71	22323	45189	1.05	782.32	4.33E+00	1.11E-01	1.9	9.26E-01
10	8	510.92	5205	46624	2.32	1020.48	3.44E+00	2.60E-02	8.9	1.27E+00
11	8	513.91	1724	19763	1.08	1026.44	3.42E+00	8.60E-03	13.3	
12	1	661.55	776934	37953	1.32	1321.48	2.72E+00	3.88E+00	0.1	2.25E+01
13	1	897.98	22837	31299	1.57	1794.09	2.03E+00	1.14E-01	1.7	2.35E+00
14	1	1173.32	500545	19886	1.75	2344.81	1.55E+00	2.50E+00	0.2	2.91E+01
15	1	1332.60	447055	7966	1.87	2663.50	1.36E+00	2.23E+00	0.2	3.48E+01
16	1	1460.82	1361	2233	2.07	2920.14	1.25E+00	6.79E-03	7.6	1.11E+00
17	1	1835.93	12509	1930	2.24	3671.32	1.02E+00	6.24E-02	1.2	2.42E+00

Spectrum : MCA0:[NDSCOUNT]TBE13$1
Calib Date: 10-MAR-2021 08:32
Detector : Geometry : 13S25030421
Fit type : 5th Degree Empirical



Analyst:

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 10-MAR-2021 08:33:36.47
TBE13 31-TP10727B HpGe ******* Aquisition Date/Time: 4-MAR-2021 08:26:35.99

LIMS No., Customer Name, Client ID: S25 BOTTLE 5ML MIXED GAMMA CALIBRATION

Sample ID : 13S25030421 Smple Date: 1-JUN-2019 12:00:00.0
Sample Type : PCI Geometry : 13S25030421
Quantity : 1.00000E+00 TOTAL BKGFILE : 13BG030521MT
Start Channel : 80 Energy Tol : 2.00000 Real Time : 2 07:44:10.81
End Channel : 4090 Pk Srch Sens: 9.00000 Live time : 2 07:39:05.39
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentfied

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	46.58	4989	51226	0.71	93.19	2.06E-01	2.49E-02	7.7	1.43E+00
2	1	74.96*	1332	35428	0.67	149.83	3.49E+00	6.65E-03	22.2	2.59E+00
3	10	85.57*	3228	72939	1.67	171.01	5.06E+00	1.61E-02	16.7	3.44E+01
4	10	88.07*	154300	33915	0.76	176.01	5.39E+00	7.70E-01	0.3	
5	1	122.09	105952	56401	0.79	243.91	7.97E+00	5.29E-01	0.5	2.91E+00
6	1	136.48	13314	45983	0.78	272.65	8.21E+00	6.65E-02	2.9	4.73E-01
7	1	165.86	25526	49624	0.83	331.30	8.00E+00	1.27E-01	1.7	6.24E-01
8	1	310.50	1311	28512	0.92	620.13	5.27E+00	6.54E-03	20.6	2.48E+00
9	1	391.71	22323	45189	1.05	782.32	4.33E+00	1.11E-01	1.9	9.26E-01
10	8	510.92*	115	46624	2.32	1020.48	3.44E+00	5.75E-04	419.6	1.27E+00
11	8	513.91	1724	19763	1.08	1026.44	3.42E+00	8.60E-03	13.3	
12	1	661.55	776934	37953	1.32	1321.48	2.72E+00	3.88E+00	0.1	2.25E+01
13	1	897.98	22837	31299	1.57	1794.09	2.03E+00	1.14E-01	1.7	2.35E+00
14	1	1173.32	500545	19886	1.75	2344.81	1.55E+00	2.50E+00	0.2	2.91E+01
15	1	1332.60	447055	7966	1.87	2663.50	1.36E+00	2.23E+00	0.2	3.48E+01
16	1	1460.82*	252	2233	2.07	2920.14	1.25E+00	1.26E-03	46.5	1.11E+00
17	1	1835.93	12509	1930	2.24	3671.32	1.02E+00	6.24E-02	1.2	2.42E+00

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	2-Sigma %Error
02-CD109	88.03	154300	3.72*	5.388E+00	3.842E+02	1.006E+03	0.63
03-CO57	122.06	105952	85.51*	7.969E+00	7.761E+00	4.022E+01	1.02
04-CE139	165.85	25526	80.35*	7.997E+00	1.983E+00	5.051E+01	3.39
06-SN113	391.69	22323	64.90*	4.330E+00	3.965E+00	1.905E+02	3.81
07-SR85	513.99	1724	99.27*	3.420E+00	2.534E-01	2.450E+02	26.51
08-CS137	661.65	776934	85.12*	2.722E+00	1.674E+02	1.743E+02	0.25
09-Y88	898.02	22837	93.40*	2.029E+00	6.014E+00	3.928E+02	3.37
10-CO60	1173.22	500545	100.00	1.549E+00	1.613E+02	2.034E+02	0.31
	1332.49	447055	100.00*	1.362E+00	1.638E+02	2.065E+02	0.31
12-Y88	1836.01	12509	99.38*	1.023E+00	6.144E+00	4.013E+02	2.41

Flag: "*" = Keyline

Sample ID : 13S25030421 Acquisition date : 4-MAR-2021 08:26:35

Total number of lines in spectrum	17	
Number of unidentified lines	7	
Number of lines tentatively identified by NID	10	58.82%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	2.62	3.842E+02	1.006E+03	0.006E+03	0.63	
03-CO57	270.90D	5.18	7.761E+00	4.022E+01	0.041E+01	1.02	
04-CE139	137.66D	25.5	1.983E+00	5.051E+01	0.171E+01	3.39	
06-SN113	115.10D	48.1	3.965E+00	1.905E+02	0.073E+02	3.81	
07-SR85	64.84D	967.	2.534E-01	2.450E+02	0.649E+02	26.51	
08-CS137	30.17Y	1.04	1.674E+02	1.743E+02	0.004E+02	0.25	
09-Y88	106.65D	65.3	6.014E+00	3.928E+02	0.132E+02	3.37	
10-CO60	5.27Y	1.26	1.638E+02	2.065E+02	0.006E+02	0.31	
12-Y88	106.65D	65.3	6.144E+00	4.013E+02	0.097E+02	2.41	
			---------	---------			
	Total Activity :		7.415E+02	2.707E+03			
	Grand Total Activity :		7.415E+02	2.707E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Sample ID : 13S25030421 Acquisition date : 4-MAR-2021 08:26:35

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
1	46.58	4989	51226	0.71	93.19	90	7	2.49E-02	15.3	2.06E-01	
1	74.96	1332	35428	0.67	149.83	148	5	6.65E-03	44.4	3.49E+00	
10	85.57	3228	72939	1.67	171.01	164	20	1.61E-02	33.4	5.06E+00	
1	136.48	13314	45983	0.78	272.65	269	8	6.65E-02	5.8	8.21E+00	
1	310.50	1311	28512	0.92	620.13	618	6	6.54E-03	41.1	5.27E+00	
8	510.92	115	46624	2.32	1020.48	1012	18	5.75E-04	****	3.44E+00	
1	1460.82	252	2233	2.07	2920.14	2914	13	1.26E-03	93.1	1.25E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	17	
Number of unidentified lines	7	
Number of lines tentatively identified by NID	10	58.82%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected BQ/TOTAL	Wtd Mean Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	2.62	3.842E+02	1.006E+03	0.006E+03	0.63	
03-CO57	270.90D	5.18	7.761E+00	4.022E+01	0.041E+01	1.02	
04-CE139	137.66D	25.5	1.983E+00	5.051E+01	0.171E+01	3.39	
06-SN113	115.10D	48.1	3.965E+00	1.905E+02	0.073E+02	3.81	
07-SR85	64.84D	967.	2.534E-01	2.450E+02	0.649E+02	26.51	
08-CS137	30.17Y	1.04	1.674E+02	1.743E+02	0.004E+02	0.25	
09-Y88	106.65D	65.3	6.014E+00	3.928E+02	0.132E+02	3.37	
10-CO60	5.27Y	1.26	1.638E+02	2.065E+02	0.006E+02	0.31	
12-Y88	106.65D	65.3	6.144E+00	4.013E+02	0.097E+02	2.41	
		Total Activity :	7.415E+02	2.707E+03			
		Grand Total Activity :	7.415E+02	2.707E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (BQ/TOTAL)	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
02-CD109	1.006E+03	6.368E+00	5.037E+00	0.000E+00	199.787
03-CO57	4.022E+01	4.086E-01	2.913E-01	0.000E+00	138.061
04-CE139	5.051E+01	1.712E+00	1.505E+00	0.000E+00	33.569
06-SN113	1.905E+02	7.250E+00	6.868E+00	0.000E+00	27.740
07-SR85	2.450E+02	6.495E+01	1.023E+02	0.000E+00	2.394
08-CS137	1.743E+02	4.422E-01	1.464E-01	0.000E+00	1190.429
09-Y88	3.928E+02	1.324E+01	1.260E+01	0.000E+00	31.174
10-CO60	2.065E+02	6.499E-01	1.422E-01	0.000E+00	1452.522
12-Y88	4.013E+02	9.652E+00	5.648E+00	0.000E+00	71.048

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (BQ/TOTAL)	K.L. Ided	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
01-AM241	-2.898E-01		4.645E-01	7.886E-01	0.000E+00	-0.368
05-HG203	-2.264E+02		7.343E+02	1.213E+03	0.000E+00	-0.187

```
A,13S25030421     ,03/10/2021 08:33,06/01/2019 12:00,   1.000E+00,S25 BOTTLE 5ML
B,13S25030421     ,CALIBRATION         ,03/10/2021 08:32,13S25030421
C,02-CD109,YES,   1.006E+03,   6.368E+00,   5.037E+00,,  199.787
C,03-CO57 ,YES,   4.022E+01,   4.086E-01,   2.913E-01,,  138.061
C,04-CE139,YES,   5.051E+01,   1.712E+00,   1.505E+00,,   33.569
C,06-SN113,YES,   1.905E+02,   7.250E+00,   6.868E+00,,   27.740
C,07-SR85 ,YES,   2.450E+02,   6.495E+01,   1.023E+02,,    2.394
C,08-CS137,YES,   1.743E+02,   4.422E-01,   1.464E-01,, 1190.429
C,09-Y88  ,YES,   3.928E+02,   1.324E+01,   1.260E+01,,   31.174
C,10-CO60 ,YES,   2.065E+02,   6.499E-01,   1.422E-01,, 1452.522
C,12-Y88  ,YES,   4.013E+02,   9.652E+00,   5.648E+00,,   71.048
C,01-AM241,NO ,  -2.898E-01,   4.645E-01,   7.886E-01,,   -0.368
C,05-HG203,NO ,  -2.264E+02,   7.343E+02,   1.213E+03,,   -0.187
```

E & Z 2088-10-1 Mixed Gamma
6/1/19 12:00 PM

S25 Bottle

		Orig. Wt	5.1617	Volume	50				
		Wt Used	4.4184	Aliquot	5.0000	Certificate	Aliquoted	Actual	Percent
	Half-Life	Energy(KeV)	.ate G/s/	%err	%abn	Bq/Tot	G/S	Bq/Tot	Diff
Cd-109	462.9d	88.0	84.75		3.72%	1006.61	37.45	1006.0	-0.06%
Co-57	271.8d	122.1	77.25		85.51%	39.92	34.13	39.9	0.04%
Ce-139	137.64d	165.9	92.68		80.35%	50.96	40.95	51.1	0.21%
Hg-203	46.6d	279.2	273		77.30%	156.04	120.62	146.7	-5.99%
Sn-113	115.09d	391.7	280		64.90%	190.62	123.72	190.2	-0.22%
Sr-85	64.849	514.0	547.9		98.40%	246.02	242.08	243.7	-0.94%
Cs-137	30.17y	661.6	330.6		85.12%	171.61	146.07	175.7	2.38%
Y-88	106.65d	898.0	858.7		93.40%	406.22	379.41	393.7	-3.08%
Co-60	5.27y	1173.2	460.4		100.00%	203.42	203.42	203.1	-0.16%
Co-60	5.27y	1332.5	460.9		100.00%	203.64	203.64	207.0	1.65%
Y-88	106.65d	1836.0	908		99.38%	403.69	401.19	401.9	-0.44%

Eff. Name: **14S25121719**

Analyst: KOJ

Analyst:

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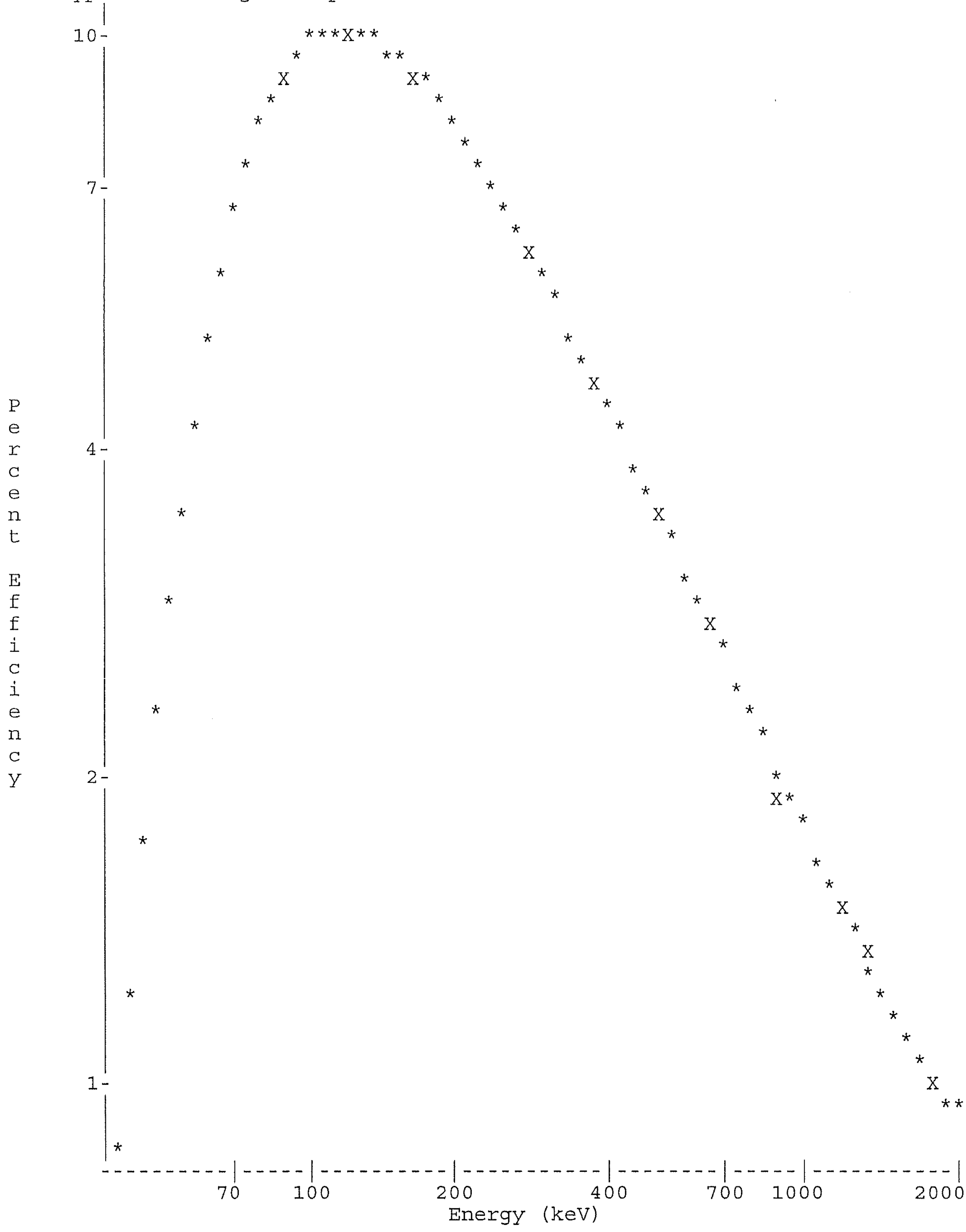
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 10:18:27.43
TBE14 54-TP42603C HpGe ******* Aquisition Date/Time: 17-DEC-2019 17:50:38.86

LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID : 14S25121719 Smple Date: 1-JUN-2019 12:00:00.0
Sample Type : STD Geometry : 14S25121719
Quantity : 1.00000E+00 TOTAL BKGFILE : 14BG112719MT
Start Channel : 80 Energy Tol : 2.00000 Real Time : 0 04:01:00.29
End Channel : 4090 Pk Srch Sens: 9.00000 Live time : 0 04:00:00.00
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	46.59	4672	6896	0.82	89.97	1.64E+00	3.24E-01	3.3	4.79E+00
2	1	88.04	35463	10516	0.84	172.85	8.86E+00	2.46E+00	0.8	4.00E+00
3	1	122.05	29780	8564	0.87	240.85	1.01E+01	2.07E+00	0.8	4.38E+00
4	1	136.46	3698	7567	0.89	269.66	9.91E+00	2.57E-01	4.7	1.24E+00
5	1	165.85	19824	6625	0.93	328.42	9.15E+00	1.38E+00	1.0	1.01E+00
6	1	255.11	1157	5861	0.95	506.90	6.71E+00	8.04E-02	12.3	3.79E-01
7	1	279.19	5512	6288	1.08	555.04	6.21E+00	3.83E-01	3.1	3.04E+00
8	1	391.70	24307	6255	1.14	780.03	4.54E+00	1.69E+00	0.9	2.52E+00
9	1	514.00	14414	5472	1.23	1024.59	3.48E+00	1.00E+00	1.4	7.45E+00
10	1	661.64	57433	5272	1.37	1319.86	2.70E+00	3.99E+00	0.5	1.58E+01
11	1	814.11	540	2411	1.47	1624.82	2.18E+00	3.75E-02	17.5	1.46E+00
12	1	898.03	28517	4449	1.54	1792.67	1.97E+00	1.98E+00	0.8	1.01E+01
13	1	1173.22	40660	2487	1.72	2343.16	1.49E+00	2.82E+00	0.6	1.86E+01
14	4	1325.51	582	1036	2.68	2647.85	1.32E+00	4.04E-02	13.1	1.27E+01
15	4	1332.48	36574	668	1.86	2661.80	1.32E+00	2.54E+00	0.5	
16	1	1836.00	15871	453	2.16	3669.35	1.01E+00	1.10E+00	0.9	1.15E+01

Spectrum : MCA0:[NDSCOUNT]TBE14$1
Calib Date: 26-DEC-2019 10:18
Detector :   Geometry   : 14S25121719
Fit type : 5th Degree Empirical



Analyst:

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 26-DEC-2019 10:19:43.49
TBE14 54-TP42603C HpGe ******* Aquisition Date/Time: 17-DEC-2019 17:50:38.86

LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID : 14S25121719
Sample Type : STD
Quantity : 1.00000E+00 TOTAL
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: CALIBRATION
Peak Evaluation - Identified and Unidentified

Smple Date: 1-JUN-2019 12:00:00.0
Geometry : 14S25121719
BKGFILE : 14BG112719MT
Real Time : 0 04:01:00.29
Live time : 0 04:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	46.59	4672	6896	0.82	89.97	1.64E+00	3.24E-01	3.3	4.79E+00
2	1	88.04*	35436	10516	0.84	172.85	8.86E+00	2.46E+00	0.8	4.00E+00
3	1	122.05	29780	8564	0.87	240.85	1.01E+01	2.07E+00	0.8	4.38E+00
4	1	136.46	3698	7567	0.89	269.66	9.91E+00	2.57E-01	4.7	1.24E+00
5	1	165.85	19824	6625	0.93	328.42	9.15E+00	1.38E+00	1.0	1.01E+00
6	1	255.11	1157	5861	0.95	506.90	6.71E+00	8.04E-02	12.3	3.79E-01
7	1	279.19	5512	6288	1.08	555.04	6.21E+00	3.83E-01	3.1	3.04E+00
8	1	391.70	24307	6255	1.14	780.03	4.54E+00	1.69E+00	0.9	2.52E+00
9	1	514.00	14414	5472	1.23	1024.59	3.48E+00	1.00E+00	1.4	7.45E+00
10	1	661.64	57433	5272	1.37	1319.86	2.70E+00	3.99E+00	0.5	1.58E+01
11	1	814.11	540	2411	1.47	1624.82	2.18E+00	3.75E-02	17.5	1.46E+00
12	1	898.03	28517	4449	1.54	1792.67	1.97E+00	1.98E+00	0.8	1.01E+01
13	1	1173.22	40660	2487	1.72	2343.16	1.49E+00	2.82E+00	0.6	1.86E+01
14	4	1325.51	582	1036	2.68	2647.85	1.32E+00	4.04E-02	13.1	1.27E+01
15	4	1332.48	36574	668	1.86	2661.80	1.32E+00	2.54E+00	0.5	
16	1	1836.00	15871	453	2.16	3669.35	1.01E+00	1.10E+00	0.9	1.15E+01

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	2-Sigma %Error
02-CD109	88.03	35436	3.72*	8.862E+00	7.464E+02	1.006E+03	1.52
03-CO57	122.06	29780	85.51*	1.009E+01	2.398E+01	3.993E+01	1.65
04-CE139	165.85	19824	80.35*	9.153E+00	1.872E+01	5.107E+01	2.06
05-HG203	279.20	5512	81.46*	6.208E+00	7.569E+00	1.467E+02	6.21
06-SN113	391.69	24307	64.90*	4.543E+00	5.725E+01	1.902E+02	1.86
07-SR85	513.99	14414	99.27*	3.485E+00	2.893E+01	2.437E+02	2.75
08-CS137	661.65	57433	85.12*	2.700E+00	1.735E+02	1.757E+02	1.01
09-Y88	898.02	28517	93.40*	1.967E+00	1.078E+02	3.937E+02	1.58
10-CO60	1173.22	40660	100.00	1.494E+00	1.890E+02	2.031E+02	1.14
	1332.49	36574	100.00*	1.318E+00	1.927E+02	2.070E+02	1.08
12-Y88	1836.01	15871	99.38*	1.008E+00	1.100E+02	4.019E+02	1.73

Flag: "*" = Keyline

Sample ID : 14S25121719
Acquisition date : 17-DEC-2019 17:50:38

Total number of lines in spectrum	16	
Number of unidentified lines	5	
Number of lines tentatively identified by NID	11	68.75%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.464E+02	1.006E+03	0.015E+03	1.52	
03-CO57	270.90D	1.67	2.398E+01	3.993E+01	0.066E+01	1.65	
04-CE139	137.66D	2.73	1.872E+01	5.107E+01	0.105E+01	2.06	
05-HG203	46.61D	19.4	7.569E+00	1.467E+02	0.091E+02	6.21	
06-SN113	115.10D	3.32	5.725E+01	1.902E+02	0.035E+02	1.86	
07-SR85	64.84D	8.42	2.893E+01	2.437E+02	0.067E+02	2.75	
08-CS137	30.17Y	1.01	1.735E+02	1.757E+02	0.018E+02	1.01	
09-Y88	106.65D	3.65	1.078E+02	3.937E+02	0.062E+02	1.58	
10-CO60	5.27Y	1.07	1.927E+02	2.070E+02	0.022E+02	1.08	
12-Y88	106.65D	3.65	1.100E+02	4.019E+02	0.070E+02	1.73	
			----------	----------			
	Total Activity :		1.467E+03	2.856E+03			
	Grand Total Activity :		1.467E+03	2.856E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
1	46.59	4672	6896	0.82	89.97	86	7	3.24E-01	6.6	1.64E+00	
1	136.46	3698	7567	0.89	269.66	265	10	2.57E-01	9.4	9.91E+00	
1	255.11	1157	5861	0.95	506.90	503	9	8.04E-02	24.6	6.71E+00	
1	814.11	540	2411	1.47	1624.82	1620	10	3.75E-02	35.0	2.18E+00	
4	1325.51	582	1036	2.68	2647.85	2637	33	4.04E-02	26.2	1.32E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum 16
Number of unidentified lines 5
Number of lines tentatively identified by NID 11 68.75%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected BQ/TOTAL	Wtd Mean Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
02-CD109	462.90D	1.35	7.464E+02	1.006E+03	0.015E+03	1.52	
03-CO57	270.90D	1.67	2.398E+01	3.993E+01	0.066E+01	1.65	
04-CE139	137.66D	2.73	1.872E+01	5.107E+01	0.105E+01	2.06	
05-HG203	46.61D	19.4	7.569E+00	1.467E+02	0.091E+02	6.21	
06-SN113	115.10D	3.32	5.725E+01	1.902E+02	0.035E+02	1.86	
07-SR85	64.84D	8.42	2.893E+01	2.437E+02	0.067E+02	2.75	
08-CS137	30.17Y	1.01	1.735E+02	1.757E+02	0.018E+02	1.01	
09-Y88	106.65D	3.65	1.078E+02	3.937E+02	0.062E+02	1.58	
10-CO60	5.27Y	1.07	1.909E+02	2.051E+02	0.016E+02	0.79	
12-Y88	106.65D	3.65	1.100E+02	4.019E+02	0.070E+02	1.73	
			---------	---------			
	Total Activity :		1.465E+03	2.854E+03			
	Grand Total Activity :		1.465E+03	2.854E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (BQ/TOTAL)	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
02-CD109	1.006E+03	1.533E+01	9.506E+00	0.000E+00	105.834
03-CO57	3.993E+01	6.577E-01	4.039E-01	0.000E+00	98.864
04-CE139	5.107E+01	1.051E+00	7.760E-01	0.000E+00	65.808
05-HG203	1.467E+02	9.105E+00	7.581E+00	0.000E+00	19.347
06-SN113	1.902E+02	3.544E+00	2.145E+00	0.000E+00	88.653

07-SR85	2.437E+02	6.705E+00	4.296E+00	0.000E+00	56.725
08-CS137	1.757E+02	1.777E+00	7.350E-01	0.000E+00	239.076
09-Y88	3.937E+02	6.236E+00	3.279E+00	0.000E+00	120.049
10-CO60	2.051E+02	1.611E+00	6.845E-01	0.000E+00	299.620
12-Y88	4.019E+02	6.973E+00	1.890E+00	0.000E+00	212.590

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (BQ/TOTAL)	K.L. Ided	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
01-AM241	3.895E-01		8.108E-01	1.321E+00	0.000E+00	0.295

```
A,14S25121719      ,12/26/2019 10:19,06/01/2019 12:00,   1.000E+00,S25 5ML MIXED
B,14S25121719      ,CALIBRATION          ,12/26/2019 10:18,14S25121719
C,02-CD109,YES,   1.006E+03,   1.533E+01,   9.506E+00,,  105.834
C,03-CO57 ,YES,   3.993E+01,   6.577E-01,   4.039E-01,,   98.864
C,04-CE139,YES,   5.107E+01,   1.051E+00,   7.760E-01,,   65.808
C,05-HG203,YES,   1.467E+02,   9.105E+00,   7.581E+00,,   19.347
C,06-SN113,YES,   1.902E+02,   3.544E+00,   2.145E+00,,   88.653
C,07-SR85 ,YES,   2.437E+02,   6.705E+00,   4.296E+00,,   56.725
C,08-CS137,YES,   1.757E+02,   1.777E+00,   7.350E-01,,  239.076
C,09-Y88  ,YES,   3.937E+02,   6.236E+00,   3.279E+00,,  120.049
C,10-CO60 ,YES,   2.051E+02,   1.611E+00,   6.845E-01,,  299.620
C,12-Y88  ,YES,   4.019E+02,   6.973E+00,   1.890E+00,,  212.590
C,01-AM241,NO ,   3.895E-01,   8.108E-01,   1.321E+00,,    0.295
```

E & Z 2088-10-1 Mixed Gamma
6/1/19 12:00 PM

S25 Bottle

		Orig. Wt	5.1617	Volume	50				
		Wt Used	4.4184	Aliquot	5.0000	Certificate	Aliquoted	Actual	Percent
	Half-Life	Energy(KeV)	ate G/s/	%err	%abn	Bq/Tot	G/S	Bq/Tot	Diff
Pb-210	22.26Y	46.6	72.1		4.18%	762.12	31.86	787.2	3.29%
Cd-109	462.9d	88.0	84.75		3.72%	1006.61	37.45	1001.0	-0.56%
Co-57	271.8d	122.1	77.25		85.51%	39.92	34.13	40.7	1.84%
Ce-139	137.64d	165.9	92.68		80.35%	50.96	40.95	49.9	-2.05%
Hg-203	46.6d	279.2	273		77.30%	156.04	120.62		
Sn-113	115.09d	391.7	280		64.90%	190.62	123.72	191.2	0.30%
Sr-85	64.849	514.0	547.9		98.40%	246.02	242.08	262.8	6.82%
Cs-137	30.17y	661.6	330.6		85.12%	171.61	146.07	172.9	0.75%
Y-88	106.65d	898.0	858.7		93.40%	406.22	379.41	392.2	-3.45%
Co-60	5.27y	1173.2	460.4		100.00%	203.42	203.42	203.5	0.04%
Co-60	5.27y	1332.5	460.9		100.00%	203.64	203.64	207.2	1.75%
Y-88	106.65d	1836.0	908		99.38%	403.69	401.19	400.7	-0.74%

Eff. Name: **23S25122820**

Analyst: KOJ

Analyst:

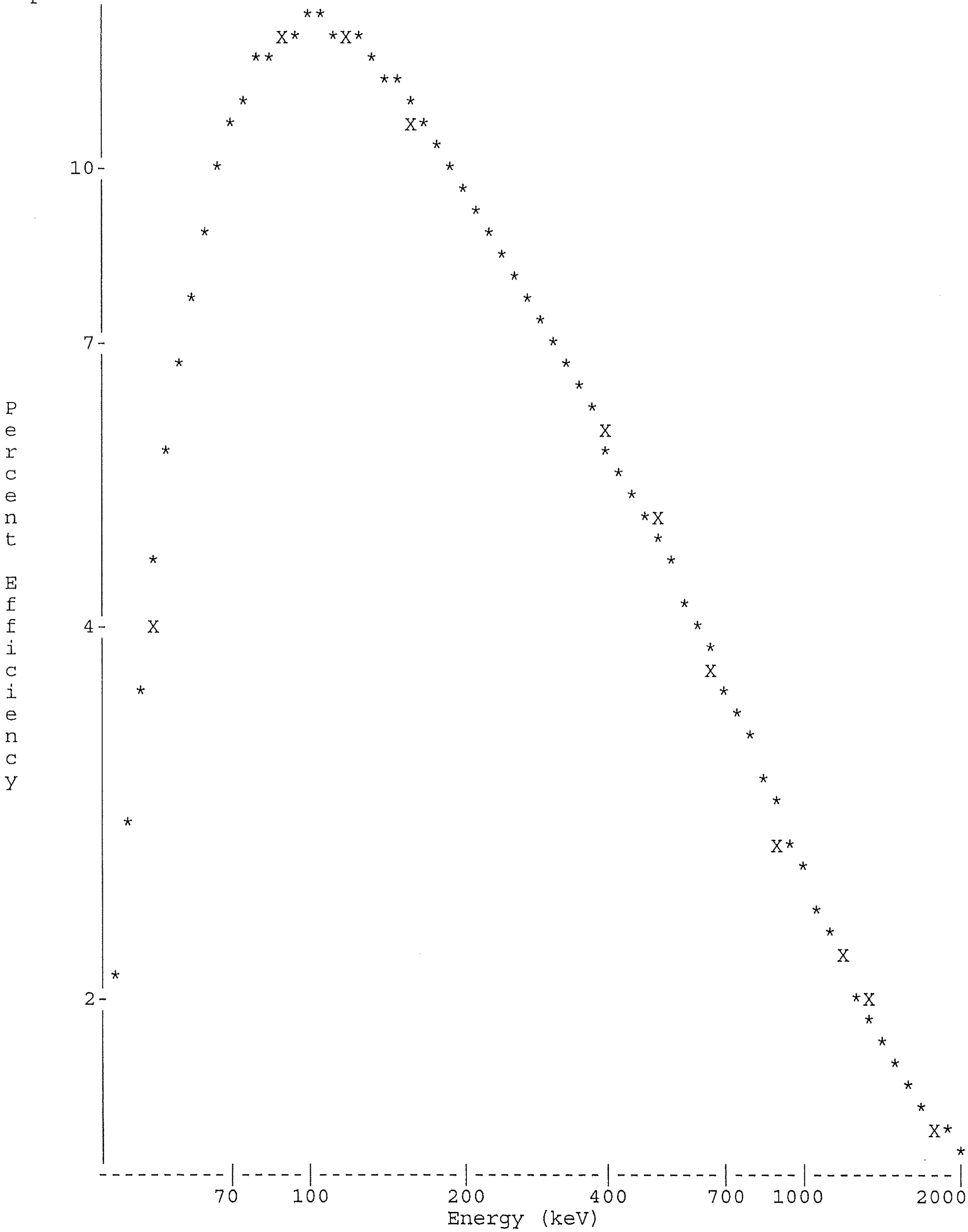
==
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 29-DEC-2020 13:35:55.26
TBE23 03017322 HpGe ********** Aquisition Date/Time: 28-DEC-2020 18:21:02.51

LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID : 23S25122820 Smple Date: 1-JUN-2019 12:00:00.0
Sample Type : STD Geometry : 23S25122820
Quantity : 1.00000E+00 TOTAL BKGFILE : 23BG121820MT
Start Channel : 80 Energy Tol : 2.00000 Real Time : 0 19:13:29.87
End Channel : 4090 Pk Srch Sens: 9.00000 Live time : 0 19:11:37.83
MDA Multiple : 4.6600 Library Used: CALIBRATION_PB
Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.53	86419	50241	0.92	92.99	4.10E+00	1.25E+00	0.6	
2	0	88.12	138391	33792	0.84	176.13	1.27E+01	2.00E+00	0.4	
3	0	122.12	68998	23643	0.85	244.08	1.26E+01	9.99E-01	0.6	
4	0	136.52	8600	18857	0.90	272.86	1.20E+01	1.24E-01	3.1	
5	0	165.87	16442	17766	1.05	331.53	1.08E+01	2.38E-01	1.7	
6	0	238.50	1672	14948	1.01	476.73	8.50E+00	2.42E-02	12.4	
7	0	255.14	919	9890	1.16	509.98	8.10E+00	1.33E-02	16.6	
8	0	391.65	15689	19175	1.13	782.93	5.90E+00	2.27E-01	1.9	
9	8	510.96	2394	16558	2.57	1021.50	4.76E+00	3.46E-02	11.3	4.72E-01
10	8	513.94	1795	8681	1.18	1027.47	4.74E+00	2.60E-02	9.1	
11	0	661.54	371403	14393	1.31	1322.68	3.79E+00	5.38E+00	0.2	
12	0	898.01	16812	13215	1.45	1795.77	2.82E+00	2.43E-01	1.6	
13	0	1173.30	247064	7466	1.63	2346.71	2.16E+00	3.58E+00	0.2	
14	0	1332.58	223705	3266	1.72	2665.57	1.92E+00	3.24E+00	0.2	
15	0	1461.05	254	975	1.45	2922.81	1.78E+00	3.68E-03	24.6	
16	0	1835.94	10026	1055	1.99	3673.69	1.55E+00	1.45E-01	1.3	

Spectrum : MCA0:[NDSCOUNT]TBE23$1
Calib Date: 29-DEC-2020 13:35
Detector : TBE17 Geometry : 23S25122820
Empirical



Analyst:

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==============================================================================
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 29-DEC-2020 13:41:19.35
TBE23 03017322 HpGe ********** Aquisition Date/Time:  28-DEC-2020 18:21:02.51
------------------------------------------------------------------------------
LIMS No., Customer Name, Client ID: S25 5ML MIXED GAMMA CALIBRATION

Sample ID      : 23S25122820                    Smple Date: 1-JUN-2019 12:00:00.0
Sample Type    : STD                            Geometry  : 23S25122820
Quantity       : 1.00000E+00 TOTAL              BKGFILE   : 23BG121820MT
Start Channel  : 80     Energy Tol   : 2.00000  Real Time : 0 19:13:29.87
End Channel    : 4090   Pk Srch Sens: 9.00000   Live time : 0 19:11:37.83
MDA Multiple   : 4.6600 Library Used: CALIBRATION_PB
Peak Evaluation - Identified and Unidentified
```

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.53*	85939	50241	0.92	92.99	4.10E+00	1.24E+00	0.6	
2	0	88.12*	138155	33792	0.84	176.13	1.27E+01	2.00E+00	0.4	
3	0	122.12	68998	23643	0.85	244.08	1.26E+01	9.99E-01	0.6	
4	0	136.52	8600	18857	0.90	272.86	1.20E+01	1.24E-01	3.1	
5	0	165.87	16442	17766	1.05	331.53	1.08E+01	2.38E-01	1.7	
6	0	238.50*	202	14948	1.01	476.73	8.50E+00	2.93E-03	103.4	
7	0	255.14	919	9890	1.16	509.98	8.10E+00	1.33E-02	16.6	
8	0	391.65	15689	19175	1.13	782.93	5.90E+00	2.27E-01	1.9	
9	8	510.96*	546	16558	2.57	1021.50	4.76E+00	7.90E-03	50.2	4.72E-01
10	8	513.94	1795	8681	1.18	1027.47	4.74E+00	2.60E-02	9.1	
11	0	661.54	371403	14393	1.31	1322.68	3.79E+00	5.38E+00	0.2	
12	0	898.01	16812	13215	1.45	1795.77	2.82E+00	2.43E-01	1.6	
13	0	1173.30	247064	7466	1.63	2346.71	2.16E+00	3.58E+00	0.2	
14	0	1332.58	223705	3266	1.72	2665.57	1.92E+00	3.24E+00	0.2	
15	0	1461.05*	53	975	1.45	2922.81	1.78E+00	7.63E-04	122.0	
16	0	1835.94	10026	1055	1.99	3673.69	1.55E+00	1.45E-01	1.3	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	2-Sigma %Error
03-PB210	46.50	85939	4.05*	4.098E+00	7.495E+02	7.872E+02	1.26
04-CD109	88.03	138155	3.72*	1.273E+01	4.223E+02	1.001E+03	0.74
05-CO57	122.06	68998	85.51*	1.256E+01	9.296E+00	4.065E+01	1.13
06-CE139	165.85	16442	80.35*	1.082E+01	2.737E+00	4.992E+01	3.31
08-SN113	391.69	15689	64.90*	5.897E+00	5.932E+00	1.912E+02	3.77
09-SR85	513.99	1795	99.27*	4.736E+00	5.524E-01	2.628E+02	18.12
10-CS137	661.65	371403	85.12*	3.787E+00	1.667E+02	1.729E+02	0.36
11-Y88	898.02	16812	93.40*	2.818E+00	9.244E+00	3.922E+02	3.14
12-CO60	1173.22	247064	100.00	2.163E+00	1.653E+02	2.035E+02	0.43
	1332.49	223705	100.00*	1.923E+00	1.684E+02	2.072E+02	0.44
14-Y88	1836.01	10026	99.38*	1.546E+00	9.444E+00	4.007E+02	2.55

Flag: "*" = Keyline

Total number of lines in spectrum	16	
Number of unidentified lines	5	
Number of lines tentatively identified by NID	11	68.75%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
03-PB210	22.26Y	1.05	7.495E+02	7.872E+02	0.099E+02	1.26	
04-CD109	462.90D	2.37	4.223E+02	1.001E+03	0.007E+03	0.74	
05-CO57	270.90D	4.37	9.296E+00	4.065E+01	0.046E+01	1.13	
06-CE139	137.66D	18.2	2.737E+00	4.992E+01	0.165E+01	3.31	
08-SN113	115.10D	32.2	5.932E+00	1.912E+02	0.072E+02	3.77	
09-SR85	64.84D	476.	5.524E-01	2.628E+02	0.476E+02	18.12	
10-CS137	30.17Y	1.04	1.667E+02	1.729E+02	0.006E+02	0.36	
11-Y88	106.65D	42.4	9.244E+00	3.922E+02	0.123E+02	3.14	
12-CO60	5.27Y	1.23	1.684E+02	2.072E+02	0.009E+02	0.44	
14-Y88	106.65D	42.4	9.444E+00	4.007E+02	0.102E+02	2.55	
			---------	---------			
	Total Activity :		1.544E+03	3.506E+03			
	Grand Total Activity :		1.544E+03	3.506E+03			

Flags: "K" = Keyline not found   "M" = Manually accepted
"E" = Manually edited   "A" = Nuclide specific abn. limit

Sample ID : 23S25122820 Acquisition date : 28-DEC-2020 18:21:02

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
0	136.52	8600	18857	0.90	272.86	269	9	1.24E-01	6.2	1.20E+01	
0	238.50	202	14948	1.01	476.73	474	7	2.93E-03	****	8.50E+00	
0	255.14	919	9890	1.16	509.98	508	5	1.33E-02	33.2	8.10E+00	
8	510.96	546	16558	2.57	1021.50	1015	17	7.90E-03	****	4.76E+00	
0	1461.05	53	975	1.45	2922.81	2917	11	7.63E-04	****	1.78E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum 16
Number of unidentified lines 5
Number of lines tentatively identified by NID 11 68.75%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected BQ/TOTAL	Wtd Mean Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
03-PB210	22.26Y	1.05	7.495E+02	7.872E+02	0.099E+02	1.26	
04-CD109	462.90D	2.37	4.223E+02	1.001E+03	0.007E+03	0.74	
05-CO57	270.90D	4.37	9.296E+00	4.065E+01	0.046E+01	1.13	
06-CE139	137.66D	18.2	2.737E+00	4.992E+01	0.165E+01	3.31	
08-SN113	115.10D	32.2	5.932E+00	1.912E+02	0.072E+02	3.77	
09-SR85	64.84D	476.	5.524E-01	2.628E+02	0.476E+02	18.12	
10-CS137	30.17Y	1.04	1.667E+02	1.729E+02	0.006E+02	0.36	
11-Y88	106.65D	42.4	9.244E+00	3.922E+02	0.123E+02	3.14	
12-CO60	5.27Y	1.23	1.684E+02	2.072E+02	0.009E+02	0.44	
14-Y88	106.65D	42.4	9.444E+00	4.007E+02	0.102E+02	2.55	
			---------	---------			
	Total Activity :		1.544E+03	3.506E+03			
	Grand Total Activity :		1.544E+03	3.506E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (BQ/TOTAL)	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
03-PB210	7.872E+02	9.939E+00	6.075E+00	0.000E+00	129.589
04-CD109	1.001E+03	7.361E+00	4.462E+00	0.000E+00	224.459
05-CO57	4.065E+01	4.593E-01	3.123E-01	0.000E+00	130.166
06-CE139	4.992E+01	1.654E+00	1.537E+00	0.000E+00	32.476
08-SN113	1.912E+02	7.215E+00	6.389E+00	0.000E+00	29.923

09-SR85	2.628E+02	4.760E+01	6.769E+01	0.000E+00	3.882
10-CS137	1.729E+02	6.173E-01	1.925E-01	0.000E+00	898.197
11-Y88	3.922E+02	1.232E+01	1.095E+01	0.000E+00	35.833
12-CO60	2.072E+02	9.144E-01	1.834E-01	0.000E+00	1129.809
14-Y88	4.007E+02	1.022E+01	4.758E+00	0.000E+00	84.219

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (BQ/TOTAL)	K.L. Ided	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
01-CO57	0.000E+00		0.000E+00	1.333E+05	0.000E+00	0.000
02-CE139	-6.502E+01		5.161E+01	8.172E+01	0.000E+00	-0.796
07-HG203	1.778E+02		4.019E+02	6.518E+02	0.000E+00	0.273

```
A,23S25122820     ,12/29/2020 13:41,06/01/2019 12:00,   1.000E+00,S25 5ML MIXED
B,23S25122820     ,CALIBRATION_PB       ,12/29/2020 13:35,23S25122820
C,03-PB210,YES,   7.872E+02,   9.939E+00,   6.075E+00,,  129.589
C,04-CD109,YES,   1.001E+03,   7.361E+00,   4.462E+00,,  224.459
C,05-CO57 ,YES,   4.065E+01,   4.593E-01,   3.123E-01,,  130.166
C,06-CE139,YES,   4.992E+01,   1.654E+00,   1.537E+00,,   32.476
C,08-SN113,YES,   1.912E+02,   7.215E+00,   6.389E+00,,   29.923
C,09-SR85 ,YES,   2.628E+02,   4.760E+01,   6.769E+01,,    3.882
C,10-CS137,YES,   1.729E+02,   6.173E-01,   1.925E-01,,  898.197
C,11-Y88  ,YES,   3.922E+02,   1.232E+01,   1.095E+01,,   35.833
C,12-CO60 ,YES,   2.072E+02,   9.144E-01,   1.834E-01,, 1129.809
C,14-Y88  ,YES,   4.007E+02,   1.022E+01,   4.758E+00,,   84.219
C,02-CE139,NO ,  -6.502E+01,   5.161E+01,   8.172E+01,,   -0.796
C,07-HG203,NO ,   1.778E+02,   4.019E+02,   6.518E+02,,    0.273
```

E & Z 2088-10-1 Mixed Gamma
6/1/19 12:00 PM

3.5L MARINELLI

		Orig. Wt	5.1617	Volume	50				
		Wt Used	4.4184	Aliquot	5.0000	Certificate	Aliquoted	Actual	Percent
	Half-Life	Energy(KeV)	ate G/s	%err	%abn	Bq/Tot	G/S	Bq/Tot	Diff
Pb-210	22.26Y	46.6	72.1		4.18%	762.12	31.86	765.5	0.44%
Cd-109	462.9d	88.0	84.75		3.72%	1006.61	37.45	1001.0	-0.56%
Co-57	271.8d	122.1	77.25		85.51%	39.92	34.13	40.0	0.26%
Ce-139	137.64d	165.9	92.68		80.35%	50.96	40.95	50.1	-1.72%
Hg-203	46.6d	279.2	273		77.30%	156.04	120.62	152.0	-2.59%
Sn-113	115.09d	391.7	280		64.90%	190.62	123.72	195.8	2.72%
Sr-85	64.849	514.0	547.9		98.40%	246.02	242.08	238.1	-3.22%
Cs-137	30.17y	661.6	330.6		85.12%	171.61	146.07	175.2	2.09%
Y-88	106.65d	898.0	858.7		93.40%	406.22	379.41	406.9	0.17%
Co-60	5.27y	1173.2	460.4		100.00%	203.42	203.42	204.5	0.53%
Co-60	5.27y	1332.5	460.9		100.00%	203.64	203.64	202.1	-0.76%
Y-88	106.65d	1836.0	908		99.38%	403.69	401.19	402.6	-0.27%

Eff. Name: **1135L1203.19**

Analyst: KOJ

Sec. Review: Analyst:

==

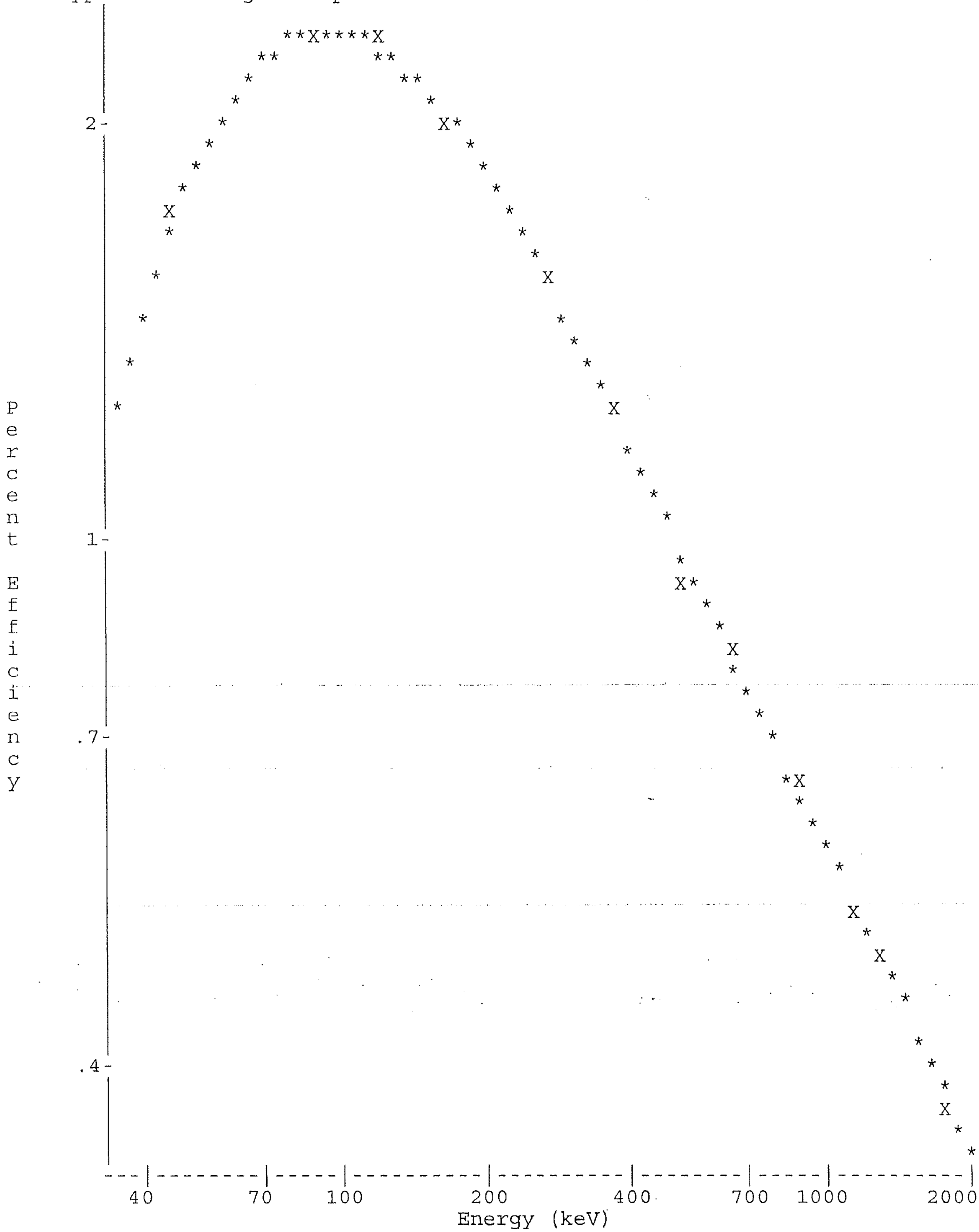
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 4-DEC-2019 09:55:50.82
TBE11 31-TP20610B HpGe ******* Aquisition Date/Time: 3-DEC-2019 18:03:23.85

LIMS No., Customer Name, Client ID: 3.5L 5ML MIXED GAMMA CALIBRATION

```
Sample ID      : 1135L120319                          Smple Date: 1-JUN-2019 12:00:00.0
Sample Type    : STD                                  Geometry   : 1135L120319
Quantity       : 1.00000E+00 TOTAL                    BKGFILE    : 11BG112719MT
Start Channel  : 70       Energy Tol   : 2.00000      Real Time  : 0 12:01:18.85
End Channel    : 4090     Pk Srch Sens: 7.00000       Live time  : 0 12:00:00.00
MDA Multiple   : 4.6600   Library Used: CALIBRATION
```

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.47	23288	21494	1.43	91.94	1.72E+00	5.39E-01	1.4	
2	0	75.04	1490	15930	1.23	149.12	2.30E+00	3.45E-02	13.7	
3	0	88.06	29119	27294	1.39	175.19	2.37E+00	6.74E-01	1.3	
4	0	122.08	21359	20676	1.44	243.27	2.32E+00	4.94E-01	1.5	
5	0	136.54	2384	13793	1.56	272.23	2.25E+00	5.52E-02	8.8	
6	0	165.90	14266	16553	1.51	330.98	2.09E+00	3.30E-01	1.9	
7	0	255.18	1030	9324	1.66	509.68	1.63E+00	2.38E-02	17.2	
8	0	279.20	5197	9831	1.56	557.74	1.53E+00	1.20E-01	3.9	
9	0	391.73	21490	7663	1.62	782.96	1.20E+00	4.97E-01	1.1	
10	0	514.03	13669	7212	1.68	1027.72	9.73E-01	3.16E-01	1.6	
11	0	661.65	51118	5928	1.78	1323.12	8.03E-01	1.18E+00	0.6	
12	0	814.14	464	3039	1.73	1628.27	6.88E-01	1.07E-02	24.2	
13	0	898.00	31453	5022	1.96	1796.07	6.40E-01	7.28E-01	0.8	
14	0	1173.15	43501	2652	2.15	2346.60	5.26E-01	1.01E+00	0.6	
15	2	1325.28	508	896	2.75	2650.95	4.81E-01	1.17E-02	11.8	2.07E+01
16	2	1332.48	39138	949	2.38	2665.36	4.79E-01	9.06E-01	0.5	
17	0	1460.95	307	999	1.89	2922.36	4.47E-01	7.11E-03	23.7	
18	0	1836.04	19366	460	2.67	3672.67	3.74E-01	4.48E-01	0.8	

Spectrum   : MCA0:[NDSCOUNT]TBE11$1
Calib Date: 4-DEC-2019 09:55:
Detector   :   Geometry   : 1135L120319
Fit type   : 5th Degree Empirical



Sec. Review: Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 4-DEC-2019 10:00:37.78
TBE11 31-TP20610B HpGe ******* Aquisition Date/Time: 3-DEC-2019 18:03:23.85

LIMS No., Customer Name, Client ID: 3.5L 5ML MIXED GAMMA CALIBRATION

Sample ID : 1135L120319		Smple Date:	1-JUN-2019 12:00:00.0
Sample Type : STD		Geometry :	1135L120319
Quantity : 1.00000E+00 TOTAL		BKGFILE :	11BG112719MT
Start Channel : 70	Energy Tol : 2.00000	Real Time :	0 12:01:18.85
End Channel : 4090	Pk Srch Sens: 7.00000	Live time :	0 12:00:00.00
MDA Multiple : 4.6600	Library Used: CALIBRATION_PB		

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.47*	22623	21494	1.43	91.94	1.72E+00	5.24E-01	1.4	
2	0	75.04*	61	15930	1.23	149.12	2.30E+00	1.41E-03	338.5	
3	0	88.06*	28919	27294	1.39	175.19	2.37E+00	6.69E-01	1.3	
4	0	122.08	21359	20676	1.44	243.27	2.32E+00	4.94E-01	1.5	
5	0	136.54	2384	13793	1.56	272.23	2.25E+00	5.52E-02	8.8	
6	0	165.90	14266	16553	1.51	330.98	2.09E+00	3.30E-01	1.9	
7	0	255.18	1030	9324	1.66	509.68	1.63E+00	2.38E-02	17.2	
8	0	279.20	5197	9831	1.56	557.74	1.53E+00	1.20E-01	3.9	
9	0	391.73	21490	7663	1.62	782.96	1.20E+00	4.97E-01	1.1	
10	0	514.03	13669	7212	1.68	1027.72	9.73E-01	3.16E-01	1.6	
11	0	661.65	51118	5928	1.78	1323.12	8.03E-01	1.18E+00	0.6	
12	0	814.14	464	3039	1.73	1628.27	6.88E-01	1.07E-02	24.2	
13	0	898.00	31453	5022	1.96	1796.07	6.40E-01	7.28E-01	0.8	
14	0	1173.15	43501	2652	2.15	2346.60	5.26E-01	1.01E+00	0.6	
15	2	1325.28	508	896	2.75	2650.95	4.81E-01	1.17E-02	11.8	2.07E+01
16	2	1332.48	39138	949	2.38	2665.36	4.79E-01	9.06E-01	0.5	
17	0	1460.95*	58	999	1.89	2922.36	4.47E-01	1.35E-03	126.9	
18	0	1836.04	19366	460	2.67	3672.67	3.74E-01	4.48E-01	0.8	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	2-Sigma %Error
03-PB210	46.50	22623	4.05*	1.716E+00	7.535E+02	7.655E+02	2.87
04-CD109	88.03	28919	3.72*	2.374E+00	7.582E+02	1.001E+03	2.52
05-CO57	122.06	21359	85.51*	2.323E+00	2.490E+01	4.002E+01	2.95
06-CE139	165.85	14266	80.35*	2.088E+00	1.968E+01	5.009E+01	3.88
07-HG203	279.20	5197	81.46*	1.533E+00	9.633E+00	1.520E+02	7.89
08-SN113	391.69	21490	64.90*	1.197E+00	6.405E+01	1.958E+02	2.20
09-SR85	513.99	13669	99.27*	9.725E-01	3.277E+01	2.381E+02	3.11
10-CS137	661.65	51118	85.12*	8.027E-01	1.732E+02	1.752E+02	1.12
11-Y88	898.02	31453	93.40*	6.397E-01	1.219E+02	4.069E+02	1.55
12-CO60	1173.22	43501	100.00	5.263E-01	1.913E+02	2.045E+02	1.12
	1332.49	39138	100.00*	4.793E-01	1.890E+02	2.021E+02	1.07
14-Y88	1836.01	19366	99.38*	3.741E-01	1.206E+02	4.026E+02	1.57

Flag: "*" = Keyline

Total number of lines in spectrum	18	
Number of unidentified lines	6	
Number of lines tentatively identified by NID	12	66.67%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected BQ/TOTAL	Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
03-PB210	22.26Y	1.02	7.535E+02	7.655E+02	0.220E+02	2.87	
04-CD109	462.90D	1.32	7.582E+02	1.001E+03	0.025E+03	2.52	
05-CO57	270.90D	1.61	2.490E+01	4.002E+01	0.118E+01	2.95	
06-CE139	137.66D	2.54	1.968E+01	5.009E+01	0.194E+01	3.88	
07-HG203	46.61D	15.8	9.633E+00	1.520E+02	0.120E+02	7.89	
08-SN113	115.10D	3.06	6.405E+01	1.958E+02	0.043E+02	2.20	
09-SR85	64.84D	7.26	3.277E+01	2.381E+02	0.074E+02	3.11	
10-CS137	30.17Y	1.01	1.732E+02	1.752E+02	0.020E+02	1.12	
11-Y88	106.65D	3.34	1.219E+02	4.069E+02	0.063E+02	1.55	
12-CO60	5.27Y	1.07	1.890E+02	2.021E+02	0.022E+02	1.07	
14-Y88	106.65D	3.34	1.206E+02	4.026E+02	0.063E+02	1.57	
			---------	---------			
	Total Activity :		2.267E+03	3.629E+03			
	Grand Total Activity :		2.267E+03	3.629E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Sample ID : 1135L120319 Acquisition date : 3-DEC-2019 18:03:23

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
0	75.04	61	15930	1.23	149.12	147	6	1.41E-03	****	2.30E+00	
0	136.54	2384	13793	1.56	272.23	268	8	5.52E-02	17.6	2.25E+00	
0	255.18	1030	9324	1.66	509.68	506	9	2.38E-02	34.4	1.63E+00	
0	814.14	464	3039	1.73	1628.27	1622	12	1.07E-02	48.5	6.88E-01	
2	1325.28	508	896	2.75	2650.95	2646	31	1.17E-02	23.5	4.81E-01	
0	1460.95	58	999	1.89	2922.36	2915	16	1.35E-03	****	4.47E-01	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	18	
Number of unidentified lines	6	
Number of lines tentatively identified by NID	12	66.67%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected BQ/TOTAL	Wtd Mean Decay Corr BQ/TOTAL	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
03-PB210	22.26Y	1.02	7.535E+02	7.655E+02	0.220E+02	2.87	
04-CD109	462.90D	1.32	7.582E+02	1.001E+03	0.025E+03	2.52	
05-CO57	270.90D	1.61	2.490E+01	4.002E+01	0.118E+01	2.95	
06-CE139	137.66D	2.54	1.968E+01	5.009E+01	0.194E+01	3.88	
07-HG203	46.61D	15.8	9.633E+00	1.520E+02	0.120E+02	7.89	
08-SN113	115.10D	3.06	6.405E+01	1.958E+02	0.043E+02	2.20	
09-SR85	64.84D	7.26	3.277E+01	2.381E+02	0.074E+02	3.11	
10-CS137	30.17Y	1.01	1.732E+02	1.752E+02	0.020E+02	1.12	
11-Y88	106.65D	3.34	1.219E+02	4.069E+02	0.063E+02	1.55	
12-CO60	5.27Y	1.07	1.901E+02	2.032E+02	0.016E+02	0.77	
14-Y88	106.65D	3.34	1.206E+02	4.026E+02	0.063E+02	1.57	
			---------	---------			
	Total Activity :		2.268E+03	3.630E+03			
	Grand Total Activity :		2.268E+03	3.630E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (BQ/TOTAL)	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
03-PB210	7.655E+02	2.196E+01	1.954E+01	0.000E+00	39.183
04-CD109	1.001E+03	2.527E+01	2.310E+01	0.000E+00	43.332
05-CO57	4.002E+01	1.180E+00	1.105E+00	0.000E+00	36.208

06-CE139	5.009E+01	1.942E+00	1.895E+00	0.000E+00	26.438
07-HG203	1.520E+02	1.199E+01	1.279E+01	0.000E+00	11.879
08-SN113	1.958E+02	4.310E+00	3.265E+00	0.000E+00	59.960
09-SR85	2.381E+02	7.394E+00	6.020E+00	0.000E+00	39.550
10-CS137	1.752E+02	1.965E+00	1.015E+00	0.000E+00	172.707
11-Y88	4.069E+02	6.288E+00	3.608E+00	0.000E+00	112.764
12-CO60	2.032E+02	1.570E+00	7.111E-01	0.000E+00	285.814
14-Y88	4.026E+02	6.308E+00	1.591E+00	0.000E+00	253.009

---- Non-Identified Nuclides ----

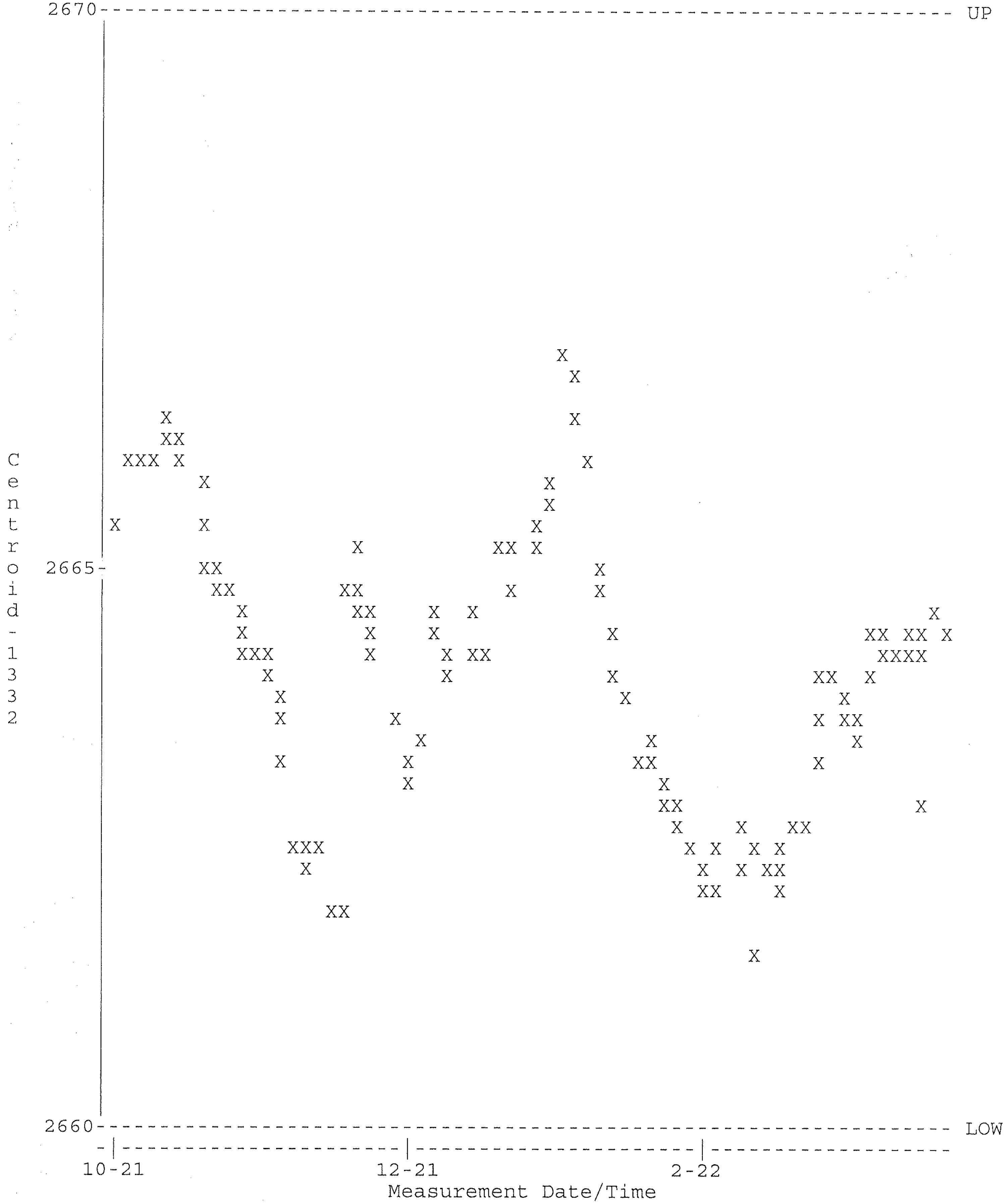
Nuclide	Key-Line Activity (BQ/TOTAL)	K.L. Ided	Act error	MDA (BQ/TOTAL)	MDA error	Act/MDA
01-CO57	1.806E+03		7.032E+01	1.295E+02	0.000E+00	13.951
02-CE139	9.777E+00		9.876E+00	1.669E+01	0.000E+00	0.586

```
A,1135L120319      ,12/04/2019 10:00,06/01/2019 12:00,   1.000E+00,3.5L 5ML MIXED
B,1135L120319      ,CALIBRATION_PB       ,12/04/2019 09:55,1135L120319
C,03-PB210,YES,    7.655E+02,   2.196E+01,   1.954E+01,,   39.183
C,04-CD109,YES,    1.001E+03,   2.527E+01,   2.310E+01,,   43.332
C,05-CO57 ,YES,    4.002E+01,   1.180E+00,   1.105E+00,,   36.208
C,06-CE139,YES,    5.009E+01,   1.942E+00,   1.895E+00,,   26.438
C,07-HG203,YES,    1.520E+02,   1.199E+01,   1.279E+01,,   11.879
C,08-SN113,YES,    1.958E+02,   4.310E+00,   3.265E+00,,   59.960
C,09-SR85 ,YES,    2.381E+02,   7.394E+00,   6.020E+00,,   39.550
C,10-CS137,YES,    1.752E+02,   1.965E+00,   1.015E+00,,  172.707
C,11-Y88  ,YES,    4.069E+02,   6.288E+00,   3.608E+00,,  112.764
C,12-CO60 ,YES,    2.032E+02,   1.570E+00,   7.111E-01,,  285.814
C,14-Y88  ,YES,    4.026E+02,   6.308E+00,   1.591E+00,,  253.009
C,01-CO57 ,NO ,    1.806E+03,   7.032E+01,   1.295E+02,,   13.951
C,02-CE139,NO ,    9.777E+00,   9.876E+00,   1.669E+01,,    0.586
```

GAMMA SPECTROSCOPY

Daily Source and Background Checks

```
QA filename          : DKB100:[GAMMA.QUALITY]NEW_TBE01_QC.QAF;1
Parameter Name       : PSCENTRD (Centroid-1332)
Start/End Dates      : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Lower/Upper Lmts: 2660.00 through 2670.00
```



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QA filename          : DKB100:[GAMMA.QUALITY]NEW_TBE01_QC.QAF;1
Parameter Name       : PSFWHM-1332 (FWHM-1332)
Start/End Dates      : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Lower/Upper Lmts: 1.70000 through 2.50000
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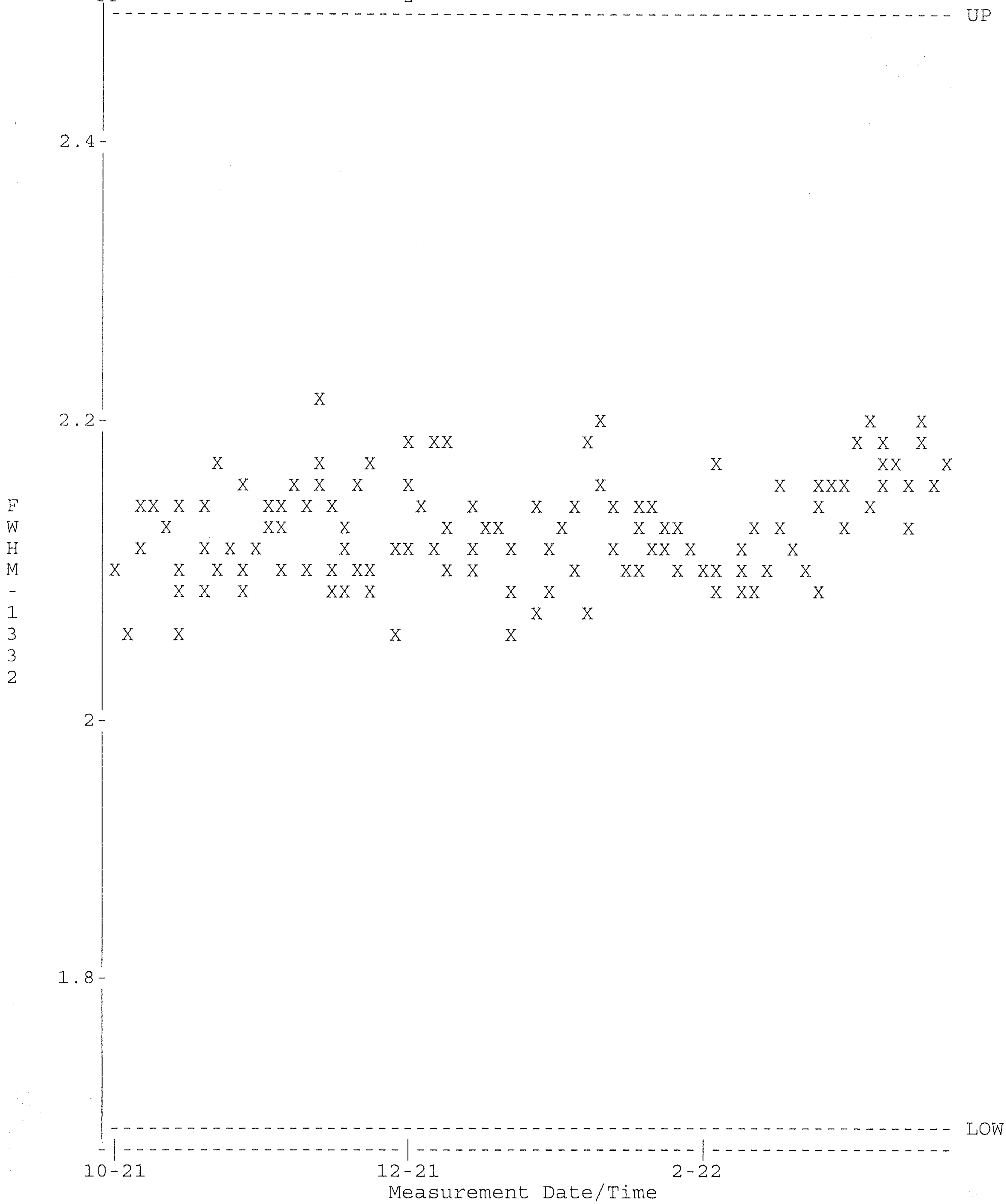
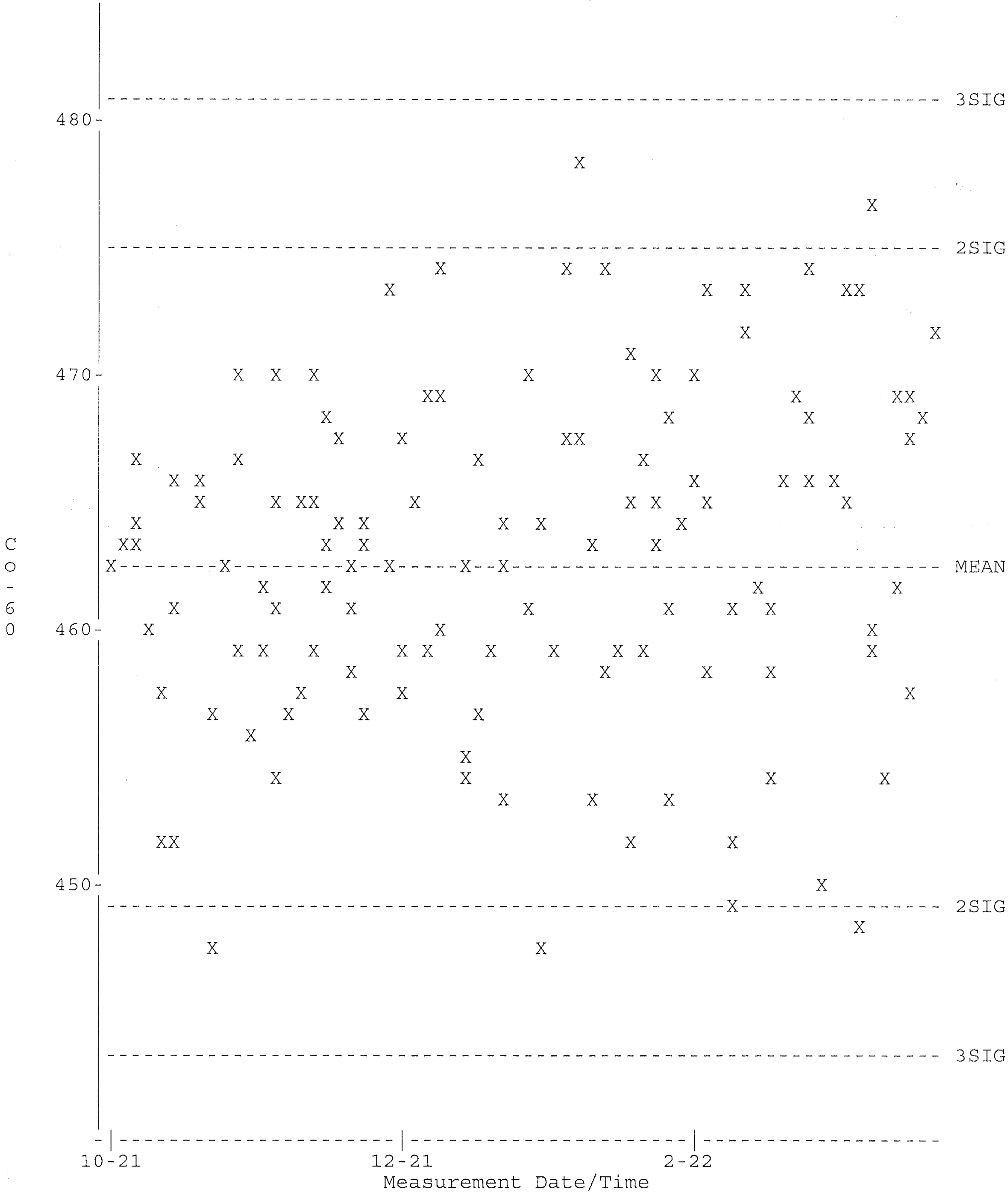
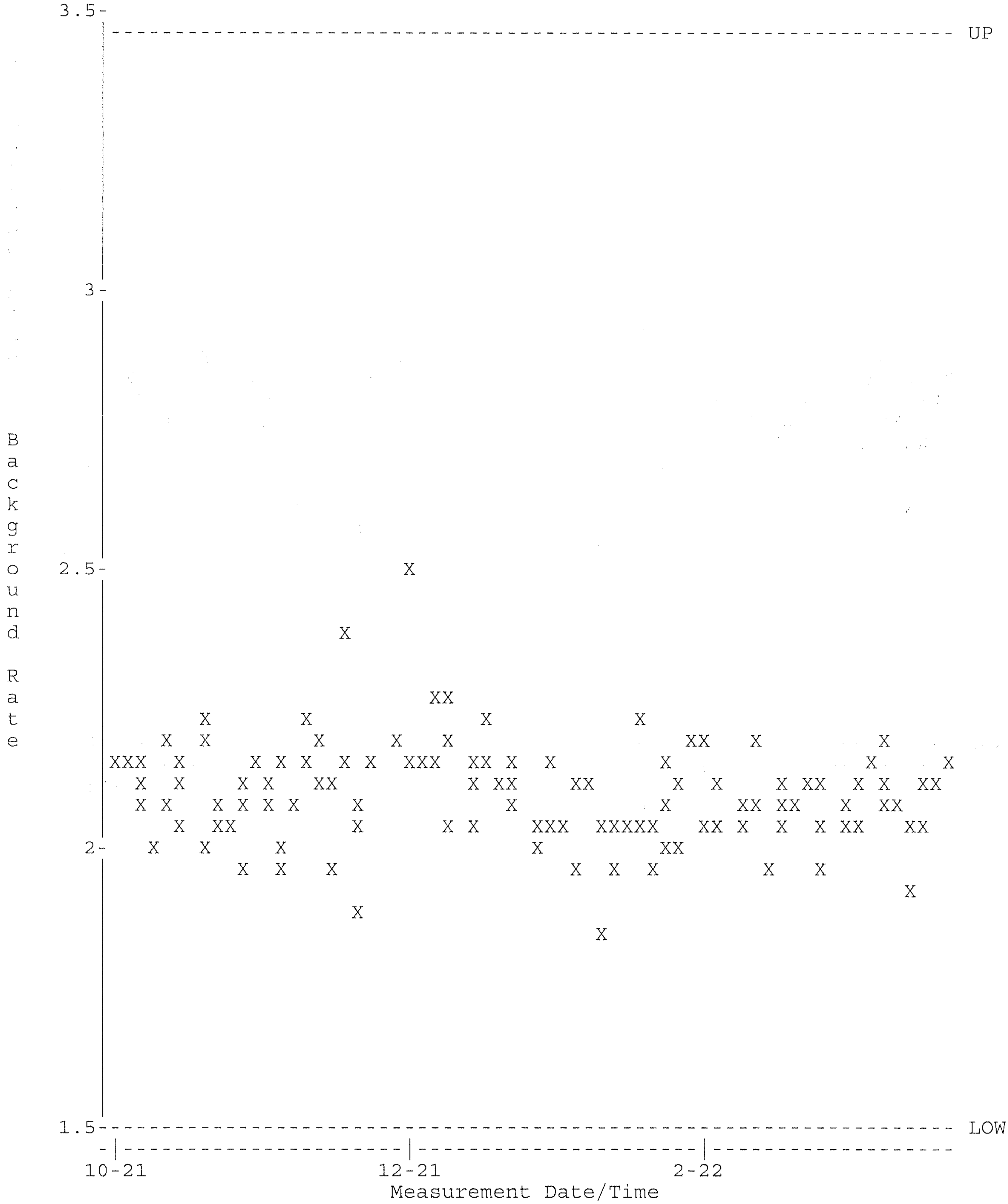


QA filename : DKB100:[GAMMA.QUALITY]NEW_TBE01_QC.QAF;1
Parameter Name : NCLWTMEAN-CO60 (Co-60)
Start/End Dates : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Mean +- Std Dev : 462.666 +- 6.27386 (1.36 %)



QA filename : DKB100:[GAMMA.QUALITY]TBE01_BKG_QC.QAF;1
Parameter Name : BACKRATE (Background Rate)
Start/End Dates : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 1.50000 through 3.50000



```
QA filename         : DKB100:[GAMMA.QUALITY]NEW_TBE01_QC.QAF;1
Parameter Name      : PSCENTRD-59 (Centroid-59)
Start/End Dates     : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Lower/Upper Lmts: 118.500 through 120.500
  120.5-
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       |                                    X
C      |     X                           XXX X
e      |XXXXXX X           X      X  X X  X   X                       X
n      |  X    XX X X     XXX    X  X XX       X                  X X   XX
t      |  X  X XXXXXXX  X  XX   X X X    X   X X XXX X   XX    X  XXXX X
r 119.5-          X  X   X    XX  X XX          X  XX X       X XX    XX
o      |               X XX                      X XX  X XXXXX X
i      |              XXX X    X                      XX X
d      |                 X     X
-      |
5      |
9      |
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   119-
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       |
  118.5-------------------------------------------------------------------- LOW
       -|----------------------|----------------------|-------------------
       10-21                  12-21                  2-22
                         Measurement Date/Time
```
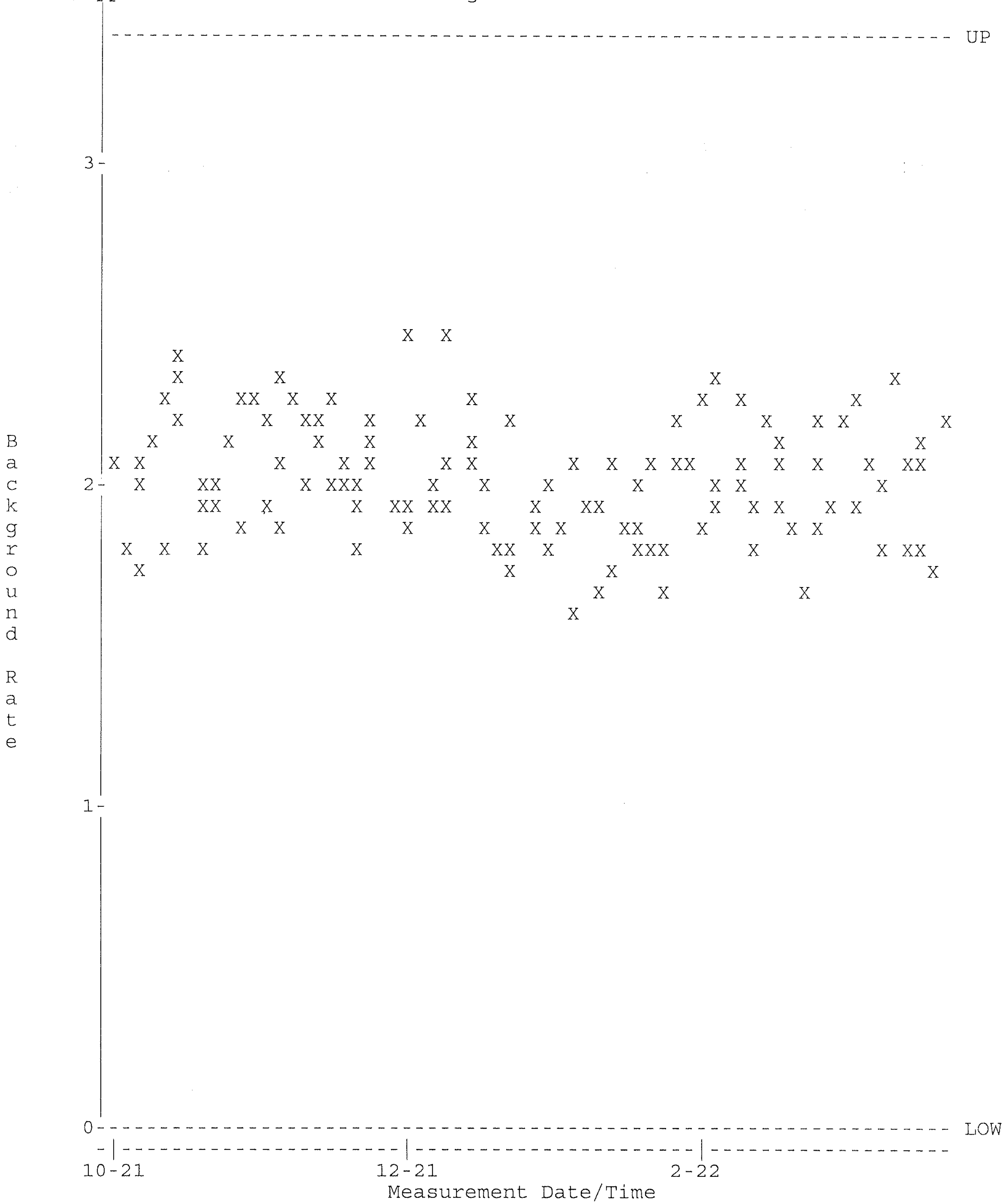
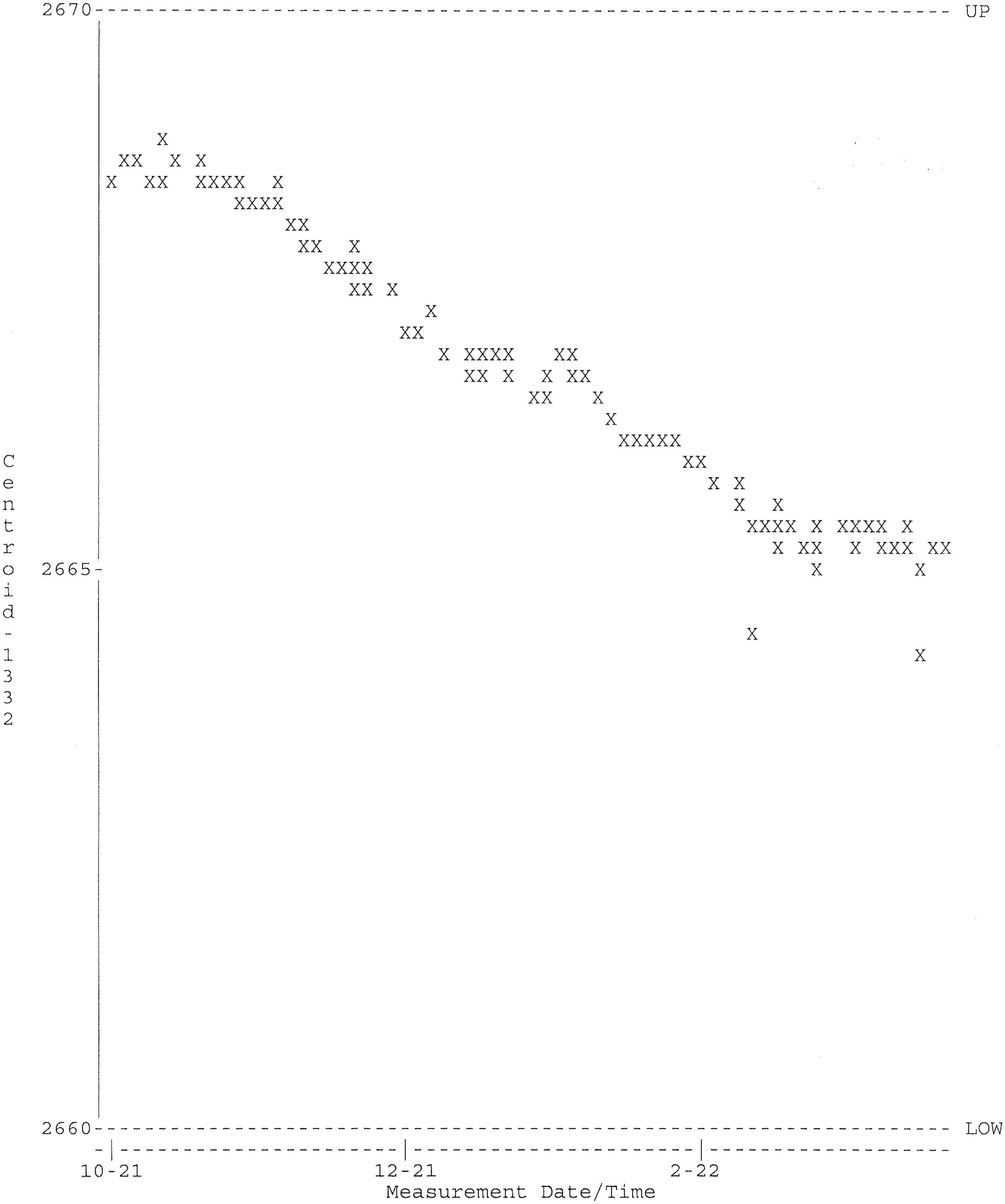
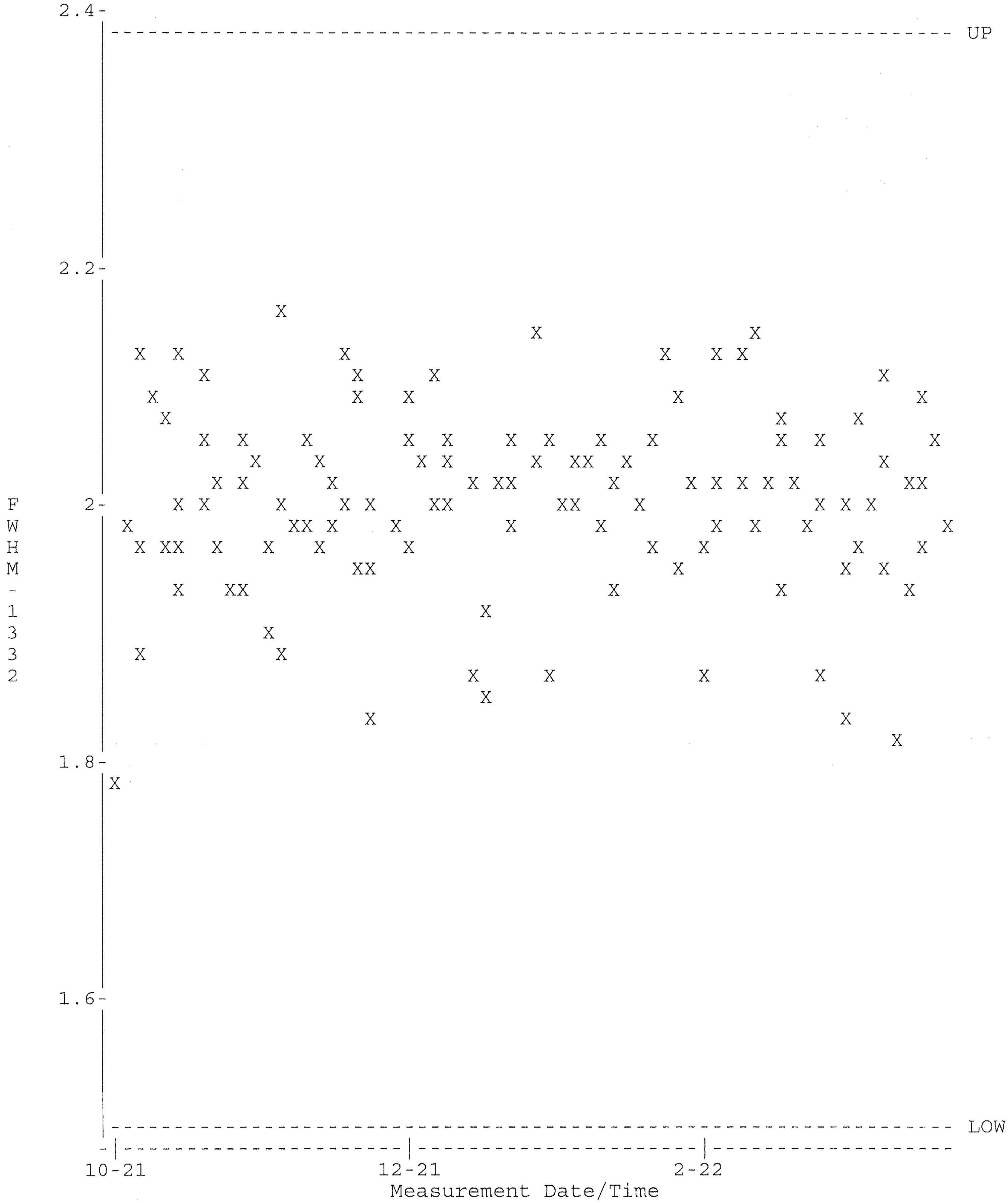

QA filename : DKB100:[GAMMA.QUALITY]TBE02_BKG_QC.QAF;1
Parameter Name : BACKRATE (Background Rate)
Start/End Dates : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Lower/Upper Lmts: 0.000000E+00 through 3.50000



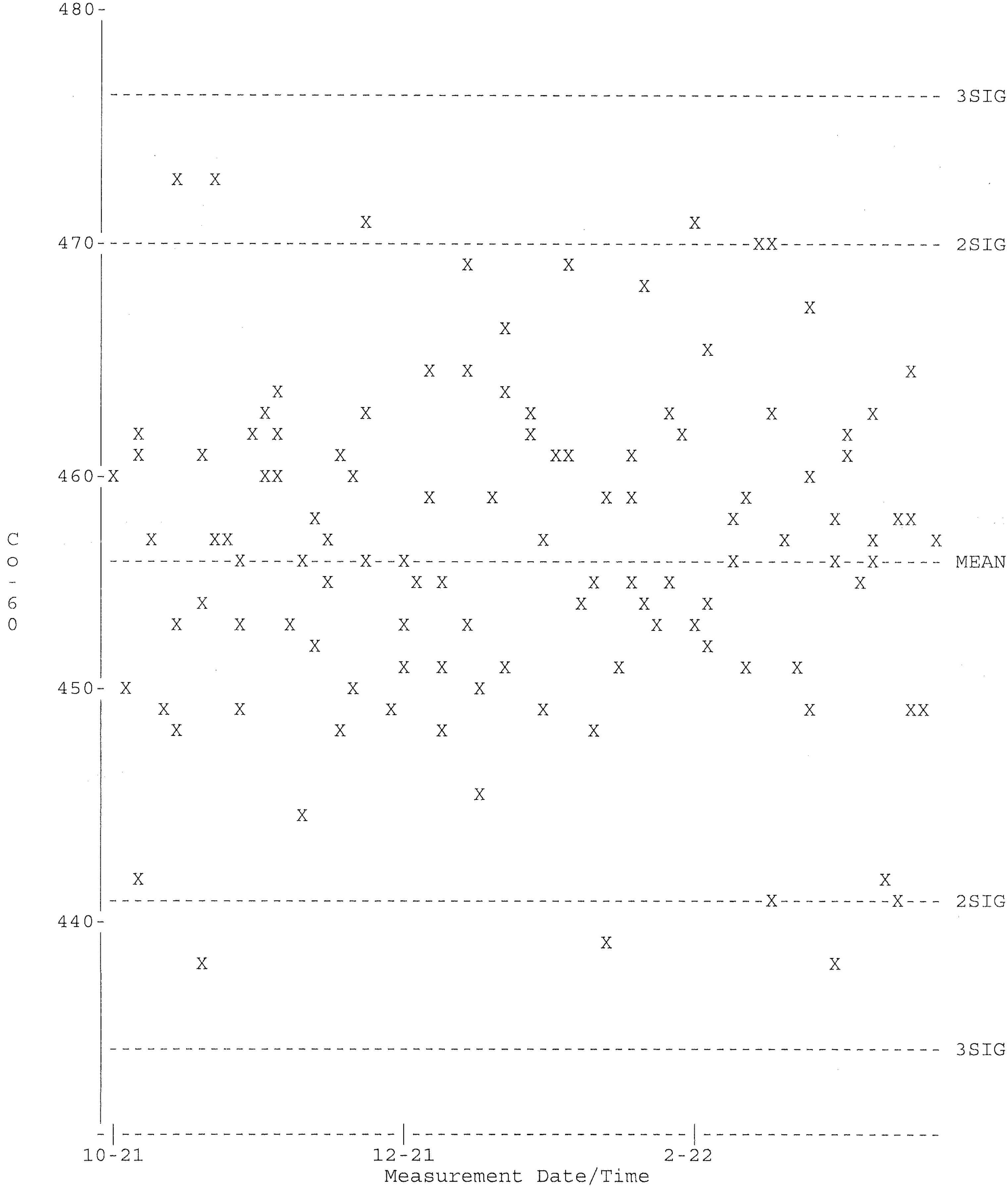
QA filename : DKB100:[GAMMA.QUALITY]NEW_TBE02_QC.QAF;1
Parameter Name : PSCENTRD (Centroid-1332)
Start/End Dates : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 2660.00 through 2670.00



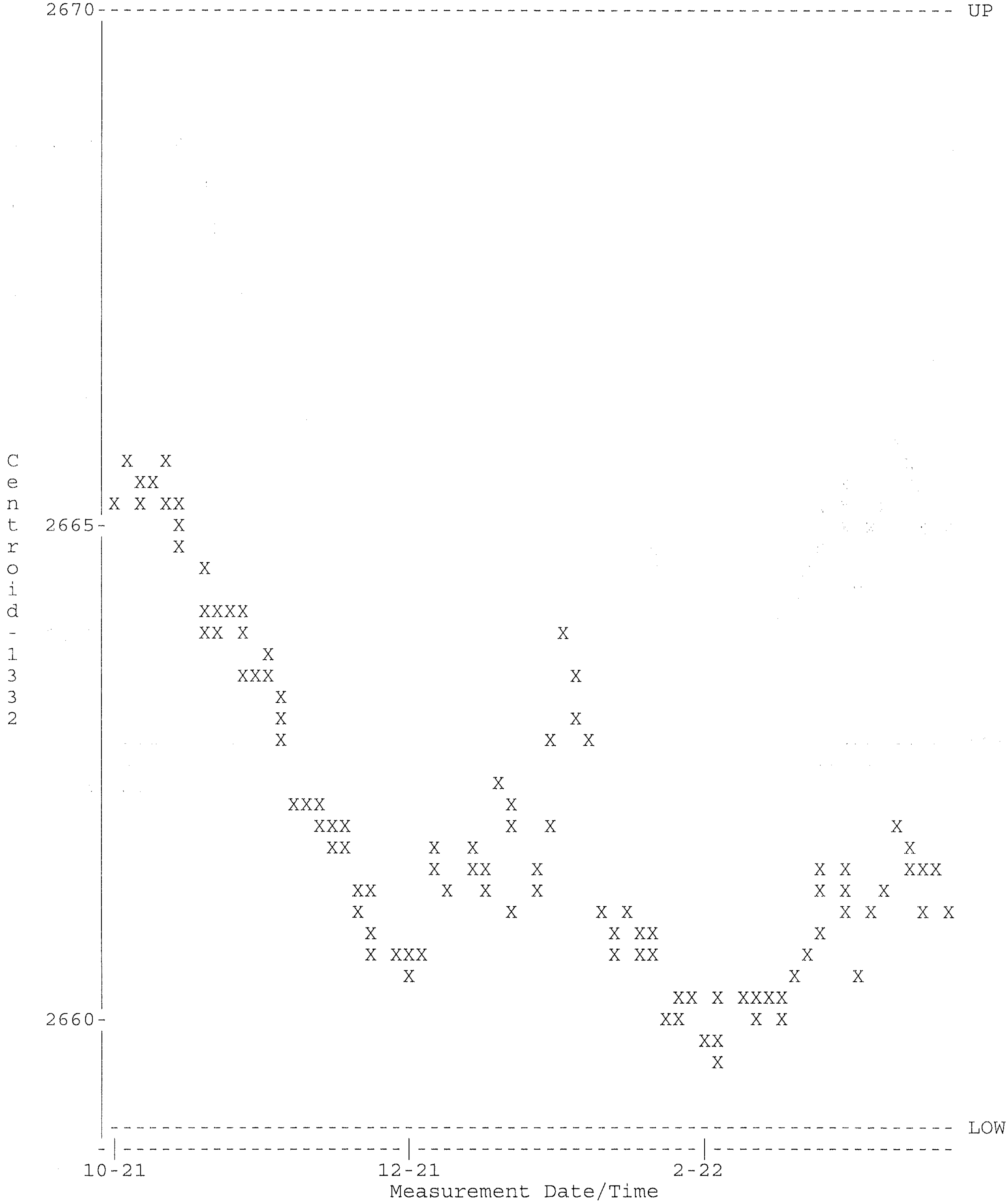
QA filename : DKB100:[GAMMA.QUALITY]NEW_TBE02_QC.QAF;1
Parameter Name : PSFWHM-1332 (FWHM-1332)
Start/End Dates : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 1.50000 through 2.40000



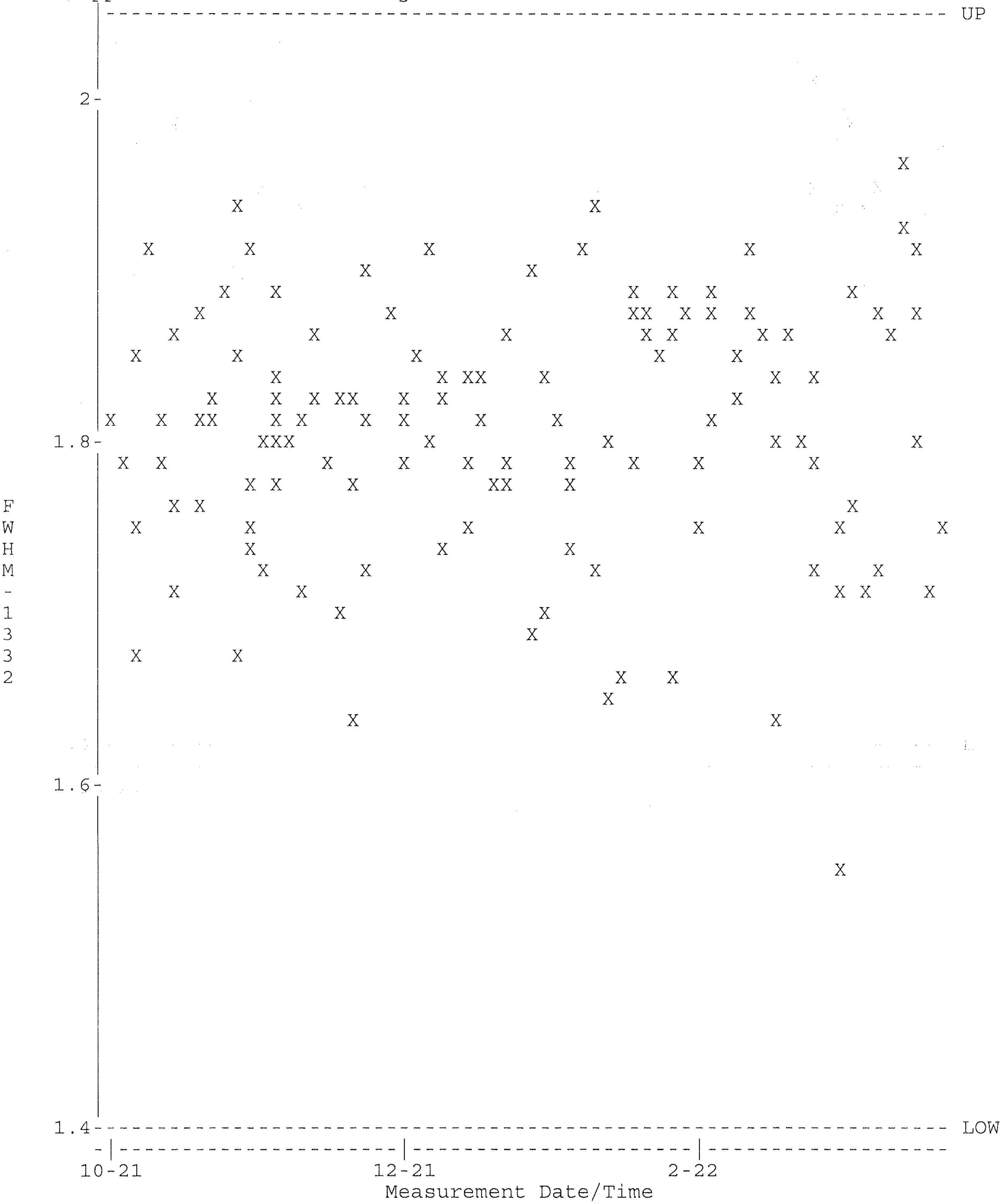
```
QA filename          : DKB100:[GAMMA.QUALITY]NEW_TBE02_QC.QAF;1
Parameter Name       : NCLWTMEAN-CO60 (Co-60)
Start/End Dates      : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Mean +- Std Dev      : 455.948 +- 7.03561 (1.54 %)
```



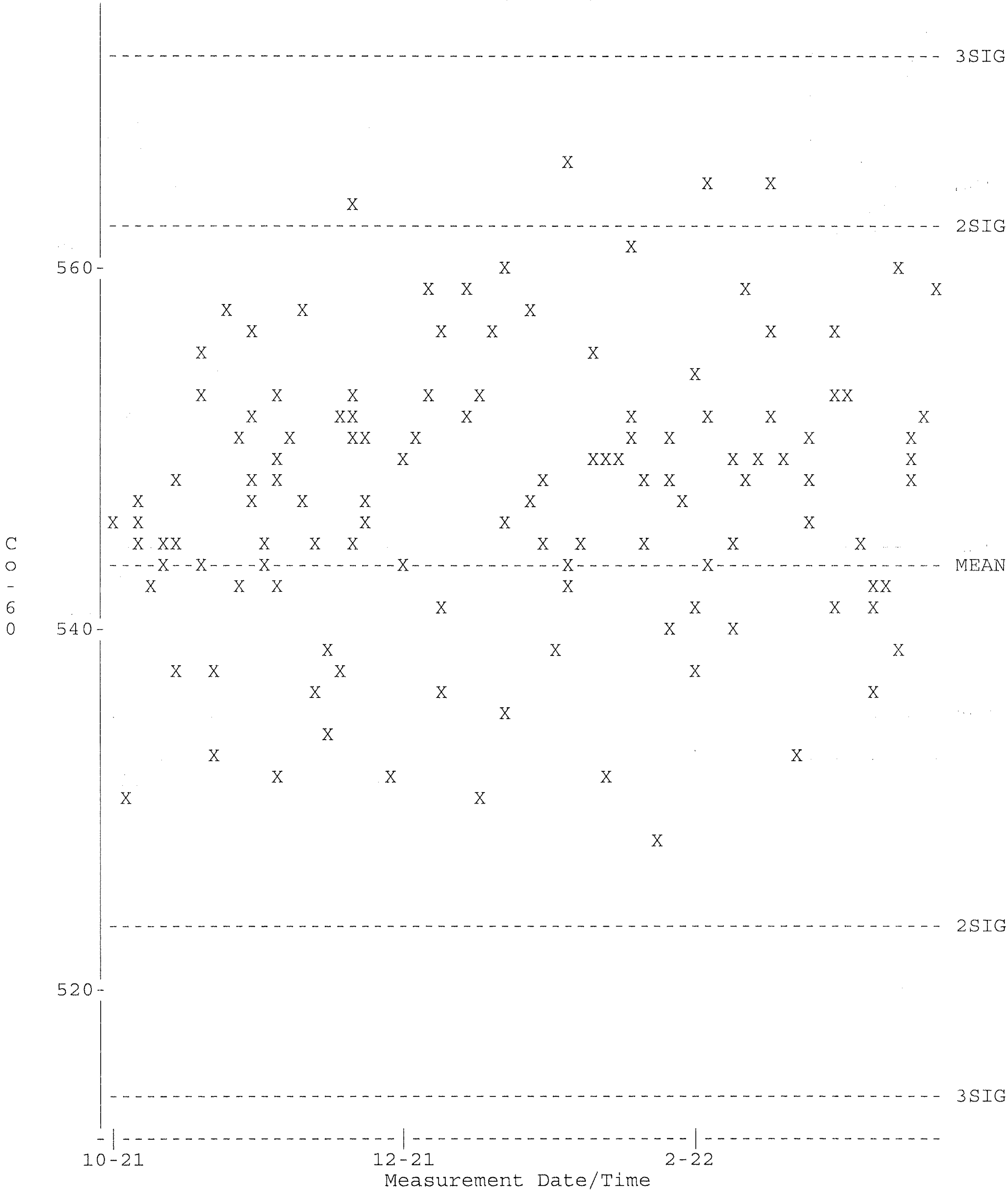
```
QA filename          : DKB100:[GAMMA.QUALITY]NEW_TBE06_QC.QAF;1
Parameter Name       : PSCENTRD (Centroid-1332)
Start/End Dates      : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 2659.00 through 2670.00
```



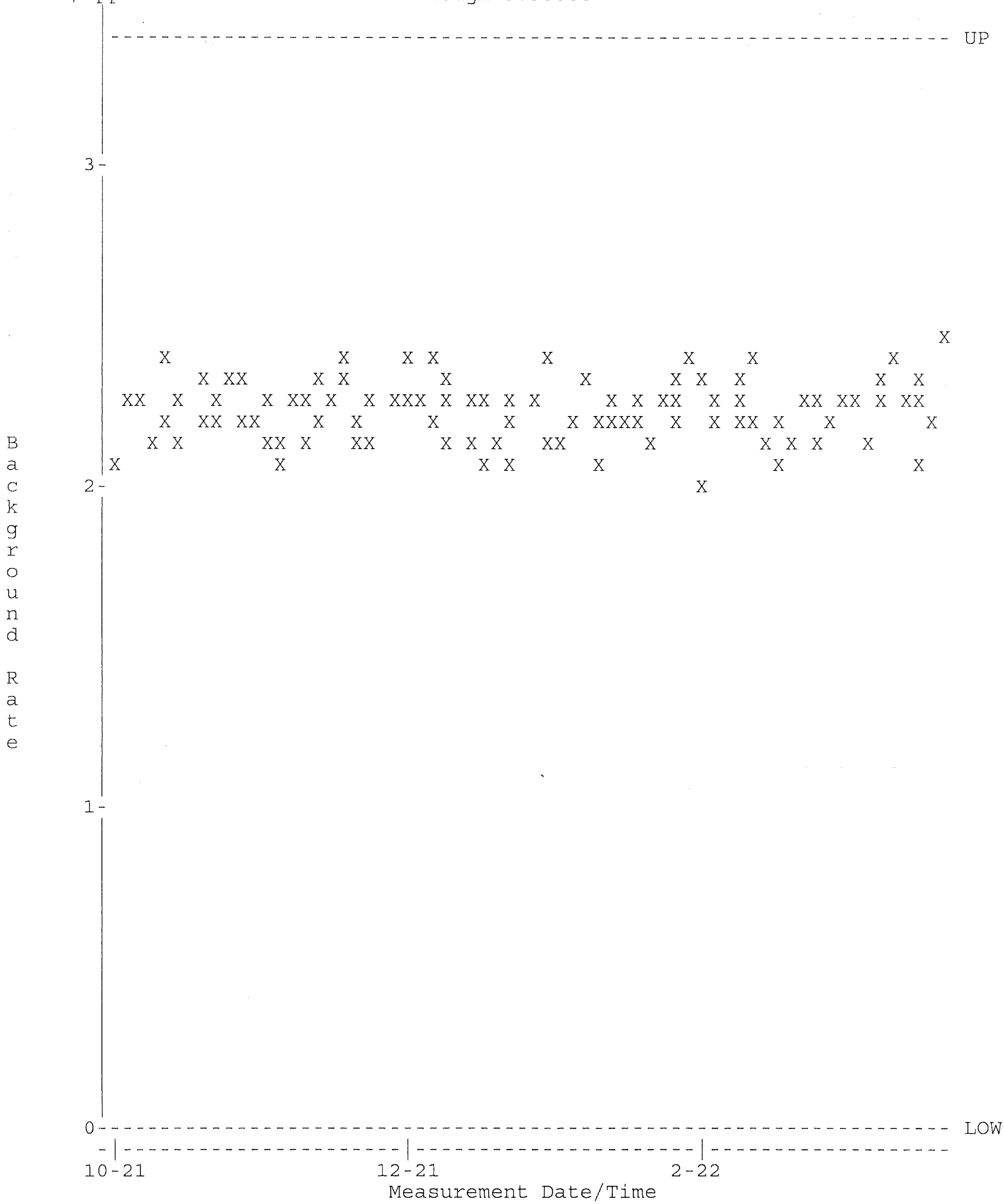
QA filename   : DKB100:[GAMMA.QUALITY]NEW_TBE06_QC.QAF;1
Parameter Name   : PSFWHM-1332 (FWHM-1332)
Start/End Dates   : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 1.40000 through 2.05000



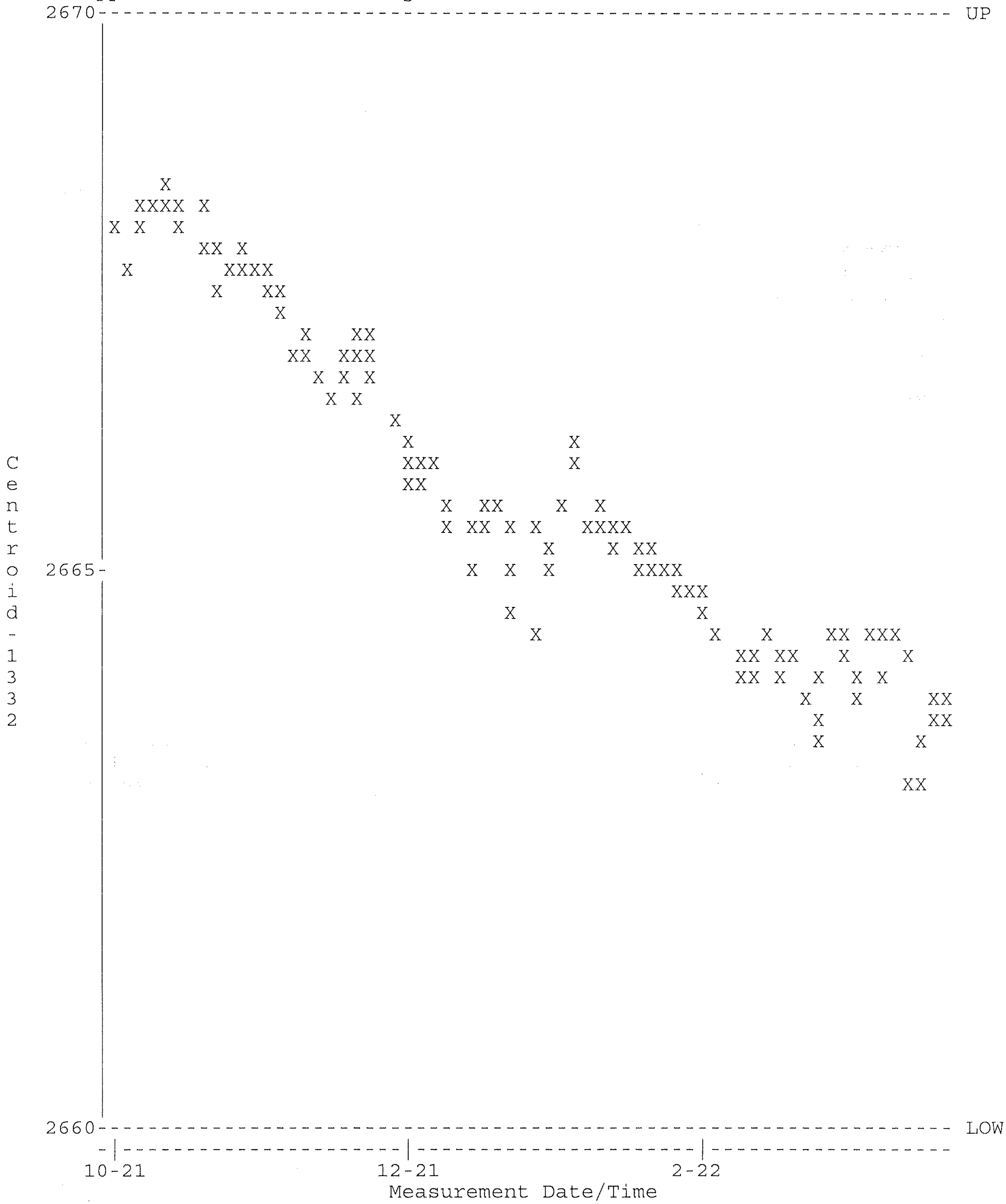
QA filename : DKB100:[GAMMA.QUALITY]NEW_TBE06_QC.QAF;1
Parameter Name : NCLWTMEAN-CO60 (Co-60)
Start/End Dates : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Mean +- Std Dev : 543.576 +- 9.55063 (1.76 %)



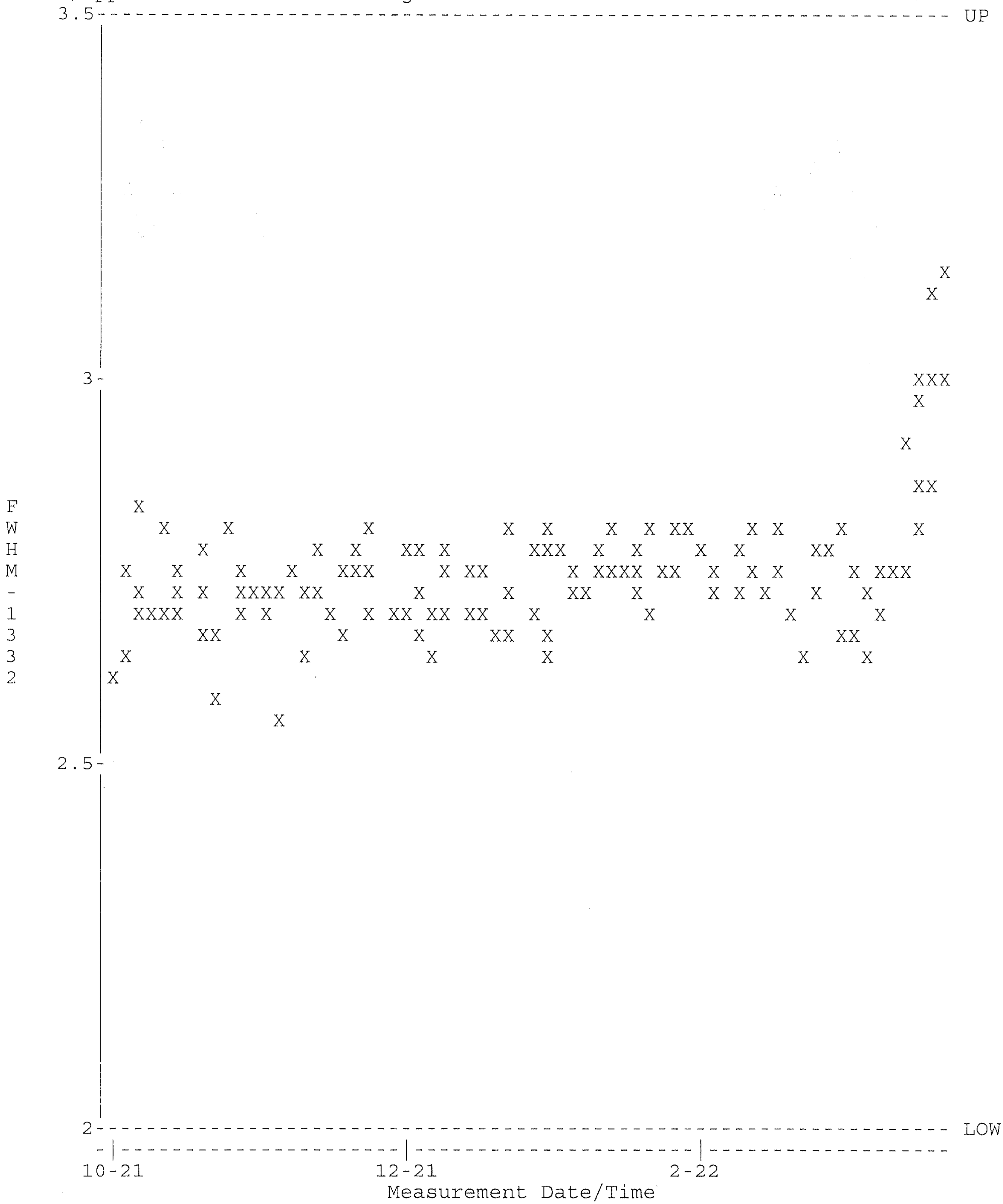
QA filename : DKB100:[GAMMA.QUALITY]TBE06_BKG_QC.QAF;1
Parameter Name : BACKRATE (Background Rate)
Start/End Dates : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Lower/Upper Lmts: 0.000000E+00 through 3.50000



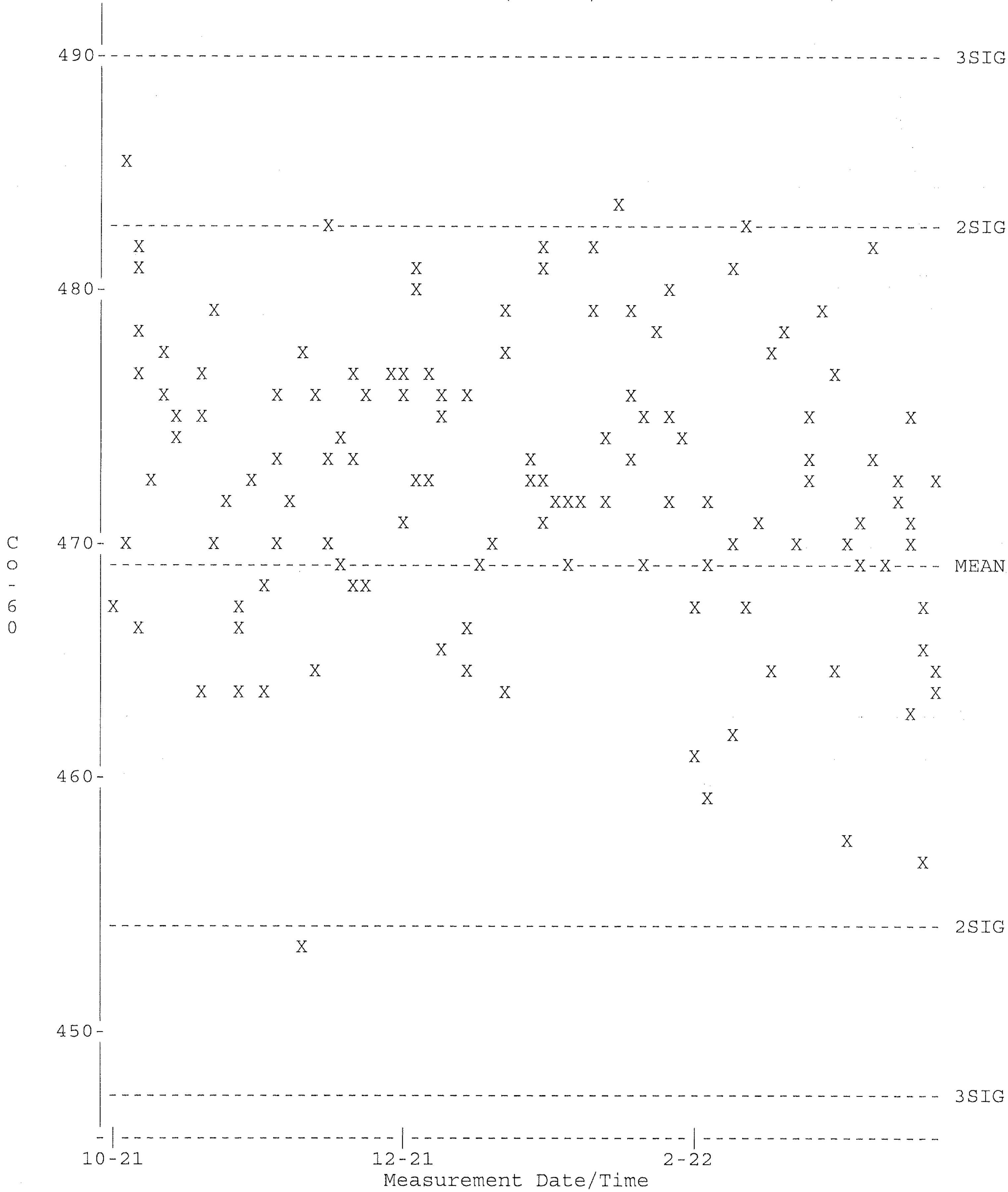
QA filename   : DKB100:[GAMMA.QUALITY]NEW_TBE07_QC.QAF;1
Parameter Name   : PSCENTRD (Centroid-1332)
Start/End Dates   : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Lower/Upper Lmts: 2660.00 through 2670.00



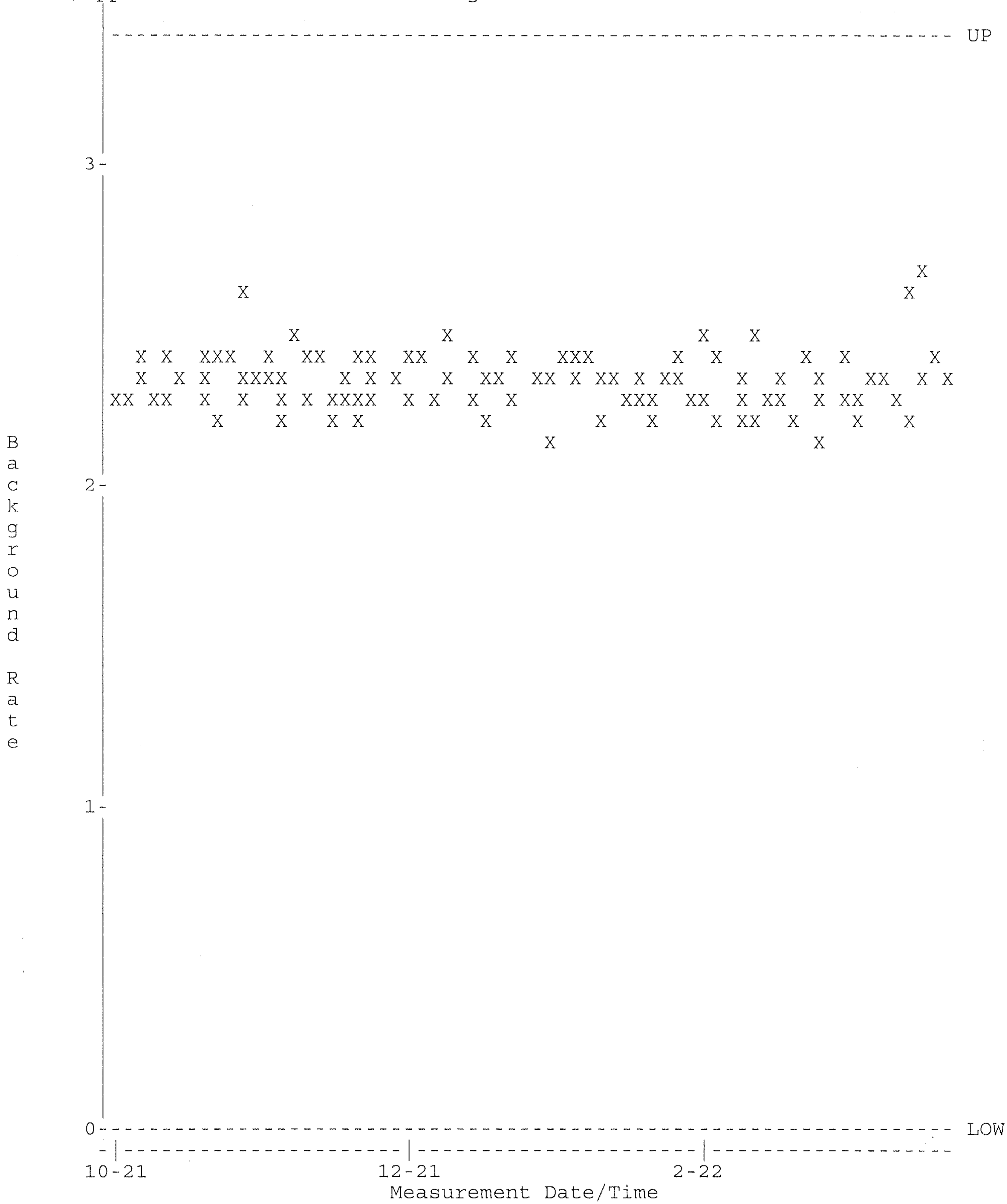
```
QA filename         : DKB100:[GAMMA.QUALITY]NEW_TBE07_QC.QAF;1
Parameter Name      : PSFWHM-1332 (FWHM-1332)
Start/End Dates     : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Lower/Upper Lmts: 2.00000 through 3.50000
```



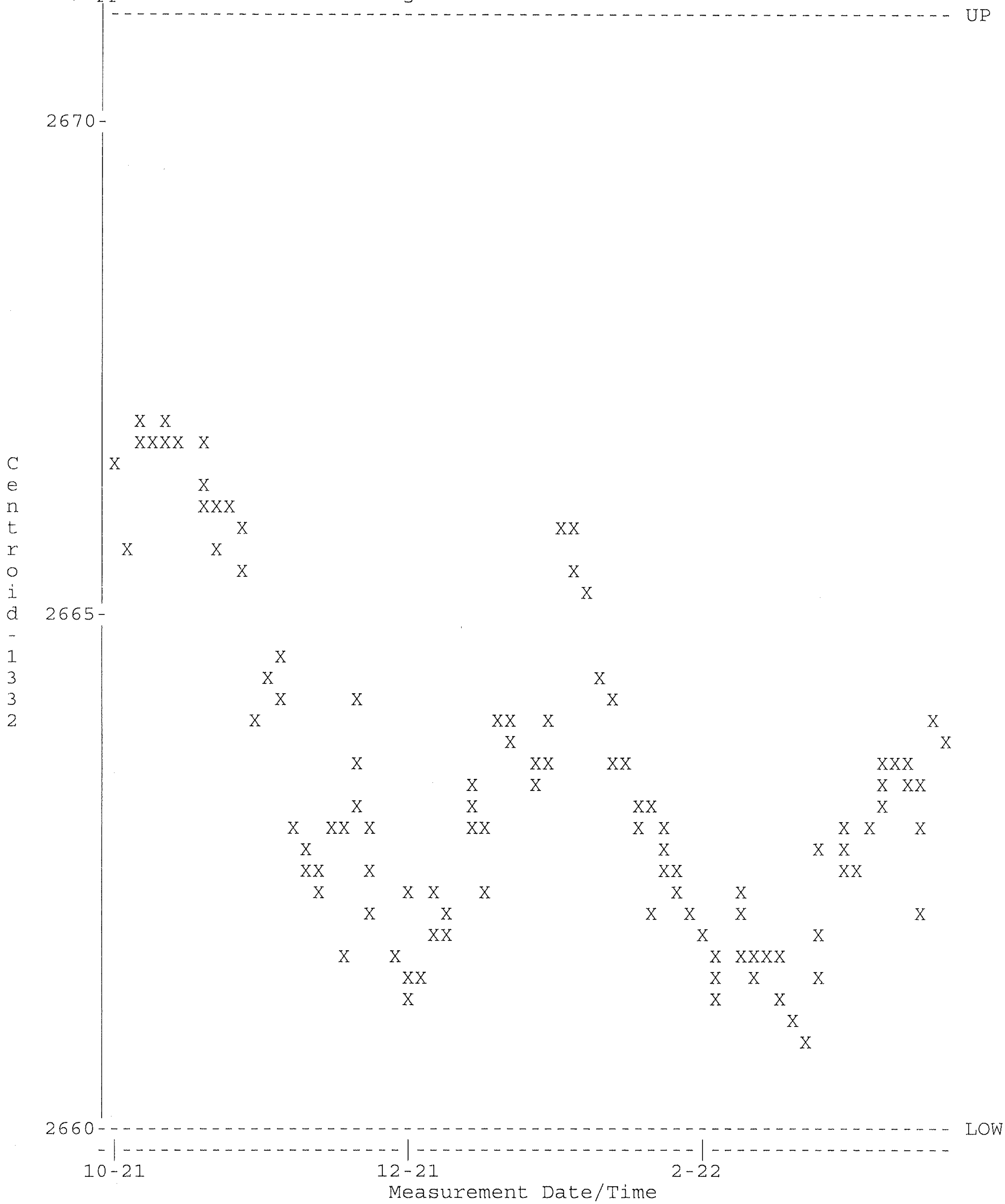
QA filename : DKB100:[GAMMA.QUALITY]NEW_TBE07_QC.QAF;1
Parameter Name : NCLWTMEAN-CO60 (Co-60)
Start/End Dates : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Mean +- Std Dev : 468.955 +- 7.11591 (1.52 %)



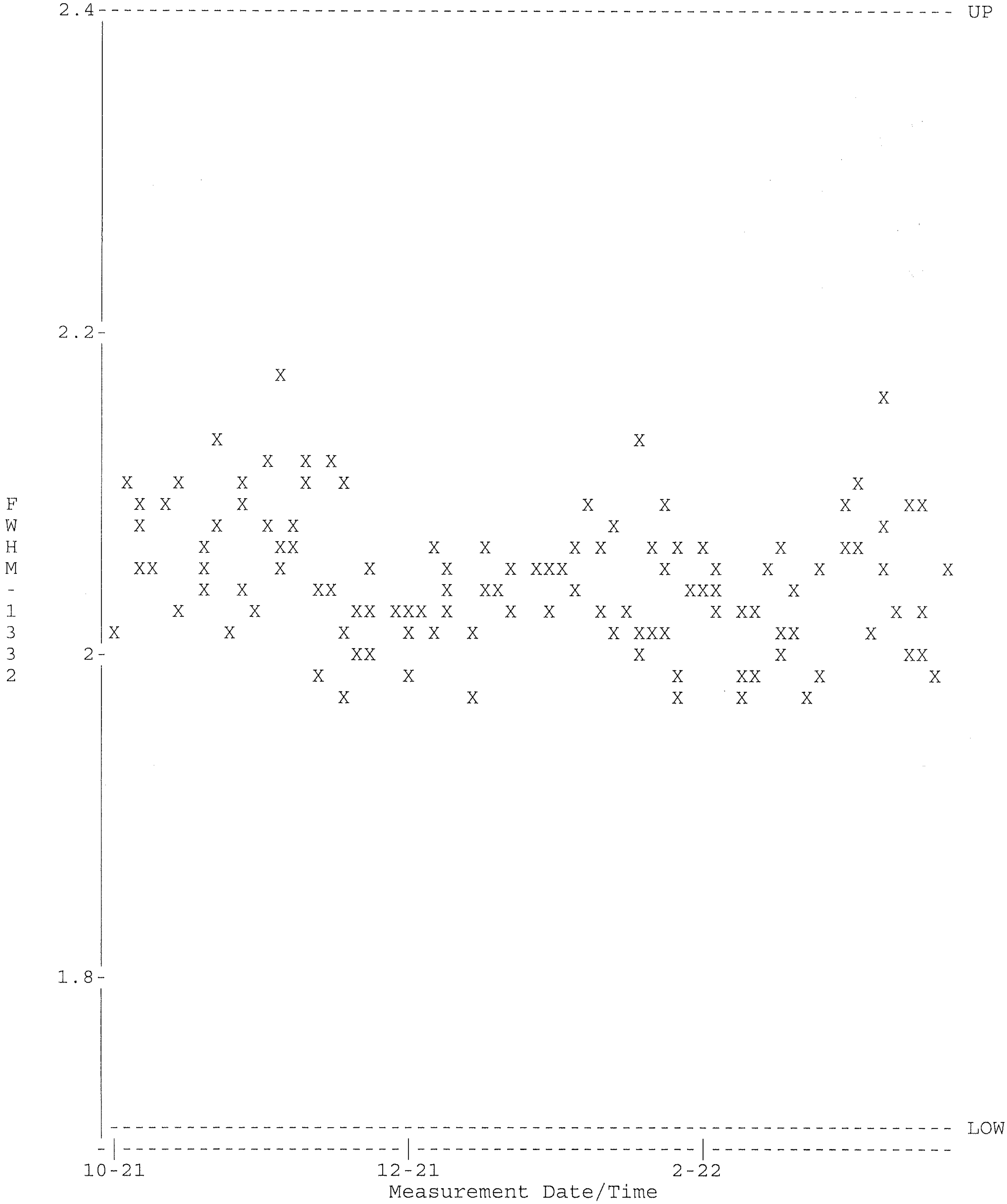
QA filename   : DKB100:[GAMMA.QUALITY]TBE07_BKG_QC.QAF;1
Parameter Name   : BACKRATE (Background Rate)
Start/End Dates   : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 0.000000E+00 through 3.50000



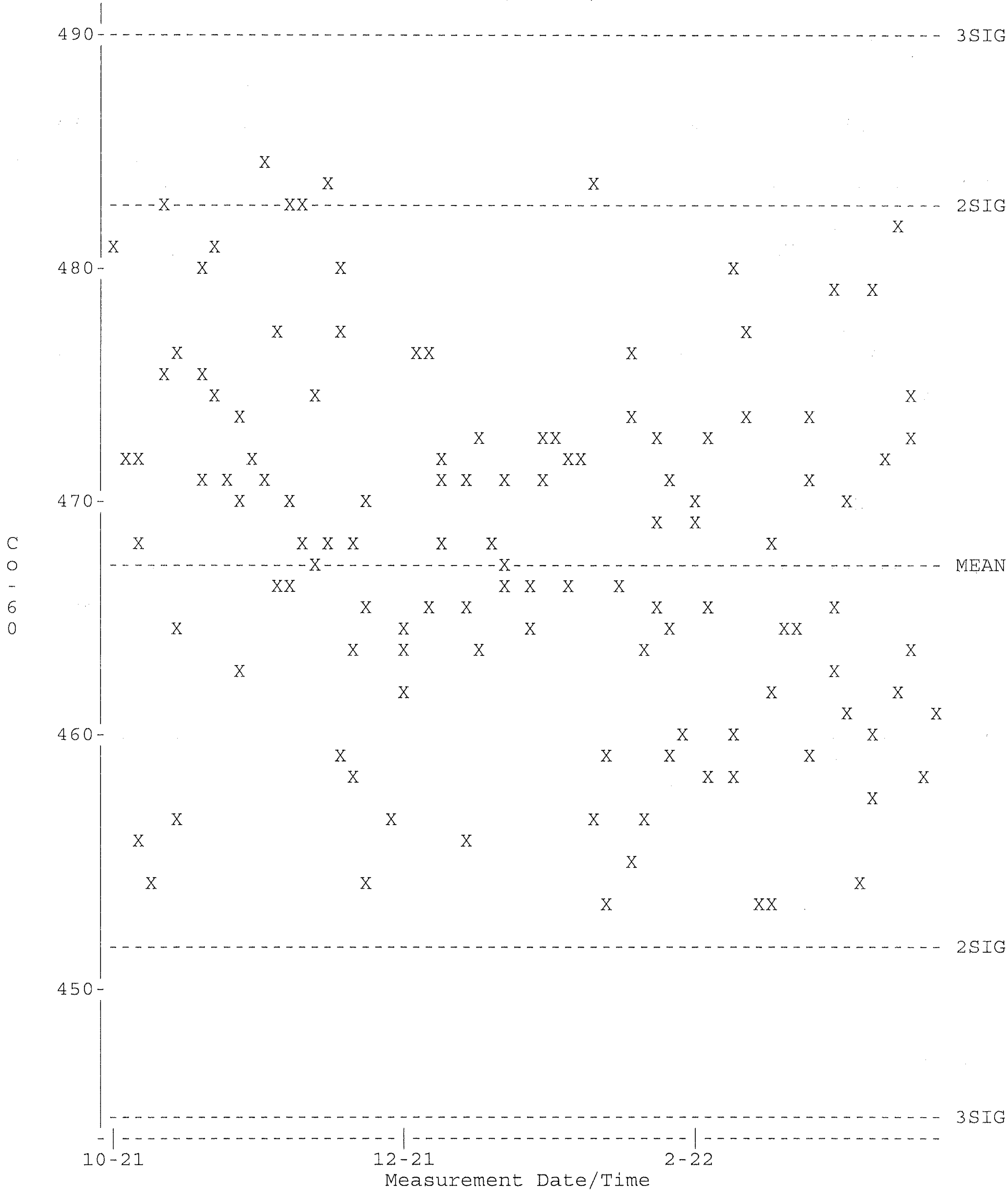
QA filename : DKB100:[GAMMA.QUALITY]NEW_TBE08_QC.QAF;1
Parameter Name : PSCENTRD (Centroid-1332)
Start/End Dates : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 2660.00 through 2671.00



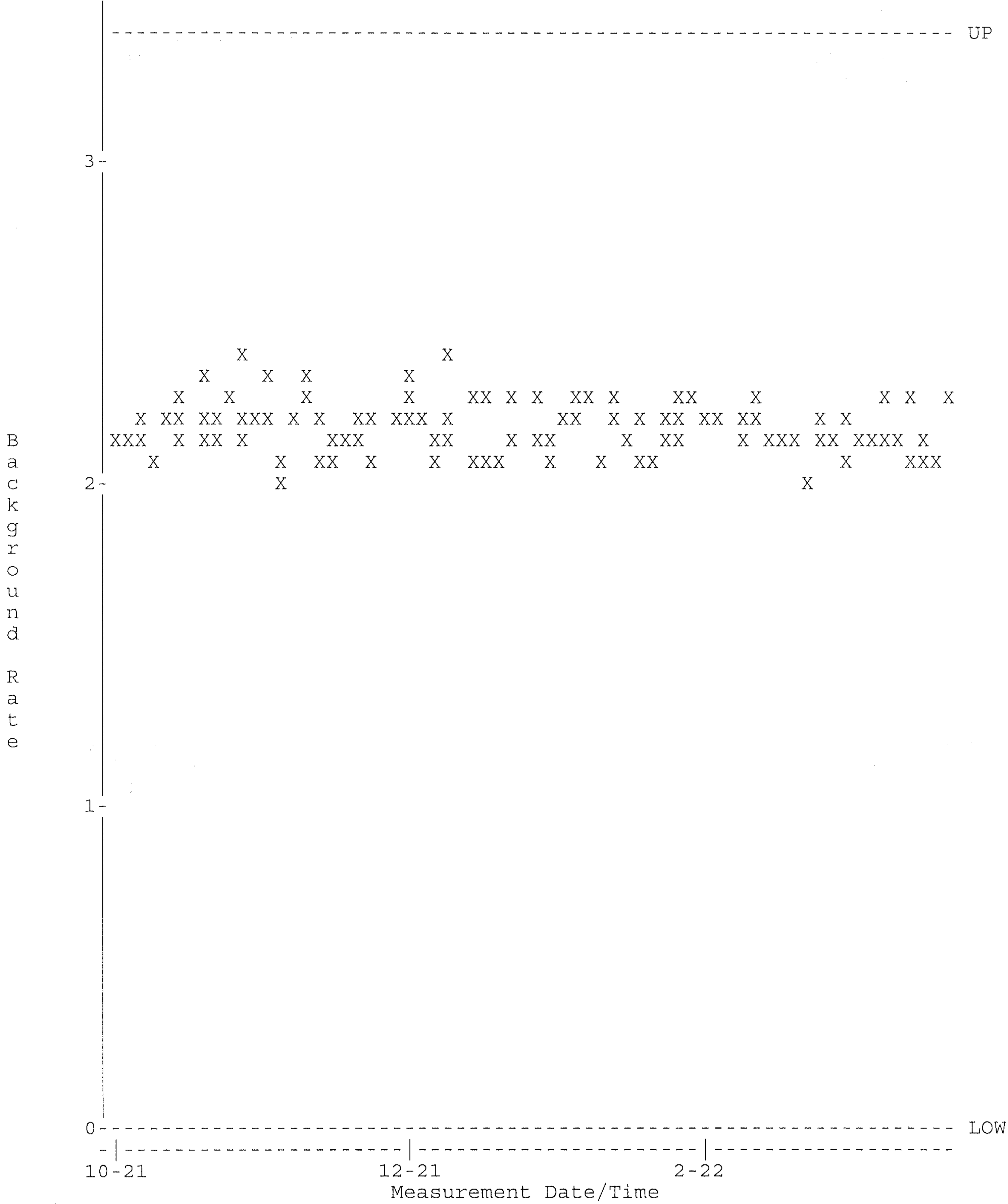
QA filename : DKB100:[GAMMA.QUALITY]NEW_TBE08_QC.QAF;1
Parameter Name : PSFWHM-1332 (FWHM-1332)
Start/End Dates : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 1.70000 through 2.40000



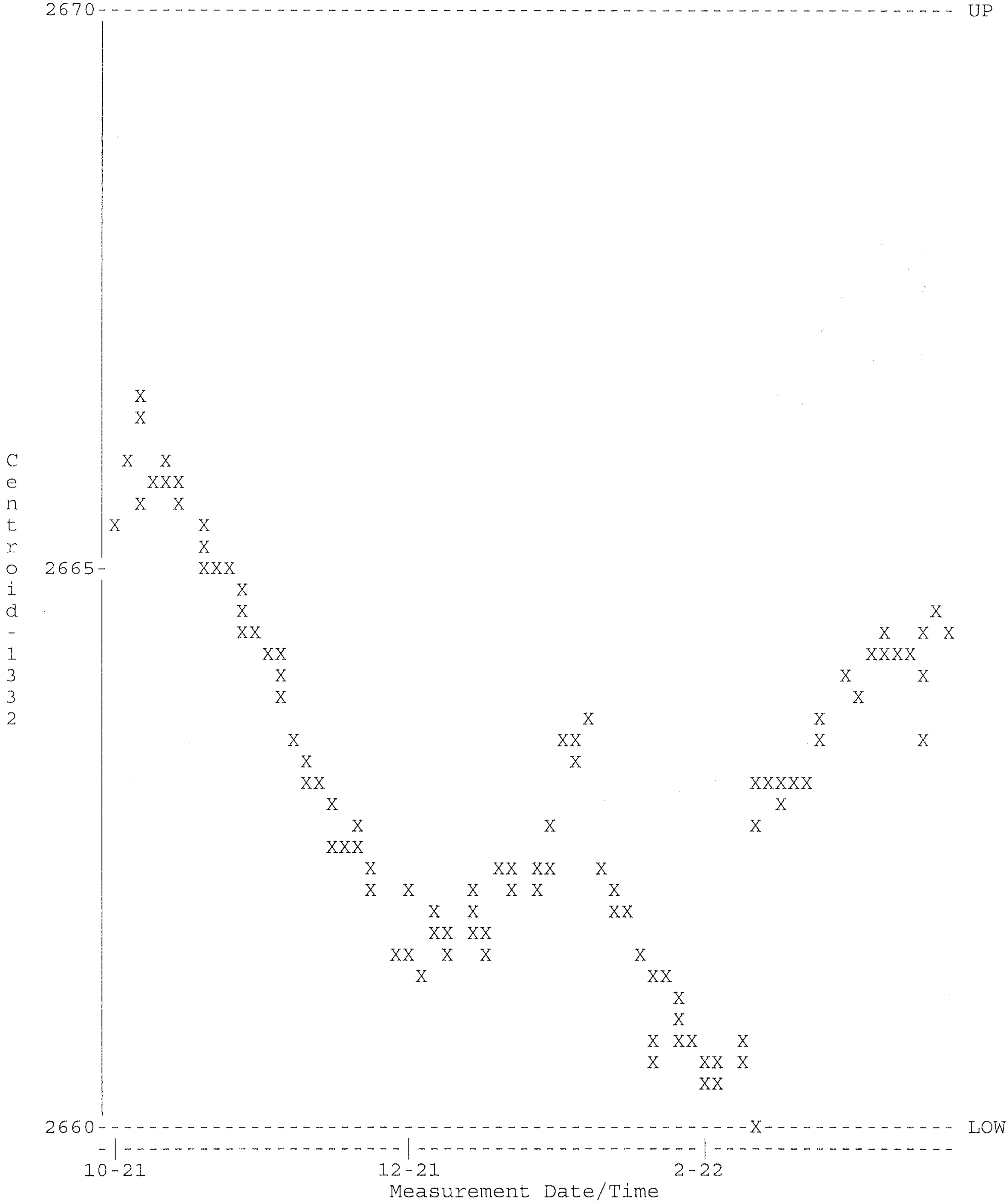
```
QA filename         : DKB100:[GAMMA.QUALITY]NEW_TBE08_QC.QAF;1
Parameter Name      : NCLWTMEAN-CO60 (Co-60)
Start/End Dates     : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Mean +- Std Dev     : 467.622 +- 7.71396 (1.65 %)
```



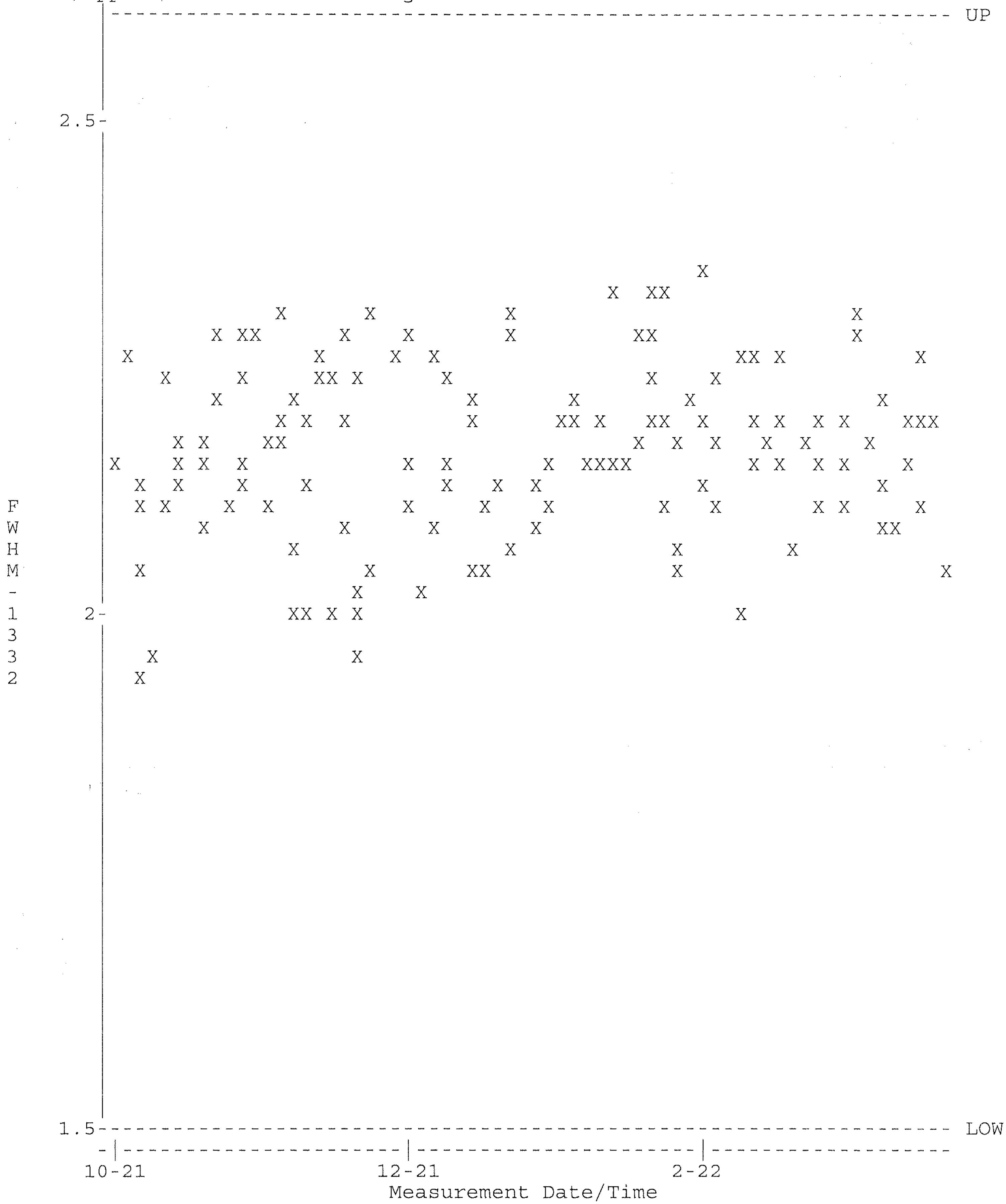
```
QA filename         : DKB100:[GAMMA.QUALITY]TBE08_BKG_QC.QAF;1
Parameter Name      : BACKRATE (Background Rate)
Start/End Dates     : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Lower/Upper Lmts: 0.000000E+00 through 3.50000
```



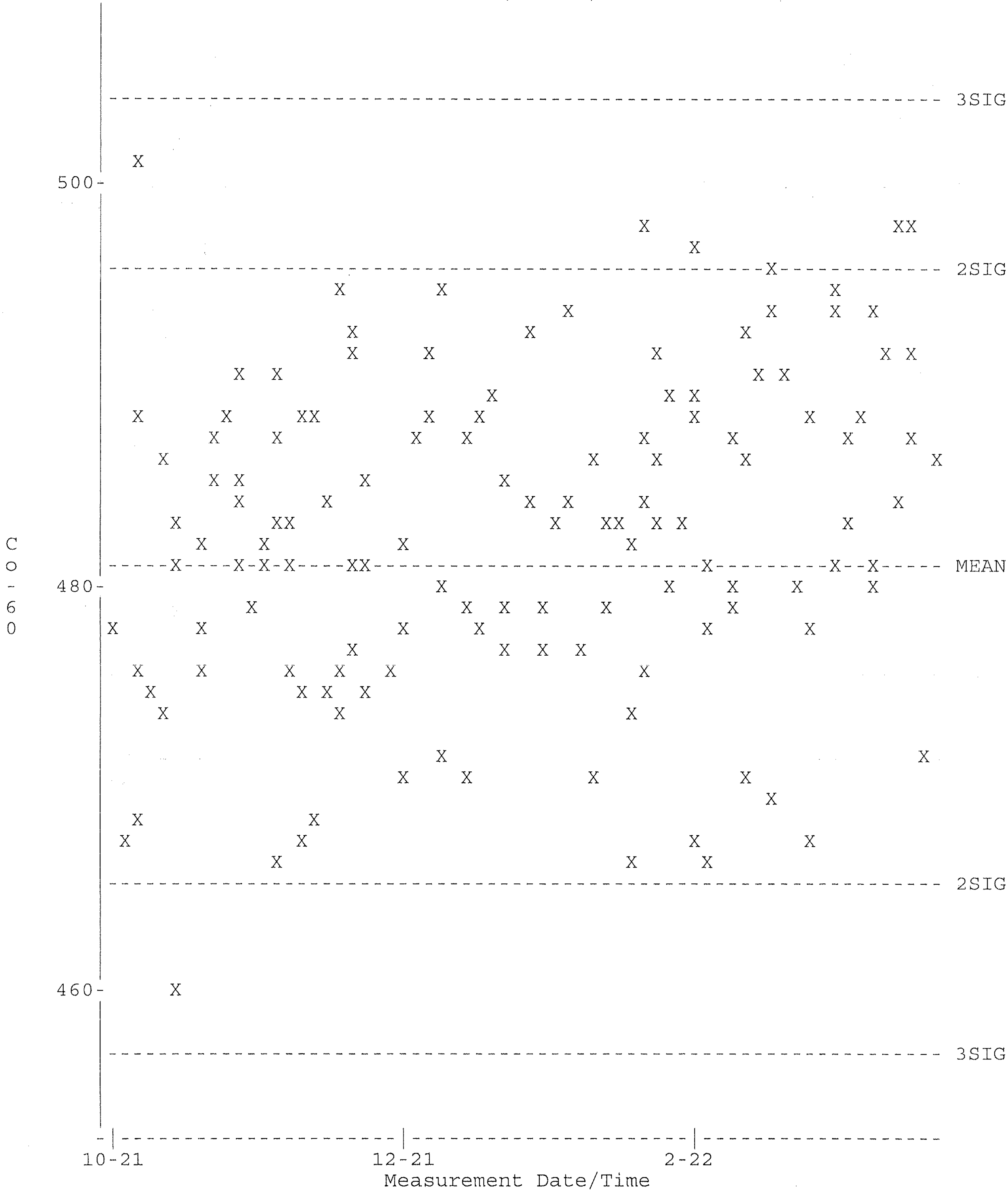
QA filename   : DKB100:[GAMMA.QUALITY]NEW_TBE11_QC.QAF;1
Parameter Name   : PSCENTRD (Centroid-1332)
Start/End Dates   : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 2660.00 through 2670.00



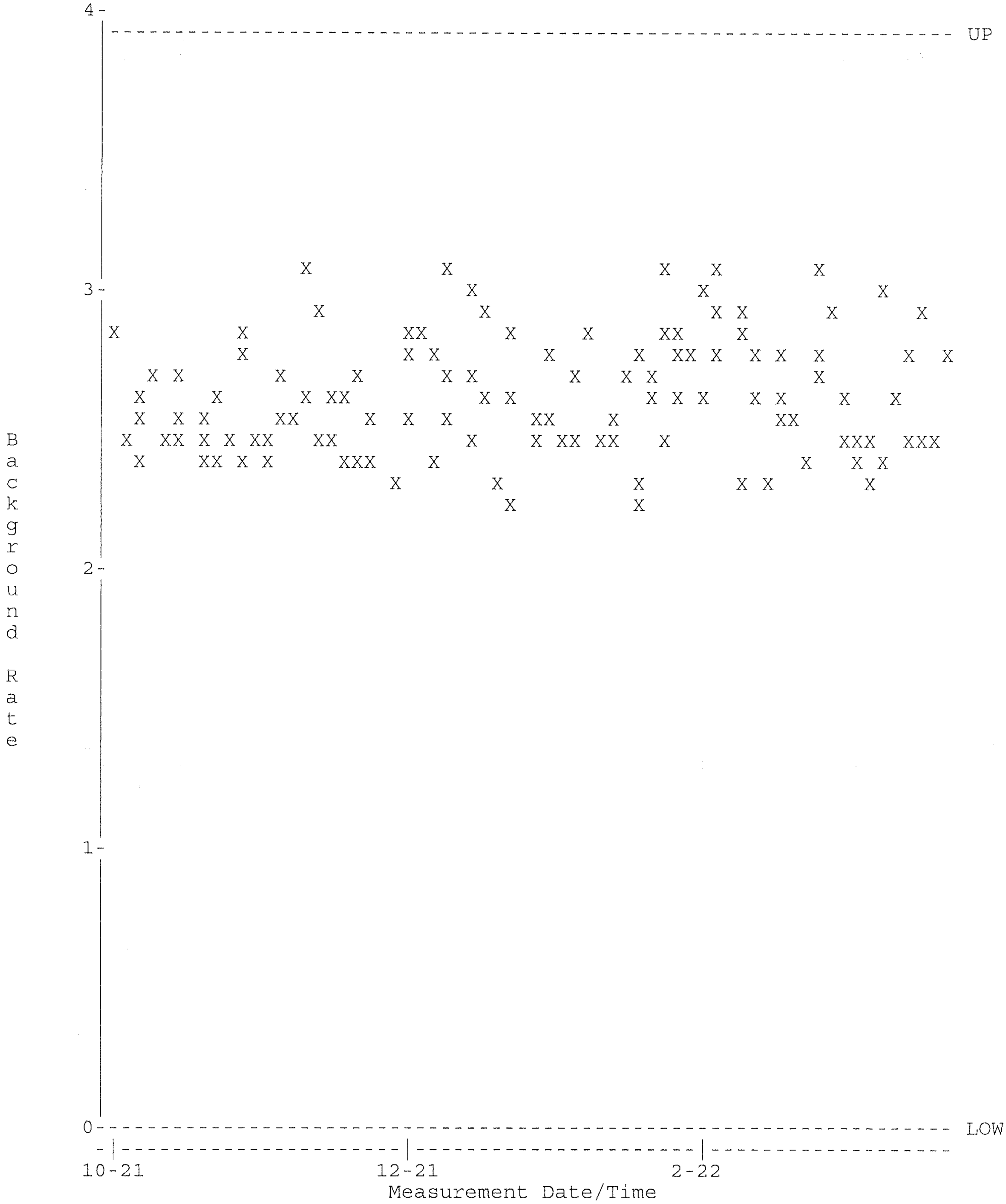
QA filename : DKB100:[GAMMA.QUALITY]NEW_TBE11_QC.QAF;1
Parameter Name : PSFWHM-1332 (FWHM-1332)
Start/End Dates : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 1.50000 through 2.60000



QA filename : DKB100:[GAMMA.QUALITY]NEW_TBE11_QC.QAF;1
Parameter Name : NCLWTMEAN-CO60 (Co-60)
Start/End Dates : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Mean +- Std Dev : 480.605 +- 7.84103 (1.63 %)

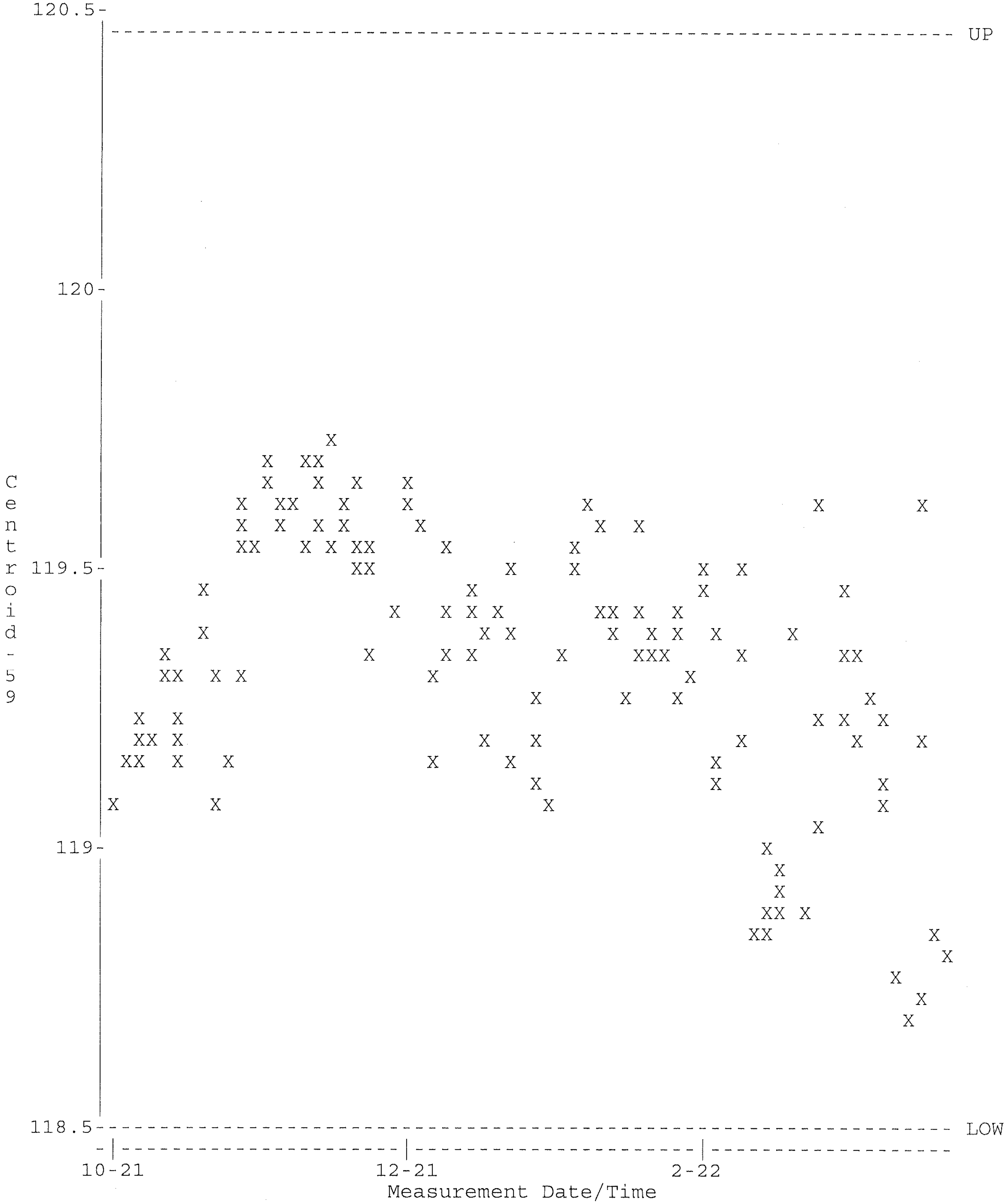


QA filename : DKB100:[GAMMA.QUALITY]TBE11_BKG_QC.QAF;1
Parameter Name : BACKRATE (Background Rate)
Start/End Dates : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Lower/Upper Lmts: 0.000000E+00 through 4.00000

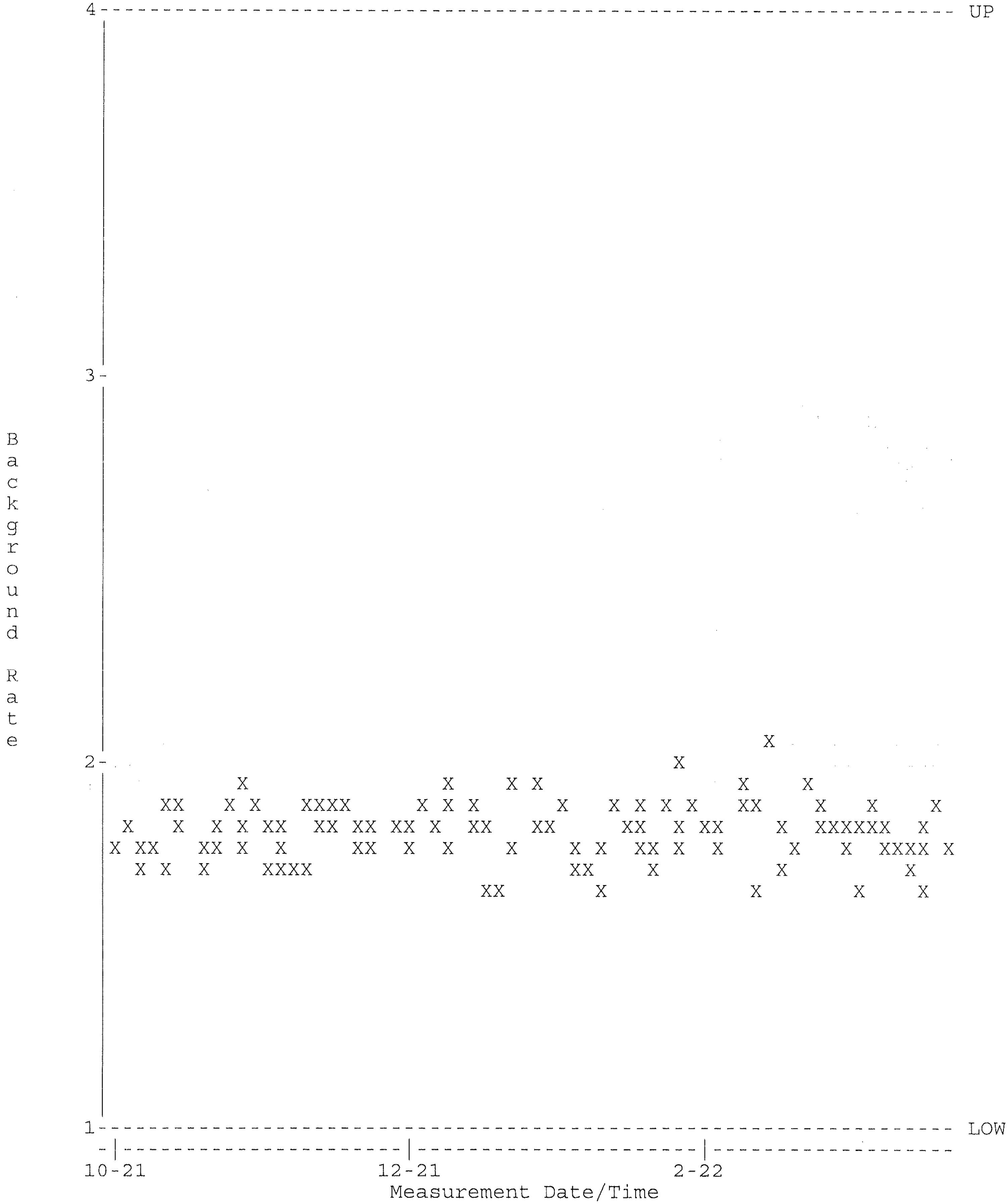


```
QA filename        : DKB100:[GAMMA.QUALITY]NEW_TBE11_QC.QAF;1
Parameter Name     : PSCENTRD-59 (Centroid-59)
Start/End Dates    : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 117.000 through 121.000
    121-
       |------------------------------------------------------------------ UP
       |
       |
       |
    120-
       |
       |
C      |
e      |
n      |
t      |
r   119-
o      |
i      |
d      |
-      |
5      |
9      |
       |
       |  X
    118-XXXXXX XX X
       |     X XXXXX X
       |       X  X XXX                                               X
       |            X XXXXXXX             XXXX               XX X X XX   XXX
       |                  XXX XX XX X XX X     X X          X X XX   X   XXX
       |                       XX   XX X      XX XXXX   X   XX
       |                                         XXXXXX X
       |                                             X  XX
       |
    117-------------------------------------------------------------------- LOW
      -|-----------------------|-----------------------|-------------------
      10-21                  12-21                   2-22
                            Measurement Date/Time
```

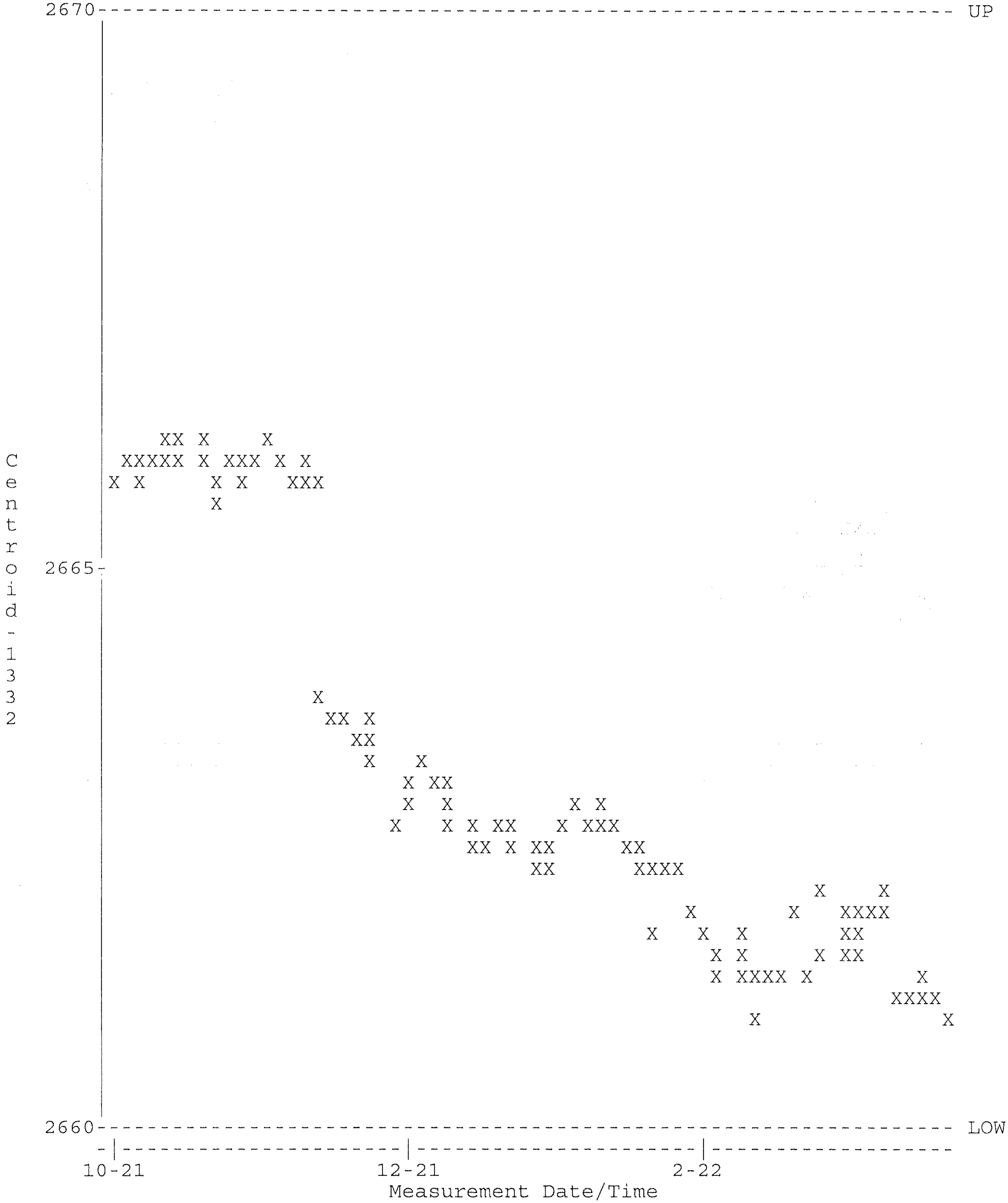
QA filename : DKB100:[GAMMA.QUALITY]NEW_TBE13_QC.QAF;1
Parameter Name : PSCENTRD-59 (Centroid-59)
Start/End Dates : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 118.500 through 120.500



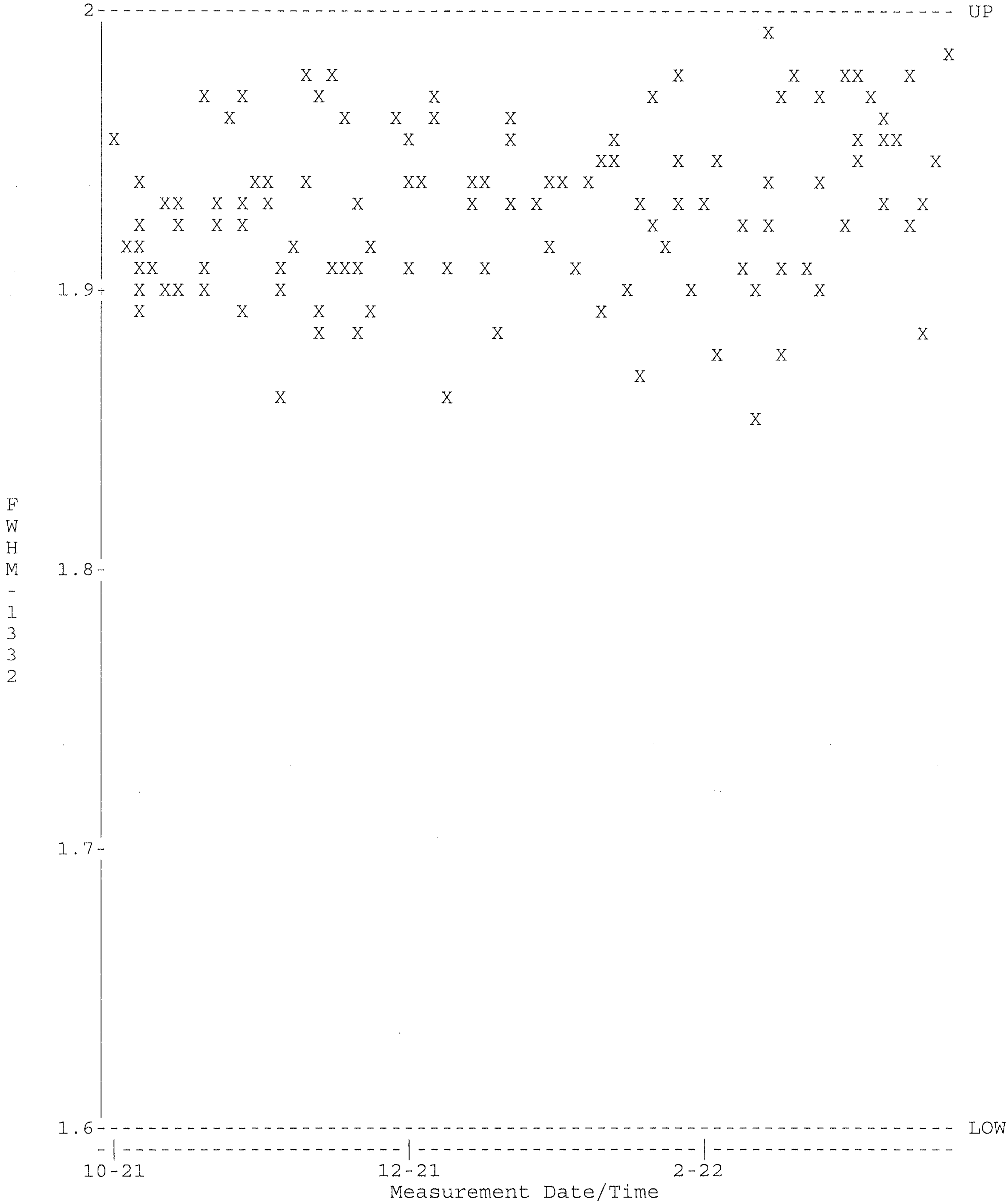
QA filename : DKB100:[GAMMA.QUALITY]TBE13_BKG_QC.QAF;1
Parameter Name : BACKRATE (Background Rate)
Start/End Dates : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Lower/Upper Lmts: 1.00000 through 4.00000



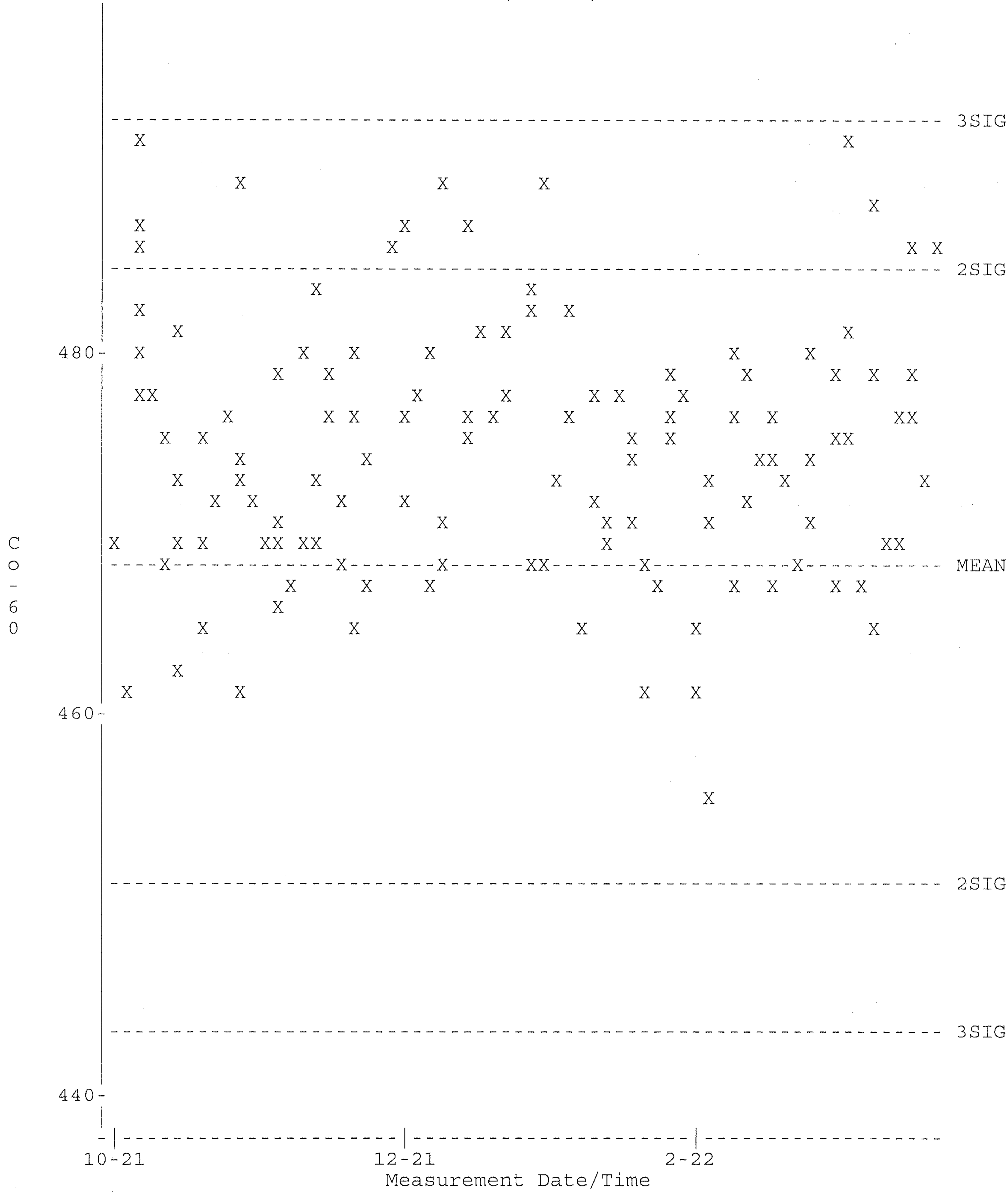
```
QA filename         : DKB100:[GAMMA.QUALITY]NEW_TBE13_QC.QAF;1
Parameter Name      : PSCENTRD (Centroid-1332)
Start/End Dates     : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 2660.00 through 2670.00
```



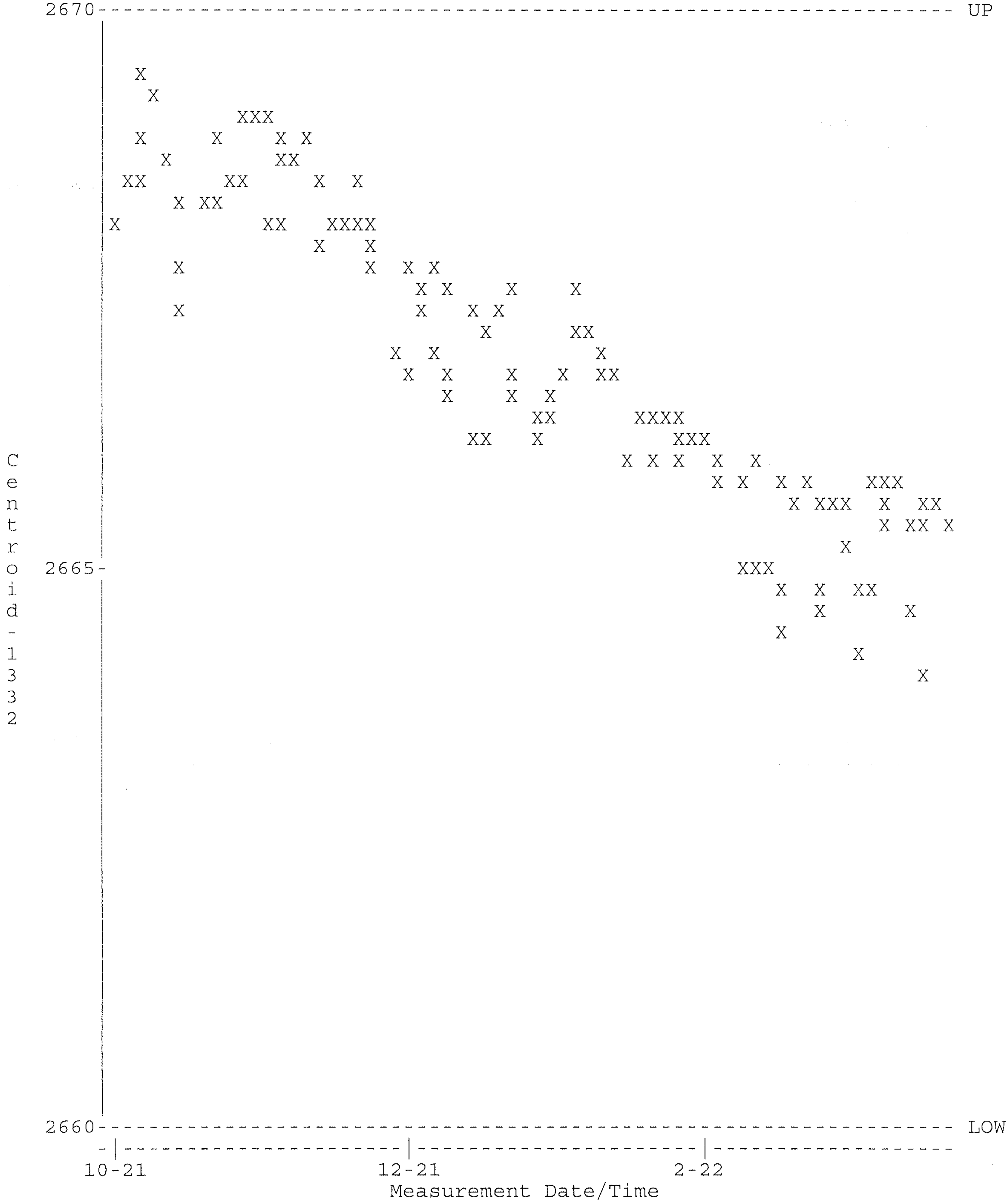
QA filename : DKB100:[GAMMA.QUALITY]NEW_TBE13_QC.QAF;1
Parameter Name : PSFWHM-1332 (FWHM-1332)
Start/End Dates : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 1.60000 through 2.00000



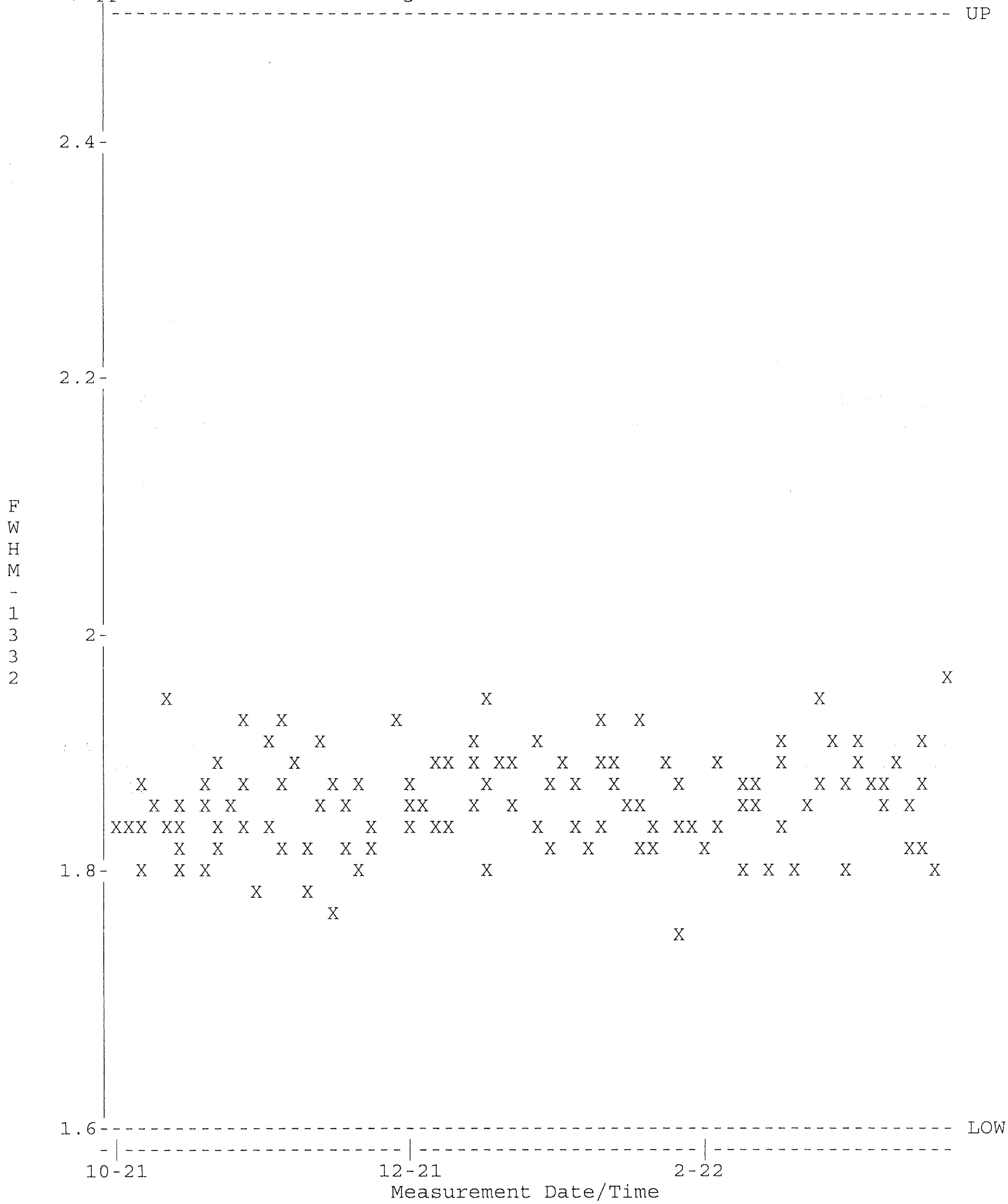
```
QA filename        : DKB100:[GAMMA.QUALITY]NEW_TBE13_QC.QAF;1
Parameter Name     : NCLWTMEAN-CO60 (Co-60)
Start/End Dates    : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Mean +- Std Dev    : 468.570 +- 8.25776 (1.76 %)
```



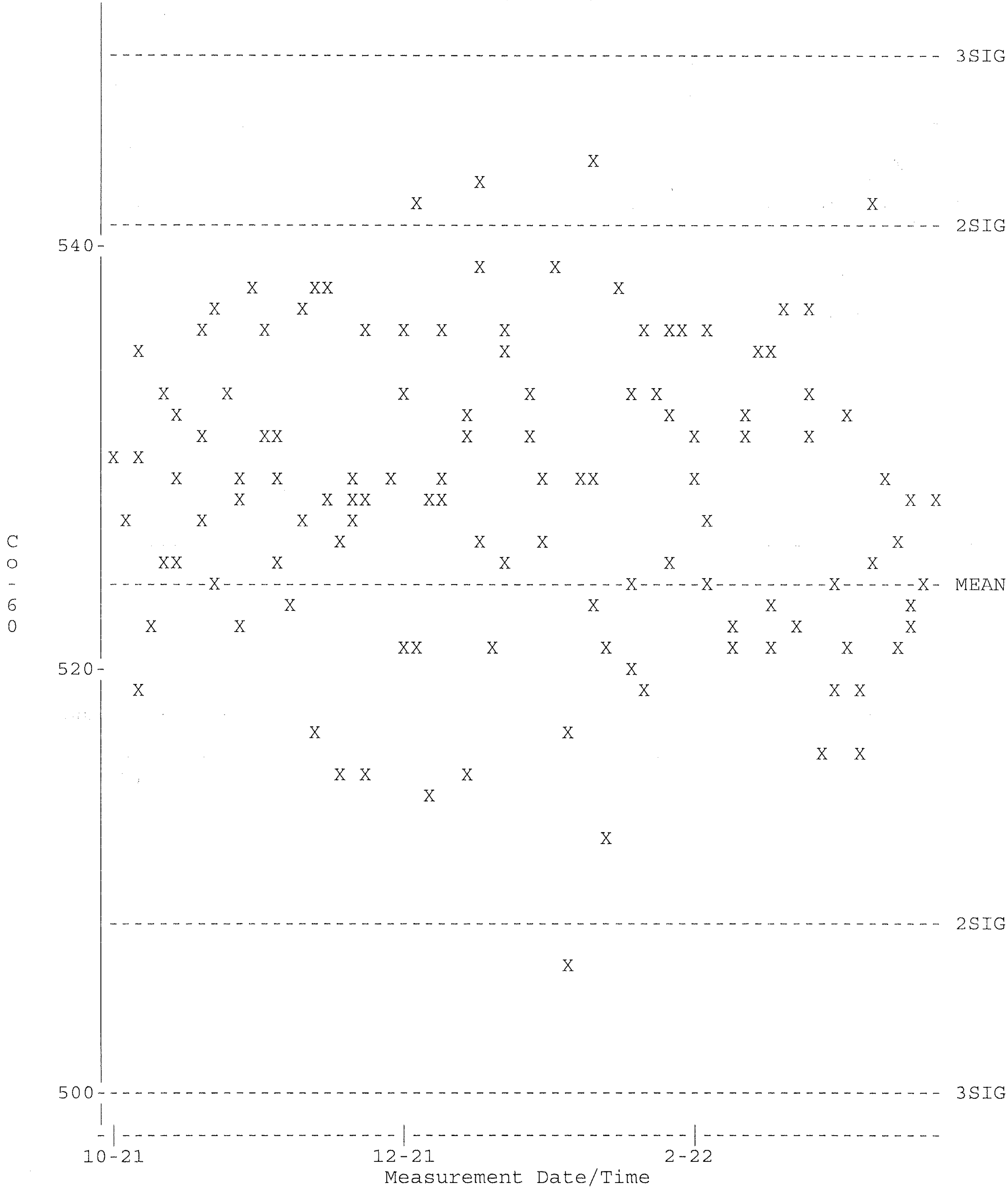
QA filename   : DKB100:[GAMMA.QUALITY]NEW_TBE14_QC.QAF;1
Parameter Name   : PSCENTRD (Centroid-1332)
Start/End Dates   : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Lower/Upper Lmts: 2660.00 through 2670.00



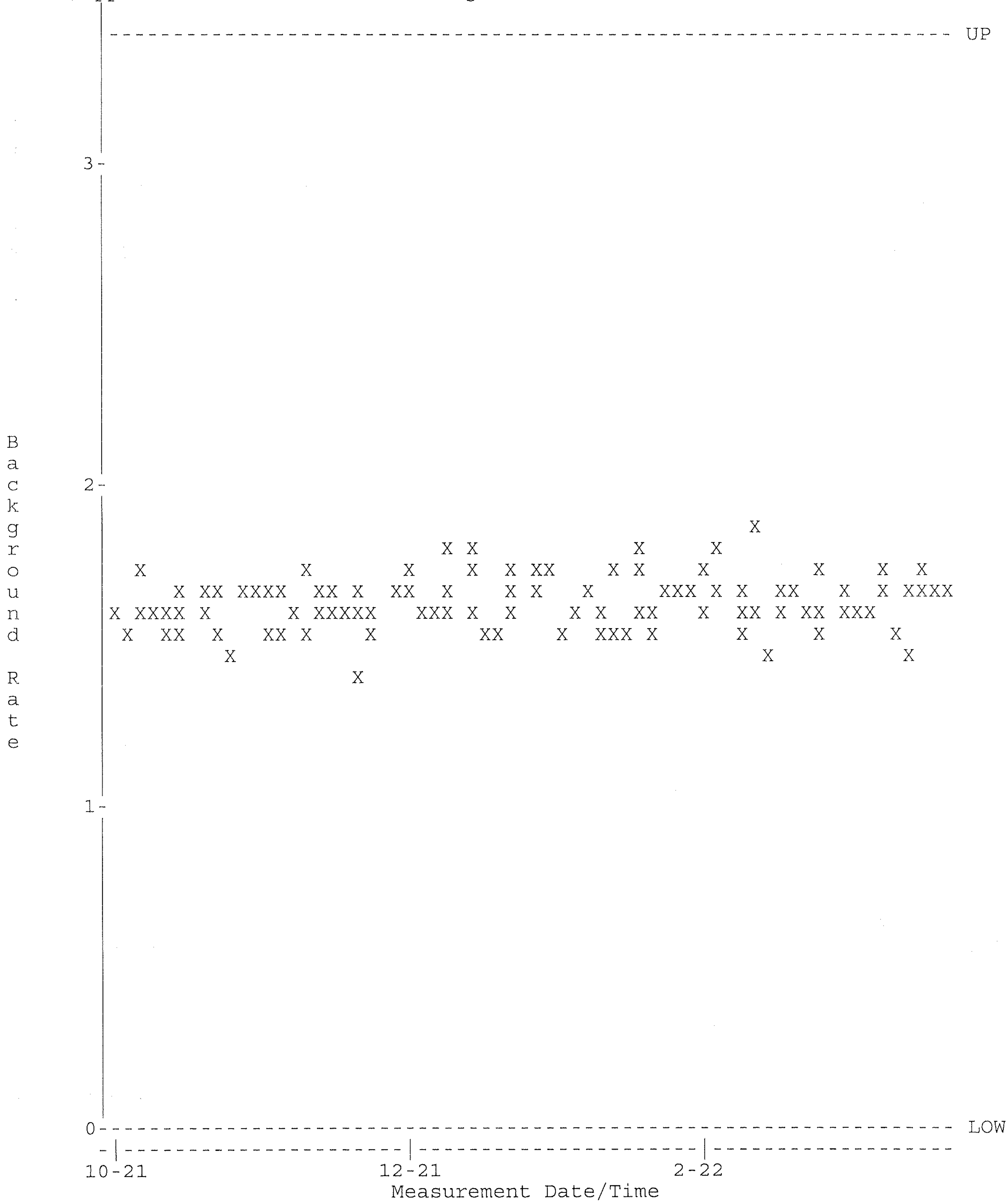
QA filename : DKB100:[GAMMA.QUALITY]NEW_TBE14_QC.QAF;1
Parameter Name : PSFWHM-1332 (FWHM-1332)
Start/End Dates : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Lower/Upper Lmts: 1.60000 through 2.50000



```
QA filename          : DKB100:[GAMMA.QUALITY]NEW_TBE14_QC.QAF;1
Parameter Name       : NCLWTMEAN-CO60 (Co-60)
Start/End Dates      : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Mean +- Std Dev      : 524.852 +- 8.11129 (1.55 %)
```



QA filename   : DKB100:[GAMMA.QUALITY]TBE14_BKG_QC.QAF;1
Parameter Name   : BACKRATE (Background Rate)
Start/End Dates   : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 0.000000E+00 through 3.50000



```
QA filename       : DKB100:[GAMMA.QUALITY]NEW_TBE23_QC.QAF;1
Parameter Name    : PSCENTRD (Centroid-1332)
Start/End Dates   : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Lower/Upper Lmts: 2660.00 through 2670.00
   2670-------------------------------------------------------------------- UP
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       |                                              X
       |                   X             X    XX  X  XXX     X X   XXX  X X
       |   XX     X XXXXXXX X  XX   XXXX XXXXXXXXXX X   X X XX  XXXXXXXXXX
C      |XXX  X XX X  X   X XX XX XX X  X           XX     XXXX X  X    XX
e      |         X X           X  X
n      |
t      |
r      |
o  2665-
i      |
d      |
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1      |
3      |
3      |
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       |
   2660-------------------------------------------------------------------- LOW
       -|----------------------|----------------------|--------------------
      10-21                  12-21                  2-22
                              Measurement Date/Time
```
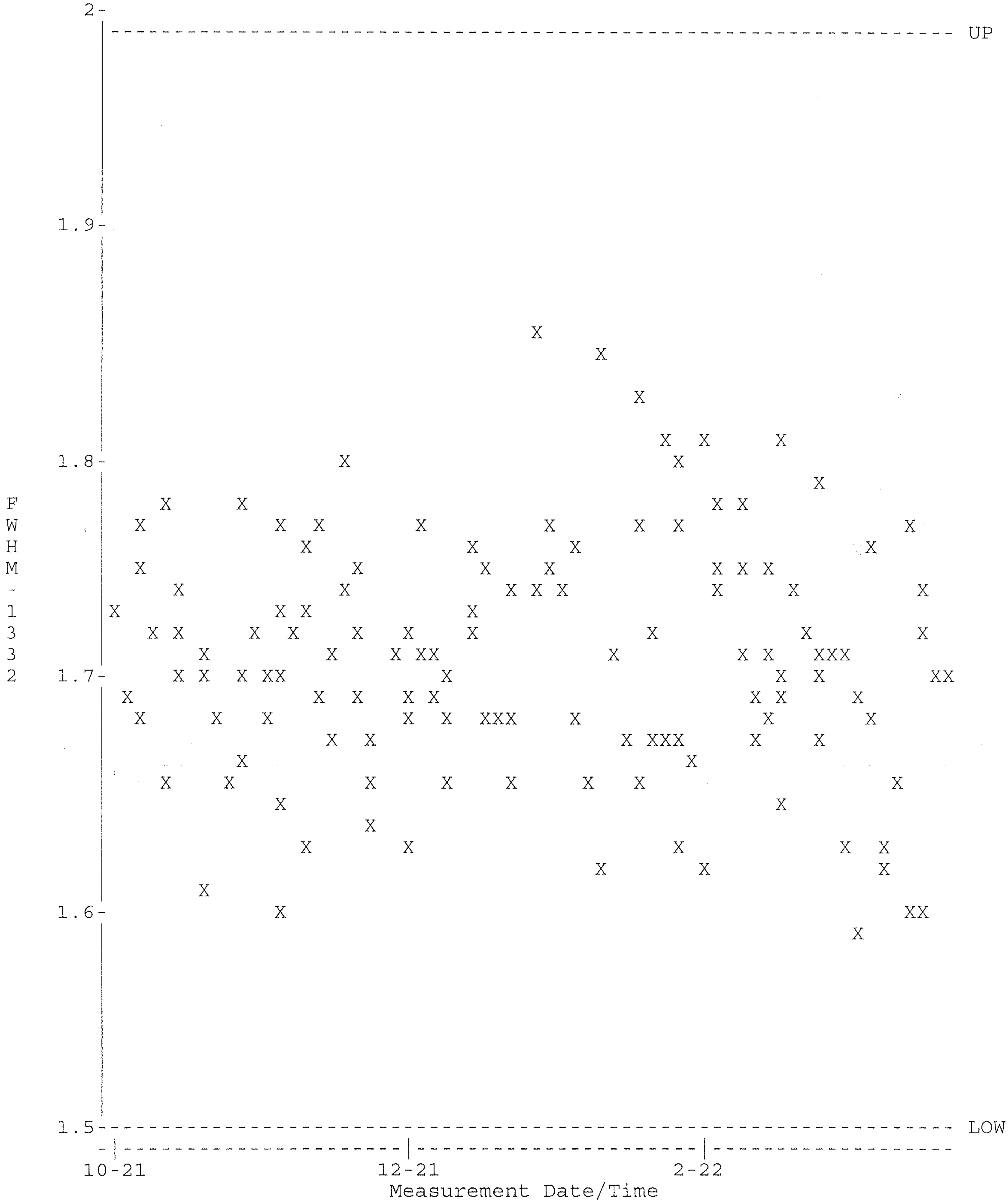
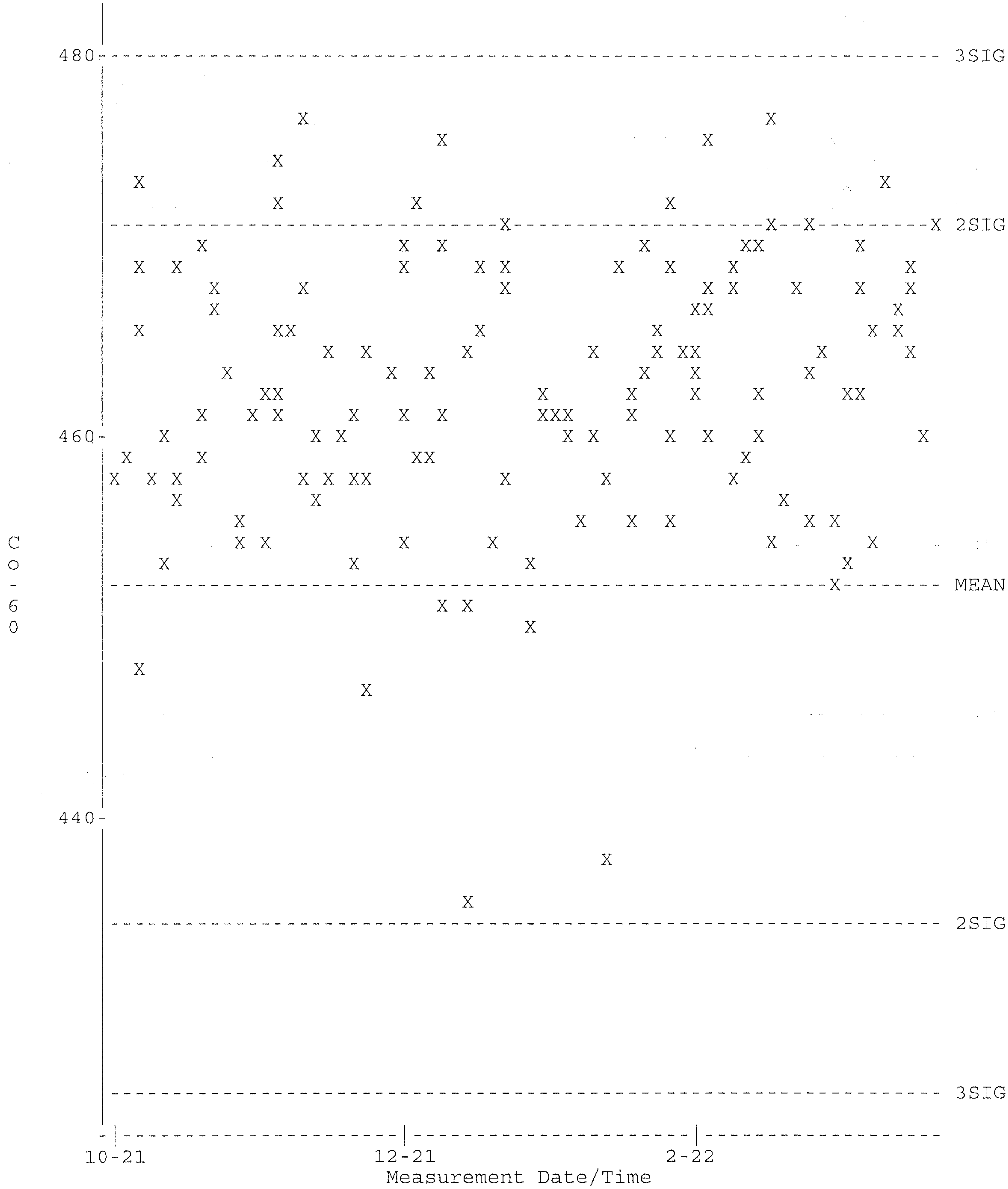

QA filename : DKB100:[GAMMA.QUALITY]NEW_TBE23_QC.QAF;1
Parameter Name : PSFWHM-1332 (FWHM-1332)
Start/End Dates : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Lower/Upper Lmts: 1.50000 through 2.00000



QA filename : DKB100:[GAMMA.QUALITY]NEW_TBE23_QC.QAF;1
Parameter Name : NCLWTMEAN-CO60 (Co-60)
Start/End Dates : 1-OCT-2021 08:41 through 23-MAR-2022 00:00
Mean +- Std Dev : 453.245 +- 9.00635 (1.99 %)



```
QA filename        : DKB100:[GAMMA.QUALITY]TBE23_BKG_QC.QAF;1
Parameter Name     : BACKRATE (Background Rate)
Start/End Dates    : 1-OCT-2021 08:57 through 23-MAR-2022 00:00
Lower/Upper Lmts: 0.000000E+00 through 3.50000
       |
       | ------------------------------------------------------------------ UP
       |
      3-
       |
       |
B      |
a      |
c     2-                             X
k      |  X  X    X  X  X X            X X         X   X
g      |  X       X  XX     X  X XX X          X    X XX X         X  X XX
r      |XX   X X X X   XXXXX  X X X X  X XX XXXX X XX  X  XXX    XXXXX XXX
o      |    X  XX X X  X   XX    XX XX    X     X XX X   XX X  X X  X X
u      |   X                          X    XX    XX X        XX   X    X
n      |
d      |
       |
R      |
a      |
t      |
e      |
      1-
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       |
       |
      0------------------------------------------------------------------- LOW
       -|-----------------------|-----------------------|--------------------
      10-21                   12-21                   2-22
                           Measurement Date/Time
```

GAMMA SPECTROSCOPY

Sample and QC Raw Data

Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 18-MAR-2022 08:06:57.99
TBE01 33-TP20784A HpGe ******* Aquisition Date/Time: 17-MAR-2022 14:52:09.25

LIMS No., Customer Name, Client ID: L95403-1 SS ANCHOR QEA

Sample ID : 01L95403-1
Sample Type : SS
Quantity : 2.14000E+01 g Dry
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: NORMK
Peak Evaluation - Identified and Unidentified

Smple Date: 13-FEB-2022 13:37:00.
Geometry : 01S25121819
BKGFILE : 01BG030422MT
Real Time : 0 17:14:38.71
Live time : 0 17:14:30.86

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	3	74.88*	211	1427	0.77	150.30	5.72E+00	3.39E-03	31.4	9.12E+00
2	3	77.11	575	1303	0.82	154.75	6.11E+00	9.27E-03	10.2	
3	1	87.32*	263	1190	1.12	175.15	7.65E+00	4.24E-03	24.0	9.79E-01
4	1	92.81*	477	1876	1.62	186.13	8.29E+00	7.69E-03	19.4	7.74E+00
5	1	185.83*	398	1411	1.38	372.03	9.12E+00	6.41E-03	20.7	1.43E+00
6	4	238.61*	1904	774	1.13	477.52	7.80E+00	3.07E-02	3.8	1.93E+00
7	4	241.56	677	1146	1.86	483.41	7.73E+00	1.09E-02	11.7	
8	1	295.13*	737	834	1.24	590.49	6.64E+00	1.19E-02	8.7	1.00E+00
9	1	338.21	466	869	1.55	676.59	5.95E+00	7.51E-03	13.1	5.31E-01
10	1	351.90*	1167	1076	1.40	703.94	5.76E+00	1.88E-02	7.4	1.77E+00
11	1	510.80*	273	925	2.66	1021.56	4.18E+00	4.40E-03	35.4	1.53E+00
12	1	583.02*	577	534	1.46	1165.93	3.71E+00	9.30E-03	10.0	9.72E-01
13	1	609.10*	828	613	1.47	1218.05	3.56E+00	1.33E-02	7.5	9.67E-01
14	1	910.89*	402	366	1.73	1821.39	2.42E+00	6.48E-03	12.4	7.36E-01
15	1	968.88*	275	180	1.92	1937.32	2.28E+00	4.43E-03	11.8	2.11E+00
16	1	1120.33*	185	215	1.98	2240.15	1.98E+00	2.97E-03	19.3	2.00E+00
17	1	1460.59*	1097	257	2.27	2920.55	1.54E+00	1.77E-02	5.0	1.30E+00
18	1	1764.45*	157	67	2.89	3528.27	1.32E+00	2.53E-03	16.5	1.38E+00

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1097	10.67*	1.540E+00	1.358E+01	1.358E+01	10.02
BI-214	609.31	828	46.30	3.560E+00	1.022E+00	1.022E+00	15.01
	1120.29	185	15.10*	1.978E+00	1.258E+00	1.258E+00	38.62
	1764.49	157	15.80	1.323E+00	1.531E+00	1.531E+00	32.92
RA-226	186.21	398	3.28*	9.116E+00	2.706E+00	2.706E+00	41.32
RA-228	93.35	477	3.50	8.292E+00	3.344E+00	3.380E+00	38.78
	969.11	275	16.60*	2.281E+00	1.476E+00	1.492E+00	23.69
TH-234	63.29	------	3.80*	3.510E+00	------	Line Not Found	------
	92.60	477	5.41	8.292E+00	2.164E+00	2.164E+00	38.78
U-235	143.76	------	10.50*	9.986E+00	------	Line Not Found	------

	163.35	------	4.70	9.656E+00	------	Line Not Found	------
	185.71	398	54.00	9.116E+00	1.644E-01	1.644E-01	41.32
	205.31	------	4.70	8.614E+00	------	Line Not Found	------

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	577	30.25*	3.705E+00	1.048E+00	1.082E+00	20.07
PB-212	238.63	1904	44.60*	7.796E+00	1.114E+00	1.151E+00	7.50
PB-214	295.21	737	19.20	6.641E+00	1.175E+00	1.176E+00	17.45
	351.92	1167	37.20*	5.756E+00	1.109E+00	1.109E+00	14.76
TH-232	911.21	402	27.70*	2.424E+00	1.219E+00	1.219E+00	24.84

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	2.638E+00	------	Line Not Found	------
	911.07	402	27.70*	2.424E+00	1.219E+00	1.232E+00	24.84

Flag: "*" = Keyline

Total number of lines in spectrum	18	
Number of unidentified lines	6	
Number of lines tentatively identified by NID	12	66.67%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.358E+01	1.358E+01	0.136E+01	10.02	
BI-214	1600.00Y	1.00	1.258E+00	1.258E+00	0.486E+00	38.62	
RA-226	1600.00Y	1.00	2.706E+00	2.706E+00	1.118E+00	41.32	
RA-228	5.75Y	1.01	1.476E+00	1.492E+00	0.354E+00	23.69	
TH-234	4.47E+09Y	1.00	2.164E+00	2.164E+00	0.839E+00	38.78	K
U-235	7.04E+08Y	1.00	1.644E-01	1.644E-01	0.679E-01	41.32	K
			---------	---------			
	Total Activity :		2.135E+01	2.136E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.048E+00	1.082E+00	0.217E+00	20.07	
PB-212	1.91Y	1.03	1.114E+00	1.151E+00	0.086E+00	7.50	
PB-214	1600.00Y	1.00	1.109E+00	1.109E+00	0.164E+00	14.76	
TH-232	1.41E+10Y	1.00	1.219E+00	1.219E+00	0.303E+00	24.84	
			---------	---------			
	Total Activity :		4.490E+00	4.561E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.219E+00	1.232E+00	0.306E+00	24.84	
			---------	---------			
	Total Activity :		1.219E+00	1.232E+00			

Grand Total Activity : 2.706E+01 2.715E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
3	74.88	211	1427	0.77	150.30	147	11	3.39E-03	62.7	5.72E+00	
3	77.11	575	1303	0.82	154.75	147	11	9.27E-03	20.4	6.11E+00	
1	87.32	263	1190	1.12	175.15	173	6	4.24E-03	47.9	7.65E+00	
4	241.56	677	1146	1.86	483.41	470	20	1.09E-02	23.3	7.73E+00	
1	338.21	466	869	1.55	676.59	671	11	7.51E-03	26.1	5.95E+00	
1	510.80	273	925	2.66	1021.56	1013	20	4.40E-03	70.9	4.18E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	18	
Number of unidentified lines	6	
Number of lines tentatively identified by NID	12	66.67%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.358E+01	1.358E+01	0.136E+01	10.02	
BI-214	1600.00Y	1.00	1.081E+00	1.081E+00	0.140E+00	12.99	
RA-226	1600.00Y	1.00	2.706E+00	2.706E+00	1.118E+00	41.32	
RA-228	5.75Y	1.01	1.476E+00	1.492E+00	0.354E+00	23.69	
			---------	---------			
	Total Activity :		1.884E+01	1.886E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.048E+00	1.082E+00	0.217E+00	20.07	
PB-212	1.91Y	1.03	1.114E+00	1.151E+00	0.086E+00	7.50	
PB-214	1600.00Y	1.00	1.135E+00	1.135E+00	0.128E+00	11.27	
TH-232	1.41E+10Y	1.00	1.219E+00	1.219E+00	0.303E+00	24.84	
			---------	---------			
	Total Activity :		4.516E+00	4.587E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.219E+00	1.232E+00	0.306E+00	24.84	
			---------	---------			
	Total Activity :		1.219E+00	1.232E+00			

Grand Total Activity : 2.458E+01 2.468E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.358E+01	1.360E+00	6.965E-01	0.000E+00	19.493
TL-208	1.082E+00	2.172E-01	1.791E-01	0.000E+00	6.043
PB-212	1.151E+00	8.629E-02	8.237E-02	0.000E+00	13.967
BI-214	1.081E+00	1.405E-01	4.700E-01	0.000E+00	2.301
PB-214	1.135E+00	1.280E-01	1.114E-01	0.000E+00	10.190
RA-226	2.706E+00	1.118E+00	1.017E+00	0.000E+00	2.661
AC-228	1.232E+00	3.061E-01	2.313E-01	0.000E+00	5.327
RA-228	1.492E+00	3.535E-01	4.220E-01	0.000E+00	3.536
TH-232	1.219E+00	3.028E-01	2.289E-01	0.000E+00	5.326

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	2.373E-02		4.376E-02	7.376E-02	0.000E+00	0.322
CS-137	1.809E-02		3.945E-02	6.620E-02	0.000E+00	0.273
LA-138	-1.311E-02		6.369E-02	1.021E-01	0.000E+00	-0.128
BI-212	1.532E+00		5.193E-01	9.377E-01	0.000E+00	1.634
PA-234M	-2.786E+00		5.066E+00	7.426E+00	0.000E+00	-0.375
TH-234	3.169E-01		1.833E+00	2.692E+00	0.000E+00	0.118
U-235	6.268E-02		2.156E-01	3.086E-01	0.000E+00	0.203
U-238	-2.786E+00		5.066E+00	7.426E+00	0.000E+00	-0.375

```
A,01L95403-1       ,03/18/2022 08:06,02/13/2022 13:37,    2.140E+01,L95403-1 SS AN
B,01L95403-1       ,NORMK                     ,11/17/2021 15:33,01S25121819
C,K-40     ,YES,   1.358E+01,   1.360E+00,   6.965E-01,,   19.493
C,TL-208   ,YES,   1.082E+00,   2.172E-01,   1.791E-01,,    6.043
C,PB-212   ,YES,   1.151E+00,   8.629E-02,   8.237E-02,,   13.967
C,BI-214   ,YES,   1.081E+00,   1.405E-01,   4.700E-01,,    2.301
C,PB-214   ,YES,   1.135E+00,   1.280E-01,   1.114E-01,,   10.190
C,RA-226   ,YES,   2.706E+00,   1.118E+00,   1.017E+00,,    2.661
C,AC-228   ,YES,   1.232E+00,   3.061E-01,   2.313E-01,,    5.327
C,RA-228   ,YES,   1.492E+00,   3.535E-01,   4.220E-01,,    3.536
C,TH-232   ,YES,   1.219E+00,   3.028E-01,   2.289E-01,,    5.326
C,CO-60    ,NO ,   2.373E-02,   4.376E-02,   7.376E-02,,    0.322
C,CS-137   ,NO ,   1.809E-02,   3.945E-02,   6.620E-02,,    0.273
C,LA-138   ,NO ,  -1.311E-02,   6.369E-02,   1.021E-01,,   -0.128
C,BI-212   ,NO ,   1.532E+00,   5.193E-01,   9.377E-01,,    1.634
C,PA-234M  ,NO ,  -2.786E+00,   5.066E+00,   7.426E+00,,   -0.375
C,TH-234   ,NO ,   3.169E-01,   1.833E+00,   2.692E+00,,    0.118
C,U-235    ,NO ,   6.268E-02,   2.156E-01,   3.086E-01,,    0.203
C,U-238    ,NO ,  -2.786E+00,   5.066E+00,   7.426E+00,,   -0.375
```

Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 19-MAR-2022 05:31:28.83
TBE02 51-TP42214B HpGe ******* Aquisition Date/Time: 18-MAR-2022 11:31:04.83

LIMS No., Customer Name, Client ID: L95403-2 SS ANCHOR QEA

Sample ID : 02L95403-2
Sample Type : SS
Quantity : 3.23000E+01 g Dry
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: NORMK
Peak Evaluation - Identified and Unidentified

Smple Date: 13-FEB-2022 13:37:00.
Geometry : 02S25121819
BKGFILE : 02BG030422MT
Real Time : 0 18:00:10.93
Live time : 0 18:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	63.14*	192	2312	1.04	111.02	6.08E+00	2.96E-03	48.5	
2	0	77.11*	1313	1760	0.91	139.12	8.44E+00	2.03E-02	6.1	
3	5	87.14*	821	1801	1.34	159.30	9.45E+00	1.27E-02	10.3	1.92E+01
4	5	89.80	547	1511	1.23	164.65	9.63E+00	8.44E-03	12.6	
5	5	92.78*	728	1650	1.38	170.64	9.81E+00	1.12E-02	12.2	
6	0	185.87*	512	1786	1.01	357.95	8.34E+00	7.91E-03	18.0	
7	0	209.21	329	1246	0.85	404.92	7.66E+00	5.07E-03	19.4	
8	5	238.60*	2652	959	1.02	464.07	6.92E+00	4.09E-02	2.9	2.70E+00
9	5	241.60*	582	1326	1.51	470.11	6.85E+00	8.99E-03	13.2	
10	0	295.07*	770	1200	1.14	577.70	5.79E+00	1.19E-02	10.4	
11	0	338.33*	524	776	0.96	664.75	5.15E+00	8.08E-03	11.2	
12	0	351.86*	1260	875	1.19	691.97	4.97E+00	1.94E-02	6.0	
13	0	463.02	212	460	1.25	915.68	3.88E+00	3.27E-03	19.6	
14	0	510.88*	373	859	2.20	1011.99	3.54E+00	5.75E-03	24.8	
15	0	583.03*	787	493	1.30	1157.19	3.12E+00	1.22E-02	7.4	
16	0	609.14*	897	681	1.38	1209.74	2.99E+00	1.38E-02	7.9	
17	0	727.15	227	252	2.04	1447.24	2.51E+00	3.50E-03	14.8	
18	0	911.06*	545	363	1.65	1817.39	2.00E+00	8.41E-03	9.6	
19	0	968.83	334	170	1.71	1933.64	1.88E+00	5.16E-03	9.2	
20	0	1120.05*	202	261	1.99	2238.04	1.63E+00	3.12E-03	21.3	
21	0	1460.37*	1549	116	2.20	2923.10	1.26E+00	2.39E-02	3.3	
22	0	1764.20*	132	55	2.07	3534.78	1.08E+00	2.03E-03	17.6	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1549	10.67*	1.263E+00	1.484E+01	1.484E+01	6.69
BI-214	609.31	897	46.30	2.991E+00	8.362E-01	8.362E-01	15.79
	1120.29	202	15.10*	1.627E+00	1.064E+00	1.064E+00	42.69
	1764.49	132	15.80	1.083E+00	9.930E-01	9.931E-01	35.26
RA-226	186.21	512	3.28*	8.336E+00	2.420E+00	2.420E+00	35.95
RA-228	93.35	728	3.50	9.805E+00	2.739E+00	2.769E+00	24.34

	969.11	334	16.60*	1.883E+00	1.381E+00	1.396E+00	18.36
TH-234	63.29	192	3.80*	6.076E+00	1.073E+00	1.073E+00	96.91
	92.60	728	5.41	9.805E+00	1.772E+00	1.772E+00	24.34
U-235	143.76	------	10.50*	9.647E+00	------	Line Not Found	------
	163.35	------	4.70	9.042E+00	------	Line Not Found	------
	185.71	512	54.00	8.336E+00	1.470E-01	1.470E-01	35.95
	205.31	------	4.70	7.767E+00	------	Line Not Found	------

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	787	30.25*	3.120E+00	1.077E+00	1.114E+00	14.83
BI-212	727.17	227	7.56*	2.514E+00	1.539E+00	1.590E+00	29.59
PB-212	238.63	2652	44.60*	6.915E+00	1.110E+00	1.147E+00	5.82
PB-214	295.21	770	19.20	5.795E+00	8.941E-01	8.942E-01	20.84
	351.92	1260	37.20*	4.970E+00	8.797E-01	8.797E-01	12.09
TH-232	911.21	545	27.70*	2.005E+00	1.267E+00	1.267E+00	19.12

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	2.188E+00	------	Line Not Found	------
	911.07	545	27.70*	2.005E+00	1.267E+00	1.281E+00	19.12

Flag: "*" = Keyline

Sample ID : 02L95403-2 Acquisition date : 18-MAR-2022 11:31:04

Total number of lines in spectrum	22	
Number of unidentified lines	8	
Number of lines tentatively identified by NID	14	63.64%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.484E+01	1.484E+01	0.099E+01	6.69	
BI-214	1600.00Y	1.00	1.064E+00	1.064E+00	0.454E+00	42.69	
RA-226	1600.00Y	1.00	2.420E+00	2.420E+00	0.870E+00	35.95	
RA-228	5.75Y	1.01	1.381E+00	1.396E+00	0.256E+00	18.36	
TH-234	4.47E+09Y	1.00	1.073E+00	1.073E+00	1.039E+00	96.91	
U-235	7.04E+08Y	1.00	1.470E-01	1.470E-01	0.528E-01	35.95	K
			---------	---------			
	Total Activity :		2.093E+01	2.094E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.077E+00	1.114E+00	0.165E+00	14.83	
BI-212	1.91Y	1.03	1.539E+00	1.590E+00	0.471E+00	29.59	
PB-212	1.91Y	1.03	1.110E+00	1.147E+00	0.067E+00	5.82	
PB-214	1600.00Y	1.00	8.797E-01	8.797E-01	1.063E-01	12.09	
TH-232	1.41E+10Y	1.00	1.267E+00	1.267E+00	0.242E+00	19.12	
			---------	---------			
	Total Activity :		5.874E+00	5.999E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.267E+00	1.281E+00	0.245E+00	19.12	
			---------	---------			
	Total Activity :		1.267E+00	1.281E+00			

Grand Total Activity : 2.807E+01 2.822E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
0	77.11	1313	1760	0.91	139.12	137	6	2.03E-02	12.2	8.44E+00	
5	87.14	821	1801	1.34	159.30	149	29	1.27E-02	20.7	9.45E+00	
5	89.80	547	1511	1.23	164.65	149	29	8.44E-03	25.3	9.63E+00	
0	209.21	329	1246	0.85	404.92	402	8	5.07E-03	38.7	7.66E+00	
5	241.60	582	1326	1.51	470.11	459	16	8.99E-03	26.3	6.85E+00	
0	338.33	524	776	0.96	664.75	661	8	8.08E-03	22.3	5.15E+00	
0	463.02	212	460	1.25	915.68	912	9	3.27E-03	39.1	3.88E+00	
0	510.88	373	859	2.20	1011.99	1003	18	5.75E-03	49.7	3.54E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	22	
Number of unidentified lines	8	
Number of lines tentatively identified by NID	14	63.64%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.484E+01	1.484E+01	0.099E+01	6.69	
BI-214	1600.00Y	1.00	8.700E-01	8.701E-01	1.192E-01	13.70	
RA-226	1600.00Y	1.00	2.420E+00	2.420E+00	0.870E+00	35.95	
RA-228	5.75Y	1.01	1.381E+00	1.396E+00	0.256E+00	18.36	
TH-234	4.47E+09Y	1.00	1.073E+00	1.073E+00	1.039E+00	96.91	
			---------	---------			
	Total Activity :		2.059E+01	2.060E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.077E+00	1.114E+00	0.165E+00	14.83	
BI-212	1.91Y	1.03	1.539E+00	1.590E+00	0.471E+00	29.59	
PB-212	1.91Y	1.03	1.110E+00	1.147E+00	0.067E+00	5.82	
PB-214	1600.00Y	1.00	8.832E-01	8.833E-01	0.924E-01	10.46	
TH-232	1.41E+10Y	1.00	1.267E+00	1.267E+00	0.242E+00	19.12	
			---------	---------			
	Total Activity :		5.877E+00	6.002E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.267E+00	1.281E+00	0.245E+00	19.12	
			---------	---------			
	Total Activity :		1.267E+00	1.281E+00			

Grand Total Activity : 2.773E+01 2.789E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.484E+01	9.933E-01	4.345E-01	0.000E+00	34.167
TL-208	1.114E+00	1.652E-01	1.200E-01	0.000E+00	9.277
BI-212	1.590E+00	4.705E-01	5.317E-01	0.000E+00	2.991
PB-212	1.147E+00	6.672E-02	6.172E-02	0.000E+00	18.590
BI-214	8.701E-01	1.192E-01	3.223E-01	0.000E+00	2.699
PB-214	8.833E-01	9.235E-02	7.771E-02	0.000E+00	11.366
RA-226	2.420E+00	8.700E-01	7.375E-01	0.000E+00	3.281
AC-228	1.281E+00	2.450E-01	1.565E-01	0.000E+00	8.189
RA-228	1.396E+00	2.563E-01	3.292E-01	0.000E+00	4.241
TH-232	1.267E+00	2.423E-01	1.548E-01	0.000E+00	8.188
TH-234	1.073E+00	1.039E+00	9.231E-01	0.000E+00	1.162

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	9.394E-03		3.120E-02	5.256E-02	0.000E+00	0.179
CS-137	3.628E-02		2.996E-02	5.245E-02	0.000E+00	0.692
LA-138	2.455E-02		4.447E-02	7.582E-02	0.000E+00	0.324
PA-234M	-6.569E-01		3.770E+00	5.480E+00	0.000E+00	-0.120
U-235	1.716E-01		1.494E-01	2.211E-01	0.000E+00	0.776
U-238	-6.569E-01		3.770E+00	5.480E+00	0.000E+00	-0.120

```
A,02L95403-2       ,03/19/2022 05:31,02/13/2022 13:37,    3.230E+01,L95403-2 SS AN
B,02L95403-2       ,NORMK                      ,08/20/2021 05:25,02S25121819
C,K-40      ,YES,   1.484E+01,    9.933E-01,    4.345E-01,,   34.167
C,TL-208    ,YES,   1.114E+00,    1.652E-01,    1.200E-01,,    9.277
C,BI-212    ,YES,   1.590E+00,    4.705E-01,    5.317E-01,,    2.991
C,PB-212    ,YES,   1.147E+00,    6.672E-02,    6.172E-02,,   18.590
C,BI-214    ,YES,   8.701E-01,    1.192E-01,    3.223E-01,,    2.699
C,PB-214    ,YES,   8.833E-01,    9.235E-02,    7.771E-02,,   11.366
C,RA-226    ,YES,   2.420E+00,    8.700E-01,    7.375E-01,,    3.281
C,AC-228    ,YES,   1.281E+00,    2.450E-01,    1.565E-01,,    8.189
C,RA-228    ,YES,   1.396E+00,    2.563E-01,    3.292E-01,,    4.241
C,TH-232    ,YES,   1.267E+00,    2.423E-01,    1.548E-01,,    8.188
C,TH-234    ,YES,   1.073E+00,    1.039E+00,    9.231E-01,,    1.162
C,CO-60     ,NO ,   9.394E-03,    3.120E-02,    5.256E-02,,    0.179
C,CS-137    ,NO ,   3.628E-02,    2.996E-02,    5.245E-02,,    0.692
C,LA-138    ,NO ,   2.455E-02,    4.447E-02,    7.582E-02,,    0.324
C,PA-234M   ,NO ,  -6.569E-01,    3.770E+00,    5.480E+00,,   -0.120
C,U-235     ,NO ,   1.716E-01,    1.494E-01,    2.211E-01,,    0.776
C,U-238     ,NO ,  -6.569E-01,    3.770E+00,    5.480E+00,,   -0.120
```

Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 19-MAR-2022 05:14:14.64
TBE14 54-TP42603C HpGe ******* Aquisition Date/Time: 18-MAR-2022 11:13:46.19

LIMS No., Customer Name, Client ID: L95403-3 SS ANCHOR QEA

Sample ID : 14L95403-3
Sample Type : SS
Quantity : 3.57000E+01 g Dry
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: NORMK
Peak Evaluation - Identified and Unidentified

Smple Date: 13-FEB-2022 13:37:00.
Geometry : 14S25121719
BKGFILE : 14BG030422MT
Real Time : 0 18:00:12.89
Live time : 0 18:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	4	74.94*	514	1425	0.77	147.04	7.23E+00	7.93E-03	13.1	8.30E+00
2	4	77.16	1220	1116	0.81	151.49	7.57E+00	1.88E-02	5.2	
3	6	84.40*	86	1467	1.20	165.98	8.49E+00	1.33E-03	83.9	4.47E+00
4	6	87.22*	351	1067	0.84	171.63	8.78E+00	5.41E-03	17.3	
5	5	89.95	405	660	0.96	177.08	9.03E+00	6.26E-03	10.2	2.67E+00
6	5	92.89*	633	1312	1.40	182.98	9.26E+00	9.77E-03	12.1	
7	1	185.97*	515	1260	1.21	369.32	8.55E+00	7.94E-03	15.4	1.40E+00
8	1	209.31	303	1062	1.13	416.06	7.87E+00	4.68E-03	20.2	1.41E+00
9	6	238.65*	2289	709	0.99	474.81	7.10E+00	3.53E-02	3.1	2.12E+00
10	6	241.46	580	1021	1.64	480.43	7.03E+00	8.95E-03	12.0	
11	1	295.22*	637	671	1.05	588.08	5.91E+00	9.83E-03	8.7	6.43E-01
12	1	338.32	497	692	0.97	674.39	5.22E+00	7.66E-03	10.5	8.49E-01
13	1	351.92*	1000	669	1.21	701.63	5.03E+00	1.54E-02	6.2	9.22E-01
14	1	510.90*	159	724	2.55	1019.97	3.51E+00	2.45E-03	52.0	1.16E+00
15	1	583.16*	604	381	1.27	1164.68	3.07E+00	9.31E-03	7.9	2.15E+00
16	1	609.27*	749	483	1.44	1216.97	2.94E+00	1.16E-02	7.6	1.84E+00
17	1	661.51	89	376	1.07	1321.59	2.70E+00	1.38E-03	43.4	1.13E+00
18	1	727.61	110	336	1.79	1454.00	2.45E+00	1.70E-03	35.0	2.16E+00
19	1	911.10*	464	245	1.81	1821.50	1.94E+00	7.15E-03	9.3	6.72E-01
20	1	968.94*	190	363	1.57	1937.38	1.82E+00	2.93E-03	22.3	4.07E+00
21	1	1120.28*	77	209	1.41	2240.54	1.57E+00	1.19E-03	41.1	2.34E+00
22	1	1460.65*	1273	168	1.92	2922.47	1.21E+00	1.97E-02	4.0	1.71E+00
23	1	1764.31*	140	67	2.36	3530.99	1.04E+00	2.16E-03	18.1	6.67E-01

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1273	10.67*	1.210E+00	1.152E+01	1.152E+01	8.00
CS-137	661.66	89	85.12*	2.701E+00	4.535E-02	4.544E-02	86.79
BI-214	609.31	749	46.30	2.937E+00	6.436E-01	6.436E-01	15.21
	1120.29	77	15.10*	1.565E+00	3.816E-01	3.816E-01	82.12
	1764.49	140	15.80	1.037E+00	9.986E-01	9.986E-01	36.28

RA-226	186.21	515	3.28*	8.546E+00	2.145E+00	2.146E+00	30.70
RA-228	93.35	633	3.50	9.263E+00	2.281E+00	2.306E+00	24.21
	969.11	190	16.60*	1.818E+00	7.363E-01	7.444E-01	44.67
TH-234	63.29	------	3.80*	5.083E+00	------	Line Not Found	------
	92.60	633	5.41	9.263E+00	1.476E+00	1.476E+00	24.21
U-235	143.76	------	10.50*	9.757E+00	------	Line Not Found	------
	163.35	------	4.70	9.227E+00	------	Line Not Found	------
	185.71	515	54.00	8.546E+00	1.303E-01	1.303E-01	30.70
	205.31	------	4.70	7.978E+00	------	Line Not Found	------

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	604	30.25*	3.071E+00	7.591E-01	7.846E-01	15.85
BI-212	727.17	110	7.56*	2.448E+00	6.959E-01	7.193E-01	69.95
PB-212	238.63	2289	44.60*	7.096E+00	8.448E-01	8.732E-01	6.21
PB-214	295.21	637	19.20	5.908E+00	6.561E-01	6.561E-01	17.47
	351.92	1000	37.20*	5.027E+00	6.246E-01	6.246E-01	12.43
TH-232	911.21	464	27.70*	1.938E+00	1.009E+00	1.009E+00	18.63

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	2.121E+00	------	Line Not Found	------
	911.07	464	27.70*	1.938E+00	1.009E+00	1.020E+00	18.63

Flag: "*" = Keyline

Total number of lines in spectrum	23	
Number of unidentified lines	9	
Number of lines tentatively identified by NID	14	60.87%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.152E+01	1.152E+01	0.092E+01	8.00	
CS-137	30.07Y	1.00	4.535E-02	4.544E-02	3.944E-02	86.79	
BI-214	1600.00Y	1.00	3.816E-01	3.816E-01	3.134E-01	82.12	
RA-226	1600.00Y	1.00	2.145E+00	2.146E+00	0.659E+00	30.70	
RA-228	5.75Y	1.01	7.363E-01	7.444E-01	3.326E-01	44.67	
TH-234	4.47E+09Y	1.00	1.476E+00	1.476E+00	0.357E+00	24.21	K
U-235	7.04E+08Y	1.00	1.303E-01	1.303E-01	0.400E-01	30.70	K
			---------	---------			
	Total Activity :		1.643E+01	1.644E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	7.591E-01	7.846E-01	1.244E-01	15.85	
BI-212	1.91Y	1.03	6.959E-01	7.193E-01	5.031E-01	69.95	
PB-212	1.91Y	1.03	8.448E-01	8.732E-01	0.542E-01	6.21	
PB-214	1600.00Y	1.00	6.246E-01	6.246E-01	0.777E-01	12.43	
TH-232	1.41E+10Y	1.00	1.009E+00	1.009E+00	0.188E+00	18.63	
			---------	---------			
	Total Activity :		3.933E+00	4.011E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.009E+00	1.020E+00	0.190E+00	18.63	
			---------	---------			
	Total Activity :		1.009E+00	1.020E+00			

Grand Total Activity : 2.138E+01 2.147E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
4	74.94	514	1425	0.77	147.04	144	11	7.93E-03	26.2	7.23E+00	
4	77.16	1220	1116	0.81	151.49	144	11	1.88E-02	10.3	7.57E+00	
6	84.40	86	1467	1.20	165.98	161	15	1.33E-03	****	8.49E+00	
6	87.22	351	1067	0.84	171.63	161	15	5.41E-03	34.5	8.78E+00	
5	89.95	405	660	0.96	177.08	175	15	6.26E-03	20.4	9.03E+00	
1	209.31	303	1062	1.13	416.06	412	9	4.68E-03	40.4	7.87E+00	
6	241.46	580	1021	1.64	480.43	470	21	8.95E-03	24.1	7.03E+00	
1	338.32	497	692	0.97	674.39	670	9	7.66E-03	21.0	5.22E+00	
1	510.90	159	724	2.55	1019.97	1012	17	2.45E-03	****	3.51E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	23	
Number of unidentified lines	9	
Number of lines tentatively identified by NID	14	60.87%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.152E+01	1.152E+01	0.092E+01	8.00	
CS-137	30.07Y	1.00	4.535E-02	4.544E-02	3.944E-02	86.79	
BI-214	1600.00Y	1.00	6.439E-01	6.439E-01	0.905E-01	14.05	
RA-226	1600.00Y	1.00	2.145E+00	2.146E+00	0.659E+00	30.70	
RA-228	5.75Y	1.01	7.363E-01	7.444E-01	3.326E-01	44.67	
			---------	---------			
	Total Activity :		1.509E+01	1.510E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	7.591E-01	7.846E-01	1.244E-01	15.85	
BI-212	1.91Y	1.03	6.959E-01	7.193E-01	5.031E-01	69.95	
PB-212	1.91Y	1.03	8.448E-01	8.732E-01	0.542E-01	6.21	
PB-214	1600.00Y	1.00	6.345E-01	6.345E-01	0.643E-01	10.13	
TH-232	1.41E+10Y	1.00	1.009E+00	1.009E+00	0.188E+00	18.63	
			---------	---------			
	Total Activity :		3.943E+00	4.020E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.009E+00	1.020E+00	0.190E+00	18.63	
			---------	---------			
	Total Activity :		1.009E+00	1.020E+00			

Grand Total Activity : 2.004E+01 2.014E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.152E+01	9.220E-01	4.250E-01	0.000E+00	27.108
CS-137	4.544E-02	3.944E-02	4.199E-02	0.000E+00	1.082
TL-208	7.846E-01	1.244E-01	1.120E-01	0.000E+00	7.003
BI-212	7.193E-01	5.031E-01	4.996E-01	0.000E+00	1.440
PB-212	8.732E-01	5.424E-02	4.816E-02	0.000E+00	18.133
BI-214	6.439E-01	9.046E-02	3.255E-01	0.000E+00	1.978
PB-214	6.345E-01	6.430E-02	6.623E-02	0.000E+00	9.581
RA-226	2.146E+00	6.587E-01	5.670E-01	0.000E+00	3.784
AC-228	1.020E+00	1.901E-01	1.412E-01	0.000E+00	7.225
RA-228	7.444E-01	3.326E-01	2.472E-01	0.000E+00	3.012
TH-232	1.009E+00	1.880E-01	1.397E-01	0.000E+00	7.224

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	-9.852E-03		2.792E-02	4.553E-02	0.000E+00	-0.216
LA-138	2.089E-02		3.731E-02	6.434E-02	0.000E+00	0.325
PA-234M	2.587E+00		2.831E+00	4.845E+00	0.000E+00	0.534
TH-234	3.381E-01		6.488E-01	9.629E-01	0.000E+00	0.351
U-235	9.583E-02		9.860E-02	1.676E-01	0.000E+00	0.572
U-238	2.587E+00		2.831E+00	4.845E+00	0.000E+00	0.534

```
A,14L95403-3       ,03/19/2022 05:14,02/13/2022 13:37,   3.570E+01,L95403-3 SS AN
B,14L95403-3       ,NORMK                     ,08/11/2021 12:59,14S25121719
C,K-40     ,YES,   1.152E+01,   9.220E-01,   4.250E-01,,   27.108
C,CS-137   ,YES,   4.544E-02,   3.944E-02,   4.199E-02,,    1.082
C,TL-208   ,YES,   7.846E-01,   1.244E-01,   1.120E-01,,    7.003
C,BI-212   ,YES,   7.193E-01,   5.031E-01,   4.996E-01,,    1.440
C,PB-212   ,YES,   8.732E-01,   5.424E-02,   4.816E-02,,   18.133
C,BI-214   ,YES,   6.439E-01,   9.046E-02,   3.255E-01,,    1.978
C,PB-214   ,YES,   6.345E-01,   6.430E-02,   6.623E-02,,    9.581
C,RA-226   ,YES,   2.146E+00,   6.587E-01,   5.670E-01,,    3.784
C,AC-228   ,YES,   1.020E+00,   1.901E-01,   1.412E-01,,    7.225
C,RA-228   ,YES,   7.444E-01,   3.326E-01,   2.472E-01,,    3.012
C,TH-232   ,YES,   1.009E+00,   1.880E-01,   1.397E-01,,    7.224
C,CO-60    ,NO ,  -9.852E-03,   2.792E-02,   4.553E-02,,   -0.216
C,LA-138   ,NO ,   2.089E-02,   3.731E-02,   6.434E-02,,    0.325
C,PA-234M  ,NO ,   2.587E+00,   2.831E+00,   4.845E+00,,    0.534
C,TH-234   ,NO ,   3.381E-01,   6.488E-01,   9.629E-01,,    0.351
C,U-235    ,NO ,   9.583E-02,   9.860E-02,   1.676E-01,,    0.572
C,U-238    ,NO ,   2.587E+00,   2.831E+00,   4.845E+00,,    0.534
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Analyst:

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===============================================================================
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 18-MAR-2022 08:07:09.71
TBE11 59-TN51806A HpGe ******* Aquisition Date/Time: 17-MAR-2022 14:52:09.62
-------------------------------------------------------------------------------
LIMS No., Customer Name, Client ID: L95403-4 SS ANCHOR QEA

Sample ID      : 11L95403-4                         Smple Date: 13-FEB-2022 13:37:00.
Sample Type    : SS                                 Geometry  : 11S25121819
Quantity       : 2.67000E+01 g Dry                  BKGFILE   : 11BG030422MT
Start Channel  : 80       Energy Tol   : 2.00000    Real Time : 0 17:14:46.96
End Channel    : 4090     Pk Srch Sens: 9.00000     Live time : 0 17:14:15.60
MDA Multiple   : 4.6600   Library Used: NORMK
Peak Evaluation - Identified and Unidentified
```

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.48*	483	2243	1.10	91.59	9.09E+00	7.78E-03	22.0	
2	0	63.39*	207	2438	1.09	125.39	1.09E+01	3.33E-03	47.7	
3	0	77.39*	1096	2306	1.00	153.39	1.09E+01	1.77E-02	8.3	
4	2	84.71*	283	1987	1.41	168.02	1.07E+01	4.55E-03	32.9	2.18E+00
5	2	87.29*	487	1529	1.08	173.17	1.06E+01	7.85E-03	15.0	
6	2	90.16	356	1218	1.13	178.91	1.04E+01	5.73E-03	15.2	4.19E+00
7	2	92.88*	556	1910	1.43	184.35	1.03E+01	8.96E-03	17.8	
8	0	186.12*	293	1817	1.33	370.78	6.83E+00	4.72E-03	31.3	
9	4	238.87*	1875	1050	1.41	476.24	5.68E+00	3.02E-02	4.2	1.77E+00
10	4	241.82	644	1445	1.79	482.15	5.63E+00	1.04E-02	12.9	
11	0	295.37*	699	1105	1.42	589.22	4.83E+00	1.13E-02	10.3	
12	0	338.34	426	1036	1.42	675.13	4.34E+00	6.87E-03	15.4	
13	0	352.26*	1403	1048	1.43	702.95	4.20E+00	2.26E-02	5.8	
14	0	511.35*	383	1107	2.59	1021.04	3.08E+00	6.17E-03	29.2	
15	0	583.60*	507	652	1.60	1165.49	2.74E+00	8.16E-03	12.5	
16	0	609.66*	1052	728	1.54	1217.60	2.64E+00	1.69E-02	7.2	
17	0	911.62*	425	316	1.92	1821.36	1.80E+00	6.86E-03	11.5	
18	0	969.56*	252	245	2.00	1937.18	1.70E+00	4.06E-03	14.8	
19	0	1120.74*	219	334	2.67	2239.48	1.48E+00	3.53E-03	22.5	
20	0	1461.39*	1265	209	1.96	2920.59	1.15E+00	2.04E-02	4.6	
21	0	1765.21*	214	133	2.21	3528.07	9.86E-01	3.45E-03	16.9	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1265	10.67*	1.152E+00	1.678E+01	1.678E+01	9.26
BI-214	609.31	1052	46.30	2.637E+00	1.405E+00	1.405E+00	14.43
	1120.29	219	15.10*	1.476E+00	1.601E+00	1.601E+00	44.98
	1764.49	214	15.80	9.865E-01	2.239E+00	2.239E+00	33.82
RA-226	186.21	293	3.28*	6.828E+00	2.132E+00	2.132E+00	62.56
RA-228	93.35	556	3.50	1.033E+01	2.508E+00	2.535E+00	35.59
	969.11	252	16.60*	1.700E+00	1.458E+00	1.473E+00	29.61

TH-234	63.29	207	3.80*	1.086E+01	8.176E-01	8.176E-01	95.47
	92.60	556	5.41	1.033E+01	1.623E+00	1.623E+00	35.59

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	507	30.25*	2.743E+00	9.958E-01	1.028E+00	24.92
PB-212	238.63	1875	44.60*	5.683E+00	1.207E+00	1.246E+00	8.43
PB-214	295.21	699	19.20	4.831E+00	1.229E+00	1.229E+00	20.66
	351.92	1403	37.20*	4.204E+00	1.464E+00	1.464E+00	11.63
TH-232	911.21	425	27.70*	1.804E+00	1.389E+00	1.389E+00	22.92

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	1.963E+00	------	Line Not Found	------
	911.07	425	27.70*	1.804E+00	1.389E+00	1.403E+00	22.92

Flag: "*" = Keyline

Sample ID : 11L95403-4 Acquisition date : 17-MAR-2022 14:52:09

Total number of lines in spectrum	21	
Number of unidentified lines	8	
Number of lines tentatively identified by NID	13	61.90%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.678E+01	1.678E+01	0.155E+01	9.26	
BI-214	1600.00Y	1.00	1.601E+00	1.601E+00	0.720E+00	44.98	
RA-226	1600.00Y	1.00	2.132E+00	2.132E+00	1.334E+00	62.56	
RA-228	5.75Y	1.01	1.458E+00	1.473E+00	0.436E+00	29.61	
TH-234	4.47E+09Y	1.00	8.176E-01	8.176E-01	7.805E-01	95.47	
			---------	---------			
	Total Activity :		2.279E+01	2.281E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	9.958E-01	1.028E+00	0.256E+00	24.92	
PB-212	1.91Y	1.03	1.207E+00	1.246E+00	0.105E+00	8.43	
PB-214	1600.00Y	1.00	1.464E+00	1.464E+00	0.170E+00	11.63	
TH-232	1.41E+10Y	1.00	1.389E+00	1.389E+00	0.318E+00	22.92	
			---------	---------			
	Total Activity :		5.055E+00	5.127E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.389E+00	1.403E+00	0.322E+00	22.92	
			---------	---------			
	Total Activity :		1.389E+00	1.403E+00			

Grand Total Activity : 2.923E+01 2.934E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
0	46.48	483	2243	1.10	91.59	86	11	7.78E-03	44.1	9.09E+00	
0	77.39	1096	2306	1.00	153.39	151	6	1.77E-02	16.5	1.09E+01	
2	84.71	283	1987	1.41	168.02	163	14	4.55E-03	65.9	1.07E+01	
2	87.29	487	1529	1.08	173.17	163	14	7.85E-03	29.9	1.06E+01	
2	90.16	356	1218	1.13	178.91	177	14	5.73E-03	30.5	1.04E+01	
4	241.82	644	1445	1.79	482.15	468	21	1.04E-02	25.8	5.63E+00	
0	338.34	426	1036	1.42	675.13	670	11	6.87E-03	30.7	4.34E+00	
0	511.35	383	1107	2.59	1021.04	1012	22	6.17E-03	58.5	3.08E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	21	
Number of unidentified lines	8	
Number of lines tentatively identified by NID	13	61.90%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.678E+01	1.678E+01	0.155E+01	9.26	
BI-214	1600.00Y	1.00	1.470E+00	1.470E+00	0.189E+00	12.85	
RA-226	1600.00Y	1.00	2.132E+00	2.132E+00	1.334E+00	62.56	
RA-228	5.75Y	1.01	1.458E+00	1.473E+00	0.436E+00	29.61	
TH-234	4.47E+09Y	1.00	8.176E-01	8.176E-01	7.805E-01	95.47	
			---------	---------			
	Total Activity :		2.266E+01	2.268E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	9.958E-01	1.028E+00	0.256E+00	24.92	
PB-212	1.91Y	1.03	1.207E+00	1.246E+00	0.105E+00	8.43	
PB-214	1600.00Y	1.00	1.391E+00	1.391E+00	0.141E+00	10.16	
TH-232	1.41E+10Y	1.00	1.389E+00	1.389E+00	0.318E+00	22.92	
			---------	---------			
	Total Activity :		4.982E+00	5.054E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.389E+00	1.403E+00	0.322E+00	22.92	
			---------	---------			
	Total Activity :		1.389E+00	1.403E+00			

Grand Total Activity : 2.903E+01 2.913E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.678E+01	1.555E+00	7.497E-01	0.000E+00	22.385
TL-208	1.028E+00	2.563E-01	2.157E-01	0.000E+00	4.768
PB-212	1.246E+00	1.050E-01	1.043E-01	0.000E+00	11.943
BI-214	1.470E+00	1.890E-01	5.569E-01	0.000E+00	2.640
PB-214	1.391E+00	1.414E-01	1.444E-01	0.000E+00	9.635
RA-226	2.132E+00	1.334E+00	1.296E+00	0.000E+00	1.644
AC-228	1.403E+00	3.216E-01	2.754E-01	0.000E+00	5.096
RA-228	1.473E+00	4.363E-01	5.049E-01	0.000E+00	2.918
TH-232	1.389E+00	3.182E-01	2.725E-01	0.000E+00	5.095
TH-234	8.176E-01	7.805E-01	7.981E-01	0.000E+00	1.024

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	6.016E-02		5.007E-02	8.966E-02	0.000E+00	0.671
CS-137	3.262E-02		4.891E-02	8.317E-02	0.000E+00	0.392
LA-138	1.077E-02		6.984E-02	1.232E-01	0.000E+00	0.087
BI-212	1.629E+00		6.298E-01	1.127E+00	0.000E+00	1.445
PA-234M	8.169E+00		5.190E+00	9.382E+00	0.000E+00	0.871
U-235	-1.355E-01		2.442E-01	3.662E-01	0.000E+00	-0.370
U-238	8.169E+00		5.190E+00	9.382E+00	0.000E+00	0.871

```
A,11L95403-4       ,03/18/2022 08:07,02/13/2022 13:37,   2.670E+01,L95403-4 SS AN
B,11L95403-4       ,NORMK                      ,02/10/2022 09:58,11S25121819
C,K-40     ,YES,   1.678E+01,    1.555E+00,    7.497E-01,,   22.385
C,TL-208   ,YES,   1.028E+00,    2.563E-01,    2.157E-01,,    4.768
C,PB-212   ,YES,   1.246E+00,    1.050E-01,    1.043E-01,,   11.943
C,BI-214   ,YES,   1.470E+00,    1.890E-01,    5.569E-01,,    2.640
C,PB-214   ,YES,   1.391E+00,    1.414E-01,    1.444E-01,,    9.635
C,RA-226   ,YES,   2.132E+00,    1.334E+00,    1.296E+00,,    1.644
C,AC-228   ,YES,   1.403E+00,    3.216E-01,    2.754E-01,,    5.096
C,RA-228   ,YES,   1.473E+00,    4.363E-01,    5.049E-01,,    2.918
C,TH-232   ,YES,   1.389E+00,    3.182E-01,    2.725E-01,,    5.095
C,TH-234   ,YES,   8.176E-01,    7.805E-01,    7.981E-01,,    1.024
C,CO-60    ,NO ,   6.016E-02,    5.007E-02,    8.966E-02,,    0.671
C,CS-137   ,NO ,   3.262E-02,    4.891E-02,    8.317E-02,,    0.392
C,LA-138   ,NO ,   1.077E-02,    6.984E-02,    1.232E-01,,    0.087
C,BI-212   ,NO ,   1.629E+00,    6.298E-01,    1.127E+00,,    1.445
C,PA-234M  ,NO ,   8.169E+00,    5.190E+00,    9.382E+00,,    0.871
C,U-235    ,NO ,  -1.355E-01,    2.442E-01,    3.662E-01,,   -0.370
C,U-238    ,NO ,   8.169E+00,    5.190E+00,    9.382E+00,,    0.871
```

Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 19-MAR-2022 05:14:38.90
TBE13 31-TP10727B HpGe ******* Aquisition Date/Time: 18-MAR-2022 11:13:56.06

LIMS No., Customer Name, Client ID: L95403-5 SS ANCHOR QEA

Sample ID : 13L95403-5
Sample Type : SS
Quantity : 3.04000E+01 g Dry
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: NORMK
Peak Evaluation - Identified and Unidentfied

Smple Date: 13-FEB-2022 13:37:00.
Geometry : 13S25030421
BKGFILE : 13BG030422MT
Real Time : 0 18:00:15.23
Live time : 0 18:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	74.95*	168	1533	0.71	149.81	3.49E+00	2.59E-03	42.9	8.98E+00
2	1	77.15*	482	1120	0.84	154.19	3.83E+00	7.43E-03	13.5	3.92E+00
3	1	84.51*	162	1375	1.36	168.88	4.91E+00	2.51E-03	44.6	4.02E+00
4	1	87.30*	285	1007	0.90	174.44	5.29E+00	4.40E-03	20.5	3.30E+00
5	1	92.71*	430	1292	1.18	185.24	5.95E+00	6.63E-03	17.1	6.73E-01
6	1	185.74*	446	1395	1.29	370.86	7.62E+00	6.89E-03	17.9	2.76E+00
7	1	209.10	242	1084	1.02	417.49	7.11E+00	3.73E-03	24.4	6.71E-01
8	6	238.51*	2079	669	0.97	476.18	6.49E+00	3.21E-02	3.4	9.37E-01
9	6	241.47	614	1108	1.68	482.07	6.43E+00	9.48E-03	11.9	
10	1	295.06*	663	880	1.10	589.04	5.49E+00	1.02E-02	10.0	1.48E+00
11	1	299.84	206	673	1.12	598.57	5.42E+00	3.18E-03	22.8	1.26E+00
12	1	338.19*	489	785	1.32	675.12	4.91E+00	7.55E-03	13.0	1.55E+00
13	1	351.72*	1065	730	1.10	702.14	4.75E+00	1.64E-02	6.3	9.47E-01
14	1	510.66*	575	887	2.59	1019.47	3.44E+00	8.87E-03	15.7	1.83E+00
15	1	582.96*	634	326	1.38	1163.84	3.06E+00	9.79E-03	7.5	1.37E+00
16	1	609.03*	804	497	1.42	1215.89	2.94E+00	1.24E-02	7.2	4.52E-01
17	1	727.16*	113	297	1.29	1451.85	2.49E+00	1.74E-03	32.2	6.32E+00
18	1	910.89*	466	323	1.72	1818.95	2.00E+00	7.19E-03	10.9	1.16E+00
19	1	968.80*	272	270	2.12	1934.68	1.88E+00	4.19E-03	14.9	1.54E+00
20	1	1120.29*	139	166	1.92	2237.48	1.62E+00	2.14E-03	23.3	8.96E-01
21	1	1460.47*	1242	142	1.97	2917.78	1.25E+00	1.92E-02	4.2	9.22E-01
22	1	1763.91*	149	63	2.14	3524.99	1.05E+00	2.29E-03	16.7	1.38E+00

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1242	10.67*	1.246E+00	1.282E+01	1.282E+01	8.31
BI-214	609.31	804	46.30	2.937E+00	8.115E-01	8.116E-01	14.41
	1120.29	139	15.10*	1.623E+00	7.773E-01	7.773E-01	46.62
	1764.49	149	15.80	1.054E+00	1.224E+00	1.224E+00	33.33
RA-226	186.21	446	3.28*	7.616E+00	2.451E+00	2.451E+00	35.88
RA-228	93.35	430	3.50	5.952E+00	2.832E+00	2.863E+00	34.29

	969.11	272	16.60*	1.881E+00	1.193E+00	1.206E+00	29.88
TH-234	63.29	------	3.80*	1.737E+00	------	Line Not Found	------
	92.60	430	5.41	5.952E+00	1.832E+00	1.832E+00	34.29
U-235	143.76	------	10.50*	8.228E+00	------	Line Not Found	------
	163.35	------	4.70	8.037E+00	------	Line Not Found	------
	185.71	446	54.00	7.616E+00	1.489E-01	1.489E-01	35.88
	205.31	------	4.70	7.191E+00	------	Line Not Found	------

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	634	30.25*	3.056E+00	9.416E-01	9.732E-01	15.04
BI-212	727.17	113	7.56*	2.491E+00	8.203E-01	8.479E-01	64.48
PB-212	238.63	2079	44.60*	6.489E+00	9.854E-01	1.019E+00	6.88
PB-214	295.21	663	19.20	5.494E+00	8.620E-01	8.621E-01	20.00
	351.92	1065	37.20*	4.746E+00	8.279E-01	8.279E-01	12.58
TH-232	911.21	466	27.70*	2.001E+00	1.154E+00	1.154E+00	21.81

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	2.179E+00	------	Line Not Found	------
	911.07	466	27.70*	2.001E+00	1.154E+00	1.166E+00	21.81

Flag: "*" = Keyline

Sample ID : 13L95403-5
Acquisition date : 18-MAR-2022 11:13:56

Total number of lines in spectrum	22	
Number of unidentified lines	9	
Number of lines tentatively identified by NID	13	59.09%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.282E+01	1.282E+01	0.106E+01	8.31	
BI-214	1600.00Y	1.00	7.773E-01	7.773E-01	3.624E-01	46.62	
RA-226	1600.00Y	1.00	2.451E+00	2.451E+00	0.879E+00	35.88	
RA-228	5.75Y	1.01	1.193E+00	1.206E+00	0.360E+00	29.88	
TH-234	4.47E+09Y	1.00	1.832E+00	1.832E+00	0.628E+00	34.29	K
U-235	7.04E+08Y	1.00	1.489E-01	1.489E-01	0.534E-01	35.88	K
			---------	---------			
	Total Activity :		1.922E+01	1.923E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	9.416E-01	9.732E-01	1.463E-01	15.04	
BI-212	1.91Y	1.03	8.203E-01	8.479E-01	5.467E-01	64.48	
PB-212	1.91Y	1.03	9.854E-01	1.019E+00	0.070E+00	6.88	
PB-214	1600.00Y	1.00	8.279E-01	8.279E-01	1.042E-01	12.58	
TH-232	1.41E+10Y	1.00	1.154E+00	1.154E+00	0.252E+00	21.81	
			---------	---------			
	Total Activity :		4.729E+00	4.821E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.154E+00	1.166E+00	0.254E+00	21.81	
			---------	---------			
	Total Activity :		1.154E+00	1.166E+00			

Grand Total Activity : 2.510E+01 2.522E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Sample ID : 13L95403-5 Acquisition date : 18-MAR-2022 11:13:56

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
1	74.95	168	1533	0.71	149.81	147	6	2.59E-03	85.7	3.49E+00	
1	77.15	482	1120	0.84	154.19	153	6	7.43E-03	27.0	3.83E+00	
1	84.51	162	1375	1.36	168.88	165	8	2.51E-03	89.1	4.91E+00	
1	87.30	285	1007	0.90	174.44	172	6	4.40E-03	41.0	5.29E+00	
1	209.10	242	1084	1.02	417.49	414	8	3.73E-03	48.7	7.11E+00	
6	241.47	614	1108	1.68	482.07	470	18	9.48E-03	23.7	6.43E+00	
1	299.84	206	673	1.12	598.57	595	8	3.18E-03	45.6	5.42E+00	
1	338.19	489	785	1.32	675.12	670	11	7.55E-03	26.1	4.91E+00	
1	510.66	575	887	2.59	1019.47	1012	19	8.87E-03	31.5	3.44E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	22	
Number of unidentified lines	9	
Number of lines tentatively identified by NID	13	59.09%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.282E+01	1.282E+01	0.106E+01	8.31	
BI-214	1600.00Y	1.00	8.371E-01	8.371E-01	1.074E-01	12.83	
RA-226	1600.00Y	1.00	2.451E+00	2.451E+00	0.879E+00	35.88	
RA-228	5.75Y	1.01	1.193E+00	1.206E+00	0.360E+00	29.88	
			---------	---------			
	Total Activity :		1.730E+01	1.731E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	9.416E-01	9.732E-01	1.463E-01	15.04	
BI-212	1.91Y	1.03	8.203E-01	8.479E-01	5.467E-01	64.48	
PB-212	1.91Y	1.03	9.854E-01	1.019E+00	0.070E+00	6.88	
PB-214	1600.00Y	1.00	8.370E-01	8.370E-01	0.891E-01	10.65	
TH-232	1.41E+10Y	1.00	1.154E+00	1.154E+00	0.252E+00	21.81	
			---------	---------			
	Total Activity :		4.738E+00	4.830E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.154E+00	1.166E+00	0.254E+00	21.81	
			---------	---------			
	Total Activity :		1.154E+00	1.166E+00			

Grand Total Activity : 2.319E+01 2.331E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.282E+01	1.065E+00	4.820E-01	0.000E+00	26.597
TL-208	9.732E-01	1.463E-01	1.243E-01	0.000E+00	7.829
BI-212	8.479E-01	5.467E-01	5.457E-01	0.000E+00	1.554
PB-212	1.019E+00	7.004E-02	5.823E-02	0.000E+00	17.492
BI-214	8.371E-01	1.074E-01	3.417E-01	0.000E+00	2.450
PB-214	8.370E-01	8.915E-02	8.110E-02	0.000E+00	10.321
RA-226	2.451E+00	8.794E-01	7.004E-01	0.000E+00	3.499
AC-228	1.166E+00	2.543E-01	1.692E-01	0.000E+00	6.892
RA-228	1.206E+00	3.605E-01	3.356E-01	0.000E+00	3.595
TH-232	1.154E+00	2.515E-01	1.674E-01	0.000E+00	6.891

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	-5.218E-03		3.143E-02	5.206E-02	0.000E+00	-0.100
CS-137	2.739E-02		3.084E-02	5.192E-02	0.000E+00	0.528
LA-138	-6.998E-04		4.726E-02	7.836E-02	0.000E+00	-0.009
PA-234M	2.694E+00		3.267E+00	5.601E+00	0.000E+00	0.481
TH-234	-2.048E-02		1.816E+00	2.663E+00	0.000E+00	-0.008
U-235	1.177E-01		1.302E-01	2.101E-01	0.000E+00	0.560
U-238	2.694E+00		3.267E+00	5.601E+00	0.000E+00	0.481

```
A,13L95403-5       ,03/19/2022 05:14,02/13/2022 13:37,   3.040E+01,L95403-5 SS AN
B,13L95403-5       ,NORMK                ,03/22/2021 07:43,13S25030421
C,K-40     ,YES,   1.282E+01,   1.065E+00,   4.820E-01,,   26.597
C,TL-208   ,YES,   9.732E-01,   1.463E-01,   1.243E-01,,    7.829
C,BI-212   ,YES,   8.479E-01,   5.467E-01,   5.457E-01,,    1.554
C,PB-212   ,YES,   1.019E+00,   7.004E-02,   5.823E-02,,   17.492
C,BI-214   ,YES,   8.371E-01,   1.074E-01,   3.417E-01,,    2.450
C,PB-214   ,YES,   8.370E-01,   8.915E-02,   8.110E-02,,   10.321
C,RA-226   ,YES,   2.451E+00,   8.794E-01,   7.004E-01,,    3.499
C,AC-228   ,YES,   1.166E+00,   2.543E-01,   1.692E-01,,    6.892
C,RA-228   ,YES,   1.206E+00,   3.605E-01,   3.356E-01,,    3.595
C,TH-232   ,YES,   1.154E+00,   2.515E-01,   1.674E-01,,    6.891
C,CO-60    ,NO ,  -5.218E-03,   3.143E-02,   5.206E-02,,   -0.100
C,CS-137   ,NO ,   2.739E-02,   3.084E-02,   5.192E-02,,    0.528
C,LA-138   ,NO ,  -6.998E-04,   4.726E-02,   7.836E-02,,   -0.009
C,PA-234M  ,NO ,   2.694E+00,   3.267E+00,   5.601E+00,,    0.481
C,TH-234   ,NO ,  -2.048E-02,   1.816E+00,   2.663E+00,,   -0.008
C,U-235    ,NO ,   1.177E-01,   1.302E-01,   2.101E-01,,    0.560
C,U-238    ,NO ,   2.694E+00,   3.267E+00,   5.601E+00,,    0.481
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Analyst: [signature]

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 18-MAR-2022 08:07:05.12
TBE02 51-TP42214B HpGe ******* Aquisition Date/Time: 17-MAR-2022 14:52:09.95

LIMS No., Customer Name, Client ID: L95403-6 SS ANCHOR QEA

Sample ID : 02L95403-6		Smple Date: 13-FEB-2022 13:37:00.	
Sample Type : SS		Geometry : 02S25121819	
Quantity : 2.46000E+01 g Dry		BKGFILE : 02BG030422MT	
Start Channel : 80	Energy Tol : 2.00000	Real Time : 0 17:14:54.85	
End Channel : 4090	Pk Srch Sens: 9.00000	Live time : 0 17:14:45.89	
MDA Multiple : 4.6600	Library Used: NORMK		

Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	74.83*	135	1788	0.90	134.52	8.13E+00	2.18E-03	57.3	
2	0	77.17*	821	1377	0.79	139.23	8.44E+00	1.32E-02	8.5	
3	5	87.18*	311	1193	0.95	159.38	9.45E+00	5.01E-03	20.4	3.50E+00
4	0	92.93*	387	1470	1.37	170.95	9.81E+00	6.24E-03	21.4	
5	0	185.90*	358	1442	1.10	358.02	8.33E+00	5.77E-03	23.9	
6	0	209.36	273	1023	1.03	405.22	7.66E+00	4.40E-03	22.0	
7	5	238.61*	1891	616	1.00	464.09	6.92E+00	3.05E-02	3.5	1.17E+00
8	5	241.71*	574	1004	1.76	470.32	6.84E+00	9.24E-03	13.4	
9	0	269.95	201	751	1.15	527.14	6.25E+00	3.24E-03	25.5	
10	0	295.08*	591	903	1.07	577.71	5.79E+00	9.52E-03	11.7	
11	0	338.19*	388	659	1.22	664.47	5.15E+00	6.24E-03	14.2	
12	0	351.88*	916	903	1.17	692.02	4.97E+00	1.47E-02	8.3	
13	0	583.21*	491	442	1.45	1157.54	3.12E+00	7.91E-03	10.7	
14	0	609.21*	758	432	1.43	1209.87	2.99E+00	1.22E-02	7.5	
15	0	727.26	161	276	1.51	1447.45	2.51E+00	2.59E-03	22.1	
16	0	911.13*	406	166	1.62	1817.52	2.00E+00	6.54E-03	9.4	
17	0	968.88	238	201	1.34	1933.74	1.88E+00	3.84E-03	13.2	
18	0	1120.28*	149	187	1.79	2238.50	1.63E+00	2.41E-03	22.4	
19	0	1460.44*	1037	128	2.10	2923.24	1.26E+00	1.67E-02	4.5	
20	0	1764.31*	115	93	2.13	3535.00	1.08E+00	1.85E-03	25.0	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1037	10.67*	1.263E+00	1.362E+01	1.362E+01	9.07
BI-214	609.31	758	46.30	2.990E+00	9.685E-01	9.685E-01	15.09
	1120.29	149	15.10*	1.627E+00	1.076E+00	1.076E+00	44.71
	1764.49	115	15.80	1.083E+00	1.186E+00	1.186E+00	50.01
RA-226	186.21	358	3.28*	8.335E+00	2.320E+00	2.320E+00	47.88
RA-228	93.35	387	3.50	9.813E+00	1.995E+00	2.016E+00	42.89
	969.11	238	16.60*	1.883E+00	1.349E+00	1.363E+00	26.42
TH-234	63.29	------	3.80*	6.106E+00	------	Line Not Found	------

	92.60	387	5.41	9.813E+00	1.291E+00	1.291E+00	42.89
U-235	143.76	------	10.50*	9.647E+00	------	Line Not Found	------
	163.35	------	4.70	9.042E+00	------	Line Not Found	------
	185.71	358	54.00	8.335E+00	1.409E-01	1.409E-01	47.88
	205.31	------	4.70	7.767E+00	------	Line Not Found	------

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	491	30.25*	3.119E+00	9.211E-01	9.512E-01	21.45
BI-212	727.17	161	7.56*	2.514E+00	1.499E+00	1.548E+00	44.18
PB-212	238.63	1891	44.60*	6.915E+00	1.085E+00	1.121E+00	6.94
PB-214	295.21	591	19.20	5.795E+00	9.400E-01	9.401E-01	23.41
	351.92	916	37.20*	4.970E+00	8.763E-01	8.763E-01	16.53
TH-232	911.21	406	27.70*	2.004E+00	1.294E+00	1.294E+00	18.73

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	2.188E+00	------	Line Not Found	------
	911.07	406	27.70*	2.004E+00	1.294E+00	1.308E+00	18.73

Flag: "*" = Keyline

Total number of lines in spectrum	20	
Number of unidentified lines	7	
Number of lines tentatively identified by NID	13	65.00%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.362E+01	1.362E+01	0.124E+01	9.07	
BI-214	1600.00Y	1.00	1.076E+00	1.076E+00	0.481E+00	44.71	
RA-226	1600.00Y	1.00	2.320E+00	2.320E+00	1.111E+00	47.88	
RA-228	5.75Y	1.01	1.349E+00	1.363E+00	0.360E+00	26.42	
TH-234	4.47E+09Y	1.00	1.291E+00	1.291E+00	0.554E+00	42.89	K
U-235	7.04E+08Y	1.00	1.409E-01	1.409E-01	0.675E-01	47.88	K
			---------	---------			
	Total Activity :		1.979E+01	1.981E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	9.211E-01	9.512E-01	2.040E-01	21.45	
BI-212	1.91Y	1.03	1.499E+00	1.548E+00	0.684E+00	44.18	
PB-212	1.91Y	1.03	1.085E+00	1.121E+00	0.078E+00	6.94	
PB-214	1600.00Y	1.00	8.763E-01	8.763E-01	1.448E-01	16.53	
TH-232	1.41E+10Y	1.00	1.294E+00	1.294E+00	0.242E+00	18.73	
			---------	---------			
	Total Activity :		5.676E+00	5.790E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.294E+00	1.308E+00	0.245E+00	18.73	
			---------	---------			
	Total Activity :		1.294E+00	1.308E+00			

Grand Total Activity : 2.676E+01 2.691E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Sample ID : 02L95403-6 Acquisition date : 17-MAR-2022 14:52:09

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
0	74.83	135	1788	0.90	134.52	132	6	2.18E-03	****	8.13E+00	
0	77.17	821	1377	0.79	139.23	137	6	1.32E-02	17.0	8.44E+00	
5	87.18	311	1193	0.95	159.38	150	14	5.01E-03	40.8	9.45E+00	
0	209.36	273	1023	1.03	405.22	401	9	4.40E-03	44.1	7.66E+00	
5	241.71	574	1004	1.76	470.32	458	18	9.24E-03	26.8	6.84E+00	
0	269.95	201	751	1.15	527.14	523	9	3.24E-03	51.0	6.25E+00	
0	338.19	388	659	1.22	664.47	661	9	6.24E-03	28.4	5.15E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	20	
Number of unidentified lines	7	
Number of lines tentatively identified by NID	13	65.00%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.362E+01	1.362E+01	0.124E+01	9.07	
BI-214	1600.00Y	1.00	9.885E-01	9.886E-01	1.361E-01	13.77	
RA-226	1600.00Y	1.00	2.320E+00	2.320E+00	1.111E+00	47.88	
RA-228	5.75Y	1.01	1.349E+00	1.363E+00	0.360E+00	26.42	
			---------	---------			
	Total Activity :		1.828E+01	1.829E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	9.211E-01	9.512E-01	2.040E-01	21.45	
BI-212	1.91Y	1.03	1.499E+00	1.548E+00	0.684E+00	44.18	
PB-212	1.91Y	1.03	1.085E+00	1.121E+00	0.078E+00	6.94	
PB-214	1600.00Y	1.00	8.956E-01	8.956E-01	1.210E-01	13.51	
TH-232	1.41E+10Y	1.00	1.294E+00	1.294E+00	0.242E+00	18.73	
			---------	---------			
	Total Activity :		5.695E+00	5.809E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.294E+00	1.308E+00	0.245E+00	18.73	
			---------	---------			
	Total Activity :		1.294E+00	1.308E+00			

Grand Total Activity : 2.526E+01 2.541E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.362E+01	1.235E+00	6.431E-01	0.000E+00	21.176
TL-208	9.512E-01	2.040E-01	1.581E-01	0.000E+00	6.017
BI-212	1.548E+00	6.840E-01	6.866E-01	0.000E+00	2.255
PB-212	1.121E+00	7.772E-02	7.368E-02	0.000E+00	15.210
BI-214	9.886E-01	1.361E-01	4.472E-01	0.000E+00	2.210
PB-214	8.956E-01	1.210E-01	1.017E-01	0.000E+00	8.809
RA-226	2.320E+00	1.111E+00	8.559E-01	0.000E+00	2.711
AC-228	1.308E+00	2.449E-01	1.978E-01	0.000E+00	6.611
RA-228	1.363E+00	3.602E-01	3.263E-01	0.000E+00	4.178
TH-232	1.294E+00	2.423E-01	1.957E-01	0.000E+00	6.610

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	1.763E-02		3.839E-02	6.545E-02	0.000E+00	0.269
CS-137	4.681E-02		3.647E-02	6.431E-02	0.000E+00	0.728
LA-138	-3.180E-03		5.866E-02	9.605E-02	0.000E+00	-0.033
PA-234M	-1.989E-01		4.702E+00	6.806E+00	0.000E+00	-0.029
TH-234	8.234E-01		8.431E-01	1.250E+00	0.000E+00	0.659
U-235	6.684E-02		1.804E-01	2.553E-01	0.000E+00	0.262
U-238	-1.989E-01		4.702E+00	6.806E+00	0.000E+00	-0.029

A,02L95403-6 ,03/18/2022 08:07,02/13/2022 13:37, 2.460E+01,L95403-6 SS AN
B,02L95403-6 ,NORMK ,08/20/2021 05:25,02S25121819
C,K-40 ,YES, 1.362E+01, 1.235E+00, 6.431E-01,, 21.176
C,TL-208 ,YES, 9.512E-01, 2.040E-01, 1.581E-01,, 6.017
C,BI-212 ,YES, 1.548E+00, 6.840E-01, 6.866E-01,, 2.255
C,PB-212 ,YES, 1.121E+00, 7.772E-02, 7.368E-02,, 15.210
C,BI-214 ,YES, 9.886E-01, 1.361E-01, 4.472E-01,, 2.210
C,PB-214 ,YES, 8.956E-01, 1.210E-01, 1.017E-01,, 8.809
C,RA-226 ,YES, 2.320E+00, 1.111E+00, 8.559E-01,, 2.711
C,AC-228 ,YES, 1.308E+00, 2.449E-01, 1.978E-01,, 6.611
C,RA-228 ,YES, 1.363E+00, 3.602E-01, 3.263E-01,, 4.178
C,TH-232 ,YES, 1.294E+00, 2.423E-01, 1.957E-01,, 6.610
C,CO-60 ,NO , 1.763E-02, 3.839E-02, 6.545E-02,, 0.269
C,CS-137 ,NO , 4.681E-02, 3.647E-02, 6.431E-02,, 0.728
C,LA-138 ,NO , -3.180E-03, 5.866E-02, 9.605E-02,, -0.033
C,PA-234M ,NO , -1.989E-01, 4.702E+00, 6.806E+00,, -0.029
C,TH-234 ,NO , 8.234E-01, 8.431E-01, 1.250E+00,, 0.659
C,U-235 ,NO , 6.684E-02, 1.804E-01, 2.553E-01,, 0.262
C,U-238 ,NO , -1.989E-01, 4.702E+00, 6.806E+00,, -0.029

Analyst: [signature]

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 19-MAR-2022 05:14:14.39
TBE23 11410 HpGe ********** Aquisition Date/Time:  18-MAR-2022 11:13:49.13
--------------------------------------------------------------------------
LIMS No., Customer Name, Client ID: L95403-7 SS ANCHOR QEA

Sample ID       : 23L95403-7                          Smple Date: 13-FEB-2022 13:37:00.
Sample Type     : SS                                  Geometry  : 23S25122820
Quantity        : 2.74000E+01 g Dry                   BKGFILE   : 23BG030422MT
Start Channel   : 80      Energy Tol   : 2.00000      Real Time : 0 18:00:09.18
End Channel     : 4090    Pk Srch Sens: 9.00000       Live time : 0 18:00:00.00
MDA Multiple    : 4.6600  Library Used: NORMK
Peak Evaluation - Identified and Unidentified
```

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.42*	42	1950	0.94	93.11	4.06E+00	6.53E-04	216.6	
2	0	63.08*	277	1786	0.93	126.41	9.27E+00	4.28E-03	30.0	
3	3	74.76*	1237	1305	0.84	149.75	1.15E+01	1.91E-02	5.8	2.31E+00
4	3	77.07*	1909	1241	0.83	154.37	1.18E+01	2.95E-02	4.0	
5	3	84.08*	403	1332	1.24	168.38	1.25E+01	6.23E-03	17.6	4.83E+00
6	3	87.18*	933	1294	1.25	174.58	1.27E+01	1.44E-02	7.7	
7	3	89.81	667	1253	1.10	179.84	1.28E+01	1.03E-02	9.7	
8	3	92.68*	912	1382	1.26	185.58	1.29E+01	1.41E-02	9.3	
9	0	128.88	238	962	0.77	257.94	1.23E+01	3.68E-03	21.6	
10	0	185.83*	666	1666	1.14	371.79	1.01E+01	1.03E-02	14.0	
11	0	209.18	287	1050	1.07	418.46	9.31E+00	4.43E-03	20.4	
12	4	238.48*	3023	703	0.98	477.05	8.50E+00	4.67E-02	2.6	1.07E+00
13	4	241.36*	697	983	1.55	482.79	8.43E+00	1.08E-02	10.9	
14	0	270.16	314	823	1.23	540.39	7.78E+00	4.85E-03	17.4	
15	0	295.09*	771	885	0.93	590.24	7.29E+00	1.19E-02	8.3	
16	0	299.57*	96	732	0.96	599.19	7.21E+00	1.49E-03	58.4	
17	0	327.72	158	601	1.00	655.50	6.75E+00	2.44E-03	27.0	
18	0	338.27	740	841	1.05	676.59	6.59E+00	1.14E-02	8.4	
19	0	351.69*	1521	723	1.14	703.44	6.40E+00	2.35E-02	4.4	
20	0	462.66	221	392	1.24	925.39	5.17E+00	3.41E-03	16.9	
21	0	510.59*	315	850	2.12	1021.28	4.76E+00	4.86E-03	28.7	
22	0	582.91*	880	351	1.38	1165.98	4.25E+00	1.36E-02	6.0	
23	0	608.96*	1084	668	1.11	1218.10	4.08E+00	1.67E-02	6.2	
24	0	661.23	197	352	0.84	1322.72	3.79E+00	3.04E-03	18.6	
25	0	726.92*	209	319	1.56	1454.19	3.47E+00	3.23E-03	19.7	
26	0	859.91*	137	315	0.75	1720.44	2.94E+00	2.11E-03	30.8	
27	0	910.70*	681	218	1.70	1822.15	2.78E+00	1.05E-02	6.0	
28	0	968.60	447	187	1.45	1938.09	2.61E+00	6.90E-03	7.4	
29	0	1119.66*	240	304	1.88	2240.68	2.26E+00	3.70E-03	17.8	
30	0	1459.97*	1952	135	1.75	2922.75	1.78E+00	3.01E-02	2.8	
31	0	1763.28*	168	74	1.73	3531.11	1.57E+00	2.59E-03	14.2	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1952	10.67*	1.781E+00	1.564E+01	1.564E+01	5.59
CS-137	661.66	197	85.12*	3.789E+00	9.297E-02	9.317E-02	37.15
BI-214	609.31	1084	46.30	4.085E+00	8.727E-01	8.728E-01	12.44
	1120.29	240	15.10*	2.263E+00	1.069E+00	1.069E+00	35.60
	1764.49	168	15.80	1.574E+00	1.028E+00	1.028E+00	28.32
RA-226	186.21	666	3.28*	1.008E+01	3.068E+00	3.068E+00	28.07
RA-228	93.35	912	3.50	1.290E+01	3.077E+00	3.111E+00	18.52
	969.11	447	16.60*	2.613E+00	1.570E+00	1.587E+00	14.89
TH-234	63.29	277	3.80*	9.271E+00	1.198E+00	1.198E+00	60.06
	92.60	912	5.41	1.290E+01	1.990E+00	1.990E+00	18.52

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	880	30.25*	4.247E+00	1.043E+00	1.078E+00	12.09
BI-212	727.17	209	7.56*	3.466E+00	1.217E+00	1.257E+00	39.44
PB-212	238.63	3023	44.60*	8.500E+00	1.214E+00	1.255E+00	5.30
PB-214	295.21	771	19.20	7.294E+00	8.384E-01	8.384E-01	16.56
	351.92	1521	37.20*	6.403E+00	9.717E-01	9.717E-01	8.83
TH-232	911.21	681	27.70*	2.779E+00	1.346E+00	1.346E+00	12.03

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	3.027E+00	------	Line Not Found	------
	911.07	681	27.70*	2.779E+00	1.346E+00	1.361E+00	12.03

Flag: "*" = Keyline

Total number of lines in spectrum	31	
Number of unidentified lines	16	
Number of lines tentatively identified by NID	15	48.39%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.564E+01	1.564E+01	0.087E+01	5.59	
CS-137	30.07Y	1.00	9.297E-02	9.317E-02	3.461E-02	37.15	
BI-214	1600.00Y	1.00	1.069E+00	1.069E+00	0.381E+00	35.60	
RA-226	1600.00Y	1.00	3.068E+00	3.068E+00	0.861E+00	28.07	
RA-228	5.75Y	1.01	1.570E+00	1.587E+00	0.236E+00	14.89	
TH-234	4.47E+09Y	1.00	1.198E+00	1.198E+00	0.720E+00	60.06	
			---------	---------			
	Total Activity :		2.263E+01	2.265E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.043E+00	1.078E+00	0.130E+00	12.09	
BI-212	1.91Y	1.03	1.217E+00	1.257E+00	0.496E+00	39.44	
PB-212	1.91Y	1.03	1.214E+00	1.255E+00	0.066E+00	5.30	
PB-214	1600.00Y	1.00	9.717E-01	9.717E-01	0.858E-01	8.83	
TH-232	1.41E+10Y	1.00	1.346E+00	1.346E+00	0.162E+00	12.03	
			---------	---------			
	Total Activity :		5.791E+00	5.907E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.346E+00	1.361E+00	0.164E+00	12.03	
			---------	---------			
	Total Activity :		1.346E+00	1.361E+00			

Grand Total Activity : 2.977E+01 2.992E+01

Flags: "K" = Keyline not found
"E" = Manually edited
"M" = Manually accepted
"A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
0	46.42	42	1950	0.94	93.11	90	9	6.53E-04	****	4.06E+00	
3	74.76	1237	1305	0.84	149.75	143	16	1.91E-02	11.6	1.15E+01	
3	77.07	1909	1241	0.83	154.37	143	16	2.95E-02	8.0	1.18E+01	
3	84.08	403	1332	1.24	168.38	165	27	6.23E-03	35.2	1.25E+01	
3	87.18	933	1294	1.25	174.58	165	27	1.44E-02	15.5	1.27E+01	
3	89.81	667	1253	1.10	179.84	165	27	1.03E-02	19.4	1.28E+01	
0	128.88	238	962	0.77	257.94	255	6	3.68E-03	43.2	1.23E+01	
0	209.18	287	1050	1.07	418.46	415	8	4.43E-03	40.9	9.31E+00	
4	241.36	697	983	1.55	482.79	470	22	1.08E-02	21.9	8.43E+00	
0	270.16	314	823	1.23	540.39	536	9	4.85E-03	34.7	7.78E+00	
0	299.57	96	732	0.96	599.19	596	8	1.49E-03	****	7.21E+00	
0	327.72	158	601	1.00	655.50	652	7	2.44E-03	54.0	6.75E+00	
0	338.27	740	841	1.05	676.59	672	11	1.14E-02	16.9	6.59E+00	
0	462.66	221	392	1.24	925.39	921	8	3.41E-03	33.9	5.17E+00	
0	510.59	315	850	2.12	1021.28	1014	18	4.86E-03	57.4	4.76E+00	
0	859.91	137	315	0.75	1720.44	1714	14	2.11E-03	61.6	2.94E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	31	
Number of unidentified lines	16	
Number of lines tentatively identified by NID	15	48.39%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.564E+01	1.564E+01	0.087E+01	5.59	
CS-137	30.07Y	1.00	9.297E-02	9.317E-02	3.461E-02	37.15	
BI-214	1600.00Y	1.00	9.035E-01	9.035E-01	0.983E-01	10.88	
RA-226	1600.00Y	1.00	3.068E+00	3.068E+00	0.861E+00	28.07	
RA-228	5.75Y	1.01	1.570E+00	1.587E+00	0.236E+00	14.89	
TH-234	4.47E+09Y	1.00	1.198E+00	1.198E+00	0.720E+00	60.06	
			---------	---------			
	Total Activity :		2.247E+01	2.249E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.043E+00	1.078E+00	0.130E+00	12.09	
BI-212	1.91Y	1.03	1.217E+00	1.257E+00	0.496E+00	39.44	
PB-212	1.91Y	1.03	1.214E+00	1.255E+00	0.066E+00	5.30	
PB-214	1600.00Y	1.00	9.349E-01	9.349E-01	0.730E-01	7.81	
TH-232	1.41E+10Y	1.00	1.346E+00	1.346E+00	0.162E+00	12.03	
			---------	---------			
	Total Activity :		5.754E+00	5.871E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.346E+00	1.361E+00	0.164E+00	12.03	

	---------	---------
Total Activity :	1.346E+00	1.361E+00
Grand Total Activity :	2.957E+01	2.972E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.564E+01	8.734E-01	4.145E-01	0.000E+00	37.724
CS-137	9.317E-02	3.461E-02	4.288E-02	0.000E+00	2.173
TL-208	1.078E+00	1.303E-01	1.048E-01	0.000E+00	10.282
BI-212	1.257E+00	4.959E-01	4.693E-01	0.000E+00	2.680
PB-212	1.255E+00	6.645E-02	5.560E-02	0.000E+00	22.565
BI-214	9.035E-01	9.831E-02	2.985E-01	0.000E+00	3.027
PB-214	9.349E-01	7.297E-02	7.113E-02	0.000E+00	13.143
RA-226	3.068E+00	8.611E-01	6.701E-01	0.000E+00	4.578
AC-228	1.361E+00	1.637E-01	1.403E-01	0.000E+00	9.700
RA-228	1.587E+00	2.363E-01	2.383E-01	0.000E+00	6.661
TH-232	1.346E+00	1.619E-01	1.422E-01	0.000E+00	9.462
TH-234	1.198E+00	7.196E-01	7.470E-01	0.000E+00	1.604

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	1.861E-02		2.722E-02	4.885E-02	0.000E+00	0.381
LA-138	1.714E-02		3.851E-02	6.854E-02	0.000E+00	0.250
PA-234M	1.181E+00		3.132E+00	4.945E+00	0.000E+00	0.239
U-235	-8.097E-03		1.265E-01	1.908E-01	0.000E+00	-0.042
U-238	1.181E+00		3.132E+00	4.945E+00	0.000E+00	0.239

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A,23L95403-7       ,03/19/2022 05:14,02/13/2022 13:37,   2.740E+01,L95403-7 SS AN
B,23L95403-7       ,NORMK                ,03/07/2022 09:36,23S25122820
C,K-40     ,YES,   1.564E+01,   8.734E-01,   4.145E-01,,   37.724
C,CS-137   ,YES,   9.317E-02,   3.461E-02,   4.288E-02,,    2.173
C,TL-208   ,YES,   1.078E+00,   1.303E-01,   1.048E-01,,   10.282
C,BI-212   ,YES,   1.257E+00,   4.959E-01,   4.693E-01,,    2.680
C,PB-212   ,YES,   1.255E+00,   6.645E-02,   5.560E-02,,   22.565
C,BI-214   ,YES,   9.035E-01,   9.831E-02,   2.985E-01,,    3.027
C,PB-214   ,YES,   9.349E-01,   7.297E-02,   7.113E-02,,   13.143
C,RA-226   ,YES,   3.068E+00,   8.611E-01,   6.701E-01,,    4.578
C,AC-228   ,YES,   1.361E+00,   1.637E-01,   1.403E-01,,    9.700
C,RA-228   ,YES,   1.587E+00,   2.363E-01,   2.383E-01,,    6.661
C,TH-232   ,YES,   1.346E+00,   1.619E-01,   1.422E-01,,    9.462
C,TH-234   ,YES,   1.198E+00,   7.196E-01,   7.470E-01,,    1.604
C,CO-60    ,NO ,   1.861E-02,   2.722E-02,   4.885E-02,,    0.381
C,LA-138   ,NO ,   1.714E-02,   3.851E-02,   6.854E-02,,    0.250
C,PA-234M  ,NO ,   1.181E+00,   3.132E+00,   4.945E+00,,    0.239
C,U-235    ,NO ,  -8.097E-03,   1.265E-01,   1.908E-01,,   -0.042
C,U-238    ,NO ,   1.181E+00,   3.132E+00,   4.945E+00,,    0.239
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Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 19-MAR-2022 05:14:26.27
TBE06 33-TP10933A HpGe ******* Aquisition Date/Time: 18-MAR-2022 11:13:49.45

LIMS No., Customer Name, Client ID: L95403-8 SS ANCHOR QEA

Sample ID : 06L95403-8
Sample Type : SS
Quantity : 4.59000E+01 g Dry
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: NORMK
Peak Evaluation - Identified and Unidentified

Smple Date: 13-FEB-2022 13:37:00.
Geometry : 06S50031621
BKGFILE : 06BG030422MT
Real Time : 0 18:00:12.15
Live time : 0 18:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	3	74.92*	454	1273	1.06	150.31	1.68E+00	7.01E-03	15.2	5.11E+00
2	3	77.10	625	1236	1.00	154.66	1.84E+00	9.64E-03	9.9	
3	0	87.11	210	1268	0.87	174.65	2.53E+00	3.25E-03	27.7	
4	0	93.31*	187	2211	1.46	187.03	2.90E+00	2.89E-03	51.4	
5	0	186.07*	396	1545	1.27	372.19	4.02E+00	6.11E-03	21.0	
6	4	238.76*	2290	962	1.15	477.39	3.48E+00	3.53E-02	3.4	2.25E+00
7	4	241.80	604	1482	1.77	483.45	3.45E+00	9.32E-03	14.2	
8	0	295.34*	646	1167	1.10	590.32	2.95E+00	9.97E-03	11.9	
9	0	338.41	535	975	1.18	676.30	2.63E+00	8.26E-03	11.7	
10	0	351.99*	1086	990	1.15	703.42	2.54E+00	1.68E-02	7.1	
11	0	511.11*	352	908	2.31	1021.03	1.83E+00	5.44E-03	26.2	
12	0	583.21*	817	662	1.39	1164.93	1.63E+00	1.26E-02	8.4	
13	0	609.49*	765	672	1.31	1217.38	1.57E+00	1.18E-02	8.4	
14	0	661.98	162	347	0.98	1322.15	1.46E+00	2.50E-03	22.2	
15	0	727.60*	131	329	1.33	1453.11	1.35E+00	2.02E-03	28.3	
16	0	911.63*	388	457	1.51	1820.40	1.11E+00	5.99E-03	13.9	
17	0	969.98*	193	419	1.50	1936.85	1.06E+00	2.97E-03	24.6	
18	0	1120.59*	220	258	1.55	2237.40	9.34E-01	3.39E-03	18.9	
19	0	1461.35*	1298	127	1.90	2917.36	7.48E-01	2.00E-02	4.0	
20	0	1765.29*	120	89	2.15	3523.76	6.42E-01	1.86E-03	23.1	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1298	10.67*	7.481E-01	1.478E+01	1.478E+01	7.95
CS-137	661.66	162	85.12*	1.462E+00	1.183E-01	1.186E-01	44.30
BI-214	609.31	765	46.30	1.570E+00	9.557E-01	9.558E-01	16.82
	1120.29	220	15.10*	9.340E-01	1.417E+00	1.417E+00	37.74
	1764.49	120	15.80	6.424E-01	1.078E+00	1.078E+00	46.30
RA-226	186.21	396	3.28*	4.017E+00	2.731E+00	2.731E+00	41.91
RA-228	93.35	187	3.50	2.901E+00	1.676E+00	1.695E+00	102.80
	969.11	193	16.60*	1.055E+00	9.986E-01	1.010E+00	49.26

TH-234	63.29	------	3.80*	8.696E-01	------	Line Not Found	------
	92.60	187	5.41	2.901E+00	1.084E+00	1.084E+00	102.80
U-235	143.76	------	10.50*	4.209E+00	------	Line Not Found	------
	163.35	------	4.70	4.183E+00	------	Line Not Found	------
	185.71	396	54.00	4.017E+00	1.659E-01	1.659E-01	41.91
	205.31	------	4.70	3.827E+00	------	Line Not Found	------

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	817	30.25*	1.632E+00	1.504E+00	1.555E+00	16.75
BI-212	727.17	131	7.56*	1.348E+00	1.169E+00	1.209E+00	56.52
PB-212	238.63	2290	44.60*	3.477E+00	1.342E+00	1.387E+00	6.78
PB-214	295.21	646	19.20	2.951E+00	1.036E+00	1.036E+00	23.78
	351.92	1086	37.20*	2.542E+00	1.044E+00	1.044E+00	14.29
TH-232	911.21	388	27.70*	1.112E+00	1.144E+00	1.144E+00	27.74

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	1.198E+00	------	Line Not Found	------
	911.07	388	27.70*	1.112E+00	1.144E+00	1.157E+00	27.74

Flag: "*" = Keyline

Total number of lines in spectrum 20
Number of unidentified lines 6
Number of lines tentatively identified by NID 14 70.00%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.478E+01	1.478E+01	0.117E+01	7.95	
CS-137	30.07Y	1.00	1.183E-01	1.186E-01	0.525E-01	44.30	
BI-214	1600.00Y	1.00	1.417E+00	1.417E+00	0.535E+00	37.74	
RA-226	1600.00Y	1.00	2.731E+00	2.731E+00	1.144E+00	41.91	
RA-228	5.75Y	1.01	9.986E-01	1.010E+00	0.497E+00	49.26	
TH-234	4.47E+09Y	1.00	1.084E+00	1.084E+00	1.115E+00	102.80	K
U-235	7.04E+08Y	1.00	1.659E-01	1.659E-01	0.695E-01	41.91	K
			---------	---------			
	Total Activity :		2.129E+01	2.130E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.504E+00	1.555E+00	0.260E+00	16.75	
BI-212	1.91Y	1.03	1.169E+00	1.209E+00	0.683E+00	56.52	
PB-212	1.91Y	1.03	1.342E+00	1.387E+00	0.094E+00	6.78	
PB-214	1600.00Y	1.00	1.044E+00	1.044E+00	0.149E+00	14.29	
TH-232	1.41E+10Y	1.00	1.144E+00	1.144E+00	0.317E+00	27.74	
			---------	---------			
	Total Activity :		6.204E+00	6.338E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.144E+00	1.157E+00	0.321E+00	27.74	
			---------	---------			
	Total Activity :		1.144E+00	1.157E+00			

Grand Total Activity : 2.864E+01 2.880E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Sample ID : 06L95403-8 Acquisition date : 18-MAR-2022 11:13:49

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
3	74.92	454	1273	1.06	150.31	143	16	7.01E-03	30.4	1.68E+00	
3	77.10	625	1236	1.00	154.66	143	16	9.64E-03	19.7	1.84E+00	
0	87.11	210	1268	0.87	174.65	173	6	3.25E-03	55.4	2.53E+00	
4	241.80	604	1482	1.77	483.45	470	19	9.32E-03	28.4	3.45E+00	
0	338.41	535	975	1.18	676.30	672	10	8.26E-03	23.4	2.63E+00	
0	511.11	352	908	2.31	1021.03	1013	17	5.44E-03	52.4	1.83E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	20	
Number of unidentified lines	6	
Number of lines tentatively identified by NID	14	70.00%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.478E+01	1.478E+01	0.117E+01	7.95	
CS-137	30.07Y	1.00	1.183E-01	1.186E-01	0.525E-01	44.30	
BI-214	1600.00Y	1.00	1.001E+00	1.001E+00	0.147E+00	14.69	
RA-226	1600.00Y	1.00	2.731E+00	2.731E+00	1.144E+00	41.91	
RA-228	5.75Y	1.01	9.986E-01	1.010E+00	0.497E+00	49.26	
			---------	---------			
	Total Activity :		1.962E+01	1.964E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.504E+00	1.555E+00	0.260E+00	16.75	
BI-212	1.91Y	1.03	1.169E+00	1.209E+00	0.683E+00	56.52	
PB-212	1.91Y	1.03	1.342E+00	1.387E+00	0.094E+00	6.78	
PB-214	1600.00Y	1.00	1.042E+00	1.042E+00	0.128E+00	12.25	
TH-232	1.41E+10Y	1.00	1.144E+00	1.144E+00	0.317E+00	27.74	
			---------	---------			
	Total Activity :		6.202E+00	6.336E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.144E+00	1.157E+00	0.321E+00	27.74	
			---------	---------			
	Total Activity :		1.144E+00	1.157E+00			

Grand Total Activity : 2.697E+01 2.713E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.478E+01	1.174E+00	6.392E-01	0.000E+00	23.114
CS-137	1.186E-01	5.253E-02	6.648E-02	0.000E+00	1.784
TL-208	1.555E+00	2.604E-01	1.831E-01	0.000E+00	8.494
BI-212	1.209E+00	6.830E-01	8.377E-01	0.000E+00	1.443
PB-212	1.387E+00	9.398E-02	8.960E-02	0.000E+00	15.480
BI-214	1.001E+00	1.471E-01	4.066E-01	0.000E+00	2.463
PB-214	1.042E+00	1.276E-01	1.197E-01	0.000E+00	8.704
RA-226	2.731E+00	1.144E+00	1.113E+00	0.000E+00	2.454
AC-228	1.157E+00	3.208E-01	2.349E-01	0.000E+00	4.925
RA-228	1.010E+00	4.974E-01	4.351E-01	0.000E+00	2.321
TH-232	1.144E+00	3.173E-01	2.324E-01	0.000E+00	4.924

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	4.897E-02		4.137E-02	7.332E-02	0.000E+00	0.668
LA-138	2.065E-03		5.691E-02	9.494E-02	0.000E+00	0.022
PA-234M	2.378E+00		4.473E+00	7.478E+00	0.000E+00	0.318
TH-234	-9.429E-02		2.785E+00	4.609E+00	0.000E+00	-0.020
U-235	1.180E-01		2.077E-01	3.376E-01	0.000E+00	0.349
U-238	2.378E+00		4.473E+00	7.478E+00	0.000E+00	0.318

```
A,06L95403-8       ,03/19/2022 05:14,02/13/2022 13:37,   4.590E+01,L95403-8 SS AN
B,06L95403-8       ,NORMK                     ,10/29/2021 09:14,06S50031621
C,K-40     ,YES,   1.478E+01,    1.174E+00,    6.392E-01,,    23.114
C,CS-137   ,YES,   1.186E-01,    5.253E-02,    6.648E-02,,     1.784
C,TL-208   ,YES,   1.555E+00,    2.604E-01,    1.831E-01,,     8.494
C,BI-212   ,YES,   1.209E+00,    6.830E-01,    8.377E-01,,     1.443
C,PB-212   ,YES,   1.387E+00,    9.398E-02,    8.960E-02,,    15.480
C,BI-214   ,YES,   1.001E+00,    1.471E-01,    4.066E-01,,     2.463
C,PB-214   ,YES,   1.042E+00,    1.276E-01,    1.197E-01,,     8.704
C,RA-226   ,YES,   2.731E+00,    1.144E+00,    1.113E+00,,     2.454
C,AC-228   ,YES,   1.157E+00,    3.208E-01,    2.349E-01,,     4.925
C,RA-228   ,YES,   1.010E+00,    4.974E-01,    4.351E-01,,     2.321
C,TH-232   ,YES,   1.144E+00,    3.173E-01,    2.324E-01,,     4.924
C,CO-60    ,NO ,   4.897E-02,    4.137E-02,    7.332E-02,,     0.668
C,LA-138   ,NO ,   2.065E-03,    5.691E-02,    9.494E-02,,     0.022
C,PA-234M  ,NO ,   2.378E+00,    4.473E+00,    7.478E+00,,     0.318
C,TH-234   ,NO ,  -9.429E-02,    2.785E+00,    4.609E+00,,    -0.020
C,U-235    ,NO ,   1.180E-01,    2.077E-01,    3.376E-01,,     0.349
C,U-238    ,NO ,   2.378E+00,    4.473E+00,    7.478E+00,,     0.318
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Analyst:

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===================================================================================
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 19-MAR-2022 05:14:44.84
TBE07 31-TP10768B HpGe ******* Aquisition Date/Time: 18-MAR-2022 11:13:49.76
-----------------------------------------------------------------------------------
LIMS No., Customer Name, Client ID: L95403-9 SS ANCHOR QEA

Sample ID      : 07L95403-9                          Smple Date: 13-FEB-2022 13:37:00.
Sample Type    : SS                                  Geometry  : 07S25121819
Quantity       : 3.11000E+01 g Dry                   BKGFILE   : 07BG030422MT
Start Channel  : 80       Energy Tol   : 2.00000     Real Time : 0 18:00:26.81
End Channel    : 4090     Pk Srch Sens: 9.00000      Live time : 0 18:00:00.00
MDA Multiple   : 4.6600   Library Used: NORMK
Peak Evaluation - Identified and Unidentified
```

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	93.05*	320	2700	1.89	185.91	7.28E+00	4.93E-03	34.7	2.51E+00
2	1	185.76*	574	1962	2.10	371.39	8.06E+00	8.86E-03	17.5	3.28E+00
3	3	238.53*	2464	1502	1.83	476.97	6.95E+00	3.80E-02	4.0	2.47E+00
4	3	241.55	622	1583	1.99	483.02	6.89E+00	9.60E-03	15.1	
5	1	295.09*	750	1487	1.89	590.13	5.96E+00	1.16E-02	11.8	7.19E-01
6	1	338.11*	445	1355	1.82	676.19	5.37E+00	6.87E-03	19.4	3.46E+00
7	1	351.80*	1276	1377	2.00	703.58	5.20E+00	1.97E-02	7.5	1.44E+00
8	1	510.78*	301	1349	3.28	1021.59	3.82E+00	4.64E-03	40.0	2.05E+00
9	1	582.94*	749	778	2.54	1165.93	3.41E+00	1.16E-02	9.8	3.71E+00
10	1	609.11*	931	1021	2.34	1218.29	3.28E+00	1.44E-02	9.7	3.12E+00
11	1	910.55*	493	525	2.24	1821.20	2.27E+00	7.60E-03	12.9	8.50E-01
12	1	968.71*	249	446	2.38	1937.52	2.15E+00	3.84E-03	21.7	1.34E+00
13	1	1459.84*	1589	307	3.10	2919.65	1.49E+00	2.45E-02	4.5	2.60E+00
14	1	1763.15*	198	98	3.39	3526.08	1.29E+00	3.06E-03	18.6	2.13E+00

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1589	10.67*	1.486E+00	1.344E+01	1.344E+01	9.02
BI-214	609.31	931	46.30	3.281E+00	8.219E-01	8.220E-01	19.34
	1120.29	------	15.10*	1.875E+00	------	Line Not Found	------
	1764.49	198	15.80	1.294E+00	1.299E+00	1.299E+00	37.24
RA-226	186.21	574	3.28*	8.057E+00	2.913E+00	2.913E+00	34.98
RA-228	93.35	320	3.50	7.276E+00	1.684E+00	1.702E+00	69.46
	969.11	249	16.60*	2.147E+00	9.357E-01	9.460E-01	43.45

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	749	30.25*	3.410E+00	9.733E-01	1.006E+00	19.61
PB-212	238.63	2464	44.60*	6.948E+00	1.066E+00	1.102E+00	7.95

PB-214	295.21	750	19.20	5.962E+00	8.789E-01	8.789E-01	23.68
	351.92	1276	37.20*	5.201E+00	8.845E-01	8.845E-01	15.08
TH-232	911.21	493	27.70*	2.274E+00	1.049E+00	1.049E+00	25.77

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	2.464E+00	------	Line Not Found	------
	911.07	493	27.70*	2.274E+00	1.049E+00	1.060E+00	25.77

Flag: "*" = Keyline

Sample ID : 07L95403-9 Acquisition date : 18-MAR-2022 11:13:49

Total number of lines in spectrum	14	
Number of unidentified lines	3	
Number of lines tentatively identified by NID	11	78.57%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.344E+01	1.344E+01	0.121E+01	9.02	
BI-214	1600.00Y	1.00	8.219E-01	8.220E-01	1.589E-01	19.34	K
RA-226	1600.00Y	1.00	2.913E+00	2.913E+00	1.019E+00	34.98	
RA-228	5.75Y	1.01	9.357E-01	9.460E-01	4.111E-01	43.45	
		Total Activity :	1.811E+01	1.813E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	9.733E-01	1.006E+00	0.197E+00	19.61	
PB-212	1.91Y	1.03	1.066E+00	1.102E+00	0.088E+00	7.95	
PB-214	1600.00Y	1.00	8.845E-01	8.845E-01	1.334E-01	15.08	
TH-232	1.41E+10Y	1.00	1.049E+00	1.049E+00	0.270E+00	25.77	
		Total Activity :	3.973E+00	4.041E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.049E+00	1.060E+00	0.273E+00	25.77	
		Total Activity :	1.049E+00	1.060E+00			

Grand Total Activity : 2.314E+01 2.323E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
3	241.55	622	1583	1.99	483.02	469	21	9.60E-03	30.3	6.89E+00	
1	338.11	445	1355	1.82	676.19	670	14	6.87E-03	38.7	5.37E+00	
1	510.78	301	1349	3.28	1021.59	1011	23	4.64E-03	79.9	3.82E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	14	
Number of unidentified lines	3	
Number of lines tentatively identified by NID	11	78.57%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.344E+01	1.344E+01	0.121E+01	9.02	
BI-214	1600.00Y	1.00	8.684E-01	8.684E-01	1.510E-01	17.39	
RA-226	1600.00Y	1.00	2.913E+00	2.913E+00	1.019E+00	34.98	
RA-228	5.75Y	1.01	1.016E+00	1.028E+00	0.388E+00	37.79	
			---------	---------			
	Total Activity :		1.824E+01	1.825E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	9.733E-01	1.006E+00	0.197E+00	19.61	
PB-212	1.91Y	1.03	1.066E+00	1.102E+00	0.088E+00	7.95	
PB-214	1600.00Y	1.00	8.829E-01	8.829E-01	1.123E-01	12.72	
TH-232	1.41E+10Y	1.00	1.049E+00	1.049E+00	0.270E+00	25.77	
			---------	---------			
	Total Activity :		3.971E+00	4.040E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.049E+00	1.060E+00	0.273E+00	25.77	
			---------	---------			
	Total Activity :		1.049E+00	1.060E+00			

Grand Total Activity : 2.326E+01 2.335E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.344E+01	1.212E+00	5.273E-01	0.000E+00	25.496
TL-208	1.006E+00	1.973E-01	1.581E-01	0.000E+00	6.363
PB-212	1.102E+00	8.760E-02	7.159E-02	0.000E+00	15.394
BI-214	8.684E-01	1.510E-01	5.283E-01	0.000E+00	1.644
PB-214	8.829E-01	1.123E-01	9.748E-02	0.000E+00	9.057
RA-226	2.913E+00	1.019E+00	8.913E-01	0.000E+00	3.268
AC-228	1.060E+00	2.732E-01	1.865E-01	0.000E+00	5.685
RA-228	1.028E+00	3.883E-01	3.753E-01	0.000E+00	2.738
TH-232	1.049E+00	2.702E-01	1.845E-01	0.000E+00	5.684

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	1.882E-02		3.556E-02	5.902E-02	0.000E+00	0.319
CS-137	4.678E-02		3.557E-02	6.081E-02	0.000E+00	0.769
LA-138	1.692E-02		5.040E-02	8.515E-02	0.000E+00	0.199
BI-212	1.094E+00		4.479E-01	7.845E-01	0.000E+00	1.395
PA-234M	3.917E+00		3.722E+00	6.399E+00	0.000E+00	0.612
TH-234	5.189E-01		1.512E+00	2.242E+00	0.000E+00	0.231
U-235	-1.392E-01		1.947E-01	2.834E-01	0.000E+00	-0.491
U-238	3.917E+00		3.722E+00	6.399E+00	0.000E+00	0.612

```
A,07L95403-9       ,03/19/2022 05:14,02/13/2022 13:37,   3.110E+01,L95403-9 SS AN
B,07L95403-9       ,NORMK               ,08/12/2021 14:20,07S25121819
C,K-40     ,YES,   1.344E+01,   1.212E+00,   5.273E-01,,   25.496
C,TL-208   ,YES,   1.006E+00,   1.973E-01,   1.581E-01,,    6.363
C,PB-212   ,YES,   1.102E+00,   8.760E-02,   7.159E-02,,   15.394
C,BI-214   ,YES,   8.684E-01,   1.510E-01,   5.283E-01,,    1.644
C,PB-214   ,YES,   8.829E-01,   1.123E-01,   9.748E-02,,    9.057
C,RA-226   ,YES,   2.913E+00,   1.019E+00,   8.913E-01,,    3.268
C,AC-228   ,YES,   1.060E+00,   2.732E-01,   1.865E-01,,    5.685
C,RA-228   ,YES,   1.028E+00,   3.883E-01,   3.753E-01,,    2.738
C,TH-232   ,YES,   1.049E+00,   2.702E-01,   1.845E-01,,    5.684
C,CO-60    ,NO ,   1.882E-02,   3.556E-02,   5.902E-02,,    0.319
C,CS-137   ,NO ,   4.678E-02,   3.557E-02,   6.081E-02,,    0.769
C,LA-138   ,NO ,   1.692E-02,   5.040E-02,   8.515E-02,,    0.199
C,BI-212   ,NO ,   1.094E+00,   4.479E-01,   7.845E-01,,    1.395
C,PA-234M  ,NO ,   3.917E+00,   3.722E+00,   6.399E+00,,    0.612
C,TH-234   ,NO ,   5.189E-01,   1.512E+00,   2.242E+00,,    0.231
C,U-235    ,NO ,  -1.392E-01,   1.947E-01,   2.834E-01,,   -0.491
C,U-238    ,NO ,   3.917E+00,   3.722E+00,   6.399E+00,,    0.612
```

Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 18-MAR-2022 08:07:13.85
TBE07 31-TP10768B HpGe ******* Aquisition Date/Time: 17-MAR-2022 14:52:10.17

LIMS No., Customer Name, Client ID: L95403-10 SS ANCHOR QEA

Sample ID : 07L95403-10
Sample Type : SS
Quantity : 2.48000E+01 g Dry
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: NORMK
Peak Evaluation - Identified and Unidentified

Smple Date: 13-FEB-2022 13:37:00.
Geometry : 07S25121819
BKGFILE : 07BG030422MT
Real Time : 0 17:14:57.54
Live time : 0 17:14:38.09

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	2	74.94*	334	1726	1.41	149.69	5.05E+00	5.37E-03	27.3	1.07E+01
2	2	77.17*	742	1857	1.42	154.15	5.39E+00	1.20E-02	12.5	
3	1	185.81*	442	2050	2.10	371.49	8.06E+00	7.12E-03	24.1	9.47E-01
4	1	238.51*	1395	2061	1.44	476.92	6.95E+00	2.25E-02	7.3	1.72E+00
5	1	295.15*	575	1221	1.73	590.24	5.96E+00	9.27E-03	13.7	2.15E+00
6	1	338.09*	381	1275	1.99	676.14	5.37E+00	6.13E-03	21.8	1.09E+00
7	1	351.74*	1141	1486	1.94	703.46	5.20E+00	1.84E-02	9.0	2.41E+00
8	1	582.82*	638	736	2.50	1165.69	3.41E+00	1.03E-02	11.3	2.38E+00
9	1	608.94*	958	693	2.14	1217.95	3.28E+00	1.54E-02	7.5	1.36E+00
10	1	910.69*	420	430	2.11	1821.49	2.27E+00	6.76E-03	12.9	9.00E-01
11	1	968.53*	183	532	2.17	1937.17	2.15E+00	2.95E-03	32.4	1.02E+00
12	1	1459.91*	1084	347	2.81	2919.80	1.49E+00	1.75E-02	6.0	1.68E+00

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1084	10.67*	1.486E+00	1.201E+01	1.201E+01	12.05
RA-226	186.21	442	3.28*	8.056E+00	2.935E+00	2.935E+00	48.13
RA-228	93.35	------	3.50	7.303E+00	------	Line Not Found	------
	969.11	183	16.60*	2.147E+00	9.021E-01	9.118E-01	64.89

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	638	30.25*	3.410E+00	1.085E+00	1.121E+00	22.56
PB-212	238.63	1395	44.60*	6.949E+00	7.900E-01	8.159E-01	14.65
PB-214	295.21	575	19.20	5.962E+00	8.826E-01	8.827E-01	27.41
	351.92	1141	37.20*	5.202E+00	1.035E+00	1.035E+00	18.09
TH-232	911.21	420	27.70*	2.274E+00	1.169E+00	1.169E+00	25.71

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	2.464E+00	------	Line Not Found	------
	911.07	420	27.70*	2.274E+00	1.169E+00	1.182E+00	25.71

Flag: "*" = Keyline

Total number of lines in spectrum	12	
Number of unidentified lines	3	
Number of lines tentatively identified by NID	9	75.00%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.201E+01	1.201E+01	0.145E+01	12.05	
RA-226	1600.00Y	1.00	2.935E+00	2.935E+00	1.413E+00	48.13	
RA-228	5.75Y	1.01	9.021E-01	9.118E-01	5.917E-01	64.89	
			---------	---------			
	Total Activity :		1.584E+01	1.585E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.085E+00	1.121E+00	0.253E+00	22.56	
PB-212	1.91Y	1.03	7.900E-01	8.159E-01	1.195E-01	14.65	
PB-214	1600.00Y	1.00	1.035E+00	1.035E+00	0.187E+00	18.09	
TH-232	1.41E+10Y	1.00	1.169E+00	1.169E+00	0.301E+00	25.71	
			---------	---------			
	Total Activity :		4.080E+00	4.141E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.169E+00	1.182E+00	0.304E+00	25.71	
			---------	---------			
	Total Activity :		1.169E+00	1.182E+00			

Grand Total Activity : 2.109E+01 2.118E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Sample ID : 07L95403-10 Acquisition date : 17-MAR-2022 14:52:10

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
2	74.94	334	1726	1.41	149.69	142	22	5.37E-03	54.5	5.05E+00	
2	77.17	742	1857	1.42	154.15	142	22	1.20E-02	25.0	5.39E+00	
1	338.09	381	1275	1.99	676.14	669	14	6.13E-03	43.6	5.37E+00	
1	608.94	958	693	2.14	1217.95	1211	14	1.54E-02	15.0	3.28E+00	T

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	12	
Number of unidentified lines	3	
Number of lines tentatively identified by NID	9	75.00%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.201E+01	1.201E+01	0.145E+01	12.05	
RA-226	1600.00Y	1.00	2.935E+00	2.935E+00	1.413E+00	48.13	
RA-228	5.75Y	1.01	9.021E-01	9.118E-01	5.917E-01	64.89	
			---------	---------			
	Total Activity :		1.584E+01	1.585E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.085E+00	1.121E+00	0.253E+00	22.56	
PB-212	1.91Y	1.03	7.900E-01	8.159E-01	1.195E-01	14.65	
PB-214	1600.00Y	1.00	9.780E-01	9.780E-01	1.481E-01	15.14	
TH-232	1.41E+10Y	1.00	1.169E+00	1.169E+00	0.301E+00	25.71	
			---------	---------			
	Total Activity :		4.023E+00	4.084E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.169E+00	1.182E+00	0.304E+00	25.71	
			---------	---------			
	Total Activity :		1.169E+00	1.182E+00			

Grand Total Activity : 2.104E+01 2.112E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.201E+01	1.446E+00	6.847E-01	0.000E+00	17.536
TL-208	1.121E+00	2.528E-01	1.909E-01	0.000E+00	5.870
PB-212	8.159E-01	1.195E-01	1.214E-01	0.000E+00	6.722
PB-214	9.780E-01	1.481E-01	1.225E-01	0.000E+00	7.986
RA-226	2.935E+00	1.413E+00	1.110E+00	0.000E+00	2.644
AC-228	1.182E+00	3.039E-01	2.316E-01	0.000E+00	5.105
RA-228	9.118E-01	5.917E-01	4.541E-01	0.000E+00	2.008
TH-232	1.169E+00	3.007E-01	2.291E-01	0.000E+00	5.104

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	-3.353E-02		4.306E-02	6.657E-02	0.000E+00	-0.504
CS-137	3.526E-02		4.476E-02	7.550E-02	0.000E+00	0.467
LA-138	1.229E-02		6.669E-02	1.118E-01	0.000E+00	0.110
BI-212	1.268E+00		5.593E-01	9.779E-01	0.000E+00	1.297
BI-214	1.221E+00		4.013E-01	6.781E-01	0.000E+00	1.800
PA-234M	6.341E+00		4.587E+00	7.997E+00	0.000E+00	0.793
TH-234	-4.950E-01		1.878E+00	2.749E+00	0.000E+00	-0.180
U-235	-1.388E-03		2.391E-01	3.511E-01	0.000E+00	-0.004
U-238	6.341E+00		4.587E+00	7.997E+00	0.000E+00	0.793

```
A,07L95403-10      ,03/18/2022 08:07,02/13/2022 13:37,    2.480E+01,L95403-10 SS A
B,07L95403-10      ,NORMK                      ,08/12/2021 14:20,07S25121819
C,K-40     ,YES,   1.201E+01,   1.446E+00,   6.847E-01,,   17.536
C,TL-208   ,YES,   1.121E+00,   2.528E-01,   1.909E-01,,    5.870
C,PB-212   ,YES,   8.159E-01,   1.195E-01,   1.214E-01,,    6.722
C,PB-214   ,YES,   9.780E-01,   1.481E-01,   1.225E-01,,    7.986
C,RA-226   ,YES,   2.935E+00,   1.413E+00,   1.110E+00,,    2.644
C,AC-228   ,YES,   1.182E+00,   3.039E-01,   2.316E-01,,    5.105
C,RA-228   ,YES,   9.118E-01,   5.917E-01,   4.541E-01,,    2.008
C,TH-232   ,YES,   1.169E+00,   3.007E-01,   2.291E-01,,    5.104
C,CO-60    ,NO ,  -3.353E-02,   4.306E-02,   6.657E-02,,   -0.504
C,CS-137   ,NO ,   3.526E-02,   4.476E-02,   7.550E-02,,    0.467
C,LA-138   ,NO ,   1.229E-02,   6.669E-02,   1.118E-01,,    0.110
C,BI-212   ,NO ,   1.268E+00,   5.593E-01,   9.779E-01,,    1.297
C,BI-214   ,NO ,   1.221E+00,   4.013E-01,   6.781E-01,,    1.800
C,PA-234M  ,NO ,   6.341E+00,   4.587E+00,   7.997E+00,,    0.793
C,TH-234   ,NO ,  -4.950E-01,   1.878E+00,   2.749E+00,,   -0.180
C,U-235    ,NO ,  -1.388E-03,   2.391E-01,   3.511E-01,,   -0.004
C,U-238    ,NO ,   6.341E+00,   4.587E+00,   7.997E+00,,    0.793
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Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 18-MAR-2022 08:07:27.64
TBE14 54-TP42603C HpGe ******* Aquisition Date/Time: 17-MAR-2022 14:52:10.82

LIMS No., Customer Name, Client ID: L95403-11 SS ANCHOR QEA

Sample ID : 14L95403-11
Sample Type : SS
Quantity : 2.55000E+01 g Dry
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: NORMK
Peak Evaluation - Identified and Unidentified

Smple Date: 13-FEB-2022 12:56:00.
Geometry : 14S25121719
BKGFILE : 14BG030422MT
Real Time : 0 17:15:04.54
Live time : 0 17:14:52.79

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	74.90*	369	1557	0.74	146.95	7.22E+00	5.94E-03	19.4	1.06E+01
2	1	77.18	911	1328	0.84	151.52	7.57E+00	1.47E-02	7.1	1.49E+01
3	4	84.52*	33	1210	1.25	166.21	8.51E+00	5.29E-04	202.9	1.98E+00
4	4	87.19*	310	913	0.89	171.55	8.78E+00	4.99E-03	18.3	
5	1	92.95*	627	1687	1.77	183.08	9.27E+00	1.01E-02	14.7	4.47E+00
6	1	185.84*	377	1366	1.15	369.07	8.55E+00	6.07E-03	22.4	2.73E+00
7	7	238.61*	1770	595	1.05	474.74	7.10E+00	2.85E-02	3.7	2.87E+00
8	7	241.66	607	1004	1.90	480.83	7.02E+00	9.78E-03	12.4	
9	1	295.19*	574	856	0.98	588.03	5.91E+00	9.25E-03	11.7	1.37E+00
10	1	338.26	387	581	1.16	674.27	5.22E+00	6.23E-03	12.3	1.74E+00
11	1	351.98*	1002	667	1.17	701.73	5.03E+00	1.61E-02	6.3	1.20E+00
12	1	510.90*	81	736	2.47	1019.98	3.51E+00	1.31E-03	101.9	1.46E+00
13	1	583.03*	465	413	1.37	1164.42	3.07E+00	7.48E-03	10.9	1.06E+00
14	1	609.24*	766	365	1.32	1216.92	2.94E+00	1.23E-02	6.9	9.42E-01
15	1	911.05*	313	214	1.70	1821.40	1.94E+00	5.05E-03	11.6	5.51E-01
16	1	969.00*	206	177	1.81	1937.49	1.82E+00	3.32E-03	15.7	1.30E+00
17	1	1120.00*	217	120	2.71	2239.98	1.57E+00	3.49E-03	13.8	1.34E+00
18	1	1460.58*	1000	72	2.02	2922.33	1.21E+00	1.61E-02	4.3	1.45E+00
19	1	1764.08*	79	87	2.07	3530.53	1.04E+00	1.27E-03	32.4	1.30E+00

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1000	10.67*	1.211E+00	1.321E+01	1.321E+01	8.55
BI-214	609.31	766	46.30	2.937E+00	9.608E-01	9.609E-01	13.72
	1120.29	217	15.10*	1.566E+00	1.564E+00	1.564E+00	27.70
	1764.49	79	15.80	1.037E+00	8.218E-01	8.219E-01	64.79
RA-226	186.21	377	3.28*	8.550E+00	2.292E+00	2.292E+00	44.80
RA-228	93.35	627	3.50	9.267E+00	3.299E+00	3.335E+00	29.39
	969.11	206	16.60*	1.817E+00	1.166E+00	1.179E+00	31.43
TH-234	63.29	------	3.80*	5.083E+00	------	Line Not Found	------
	92.60	627	5.41	9.267E+00	2.134E+00	2.134E+00	29.39

U-235	143.76	------	10.50*	9.757E+00	------	Line Not Found	------
	163.35	------	4.70	9.227E+00	------	Line Not Found	------
	185.71	377	54.00	8.550E+00	1.392E-01	1.392E-01	44.80
	205.31	------	4.70	7.978E+00	------	Line Not Found	------

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	465	30.25*	3.071E+00	8.539E-01	8.818E-01	21.82
PB-212	238.63	1770	44.60*	7.097E+00	9.548E-01	9.860E-01	7.32
PB-214	295.21	574	19.20	5.908E+00	8.642E-01	8.642E-01	23.31
	351.92	1002	37.20*	5.027E+00	9.150E-01	9.150E-01	12.67
TH-232	911.21	313	27.70*	1.938E+00	9.964E-01	9.964E-01	23.28

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	2.121E+00	------	Line Not Found	------
	911.07	313	27.70*	1.938E+00	9.964E-01	1.007E+00	23.28

Flag: "*" = Keyline

Total number of lines in spectrum 19
Number of unidentified lines 7
Number of lines tentatively identified by NID 12 63.16%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.321E+01	1.321E+01	0.113E+01	8.55	
BI-214	1600.00Y	1.00	1.564E+00	1.564E+00	0.433E+00	27.70	
RA-226	1600.00Y	1.00	2.292E+00	2.292E+00	1.027E+00	44.80	
RA-228	5.75Y	1.01	1.166E+00	1.179E+00	0.371E+00	31.43	
TH-234	4.47E+09Y	1.00	2.134E+00	2.134E+00	0.627E+00	29.39	K
U-235	7.04E+08Y	1.00	1.392E-01	1.392E-01	0.624E-01	44.80	K
			---------	---------			
	Total Activity :		2.051E+01	2.052E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	8.539E-01	8.818E-01	1.925E-01	21.82	
PB-212	1.91Y	1.03	9.548E-01	9.860E-01	0.722E-01	7.32	
PB-214	1600.00Y	1.00	9.150E-01	9.150E-01	1.159E-01	12.67	
TH-232	1.41E+10Y	1.00	9.964E-01	9.964E-01	2.320E-01	23.28	
			---------	---------			
	Total Activity :		3.720E+00	3.779E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	9.964E-01	1.007E+00	0.235E+00	23.28	
			---------	---------			
	Total Activity :		9.964E-01	1.007E+00			

Grand Total Activity : 2.522E+01 2.531E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
1	74.90	369	1557	0.74	146.95	144	6	5.94E-03	38.9	7.22E+00	
1	77.18	911	1328	0.84	151.52	149	6	1.47E-02	14.3	7.57E+00	
4	84.52	33	1210	1.25	166.21	162	14	5.29E-04	****	8.51E+00	
4	87.19	310	913	0.89	171.55	162	14	4.99E-03	36.5	8.78E+00	
7	241.66	607	1004	1.90	480.83	470	17	9.78E-03	24.8	7.02E+00	
1	338.26	387	581	1.16	674.27	669	9	6.23E-03	24.6	5.22E+00	
1	510.90	81	736	2.47	1019.98	1013	18	1.31E-03	****	3.51E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	19	
Number of unidentified lines	7	
Number of lines tentatively identified by NID	12	63.16%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.321E+01	1.321E+01	0.113E+01	8.55	
BI-214	1600.00Y	1.00	1.002E+00	1.002E+00	0.123E+00	12.25	
RA-226	1600.00Y	1.00	2.292E+00	2.292E+00	1.027E+00	44.80	
RA-228	5.75Y	1.01	1.166E+00	1.179E+00	0.371E+00	31.43	
			---------	---------			
	Total Activity :		1.767E+01	1.768E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	8.539E-01	8.818E-01	1.925E-01	21.82	
PB-212	1.91Y	1.03	9.548E-01	9.860E-01	0.722E-01	7.32	
PB-214	1600.00Y	1.00	9.024E-01	9.024E-01	1.005E-01	11.14	
TH-232	1.41E+10Y	1.00	9.964E-01	9.964E-01	2.320E-01	23.28	
			---------	---------			
	Total Activity :		3.707E+00	3.767E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	9.964E-01	1.007E+00	0.235E+00	23.28	
			---------	---------			
	Total Activity :		9.964E-01	1.007E+00			

Grand Total Activity : 2.237E+01 2.246E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.321E+01	1.129E+00	5.472E-01	0.000E+00	24.143
TL-208	8.818E-01	1.925E-01	1.457E-01	0.000E+00	6.054
PB-212	9.860E-01	7.222E-02	6.547E-02	0.000E+00	15.060
BI-214	1.002E+00	1.227E-01	4.151E-01	0.000E+00	2.414
PB-214	9.024E-01	1.005E-01	9.283E-02	0.000E+00	9.721
RA-226	2.292E+00	1.027E+00	7.700E-01	0.000E+00	2.977
AC-228	1.007E+00	2.345E-01	1.956E-01	0.000E+00	5.149
RA-228	1.179E+00	3.705E-01	3.937E-01	0.000E+00	2.994
TH-232	9.964E-01	2.320E-01	1.936E-01	0.000E+00	5.148

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	-3.210E-03		3.552E-02	5.883E-02	0.000E+00	-0.055
CS-137	2.678E-02		3.921E-02	6.457E-02	0.000E+00	0.415
LA-138	4.274E-03		5.562E-02	9.262E-02	0.000E+00	0.046
BI-212	7.248E-01		4.450E-01	7.943E-01	0.000E+00	0.913
PA-234M	4.230E+00		3.951E+00	6.830E+00	0.000E+00	0.619
TH-234	1.237E+00		8.768E-01	1.328E+00	0.000E+00	0.932
U-235	2.024E-01		1.314E-01	2.267E-01	0.000E+00	0.893
U-238	4.230E+00		3.951E+00	6.830E+00	0.000E+00	0.619

```
A,14L95403-11      ,03/18/2022 08:07,02/13/2022 12:56,    2.550E+01,L95403-11 SS A
B,14L95403-11      ,NORMK                       ,08/11/2021 12:59,14S25121719
C,K-40      ,YES,   1.321E+01,    1.129E+00,    5.472E-01,,    24.143
C,TL-208    ,YES,   8.818E-01,    1.925E-01,    1.457E-01,,     6.054
C,PB-212    ,YES,   9.860E-01,    7.222E-02,    6.547E-02,,    15.060
C,BI-214    ,YES,   1.002E+00,    1.227E-01,    4.151E-01,,     2.414
C,PB-214    ,YES,   9.024E-01,    1.005E-01,    9.283E-02,,     9.721
C,RA-226    ,YES,   2.292E+00,    1.027E+00,    7.700E-01,,     2.977
C,AC-228    ,YES,   1.007E+00,    2.345E-01,    1.956E-01,,     5.149
C,RA-228    ,YES,   1.179E+00,    3.705E-01,    3.937E-01,,     2.994
C,TH-232    ,YES,   9.964E-01,    2.320E-01,    1.936E-01,,     5.148
C,CO-60     ,NO ,  -3.210E-03,    3.552E-02,    5.883E-02,,    -0.055
C,CS-137    ,NO ,   2.678E-02,    3.921E-02,    6.457E-02,,     0.415
C,LA-138    ,NO ,   4.274E-03,    5.562E-02,    9.262E-02,,     0.046
C,BI-212    ,NO ,   7.248E-01,    4.450E-01,    7.943E-01,,     0.913
C,PA-234M   ,NO ,   4.230E+00,    3.951E+00,    6.830E+00,,     0.619
C,TH-234    ,NO ,   1.237E+00,    8.768E-01,    1.328E+00,,     0.932
C,U-235     ,NO ,   2.024E-01,    1.314E-01,    2.267E-01,,     0.893
C,U-238     ,NO ,   4.230E+00,    3.951E+00,    6.830E+00,,     0.619
```

Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 18-MAR-2022 08:07:27.82
TBE08 31-TP20610B HpGe ******** Aquisition Date/Time: 17-MAR-2022 14:52:11.25

LIMS No., Customer Name, Client ID: L95403-12 SS ANCHOR QEA

Sample ID : 08L95403-12
Sample Type : SS
Quantity : 2.69000E+01 g Dry
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: NORMK
Peak Evaluation - Identified and Unidentified

Smple Date: 13-FEB-2022 12:56:00.
Geometry : 08S25121919
BKGFILE : 08BG030422MT
Real Time : 0 17:15:07.49
Live time : 0 17:14:41.40

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	75.30*	0	1522	0.94	156.70	5.38E+00	3.25E-06	*****	1.70E+00
2	1	85.00*	26	1059	1.20	176.06	6.66E+00	4.21E-04	249.7	1.89E+00
3	1	93.28*	144	1413	1.76	192.58	7.47E+00	2.33E-03	55.9	3.71E+00
4	1	186.23*	25	1589	1.23	377.95	7.69E+00	3.97E-04	356.9	6.92E-01
5	1	239.09*	216	1213	1.27	483.37	6.48E+00	3.48E-03	34.5	9.91E-01
6	1	295.70*	240	866	1.43	596.25	5.45E+00	3.87E-03	27.0	8.37E-01
7	1	352.39*	323	716	1.71	709.30	4.68E+00	5.20E-03	20.5	1.42E+00
8	1	511.35*	33	825	2.77	1026.20	3.32E+00	5.39E-04	265.1	1.77E+00
9	1	583.77*	113	404	1.92	1170.55	2.93E+00	1.83E-03	42.8	1.42E+00
10	1	609.73*	348	623	1.96	1222.30	2.81E+00	5.61E-03	19.0	2.14E+00
11	1	911.27*	30	219	2.03	1823.20	1.89E+00	4.87E-04	126.8	1.45E+00
12	1	1120.18*	104	159	2.86	2239.36	1.54E+00	1.67E-03	31.3	1.97E+00
13	1	1461.06*	181	118	2.33	2918.17	1.21E+00	2.91E-03	22.3	1.51E+00
14	1	1765.09*	96	32	2.63	3523.35	1.05E+00	1.54E-03	23.4	1.23E+00

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	181	10.67*	1.209E+00	2.266E+00	2.266E+00	44.52
BI-214	609.31	348	46.30	2.808E+00	4.337E-01	4.337E-01	38.08
	1120.29	104	15.10*	1.542E+00	7.201E-01	7.201E-01	62.58
	1764.49	96	15.80	1.049E+00	9.355E-01	9.355E-01	46.79
RA-226	186.21	25	3.28*	7.690E+00	1.581E-01	1.582E-01	713.77

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	113	30.25*	2.929E+00	2.070E-01	2.138E-01	85.66
PB-212	238.63	216	44.60*	6.480E+00	1.210E-01	1.250E-01	69.07
PB-214	295.21	240	19.20	5.452E+00	3.714E-01	3.714E-01	53.91
	351.92	323	37.20*	4.679E+00	3.001E-01	3.001E-01	40.92

TH-232	911.21	30	27.70*	1.890E+00	9.349E-02	9.349E-02	253.55

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	2.061E+00	------	Line Not Found	------
	911.07	30	27.70*	1.890E+00	9.349E-02	9.450E-02	253.55

Flag: "*" = Keyline

Total number of lines in spectrum 14
Number of unidentified lines 3
Number of lines tentatively identified by NID 11 78.57%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	2.266E+00	2.266E+00	1.009E+00	44.52	
BI-214	1600.00Y	1.00	7.201E-01	7.201E-01	4.507E-01	62.58	
RA-226	1600.00Y	1.00	1.581E-01	1.582E-01	11.29E-01	713.77	
			---------	---------			
	Total Activity :		3.144E+00	3.144E+00			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	2.070E-01	2.138E-01	1.831E-01	85.66	
PB-212	1.91Y	1.03	1.210E-01	1.250E-01	0.863E-01	69.07	
PB-214	1600.00Y	1.00	3.001E-01	3.001E-01	1.228E-01	40.92	
TH-232	1.41E+10Y	1.00	9.349E-02	9.349E-02	23.70E-02	253.55	
			---------	---------			
	Total Activity :		7.216E-01	7.324E-01			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	9.349E-02	9.450E-02	23.96E-02	253.55	
			---------	---------			
	Total Activity :		9.349E-02	9.450E-02			

Grand Total Activity : 3.959E+00 3.971E+00

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
1	75.30	0	1522	0.94	156.70	153	7	3.25E-06	****	5.38E+00	
1	85.00	26	1059	1.20	176.06	173	7	4.21E-04	****	6.66E+00	
1	93.28	144	1413	1.76	192.58	188	10	2.33E-03	****	7.47E+00	T
1	511.35	33	825	2.77	1026.20	1017	19	5.39E-04	****	3.32E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	14	
Number of unidentified lines	3	
Number of lines tentatively identified by NID	11	78.57%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	2.266E+00	2.266E+00	1.009E+00	44.52	
BI-214	1600.00Y	1.00	5.197E-01	5.197E-01	1.462E-01	28.12	
RA-226	1600.00Y	1.00	1.581E-01	1.582E-01	11.29E-01	713.77	
	Total Activity :		2.944E+00	2.944E+00			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	2.070E-01	2.138E-01	1.831E-01	85.66	
PB-212	1.91Y	1.03	1.210E-01	1.250E-01	0.863E-01	69.07	
PB-214	1600.00Y	1.00	3.196E-01	3.196E-01	1.047E-01	32.75	
TH-232	1.41E+10Y	1.00	9.349E-02	9.349E-02	23.70E-02	253.55	
	Total Activity :		7.411E-01	7.519E-01			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	9.349E-02	9.450E-02	23.96E-02	253.55	
	Total Activity :		9.349E-02	9.450E-02			

Grand Total Activity : 3.778E+00 3.790E+00

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	2.266E+00	1.009E+00	5.480E-01	0.000E+00	4.135
TL-208	2.138E-01	1.831E-01	1.656E-01	0.000E+00	1.291
PB-212	1.250E-01	8.633E-02	7.932E-02	0.000E+00	1.576
BI-214	5.197E-01	1.462E-01	4.251E-01	0.000E+00	1.223
PB-214	3.196E-01	1.047E-01	1.076E-01	0.000E+00	2.971
RA-226	1.582E-01	1.129E+00	9.285E-01	0.000E+00	0.170
AC-228	9.450E-02	2.396E-01	1.974E-01	0.000E+00	0.479
TH-232	9.349E-02	2.370E-01	1.963E-01	0.000E+00	0.476

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	3.182E-02		3.506E-02	6.168E-02	0.000E+00	0.516
CS-137	-1.163E-02		3.622E-02	5.912E-02	0.000E+00	-0.197
LA-138	1.051E-02		5.619E-02	9.391E-02	0.000E+00	0.112
BI-212	2.862E-01		4.534E-01	7.651E-01	0.000E+00	0.374
RA-228	-2.899E-02		2.950E-01	4.197E-01	0.000E+00	-0.069
PA-234M	3.390E+00		3.971E+00	6.704E+00	0.000E+00	0.506
TH-234	-2.814E-01		1.237E+00	1.962E+00	0.000E+00	-0.143
U-235	1.243E-03		1.636E-01	2.739E-01	0.000E+00	0.005
U-238	3.390E+00		3.971E+00	6.704E+00	0.000E+00	0.506

```
A,08L95403-12      ,03/18/2022 08:07,02/13/2022 12:56,   2.690E+01,L95403-12 SS A
B,08L95403-12      ,NORMK                     ,11/17/2021 15:23,08S25121919
C,K-40     ,YES,    2.266E+00,    1.009E+00,    5.480E-01,,      4.135
C,TL-208   ,YES,    2.138E-01,    1.831E-01,    1.656E-01,,      1.291
C,PB-212   ,YES,    1.250E-01,    8.633E-02,    7.932E-02,,      1.576
C,BI-214   ,YES,    5.197E-01,    1.462E-01,    4.251E-01,,      1.223
C,PB-214   ,YES,    3.196E-01,    1.047E-01,    1.076E-01,,      2.971
C,RA-226   ,YES,    1.582E-01,    1.129E+00,    9.285E-01,,      0.170
C,AC-228   ,YES,    9.450E-02,    2.396E-01,    1.974E-01,,      0.479
C,TH-232   ,YES,    9.349E-02,    2.370E-01,    1.963E-01,,      0.476
C,CO-60    ,NO ,    3.182E-02,    3.506E-02,    6.168E-02,,      0.516
C,CS-137   ,NO ,   -1.163E-02,    3.622E-02,    5.912E-02,,     -0.197
C,LA-138   ,NO ,    1.051E-02,    5.619E-02,    9.391E-02,,      0.112
C,BI-212   ,NO ,    2.862E-01,    4.534E-01,    7.651E-01,,      0.374
C,RA-228   ,NO ,   -2.899E-02,    2.950E-01,    4.197E-01,,     -0.069
C,PA-234M  ,NO ,    3.390E+00,    3.971E+00,    6.704E+00,,      0.506
C,TH-234   ,NO ,   -2.814E-01,    1.237E+00,    1.962E+00,,     -0.143
C,U-235    ,NO ,    1.243E-03,    1.636E-01,    2.739E-01,,      0.005
C,U-238    ,NO ,    3.390E+00,    3.971E+00,    6.704E+00,,      0.506
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Analyst: [signature]

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 18-MAR-2022 08:07:41.69
TBE23 11410 HpGe ********** Aquisition Date/Time: 17-MAR-2022 14:52:11.98

LIMS No., Customer Name, Client ID: L95403-13 SS ANCHOR QEA

Sample ID : 23L95403-13
Sample Type : SS
Quantity : 2.14000E+01 g Dry
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: NORMK
Peak Evaluation - Identified and Unidentified

Smple Date: 13-FEB-2022 12:56:00.
Geometry : 23S25122820
BKGFILE : 23BG030422MT
Real Time : 0 17:15:14.38
Live time : 0 17:15:06.03

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.13*	334	1859	0.95	92.54	3.97E+00	5.37E-03	28.5	
2	0	63.27*	58	1627	0.92	126.80	9.32E+00	9.27E-04	135.9	
3	2	74.78*	1054	1050	0.89	149.79	1.15E+01	1.70E-02	6.2	2.89E+00
4	2	77.04*	1551	941	0.86	154.31	1.18E+01	2.50E-02	4.5	
5	0	84.11*	202	1061	1.09	168.45	1.25E+01	3.26E-03	30.4	
6	0	86.94*	444	1414	1.07	174.10	1.27E+01	7.15E-03	16.0	
7	0	92.72*	538	1446	1.25	185.65	1.29E+01	8.66E-03	15.1	
8	0	185.76*	559	1309	1.19	371.64	1.01E+01	9.00E-03	14.7	
9	0	209.11	303	734	1.12	418.33	9.31E+00	4.88E-03	16.0	
10	6	238.48*	2220	666	0.99	477.04	8.50E+00	3.57E-02	3.3	1.71E+00
11	6	241.49*	619	957	1.67	483.07	8.42E+00	9.97E-03	12.2	
12	0	270.19	224	888	1.47	540.45	7.78E+00	3.61E-03	25.8	
13	0	295.04*	778	777	1.10	590.15	7.29E+00	1.25E-02	8.0	
14	0	338.11	536	784	1.00	676.27	6.60E+00	8.64E-03	11.0	
15	0	351.70*	1265	606	1.18	703.45	6.40E+00	2.04E-02	4.9	
16	0	462.59	134	383	1.09	925.26	5.17E+00	2.15E-03	26.8	
17	0	510.83*	411	733	1.95	1021.76	4.76E+00	6.62E-03	21.4	
18	0	582.92*	614	453	1.17	1166.00	4.25E+00	9.89E-03	9.1	
19	0	608.94*	1010	479	1.26	1218.06	4.08E+00	1.63E-02	5.5	
20	0	727.08*	213	338	1.20	1454.52	3.47E+00	3.44E-03	20.6	
21	0	860.33*	91	194	1.40	1721.27	2.94E+00	1.47E-03	34.3	
22	0	910.82*	388	231	1.51	1822.37	2.78E+00	6.25E-03	9.9	
23	0	968.43	306	209	1.60	1937.75	2.61E+00	4.93E-03	10.8	
24	0	1119.94*	170	174	1.37	2241.24	2.26E+00	2.74E-03	18.0	
25	0	1459.93*	1420	115	1.94	2922.68	1.78E+00	2.29E-02	3.3	
26	0	1763.21*	224	54	2.32	3530.96	1.57E+00	3.61E-03	10.7	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1420	10.67*	1.781E+00	1.520E+01	1.520E+01	6.68
BI-214	609.31	1010	46.30	4.085E+00	1.086E+00	1.086E+00	11.05

	1120.29	170	15.10*	2.263E+00	1.014E+00	1.014E+00	35.92
	1764.49	224	15.80	1.574E+00	1.834E+00	1.834E+00	21.33
RA-226	186.21	559	3.28*	1.008E+01	3.437E+00	3.438E+00	29.43
RA-228	93.35	538	3.50	1.290E+01	2.422E+00	2.448E+00	30.24
	969.11	306	16.60*	2.613E+00	1.434E+00	1.450E+00	21.58
TH-234	63.29	58	3.80*	9.319E+00	3.308E-01	3.308E-01	271.77
	92.60	538	5.41	1.290E+01	1.567E+00	1.567E+00	30.24

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	614	30.25*	4.247E+00	9.719E-01	1.004E+00	18.24
BI-212	727.17	213	7.56*	3.465E+00	1.657E+00	1.711E+00	41.17
PB-212	238.63	2220	44.60*	8.500E+00	1.191E+00	1.230E+00	6.60
PB-214	295.21	778	19.20	7.295E+00	1.129E+00	1.129E+00	16.03
	351.92	1265	37.20*	6.403E+00	1.080E+00	1.080E+00	9.75
TH-232	911.21	388	27.70*	2.779E+00	1.025E+00	1.025E+00	19.84

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	3.027E+00	------	Line Not Found	------
	911.07	388	27.70*	2.779E+00	1.025E+00	1.037E+00	19.84

Flag: "*" = Keyline

Total number of lines in spectrum 26
Number of unidentified lines 12
Number of lines tentatively identified by NID 14 53.85%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.520E+01	1.520E+01	0.101E+01	6.68	
BI-214	1600.00Y	1.00	1.014E+00	1.014E+00	0.364E+00	35.92	
RA-226	1600.00Y	1.00	3.437E+00	3.438E+00	1.012E+00	29.43	
RA-228	5.75Y	1.01	1.434E+00	1.450E+00	0.313E+00	21.58	
TH-234	4.47E+09Y	1.00	3.308E-01	3.308E-01	8.989E-01	271.77	
			---------	---------			
	Total Activity :		2.142E+01	2.143E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	9.719E-01	1.004E+00	0.183E+00	18.24	
BI-212	1.91Y	1.03	1.657E+00	1.711E+00	0.704E+00	41.17	
PB-212	1.91Y	1.03	1.191E+00	1.230E+00	0.081E+00	6.60	
PB-214	1600.00Y	1.00	1.080E+00	1.080E+00	0.105E+00	9.75	
TH-232	1.41E+10Y	1.00	1.025E+00	1.025E+00	0.203E+00	19.84	
			---------	---------			
	Total Activity :		5.925E+00	6.050E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.025E+00	1.037E+00	0.206E+00	19.84	
			---------	---------			
	Total Activity :		1.025E+00	1.037E+00			

Grand Total Activity : 2.837E+01 2.852E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Sample ID : 23L95403-13 Acquisition date : 17-MAR-2022 14:52:11

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
0	46.13	334	1859	0.95	92.54	87	11	5.37E-03	57.1	3.97E+00	
2	74.78	1054	1050	0.89	149.79	144	21	1.70E-02	12.3	1.15E+01	
2	77.04	1551	941	0.86	154.31	144	21	2.50E-02	8.9	1.18E+01	
0	84.11	202	1061	1.09	168.45	166	6	3.26E-03	60.9	1.25E+01	
0	86.94	444	1414	1.07	174.10	172	7	7.15E-03	32.0	1.27E+01	
0	209.11	303	734	1.12	418.33	415	7	4.88E-03	31.9	9.31E+00	
6	241.49	619	957	1.67	483.07	472	17	9.97E-03	24.5	8.42E+00	
0	270.19	224	888	1.47	540.45	535	10	3.61E-03	51.6	7.78E+00	
0	338.11	536	784	1.00	676.27	671	11	8.64E-03	22.0	6.60E+00	
0	462.59	134	383	1.09	925.26	922	8	2.15E-03	53.6	5.17E+00	
0	510.83	411	733	1.95	1021.76	1014	19	6.62E-03	42.7	4.76E+00	
0	860.33	91	194	1.40	1721.27	1717	10	1.47E-03	68.5	2.94E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	26	
Number of unidentified lines	12	
Number of lines tentatively identified by NID	14	53.85%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.520E+01	1.520E+01	0.101E+01	6.68	
BI-214	1600.00Y	1.00	1.079E+00	1.079E+00	0.114E+00	10.57	
RA-226	1600.00Y	1.00	3.437E+00	3.438E+00	1.012E+00	29.43	
RA-228	5.75Y	1.01	1.434E+00	1.450E+00	0.313E+00	21.58	
TH-234	4.47E+09Y	1.00	3.308E-01	3.308E-01	8.989E-01	271.77	
			---------	---------			
	Total Activity :		2.148E+01	2.150E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	9.719E-01	1.004E+00	0.183E+00	18.24	
BI-212	1.91Y	1.03	1.657E+00	1.711E+00	0.704E+00	41.17	
PB-212	1.91Y	1.03	1.191E+00	1.230E+00	0.081E+00	6.60	
PB-214	1600.00Y	1.00	1.093E+00	1.093E+00	0.091E+00	8.33	
TH-232	1.41E+10Y	1.00	1.025E+00	1.025E+00	0.203E+00	19.84	
			---------	---------			
	Total Activity :		5.938E+00	6.063E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.025E+00	1.037E+00	0.206E+00	19.84	
			---------	---------			
	Total Activity :		1.025E+00	1.037E+00			

Grand Total Activity : 2.844E+01 2.860E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.520E+01	1.015E+00	4.903E-01	0.000E+00	31.003
TL-208	1.004E+00	1.830E-01	1.441E-01	0.000E+00	6.966
BI-212	1.711E+00	7.044E-01	5.815E-01	0.000E+00	2.942
PB-212	1.230E+00	8.120E-02	7.032E-02	0.000E+00	17.491
BI-214	1.079E+00	1.140E-01	3.550E-01	0.000E+00	3.039
PB-214	1.093E+00	9.105E-02	9.142E-02	0.000E+00	11.951
RA-226	3.438E+00	1.012E+00	8.055E-01	0.000E+00	4.267
AC-228	1.037E+00	2.057E-01	1.835E-01	0.000E+00	5.649
RA-228	1.450E+00	3.128E-01	2.869E-01	0.000E+00	5.054
TH-232	1.025E+00	2.035E-01	1.723E-01	0.000E+00	5.951
TH-234	3.308E-01	8.989E-01	9.145E-01	0.000E+00	0.362

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	1.518E-02		3.319E-02	5.925E-02	0.000E+00	0.256
CS-137	3.936E-02		3.155E-02	5.589E-02	0.000E+00	0.704
LA-138	1.418E-02		4.498E-02	8.022E-02	0.000E+00	0.177
PA-234M	-1.230E+00		3.940E+00	6.019E+00	0.000E+00	-0.204
U-235	-9.843E-02		1.595E-01	2.368E-01	0.000E+00	-0.416
U-238	-1.230E+00		3.940E+00	6.019E+00	0.000E+00	-0.204

```
A,23L95403-13      ,03/18/2022 08:07,02/13/2022 12:56,   2.140E+01,L95403-13 SS A
B,23L95403-13      ,NORMK                     ,03/07/2022 09:36,23S25122820
C,K-40     ,YES,   1.520E+01,   1.015E+00,   4.903E-01,,   31.003
C,TL-208   ,YES,   1.004E+00,   1.830E-01,   1.441E-01,,    6.966
C,BI-212   ,YES,   1.711E+00,   7.044E-01,   5.815E-01,,    2.942
C,PB-212   ,YES,   1.230E+00,   8.120E-02,   7.032E-02,,   17.491
C,BI-214   ,YES,   1.079E+00,   1.140E-01,   3.550E-01,,    3.039
C,PB-214   ,YES,   1.093E+00,   9.105E-02,   9.142E-02,,   11.951
C,RA-226   ,YES,   3.438E+00,   1.012E+00,   8.055E-01,,    4.267
C,AC-228   ,YES,   1.037E+00,   2.057E-01,   1.835E-01,,    5.649
C,RA-228   ,YES,   1.450E+00,   3.128E-01,   2.869E-01,,    5.054
C,TH-232   ,YES,   1.025E+00,   2.035E-01,   1.723E-01,,    5.951
C,TH-234   ,YES,   3.308E-01,   8.989E-01,   9.145E-01,,    0.362
C,CO-60    ,NO ,   1.518E-02,   3.319E-02,   5.925E-02,,    0.256
C,CS-137   ,NO ,   3.936E-02,   3.155E-02,   5.589E-02,,    0.704
C,LA-138   ,NO ,   1.418E-02,   4.498E-02,   8.022E-02,,    0.177
C,PA-234M  ,NO ,  -1.230E+00,   3.940E+00,   6.019E+00,,   -0.204
C,U-235    ,NO ,  -9.843E-02,   1.595E-01,   2.368E-01,,   -0.416
C,U-238    ,NO ,  -1.230E+00,   3.940E+00,   6.019E+00,,   -0.204
```

Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 19-MAR-2022 05:14:47.09
TBE11 59-TN51806A HpGe ******* Aquisition Date/Time: 18-MAR-2022 11:13:52.41

LIMS No., Customer Name, Client ID: L95403-14 SS ANCHOR QEA

Sample ID : 11L95403-14
Sample Type : SS
Quantity : 4.17000E+01 g Dry
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: NORMK
Peak Evaluation - Identified and Unidentified

Smple Date: 13-FEB-2022 12:56:00.
Geometry : 11S50121819
BKGFILE : 11BG030422MT
Real Time : 0 18:00:32.57
Live time : 0 18:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	46.49*	680	2219	1.14	91.61	6.56E+00	1.05E-02	15.9	
2	0	63.36*	275	2084	1.33	125.34	7.37E+00	4.25E-03	33.0	
3	0	77.36*	1294	2679	1.07	153.33	7.42E+00	2.00E-02	7.9	
4	3	84.68*	329	1666	1.55	167.97	7.33E+00	5.07E-03	26.2	1.67E+00
5	3	87.36*	507	1494	1.05	173.31	7.28E+00	7.82E-03	14.4	
6	0	92.95*	645	2202	1.42	184.50	7.17E+00	9.95E-03	16.6	
7	0	185.96*	405	2097	1.46	370.45	4.98E+00	6.25E-03	25.5	
8	0	209.46	219	1285	1.42	417.44	4.56E+00	3.38E-03	29.1	
9	3	238.86*	2671	1055	1.35	476.22	4.12E+00	4.12E-02	3.2	1.97E+00
10	3	241.79	735	1432	1.84	482.08	4.08E+00	1.13E-02	11.6	
11	0	295.32*	722	1271	1.44	589.12	3.47E+00	1.11E-02	11.2	
12	0	338.60	509	1047	1.16	675.65	3.09E+00	7.86E-03	12.7	
13	0	352.13*	1402	1159	1.54	702.69	2.99E+00	2.16E-02	6.3	
14	0	511.27*	350	1045	2.56	1020.88	2.18E+00	5.40E-03	31.1	
15	0	583.49*	664	548	1.56	1165.29	1.95E+00	1.02E-02	9.0	
16	0	609.72*	842	823	1.50	1217.72	1.87E+00	1.30E-02	9.1	
17	0	727.75	198	459	1.51	1453.72	1.62E+00	3.05E-03	23.5	
18	0	846.88*	98	409	1.80	1691.90	1.42E+00	1.52E-03	53.2	
19	0	911.39*	490	359	2.04	1820.89	1.34E+00	7.57E-03	10.6	
20	0	969.61*	295	412	1.56	1937.29	1.27E+00	4.55E-03	17.0	
21	0	1121.43*	137	352	2.04	2240.85	1.13E+00	2.12E-03	34.3	
22	0	1461.37*	1456	293	2.27	2920.56	9.01E-01	2.25E-02	4.5	
23	0	1765.80*	134	108	1.61	3529.25	7.61E-01	2.07E-03	22.8	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1456	10.67*	9.006E-01	1.515E+01	1.515E+01	9.01
BI-214	609.31	842	46.30	1.875E+00	9.706E-01	9.706E-01	18.20
	1120.29	137	15.10*	1.128E+00	8.076E-01	8.076E-01	68.63
	1764.49	134	15.80	7.611E-01	1.113E+00	1.113E+00	45.55
RA-226	186.21	405	3.28*	4.982E+00	2.480E+00	2.480E+00	50.95

RA-228	93.35	645	3.50	7.173E+00	2.568E+00	2.597E+00	33.16
	969.11	295	16.60*	1.273E+00	1.396E+00	1.411E+00	34.01
TH-234	63.29	275	3.80*	7.368E+00	9.842E-01	9.842E-01	66.05
	92.60	645	5.41	7.173E+00	1.662E+00	1.662E+00	33.16

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	664	30.25*	1.946E+00	1.128E+00	1.166E+00	18.06
BI-212	727.17	198	7.56*	1.616E+00	1.617E+00	1.671E+00	47.03
PB-212	238.63	2671	44.60*	4.120E+00	1.454E+00	1.503E+00	6.34
PB-214	295.21	722	19.20	3.467E+00	1.085E+00	1.085E+00	22.36
	351.92	1402	37.20*	2.990E+00	1.261E+00	1.261E+00	12.53
TH-232	911.21	490	27.70*	1.340E+00	1.321E+00	1.321E+00	21.15

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	1.440E+00	------	Line Not Found	------
	911.07	490	27.70*	1.340E+00	1.321E+00	1.336E+00	21.15

Flag: "*" = Keyline

Total number of lines in spectrum	23	
Number of unidentified lines	9	
Number of lines tentatively identified by NID	14	60.87%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.515E+01	1.515E+01	0.136E+01	9.01	
BI-214	1600.00Y	1.00	8.076E-01	8.076E-01	5.542E-01	68.63	
RA-226	1600.00Y	1.00	2.480E+00	2.480E+00	1.263E+00	50.95	
RA-228	5.75Y	1.01	1.396E+00	1.411E+00	0.480E+00	34.01	
TH-234	4.47E+09Y	1.00	9.842E-01	9.842E-01	6.501E-01	66.05	
			---------	---------			
	Total Activity :		2.082E+01	2.084E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.128E+00	1.166E+00	0.211E+00	18.06	
BI-212	1.91Y	1.03	1.617E+00	1.671E+00	0.786E+00	47.03	
PB-212	1.91Y	1.03	1.454E+00	1.503E+00	0.095E+00	6.34	
PB-214	1600.00Y	1.00	1.261E+00	1.261E+00	0.158E+00	12.53	
TH-232	1.41E+10Y	1.00	1.321E+00	1.321E+00	0.280E+00	21.15	
			---------	---------			
	Total Activity :		6.782E+00	6.923E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.321E+00	1.336E+00	0.283E+00	21.15	
			---------	---------			
	Total Activity :		1.321E+00	1.336E+00			

Grand Total Activity : 2.892E+01 2.909E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
0	46.49	680	2219	1.14	91.61	87	11	1.05E-02	31.7	6.56E+00	
0	77.36	1294	2679	1.07	153.33	151	7	2.00E-02	15.8	7.42E+00	
3	84.68	329	1666	1.55	167.97	164	13	5.07E-03	52.4	7.33E+00	
3	87.36	507	1494	1.05	173.31	164	13	7.82E-03	28.8	7.28E+00	
0	209.46	219	1285	1.42	417.44	414	8	3.38E-03	58.3	4.56E+00	
3	241.79	735	1432	1.84	482.08	469	19	1.13E-02	23.1	4.08E+00	
0	338.60	509	1047	1.16	675.65	671	10	7.86E-03	25.4	3.09E+00	
0	511.27	350	1045	2.56	1020.88	1012	20	5.40E-03	62.1	2.18E+00	
0	846.88	98	409	1.80	1691.90	1684	15	1.52E-03	****	1.42E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	23	
Number of unidentified lines	9	
Number of lines tentatively identified by NID	14	60.87%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.515E+01	1.515E+01	0.136E+01	9.01	
BI-214	1600.00Y	1.00	9.712E-01	9.712E-01	1.597E-01	16.45	
RA-226	1600.00Y	1.00	2.480E+00	2.480E+00	1.263E+00	50.95	
RA-228	5.75Y	1.01	1.396E+00	1.411E+00	0.480E+00	34.01	
TH-234	4.47E+09Y	1.00	9.842E-01	9.842E-01	6.501E-01	66.05	
			---------	---------			
	Total Activity :		2.098E+01	2.100E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.128E+00	1.166E+00	0.211E+00	18.06	
BI-212	1.91Y	1.03	1.617E+00	1.671E+00	0.786E+00	47.03	
PB-212	1.91Y	1.03	1.454E+00	1.503E+00	0.095E+00	6.34	
PB-214	1600.00Y	1.00	1.208E+00	1.208E+00	0.132E+00	10.96	
TH-232	1.41E+10Y	1.00	1.321E+00	1.321E+00	0.280E+00	21.15	
			---------	---------			
	Total Activity :		6.729E+00	6.870E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.321E+00	1.336E+00	0.283E+00	21.15	
			---------	---------			
	Total Activity :		1.321E+00	1.336E+00			

Grand Total Activity : 2.903E+01 2.921E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.515E+01	1.365E+00	5.901E-01	0.000E+00	25.680
TL-208	1.166E+00	2.106E-01	1.934E-01	0.000E+00	6.030
BI-212	1.671E+00	7.860E-01	8.171E-01	0.000E+00	2.046
PB-212	1.503E+00	9.526E-02	8.974E-02	0.000E+00	16.747
BI-214	9.712E-01	1.597E-01	4.827E-01	0.000E+00	2.012
PB-214	1.208E+00	1.324E-01	1.236E-01	0.000E+00	9.777
RA-226	2.480E+00	1.263E+00	1.063E+00	0.000E+00	2.332
AC-228	1.336E+00	2.826E-01	2.405E-01	0.000E+00	5.555
RA-228	1.411E+00	4.801E-01	4.568E-01	0.000E+00	3.090
TH-232	1.321E+00	2.795E-01	2.379E-01	0.000E+00	5.554
TH-234	9.842E-01	6.501E-01	7.594E-01	0.000E+00	1.296

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	5.008E-03		3.931E-02	6.667E-02	0.000E+00	0.075
CS-137	1.830E-02		4.361E-02	7.346E-02	0.000E+00	0.249
LA-138	-2.932E-04		5.592E-02	9.768E-02	0.000E+00	-0.003
PA-234M	4.433E+00		4.301E+00	7.617E+00	0.000E+00	0.582
U-235	-2.692E-01		2.017E-01	2.921E-01	0.000E+00	-0.922
U-238	4.433E+00		4.301E+00	7.617E+00	0.000E+00	0.582

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A,11L95403-14      ,03/19/2022 05:14,02/13/2022 12:56,   4.170E+01,L95403-14 SS A
B,11L95403-14      ,NORMK                  ,02/10/2022 09:58,11S50121819
C,K-40     ,YES,   1.515E+01,    1.365E+00,    5.901E-01,,   25.680
C,TL-208   ,YES,   1.166E+00,    2.106E-01,    1.934E-01,,    6.030
C,BI-212   ,YES,   1.671E+00,    7.860E-01,    8.171E-01,,    2.046
C,PB-212   ,YES,   1.503E+00,    9.526E-02,    8.974E-02,,   16.747
C,BI-214   ,YES,   9.712E-01,    1.597E-01,    4.827E-01,,    2.012
C,PB-214   ,YES,   1.208E+00,    1.324E-01,    1.236E-01,,    9.777
C,RA-226   ,YES,   2.480E+00,    1.263E+00,    1.063E+00,,    2.332
C,AC-228   ,YES,   1.336E+00,    2.826E-01,    2.405E-01,,    5.555
C,RA-228   ,YES,   1.411E+00,    4.801E-01,    4.568E-01,,    3.090
C,TH-232   ,YES,   1.321E+00,    2.795E-01,    2.379E-01,,    5.554
C,TH-234   ,YES,   9.842E-01,    6.501E-01,    7.594E-01,,    1.296
C,CO-60    ,NO ,   5.008E-03,    3.931E-02,    6.667E-02,,    0.075
C,CS-137   ,NO ,   1.830E-02,    4.361E-02,    7.346E-02,,    0.249
C,LA-138   ,NO ,  -2.932E-04,    5.592E-02,    9.768E-02,,   -0.003
C,PA-234M  ,NO ,   4.433E+00,    4.301E+00,    7.617E+00,,    0.582
C,U-235    ,NO ,  -2.692E-01,    2.017E-01,    2.921E-01,,   -0.922
C,U-238    ,NO ,   4.433E+00,    4.301E+00,    7.617E+00,,    0.582
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Analyst:

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 18-MAR-2022 08:07:48.56
TBE06 33-TP10933A HpGe ******* Aquisition Date/Time: 17-MAR-2022 14:52:13.44

LIMS No., Customer Name, Client ID: L95403-15 SS ANCHOR QEA

Sample ID : 06L95403-15
Sample Type : SS
Quantity : 2.73000E+01 g Dry
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: NORMK
Peak Evaluation - Identified and Unidentified

Smple Date: 13-FEB-2022 12:56:00.
Geometry : 06S25031921
BKGFILE : 06BG030422MT
Real Time : 0 17:15:25.24
Live time : 0 17:15:14.02

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	77.22	365	1158	0.85	154.90	2.68E+00	5.88E-03	15.7	
2	0	92.95*	313	1500	1.71	186.30	4.44E+00	5.05E-03	25.5	
3	0	185.64*	276	1672	0.93	371.33	6.13E+00	4.45E-03	32.1	
4	4	238.73*	1535	878	1.10	477.32	5.23E+00	2.47E-02	4.6	1.02E+00
5	4	242.02	483	1056	1.77	483.90	5.18E+00	7.78E-03	13.2	
6	0	295.50*	501	1130	1.19	590.64	4.43E+00	8.07E-03	14.9	
7	0	338.40	439	804	1.18	676.28	3.96E+00	7.06E-03	12.6	
8	0	352.12*	1078	761	1.22	703.67	3.83E+00	1.74E-02	6.5	
9	0	583.24*	416	517	1.37	1164.99	2.48E+00	6.69E-03	12.9	
10	0	609.40*	742	604	1.23	1217.21	2.38E+00	1.20E-02	8.4	
11	0	911.59*	334	332	1.78	1820.33	1.65E+00	5.38E-03	14.7	
12	0	969.40*	214	316	1.69	1935.69	1.56E+00	3.45E-03	20.4	
13	0	1120.55*	112	290	1.39	2237.33	1.36E+00	1.80E-03	35.8	
14	0	1461.16*	935	58	1.67	2916.98	1.07E+00	1.50E-02	4.8	
15	0	1765.00*	133	96	1.90	3523.18	9.41E-01	2.14E-03	21.2	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	935	10.67*	1.074E+00	1.300E+01	1.300E+01	9.61
BI-214	609.31	742	46.30	2.384E+00	1.072E+00	1.072E+00	16.87
	1120.29	112	15.10*	1.357E+00	8.709E-01	8.709E-01	71.67
	1764.49	133	15.80	9.412E-01	1.425E+00	1.425E+00	42.45
RA-226	186.21	276	3.28*	6.127E+00	2.192E+00	2.192E+00	64.30
RA-228	93.35	313	3.50	4.441E+00	3.214E+00	3.249E+00	51.09
	969.11	214	16.60*	1.555E+00	1.322E+00	1.337E+00	40.74
TH-234	63.29	------	3.80*	1.100E+00	------	Line Not Found	------
	92.60	313	5.41	4.441E+00	2.080E+00	2.080E+00	51.09
U-235	143.76	------	10.50*	6.538E+00	------	Line Not Found	------
	163.35	------	4.70	6.435E+00	------	Line Not Found	------
	185.71	276	54.00	6.127E+00	1.332E-01	1.332E-01	64.30
	205.31	------	4.70	5.795E+00	------	Line Not Found	------

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	416	30.25*	2.478E+00	8.836E-01	9.125E-01	25.72
PB-212	238.63	1535	44.60*	5.234E+00	1.048E+00	1.082E+00	9.14
PB-214	295.21	501	19.20	4.431E+00	9.393E-01	9.393E-01	29.72
	351.92	1078	37.20*	3.829E+00	1.207E+00	1.207E+00	12.92
TH-232	911.21	334	27.70*	1.648E+00	1.167E+00	1.167E+00	29.33

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	1.788E+00	------	Line Not Found	------
	911.07	334	27.70*	1.648E+00	1.167E+00	1.179E+00	29.33

Flag: "*" = Keyline

Total number of lines in spectrum	15	
Number of unidentified lines	3	
Number of lines tentatively identified by NID	12	80.00%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.300E+01	1.300E+01	0.125E+01	9.61	
BI-214	1600.00Y	1.00	8.709E-01	8.709E-01	6.242E-01	71.67	
RA-226	1600.00Y	1.00	2.192E+00	2.192E+00	1.410E+00	64.30	
RA-228	5.75Y	1.01	1.322E+00	1.337E+00	0.545E+00	40.74	
TH-234	4.47E+09Y	1.00	2.080E+00	2.080E+00	1.063E+00	51.09	K
U-235	7.04E+08Y	1.00	1.332E-01	1.332E-01	0.856E-01	64.30	K
			---------	---------			
	Total Activity :		1.960E+01	1.961E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	8.836E-01	9.125E-01	2.347E-01	25.72	
PB-212	1.91Y	1.03	1.048E+00	1.082E+00	0.099E+00	9.14	
PB-214	1600.00Y	1.00	1.207E+00	1.207E+00	0.156E+00	12.92	
TH-232	1.41E+10Y	1.00	1.167E+00	1.167E+00	0.342E+00	29.33	
			---------	---------			
	Total Activity :		4.305E+00	4.368E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.167E+00	1.179E+00	0.346E+00	29.33	
			---------	---------			
	Total Activity :		1.167E+00	1.179E+00			

Grand Total Activity : 2.507E+01 2.516E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
0	77.22	365	1158	0.85	154.90	153	6	5.88E-03	31.5	2.68E+00	
4	242.02	483	1056	1.77	483.90	472	17	7.78E-03	26.3	5.18E+00	
0	338.40	439	804	1.18	676.28	672	9	7.06E-03	25.2	3.96E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	15	
Number of unidentified lines	3	
Number of lines tentatively identified by NID	12	80.00%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.300E+01	1.300E+01	0.125E+01	9.61	
BI-214	1600.00Y	1.00	1.085E+00	1.085E+00	0.167E+00	15.39	
RA-226	1600.00Y	1.00	2.192E+00	2.192E+00	1.410E+00	64.30	
RA-228	5.75Y	1.01	1.322E+00	1.337E+00	0.545E+00	40.74	
	Total Activity :		1.760E+01	1.761E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	8.836E-01	9.125E-01	2.347E-01	25.72	
PB-212	1.91Y	1.03	1.048E+00	1.082E+00	0.099E+00	9.14	
PB-214	1600.00Y	1.00	1.143E+00	1.143E+00	0.136E+00	11.91	
TH-232	1.41E+10Y	1.00	1.167E+00	1.167E+00	0.342E+00	29.33	
	Total Activity :		4.241E+00	4.305E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.167E+00	1.179E+00	0.346E+00	29.33	
	Total Activity :		1.167E+00	1.179E+00			

Grand Total Activity : 2.301E+01 2.310E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

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A,06L95403-15      ,03/18/2022 08:07,02/13/2022 12:56,   2.730E+01,L95403-15 SS A
B,06L95403-15      ,NORMK                ,10/29/2021 09:14,06S25031921
C,K-40     ,YES,   1.300E+01,   1.249E+00,   6.662E-01,,    19.510
C,TL-208   ,YES,   9.125E-01,   2.347E-01,   2.057E-01,,     4.437
C,PB-212   ,YES,   1.082E+00,   9.896E-02,   9.928E-02,,    10.901
C,BI-214   ,YES,   1.085E+00,   1.670E-01,   5.182E-01,,     2.093
C,PB-214   ,YES,   1.143E+00,   1.361E-01,   1.323E-01,,     8.641
C,RA-226   ,YES,   2.192E+00,   1.410E+00,   1.229E+00,,     1.783
C,AC-228   ,YES,   1.179E+00,   3.459E-01,   2.543E-01,,     4.637
C,RA-228   ,YES,   1.337E+00,   5.446E-01,   5.559E-01,,     2.404
C,TH-232   ,YES,   1.167E+00,   3.423E-01,   2.517E-01,,     4.636
C,CO-60    ,NO ,   8.179E-02,   4.951E-02,   8.972E-02,,     0.912
C,CS-137   ,NO ,   7.635E-02,   4.737E-02,   8.369E-02,,     0.912
C,LA-138   ,NO ,  -1.622E-03,   6.178E-02,   1.026E-01,,    -0.016
C,BI-212   ,NO ,   4.119E-01,   6.205E-01,   1.005E+00,,     0.410
C,PA-234M  ,NO ,   7.441E+00,   5.008E+00,   8.736E+00,,     0.852
C,TH-234   ,NO ,   1.282E+00,   3.628E+00,   6.052E+00,,     0.212
C,U-235    ,NO ,   1.491E-02,   2.197E-01,   3.533E-01,,     0.042
C,U-238    ,NO ,   7.441E+00,   5.008E+00,   8.736E+00,,     0.852
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Analyst:

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 19-MAR-2022 05:14:35.81
TBE01 33-TP20784A HpGe ******* Aquisition Date/Time: 18-MAR-2022 11:13:54.25

LIMS No., Customer Name, Client ID: L95403-16 SS ANCHOR QEA

Sample ID : 01L95403-16
Sample Type : SS
Quantity : 3.00000E+01 g Dry
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: NORMK
Peak Evaluation - Identified and Unidentified

Smple Date: 13-FEB-2022 12:56:00.
Geometry : 01S25121819
BKGFILE : 01BG030422MT
Real Time : 0 18:00:08.67
Live time : 0 18:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	2	74.79*	642	1734	1.22	150.12	5.71E+00	9.91E-03	12.8	6.88E+00
2	2	77.04	1005	1336	0.94	154.61	6.10E+00	1.55E-02	6.7	
3	1	87.35*	214	2424	0.93	175.21	7.65E+00	3.31E-03	44.0	3.72E+00
4	1	92.86*	570	2067	1.64	186.22	8.30E+00	8.80E-03	17.5	4.02E+00
5	1	185.81*	601	1727	1.47	371.98	9.12E+00	9.27E-03	15.4	1.20E+00
6	1	209.36	321	1163	1.10	419.06	8.51E+00	4.96E-03	19.2	1.87E+00
7	3	238.61*	2690	897	1.13	477.51	7.80E+00	4.15E-02	2.9	1.67E+00
8	3	241.58	690	1172	1.52	483.45	7.73E+00	1.06E-02	10.1	
9	1	270.36	390	923	1.69	540.96	7.11E+00	6.02E-03	14.9	1.25E+00
10	1	295.19*	744	997	1.16	590.61	6.64E+00	1.15E-02	9.5	6.46E-01
11	1	338.31	708	934	1.31	676.78	5.95E+00	1.09E-02	9.2	2.23E+00
12	1	351.91*	1300	1132	1.29	703.96	5.76E+00	2.01E-02	6.8	1.15E+00
13	1	462.96	261	716	1.85	925.93	4.55E+00	4.03E-03	22.8	1.35E+00
14	1	510.85*	307	921	2.79	1021.65	4.17E+00	4.74E-03	31.5	2.30E+00
15	1	583.06*	804	456	1.67	1166.00	3.71E+00	1.24E-02	6.9	3.63E+00
16	1	609.16*	878	440	1.55	1218.19	3.56E+00	1.36E-02	6.1	5.21E+00
17	1	661.68	102	387	1.31	1323.17	3.30E+00	1.58E-03	37.5	7.54E-01
18	1	727.11	316	405	3.03	1453.97	3.02E+00	4.88E-03	15.0	3.02E+00
19	1	911.05*	581	472	1.68	1821.71	2.42E+00	8.97E-03	9.9	3.23E+00
20	1	968.99*	301	297	1.85	1937.55	2.28E+00	4.64E-03	13.7	2.22E+00
21	1	1120.42*	130	284	1.99	2240.33	1.98E+00	2.00E-03	30.8	1.61E+00
22	1	1460.71*	1670	123	2.38	2920.80	1.54E+00	2.58E-02	3.2	2.57E+00
23	1	1764.34*	153	74	2.44	3528.06	1.32E+00	2.36E-03	17.7	2.37E+00

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1670	10.67*	1.540E+00	1.413E+01	1.413E+01	6.39
CS-137	661.66	102	85.12*	3.296E+00	5.072E-02	5.083E-02	74.99
BI-214	609.31	878	46.30	3.559E+00	7.411E-01	7.411E-01	12.28
	1120.29	130	15.10*	1.977E+00	6.047E-01	6.047E-01	61.55
	1764.49	153	15.80	1.323E+00	1.015E+00	1.016E+00	35.33

RA-226	186.21	601	3.28*	9.117E+00	2.794E+00	2.794E+00	30.87
RA-228	93.35	570	3.50	8.297E+00	2.729E+00	2.759E+00	35.07
	969.11	301	16.60*	2.281E+00	1.105E+00	1.117E+00	27.39
TH-234	63.29	------	3.80*	3.510E+00	------	Line Not Found	------
	92.60	570	5.41	8.297E+00	1.765E+00	1.765E+00	35.07
U-235	143.76	------	10.50*	9.986E+00	------	Line Not Found	------
	163.35	------	4.70	9.656E+00	------	Line Not Found	------
	185.71	601	54.00	9.117E+00	1.697E-01	1.697E-01	30.87
	205.31	------	4.70	8.614E+00	------	Line Not Found	------

Nuclide Type: NATURAL

					Uncorrected	Decay Corr	2-Sigma
Nuclide	Energy	Area	%Abn	%Eff	pCi/g Dry	pCi/g Dry	%Error
TL-208	583.17	804	30.25*	3.705E+00	9.968E-01	1.030E+00	13.73
BI-212	727.17	316	7.56*	3.015E+00	1.928E+00	1.993E+00	29.96
PB-212	238.63	2690	44.60*	7.796E+00	1.076E+00	1.112E+00	5.90
PB-214	295.21	744	19.20	6.640E+00	8.117E-01	8.117E-01	19.02
	351.92	1300	37.20*	5.756E+00	8.442E-01	8.442E-01	13.51
TH-232	911.21	581	27.70*	2.424E+00	1.204E+00	1.204E+00	19.75

Nuclide Type: natural

					Uncorrected	Decay Corr	2-Sigma
Nuclide	Energy	Area	%Abn	%Eff	pCi/g Dry	pCi/g Dry	%Error
AC-228	835.50	------	1.75	2.638E+00	------	Line Not Found	------
	911.07	581	27.70*	2.424E+00	1.204E+00	1.217E+00	19.75

Flag: "*" = Keyline

Total number of lines in spectrum	23	
Number of unidentified lines	9	
Number of lines tentatively identified by NID	14	60.87%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.413E+01	1.413E+01	0.090E+01	6.39	
CS-137	30.07Y	1.00	5.072E-02	5.083E-02	3.811E-02	74.99	
BI-214	1600.00Y	1.00	6.047E-01	6.047E-01	3.722E-01	61.55	
RA-226	1600.00Y	1.00	2.794E+00	2.794E+00	0.863E+00	30.87	
RA-228	5.75Y	1.01	1.105E+00	1.117E+00	0.306E+00	27.39	
TH-234	4.47E+09Y	1.00	1.765E+00	1.765E+00	0.619E+00	35.07	K
U-235	7.04E+08Y	1.00	1.697E-01	1.697E-01	0.524E-01	30.87	K
			---------	---------			
	Total Activity :		2.062E+01	2.063E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	9.968E-01	1.030E+00	0.141E+00	13.73	
BI-212	1.91Y	1.03	1.928E+00	1.993E+00	0.597E+00	29.96	
PB-212	1.91Y	1.03	1.076E+00	1.112E+00	0.066E+00	5.90	
PB-214	1600.00Y	1.00	8.442E-01	8.442E-01	1.140E-01	13.51	
TH-232	1.41E+10Y	1.00	1.204E+00	1.204E+00	0.238E+00	19.75	
			---------	---------			
	Total Activity :		6.049E+00	6.183E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.204E+00	1.217E+00	0.240E+00	19.75	
			---------	---------			
	Total Activity :		1.204E+00	1.217E+00			

Grand Total Activity : 2.787E+01 2.803E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
2	74.79	642	1734	1.22	150.12	144	14	9.91E-03	25.6	5.71E+00	
2	77.04	1005	1336	0.94	154.61	144	14	1.55E-02	13.5	6.10E+00	
1	87.35	214	2424	0.93	175.21	170	9	3.31E-03	88.0	7.65E+00	
1	209.36	321	1163	1.10	419.06	415	8	4.96E-03	38.3	8.51E+00	
3	241.58	690	1172	1.52	483.45	470	19	1.06E-02	20.2	7.73E+00	
1	270.36	390	923	1.69	540.96	537	9	6.02E-03	29.8	7.11E+00	
1	338.31	708	934	1.31	676.78	671	11	1.09E-02	18.4	5.95E+00	
1	462.96	261	716	1.85	925.93	919	14	4.03E-03	45.6	4.55E+00	
1	510.85	307	921	2.79	1021.65	1013	19	4.74E-03	62.9	4.17E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	23	
Number of unidentified lines	9	
Number of lines tentatively identified by NID	14	60.87%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.413E+01	1.413E+01	0.090E+01	6.39	
CS-137	30.07Y	1.00	5.072E-02	5.083E-02	3.811E-02	74.99	
BI-214	1600.00Y	1.00	7.495E-01	7.496E-01	0.859E-01	11.45	
RA-226	1600.00Y	1.00	2.794E+00	2.794E+00	0.863E+00	30.87	
RA-228	5.75Y	1.01	1.105E+00	1.117E+00	0.306E+00	27.39	
			---------	---------			
	Total Activity :		1.883E+01	1.884E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	9.968E-01	1.030E+00	0.141E+00	13.73	
BI-212	1.91Y	1.03	1.928E+00	1.993E+00	0.597E+00	29.96	
PB-212	1.91Y	1.03	1.076E+00	1.112E+00	0.066E+00	5.90	
PB-214	1600.00Y	1.00	8.327E-01	8.327E-01	0.917E-01	11.01	
TH-232	1.41E+10Y	1.00	1.204E+00	1.204E+00	0.238E+00	19.75	
			---------	---------			
	Total Activity :		6.037E+00	6.172E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.204E+00	1.217E+00	0.240E+00	19.75	
			---------	---------			
	Total Activity :		1.204E+00	1.217E+00			

Grand Total Activity : 2.607E+01 2.623E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.413E+01	9.021E-01	4.186E-01	0.000E+00	33.745
CS-137	5.083E-02	3.811E-02	4.702E-02	0.000E+00	1.081
TL-208	1.030E+00	1.415E-01	1.276E-01	0.000E+00	8.074
BI-212	1.993E+00	5.971E-01	5.521E-01	0.000E+00	3.610
PB-212	1.112E+00	6.556E-02	6.110E-02	0.000E+00	18.197
BI-214	7.496E-01	8.586E-02	3.184E-01	0.000E+00	2.354
PB-214	8.327E-01	9.171E-02	8.104E-02	0.000E+00	10.276
RA-226	2.794E+00	8.625E-01	7.439E-01	0.000E+00	3.756
AC-228	1.217E+00	2.404E-01	1.597E-01	0.000E+00	7.620
RA-228	1.117E+00	3.059E-01	3.209E-01	0.000E+00	3.480
TH-232	1.204E+00	2.377E-01	1.580E-01	0.000E+00	7.618

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	2.590E-02		3.103E-02	5.304E-02	0.000E+00	0.488
LA-138	-1.497E-02		4.241E-02	6.723E-02	0.000E+00	-0.223
PA-234M	1.675E+00		3.619E+00	5.544E+00	0.000E+00	0.302
TH-234	-1.911E-01		1.304E+00	1.899E+00	0.000E+00	-0.101
U-235	-9.953E-02		1.562E-01	2.190E-01	0.000E+00	-0.454
U-238	1.675E+00		3.619E+00	5.544E+00	0.000E+00	0.302

```
A,01L95403-16      ,03/19/2022 05:14,02/13/2022 12:56,   3.000E+01,L95403-16 SS A
B,01L95403-16      ,NORMK                    ,11/17/2021 15:33,01S25121819
C,K-40     ,YES,   1.413E+01,    9.021E-01,    4.186E-01,,    33.745
C,CS-137   ,YES,   5.083E-02,    3.811E-02,    4.702E-02,,     1.081
C,TL-208   ,YES,   1.030E+00,    1.415E-01,    1.276E-01,,     8.074
C,BI-212   ,YES,   1.993E+00,    5.971E-01,    5.521E-01,,     3.610
C,PB-212   ,YES,   1.112E+00,    6.556E-02,    6.110E-02,,    18.197
C,BI-214   ,YES,   7.496E-01,    8.586E-02,    3.184E-01,,     2.354
C,PB-214   ,YES,   8.327E-01,    9.171E-02,    8.104E-02,,    10.276
C,RA-226   ,YES,   2.794E+00,    8.625E-01,    7.439E-01,,     3.756
C,AC-228   ,YES,   1.217E+00,    2.404E-01,    1.597E-01,,     7.620
C,RA-228   ,YES,   1.117E+00,    3.059E-01,    3.209E-01,,     3.480
C,TH-232   ,YES,   1.204E+00,    2.377E-01,    1.580E-01,,     7.618
C,CO-60    ,NO ,   2.590E-02,    3.103E-02,    5.304E-02,,     0.488
C,LA-138   ,NO ,  -1.497E-02,    4.241E-02,    6.723E-02,,    -0.223
C,PA-234M  ,NO ,   1.675E+00,    3.619E+00,    5.544E+00,,     0.302
C,TH-234   ,NO ,  -1.911E-01,    1.304E+00,    1.899E+00,,    -0.101
C,U-235    ,NO ,  -9.953E-02,    1.562E-01,    2.190E-01,,    -0.454
C,U-238    ,NO ,   1.675E+00,    3.619E+00,    5.544E+00,,     0.302
```

Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 19-MAR-2022 05:19:13.81
TBE08 31-TP20610B HpGe ******** Aquisition Date/Time: 18-MAR-2022 11:18:21.75

LIMS No., Customer Name, Client ID: L95403-17 SS ANCHOR QEA

Sample ID	: 08L95403-17		Smple Date:	13-FEB-2022 12:56:00.
Sample Type	: SS		Geometry :	08S50121919
Quantity	: 4.41000E+01 g Dry		BKGFILE :	08BG030422MT
Start Channel	: 80	Energy Tol : 2.00000	Real Time :	0 18:00:31.65
End Channel	: 4090	Pk Srch Sens: 9.00000	Live time :	0 18:00:00.00
MDA Multiple	: 4.6600	Library Used: NORMK		

Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	4	75.26*	914	2487	1.70	156.63	3.71E+00	1.41E-02	12.1	6.17E+00
2	4	77.50*	820	1870	1.29	161.10	3.92E+00	1.27E-02	11.6	
3	2	87.73	430	1485	1.27	181.49	4.72E+00	6.64E-03	14.6	4.52E+00
4	2	90.30	354	2056	1.43	186.63	4.89E+00	5.46E-03	23.8	
5	2	93.17*	362	1419	1.25	192.36	5.05E+00	5.58E-03	21.8	
6	1	186.47*	543	2117	1.61	378.43	5.38E+00	8.37E-03	19.4	1.88E+00
7	1	209.84	365	1335	1.55	425.04	5.01E+00	5.63E-03	18.8	9.23E-01
8	5	239.22*	2770	1174	1.44	483.62	4.57E+00	4.28E-02	3.2	9.76E-01
9	5	242.16*	624	1424	2.01	489.48	4.53E+00	9.62E-03	16.2	
10	1	295.77*	754	951	1.51	596.39	3.86E+00	1.16E-02	9.2	2.27E+00
11	1	338.98*	670	1200	1.63	682.55	3.43E+00	1.03E-02	11.6	2.59E+00
12	1	352.43*	1137	1211	1.62	709.37	3.31E+00	1.75E-02	7.9	2.12E+00
13	1	463.55	183	622	1.75	930.91	2.57E+00	2.83E-03	26.7	1.27E+00
14	1	511.40*	263	1159	3.15	1026.29	2.35E+00	4.06E-03	40.3	1.39E+00
15	1	583.63*	801	631	1.60	1170.27	2.08E+00	1.24E-02	8.2	1.63E+00
16	1	609.63*	868	1052	1.74	1222.11	1.99E+00	1.34E-02	10.0	2.01E+00
17	1	727.31	214	441	1.93	1456.63	1.69E+00	3.30E-03	20.7	1.66E+00
18	1	911.28*	547	256	2.48	1823.21	1.37E+00	8.45E-03	8.8	4.86E+00
19	1	969.38*	335	270	2.11	1938.98	1.29E+00	5.18E-03	12.2	1.23E+00
20	1	1120.48*	223	310	2.36	2239.97	1.13E+00	3.44E-03	20.6	8.50E-01
21	1	1461.21*	1489	185	2.13	2918.48	8.98E-01	2.30E-02	3.9	5.21E-01
22	1	1765.13*	144	73	2.53	3523.42	7.71E-01	2.23E-03	19.3	1.43E+00

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1489	10.67*	8.978E-01	1.470E+01	1.470E+01	7.76
BI-214	609.31	868	46.30	1.993E+00	8.898E-01	8.898E-01	20.09
	1120.29	223	15.10*	1.134E+00	1.231E+00	1.231E+00	41.22
	1764.49	144	15.80	7.706E-01	1.121E+00	1.121E+00	38.60
RA-226	186.21	543	3.28*	5.376E+00	2.910E+00	2.910E+00	38.72
RA-228	93.35	362	3.50	5.054E+00	1.934E+00	1.955E+00	43.66

	969.11	335	16.60*	1.294E+00	1.477E+00	1.493E+00	24.32

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	801	30.25*	2.076E+00	1.205E+00	1.246E+00	16.41
BI-212	727.17	214	7.56*	1.690E+00	1.585E+00	1.638E+00	41.43
PB-212	238.63	2770	44.60*	4.572E+00	1.285E+00	1.328E+00	6.41
PB-214	295.21	754	19.20	3.857E+00	9.632E-01	9.633E-01	18.45
	351.92	1137	37.20*	3.309E+00	8.735E-01	8.735E-01	15.82
TH-232	911.21	547	27.70*	1.370E+00	1.364E+00	1.364E+00	17.61

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	1.485E+00	------	Line Not Found	------
	911.07	547	27.70*	1.370E+00	1.364E+00	1.379E+00	17.61

Flag: "*" = Keyline

Total number of lines in spectrum	22	
Number of unidentified lines	9	
Number of lines tentatively identified by NID	13	59.09%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.470E+01	1.470E+01	0.114E+01	7.76	
BI-214	1600.00Y	1.00	1.231E+00	1.231E+00	0.507E+00	41.22	
RA-226	1600.00Y	1.00	2.910E+00	2.910E+00	1.127E+00	38.72	
RA-228	5.75Y	1.01	1.477E+00	1.493E+00	0.363E+00	24.32	
			---------	---------			
	Total Activity :		2.031E+01	2.033E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.205E+00	1.246E+00	0.204E+00	16.41	
BI-212	1.91Y	1.03	1.585E+00	1.638E+00	0.679E+00	41.43	
PB-212	1.91Y	1.03	1.285E+00	1.328E+00	0.085E+00	6.41	
PB-214	1600.00Y	1.00	8.735E-01	8.735E-01	1.382E-01	15.82	
TH-232	1.41E+10Y	1.00	1.364E+00	1.364E+00	0.240E+00	17.61	
			---------	---------			
	Total Activity :		6.312E+00	6.449E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.364E+00	1.379E+00	0.243E+00	17.61	
			---------	---------			
	Total Activity :		1.364E+00	1.379E+00			

Grand Total Activity : 2.799E+01 2.816E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
4	75.26	914	2487	1.70	156.63	149	17	1.41E-02	24.2	3.71E+00	
4	77.50	820	1870	1.29	161.10	149	17	1.27E-02	23.2	3.92E+00	
2	87.73	430	1485	1.27	181.49	179	20	6.64E-03	29.1	4.72E+00	
2	90.30	354	2056	1.43	186.63	179	20	5.46E-03	47.5	4.89E+00	
1	209.84	365	1335	1.55	425.04	421	9	5.63E-03	37.6	5.01E+00	
5	242.16	624	1424	2.01	489.48	476	19	9.62E-03	32.3	4.53E+00	
1	338.98	670	1200	1.63	682.55	676	12	1.03E-02	23.2	3.43E+00	
1	463.55	183	622	1.75	930.91	926	10	2.83E-03	53.4	2.57E+00	
1	511.40	263	1159	3.15	1026.29	1018	22	4.06E-03	80.7	2.35E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	22	
Number of unidentified lines	9	
Number of lines tentatively identified by NID	13	59.09%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.470E+01	1.470E+01	0.114E+01	7.76	
BI-214	1600.00Y	1.00	9.530E-01	9.530E-01	1.571E-01	16.49	
RA-226	1600.00Y	1.00	2.910E+00	2.910E+00	1.127E+00	38.72	
RA-228	5.75Y	1.01	1.547E+00	1.564E+00	0.334E+00	21.37	
			---------	---------			
	Total Activity :		2.011E+01	2.012E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.205E+00	1.246E+00	0.204E+00	16.41	
BI-212	1.91Y	1.03	1.585E+00	1.638E+00	0.679E+00	41.43	
PB-212	1.91Y	1.03	1.285E+00	1.328E+00	0.085E+00	6.41	
PB-214	1600.00Y	1.00	9.073E-01	9.074E-01	1.091E-01	12.02	
TH-232	1.41E+10Y	1.00	1.364E+00	1.364E+00	0.240E+00	17.61	
			---------	---------			
	Total Activity :		6.346E+00	6.483E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.364E+00	1.379E+00	0.243E+00	17.61	
			---------	---------			
	Total Activity :		1.364E+00	1.379E+00			

Grand Total Activity : 2.782E+01 2.798E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.470E+01	1.140E+00	4.844E-01	0.000E+00	30.336
TL-208	1.246E+00	2.045E-01	1.597E-01	0.000E+00	7.800
BI-212	1.638E+00	6.786E-01	7.183E-01	0.000E+00	2.280
PB-212	1.328E+00	8.515E-02	7.475E-02	0.000E+00	17.767
BI-214	9.530E-01	1.571E-01	3.643E-01	0.000E+00	2.616
PB-214	9.074E-01	1.091E-01	9.955E-02	0.000E+00	9.115
RA-226	2.910E+00	1.127E+00	9.135E-01	0.000E+00	3.186
AC-228	1.379E+00	2.429E-01	1.870E-01	0.000E+00	7.375
RA-228	1.564E+00	3.341E-01	4.057E-01	0.000E+00	3.855
TH-232	1.364E+00	2.402E-01	1.850E-01	0.000E+00	7.374

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	2.719E-02		3.567E-02	6.152E-02	0.000E+00	0.442
CS-137	6.139E-02		3.749E-02	6.514E-02	0.000E+00	0.942
LA-138	-1.650E-02		4.947E-02	7.987E-02	0.000E+00	-0.207
PA-234M	3.558E+00		3.697E+00	6.234E+00	0.000E+00	0.571
TH-234	1.751E+00		1.207E+00	1.978E+00	0.000E+00	0.885
U-235	1.195E-01		1.628E-01	2.761E-01	0.000E+00	0.433
U-238	3.558E+00		3.697E+00	6.234E+00	0.000E+00	0.571

```
A,08L95403-17      ,03/19/2022 05:19,02/13/2022 12:56,   4.410E+01,L95403-17 SS A
B,08L95403-17      ,NORMK                  ,11/17/2021 15:23,08S50121919
C,K-40     ,YES,   1.470E+01,    1.140E+00,    4.844E-01,,    30.336
C,TL-208   ,YES,   1.246E+00,    2.045E-01,    1.597E-01,,     7.800
C,BI-212   ,YES,   1.638E+00,    6.786E-01,    7.183E-01,,     2.280
C,PB-212   ,YES,   1.328E+00,    8.515E-02,    7.475E-02,,    17.767
C,BI-214   ,YES,   9.530E-01,    1.571E-01,    3.643E-01,,     2.616
C,PB-214   ,YES,   9.074E-01,    1.091E-01,    9.955E-02,,     9.115
C,RA-226   ,YES,   2.910E+00,    1.127E+00,    9.135E-01,,     3.186
C,AC-228   ,YES,   1.379E+00,    2.429E-01,    1.870E-01,,     7.375
C,RA-228   ,YES,   1.564E+00,    3.341E-01,    4.057E-01,,     3.855
C,TH-232   ,YES,   1.364E+00,    2.402E-01,    1.850E-01,,     7.374
C,CO-60    ,NO ,   2.719E-02,    3.567E-02,    6.152E-02,,     0.442
C,CS-137   ,NO ,   6.139E-02,    3.749E-02,    6.514E-02,,     0.942
C,LA-138   ,NO ,  -1.650E-02,    4.947E-02,    7.987E-02,,    -0.207
C,PA-234M  ,NO ,   3.558E+00,    3.697E+00,    6.234E+00,,     0.571
C,TH-234   ,NO ,   1.751E+00,    1.207E+00,    1.978E+00,,     0.885
C,U-235    ,NO ,   1.195E-01,    1.628E-01,    2.761E-01,,     0.433
C,U-238    ,NO ,   3.558E+00,    3.697E+00,    6.234E+00,,     0.571
```

Analyst:

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 18-MAR-2022 08:08:11.83
TBE13 31-TP10727B HpGe ******* Aquisition Date/Time: 17-MAR-2022 14:52:14.24

LIMS No., Customer Name, Client ID: L95403-18 SS ANCHOR QEA

Sample ID : 13L95403-18
Sample Type : SS
Quantity : 2.36000E+01 g Dry
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: NORMK
Peak Evaluation - Identified and Unidentfied

Smple Date: 13-FEB-2022 12:56:00.
Geometry : 13S25030421
BKGFILE : 13BG030422MT
Real Time : 0 17:15:47.79
Live time : 0 17:15:33.44

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	1	74.93*	160	1516	0.70	149.77	3.49E+00	2.58E-03	43.3	1.95E+01
2	1	77.16*	338	927	0.69	154.21	3.83E+00	5.43E-03	15.7	4.61E+01
3	8	84.63*	182	1231	1.28	169.11	4.93E+00	2.93E-03	37.9	1.48E+00
4	8	87.18*	348	1017	1.10	174.20	5.27E+00	5.60E-03	17.8	
5	1	92.78*	366	1123	1.13	185.37	5.96E+00	5.90E-03	18.3	5.19E+00
6	1	185.74*	327	1279	1.06	370.86	7.62E+00	5.26E-03	22.6	1.78E+00
7	1	208.79	316	932	1.36	416.86	7.12E+00	5.09E-03	17.4	5.76E+00
8	5	238.47*	1991	650	0.94	476.10	6.49E+00	3.20E-02	3.5	5.76E+00
9	5	241.36	659	857	1.53	481.87	6.43E+00	1.06E-02	10.0	
10	1	295.01*	684	987	1.20	588.94	5.49E+00	1.10E-02	10.6	1.05E+00
11	1	338.13*	428	669	1.05	675.01	4.91E+00	6.90E-03	13.1	1.15E+00
12	1	351.70*	997	809	1.12	702.09	4.75E+00	1.60E-02	7.2	1.59E+00
13	1	463.01	157	477	1.46	924.32	3.75E+00	2.53E-03	27.3	3.58E+00
14	1	510.70*	436	856	2.38	1019.53	3.44E+00	7.01E-03	19.3	1.16E+00
15	1	582.90*	516	469	1.30	1163.72	3.06E+00	8.31E-03	10.2	6.49E-01
16	1	608.97*	784	463	1.26	1215.79	2.94E+00	1.26E-02	7.3	2.00E+00
17	1	661.33	186	254	1.96	1320.36	2.72E+00	2.99E-03	17.9	2.32E+00
18	1	726.93*	122	392	1.53	1451.39	2.49E+00	1.96E-03	36.3	9.36E-01
19	1	910.82*	436	189	2.03	1818.80	2.00E+00	7.02E-03	9.4	3.59E+00
20	1	968.83*	218	183	1.76	1934.73	1.88E+00	3.51E-03	14.6	2.49E+00
21	1	1120.24*	148	234	2.21	2237.39	1.62E+00	2.38E-03	27.4	8.74E-01
22	1	1460.38*	1182	77	2.15	2917.62	1.25E+00	1.90E-02	3.9	2.22E+00
23	1	1764.09*	102	84	2.15	3525.35	1.05E+00	1.65E-03	27.0	8.73E-01

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1182	10.67*	1.246E+00	1.639E+01	1.639E+01	7.86
CS-137	661.66	186	85.12*	2.723E+00	1.477E-01	1.480E-01	35.79
BI-214	609.31	784	46.30	2.937E+00	1.062E+00	1.062E+00	14.69
	1120.29	148	15.10*	1.623E+00	1.114E+00	1.114E+00	54.78
	1764.49	102	15.80	1.054E+00	1.134E+00	1.134E+00	54.01

RA-226	186.21	327	3.28*	7.616E+00	2.413E+00	2.413E+00	45.13
RA-228	93.35	366	3.50	5.959E+00	3.238E+00	3.273E+00	36.56
	969.11	218	16.60*	1.881E+00	1.287E+00	1.301E+00	29.28
TH-234	63.29	------	3.80*	1.737E+00	------	Line Not Found	------
	92.60	366	5.41	5.959E+00	2.095E+00	2.095E+00	36.56
U-235	143.76	------	10.50*	8.228E+00	------	Line Not Found	------
	163.35	------	4.70	8.037E+00	------	Line Not Found	------
	185.71	327	54.00	7.616E+00	1.466E-01	1.466E-01	45.13
	205.31	------	4.70	7.191E+00	------	Line Not Found	------

Nuclide Type: NATURAL

					Uncorrected	Decay Corr	2-Sigma
Nuclide	Energy	Area	%Abn	%Eff	pCi/g Dry	pCi/g Dry	%Error
TL-208	583.17	516	30.25*	3.056E+00	1.030E+00	1.063E+00	20.35
BI-212	727.17	122	7.56*	2.492E+00	1.194E+00	1.233E+00	72.64
PB-212	238.63	1991	44.60*	6.490E+00	1.268E+00	1.310E+00	6.97
PB-214	295.21	684	19.20	5.495E+00	1.195E+00	1.195E+00	21.13
	351.92	997	37.20*	4.746E+00	1.041E+00	1.041E+00	14.32
TH-232	911.21	436	27.70*	2.001E+00	1.451E+00	1.451E+00	18.81

Nuclide Type: natural

					Uncorrected	Decay Corr	2-Sigma
Nuclide	Energy	Area	%Abn	%Eff	pCi/g Dry	pCi/g Dry	%Error
AC-228	835.50	------	1.75	2.179E+00	------	Line Not Found	------
	911.07	436	27.70*	2.001E+00	1.451E+00	1.466E+00	18.81

Flag: "*" = Keyline

Total number of lines in spectrum	23	
Number of unidentified lines	9	
Number of lines tentatively identified by NID	14	60.87%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.639E+01	1.639E+01	0.129E+01	7.86	
CS-137	30.07Y	1.00	1.477E-01	1.480E-01	0.530E-01	35.79	
BI-214	1600.00Y	1.00	1.114E+00	1.114E+00	0.610E+00	54.78	
RA-226	1600.00Y	1.00	2.413E+00	2.413E+00	1.089E+00	45.13	
RA-228	5.75Y	1.01	1.287E+00	1.301E+00	0.381E+00	29.28	
TH-234	4.47E+09Y	1.00	2.095E+00	2.095E+00	0.766E+00	36.56	K
U-235	7.04E+08Y	1.00	1.466E-01	1.466E-01	0.662E-01	45.13	K
			---------	---------			
	Total Activity :		2.360E+01	2.361E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.030E+00	1.063E+00	0.216E+00	20.35	
BI-212	1.91Y	1.03	1.194E+00	1.233E+00	0.896E+00	72.64	
PB-212	1.91Y	1.03	1.268E+00	1.310E+00	0.091E+00	6.97	
PB-214	1600.00Y	1.00	1.041E+00	1.041E+00	0.149E+00	14.32	
TH-232	1.41E+10Y	1.00	1.451E+00	1.451E+00	0.273E+00	18.81	
			---------	---------			
	Total Activity :		5.983E+00	6.097E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.451E+00	1.466E+00	0.276E+00	18.81	
			---------	---------			
	Total Activity :		1.451E+00	1.466E+00			

Grand Total Activity : 3.103E+01 3.117E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Sample ID : 13L95403-18 Acquisition date : 17-MAR-2022 14:52:14

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
1	74.93	160	1516	0.70	149.77	147	6	2.58E-03	86.6	3.49E+00	
1	77.16	338	927	0.69	154.21	153	4	5.43E-03	31.5	3.83E+00	
8	84.63	182	1231	1.28	169.11	165	13	2.93E-03	75.9	4.93E+00	
8	87.18	348	1017	1.10	174.20	165	13	5.60E-03	35.6	5.27E+00	
1	208.79	316	932	1.36	416.86	413	8	5.09E-03	34.9	7.12E+00	
5	241.36	659	857	1.53	481.87	472	14	1.06E-02	19.9	6.43E+00	
1	338.13	428	669	1.05	675.01	671	9	6.90E-03	26.2	4.91E+00	
1	463.01	157	477	1.46	924.32	920	10	2.53E-03	54.6	3.75E+00	
1	510.70	436	856	2.38	1019.53	1013	16	7.01E-03	38.5	3.44E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	23	
Number of unidentified lines	9	
Number of lines tentatively identified by NID	14	60.87%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.639E+01	1.639E+01	0.129E+01	7.86	
CS-137	30.07Y	1.00	1.477E-01	1.480E-01	0.530E-01	35.79	
BI-214	1600.00Y	1.00	1.069E+00	1.069E+00	0.147E+00	13.73	
RA-226	1600.00Y	1.00	2.413E+00	2.413E+00	1.089E+00	45.13	
RA-228	5.75Y	1.01	1.287E+00	1.301E+00	0.381E+00	29.28	
			---------	---------			
	Total Activity :		2.131E+01	2.132E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.03	1.030E+00	1.063E+00	0.216E+00	20.35	
BI-212	1.91Y	1.03	1.194E+00	1.233E+00	0.896E+00	72.64	
PB-212	1.91Y	1.03	1.268E+00	1.310E+00	0.091E+00	6.97	
PB-214	1600.00Y	1.00	1.081E+00	1.081E+00	0.128E+00	11.88	
TH-232	1.41E+10Y	1.00	1.451E+00	1.451E+00	0.273E+00	18.81	
			---------	---------			
	Total Activity :		6.023E+00	6.137E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.451E+00	1.466E+00	0.276E+00	18.81	
			---------	---------			
	Total Activity :		1.451E+00	1.466E+00			

Grand Total Activity : 2.878E+01 2.893E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.639E+01	1.289E+00	6.188E-01	0.000E+00	26.492
CS-137	1.480E-01	5.297E-02	6.012E-02	0.000E+00	2.462
TL-208	1.063E+00	2.164E-01	1.671E-01	0.000E+00	6.361
BI-212	1.233E+00	8.959E-01	7.092E-01	0.000E+00	1.739
PB-212	1.310E+00	9.121E-02	7.900E-02	0.000E+00	16.576
BI-214	1.069E+00	1.468E-01	4.646E-01	0.000E+00	2.302
PB-214	1.081E+00	1.284E-01	1.014E-01	0.000E+00	10.659
RA-226	2.413E+00	1.089E+00	9.201E-01	0.000E+00	2.623
AC-228	1.466E+00	2.758E-01	2.018E-01	0.000E+00	7.266
RA-228	1.301E+00	3.809E-01	4.371E-01	0.000E+00	2.975
TH-232	1.451E+00	2.728E-01	1.997E-01	0.000E+00	7.265

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	-7.143E-03		4.221E-02	6.988E-02	0.000E+00	-0.102
LA-138	-8.849E-03		5.964E-02	9.794E-02	0.000E+00	-0.090
PA-234M	2.807E+00		4.029E+00	6.886E+00	0.000E+00	0.408
TH-234	6.827E-01		2.341E+00	3.468E+00	0.000E+00	0.197
U-235	4.240E-02		1.709E-01	2.707E-01	0.000E+00	0.157
U-238	2.807E+00		4.029E+00	6.886E+00	0.000E+00	0.408

```
A,13L95403-18      ,03/18/2022 08:08,02/13/2022 12:56,    2.360E+01,L95403-18 SS A
B,13L95403-18      ,NORMK                       ,03/22/2021 07:43,13S25030421
C,K-40     ,YES,   1.639E+01,    1.289E+00,    6.188E-01,,   26.492
C,CS-137   ,YES,   1.480E-01,    5.297E-02,    6.012E-02,,    2.462
C,TL-208   ,YES,   1.063E+00,    2.164E-01,    1.671E-01,,    6.361
C,BI-212   ,YES,   1.233E+00,    8.959E-01,    7.092E-01,,    1.739
C,PB-212   ,YES,   1.310E+00,    9.121E-02,    7.900E-02,,   16.576
C,BI-214   ,YES,   1.069E+00,    1.468E-01,    4.646E-01,,    2.302
C,PB-214   ,YES,   1.081E+00,    1.284E-01,    1.014E-01,,   10.659
C,RA-226   ,YES,   2.413E+00,    1.089E+00,    9.201E-01,,    2.623
C,AC-228   ,YES,   1.466E+00,    2.758E-01,    2.018E-01,,    7.266
C,RA-228   ,YES,   1.301E+00,    3.809E-01,    4.371E-01,,    2.975
C,TH-232   ,YES,   1.451E+00,    2.728E-01,    1.997E-01,,    7.265
C,CO-60    ,NO ,  -7.143E-03,    4.221E-02,    6.988E-02,,   -0.102
C,LA-138   ,NO ,  -8.849E-03,    5.964E-02,    9.794E-02,,   -0.090
C,PA-234M  ,NO ,   2.807E+00,    4.029E+00,    6.886E+00,,    0.408
C,TH-234   ,NO ,   6.827E-01,    2.341E+00,    3.468E+00,,    0.197
C,U-235    ,NO ,   4.240E-02,    1.709E-01,    2.707E-01,,    0.157
C,U-238    ,NO ,   2.807E+00,    4.029E+00,    6.886E+00,,    0.408
```

Analyst:

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VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 22-MAR-2022 07:26:21.60
TBE08 31-TP20610B HpGe ******** Aquisition Date/Time: 21-MAR-2022 13:49:14.08

LIMS No., Customer Name, Client ID: L95403-19 SS ANCHOR QEA

Sample ID : 08L95403-19
Sample Type : SS
Quantity : 4.91000E+01 g Dry
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: NORMK
Peak Evaluation - Identified and Unidentified

Smple Date: 13-FEB-2022 12:56:00.
Geometry : 08S50121919
BKGFILE : 08BG030422MT
Real Time : 0 17:36:58.83
Live time : 0 17:36:27.25

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	3	73.36	461	1741	1.54	152.83	3.53E+00	7.27E-03	15.8	1.51E+00
2	3	75.58*	975	1974	1.26	157.26	3.74E+00	1.54E-02	9.7	
3	3	77.72	1319	1709	1.19	161.54	3.94E+00	2.08E-02	6.1	
4	6	85.22*	443	1860	1.89	176.49	4.55E+00	6.99E-03	19.9	2.78E+00
5	6	88.00	599	1411	1.22	182.04	4.74E+00	9.45E-03	11.4	
6	6	90.59	452	1764	1.44	187.21	4.91E+00	7.13E-03	17.8	
7	6	93.43*	600	1720	1.49	192.87	5.07E+00	9.46E-03	15.0	
8	1	186.78*	529	1955	1.47	379.05	5.37E+00	8.35E-03	18.2	1.18E+00
9	1	210.01	290	1681	1.37	425.37	5.01E+00	4.57E-03	27.0	1.89E+00
10	1	239.46*	2563	1800	1.22	484.10	4.57E+00	4.04E-02	3.8	1.94E+00
11	1	242.58*	454	1088	1.44	490.33	4.52E+00	7.17E-03	14.7	3.79E-01
12	1	296.03*	1003	1321	1.43	596.90	3.85E+00	1.58E-02	8.5	4.96E-01
13	1	339.16*	649	918	1.44	682.90	3.42E+00	1.02E-02	10.3	6.11E-01
14	1	352.71*	1557	962	1.47	709.93	3.31E+00	2.46E-02	5.2	1.00E+00
15	1	511.54*	453	1006	2.87	1026.58	2.35E+00	7.15E-03	21.4	2.09E+00
16	1	583.89*	816	631	1.57	1170.79	2.08E+00	1.29E-02	7.8	3.07E-01
17	1	609.95*	1167	612	1.67	1222.74	1.99E+00	1.84E-02	5.8	8.70E-01
18	1	662.38	146	531	1.43	1327.23	1.84E+00	2.30E-03	32.6	8.81E-01
19	1	727.77	235	317	1.66	1457.56	1.69E+00	3.71E-03	15.2	4.92E+00
20	1	768.74	242	375	2.83	1539.21	1.60E+00	3.83E-03	17.7	1.55E+00
21	1	911.81*	549	356	1.76	1824.28	1.37E+00	8.66E-03	9.2	6.68E-01
22	1	969.90*	391	304	2.20	1940.00	1.29E+00	6.17E-03	11.9	3.48E+00
23	1	1120.87*	242	247	2.34	2240.73	1.13E+00	3.83E-03	16.1	5.38E-01
24	1	1461.59*	1659	122	2.19	2919.24	8.98E-01	2.62E-02	3.3	1.21E+00
25	1	1765.70*	234	79	2.27	3524.56	7.70E-01	3.70E-03	12.8	9.21E-01

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1659	10.67*	8.976E-01	1.505E+01	1.505E+01	6.69
CS-137	661.66	146	85.12*	1.844E+00	8.068E-02	8.087E-02	65.27
BI-214	609.31	1167	46.30	1.992E+00	1.099E+00	1.099E+00	11.52

	1120.29	242	15.10*	1.133E+00	1.230E+00	1.231E+00	32.18
	1764.49	234	15.80	7.704E-01	1.672E+00	1.673E+00	25.64
RA-226	186.21	529	3.28*	5.371E+00	2.610E+00	2.610E+00	36.32
RA-228	93.35	600	3.50	5.068E+00	2.937E+00	2.973E+00	30.05
	969.11	391	16.60*	1.293E+00	1.582E+00	1.601E+00	23.86

Nuclide Type: NATURAL

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
TL-208	583.17	816	30.25*	2.076E+00	1.129E+00	1.170E+00	15.70
BI-212	727.17	235	7.56*	1.689E+00	1.598E+00	1.657E+00	30.36
PB-212	238.63	2563	44.60*	4.569E+00	1.092E+00	1.132E+00	7.65
PB-214	295.21	1003	19.20	3.854E+00	1.178E+00	1.178E+00	16.99
	351.92	1557	37.20*	3.307E+00	1.099E+00	1.099E+00	10.42
TH-232	911.21	549	27.70*	1.369E+00	1.257E+00	1.257E+00	18.44

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
AC-228	835.50	------	1.75	1.485E+00	------	Line Not Found	------
	911.07	549	27.70*	1.369E+00	1.257E+00	1.272E+00	18.44

Flag: "*" = Keyline

Total number of lines in spectrum 25
Number of unidentified lines 11
Number of lines tentatively identified by NID 14 56.00%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.505E+01	1.505E+01	0.101E+01	6.69	
CS-137	30.07Y	1.00	8.068E-02	8.087E-02	5.278E-02	65.27	
BI-214	1600.00Y	1.00	1.230E+00	1.231E+00	0.396E+00	32.18	
RA-226	1600.00Y	1.00	2.610E+00	2.610E+00	0.948E+00	36.32	
RA-228	5.75Y	1.01	1.582E+00	1.601E+00	0.382E+00	23.86	
			---------	---------			
	Total Activity :		2.055E+01	2.057E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.04	1.129E+00	1.170E+00	0.184E+00	15.70	
BI-212	1.91Y	1.04	1.598E+00	1.657E+00	0.503E+00	30.36	
PB-212	1.91Y	1.04	1.092E+00	1.132E+00	0.087E+00	7.65	
PB-214	1600.00Y	1.00	1.099E+00	1.099E+00	0.115E+00	10.42	
TH-232	1.41E+10Y	1.00	1.257E+00	1.257E+00	0.232E+00	18.44	
			---------	---------			
	Total Activity :		6.176E+00	6.316E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.257E+00	1.272E+00	0.235E+00	18.44	
			---------	---------			
	Total Activity :		1.257E+00	1.272E+00			

Grand Total Activity : 2.798E+01 2.816E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
3	73.36	461	1741	1.54	152.83	149	17	7.27E-03	31.6	3.53E+00	
3	75.58	975	1974	1.26	157.26	149	17	1.54E-02	19.4	3.74E+00	
3	77.72	1319	1709	1.19	161.54	149	17	2.08E-02	12.3	3.94E+00	
6	85.22	443	1860	1.89	176.49	172	28	6.99E-03	39.7	4.55E+00	
6	88.00	599	1411	1.22	182.04	172	28	9.45E-03	22.8	4.74E+00	
6	90.59	452	1764	1.44	187.21	172	28	7.13E-03	35.7	4.91E+00	
1	210.01	290	1681	1.37	425.37	421	10	4.57E-03	53.9	5.01E+00	
1	242.58	454	1088	1.44	490.33	488	7	7.17E-03	29.5	4.52E+00	
1	339.16	649	918	1.44	682.90	678	10	1.02E-02	20.5	3.42E+00	
1	511.54	453	1006	2.87	1026.58	1019	19	7.15E-03	42.7	2.35E+00	
1	768.74	242	375	2.83	1539.21	1533	13	3.83E-03	35.5	1.60E+00	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	25	
Number of unidentified lines	11	
Number of lines tentatively identified by NID	14	56.00%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.505E+01	1.505E+01	0.101E+01	6.69	
CS-137	30.07Y	1.00	8.068E-02	8.087E-02	5.278E-02	65.27	
BI-214	1600.00Y	1.00	1.152E+00	1.152E+00	0.116E+00	10.07	
RA-226	1600.00Y	1.00	2.610E+00	2.610E+00	0.948E+00	36.32	
RA-228	5.75Y	1.01	1.791E+00	1.813E+00	0.351E+00	19.37	
			---------	---------			
	Total Activity :		2.068E+01	2.070E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.04	1.129E+00	1.170E+00	0.184E+00	15.70	
BI-212	1.91Y	1.04	1.598E+00	1.657E+00	0.503E+00	30.36	
PB-212	1.91Y	1.04	1.092E+00	1.132E+00	0.087E+00	7.65	
PB-214	1600.00Y	1.00	1.119E+00	1.119E+00	0.099E+00	8.89	
TH-232	1.41E+10Y	1.00	1.257E+00	1.257E+00	0.232E+00	18.44	
			---------	---------			
	Total Activity :		6.195E+00	6.335E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.257E+00	1.272E+00	0.235E+00	18.44	
			---------	---------			
	Total Activity :		1.257E+00	1.272E+00			

Grand Total Activity : 2.813E+01 2.831E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.505E+01	1.007E+00	4.644E-01	0.000E+00	32.397
CS-137	8.087E-02	5.278E-02	5.564E-02	0.000E+00	1.454
TL-208	1.170E+00	1.837E-01	1.391E-01	0.000E+00	8.417
BI-212	1.657E+00	5.030E-01	6.480E-01	0.000E+00	2.557
PB-212	1.132E+00	8.669E-02	7.357E-02	0.000E+00	15.392
BI-214	1.152E+00	1.161E-01	3.670E-01	0.000E+00	3.139
PB-214	1.119E+00	9.945E-02	9.115E-02	0.000E+00	12.274
RA-226	2.610E+00	9.479E-01	8.758E-01	0.000E+00	2.980
AC-228	1.272E+00	2.347E-01	1.936E-01	0.000E+00	6.571
RA-228	1.813E+00	3.512E-01	3.933E-01	0.000E+00	4.609
TH-232	1.257E+00	2.319E-01	1.858E-01	0.000E+00	6.766

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	3.305E-03		3.066E-02	5.114E-02	0.000E+00	0.065
LA-138	2.527E-03		4.490E-02	7.435E-02	0.000E+00	0.034
PA-234M	3.023E+00		3.568E+00	5.974E+00	0.000E+00	0.506
TH-234	3.321E-02		1.124E+00	1.793E+00	0.000E+00	0.019
U-235	-5.777E-02		1.509E-01	2.508E-01	0.000E+00	-0.230
U-238	3.023E+00		3.568E+00	5.974E+00	0.000E+00	0.506

```
A,08L95403-19      ,03/22/2022 07:26,02/13/2022 12:56,   4.910E+01,L95403-19 SS A
B,08L95403-19      ,NORMK                   ,11/17/2021 15:23,08S50121919
C,K-40     ,YES,   1.505E+01,   1.007E+00,   4.644E-01,,   32.397
C,CS-137   ,YES,   8.087E-02,   5.278E-02,   5.564E-02,,    1.454
C,TL-208   ,YES,   1.170E+00,   1.837E-01,   1.391E-01,,    8.417
C,BI-212   ,YES,   1.657E+00,   5.030E-01,   6.480E-01,,    2.557
C,PB-212   ,YES,   1.132E+00,   8.669E-02,   7.357E-02,,   15.392
C,BI-214   ,YES,   1.152E+00,   1.161E-01,   3.670E-01,,    3.139
C,PB-214   ,YES,   1.119E+00,   9.945E-02,   9.115E-02,,   12.274
C,RA-226   ,YES,   2.610E+00,   9.479E-01,   8.758E-01,,    2.980
C,AC-228   ,YES,   1.272E+00,   2.347E-01,   1.936E-01,,    6.571
C,RA-228   ,YES,   1.813E+00,   3.512E-01,   3.933E-01,,    4.609
C,TH-232   ,YES,   1.257E+00,   2.319E-01,   1.858E-01,,    6.766
C,CO-60    ,NO ,   3.305E-03,   3.066E-02,   5.114E-02,,    0.065
C,LA-138   ,NO ,   2.527E-03,   4.490E-02,   7.435E-02,,    0.034
C,PA-234M  ,NO ,   3.023E+00,   3.568E+00,   5.974E+00,,    0.506
C,TH-234   ,NO ,   3.321E-02,   1.124E+00,   1.793E+00,,    0.019
C,U-235    ,NO ,  -5.777E-02,   1.509E-01,   2.508E-01,,   -0.230
C,U-238    ,NO ,   3.023E+00,   3.568E+00,   5.974E+00,,    0.506
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Analyst: [signature]

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 22-MAR-2022 07:26:34.51
TBE06 33-TP10933A HpGe ******* Aquisition Date/Time: 21-MAR-2022 13:49:13.85

LIMS No., Customer Name, Client ID: L95403-20 SS ANCHOR QEA

Sample ID : 06L95403-20		Smple Date: 13-FEB-2022 13:00:00.	
Sample Type : SS		Geometry : 06S50031621	
Quantity : 5.36000E+01 g Dry		BKGFILE : 06BG030422MT	
Start Channel : 80	Energy Tol : 2.00000	Real Time : 0 17:37:14.99	
End Channel : 4090	Pk Srch Sens: 9.00000	Live time : 0 17:37:02.96	
MDA Multiple : 4.6600	Library Used: NORMK		

Peak Evaluation - Identified and Unidentified

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	3	74.90*	407	1332	0.85	150.27	1.68E+00	6.42E-03	16.1	1.44E+00
2	3	77.14	573	1215	0.82	154.74	1.84E+00	9.04E-03	10.1	
3	0	87.24	376	1309	1.19	174.90	2.53E+00	5.93E-03	16.0	
4	0	92.84*	383	1504	1.32	186.09	2.87E+00	6.04E-03	19.8	
5	0	185.91*	437	1412	1.21	371.89	4.02E+00	6.88E-03	17.9	
6	0	209.33	250	1136	0.79	418.63	3.79E+00	3.94E-03	23.2	
7	4	238.78*	2518	947	1.08	477.41	3.48E+00	3.97E-02	3.0	1.82E+00
8	4	241.75	812	1507	1.77	483.35	3.45E+00	1.28E-02	11.1	
9	0	295.39*	862	1477	1.21	590.42	2.95E+00	1.36E-02	10.1	
10	0	338.56	596	1168	1.25	676.60	2.63E+00	9.39E-03	11.8	
11	0	352.11*	1795	1155	1.18	703.66	2.54E+00	2.83E-02	4.9	
12	0	511.16*	339	1140	2.20	1021.12	1.83E+00	5.34E-03	30.6	
13	0	583.26*	840	724	1.45	1165.03	1.63E+00	1.32E-02	8.1	
14	0	609.41*	1364	701	1.41	1217.23	1.57E+00	2.15E-02	5.3	
15	0	661.61	271	422	1.62	1321.42	1.46E+00	4.27E-03	15.4	
16	0	727.55*	221	410	1.51	1453.02	1.35E+00	3.48E-03	20.9	
17	0	911.49*	510	269	1.69	1820.12	1.11E+00	8.04E-03	8.6	
18	0	969.68*	254	397	1.31	1936.25	1.06E+00	4.01E-03	18.4	
19	0	1120.69*	300	256	1.77	2237.61	9.34E-01	4.73E-03	13.8	
20	0	1238.39*	113	236	1.29	2472.48	8.59E-01	1.79E-03	29.7	
21	0	1461.35*	1539	136	2.00	2917.36	7.48E-01	2.43E-02	3.6	
22	0	1765.31*	225	120	2.03	3523.80	6.42E-01	3.55E-03	15.1	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type:

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	2-Sigma %Error
K-40	1460.81	1539	10.67*	7.481E-01	1.532E+01	1.532E+01	7.17
CS-137	661.66	271	85.12*	1.463E+00	1.730E-01	1.734E-01	30.87
BI-214	609.31	1364	46.30	1.570E+00	1.491E+00	1.491E+00	10.53
	1120.29	300	15.10*	9.340E-01	1.691E+00	1.691E+00	27.62
	1764.49	225	15.80	6.424E-01	1.765E+00	1.765E+00	30.14
RA-226	186.21	437	3.28*	4.018E+00	2.633E+00	2.633E+00	35.74

RA-228	93.35	383	3.50	2.875E+00	3.027E+00	3.064E+00	39.60
	969.11	254	16.60*	1.056E+00	1.154E+00	1.168E+00	36.83
TH-234	63.29	------	3.80*	8.696E-01	------	Line Not Found	------
	92.60	383	5.41	2.875E+00	1.958E+00	1.958E+00	39.60
U-235	143.76	------	10.50*	4.209E+00	------	Line Not Found	------
	163.35	------	4.70	4.183E+00	------	Line Not Found	------
	185.71	437	54.00	4.018E+00	1.599E-01	1.599E-01	35.74
	205.31	------	4.70	3.827E+00	------	Line Not Found	------

Nuclide Type: NATURAL

					Uncorrected	Decay Corr	2-Sigma
Nuclide	Energy	Area	%Abn	%Eff	pCi/g Dry	pCi/g Dry	%Error
TL-208	583.17	840	30.25*	1.631E+00	1.353E+00	1.403E+00	16.20
BI-212	727.17	221	7.56*	1.348E+00	1.723E+00	1.786E+00	41.74
PB-212	238.63	2518	44.60*	3.477E+00	1.291E+00	1.339E+00	6.07
PB-214	295.21	862	19.20	2.950E+00	1.210E+00	1.210E+00	20.25
	351.92	1795	37.20*	2.541E+00	1.510E+00	1.510E+00	9.75
TH-232	911.21	510	27.70*	1.112E+00	1.316E+00	1.316E+00	17.20

Nuclide Type: natural

					Uncorrected	Decay Corr	2-Sigma
Nuclide	Energy	Area	%Abn	%Eff	pCi/g Dry	pCi/g Dry	%Error
AC-228	835.50	------	1.75	1.198E+00	------	Line Not Found	------
	911.07	510	27.70*	1.112E+00	1.316E+00	1.332E+00	17.20

Flag: "*" = Keyline

Total number of lines in spectrum 22
Number of unidentified lines 8
Number of lines tentatively identified by NID 14 63.64%

Nuclide Type :

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.532E+01	1.532E+01	0.110E+01	7.17	
CS-137	30.07Y	1.00	1.730E-01	1.734E-01	0.535E-01	30.87	
BI-214	1600.00Y	1.00	1.691E+00	1.691E+00	0.467E+00	27.62	
RA-226	1600.00Y	1.00	2.633E+00	2.633E+00	0.941E+00	35.74	
RA-228	5.75Y	1.01	1.154E+00	1.168E+00	0.430E+00	36.83	
TH-234	4.47E+09Y	1.00	1.958E+00	1.958E+00	0.775E+00	39.60	K
U-235	7.04E+08Y	1.00	1.599E-01	1.599E-01	0.572E-01	35.74	K
			---------	---------			
	Total Activity :		2.309E+01	2.311E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.04	1.353E+00	1.403E+00	0.227E+00	16.20	
BI-212	1.91Y	1.04	1.723E+00	1.786E+00	0.746E+00	41.74	
PB-212	1.91Y	1.04	1.291E+00	1.339E+00	0.081E+00	6.07	
PB-214	1600.00Y	1.00	1.510E+00	1.510E+00	0.147E+00	9.75	
TH-232	1.41E+10Y	1.00	1.316E+00	1.316E+00	0.226E+00	17.20	
			---------	---------			
	Total Activity :		7.193E+00	7.354E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Dry	Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.316E+00	1.332E+00	0.229E+00	17.20	
			---------	---------			
	Total Activity :		1.316E+00	1.332E+00			

Grand Total Activity : 3.160E+01 3.180E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	%Eff	Flags
3	74.90	407	1332	0.85	150.27	147	19	6.42E-03	32.2	1.68E+00	
3	77.14	573	1215	0.82	154.74	147	19	9.04E-03	20.2	1.84E+00	
0	87.24	376	1309	1.19	174.90	173	6	5.93E-03	32.0	2.53E+00	
0	209.33	250	1136	0.79	418.63	415	7	3.94E-03	46.5	3.79E+00	
4	241.75	812	1507	1.77	483.35	473	17	1.28E-02	22.2	3.45E+00	
0	338.56	596	1168	1.25	676.60	672	11	9.39E-03	23.7	2.63E+00	
0	511.16	339	1140	2.20	1021.12	1012	21	5.34E-03	61.3	1.83E+00	
0	1238.39	113	236	1.29	2472.48	2468	11	1.79E-03	59.5	8.59E-01	

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum 22
Number of unidentified lines 8
Number of lines tentatively identified by NID 14 63.64%

Nuclide Type :

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	1.532E+01	1.532E+01	0.110E+01	7.17	
CS-137	30.07Y	1.00	1.730E-01	1.734E-01	0.535E-01	30.87	
BI-214	1600.00Y	1.00	1.530E+00	1.530E+00	0.143E+00	9.37	
RA-226	1600.00Y	1.00	2.633E+00	2.633E+00	0.941E+00	35.74	
RA-228	5.75Y	1.01	1.154E+00	1.168E+00	0.430E+00	36.83	
			---------	---------			
	Total Activity :		2.082E+01	2.083E+01			

Nuclide Type : NATURAL

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
TL-208	1.91Y	1.04	1.353E+00	1.403E+00	0.227E+00	16.20	
BI-212	1.91Y	1.04	1.723E+00	1.786E+00	0.746E+00	41.74	
PB-212	1.91Y	1.04	1.291E+00	1.339E+00	0.081E+00	6.07	
PB-214	1600.00Y	1.00	1.430E+00	1.430E+00	0.126E+00	8.82	
TH-232	1.41E+10Y	1.00	1.316E+00	1.316E+00	0.226E+00	17.20	
			---------	---------			
	Total Activity :		7.114E+00	7.275E+00			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Dry	Wtd Mean Decay Corr pCi/g Dry	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
AC-228	5.75Y	1.01	1.316E+00	1.332E+00	0.229E+00	17.20	
			---------	---------			
	Total Activity :		1.316E+00	1.332E+00			

Grand Total Activity : 2.925E+01 2.944E+01

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Dry)	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
K-40	1.532E+01	1.098E+00	4.834E-01	0.000E+00	31.699
CS-137	1.734E-01	5.354E-02	6.114E-02	0.000E+00	2.836
TL-208	1.403E+00	2.272E-01	1.637E-01	0.000E+00	8.568
BI-212	1.786E+00	7.457E-01	7.206E-01	0.000E+00	2.479
PB-212	1.339E+00	8.121E-02	8.068E-02	0.000E+00	16.591
BI-214	1.530E+00	1.434E-01	3.973E-01	0.000E+00	3.852
PB-214	1.430E+00	1.261E-01	1.057E-01	0.000E+00	13.530
RA-226	2.633E+00	9.411E-01	1.004E+00	0.000E+00	2.623
AC-228	1.332E+00	2.292E-01	1.973E-01	0.000E+00	6.751
RA-228	1.168E+00	4.302E-01	4.328E-01	0.000E+00	2.699
TH-232	1.316E+00	2.264E-01	1.975E-01	0.000E+00	6.667

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Dry)	K.L. Ided	Act error	MDA (pCi/g Dry)	MDA error	Act/MDA
CO-60	4.112E-02		3.663E-02	6.470E-02	0.000E+00	0.636
LA-138	-8.255E-03		4.780E-02	7.869E-02	0.000E+00	-0.105
PA-234M	3.466E+00		3.837E+00	6.520E+00	0.000E+00	0.532
TH-234	1.674E+00		2.469E+00	4.141E+00	0.000E+00	0.404
U-235	4.466E-02		1.898E-01	3.063E-01	0.000E+00	0.146
U-238	3.466E+00		3.837E+00	6.520E+00	0.000E+00	0.532

```
A,06L95403-20      ,03/22/2022 07:26,02/13/2022 13:00,   5.360E+01,L95403-20 SS A
B,06L95403-20      ,NORMK                     ,10/29/2021 09:14,06S50031621
C,K-40     ,YES,   1.532E+01,   1.098E+00,   4.834E-01,,   31.699
C,CS-137   ,YES,   1.734E-01,   5.354E-02,   6.114E-02,,    2.836
C,TL-208   ,YES,   1.403E+00,   2.272E-01,   1.637E-01,,    8.568
C,BI-212   ,YES,   1.786E+00,   7.457E-01,   7.206E-01,,    2.479
C,PB-212   ,YES,   1.339E+00,   8.121E-02,   8.068E-02,,   16.591
C,BI-214   ,YES,   1.530E+00,   1.434E-01,   3.973E-01,,    3.852
C,PB-214   ,YES,   1.430E+00,   1.261E-01,   1.057E-01,,   13.530
C,RA-226   ,YES,   2.633E+00,   9.411E-01,   1.004E+00,,    2.623
C,AC-228   ,YES,   1.332E+00,   2.292E-01,   1.973E-01,,    6.751
C,RA-228   ,YES,   1.168E+00,   4.302E-01,   4.328E-01,,    2.699
C,TH-232   ,YES,   1.316E+00,   2.264E-01,   1.975E-01,,    6.667
C,CO-60    ,NO ,   4.112E-02,   3.663E-02,   6.470E-02,,    0.636
C,LA-138   ,NO ,  -8.255E-03,   4.780E-02,   7.869E-02,,   -0.105
C,PA-234M  ,NO ,   3.466E+00,   3.837E+00,   6.520E+00,,    0.532
C,TH-234   ,NO ,   1.674E+00,   2.469E+00,   4.141E+00,,    0.404
C,U-235    ,NO ,   4.466E-02,   1.898E-01,   3.063E-01,,    0.146
C,U-238    ,NO ,   3.466E+00,   3.837E+00,   6.520E+00,,    0.532
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Analyst:

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==============================================================================
VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 11-MAR-2022 12:49:49.47
TBE11 59-TN51806A HpGe ******* Aquisition Date/Time: 11-MAR-2022 11:21:02.87
------------------------------------------------------------------------------
LIMS No., Customer Name, Client ID: WG38795-1 AN PSEG -SALEM/HC

Sample ID      : 11WG38795-1                        Smple Date: 7-MAR-2022 12:00:00.0
Sample Type    : AN                                 Geometry  : 1135L120319
Quantity       : 2.48010E+00 Kg Wet                 BKGFILE   : 11BG030422MT
Start Channel  : 80       Energy Tol   : 2.00000    Real Time : 0 01:28:36.82
End Channel    : 4090     Pk Srch Sens: 9.00000     Live time : 0 01:28:33.85
MDA Multiple   : 4.6600   Library Used: LIBD
Peak Evaluation - Identified and Unidentified
```

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	1461.17*	701	8	2.35	2920.16	4.47E-01	1.32E-01	4.0	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/Kg Wet	Decay Corr pCi/Kg Wet	2-Sigma %Error
K-40	1460.81	701	10.67*	4.474E-01	3.013E+03	3.013E+03	7.92

Flag: "*" = Keyline

Sample ID : 11WG38795-1 Acquisition date : 11-MAR-2022 11:21:02

Total number of lines in spectrum	1	
Number of unidentified lines	0	
Number of lines tentatively identified by NID	1	100.00%

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/Kg Wet	Decay Corr pCi/Kg Wet	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	3.013E+03	3.013E+03	0.239E+03	7.92	
			---------	---------			
	Total Activity :		3.013E+03	3.013E+03			
	Grand Total Activity :		3.013E+03	3.013E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

None

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	1	
Number of unidentified lines	0	
Number of lines tentatively identified by NID	1	100.00%

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/Kg Wet	Wtd Mean Decay Corr pCi/Kg Wet	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	3.013E+03	3.013E+03	0.239E+03	7.92	
			---------	---------			
	Total Activity :		3.013E+03	3.013E+03			
	Grand Total Activity :		3.013E+03	3.013E+03			

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/Kg Wet)	Act error	MDA (pCi/Kg Wet)	MDA error	Act/MDA
K-40	3.013E+03	2.385E+02	9.648E+01	0.000E+00	31.230

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/Kg Wet)	K.L. Ided	Act error	MDA (pCi/Kg Wet)	MDA error	Act/MDA
BE-7	-1.223E+00		4.457E+01	7.903E+01	0.000E+00	-0.015
NA-22	-5.402E-01		6.323E+00	1.124E+01	0.000E+00	-0.048
NA-24	-1.034E+02		3.900E+02	7.212E+02	0.000E+00	-0.143
CR-51	-1.599E+01		4.417E+01	7.304E+01	0.000E+00	-0.219
MN-54	-9.385E-01		5.571E+00	9.966E+00	0.000E+00	-0.094
CO-56	2.315E+00		6.231E+00	1.220E+01	0.000E+00	0.190
CO-57	3.046E+00		3.874E+00	7.027E+00	0.000E+00	0.433
CO-58	5.002E+00		5.717E+00	1.122E+01	0.000E+00	0.446
FE-59	3.696E+00		1.261E+01	2.320E+01	0.000E+00	0.159
CO-60	-1.905E+00		5.441E+00	9.398E+00	0.000E+00	-0.203
ZN-65	-1.521E+01		1.328E+01	2.066E+01	0.000E+00	-0.736
SE-75	-1.224E+00		6.845E+00	1.154E+01	0.000E+00	-0.106

Y-88	2.210E+00	4.273E+00	9.435E+00	0.000E+00	0.234
NB-94	-4.073E+00	5.725E+00	9.645E+00	0.000E+00	-0.422
NB-95	7.055E+00	5.152E+00	1.064E+01	0.000E+00	0.663
ZR-95	-8.294E+00	8.748E+00	1.358E+01	0.000E+00	-0.611
ZRNB-95	7.054E+00	5.152E+00	1.064E+01	0.000E+00	0.663
MO-99	8.811E+01	1.055E+02	2.024E+02	0.000E+00	0.435
RU-103	-2.934E+00	5.266E+00	8.904E+00	0.000E+00	-0.329
RU-106	-3.857E+00	4.636E+01	8.152E+01	0.000E+00	-0.047
AG-110m	-2.055E+00	5.100E+00	8.621E+00	0.000E+00	-0.238
SN-113	-3.922E+00	5.876E+00	9.991E+00	0.000E+00	-0.393
SB-124	-3.638E+00	4.849E+00	7.925E+00	0.000E+00	-0.459
SB-125	-1.749E+00	1.450E+01	2.560E+01	0.000E+00	-0.068
TE-129M	-3.901E+01	5.843E+01	9.829E+01	0.000E+00	-0.397
I-131	4.583E+00	7.012E+00	1.310E+01	0.000E+00	0.350
TE-132	8.088E+00	1.035E+01	1.852E+01	0.000E+00	0.437
BA-133	-9.175E+00	7.215E+00	1.178E+01	0.000E+00	-0.779
CS-134	2.368E+00	5.674E+00	1.088E+01	0.000E+00	0.218
CS-136	-2.543E+00	5.997E+00	1.053E+01	0.000E+00	-0.242
CS-137	4.715E+00	6.151E+00	1.154E+01	0.000E+00	0.409
CE-139	-1.216E+00	4.435E+00	7.569E+00	0.000E+00	-0.161
BA-140	3.626E+00	2.271E+01	4.081E+01	0.000E+00	0.089
BALA140	3.975E+00	6.451E+00	1.359E+01	0.000E+00	0.292
LA-140	3.975E+00	6.451E+00	1.359E+01	0.000E+00	0.292
CE-141	-9.139E-01	7.993E+00	1.386E+01	0.000E+00	-0.066
CE-144	-1.571E+01	3.135E+01	5.333E+01	0.000E+00	-0.295
EU-152	-1.006E+01	1.515E+01	2.591E+01	0.000E+00	-0.388
EU-154	-9.827E-01	8.353E+00	1.452E+01	0.000E+00	-0.068
RA-226	7.227E+00	1.145E+02	2.042E+02	0.000E+00	0.035
AC-228	1.504E+01	2.328E+01	4.541E+01	0.000E+00	0.331
TH-228	7.433E+00	9.813E+00	1.761E+01	0.000E+00	0.422
TH-232	1.502E+01	2.325E+01	4.535E+01	0.000E+00	0.331

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/Kg Wet)	K.L. Ided	Act error	MDA (pCi/Kg Wet)	MDA error	Act/MDA
U-235	-1.460E+01		3.493E+01	5.963E+01	0.000E+00	-0.245
U-238	4.322E+02		6.508E+02	1.254E+03	0.000E+00	0.345
NP-239	-2.862E+01		4.828E+01	8.247E+01	0.000E+00	-0.347
AM-241	1.549E+00		1.158E+01	1.941E+01	0.000E+00	0.080

```
A,11WG38795-1      ,03/11/2022 12:49,03/07/2022 12:00,   2.480E+00,WG38795-1 AN P
B,11WG38795-1      ,LIBD                      ,02/10/2022 09:58,1135L120319
C,K-40     ,YES,   3.013E+03,   2.385E+02,   9.648E+01,,   31.230
C,BE-7     ,NO ,  -1.223E+00,   4.457E+01,   7.903E+01,,   -0.015
C,NA-22    ,NO ,  -5.402E-01,   6.323E+00,   1.124E+01,,   -0.048
C,NA-24    ,NO ,  -1.034E+02,   3.900E+02,   7.212E+02,,   -0.143
C,CR-51    ,NO ,  -1.599E+01,   4.417E+01,   7.304E+01,,   -0.219
C,MN-54    ,NO ,  -9.385E-01,   5.571E+00,   9.966E+00,,   -0.094
C,CO-56    ,NO ,   2.315E+00,   6.231E+00,   1.220E+01,,    0.190
C,CO-57    ,NO ,   3.046E+00,   3.874E+00,   7.027E+00,,    0.433
C,CO-58    ,NO ,   5.002E+00,   5.717E+00,   1.122E+01,,    0.446
C,FE-59    ,NO ,   3.696E+00,   1.261E+01,   2.320E+01,,    0.159
C,CO-60    ,NO ,  -1.905E+00,   5.441E+00,   9.398E+00,,   -0.203
C,ZN-65    ,NO ,  -1.521E+01,   1.328E+01,   2.066E+01,,   -0.736
C,SE-75    ,NO ,  -1.224E+00,   6.845E+00,   1.154E+01,,   -0.106
C,Y-88     ,NO ,   2.210E+00,   4.273E+00,   9.435E+00,,    0.234
C,NB-94    ,NO ,  -4.073E+00,   5.725E+00,   9.645E+00,,   -0.422
C,NB-95    ,NO ,   7.055E+00,   5.152E+00,   1.064E+01,,    0.663
C,ZR-95    ,NO ,  -8.294E+00,   8.748E+00,   1.358E+01,,   -0.611
C,ZRNB-95  ,NO ,   7.054E+00,   5.152E+00,   1.064E+01,,    0.663
C,MO-99    ,NO ,   8.811E+01,   1.055E+02,   2.024E+02,,    0.435
C,RU-103   ,NO ,  -2.934E+00,   5.266E+00,   8.904E+00,,   -0.329
C,RU-106   ,NO ,  -3.857E+00,   4.636E+01,   8.152E+01,,   -0.047
C,AG-110m  ,NO ,  -2.055E+00,   5.100E+00,   8.621E+00,,   -0.238
C,SN-113   ,NO ,  -3.922E+00,   5.876E+00,   9.991E+00,,   -0.393
C,SB-124   ,NO ,  -3.638E+00,   4.849E+00,   7.925E+00,,   -0.459
C,SB-125   ,NO ,  -1.749E+00,   1.450E+01,   2.560E+01,,   -0.068
C,TE-129M  ,NO ,  -3.901E+01,   5.843E+01,   9.829E+01,,   -0.397
C,I-131    ,NO ,   4.583E+00,   7.012E+00,   1.310E+01,,    0.350
C,TE-132   ,NO ,   8.088E+00,   1.035E+01,   1.852E+01,,    0.437
C,BA-133   ,NO ,  -9.175E+00,   7.215E+00,   1.178E+01,,   -0.779
C,CS-134   ,NO ,   2.368E+00,   5.674E+00,   1.088E+01,,    0.218
C,CS-136   ,NO ,  -2.543E+00,   5.997E+00,   1.053E+01,,   -0.242
C,CS-137   ,NO ,   4.715E+00,   6.151E+00,   1.154E+01,,    0.409
C,CE-139   ,NO ,  -1.216E+00,   4.435E+00,   7.569E+00,,   -0.161
C,BA-140   ,NO ,   3.626E+00,   2.271E+01,   4.081E+01,,    0.089
C,BALA140  ,NO ,   3.975E+00,   6.451E+00,   1.359E+01,,    0.292
C,LA-140   ,NO ,   3.975E+00,   6.451E+00,   1.359E+01,,    0.292
C,CE-141   ,NO ,  -9.139E-01,   7.993E+00,   1.386E+01,,   -0.066
C,CE-144   ,NO ,  -1.571E+01,   3.135E+01,   5.333E+01,,   -0.295
C,EU-152   ,NO ,  -1.006E+01,   1.515E+01,   2.591E+01,,   -0.388
C,EU-154   ,NO ,  -9.827E-01,   8.353E+00,   1.452E+01,,   -0.068
C,RA-226   ,NO ,   7.227E+00,   1.145E+02,   2.042E+02,,    0.035
C,AC-228   ,NO ,   1.504E+01,   2.328E+01,   4.541E+01,,    0.331
C,TH-228   ,NO ,   7.433E+00,   9.813E+00,   1.761E+01,,    0.422
C,TH-232   ,NO ,   1.502E+01,   2.325E+01,   4.535E+01,,    0.331
C,U-235    ,NO ,  -1.460E+01,   3.493E+01,   5.963E+01,,   -0.245
C,U-238    ,NO ,   4.322E+02,   6.508E+02,   1.254E+03,,    0.345
C,NP-239   ,NO ,  -2.862E+01,   4.828E+01,   8.247E+01,,   -0.347
C,AM-241   ,NO ,   1.549E+00,   1.158E+01,   1.941E+01,,    0.080
```

Analyst:

VAX/VMS Teledyne Brown Eng. Laboratory Gamma Report: 10-MAR-2022 13:48:57.49
TBE11 59-TN51806A HpGe ******* Aquisition Date/Time: 10-MAR-2022 12:48:40.89

LIMS No., Customer Name, Client ID: WG38781-1 VA DOMINION - MILLSTONE REMP

Sample ID : 11WG38781-1
Sample Type : VA
Quantity : 1.37640E+03 g Wet
Start Channel : 80 Energy Tol : 2.00000
End Channel : 4090 Pk Srch Sens: 9.00000
MDA Multiple : 4.6600 Library Used: LIBD
Peak Evaluation - Identified and Unidentified

Smple Date: 7-MAR-2022 08:55:00.0
Geometry : 1135L120319
BKGFILE : 11BG030422MT
Real Time : 0 01:00:01.96
Live time : 0 01:00:00.00

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	%Eff	Cts/Sec	%Err	Fit
1	0	239.51*	80	102	1.39	477.53	1.70E+00	2.23E-02	28.5	
2	0	478.29	39	33	0.68	954.93	1.03E+00	1.07E-02	34.6	
3	0	1461.36*	504	0	2.38	2920.52	4.47E-01	1.40E-01	4.6	

Flag: "*" = Peak area was modified by background subtraction

Nuclide Line Activity Report

Nuclide Type: activation

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Wet	Decay Corr pCi/g Wet	2-Sigma %Error
BE-7	477.59	39	10.42*	1.028E+00	1.964E-01	2.047E-01	69.25

Nuclide Type: natural

Nuclide	Energy	Area	%Abn	%Eff	Uncorrected pCi/g Wet	Decay Corr pCi/g Wet	2-Sigma %Error
K-40	1460.81	504	10.67*	4.473E-01	5.754E+00	5.754E+00	9.11
TH-228	238.63	80	44.60*	1.700E+00	5.779E-02	5.797E-02	57.05
	240.98	80	3.95	1.700E+00	6.525E-01	6.545E-01	57.05

Flag: "*" = Keyline

Total number of lines in spectrum	3	
Number of unidentified lines	0	
Number of lines tentatively identified by NID	3	100.00%

Nuclide Type : activation

Nuclide	Hlife	Decay	Uncorrected pCi/g Wet	Decay Corr pCi/g Wet	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
BE-7	53.44D	1.04	1.964E-01	2.047E-01	1.418E-01	69.25	
			---------	---------			
	Total Activity :		1.964E-01	2.047E-01			

Nuclide Type : natural

Nuclide	Hlife	Decay	Uncorrected pCi/g Wet	Decay Corr pCi/g Wet	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	5.754E+00	5.754E+00	0.524E+00	9.11	
TH-228	1.91Y	1.00	5.779E-02	5.797E-02	3.307E-02	57.05	
			---------	---------			
	Total Activity :		5.812E+00	5.812E+00			

Grand Total Activity : 6.009E+00 6.017E+00

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

None

Flags: "T" = Tentatively associated

Summary of Nuclide Activity

Total number of lines in spectrum	3	
Number of unidentified lines	0	
Number of lines tentatively identified by NID	3	100.00%

Nuclide Type : activation

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Wet	Wtd Mean Decay Corr pCi/g Wet	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
BE-7	53.44D	1.04	1.964E-01	2.047E-01	1.418E-01	69.25	
			---------	---------			
	Total Activity :		1.964E-01	2.047E-01			

Nuclide Type : natural

Nuclide	Hlife	Decay	Wtd Mean Uncorrected pCi/g Wet	Wtd Mean Decay Corr pCi/g Wet	Decay Corr 2-Sigma Error	2-Sigma %Error	Flags
K-40	1.28E+09Y	1.00	5.754E+00	5.754E+00	0.524E+00	9.11	
TH-228	1.91Y	1.00	5.779E-02	5.797E-02	3.307E-02	57.05	
			---------	---------			
	Total Activity :		5.812E+00	5.812E+00			

Grand Total Activity : 6.009E+00 6.017E+00

Flags: "K" = Keyline not found "M" = Manually accepted
"E" = Manually edited "A" = Nuclide specific abn. limit

Interference Report

No interference correction performed

Combined Activity-MDA Report

---- Identified Nuclides ----

Nuclide	Activity (pCi/g Wet)	Act error	MDA (pCi/g Wet)	MDA error	Act/MDA
BE-7	2.047E-01	1.418E-01	1.582E-01	0.000E+00	1.294
K-40	5.754E+00	5.240E-01	1.862E-01	0.000E+00	30.900
TH-228	5.797E-02	3.307E-02	3.095E-02	0.000E+00	1.873

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Wet)	K.L. Ided	Act error	MDA (pCi/g Wet)	MDA error	Act/MDA
NA-22	-4.033E-03		1.475E-02	2.580E-02	0.000E+00	-0.156

NA-24	9.854E-02	3.254E-01	6.877E-01	0.000E+00	0.143
CR-51	8.129E-03	1.013E-01	1.751E-01	0.000E+00	0.046
MN-54	-8.210E-03	1.290E-02	2.204E-02	0.000E+00	-0.372
CO-56	-2.661E-03	1.284E-02	2.468E-02	0.000E+00	-0.108
CO-57	-1.934E-03	8.011E-03	1.397E-02	0.000E+00	-0.138
CO-58	1.671E-04	1.125E-02	2.108E-02	0.000E+00	0.008
FE-59	-1.338E-02	2.655E-02	4.523E-02	0.000E+00	-0.296
CO-60	-4.402E-04	1.398E-02	2.551E-02	0.000E+00	-0.017
ZN-65	-2.706E-02	2.818E-02	4.458E-02	0.000E+00	-0.607
SE-75	1.072E-03	1.437E-02	2.498E-02	0.000E+00	0.043
Y-88	-1.622E-03	9.112E-03	1.803E-02	0.000E+00	-0.090
NB-94	-5.926E-03	1.161E-02	2.019E-02	0.000E+00	-0.293
NB-95	1.162E-03	1.100E-02	2.085E-02	0.000E+00	0.056
ZR-95	2.782E-02	2.115E-02	4.375E-02	0.000E+00	0.636
ZRNB-95	1.162E-03	1.100E-02	2.085E-02	0.000E+00	0.056
MO-99	1.017E-01	1.998E-01	3.784E-01	0.000E+00	0.269
RU-103	1.023E-02	1.191E-02	2.315E-02	0.000E+00	0.442
RU-106	-2.488E-02	1.067E-01	1.863E-01	0.000E+00	-0.134
AG-110m	2.894E-03	1.162E-02	2.139E-02	0.000E+00	0.135
SN-113	-4.192E-03	1.364E-02	2.409E-02	0.000E+00	-0.174
SB-124	3.361E-03	1.123E-02	2.080E-02	0.000E+00	0.162
SB-125	1.549E-02	2.969E-02	5.664E-02	0.000E+00	0.274
TE-129M	-1.145E-01	1.369E-01	2.264E-01	0.000E+00	-0.506
I-131	2.224E-02	1.593E-02	3.151E-02	0.000E+00	0.706
TE-132	-7.551E-03	1.836E-02	3.083E-02	0.000E+00	-0.245
BA-133	-8.112E-03	1.518E-02	2.627E-02	0.000E+00	-0.309
CS-134	9.141E-03	1.336E-02	2.682E-02	0.000E+00	0.341
CS-136	-1.734E-03	1.217E-02	2.248E-02	0.000E+00	-0.077
CS-137	-9.355E-03	1.345E-02	2.197E-02	0.000E+00	-0.426
CE-139	2.000E-03	9.336E-03	1.658E-02	0.000E+00	0.121
BA-140	2.215E-02	4.280E-02	8.232E-02	0.000E+00	0.269
BALA140	-3.950E-04	1.094E-02	2.228E-02	0.000E+00	-0.018
LA-140	-3.950E-04	1.094E-02	2.228E-02	0.000E+00	-0.018
CE-141	-2.846E-04	1.632E-02	2.884E-02	0.000E+00	-0.010
CE-144	-3.393E-02	6.718E-02	1.147E-01	0.000E+00	-0.296
EU-152	1.714E-02	3.575E-02	6.674E-02	0.000E+00	0.257
EU-154	-9.943E-03	1.726E-02	2.944E-02	0.000E+00	-0.338
RA-226	2.668E-01	2.668E-01	5.032E-01	0.000E+00	0.530
AC-228	5.458E-02	5.441E-02	1.110E-01	0.000E+00	0.492
TH-232	5.452E-02	5.435E-02	1.109E-01	0.000E+00	0.492

---- Non-Identified Nuclides ----

Nuclide	Key-Line Activity (pCi/g Wet)	K.L. Ided	Act error	MDA (pCi/g Wet)	MDA error	Act/MDA
U-235	-3.331E-02		7.320E-02	1.258E-01	0.000E+00	-0.265
U-238	3.423E-01		1.535E+00	2.873E+00	0.000E+00	0.119
NP-239	-9.673E-03		7.295E-02	1.289E-01	0.000E+00	-0.075
AM-241	1.040E-02		2.512E-02	4.325E-02	0.000E+00	0.240

```
A,11WG38781-1     ,03/10/2022 13:48,03/07/2022 08:55,   1.376E+03,WG38781-1 VA D
B,11WG38781-1     ,LIBD                       ,02/10/2022 09:58,1135L120319
C,BE-7     ,YES,   2.047E-01,   1.418E-01,   1.582E-01,,    1.294
C,K-40     ,YES,   5.754E+00,   5.240E-01,   1.862E-01,,   30.900
C,TH-228   ,YES,   5.797E-02,   3.307E-02,   3.095E-02,,    1.873
C,NA-22    ,NO ,  -4.033E-03,   1.475E-02,   2.580E-02,,   -0.156
C,NA-24    ,NO ,   9.854E-02,   3.254E-01,   6.877E-01,,    0.143
C,CR-51    ,NO ,   8.129E-03,   1.013E-01,   1.751E-01,,    0.046
C,MN-54    ,NO ,  -8.210E-03,   1.290E-02,   2.204E-02,,   -0.372
C,CO-56    ,NO ,  -2.661E-03,   1.284E-02,   2.468E-02,,   -0.108
C,CO-57    ,NO ,  -1.934E-03,   8.011E-03,   1.397E-02,,   -0.138
C,CO-58    ,NO ,   1.671E-04,   1.125E-02,   2.108E-02,,    0.008
C,FE-59    ,NO ,  -1.338E-02,   2.655E-02,   4.523E-02,,   -0.296
C,CO-60    ,NO ,  -4.402E-04,   1.398E-02,   2.551E-02,,   -0.017
C,ZN-65    ,NO ,  -2.706E-02,   2.818E-02,   4.458E-02,,   -0.607
C,SE-75    ,NO ,   1.072E-03,   1.437E-02,   2.498E-02,,    0.043
C,Y-88     ,NO ,  -1.622E-03,   9.112E-03,   1.803E-02,,   -0.090
C,NB-94    ,NO ,  -5.926E-03,   1.161E-02,   2.019E-02,,   -0.293
C,NB-95    ,NO ,   1.162E-03,   1.100E-02,   2.085E-02,,    0.056
C,ZR-95    ,NO ,   2.782E-02,   2.115E-02,   4.375E-02,,    0.636
C,ZRNB-95  ,NO ,   1.162E-03,   1.100E-02,   2.085E-02,,    0.056
C,MO-99    ,NO ,   1.017E-01,   1.998E-01,   3.784E-01,,    0.269
C,RU-103   ,NO ,   1.023E-02,   1.191E-02,   2.315E-02,,    0.442
C,RU-106   ,NO ,  -2.488E-02,   1.067E-01,   1.863E-01,,   -0.134
C,AG-110m  ,NO ,   2.894E-03,   1.162E-02,   2.139E-02,,    0.135
C,SN-113   ,NO ,  -4.192E-03,   1.364E-02,   2.409E-02,,   -0.174
C,SB-124   ,NO ,   3.361E-03,   1.123E-02,   2.080E-02,,    0.162
C,SB-125   ,NO ,   1.549E-02,   2.969E-02,   5.664E-02,,    0.274
C,TE-129M  ,NO ,  -1.145E-01,   1.369E-01,   2.264E-01,,   -0.506
C,I-131    ,NO ,   2.224E-02,   1.593E-02,   3.151E-02,,    0.706
C,TE-132   ,NO ,  -7.551E-03,   1.836E-02,   3.083E-02,,   -0.245
C,BA-133   ,NO ,  -8.112E-03,   1.518E-02,   2.627E-02,,   -0.309
C,CS-134   ,NO ,   9.141E-03,   1.336E-02,   2.682E-02,,    0.341
C,CS-136   ,NO ,  -1.734E-03,   1.217E-02,   2.248E-02,,   -0.077
C,CS-137   ,NO ,  -9.355E-03,   1.345E-02,   2.197E-02,,   -0.426
C,CE-139   ,NO ,   2.000E-03,   9.336E-03,   1.658E-02,,    0.121
C,BA-140   ,NO ,   2.215E-02,   4.280E-02,   8.232E-02,,    0.269
C,BALA140  ,NO ,  -3.950E-04,   1.094E-02,   2.228E-02,,   -0.018
C,LA-140   ,NO ,  -3.950E-04,   1.094E-02,   2.228E-02,,   -0.018
C,CE-141   ,NO ,  -2.846E-04,   1.632E-02,   2.884E-02,,   -0.010
C,CE-144   ,NO ,  -3.393E-02,   6.718E-02,   1.147E-01,,   -0.296
C,EU-152   ,NO ,   1.714E-02,   3.575E-02,   6.674E-02,,    0.257
C,EU-154   ,NO ,  -9.943E-03,   1.726E-02,   2.944E-02,,   -0.338
C,RA-226   ,NO ,   2.668E-01,   2.668E-01,   5.032E-01,,    0.530
C,AC-228   ,NO ,   5.458E-02,   5.441E-02,   1.110E-01,,    0.492
C,TH-232   ,NO ,   5.452E-02,   5.435E-02,   1.109E-01,,    0.492
C,U-235    ,NO ,  -3.331E-02,   7.320E-02,   1.258E-01,,   -0.265
C,U-238    ,NO ,   3.423E-01,   1.535E+00,   2.873E+00,,    0.119
C,NP-239   ,NO ,  -9.673E-03,   7.295E-02,   1.289E-01,,   -0.075
C,AM-241   ,NO ,   1.040E-02,   2.512E-02,   4.325E-02,,    0.240
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GAMMA SPECTROSCOPY

Prep and Run Logs

Logbook Page

L95403

GELI

Sample#	Matrix	QC	Analysis	Aliquot Volume / Units	Aliquot Date	Analyst	Aliquot Instrument	Tare Weight	Tare Balance	Final Weight	Final Balance	Mount Weight	Mount Date	Workgroup
WG38781-1	VA	DUP	GELI	1376.4 g wet	03/10/22	DH	BALANCE 15							WG38781
WG38795-1	AN	DUP	GELI	2480.1 g wet	03/10/22	DH	BALANCE 15							WG38795
L95403-1	SS		GELI	21.4 g dry	03/16/22	DH	BALANCE 15							WG38781
L95403-2	SS		GELI	32.3 g dry	03/16/22	DH	BALANCE 15							WG38781
L95403-3	SS		GELI	35.7 g dry	03/16/22	DH	BALANCE 15							WG38781
L95403-4	SS		GELI	26.7 g dry	03/16/22	DH	BALANCE 15							WG38781
L95403-5	SS		GELI	30.4 g dry	03/16/22	DH	BALANCE 15							WG38781
L95403-6	SS		GELI	24.6 g dry	03/16/22	DH	BALANCE 15							WG38781
L95403-7	SS		GELI	27.4 g dry	03/16/22	DH	BALANCE 15							WG38781
L95403-8	SS		GELI	45.9 g dry	03/16/22	DH	BALANCE 15							WG38781
L95403-9	SS		GELI	31.1 g dry	03/16/22	DH	BALANCE 15							WG38781
L95403-10	SS		GELI	24.8 g dry	03/16/22	DH	BALANCE 15							WG38781
L95403-11	SS		GELI	25.5 g dry	03/16/22	DH	BALANCE 15							WG38795
L95403-12	SS		GELI	26.9 g dry	03/16/22	DH	BALANCE 15							WG38795
L95403-13	SS		GELI	21.4 g dry	03/16/22	DH	BALANCE 15							WG38795
L95403-14	SS		GELI	41.7 g dry	03/16/22	DH	BALANCE 15							WG38795
L95403-15	SS		GELI	27.3 g dry	03/16/22	DH	BALANCE 15							WG38795
L95403-16	SS		GELI	30 g dry	03/16/22	DH	BALANCE 15							WG38795
L95403-17	SS		GELI	44.1 g dry	03/16/22	DH	BALANCE 15							WG38795
L95403-18	SS		GELI	23.6 g dry	03/16/22	DH	BALANCE 15							WG38795
L95403-19	SS		GELI	49.1 g dry	03/16/22	DH	BALANCE 15							WG38795
L95403-20	SS		GELI	53.6 g dry	03/16/22	DH	BALANCE 15							WG38795

Teledyne Analytical Laboratory
2508 Quality Lane
Knoxville, Tennessee 37931

TELEDYNE BROWN ENGINEERING
Gamma Worksheet/Run log (gammaws_L)
Mar 23 2022, 02:04 pm

L95403 - Origin: E

GELI **Due Date: 03/21/22**

Det. ID/Date	Sample ID	Client ID / ID Verification	Reference Date/Time	Mat	Product		Reporting Units		Nuclide	MDC

Anchor QEA, LLC
AN003-3EREGBTESKE-22 ANCHOR QEA
Report Format: Level 4 - Full 3Sigma
LLD Formula None
Countroom Library: NORMK
Project Manager: K.ARTERBURN

Technical Notes/Instructions

MS/MSD recovery 70 - 130, RPD < 30%
Uncertainty Less than 30%.

Due Date: 03/21/22

Det.	CountDate	Verify		Reference Date/Time		Mat	Product		Reporting Units		Nuclide	MDC
01	031722	☑ L95403-1 S25	1; 5.21	02/13/2022 13:37	(P/M)	SS	GELI	2.1400E+01 Dry	pCi/g Dry	SS	CS-137	1.000E-01
02	031822	☑ L95403-2 S25	8; 5.21	02/13/2022 13:37	(P/M)	SS	GELI	3.2300E+01 Dry	pCi/g Dry			
14	↓	☑ L95403-3 S25	15; 5.21	02/13/2022 13:37	(P/M)	SS	GELI	3.5700E+01 Dry	pCi/g Dry			
11	031722	☑ L95403-4 S25	22; 5.21	02/13/2022 13:37	(P/M)	SS	GELI	2.6700E+01 Dry	pCi/g Dry			
13	031822	☑ L95403-5 S25	29; 5.21	02/13/2022 13:37	(P/M)	SS	GELI	3.0400E+01 Dry	pCi/g Dry			
02	031722	☑ L95403-6 S25	36; 5.21	02/13/2022 13:37	(P/M)	SS	GELI	2.4600E+01 Dry	pCi/g Dry			
23	031822	☑ L95403-7 S25	43; 5.21	02/13/2022 13:37	(P/M)	SS	GELI	2.7400E+01 Dry	pCi/g Dry			
06	|	☑ L95403-8 S50	50; 5.21	02/13/2022 13:37	(P/M)	SS	GELI	4.5900E+01 Dry	pCi/g Dry			
07	↓	☑ L95403-9 S25	57; 5.21	02/13/2022 13:37	(P/M)	SS	GELI	3.1100E+01 Dry	pCi/g Dry			
07	031722	☑ L95403-10 S25	63; 5.21	02/13/2022 13:37	(P/M)	SS	GELI	2.4800E+01 Dry	pCi/g Dry			
14	|	☑ L95403-11 S25	64; 5.11	02/13/2022 12:56	(P/M)	SS	GELI	2.5500E+01 Dry	pCi/g Dry			
08	|	☑ L95403-12 S25	72; 5.11	02/13/2022 12:56	(P/M)	SS	GELI	2.6900E+01 Dry	pCi/g Dry			
23	↓	☑ L95403-13 S25	80; 5.11	02/13/2022 12:56	(P/M)	SS	GELI	2.1400E+01 Dry	pCi/g Dry			
11	031822	☑ L95403-14 S50	88; 5.11	02/13/2022 12:56	(P/M)	SS	GELI	4.1700E+01 Dry	pCi/g Dry			
06	031722	☑ L95403-15 S25	96; 5.11	02/13/2022 12:56	(P/M)	SS	GELI	2.7300E+01 Dry	pCi/g Dry			
01	031822	☑ L95403-16 S25	104; 5.11	02/13/2022 12:56	(P/M)	SS	GELI	3.0000E+01 Dry	pCi/g Dry			
06	↓	☑ L95403-17 S50	112; 5.11	02/13/2022 12:56	(P/M)	SS	GELI	4.4100E+01 Dry	pCi/g Dry			
13	031722	☑ L95403-18 S25	120; 5.11	02/13/2022 12:56	(P/M)	SS	GELI	2.3600E+01 Dry	pCi/g Dry			
08	032122	☑ L95403-19 S50	128; 5.11	02/13/2022 12:56	(P/M)	SS	GELI	4.9100E+01 Dry	pCi/g Dry			
06	↓	☑ L95403-20 S50	137; 5.11	02/13/2022 13:00	(P/M)	SS	GELI	5.3600E+01 Dry	pCi/g Dry			

Teledyne Analytical Laboratory
2508 Quality Lane
Knoxville, Tennessee 37931

TELEDYNE BROWN ENGINEERING
Gamma Worksheet/Run log (gammaws_wg)
Mar 23 2022, 02:05 pm

WG38781 - Origin: E
Due Date: 03/21/22

GELI

Det. ID/Date	ID Verification Sample ID	Client ID	Reference Date/Time	Mat	Product	Reporting Units	Nuclide	MDC

Teledyne Brown Engineering
TE511-LABQC Internal Lab QC (Bla
Report Format: Level 1 - Full 3Sigma
LLD Formula None
Countroom Library: LIBD
Project Manager: S.NORTHCUTT

Technical Notes/Instructions

Due Date: 04/04/22

Det.	CountDate	Verify	Sample ID	Client ID	Reference Date/Time	Mat	Product		Reporting Units
11	03/11/22	☑	WG38781-1 (L95387-1)	JORDAN COVE W	03/07/2022 08:55 (F/M)	VA	GELI	1.3764E+03 Wet	pCi/g Wet

Teledyne Analytical Laboratory
2508 Quality Lane
Knoxville, Tennessee 37931

TELEDYNE BROWN ENGINEERING
Gamma Worksheet/Run log (gammaws_wg)
Mar 23 2022, 02:04 pm

WG38795 - Origin: E

Due Date: 03/21/22

GELI

Det. ID/Date	ID Verification Sample ID	Client ID	Reference Date/Time	Mat	Product	Reporting Units	Nuclide	MDC

Teledyne Brown Engineering
TE511-LABQC Internal Lab QC (Bla
Report Format: Level 1 - Full 3Sigma
LLD Formula None
Countroom Library: LIBD
Project Manager: S.NORTHCUTT

Technical Notes/Instructions

Due Date: 04/04/22

Det.	CountDate	Verify	Sample ID	Client ID	Reference Date/Time	Mat	Product		Reporting Units
11	031022	☐	WG38795-1 (L95392-1)	SAGAM13E3	03/07/2022 12:00 (F/E)	AN	GELI	2.4801E+00 Wet	pCi/Kg Wet

GAMMA SPECTROSCOPY

Balance and Pipette Check

Daily Balance Tolerance Check Reports

for : L95403

Instrument: BALANCE 15

Model: A&D GX-6001A

Serial Number: T2008157

Description: A&D 6100 g capacity top loading balance.

Known Weight Initial calibration by PCS 06/17/21

Check Date: 10-MAR-22

Analyst: DH

Weight Set Used: WTSET 3

Tolerance: 1%

Out of Range: N

	Result Weight
1.0000	1.0000
100.0000	100.0000
1000.0000	1000.0000

Prod

NONE BALANCE 15 10-MAR-22

Daily Balance Tolerance Check Reports

for : L95403

Instrument: BALANCE 15

Model: A&D GX-6001A

Serial Number: T2008157

Description: A&D 6100 g capacity top loading balance.

Known Weight: Initial calibration by PCS 06/17/21

Check Date: 16-MAR-22

Analyst: DH

Weight Set Used: WTSET 3

Tolerance: 1%

Out of Range: N

	Result Weight
1.0000	1.0000
100.0000	100.0000
1000.0000	1000.0000

Prod		
GELI	BALANCE 15	16-MAR-22
NONE	BALANCE 15	16-MAR-22

Gamma Standard

Eckert & Ziegler
Isotope Products

24937 Avenue Tibbitts
Valencia, California 91355

Tel 661•309•1010
Fax 661•257•8303

CERTIFICATE OF CALIBRATION
MULTINUCLIDE STANDARD SOLUTION

Customer:	TELEDYNE BROWN ENGINEERING, INC.	**Source No.:**	2088-10-1
P.O. No.:	PO00149995	**Reference Date:**	1-Jun-19 12:00 PST
Catalog No.:	7602	**Contained Radioactivity:**	1.026 µCi 37.96 kBq

Physical Description:

A. Mass of solution: 5.16168 grams in 5 mL flame-sealed ampoule
B. Chemical form: Multinuclide in 2M HCl
C. Carrier content: See attached sheet
D. Density: 1.033 g/mL @ 20°C

Total wt. 8.7382
tare wt. 8.0137
Final wt. = 0.7245g
empty wt. 3.5953
4.4184g

Gamma-Ray Energy (keV)	Nuclide	Half-life	Branching Ratio (%)	Conc. (nCi/g)	Gammas per second per gram	Total Uncert.
47	Pb-210	22.3 ± 0.2 years	4.18	46.62	72.10	4.1 %
88	Cd-109	462.6 ± 0.7 days	3.63	63.10	84.75	3.0 %
122	Co-57	271.79 ± 0.09 days	85.6	2.439	77.25	3.1 %
166	Ce-139	137.640 ± 0.023 days	79.9	3.135	92.68	3.1 %
279	Hg-203	46.595 ± 0.013 days	81.5	9.054	273.0	3.1 %
392	Sn-113	115.09 ± 0.04 days	64.9	11.66	280.0	3.0 %
514	Sr-85	64.849 ± 0.004 days	98.4	15.05	547.9	3.0 %
662	Cs-137	30.17 ± 0.16 years	85.1	10.50	330.6	3.0 %
898	Y-88	106.630 ± 0.025 days	94.0	24.69	858.7	3.0 %
1173	Co-60	5.272 ± 0.001 years	99.86	12.46	460.4	3.0 %
1333	Co-60	5.272 ± 0.001 years	99.98	12.46	460.9	3.0 %
1836	Y-88	106.630 ± 0.025 days	99.4	24.69	908.0	3.0 %

Method of Calibration:

This source was prepared from weighed aliquots of solutions whose concentrations in µCi/g were determined by gamma spectrometry.

Undiluted STD
0.7245 g in Filter Petri Dish

Diluted STD
4.4184g / 50ml (85.6%)

Notes:

- See reverse side for leak test(s) performed on this source.
- EZIP participates in a NIST measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NIST certification) of Standard Reference Materials (as in NRC Regulatory Guide 4.15).
- Nuclear data was taken from IAEA-TECDOC-619, 1991.
- Overall uncertainty is calculated at the 99% confidence level.
- This source has a recommended working life of 1 year.

Dilution by: Keith [signature] 6/17/19

Daniel James VanDalsem
Quality Control

27-May-19
Date

EZIP Ref. No.: 2088-10

ISO 9001 CERTIFIED

Medical Imaging Laboratory
24937 Avenue Tibbitts Valencia, California 91355

Industrial Gauging Laboratory
1800 North Keystone Street Burbank, California 91504

E & Z 2088-10-1 Mixed Gamma
6/1/19 12:00 PM

FULL 20 ML LSC VIAL

		Orig. Wt	5.1617	Volume	50				
		Wt Used	4.4184	Aliquot	2.0000	Certificate	Aliquoted	Actual	Percent
Nuclide	Half-Life	Energy(KeV)	.ate G/s/	%err	%abn	Bq/Tot	G/S	Bq/Tot	Diff
Cd-109	462.9d	88.0	84.75		3.72%	402.64	14.98		
Co-57	271.8d	122.1	77.25		85.51%	15.97	13.65		
Ce-139	137.64d	165.9	92.68		80.35%	20.39	16.38		
Hg-203	46.6d	279.2	273		77.30%	62.42	48.25		
Sn-113	115.09d	391.7	280		64.90%	76.25	49.49		
Sr-85	64.849	514.0	547.9		98.40%	98.41	96.83		
Cs-137	30.17y	661.6	330.6		85.12%	68.64	58.43		
Y-88	106.65d	898.0	858.7		93.40%	162.49	151.76		
Co-60	5.27y	1173.2	460.4		100.00%	81.37	81.37		
Co-60	5.27y	1332.5	460.9		100.00%	81.46	81.46		
Y-88	106.65d	1836.0	908		99.38%	161.48	160.48		

Eff. Name:

Analyst: KOJ

PERCENT MOISTURE

Percent Moisture Report

Run Date: 03/23/2022

L95403

Sample#	Client ID	Tare Wt	Wet Wt	Dry Wt	Tare Balance/Date		Dry Balance/Date		Analyst	% Moist
L95403-1	1; 5.2-1	124.5	159.4	147	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	35.53
L95403-2	8; 5.2-1	124.6	211.5	182.4	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	33.49
L95403-3	15; 5.2-1	124.5	200.2	173.1	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	35.8
L95403-4	22; 5.2-1	124.2	175.8	156.8	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	36.82
L95403-5	29; 5.2-1	124.2	176	160.1	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	30.69
L95403-6	36; 5.2-1	123.8	173.3	152.9	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	41.21
L95403-7	43; 5.2-1	123.8	181.1	158.1	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	40.14
L95403-8	50; 5.2-1	123.8	196.6	171.8	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	34.07
L95403-9	57; 5.2-1	123.3	177.1	162.2	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	27.7
L95403-10	63; 5.2-1	123.3	166.9	151.7	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	34.86
L95403-11	64; 5.1-1	123.3	166.2	150.7	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	36.13
L95403-12	72; 5.1-1	124	175.1	154.2	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	40.9
L95403-13	80; 5.1-1	123.7	156.6	146.8	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	29.79
L95403-14	88; 5.1-1	124.1	192.3	168	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	35.63
L95403-15	96; 5.1-1	123.4	169.3	152.9	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	35.73
L95403-16	104; 5.1-1	123.7	180.4	161.3	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	33.69
L95403-17	112; 5.1-1	123.8	194.7	170.5	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	34.13
L95403-18	120; 5.1-1	123	162.4	148.9	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	34.26
L95403-19	128; 5.1-1	124.2	199.5	175.6	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	31.74
L95403-20	137; 5.1-1	123	208.2	179.9	BALANCE 15	03/10/22	BALANCE 15	03/16/22	DH	33.22

Appendix IV
Field Notes

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**08.1-1**
Job No: 212451-01.01		**Attempt No.**	1
Field Staff: RC, TK, BT		**Date:**	2/10/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing: 619980 ft

Long/Easting: 2915758 ft

A. Water Depth

DTM Depth Sounder: 23 ft

DTM Lead Line:

B. Water Level Measurements

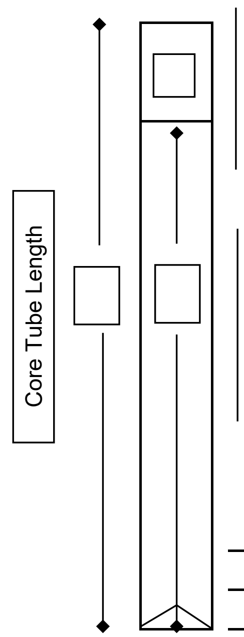
Time: 14:09

Height: 743.5 ft

C. Mudline Elevation

723.5 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 16 ft

Drive Penetration: 9.5-10 ft

Headspace Measurement: 3 in

Recovery Measurement: 93 in

Recovery Percentage: 82%

Total Length of Core To Process: 93 in (7.75 ft)

Drive Notes:

Soft sediment

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Gray w/ brownish streaks, silt-clay, firmer in deeper part of core

Notes:

Took grain size sample from top & bottom 1 ft of core

Sediment Core Collection Log

Job: Grand Lake Vibracore	**Station ID:** **08.1-2**
Job No: 212451-01.01	**Attempt No.** 2
Field Staff: RC, TK, BT	**Date:** 2/10/2022
Contractor: N/A	**Logged By:** **BT**
Vertical Datum: NAVD88	**Horizontal Datum:** OK State Plane N

Field Collection Coordinates:

Lat/Northing: 619980 ft

Long/Easting: 2915758 ft

A. Water Depth

DTM Depth Sounder: 23 ft

DTM Lead Line:

B. Water Level Measurements

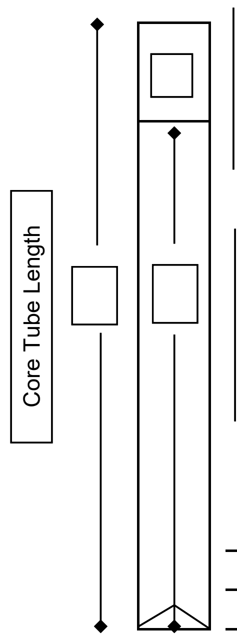
Time: 14:30

Height: 743.5 ft

C. Mudline Elevation

723.5 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 11 ft

Drive Penetration: 144 in

Headspace Measurement: 3 in

Recovery Measurement: 129 in

Recovery Percentage: 90%

Total Length of Core To Process: 129 in

Drive Notes:

Soft sediment; drive to refusal at ~12 ft

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Gray w/ brownish streaks, silt-clay, firmer in deeper part of core; no visible layering

Notes:

Took grain size sample from top & bottom 1 ft of core

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**01.1-1**
Job No: 212451-01.01		**Attempt No.**	1
Field Staff: RC, TK, BT		**Date:**	2/11/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing: 669690 ft

Long/Easting: 2905562 ft

A. Water Depth

DTM Depth Sounder: 18 ft

DTM Lead Line:

B. Water Level Measurements

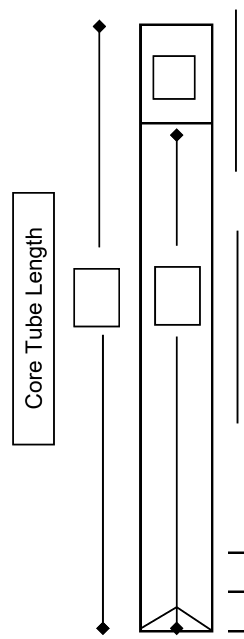
Time: 13:30

Height: 744.3 ft

C. Mudline Elevation

726.3 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 16 ft

Drive Penetration: 4.5 ft

Headspace Measurement: 2 in

Recovery Measurement: 48 in

Recovery Percentage: 89%

Total Length of Core To Process: 48 in

Drive Notes:

Drove to refusal

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

No visible layers, grayish clay throughout core

Firmer material at bottom of core tube

Notes:

Grain size samples @ 1 ft intervals

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**01.1-2**
Job No: 212451-01.01		**Attempt No.**	2
Field Staff: RC, TK, BT		**Date:**	2/11/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing: 669690 ft

Long/Easting: 2905562 ft

A. Water Depth

DTM Depth Sounder: 18 ft

DTM Lead Line:

B. Water Level Measurements

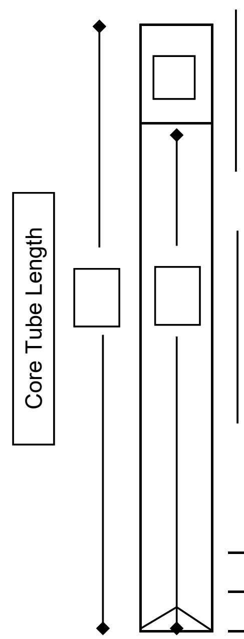
Time: 13:45

Height: 744.3 ft

C. Mudline Elevation

726.3 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 8 ft

Drive Penetration: 6 ft

Headspace Measurement: 3in

Recovery Measurement: 5 ft 3 in = 63 in

Recovery Percentage: 66%

Total Length of Core To Process: 63 in

Drive Notes:

Drive went to refusal

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

No visible layers, grayish clay throughout core

Firmer near bottom, no significant difference in texture otherwise

Notes:

Grain size samples @ 1 ft intervals

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**02.1-1**
Job No: 212451-01.01		**Attempt No.**	1
Field Staff: RC, TK, BT		**Date:**	2/11/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing: 669340 ft

Long/Easting: 2911790 ft

A. Water Depth

DTM Depth Sounder: 14 ft

DTM Lead Line:

B. Water Level Measurements

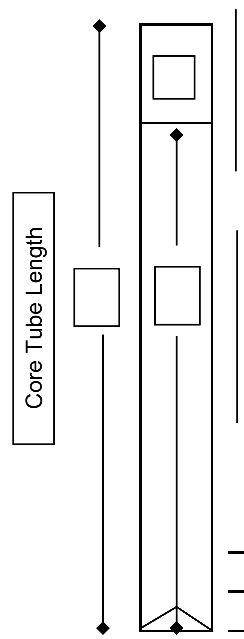
Time: 14:30

Height: 744.0 ft

C. Mudline Elevation

730.0 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 16 ft

Drive Penetration: 6 ft

Headspace Measurement: 1 in

Recovery Measurement: 5' 3" = 63 in

Recovery Percentage: 88%

Total Length of Core To Process: 63 in

Drive Notes:

Drove to refusal

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

No visible layers in core, grayish clay throughout

Softer near surface

Notes:

Grain size samples @ 1 ft intervals

ANCHOR QEA

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**02.1-2**
Job No: 212451-01.01		**Attempt No.**	2
Field Staff: RC, TK, BT		**Date:**	2/11/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing:	669340 ft	Long/Easting:	2911790 ft

A. Water Depth

DTM Depth Sounder: 14 ft

DTM Lead Line:

B. Water Level Measurements

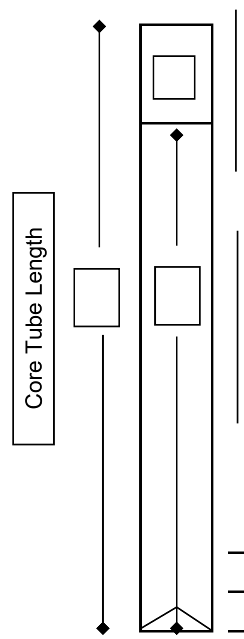
Time: 14:45

Height: 744.0 ft

C. Mudline Elevation

730.0 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted:	Yes
Core Tube Length:	8 ft
Drive Penetration:	7 ft
Headspace Measurement:	1 in
Recovery Measurement:	6 ft = 72 in
Recovery Percentage:	86%
Total Length of Core To Process:	72 in

Drive Notes:

Drove to refusal

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

No visible layers, grayish clay throughout core

Notes:

Grain size samples @ 1-ft intervals

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**03.1-1**
Job No: 212451-01.01		**Attempt No.**	1
Field Staff: RC, TK, BT		**Date:**	2/11/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plan N

Field Collection Coordinates:

Lat/Northing:	660811 ft	Long/Easting:	2910646 ft

A. Water Depth

DTM Depth Sounder: 1.5 ft

DTM Lead Line:

B. Water Level Measurements

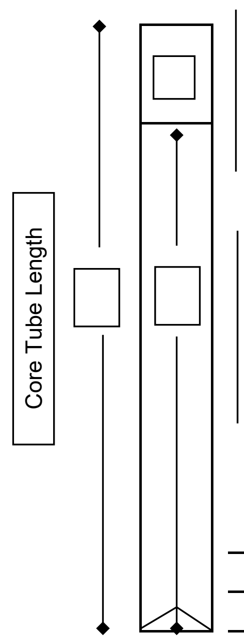
Time: 15:30

Height: 744.2 ft

C. Mudline Elevation

742.7 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted:	Yes
Core Tube Length:	11 ft
Drive Penetration:	36 in
Headspace Measurement:	3 in
Recovery Measurement:	2 ft 9 in = 33 in
Recovery Percentage:	92%
Total Length of Core To Process:	33 in

Drive Notes:

Drove to refusal

Thick clay

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Appears to be clay, no visible layers

Very firm, limited penetration

Notes:

Grain size samples @ 1-ft intervals

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**03.1-2**
Job No: 212451-01.01		**Attempt No.**	2
Field Staff: RC, TK, BT		**Date:**	2/11/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plan N

Field Collection Coordinates:

Lat/Northing: 660811 ft

Long/Easting: 2910646 ft

A. Water Depth

DTM Depth Sounder: 1.5 ft

DTM Lead Line:

B. Water Level Measurements

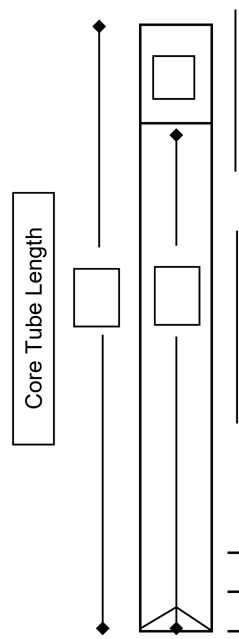
Time: 15:45

Height: 744.2 ft

C. Mudline Elevation

742.7 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 8 ft

Drive Penetration: 3.0 ft

Headspace Measurement: 1 in

Recovery Measurement: 35 in

Recovery Percentage: 97%

Total Length of Core To Process: 35 in

Drive Notes:

Drove to refusal

Core Field Observations and Description:	Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Some air bubbles in top foot; limited elsewhere

Thick, hard clay material

Notes:

Grain size samples @ 1-ft intervals

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**9.1-1**
Job No: 212451-01.01		**Attempt No.**	1
Field Staff: RC, TK, BT		**Date:**	2/12/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing: 612772 ft

Long/Easting: 2912054 ft

A. Water Depth

DTM Depth Sounder: 14.5 ft

DTM Lead Line:

B. Water Level Measurements

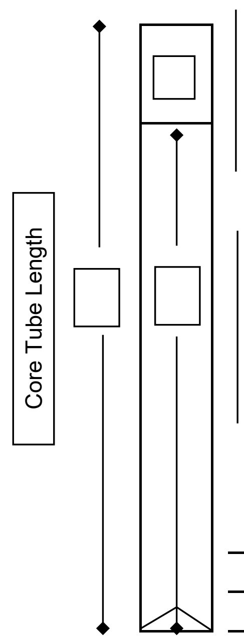
Time: 12:55

Height: 744.5 ft

C. Mudline Elevation

730.0 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 16 ft

Drive Penetration: 2 ft

Headspace Measurement: 3 in

Recovery Measurement: 18 in

Recovery Percentage: 75%

Total Length of Core To Process: 18 in

Drive Notes:

Driven to refusal

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Soft to ~6 in, firmer below

Gray silt/clay with no apparent layering

Notes:

Collected grain size samples @ 1-ft intervals

Sediment Core Collection Log

Job:	**Grand Lake Vibracore**	**Station ID:**	**9.1-2**
Job No:	**212451-01.01**	**Attempt No.**	2
Field Staff:	**RC, TK, BT**	**Date:**	2/12/2022
Contractor:	**N/A**	**Logged By:**	**BT**
Vertical Datum:	**NAVD88**	**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing: 612772 ft

Long/Easting: 2912054 ft

A. Water Depth

DTM Depth Sounder: 14.5 ft

DTM Lead Line:

B. Water Level Measurements

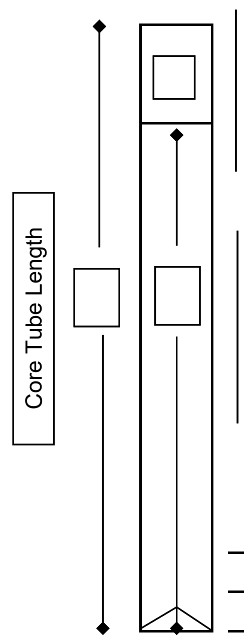
Time: 12:55

Height: 744.5 ft

C. Mudline Elevation

730.0 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length:	8 ft
Drive Penetration:	2 ft
Headspace Measurement:	8 in
Recovery Measurement:	12 in
Recovery Percentage:	50%
Total Length of Core To Process:	12 in

Drive Notes:

Driven to refusal

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Soft material in top ~6 in, firmer below

Gray silt/clay with no visible layers

Notes:

Grain size sampling @ 1-ft intervals

Sediment Core Collection Log

Job: Grand Lake Vibracore	**Station ID:** 8.2-1
Job No: 212451-01.01	**Attempt No.** 1
Field Staff: RC, TK, BT	**Date:** 2/12/2022
Contractor: N/A	**Logged By:** BT
Vertical Datum: NAVD88	**Horizontal Datum:** OK State Plane N

Field Collection Coordinates:

Lat/Northing: 619613 ft

Long/Easting: 2917399 ft

A. Water Depth

DTM Depth Sounder: 17.5 ft

DTM Lead Line:

B. Water Level Measurements

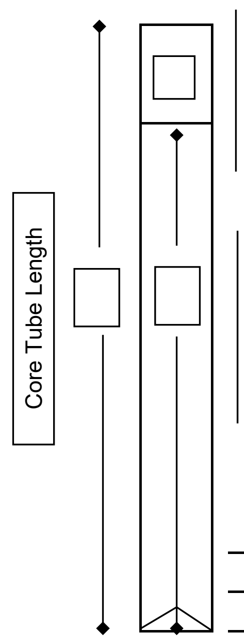
Time: 13:55

Height: 744.5 ft

C. Mudline Elevation

727.0 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 16 ft

Drive Penetration: 3 ft

Headspace Measurement: 2 in

Recovery Measurement: 24 in

Recovery Percentage: 67%

Total Length of Core To Process: 24 in

Drive Notes:

Driven to refusal

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Softer, water-logged clay in first ~12 in, firmer ~12-24 in

Notes:

Grain size sampling @ 1-ft intervals

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**6.1-1**
Job No: 212451-01.01		**Attempt No.**	1
Field Staff: RC, TK, BT		**Date:**	2/12/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing: 636016 ft

Long/Easting: 2923350 ft

A. Water Depth

DTM Depth Sounder: 7.5 ft

DTM Lead Line:

B. Water Level Measurements

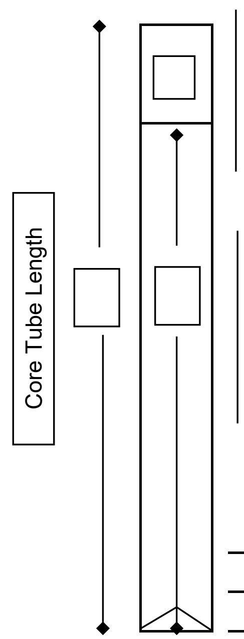
Time: 14:45

Height: 744.4 ft

C. Mudline Elevation

726.9 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length:	16 ft
Drive Penetration:	1.5 ft
Headspace Measurement:	6 in
Recovery Measurement:	12 in
Recovery Percentage:	67%
Total Length of Core To Process:	12 in

Drive Notes:

Driven to refusal

Possibly hung up on underwater debris or buried log/rock

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Soft, grayish silt/clay - suggests caught on buried material or would have driven further

Notes:

Grain size samples collected @ 1-ft intervals

Sediment Core Collection Log

Job: Grand Lake Vibracore	**Station ID:** **06.2-1**
Job No: 212451-01.01	**Attempt No.** 1
Field Staff: RC, TK, BT	**Date:** 2/12/2022
Contractor: N/A	**Logged By:** **BT**
Vertical Datum: NAVD88	**Horizontal Datum:** OK State Plane N

Field Collection Coordinates:

Lat/Northing: 636017 ft

Long/Easting: 2923048 ft

A. Water Depth

DTM Depth Sounder: 4.5 ft

DTM Lead Line:

B. Water Level Measurements

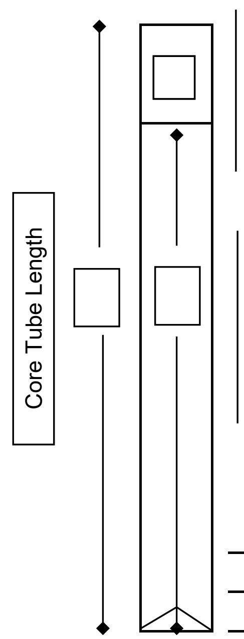
Time: 15:00

Height: 744.2 ft

C. Mudline Elevation

739.7 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 16 ft

Drive Penetration: 7 ft

Headspace Measurement: 4 in

Recovery Measurement: 76 in

Recovery Percentage: 90%

Total Length of Core To Process: 76 in

Drive Notes:

Driven to refusal

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Grayish silt/clay throughout, no obvious layers

Firmer clay near bottom

Notes:

Grain size samples @ 1-ft intervals

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**06.2-2**
Job No: 212451-01.01		**Attempt No.**	2
Field Staff: RC, TK, BT		**Date:**	2/12/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing: 636017 ft

Long/Easting: 2923048 ft

A. Water Depth

DTM Depth Sounder: 4.5 ft

DTM Lead Line:

B. Water Level Measurements

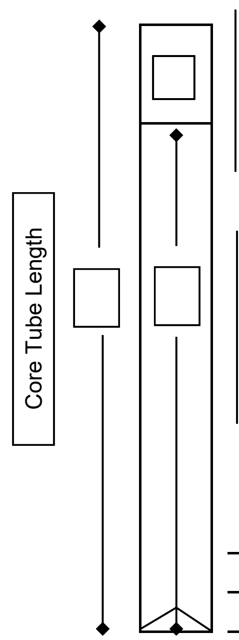
Time: 15:20

Height: 744.2 ft

C. Mudline Elevation

739.7 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 10 ft

Drive Penetration: 7 ft

Headspace Measurement: 2 in

Recovery Measurement: 81 in

Recovery Percentage: 96%

Total Length of Core To Process: 81 in

Drive Notes:

Driven to refusal

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Grayish silt/clay throughout, no obvious layers

Firm, especially near bottom of core

Notes:

Grain size sampling @ 1 ft intervals

ANCHOR QEA

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**07.1-1**
Job No: 212451-01.01		**Attempt No.**	1
Field Staff: RC, TK, BT		**Date:**	2/12/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing: 626482 ft

Long/Easting: 2914670 ft

A. Water Depth

DTM Depth Sounder: 6 ft

DTM Lead Line:

B. Water Level Measurements

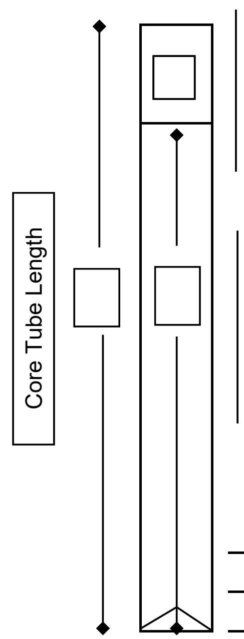
Time: 16:00

Height: 744.5 ft

C. Mudline Elevation

738.5 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 16 ft

Drive Penetration: 5.5 ft

Headspace Measurement: 5 in

Recovery Measurement: 57 in

Recovery Percentage: 86%

Total Length of Core To Process: 57 in

Drive Notes:

Driven to refusal

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Worm @ ~6 in from surface, signs of biotic activity

Gray silt/clay, no visible layers

Notes:

Grain size samples @ 1 ft intervals

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**7.2-1**
Job No: 212451-01.01		**Attempt No.**	1
Field Staff: RC, TK, BT		**Date:**	2/12/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing: 626591 ft

Long/Easting: 2914380 ft

A. Water Depth

DTM Depth Sounder: 17.5 ft

DTM Lead Line:

B. Water Level Measurements

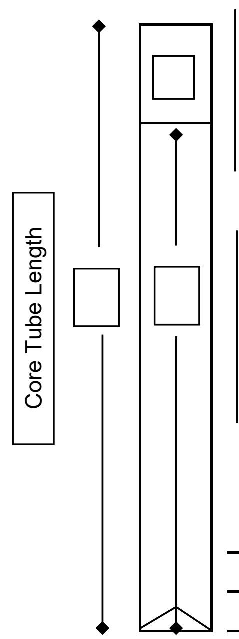
Time: 16:15

Height: 744.3 ft

C. Mudline Elevation

726.8 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 16 ft

Drive Penetration: 7 ft

Headspace Measurement: 2 in

Recovery Measurement: 79 in

Recovery Percentage: 94%

Total Length of Core To Process: 79 in

Drive Notes:

Driven to refusal

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Significant texture change @ ~12 in, softer above, visibly similar clay/silt

Notes:

Grain size samples @ 1-ft interval

Sediment Core Collection Log

Job: Grand Lake Vibracore	**Station ID:** 4.1-1
Job No: 212451-01.01	**Attempt No.** 1
Field Staff: RC, TK, BT	**Date:** 2/13/2022
Contractor: N/A	**Logged By:** BT
Vertical Datum: NAVD88	**Horizontal Datum:** OK State Plane N

Field Collection Coordinates:

Lat/Northing: 649883 ft

Long/Easting: 2925261 ft

A. Water Depth

DTM Depth Sounder: 6 ft

DTM Lead Line:

B. Water Level Measurements

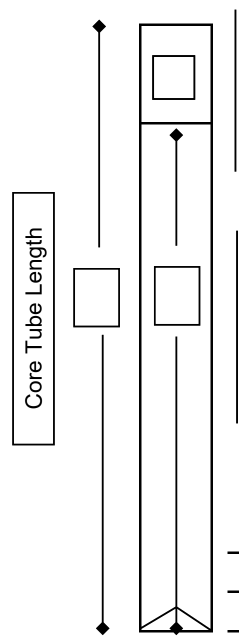
Time: 10:50

Height: 744.5 ft

C. Mudline Elevation

738.5 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 11 ft

Drive Penetration: 5 ft

Headspace Measurement: 3 in

Recovery Measurement: 49 in

Recovery Percentage: 82%

Total Length of Core To Process: 49 in

Drive Notes:

Possibly caught on buried tree branch or other debris

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Core catcher shoved into core tube suggests it wasn't caught on debris; thick clay layer stopping drive more likely

Firm clay near bottom, soft silty/clayey layers above; gradual transition with no distinct layering

Notes:

Grain size sampling @ 1-ft intervals

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**4.2-1**
Job No: 212451-01.01		**Attempt No.**	1
Field Staff: RC, TK, BT		**Date:**	2/13/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing: 650123 ft

Long/Easting: 2926237 ft

A. Water Depth

DTM Depth Sounder: 2 ft

DTM Lead Line:

B. Water Level Measurements

Time: 11:20

Height: 744.5 ft

C. Mudline Elevation

742.5 ft

Recovery Measurements (prior to cuts)

Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 12 ft

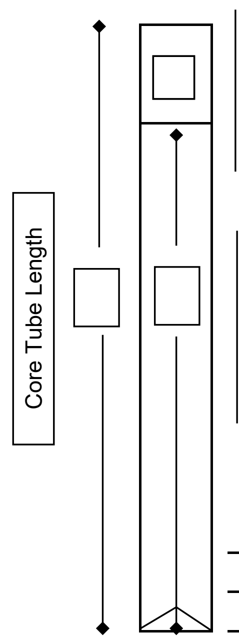
Drive Penetration: 8 ft

Headspace Measurement: 2 in

Recovery Measurement: 92 in

Recovery Percentage: 96%

Total Length of Core To Process: 92 in



Drive Notes:

Significantly deeper penetration here than nearby Site 4.1

Drove to refusal

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Organic debris on surface of core (~1-2 inches) - sticks & leaves

Softer material @ surface, firmer in deeper parts of core

Notes:

Grain size samples @ 1-ft interval

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**GL1-1**
Job No: 212451-01.01		**Attempt No.**	1
Field Staff: RC, TK, BT		**Date:**	2/13/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing: 647148 ft

Long/Easting: 2915104 ft

A. Water Depth

DTM Depth Sounder: 2 ft

DTM Lead Line:

B. Water Level Measurements

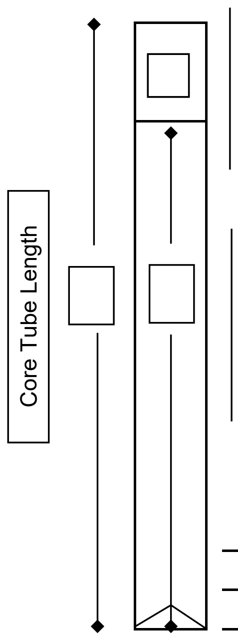
Time: 12:05

Height: 744.4 ft

C. Mudline Elevation

742.4 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 14 ft

Drive Penetration: 8 ft

Headspace Measurement: 3 in

Recovery Measurement: 90 in

Recovery Percentage: 94%

Total Length of Core To Process: 90 in

Drive Notes:

Drove to refusal

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Silt and clay, no clear layering

Notes:

Grain size sampling @ 1 ft intervals

Sediment Core Collection Log

Job: Grand Lake Vibracore	**Station ID:** **GL1-2**
Job No: 212451-01.01	**Attempt No.** 2
Field Staff: RC, TK, BT	**Date:** 2/13/2022
Contractor: N/A	**Logged By:** **BT**
Vertical Datum: NAVD88	**Horizontal Datum:** OK State Plane N

Field Collection Coordinates:

Lat/Northing: 647148 ft

Long/Easting: 2915104 ft

A. Water Depth

DTM Depth Sounder: 2 ft

DTM Lead Line:

B. Water Level Measurements

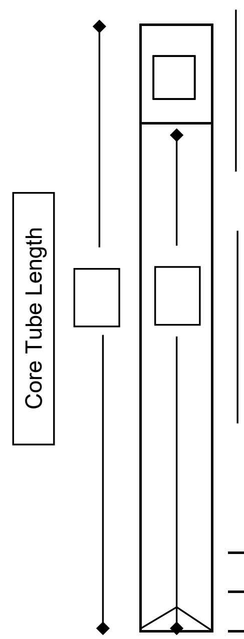
Time: 12:22

Height: 744.4 ft

C. Mudline Elevation

742.4 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length:	14 ft
Drive Penetration:	8 ft
Headspace Measurement:	5 in
Recovery Measurement:	84 in
Recovery Percentage:	88%
Total Length of Core To Process:	84 in

Drive Notes:

Driven to refusal

Core Field Observations and Description:	Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Sticks and organic debris in top ~12 in of core

Notes:

Grain size samples @ 1-ft interval

ANCHOR QEA

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**05.1-1**
Job No: 212451-01.01		**Attempt No.**	1
Field Staff: RC, TK, BT		**Date:**	2/13/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing: 644108 ft

Long/Easting: 2913784 ft

A. Water Depth

DTM Depth Sounder: 2 ft

DTM Lead Line:

B. Water Level Measurements

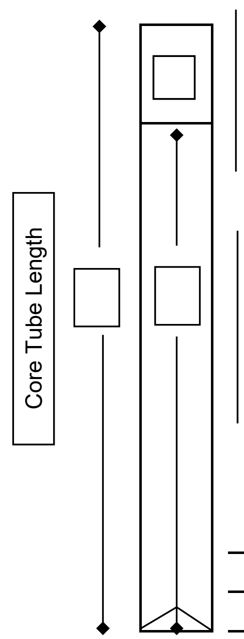
Time: 13:00

Height: 744.5 ft

C. Mudline Elevation

742.5 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 12 ft

Drive Penetration: 11 ft

Headspace Measurement: 1 in

Recovery Measurement: 117 in (9'9")

Recovery Percentage: 89%

Total Length of Core To Process: 117 in (9'9")

Drive Notes:

Driven to refusal, firmer material near bottom of drive

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Air bubbles in top ~18 in

Relatively soft silt/clay material throughout, no visible layers; grayish sediment

Notes:

Divided into 4 cm samples for Cs-137 testing

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**05.1-2**
Job No: 212451-01.01		**Attempt No.**	2
Field Staff: RC, TK, BT		**Date:**	2/13/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing:	644108 ft	Long/Easting:	2913784 ft

A. Water Depth

DTM Depth Sounder: 2 ft

DTM Lead Line:

B. Water Level Measurements

Time: 13:00

Height: 744.5 ft

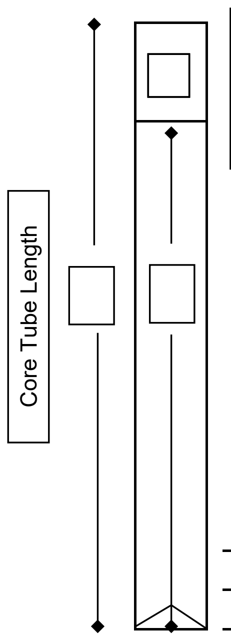
C. Mudline Elevation

Recovery Measurements (prior to cuts)

Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length:	12 ft
Drive Penetration:	9.5 ft
Headspace Measurement:	2 in
Recovery Measurement:	102 in
Recovery Percentage:	89%
Total Length of Core To Process:	102 in



Drive Notes:

Driven to refusal, similar to core 05.1-1

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

Silt/clay misture throughout core, no obvious layers

Grayish material, firmer at bottom

Notes:

Grain size samples @ 1 ft intervals

ANCHOR QEA

Sediment Core Collection Log

Job: Grand Lake Vibracore		**Station ID:**	**05.2-1**
Job No: 212451-01.01		**Attempt No.**	1
Field Staff: RC, TK, BT		**Date:**	2/13/2022
Contractor: N/A		**Logged By:**	**BT**
Vertical Datum: NAVD88		**Horizontal Datum:**	OK State Plane N

Field Collection Coordinates:

Lat/Northing: 644002 ft

Long/Easting: 2913396 ft

A. Water Depth

DTM Depth Sounder: 5.5 ft

DTM Lead Line:

B. Water Level Measurements

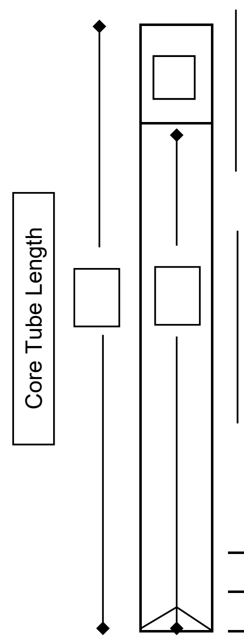
Time: 13:22

Height: 744.4 ft

C. Mudline Elevation

738.9 ft

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 16 ft

Drive Penetration: 10 ft

Headspace Measurement: 1 in

Recovery Measurement: 107 in

Recovery Percentage: 89%

Total Length of Core To Process: 107 in

Drive Notes:

Driven to refusal; Similar to Site 05.1

Core Field Observations and Description:

Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

No visible layers; grayish silt/clay throughout core, softer near surface, but all was malleable

Notes:

Collected samples for cesium-137 analysis every 4 cm

ANCHOR QEA

Sediment Core Collection Log

Job: Grand Lake Vibracore	**Station ID:** **05.2-2**
Job No: 212451-01.01	**Attempt No.** 2
Field Staff: RC, TK, BT	**Date:** 2/13/2022
Contractor: N/A	**Logged By:** **BT**
Vertical Datum: NAVD88	**Horizontal Datum:** OK State Plane N

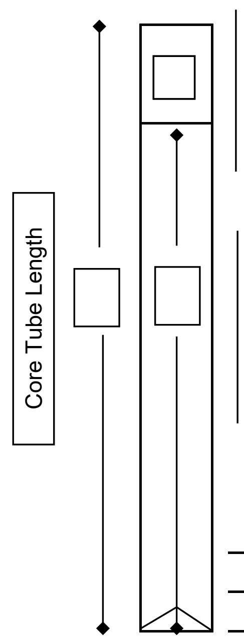
Field Collection Coordinates:

Lat/Northing: 644002 ft

Long/Easting: 2913396 ft

A. Water Depth	**B. Water Level Measurements**	**C. Mudline Elevation**
DTM Depth Sounder: 5.5 ft	Time: 13:40	738.9 ft
DTM Lead Line:	Height: 744.4 ft	

Recovery Measurements (prior to cuts)



Core Collection Recovery Details:

Core Accepted: Yes

Core Tube Length: 16ft

Drive Penetration: 10 ft

Headspace Measurement: 2 in

Recovery Measurement: 102 in

Recovery Percentage: 85%

Total Length of Core To Process: 102 in

Drive Notes:

Driven to refusal

Core Field Observations and Description: Sediment type, moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota

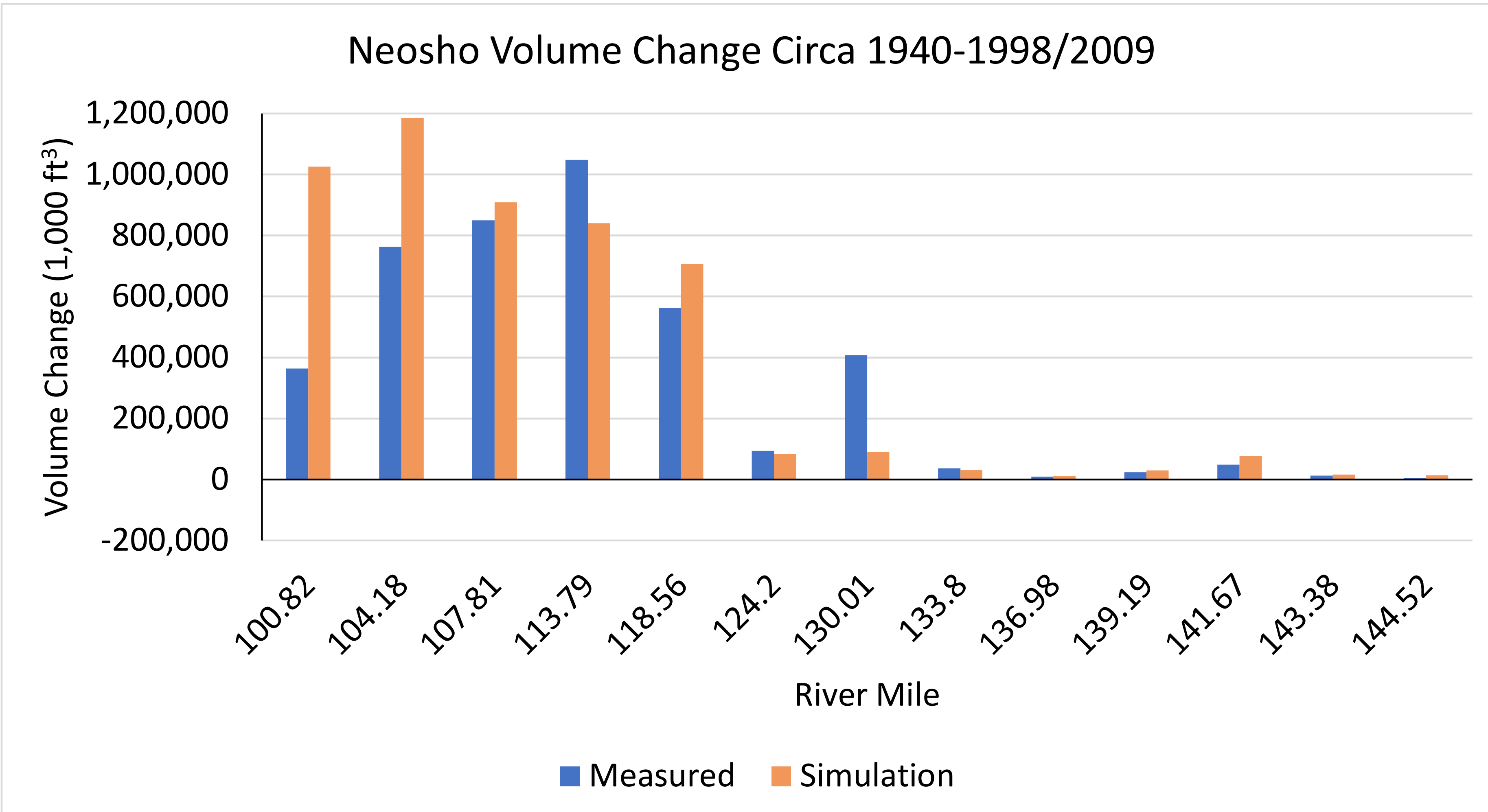
Grayish silt/clay throughout, very malleable; softer at surface, no visible layers

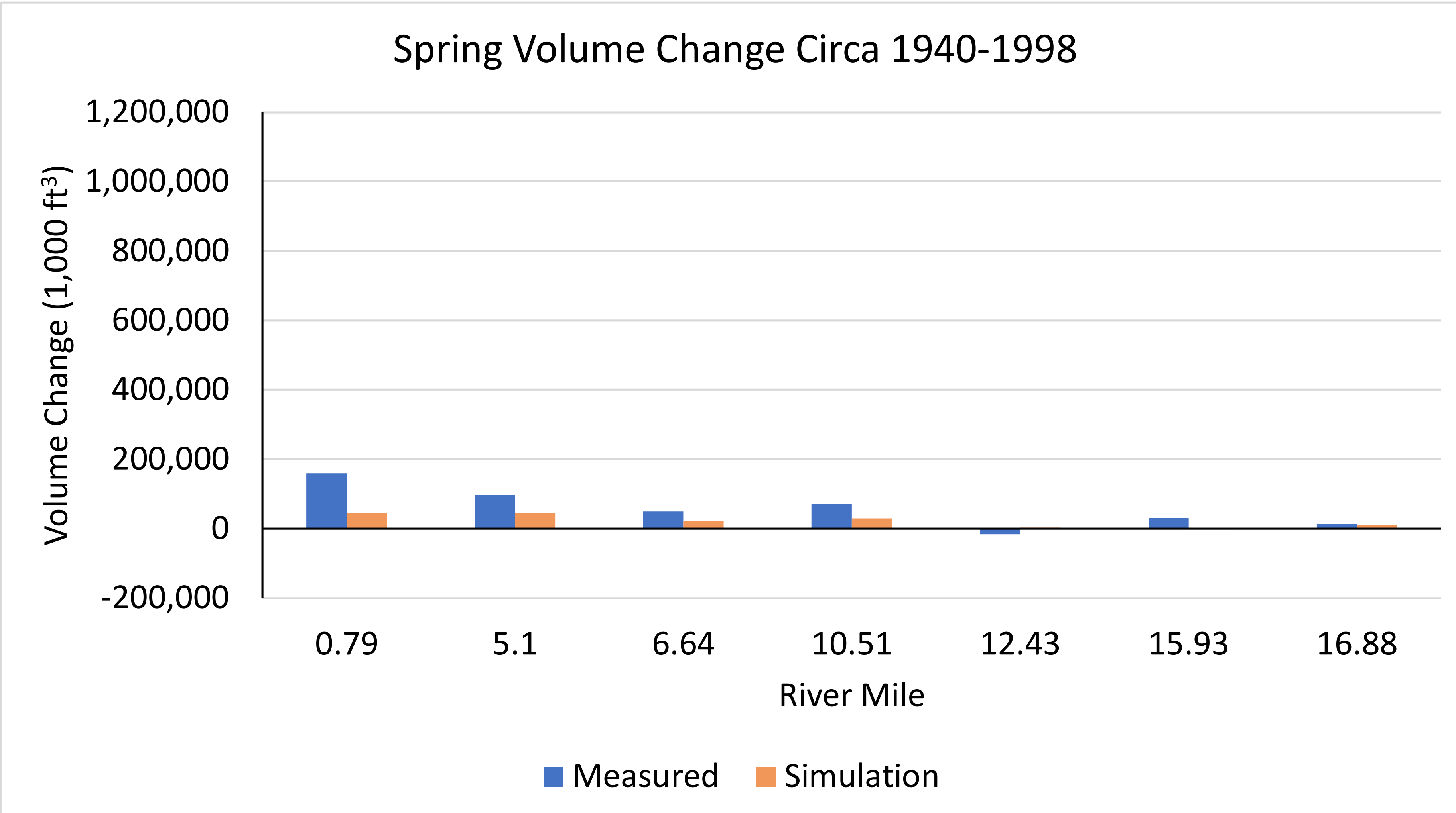
Notes:

Collected grain size samples @ 1 ft intervals

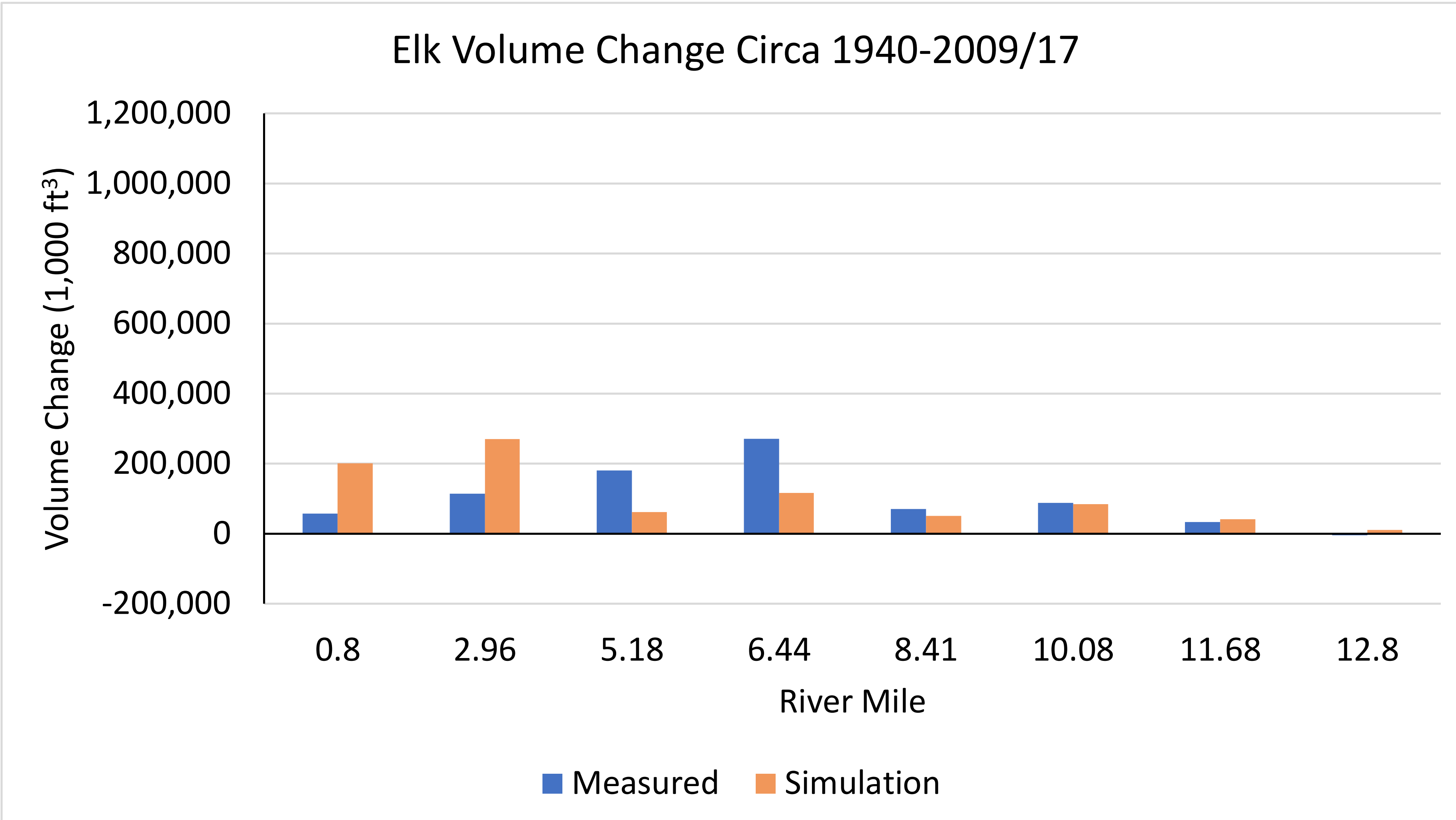
Appendix F
STM Results

Calibration Plots

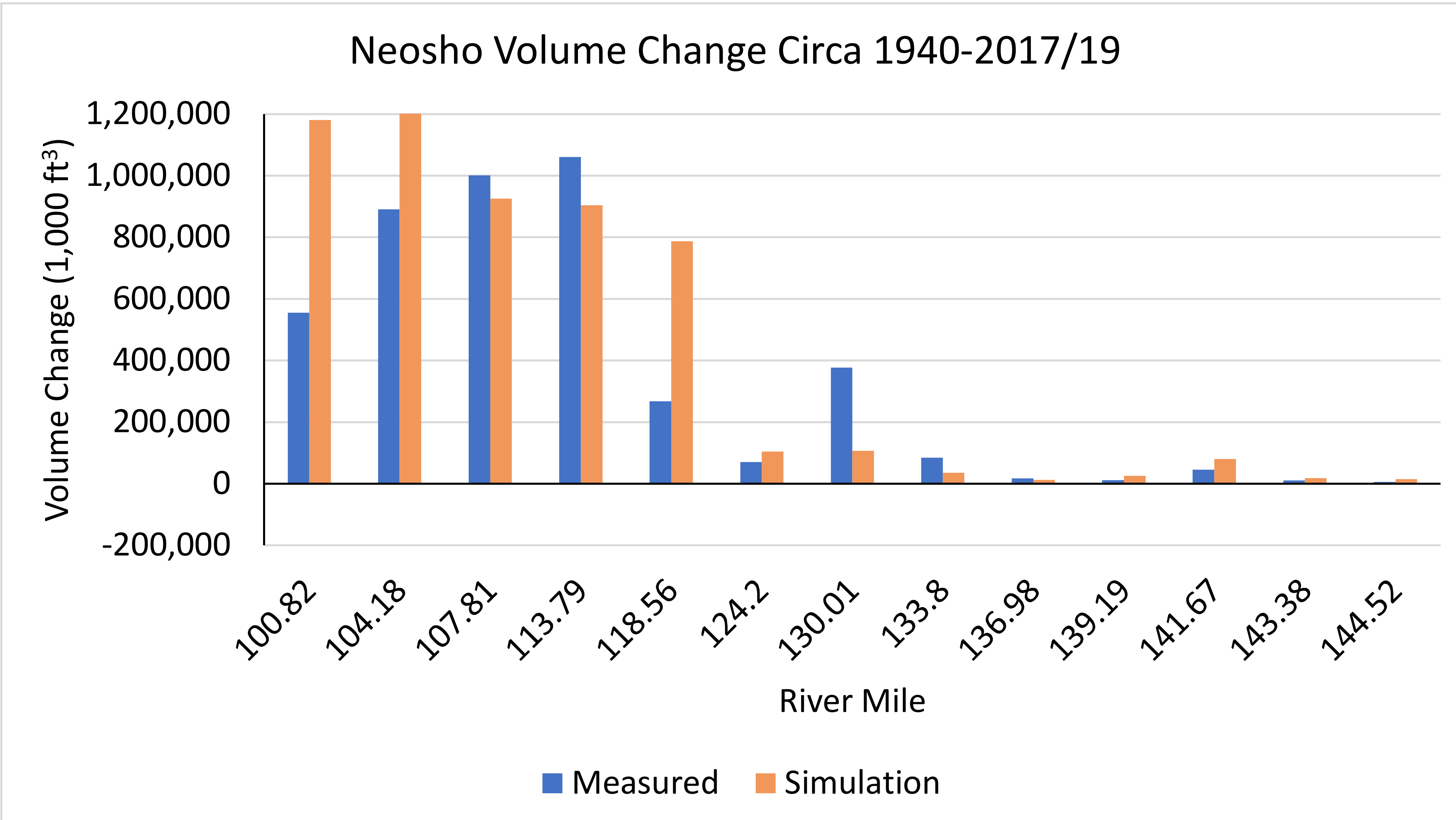

Neosho Volume Change Circa 1940-1998/2009
Volume Change (1,000 ft³)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
-200,000
100.82
104.18
107.81
113.79
118.56
124.2
130.01
133.8
136.98
139.19
141.67
143.38
144.52
River Mile
Measured
Simulation



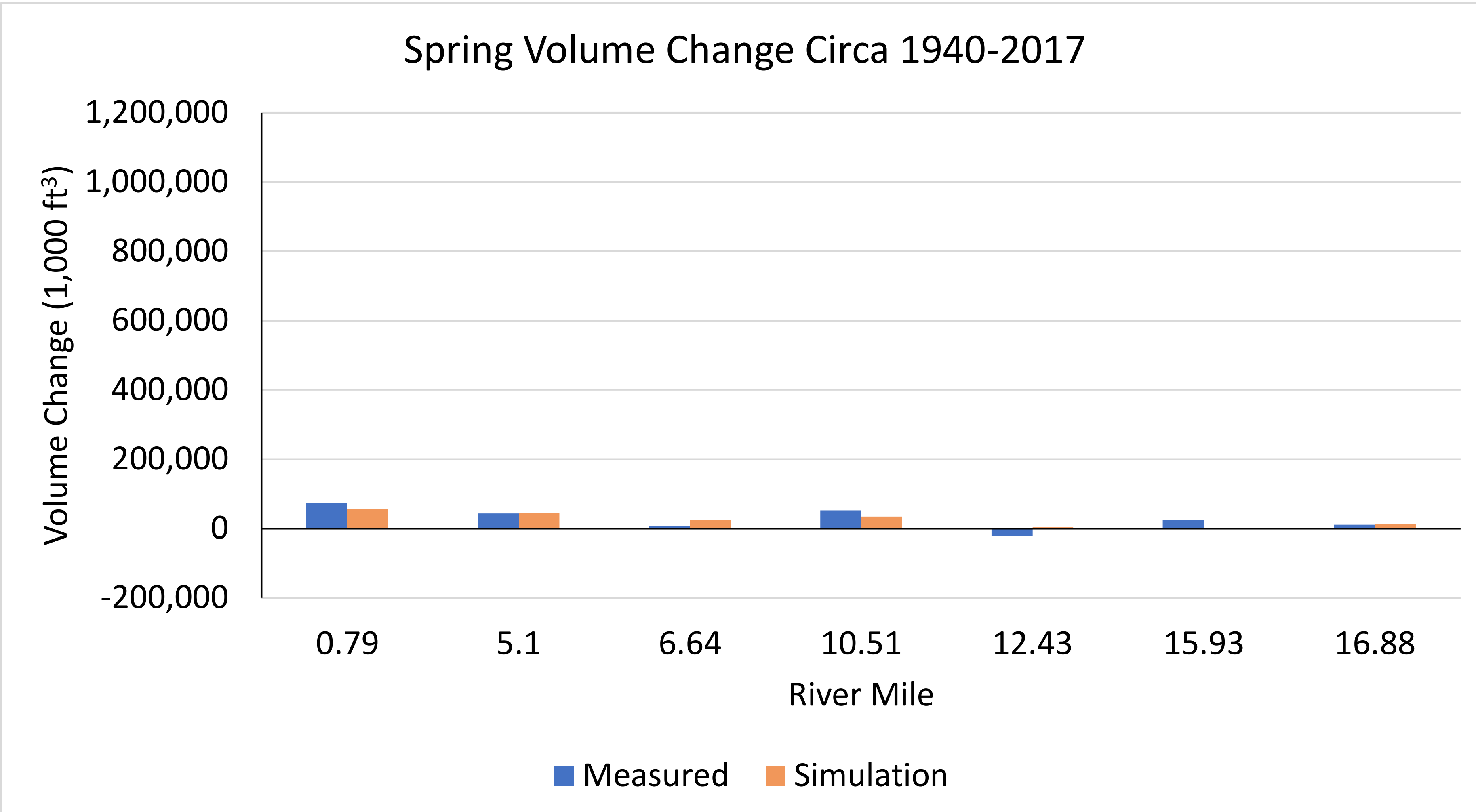
Spring Volume Change Circa 1940-1998
Volume Change (1,000 ft3)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
-200,000
0.79
5.1
6.64
10.51
12.43
15.93
16.88
River Mile
Measured
Simulation

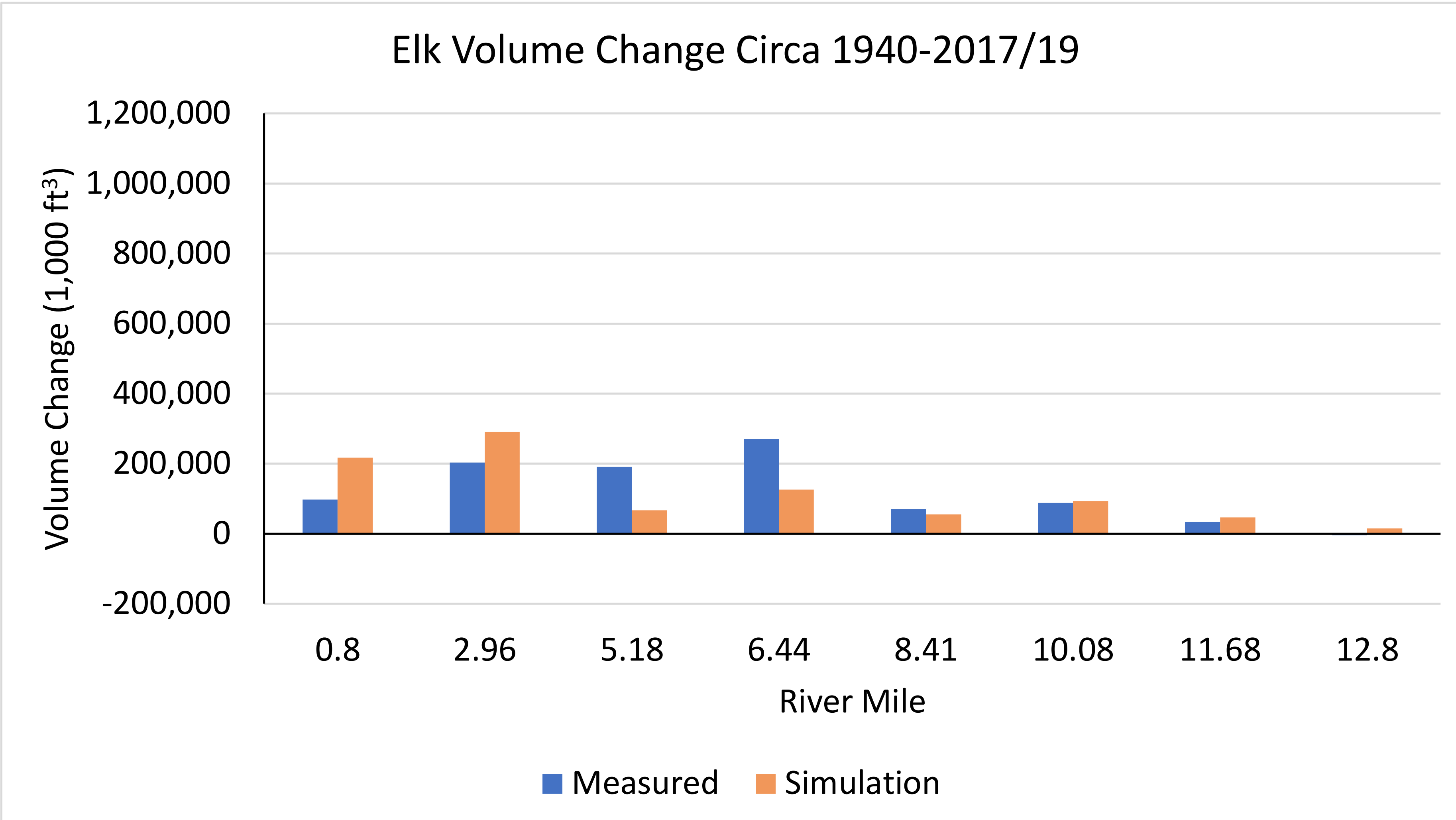

Elk Volume Change Circa 1940-2009/17
Volume Change (1,000 ft^3)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
-200,000
0.8
2.96
5.18
6.44
8.41
10.08
11.68
12.8
River Mile
Measured
Simulation

Validation Plots



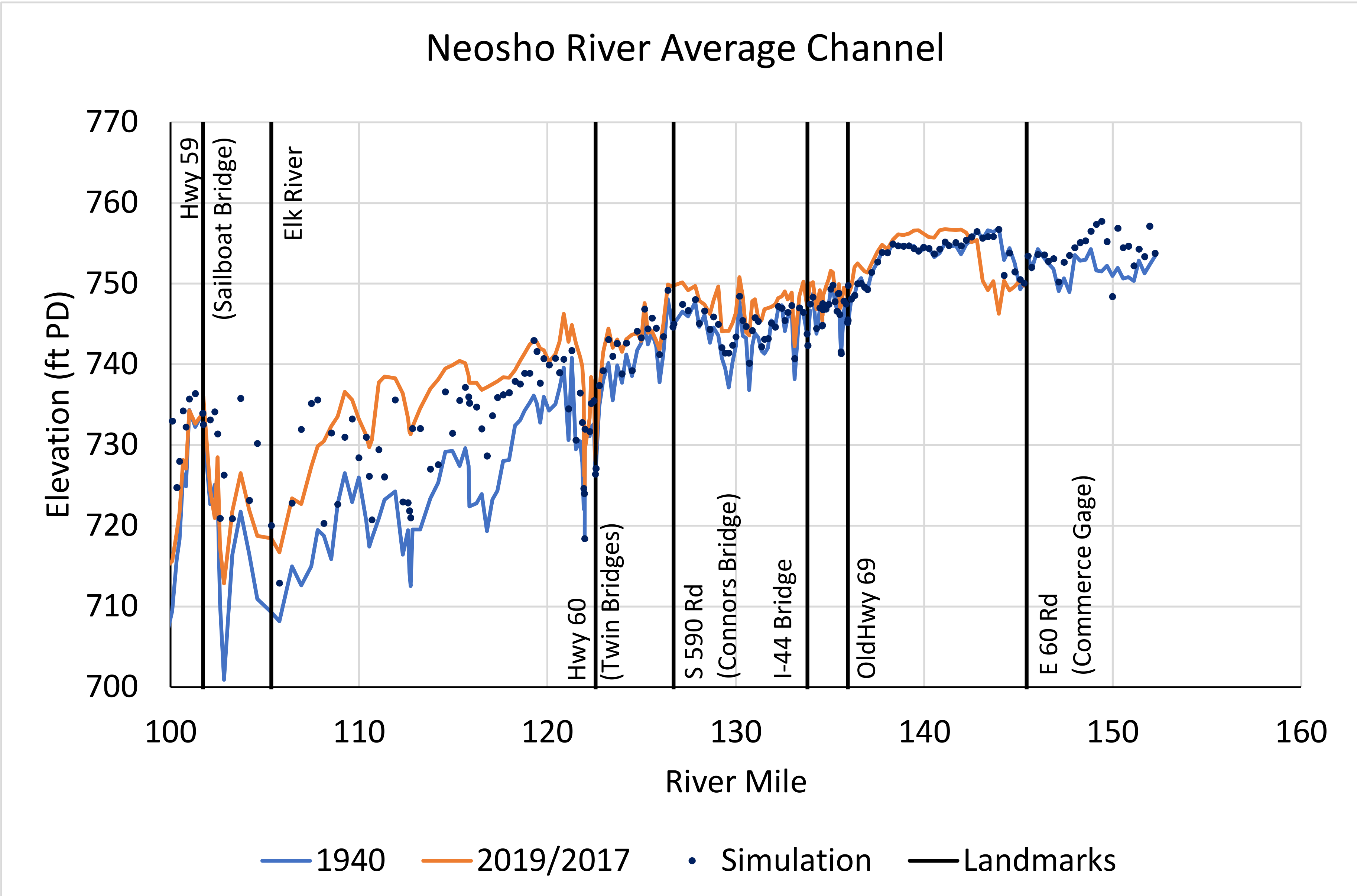
Neosho Volume Change Circa 1940-2017/19
Volume Change (1,000 ft³)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
-200,000
100.82
104.18
107.81
113.79
118.56
124.2
130.01
133.8
136.98
139.19
141.67
143.38
144.52
River Mile
Measured
Simulation


Spring Volume Change Circa 1940-2017
Volume Change (1,000 ft³)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
-200,000
0.79
5.1
6.64
10.51
12.43
15.93
16.88
River Mile
Measured
Simulation

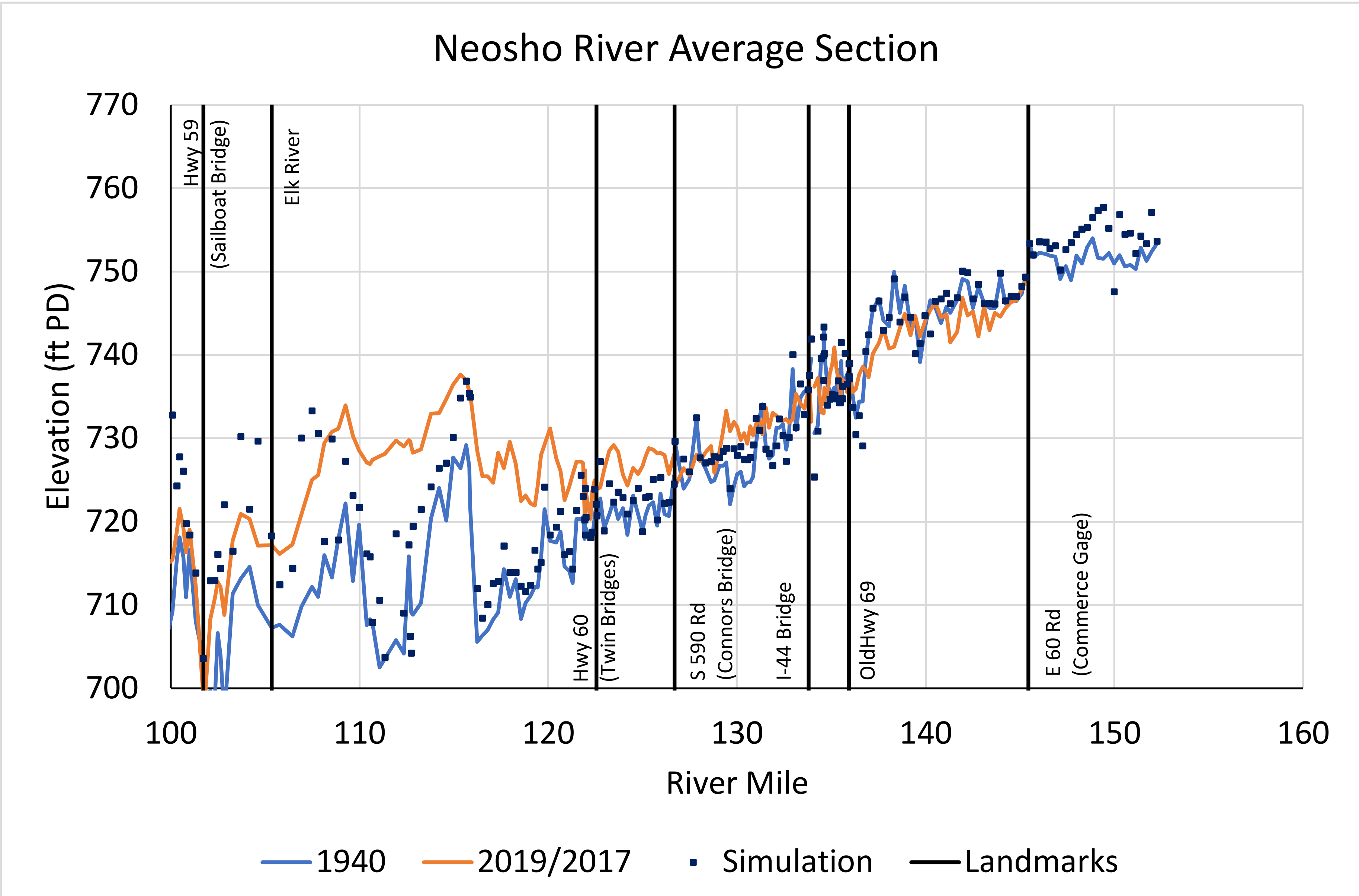


Elk Volume Change Circa 1940-2017/19
Volume Change (1,000 ft^3)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
-200,000
0.8
2.96
5.18
6.44
8.41
10.08
11.68
12.8
River Mile
Measured
Simulation

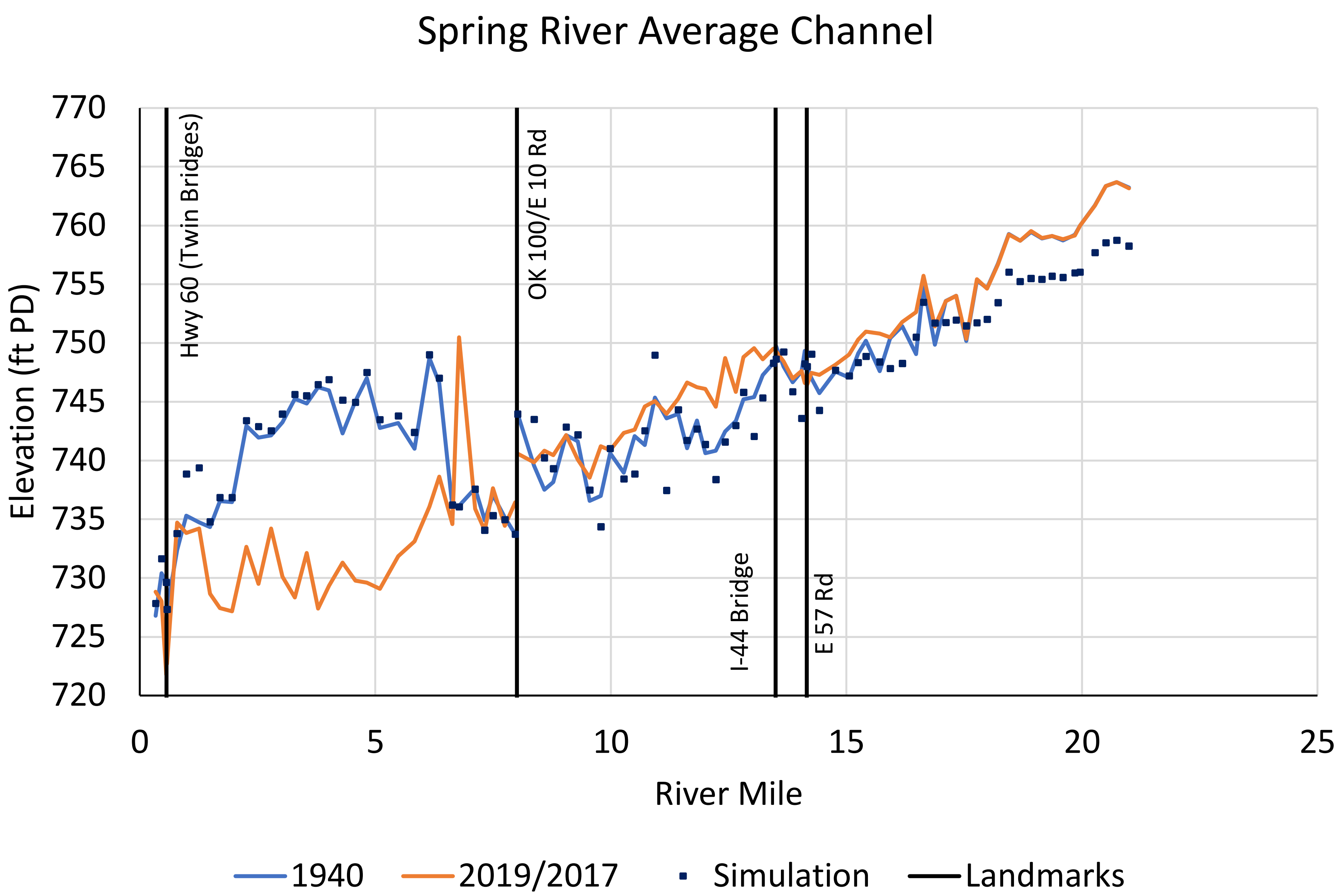
Simulated 2019 Average Channel and Average Section Plots



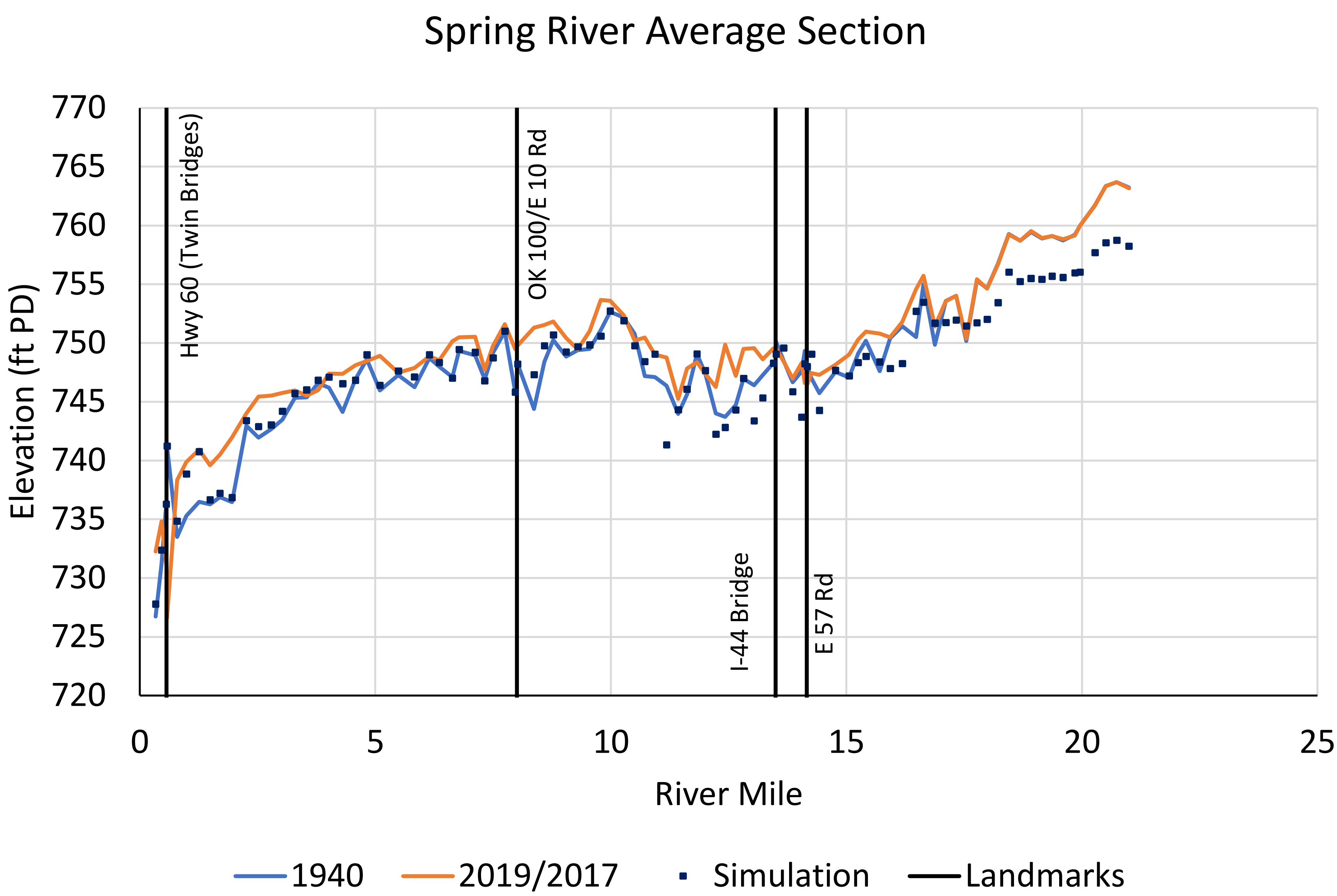
Neosho River Average Channel
Elevation (ft PD)
770
760
750
740
730
720
710
700
100
110
120
130
140
150
160
River Mile
Hwy 59
(Sailboat Bridge)
Elk River
Hwy 60
(Twin Bridges)
S 590 Rd
(Connors Bridge)
I-44 Bridge
OldHwy 69
E 60 Rd
(Commerce Gage)
1940
2019/2017
Simulation
Landmarks

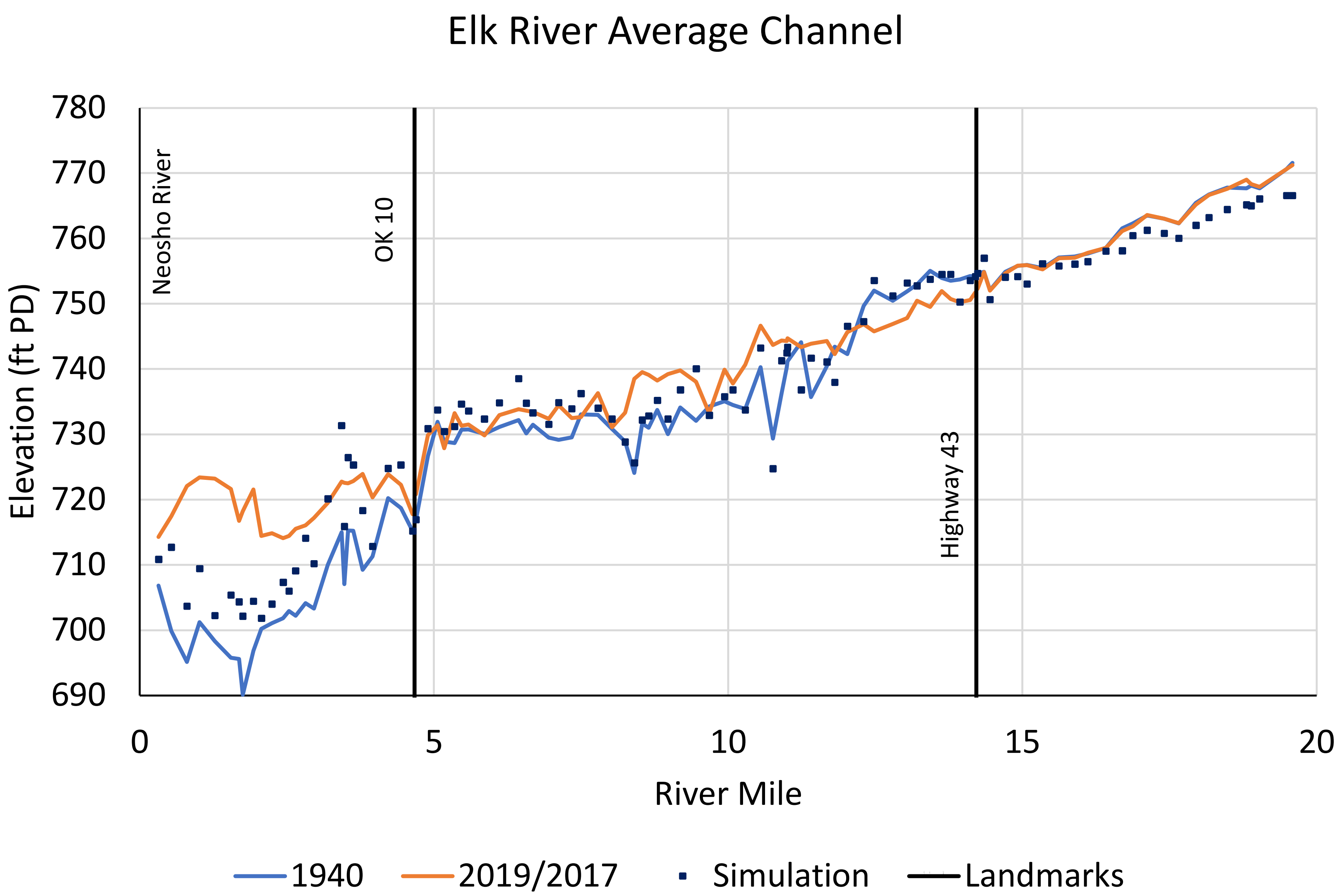


Neosho River Average Section
Elevation (ft PD)
770
760
750
740
730
720
710
700
Hwy 59
(Sailboat Bridge)
Elk River
Hwy 60
(Twin Bridges)
S 590 Rd
(Connors Bridge)
I-44 Bridge
OldHwy 69
E 60 Rd
(Commerce Gage)
100
110
120
130
140
150
160
River Mile
1940
2019/2017
Simulation
Landmarks

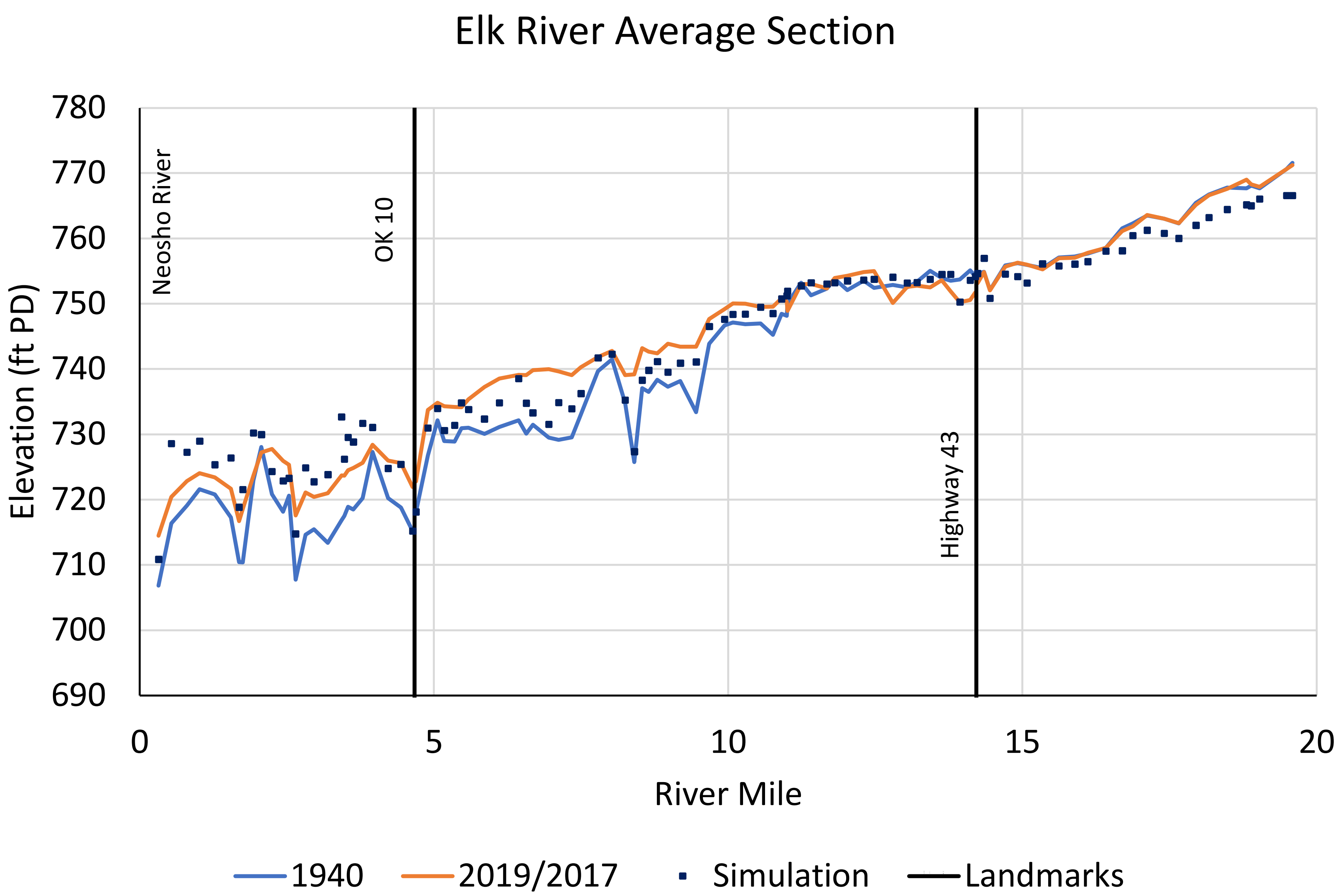


Spring River Average Channel
770
765
760
755
750
745
740
735
730
725
720
Elevation (ft PD)
0
5
10
15
20
25
River Mile
Hwy 60 (Twin Bridges)
OK 100/E 10 Rd
I-44 Bridge
E 57 Rd
1940
2019/2017
Simulation
Landmarks

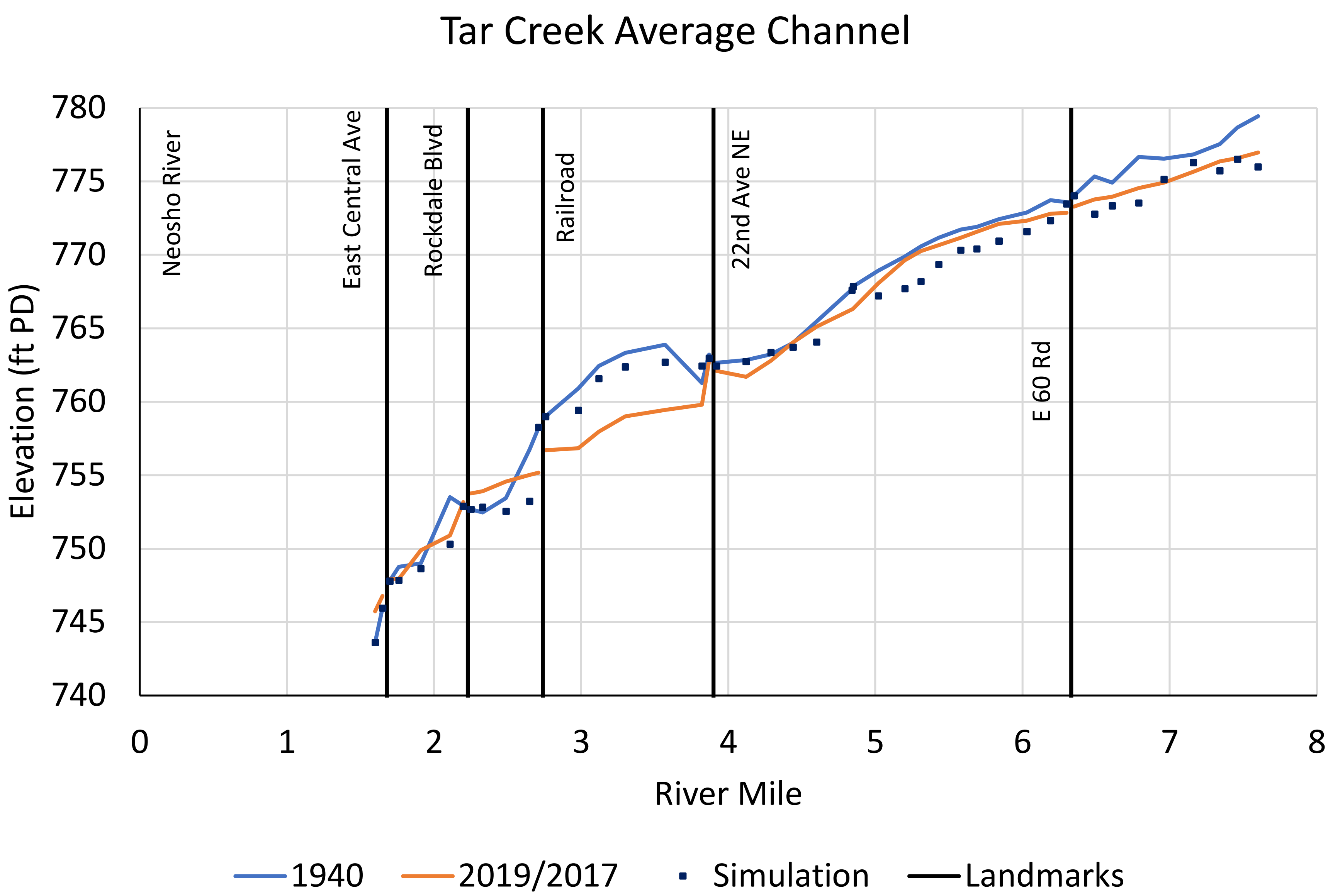

Spring River Average Section
Elevation (ft PD)
770
765
760
755
750
745
740
735
730
725
720
0
5
10
15
20
25
River Mile
Hwy 60 (Twin Bridges)
OK 100/E 10 Rd
I-44 Bridge
E 57 Rd
1940
2019/2017
Simulation
Landmarks



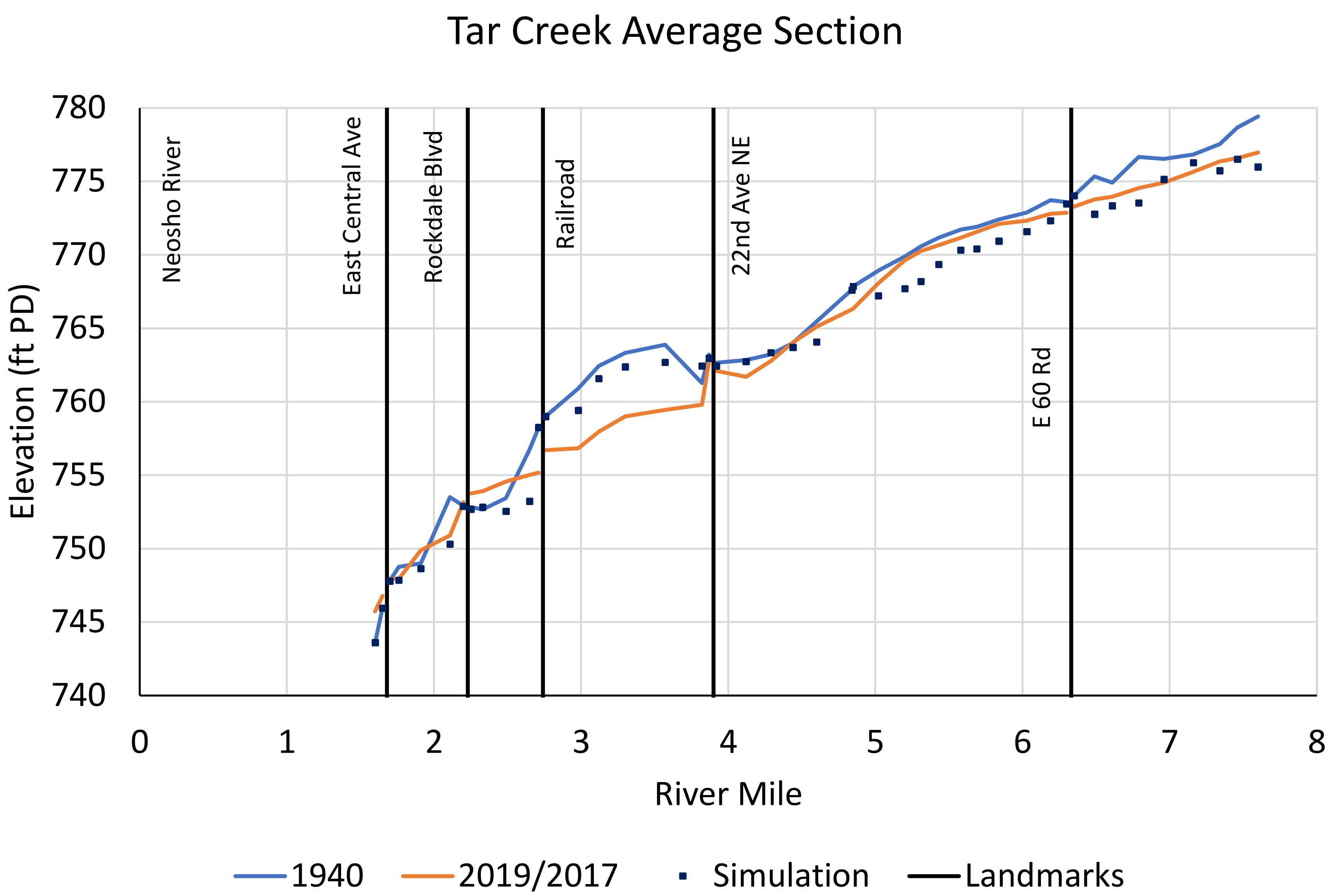
Elk River Average Channel
780
770
760
750
740
730
720
710
700
690
Elevation (ft PD)
0
5
10
15
20
River Mile
Neosho River
OK 10
Highway 43
1940
2019/2017
Simulation
Landmarks



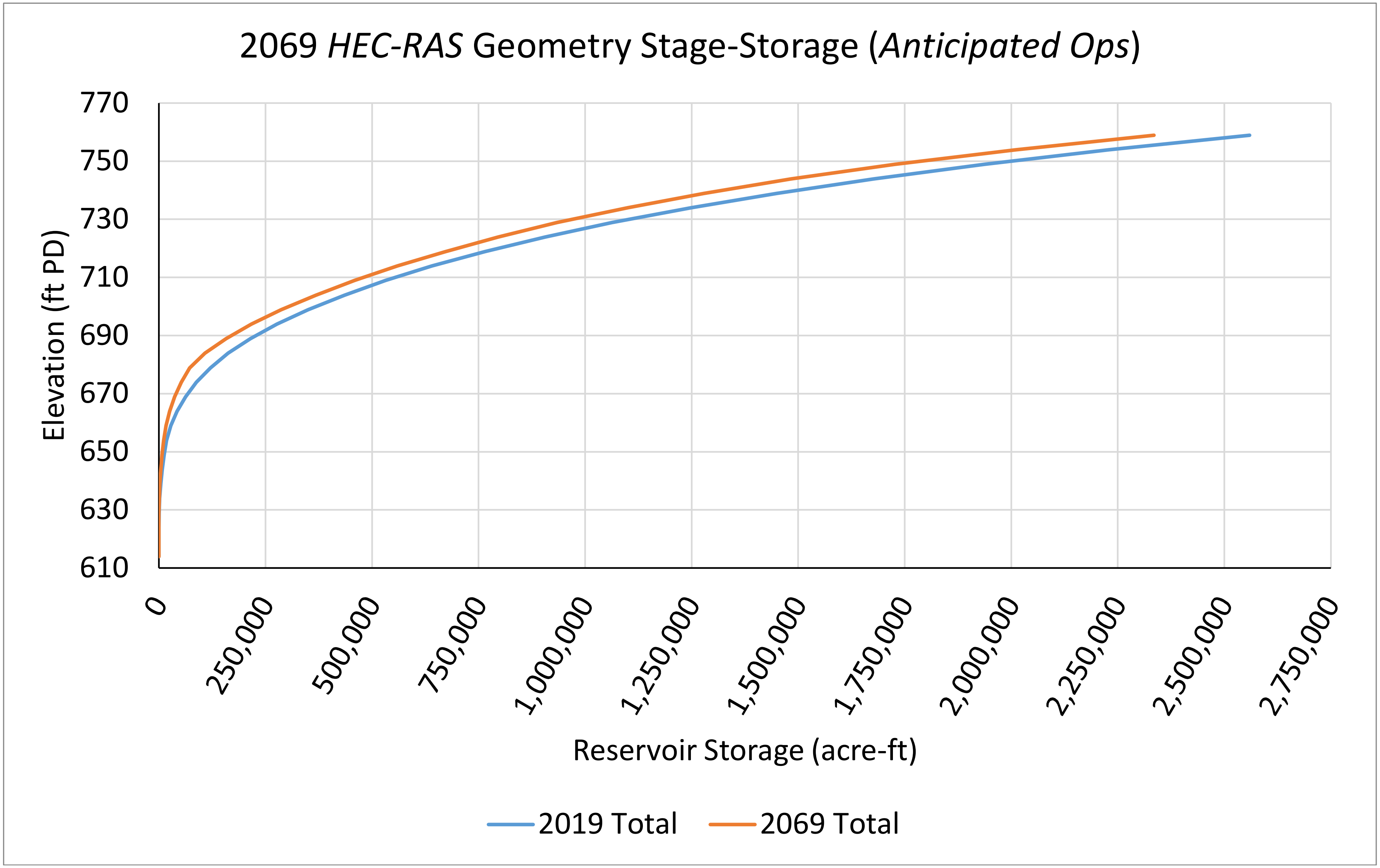
Elk River Average Section
Elevation (ft PD)
780
770
760
750
740
730
720
710
700
690
0
5
10
15
20
River Mile
Neosho River
OK 10
Highway 43
1940
2019/2017
Simulation
Landmarks

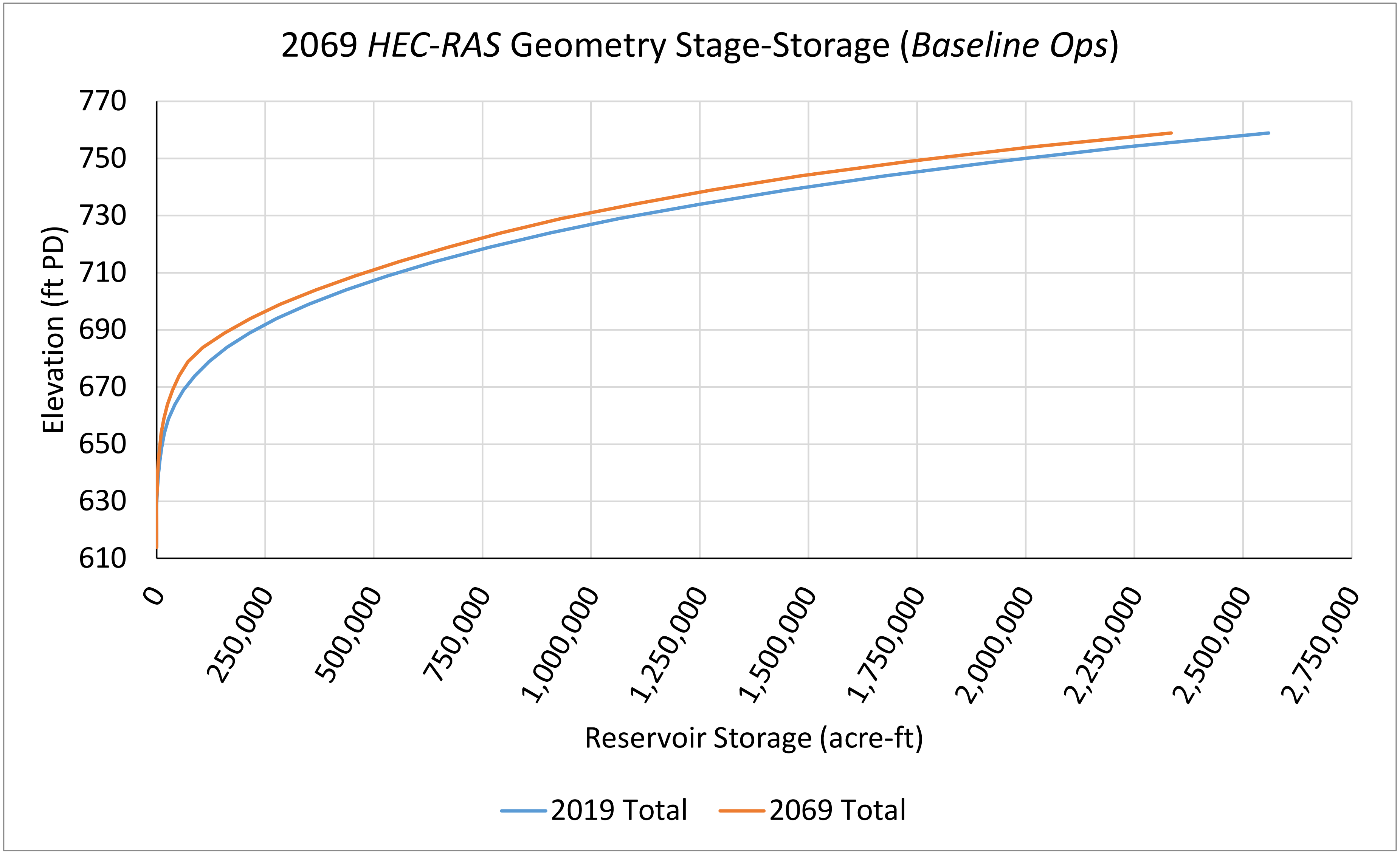


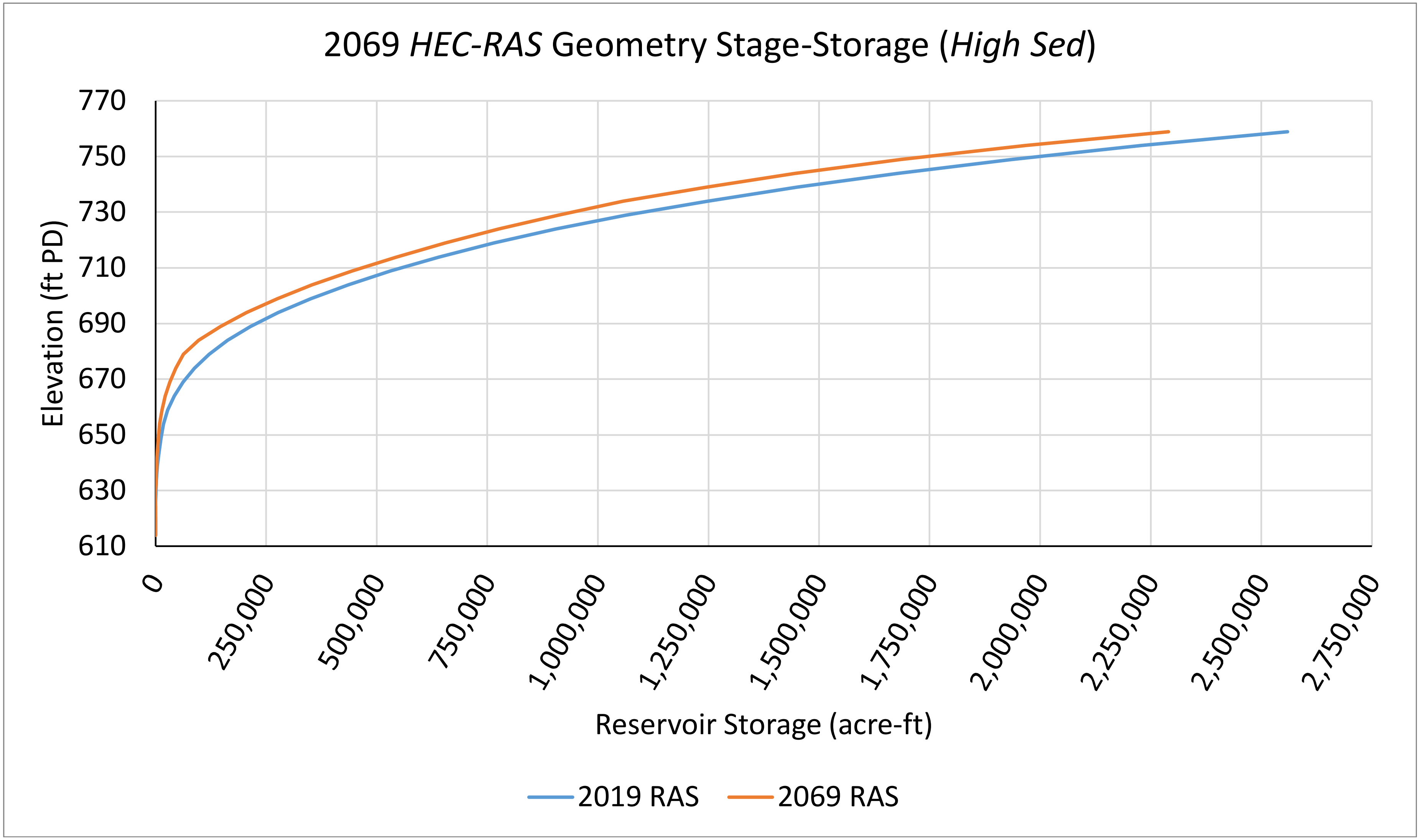
Tar Creek Average Channel
780
775
770
765
760
755
750
745
740
Elevation (ft PD)
0
1
2
3
4
5
6
7
8
River Mile
Neosho River
East Central Ave
Rockdale Blvd
Railroad
22nd Ave NE
E 60 Rd
1940
2019/2017
Simulation
Landmarks

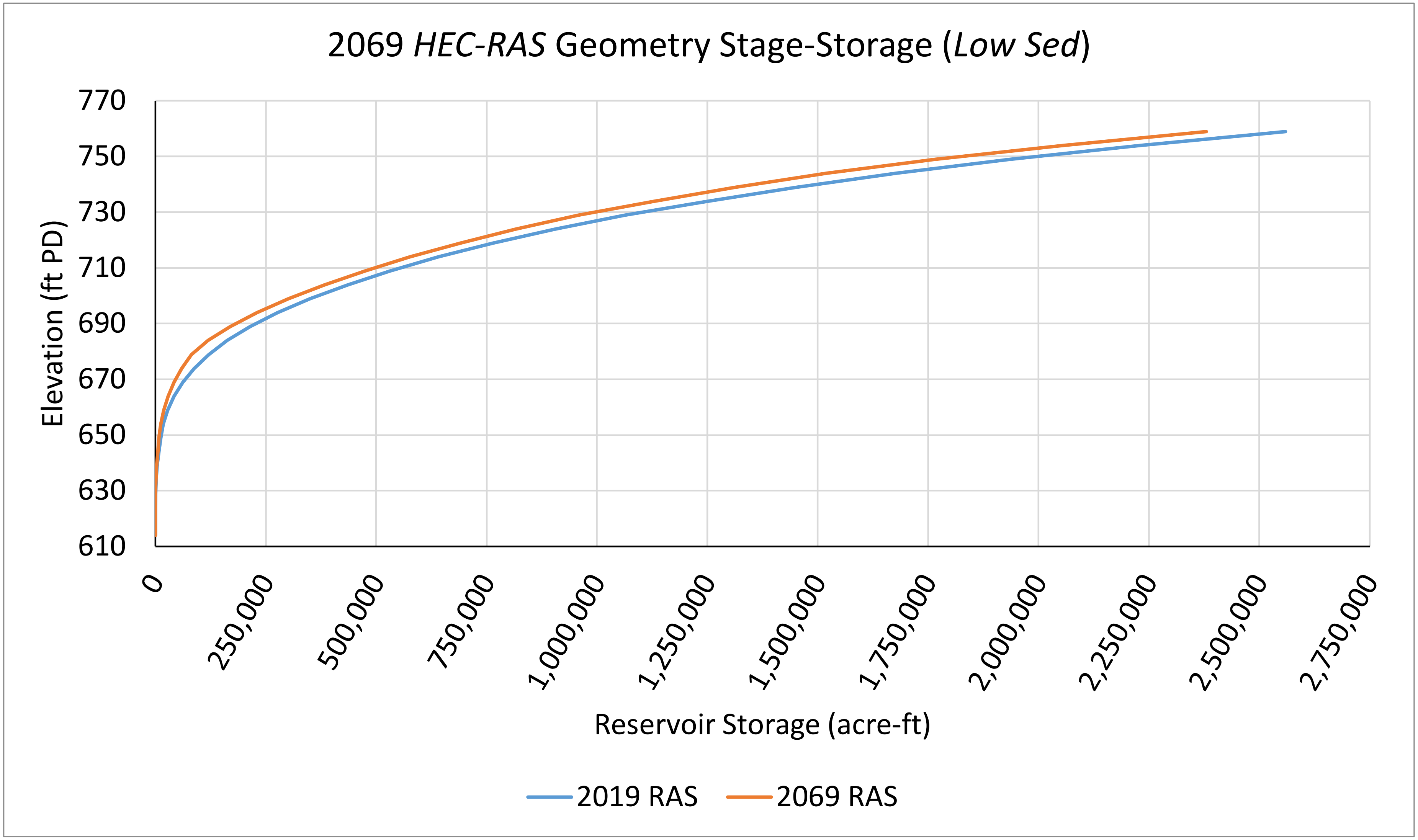

Tar Creek Average Section
Elevation (ft PD)
River Mile
780
775
770
765
760
755
750
745
740
0
1
2
3
4
5
6
7
8
Neosho River
East Central Ave
Rockdale Blvd
Railroad
22nd Ave NE
E 60 Rd
1940
2019/2017
Simulation
Landmarks

Simulated HEC-RAS Stage-Storage Curves


2069 *HEC-RAS* Geometry Stage-Storage (*Anticipated Ops*)
Elevation (ft PD)
770
750
730
710
690
670
650
630
610
0
250,000
500,000
750,000
1,000,000
1,250,000
1,500,000
1,750,000
2,000,000
2,250,000
2,500,000
2,750,000
Reservoir Storage (acre-ft)
2019 Total
2069 Total

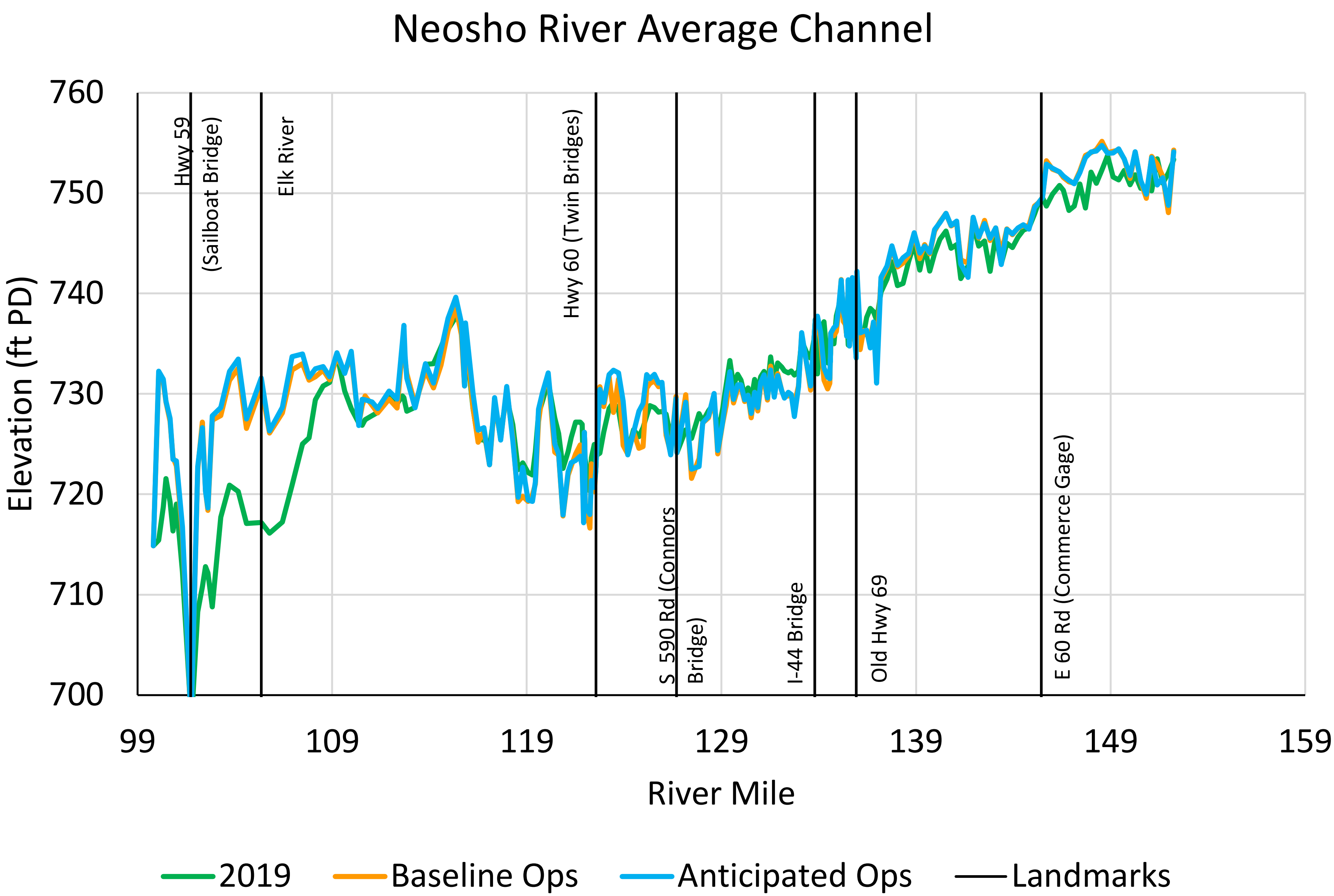

2069 *HEC-RAS* Geometry Stage-Storage (*Baseline Ops*)
Elevation (ft PD)
770
750
730
710
690
670
650
630
610
0
250,000
500,000
750,000
1,000,000
1,250,000
1,500,000
1,750,000
2,000,000
2,250,000
2,500,000
2,750,000
Reservoir Storage (acre-ft)
2019 Total
2069 Total

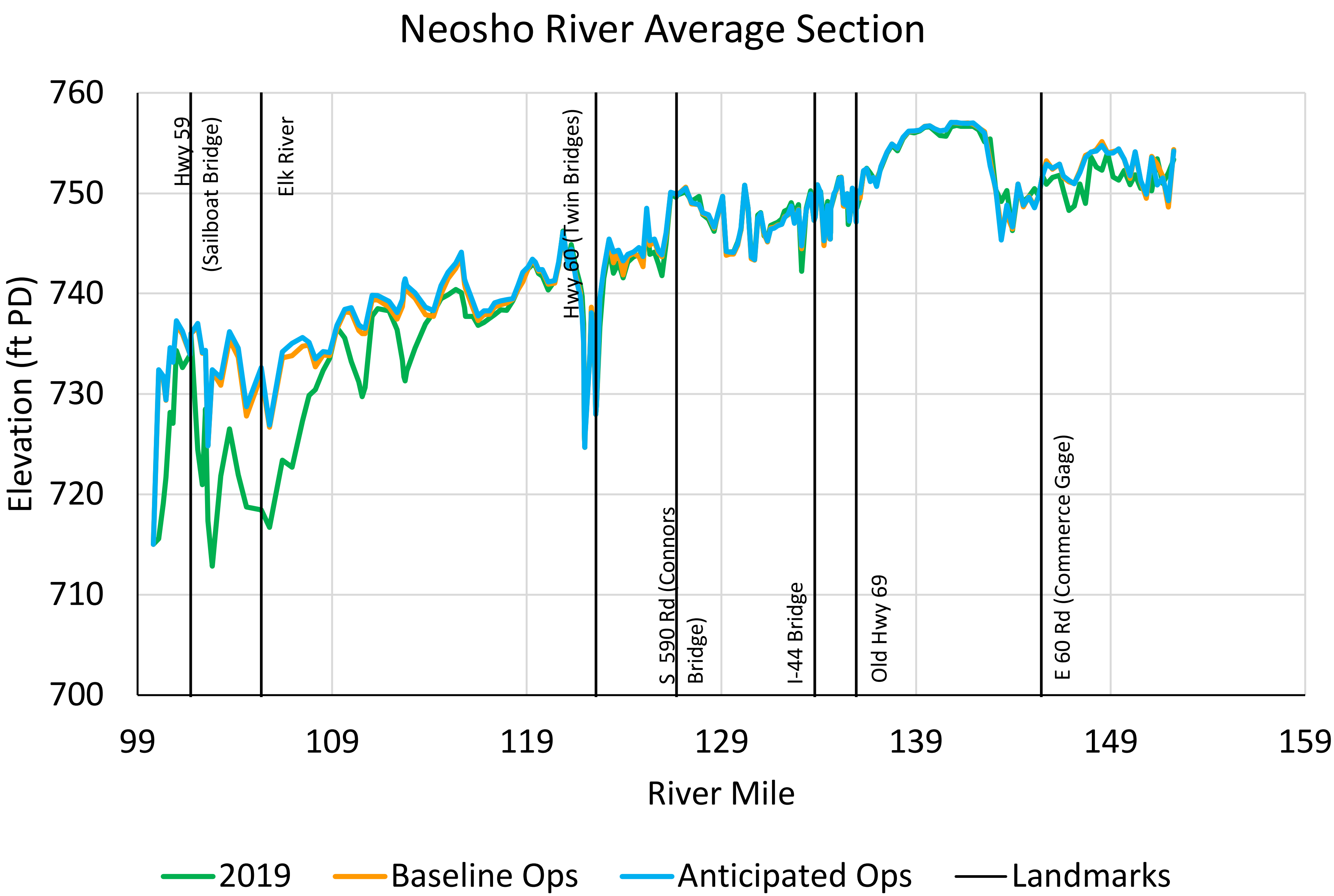

2069 *HEC-RAS* Geometry Stage-Storage (*High Sed*)
Elevation (ft PD)
770
750
730
710
690
670
650
630
610
0
250,000
500,000
750,000
1,000,000
1,250,000
1,500,000
1,750,000
2,000,000
2,250,000
2,500,000
2,750,000
Reservoir Storage (acre-ft)
2019 RAS
2069 RAS



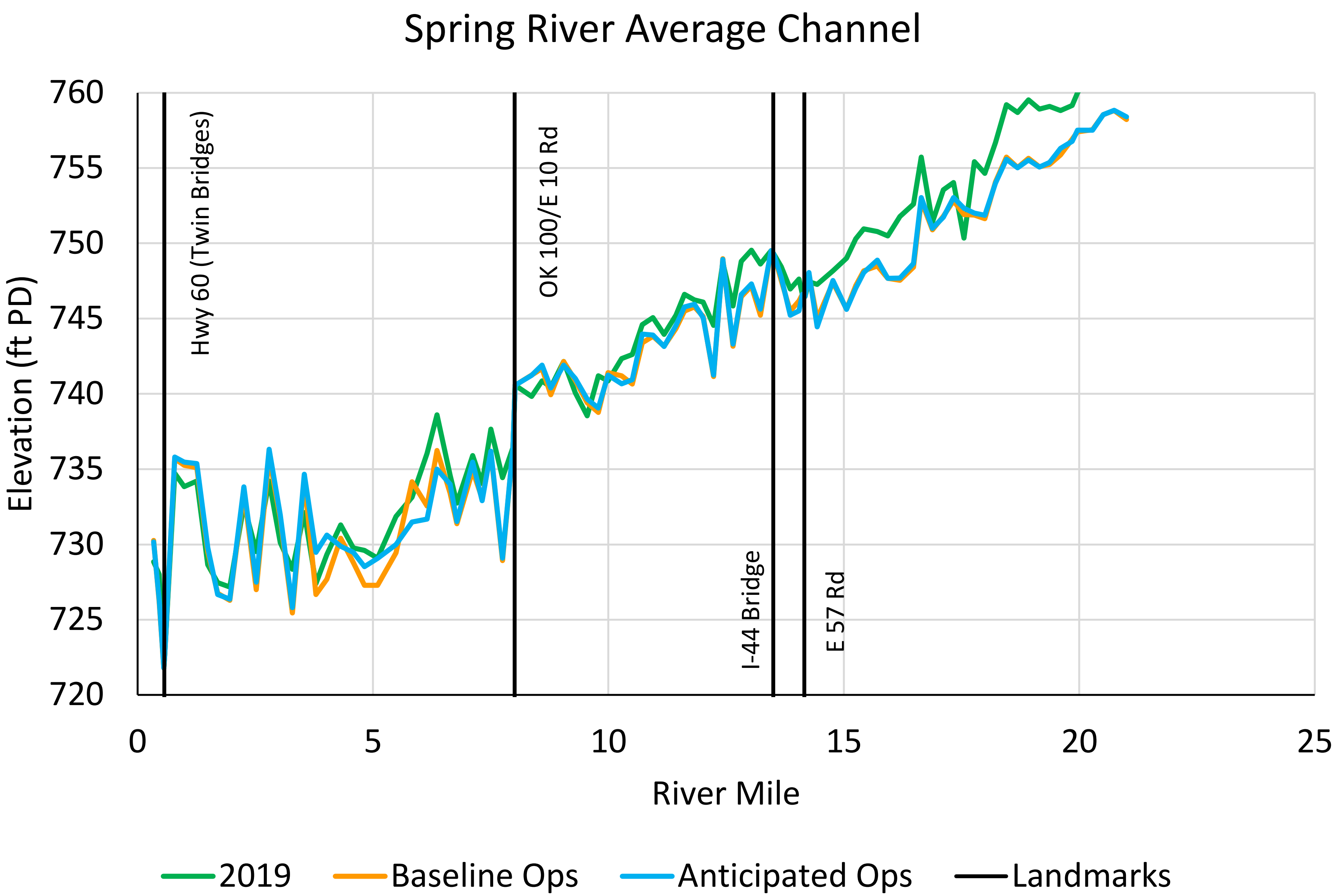
2069 *HEC-RAS* Geometry Stage-Storage (*Low Sed*)
Elevation (ft PD)
770
750
730
710
690
670
650
630
610
0
250,000
500,000
750,000
1,000,000
1,250,000
1,500,000
1,750,000
2,000,000
2,250,000
2,500,000
2,750,000
Reservoir Storage (acre-ft)
2019 RAS
2069 RAS

Simulated Future Average Channel and Average Section Plots – Operations Comparison

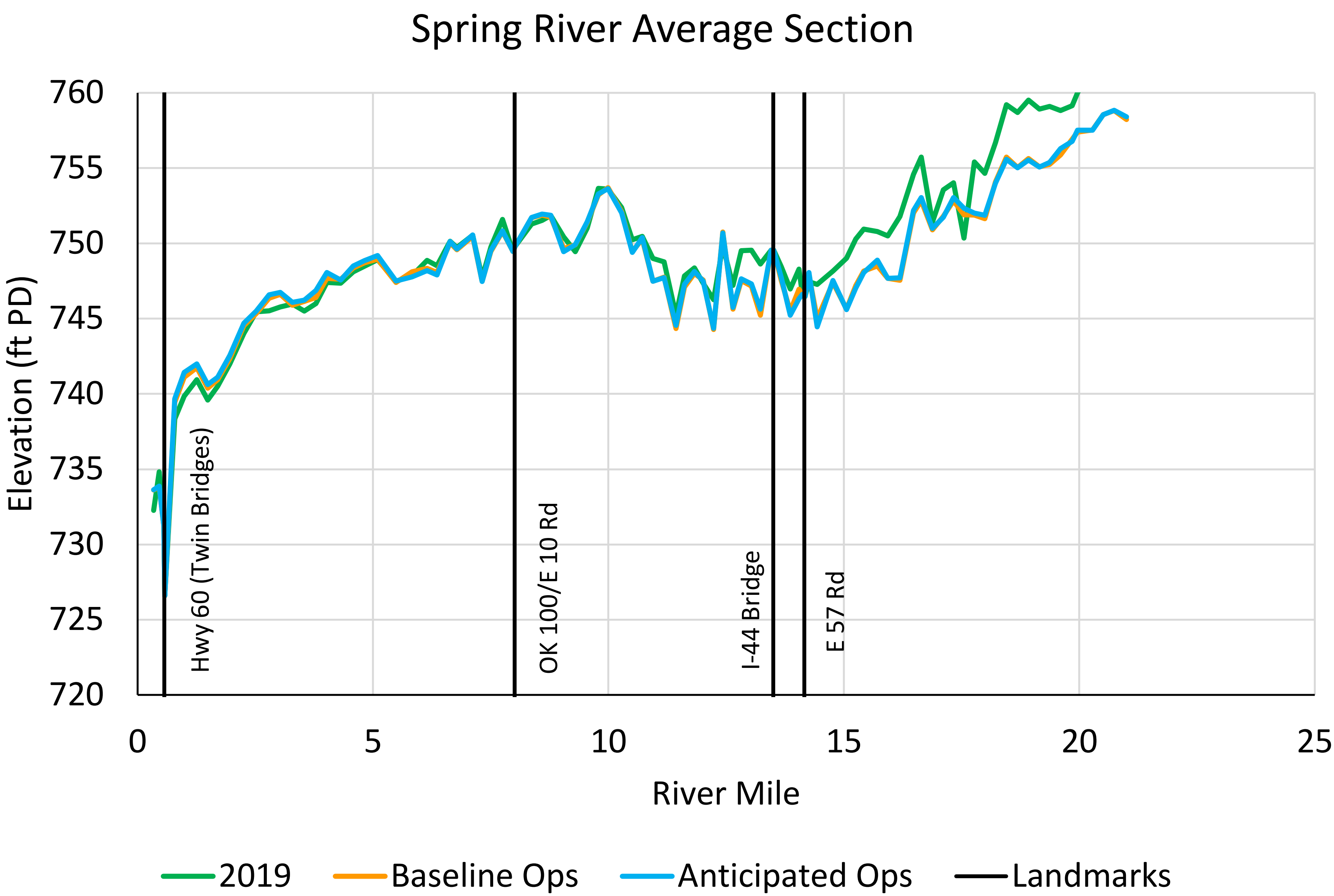

Neosho River Average Channel
Elevation (ft PD)
760
750
740
730
720
710
700
99
109
119
129
139
149
159
River Mile
Hwy 59
(Sailboat Bridge)
Elk River
Hwy 60 (Twin Bridges)
S 590 Rd (Connors
Bridge)
I-44 Bridge
Old Hwy 69
E 60 Rd (Commerce Gage)
2019
Baseline Ops
Anticipated Ops
Landmarks

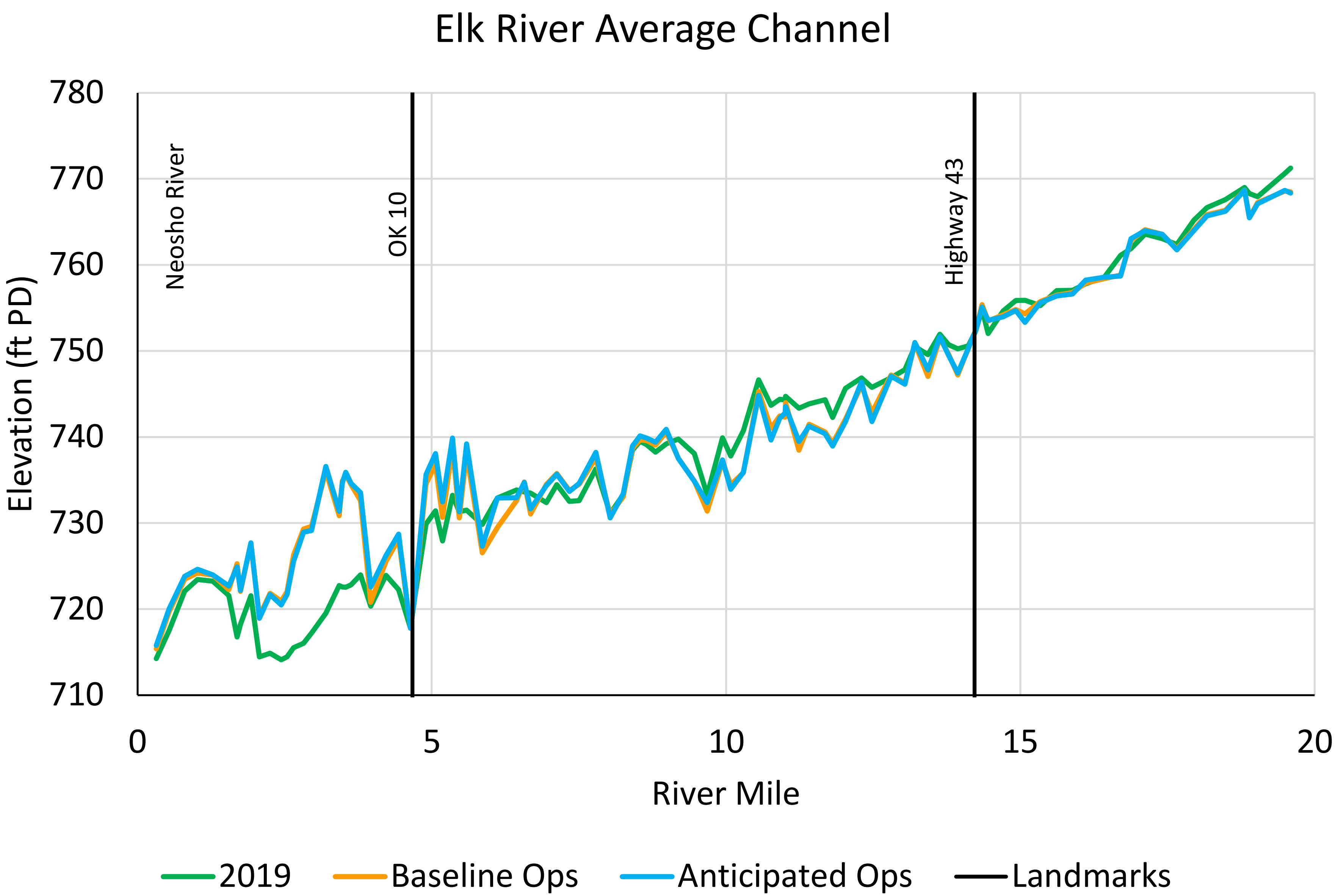


Neosho River Average Section
Elevation (ft PD)
River Mile
760
750
740
730
720
710
700
99
109
119
129
139
149
159
Hwy 59
(Sailboat Bridge)
Elk River
Hwy 60 (Twin Bridges)
S 590 Rd (Connors
Bridge)
I-44 Bridge
Old Hwy 69
E 60 Rd (Commerce Gage)
2019
Baseline Ops
Anticipated Ops
Landmarks

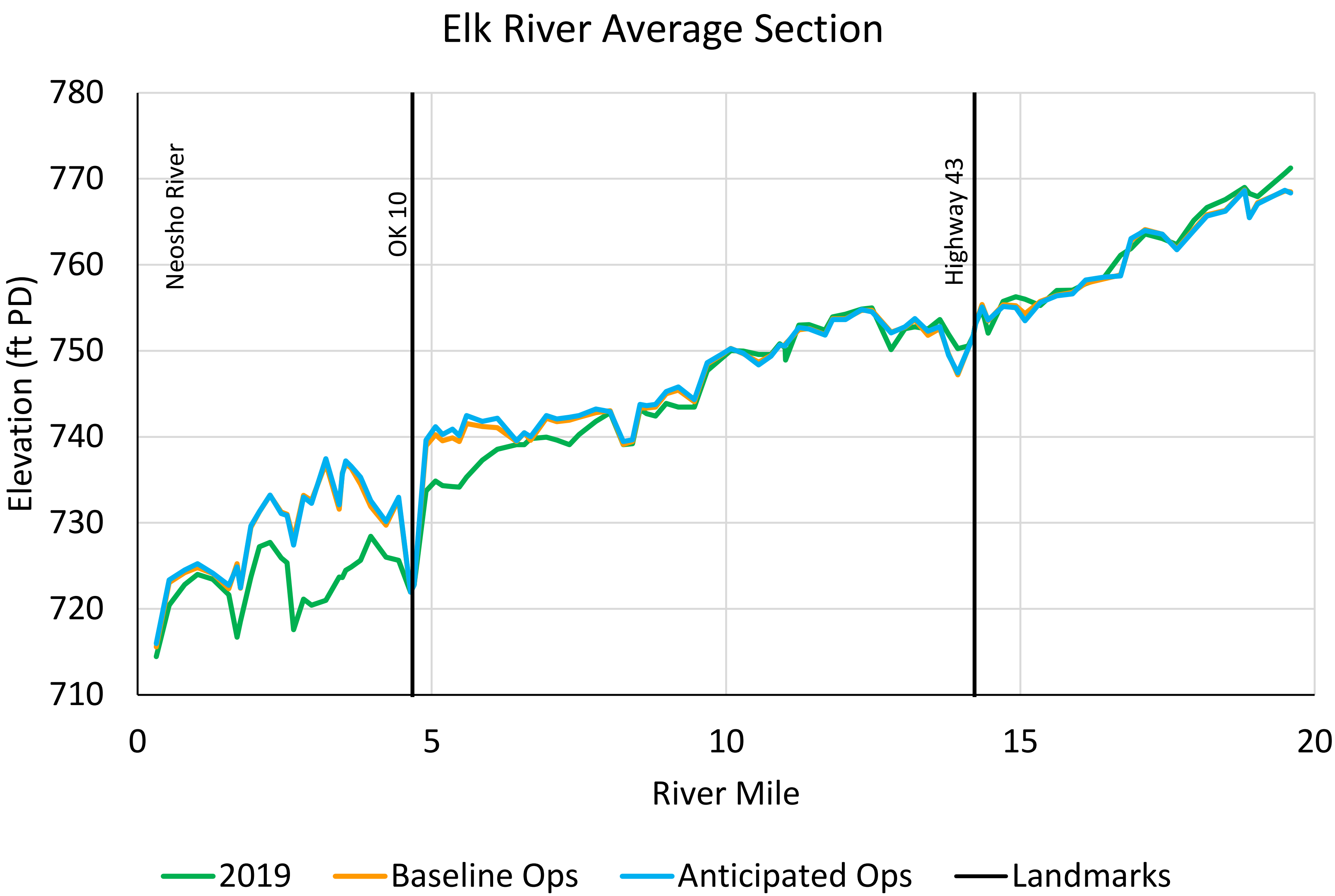


Spring River Average Channel
Elevation (ft PD)
River Mile
760
755
750
745
740
735
730
725
720
0
5
10
15
20
25
Hwy 60 (Twin Bridges)
OK 100/E 10 Rd
I-44 Bridge
E 57 Rd
2019
Baseline Ops
Anticipated Ops
Landmarks

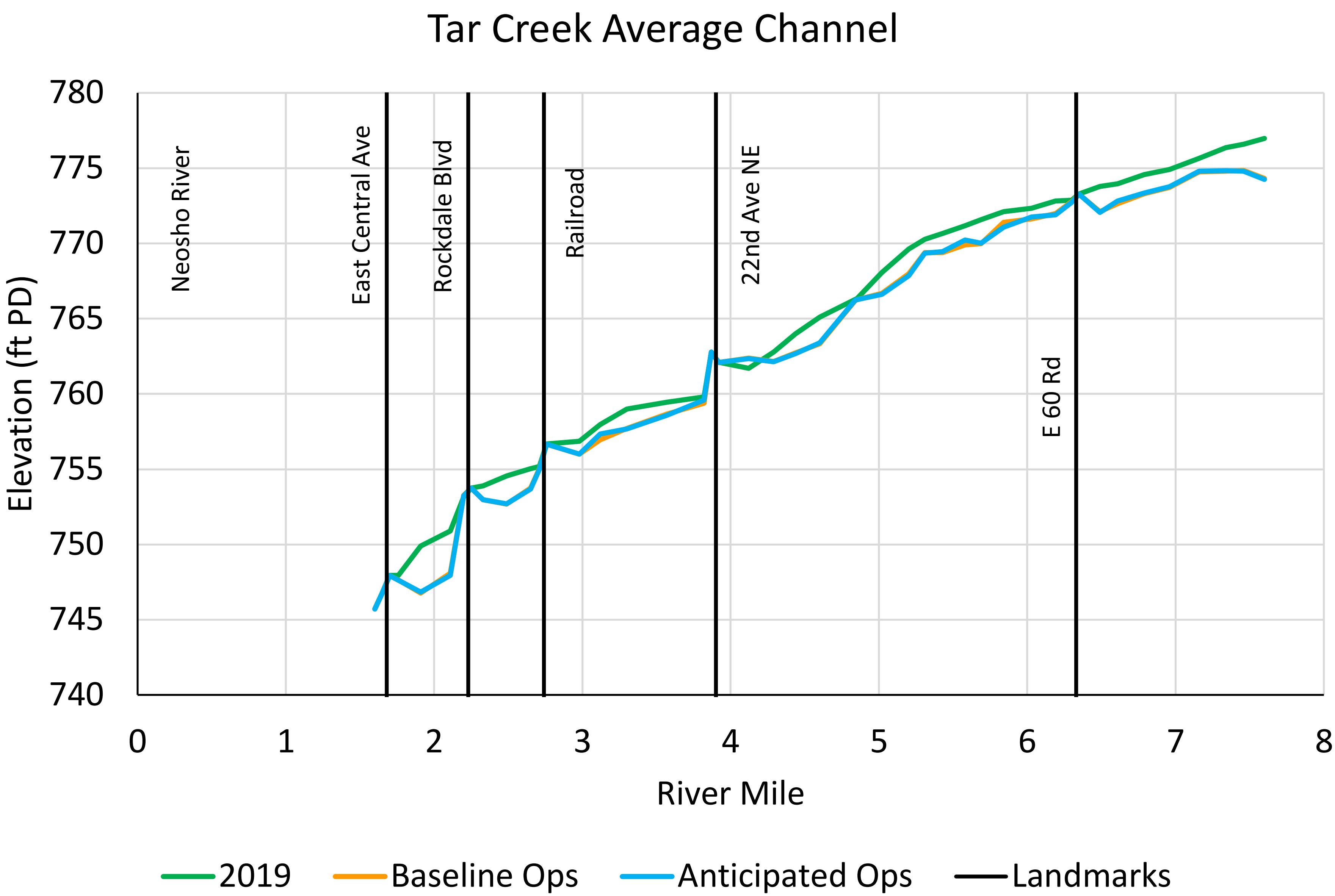

Spring River Average Section
Elevation (ft PD)
760
755
750
745
740
735
730
725
720
0
5
10
15
20
25
River Mile
Hwy 60 (Twin Bridges)
OK 100/E 10 Rd
I-44 Bridge
E 57 Rd
2019
Baseline Ops
Anticipated Ops
Landmarks



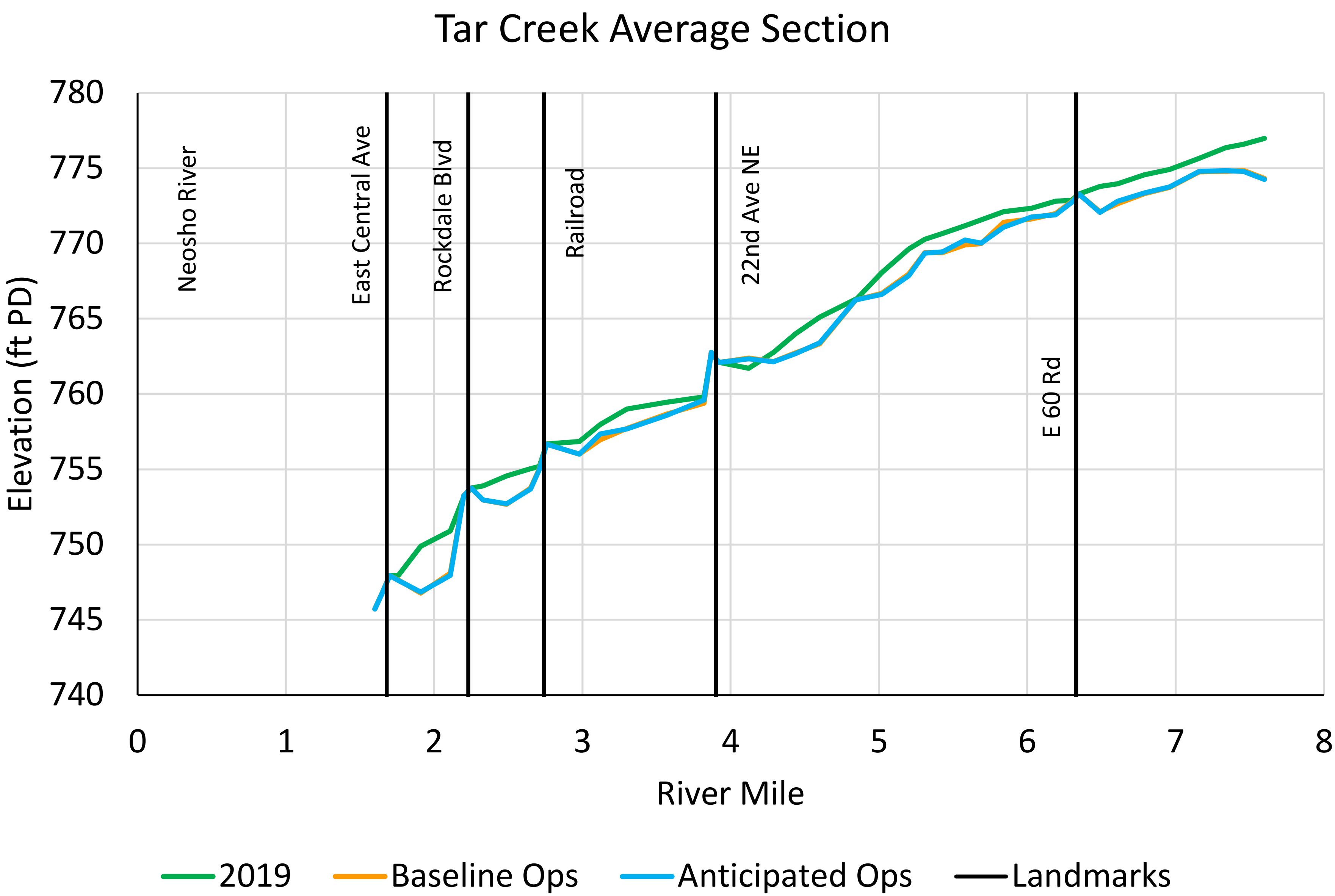
Elk River Average Channel
780
770
760
750
740
730
720
710
Elevation (ft PD)
0
5
10
15
20
River Mile
Neosho River
OK 10
Highway 43
2019
Baseline Ops
Anticipated Ops
Landmarks



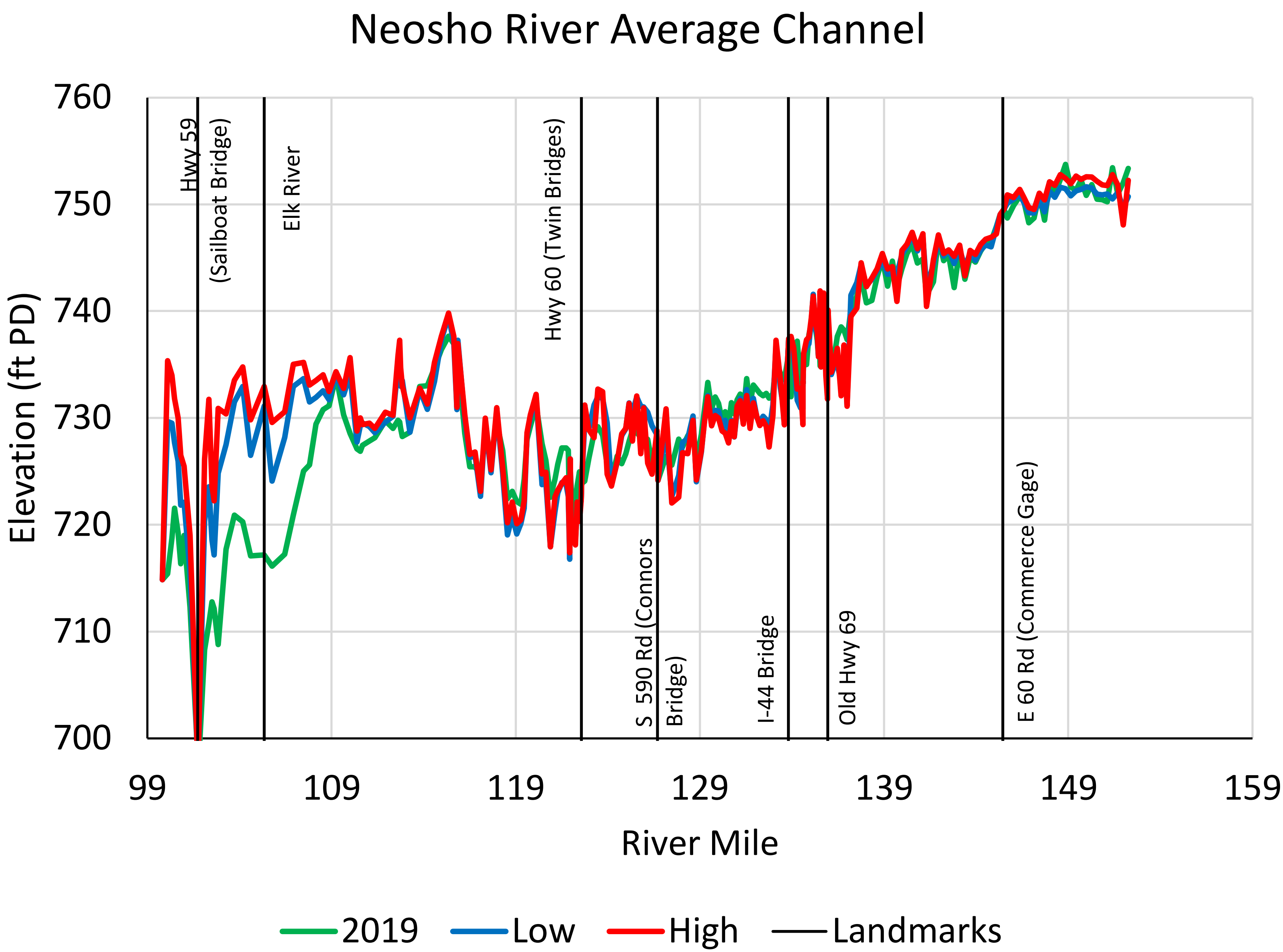
Elk River Average Section
780
770
760
750
740
730
720
710
Elevation (ft PD)
0
5
10
15
20
River Mile
Neosho River
OK 10
Highway 43
2019
Baseline Ops
Anticipated Ops
Landmarks

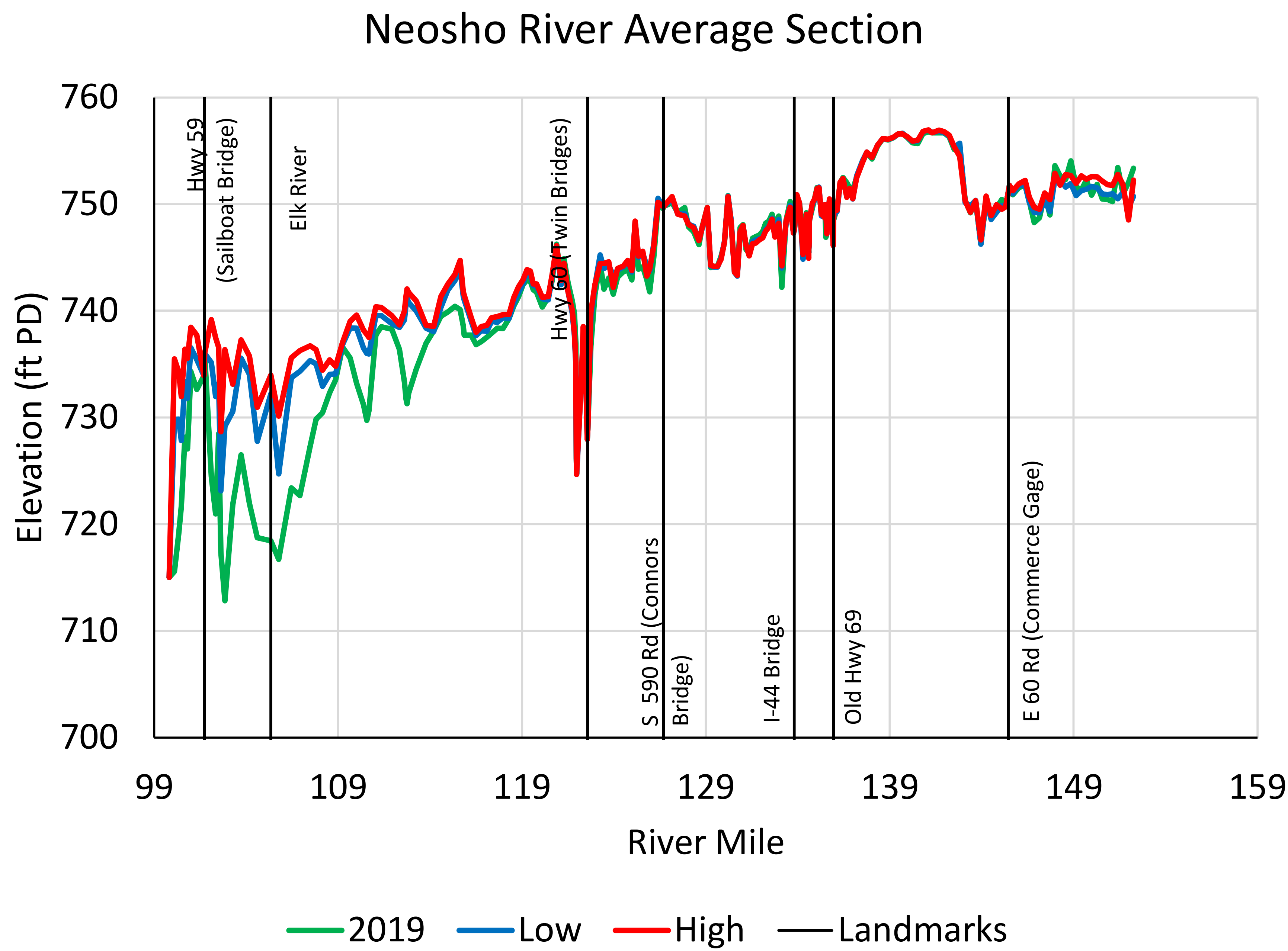


Tar Creek Average Channel
Elevation (ft PD)
780
775
770
765
760
755
750
745
740
0
1
2
3
4
5
6
7
8
River Mile
Neosho River
East Central Ave
Rockdale Blvd
Railroad
22nd Ave NE
E 60 Rd
2019
Baseline Ops
Anticipated Ops
Landmarks

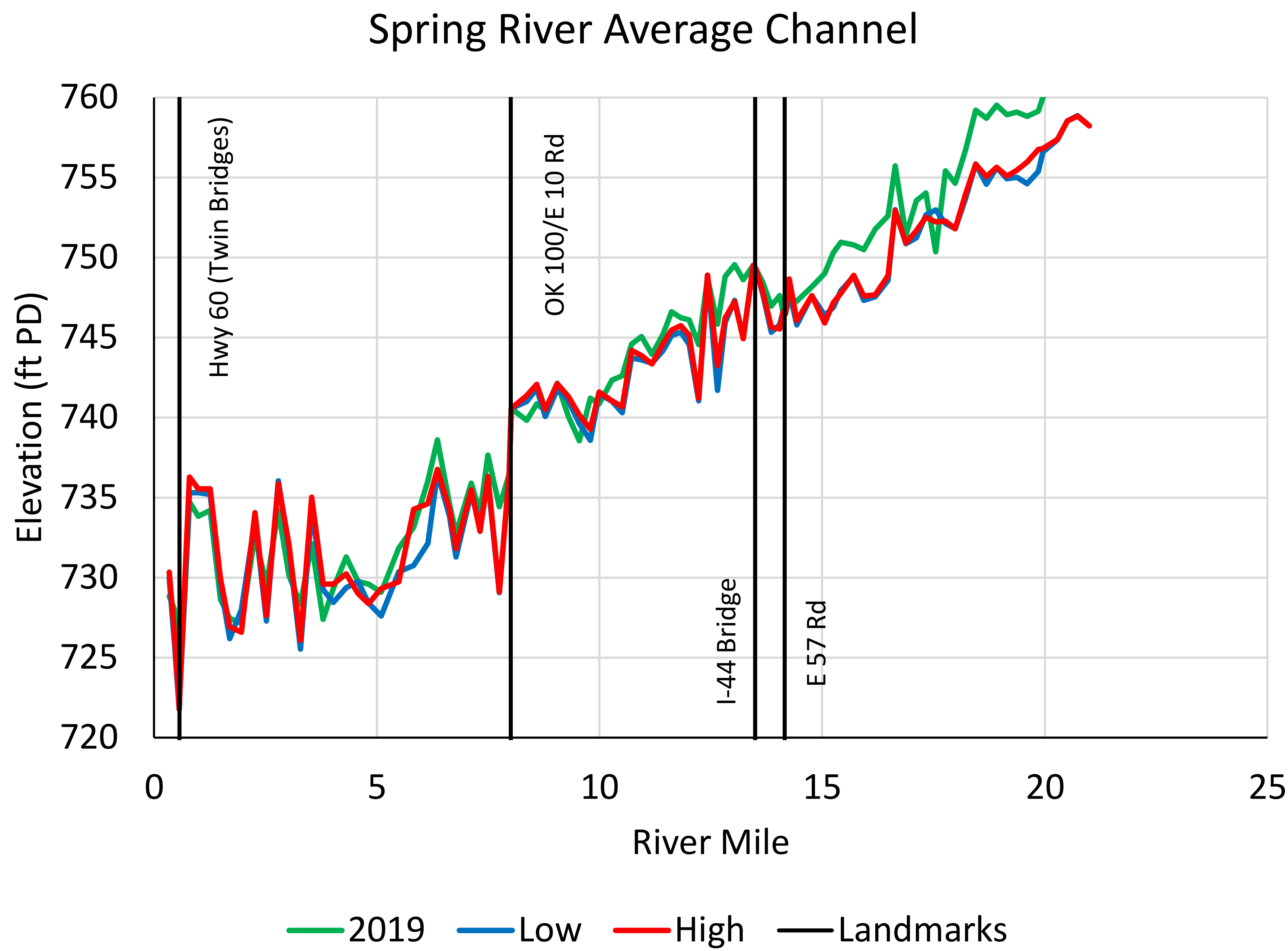

Tar Creek Average Section
Elevation (ft PD)
780
775
770
765
760
755
750
745
740
0
1
2
3
4
5
6
7
8
River Mile
Neosho River
East Central Ave
Rockdale Blvd
Railroad
22nd Ave NE
E 60 Rd
2019
Baseline Ops
Anticipated Ops
Landmarks

Simulated Future Average Channel and Average Section Plots – Sediment Loading Comparison

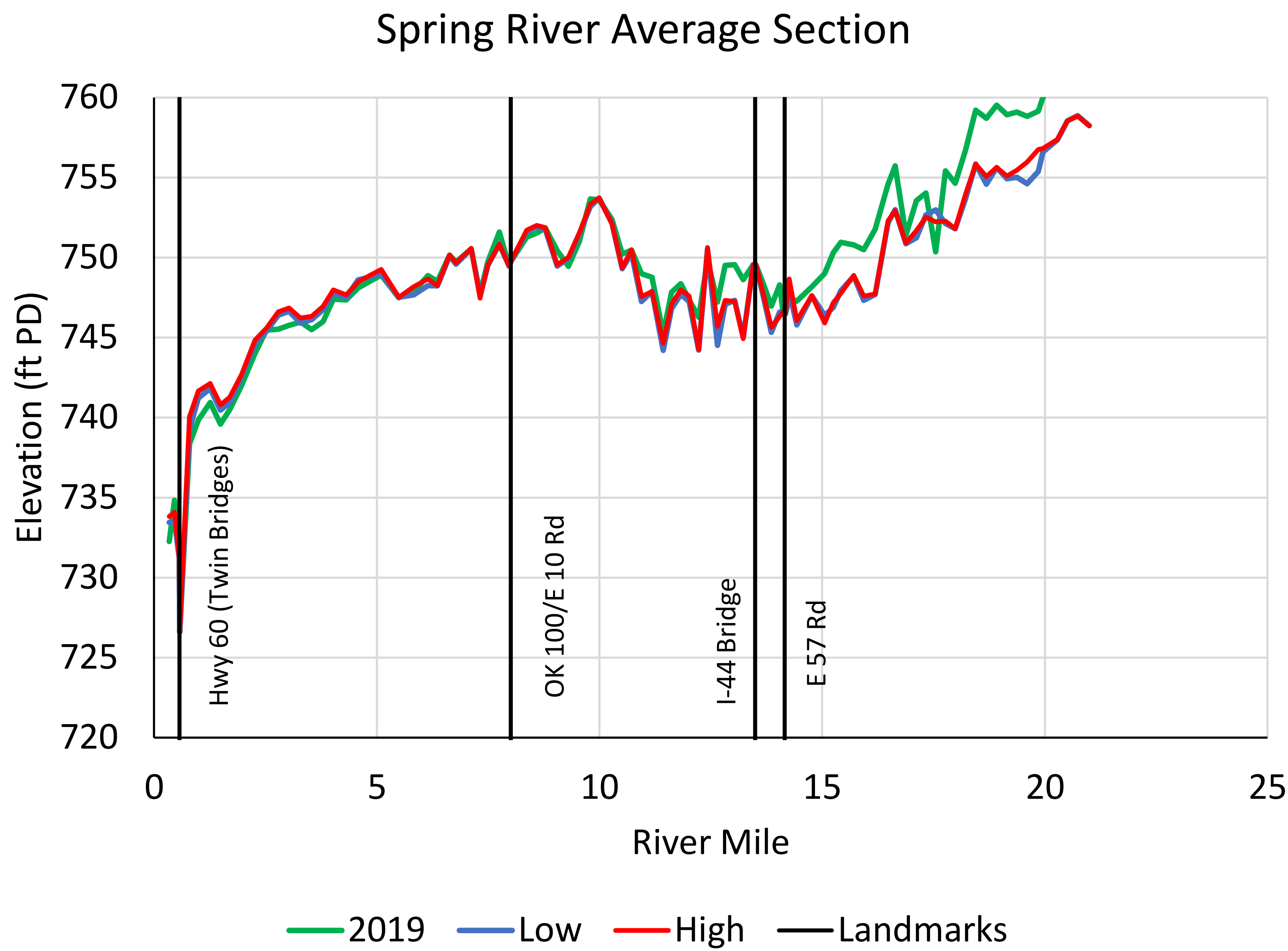

Neosho River Average Channel
Elevation (ft PD)
760
750
740
730
720
710
700
99
109
119
129
139
149
159
River Mile
Hwy 59
(Sailboat Bridge)
Elk River
Hwy 60 (Twin Bridges)
S 590 Rd (Connors
Bridge)
I-44 Bridge
Old Hwy 69
E 60 Rd (Commerce Gage)
2019
Low
High
Landmarks



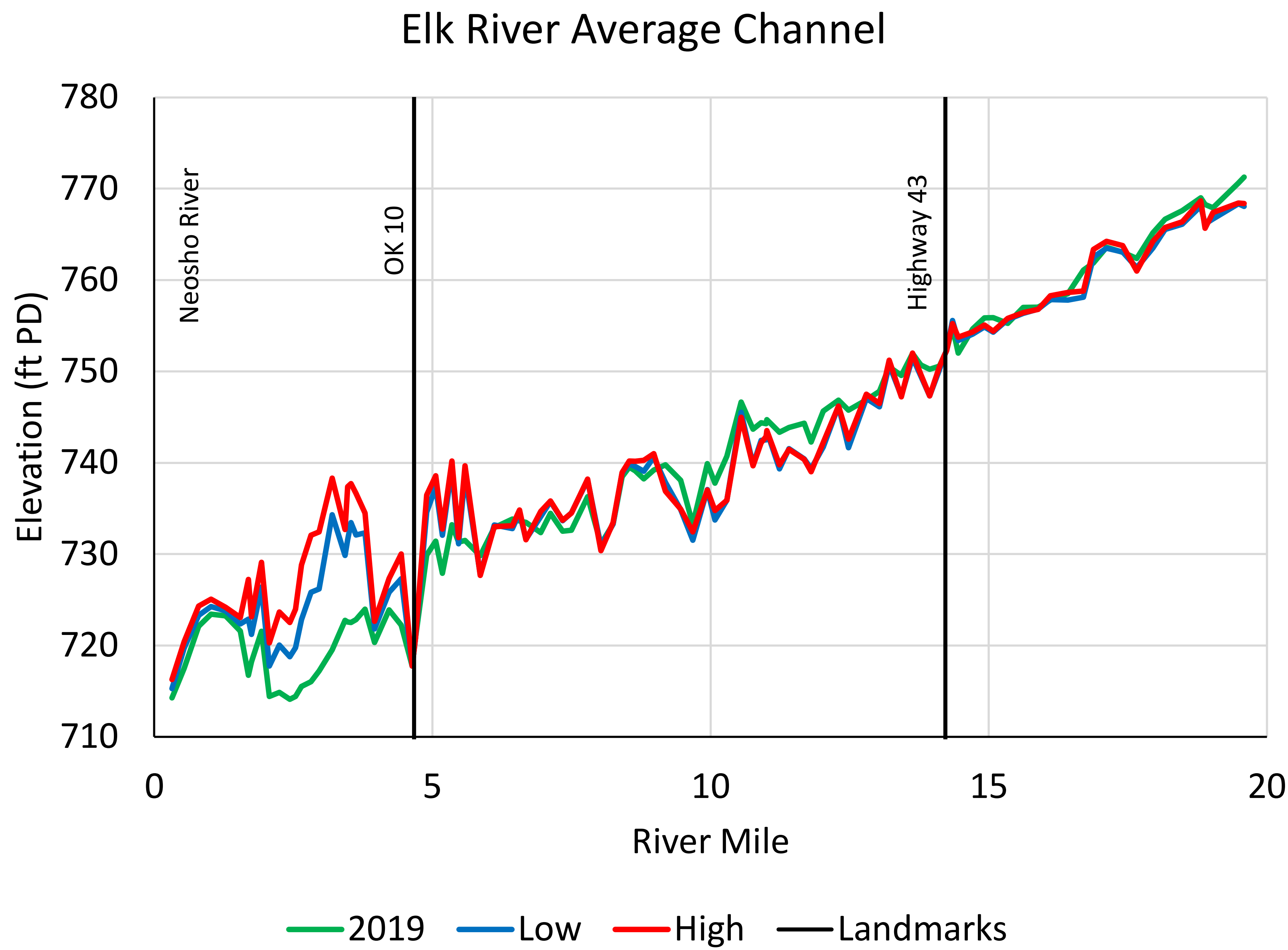
Neosho River Average Section
Elevation (ft PD)
760
750
740
730
720
710
700
99
109
119
129
139
149
159
River Mile
Hwy 59
(Sailboat Bridge)
Elk River
Hwy 60 (Twin Bridges)
S 590 Rd (Connors
Bridge)
I-44 Bridge
Old Hwy 69
E 60 Rd (Commerce Gage)
2019
Low
High
Landmarks

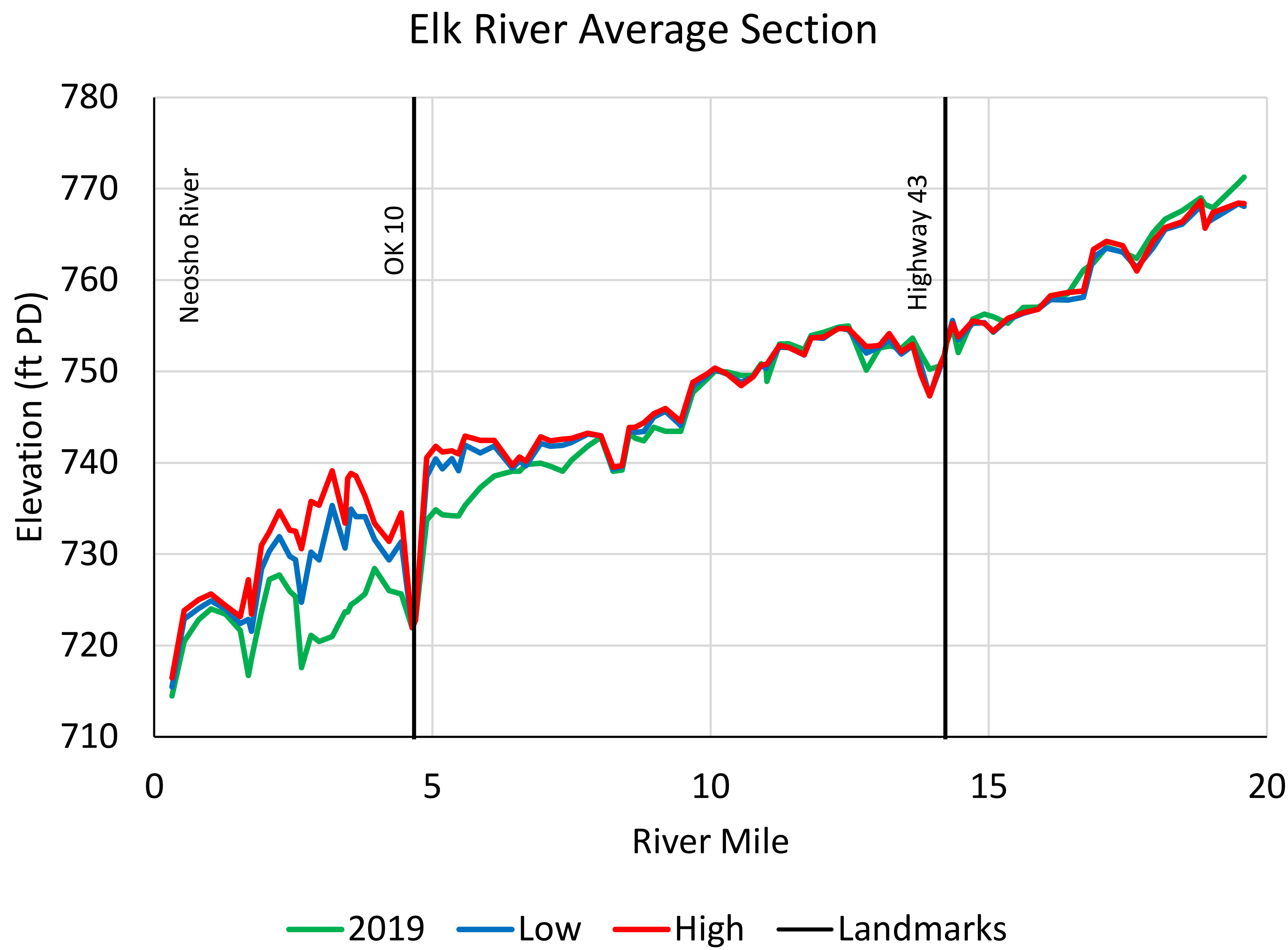


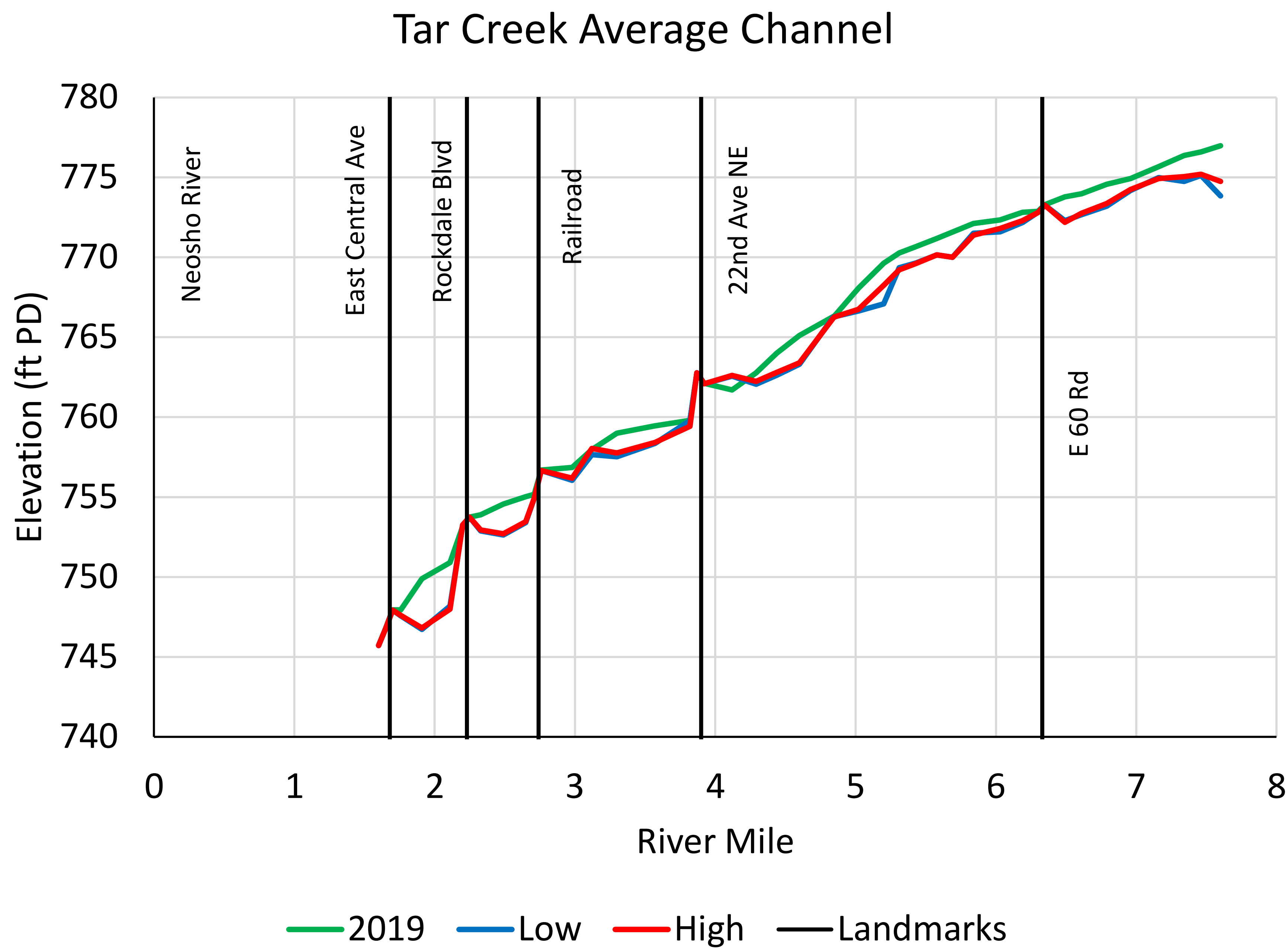
Spring River Average Channel
Elevation (ft PD)
760
755
750
745
740
735
730
725
720
River Mile
0
5
10
15
20
25
Hwy 60 (Twin Bridges)
OK 100/E 10 Rd
I-44 Bridge
E 57 Rd
2019
Low
High
Landmarks



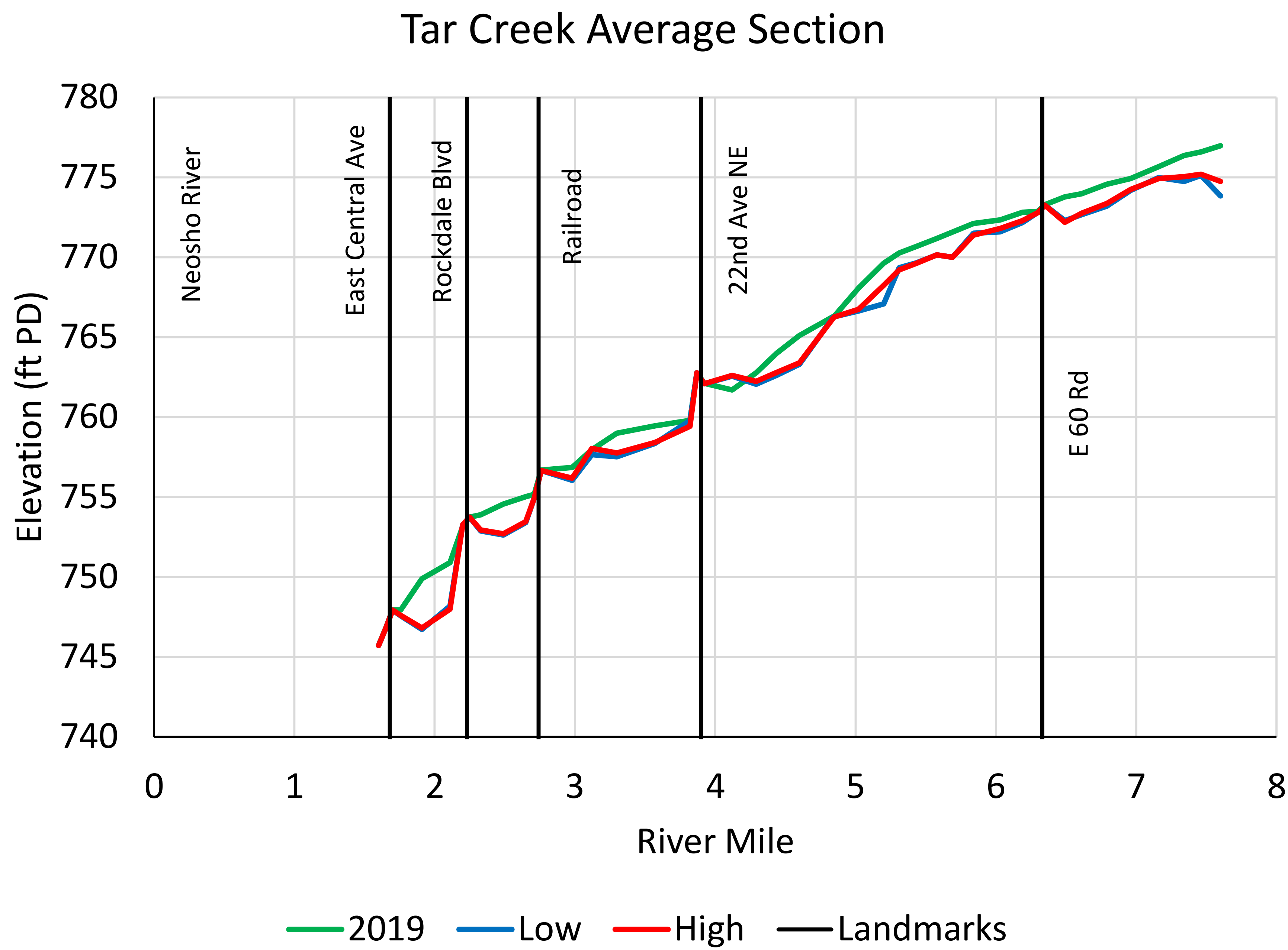
Spring River Average Section
Elevation (ft PD)
760
755
750
745
740
735
730
725
720
0
5
10
15
20
25
River Mile
Hwy 60 (Twin Bridges)
OK 100/E 10 Rd
I-44 Bridge
E 57 Rd
2019
Low
High
Landmarks


Elk River Average Channel
Elevation (ft PD)
780
770
760
750
740
730
720
710
0
5
10
15
20
River Mile
Neosho River
OK 10
Highway 43
2019
Low
High
Landmarks


Elk River Average Section
780
770
760
750
740
730
720
710
Elevation (ft PD)
0
5
10
15
20
River Mile
Neosho River
OK 10
Highway 43
2019
Low
High
Landmarks



Tar Creek Average Channel
Elevation (ft PD)
780
775
770
765
760
755
750
745
740
0
1
2
3
4
5
6
7
8
River Mile
Neosho River
East Central Ave
Rockdale Blvd
Railroad
22nd Ave NE
E 60 Rd
2019
Low
High
Landmarks

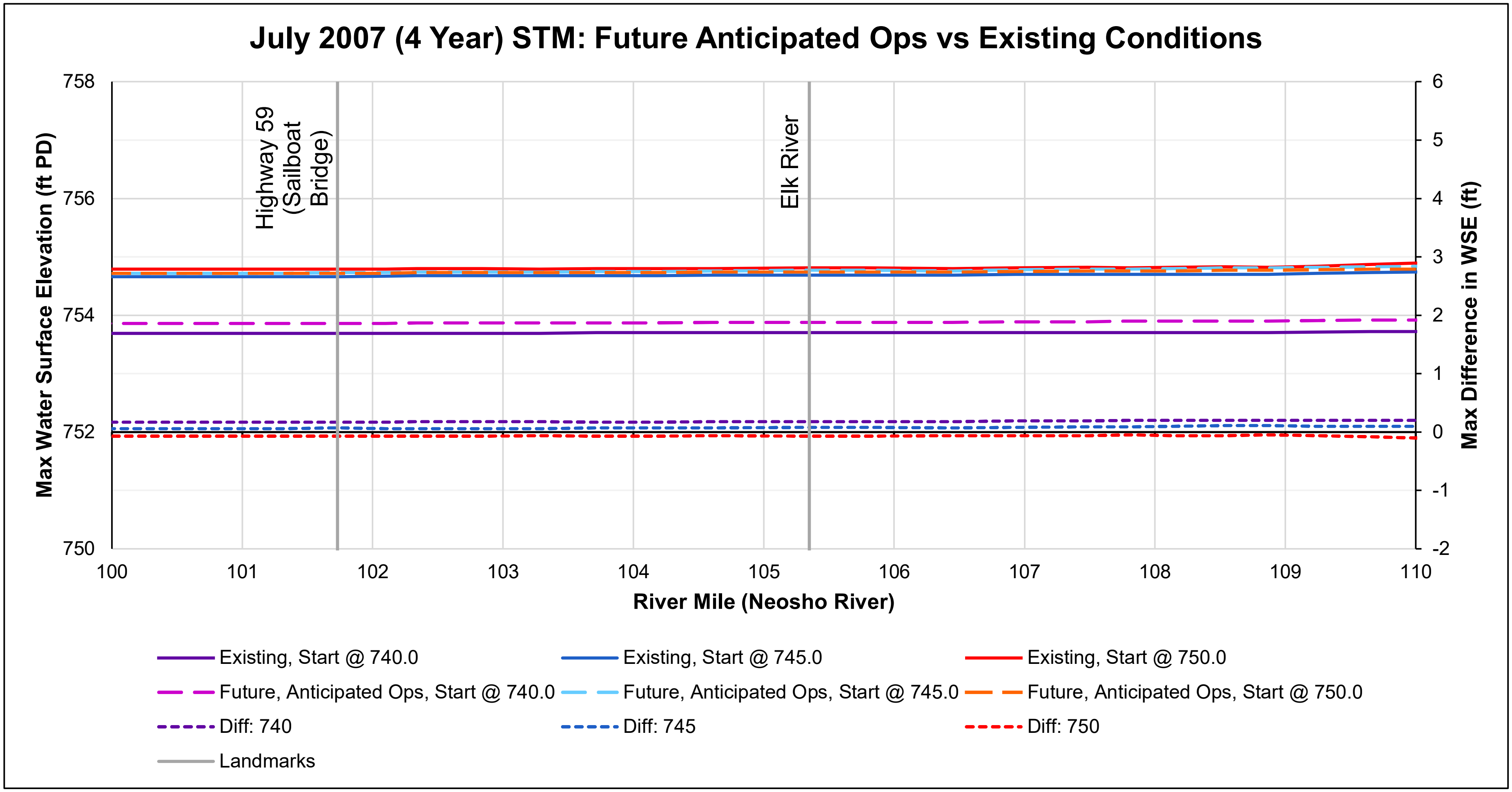


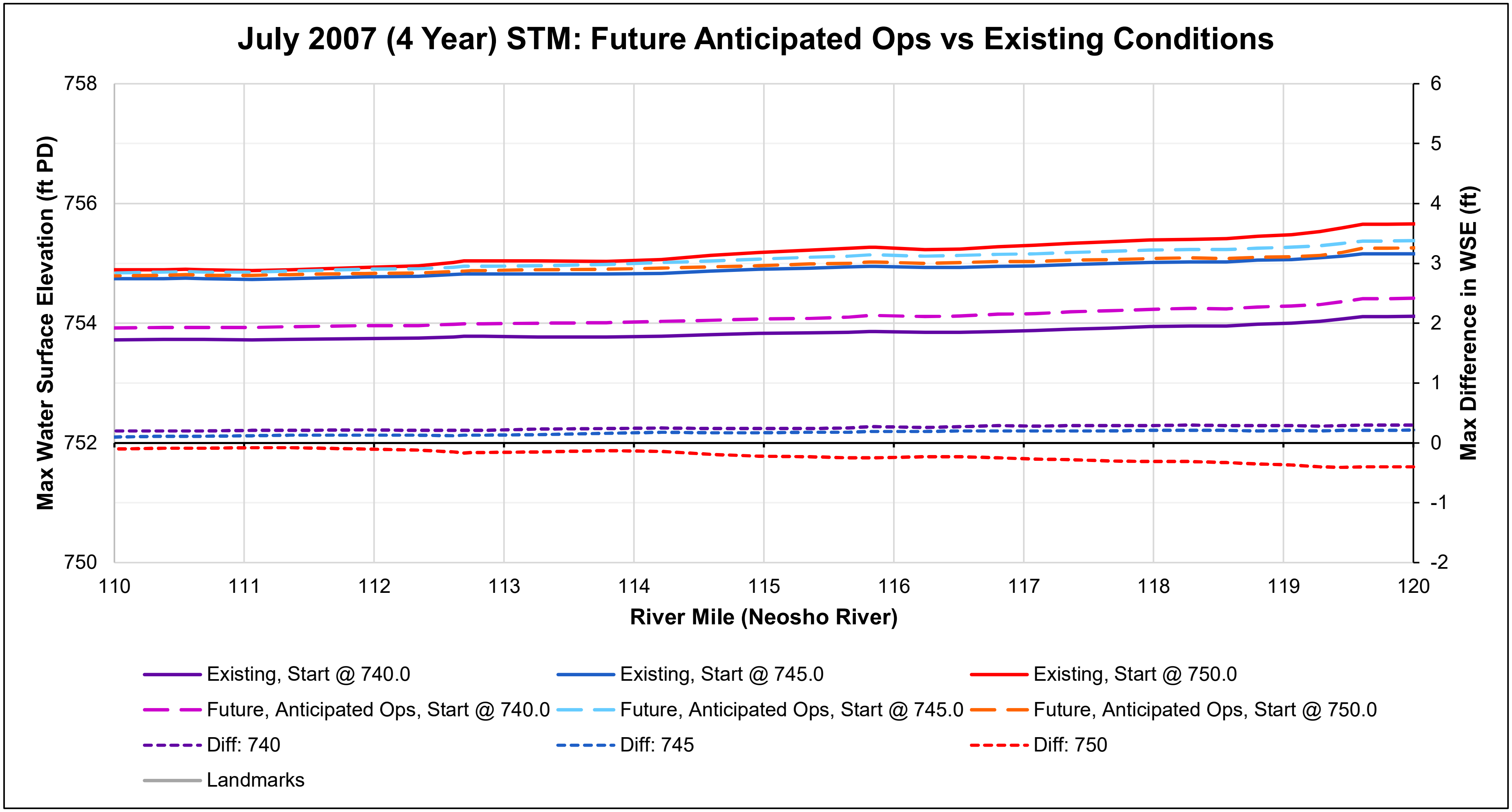
Tar Creek Average Section
Elevation (ft PD)
780
775
770
765
760
755
750
745
740
0
1
2
3
4
5
6
7
8
River Mile
Neosho River
East Central Ave
Rockdale Blvd
Railroad
22nd Ave NE
E 60 Rd
2019
Low
High
Landmarks

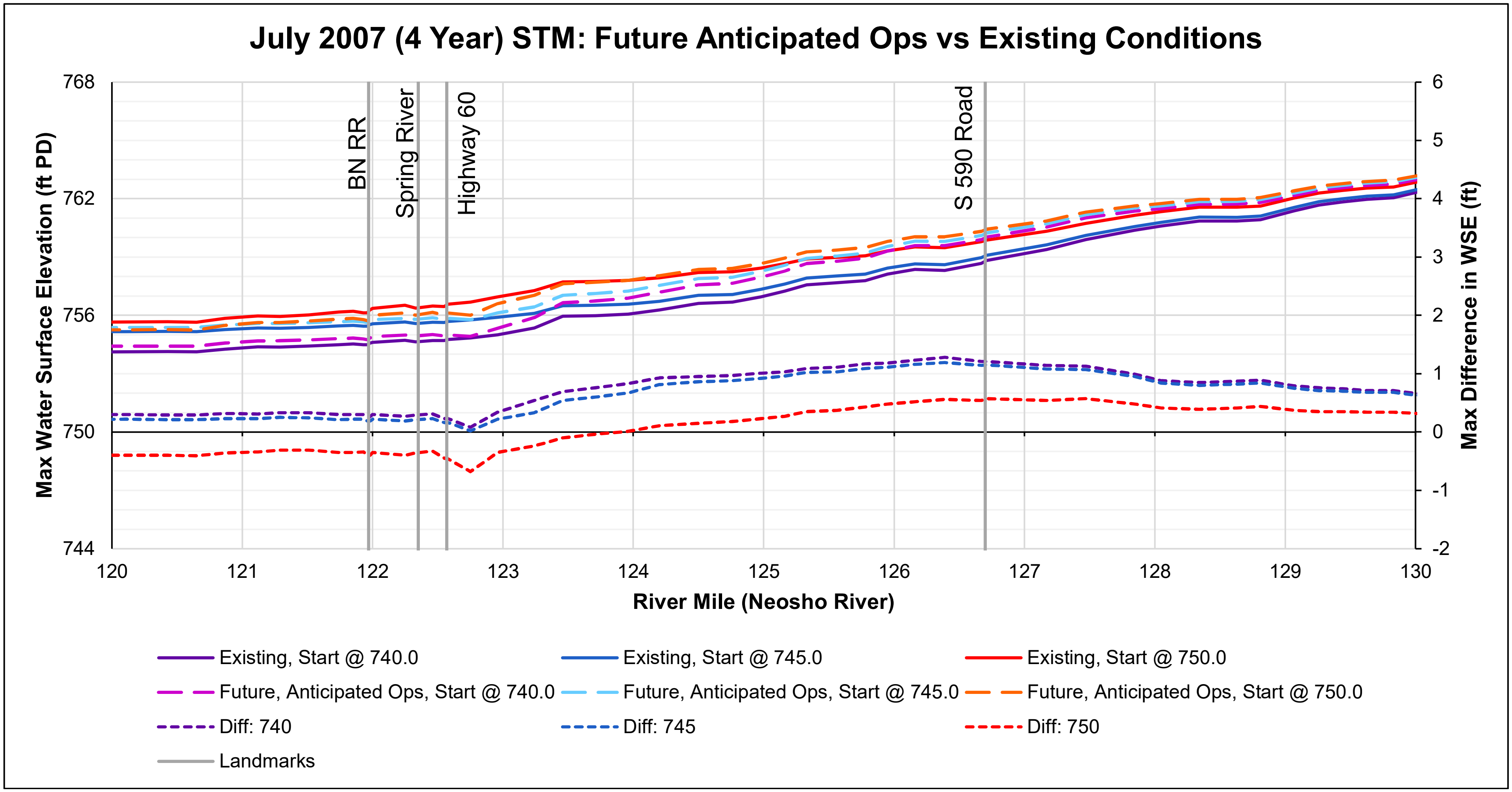
Please see following spreadsheets for cross section analyses:

- ElkRiver-XS_Analysis
- NeoshoRiver-XS_Analysis-01
- NeoshoRiver-XS_Analysis-02
- NeoshoRiver-XS_Analysis-03
- SpringRiver-XS_Analysis

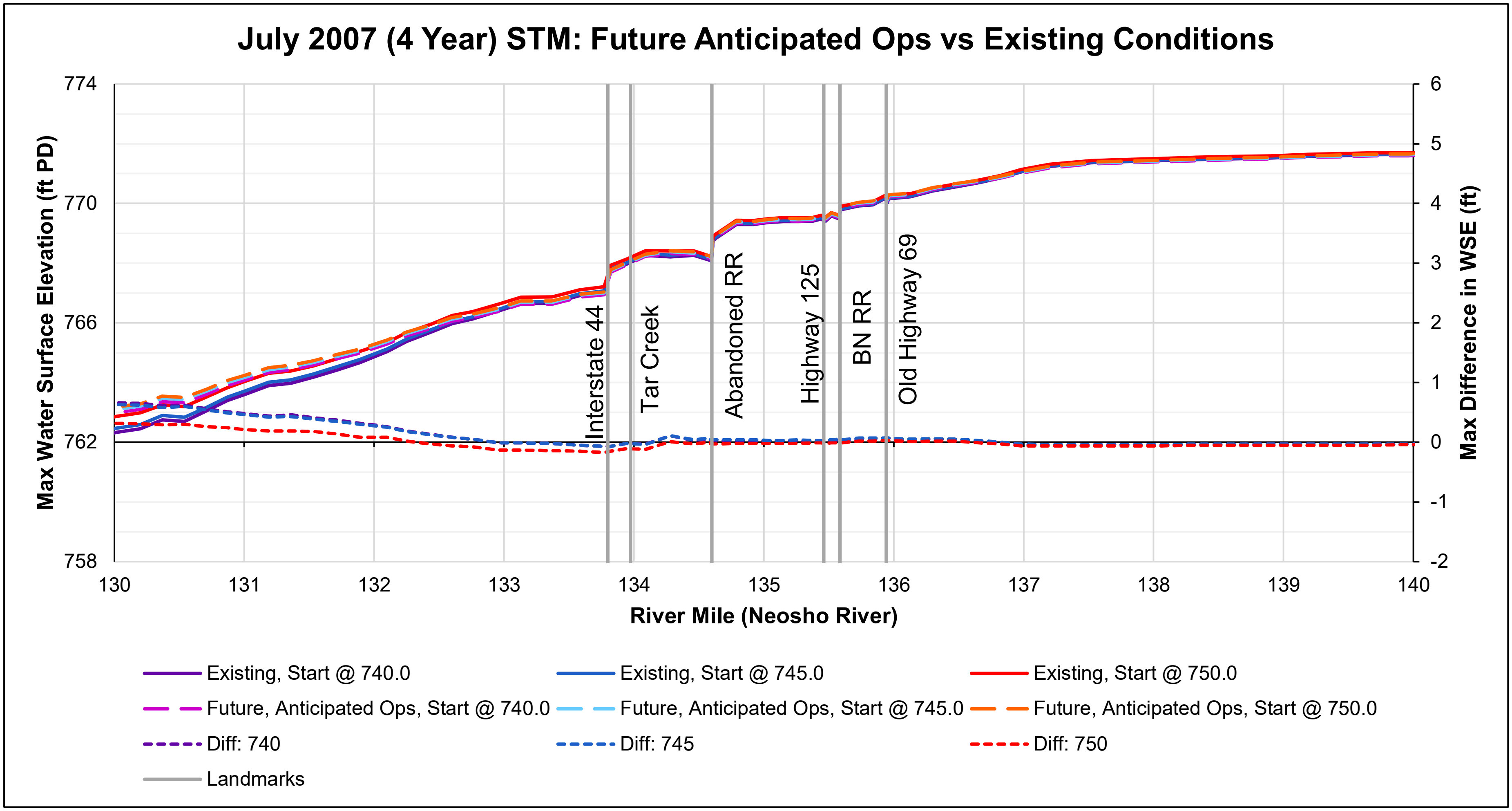
Appendix G
1D UHM Results

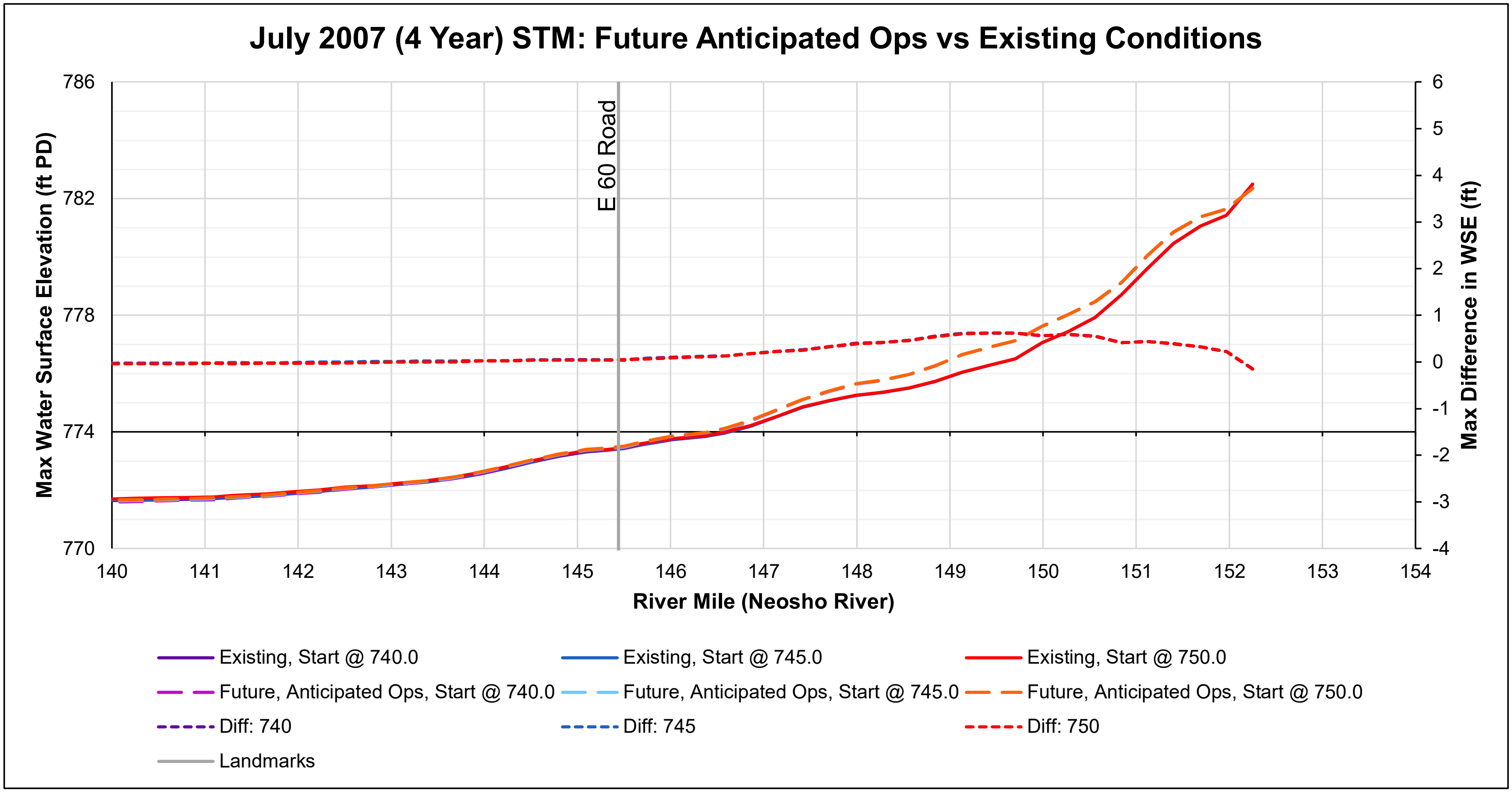

July 2007 (4 Year) STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
758
756
754
752
750
Max Difference in WSE (ft)
6
5
4
3
2
1
0
-1
-2
Highway 59 (Sailboat Bridge)
Elk River
100
101
102
103
104
105
106
107
108
109
110
River Mile (Neosho River)
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


July 2007 (4 Year) STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
758
756
754
752
750
6
5
4
3
2
1
0
-1
-2
110
111
112
113
114
115
116
117
118
119
120
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

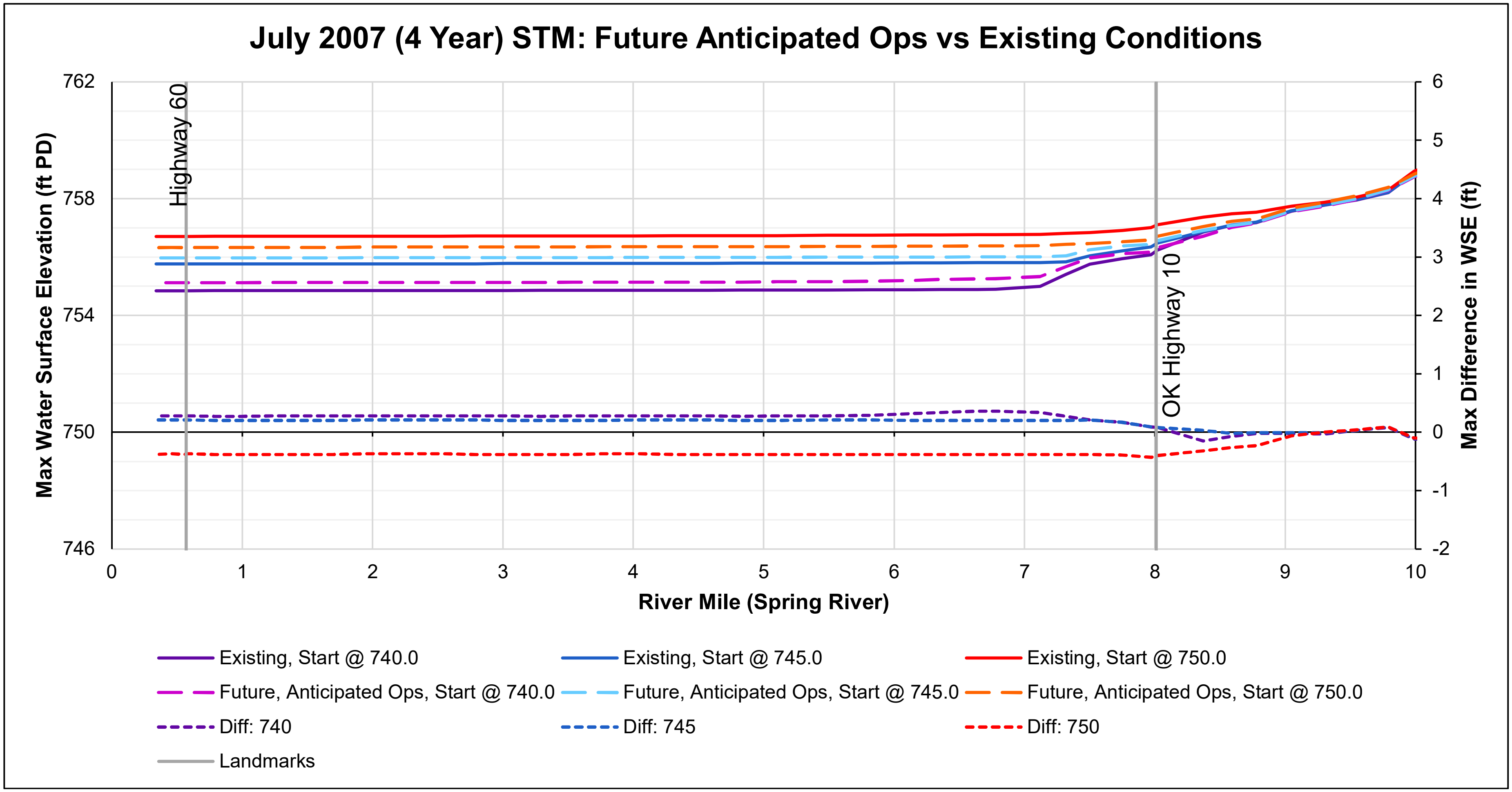


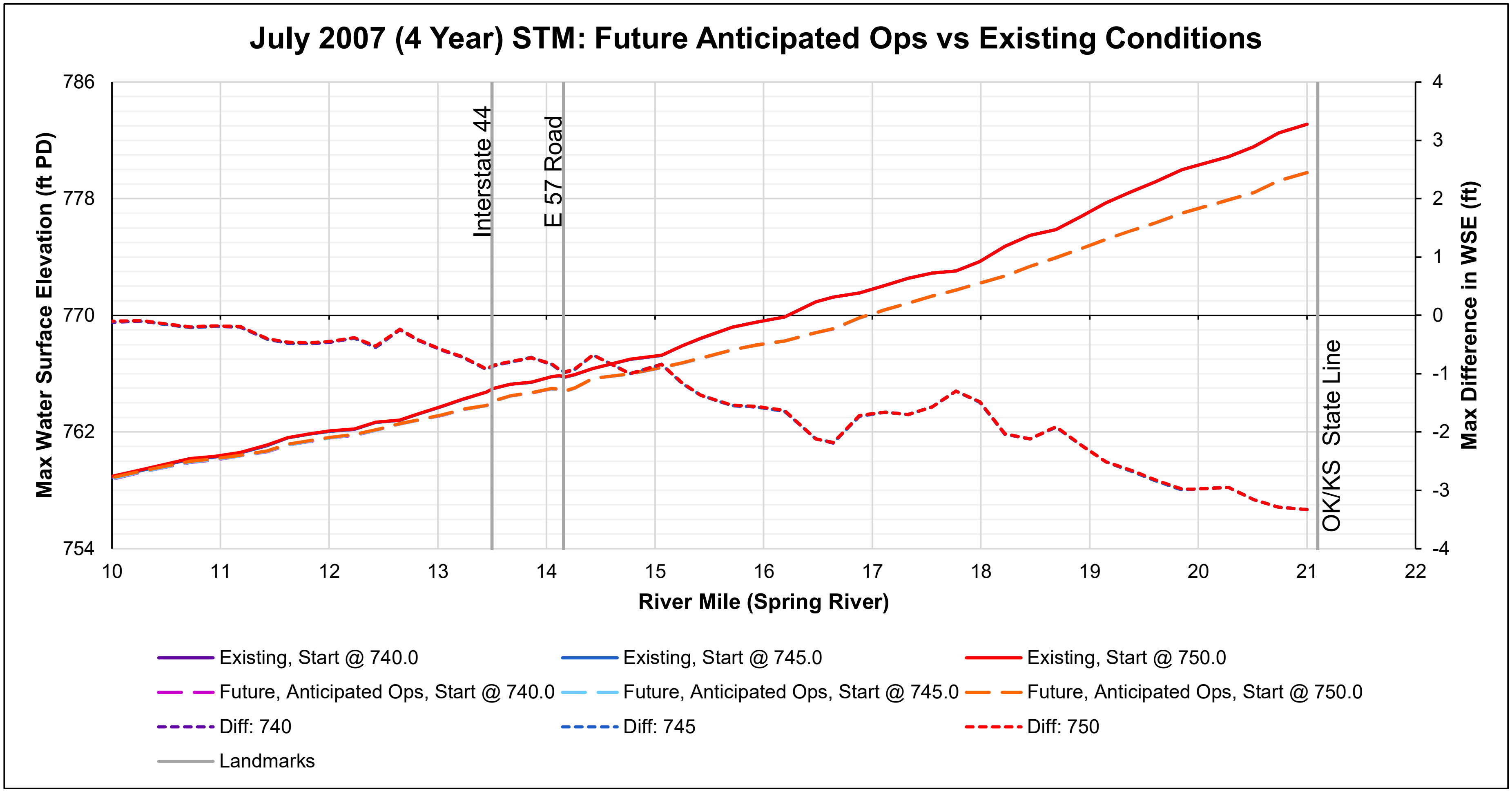
July 2007 (4 Year) STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
BN RR
Spring River
Highway 60
S 590 Road
768
762
756
750
744
6
5
4
3
2
1
0
-1
-2
120
121
122
123
124
125
126
127
128
129
130
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


July 2007 (4 Year) STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
774
770
766
762
758
6
5
4
3
2
1
0
-1
-2
130
131
132
133
134
135
136
137
138
139
140
Interstate 44
Tar Creek
Abandoned RR
Highway 125
BN RR
Old Highway 69
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

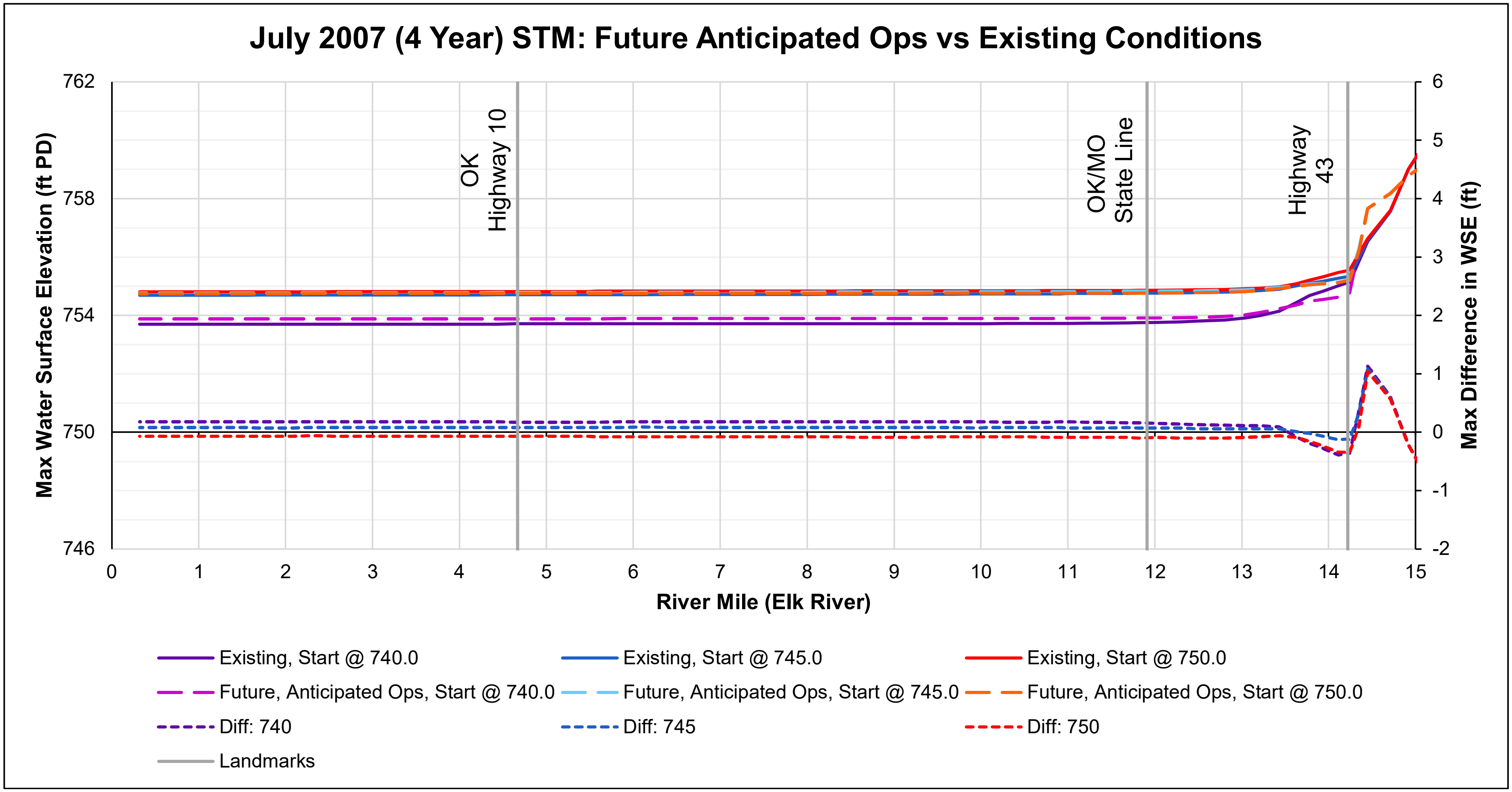


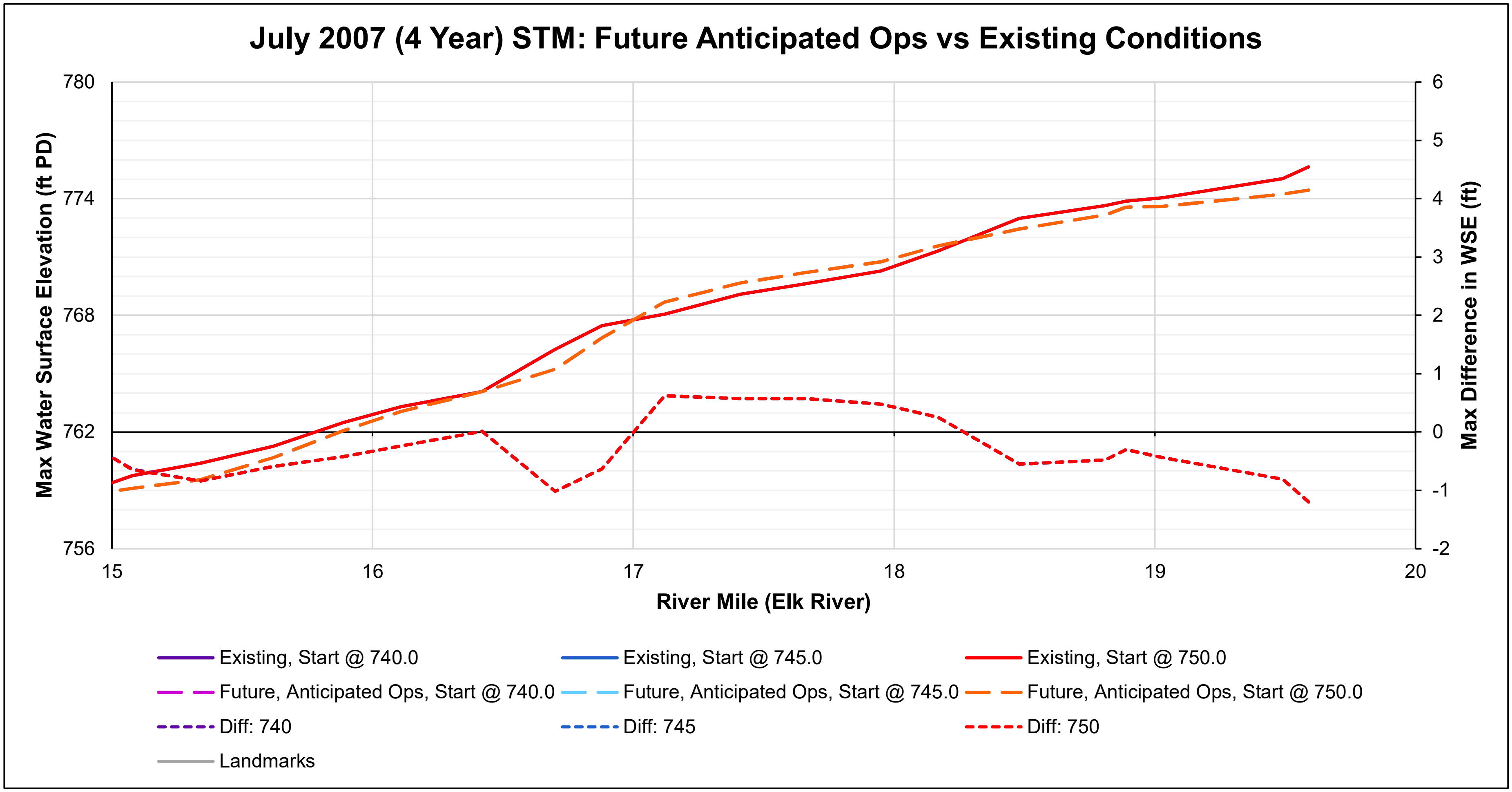
July 2007 (4 Year) STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
786
782
778
774
770
E 60 Road
Max Difference in WSE (ft)
6
5
4
3
2
1
0
-1
-2
-3
-4
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
River Mile (Neosho River)
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


July 2007 (4 Year) STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Spring River)
Highway 60
OK Highway 10
762
758
754
750
746
6
5
4
3
2
1
0
-1
-2
0
1
2
3
4
5
6
7
8
9
10
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

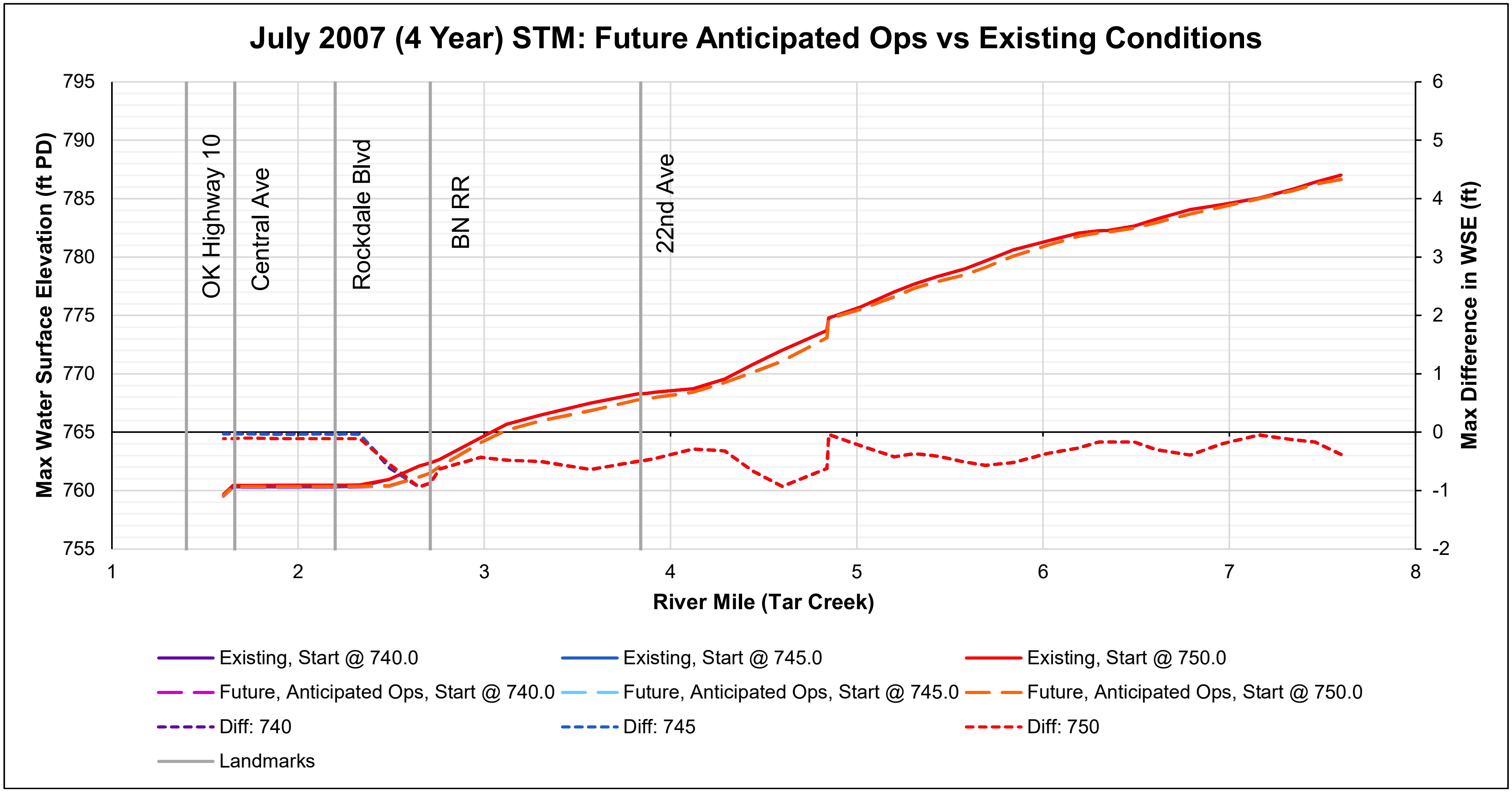


July 2007 (4 Year) STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Spring River)
786
778
770
762
754
4
3
2
1
0
-1
-2
-3
-4
10
11
12
13
14
15
16
17
18
19
20
21
22
Interstate 44
E 57 Road
OK/KS State Line
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

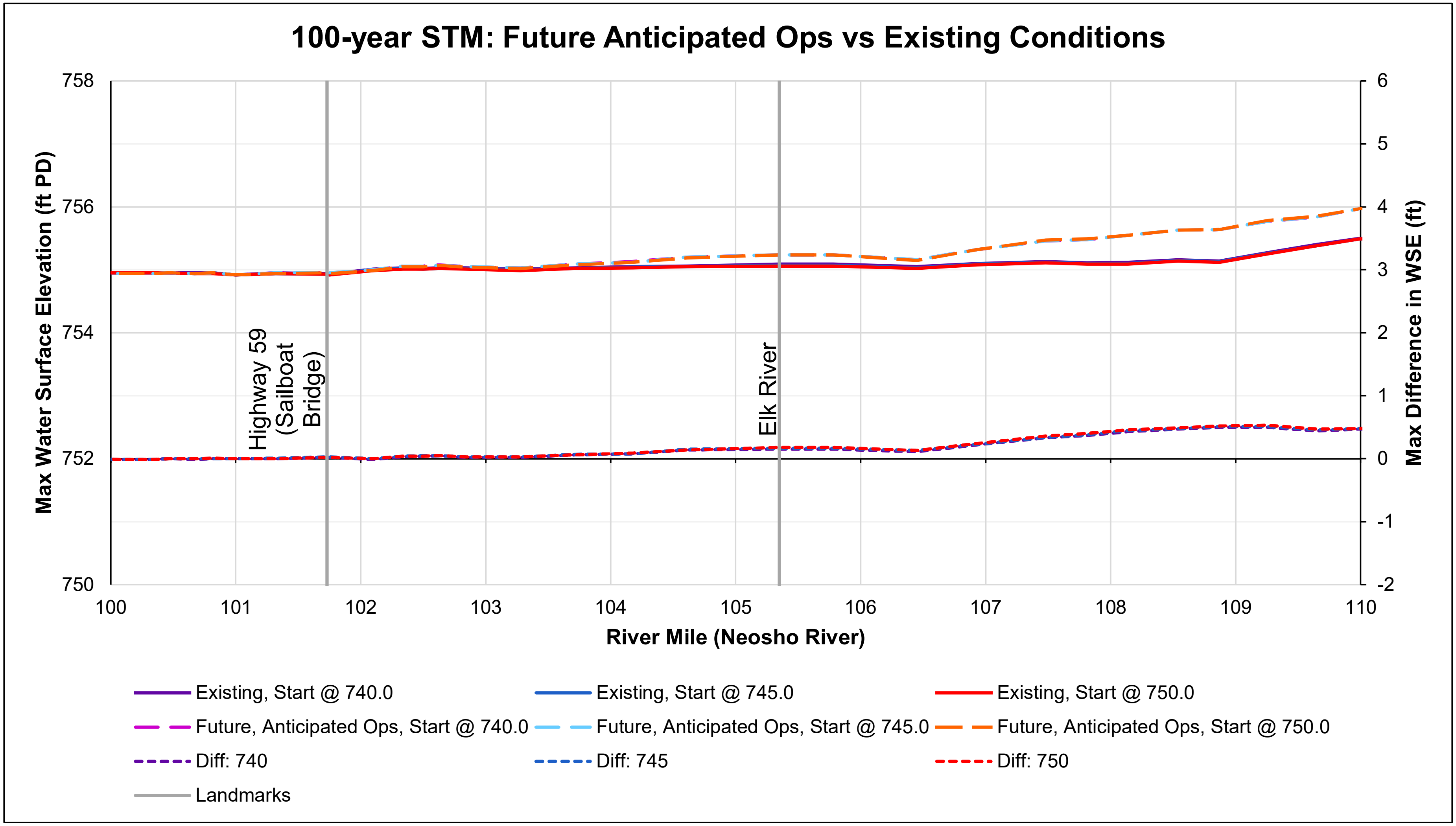

July 2007 (4 Year) STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Elk River)
762
758
754
750
746
6
5
4
3
2
1
0
-1
-2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
OK Highway 10
OK/MO State Line
Highway 43
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks



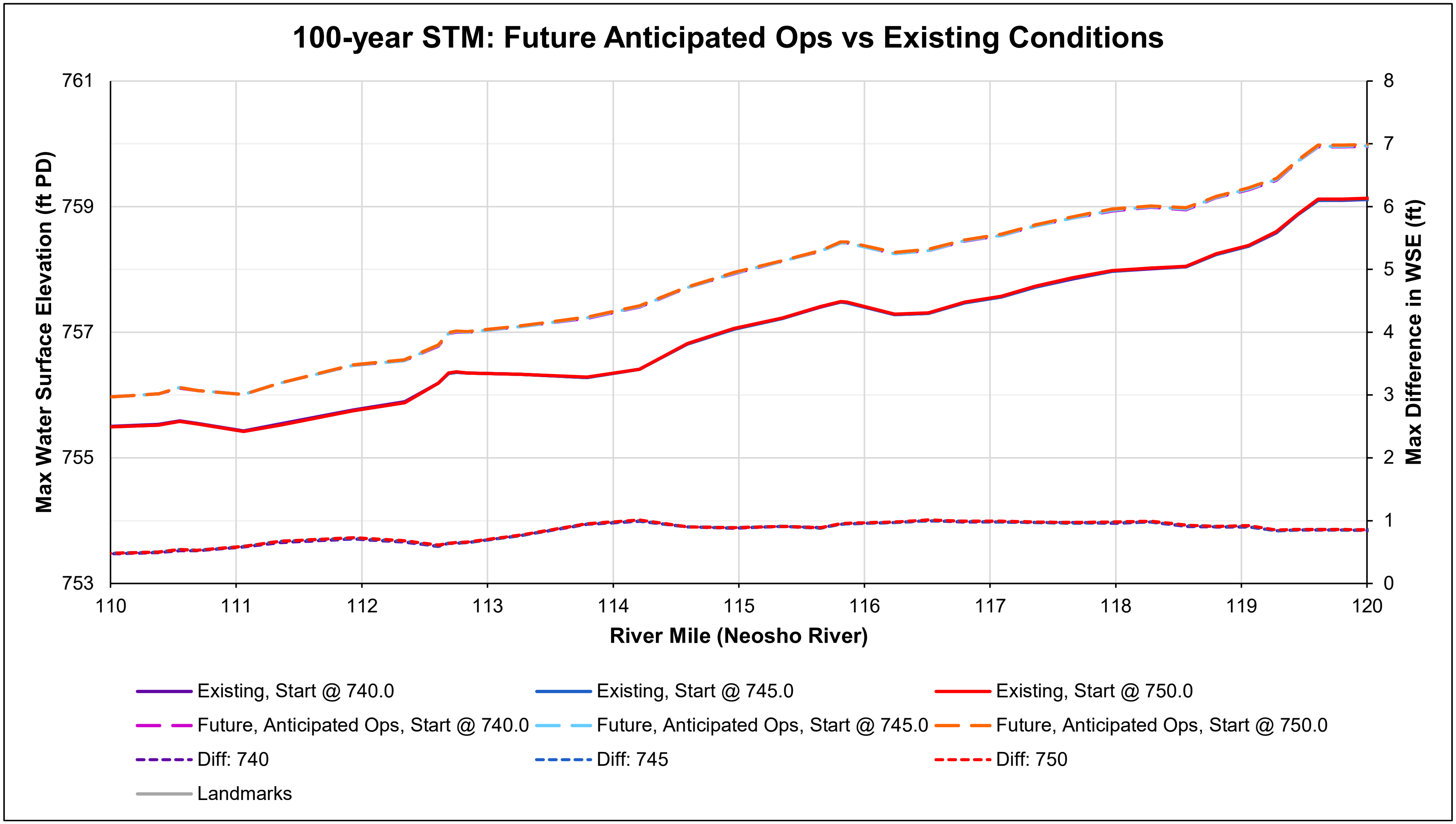
July 2007 (4 Year) STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
780
774
768
762
756
Max Difference in WSE (ft)
6
5
4
3
2
1
0
-1
-2
15
16
17
18
19
20
River Mile (Elk River)
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks



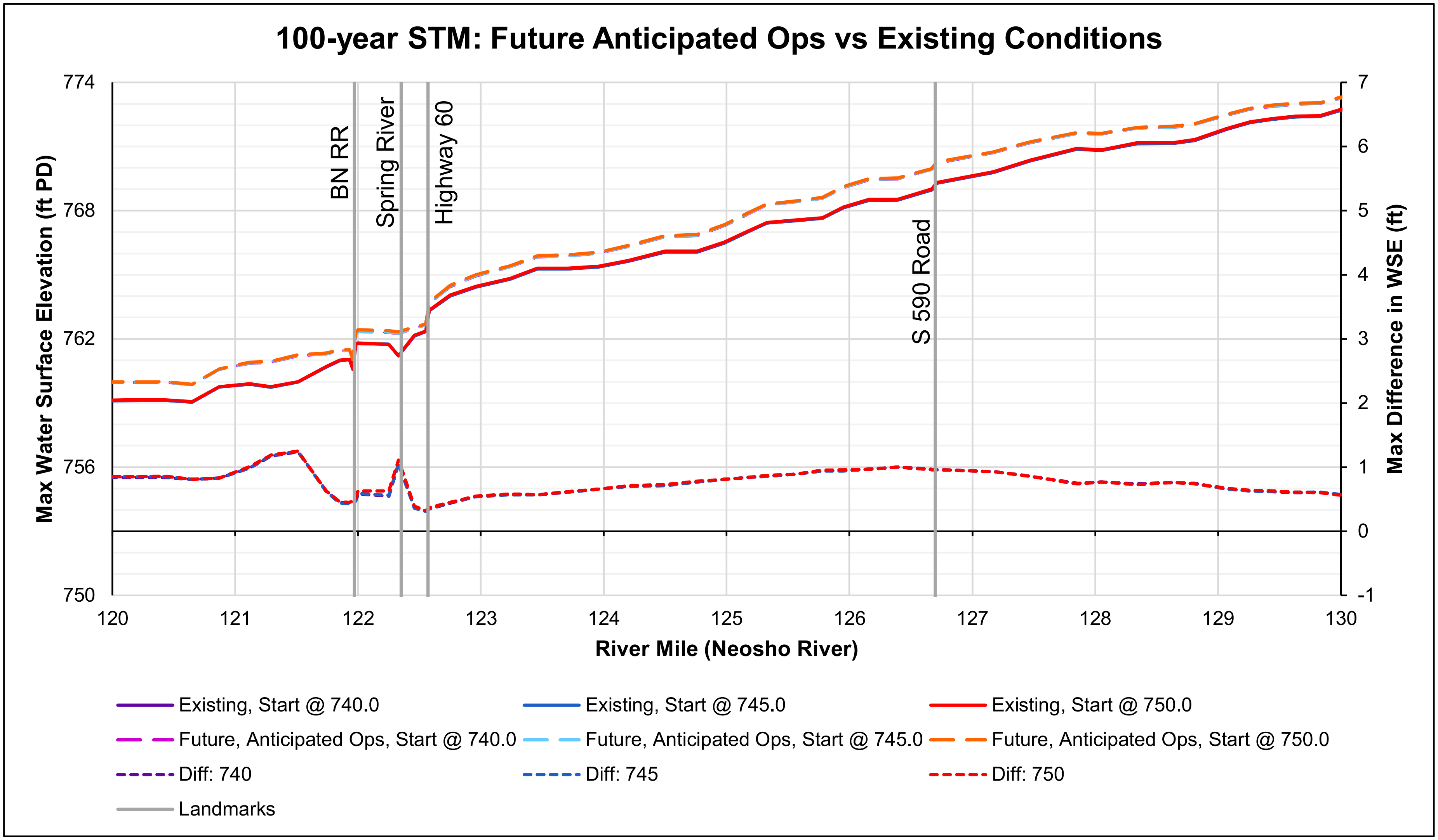
July 2007 (4 Year) STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Tar Creek)
OK Highway 10
Central Ave
Rockdale Blvd
BN RR
22nd Ave
795
790
785
780
775
770
765
760
755
6
5
4
3
2
1
0
-1
-2
1
2
3
4
5
6
7
8
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks



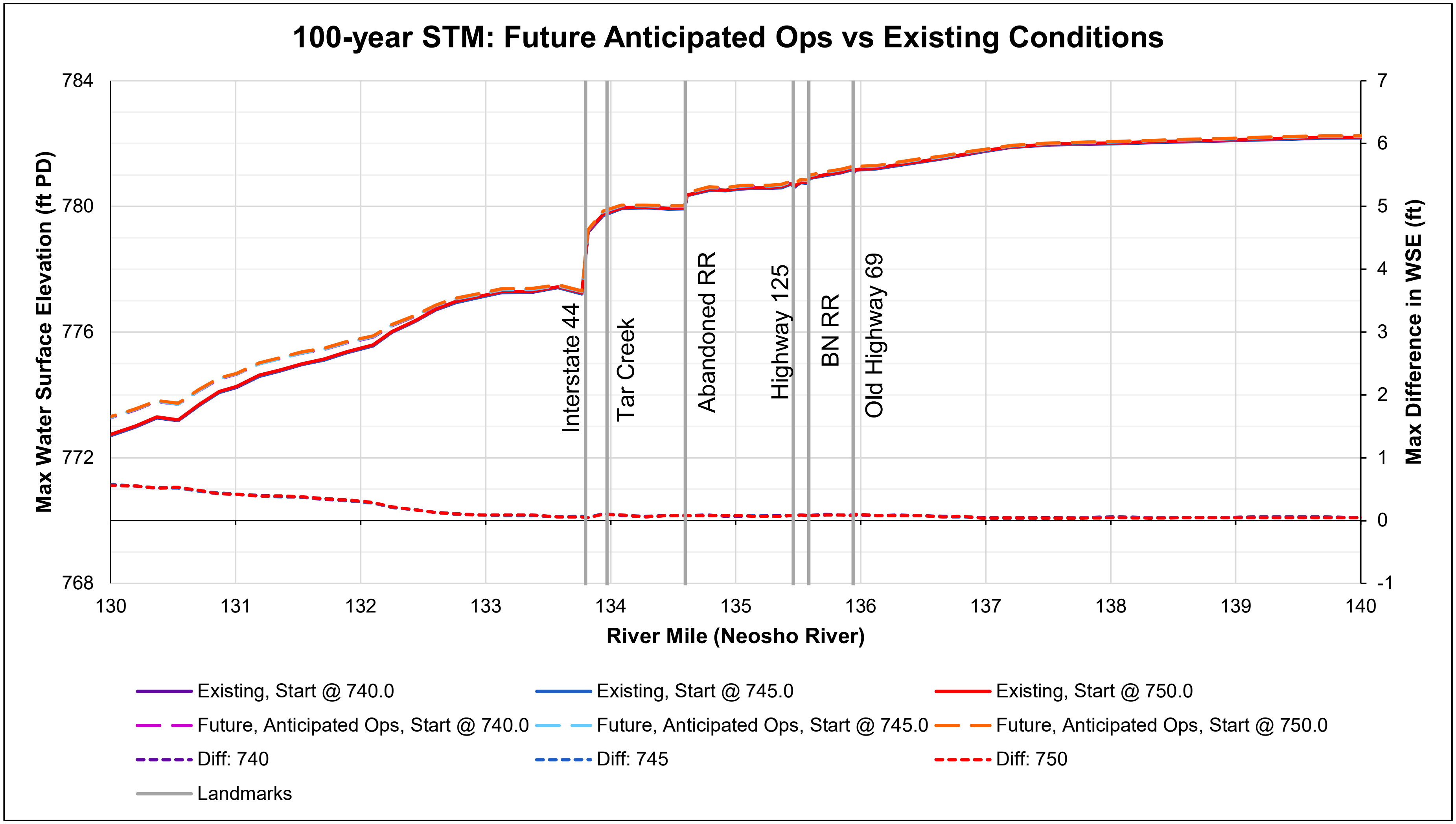
100-year STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
758
756
754
752
750
Max Difference in WSE (ft)
6
5
4
3
2
1
0
-1
-2
100
101
102
103
104
105
106
107
108
109
110
River Mile (Neosho River)
Highway 59 (Sailboat Bridge)
Elk River
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

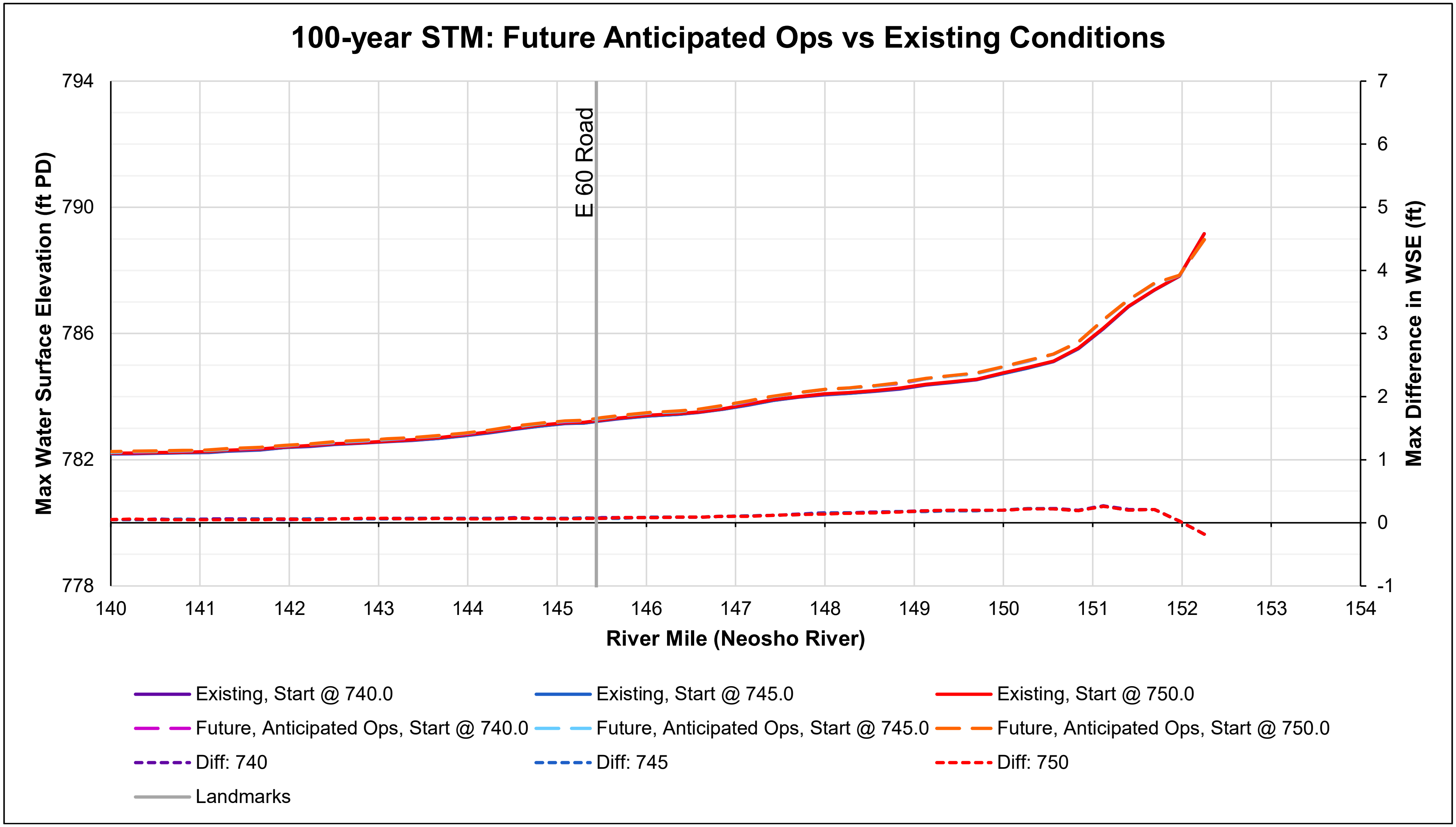


100-year STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
761
759
757
755
753
Max Difference in WSE (ft)
8
7
6
5
4
3
2
1
0
110
111
112
113
114
115
116
117
118
119
120
River Mile (Neosho River)
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

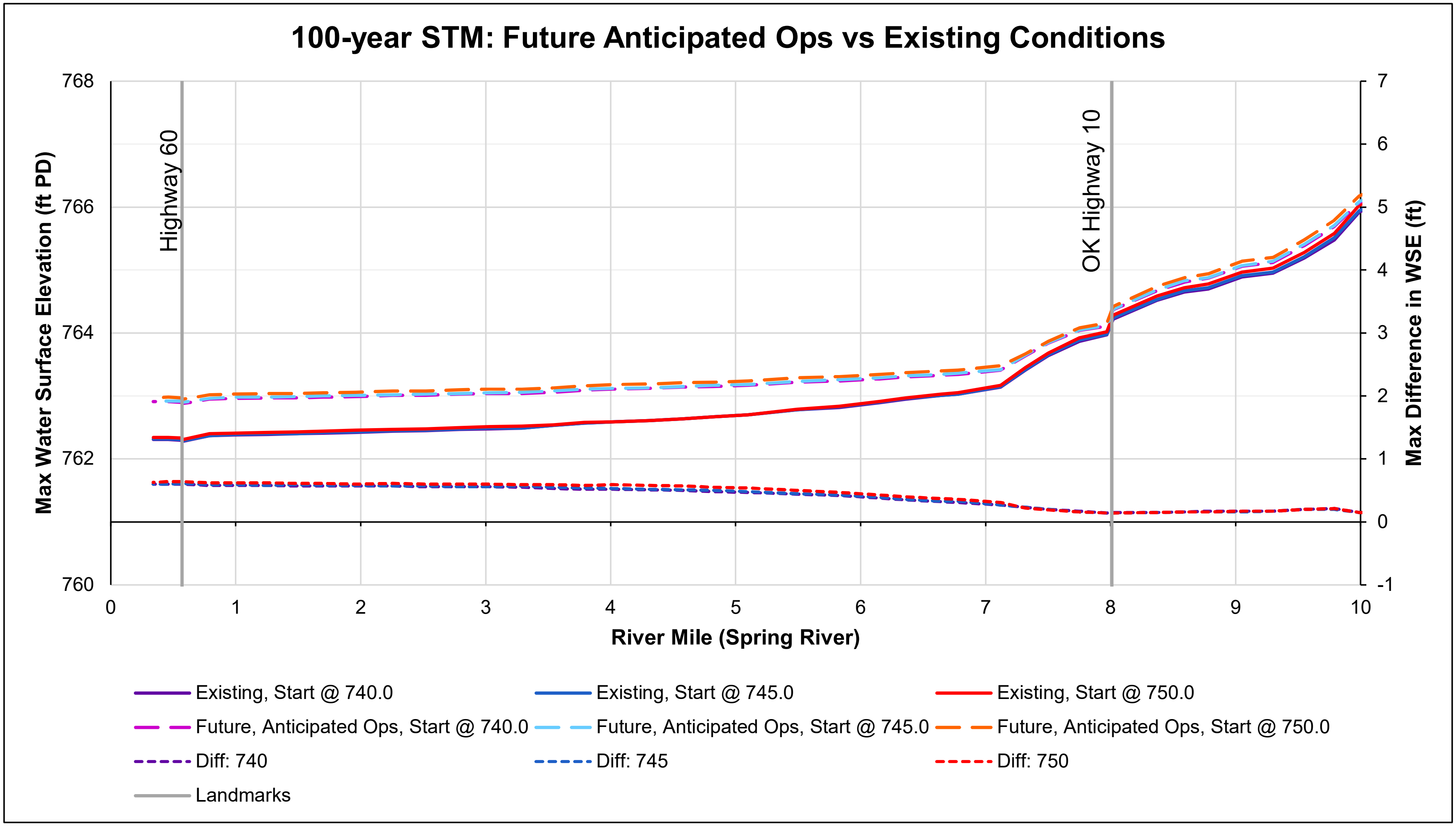


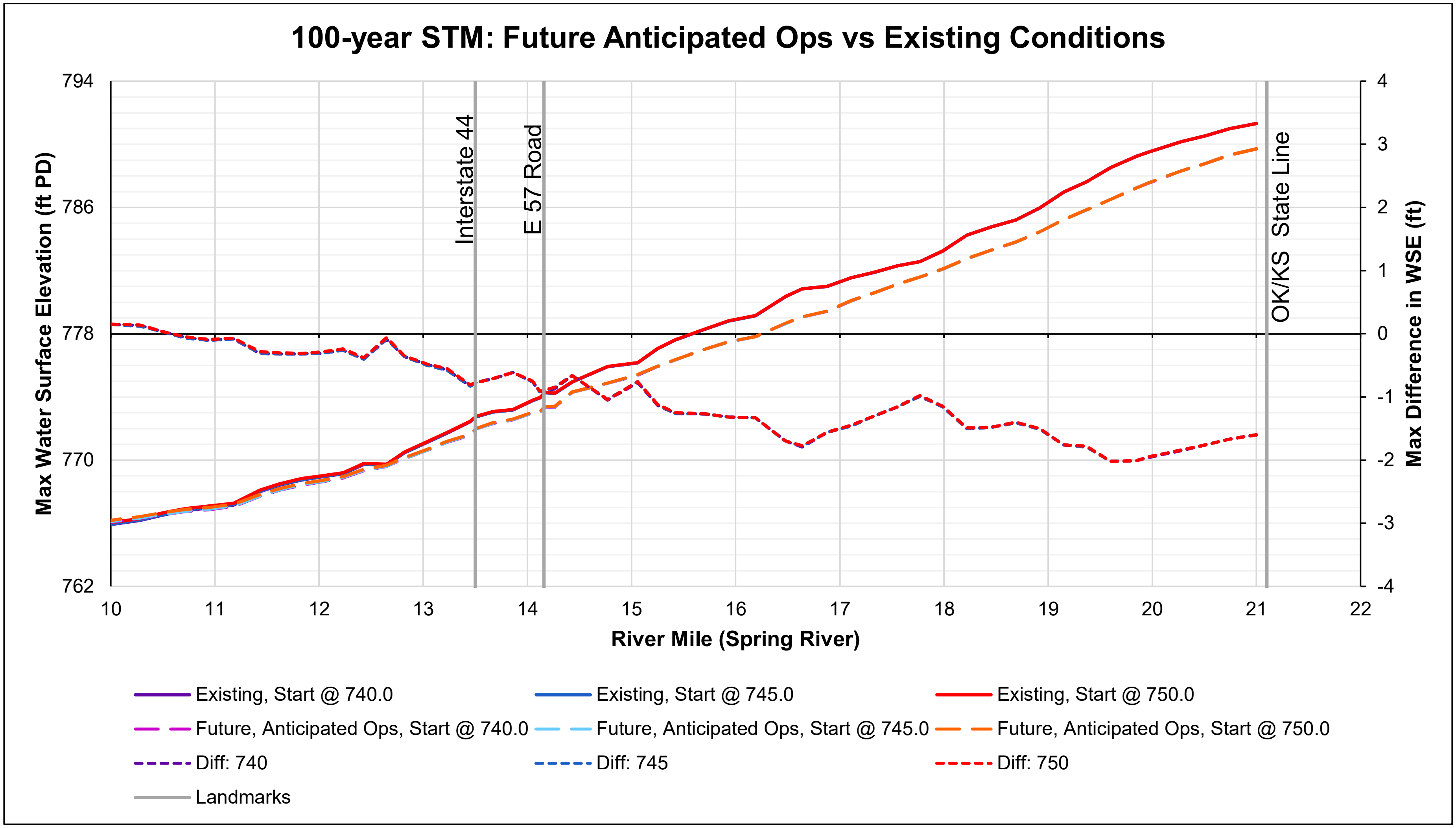
100-year STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
BN RR
Spring River
Highway 60
S 590 Road
774
768
762
756
750
7
6
5
4
3
2
1
0
-1
120
121
122
123
124
125
126
127
128
129
130
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

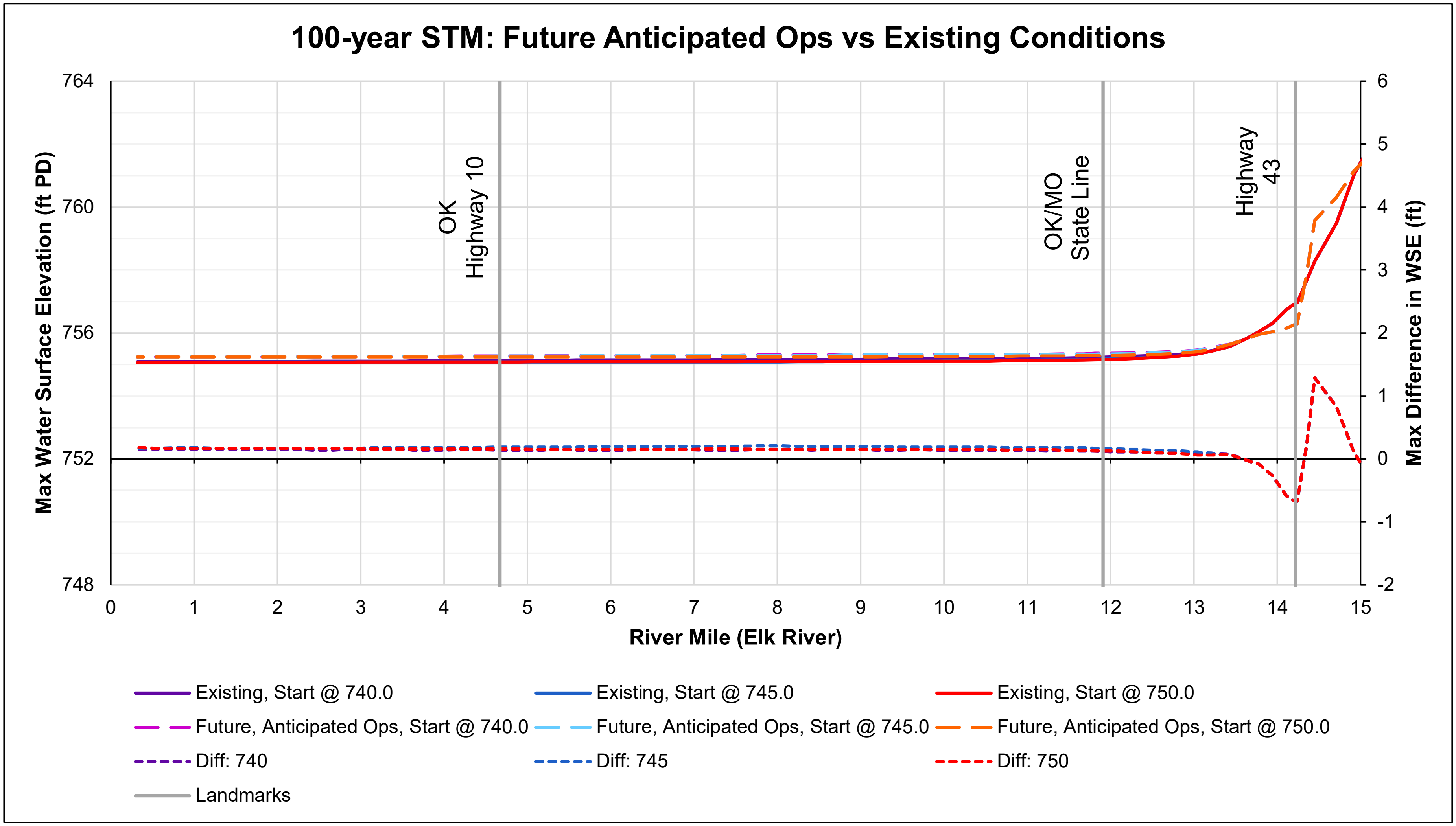

100-year STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
784
780
776
772
768
7
6
5
4
3
2
1
0
-1
130
131
132
133
134
135
136
137
138
139
140
Interstate 44
Tar Creek
Abandoned RR
Highway 125
BN RR
Old Highway 69
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

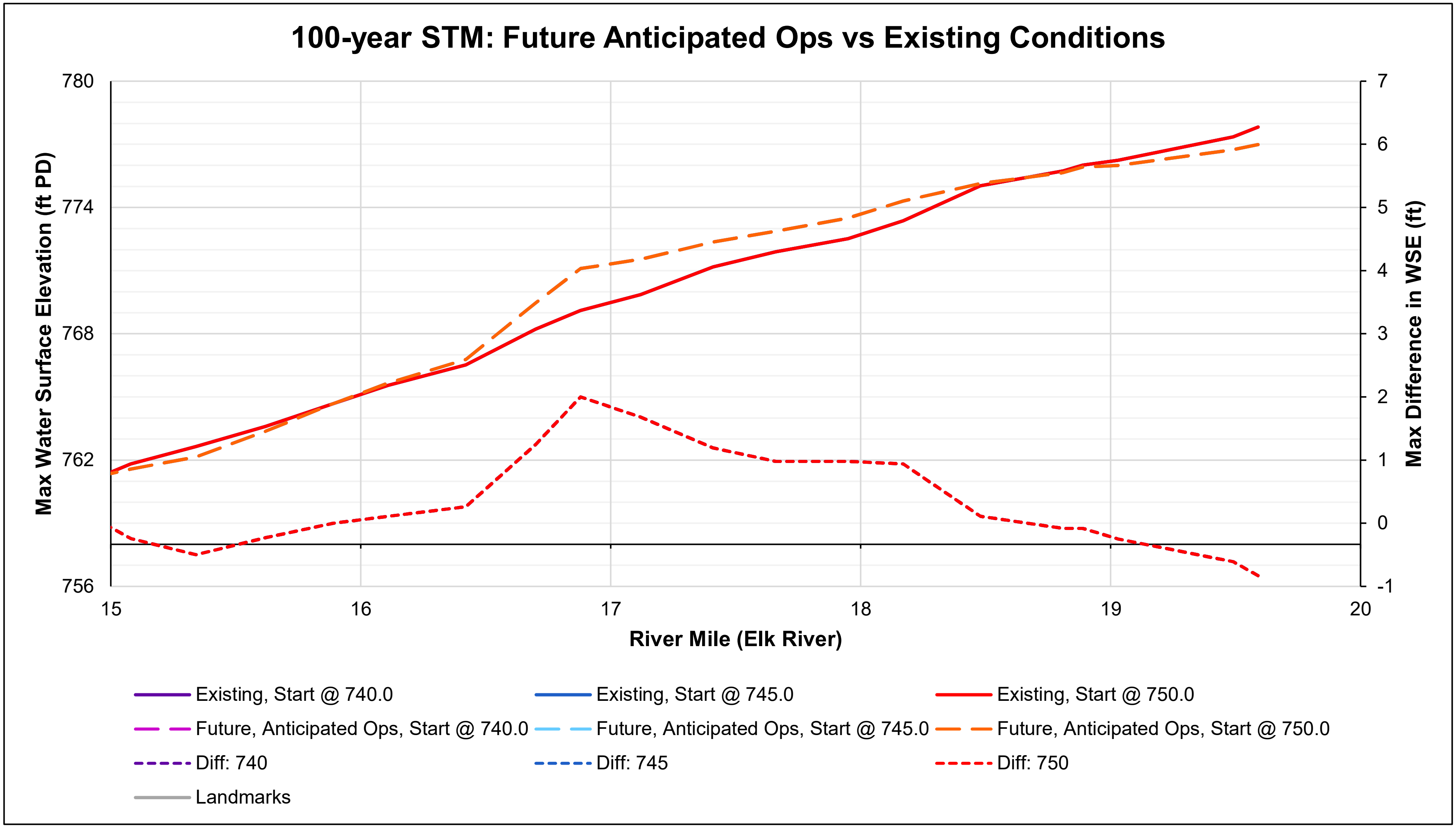


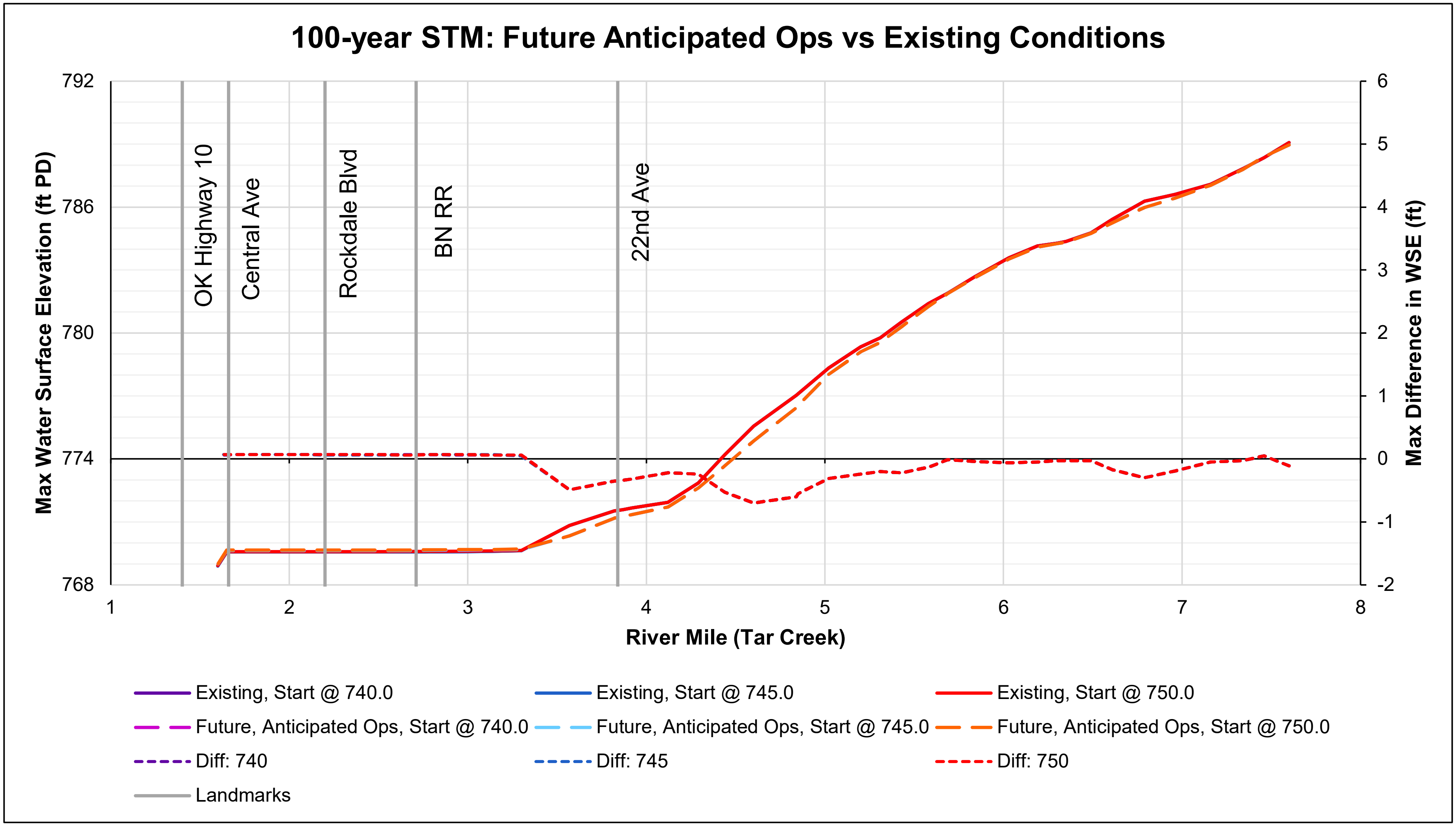
100-year STM: Future Anticipated Ops vs Existing Conditions
E 60 Road
Max Water Surface Elevation (ft PD)
794
790
786
782
778
Max Difference in WSE (ft)
7
6
5
4
3
2
1
0
-1
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
River Mile (Neosho River)
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


100-year STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Spring River)
Highway 60
OK Highway 10
768
766
764
762
760
7
6
5
4
3
2
1
0
-1
0
1
2
3
4
5
6
7
8
9
10
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

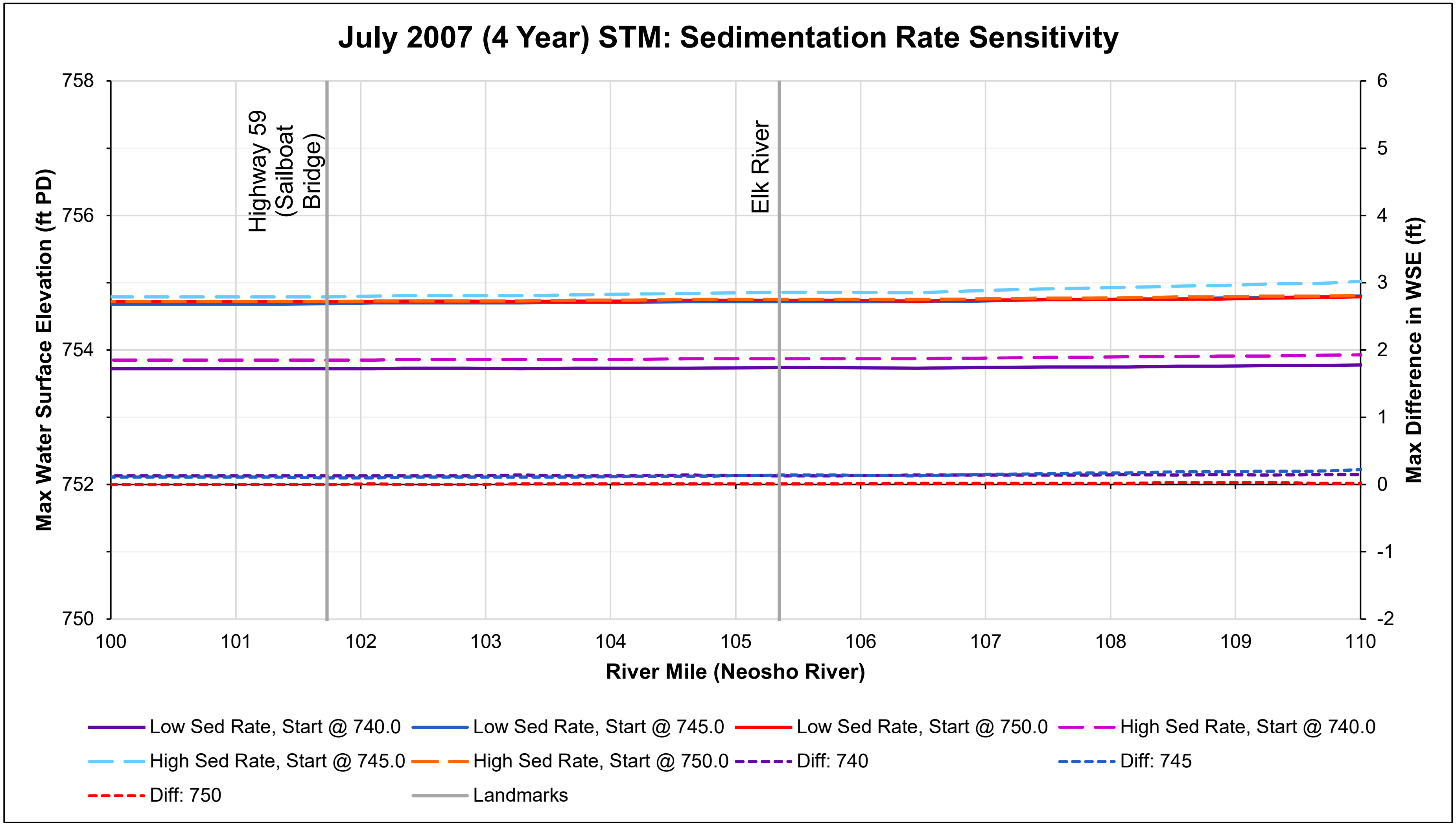

100-year STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
794
786
778
770
762
Max Difference in WSE (ft)
4
3
2
1
0
-1
-2
-3
-4
10
11
12
13
14
15
16
17
18
19
20
21
22
River Mile (Spring River)
Interstate 44
E 57 Road
OK/KS State Line
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


100-year STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Elk River)
764
760
756
752
748
6
5
4
3
2
1
0
-1
-2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
OK Highway 10
OK/MO State Line
Highway 43
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

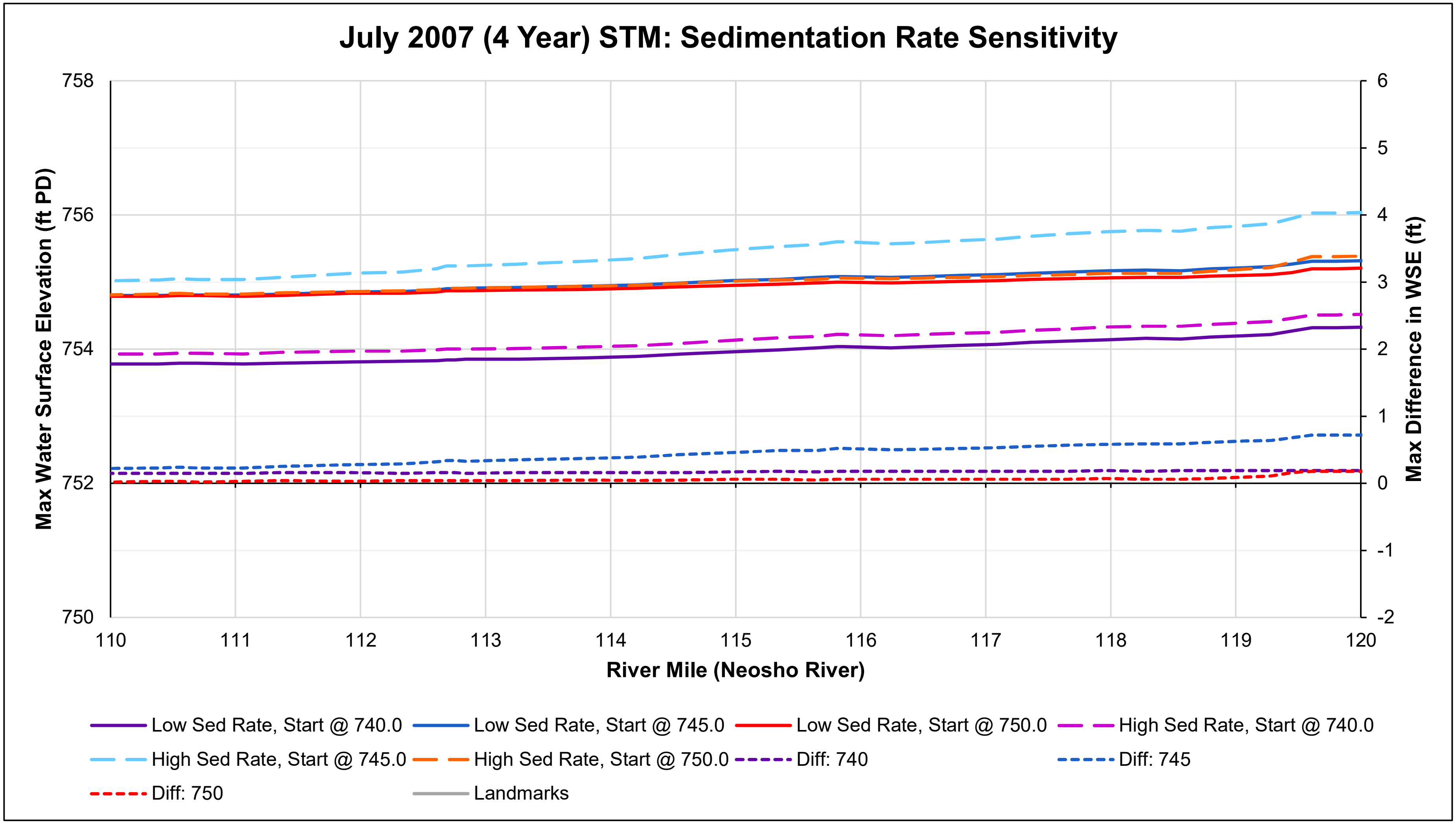

100-year STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
780
774
768
762
756
Max Difference in WSE (ft)
7
6
5
4
3
2
1
0
-1
15
16
17
18
19
20
River Mile (Elk River)
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks



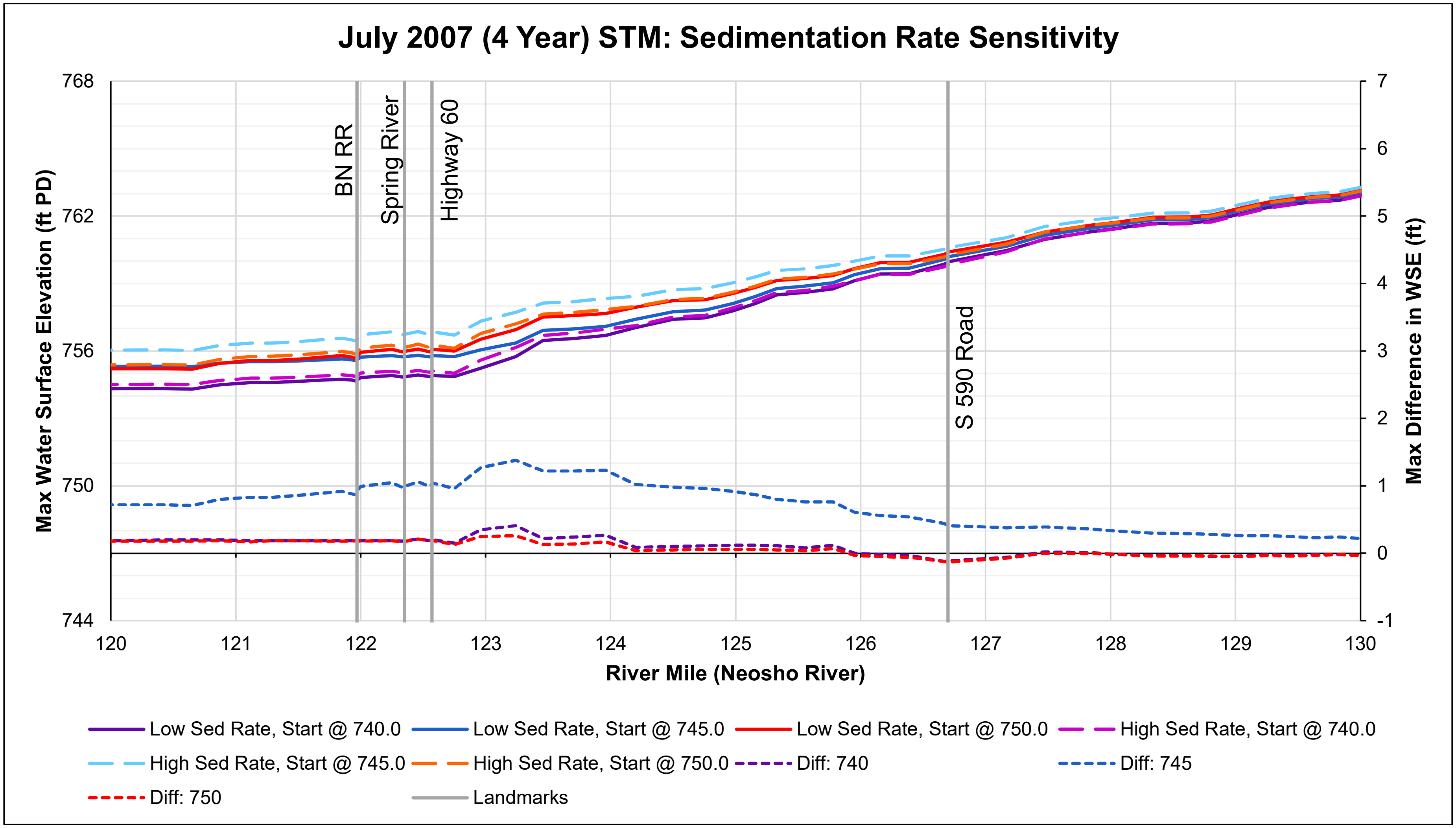
100-year STM: Future Anticipated Ops vs Existing Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Tar Creek)
792
786
780
774
768
6
5
4
3
2
1
0
-1
-2
1
2
3
4
5
6
7
8
OK Highway 10
Central Ave
Rockdale Blvd
BN RR
22nd Ave
Existing, Start @ 740.0
Existing, Start @ 745.0
Existing, Start @ 750.0
Future, Anticipated Ops, Start @ 740.0
Future, Anticipated Ops, Start @ 745.0
Future, Anticipated Ops, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks



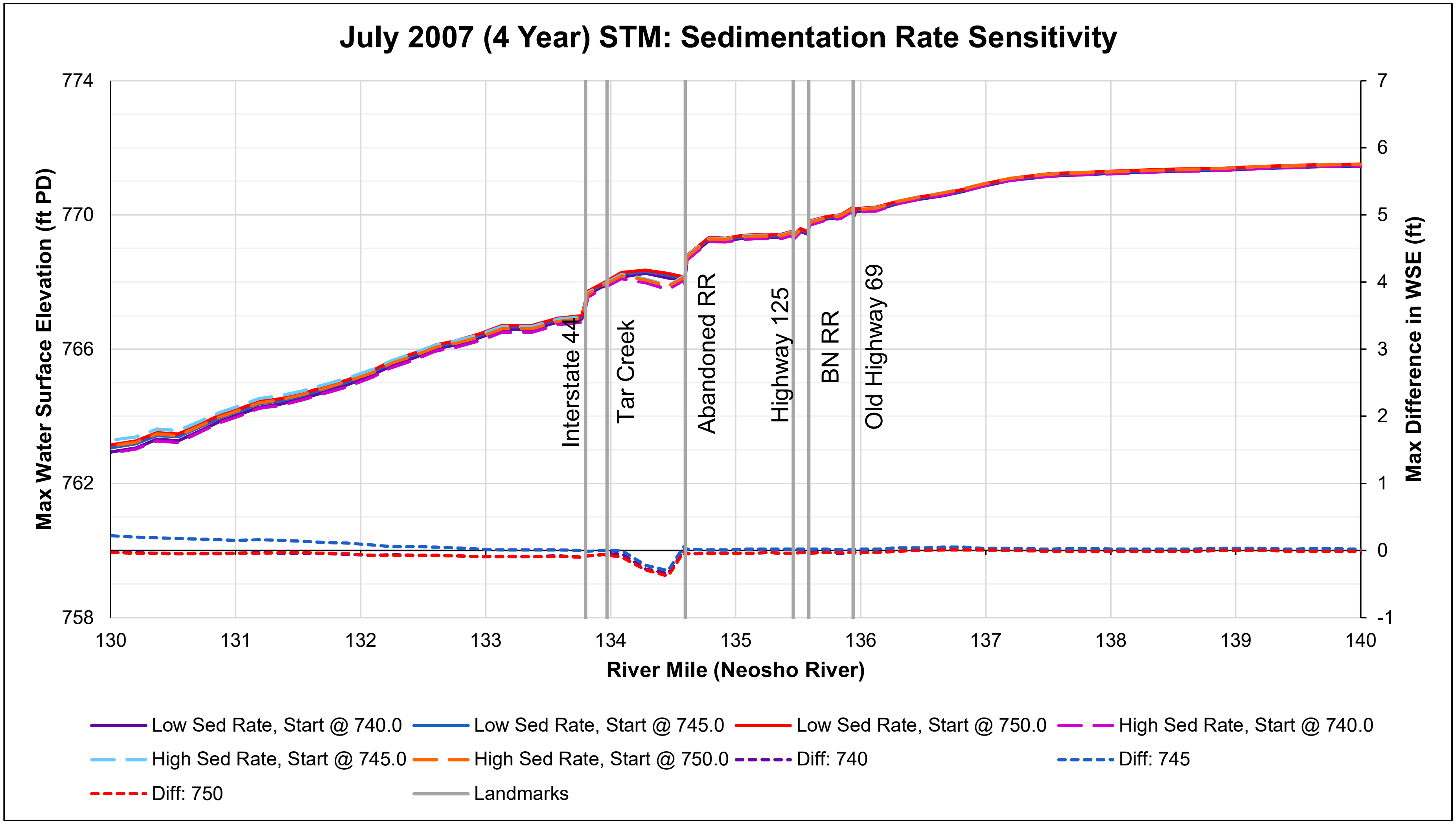
July 2007 (4 Year) STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
758
756
754
752
750
6
5
4
3
2
1
0
-1
-2
100
101
102
103
104
105
106
107
108
109
110
Highway 59 (Sailboat Bridge)
Elk River
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

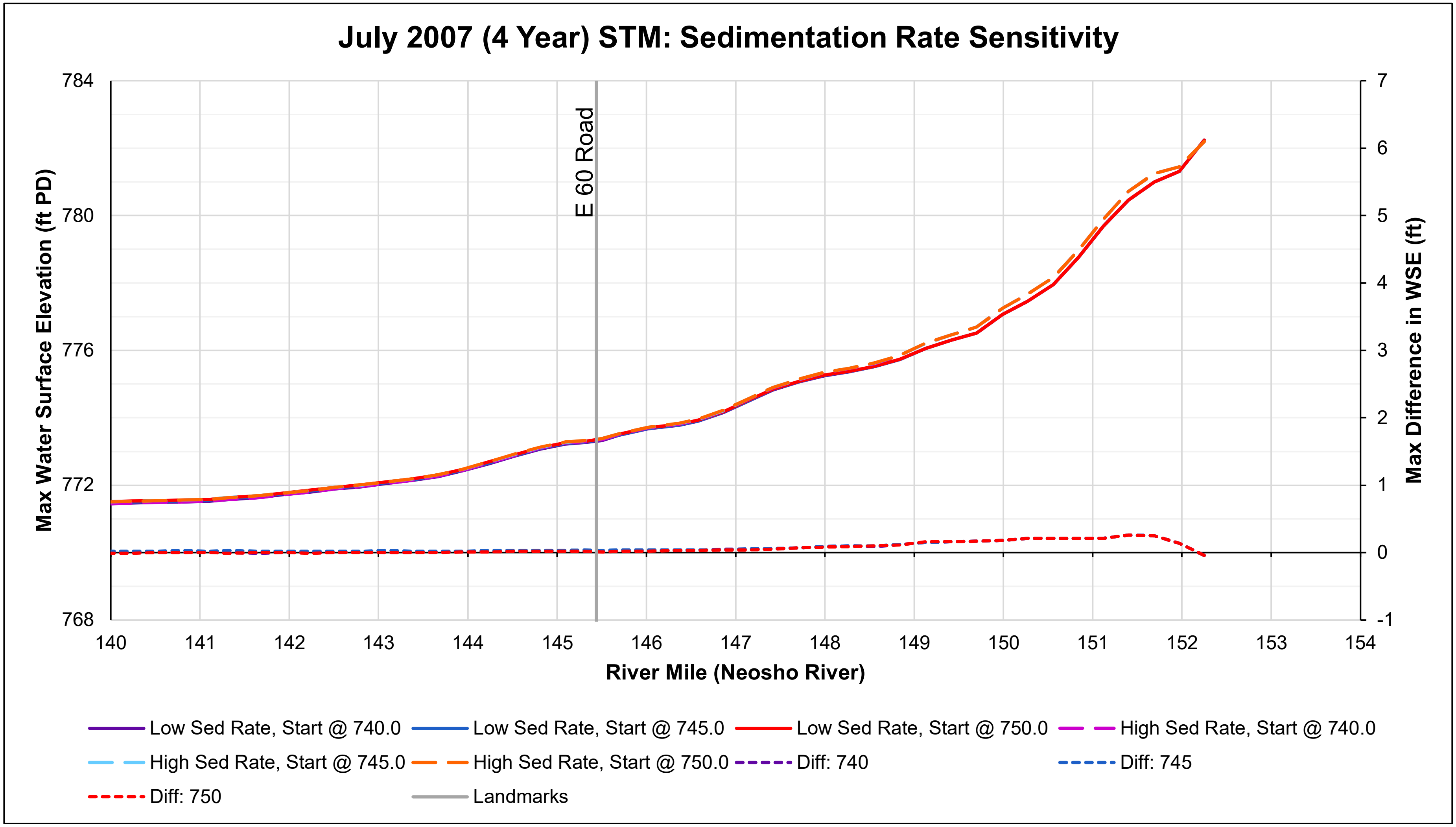


July 2007 (4 Year) STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
758
756
754
752
750
Max Difference in WSE (ft)
6
5
4
3
2
1
0
-1
-2
110
111
112
113
114
115
116
117
118
119
120
River Mile (Neosho River)
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

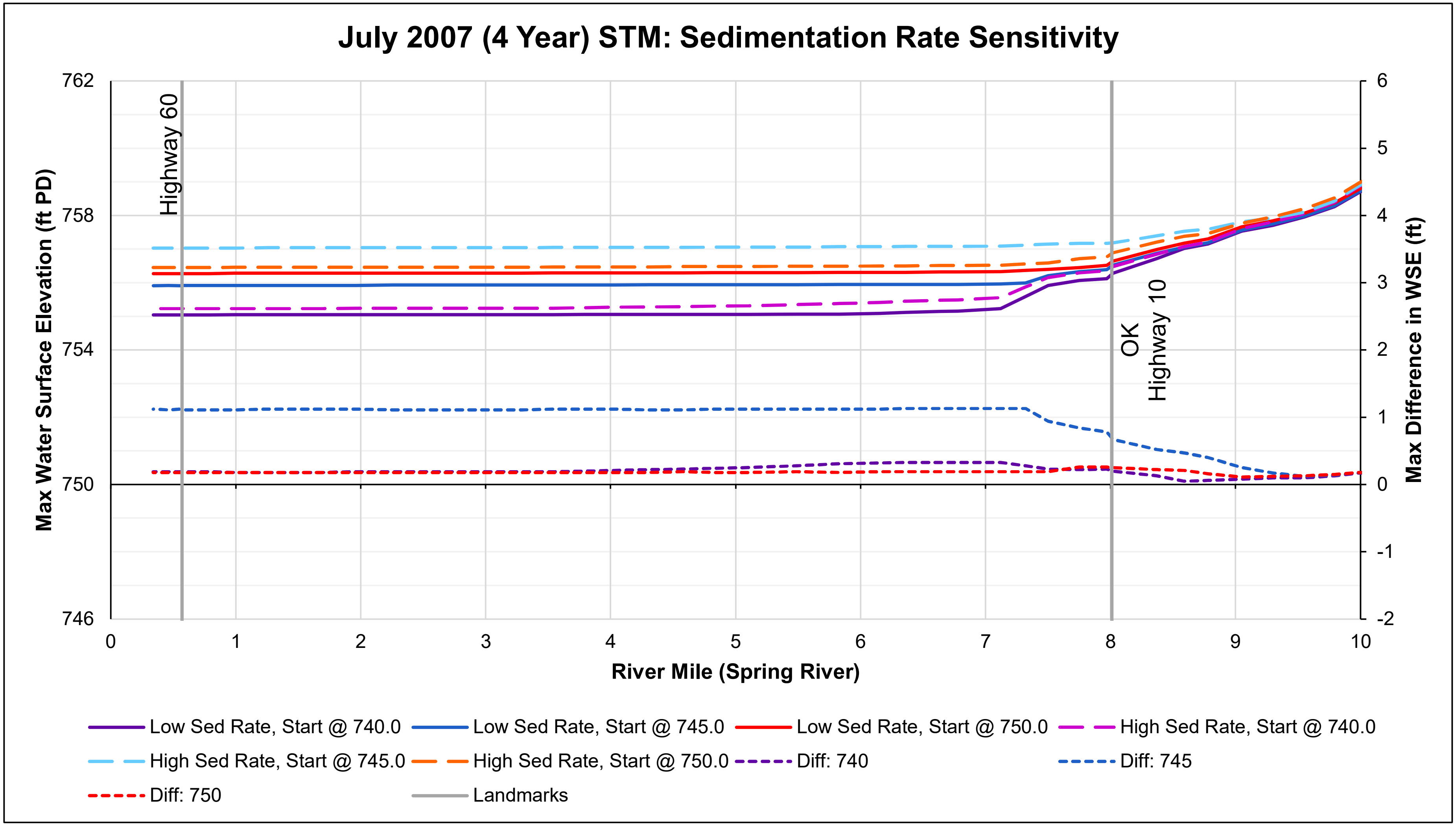


July 2007 (4 Year) STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
768
762
756
750
744
7
6
5
4
3
2
1
0
-1
120
121
122
123
124
125
126
127
128
129
130
BN RR
Spring River
Highway 60
S 590 Road
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

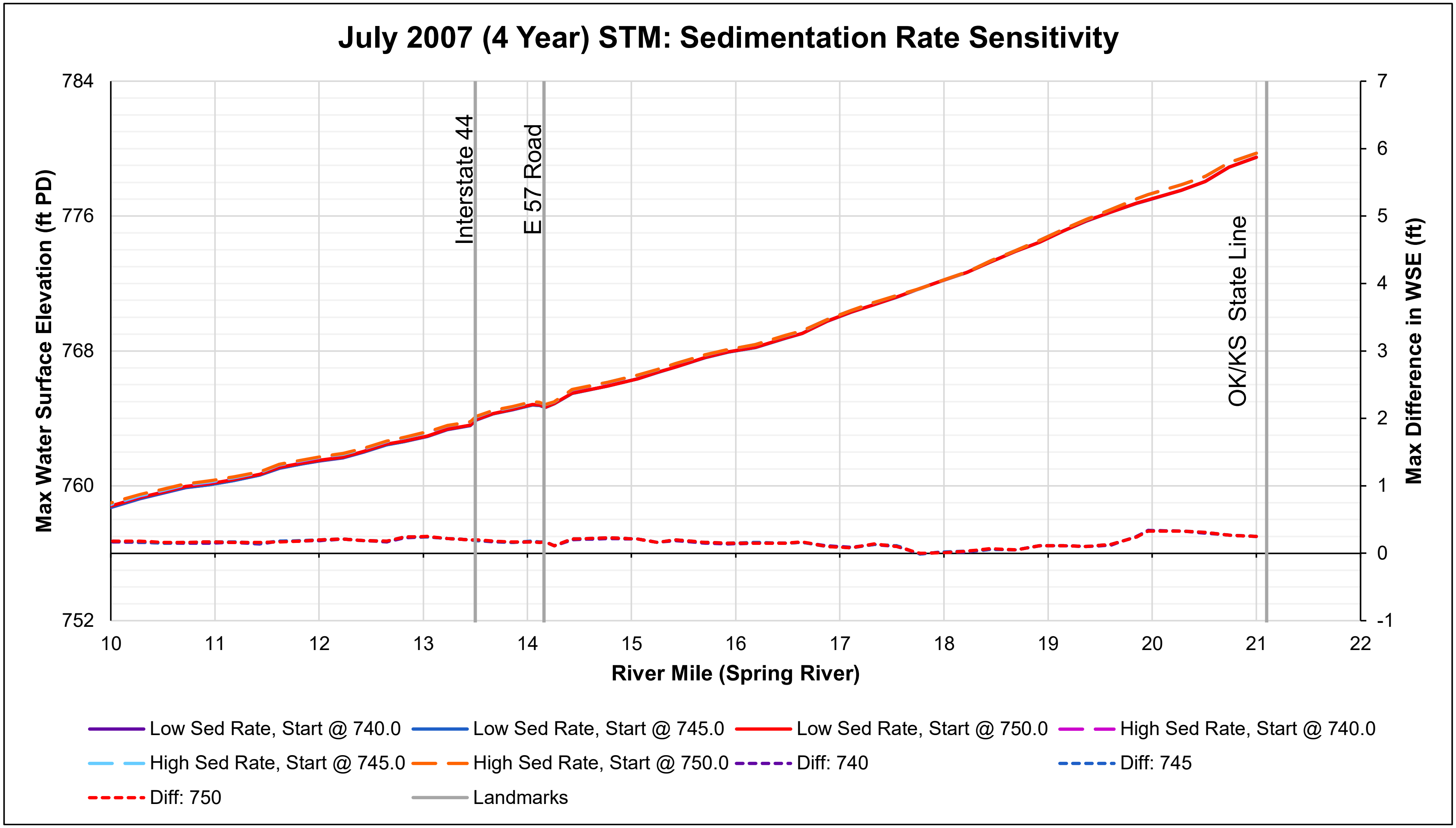

July 2007 (4 Year) STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
774
770
766
762
758
7
6
5
4
3
2
1
0
-1
130
131
132
133
134
135
136
137
138
139
140
Interstate 44
Tar Creek
Abandoned RR
Highway 125
BN RR
Old Highway 69
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

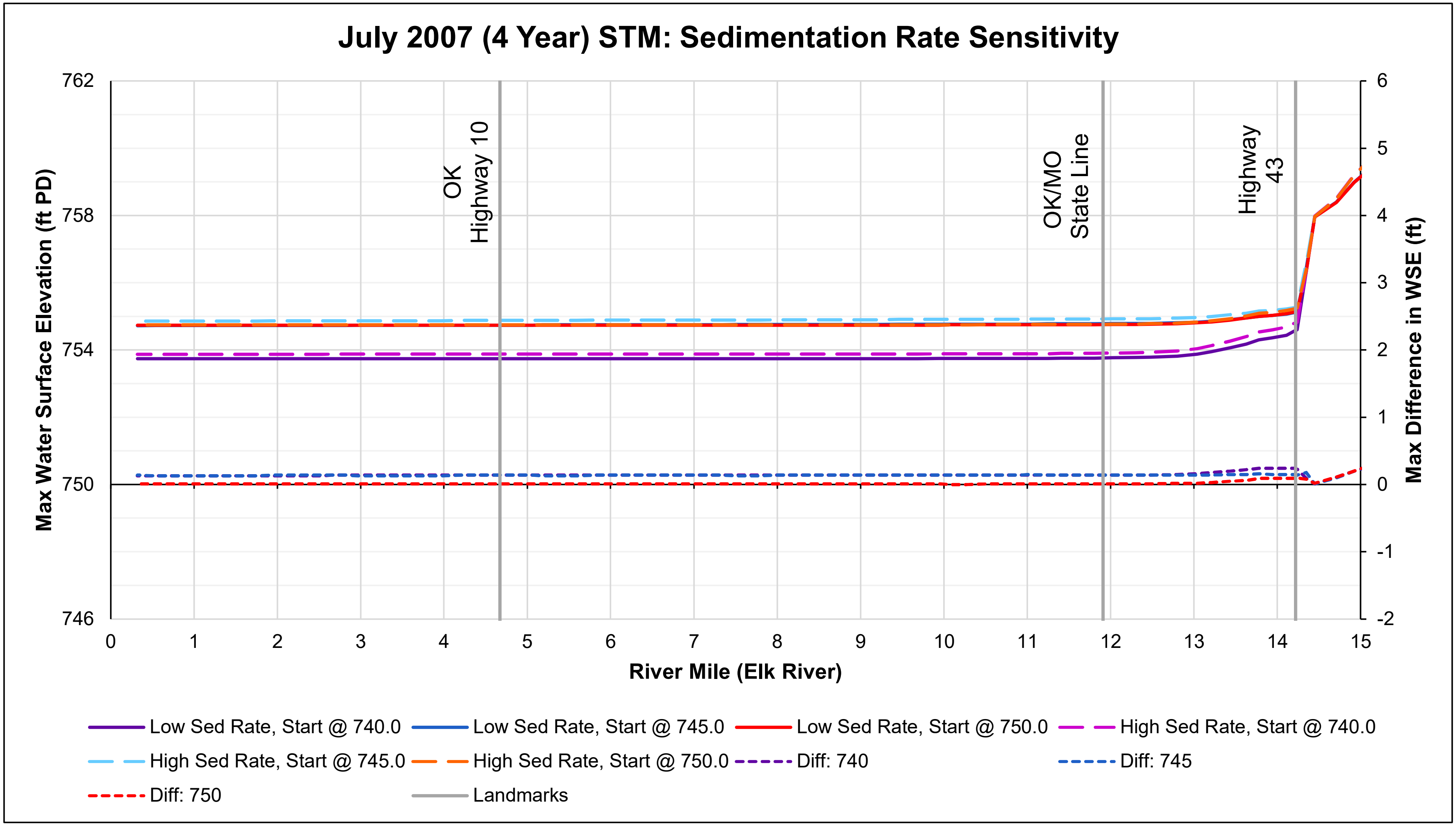


July 2007 (4 Year) STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
784
780
776
772
768
Max Difference in WSE (ft)
7
6
5
4
3
2
1
0
-1
River Mile (Neosho River)
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
E 60 Road
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

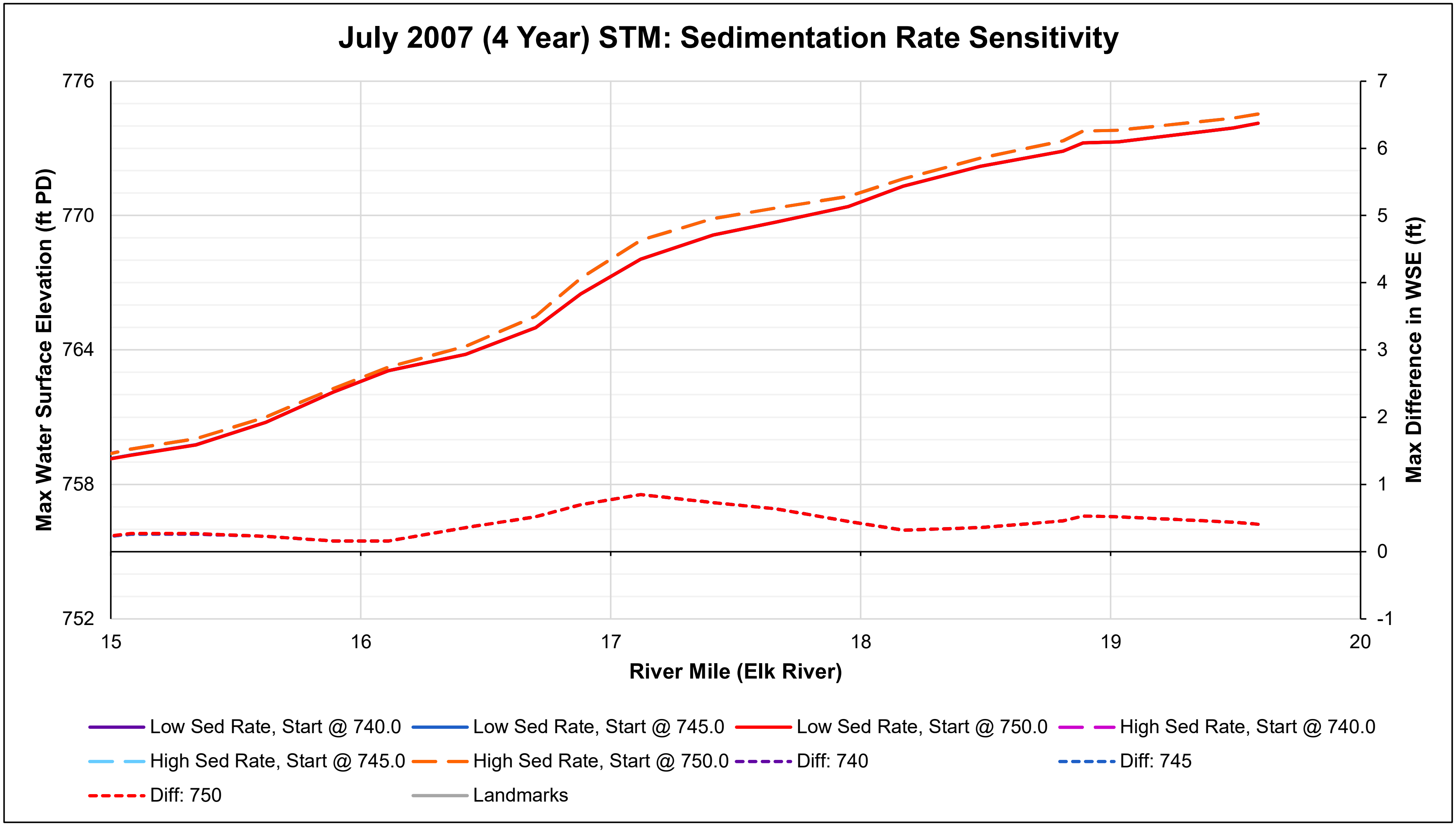


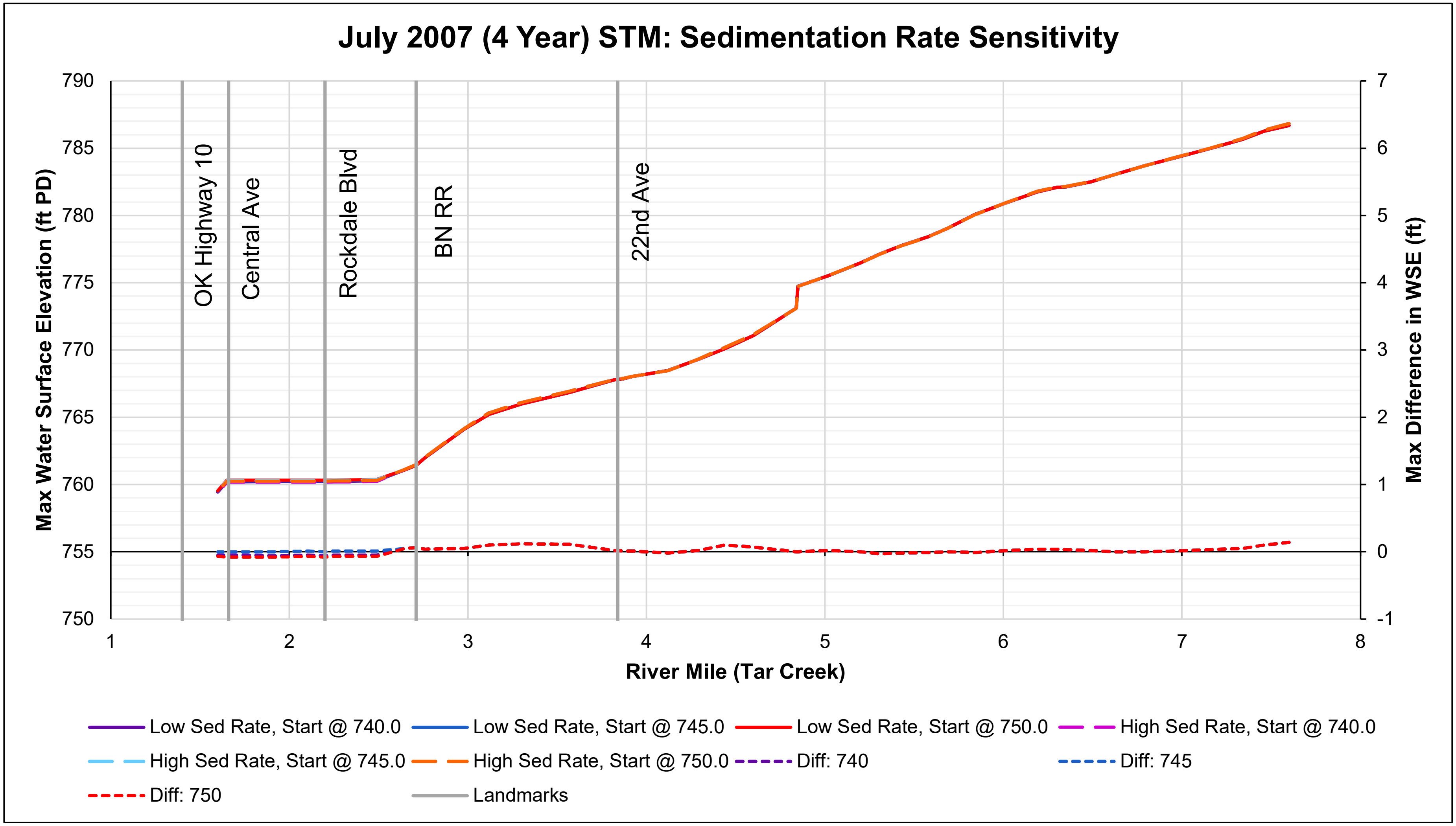
July 2007 (4 Year) STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Spring River)
Highway 60
OK Highway 10
762
758
754
750
746
6
5
4
3
2
1
0
-1
-2
0
1
2
3
4
5
6
7
8
9
10
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


July 2007 (4 Year) STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
784
776
768
760
752
Max Difference in WSE (ft)
7
6
5
4
3
2
1
0
-1
10
11
12
13
14
15
16
17
18
19
20
21
22
River Mile (Spring River)
Interstate 44
E 57 Road
OK/KS State Line
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

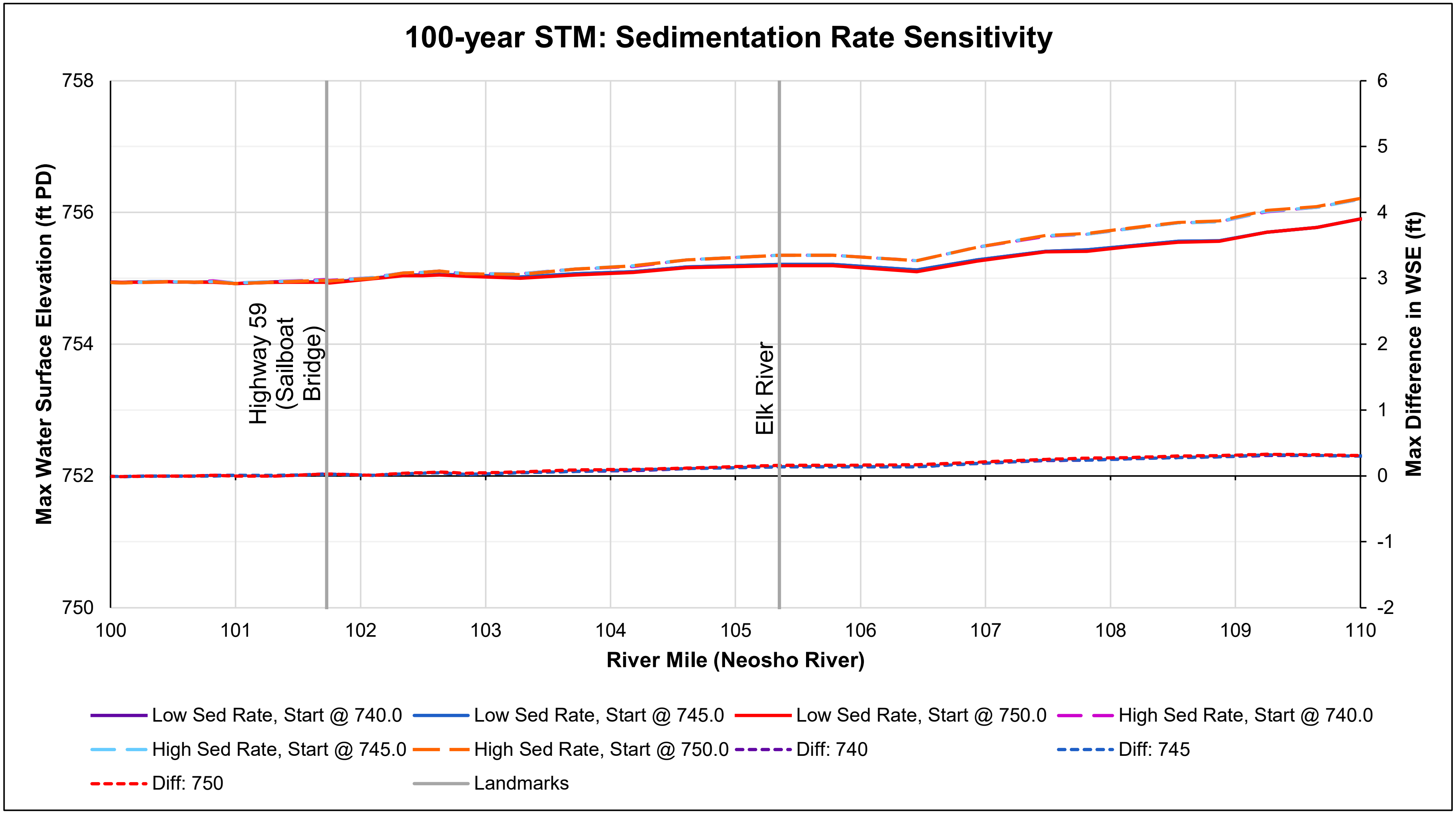


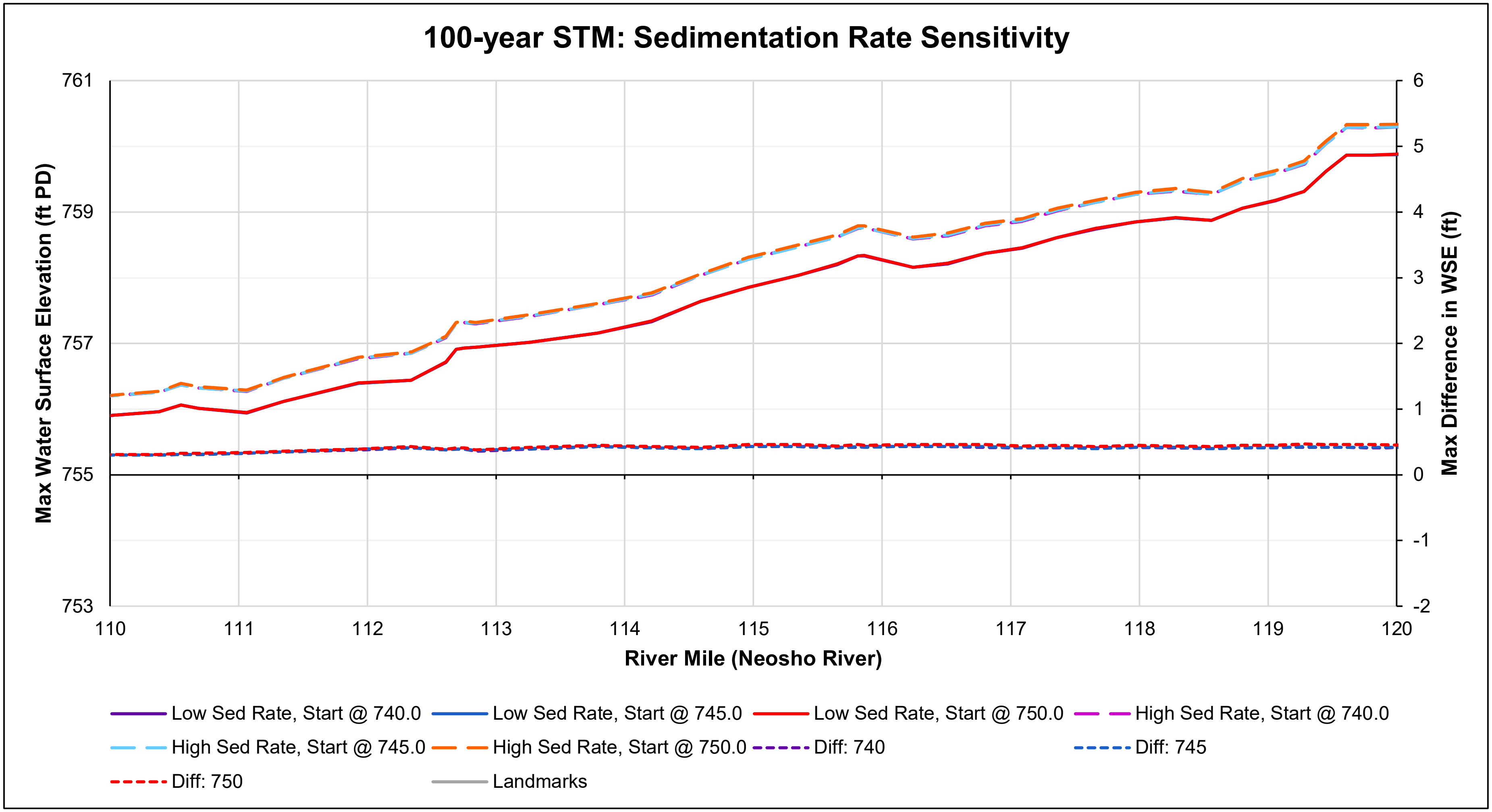
July 2007 (4 Year) STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Elk River)
762
758
754
750
746
6
5
4
3
2
1
0
-1
-2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
OK Highway 10
OK/MO State Line
Highway 43
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

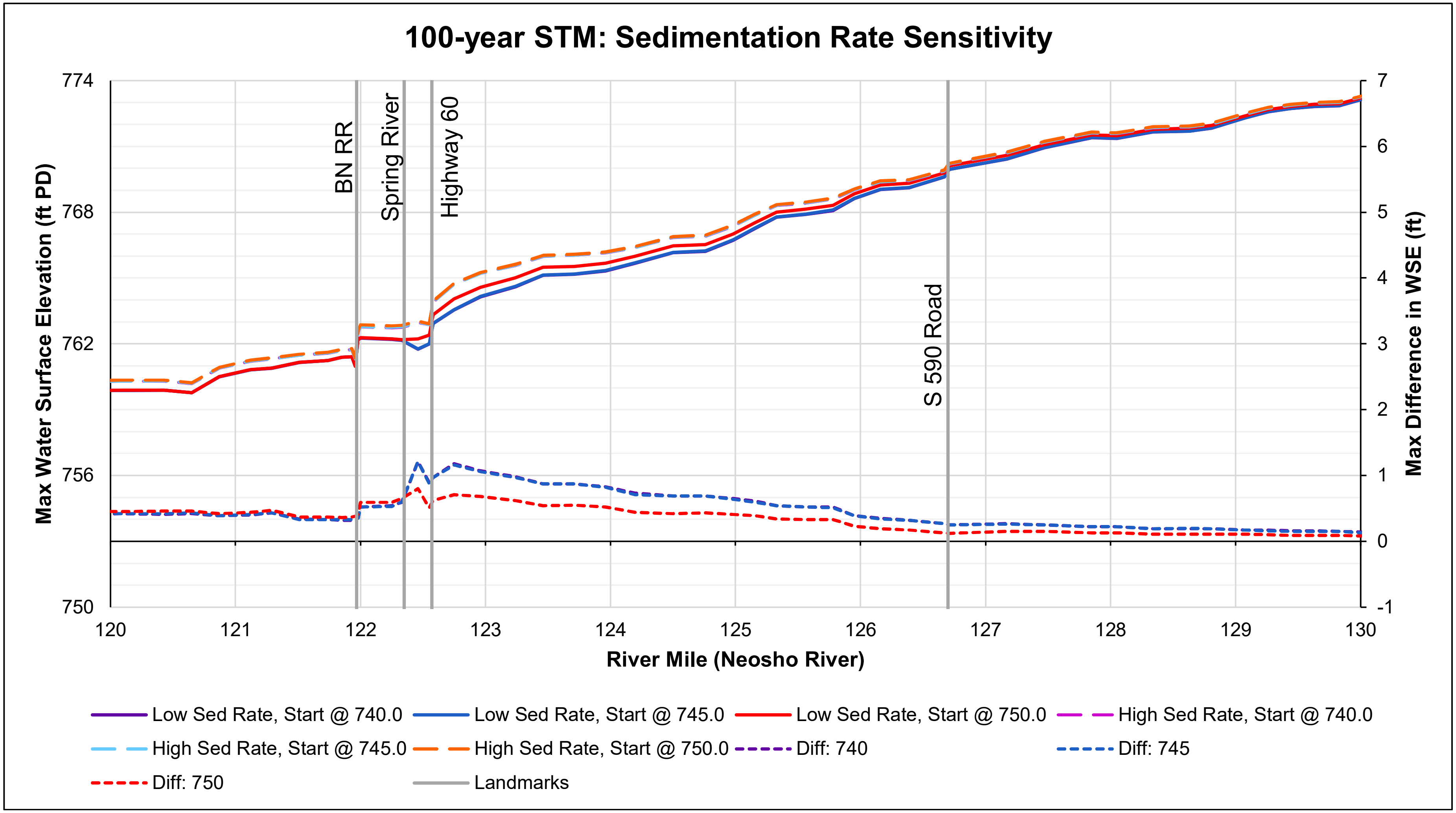

July 2007 (4 Year) STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Elk River)
776
770
764
758
752
7
6
5
4
3
2
1
0
-1
15
16
17
18
19
20
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

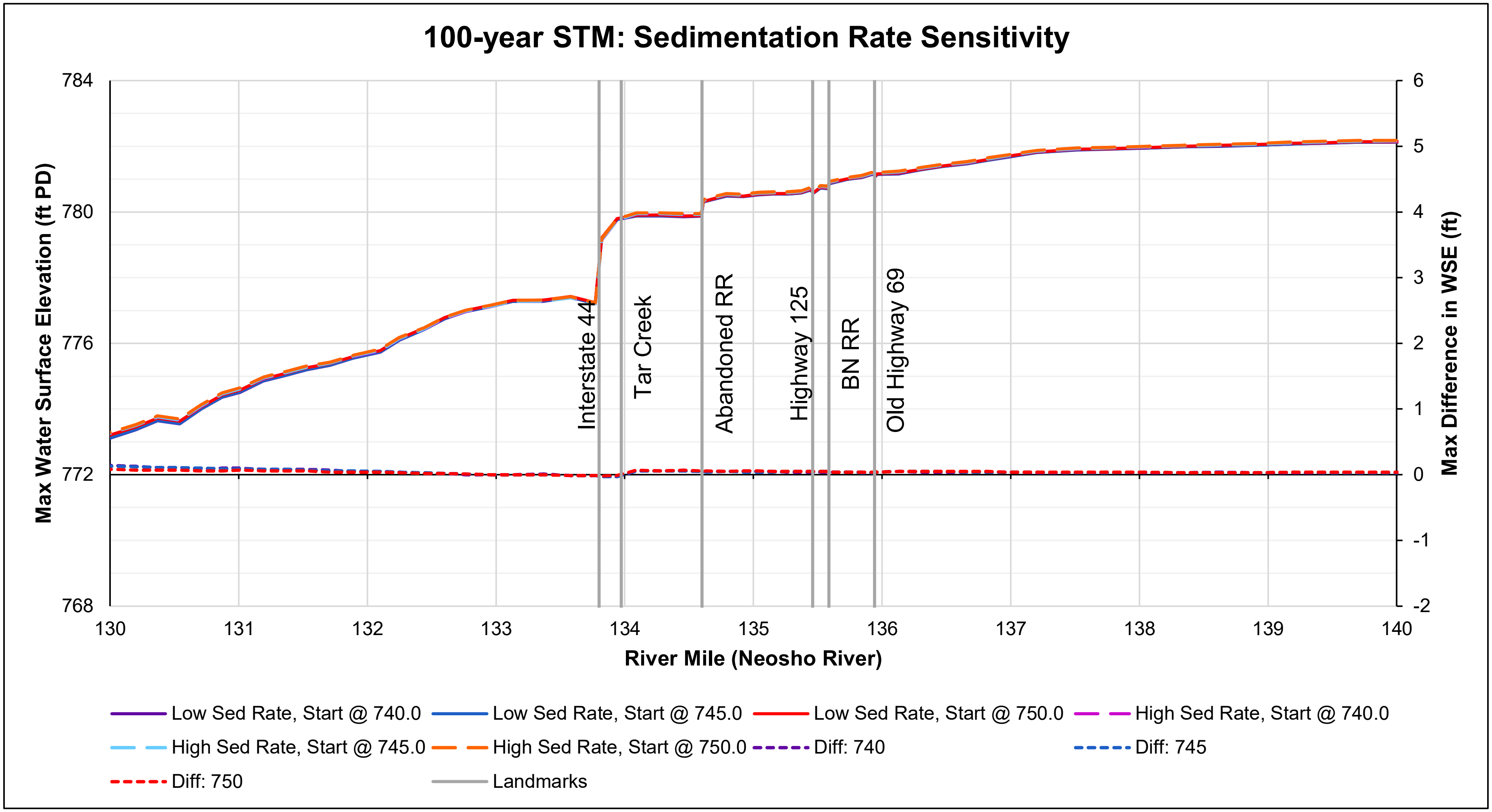


July 2007 (4 Year) STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Tar Creek)
OK Highway 10
Central Ave
Rockdale Blvd
BN RR
22nd Ave
790
785
780
775
770
765
760
755
750
7
6
5
4
3
2
1
0
-1
1
2
3
4
5
6
7
8
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


100-year STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
Highway 59 (Sailboat Bridge)
Elk River
758
756
754
752
750
6
5
4
3
2
1
0
-1
-2
100
101
102
103
104
105
106
107
108
109
110
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


100-year STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
761
759
757
755
753
6
5
4
3
2
1
0
-1
-2
110
111
112
113
114
115
116
117
118
119
120
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


100-year STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
BN RR
Spring River
Highway 60
S 590 Road
774
768
762
756
750
7
6
5
4
3
2
1
0
-1
120
121
122
123
124
125
126
127
128
129
130
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


100-year STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
784
780
776
772
768
6
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130
131
132
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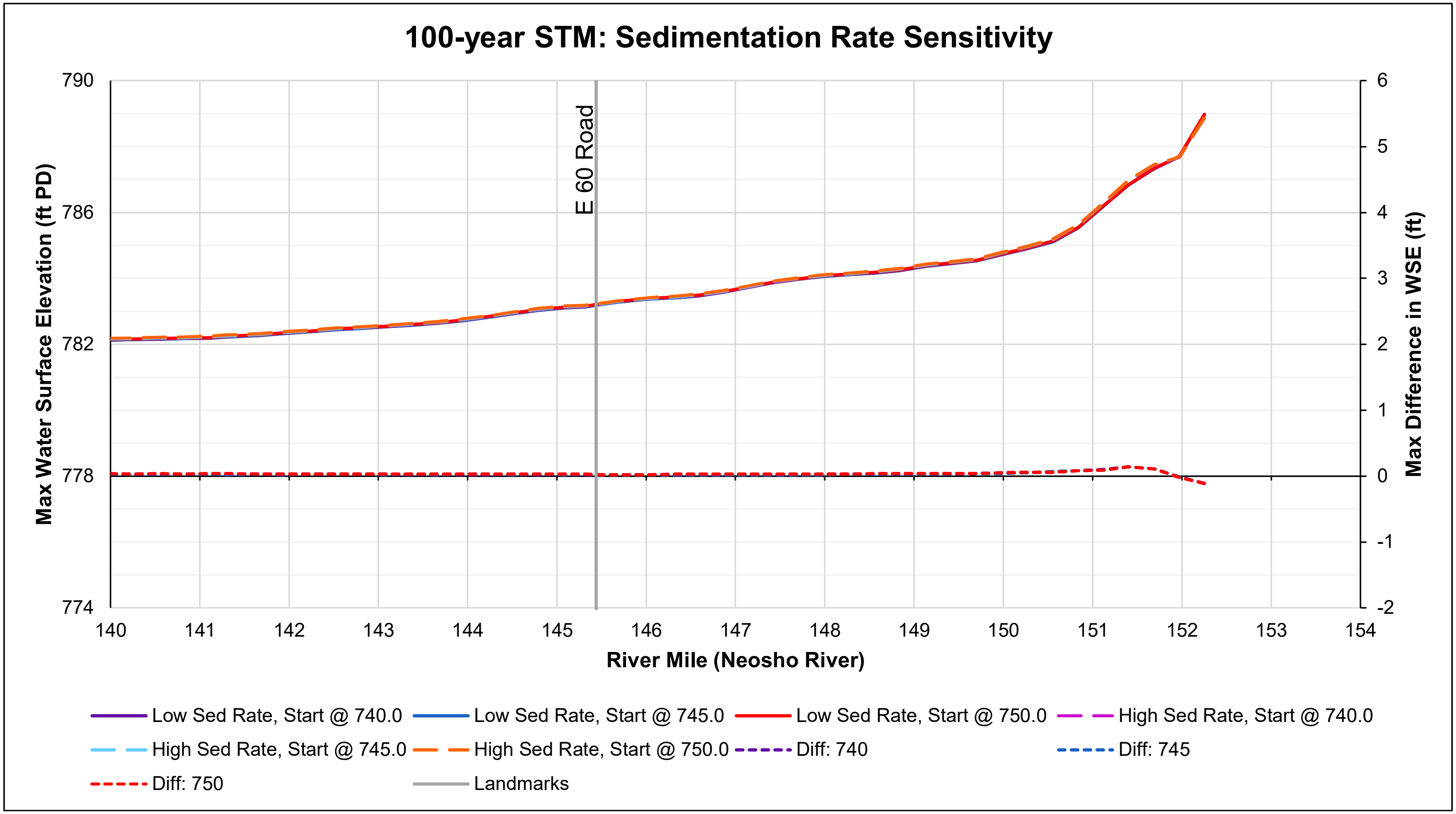
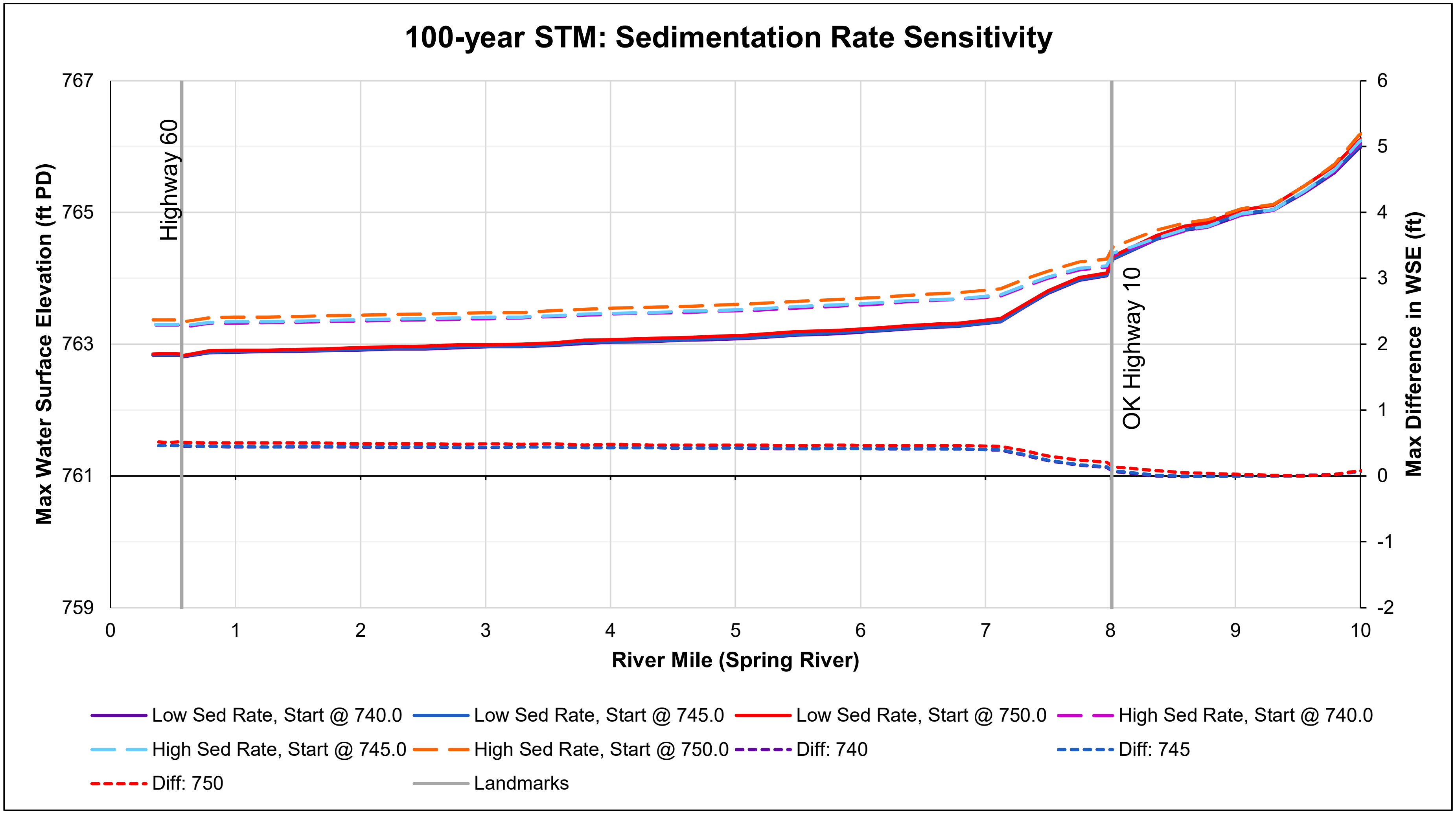
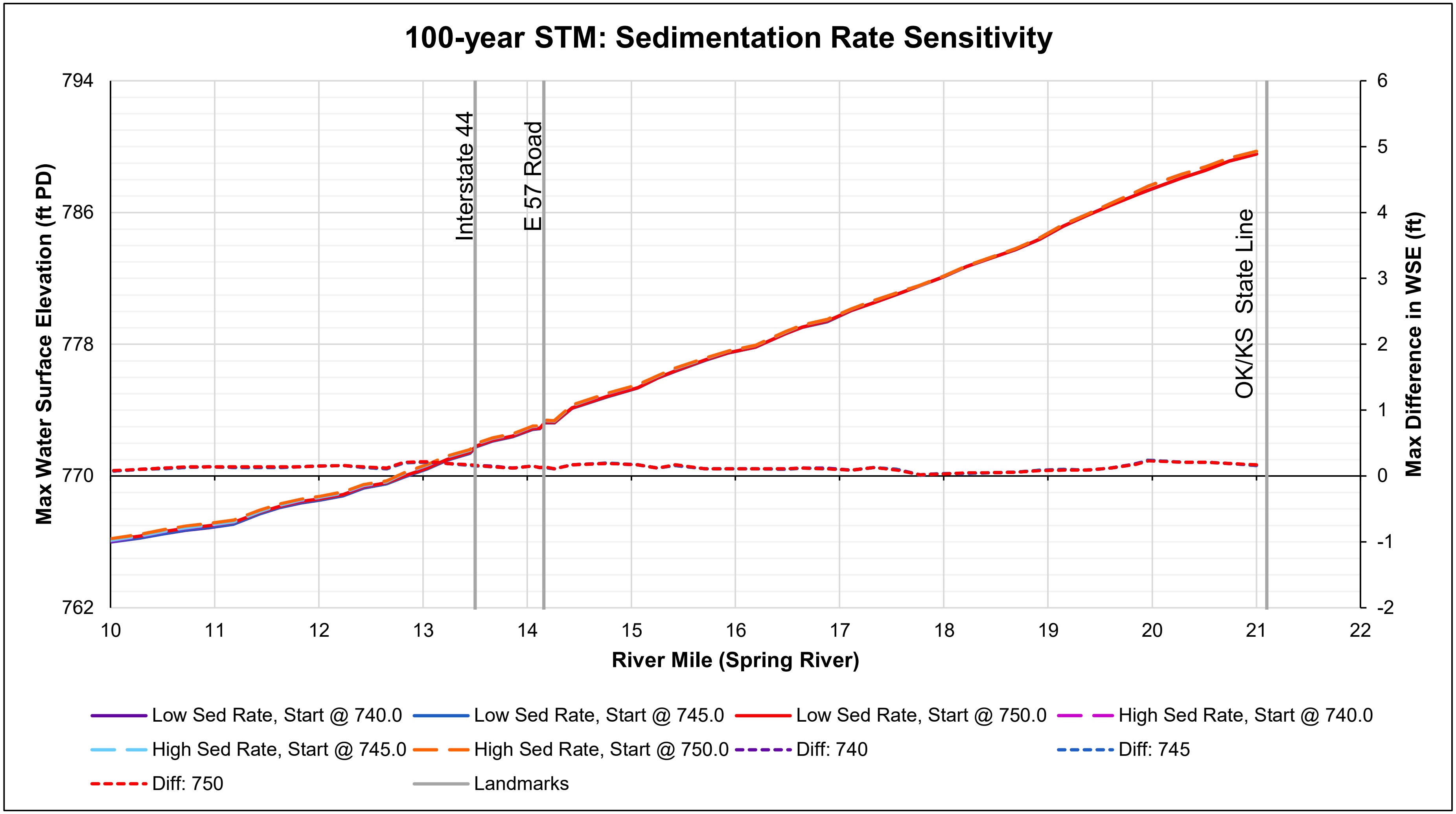
136
137
138
139
140
Interstate 44
Tar Creek
Abandoned RR
Highway 125
BN RR
Old Highway 69
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

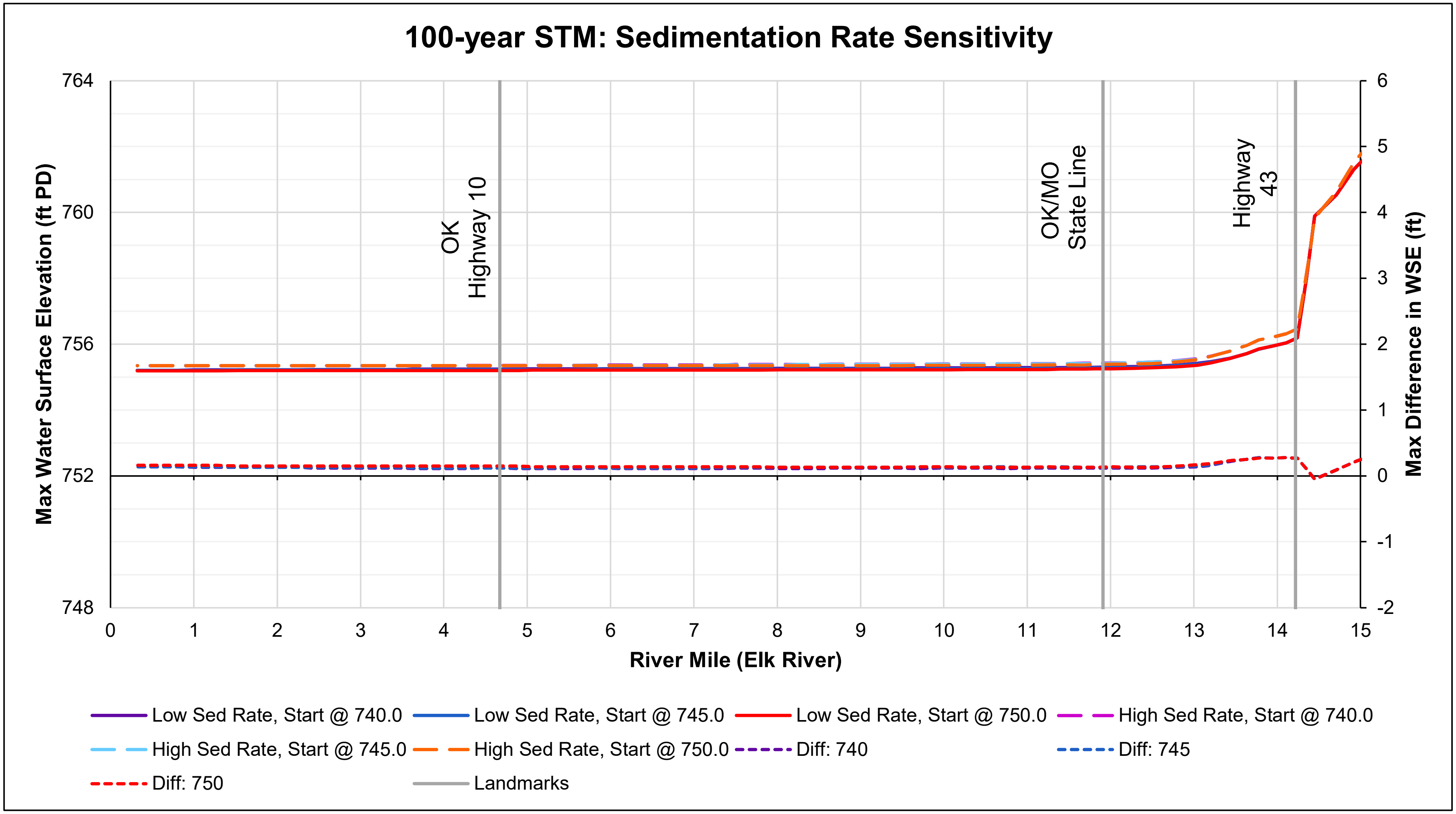

100-year STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
E 60 Road
790
786
782
778
774
6
5
4
3
2
1
0
-1
-2
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

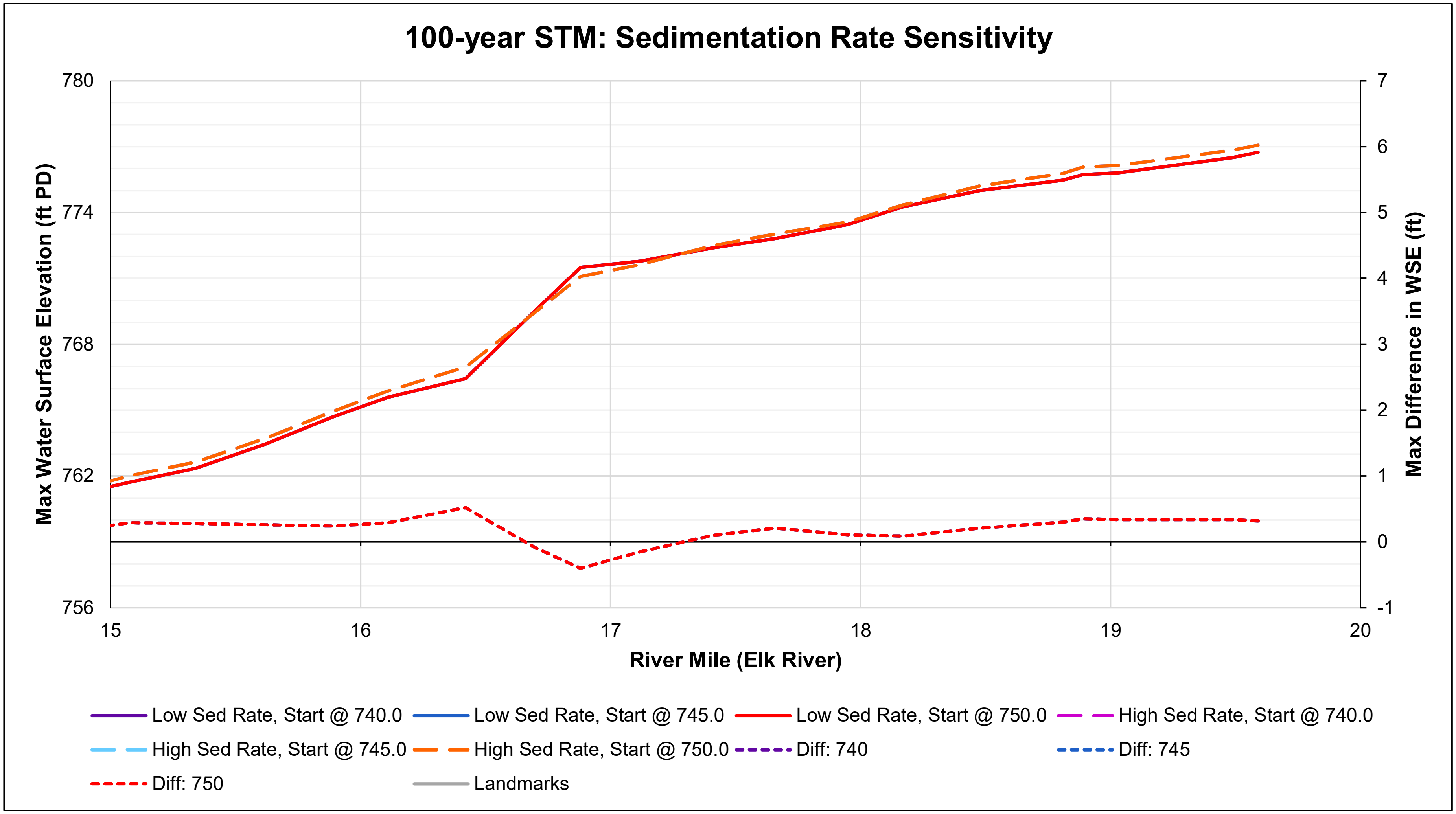


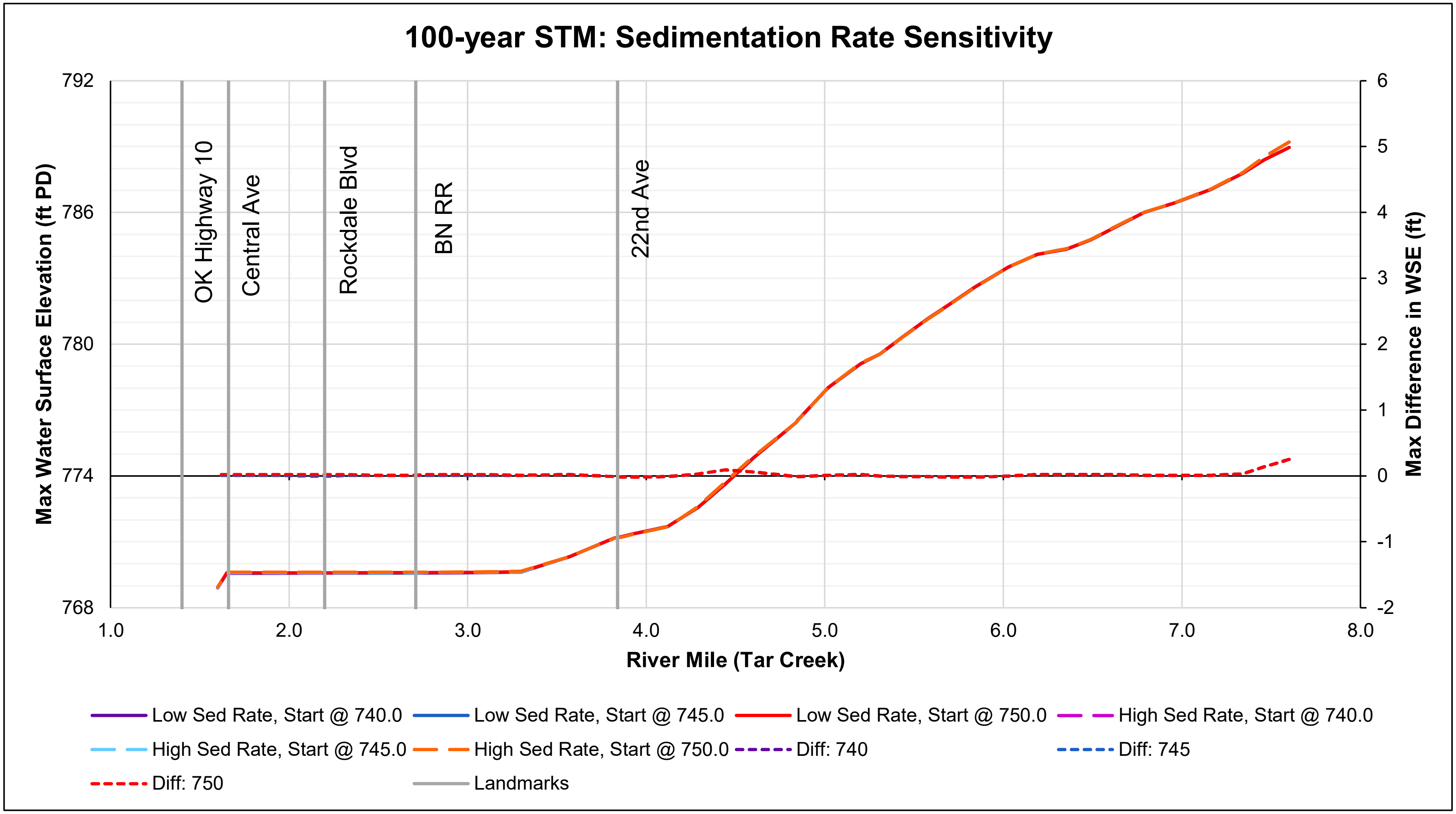
100-year STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Spring River)
Highway 60
OK Highway 10
767
765
763
761
759
6
5
4
3
2
1
0
-1
-2
0
1
2
3
4
5
6
7
8
9
10
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

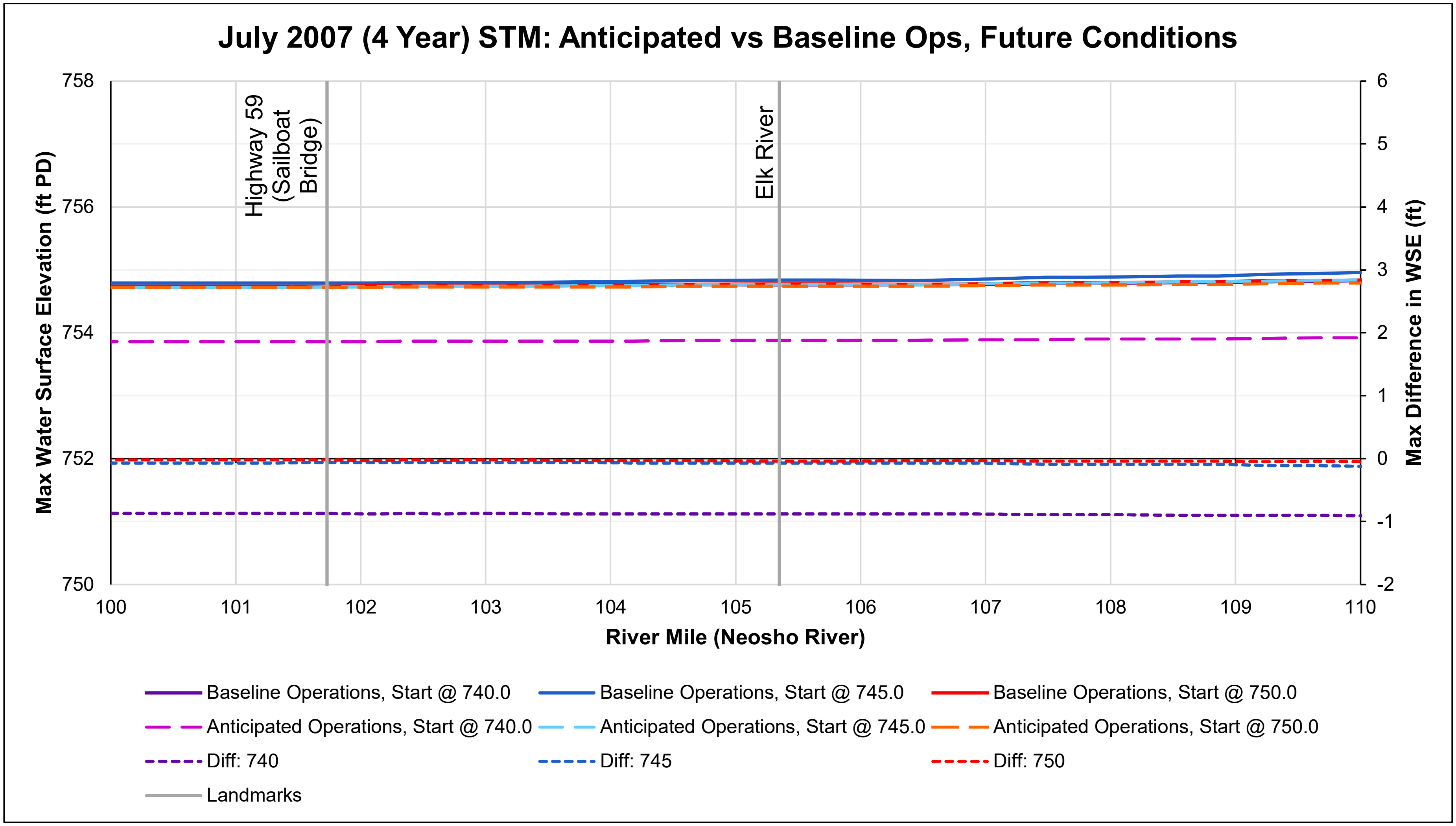


100-year STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
794
786
778
770
762
Max Difference in WSE (ft)
6
5
4
3
2
1
0
-1
-2
River Mile (Spring River)
10
11
12
13
14
15
16
17
18
19
20
21
22
Interstate 44
E 57 Road
OK/KS State Line
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

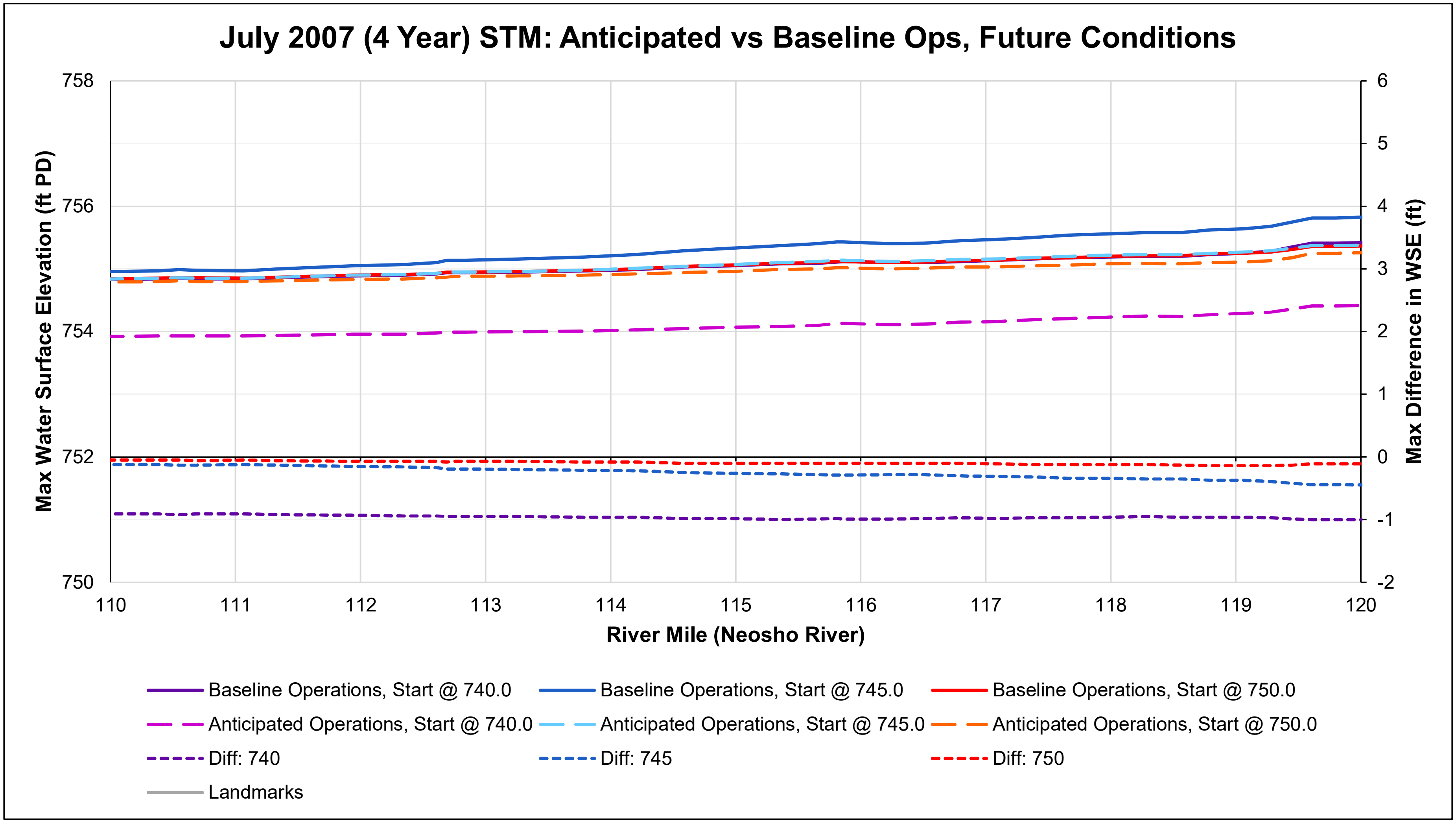

100-year STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
764
760
756
752
748
Max Difference in WSE (ft)
6
5
4
3
2
1
0
-1
-2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
River Mile (Elk River)
OK Highway 10
OK/MO State Line
Highway 43
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


100-year STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
780
774
768
762
756
Max Difference in WSE (ft)
7
6
5
4
3
2
1
0
-1
15
16
17
18
19
20
River Mile (Elk River)
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


100-year STM: Sedimentation Rate Sensitivity
Max Water Surface Elevation (ft PD)
792
786
780
774
768
Max Difference in WSE (ft)
6
5
4
3
2
1
0
-1
-2
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
River Mile (Tar Creek)
OK Highway 10
Central Ave
Rockdale Blvd
BN RR
22nd Ave
Low Sed Rate, Start @ 740.0
Low Sed Rate, Start @ 745.0
Low Sed Rate, Start @ 750.0
High Sed Rate, Start @ 740.0
High Sed Rate, Start @ 745.0
High Sed Rate, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks



July 2007 (4 Year) STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
758
756
754
752
750
Max Difference in WSE (ft)
6
5
4
3
2
1
0
-1
-2
Highway 59 (Sailboat Bridge)
Elk River
100
101
102
103
104
105
106
107
108
109
110
River Mile (Neosho River)
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks



July 2007 (4 Year) STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
758
756
754
752
750
Max Difference in WSE (ft)
6
5
4
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2
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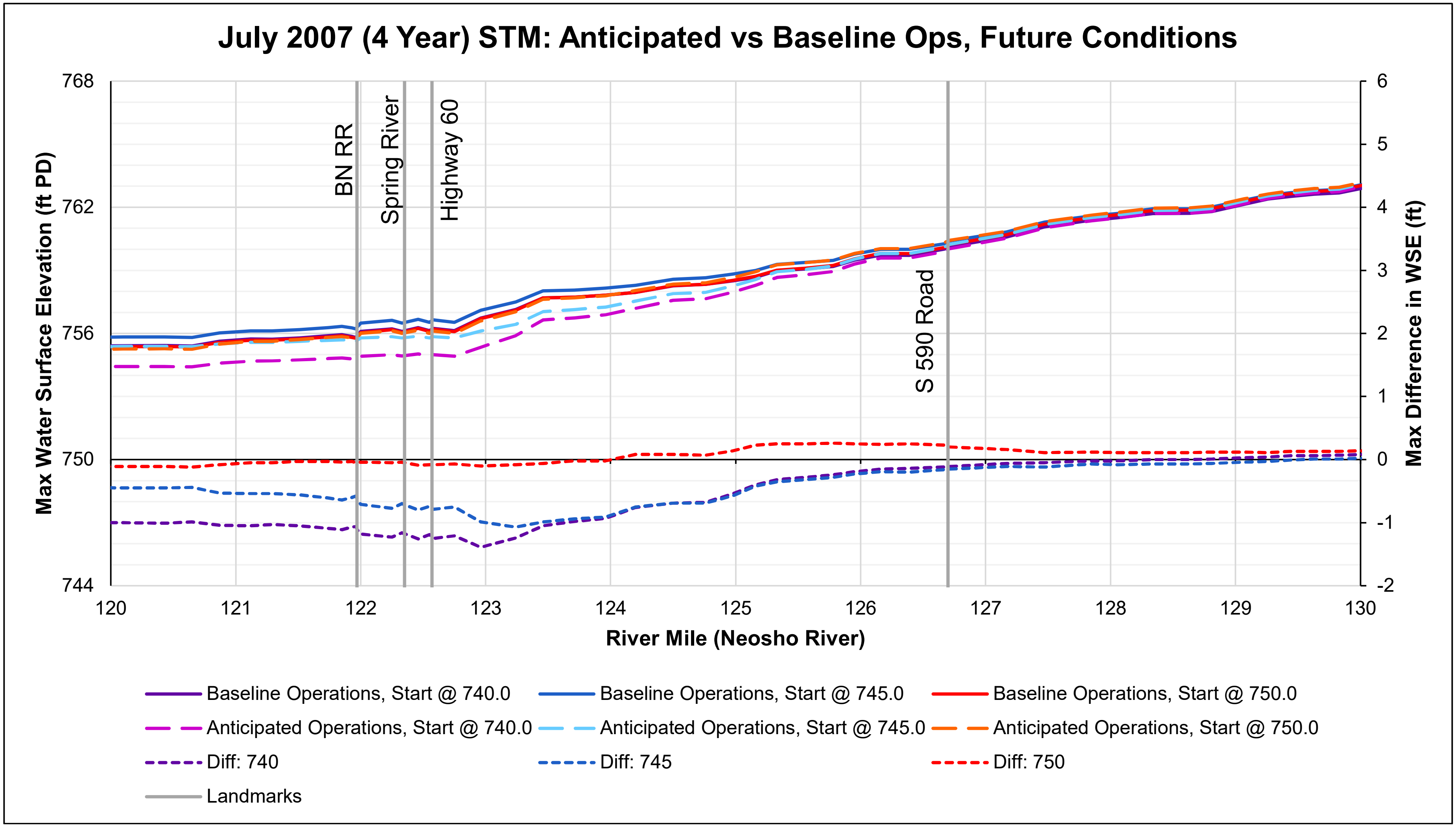
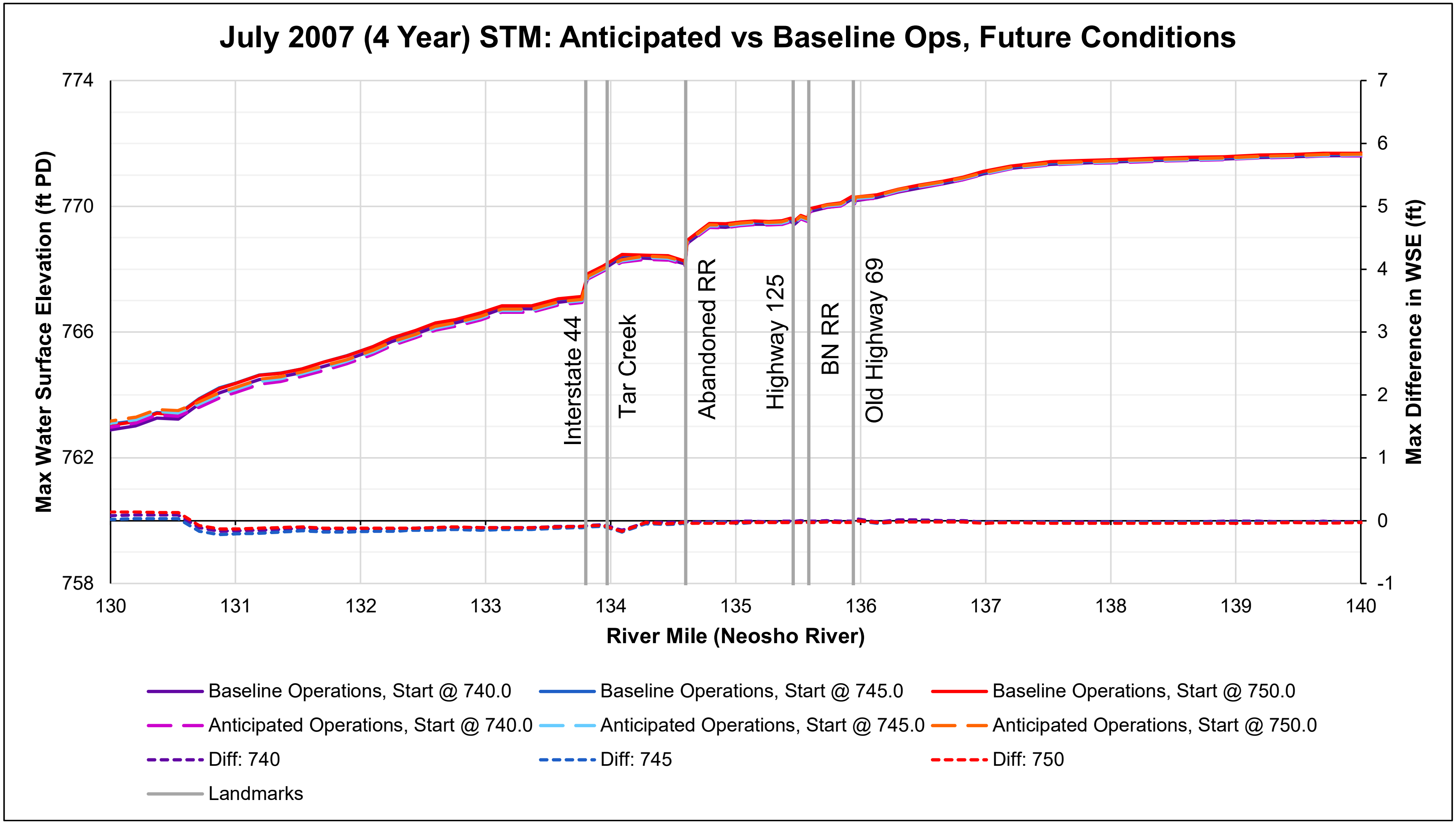
-1
-2
110
111
112
113
114
115
116
117
118
119
120
River Mile (Neosho River)
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks



July 2007 (4 Year) STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
768
762
756
750
744
6
5
4
3
2
1
0
-1
-2
120
121
122
123
124
125
126
127
128
129
130
BN RR
Spring River
Highway 60
S 590 Road
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks



July 2007 (4 Year) STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
774
770
766
762
758
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1
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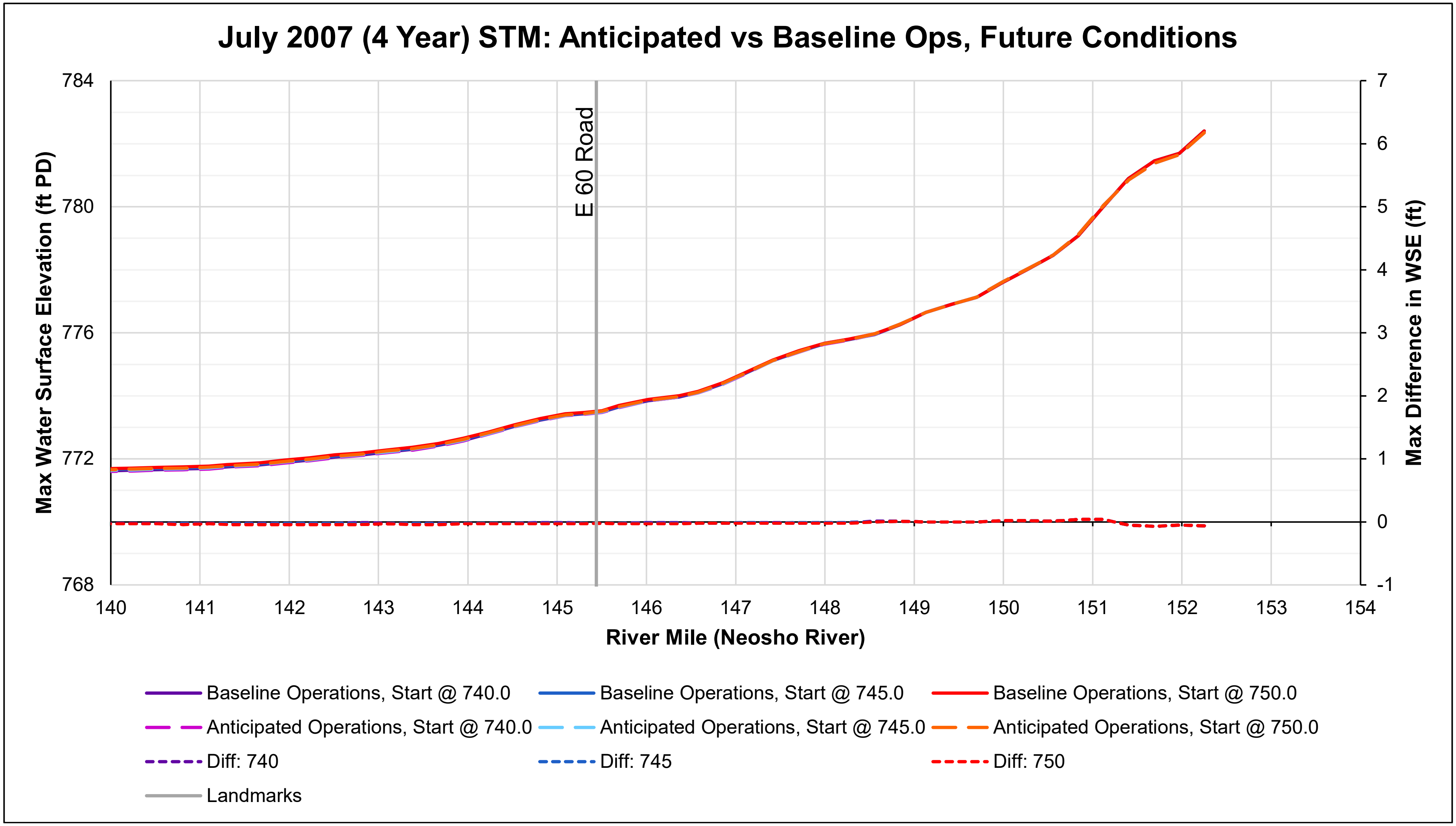
-1
130
131
132
133
134
135
136
137
138
139
140
Interstate 44
Tar Creek
Abandoned RR
Highway 125
BN RR
Old Highway 69
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks



July 2007 (4 Year) STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
E 60 Road
784
780
776
772
768
7
6
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4
3
2
1
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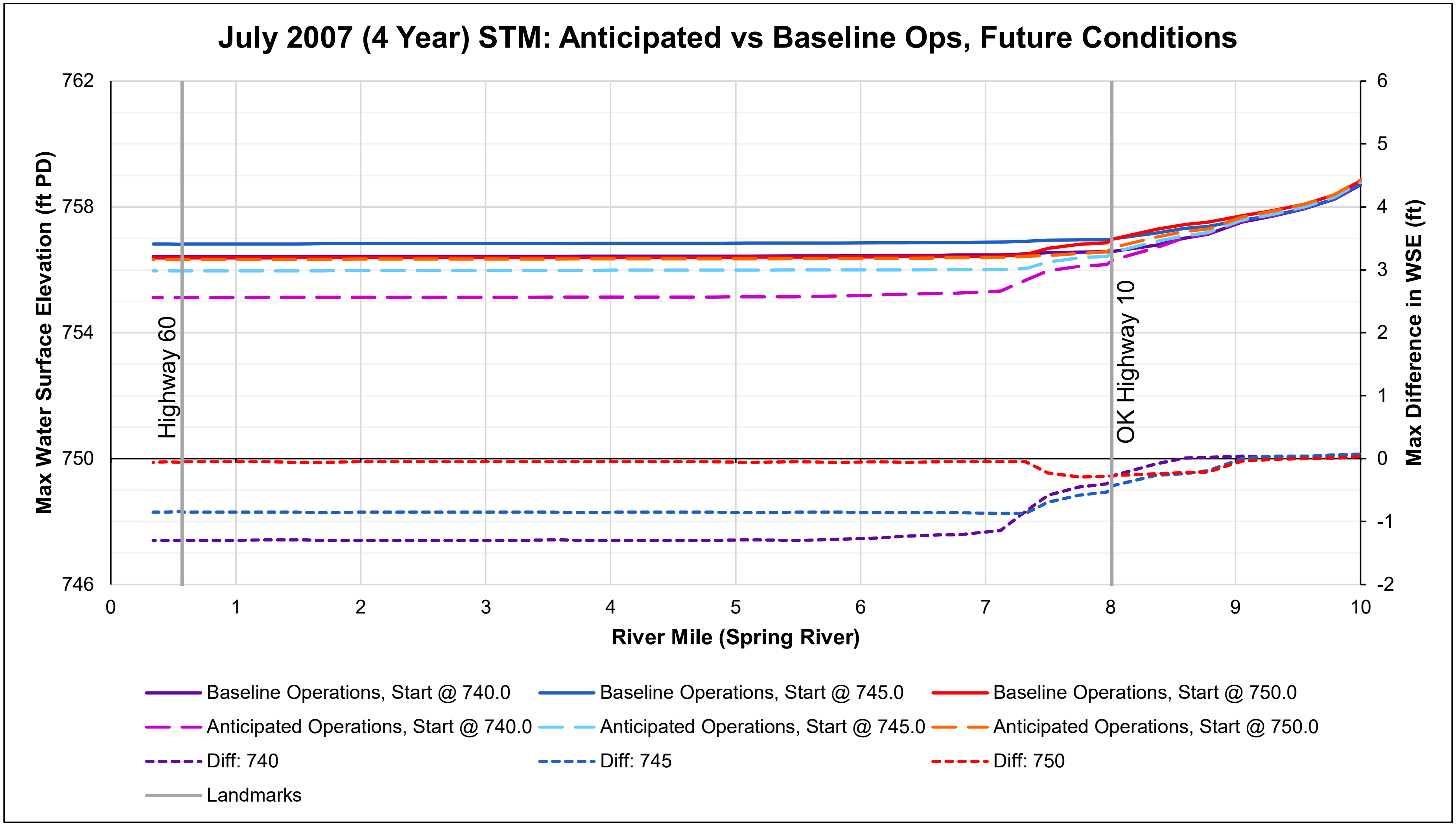
-1
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks



July 2007 (4 Year) STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Spring River)
Highway 60
OK Highway 10
762
758
754
750
746
6
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4
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-1
-2
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1
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3
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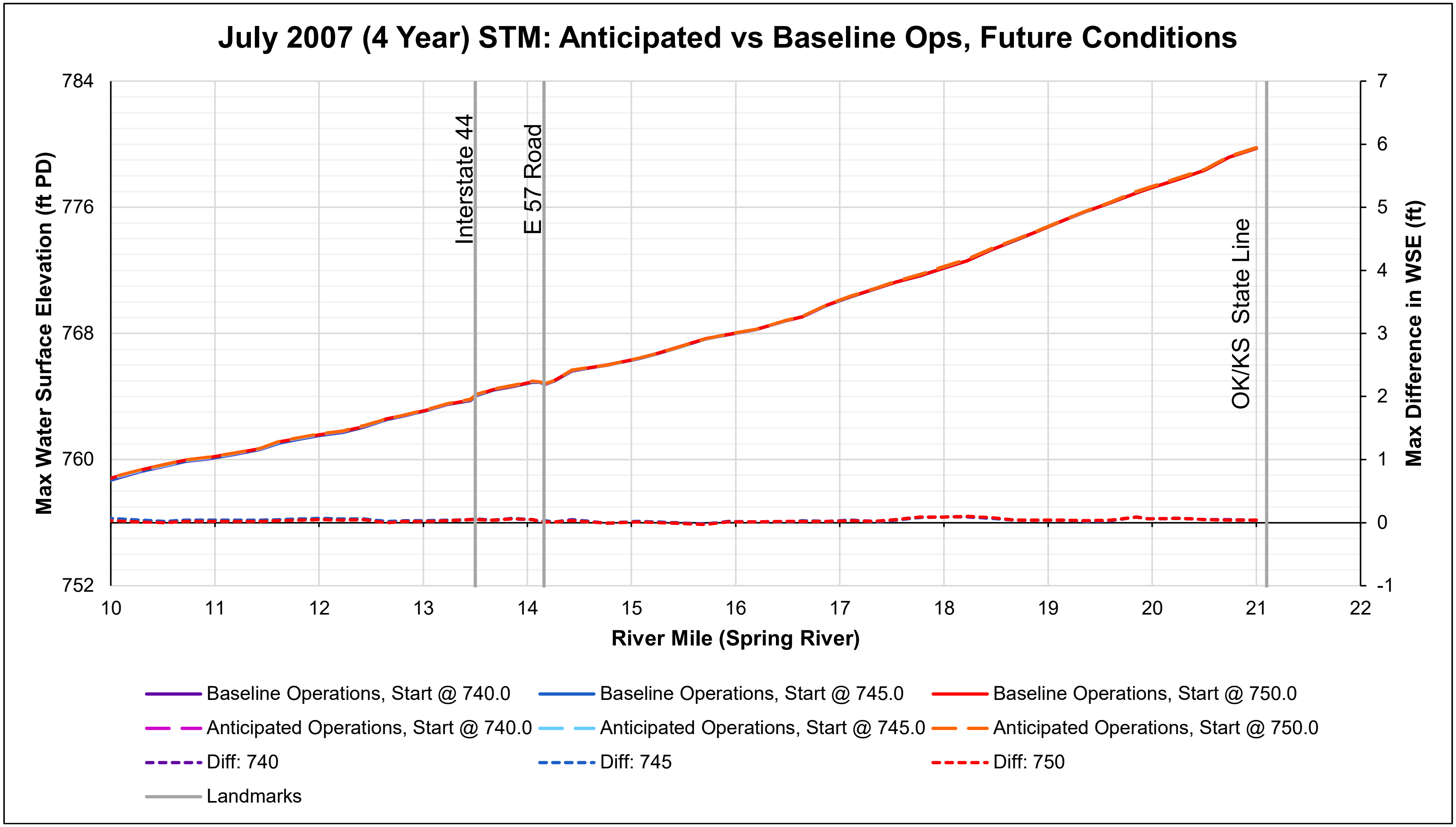
5
6
7
8
9
10
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks



July 2007 (4 Year) STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Spring River)
784
776
768
760
752
7
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15
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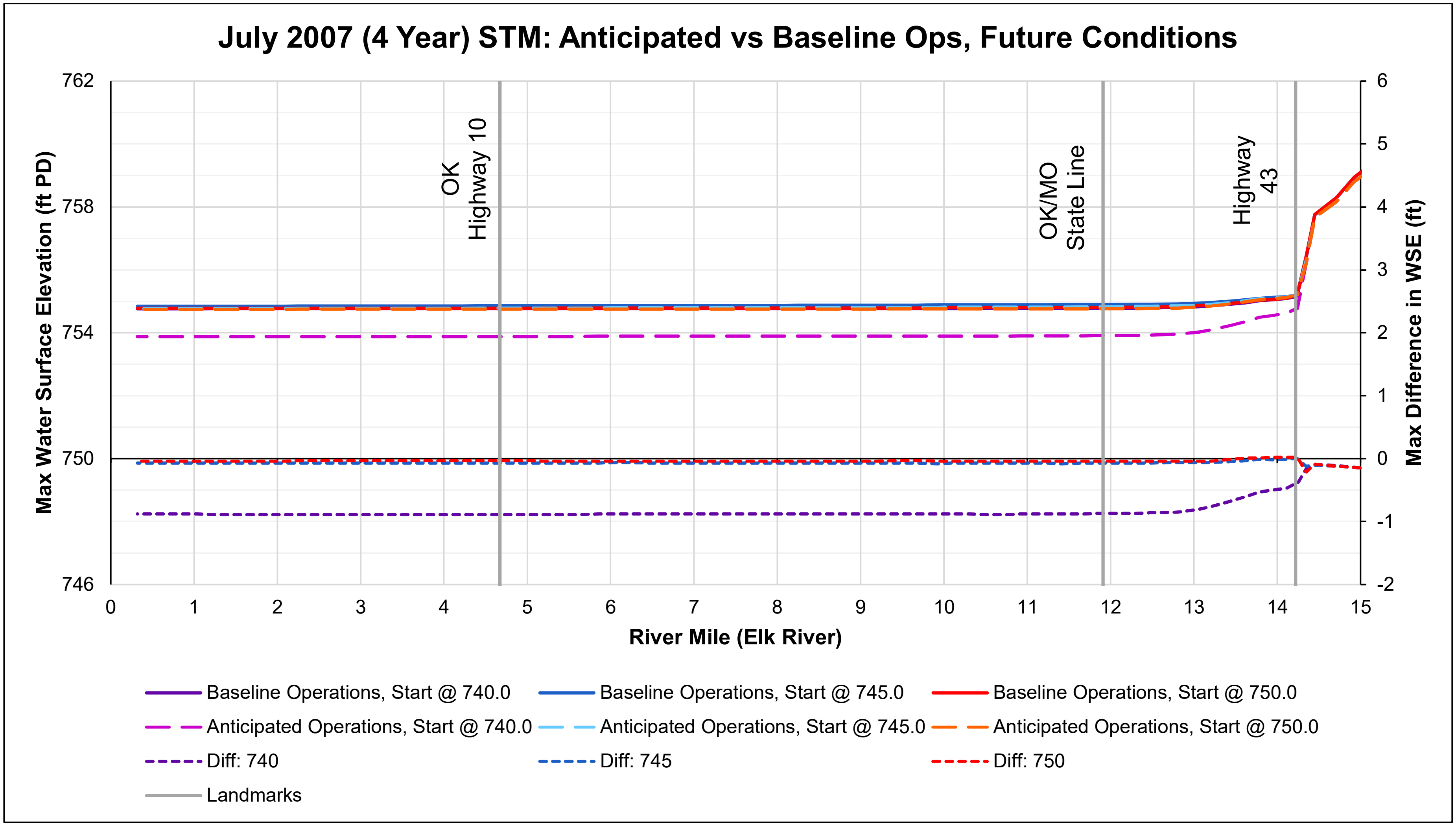
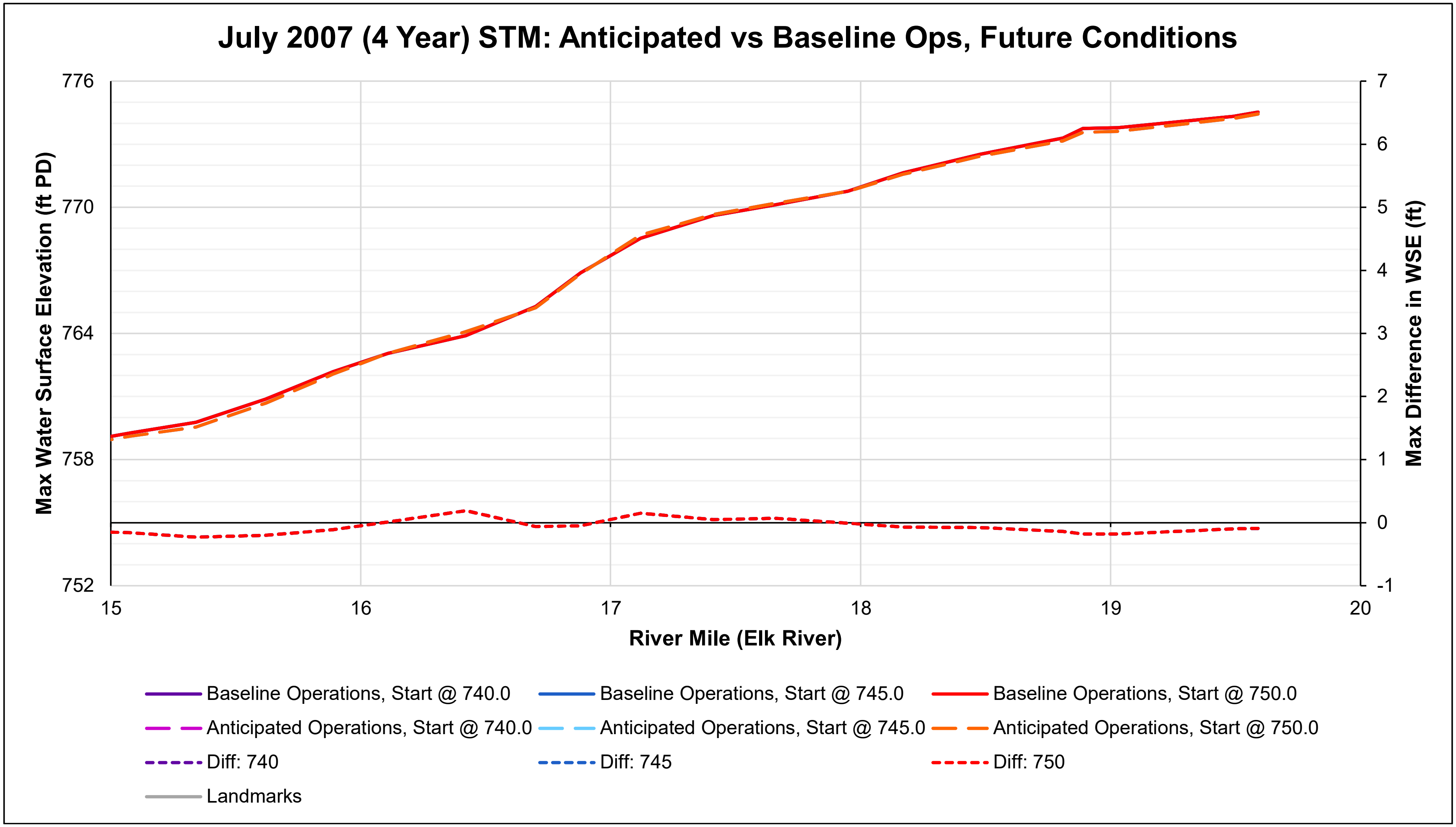
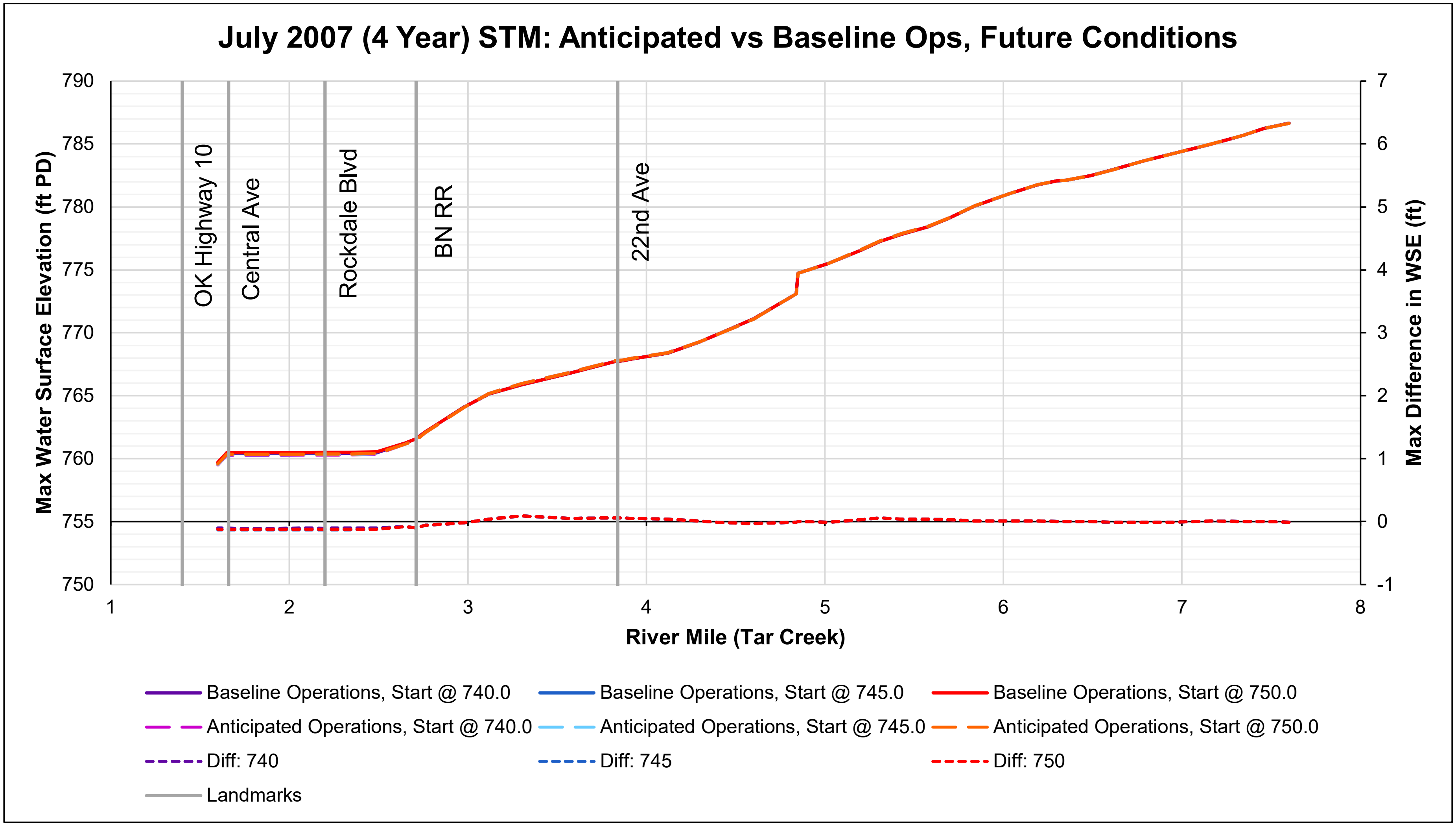
17
18
19
20
21
22
Interstate 44
E 57 Road
OK/KS State Line
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

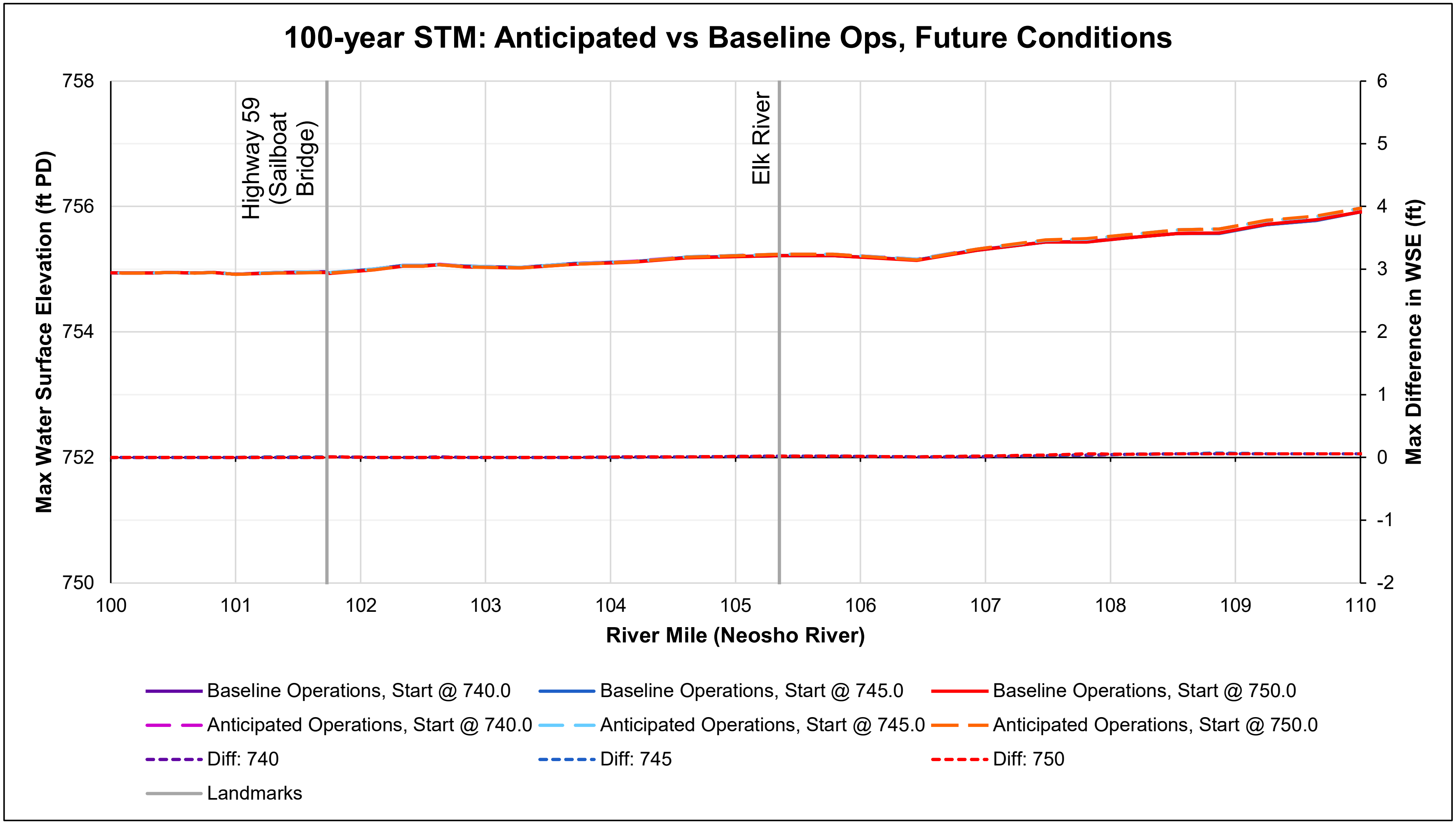


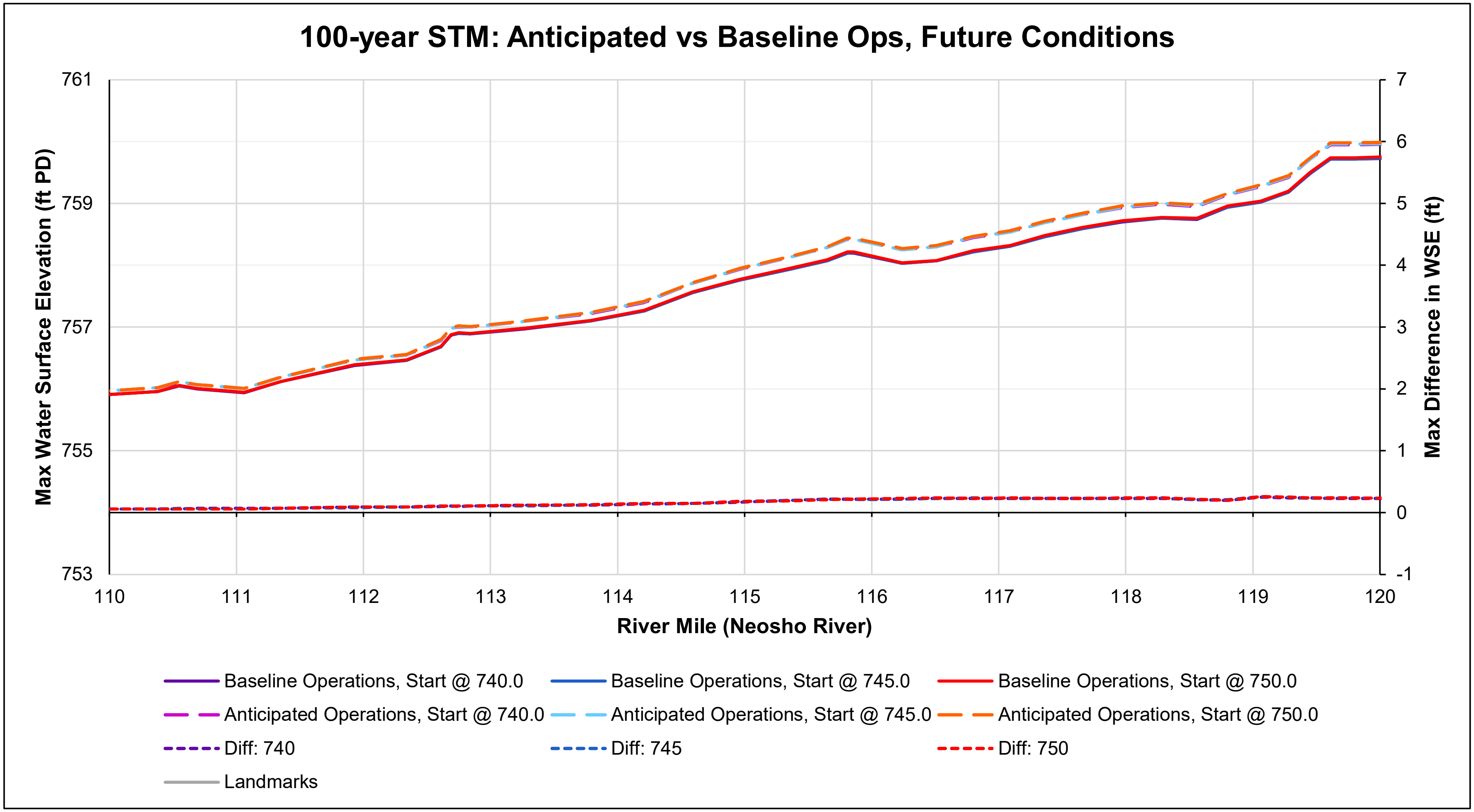
July 2007 (4 Year) STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Elk River)
762
758
754
750
746
6
5
4
3
2
1
0
-1
-2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
OK Highway 10
OK/MO State Line
Highway 43
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

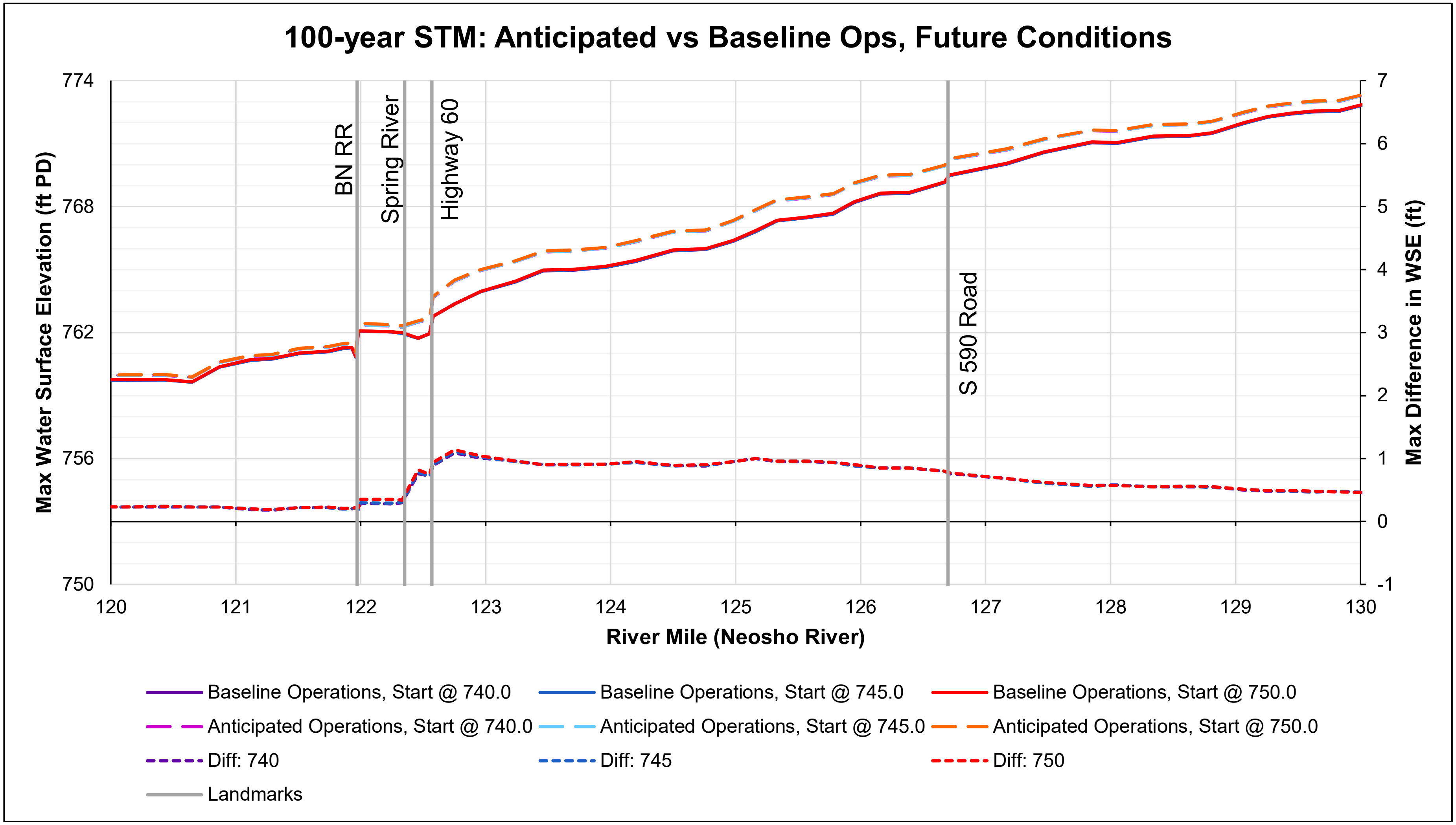

July 2007 (4 Year) STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
776
770
764
758
752
Max Difference in WSE (ft)
7
6
5
4
3
2
1
0
-1
15
16
17
18
19
20
River Mile (Elk River)
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks



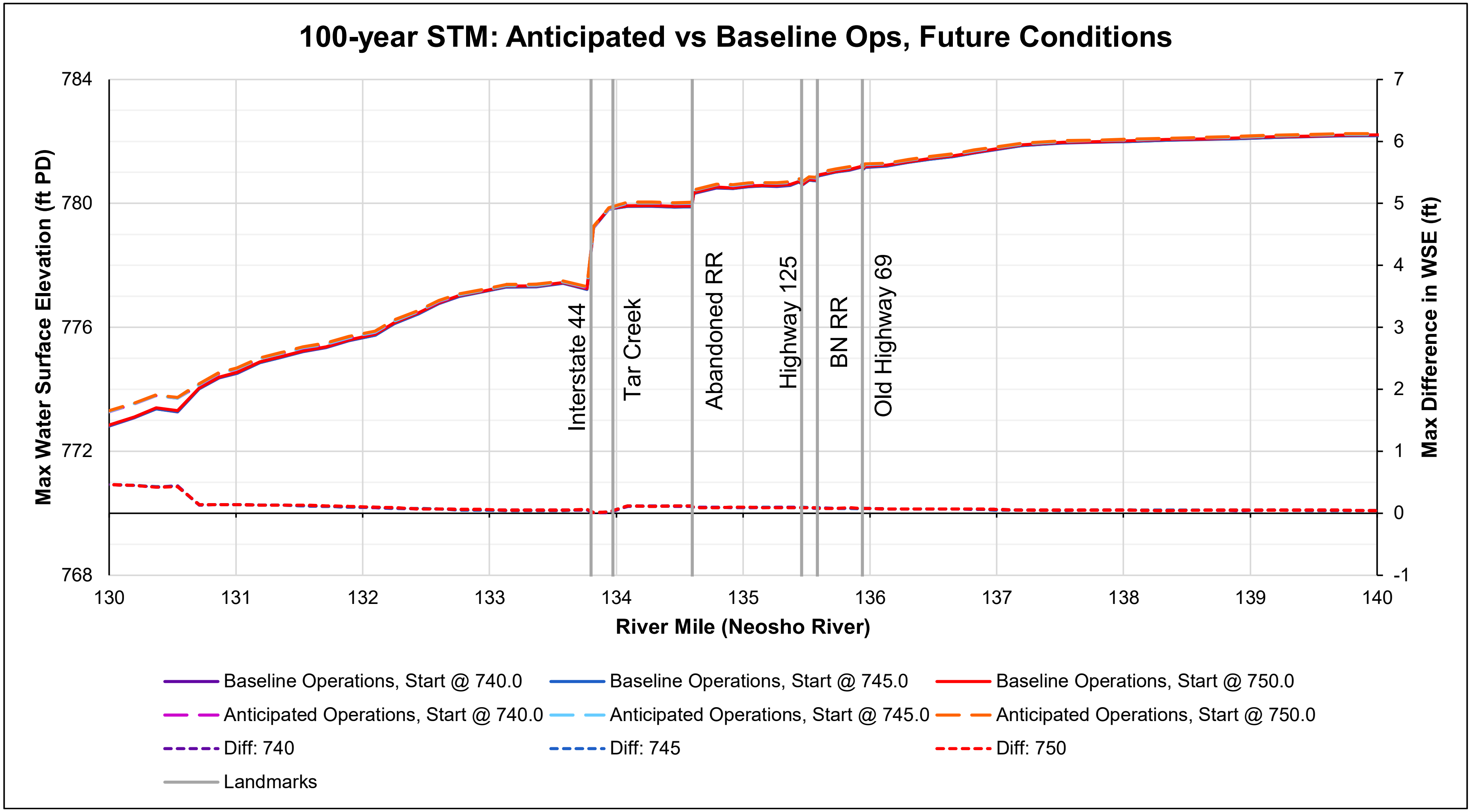
July 2007 (4 Year) STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Tar Creek)
OK Highway 10
Central Ave
Rockdale Blvd
BN RR
22nd Ave
790
785
780
775
770
765
760
755
750
7
6
5
4
3
2
1
0
-1
1
2
3
4
5
6
7
8
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


100-year STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
Highway 59 (Sailboat Bridge)
Elk River
758
756
754
752
750
6
5
4
3
2
1
0
-1
-2
100
101
102
103
104
105
106
107
108
109
110
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

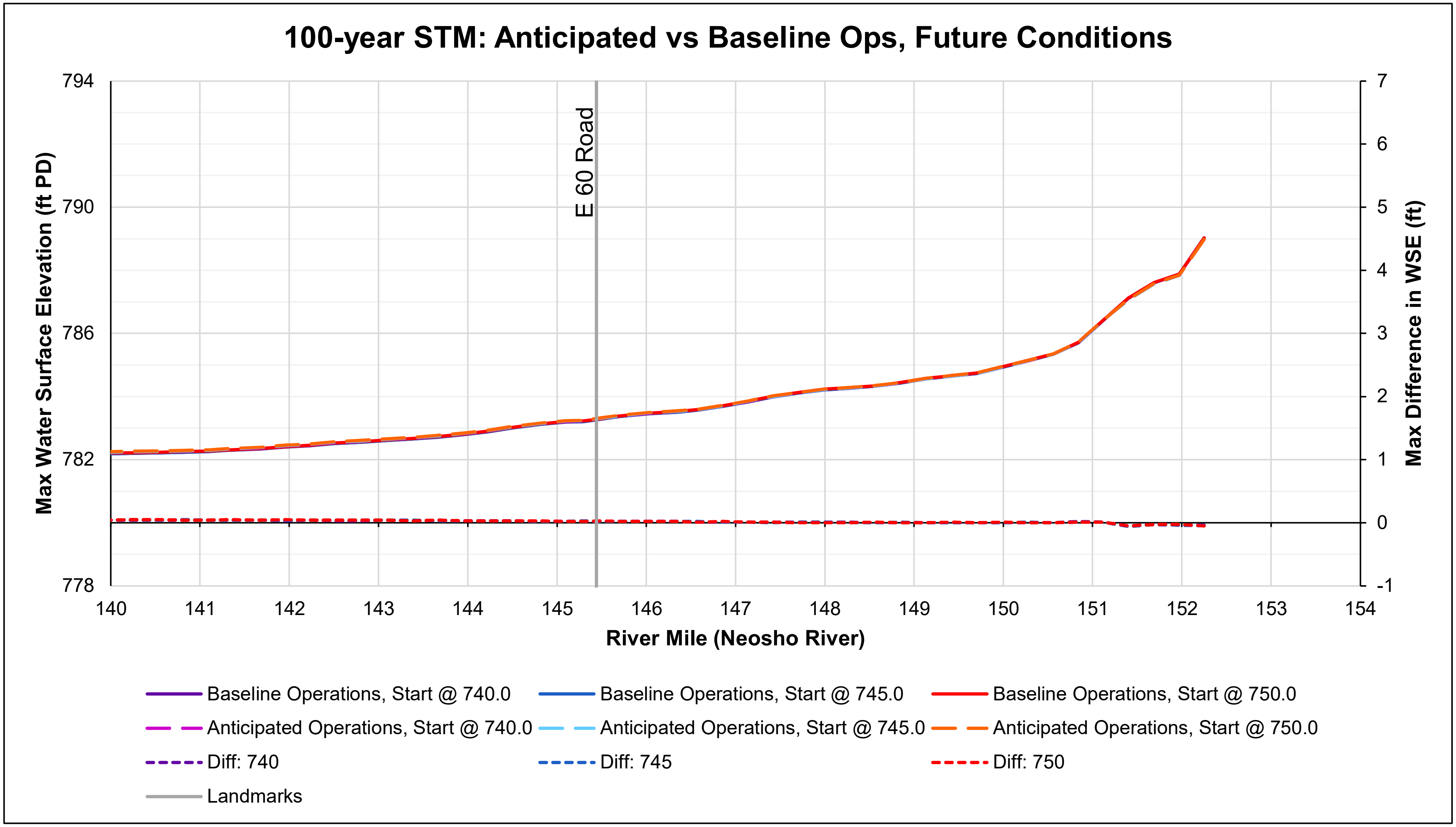

100-year STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
761
759
757
755
753
Max Difference in WSE (ft)
7
6
5
4
3
2
1
0
-1
110
111
112
113
114
115
116
117
118
119
120
River Mile (Neosho River)
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

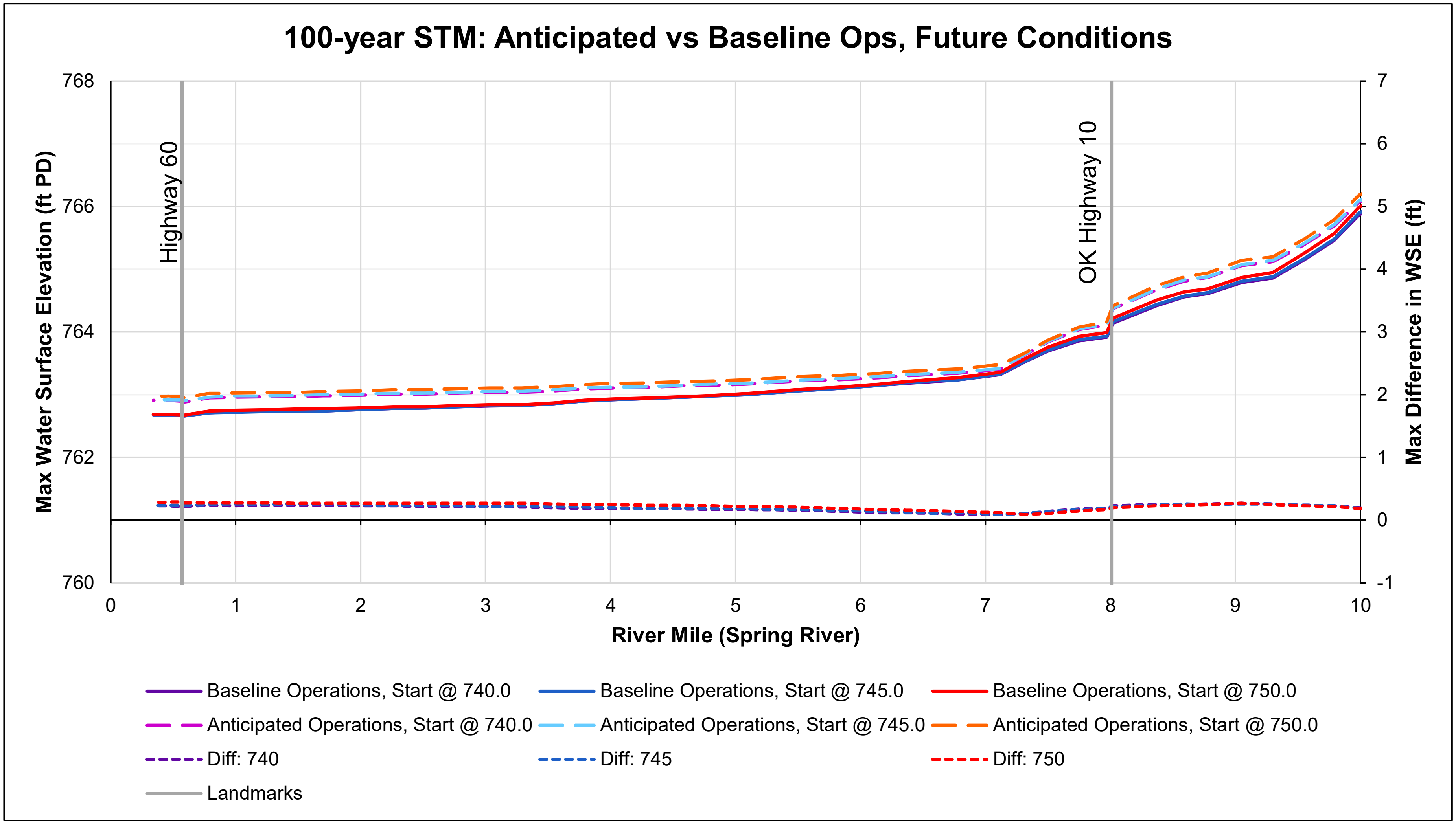


100-year STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Neosho River)
BN RR
Spring River
Highway 60
S 590 Road
774
768
762
756
750
7
6
5
4
3
2
1
0
-1
120
121
122
123
124
125
126
127
128
129
130
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

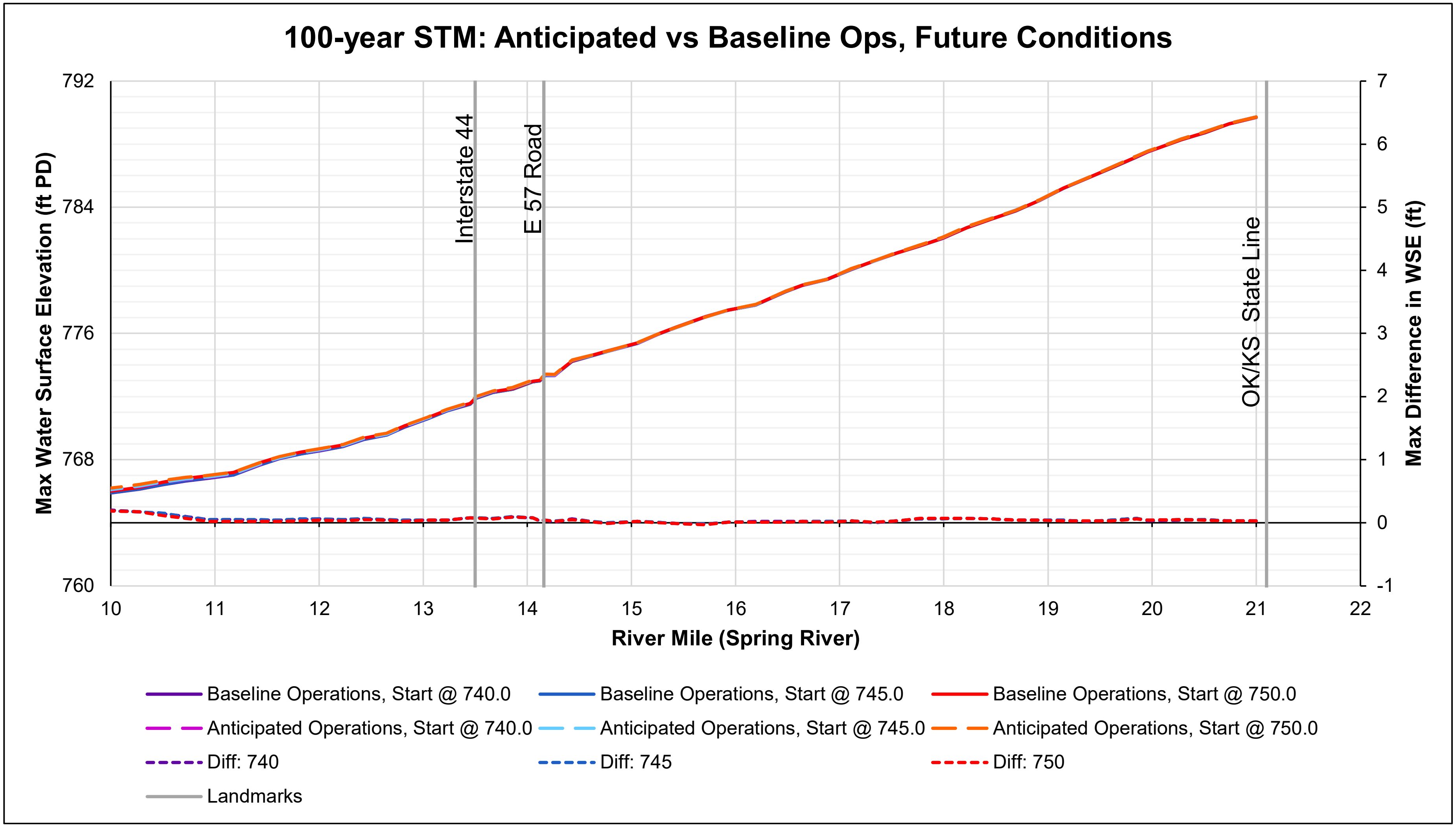


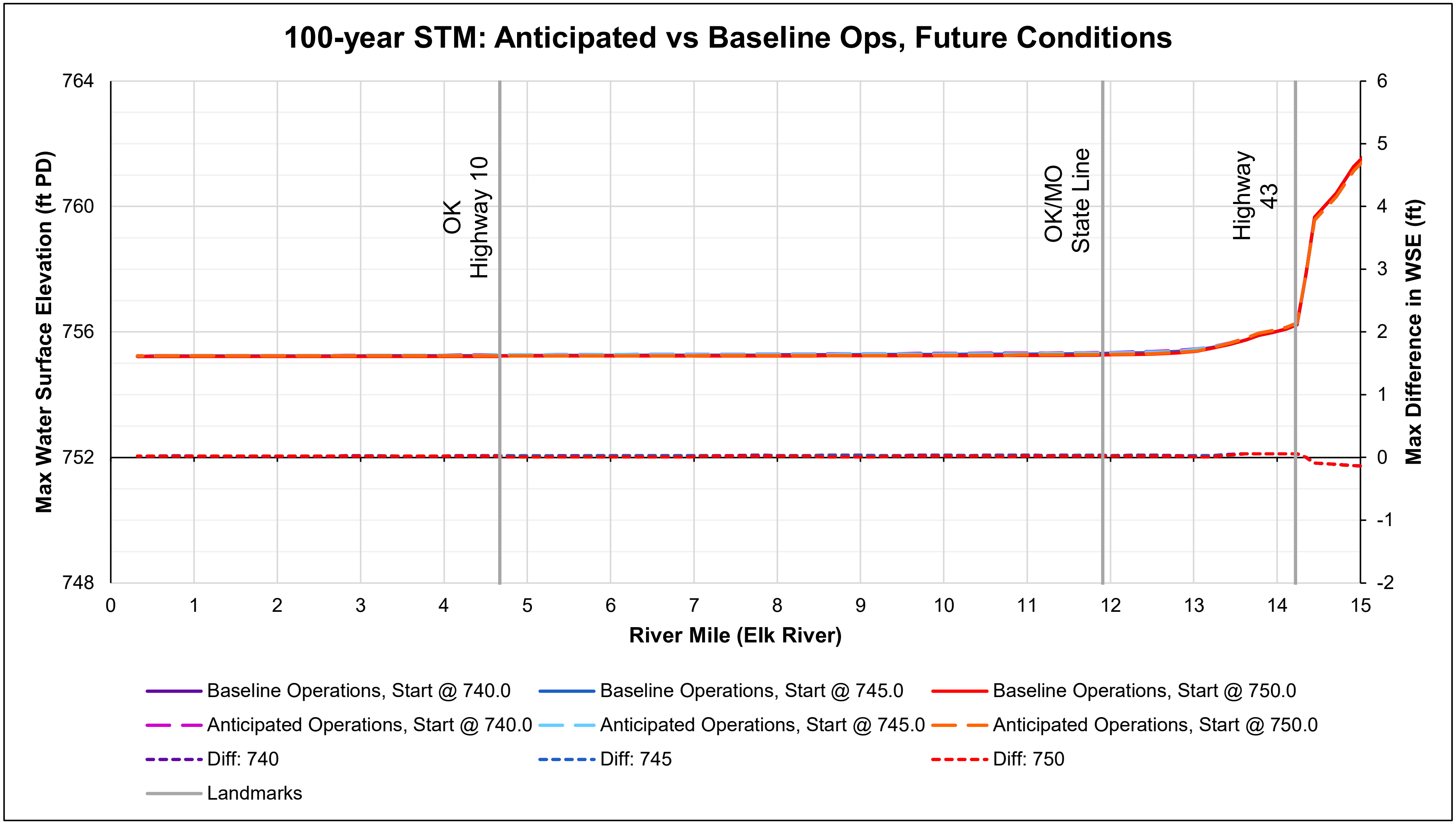
100-year STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
784
780
776
772
768
Max Difference in WSE (ft)
7
6
5
4
3
2
1
0
-1
130
131
132
133
134
135
136
137
138
139
140
River Mile (Neosho River)
Interstate 44
Tar Creek
Abandoned RR
Highway 125
BN RR
Old Highway 69
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


100-year STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
794
790
786
782
778
Max Difference in WSE (ft)
7
6
5
4
3
2
1
0
-1
E 60 Road
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
River Mile (Neosho River)
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

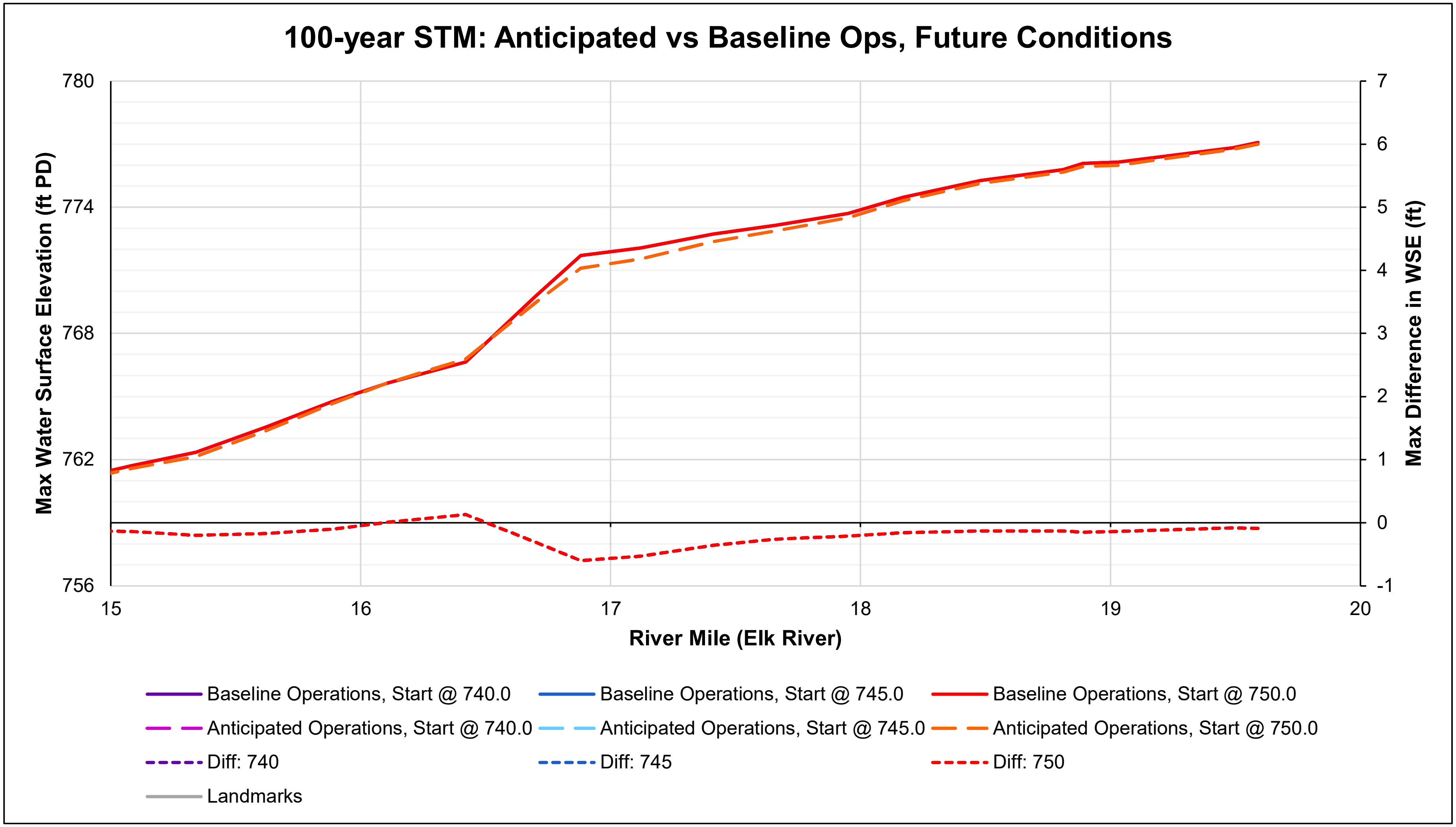


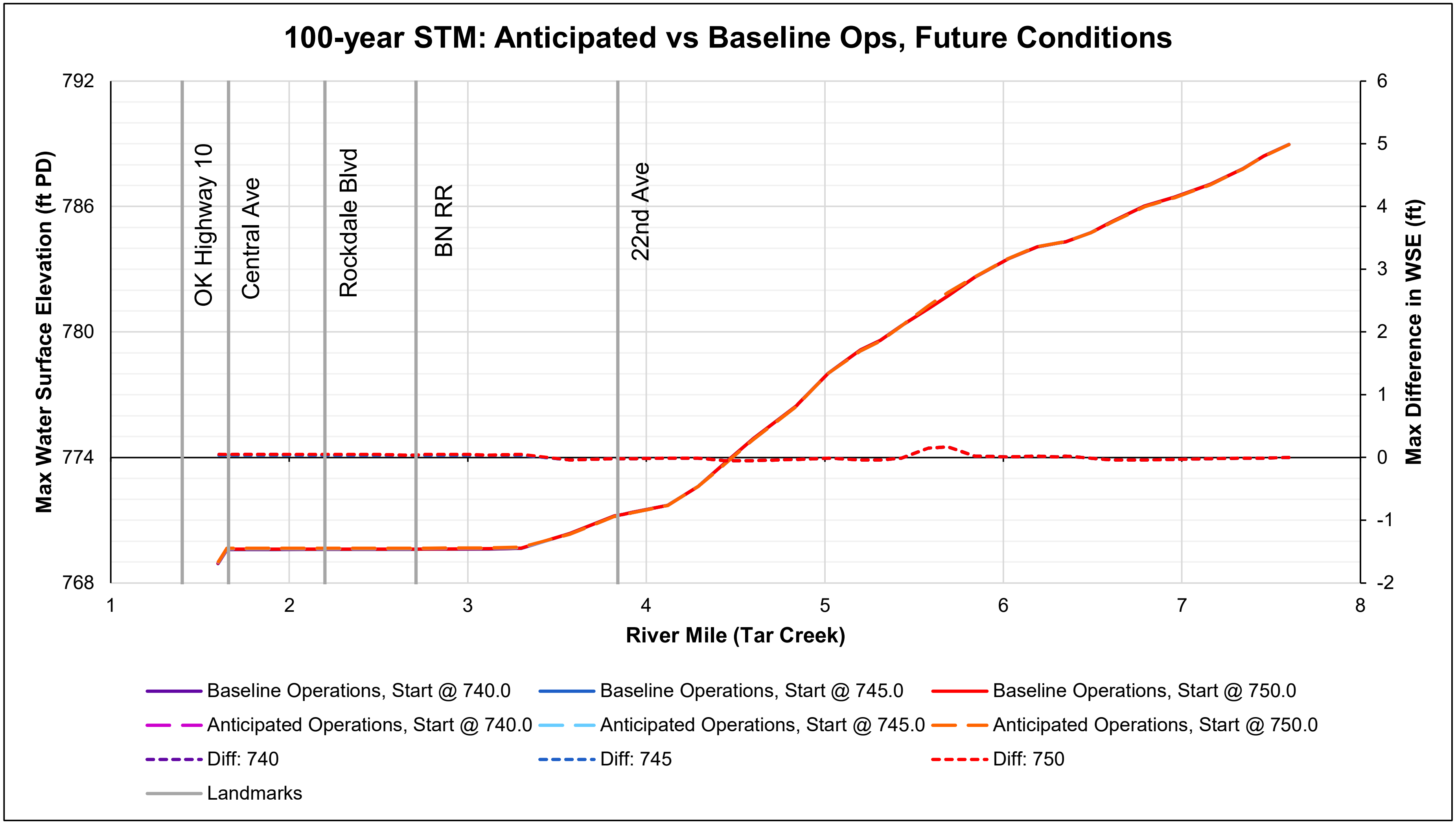
100-year STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Spring River)
Highway 60
OK Highway 10
768
766
764
762
760
7
6
5
4
3
2
1
0
-1
0
1
2
3
4
5
6
7
8
9
10
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


100-year STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Spring River)
Interstate 44
E 57 Road
OK/KS State Line
792
784
776
768
760
7
6
5
4
3
2
1
0
-1
10
11
12
13
14
15
16
17
18
19
20
21
22
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks



100-year STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Elk River)
764
760
756
752
748
6
5
4
3
2
1
0
-1
-2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
OK Highway 10
OK/MO State Line
Highway 43
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


100-year STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
780
774
768
762
756
Max Difference in WSE (ft)
7
6
5
4
3
2
1
0
-1
15
16
17
18
19
20
River Mile (Elk River)
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks


100-year STM: Anticipated vs Baseline Ops, Future Conditions
Max Water Surface Elevation (ft PD)
Max Difference in WSE (ft)
River Mile (Tar Creek)
OK Highway 10
Central Ave
Rockdale Blvd
BN RR
22nd Ave
792
786
780
774
768
6
5
4
3
2
1
0
-1
-2
1
2
3
4
5
6
7
8
Baseline Operations, Start @ 740.0
Baseline Operations, Start @ 745.0
Baseline Operations, Start @ 750.0
Anticipated Operations, Start @ 740.0
Anticipated Operations, Start @ 745.0
Anticipated Operations, Start @ 750.0
Diff: 740
Diff: 745
Diff: 750
Landmarks

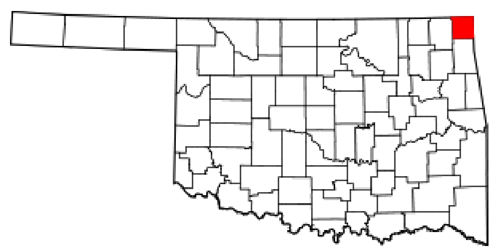
APPENDIX E-8 Ottawa County Flood Insurance Studies

FLOOD INSURANCE STUDY

OTTAWA COUNTY, OKLAHOMA

AND INCORPORATED AREAS

Community Name	Community Number
AFTON, TOWN OF	400155
COMMERCE, CITY OF	400156
FAIRLAND, TOWN OF	400377
MIAMI, CITY OF	400157
NORTH MIAMI, TOWN OF	400426
PEORIA, TOWN OF	400158
PICHER, CITY OF	400159
QUAPAW, TOWN OF	400436
WYANDOTTE, TOWN OF	400161
OTTAWA COUNTY, UNINCORPORATED AREAS	400154



EFFECTIVE: AUGUST 5, 2010

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
40115CV000A

**NOTICE TO
FLOOD INSURANCE STUDY USERS**

Communities participating in the National Flood Insurance Program have established repositories of flood hazard data for floodplain management and flood insurance purposes. This Flood Insurance Study may not contain all data available within the repository. It is advisable to contact the community repository for any additional data.

Selected Flood Insurance Rate Map panels for the community contain information that was previously shown separately on the corresponding Flood Boundary and Floodway Map panels (e.g., floodways, cross sections). In addition, former flood hazard zone designations have been changed as follows:

Old Zone	New Zone
A1 through A30	AE
V1 through V30	VE
B	X
C	X

Part or all of this Flood Insurance Study may be revised and republished at any time. In addition, part of this Flood Insurance Study may be revised by the Letter of Map Revision process, which does not involve republication or redistribution of the Flood Insurance Study. It is, therefore, the responsibility of the user to consult with community officials and to check the community repository to obtain the most current Flood Insurance Study components. A listing of the Community Map Repositories can be found on the Index Map.

Initial Countywide FIS Effective Date: August 5, 2010

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EXHIBITS

FLOOD INSURANCE STUDY
OTTAWA COUNTY, OKLAHOMA AND INCORPORATED AREAS

1.0 INTRODUCTION

1.1 Purpose of Study

This Flood Insurance Study (FIS) revises and updates information about the existence and severity of flood hazards in the geographic area of Ottawa County, including the Cities of Commerce, Miami, and Picher; the Towns of Afton, Fairland, North Miami, Peoria, Quapaw, and Wyandotte; and the unincorporated areas of Ottawa County (referred to collectively herein as Ottawa County), and aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This study has developed flood-risk data for various areas of the community that will be used to establish actuarial flood insurance rates and to assist the community in its efforts to promote sound floodplain management. Minimum floodplain management requirements for participation in the National Flood Insurance Program (NFIP) are set forth in the Code of Federal Regulations at 44 CFR, 60.3.

Please note that the Towns of North Miami, Peoria, and Quapaw are currently non-participating communities. The Flood Hazard areas shown for these communities are for information only.

In some States or communities, floodplain management criteria or regulations may exist that are more restrictive or comprehensive than the minimum Federal requirements. In such cases, the more restrictive criteria take precedence, and the State (or other jurisdictional agency) will be able to explain them.

1.2 Authority and Acknowledgments

The sources of authority for this FIS report are the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973.

The new hydrologic and hydraulic analyses for this study were performed by Watershed VI Alliance, for the Federal Emergency Management Agency (FEMA), under Contract No. EMT-2002-CO-0048, Project Order No. J034. This study was completed in June 2008. The histories of the individual communities before the first countywide FIS are presented below.

City of Miami
The hydrologic and hydraulic analyses for the original FIS for the City of Miami represent a revision of the original analyses prepared by Benham-Blair Affiliates, Inc., for FEMA under Contract No. H-4642. That work was completed in June 1979 (Reference 1).

The hydrologic and hydraulic analyses for the revised FIS was based were prepared by the Tulsa District of the U.S. Army Corps of Engineers (USACE). That work was completed in September 1986 (Reference 1).

Town of Wyandotte
The hydrologic and hydraulic analyses for the original FIS for the Town of Wyandotte

were prepared by the USACE, Tulsa District, for FEMA under Inter-Agency Agreement No. EMW-84-E-1506, Project Order No. 1, Amendment No. 32 and 32b. That work was completed in June 1986 (Reference 2).

The FIS for the Town of Wyandotte was revised on December 19, 1997 to incorporate the results of a reevaluation of the flood hazards along Wyandotte Ditch and the adequacy of a levee protecting a school from flooding from Grand Lake O' the Cherokees (Grand Lake).

A reevaluation was performed by the USACE, Tulsa District, under Contract No. EMW-93-E-4119, and by Michael Baker Jr., Inc., under a Technical Evaluation Contract. That work was completed on February 11, 1997 (Reference 2).

Unincorporated Areas of Ottawa County
The hydrologic and hydraulic analyses for the unincorporated areas of Ottawa County were prepared by the Tulsa District of the USACE for FEMA, under Inter-Agency Agreement No. EMW-84-E-1506, Project Order No. 1, Amendment No. 29 and 29b. That work was completed in September 1986 (Reference 3).

1.3 Coordination

The initial Consultation Coordination Officer (CCO) meeting was held on April 10, 2007, and attended by representatives of the Cities of Commerce and Miami; the Towns of Afton, Fairland, and Wyandotte; Ottawa County; the Oklahoma Water Resources Board (OWRB); FEMA; and Watershed VI Alliance (the study contractor).

The results of the study were reviewed at the final CCO meeting held on December 8, 2008, and attended by representatives of the Cities of Commerce, Miami, and Wyandotte, the Seneca Tribe, the Eastern Shawnee Tribe, FEMA, and the study contractor. All problems raised at that meeting have been addressed in this study.

The history of the coordination activities for the individual communities before the first countywide meeting is presented below.

City of Miami
On March 14, 1978, an initial CCO meeting was held with representatives of FEMA, the City of Miami, and Benham-Blair & Affiliates, Inc. (the study contractor) to explain the nature and purpose of the FIS. A legal notice announcing the initiation of the study and stating its objectives was placed in the local newspaper. Contact was maintained during the course of that study with the Tulsa District of the USACE, the Ottawa County Soil Conservation Service, and the City of Miami for general community information.

On January 10, 1980, the results of that study were reviewed at a final CCO meeting attended by representatives of FEMA, the City, and the study contractor.

Town of Wyandotte
On February 13, 1984, an initial CCO meeting was held with representatives from FEMA, the Town of Wyandotte, and the Tulsa District of the USACE (the study contractor) to determine the streams to be studied by detailed methods. Coordination between town officials and Federal, State, and regional agencies produced a variety of information pertaining to floodplain regulations, available community maps, flood history, and other hydrologic data.

The U.S. Geological Survey (USGS), the Bureau of Reclamation, the National Weather Service, the Soil Conservation Service, the State Conservationist, and the OWRB were contacted for information related to the study.

On December 8, 1986, a final CCO meeting was held with representatives from FEMA, the Town, and the study contractor to review the results of the study.

The results of the revision to Wyandotte Ditch were reviewed at a final CCO meeting held on February 11, 1997, and attended by representatives of FEMA and the Town of Wyandotte. All problems raised at that meeting were addressed in the 1997 FIS.

Unincorporated Areas of Ottawa County

On February 14, 1984, an initial CCO meeting was held with representatives of FEMA, Ottawa County, and the USACE (the study contractor) to determine the streams to be studied by detailed methods. Coordination between county officials and Federal, State, and regional agencies produced a variety of information pertaining to floodplain regulations, available community maps, flood history, and other hydrologic data.

Agencies that contributed significant data to this study were the USGS, the Oklahoma Department of Transportation, the National Weather Service, the Soil Conservation Service, and the Oklahoma Water Resources Board.

Contact between Ottawa County and the Tulsa District of the USACE was maintained during the course of this study for general community information.

On January 12, 1988, a final CCO meeting was held with representatives of FEMA, the County, and the study contractor to review the results of the study.

2.0 AREA STUDIED

2.1 Scope of Study

This FIS report covers the geographic area of Ottawa County, Oklahoma, including the incorporated communities listed in Section 1.1.

The areas studied by detailed methods were studied in a previous study. The detail studied streams in this revision were digitally converted from the previous study. The previous study selected streams with priority given to all known flood hazards and areas of projected development or proposed construction through September 1991. Approximate analyses were used to study those areas having a low development potential or minimal flood hazards. The scope and methods of study were proposed to, and agreed upon, by FEMA and Watershed VI Alliance. "Streams Digitally Converted" are presented in Table 1.

Table 1: Streams Digitally Converted

Flooding Source	Reach Length (miles)	Study Area
Belmont Run	2.99	From its confluence with Tar Creek to a point approximately 0.23 mile upstream of Newman Road
Fairgrounds Branch	1.71	From its confluence with the Neosho River to a point approximately 1.15 miles upstream of US Highway 125
Little Elm Creek	3.28	From its confluence with the Neosho River to a point approximately 0.20 mile upstream of State Route 10
Lost Creek (Lower Reach)	1.66	From its confluence with Grand Lake to a point approximately 2.70 miles upstream
Lost Creek (Upper Reach)	1.30	From a point approximately 0.60 mile downstream of Burlington Northern Railroad to the upstream county boundary
Neosho River	3.86	From a point approximately 1.12 miles downstream of the confluence of Little Elm Creek to a point approximately 0.52 mile upstream of the confluence of Tar Creek
Quail Creek	0.98	From its confluence with the Neosho River to P street NW in the City of Miami
Tar Creek	6.92	From its confluence with the Neosho River to a point approximately 1.24 miles upstream of D Street
Warren Branch	1.90	From a point approximately 0.32 mile downstream of the downstream Town of Peoria corporate limits to a point approximately 0.58 mile upstream of the upstream Town of Peoria corporate limits
Wyandotte Ditch (including the effects of Grand Lake)	1.05	Entire length within the Town of Wyandotte

Approximate methods of analysis were used to study all remaining areas having a potential flood hazard that did not have available scientific or technical data. The following streams and their tributaries were studied by approximate methods: Garrett Creek; Sycamore Creek; the Spring River; Brush Creek; Roark Creek; Mud Creek; Fourmile Creek; Hudson Creek; Horse Creek; Little Horse Creek; Ogeechee Creek; Winds Creek; Fivemile Creek; Little Fivemile Creek; Wolf Creek; Coal Creek; Slow Creek; Squaw Creek; Cow Creek; Lytle Creek; Flint Branch; Devils Hollow; Grand Lake; Bee Creek; Hickory Creek; Council Hollow; and portions of Little Elm Creek, Lost Creek (Lower Reach), Lost Creek (Upper Reach), Neosho River, Tar Creek, and Warren Branch.

Mapping for Ottawa County, Oklahoma, and Incorporated Areas has been prepared using digital data. Previously published Flood Insurance Rate Map (FIRM) and Flood

Boundary and Floodway Map data produced manually have been converted to vector digital data by a digitizing process.

2.2 Community Description

Ottawa County is located in the extreme northeast corner of the State of Oklahoma. It is bordered by Cherokee County to the north; Newton County, Missouri to the east; McDonald County, Missouri to the southeast; Delaware County to the south; and Craig County to the west. The county encompasses an area of 485 square miles, with 471 square miles on land. There are nine incorporated towns and cities in Ottawa County, with the City of Miami as the largest city and county seat.

Ottawa County is a mostly rural agricultural area with small areas of residential and industrial development associated with its cities. There are also mining operations along Tar Creek. The year 2000 population of the county was 33,194, an increase of approximately nine percent over the 1990 population of 30,561 (Reference 4). The population was estimated at 33,026 in 2006. There is a tremendous amount of new housing and commercial development in the floodplain of the Neosho River. The county is served by several Federal, State, and local roads, with Interstate Route 44 (Will Rogers Turnpike) being the most widely traveled. The turnpike runs from southwest to northeast. Other highways serving Ottawa County are: U.S. Routes 59, 60, and 69, and State Route 10.

The climate of Oklahoma is continental, with long hot summers and winters that are shorter and milder than those of more northern Plains states. Ottawa County is characterized by a wide range of temperatures across the county, ranging from near 59 degrees in southern parts to less than 56 degrees in the northeast (Reference 5). Daily temperatures range from an average of 92 degrees Fahrenheit (°F) in July to an average of 22°F in January. The mean annual temperature of the area is 59°F. Winds from the south are dominant, averaging less than eight miles-per-hour. Annual average precipitation for the county is 44.85 inches. May and September are the wettest months on average, but abundant rain falls from March through November. Most winters have at least one inch of snow, with about one year in four having ten or more inches.

The terrain in Ottawa County consists of rolling hills with moderate slopes. In the Neosho River drainage basin, rolling uplands with elevations above 1,500 feet quickly descend 150 feet to a broad valley, generally 1 to 5 miles back from the river. The floodplains of the Neosho River, Tar Creek, and their tributaries are associated with the Lightning soil series, which is described as deep, poorly drained, nearly level soils formed from alluvium washed from soils of the prairies. The native vegetation in the floodplains is mainly tall grass prairie, due to the availability of water, but includes some hardwood trees.

Most of the area of Ottawa County is divided between the Neosho River basin and the Spring River basin. The major tributaries to the Neosho River are Tar Creek and Little Elm Creek, but the small tributary Fairgrounds Branch is also included in this study. The major tributaries to Spring River that are included in this study are Lost Creek with its tributary Wyandotte Ditch in the south central portion of the county and Warren Branch in the northeastern part of the county.

The Neosho River flows from the northwest to the southeast across the county through a wide floodplain. The river begins in the Flint Hills region of Morris County, Kansas, and flows southeast more than 300 river miles in Kansas. It then flows south approximately

164 river miles across northeastern Oklahoma to its confluence with the Arkansas River near Muskogee, Oklahoma. About 10 miles downstream of the City of Miami, the Neosho River joins the Spring River and is impounded to form the Grand Lake O' the Cherokees. This 46,500-acre reservoir was created by the construction of the Pensacola Dam in 1940 as a source for hydroelectric power.

The Neosho River channel is well defined and very crooked. It varies in width from approximately 100 feet near Council Grove, Kansas, to approximately 300 feet near the City of Miami, Oklahoma, and is occasionally obstructed by snags, trash heaps, and gravel bars. Throughout its course, the river occupies a bed of gravel, boulders, and rock ledges. The banks are generally stable, varying in height from 15 to 30 feet and are covered with brush and trees above the lower water line. The total fall of the Neosho River from its headwaters to its junction with the Arkansas River is 1,000 feet. Throughout most of its length, excluding the upper reach, the average fall of the streambed is slightly over 1 foot per mile.

Fairgrounds Branch is a small tributary of the Neosho River in the City of Miami. Its basin is approximately 2 square miles in drainage area, which is devoted mainly to agricultural usage. There are small residential developments adjacent to Highway 125, which is on the ridge line for the Fairgrounds Branch basin.

Tar Creek originates in Cherokee County, Kansas, and flows from north to south through the central part of Ottawa County to its confluence with the Neosho River just upstream of Highway 44 above Little Elm Creek. Most of the total drainage area of 53.3 square mile lies within Ottawa County. The creek flows near the City of Commerce and through the City of Miami, so the floodplain is the most developed of any stream in the study area. Tar Creek flows reasonably straight through a channel in a floodplain varying from approximately 1,800 feet to approximately 3,800 feet in width. The average slope is approximately 10.4 feet per mile.

Two tributaries of Tar Creek are included in this study: Belmont Run and Quail Creek. Belmont Run is the most significant tributary within the Miami corporate limits. It has a drainage area of 3.1 square miles, mostly on the west side of Miami which includes the industrial park development and commercial districts. Quail Creek intercepts Tar Creek upstream of Rockdale Bridge. Its watershed is 2.8 square miles of mostly residential development and the local country club. Quail Creek has a greater average stream slope of approximately 22 feet per mile than Belmont Run's 12.5 feet per mile.

Little Elm Creek runs through the central portion of the county from north to south and empties into the Neosho River. The river is just east of Miami and its floodplain is currently all agricultural and residential.

Lost Creek runs in most of the southeastern part of the county before emptying into Grand Lake. This creek crosses the northern edge of the Town of Wyandotte in a western direction and has a drainage area of approximately 95 square miles that is approximately 20 miles long. The average slope of the Lost Creek streambed is approximately 17 feet per mile.

Wyandotte Ditch is the local name for a drainage channel that runs from east to west on the south side of Wyandotte before emptying into Lost Creek. Wyandotte Ditch has a drainage area of approximately 1.0 square mile. The average stream slope is a steep 75 feet per mile; however, through the community, the streambed slope is approximately 35 feet per mile.

Warren Branch flows through the Town of Peoria, in the northeastern part of the county. This area floods regularly, mainly due to heavy rains and fast runoff from the high hills. There is little overall new development expected in this area.

City of Miami

The City of Miami is located in the northwestern portion of Ottawa County, only 95 miles northeast of Tulsa and 15 miles southwest of Joplin, Missouri. It is bordered by the City of Commerce to the north and the unincorporated areas of Ottawa County to the east, south, and west. With a year 2000 population of 13,704, Miami is by far the largest city in the county (Reference 4). The other cities and towns in Ottawa County have populations of 2,700 or less. The City of Miami does not exercise its extraterritorial jurisdiction at the present time.

The topography of Miami and its general vicinity is gently rolling, with no areas over 3 to 5 percent slopes. Much of the City lies on the northern bank of the Neosho River and along Tar Creek, but the Fairgrounds and newer residential areas are expanding on the south side of the Neosho River. While most residential properties and the larger part of Miami's business district are above flooding elevations, existing residential, commercial, and industrial areas have been inundated by past floods. U.S. Highway 66 and 69 and Oklahoma State Highway 10 cross the Neosho River on a common bridge from the west and the Main Street Bridge crosses at a southwestern area of the City. Both of these bridges were overtopped by the July 1951 flood.

A near record flood occurred on the Neosho River in June of 2007. Significant property damage was reported in the City of Miami. Approximately 2,500 residents were evacuated and 574 structures were inundated with water. Some buildings had up to 3 feet of water in them and approximately 148 homes and businesses were damaged to the degree that they were not given permission to renovate. All highways except for one and approximately 40 streets in Miami were closed due to high water causing limited access into and out of the city (Reference 6).

Town of Wyandotte

The Town of Wyandotte is located in the southeastern portion of Ottawa County and is completely bordered by unincorporated areas. In 2000, the population of the town was approximately 363 (Reference 4).

The topography of the town and its surrounding area can be described as gently rolling. Wyandotte is adjacent to the Spring River arm of Grand Lake and includes Lost Creek and Wyandotte Ditch.

2.3 Principal Flood Problems

Floods can occur in Ottawa County during any season but are most frequent during May and September. Autumn floods are often associated with widespread heavy rains north of a stalled cold front, or the interaction between a surface front and remnants of a tropical storm. Springtime floods usually occur in the warm sector of a slow-moving cyclone (Reference 5). Major flooding during the spring and summer months can also be produced by the intense rainfall associated with intense localized thunderstorms (Reference 3).

Major flood problems in Ottawa County have occurred in all of the floodplains of the streams studied in this report.

Major floods of record occurred on the Neosho River and Tar Creek in July 1951, May 1943, April 1944, July 1948, February 1985, October 1986, and July 2007. The July 1951 flood is believed to be the greatest flood known to have occurred in this area, with the Neosho River cresting at 34.03 in nearby Commerce. Newspapers pointed out the hazard to life and the substantial damage to property occasioned by this flood, which left 3,000 persons homeless (Reference 1). The July 2007 flood is believed to be the second highest flood in the City of Miami, with the Neosho River cresting at 29.25 feet. Over 200 homes were destroyed and 266 more homes suffered major damage in this flood (Reference 7). The May 1943 flood was the highest flood on the upper reaches of Tar Creek and the third highest flood on the Neosho River at Miami. The February 1985 flood, according to surveyed high water-marks, was between a 10- and 50-year flood for the Neosho River and Tar Creek (Reference 1).

Past flood records on Little Elm Creek, Lost Creek, and Warren Branch are scarce. The February 1985 flood is the only record of flooding in these areas. Surveyed high-water marks indicate that this flood was less than a 10-year flood on Little Elm Creek, Lost Creek, and Warren Branch (Reference 2).

Officials for the Town of Wyandotte have indicated that overland flooding has occurred along Wyandotte Ditch, while most flooding is the result of the backwater effects of Grand Lake or from a combination of surface runoff and poor drainage.

2.4 Flood Protection Measures

There are three USACE flood control reservoirs operating in the Neosho River Basin above the City of Miami in the State of Kansas: Council Grove, Marion, and John Redmond Reservoirs. These reservoirs, which were completed since the July 1951 flood, reduce flood stages significantly at Miami. In addition, the Natural Resources Conservation Service has six watershed programs in various stages of development in the basin above Miami. However, these programs have very little effect on the Neosho River flooding in the Miami area.

The National Weather Service (NWS) of the National Oceanic and Atmospheric Administration provides flood warning service to the City of Miami for crests on the Neosho River. These warnings are related to the river gage near Commerce, approximately 9 miles upstream. When flooding is expected at the Commerce gage, the police dispatcher at Miami is notified by telephone from the Tulsa River Forecast Center. The police dispatcher is asked to relay this information to the Miami City Engineer and the Ottawa County Civil Defense Office. These warnings are also published on http://www.weather.gov/alerts for further dissemination by news media.

Specific river and flood forecasts and warnings are not provided for Tar Creek or its tributaries, since economic restraints do not permit NWS funding of the relatively dense networks of the river and rainfall stations required to produce accurate forecasts for this area. At present, the principal service the NWS can provide the Tar Creek area is a general alert to the danger of flash flooding by means of forecasts of approaching storm systems and/or radar indications of imminent or occurring heavy rainfall. Warnings of this type are published on the Internet.

There is currently a flood control project being planned for Tar Creek that would alleviate a large amount of local flooding now being experienced. There are no other flood protection measures known to exist or to be planned in the near future on Little Elm Creek, Tar Creek, Lost Creek, or Warren Branch.

There was a provisionally accredited levee (PAL) in the northwestern part of the Town of Wyandotte which was certified to protect the school and surrounding area from the 1-percent-annual-chance flood resulting from backwater (elevation 756) from Grand Lake. Information about this PAL was available in the revised Wyandotte FIS dated December 19, 1997. The ground behind the PAL, however, has been filled in and has ceased to act as a levee; therefore it has been removed from the FIRM. The previous PAL was not certified to protect from the 0.2-percent-annual-chance flood.

There are no other known structural flood control measures that affect the study area.

3.0 ENGINEERING METHODS

For the flooding sources studied by detailed methods in the community, standard hydrologic and hydraulic study methods were used to determine the flood-hazard data required for this study. Flood events of a magnitude that is expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10-, 2-, 1-, and 0.2-percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term, average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood that equals or exceeds the 1-percent-annual-chance flood in any 50-year period is approximately 40 percent (4 in 10); for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this study. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish peak discharge-frequency relationships for each flooding source studied by detailed methods affecting the community.

The upper reaches of the Neosho River basin are presently regulated by the John Redmond, Council Grove, and Marion Flood Control Reservoirs. Accordingly, the annual peak discharge-frequency curve at the USGS stream gage near Commerce was derived using a graphical analysis of output from the Southwestern Division Reservoir Regulation Simulation Model of the Arkansas River Basin, Run No. 85-01. This simulation used present regulation criteria and the existing basin conditions for the hydrologic period of record from January 1940 through December 1974. The set of frequency data obtained from this exercise was the natural (without flood control reservoirs) annual peak discharge-frequency curve, which was used as a guide for extrapolation of the frequency interval (Reference 7) (Reference 8). To estimate frequency flows for the study reach, which is approximately 11 miles downstream from the gage, the frequency flows at the Commerce gage were increased using a drainage area ratio to the 0.7 power to account for the 195 square miles of tributary drainage area between the Commerce gage and the downstream study limit. The hydrologic analysis of the Neosho River was reevaluated for comparison with the discharges developed by the USACE Flood Plain Information report (Reference 9)

As part of the Tar Creek Feasibility Investigation under the authority of the OWRB, a hydrologic model for the Tar Creek basin was developed by the SCS (Reference 8). Discharge estimates from this model were used in the design of channels to divert surface water away from mining subsidence areas and into the Tar Creek drainage system.

Frequency discharges for Little Elm Creek were estimated using the USACE HEC-1 watershed modeling of the basin (Reference 10). Based on Snyder's unit hydrograph method (Reference 11), the coefficients for this hydrograph were determined by the Tulsa District USACE regional relationships (Reference 12). Typical precipitation losses of 1.0 inch initial and 0.05 inch constant were assumed.

For Belmont Run, Quail Creek, and Fairgrounds Branch, hydrological and meteorological data were examined from the U.S. Weather Service Bureau Paper and climatological bulletins. Mean annual precipitation figures from USGS Water Resources Investigations 77-54 were used in conjunction with the regression formulas for rural and urbanized areas for establishing the peak discharges for the selected recurrence intervals (Reference 13).

Frequency discharges for the upper and lower reaches of Lost Creek, Wyandotte Ditch, and Warren Branch were also estimated using the USACE HEC-1 watershed modeling (Reference 10). Coefficients for the Lost Creek and Warren Branch hydrographs were determined by the Tulsa District USACE regional relationships (Reference 12) based on Snyder's unit hydrograph method (Reference 11). Lost Creek was based on 1.05 inches initial loss (Reference 13) and an SCS curve number 72 (Reference 15) while Warren Branch was based on 1.0 inch initial loss and 0.05 inch constant. The 10-, 2-, and 1-percent-annual-chance rainfall for Wyandotte Ditch was based on extrapolated data from the National Weather Service Technical Paper No. 40 (Reference 7).

Above the confluence of Lost Creek (Upper Reach) and Little Lost Creek, there are presently three SCS floodwater retarding structures and three debris basins, each having ultimate, base flood storage. A summary of stillwater elevations is provided in Table 3. To account for the operation of these structures, the total contributing drainage area was reduced by an amount equal to the area above the six SCS structures. Then, a TP-40, 1-percent-annual-chance, 48-hour storm rainfall was applied to each HEC-1 model to estimate the respective 1-percent-annual-chance peak discharges (Reference 16). To determine the proper slope for the discharge-frequency curves, two reference discharge-frequency relationships were developed using data from the Shoal Creek gage near Big Cabin with the Flood Flow Frequency Analysis program (Reference 17). The reference discharge-frequency relationships were combined to obtain an intermediate slope for the discharge-frequency curves for each basin; the curves were then plotted through their respective 1-percent-annual-chance discharge points.

Peak discharge-drainage area relationships for streams studied by detailed methods are shown in Table 2, "Summary of Discharges."

Table 2: Summary of Discharges

Flooding Source and Location	Drainage Area (Square miles)	Peak Discharges (Cubic Feet per Second) 10-percent	2-percent	1-percent	0.2-percent
BELMONT RUN					
At its confluence with Tar Creek	3.12	1,791	2,649	3,072	4,059
Upstream of Main Street	2.09	1,368	2,017	2,333	3,072
Upstream of 22nd Avenue Northeast	1.70	1,191	1,753	2,024	2,661
Upstream of Highland Avenue	1.24	963	1,415	1,630	2,137
FAIRGROUNDS BRANCH					
At its confluence with the Neosho River	2.04	1,111	1,775	2,109	2,898
Upstream of confluence of South Tributary	1.43	872	1,389	1,645	2,252
Upstream of South Main Street	1.08	721	1,145	1,351	1,845
LITTLE ELM CREEK					
At its confluence with the Neosho River	12.65	3,700	6,990	8,720	13,700
LOST CREEK (LOWER REACH)					
Approximately 4,600 feet above its confluence with Grand Lake	95.19	13,800	22,700	27,400	38,300
At its confluence with Grand Lake	91.90	13,800	22,700	27,400	38,300
LOST CREEK (UPPER REACH)					
Approximately 5,000 feet above its confluence with Grand Lake	59.84	8,200	15,500	19,310	30,400

Table 2: Summary of Discharges (Cont'd)

Flooding Source and Location	Drainage Area (Square miles)	Peak Discharges (Cubic Feet per Second) 10-percent	2-percent	1-percent	0.2-percent
NEOSHO RIVER					
Entire reach within City of Miami	6,057	86,300	147,000	177,000	260,000
Approximately 50,000 feet above its confluence with Spring River	6,071	69,600	139,100	175,000	279,500
QUAIL CREEK					
Entire reach within City of Miami	2.79	1,351	2,161	2,576	3,547
TAR CREEK					
At its confluence with the Neosho River	50.5	8,470	12,200	14,300	19,440
Upstream of 22nd Avenue Northeast	47.23	8,200	11,860	13,920	18,950
Upstream of private road	43.29	7,930	11,560	13,580	18,500
Below D Street bridge	37.68	7,220	10,610	12,480	17,020
Below U.S. Route 69 bridge	34.23	6,910	10,190	11,990	16,370
WARREN BRANCH					
Approximately 20,000 feet above its confluence with Spring River	18.86	4,830	9,100	11,330	17,900
WYANDOTTE DITCH					
At its confluence with Grand Lake	0.86	*	*	1,650	*

* Data Not Available

Table 3: Summary of Stillwater Elevations

Flooding Source and Location	Elevation (Feet) 10-percent	2-percent	1-percent	0.2-percent
GRAND LAKE O' THE CHEROKEES				
Just downstream of the confluence of Council Hollow	*	*	755.0	*
LOST CREEK				
Approximately 250 feet upstream of Lost Creek County Highway	755.8	757.3	758.0	760.0

* Not determined

3.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of flooding from the sources studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals. Users should be aware that flood elevations shown on the Flood Insurance Rate Map represent rounded whole-foot elevations and may not exactly reflect the elevations shown on the Flood Profiles or in the Floodway Data tables in the FIS report. Flood elevations shown on the FIRM are primarily intended for flood insurance rating purposes. For construction and/or floodplain management purposes, users are cautioned to use the flood elevation data presented in this FIS in conjunction with the data shown on the FIRM.

Cross-sectional data for the backwater analyses of the Neosho River, Little Elm Creek, Tar Creek, and Fairgrounds Branch were obtained from topographic maps compiled from aerial photographs (Reference 18). All bridges and culverts were surveyed to obtain elevation data and structural geometry. Within the City of Miami, cross sections for the backwater analyses for the Neosho River were obtained from the 1969 USACE study in conjunction with field checks at all structures on the reach (Reference 9). Dimensions for the new structure on Main Street were obtained from Oklahoma State Highway Department, and structural plans for the railway bridge upstream of Main Street were provided by the St. Louis-San Francisco Railway. The cross sections for Tar Creek were obtained by the USACE in September 1986. The field cross sections for Belmont Run, Quail Creek, and Fairgrounds Branch were obtained by the study contractor in March 1979.

Water-surface elevations of floods of the selected recurrence intervals were computed using the USACE HEC-2 step-backwater computer program (Reference 19). The HEC-2 model was calibrated for all the streams studied using flows from the February 22-24, 1985 storm. High-water marks from the February 1985 flood were matched to within 1 foot. Flood profiles were drawn showing computed water-surface elevations for floods of the selected recurrence intervals. Starting water surface elevations for all sources studied in detail were determined using the slope/area method. Within the City of Miami, starting water-surface elevations for the Neosho River were calculated using known high-water marks. Starting water-surface elevations for Belmont Run and Quail Creek were coincident with flood elevations on Tar Creek since coincident floods on the tributaries and main stream of Tar Creek are probable.

Comparisons of the results for the Neosho River and Tar Creek were analyzed with results of the 1969 USACE study on the Neosho River and Tar Creek. Adjustments to the model reflect additional residential development and commercial growth. The final comparisons on the Neosho River resulted in differences of 0.5-foot or less. The present model flood levels were shown in this study as it reflects the Main Street Bridge and rebuilt Frisco Railroad Bridge.

The acceptability of all assumed hydraulic factors, cross sections, and hydraulic structure data was checked by computations that duplicated historic floodwater profiles on the Neosho River and Tar Creek study reaches. For Belmont Run, Quail Creek, and Fairgrounds Branch, there are no historic flood profiles available.

Cross-sectional data for the backwater analyses for Lost Creek and Warren Branch were obtained from topographic maps compiled from aerial photographs (Reference 18). All bridges and culverts were surveyed to obtain elevation data and structural geometry.

Water-surface elevations of floods of the selected recurrence intervals in Lost Creek and Warren Branch were computed using the USACE HEC-2 step-backwater computer program (Reference 19). The HEC-2 model was calibrated for these streams studied using flows from the February 22-24, 1985 storm. High-water marks from the February 1985 flood were matched to within 1 foot. Flood profiles were drawn showing computed water-surface elevations for floods of the selected recurrence intervals. Starting water surface elevations for all sources studied in detail were determined using the slope/area method.

The original analysis on Wyandotte Ditch indicated a sheet flow situation. Cross sections were developed from the 2 foot contour interval maps perpendicular to the sheet flow. Normal depth computations resulted in an average 1 percent annual chance recurrence interval flood depth of approximately 1 foot. Grand Lake was examined for its effects on the Town of Wyandotte. It has an elevation of approximately 755 feet for a 10 percent annual chance frequency storm and a Government Flowage Easement of approximately 760 feet. (Reference 20). The original hydraulic model for Wyandotte Ditch was modified to incorporate overflow from Wyandotte Ditch that flows to the north. Revised hydraulic analyses for the 1-percent-annual-chance flood event for Wyandotte Ditch were performed using the USACE HEC-2 computer program (Reference 21). Cross sections were compiled based on topographic mapping and linear interpolation between contours. The slope-area method was used to determine the starting water-surface elevation (Reference 22). Channel roughness factors (Manning's "n" values) used in the hydraulic computations were chosen by engineering judgment after field reconnaissance of the watershed. Channel and over bank "n" values for the streams studied by detailed methods are shown in 4, “Summary of Roughness Coefficients.”

Table 4: Summary of Roughness Coefficients

Flooding Source	Roughness Coefficients	
	Channel	Overbanks
Belmont Run (within the City of Miami)	0.035–0.095*	0.045–0.095
Fairgrounds Branch (within the City of Miami)	0.035–0.095*	0.045–0.095
Little Elm Creek (within the City of Miami)	0.035–0.095*	0.045–0.095
Little Elm Creek (all other reaches)	0.035–0.045	0.08–0.12
Lost Creek (Lower Reach)	0.045–0.060	0.07
Lost Creek (Upper Reach)	0.045–0.050	0.08–0.12
Neosho River (within the City of Miami)**	0.040–0.045	0.045–0.060
Neosho River (all other reaches)	0.030	0.04–0.95
Quail Creek (within the City of Miami)	0.035–0.095*	0.045–0.095
Tar Creek (within the City of Miami)	0.035–0.095*	0.045–0.095
Tar Creek (all other reaches)	0.050–0.060	0.08–0.14
Warren Branch	0.050–0.075	0.06–0.10
Wyandotte Ditch	0.040	0.065–0.070

* Through culverts, values were reduced to 0.018–0.024

** Occasional obstructions of snags and trash heaps on the upstream side of bridge piers were not considered.

Locations of selected cross sections used in the hydraulic analyses are shown on the Flood Profiles (Exhibit 1). For stream segments for which a floodway was computed (Section 4.2), selected cross-section locations are also shown on the FIRM (Exhibit 2).

The hydraulic analyses for this study were based on unobstructed flow. The flood elevations shown on the Flood Profiles (Exhibit 1) are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

3.3 Vertical Datum

All FIS reports and FIRMs are referenced to a specific vertical datum. The vertical datum provides a starting point against which flood, ground, and structure elevations can be referenced and compared. Until recently, the standard vertical datum used for newly created or revised FIS reports and FIRMs was the National Geodetic Vertical Datum of 1929 (NGVD). With the completion of the North American Vertical Datum of 1988 (NAVD), many FIS reports and FIRMs are now prepared using NAVD as the referenced vertical datum.

Flood elevations shown in this FIS report and on the FIRM are referenced to the NAVD88. These flood elevations must be compared to structure and ground elevations referenced to the same vertical datum. Some of the data used in this revision were taken from the prior effective FIS reports and FIRMs and adjusted to NAVD88. The datum conversion factor from NGVD29 to NAVD88 in Ottawa County is +0.353 feet.

For information regarding conversion between the NGVD and NAVD, visit the National Geodetic Survey website at www.ngs.noaa.gov, or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

Temporary vertical monuments are often established during the preparation of a flood hazard analysis for the purpose of establishing local vertical control. Although these monuments are not shown on the FIRM, they may be found in the Technical Support Data Notebook associated with the FIS report and FIRM for this community. Interested individuals may contact FEMA to access these data.

To obtain current elevation, description, and/or location information for benchmarks shown on this map, please contact the Information Services Branch of the NGS at (301) 713-3242, or visit their Web site at www.ngs.noaa.gov.

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

The NFIP encourages State and local governments to adopt sound floodplain management programs. To assist in this endeavor, each FIS report provides 1-percent-annual-chance floodplain data, which may include a combination of the following: 10-, 2-, 1-, and 0.2-percent-annual-chance flood elevations; delineations of the 1- and 0.2-percent-annual-chance floodplains; and a 1-percent-annual-chance floodway. This information is presented on the FIRM and in many components of the FIS report, including Flood Profiles, Floodway Data tables, and Summary of Stillwater Elevation tables. Users should reference the data presented in the FIS report as well as additional information that may be available at the local community map repository before making flood elevation and/or floodplain boundary determinations.

4.1 Floodplain Boundaries

To provide a national standard without regional discrimination, the 1-percent-annual-chance flood has been adopted by FEMA as the base flood for floodplain management purposes. The 0.2-percent-annual-chance flood is employed to indicate additional areas of flood risk in the community. For each stream studied by detailed methods, the 1- and 0.2-percent-annual-chance floodplain boundaries have been delineated using the flood elevations determined at each cross section.

Between cross sections, the boundaries were interpolated using topographic maps for the original studies and restudies as follows:

City of Miami
Topographic maps at a scale of 1:24,000 with a contour interval of 10 feet (Reference 22).

Town of Wyandotte
Topographic maps at a scale of 1:2,400 with a contour interval of 2 feet (Reference 23).

Unincorporated Areas of Ottawa County
Topographic maps at a scale of 1:7,200 with a contour interval of 2 feet (Reference 18).

The 1- and 0.2-percent-annual-chance floodplain boundaries are shown on the FIRM. On this map, the 1-percent-annual-chance floodplain boundary corresponds to the boundary of the areas of special flood hazards (Zones A and AE), and the 0.2-percent-annual-chance floodplain boundary corresponds to the boundary of areas of moderate flood hazards. In cases where the 1- and 0.2-percent-annual-chance floodplain boundaries are close together, only the 1-percent-annual-chance floodplain boundary has been shown. Small areas within the floodplain boundaries may lie above the flood elevations, but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

For the streams studied by approximate methods, only the 1-percent-annual-chance floodplain boundary is shown on the FIRM.

4.2 Floodways

Encroachment on floodplains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. For purposes of the NFIP, a floodway is used as a tool to assist local communities in this aspect of floodplain management. Under this concept, the area of the 1-percent-annual-chance floodplain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment so that the base flood can be carried without substantial increases in flood heights. Minimum Federal standards limit such increases to 1 foot, provided that hazardous velocities are not produced. The floodways in this study are presented to local agencies as minimum standards that can be adopted directly or that can be used as a basis for additional floodway studies.

The floodways presented in this study were computed for certain stream segments on the basis of equal-conveyance reduction from each side of the floodplain. Floodway widths were computed at cross sections. Between cross sections, the floodway boundaries were interpolated. The results of the floodway computations are tabulated for selected cross sections (see Table 5, “Floodway Data Table” of this FIS report). In cases where the floodway and 1-percent-annual-chance floodplain boundaries are either close together or collinear, only the floodway boundary is shown.

A floodway was not determined for the Neosho River; however, results of the hydraulic analysis are shown in Table 5. Portions of the floodway widths for the Neosho River, Tar Creek, and Warren Branch extend beyond the county boundary.

Near the confluence of streams studied in detail, floodway computations are made without regard to flood elevations on the receiving water body. Therefore, "Without Floodway" elevations presented in Table 5 for certain downstream cross sections of Tar Creek and Quail Creek are lower than the regulatory flood elevations in that area, which must take into account the 1-percent-annual-chance flooding due to backwater from other sources.

No floodways were computed for Wyandotte Ditch as part of this restudy; however, a floodway along Lost Creek (Lower Reach) has been annexed at the Main Street right-of-way crossing of Lost Creek.

The area between the floodway and 1-percent-annual-chance floodplain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the floodplain that could be completely obstructed without increasing the water-surface elevation (WSEL) of the base flood more than 1 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to floodplain development are shown in Figure 1.

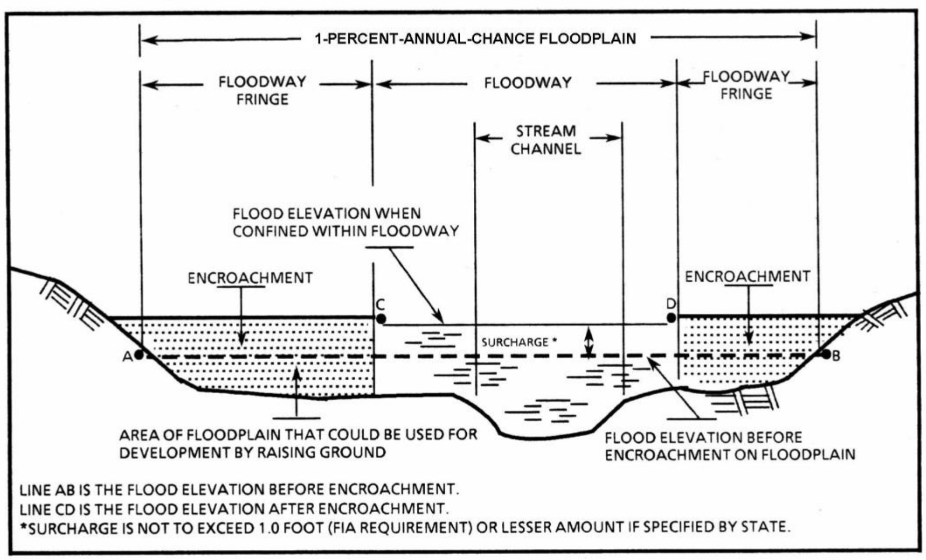


Figure 1: Floodway Schematic

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE-FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE (FEET)
BELMONT RUN								
A	1,474	157	630	4.9	775.1	775.1	776.0	0.9
B	1,626	310	1,311	2.3	776.0	776.0	777.0	1.0
C	2,015	297	1,196	2.6	777.0	777.0	777.7	0.7
D	2,433	124	511	6.0	781.6	781.6	782.4	0.8
E	2,717	259	1,335	2.3	782.8	782.8	783.6	0.8
F	5,125	439	1,413	1.7	786.0	786.0	786.9	0.9
G	6,917	700	3,495	0.6	791.8	791.8	792.5	0.7
H	8,550	678	1,576	1.3	792.6	792.6	793.1	0.5
I	10,126	380	4,239	0.5	798.1	798.1	798.8	0.7
J	10,718	357	1,945	1.0	798.4	798.4	799.0	0.6
K	12,018	282	1,486	1.4	798.7	798.7	799.3	0.6
L	13,569	206	1,228	1.3	801.7	801.7	802.5	0.8
M	14,619	120	625	2.6	802.3	802.3	802.9	0.6
N	15,819	211	972	1.7	803.7	803.7	804.3	0.6
O	17,000	192	770	2.1	804.6	804.6	805.2	0.6

[1]Feet above confluence with Tar Creek

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

FLOODWAY DATA

BELMONT RUN

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE-FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE (FEET)
FAIRGROUNDS BRANCH								
A	7,250	100	474	2.9	775.3	775.3	776.1	0.8
B	8,250	51	177	4.5	781.7	781.7	782.6	0.9
C	9,250	145	302	2.7	790.0	790.0	790.7	0.7

[1]Feet above confluence with Neosho River

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

FLOODWAY DATA

FAIRGROUNDS BRANCH

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE-FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE (FEET)
LITTLE ELM CREEK								
A	3,053	320	3,126	2.8	772.3	755.3[2]	756.2[2]	0.9
B	4,343	258	1,978	4.4	772.3	757.2[2]	758.1[2]	0.9
C	5,668	349	2,001	4.4	772.3	761.7[2]	762.7[2]	1.0
D	6,250	276	1,830	4.8	772.3	764.0[2]	765.0[2]	1.0
E	7,340	393	2,795	3.1	772.3	766.9[2]	767.8[2]	0.9
F	7,808	261	1,522	5.7	772.3	769.3[2]	770.0[2]	0.7
G	9,478	650	3,354	2.6	774.2	774.2	775.2	1.0
H	10,319	373	2,059	4.2	775.7	775.7	776.6	0.9
I	11,280	573	3,132	2.8	778.0	778.0	778.9	0.9
J	12,363	466	2,351	3.7	780.4	780.4	781.2	0.8
K	14,842	494	2,864	3.8	785.2	785.2	786.2	1.0
L	15,718	514	3,829	2.3	786.1	786.1	787.1	1.0
M	16,100	501	3,273	2.7	787.5	787.5	788.5	1.0
N	16,460	727	5,026	1.7	787.9	787.9	788.9	1.0
O	16,652	542	3,434	2.5	788.1	788.1	789.1	1.0
P	18,300	402	2,459	3.5	789.8	789.8	790.8	1.0

[1]Feet above confluence with Neosho River
[2]Elevation computed without consideration of backwater effects from the Neosho River

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

FLOODWAY DATA

LITTLE ELM CREEK

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE-FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE (FEET)
LOST CREEK (LOWER REACH)								
A	5,090	497	4,128	6.6	755.9	755.9	756.9	1.0
B	7,040	1,431	14,046	2.0	758.9	758.9	759.7	0.8
C	8,000	1,494	10,886	2.5	759.2	759.2	760.2	1.0
D	10,000	1,513	6,840	4.0	761.6	761.6	762.6	1.0
E	11,960	959	9,040	3.0	764.6	764.6	765.6	1.0
F	12,840	735	4,945	5.5	765.6	765.6	766.6	1.0
G	13,700	590	4,861	5.6	768.4	768.4	769.4	1.0

[1]Feet above confluence with Grand Lake O' the Cherokees

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

FLOODWAY DATA

LOST CREEK (LOWER REACH)

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE-FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE (FEET)
LOST CREEK (UPPER REACH)								
A	45,800	787	6,115	3.2	829.4	829.4	830.4	1.0
B	46,240	618	3,750	5.1	830.3	830.3	831.3	1.0
C	47,295	1,073	6,074	3.2	833.6	833.6	834.6	1.0
D	48,315	770	4,183	5.6	835.6	835.6	836.5	0.9
E	48,705	605	3,823	5.1	836.7	836.7	837.7	1.0
F	49,065	353	2,237	8.6	838.5	838.5	838.7	0.2
G	49,755	410	2,661	7.3	841.9	841.9	842.2	0.3
H	49,970	407	3,104	6.2	843.5	843.5	844.4	0.9
I	50,465	730	6,421	3.0	845.5	845.5	846.1	0.6
J	50,900	803	8,395	2.3	845.9	845.9	846.5	0.6
K	51,800	850	7,120	2.7	846.4	846.4	847.2	0.8
L	52,845	850	7,127	2.7	847.6	847.6	848.6	1.0
M	52,890	850	6,880	2.8	847.6	847.6	848.6	1.0

[1]Feet above confluence with Grand Lake O' the Cherokees

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

FLOODWAY DATA

LOST CREEK (UPPER REACH)

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE-FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE (FEET)
NEOSHO RIVER								
A	51,080	1,846	32,453	5.4	770.1	770.1	771.1	1.0
B	53,210	1,900	35,431	4.9	771.1	771.1	771.9	0.8
C	54,266	1,920	38,645	4.5	771.7	771.7	772.5	0.8
D	55,820	2,480	46,866	3.7	772.1	772.1	773.0	0.9
E	58,520	1,280	33,895	5.2	772.6	772.6	773.6	1.0
F	58,640	1,250	33,921	5.2	772.7	772.7	773.7	1.0
G	60,315	2,990	70,260	2.5	773.7	773.7	774.6	0.9
H	62,265	2,590	43,130	4.1	774.0	774.0	774.6	0.6
I	62,787	*	*	*	773.2	773.2	*	*
J	67,381	*	*	*	774.9	774.9	*	*
K	67,979	*	*	*	775.2	775.2	*	*
L	69,939	*	*	*	775.8	775.8	*	*
M	74,652	*	*	*	776.4	776.4	*	*

[1]Feet above confluence with Spring River
*Floodway not computed

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

FLOODWAY DATA

NEOSHO RIVER

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE-FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE (FEET)
QUAIL CREEK								
A[2]	375	655	5,408	2.6	774.0	768.4[4]	769.3[4]	0.9
B[3]	850	1,130	8,602	2.7	774.0	769.6[4]	770.5[4]	0.9
C	1,950	84	316	8.1	774.0	769.2[4]	769.2[4]	0.0
D	3,450	354	1,064	2.4	774.0	773.2[4]	773.8[4]	0.6
E	4,513	77	405	6.4	775.4	775.4	775.6	0.2
F	4,637	137	407	6.3	776.3	776.3	776.4	0.1
G	5,012	136	614	4.2	777.6	777.6	778.5	0.9
H	5,612	107	451	5.7	779.4	779.4	780.3	0.9

[1]Feet above confluence with Tar Creek
[2]Mapped coincident with cross-section B on Tar Creek
[3]Mapped coincident with cross-section C on Tar Creek
[4]Elevation computed without consideration of backwater effects from the Neosho River

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

FLOODWAY DATA

QUAIL CREEK

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE-FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE (FEET)
TAR CREEK								
A	11,250	1,046	6,474	2.2	774.0	766.0[4]	767.0[4]	1.0
B[2]	12,100	655	5,408	2.6	774.0	768.4[4]	769.3[4]	0.9
C[3]	12,900	1,130	8,602	1.7	774.0	769.6[4]	770.5[4]	0.9
D	13,800	1,130	7,180	2.0	774.0	770.5[4]	771.3[4]	0.8
E	14,500	470	2,682	5.3	774.0	774.0	774.0	0.0
F	14,970	900	6,739	2.1	775.1	775.1	775.6	0.5
G	15,720	790	7,114	2.0	775.5	775.5	776.3	0.8
H	16,950	895	5,665	2.5	776.3	776.3	777.3	1.0
I	18,205	1,190	7,710	1.8	777.8	777.8	778.8	1.0
J	19,400	1,221	7,746	1.8	778.3	778.3	779.2	0.9
K	19,918	1,046	7,222	1.9	778.6	778.6	779.5	0.9
L	20,250	1,007	6,503	2.1	779.0	779.0	779.9	0.9
M	21,255	974	6,130	2.3	779.9	779.9	780.8	0.9
N	22,465	1,513	8,804	1.6	780.8	780.8	781.7	0.9
O	23,760	1,200	7,322	1.9	781.6	781.6	782.6	1.0
P	24,625	1,490	10,022	1.4	782.1	782.1	783.1	1.0
Q	25,020	1,340	7,762	1.7	782.2	782.2	783.2	1.0
R	25,210	1,350	8,024	1.7	782.5	782.5	783.4	0.9
S	25,910	1,585	9,131	1.5	782.8	782.8	783.7	0.9

[1]Feet above confluence with Neosho River
[2]Mapped coincident with cross-section A on Quail Creek
[3]Mapped coincident with cross-section B on Quail Creek
[4]Elevation computed without consideration of backwater effects from the Neosho River

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

FLOODWAY DATA

TAR CREEK

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE-FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE (FEET)
TAR CREEK (CONTINUED)								
T	27,500	1,420	6,700	2.0	783.6	783.6	784.6	1.0
U	28,910	756	3,977	3.3	785.8	785.8	786.8	1.0
V	31,135	1,500	10,360	1.2	788.5	788.5	789.5	1.0
W	32,830	983	6,774	1.8	789.5	789.5	790.4	0.9
X	33,180	1,030	5651	2.2	790.1	790.1	791.1	1.0
Y	33,520	880	4236	2.9	790.6	790.6	791.4	0.8
Z	34,660	725	4,150	3.0	793.2	793.2	793.4	0.2
AA	35,720	840	6,174	2.0	793.9	793.9	794.7	0.8
AB	36,630	890	7,598	1.6	794.3	794.3	795.1	0.8
AC	37,640	758	6,216	2.0	794.8	794.8	795.6	0.8
AD	38,885	757	8,162	1.5	795.3	795.3	796.2	0.9
AE	39,525	812	7,238	1.7	795.6	795.6	796.5	0.9

[1]Feet above confluence with Neosho River

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

FLOODWAY DATA

TAR CREEK

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE-FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE (FEET)
WARREN BRANCH								
A	19,600	137	1,706	6.6	855.4	855.4	856.4	1.0
B	20,285	130	1,611	7.0	858.3	858.3	859.3	1.0
C	20,805	140	1,756	6.5	861.3	861.3	861.9	0.6
D	21,015	186	2,740	4.1	868.8	868.8	869.1	0.3
E	24,230	464	2,760	4.1	878.9	878.9	879.9	1.0
F	25,165	349	1,706	6.6	885.2	885.2	886.2	1.0
G	25,800	320	2,246	5.0	890.3	890.3	891.2	0.9
H	27,000	492	3,205	3.5	895.8	895.8	896.8	1.0

[1]Feet above confluence with Spring River

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

FLOODWAY DATA

WARREN BRANCH

5.0 INSURANCE APPLICATION

For flood insurance rating purposes, flood insurance zone designations are assigned to a community based on the results of the engineering analyses. These zones are as follows:

Zone A

Zone A is the flood insurance rate zone that corresponds to the 1-percent-annual-chance floodplains that are determined in the FIS report by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no base (1-percent-annual-chance) flood elevations (BFEs) or depths are shown within this zone.

Zone AE

Zone AE is the flood insurance rate zone that corresponds to the 1-percent-annual-chance floodplains that are determined in the FIS report by detailed methods. Whole-foot BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone X

Zone X is the flood insurance rate zone that corresponds to areas outside the 0.2-percent-annual-chance floodplain, areas within the 0.2-percent-annual-chance floodplain, areas of 1-percent-annual-chance flooding where average depths are less than 1 foot, areas of 1-percent-annual-chance flooding where the contributing drainage area is less than 1 square mile (sq. mi.), and areas protected from the base flood by levees. No BFEs or depths are shown within this zone.

6.0 FLOOD INSURANCE RATE MAP

The FIRM is designed for flood insurance and floodplain management applications.

For flood insurance applications, the map designates flood insurance rate zones as described in Section 5.0 and, in the 1-percent-annual-chance floodplains that were studied by detailed methods, shows selected whole-foot BFEs or average depths. Insurance agents use zones and BFEs in conjunction with information on structures and their contents to assign premium rates for flood insurance policies.

For floodplain management applications, the map shows by tints, screens, and symbols, the 1- and 0.2-percent-annual-chance floodplains, floodways, and the locations of selected cross sections used in the hydraulic analyses and floodway computations.

The countywide FIRM presents flooding information for the entire geographic area of Ottawa County. Previously, FIRMs were prepared for each incorporated community and the unincorporated areas of the County identified as flood-prone. This countywide FIRM also includes flood-hazard information that was presented separately on Flood Boundary and Floodway Maps (FBFMs), where applicable. Historical data relating to the maps prepared for each community are presented in Table 6, “Community Map History.”

COMMUNITY NAME	INITIAL IDENTIFICATION	FLOOD HAZARD BOUNDARY MAP REVISIONS DATE	FIRM EFFECTIVE DATE	FIRM REVISIONS DATE
Afton, Town of	February 7, 1975	None	January 3, 1986	None
Commerce, City of	June 4, 1976	None	July 18, 1985	None
Fairland, Town of	April 9, 1976	None	January 1, 1992	None
Miami, City of	February 1, 1974	December 5, 1975	December 16, 1980	April 19, 1983 September 30, 1988 September 3, 1997
North Miami, Town of	April 9, 1976	None	August 5, 2010	None
Ottawa County (Unincorporated Areas)	May 20, 1977	None	December 2, 1988	December 19, 1997
Peoria, Town of	November 22, 1974	None	August 5, 2010	None
Picher, City of	July 23, 1976	None	September 21, 1982	None
Quapaw, Town of	August 13, 1976	None	August 5, 2010	None
Wyandotte, Town of	June 28, 1974	December 12, 1975 December 10, 1976	December 17, 1987	December 19, 1997

TABLE 6

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS

COMMUNITY MAP HISTORY

7.0 OTHER STUDIES

In June 1969, the USACE published a Flood Plain Information report for the Neosho River and Tar Creek (Reference 10). The USACE presented the 1-percent-annual-chance Standard Project Flood and July 1951 flood elevations for these streams. The study updated Manning's coefficients, bridge structural changes, and residential development since 1969. Comparisons of the results of the backwater analysis by the study contractor with the USACE flood levels resulted in differences not greater than 0.5 foot; therefore, the study flood levels were used in this study to show the latest topographic development.

A FIS for the City of Seneca, Missouri, has been published (Reference 22). The results of this study are in exact agreement with the results of that study.

FIS reports have been prepared for the City of Miami (Reference 1) and the Town of Wyandotte (Reference 2) as well as the unincorporated areas of Ottawa County (Reference 3). This FIS report either supersedes or is compatible with all previous studies published on streams studied in this report and should be considered authoritative for the purposes of the NFIP.

8.0 LOCATION OF DATA

Information concerning the pertinent data used in the preparation of this study can be obtained by contacting FEMA Region VI, Federal Insurance and Mitigation Division, 800 North Loop 288, Denton, Texas 76209.

9.0 BIBLIOGRAPHY AND REFERENCES

1. Federal Emergency Management Agency. Flood Insurance Study, City of Miami, Ottawa County, Oklahoma. Washington, D.C., September 30, 1988.

2. Federal Emergency Management Agency. Flood Insurance Study, City of Wyandotte, Ottawa County, Oklahoma. Washington, D.C., December 19, 1997.

3. Federal Emergency Management Agency. Flood Insurance Study, Ottawa County, Unincorporated Areas. Washington, D.C., March 31, 1997.

4. U.S. Department of Commerce, Bureau of the Census. *"State & County Quickfacts, Oklahoma Quicklinks"*. [Online] 2007. Available http://www.census.gov/census2000/states/ok.html.

5. Oklahoma Climatological Survey. *"Climatological Information for Ottawa County, OK"*. [Online] 2007. Available http://climate.ocs.ou.edu/county/ottawa.html.

6. National Climatic Data Center. *Event Record Details - 01 Jul 2007 Flood - Commerce, OK.* [Online. http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~ShowEvent~676070] July 2007.

7. Miami News Record. Preliminary damage assessment continues after Oklahoma Floods. *Miami News Record.* [Online] July 9, 2007. http://www.miaminewsrecord.com/archives.

8. U.S. Department of Agriculture, Soil Conservation Service. Tar Creek Feasibility Investigation, Task II.3.E.f: Assessment of Changes in Drainage Patterns Resulting from Proposed Diversion and Diking. Stillwater, Oklahoma, December 1983.

9. U.S. Department of the Army, Corps of Engineers, Tulsa District. Flood Plain Information, Neosho River and Tar Creek, Miami, Oklahoma. Tulsa, Oklahoma, June 1969.

10. U.S. Department of the Army, Corps of Engineers, Hydrologic Engineering Center. *HEC-1 Flood Hydrograph Package: Computer Program.* Davis, California, January 1985.

11. Snyder, Franklin F. "Synthetic Unit Hydrographs" in. *Transactions of the American Geophysical Union.* Vols. 19, Part 1, pp. 447-454.

12. U.S. Department of the Army, Corps of Engineers. Regional Relationships for Unit Hydrograph Coefficients, Natural and Urbanized Basins. Tulsa, Oklahoma, May 1980.

13. U.S. Department of the Army, Corps of Engineers, Hydrologic Engineering Center. *HEC-2 Water Surface Profiles, Generalized Computer Program.* Davis, California, October 1973.

14. U.S. Department of the Army, Corps of Engineers. Detailed Project Report: Lost and Little Creeks, Seneca, Missouri. January 1976.

15. U.S. Department of Agriculture, Soil Conservation Service. Technical Release No. 55: Urban Hydrology for Small Watersheds. Washington, D.C., January 1975.

16. U.S. Department of Commerce, Weather Bureau. Technical Paper No. 40: Rainfall Frequency Atlas of the United States. Washington, D.C., 1961, Revised 1963.

17. U.S. Department of the Army, Corps of Engineers, Hydrologic Engineering Center. *Flood Flow Frequency Analysis, Computer Program 723-X6-L7550.* Davis, California, February 1982.

18. Aerial Data Service. Photogrammetric Topographic Survey, Scale 1:2,400, Contour Interval 2 Feet: Ottawa County, Oklahoma. Tulsa, Oklahoma, April 1984.

19. U.S. Army Corps of Engineers, Hydrologic Engineering Center. *HEC-2 Water Surface Profiles, Generalized Computer Program.* Davis, California, April 1984.

20. U.S. Department of the Army, Corps of Engineers, Tulsa District. Civil Works Project Maps. Tulsa, Oklahoma, September 30, 1979.

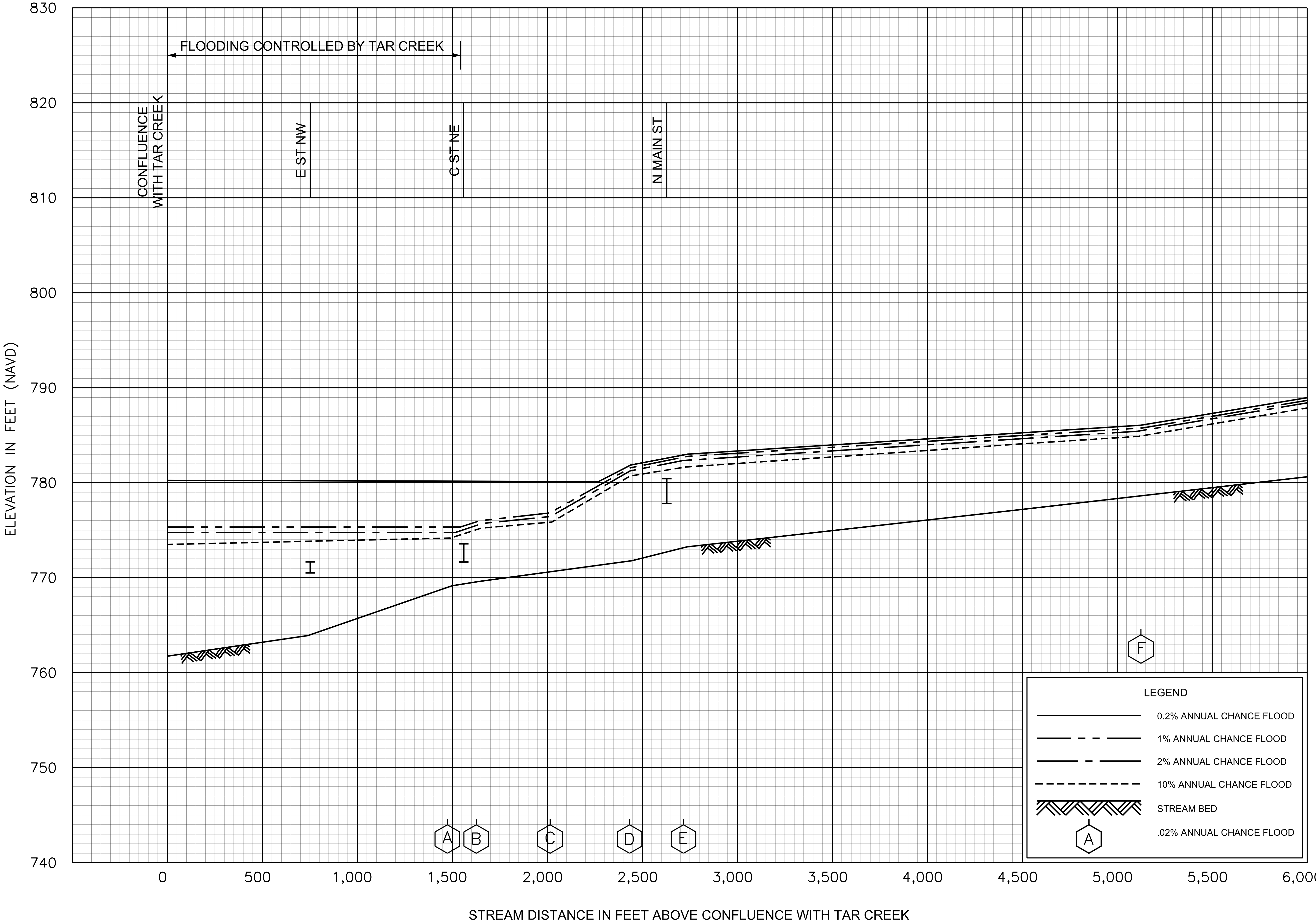
21. U.S. Department of the Army, Corps of Engineers, Hydrologic Engineering Center. *HEC-2 Water Surface Profiles, Generalized Computer Program, Version 4.6.2.* Davis, California, May 1991.

22. Federal Emergency Management Agency. Flood Insurance Study, City of Seneca, Newton County, Missouri. Washington, D.C., June 29, 1982.

23. U.S. Department of the Army, Corps of Engineers, Hydrologic Engineering Center. Report on Reservoir System Operation for Flood Control, Neosho River Basin, Kansas-Oklahoma. Davis, California, October 1973.

24. U.S. Department of the Interior, Geological Survey. 7.5-Minutes Series of Topographic Maps, Scale 1:24,000, Contour Interval 10 Feet: Miami, SE, Oklahoma, 1961; Miami SW, Oklahoma, 1961; Picher, Oklahoma, 1961; Miami NW, Oklahoma-Kansas. 1961.

25. Aerial Data Service, Inc. Topographic Maps, Scale 1:2,400, Contour Interval 2 Feet, Wyandotte, Oklahoma. , April 1984.



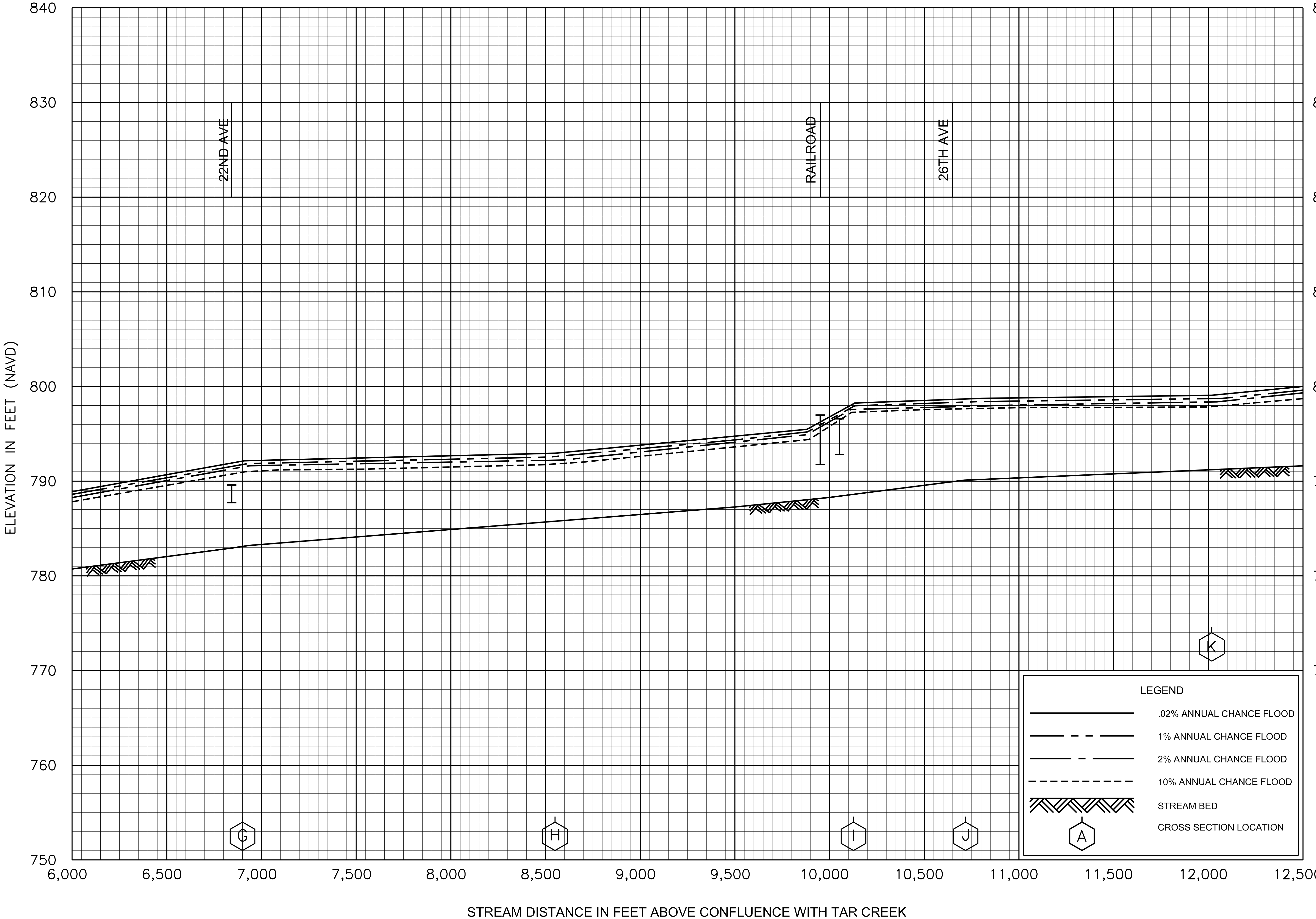
FLOOD PROFILES

BELMONT RUN

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

01P



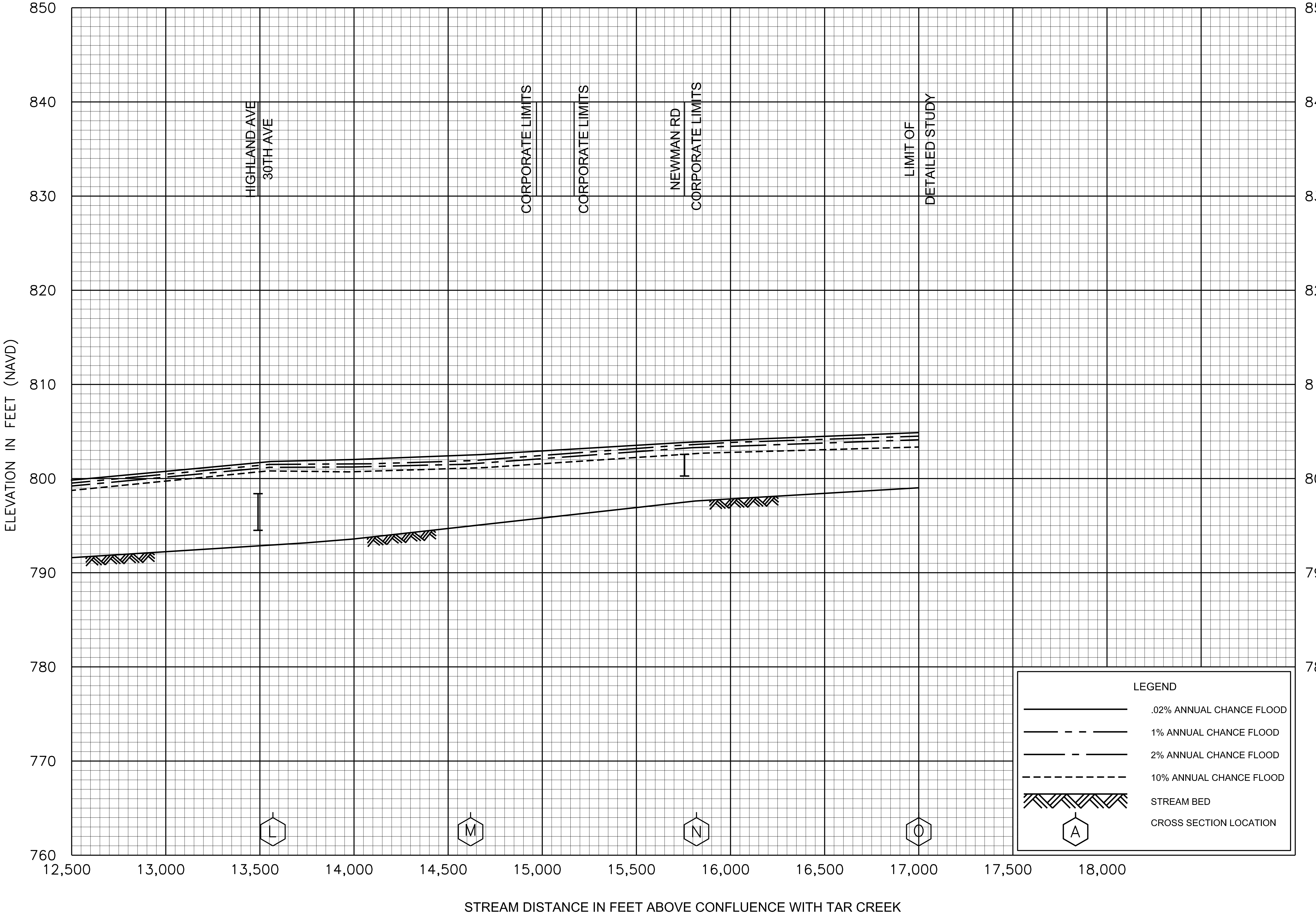
FLOOD PROFILES

BELMONT RUN

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

02P



FLOOD PROFILES

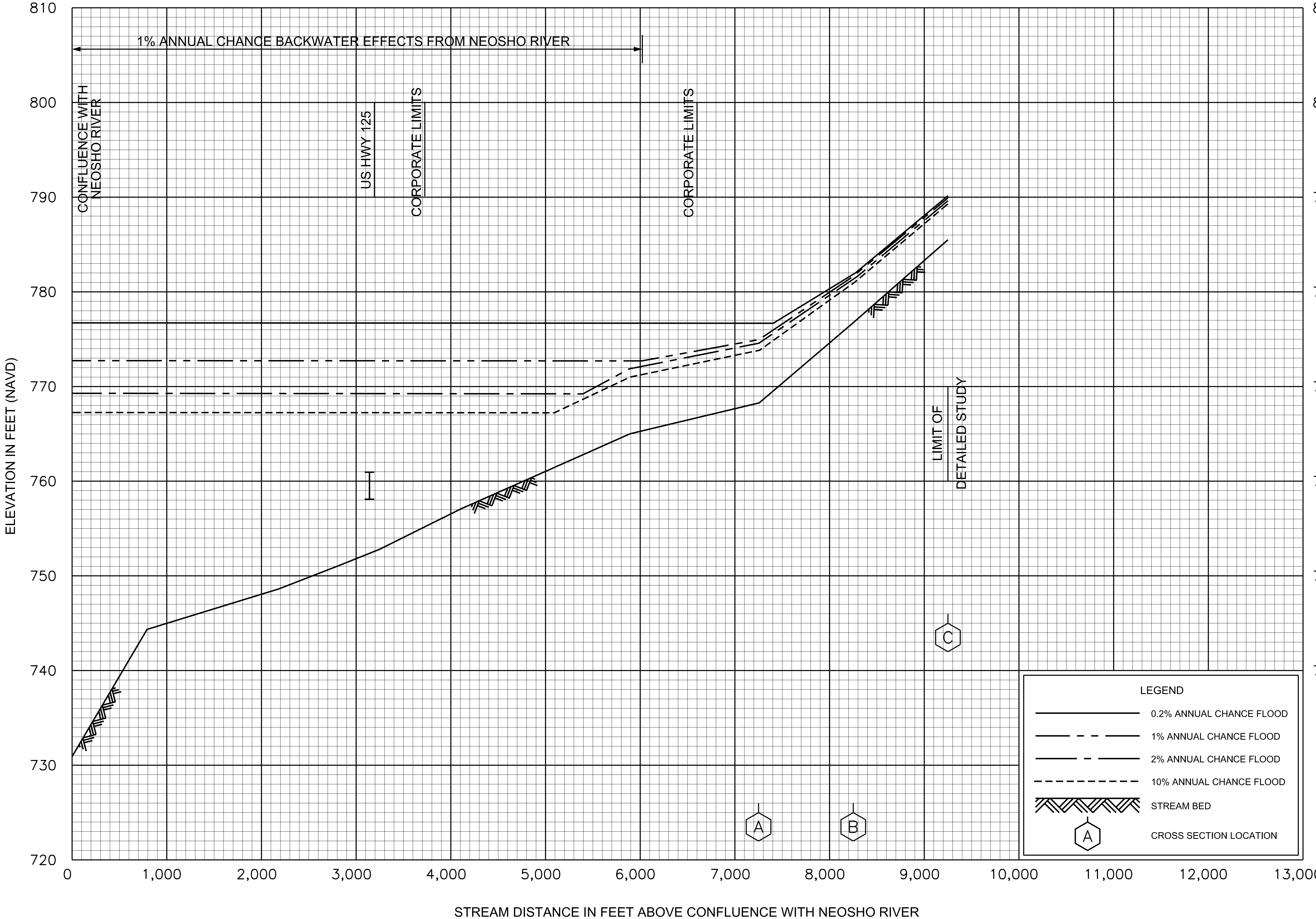
BELMONT RUN

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS

03P



FLOOD PROFILES

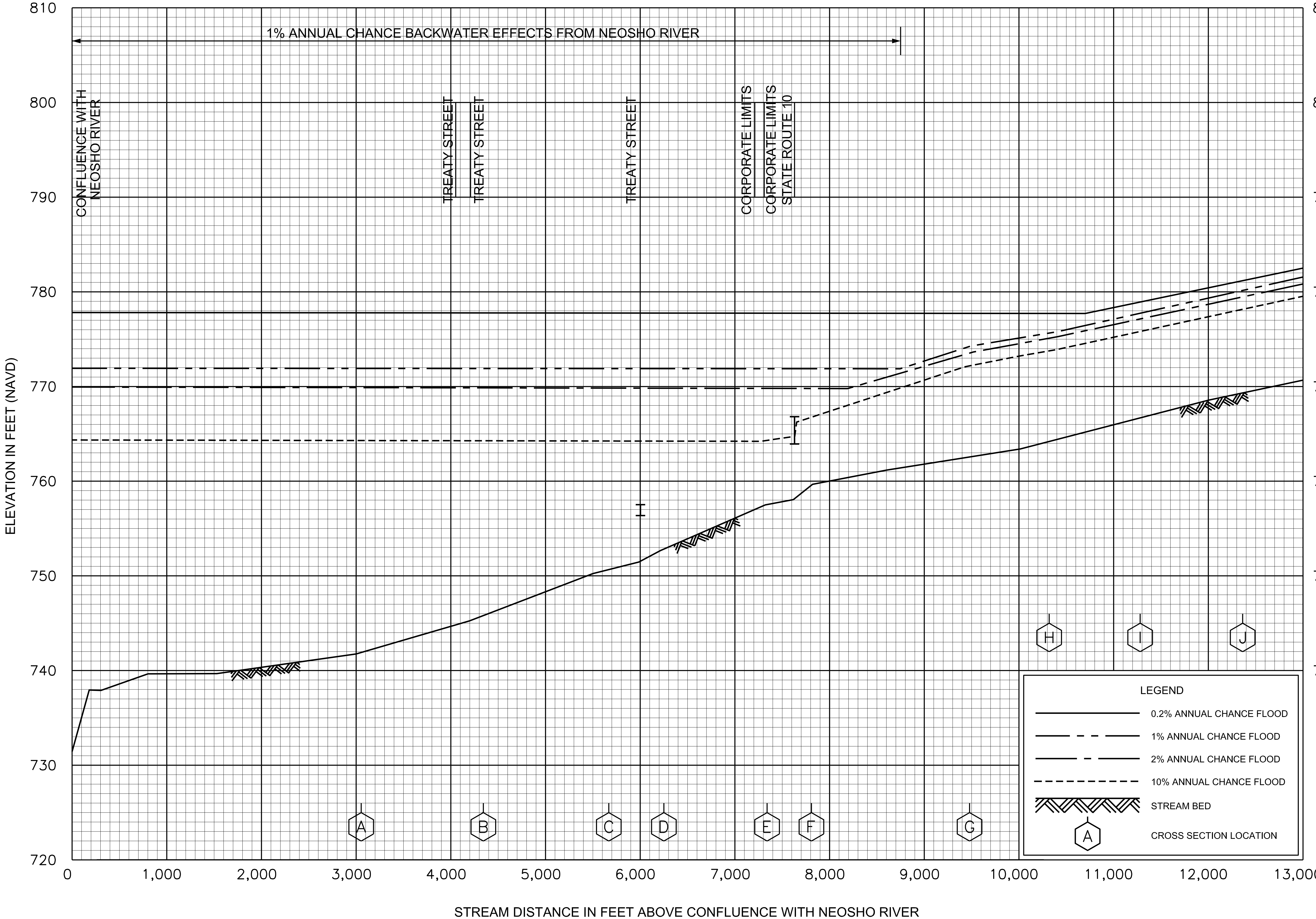
FAIRGROUNDS BRANCH

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS

04P

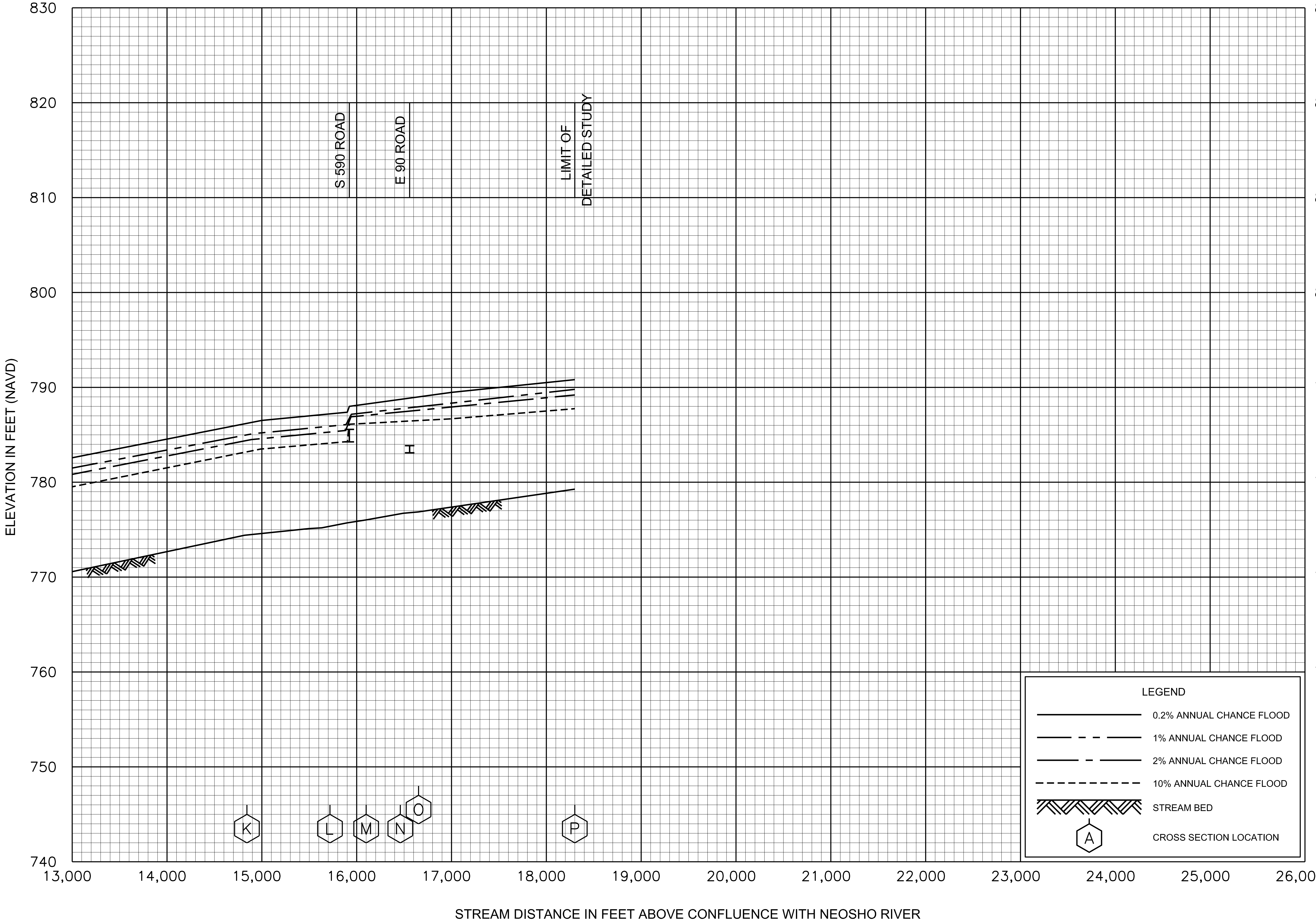


FLOOD PROFILES

LITTLE ELM CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS



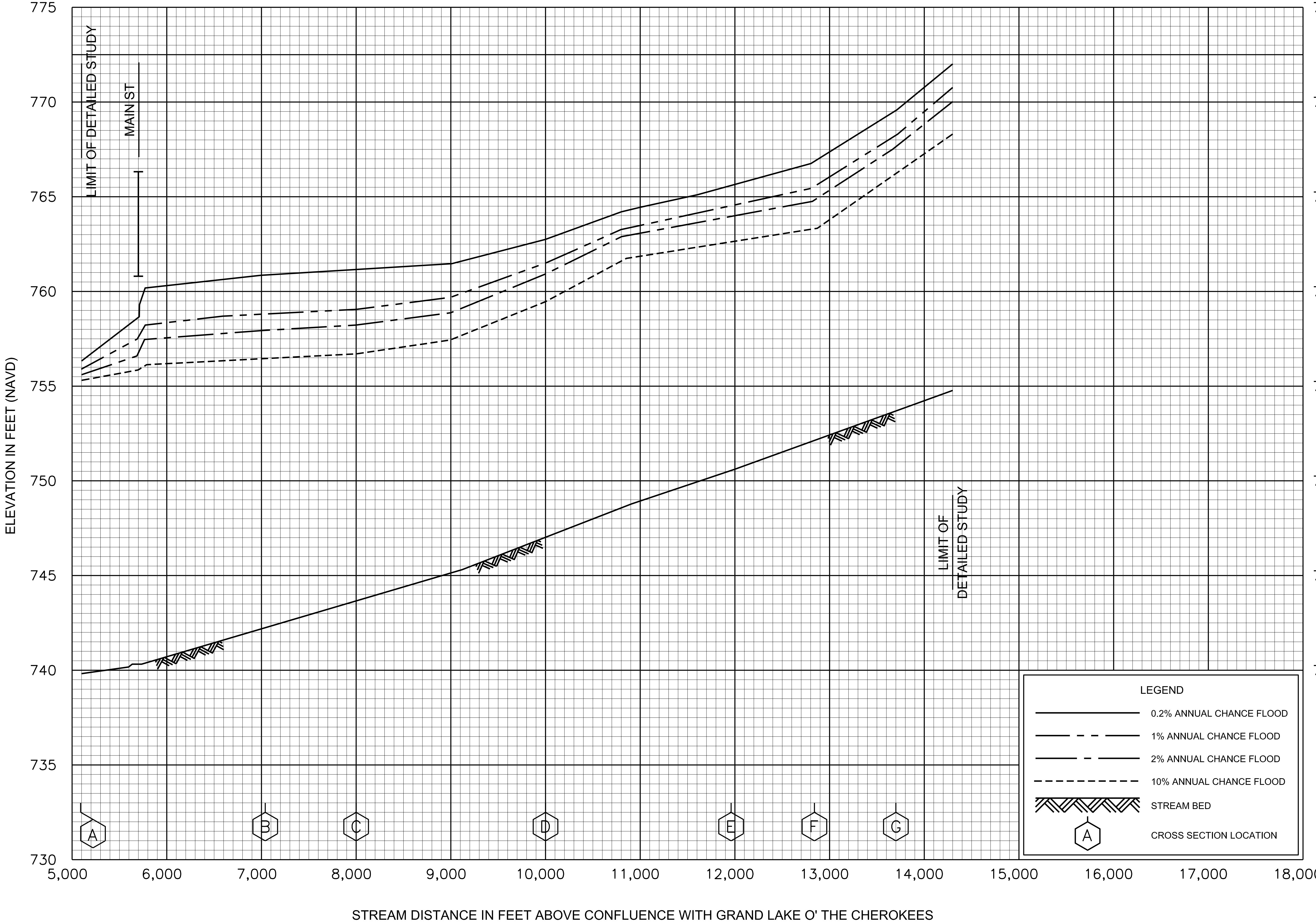
FLOOD PROFILES

LITTLE ELM CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

06P



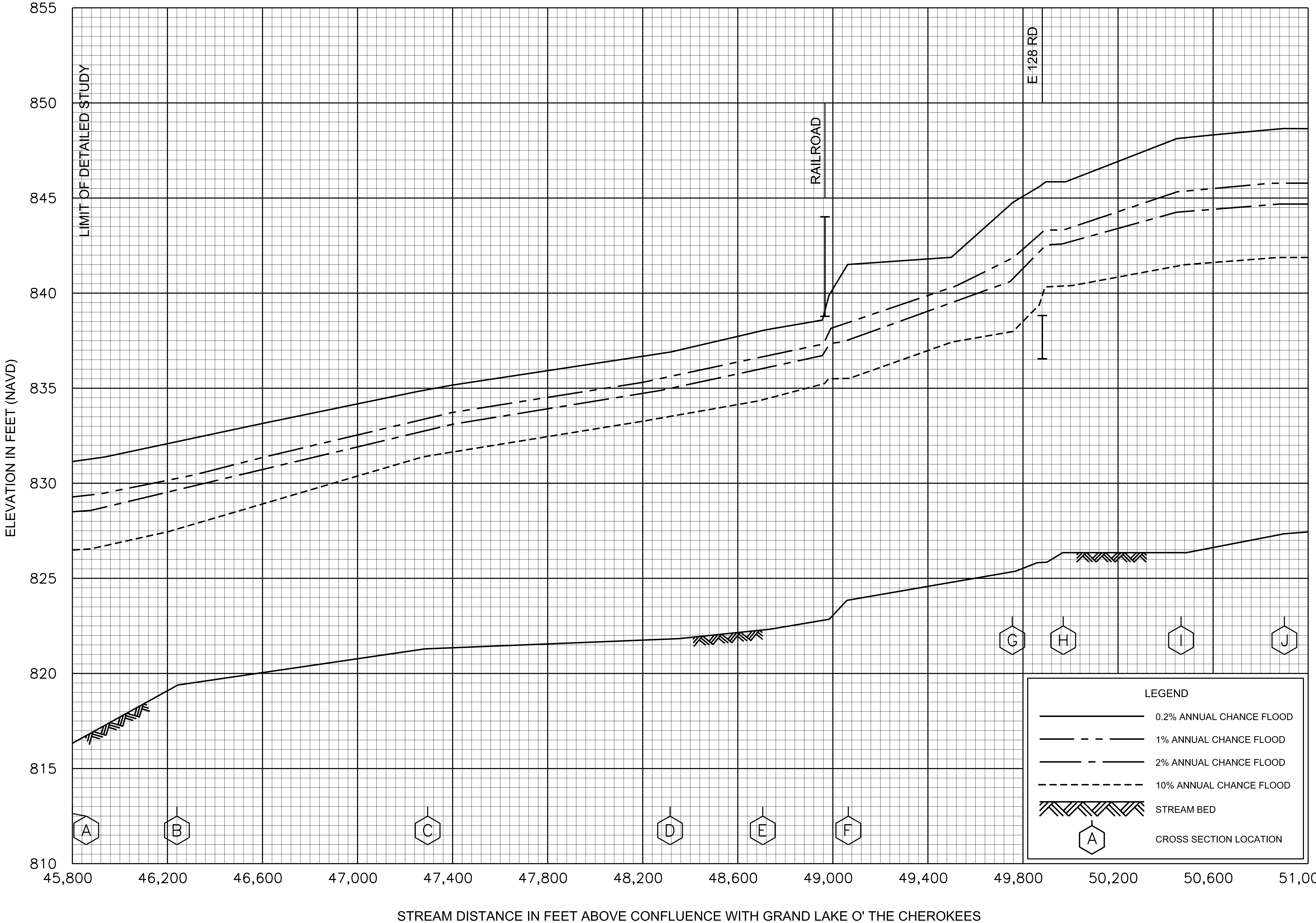
FLOOD PROFILES

LOST CREEK (LOWER REACH)

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



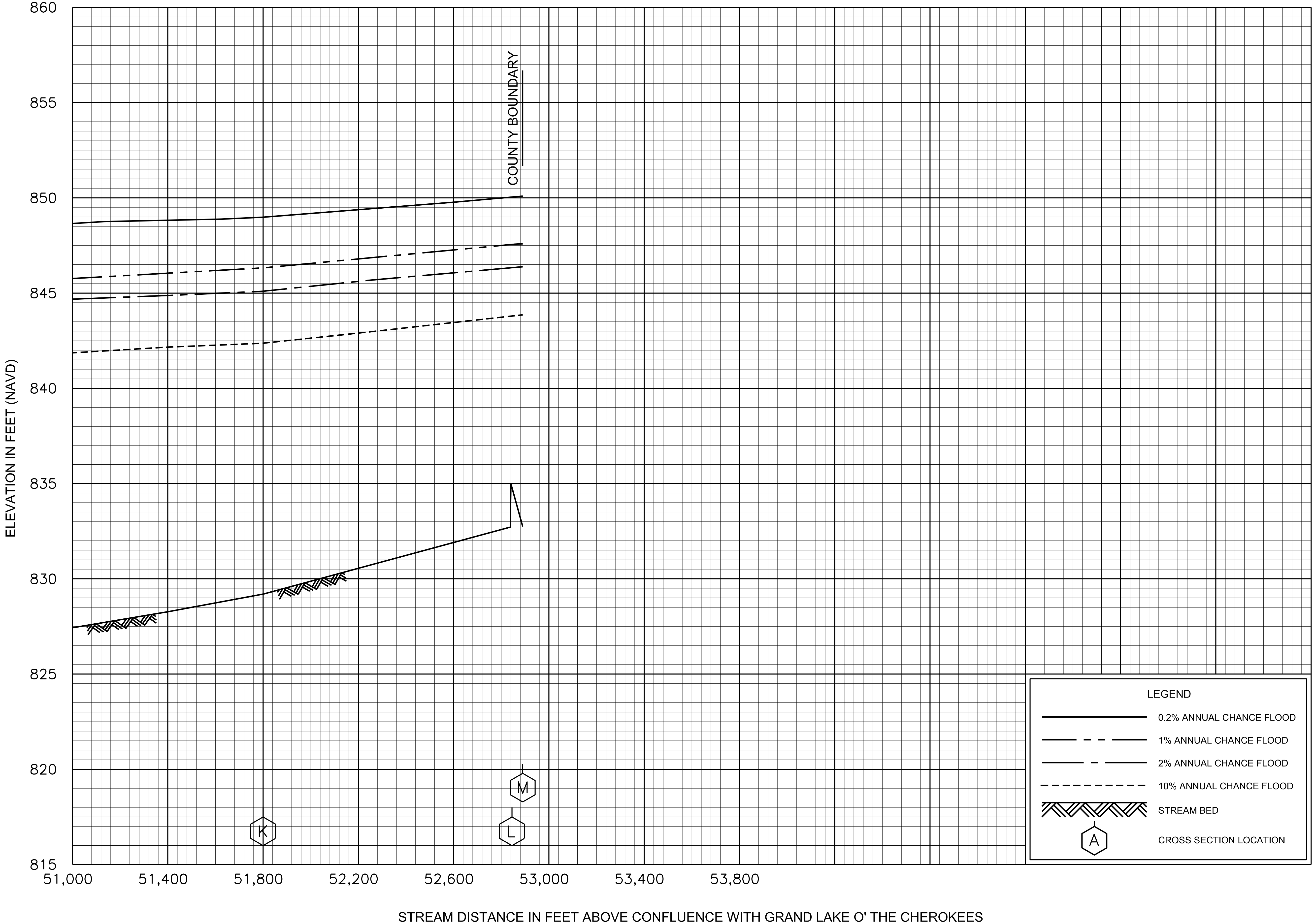
FLOOD PROFILES

LOST CREEK (UPPER REACH)

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



FLOOD PROFILES

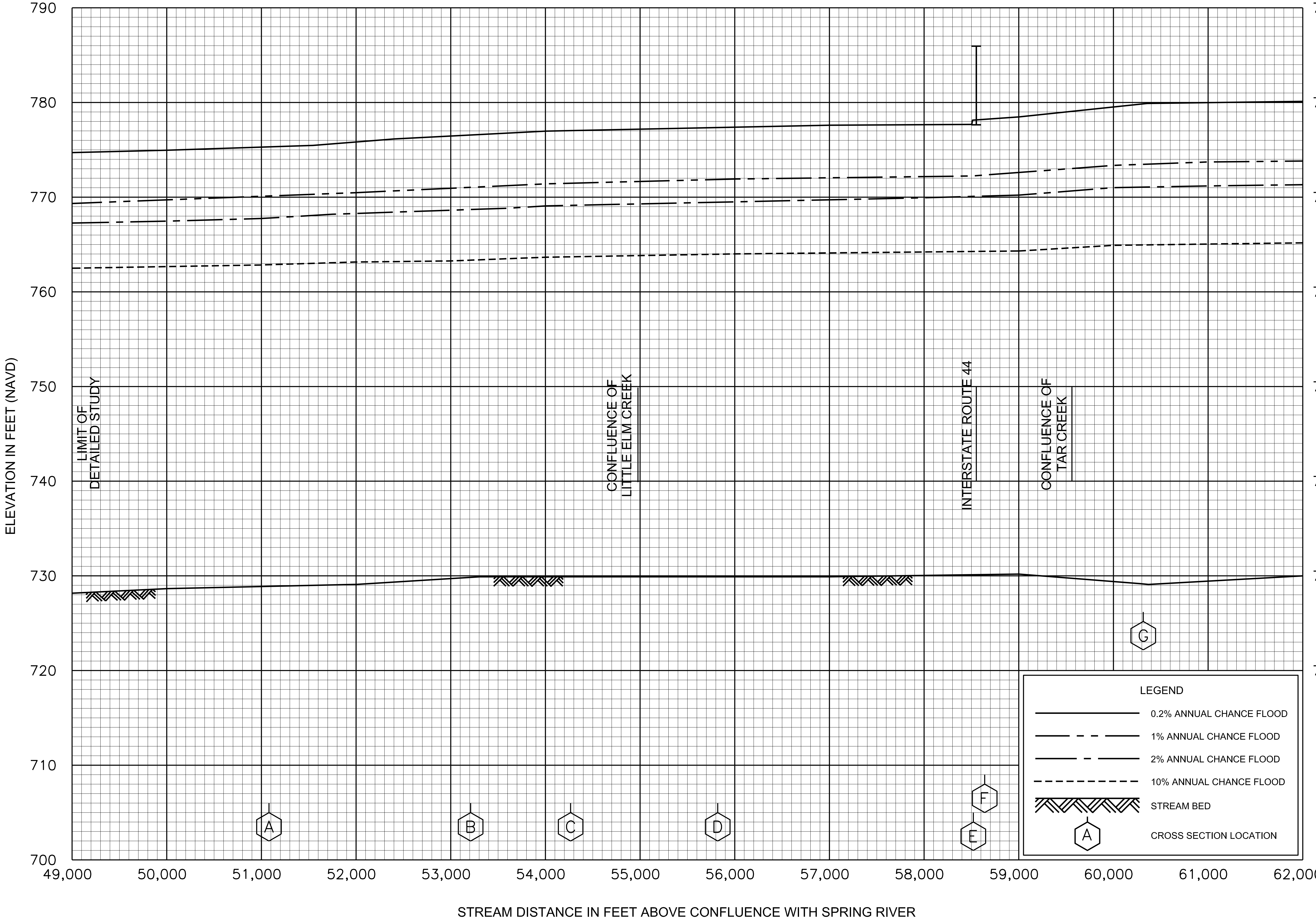
LOST CREEK (UPPER REACH)

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS

09P



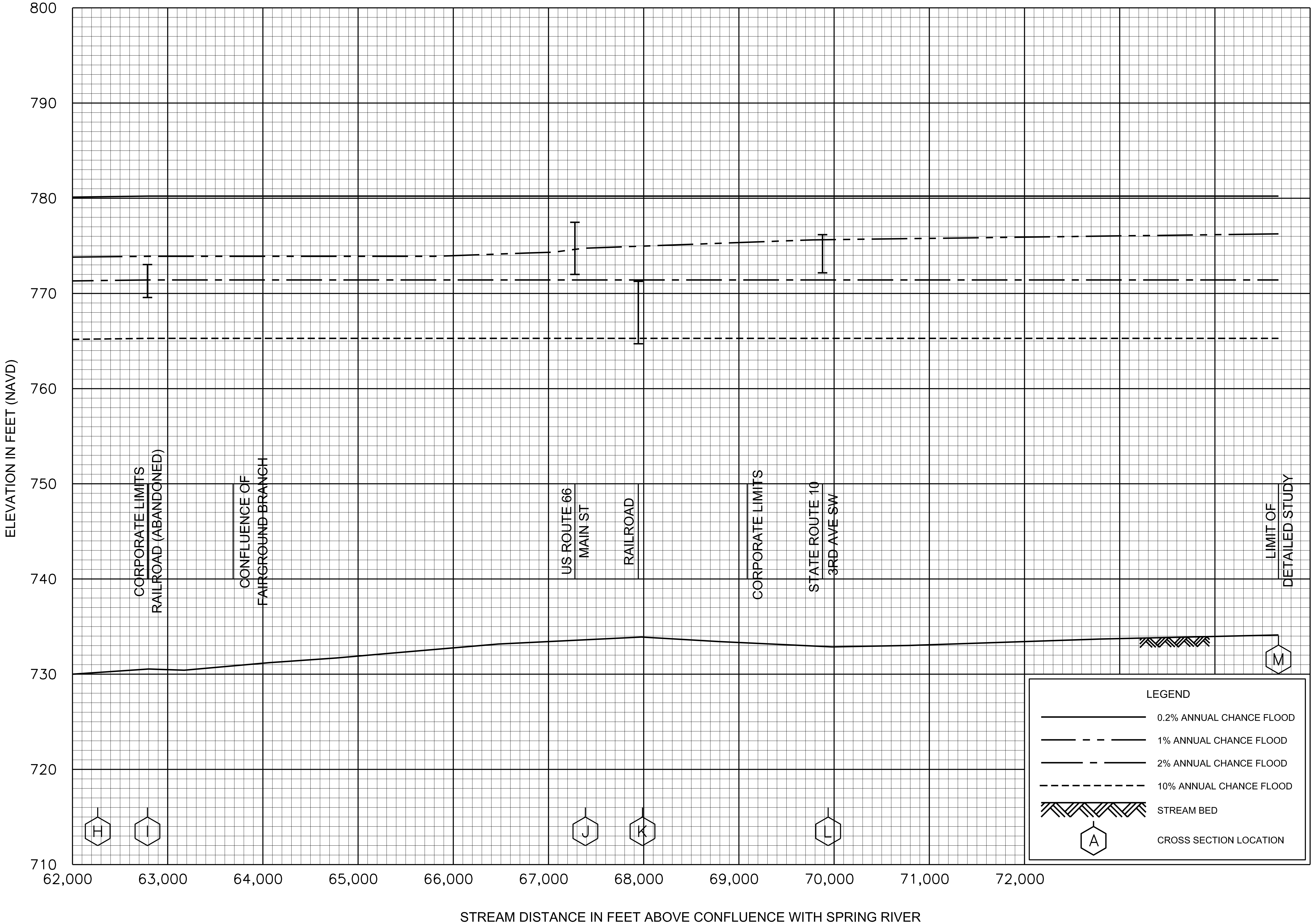
FLOOD PROFILES

NEOSHO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



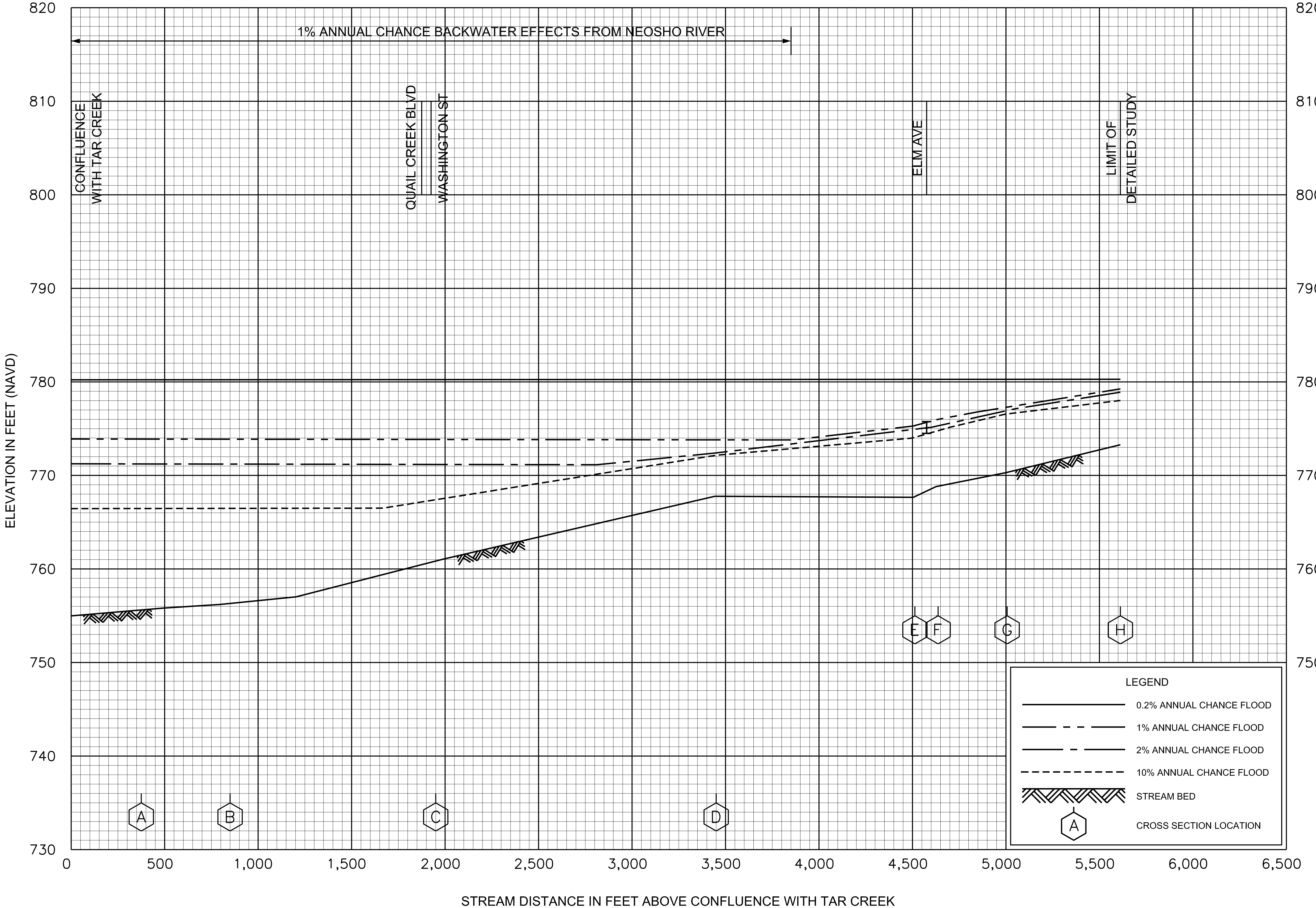
FLOOD PROFILES

NEOSHO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



FLOOD PROFILES

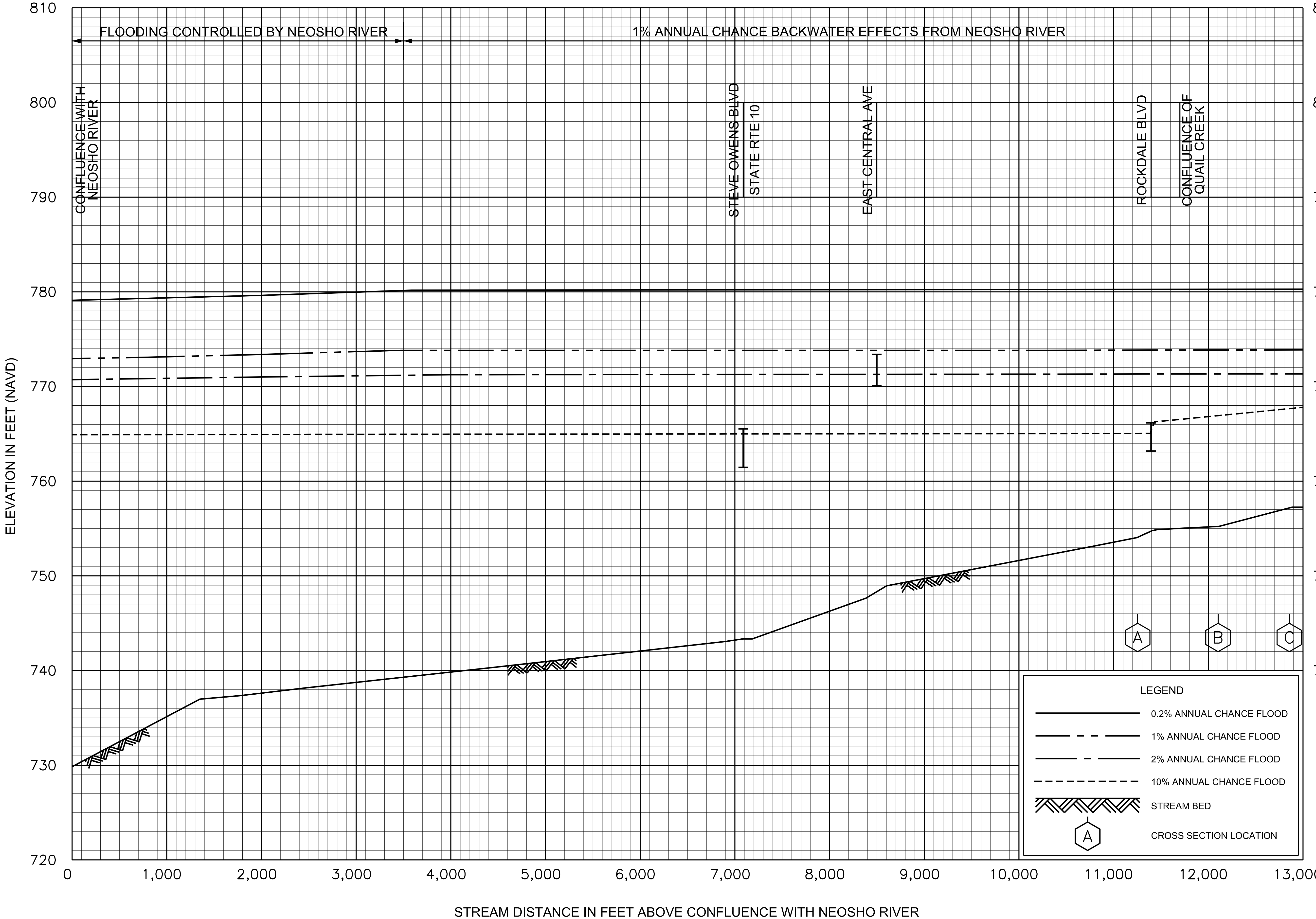
QUAIL CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS

12P



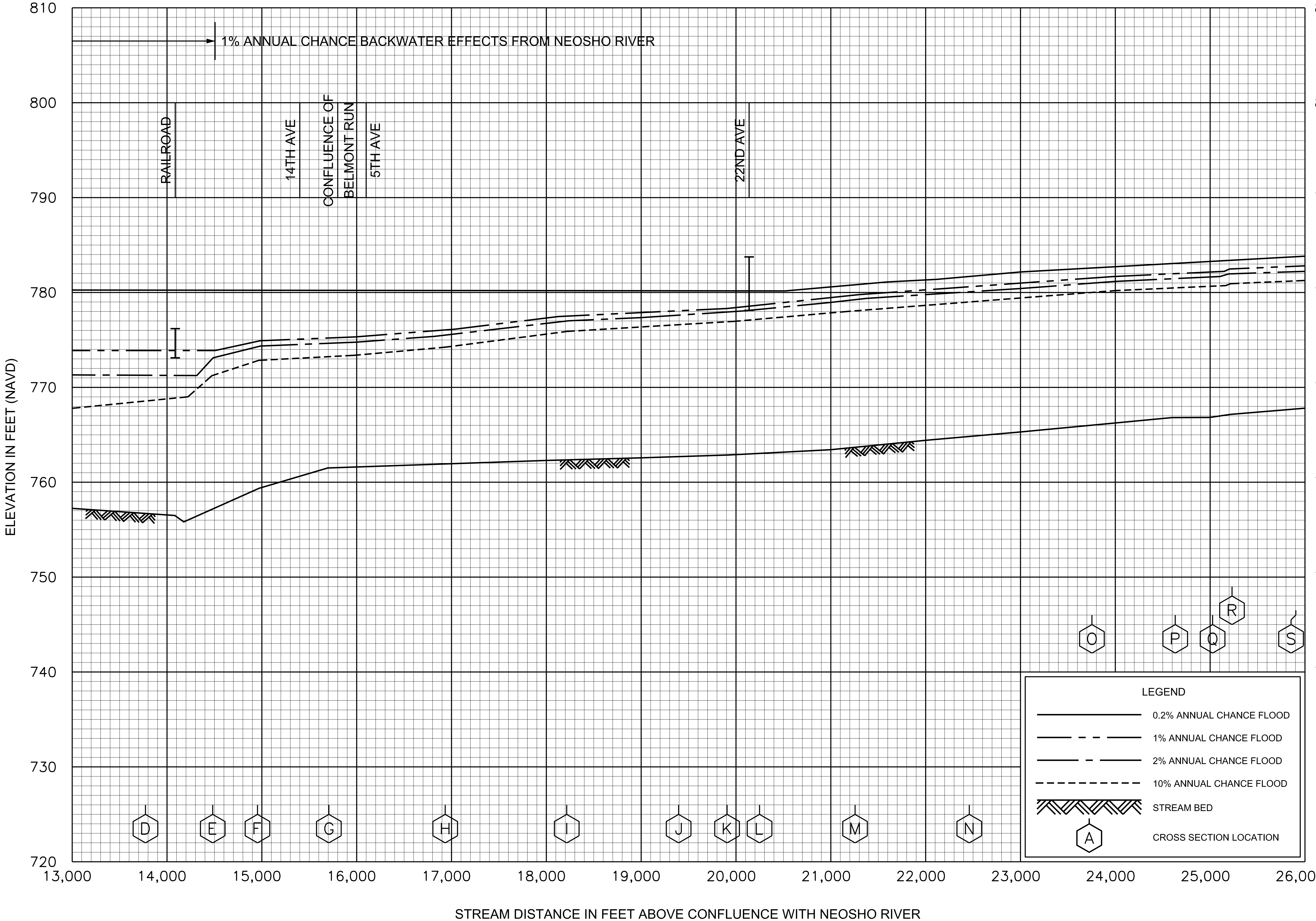
FLOOD PROFILES

TAR CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

13P

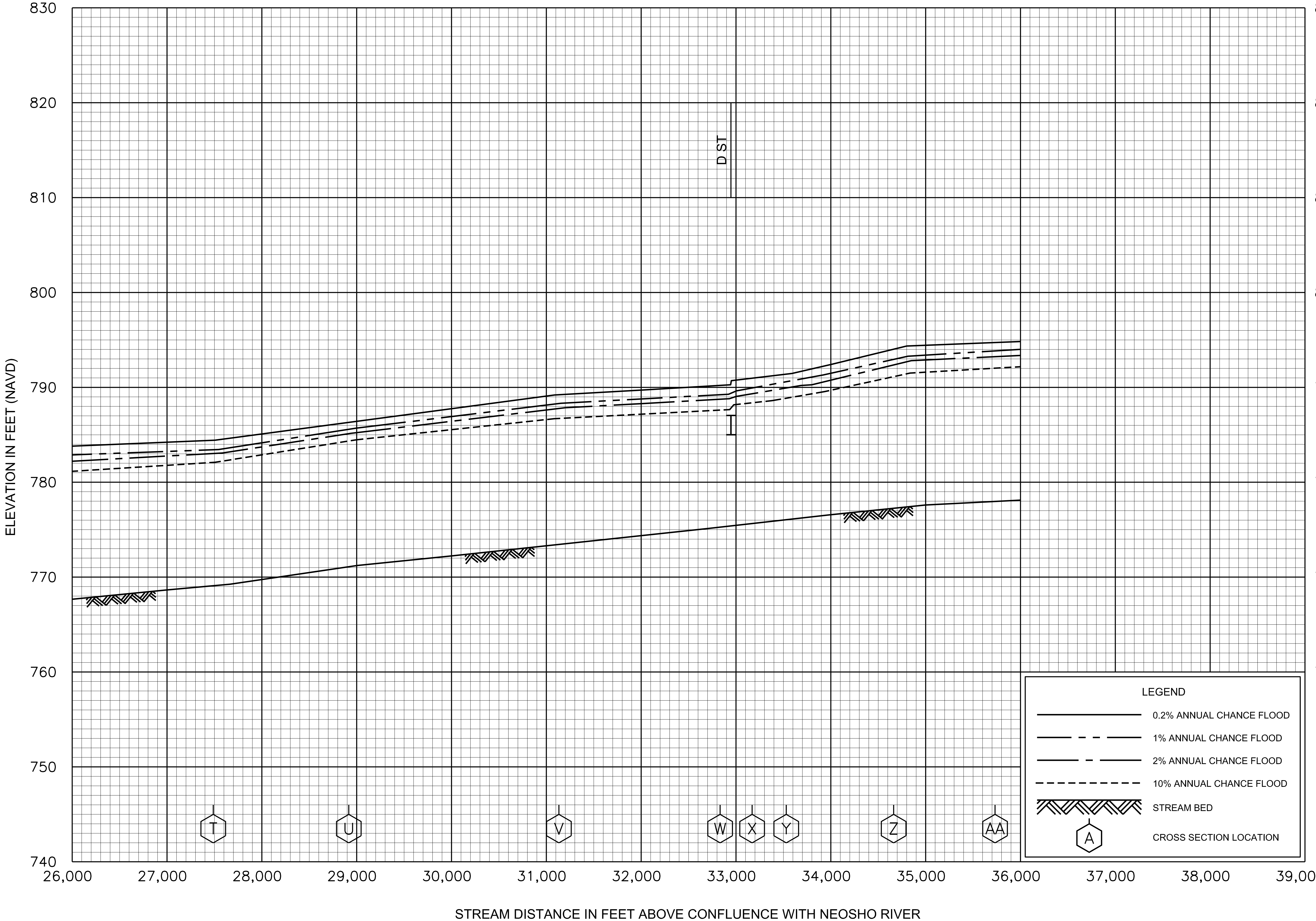


FLOOD PROFILES

TAR CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS



FLOOD PROFILES

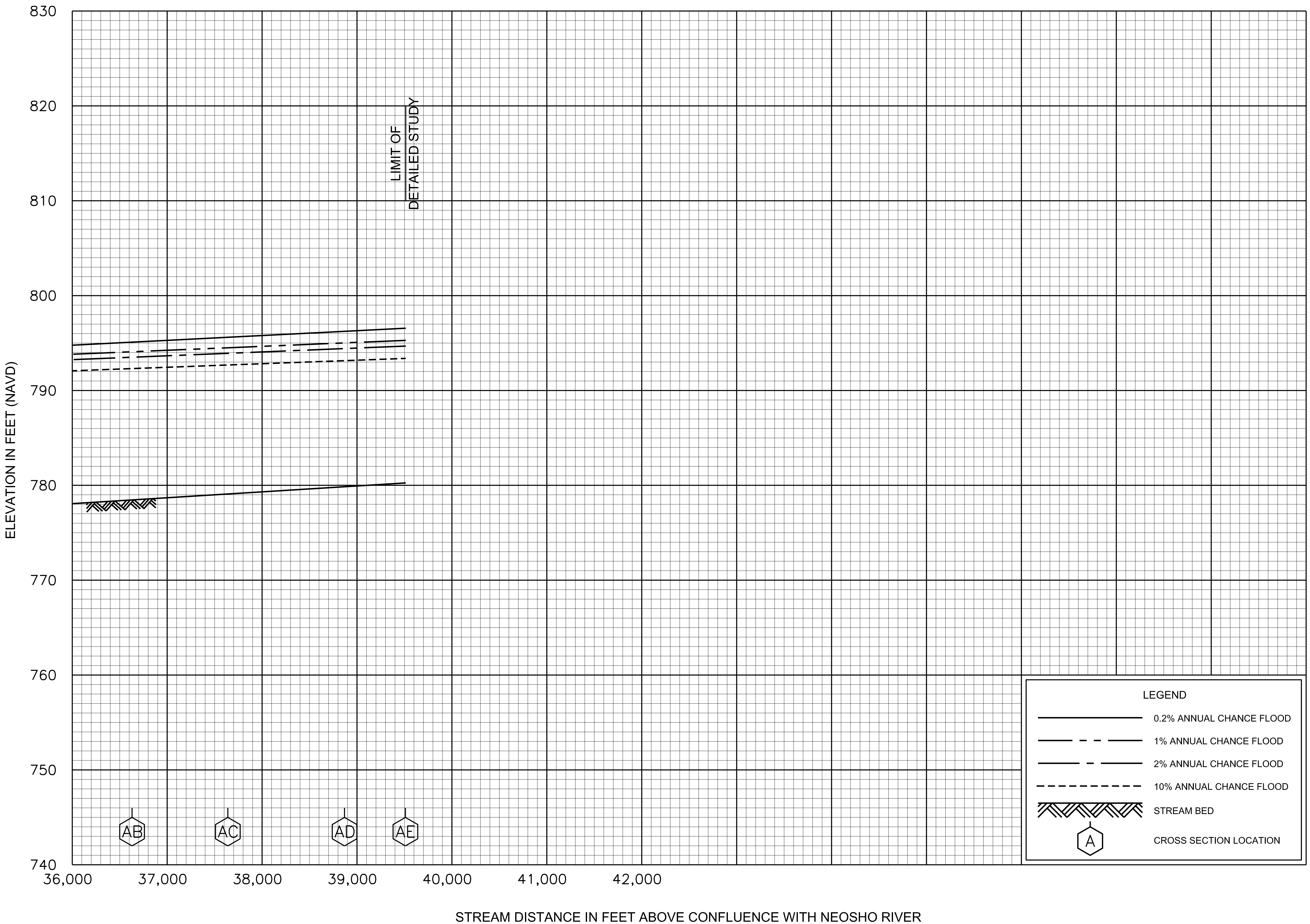
TAR CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS

15P

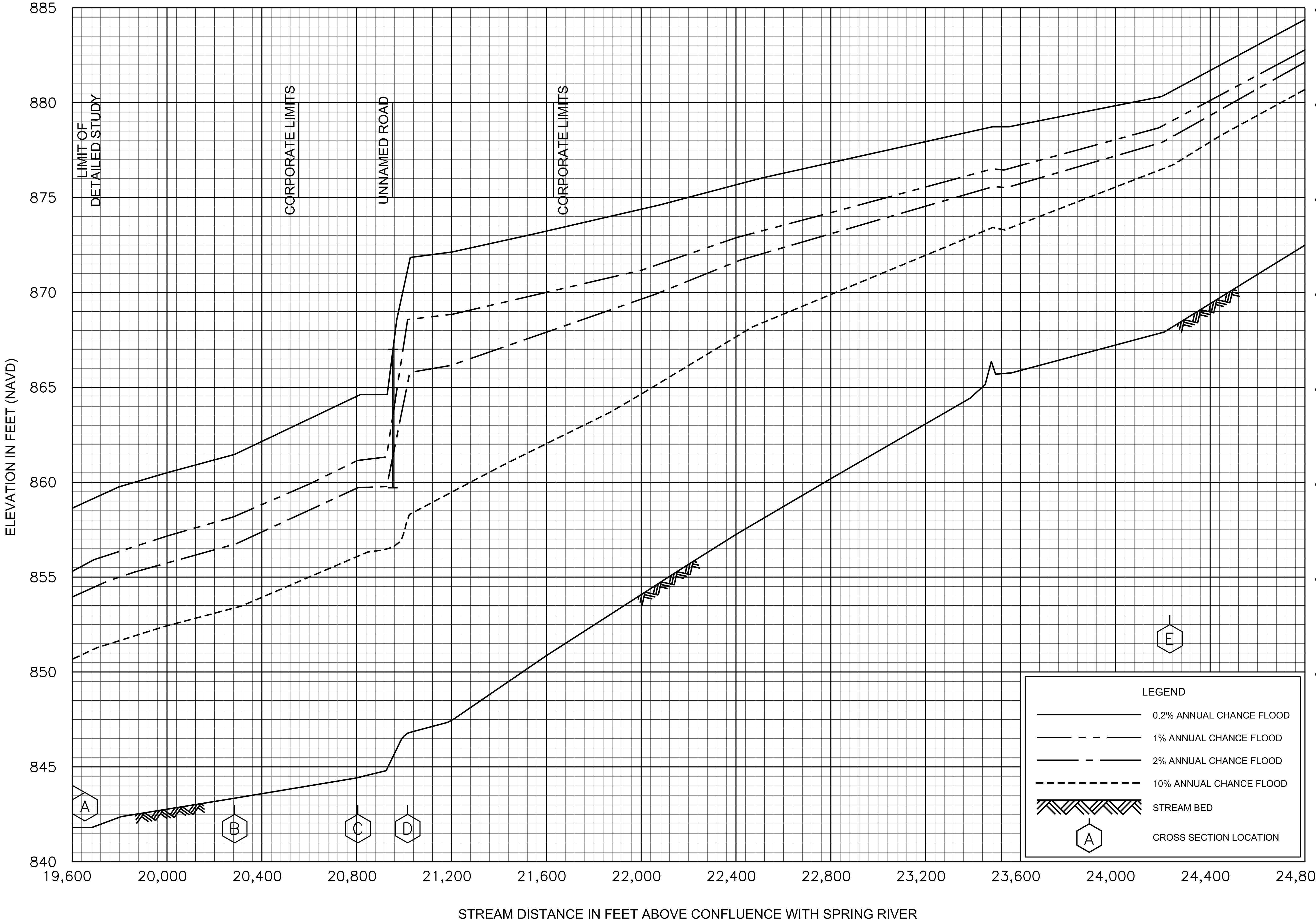


FLOOD PROFILES

TAR CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

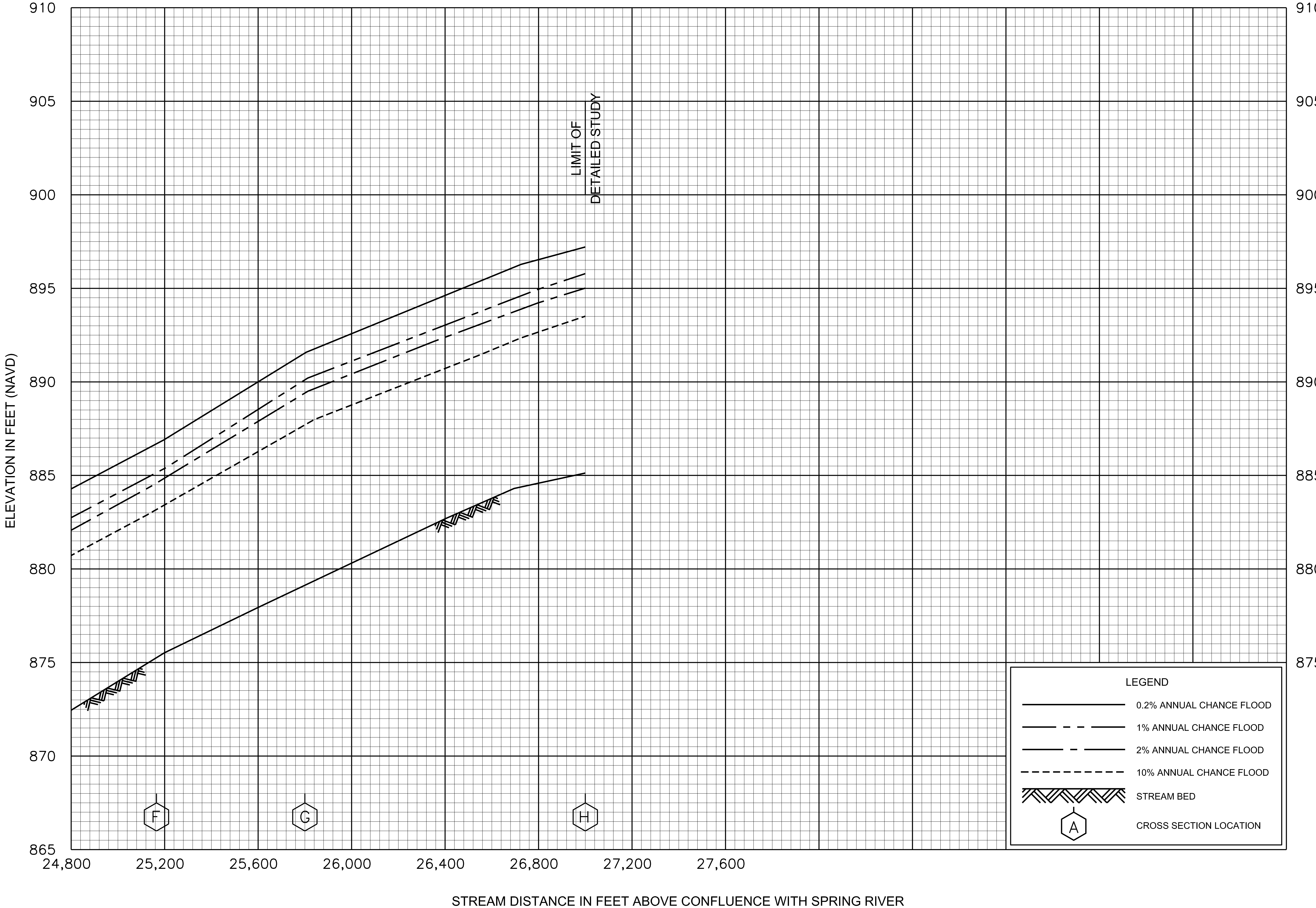


FLOOD PROFILES

WARREN BRANCH

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS



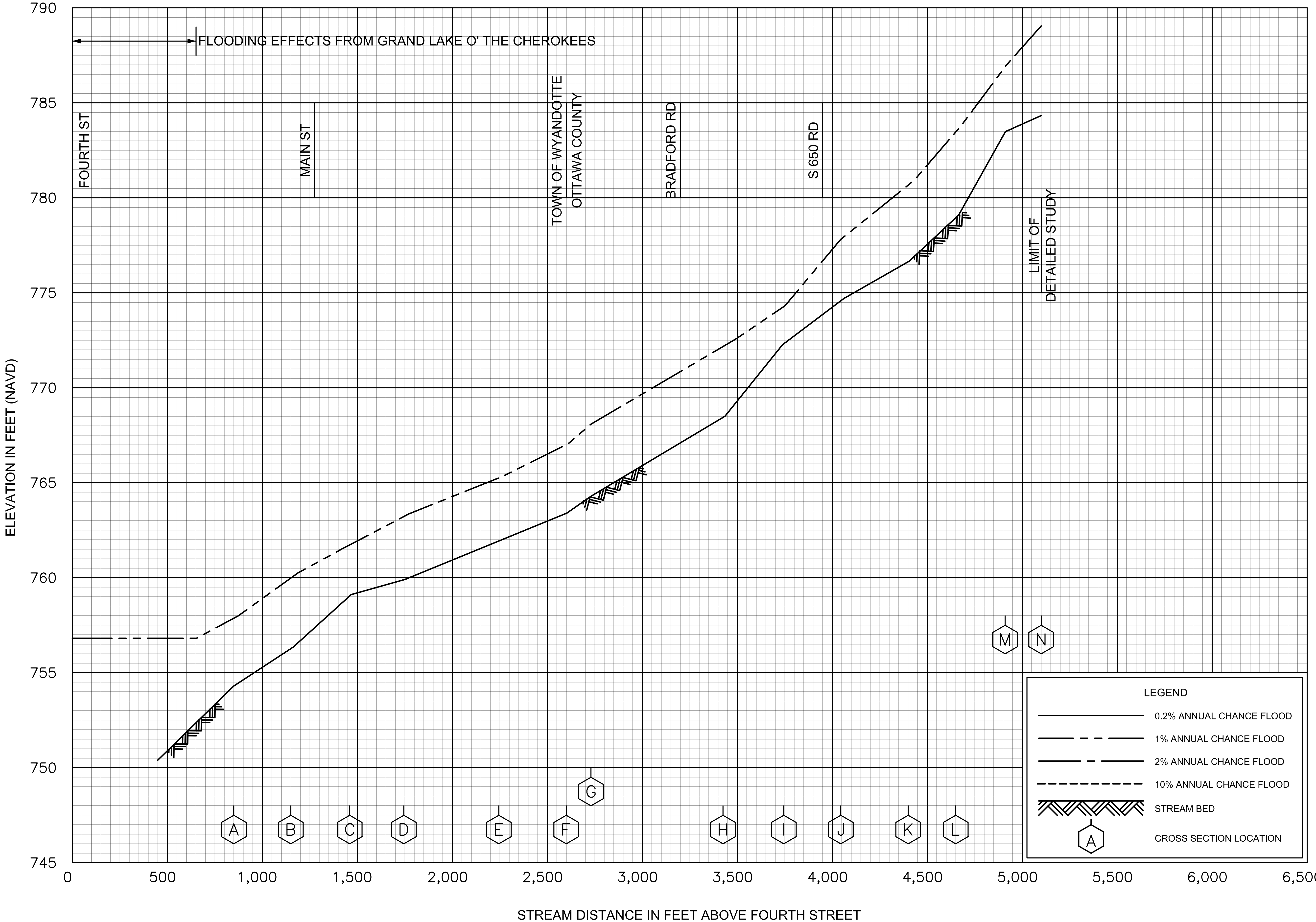
FLOOD PROFILES

WARREN BRANCH

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



FLOOD PROFILES

WYANDOTTE DITCH

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS

FLOOD INSURANCE STUDY

FEDERAL EMERGENCY MANAGEMENT AGENCY

VOLUME 1 OF 1

OTTAWA COUNTY, OKLAHOMA

AND INCORPORATED AREAS

COMMUNITY NAME	COMMUNITY NUMBER
AFTON, TOWN OF	400155
COMMERCE, CITY OF	400156
FAIRLAND, TOWN OF	400377
MIAMI, CITY OF	400157
NORTH MIAMI, TOWN OF*	400426
OTTAWA COUNTY, UNINCORPORATED AREAS	400154
PEORIA, TOWN OF	400158
QUAPAW, TOWN OF	400436
WYANDOTTE, TOWN OF	400161
WYANDOTTE NATION	405451

*No Special Flood Hazard Areas Identified

FEMA

REVISED:

SEPTEMBER 13, 2019

FLOOD INSURANCE STUDY NUMBER
40115CV000B

Version Number 2.3.3.2

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Published Separately

FLOOD INSURANCE STUDY REPORT
OTTAWA COUNTY, OKLAHOMA

SECTION 1.0 – INTRODUCTION

1.1 The National Flood Insurance Program

The National Flood Insurance Program (NFIP) is a voluntary Federal program that enables property owners in participating communities to purchase insurance protection against losses from flooding. This insurance is designed to provide an alternative to disaster assistance to meet the escalating costs of repairing damage to buildings and their contents caused by floods.

For decades, the national response to flood disasters was generally limited to constructing flood-control works such as dams, levees, sea-walls, and the like, and providing disaster relief to flood victims. This approach did not reduce losses nor did it discourage unwise development. In some instances, it may have actually encouraged additional development. To compound the problem, the public generally could not buy flood coverage from insurance companies, and building techniques to reduce flood damage were often overlooked.

In the face of mounting flood losses and escalating costs of disaster relief to the general taxpayers, the U.S. Congress created the NFIP. The intent was to reduce future flood damage through community floodplain management ordinances, and provide protection for property owners against potential losses through an insurance mechanism that requires a premium to be paid for the protection.

The U.S. Congress established the NFIP on August 1, 1968, with the passage of the National Flood Insurance Act of 1968. The NFIP was broadened and modified with the passage of the Flood Disaster Protection Act of 1973 and other legislative measures. It was further modified by the National Flood Insurance Reform Act of 1994 and the Flood Insurance Reform Act of 2004. The NFIP is administered by the Federal Emergency Management Agency (FEMA), which is a component of the Department of Homeland Security (DHS).

Participation in the NFIP is based on an agreement between local communities and the Federal Government. If a community adopts and enforces floodplain management regulations to reduce future flood risks to new construction and substantially improved structures in Special Flood Hazard Areas (SFHAs), the Federal Government will make flood insurance available within the community as a financial protection against flood losses. The community's floodplain management regulations must meet or exceed criteria established in accordance with Title 44 Code of Federal Regulations (CFR) Part 60, *Criteria for Land Management and Use*.

SFHAs are delineated on the community's Flood Insurance Rate Maps (FIRMs). Under the NFIP, buildings that were built before the flood hazard was identified on the community's FIRMs are generally referred to as "Pre-FIRM" buildings. When the NFIP was created, the U.S. Congress recognized that insurance for Pre-FIRM buildings would be prohibitively expensive if the premiums were not subsidized by the Federal

Government. Congress also recognized that most of these floodprone buildings were built by individuals who did not have sufficient knowledge of the flood hazard to make informed decisions. The NFIP requires that full actuarial rates reflecting the complete flood risk be charged on all buildings constructed or substantially improved on or after the effective date of the initial FIRM for the community or after December 31, 1974, whichever is later. These buildings are generally referred to as “Post-FIRM” buildings.

1.2 Purpose of this Flood Insurance Study Report

This Flood Insurance Study (FIS) Report revises and updates information on the existence and severity of flood hazards for the study area. The studies described in this report developed flood hazard data that will be used to establish actuarial flood insurance rates and to assist communities in efforts to implement sound floodplain management.

In some states or communities, floodplain management criteria or regulations may exist that are more restrictive than the minimum Federal requirements. Contact your State NFIP Coordinator to ensure that any higher State standards are included in the community’s regulations.

1.3 Jurisdictions Included in the Flood Insurance Study Project

This FIS Report covers the entire geographic area of Ottawa County, Oklahoma.

The jurisdictions that are included in this project area, along with the Community Identification Number (CID) for each community and the United States Geological Survey (USGS) 8-digit Hydrologic Unit Code (HUC-8) sub-basins affecting each, are shown in Table 1. The FIRM panel numbers that affect each community are listed. If the flood hazard data for the community is not included in this FIS Report, the location of that data is identified.

Jurisdictions that have no identified SFHAs as of the effective date of this study are indicated in the table. Changed conditions in these communities (such as urbanization or annexation) or the availability of new scientific or technical data about flood hazards could make it necessary to determine SFHAs in these jurisdictions in the future.

Table 1: Listing of NFIP Jurisdictions

Community	CID	HUC-8 Sub-Basin(s)	Located on FIRM Panel(s)	If Not Included, Location of Flood Hazard Data
Afton, Town of	400155	11070206	40115C0228G 40115C0229G 40115C0235G 40115C0236G 40115C0237G	
Commerce, City of	400156	11070206	40115C0035G 40115C0045G 40115C0055G 40115C0065G	

Table 1: Listing of NFIP Jurisdictions, continued

Community	CID	HUC-8 Sub-Basin(s)	Located on FIRM Panel(s)	If Not Included, Location of Flood Hazard Data
Fairland, Town of	400377	11070206	40115C0165G 40115C0255G	
Miami, City of	400157	11070206	40115C0045G 40115C0065G 40115C0135G 40115C0155G	
North Miami, Town of[1]	400426	11070206	40115C0045G	
Ottawa County Unincorporated Areas	400154	11070205, 11070206, 11070207, 11070208, 11070209	40115C0025G 40115C0035G 40115C0045G 40115C0050G 40115C0055G 40115C0065G 40115C0075G 40115C0095F 40115C0100F 40115C0125F 40115C0135G 40115C0150G 40115C0155G 40115C0165G 40115C0175G 40115C0180G 40115C0185G 40115C0190G 40115C0195G 40115C0205G 40115C0215F 40115C0228G 40115C0229G 40115C0230G 40115C0235G 40115C0236G 40115C0237G 40115C0245G 40115C0255G 40115C0275G 40115C0300G 40115C0325F[2]	
Peoria, Town of	400158	11070207	40115C0095F	

Table 1: Listing of NFIP Jurisdictions, continued

Community	CID	HUC-8 Sub-Basin(s)	Located on FIRM Panel(s)	If Not Included, Location of Flood Hazard Data
Quapaw, Town of	400436	11070206, 11070207	40115C0075G	
Wyandotte, Town of	400161	11070206	40115C0190G	
Wyandotte Nation	405451	11070206, 11070207	40115C0175G 40115C0180G 40115C0185G 40115C0190G 40115C0195G	

[1]No Special Flood Hazard Areas Identified

[2]Panel Not Printed

1.4 Considerations for using this Flood Insurance Study Report

The NFIP encourages State and local governments to implement sound floodplain management programs. To assist in this endeavor, each FIS Report provides floodplain data, which may include a combination of the following: 10-, 4-, 2-, 1-, and 0.2-percent annual chance flood elevations (the 1% annual chance flood elevation is also referred to as the Base Flood Elevation (BFE)); delineations of the 1% annual chance and 0.2% annual chance floodplains; and 1% annual chance floodway. This information is presented on the FIRM and/or in many components of the FIS Report, including Flood Profiles, Floodway Data tables, Summary of Non-Coastal Stillwater Elevations tables, and Coastal Transect Parameters tables (not all components may be provided for a specific FIS).

This section presents important considerations for using the information contained in this FIS Report and the FIRM, including changes in format and content. Figures 1, 2, and 3 present information that applies to using the FIRM with the FIS Report.

- Part or all of this FIS Report may be revised and republished at any time. In addition, part of this FIS Report may be revised by a Letter of Map Revision (LOMR), which does not involve republication or redistribution of the FIS Report. Refer to Section 6.5 of this FIS Report for information about the process to revise the FIS Report and/or FIRM.

  It is, therefore, the responsibility of the user to consult with community officials by contacting the community repository to obtain the most current FIS Report components. Communities participating in the NFIP have established repositories of flood hazard data for floodplain management and flood insurance purposes. Community map repository addresses are provided in Table 30, “Map Repositories,” within this FIS Report.

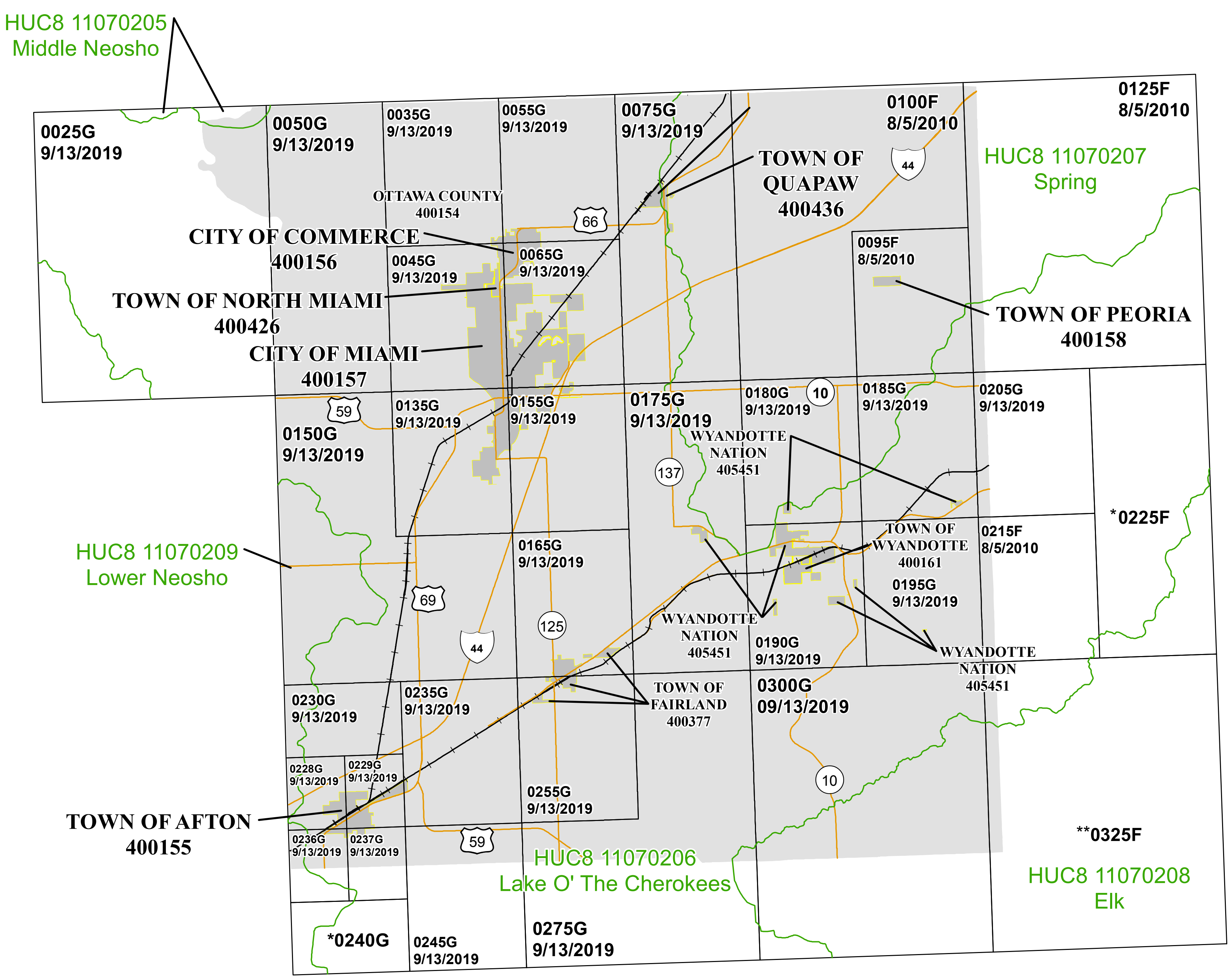
- New FIS Reports are frequently developed for multiple communities, such as entire counties. A countywide FIS Report incorporates previous FIS Reports for individual communities and the unincorporated area of the county (if not jurisdictional) into a single document and supersedes those documents for the purposes of the NFIP.

The initial Countywide FIS Report for Ottawa County became effective on August 5, 2010. Refer to Table 27 for information about subsequent revisions to the FIRMs.

- FEMA has developed a *Guide to Flood Maps* (FEMA 258) and online tutorials to assist users in accessing the information contained on the FIRM. These include how to read panels and step-by-step instructions to obtain specific information. To obtain this guide and other assistance in using the FIRM, visit the FEMA Web site at www.fema.gov/online-tutorials.

The FIRM Index in Figure 1 shows the overall FIRM panel layout within Ottawa County, and also displays the panel number and effective date for each FIRM panel in the county. Other information shown on the FIRM Index includes community boundaries, watershed boundaries, and USGS HUC-8 codes.

Figure 1: FIRM Panel Index



ATTENTION: The corporate limits shown on this FIRM Index are based on the best information available at the time of publication. As such, they may be more current than those shown on FIRM panels issued before September 13, 2019

N

1 inch = 20,833 feet 1:250,000

0 11,250 22,500 45,000 Feet

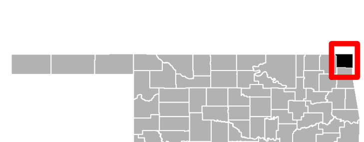
Map Projection:
Lambert Conformal Conic, State Plane Oklahoma North Zone FIPS 3501; North American Datum 1983

THE INFORMATION DEPICTED ON THIS MAP AND SUPPORTING DOCUMENTATION ARE ALSO AVAILABLE IN DIGITAL FORMAT AT
HTTP://MSC.FEMA.GOV

SEE FLOOD INSURANCE STUDY FOR ADDITIONAL INFORMATION

*PANEL NOT PRINTED - AREA OUTSIDE COUNTY BOUNDARY
**PANEL NOT PRINTED - NO SPECIAL FLOOD HAZARD AREAS

COUNTY LOCATOR



NATIONAL FLOOD INSURANCE PROGRAM

FLOOD INSURANCE RATE MAP PANEL INDEX

OTTAWA COUNTY, OKLAHOMA And Incorporated Areas

PANELS PRINTED:

0025, 0035, 0045, 0050, 0055. 0065, 0075, 0095, 0100, 0125, 0135, 0150, 0155, 0165, 0175, 0180, 0185, 0190, 0195, 0205, 0215, 0228, 0229, 0230, 0235, 0236, 0237, 0245, 0255, 0275, 0300

FEMA

MAP NUMBER
40115CIND0B

MAP REVISED
SEPTEMBER 13, 2019

Each FIRM panel may contain specific notes to the user that provide additional information regarding the flood hazard data shown on that map. However, the FIRM panel does not contain enough space to show all the notes that may be relevant in helping to better understand the information on the panel. Figure 2 contains the full list of these notes.

Figure 2: FIRM Notes to Users

NOTES TO USERS

For information and questions about this map, available products associated with this FIRM including historic versions of this FIRM, how to order products, or the National Flood Insurance Program in general, please call the FEMA Map Information eXchange at 1-877-FEMA-MAP (1-877-336-2627) or visit the FEMA Flood Map Service Center website at msc.fema.gov. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the website. Users may determine the current map date for each FIRM panel by visiting the FEMA Flood Map Service Center website or by calling the FEMA Map Information eXchange.

Communities annexing land on adjacent FIRM panels must obtain a current copy of the adjacent panel as well as the current FIRM Index. These may be ordered directly from the Flood Map Service Center at the number listed above.

For community and countywide map dates, refer to Table 27 in this FIS Report.

To determine if flood insurance is available in the community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

The map is for use in administering the NFIP. It may not identify all areas subject to flooding, particularly from local drainage sources of small size. Consult the community map repository to find updated or additional flood hazard information.

BASE FLOOD ELEVATIONS: For more detailed information in areas where Base Flood Elevations (BFEs) and/or floodways have been determined, consult the Flood Profiles and Floodway Data and/or Summary of Non-Coastal Stillwater Elevations tables within this FIS Report. Use the flood elevation data within the FIS Report in conjunction with the FIRM for construction and/or floodplain management.

FLOODWAY INFORMATION: Boundaries of the floodways were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the FIS Report for this jurisdiction.

FLOOD CONTROL STRUCTURE INFORMATION: Certain areas not in Special Flood Hazard Areas may be protected by flood control structures. Refer to Section 4.3 "Non-Levee Flood Protection Measures" of this FIS Report for information on flood control structures for this jurisdiction.

Figure 2. FIRM Notes to Users, continued

PROJECTION INFORMATION: The projection used in the preparation of the map was State Plane Lambert Conformal Conic, Oklahoma North Zone FIPS 3501. The horizontal datum was the North American Datum of 1983 NAD83, GRS1980 spheroid. Differences in datum, spheroid, projection or State Plane zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of the FIRM.

ELEVATION DATUM: Flood elevations on the FIRM are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same vertical datum. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at www.ngs.noaa.gov.

Local vertical monuments may have been used to create the map. To obtain current monument information, please contact the appropriate local community listed in Table 30 of this FIS Report.

BASE MAP INFORMATION: Base map information shown on this FIRM was provided by United States Census Bureau, dated 2016; Wyandotte Nation, dated 2009; United States Bureau of Land Management, dated 2006; United States Geologic Survey, dated 2005; and digital orthophotography was collected by the U.S. Department of Agriculture Farm Service Agency. This imagery was flown in 2015 and was produced with a 1-meter ground sample distance. For information about base maps, refer to Section 6.2 “Base Map” in this FIS Report.

The map reflects more detailed and up-to-date stream channel configurations than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables may reflect stream channel distances that differ from what is shown on the map.

Corporate limits shown on the map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after the map was published, map users should contact appropriate community officials to verify current corporate limit locations.

NOTES FOR FIRM INDEX

REVISIONS TO INDEX: As new studies are performed and FIRM panels are updated within Ottawa County, Oklahoma, corresponding revisions to the FIRM Index will be incorporated within the FIS Report to reflect the effective dates of those panels. Please refer to Table 27 of this FIS Report to determine the most recent FIRM revision date for each community. The most recent FIRM panel effective date will correspond to the most recent index date.

ATTENTION: The corporate limits shown on this FIRM Index are based on the best information available at the time of publication. As such, they may be more current than those shown on FIRM panels issued before September 13, 2019.

SPECIAL NOTES FOR SPECIFIC FIRM PANELS

This Notes to Users section was created specifically for Ottawa County, Oklahoma, effective September 13, 2019.

Figure 2. FIRM Notes to Users, continued

FLOOD RISK REPORT: A Flood Risk Report (FRR) may be available for many of the flooding sources and communities referenced in this FIS Report. The FRR is provided to increase public awareness of flood risk by helping communities identify the areas within their jurisdictions that have the greatest risks. Although non-regulatory, the information provided within the FRR can assist communities in assessing and evaluating mitigation opportunities to reduce these risks. It can also be used by communities developing or updating flood risk mitigation plans. These plans allow communities to identify and evaluate opportunities to reduce potential loss of life and property. However, the FRR is not intended to be the final authoritative source of all flood risk data for a project area; rather, it should be used with other data sources to paint a comprehensive picture of flood risk.

Each FIRM panel contains an abbreviated legend for the features shown on the maps. However, the FIRM panel does not contain enough space to show the legend for all map features. Figure 3 shows the full legend of all map features. Note that not all of these features may appear on the FIRM panels in Ottawa County.

Figure 3: Map Legend for FIRM

SPECIAL FLOOD HAZARD AREAS: *The 1% annual chance flood, also known as the base flood or 100-year flood, has a 1% chance of happening or being exceeded each year. Special Flood Hazard Areas are subject to flooding by the 1% annual chance flood. The Base Flood Elevation is the water surface elevation of the 1% annual chance flood. The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights. See note for specific types. If the floodway is too narrow to be shown, a note is shown.*

	Special Flood Hazard Areas subject to inundation by the 1% annual chance flood (Zones A, AE, AH, AO, AR, A99, V and VE)
Zone A	The flood insurance rate zone that corresponds to the 1% annual chance floodplains. No base (1% annual chance) flood elevations (BFEs) or depths are shown within this zone.
Zone AE	The flood insurance rate zone that corresponds to the 1% annual chance floodplains. Base flood elevations derived from the hydraulic analyses are shown within this zone.
Zone AH	The flood insurance rate zone that corresponds to the areas of 1% annual chance shallow flooding (usually areas of ponding) where average depths are between 1 and 3 feet. Whole-foot BFEs derived from the hydraulic analyses are shown at selected intervals within this zone.
Zone AO	The flood insurance rate zone that corresponds to the areas of 1% annual chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average whole-foot depths derived from the hydraulic analyses are shown within this zone.
Zone AR	The flood insurance rate zone that corresponds to areas that were formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
Zone A99	The flood insurance rate zone that corresponds to areas of the 1% annual chance floodplain that will be protected by a Federal flood protection system where construction has reached specified statutory milestones. No base flood elevations or flood depths are shown within this zone.
Zone V	The flood insurance rate zone that corresponds to the 1% annual chance coastal floodplains that have additional hazards associated with storm waves. Base flood elevations are not shown within this zone.
Zone VE	Zone VE is the flood insurance rate zone that corresponds to the 1% annual chance coastal floodplains that have additional hazards associated with storm waves. Base flood elevations derived from the coastal analyses are shown within this zone as static whole-foot elevations that apply throughout the zone.

Figure 3: Map Legend for FIRM, continued

	Regulatory Floodway determined in Zone AE.
OTHER AREAS OF FLOOD HAZARD	
	Shaded Zone X: Areas of 0.2% annual chance flood hazards and areas of 1% annual chance flood hazards with average depths of less than 1 foot or with drainage areas less than 1 square mile.
	Future Conditions 1% Annual Chance Flood Hazard – Zone X: The flood insurance rate zone that corresponds to the 1% annual chance floodplains that are determined based on future-conditions hydrology. No base flood elevations or flood depths are shown within this zone.
	Area with Reduced Flood Risk due to Levee: Areas where an accredited levee, dike, or other flood control structure has reduced the flood risk from the 1% annual chance flood.
	Area with Flood Risk due to Levee: Areas where a non-accredited levee, dike, or other flood control structure is shown as providing protection to less than the 1% annual chance flood.
OTHER AREAS	
	Zone D (Areas of Undetermined Flood Hazard): The flood insurance rate zone that corresponds to unstudied areas where flood hazards are undetermined, but possible.
NO SCREEN	Unshaded Zone X: Areas of minimal flood hazard.
FLOOD HAZARD AND OTHER BOUNDARY LINES	
(ortho) (vector)	Flood Zone Boundary (white line on ortho-photography-based mapping; gray line on vector-based mapping)
	Limit of Study
	Jurisdiction Boundary
	Limit of Moderate Wave Action (LiMWA): Indicates the inland limit of the area affected by waves greater than 1.5 feet
GENERAL STRUCTURES	
Aqueduct Channel Culvert Storm Sewer	Channel, Culvert, Aqueduct, or Storm Sewer
Dam Jetty Weir	Dam, Jetty, Weir

Figure 3: Map Legend for FIRM, continued

	Levee, Dike, or Floodwall
Bridge	Bridge
REFERENCE MARKERS	
22.0	River mile Markers
CROSS SECTION & TRANSECT INFORMATION	
B 20.2	Lettered Cross Section with Regulatory Water Surface Elevation (BFE)
5280 21.1	Numbered Cross Section with Regulatory Water Surface Elevation (BFE)
17.5	Unlettered Cross Section with Regulatory Water Surface Elevation (BFE)
8	Coastal Transect
	Profile Baseline: Indicates the modeled flow path of a stream and is shown on FIRM panels for all valid studies with profiles or otherwise established base flood elevation.
	Coastal Transect Baseline: Used in the coastal flood hazard model to represent the 0.0-foot elevation contour and the starting point for the transect and the measuring point for the coastal mapping.
513	Base Flood Elevation Line
ZONE AE (EL 16)	Static Base Flood Elevation value (shown under zone label)
ZONE AO (DEPTH 2)	Zone designation with Depth
ZONE AO (DEPTH 2) (VEL 15 FPS)	Zone designation with Depth and Velocity
BASE MAP FEATURES	
Missouri Creek	River, Stream or Other Hydrographic Feature
234	Interstate Highway
234	U.S. Highway

Figure 3: Map Legend for FIRM, continued

(234)	State Highway
[234]	County Highway
MAPLE LANE	Street, Road, Avenue Name, or Private Drive if shown on Flood Profile
RAILROAD	Railroad
______________	Horizontal Reference Grid Line
___	Horizontal Reference Grid Ticks
+	Secondary Grid Crosshairs
Land Grant	Name of Land Grant
7	Section Number
R. 43 W. T. 22 N.	Range, Township Number
$^{42}76^{000m}$E	Horizontal Reference Grid Coordinates (UTM)
365000 FT	Horizontal Reference Grid Coordinates (State Plane)
80° 16’ 52.5”	Corner Coordinates (Latitude, Longitude)

SECTION 2.0 – FLOODPLAIN MANAGEMENT APPLICATIONS

2.1 Floodplain Boundaries

To provide a national standard without regional discrimination, the 1% annual chance (100-year) flood has been adopted by FEMA as the base flood for floodplain management purposes. The 0.2% annual chance (500-year) flood is employed to indicate additional areas of flood hazard in the community.

Each flooding source included in the project scope has been studied and mapped using professional engineering and mapping methodologies that were agreed upon by FEMA and Ottawa County as appropriate to the risk level. Flood risk is evaluated based on factors such as known flood hazards and projected impact on the built environment. Engineering analyses were performed for each studied flooding source to calculate its 1% annual chance flood elevations; elevations corresponding to other floods (e.g. 10-, 4-, 2-, 0.2-percent annual chance, etc.) may have also been computed for certain flooding sources. Engineering models and methods are described in detail in Section 5.0 of this FIS Report. The modeled elevations at cross sections were used to delineate the floodplain boundaries on the FIRM; between cross sections, the boundaries were interpolated using elevation data from various sources. More information on specific mapping methods is provided in Section 6.0 of this FIS Report.

Depending on the accuracy of available topographic data (Table 22), study methodologies employed (Section 5.0), and flood risk, certain flooding sources may be mapped to show both the 1% and 0.2% annual chance floodplain boundaries, regulatory water surface elevations (BFEs), and/or a regulatory floodway. Similarly, other flooding sources may be mapped to show only the 1% annual chance floodplain boundary on the FIRM, without published water surface elevations. In cases where the 1% and 0.2% annual chance floodplain boundaries are close together, only the 1% annual chance floodplain boundary is shown on the FIRM. Figure 3, “Map Legend for FIRM”, describes the flood zones that are used on the FIRMs to account for the varying levels of flood risk that exist along flooding sources within the project area. Table 2 and Table 3 indicate the flood zone designations for each flooding source and each community within Ottawa County, respectively.

Table 2, “Flooding Sources Included in this FIS Report,” lists each flooding source, including its study limits, affected communities, mapped zone on the FIRM, and the completion date of its engineering analysis from which the flood elevations on the FIRM and in the FIS Report were derived. Descriptions and dates for the latest hydrologic and hydraulic analyses of the flooding sources are shown in Table 12. Floodplain boundaries for these flooding sources are shown on the FIRM (published separately) using the symbology described in Figure 3. On the map, the 1% annual chance floodplain corresponds to the SFHAs. The 0.2% annual chance floodplain shows areas that, although out of the regulatory floodplain, are still subject to flood hazards.

Small areas within the floodplain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data. The procedures to remove these areas from the SFHA are described in Section 6.5 of this FIS Report.

Table 2: Flooding Sources Included in this FIS Report

Flooding Source	Community	Downstream Limit	Upstream Limit	HUC-8 Sub-Basin(s)	Length (mi) (streams or coastlines)	Area (mi^2) (estuaries or ponding)	Floodway (Y/N)	Zone shown on FIRM	Date of Analysis
Bee Creek and Zone A tributaries	Ottawa County, Unincorporated Areas	N/A	N/A	11070206	5.7		N	A	2016
Belmont Run	Miami, City of; Ottawa County, Unincorporated Areas	At confluence with Tar Creek (at Miami)	Just downstream of U.S. Highway 60	11070206	3.5		Y	AE	2016
Coal Creek and Zone A tributaries	Ottawa County, Unincorporated Areas	N/A	N/A	11070206	25.4		N	A	2016
Council Hollow Creek and Zone A tributaries	Ottawa County, Unincorporated Areas	N/A	N/A	11070206	2.6		N	A	2016
Cow Creek	Ottawa County, Unincorporated Areas	At confluence with Neosho River	Ottawa county line	11070206	7.9		N	A	2016
Elm Creek and Zone A tributaries	Ottawa County, Unincorporated Areas	N/A	N/A	11070206	26.2		N	A	2016
Fairgrounds Branch	Miami, City of; Ottawa County, Unincorporated Areas	At confluence with the Neosho River	Approximately 2.7 miles upstream of confluence with Neosho River	11070206	2.8		Y	AE	2016
Garrett Creek and Zone A tributaries	Miami, City of; Ottawa County, Unincorporated Areas	N/A	N/A	11070206	7		N	A	2016
Grand Lake O' The Cherokees	Ottawa County, Unincorporated Areas	N/A	N/A			0.4	N	AE	2016
Grand Lake Tributary 2 and Zone A tributaries	Ottawa County, Unincorporated Areas	N/A	N/A	11070206	4.5		N	A	2016
Hickory Creek and Zone A tributaries	Ottawa County, Unincorporated Areas	N/A	N/A	11070206	4.2		N	A	2016

Table 2: Flooding Sources Included in this FIS Report, continued

Flooding Source	Community	Downstream Limit	Upstream Limit	HUC-8 Sub-Basin(s)	Length (mi) (streams or coastlines)	Area (mi^2) (estuaries or ponding)	Floodway (Y/N)	Zone shown on FIRM	Date of Analysis
Horse Creek and Zone A tributaries	Afton, Town of; Ottawa County, Unincorporated Areas	N/A	N/A	11070206	26.8		N	A	2016
Horse Creek	Afton, Town of; Ottawa County, Unincorporated Areas	Approximately 0.36 mile upstream of confluence of Horse Creek Tributary 1	Approximately 0.2 mile downstream of confluence with Horse Creek Tributary 5	11070206	3.4		N	AE	2016
Horse Creek Tributary 3	Afton, Town of; Ottawa County, Unincorporated Areas	At confluence with Horse Creek	Approximately 1.08 miles upstream of confluence with Horse Creek Tributary 3-2	11070206	2		N	AE	2016
Horse Creek Tributary 3-1	Afton, Town of; Ottawa County, Unincorporated Areas	At confluence with Horse Creek Tributary 3	Approximately 0.9 mile upstream of confluence with Horse Creek Tributary 3	11070206	0.9		N	AE	2016
Horse Creek Tributary 3-2	Afton, Town of; Ottawa County, Unincorporated Areas	At confluence with Horse Creek Tributary 3	Approximately 1,700 feet upstream from South Main Avenue	11070206	1.4		N	AE	2016
Horse Creek Tributary 3-2-1	Afton, Town of; Ottawa County, Unincorporated Areas	At confluence with Horse Creek Tributary 3-2	Approximately 2.12 miles upstream of confluence with Horse Creek Tributary 3-2	11070206	2.1		N	AE	2016
Hudson Creek and Zone A tributaries	Fairland, Town of; Ottawa County, Unincorporated Areas	N/A	N/A	11070206	38		N	A	2016
Little Elm Creek and Zone A tributaries	Ottawa County, Unincorporated Areas	N/A	N/A	11070206	18.3		N	A	2016

Table 2: Flooding Sources Included in this FIS Report, continued

Flooding Source	Community	Downstream Limit	Upstream Limit	HUC-8 Sub-Basin(s)	Length (mi) (streams or coastlines)	Area (mi^2) (estuaries or ponding)	Floodway (Y/N)	Zone shown on FIRM	Date of Analysis
Little Elm Creek	Miami, City of; Ottawa County, Unincorporated Areas	At confluence with the Neosho River	At confluence with Little Elm Creek Tributary 2	11070206	3.5		Y	AE	2008
Little Horse Creek and Zone A tributaries	Fairland, Town of; Ottawa County, Unincorporated Areas	N/A	N/A	11070206	27.3		N	A	2016
Lost Creek and Zone A tributaries	Ottawa County, Unincorporated Areas; Wyandotte Nation of Oklahoma; Wyandotte, Town of	N/A	N/A	11070206	8.4		N	A	2016
Lost Creek (at Wyandotte)	Ottawa County, Unincorporated Areas; Wyandotte Nation of Oklahoma; Wyandotte, Town of	At confluence with Grand Lake O' The Cherokees	Approximately 1.0 miles upstream of confluence with Lost Creek Tributary 2	11070206	2.8		Y	AE	2016
Lost Creek (Upper Reach)	Ottawa County, Unincorporated Areas; Wyandotte Nation of Oklahoma; Wyandotte, Town of	Approximately 6.9 miles upstream of confluence with Lost Creek Tributary 2	Approximately 8.2 miles upstream of confluence with Lost Creek Tributary 2	11070206	1.3		Y	AE	2008
Lytle Creek and Zone A tributaries	Ottawa County, Unincorporated Areas;	N/A	N/A	11070206	8.6		N	A	2016
Mud Creek	Ottawa County, Unincorporated Areas	At confluence with Neosho River	Ottawa county line	11070206	0.4		N	A	2016
Neosho River	Miami, City of; Ottawa County, Unincorporated Areas	Approximately 1,000 feet upstream of US Highway 60	Approximately 1,400 upstream of E 60 Road	11070206	23		Y	AE	2016
Neosho River	Ottawa County, Unincorporated Areas	Ottawa County line	Approximately 1,000 feet upstream of US Highway 60	11070206	16.4		N	AE	2016
Neosho River and Zone A tributaries	Ottawa County, Unincorporated Areas	N/A	N/A	11070206	27.7		N	A	2016

Table 2: Flooding Sources Included in this FIS Report, continued

Flooding Source	Community	Downstream Limit	Upstream Limit	HUC-8 Sub-Basin(s)	Length (mi) (streams or coastlines)	Area (mi^2) (estuaries or ponding)	Floodway (Y/N)	Zone shown on FIRM	Date of Analysis
Ogeechee Creek and Zone A tributaries	Fairland, Town of; Ottawa County, Unincorporated Areas	N/A	N/A	11070206	13.8		N	A	2016
Quail Creek and Zone A tributaries	Miami, City of; Ottawa County, Unincorporated Areas	N/A	N/A	11070206	2.4		N	A	2016
Quail Creek	Miami, City of; Ottawa County, Unincorporated Areas	At confluence with Tar Creek (at Miami)	At confluence with Quail Creek Tributary 1	11070206	2.8		Y	AE	2016
Tar Creek and Zone A tributaries	Commerce, City of; Miami, City of; Ottawa County, Unincorporated Areas;	N/A	N/A	11070206	21		N	A	2016
Tar Creek (at Miami)	Commerce, City of; Miami, City of; Ottawa County, Unincorporated Areas;	At confluence with Neosho River	Approximately 0.3 miles of upstream of confluence with Tar Creek Tributary 2	11070206	7.6		Y	AE	2016
Unnamed Creek 1 and Zone A tributaries	Ottawa County, Unincorporated Areas	N/A	N/A	11070206	5.5		N	A	2016
Unnamed Creek 2	Ottawa County, Unincorporated Areas	N/A	N/A	11070206	1.6		N	A	2016
Warren Branch	Ottawa County, Unincorporated Areas; Peoria, Town of	Approximately 0.32 mile downstream of the downstream Town of Peoria corporate limits	Approximately 0.58 mile upstream of the upstream Town of Peoria corporate Limits	11070207	1.9		Y	AE	1986
Windy Creek	Ottawa County, Unincorporated Areas	At confluence with Cow Creek	Ottawa county line	11070206	5.8		N	A	2016
Wyandotte Ditch	Ottawa County, Unincorporated Areas; Wyandotte, Town of	Approximately 3,300 feet upstream of the confluence with Lost Creek	Approximately 950 feet upstream of S 650 Road	11070206	0.96		N	AE	2016

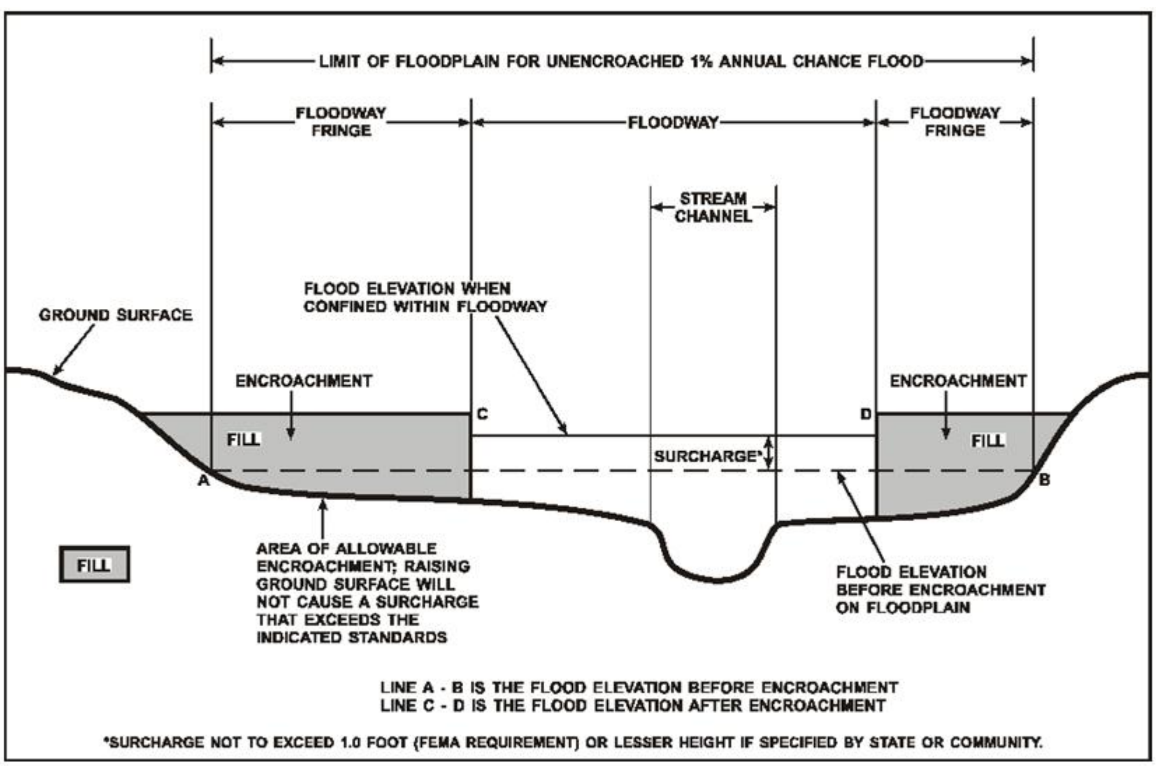
2.2 Floodways

Encroachment on floodplains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard.

For purposes of the NFIP, a floodway is used as a tool to assist local communities in balancing floodplain development against increasing flood hazard. With this approach, the area of the 1% annual chance floodplain on a river is divided into a floodway and a floodway fringe based on hydraulic modeling. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment in order to carry the 1% annual chance flood. The floodway fringe is the area between the floodway and the 1% annual chance floodplain boundaries where encroachment is permitted. The floodway must be wide enough so that the floodway fringe could be completely obstructed without increasing the water surface elevation of the 1% annual chance flood more than 1 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to floodplain development are shown in Figure 4.

To participate in the NFIP, Federal regulations require communities to limit increases caused by encroachment to 1.0 foot, provided that hazardous velocities are not produced. The floodways in this project are presented to local agencies as minimum standards that can be adopted directly or that can be used as a basis for additional floodway projects.

Figure 4: Floodway Schematic



Floodway widths presented in this FIS Report and on the FIRM were computed at cross sections. Between cross sections, the floodway boundaries were interpolated. For certain stream segments, floodways were adjusted so that the amount of floodwaters conveyed on each side of the floodplain would be reduced equally. The results of the floodway computations have been tabulated for selected cross sections and are shown in Table 23, “Floodway Data.”

All floodways that were developed for this Flood Risk Project are shown on the FIRM using the symbology described in Figure 3. In cases where the floodway and 1% annual chance floodplain boundaries are either close together or collinear, only the floodway boundary has been shown on the FIRM. For information about the delineation of floodways on the FIRM, refer to Section 6.3.

2.3 Base Flood Elevations

The hydraulic characteristics of flooding sources were analyzed to provide estimates of the elevations of floods of the selected recurrence intervals. The Base Flood Elevation (BFE) is the elevation of the 1% annual chance flood. These BFEs are most commonly rounded to the whole foot, as shown on the FIRM, but in certain circumstances or locations they may be rounded to 0.1 foot. Cross section lines shown on the FIRM may also be labeled with the BFE rounded to 0.1 foot. Whole-foot BFEs derived from engineering analyses that apply to coastal areas, areas of ponding, or other static areas with little elevation change may also be shown at selected intervals on the FIRM.

Cross sections with BFEs shown on the FIRM correspond to the cross sections shown in the Floodway Data table and Flood Profiles in this FIS Report. BFEs are primarily intended for flood insurance rating purposes. For construction and/or floodplain management purposes, users are cautioned to use the flood elevation data presented in this FIS Report in conjunction with the data shown on the FIRM.

2.4 Non-Encroachment Zones

This section is not applicable to this Flood Risk Project.

2.5 Coastal Flood Hazard Areas

This section is not applicable to this Flood Risk Project.

2.5.1 Water Elevations and the Effects of Waves

This section is not applicable to this Flood Risk Project.

Figure 5: Wave Runup Transect Schematic

[Not Applicable to this Flood Risk Project]

2.5.2 Floodplain Boundaries and BFEs for Coastal Areas

This section is not applicable to this Flood Risk Project.

2.5.3 Coastal High Hazard Areas

This section is not applicable to this Flood Risk Project.

Figure 6: Coastal Transect Schematic

[Not Applicable to this Flood Risk Project]

2.5.4 Limit of Moderate Wave Action

This section is not applicable to this Flood Risk Project.

SECTION 3.0 – INSURANCE APPLICATIONS

3.1 National Flood Insurance Program Insurance Zones

For flood insurance applications, the FIRM designates flood insurance rate zones as described in Figure 3, "Map Legend for FIRM." Flood insurance zone designations are assigned to flooding sources based on the results of the hydraulic or coastal analyses. Insurance agents use the zones shown on the FIRM and depths and base flood elevations in this FIS Report in conjunction with information on structures and their contents to assign premium rates for flood insurance policies.

The 1% annual chance floodplain boundary corresponds to the boundary of the areas of special flood hazards (e.g. Zones A, AE, V, VE, etc.), and the 0.2% annual chance floodplain boundary corresponds to the boundary of areas of additional flood hazards.

Table 3 lists the flood insurance zones in Ottawa County.

Table 3: Flood Zone Designations by Community

Community	Flood Zone(s)
Afton, Town of	AE, A, X
Commerce, City of	AE, A, X
Fairland, Town of	A, X
Miami, City of	AE, A, X
North Miami, Town of	X
Ottawa County, Unincorporated Areas	AE, A, X
Peoria, Town of	AE, A, X
Quapaw, Town of	A, X
Wyandotte, Town of	AE, A, X
Wyandotte Nation	AE, A, X

SECTION 4.0 – AREA STUDIED

4.1 Basin Description

Table 4 contains a description of the characteristics of the HUC-8 sub-basins within which each community falls. The table includes the main flooding sources within each basin, a brief description of the basin, and its drainage area.

Table 4: Basin Characteristics

HUC-8 Sub-Basin Name	HUC-8 Sub-Basin Number	Primary Flooding Source	Description of Affected Area	Drainage Area (square miles)
Elk	11070208	Elk River	Begins at the southeast portion of Ottawa County, continuing into McDonald County, Missouri, also covering portions of Newton and Barry counties in Missouri and Benton County, Arkansas.	1,026
Lake O' The Cherokees	11070206	Grand Lake O' The Cherokees	Begins at the Oklahoma State line in Craig and Ottawa Counties and continues south into Delaware and Mayes counties. The basin also extends into Newton and McDonald counties, Missouri and Benton County, Arkansas.	909
Lower Neosho	11070209	Neosho River	Begins south of the Pensacola Dam at the downstream end of the Grand Lake O' The Cherokees in Mayes County. The basin contains Big Cabin Creek in Craig County and also contains portions of Cherokee, Delaware, Ottawa, Rogers and Wagoner counties.	2,225
Middle Neosho	11070205	Neosho River	Begins at the confluence of Neosho River and Big Creek in Neosho County, Kansas and flows south, including Allen, Bourbon, Cherokee, and Crawford Counties in Kansas and Ottawa and Craig Counties, Oklahoma.	1,425
Spring	11070207	Spring River	Is located within the northeast corner of Ottawa County heading east. Also covers the eastern half of Cherokee and Crawford Counties in Kansas and all or portions of Barry, Barton, Christian, Jasper and Newton Counties in Missouri, ending in Lawrence County, Missouri.	2,591

4.2 Principal Flood Problems

Table 5 contains a description of the principal flood problems that have been noted for Ottawa County by flooding source.

Table 5: Principal Flood Problems

Flooding Source	Description of Flood Problems
All major streams	Flooding is most frequent in May and September due to intense localized thunderstorms, slow-moving cyclones, or weather fronts. Major flood problems have occurred in all of the floodplains of the studied streams.

Table 6 contains information about historic flood elevations in the communities within Ottawa County.

Table 6: Historic Flooding Elevations

Flooding Source	Location	Historic Peak (Feet NAVD88)	Event Date	Approximate Recurrence Interval (years)	Source of Data
Neosho River	2nd Street, Miami, City of	772.46	1993	100	USACE, HWM
Neosho River	M Street NW, Miami, City of	772.96	1994	100	USACE, HWM
Neosho River	I-44, Miami, City of	766.96	1994	100	USACE, HWM

4.3 Non-Levee Flood Protection Measures

Table 7 contains information about non-levee flood protection measures within Ottawa County such as dams, jetties, and or dikes. Levees are addressed in Section 4.4 of this FIS Report.

Table 7: Non-Levee Flood Protection Measures

Flooding Source	Structure Name	Type of Measure	Location	Description of Measure
Grand Lake O' The Cherokees	Pensacola Dam	Dam	Downstream end of Grand Lake O' The Cherokees in Mayes County	Hydroelectric dam that created the 46,500 acre reservoir

4.4 Levees

This section is not applicable to this flood risk project.

Table 8: Levees

[Not Applicable to this Flood Risk Project]

SECTION 5.0 – ENGINEERING METHODS

For the flooding sources in the community, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this study. Flood events of a magnitude that are expected to be equaled or exceeded at least once on the average during any 10-, 25-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 25-, 50-, 100-, and 500-year floods, have a 10-, 4-, 2-, 1-, and 0.2% annual chance, respectively, of being equaled or exceeded during any year.

Although the recurrence interval represents the long-term, average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood that equals or exceeds the 100-year flood (1-percent chance of annual exceedance) during the term of a 30-year mortgage is approximately 26 percent (about 3 in 10); for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this study. Maps and flood elevations will be amended periodically to reflect future changes.

5.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish the peak elevation-frequency relationships for floods of the selected recurrence intervals for each flooding source studied. Hydrologic analyses are typically performed at the watershed level. Depending on factors such as watershed size and shape, land use and urbanization, and natural or man-made storage, various models or methodologies may be applied. A summary of the hydrologic methods applied to develop the discharges used in the hydraulic analyses for each stream is provided in Table 12. Greater detail (including assumptions, analysis, and results) is available in the archived project documentation.

A summary of the discharges is provided in Table 9. A summary of stillwater elevations developed for non-coastal flooding sources is provided in Table 10. Stream gage information is provided in Table 11.

Table 9: Summary of Discharges

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Belmont Run	27 ft upstream of confluence with Tar Creek (at Miami)	2.49	1,776	2,394	2,854	3,384	4,794
Belmont Run	489 ft upstream of confluence with Tar Creek (at Miami)	2.48	1,730	2,327	2,779	3,294	4,674
Belmont Run	654 ft upstream of confluence with Tar Creek (at Miami)	1.68	1,374	1,852	2,208	2,625	3,730
Belmont Run	1,301 ft upstream of confluence with Tar Creek (at Miami)	1.65	1,359	1,832	2,184	2,596	3,689
Belmont Run	1,951 ft upstream of confluence with Tar Creek (at Miami)	1.63	1,336	1,801	2,148	2,553	3,630
Belmont Run	2,218 ft upstream of confluence with Tar Creek (at Miami)	1.61	1,315	1,771	2,114	2,513	3,574
Belmont Run	2,052 ft downstream of confluence with Belmont Creek	1.25	1,115	1,502	1,795	2,134	3,041
Belmont Run	3,616 ft upstream of confluence with Tar Creek (at Miami)	1.24	1,111	1,497	1,786	2,127	3,031

Table 9: Summary of Discharges, continued

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Belmont Run	4,625 ft upstream of confluence with Tar Creek (at Miami)	1.19	870	1,217	1,482	1,798	2,657
Belmont Run	5,401 ft upstream of confluence with Tar Creek (at Miami)	1.13	850	1,189	1,447	1,756	2,595
Belmont Run	6,738 ft upstream of confluence with Tar Creek (at Miami)	0.96	756	1,057	1,287	1,564	2,316
Belmont Run	7,694 ft upstream of confluence with Tar Creek (at Miami)	0.87	737	1,035	1,256	1,528	2,258
Belmont Run	8,705 ft upstream of confluence with Tar Creek (at Miami)	0.86	745	1,047	1,270	1,545	2,279
Belmont Run	10,143 ft upstream of confluence with Tar Creek (at Miami)	0.79	693	973	1,181	1,438	2,126
Belmont Run	11,526 ft upstream of confluence with Tar Creek (at Miami)	0.62	445	660	825	1,031	1,600
Belmont Run	11,970 ft upstream of confluence with Tar Creek (at Miami)	0.59	441	655	817	1,022	1,585
Belmont Run	13,747 ft upstream of confluence with Tar Creek (at Miami)	0.42	375	561	695	872	1,348

Table 9: Summary of Discharges, continued

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Fairgrounds Branch	At confluence with Neosho River	1.89	1,159	1,754	2,146	2,653	3,988
Fairgrounds Branch	1,137 ft upstream of confluence with Neosho River	1.34	938	1,422	1,737	2,155	3,246
Fairgrounds Branch	1,751 ft upstream of confluence with Neosho River	1.23	895	1,357	1,657	2,058	3,099
Fairgrounds Branch	2,883 ft upstream of confluence with Neosho River	1.2	893	1,357	1,654	2,055	3,091
Fairgrounds Branch	3,240 ft upstream of confluence with Neosho River	1.08	833	1,266	1,544	1,919	2,890
Fairgrounds Branch	4,177 ft upstream of confluence with Neosho River	1.04	814	1,237	1,508	1,875	2,825
Fairgrounds Branch	6,317 ft upstream of confluence with Neosho River	0.9	952	1,365	1,629	1,983	2,876
Fairgrounds Branch	6,996 ft upstream of confluence with Neosho River	0.87	942	1,352	1,611	1,962	2,844
Fairgrounds Branch	7,632 ft upstream of confluence with Neosho River	0.56	573	875	1,061	1,328	2,002

Table 9: Summary of Discharges, continued

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Fairgrounds Branch	8,315 ft upstream of confluence with Neosho River	0.49	531	812	983	1,232	1,858
Fairgrounds Branch	9,032 ft upstream of confluence with Neosho River	0.46	519	795	961	1,205	1,814
Fairgrounds Branch	9,483 ft upstream of confluence with Neosho River	0.43	509	782	943	1,183	1,779
Fairgrounds Branch	10,090 ft upstream of confluence with Neosho River	0.36	462	711	855	1,075	1,615
Fairgrounds Branch	10,598 ft upstream of confluence with Neosho River	0.22	352	544	652	824	1,239
Fairgrounds Branch	10,957 ft upstream of confluence with Neosho River	0.21	347	539	643	813	1,219
Fairgrounds Branch	11,859 ft upstream of confluence with Neosho River	0.13	274	428	508	645	967
Grand Lake O' The Cherokees	At station 138,727 of Neosho River study	10,351	87,598	124,837	159,203	197,642	307,356
Horse Creek	At confluence with Horse Creek Tributary 2	23.52	4,468	6,614	8,344	10,090	15,282
Horse Creek	3,179 ft downstream of confluence with Horse Creek Tributary 3	23.06	4,442	6,579	8,295	10,033	15,188

Table 9: Summary of Discharges, continued

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Horse Creek	167 ft downstream of confluence with Horse Creek	22.75	4,437	6,573	8,286	10,022	15,169
Horse Creek	At confluence with Horse Creek Tributary 3	16.58	3,651	5,418	6,818	8,274	12,542
Horse Creek	At confluence with Horse Creek Tributary 4	15.01	3,439	5,105	6,423	7,801	11,835
Horse Creek Tributary 3	At confluence with Horse Creek	5.69	2,007	3,008	3,748	4,597	6,973
Horse Creek Tributary 3	2,393 ft downstream of confluence with Horse Creek Tributary 3-1	5.66	2,006	3,007	3,747	4,595	6,970
Horse Creek Tributary 3	1,500 ft downstream of confluence with Horse Creek Tributary 3-1	5.62	2,000	2,999	3,736	4,582	6,950
Horse Creek Tributary 3	433 ft downstream of confluence with Horse Creek Tributary 3-1	5.59	1,996	2,993	3,728	4,573	6,935
Horse Creek Tributary 3	At confluence with Horse Creek Tributary 3-1	3.75	1,538	2,307	2,873	3,538	5,385
Horse Creek Tributary 3	At confluence with Horse Creek 3-2	3.00	1,315	1,971	2,457	30,302	4,630
Horse Creek Tributary 3	915 ft upstream of confluence with Horse Creek Tributary 3-2	1.56	866	1,300	1,618	2,010	3,084

Table 9: Summary of Discharges, continued

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Horse Creek Tributary 3	2,210 ft upstream of confluence with Horse Creek Tributary 3-2	1.41	816	1,226	1,524	1,896	2,911
Horse Creek Tributary 3	3,394 ft upstream of confluence with Horse Creek Tributary 3-2	1.33	791	1,189	1,477	1,838	2,822
Horse Creek Tributary 3-1	At confluence with Horse Creek Tributary 3	1.75	879	1,311	1,641	2,037	3,141
Horse Creek Tributary 3-1	1,316 ft upstream of confluence with Horse Creek Tributary 3	1.68	841	1,252	1,570	1,949	3,012
Horse Creek Tributary 3-1	2,412 ft upstream of confluence with Horse Creek Tributary 3	1.57	819	1,223	1,530	1,901	2,934
Horse Creek Tributary 3-1	3,776 ft upstream of confluence with Horse Creek Tributary 3	1.3	743	1,112	1,388	1,728	2,665
Horse Creek Tributary 3-2	At confluence with Horse Creek Tributary 3	0.54	621	890	1,069	1,310	1,929
Horse Creek Tributary 3-2	1,132 ft upstream of confluence with Horse Creek Tributary 3	0.45	561	805	966	1,186	1,746
Horse Creek Tributary 3-2	1,692 ft upstream of confluence with Horse Creek Tributary 3	0.43	557	801	960	1,179	1,734

Table 9: Summary of Discharges, continued

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Horse Creek Tributary 3-2	2,093 ft upstream of confluence with Horse Creek Tributary 3	0.36	401	612	748	943	1,443
Horse Creek Tributary 3-2	2,916 ft upstream of confluence with Horse Creek Tributary 3	0.35	393	602	734	926	1,415
Horse Creek Tributary 3-2	1,032 ft upstream of confluence with Horse Creek Tributary 3	0.23	308	473	576	729	1,116
Horse Creek Tributary 3-2	4,264 ft upstream of confluence with Horse Creek Tributary 3	0.21	299	460	559	709	1,083
Horse Creek Tributary 3-2	4,890 ft upstream of confluence with Horse Creek Tributary 3	0.13	224	346	418	533	815
Horse Creek Tributary 3-2	3,590 ft upstream of confluence with Horse Creek Tributary 3	0.04	99	153	185	238	368
Horse Creek Tributary 3-2-1	764 ft upstream of confluence with Horse Creek Tributary 3-2	1.42	895	1,355	1,671	2,078	3,165
Horse Creek Tributary 3-2-1	1,842 ft upstream of confluence with Horse Creek Tributary 3-2	1.36	890	1,351	1,663	2,068	3,144
Horse Creek Tributary 3-2-1	3,123 ft upstream of confluence with Horse Creek Tributary 3-2	1.33	880	1,336	1,643	2,044	3,106

Table 9: Summary of Discharges, continued

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Horse Creek Tributary 3-2-1	4,139 ft upstream of confluence with Horse Creek Tributary 3-2	1.13	801	1,218	1,496	1,865	2,835
Little Elm Creek	32 ft upstream of confluence with Neosho River	12.78	3,700	5,133	6,990	8,720	13,700
Little Elm Creek	At confluence with Little Elm Creek Tributary 1	7.53	2,640	3,667	4,988	6,255	9,869
Lost Creek (at Wyandotte)	At confluence with Grand Lake O' The Cherokees	91.74	13,770	17,641	22,664	27,360	38,263
Lost Creek (at Wyandotte)	788 ft upstream of confluence with Grand Lake O' The Cherokees	91.69	13,762	17,632	22,654	27,349	38,253
Lost Creek (at Wyandotte)	1,737 ft upstream of confluence with Grand Lake	91.66	13,757	17,626	22,648	27,342	38,247
Lost Creek (at Wyandotte)	174 ft downstream of confluence with Lost Creek Tributary 1	91.61	13,746	17,615	22,635	27,328	38,234
Lost Creek (at Wyandotte)	At confluence with Lost Creek Tributary 1	90.19	13,489	17,336	22,324	26,983	37,914
Lost Creek (at Wyandotte)	903 ft upstream of confluence with Lost Creek Tributary 1	90.06	13,465	17,309	22,295	26,951	37,884

Table 9: Summary of Discharges, continued

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Lost Creek (at Wyandotte)	At confluence with Lost Creek Tributary 2	88.8	13,237	17,062	22,018	26,644	37,599
Lost Creek (at Wyandotte)	1,323 ft upstream of confluence with Lost Creek Tributary 2	88.48	13,180	16,999	21,947	26,566	37,526
Lost Creek (at Wyandotte)	3,103 ft upstream of Confluence with Lost Creek Tributary 2	88.14	13,117	16,931	21,872	26,481	37,447
Lost Creek (at Wyandotte)	5,158 ft upstream of confluence with Lost Creek Tributary 2	87.74	13,046	16,853	21,784	26,385	37,357
Lost Creek (Upper Reach)	Approximately 5,000 feet above its confluence with Grand Lake O' The Cherokees	59.84	8,200	*	15,500	19,310	30,400
Neosho River	Station 232,186	8,726	89,236	129,519	170,004	212,405	322,521
Neosho River	Station 305,167	6,136	51,980	88,681	117,066	146,597	222,987
Neosho River	At gage 07185000, station 353626	5,927	62,110	101,223	132,595	165,272	247,751
Tar Creek (at Miami)	71 ft upstream of confluence with Neosho River	54.71	8,884	10,550	12,743	14,930	20,290
Tar Creek (at Miami)	1,856 ft upstream of confluence with Neosho River	54.51	8,866	10,530	12,720	14,904	20,255

Table 9: Summary of Discharges, continued

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Tar Creek (at Miami)	3,949 ft upstream of confluence with Neosho River	54.34	8,851	10,513	12,702	14,882	20,226
Tar Creek (at Miami)	4,885 ft upstream of confluence with Neosho River	53.84	8,807	10,465	12,646	14,818	20,141
Tar Creek (at Miami)	5,947 ft downstream of confluence with Quail Creek	53.8	8,804	10,461	12,641	14,813	20,134
Tar Creek (at Miami)	4,914 ft downstream of confluence with Quail Creek	53.61	8,788	10,443	12,621	14,789	20,103
Tar Creek (at Miami)	4,603 ft downstream of confluence with Quail Creek	53.23	8,754	10,405	12,578	14,740	20,037
Tar Creek (at Miami)	3,300 ft downstream of confluence with Quail Creek	53.1	8,742	10,392	12,563	14,723	20,015
Tar Creek (at Miami)	3,057 ft downstream of confluence with Quail Creek	52.91	8,726	10,374	12,542	14,699	19,983
Tar Creek (at Miami)	1,685 ft downstream of confluence with Quail Creek	52.66	8,704	10,349	12,514	14,667	19,940
Tar Creek (at Miami)	968 ft downstream of confluence with Quail Creek	52.43	8,683	10,327	12,488	14,637	19,900

Table 9: Summary of Discharges, continued

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Tar Creek (at Miami)	359 ft downstream of confluence with Quail Creek	52.27	8,669	10,310	12,469	14,615	19,872
Tar Creek (at Miami)	108 ft upstream of confluence with Quail Creek	49.68	8,435	10,050	12,172	14,274	19,417
Tar Creek (at Miami)	1,452 ft upstream of confluence with Quail Creek	49.14	8,386	9,995	12,110	14,202	19,322
Tar Creek (at Miami)	2,052 ft downstream of confluence with Belmont Creek	49.13	8,385	9,994	12,109	14,201	19,320
Tar Creek (at Miami)	1,013 ft downstream of confluence with Belmont Creek	49.01	8,374	9,982	12,094	14,185	19,298
Tar Creek (at Miami)	387 ft downstream of confluence with Belmont Run	48.84	8,359	9,965	12,075	14,162	19,269
Tar Creek (at Miami)	5 ft upstream of confluence with Belmont Run	46.35	8,127	9,705	11,778	13,821	18,814
Tar Creek (at Miami)	1,348 ft upstream of confluence with Belmont Run	46.27	8,120	9,697	11,769	13,810	18,800
Tar Creek (at Miami)	2,839 ft upstream of confluence with Belmont Run	46.08	8,102	9,677	11,745	16,784	18,765

Table 9: Summary of Discharges, continued

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Tar Creek (at Miami)	3,686 ft upstream of confluence with Belmont Run	46.07	8,100	9,675	11,744	13,781	18,762
Tar Creek (at Miami)	3,910 ft upstream of confluence with Belmont Run	45.61	8,057	9,627	11,688	13,717	18,676
Tar Creek (at Miami)	7,131 ft downstream of confluence with Garrett Creek	45.37	8,034	9,601	11,659	13,684	18,632
Tar Creek (at Miami)	3,754 ft downstream of confluence with Garrett Creek	44.54	7,955	9,513	11,558	13,568	18,477
Tar Creek (at Miami)	2,706 ft downstream of confluence with Garrett Creek	43.12	7,817	9,359	11,380	13,364	18,205
Tar Creek (at Miami)	600 ft upstream of confluence with Garrett Creek	39.03	7,410	8,901	10,855	12,759	17,398
Tar Creek (at Miami)	2,592 ft upstream of confluence with Garrett Creek	38.8	7,387	8,875	10,825	12,724	17,352
Tar Creek (at Miami)	1,817 ft downstream of confluence with Tar Creek Tributary 1	38.77	7,383	8,871	10,820	12,719	17,345
Tar Creek (at Miami)	53 ft upstream of confluence with Tar Creek Tributary 1	37.27	7,229	8,697	10,619	12,488	17,037

Table 9: Summary of Discharges, continued

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Tar Creek (at Miami)	61 ft upstream of confluence with Tar Creek Tributary 2	35.91	7,086	8,536	10,434	12,274	16,751
Tar Creek (at Miami)	1,942 ft upstream of confluence with Tar Creek Tributary 2	35.7	7,063	8,510	10,404	12,240	16,706
Tar Creek (at Miami)	73 ft upstream of confluence with Tar Creek Tributary 3	29.49	6,374	7,730	9,501	11,198	15,314
Tar Creek (at Miami)	85 ft upstream of confluence with Lytle Creek	16.83	4,715	5,828	7,278	8,625	11,862
Tar Creek (at Miami)	39 ft upstream of confluence with Tar Creek Tributary 4	16.04	4,595	5,689	7,114	8,434	11,605
Tar Creek (at Miami)	1,427 ft upstream of confluence with Tar Creek Tributary 4	15.12	4,452	5,524	6,919	8,207	11,300
Tar Creek (at Miami)	65 ft upstream of confluence with Tar Creek Tributary 5	14.3	4,320	5,370	6,737	7,996	11,015
Tar Creek (at Miami)	1,740 ft upstream of confluence with Tar Creek Tributary 5	13.93	4,261	5,301	6,655	7,900	10,887
Tar Creek (at Miami)	1,178 ft downstream of confluence with Tar Creek Tributary 6	13.24	4,145	5,166	6,494	7,714	10,635

Table 9: Summary of Discharges, continued

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Warren Branch	Approximately 20,000 feet above its confluence with Spring River	18.86	4,830	*	9,100	11,330	17,900
Wyandotte Ditch	At confluence with Grand Lake O' The Cherokees	0.50	553	854	1,033	1,650	1,957

Figure 7: Frequency Discharge-Drainage Area Curves

[Not Applicable to this Flood Risk Project]

Table 10: Summary of Non-Coastal Stillwater Elevations

		Elevations (feet NAVD88)				
Flooding Source	Location	10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Grand Lake O' The Cherokees	Ottawa County, Unincorporated Areas Wyandotte, Town of	755.6	756.3	756.4	756.5	756.7

Table 11: Stream Gage Information used to Determine Discharges

Flooding Source	Gage Identifier	Agency that Maintains Gage	Site Name	Drainage Area (Square Miles)	Period of Record	
					From	To
Neosho River	07185000	USGS	Neosho River near Commerce, OK	5,926	01/06/1904	05/02/2012
Neosho River[1]	07189500	USGS	Neosho River near Grove, OK	9,969	10/01/1924	09/30/1939

[1]Prior to dam construction and used only for flow verifications

5.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of flooding from the sources studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals. Base flood elevations on the FIRM represent the elevations shown on the Flood Profiles and in the Floodway Data tables in the FIS Report. Rounded whole-foot elevations may be shown on the FIRM in coastal areas, areas of ponding, and other areas with static base flood elevations. These whole-foot elevations may not exactly reflect the elevations derived from the hydraulic analyses. Flood elevations shown on the FIRM are primarily intended for flood insurance rating purposes. For construction and/or floodplain management purposes, users are cautioned to use the flood elevation data presented in this FIS Report in conjunction with the data shown on the FIRM.

For streams for which hydraulic analyses were based on cross sections, locations of selected cross sections are shown on the Flood Profiles (Exhibit 1). For stream segments for which a floodway was computed (Section 6.3), selected cross sections are also listed in Table 23, “Floodway Data.”

A summary of the methods used in hydraulic analyses performed for this project is provided in Table 12. Roughness coefficients are provided in Table 13. Roughness coefficients are values representing the frictional resistance water experiences when passing overland or through a channel. They are used in the calculations to determine water surface elevations. Greater detail (including assumptions, analysis, and results) is available in the archived project documentation.

Table 12: Summary of Hydrologic and Hydraulic Analyses

Flooding Source	Study Limits Downstream Limit	Study Limits Upstream Limit	Hydrologic Model or Method Used	Hydraulic Model or Method Used	Date Analyses Completed	Flood Zone on FIRM	Special Considerations
Bee Creek and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Belmont Run	At confluence with Tar Creek (at Miami)	Just downstream of U.S. Highway 60	Regression Equations	HEC-RAS Version 4.1	2016	AE w/ Floodway	
Coal Creek and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Council Hollow Creek and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Cow Creek	At confluence with Neosho River	Ottawa county line	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Elm Creek and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Fairgrounds Branch	At confluence with the Neosho River	Approximately 2.7 miles upstream of confluence with Neosho River	Regression Equations	HEC-RAS Version 4.1	2016	AE w/ Floodway	

Table 12: Summary of Hydrologic and Hydraulic Analyses, continued

Flooding Source	Study Limits Downstream Limit	Study Limits Upstream Limit	Hydrologic Model or Method Used	Hydraulic Model or Method Used	Date Analyses Completed	Flood Zone on FIRM	Special Considerations
Garrett Creek and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Grand Lake O' The Cherokees	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	AE	
Grand Lake Tributary 2 and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Hickory Creek and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Horse Creek	Approximately 0.36 mile upstream of confluence of Horse Creek Tributary 1	Approximately 0.2 mile downstream of confluence with Horse Creek Tributary 5	Regression Equations	HEC-RAS Version 4.1	2016	AE	
Horse Creek Tributary 3	At confluence with Horse Creek	Approximately 1.08 miles upstream of confluence with Horse Creek Tributary 3-2	Regression Equations	HEC-RAS Version 4.1	2016	AE	

Table 12: Summary of Hydrologic and Hydraulic Analyses, continued

Flooding Source	Study Limits Downstream Limit	Study Limits Upstream Limit	Hydrologic Model or Method Used	Hydraulic Model or Method Used	Date Analyses Completed	Flood Zone on FIRM	Special Considerations
Horse Creek Tributary 3-1	At confluence with Horse Creek Tributary 3	Approximately 0.9 mile upstream of confluence with Horse Creek Tributary 3	Regression Equations	HEC-RAS Version 4.1	2016	AE	
Horse Creek Tributary 3-2	At confluence with Horse Creek Tributary 3	Approximately 1,700 feet upstream from South Main Avenue	Regression Equations	HEC-RAS Version 4.1	2016	AE	
Horse Creek Tributary 3-2-1	At confluence with Horse Creek Tributary 3-2	Approximately 2.12 miles upstream of confluence with Horse Creek Tributary 3-2	Regression Equations	HEC-RAS Version 4.1	2016	AE	
Hudson Creek and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Little Elm Creek and Zone A Tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Little Elm Creek	At confluence with the Neosho River	At confluence with Little Elm Creek Tributary 2	Various	HEC-2	2008	AE	Redelineated in 2015

Table 12: Summary of Hydrologic and Hydraulic Analyses, continued

Flooding Source	Study Limits Downstream Limit	Study Limits Upstream Limit	Hydrologic Model or Method Used	Hydraulic Model or Method Used	Date Analyses Completed	Flood Zone on FIRM	Special Considerations
Little Horse Creek and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Lost Creek and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Lost Creek (at Wyandotte)	At confluence with Grand Lake O' The Cherokees	Approximately 1.0 miles upstream of confluence with Lost Creek Tributary 2	Various	HEC-RAS Version 4.1	2016	AE w/ Floodway	
Lost Creek (Upper Reach)	Approximately 6.9 miles upstream of confluence with Lost Creek Tributary 2	Approximately 8.2 miles upstream of confluence with Lost Creek Tributary 2	COE HEC-1	HEC-2	2008	AE w/ Floodway	Redelineated in 2015
Lytle Creek and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Mud Creek	At confluence with Neosho River	Ottawa county line	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Neosho River	Approximately 1,000 feet upstream of US Highway 60	Approximately 1,400 upstream of E 60 Road	USGS Gage Analysis	HEC_RAS Version 4.1	2016	AE w/ Floodway	Only portion with floodway

Table 12: Summary of Hydrologic and Hydraulic Analyses, continued

Flooding Source	Study Limits Downstream Limit	Study Limits Upstream Limit	Hydrologic Model or Method Used	Hydraulic Model or Method Used	Date Analyses Completed	Flood Zone on FIRM	Special Considerations
Neosho River	Ottawa County line	Approximately 1,000 feet upstream of US Highway 60	Regression Equations	HEC-RAS Version 4.1	2016	AE	Limited Detail Study
Neosho River and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Ogeechee Creek and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Quail Creek and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Quail Creek	At confluence with Tar Creek (at Miami)	At confluence with Quail Creek Tributary 1	Regression Equations	HEC-RAS Version 4.1	2016	AE w/ Floodway	
Tar Creek and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Tar Creek (at Miami)	At confluence with Neosho River	Approximately 0.3 miles of upstream of confluence with Tar Creek Tributary 2	Effective Study/Curve Fitting	HEC-RAS Version 4.1	2016	AE w/ Floodway	

Table 12: Summary of Hydrologic and Hydraulic Analyses, continued

Flooding Source	Study Limits Downstream Limit	Study Limits Upstream Limit	Hydrologic Model or Method Used	Hydraulic Model or Method Used	Date Analyses Completed	Flood Zone on FIRM	Special Considerations
Unnamed Creek 1 and Zone A tributaries	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Unnamed Creek 2	N/A	N/A	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Warren Branch	Approximately 0.32 mile downstream of the downstream Town of Peoria corporate limits	Approximately 0.58 mile upstream of the upstream Town of Peoria corporate Limits	USACE HEC-1	USACE HEC-2	1986	AE w/ Floodway	
Windy Creek	At confluence with Cow Creek	Ottawa county line	USGS Gage Analyses/ Regression Equations	HEC-RAS Version 4.1	2016	A	
Wyandotte Ditch	Approximately 3,300 feet upstream of the confluence with Lost Creek	Approximately 950 feet upstream of S 650 Road	Various	HEC-RAS Version 4.1	2016	AE	

Table 13: Roughness Coefficients

Flooding Source	Channel "n"	Overbank "n"
Belmont Run	0.05 – 0.06	0.05 – 0.13
Fairground Branch	0.05 – 0.055	0.06 – 0.13
Grand Lake O' The Cherokees	0.035	0.06 – 0.12
Horse Creek	0.045	0.06 – 0.12
Horse Creek Tributary 3	0.045	0.06 – 0.12
Horse Creek Tributary 3-1	0.04	0.06 – 0.12
Horse Creek Tributary 3-2	0.04	0.06 – 0.12
Horse Creek Tributary 3-2-1	0.04 – 0.045	0.06 – 0.12
Little Elm Creek (within the City of Miami)	0.035 – 0.095[1]	0.045 – 0.095
Little Elm Creek (all other reaches)	0.035 – 0.045	0.08 – 0.12
Lost Creek (at Wyandotte)	0.04 – 0.05	0.06 – 0.13
Lost Creek (Upper Reach)	0.045 - 0.050	0.08 – 0.12
Neosho River	0.02 - 0.055	0.04 – 0.15
Quail Creek	0.04 – 0.05	0.06 – 0.13
Tar Creek (at Miami)	0.045 – 0.05	0.05 – 0.13
Warren Branch	0.050 – 0.075	0.06 – 0.10
Wyandotte Ditch	0.040	0.065 – 0.070

[1]Through culverts, values were reduced to 0.018-0.024

5.3 Coastal Analyses

This section is not applicable to this flood risk project.

Table 14: Summary of Coastal Analyses

[Not Applicable to this Flood Risk Project]

5.3.1 Total Stillwater Elevations

This section is not applicable to this flood risk project.

Figure 8: 1% Annual Chance Total Stillwater Elevations for Coastal Areas

[Not Applicable to this Flood Risk Project]

Table 15: Tide Gage Analysis Specifics

[Not Applicable to this Flood Risk Project]

5.3.2 Waves

This section is not applicable to this flood risk project.

5.3.3 Coastal Erosion

This section is not applicable to this flood risk project.

5.3.4 Wave Hazard Analyses

This section is not applicable to this flood risk project.

Figure 9: Transect Location Map

[Not Applicable to this Flood Risk Project]

5.4 Alluvial Fan Analyses

This section is not applicable to this flood risk project.

Table 16: Coastal Transect Parameters

[Not Applicable to this Flood Risk Project]

Table 17: Summary of Alluvial Fan Analyses

[Not Applicable to this Flood Risk Project]

Table 18: Results of Alluvial Fan Analyses

[Not Applicable to this Flood Risk Project]

SECTION 6.0 – MAPPING METHODS

6.1 Vertical and Horizontal Control

All FIS Reports and FIRMs are referenced to a specific vertical datum. The vertical datum provides a starting point against which flood, ground, and structure elevations can be referenced and compared. Until recently, the standard vertical datum used for newly created or revised FIS Reports and FIRMs was the National Geodetic Vertical Datum of 1929 (NGVD29). With the completion of the North American Vertical Datum of 1988 (NAVD88), many FIS Reports and FIRMs are now prepared using NAVD88 as the referenced vertical datum.

Flood elevations shown in this FIS Report and on the FIRMs are referenced to NAVD88. These flood elevations must be compared to structure and ground elevations referenced to the same vertical datum. For information regarding conversion between NGVD29 and NAVD88 or other datum conversion, visit the National Geodetic Survey website at www.ngs.noaa.gov.

Temporary vertical monuments are often established during the preparation of a flood hazard analysis for the purpose of establishing local vertical control. Although these monuments are not shown on the FIRM, they may be found in the archived project documentation associated with the FIS Report and the FIRMs for this community. Interested individuals may contact FEMA to access these data.

To obtain current elevation, description, and/or location information for benchmarks in the area, please visit the NGS website at www.ngs.noaa.gov.

The countywide conversion factor of +0.353 feet was calculated for Ottawa County.

Table 19: Countywide Vertical Datum Conversion

[Not Applicable to this Flood Risk Project]

Table 20: Stream-Based Vertical Datum Conversion

[Not Applicable to this Flood Risk Project]

6.2 Base Map

The FIRMs and FIS Report for this project have been produced in a digital format. The flood hazard information was converted to a Geographic Information System (GIS) format that meets FEMA's FIRM Database specifications and geographic information standards. This information is provided in a digital format so that it can be incorporated into a local GIS and be accessed more easily by the community. The FIRM Database includes most of the tabular information contained in the FIS Report in such a way that the data can be associated with pertinent spatial features. For example, the information contained in the Floodway Data table and Flood Profiles can be linked to the cross sections that are shown on the FIRMs. Additional information about the FIRM Database and its contents can be found in FEMA's *Guidelines and Standards for Flood Risk Analysis and Mapping*, www.fema.gov/guidelines-and-standards-flood-risk-analysis-and-mapping.

Base map information shown on the FIRM was derived from the sources described in Table 21.

Table 21: Base Map Sources

Data Type	Data Provider	Data Date	Data Scale	Data Description
Digital Orthoimagery	USDA/FSA	2015	1:12,000	NAIP 2015 Color orthoimagery
Political Boundaries	Wyandotte Nation	2009	1:24,000	Community boundaries
Public Land Survey System (PLSS)	Bureau of Land Management	2006	1:24,000	PLSS quadrangles
Surface Water Features	United States Geological Survey	2005	1:24,000	Streams, rivers, and lakes were derived from NHD data
Transportation Features	U.S. Census Bureau	2016	1:24,000	Ottawa County roads and railroads from TIGER/Line Shapefile.

6.3 Floodplain and Floodway Delineation

The FIRM shows tints, screens, and symbols to indicate floodplains and floodways as well as the locations of selected cross sections used in the hydraulic analyses and floodway computations.

For riverine flooding sources, the mapped floodplain boundaries shown on the FIRM have been delineated using the flood elevations determined at each cross section; between cross sections, the boundaries were interpolated using the topographic elevation data described in Table 22.

In cases where the 1% and 0.2% annual chance floodplain boundaries are close together, only the 1% annual chance floodplain boundary has been shown. Small areas within the floodplain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

The floodway widths presented in this FIS Report and on the FIRM were computed for certain stream segments on the basis of equal conveyance reduction from each side of the floodplain. Floodway widths were computed at cross sections. Between cross sections, the floodway boundaries were interpolated. Table 2 indicates the flooding sources for which floodways have been determined. The results of the floodway computations for those flooding sources have been tabulated for selected cross sections and are shown in Table 23, "Floodway Data."

Table 22: Summary of Topographic Elevation Data used in Mapping

Community	Flooding Source	Source for Topographic Elevation Data			
		Description	Vertical Accuracy	Horizontal Accuracy	Citation
Afton, Town of	All within 11070206	Light Detection and Ranging data (LiDAR)	0.06 meter RMSEz	2 centimeters at 95% confidence level	RAMPP, 2013
Commerce, City of	All within 11070206	Light Detection and Ranging data (LiDAR)	0.06 meter RMSEz	2 centimeters at 95% confidence level	RAMPP, 2013
Fairland, Town of	All within 11070206	Light Detection and Ranging data (LiDAR)	0.06 meter RMSEz	2 centimeters at 95% confidence level	RAMPP, 2013
Miami, City of	All within 11070206	Light Detection and Ranging data (LiDAR)	0.06 meter RMSEz	2 centimeters at 95% confidence level	RAMPP, 2013
North Miami, Town of	All within 11070206	Light Detection and Ranging data (LiDAR)	0.06 meter RMSEz	2 centimeters at 95% confidence level	RAMPP, 2013
Ottawa County, Unincorporated Areas	All within 11070206	Light Detection and Ranging data (LiDAR)	0.06 meter RMSEz	2 centimeters at 95% confidence level	RAMPP, 2013
Peoria, Town of	Warren Branch	Topographic Maps	10 Ft	1:24,000	USGS 1961
Quapaw, Town of	All within 11070206	Light Detection and Ranging data (LiDAR)	0.06 meter RMSEz	2 centimeters at 95% confidence level	RAMPP, 2013
Wyandotte, Town of	All within 11070206	Light Detection and Ranging data (LiDAR)	0.06 meter RMSEz	2 centimeters at 95% confidence level	RAMPP, 2013
Wyandotte Nation	All within 11070206	Light Detection and Ranging data (LiDAR)	0.06 meter RMSEz	2 centimeters at 95% confidence level	RAMPP, 2013

BFEs shown at cross sections on the FIRM represent the 1% annual chance water surface elevations shown on the Flood Profiles and in the Floodway Data tables in the FIS Report.

Table 23: Floodway Data

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/ SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
A	1,705	189	658	3.1	778.8	776.8[2]	777.6	0.8
B	2,455	166	601	3.3	781.5	781.5	782.2	0.7
C	3,081	184	880	2.2	782.6	782.6	783.5	0.9
D	3,653	282	1,402	1.2	783.3	783.3	784.3	1.0
E	4,147	281	1,017	1.6	783.9	783.9	784.6	0.7
F	4,777	408	1,380	1.2	784.8	784.8	785.2	0.4
G	5,624	127	471	3.5	786.2	786.2	786.3	0.1
H	7,172	247	1,030	1.5	791.1	791.1	792.1	1.0
I	7,588	356	1,437	1.1	791.5	791.5	792.5	1.0
J	8,159	286	672	2.0	792.5	792.5	793.0	0.5
K	8,627	267	518	2.6	793.7	793.7	794.0	0.3
L	9,133	641	1,485	0.9	794.6	794.6	795.0	0.4
M	10,625	181	1,026	1.3	797.5	797.5	798.2	0.7
N	11,830	132	920	1.4	799.4	799.4	799.9	0.5
O	12,143	156	968	1.3	799.6	799.6	800.1	0.5
P	13,267	86	581	1.8	800.5	800.5	800.9	0.4

[1]Feet above confluence with Tar Creek (at Miami)

[2]Elevation computed without consideration of backwater effects

TABLE 23

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OKLAHOMA

AND INCORPORATED AREAS

FLOODWAY DATA

FLOODING SOURCE: BELMONT RUN

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Q	13,663	97	625	1.6	800.8	800.8	801.3	0.5
R	14,056	102	642	1.6	801.0	801.0	801.7	0.7
S	14,571	127	687	1.5	801.3	801.3	802.1	0.8
T	15,653	140	767	1.1	803.4	803.4	804.3	0.9
U	16,221	114	531	1.6	803.9	803.9	804.6	0.7
V	16,694	128	559	1.6	804.5	804.5	805.2	0.7
W	17,136	97	389	2.2	805.2	805.2	806.1	0.9
X	17,679	86	392	2.2	806.9	806.9	807.8	0.9
Y	18,200	117	479	1.8	807.9	807.9	808.8	0.9
Z	18,716	50	142	6.2	809.3	809.3	810.0	0.7

[1]Feet above confluence with Tar Creek (at Miami)

TABLE 23

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OKLAHOMA

AND INCORPORATED AREAS

FLOODWAY DATA

FLOODING SOURCE: BELMONT RUN

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
A	6,214	149	635	3.0	779.5	770.1[2]	770.4	0.3
B	6,824	158	606	3.1	779.5	772.9[2]	773.2	0.3
C	7,665	231	824	2.1	779.5	776.1[2]	776.5	0.4
D	8,835	175	447	3.9	780.4	780.4	781.1	0.7
E	9,811	164	508	2.4	785.8	785.8	786.7	0.9
F	10,239	97	376	3.3	789.0	789.0	789.8	0.8
G - P[3]								

[1]Feet above confluence with Neosho River
[2]Elevation computed without consideration of backwater effects
[3]Floodway not computed

TABLE 23	FEDERAL EMERGENCY MANAGEMENT AGENCY **OTTAWA COUNTY, OKLAHOMA** AND INCORPORATED AREAS	**FLOODWAY DATA** **FLOODING SOURCE: FAIRGROUNDS BRANCH**

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
A	3,053	320	3,126	2.8	777.4	755.3[2]	756.2	0.9
B	4,343	258	1,978	4.4	777.4	757.2[2]	758.1	0.9
C	5,668	349	2,001	4.4	777.4	761.7[2]	762.7	1.0
D	6,250	276	1,830	4.8	777.4	764.0[2]	765.0	1.0
E	7,340	393	2,795	3.1	777.4	766.9[2]	767.8	0.9
F	7,808	261	1,522	5.7	777.4	769.3[2]	770.0	0.7
G	9,478	650	3,354	2.6	777.4	774.2[2]	775.2	1.0
H	10,319	373	2,059	4.2	777.4	775.7[2]	775.7	0.9
I	11,280	573	3,132	2.8	778.0	778.0	778.9	0.9
J	12,362	466	2,351	3.7	780.4	780.4	781.2	0.8
K	14,842	494	2,864	3.8	785.2	785.2	786.2	1.0
L	15,718	514	3,829	2.3	786.1	786.1	787.1	1.0
M	16,100	501	3,273	2.7	787.5	787.5	788.5	1.0
N	16,460	727	5,026	1.7	787.9	787.9	788.9	1.0
O	16,652	542	3,434	2.5	788.1	788.1	789.1	1.0
P	18,300	402	2,459	3.5	789.8	789.8	790.8	1.0

[1]Feet above confluence with Neosho River
[2]Elevation computed without consideration of backwater effects

TABLE 23

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OKLAHOMA

AND INCORPORATED AREAS

FLOODWAY DATA

FLOODING SOURCE: LITTLE ELM CREEK

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
A	4,432	948	9,832	2.8	758.4	754.7[2]	755.6	0.9
B	4,922	746	6,936	3.9	758.4	755.2[2]	755.9	0.7
C	5,561	417	4,801	5.7	758.4	756.2[2]	757.1	0.9
D	5,698	439	5,342	5.1	758.4	757.2[2]	757.9	0.7
E	6,099	1,141	12,810	2.1	758.7	758.7	759.4	0.7
F	6,659	1,640	16,340	1.7	758.9	758.9	759.7	0.8
G	6,928	1,950	17,577	1.5	759.0	759.0	759.9	0.9
H	7,564	1,950	15,762	1.7	759.4	759.4	760.3	0.9
I	8,864	1,750	12,951	2.1	759.9	759.9	760.7	0.8
J	9,337	1,480	10,311	2.6	760.6	760.6	761.5	0.9
K	9,855	1,219	7,017	3.8	761.1	761.1	762.0	0.9
L	10,393	1,153	7,593	3.5	762.2	762.2	763.1	0.9
M	10,849	1,128	7,967	3.3	763.1	763.1	763.9	0.8
N	11,165	1,053	7,946	3.3	764.1	764.1	764.8	0.7
O	12,005	1,110	8,446	3.1	765.1	765.1	765.9	0.8
P	12,499	1,073	7,715	3.4	765.8	765.8	766.6	0.8

[1]Feet above confluence with Neosho River

[2]Elevation computed without consideration of backwater effects

TABLE 23

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OKLAHOMA

AND INCORPORATED AREAS

FLOODWAY DATA

FLOODING SOURCE: LOST CREEK (AT WYANDOTTE)

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Q	12,878	994	7,239	3.7	766.4	766.4	767.2	0.8
R	13,403	963	6,699	4.0	767.4	767.4	768.0	0.6
S	13,854	697	5,441	4.9	768.8	768.8	769.2	0.4
T	14,310	501	4,552	5.8	770.8	770.8	771.6	0.8
U	14,829	266	3,271	8.1	772.3	772.3	773.2	0.9

[1]Feet above confluence with Neosho River

TABLE 23

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OKLAHOMA

AND INCORPORATED AREAS

FLOODWAY DATA

FLOODING SOURCE: LOST CREEK (AT WYANDOTTE)

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
A	45,800	787	6,115	3.2	829.4	829.4	830.4	1.0
B	46,240	618	3,750	5.1	830.3	830.3	831.3	1.0
C	47,295	1,073	6,074	3.2	833.6	833.6	834.6	1.0
D	48,315	770	4,183	5.6	835.6	835.6	836.5	0.9
E	48,705	605	3,823	5.1	836.7	836.7	837.7	1.0
F	49,065	353	2,237	8.6	838.5	838.5	838.7	0.2
G	49,755	410	2,661	7.3	841.9	841.9	842.2	0.3
H	49,970	407	3,104	6.2	843.5	843.5	844.4	0.9
I	50,465	730	6,421	3.0	845.5	845.5	846.1	0.6
J	50,900	803	8,395	2.3	845.9	845.9	846.5	0.6
K	51,800	850	7,120	2.7	846.4	846.4	847.2	0.8
L	52,845	850	7,127	2.7	847.6	847.6	848.6	1.0
M	52,890	850	6,880	2.8	847.6	847.6	848.6	1.0

[1]Feet above confluence with Grand Lake O' The Cherokees

TABLE 23	FEDERAL EMERGENCY MANAGEMENT AGENCY **OTTAWA COUNTY, OKLAHOMA** AND INCORPORATED AREAS	**FLOODWAY DATA** **FLOODING SOURCE: LOST CREEK (UPPER REACH)**

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/ SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
A - L[2]								
M	284,443	3,700	74,848	1.9	776.9	776.9	776.9	0.0
N	293,841	3,600	76,820	1.9	778.9	778.9	779.4	0.5
O	298,512	4,029	85,698	1.7	779.5	779.5	780.5	1.0
P	300,747	5,165	92,095	1.6	779.9	779.9	780.9	1.0
Q	310,110	13,550	281,551	0.5	780.4	780.4	781.4	1.0
R	314,238	16,000	368,018	0.4	780.5	780.5	781.5	1.0
S - X[2]								

[1]Feet above Pensacola Dam

[2]Floodway not computed

TABLE 23

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OKLAHOMA

AND INCORPORATED AREAS

FLOODWAY DATA

FLOODING SOURCE: NEOSHO RIVER

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
A	4,337	250	1,142	2.5	778.8	778.0[2]	778.9	0.9
B – Q[3]								

[1]Feet above confluence with Tar Creek (at Miami)

[2]Elevation is computed without consideration of backwater effects

[3]Floodway is not computed

TABLE 23

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OKLAHOMA

AND INCORPORATED AREAS

FLOODWAY DATA

FLOODING SOURCE: QUAIL CREEK

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
A	16,488	1,048	6,723	2.1	778.8	774.2[2]	775.2	1.0
B	18,840	1,314	8,415	1.6	778.8	777.6[2]	778.4	0.8
C	20,151	1,108	7,830	1.8	778.8	778.5[2]	779.3	0.8
D	21,760	1,107	7,468	1.8	780.7	780.7	781.4	0.7
E	22,672	1,485	7,875	1.7	781.5	781.5	782.1	0.6
F	24,295	1,583	9,018	1.5	782.5	782.5	783.2	0.7
G	26,488	1,748	9,091	1.5	783.8	783.8	784.7	0.9
H	28,040	1,375	7,314	1.8	784.8	784.8	785.5	0.7
I	29,452	1,365	7,060	1.9	786.2	786.2	786.9	0.7
J	30,833	1,228	7,245	1.8	787.7	787.7	788.5	0.8
K	31,828	1,121	6,593	1.9	788.9	788.9	789.6	0.7
L	33,639	1,005	5,906	2.2	790.6	790.6	791.4	0.8
M	34,912	565	3,728	3.4	791.7	791.7	792.4	0.7
N	35,842	1,024	7,849	1.6	793.0	793.0	793.7	0.7
O	36,724	1,483	10,468	1.2	793.4	793.4	794.1	0.7
P	37,806	913	6,365	2.0	793.8	793.8	794.4	0.6

[1]Feet above confluence with Neosho River
[2]Elevation computed without consideration of backwater effects

TABLE 23

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OKLAHOMA

AND INCORPORATED AREAS

FLOODWAY DATA

FLOODING SOURCE: TAR CREEK (AT MIAMI)

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Q	38,764	923	6,139	2.0	794.5	794.5	795.1	0.6
R	39,414	758	5,548	2.2	794.9	794.9	795.6	0.7
S	40,104	707	6,032	2.0	795.8	795.8	796.6	0.8

[1]Feet above confluence with Neosho River

TABLE 23

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OKLAHOMA

AND INCORPORATED AREAS

FLOODWAY DATA

FLOODING SOURCE: TAR CREEK (AT MIAMI)

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
A	19,600	137	1,706	6.6	855.4	855.4	856.4	1.0
B	20,285	130	1,611	7.0	858.3	858.3	859.3	1.0
C	20,805	140	1,756	6.5	861.3	861.3	861.9	0.6
D	21,015	186	2,740	4.1	868.8	868.8	869.1	0.3
E	24,230	464	2,760	4.1	878.9	878.9	879.9	1.0
F	25,165	349	1,706	6.6	885.2	885.2	886.2	1.0
G	25,800	320	2,246	5.0	890.3	890.3	891.2	0.9
H	27,000	492	3,205	3.5	895.8	895.8	896.8	1.0

[1]Feet above confluence with Spring River

TABLE 23

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OKLAHOMA

AND INCORPORATED AREAS

FLOODWAY DATA

FLOODING SOURCE: WARREN BRANCH

Table 24: Flood Hazard and Non-Encroachment Data for Selected Streams

[Not Applicable to this Flood Risk Project]

6.4 Coastal Flood Hazard Mapping

This section is not applicable to this flood risk project.

Table 25: Summary of Coastal Transect Mapping Considerations

[Not Applicable to this Flood Risk Project]

6.5 FIRM Revisions

This FIS Report and the FIRM are based on the most up-to-date information available to FEMA at the time of its publication; however, flood hazard conditions change over time. Communities or private parties may request flood map revisions at any time. Certain types of requests require submission of supporting data. FEMA may also initiate a revision. Revisions may take several forms, including Letters of Map Amendment (LOMAs), Letters of Map Revision Based on Fill (LOMR-Fs), Letters of Map Revision (LOMRs) (referred to collectively as Letters of Map Change (LOMCs)), Physical Map Revisions (PMRs), and FEMA-contracted restudies. These types of revisions are further described below. Some of these types of revisions do not result in the republishing of the FIS Report. To assure that any user is aware of all revisions, it is advisable to contact the community repository of flood-hazard data (shown in Table 30, “Map Repositories”).

6.5.1 Letters of Map Amendment

A LOMA is an official revision by letter to an effective NFIP map. A LOMA results from an administrative process that involves the review of scientific or technical data submitted by the owner or lessee of property who believes the property has incorrectly been included in a designated SFHA. A LOMA amends the currently effective FEMA map and establishes that a specific property is not located in a SFHA.

To obtain an application for a LOMA, visit www.fema.gov/floodplain-management/letter-map-amendment-loma and download the form “MT-1 Application Forms and Instructions for Conditional and Final Letters of Map Amendment and Letters of Map Revision Based on Fill”. Visit the “Flood Map-Related Fees” section to determine the cost, if any, of applying for a LOMA.

FEMA offers a tutorial on how to apply for a LOMA. The LOMA Tutorial Series can be accessed at www.fema.gov/online-tutorials.

For more information about how to apply for a LOMA, call the FEMA Map Information eXchange; toll free, at 1-877-FEMA MAP (1-877-336-2627).

6.5.2 Letters of Map Revision Based on Fill

A LOMR-F is an official revision by letter to an effective NFIP map. A LOMR-F states FEMA's determination concerning whether a structure or parcel has been elevated on fill above the base flood elevation and is, therefore, excluded from the SFHA.

Information about obtaining an application for a LOMR-F can be obtained in the same manner as that for a LOMA, by visiting www.fema.gov/floodplain-management/letter-map-amendment-loma for the "MT-1 Application Forms and Instructions for Conditional and Final Letters of Map Amendment and Letters of Map Revision Based on Fill" or by calling the FEMA Map Information eXchange, toll free, at 1-877-FEMA MAP (1-877-336-2627). Fees for applying for a LOMR-F, if any, are listed in the "Flood Map-Related Fees" section.

A tutorial for LOMR-F is available at www.fema.gov/online-tutorials.

6.5.3 Letters of Map Revision

A LOMR is an official revision to the currently effective FEMA map. It is used to change flood zones, floodplain and floodway delineations, flood elevations and planimetric features. All requests for LOMRs should be made to FEMA through the chief executive officer of the community, since it is the community that must adopt any changes and revisions to the map. If the request for a LOMR is not submitted through the chief executive officer of the community, evidence must be submitted that the community has been notified of the request.

To obtain an application for a LOMR, visit www.fema.gov/national-flood-insurance-program-flood-hazard-mapping/mt-2-application-forms-and-instructions and download the form "MT-2 Application Forms and Instructions for Conditional Letters of Map Revision and Letters of Map Revision". Visit the "Flood Map-Related Fees" section to determine the cost of applying for a LOMR. For more information about how to apply for a LOMR, call the FEMA Map Information eXchange; toll free, at 1-877-FEMA MAP (1-877-336-2627) to speak to a Map Specialist.

Previously issued mappable LOMCs (including LOMRs) that have been incorporated into the Ottawa County FIRM are listed in Table 26.

Table 26: Incorporated Letters of Map Change

[Not Applicable to this Flood Risk Project]

6.5.4 Physical Map Revisions

A Physical Map Revisions (PMR) is an official republication of a community's NFIP map to effect changes to base flood elevations, floodplain boundary delineations, regulatory floodways and planimetric features. These changes typically occur as a result of structural works or improvements, annexations resulting in additional flood hazard areas or correction to base flood elevations or SFHAs.

The community's chief executive officer must submit scientific and technical data to FEMA to support the request for a PMR. The data will be analyzed and the map will be revised if warranted. The community is provided with copies of the revised information and is afforded a review period. When the base flood elevations are changed, a 90-day appeal period is provided. A 6-month adoption period for formal approval of the revised map(s) is also provided.

For more information about the PMR process, please visit www.fema.gov and visit the "Flood Map Revision Processes" section.

6.5.5 Contracted Restudies

The NFIP provides for a periodic review and restudy of flood hazards within a given community. FEMA accomplishes this through a national watershed-based mapping needs assessment strategy, known as the Coordinated Needs Management Strategy (CNMS). The CNMS is used by FEMA to assign priorities and allocate funding for new flood hazard analyses used to update the FIS Report and FIRM. The goal of CNMS is to define the validity of the engineering study data within a mapped inventory. The CNMS is used to track the assessment process, document engineering gaps and their resolution, and aid in prioritization for using flood risk as a key factor for areas identified for flood map updates. Visit www.fema.gov to learn more about the CNMS or contact the FEMA Regional Office listed in Section 8 of this FIS Report.

6.5.6 Community Map History

The current FIRM presents flooding information for the entire geographic area of Ottawa County. Previously, separate FIRMs, Flood Hazard Boundary Maps (FHBMs) and/or Flood Boundary and Floodway Maps (FBFMs) may have been prepared for the incorporated communities and the unincorporated areas in the county that had identified SFHAs. Current and historical data relating to the maps prepared for the project area are presented in Table 27, "Community Map History." A description of each of the column headings and the source of the date is also listed below.

- *Community Name* includes communities falling within the geographic area shown on the FIRM, including those that fall on the boundary line, nonparticipating communities, and communities with maps that have been rescinded. Communities with No Special Flood Hazards are indicated by a footnote. If all maps (FHBM, FBFM, and FIRM) were rescinded for a community, it is not listed in this table unless SFHAs have been identified in this community.

- *Initial Identification Date (First NFIP Map Published)* is the date of the first NFIP map that identified flood hazards in the community. If the FHBM has been converted to a FIRM, the initial FHBM date is shown. If the community has never been mapped, the upcoming effective date or "pending" (for Preliminary FIS Reports) is shown. If the community is listed in Table 27 but not identified on the map, the community is treated as if it were unmapped.

- *Initial FHBM Effective Date* is the effective date of the first FHBM. This date may be the same date as the Initial NFIP Map Date.

- *FHBM Revision Date(s)* is the date(s) that the FHBM was revised, if applicable.

- *Initial FIRM Effective Date* is the date of the first effective FIRM for the community.

- *FIRM Revision Date(s)* is the date(s) the FIRM was revised, if applicable. This is the revised date that is shown on the FIRM panel, if applicable. As countywide studies are completed or revised, each community listed should have its FIRM dates updated accordingly to reflect the date of the countywide study. Once the FIRMs exist in countywide format, as PMRs of FIRM panels within the county are completed, the FIRM Revision Dates in the table for each community affected by the PMR are updated with the date of the PMR, even if the PMR did not revise all the panels within that community.

The initial effective date for the Ottawa County FIRMs in countywide format was 08/05/2010.

Table 27: Community Map History

Community Name	Initial Identification Date	Initial FHBM Effective Date	FHBM Revision Date(s)	Initial FIRM Effective Date	FIRM Revision Date(s)
Afton, Town of	02/07/1975	2/07/1975	None	01/03/1986	09/13/2019 08/05/2010
Commerce, City of	06/04/1976	06/04/1976	None	07/18/1985	09/13/2019 08/05/2010
Fairland, Town of	04/09/1976	04/09/1976	None	01/01/1992	09/13/2019 08/05/2010
Miami, City of	01/25/1974	01/25/1974	12/05/1975	12/16/1980	09/13/2019 08/05/2010 09/03/1997 09/30/1988 04/19/1983
North Miami, Town of[1]	04/09/1976	04/09/1976	None	08/05/2010	09/13/2019
Ottawa County, Unincorporated Areas	05/20/1977	05/20/1977	None	12/02/1988	09/13/2019 08/05/2010 12/19/1997
Peoria, Town of	11/22/1974	11/22/1974	None	08/05/2010	N/A
Quapaw, Town of	08/13/1976	08/13/1976	None	08/05/2010	09/13/2019
Wyandotte, Town of	06/28/1974	06/28/1974	12/10/1976 12/12/1975	12/17/1987	09/13/2019 08/05/2010 12/19/1997

Community Name	Initial Identification Date	Initial FHBM Effective Date	FHBM Revision Date(s)	Initial FIRM Effective Date	FIRM Revision Date(s)
Wyandotte Nation[2]	5/20/1977	5/20/1977	N/A	12/02/1988	09/13/2019 08/05/2010 12/19/1997

[1]No Special Flood Hazard Areas Identified

[2]Dates for this community were taken from Ottawa County, Unincorporated Areas

SECTION 7.0 – CONTRACTED STUDIES AND COMMUNITY COORDINATION

7.1 Contracted Studies

Table 28 provides a summary of the contracted studies, by flooding source, that are included in this FIS Report

Table 28: Summary of Contracted Studies Included in this FIS Report

Flooding Source	FIS Report Dated	Contractor	Number	Work Completed Date	Affected Communities
Bee Creek and Zone A Tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County, Unincorporated Areas
Belmont Run	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Miami, City of; Ottawa County, Unincorporated Areas; North Miami, Town of
Coal Creek and Zone A tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County, Unincorporated Areas
Council Hollow Creek and Zone A tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County, Unincorporated Areas
Cow Creek	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County, Unincorporated Areas
Elm Creek and Zone A tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County, Unincorporated Areas
Fairgrounds Branch	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Miami, City of; Ottawa County, Unincorporated Areas

Table 28: Summary of Contracted Studies Included in this FIS Report, continued

Flooding Source	FIS Report Dated	Contractor	Number	Work Completed Date	Affected Communities
Garrett Creek and Zone A tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Miami, City of; Ottawa County, Unincorporated Areas
Grand Lake O The Cherokees	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County, Unincorporated Areas; Wyandotte, Town of
Grand Lake Tributary 2 and Zone A tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County, Unincorporated Areas
Hickory Creek and Zone A tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County, Unincorporated Areas
Horse Creek and Zone A tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Afton, Town of; Ottawa County, Unincorporated Areas
Horse Creek	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Afton, Town of; Ottawa County, Unincorporated Areas
Horse Creek Tributary 3	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Afton, Town of; Ottawa County, Unincorporated Areas
Horse Creek Tributary 3-1	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Afton, Town of; Ottawa County, Unincorporated Areas
Horse Creek Tributary 3-2	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Afton, Town of; Ottawa County, Unincorporated Areas
Horse Creek Tributary 3-2-1	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Afton, Town of; Ottawa County, Unincorporated Areas
Hudson Creek and Zone A Tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Fairland, Town of; Ottawa County, Unincorporated Areas
Little Elm Creek and Zone A tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Miami, City of; Ottawa County, Unincorporated Areas

Table 28: Summary of Contracted Studies Included in this FIS Report, continued

Flooding Source	FIS Report Dated	Contractor	Number	Work Completed Date	Affected Communities
Little Elm Creek	12/19/1997	Coe	EMW-84-1506	September 1986	Miami, City of; Ottawa County, Unincorporated Areas
Little Horse Creek and Zone A tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Fairland, Town of; Ottawa County, Unincorporated Areas
Lost Creek and Zone A tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County, Unincorporated Areas; Wyandotte Nation; Wyandotte, Town of
Lost Creek (at Wyandotte)	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County, Unincorporated Areas; Wyandotte, Town of; Wyandotte Nation
Lost Creek (Upper Reach)	12/19/1997	Coe	EMW-84-E-1506	September 1986	Ottawa County, Unincorporated Areas; Wyandotte, Town of; Wyandotte Nation
Lytle Creek and Zone A tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County, Unincorporated Areas;
Mud Creek	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County, Unincorporated Areas
Neosho River	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Miami, City of; Ottawa County, Unincorporated Areas
Neosho River	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County, Unincorporated Areas
Neosho River and Zone A tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Miami, City of; Ottawa County, Unincorporated Areas
Ogeechee Creek and Zone A tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Fairland, Town of; Ottawa County, Unincorporated Areas

Table 28: Summary of Contracted Studies Included in this FIS Report, continued

Flooding Source	FIS Report Dated	Contractor	Number	Work Completed Date	Affected Communities
Quail Creek and Zone A tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Miami, City of; Ottawa County, Unincorporated Areas
Quail Creek	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Miami, City of; Ottawa County, Unincorporated Areas
Tar Creek (at Miami)	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Commerce, City of; Miami, City of; Ottawa County, Unincorporated Areas;
Unnamed Creek 1 and Zone A tributaries	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County, Unincorporated Areas
Unnamed Creek 2	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County, Unincorporated Areas
Warren Branch	12/19/1997	Coe	EMW-84-1506	September 1986	Ottawa County, Unincorporated Areas; Peoria, Town of
Windy Creek	09/13/2019	RAMPP	HSFE06-11-J-0001	September 2016	Ottawa County Unincorporated Areas
Wyandotte Ditch	12/19/1997	Coe	EMW-84-1506	September 1986	Ottawa County, Unincorporated Areas; Wyandotte, Town of

7.2 Community Meetings

The dates of the community meetings held for this Flood Risk Project and previous Flood Risk Projects are shown in Table 29. These meetings may have previously been referred to by a variety of names (Community Coordination Officer (CCO), Scoping, Discovery, etc.), but all meetings represent opportunities for FEMA, community officials, study contractors, and other invited guests to discuss the planning for and results of the project.

Table 29: Community Meetings

Community	FIS Report Dated	Date of Meeting	Meeting Type	Attended By
Afton, Town of	09/13/2019	9/14/2011	Discovery	The Town of Afton, FEMA and RAMPP
		1/20/2016	Flood Risk Review	The Town of Afton, FEMA and RAMPP
		08/24/2016	Flood Risk Review	The Town of Afton, FEMA and RAMPP
		11/30/2017	Final CCO	Representatives of Ottawa County, Wyandotte Nation and the City of Miami
Commerce, City of	09/13/2019	9/14/2011	Flood Risk Review	The City of Commerce, FEMA and RAMPP
		1/20/2016	Flood Risk Review	The City of Commerce, FEMA and RAMPP
		08/24/2016	Flood Risk Review	The City of Commerce, FEMA and RAMPP
		11/30/2017	Final CCO	Representatives of Ottawa County, Wyandotte Nation and the City of Miami

Table 29: Community Meetings, continued

Community	FIS Report Dated	Date of Meeting	Meeting Type	Attended By
Fairland, Town of	09/13/2019	9/14/2011	Flood Risk Review	The City of Fairland, FEMA and RAMPP
		1/20/2016	Flood Risk Review	The City of Fairland, FEMA and RAMPP
		08/24/2016	Flood Risk Review	The City of Fairland, FEMA and RAMPP
		11/30/2017	Final CCO	Representatives of Ottawa County, Wyandotte Nation and the City of Miami
Miami, City of	09/13/2019	9/14/2011	Flood Risk Review	The City of Miami, FEMA and RAMPP
		1/20/2016	Flood Risk Review	The City of Miami, FEMA and RAMPP
		08/24/2016	Flood Risk Review	The City of Miami, FEMA and RAMPP
		11/30/2017	Final CCO	Representatives of Ottawa County, Wyandotte Nation and the City of Miami
North Miami, Town of	09/13/2019	9/14/2011	Flood Risk Review	The Town of North Miami, FEMA and RAMPP
		1/20/2016	Flood Risk Review	The Town of North Miami, FEMA and RAMPP

Table 29: Community Meetings, continued

Community	FIS Report Dated	Date of Meeting	Meeting Type	Attended By
North Miami, Town of (continued)	9/13/2019	08/24/2016	Flood Risk Review	The Town of North Miami, FEMA and RAMPP
		11/30/2017	Final CCO	Representatives of Ottawa County, Wyandotte Nation and the City of Miami
Ottawa County, Unincorporated Areas	09/13/2019	9/14/2011	Flood Risk Review	Ottawa County, FEMA and RAMPP
		1/20/2016	Flood Risk Review	Ottawa County, FEMA and RAMPP
		08/24/2016	Flood Risk Review	Ottawa County, FEMA and RAMPP
		11/30/2017	Final CCO	Representatives of Ottawa County, Wyandotte Nation and the City of Miami
Peoria, Town of	08/05/2010	04/10/2007	Initial CCO	Cities of Commerce and Miami; the Towns of Afton, Fairland, and Wyandotte; Ottawa County, The Oklahoma Water Resources Board; FEMA; and Watershed VI Alliance
		12/08/2008	Final CCO	Cities of Commerce, Miami, and Wyandotte, the Seneca Tribe, the Eastern Shawnee tribe, FEMA and Watershed VI Alliance
Quapaw, Town of	09/13/2019	9/14/2011	Flood Risk Review	The Town of Quapaw, FEMA and RAMPP
		1/20/2016	Flood Risk Review	The Town of Quapaw, FEMA and RAMPP
		08/24/2016	Flood Risk Review	The Town of Quapaw, FEMA and RAMPP
		11/30/2017	Final CCO	Representatives of Ottawa County, Wyandotte Nation and the City of Miami

Table 29: Community Meetings, continued

Community	FIS Report Dated	Date of Meeting	Meeting Type	Attended By
Wyandotte, Town of	09/13/2019	9/14/2011	Flood Risk Review	The Town of Wyandotte, FEMA and RAMPP
		1/20/2016	Flood Risk Review	The Town of Wyandotte, FEMA and RAMPP
		08/24/2016	Flood Risk Review	The Town of Wyandotte, FEMA and RAMPP
		11/30/2017	Final CCO	Representatives of Ottawa County, Wyandotte Nation and the City of Miami
Wyandotte Nation	09/13/2019	9/14/2011	Flood Risk Review	The Town of Wyandotte, FEMA and RAMPP
		1/20/2016	Flood Risk Review	The Town of Wyandotte, FEMA and RAMPP
		08/24/2016	Flood Risk Review	The Town of Wyandotte, FEMA and RAMPP
		11/30/2017	Final CCO	Representatives of Ottawa County, Wyandotte Nation and the City of Miami

SECTION 8.0 – ADDITIONAL INFORMATION

Information concerning the pertinent data used in the preparation of this FIS Report can be obtained by submitting an order with any required payment to the FEMA Engineering Library. For more information on this process, see www.fema.gov.

The additional data that was used for this project includes the FIS Report and FIRM that were previously prepared for Ottawa County (FEMA 2010).

Table 30 is a list of the locations where FIRMs for Ottawa County can be viewed. Please note that the maps at these locations are for reference only and are not for distribution. Also, please note that only the maps for the community listed in the table are available at that particular repository. A user may need to visit another repository to view maps from an adjacent community.

Table 30: Map Repositories

Community	Address	City	State	Zip Code
Afton, Town of	Town Hall 201 Southwest 1st Street	Afton	OK	74331
Commerce, City of	City Hall 618 Commerce Street	Commerce	OK	74339
Fairland, Town of	Town Hall 28 North Main Street	Fairland	OK	74343
Miami, City of	Civic Center 129 5th Avenue Northwest	Miami	OK	74355
North Miami, Town of[1]	Town Hall 309 Pine Street	North Miami	OK	74358
Ottawa County, Unincorporated Areas	Ottawa County Courthouse Annex 123 East Central Boulevard Suite 103	Miami	OK	74354
Peoria, Town of	Courthouse Annex 123 East Central Boulevard Suite 103	Miami	OK	74354
Quapaw, Town of	Town Hall 410 South Main Street	Quapaw	OK	74363
Wyandotte, Town of	Town Hall 212 South Main Street	Wyandotte	OK	74370
Wyandotte Nation	Tribal Administration 64700 East Highway 60	Wyandotte	OK	74370

[1]No Special Flood Hazard Areas identified

The National Flood Hazard Layer (NFHL) dataset is a compilation of effective FIRM Databases and LOMCs. Together they create a GIS data layer for a State or Territory. The NFHL is updated as studies become effective and extracts are made available to the public monthly. NFHL data can be viewed or ordered from the website shown in Table 31.

Table 31 contains useful contact information regarding the FIS Report, the FIRM, and other relevant flood hazard and GIS data. In addition, information about the State NFIP Coordinator and GIS Coordinator is shown in this table. At the request of FEMA, each Governor has designated an agency of State or territorial government to coordinate that State's or territory's NFIP activities. These agencies often assist communities in developing and adopting necessary floodplain management measures. State GIS Coordinators are knowledgeable about the availability and location of State and local GIS data in their state.

Table 31: Additional Information

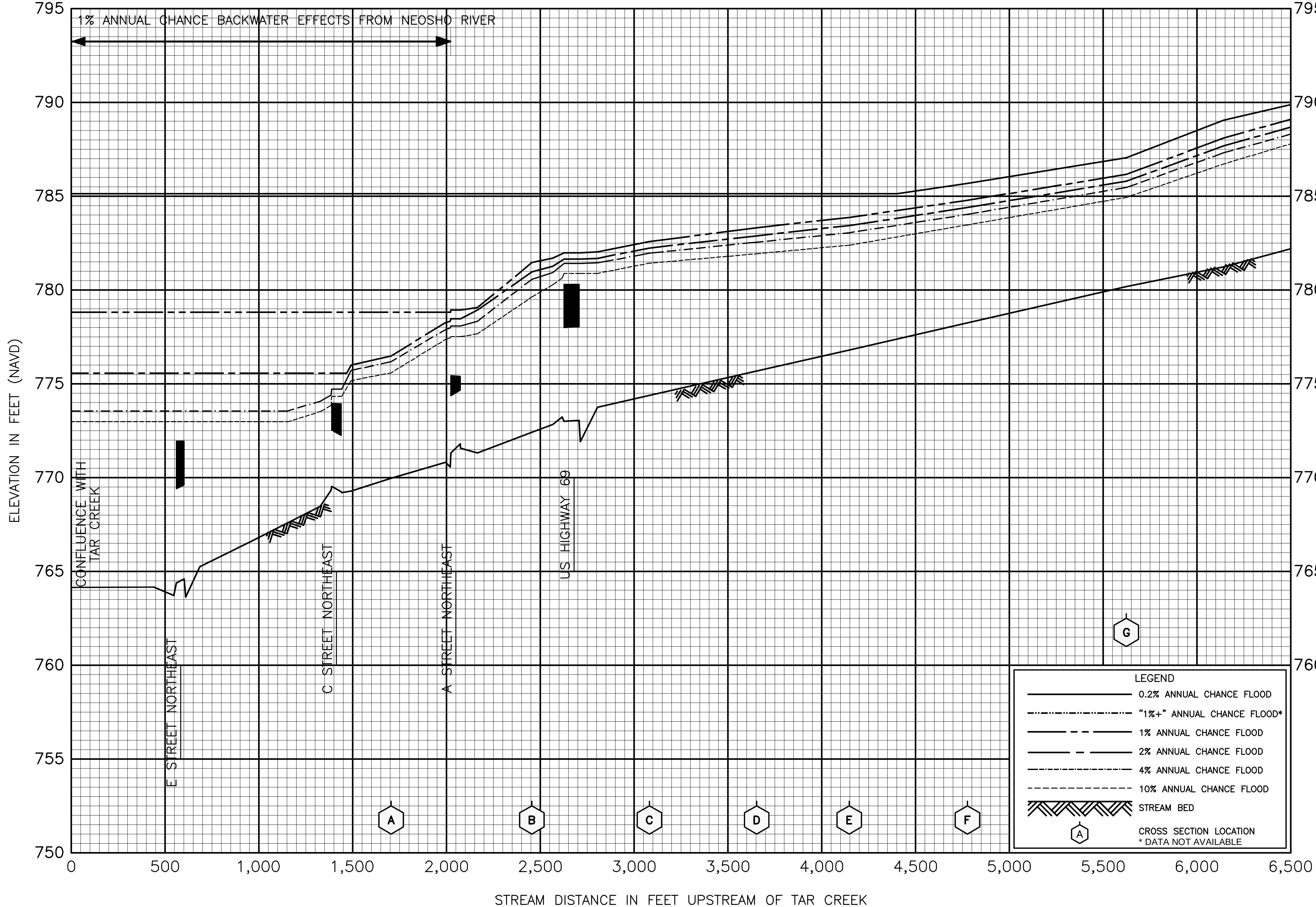
FEMA and the NFIP	
FEMA and FEMA Engineering Library website	www.fema.gov/national-flood-insurance-program-flood-hazard-mapping/engineering-library
NFIP website	www.fema.gov/national-flood-insurance-program
NFHL Dataset	msc.fema.gov
FEMA Region VI	Jennifer Knecht FEMA Region Representative FEMA Region VI 800 North Loop 288 Denton, TX 76209 (940) 898-5553 Jennifer.Knecht@fema.dhs.gov
Other Federal Agencies	
USGS website	www.usgs.gov
Hydraulic Engineering Center website	www.hec.usace.army.mil
State Agencies and Organizations	
State NFIP Coordinator	Yohanes Sugeng, PE, CFM Oklahoma Water Resources Board 3800 North Classen Boulevard Oklahoma City, Oklahoma 73118 (405) 530-8800 yohanes.sugeng@owrb.ok.gov
State GIS Coordinator	Mike Sharp Acting State Geographic Information Coordinator Lincoln Plaza Office Building 4545 N. Lincoln Blvd, Suite 11A Oklahoma City, OK 73105 Phone: (405) 521-4813 mike.sharp@conservaton.ok.gov

SECTION 9.0 – BIBLIOGRAPHY AND REFERENCES

Table 32 includes sources used in the preparation of and cited in this FIS Report as well as additional studies that have been conducted in the study area.

Table 32: Bibliography and References

Citation in this FIS	Publisher/ Issuer	*Publication Title,* "Article," Volume, Number, etc.	Author/Editor	Place of Publication	Publication Date/ Date of Issuance	Link
RAMPP, 2013	Federal Emergency Management Agency	*Light Detection and Ranging data (LiDAR) 0.06 meter RMSEz, 2 cm at 95% confidence*	RAMPP	Denton, TX	September 30, 2013	
USACE, HWM	U.S. Department of the Army, Corps of Engineers	*High Water Marks of the Neosho River*	U.S. Department of the Army, Corps of Engineers	Davis, CA		
USGS, 1961	United States Geologic Survey	*7.5-Minutes Series of Topographic Maps, Scale 1:24,000, Contour Interval 10 Feet: Miami, SE, Oklahoma, 1961; Miami SW, Oklahoma, 1961; Picher, Oklahoma, 1961; Miami NW, Oklahoma-Kansas.*	U.S. Department of the Interior, Geological Survey	N/A	1961	



FLOOD PROFILES

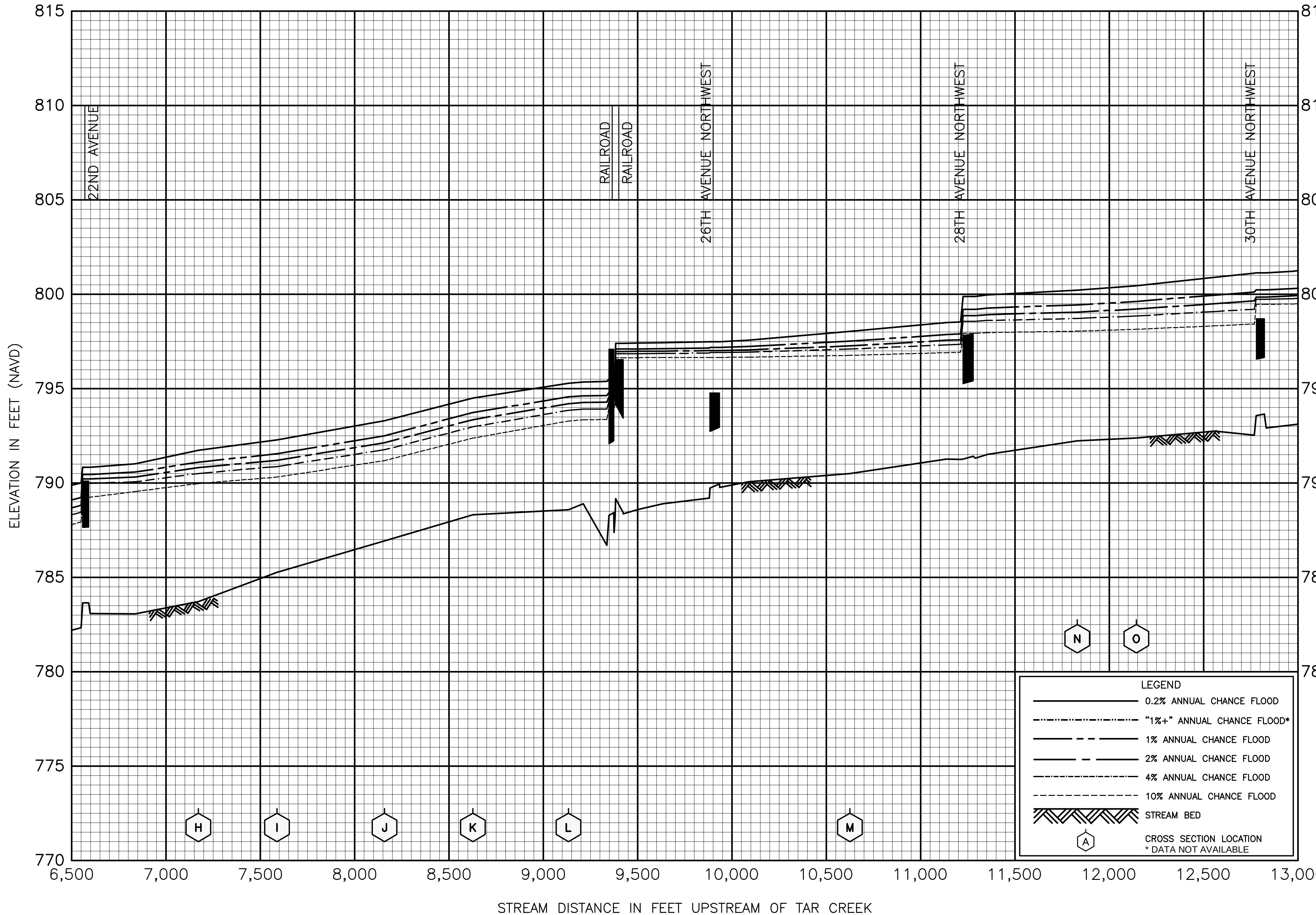
BELMONT RUN

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS

01P



FLOOD PROFILES

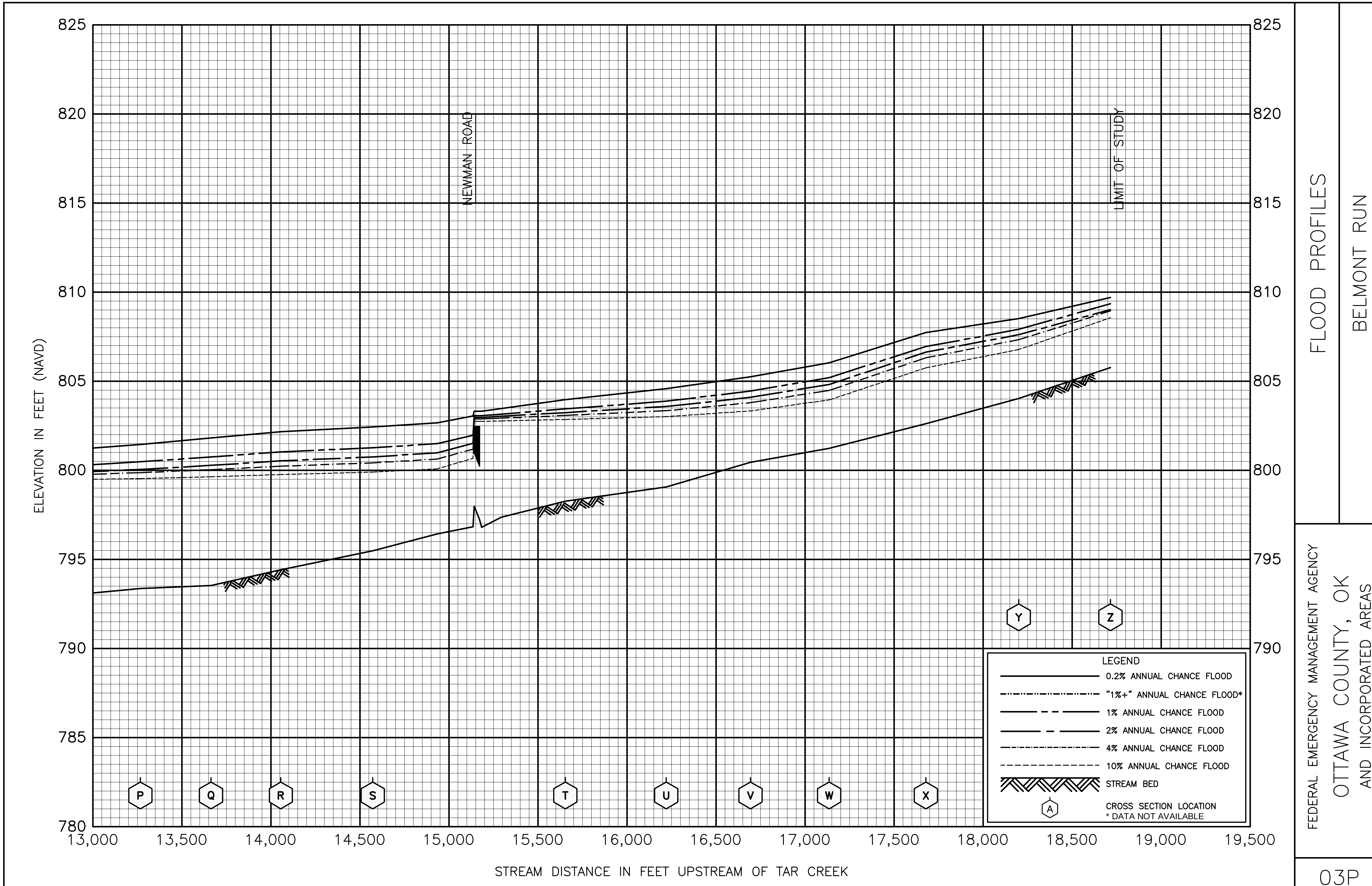
BELMONT RUN

FEDERAL EMERGENCY MANAGEMENT AGENCY

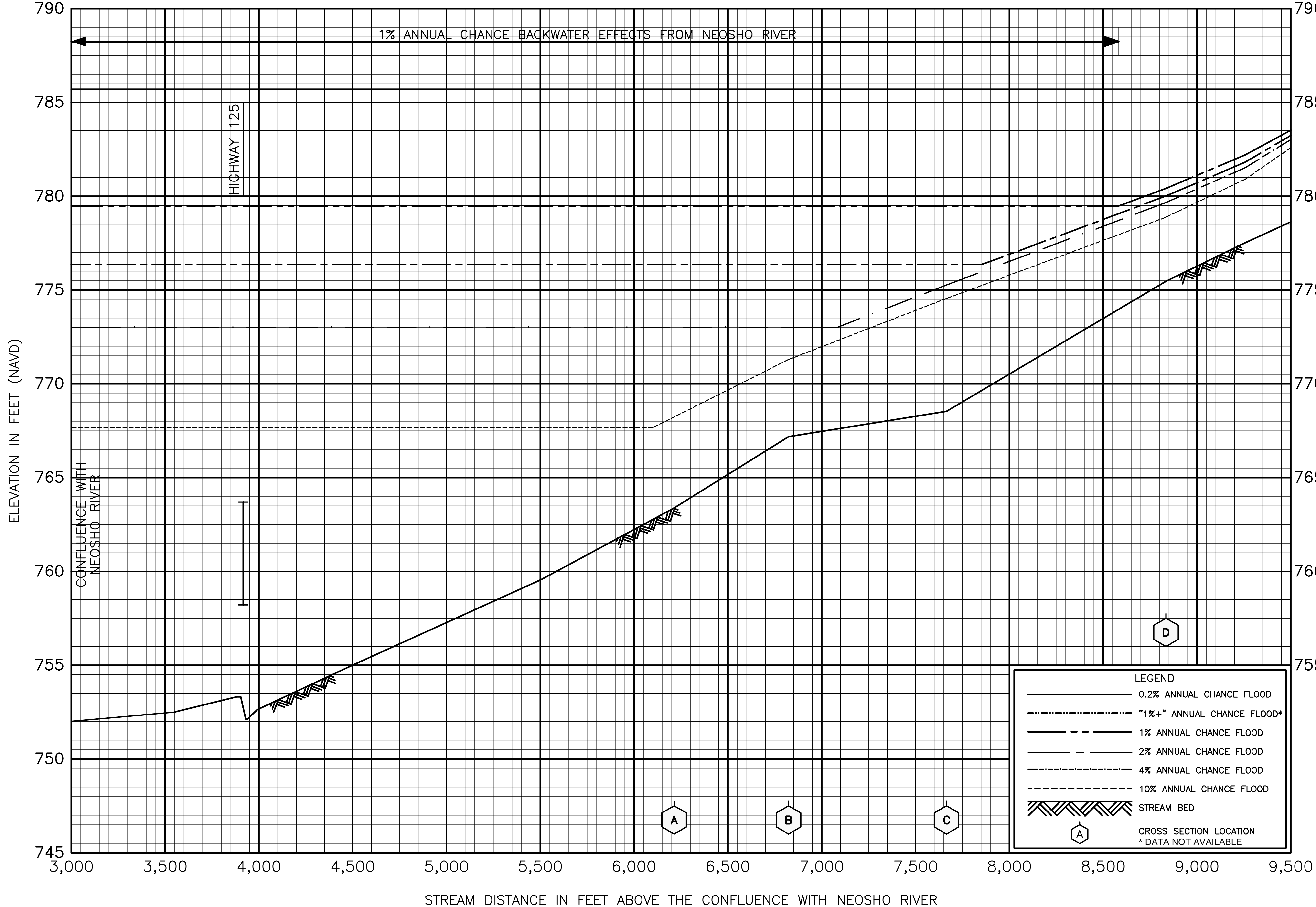
OTTAWA COUNTY, OK

AND INCORPORATED AREAS

02P



FLOOD PROFILES
BELMONT RUN
FEDERAL EMERGENCY MANAGEMENT AGENCY
OTTAWA COUNTY, OK
AND INCORPORATED AREAS
03P
ELEVATION IN FEET (NAVD)
STREAM DISTANCE IN FEET UPSTREAM OF TAR CREEK
NEWMAN ROAD
LIMIT OF STUDY
825
820
815
810
805
800
795
790
785
780
13,000
13,500
14,000
14,500
15,000
15,500
16,000
16,500
17,000
17,500
18,000
18,500
19,000
19,500
P
Q
R
S
T
U
V
W
X
Y
Z
LEGEND
0.2% ANNUAL CHANCE FLOOD
"1%+" ANNUAL CHANCE FLOOD*
1% ANNUAL CHANCE FLOOD
2% ANNUAL CHANCE FLOOD
4% ANNUAL CHANCE FLOOD
10% ANNUAL CHANCE FLOOD
STREAM BED
A
CROSS SECTION LOCATION
* DATA NOT AVAILABLE



FLOOD PROFILES

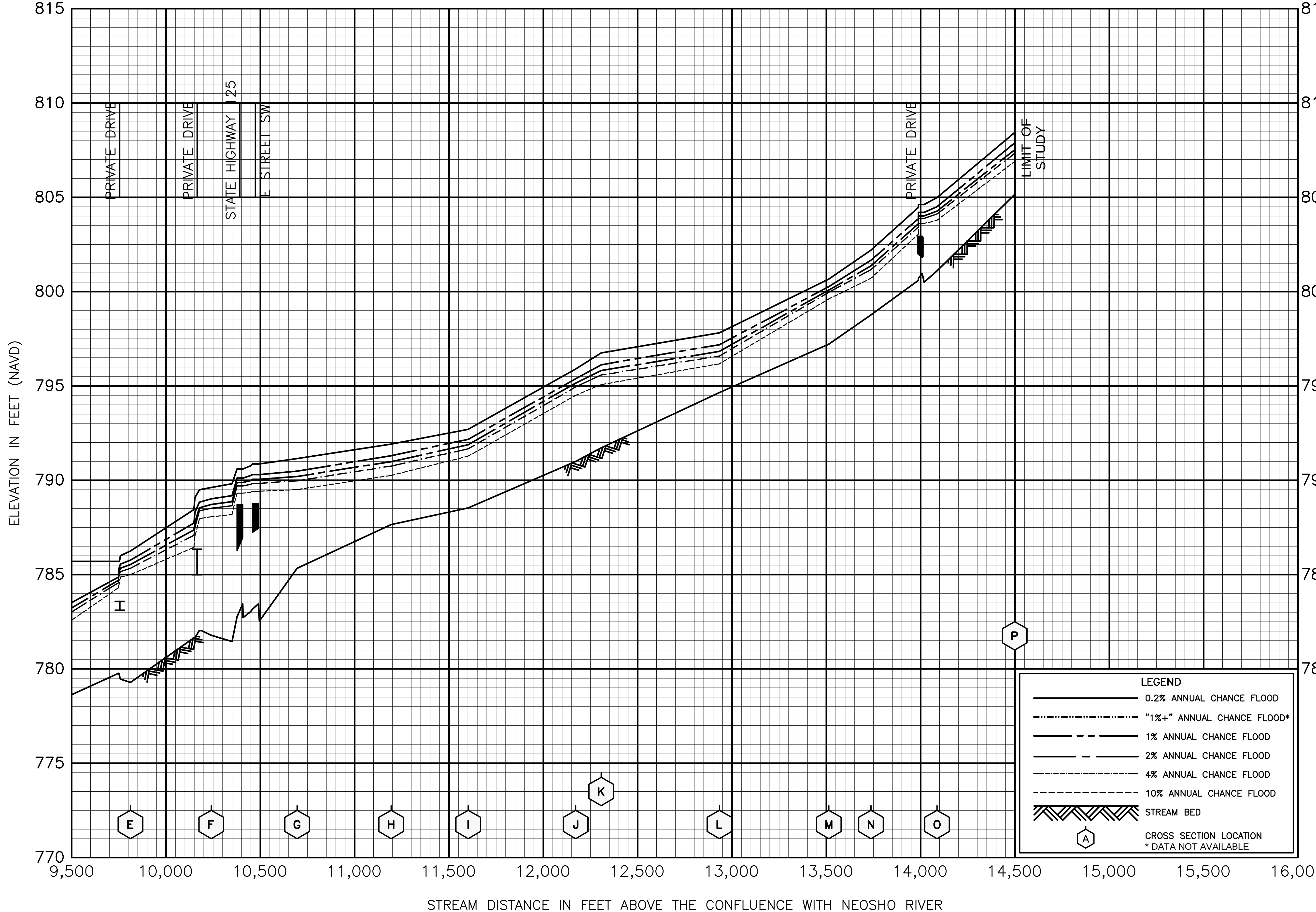
FAIRGROUNDS BRANCH

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS

04P



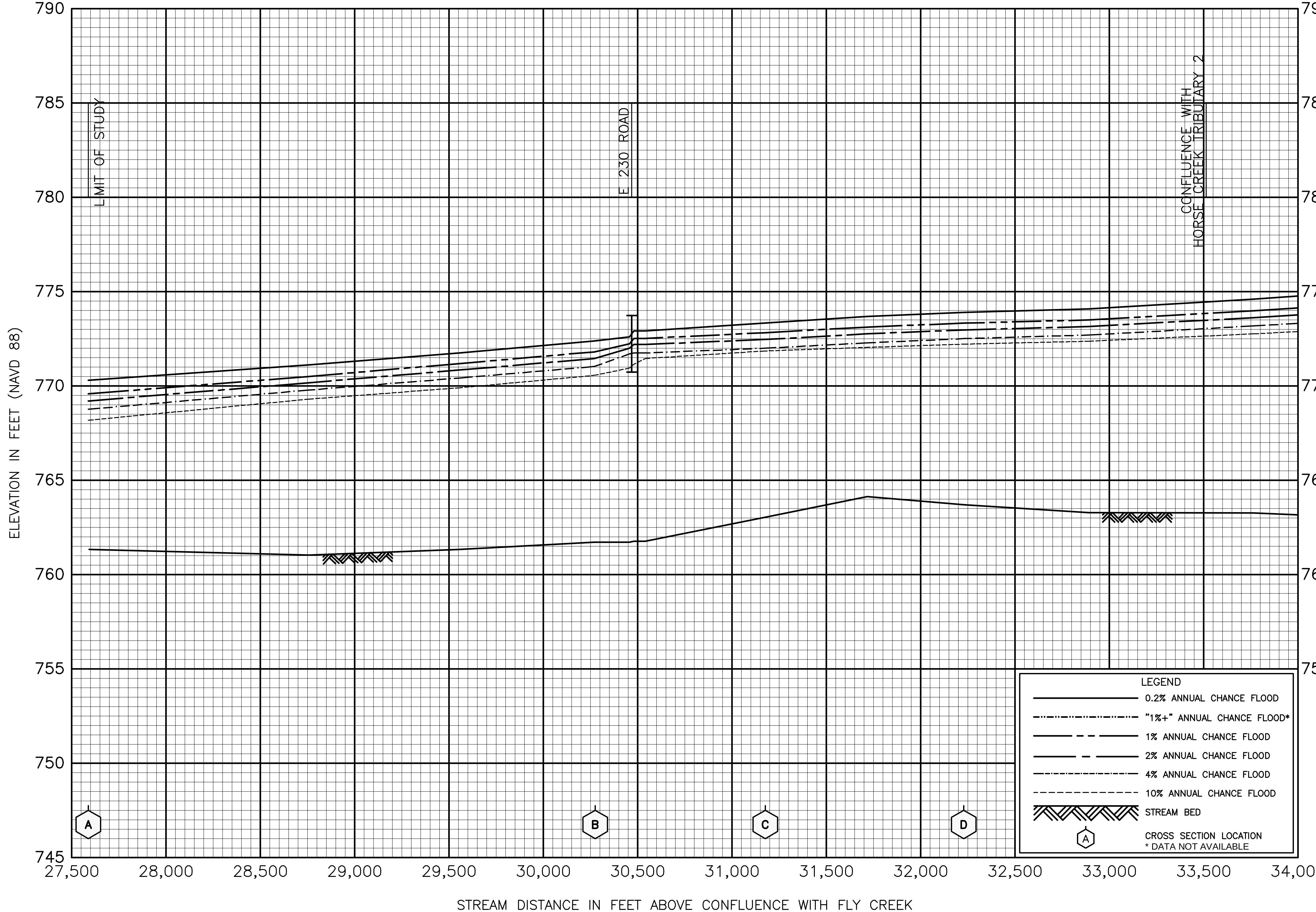
FLOOD PROFILES

FAIRGROUNDS BRANCH

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



FLOOD PROFILES

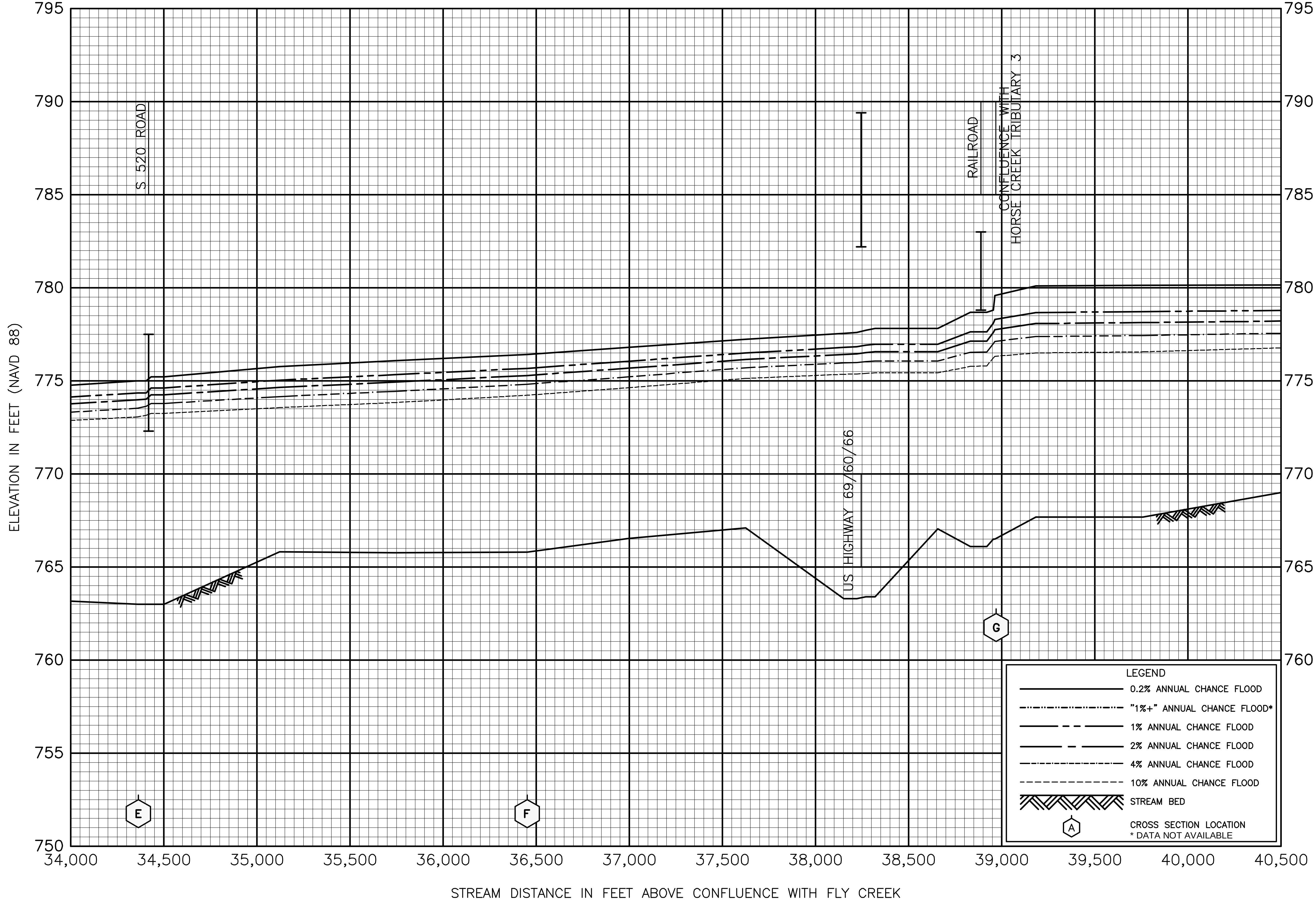
HORSE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS

06P



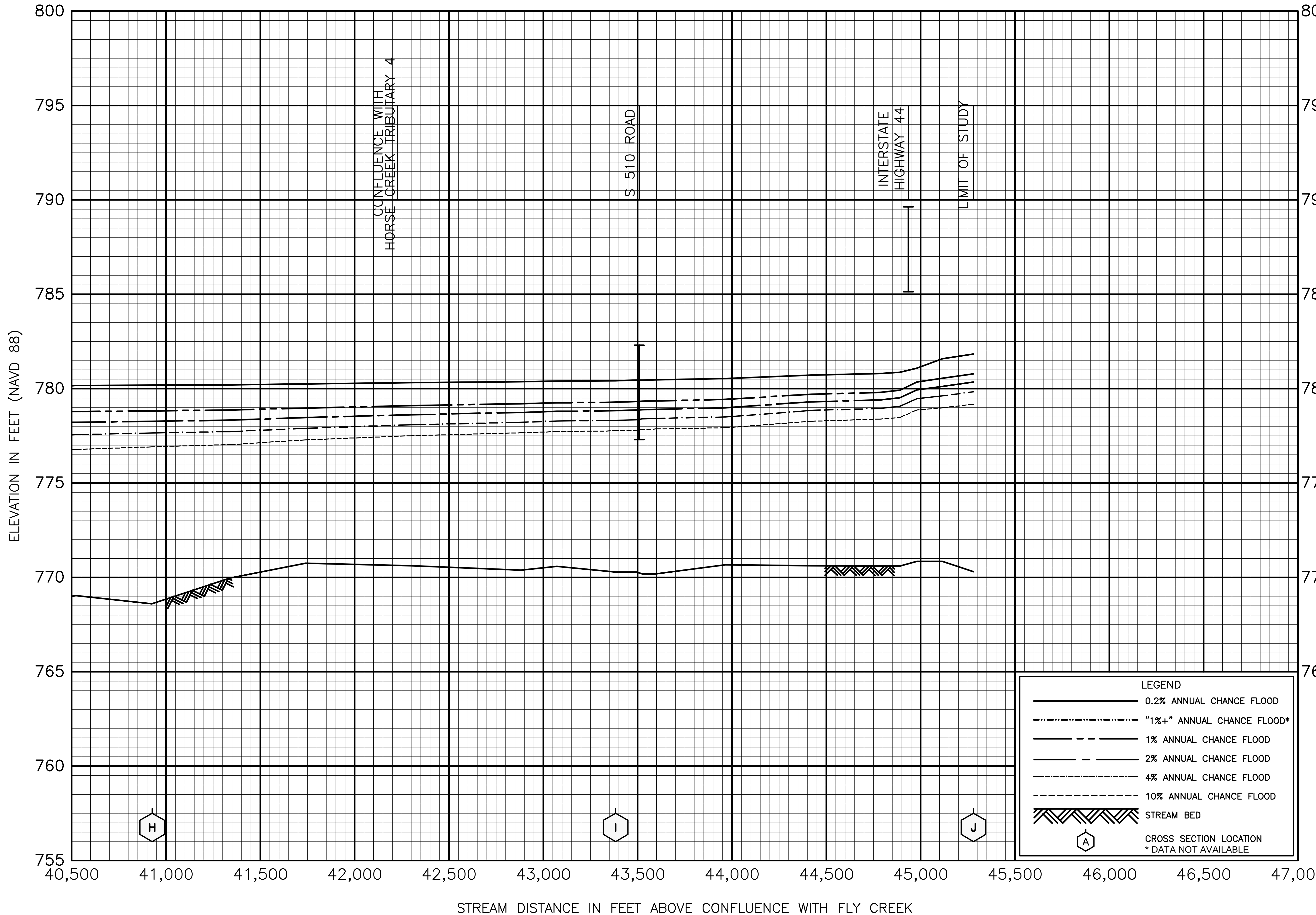
FLOOD PROFILES

HORSE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



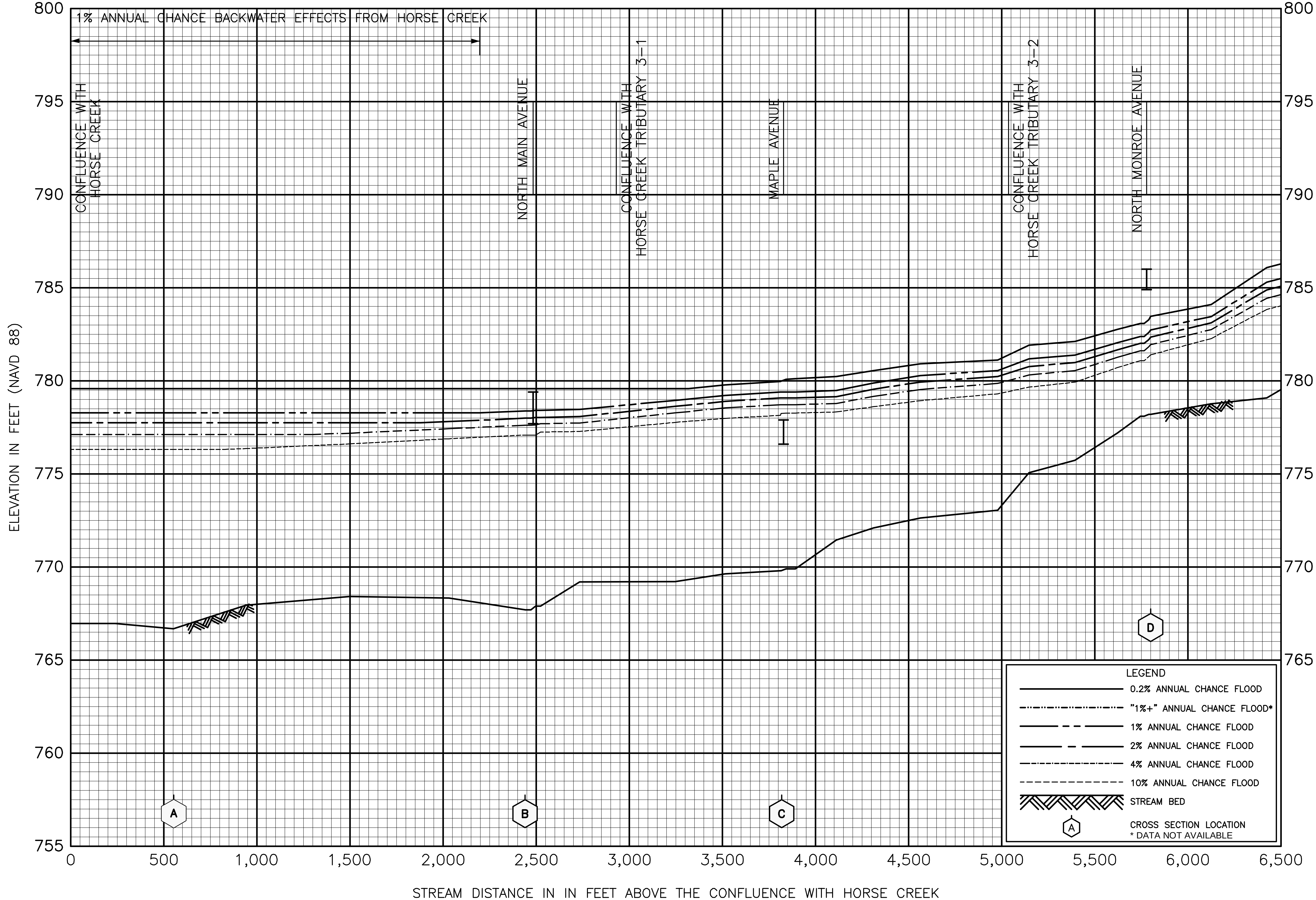
FLOOD PROFILES

HORSE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



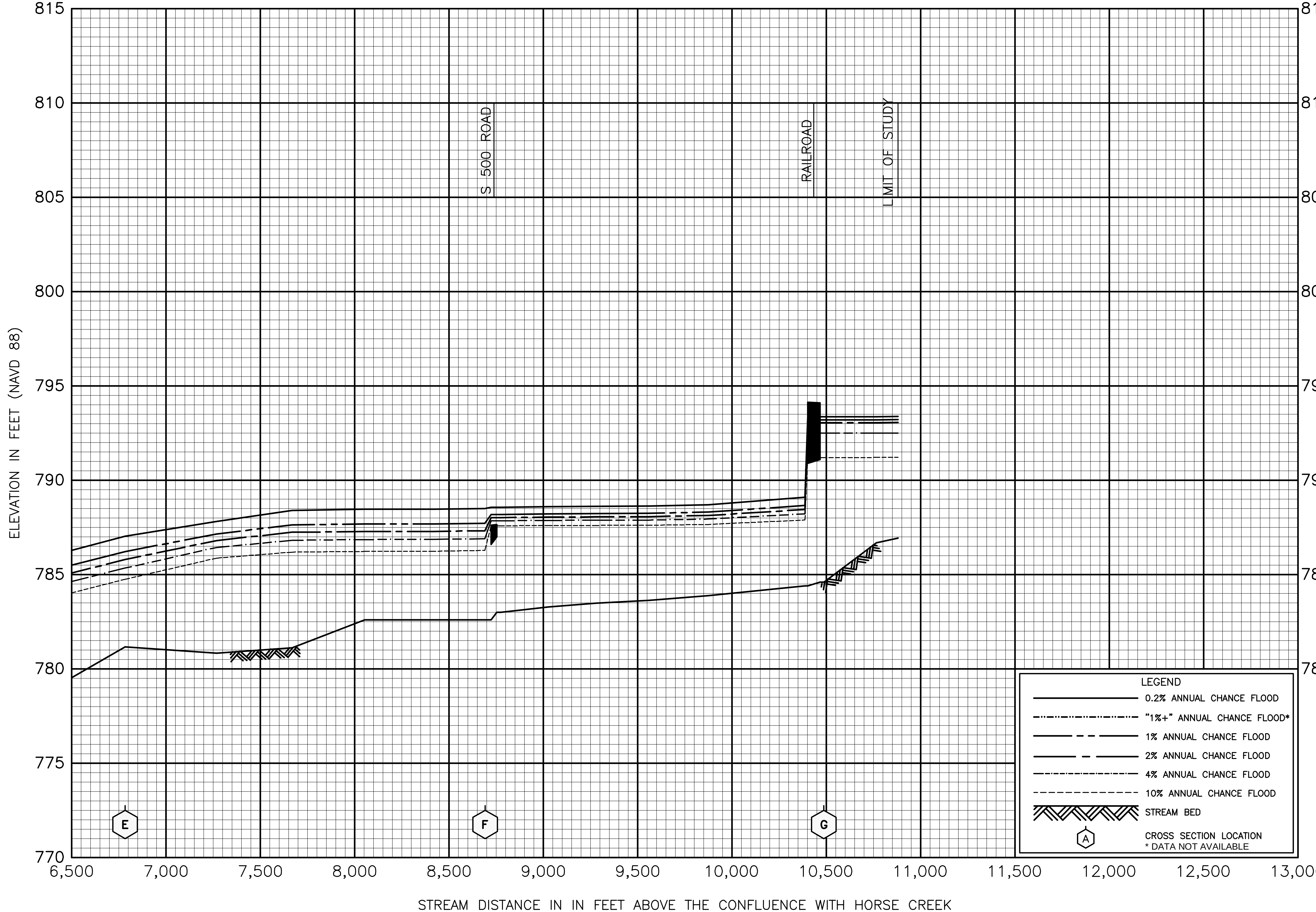
FLOOD PROFILES

HORSE CREEK TRIBUTARY 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



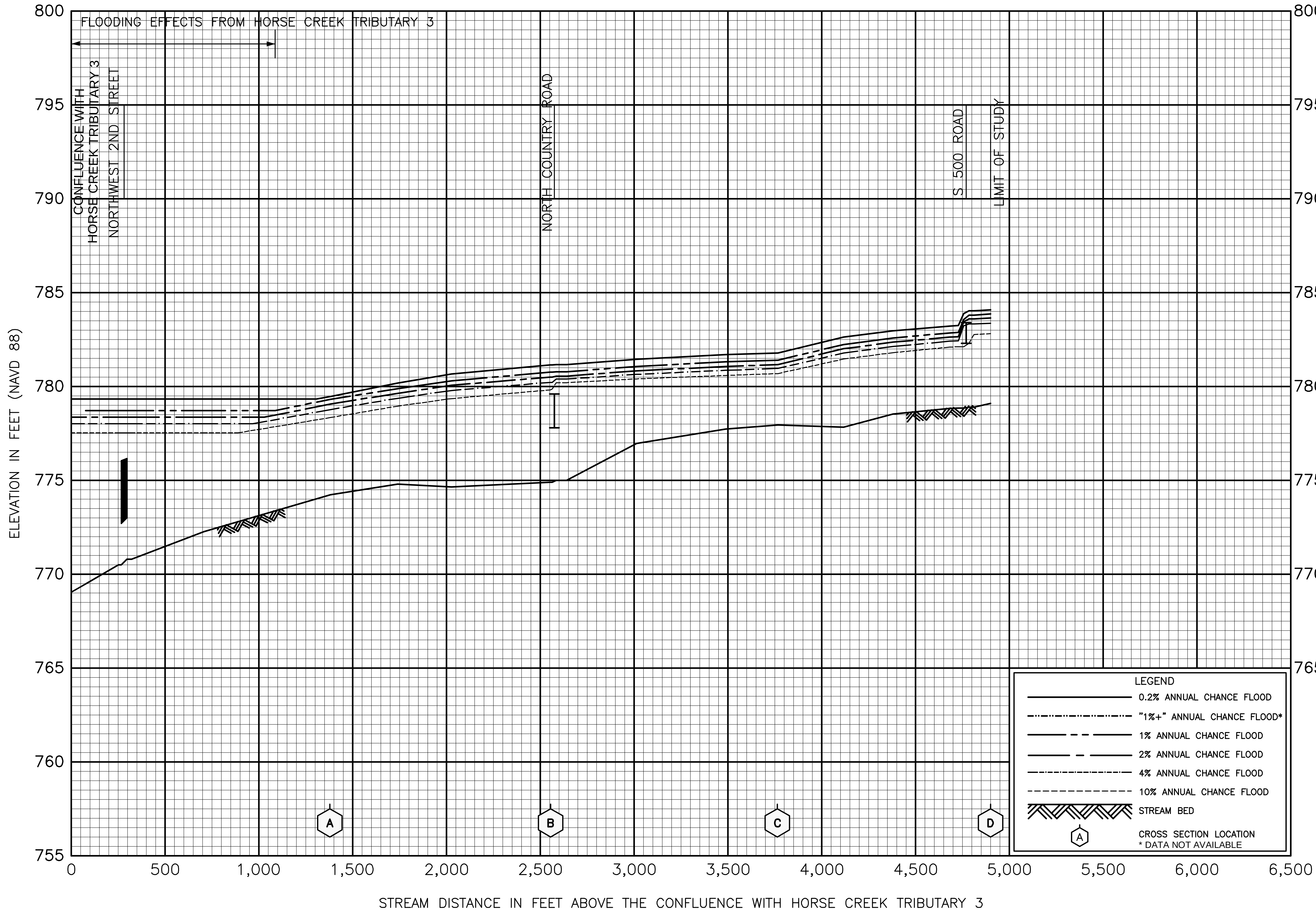
FLOOD PROFILES

HORSE CREEK TRIBUTARY 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



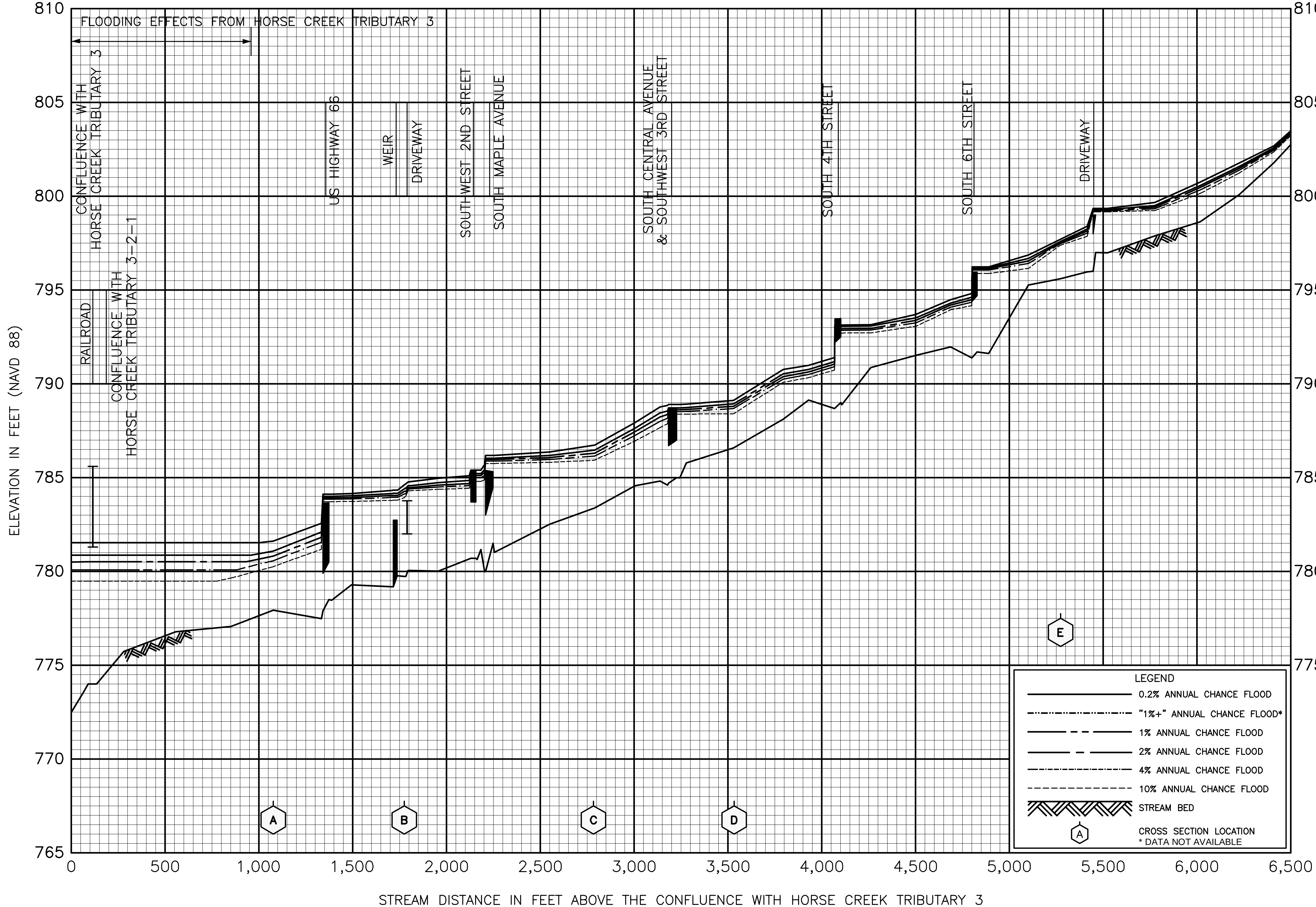
FLOOD PROFILES

HORSE CREEK TRIBUTARY 3–1

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



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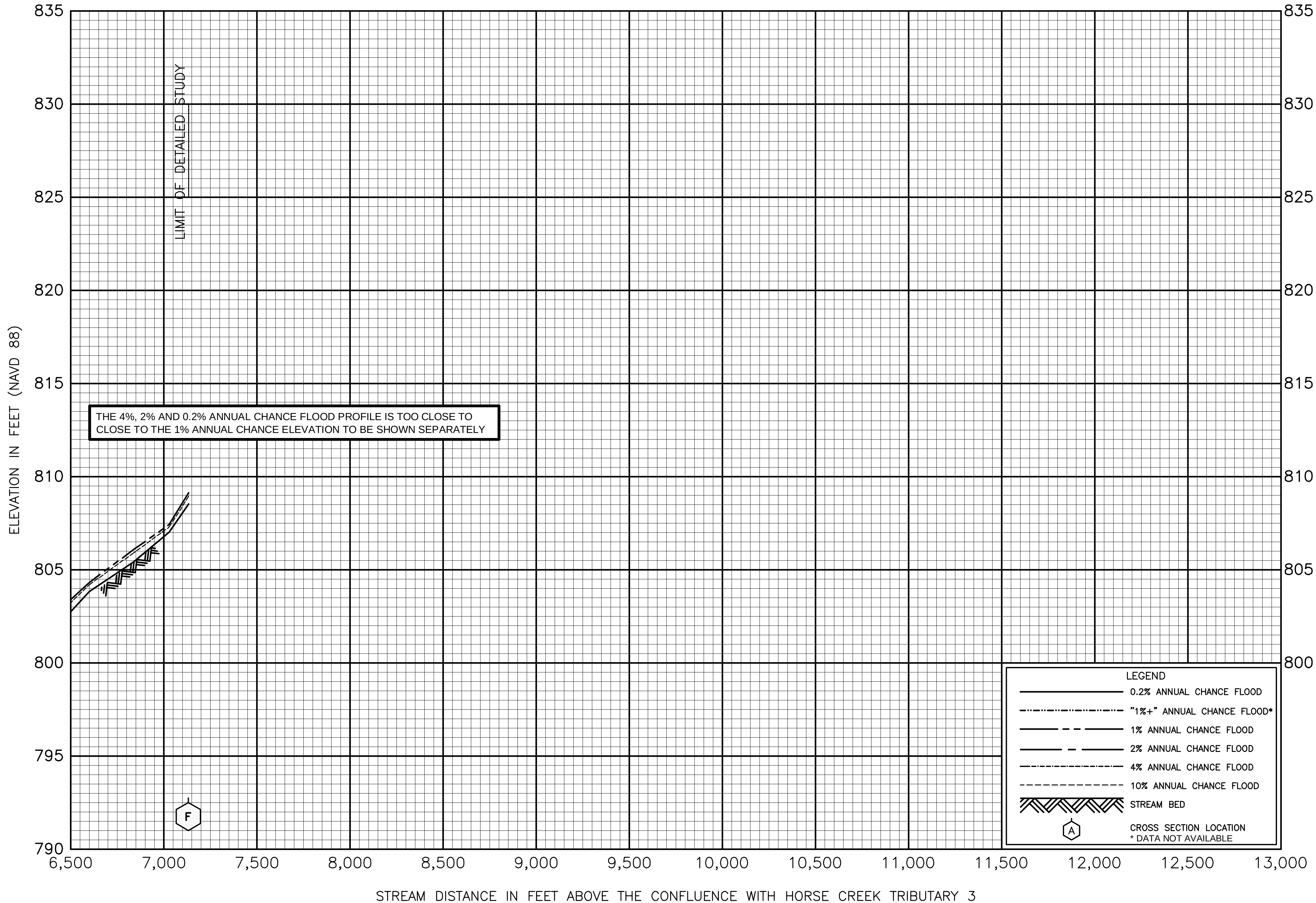
HORSE CREEK TRIBUTARY 3-2

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



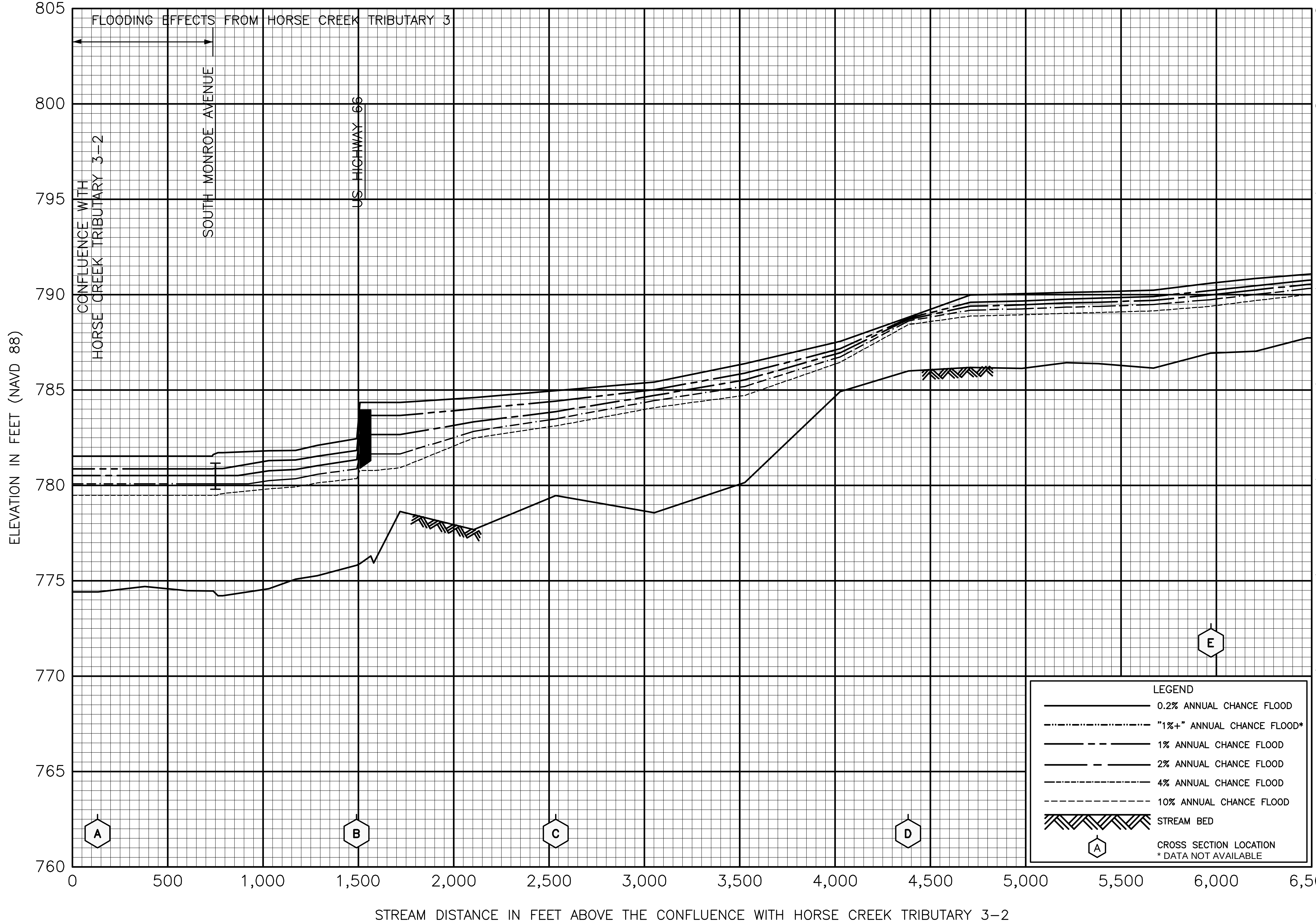
FLOOD PROFILES

HORSE CREEK TRIBUTARY 3-2

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



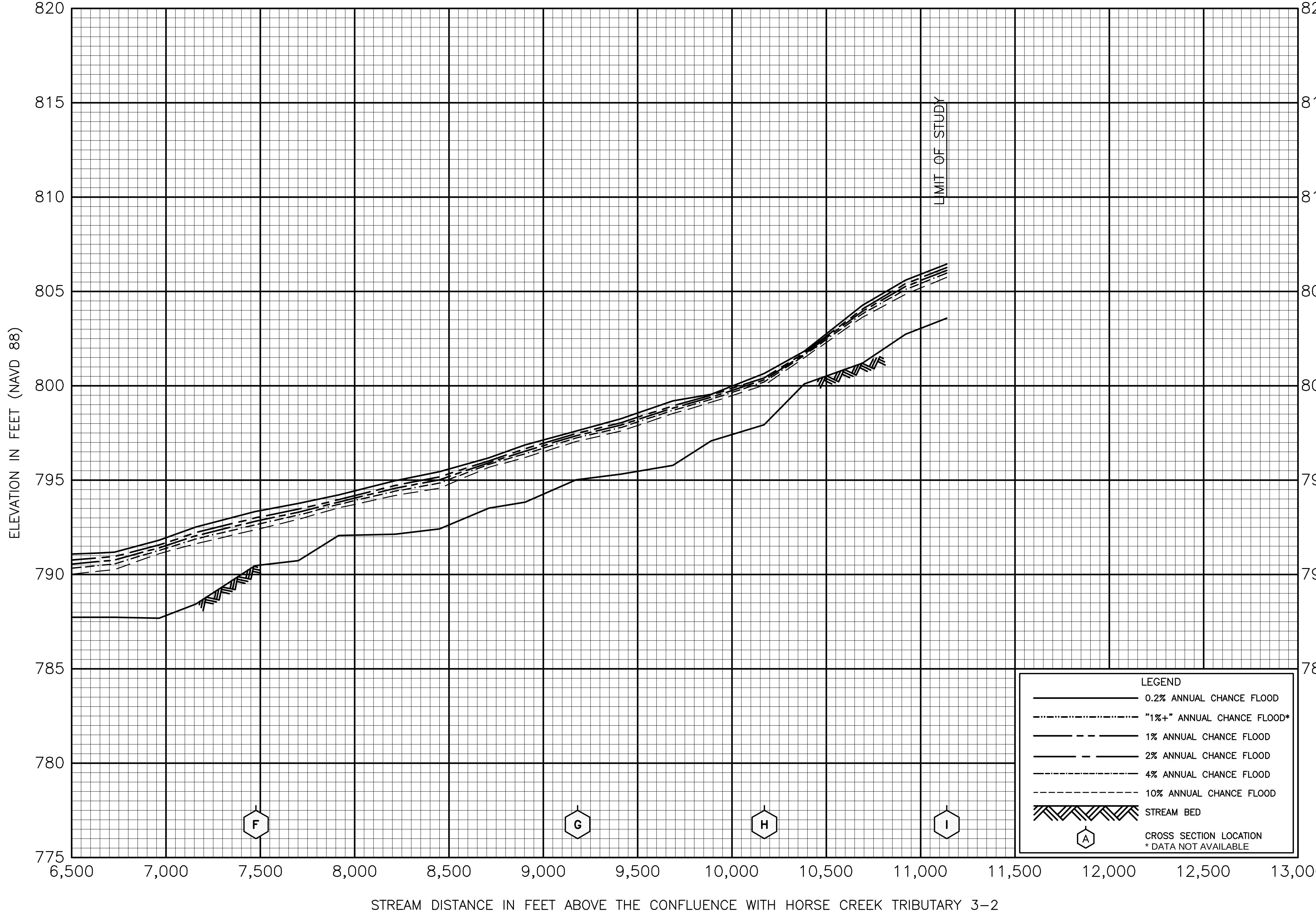
FLOOD PROFILES

HORSE CREEK TRIBUTARY 3-2-1

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



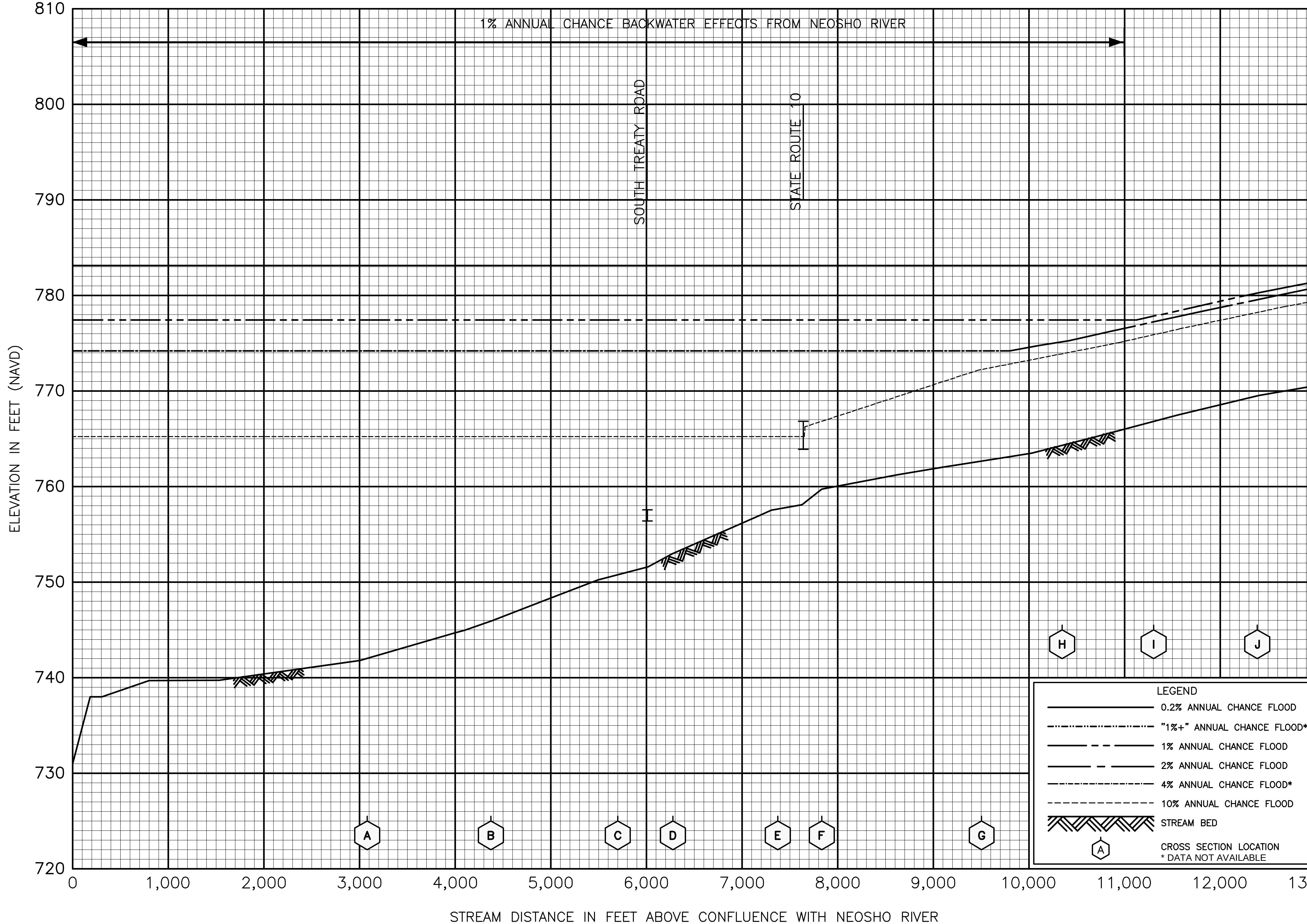
FLOOD PROFILES

HORSE CREEK TRIBUTARY 3–2–1

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



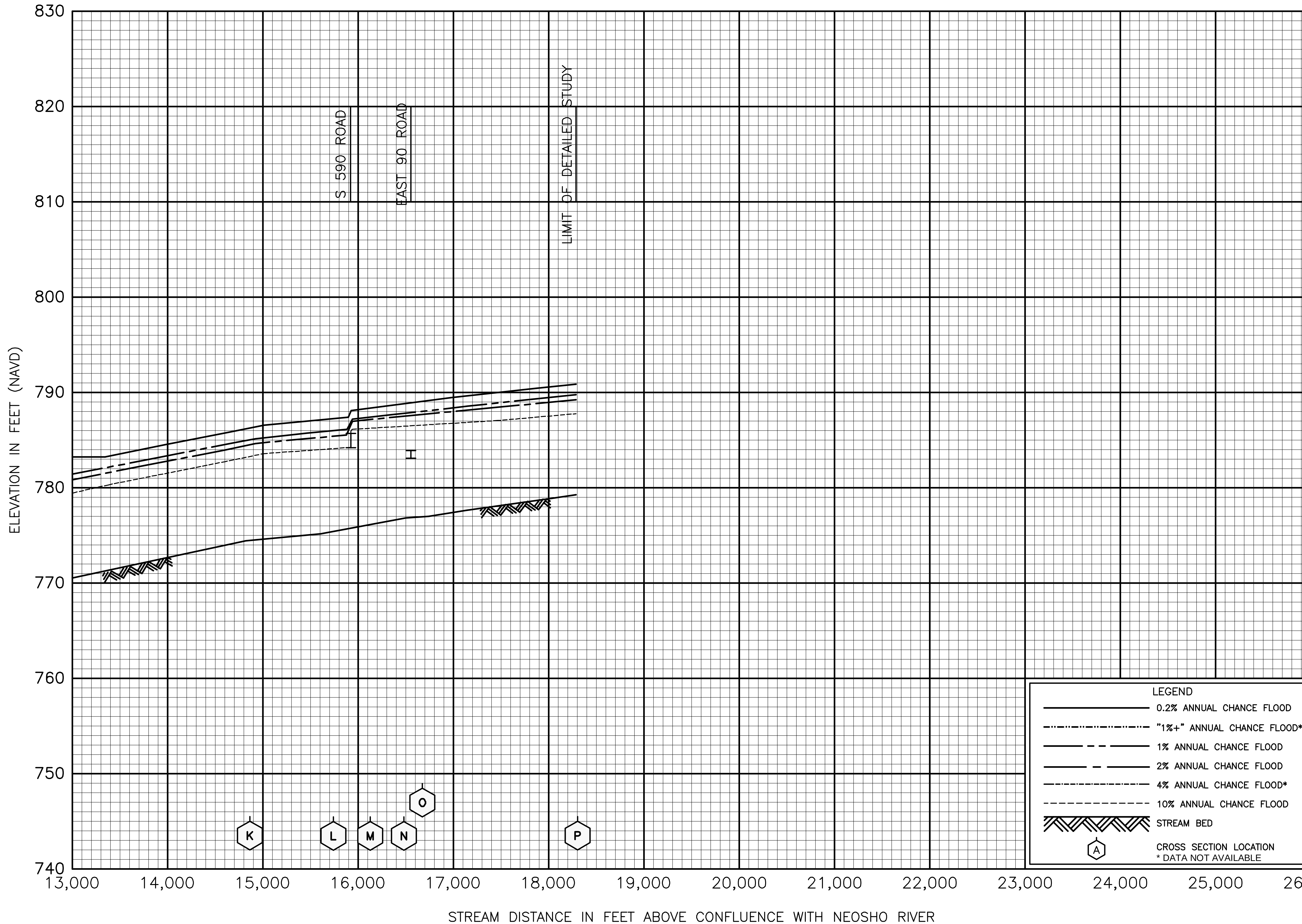
FLOOD PROFILES

LITTLE ELM CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



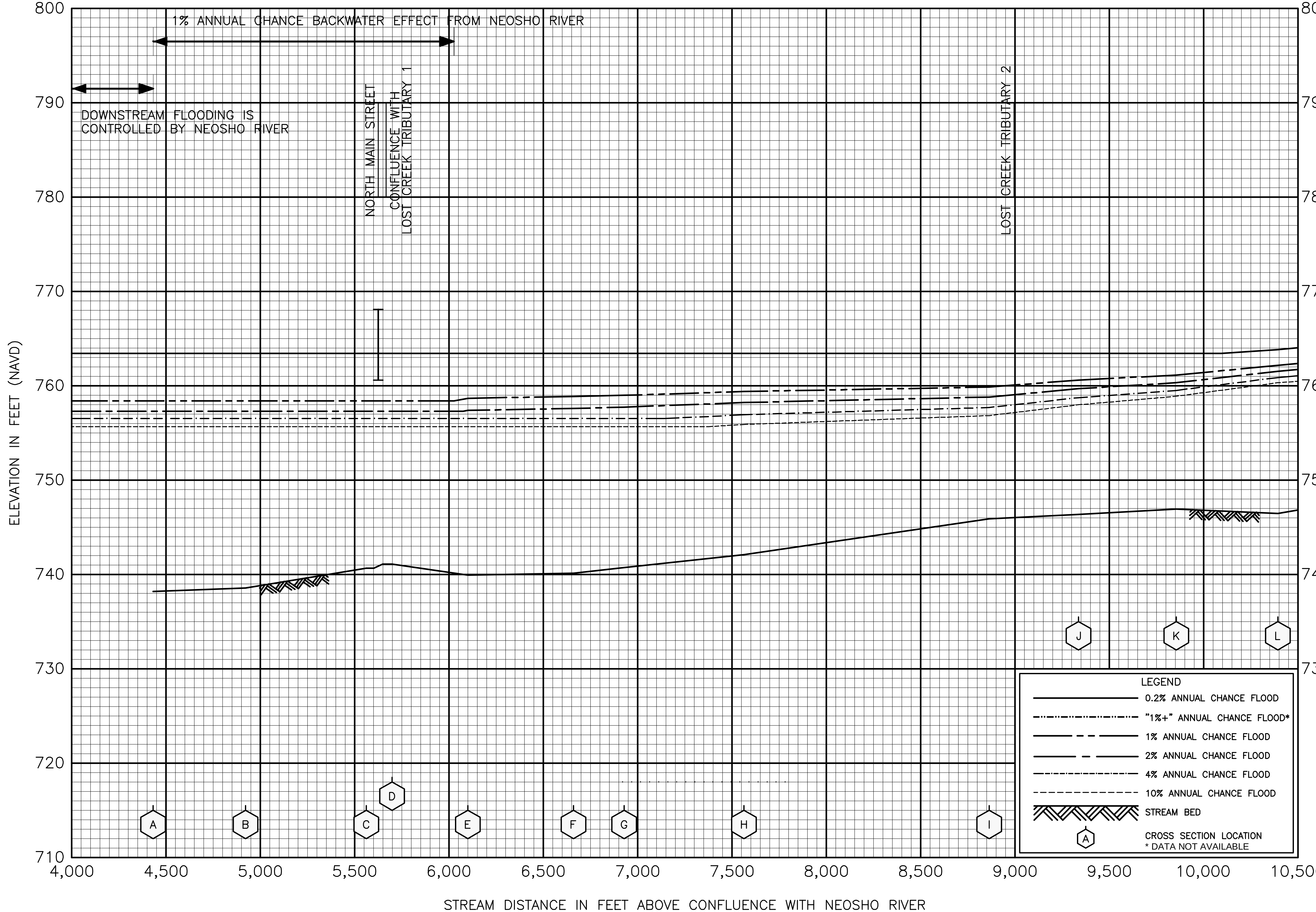
FLOOD PROFILES

LITTLE ELM CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



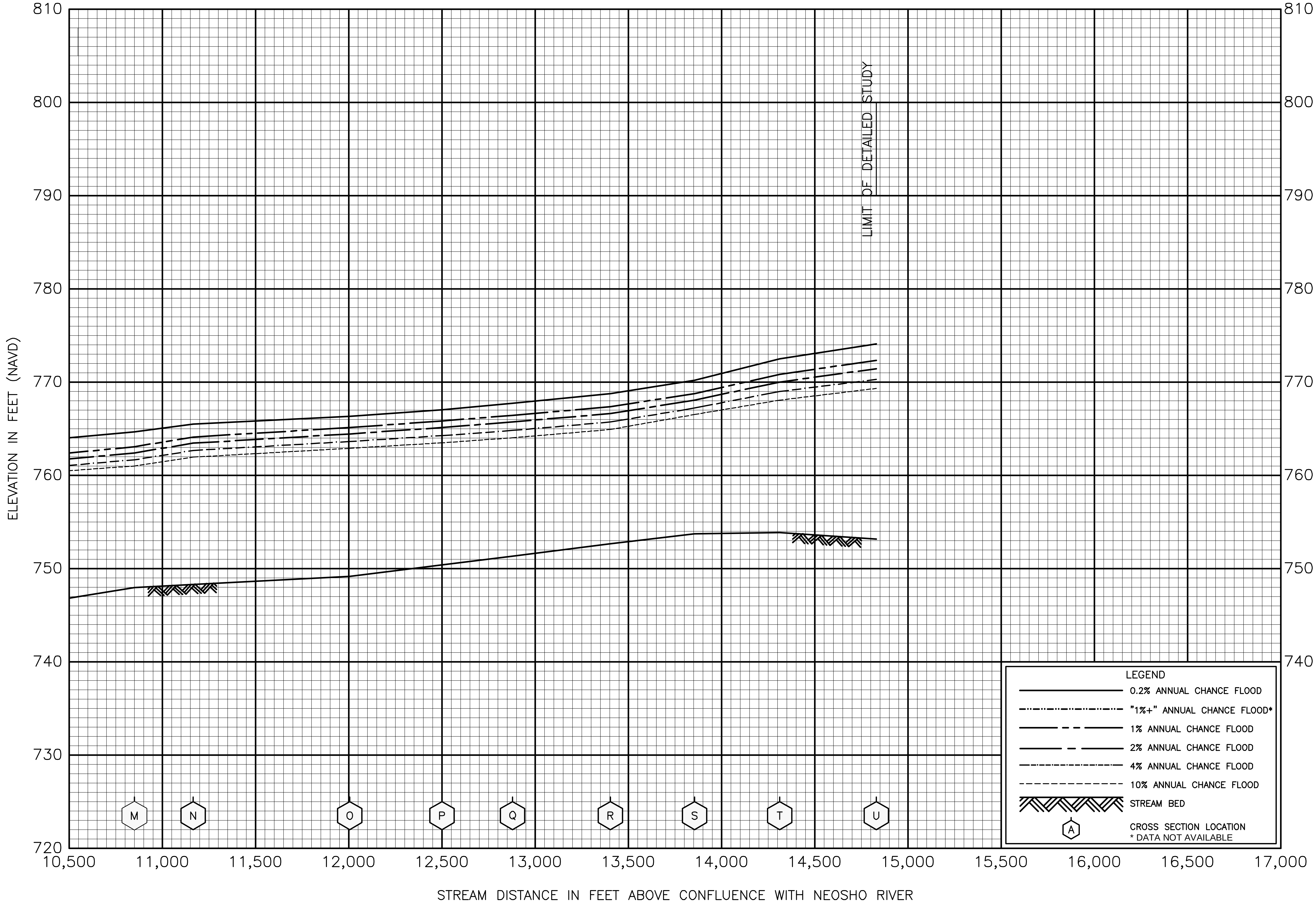
FLOOD PROFILES

LOST CREEK (AT WYANDOTTE)

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS

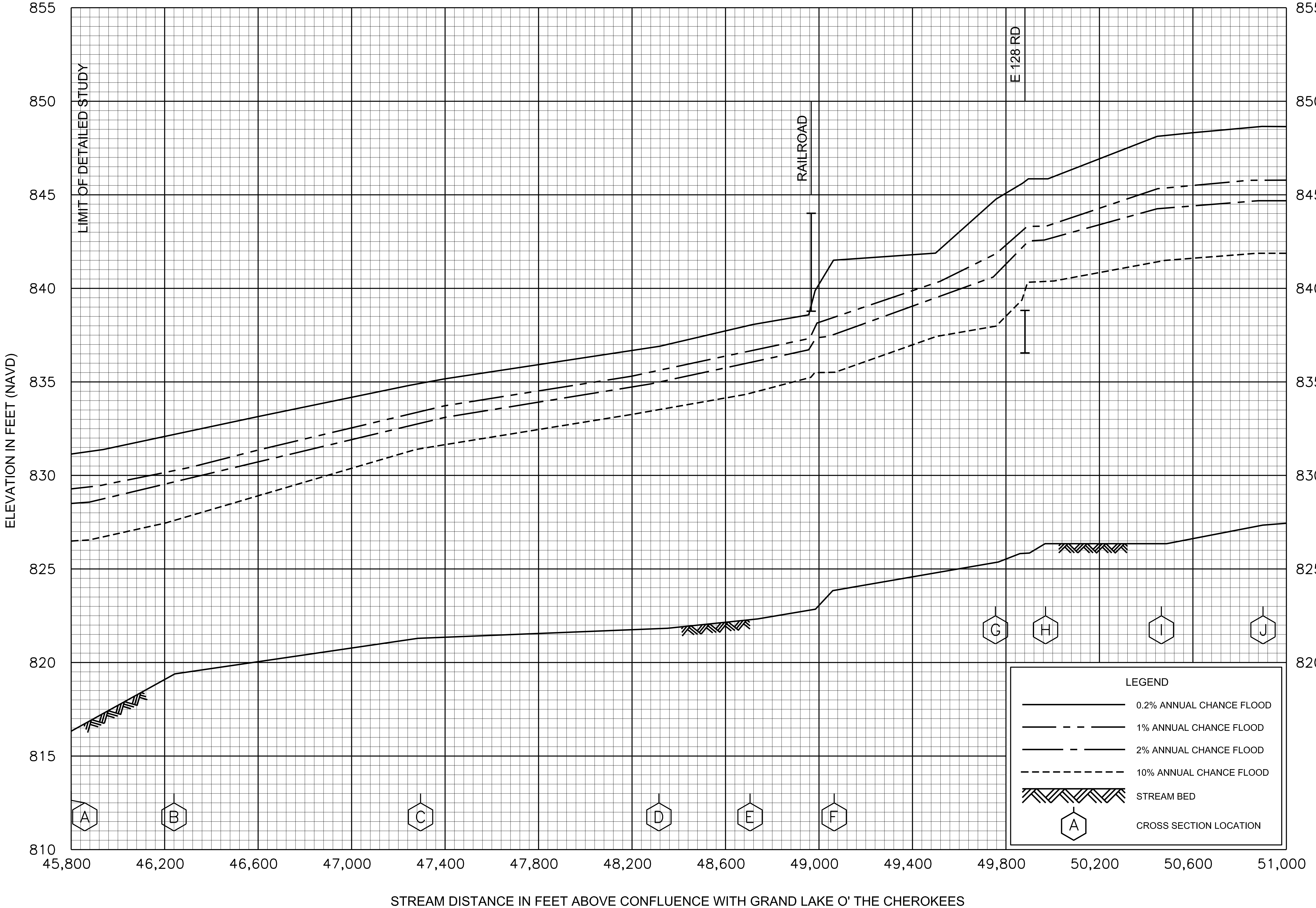


FLOOD PROFILES

LOST CREEK (AT WYANDOTTE)

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS



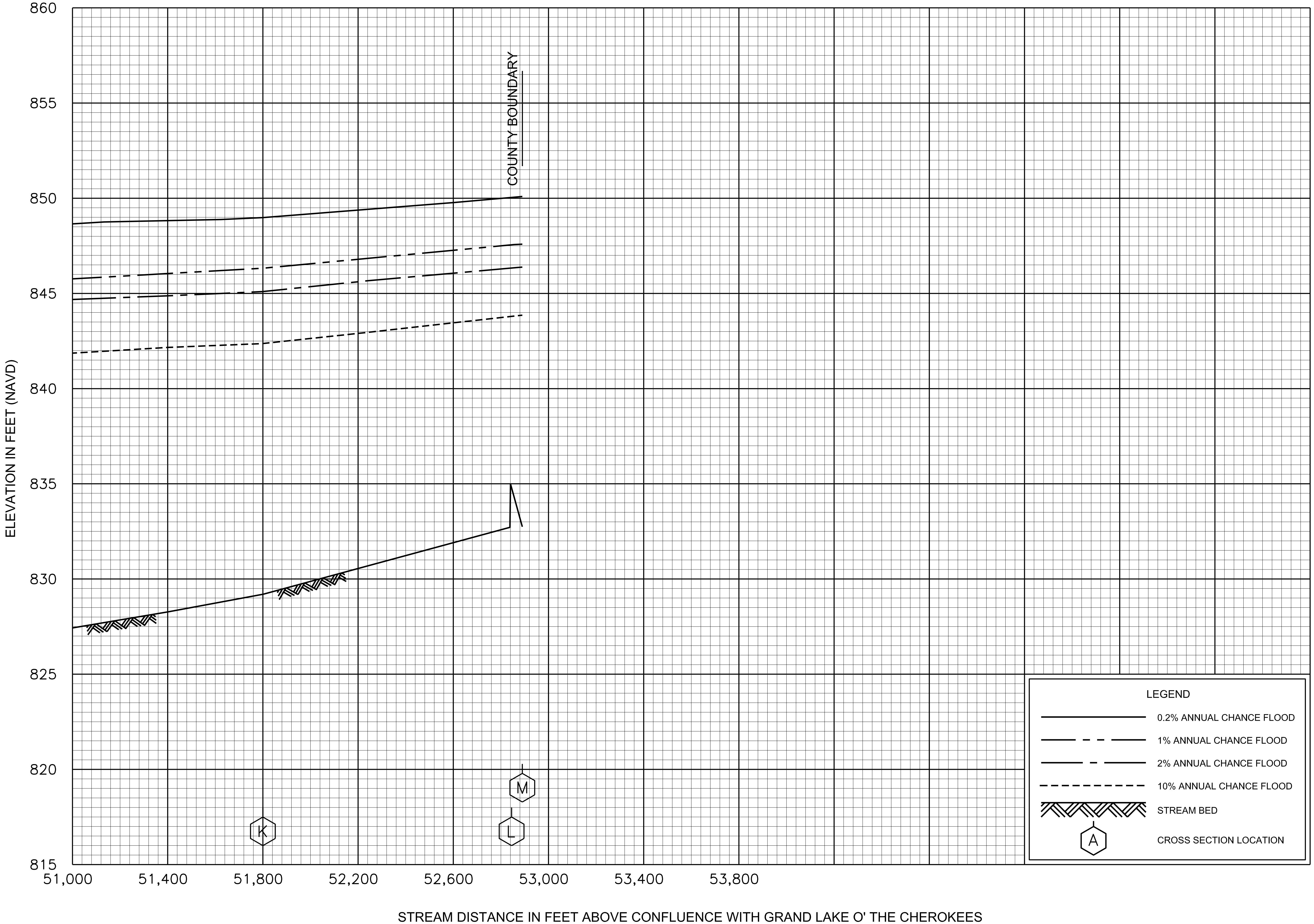
FLOOD PROFILES

LOST CREEK (UPPER REACH)

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



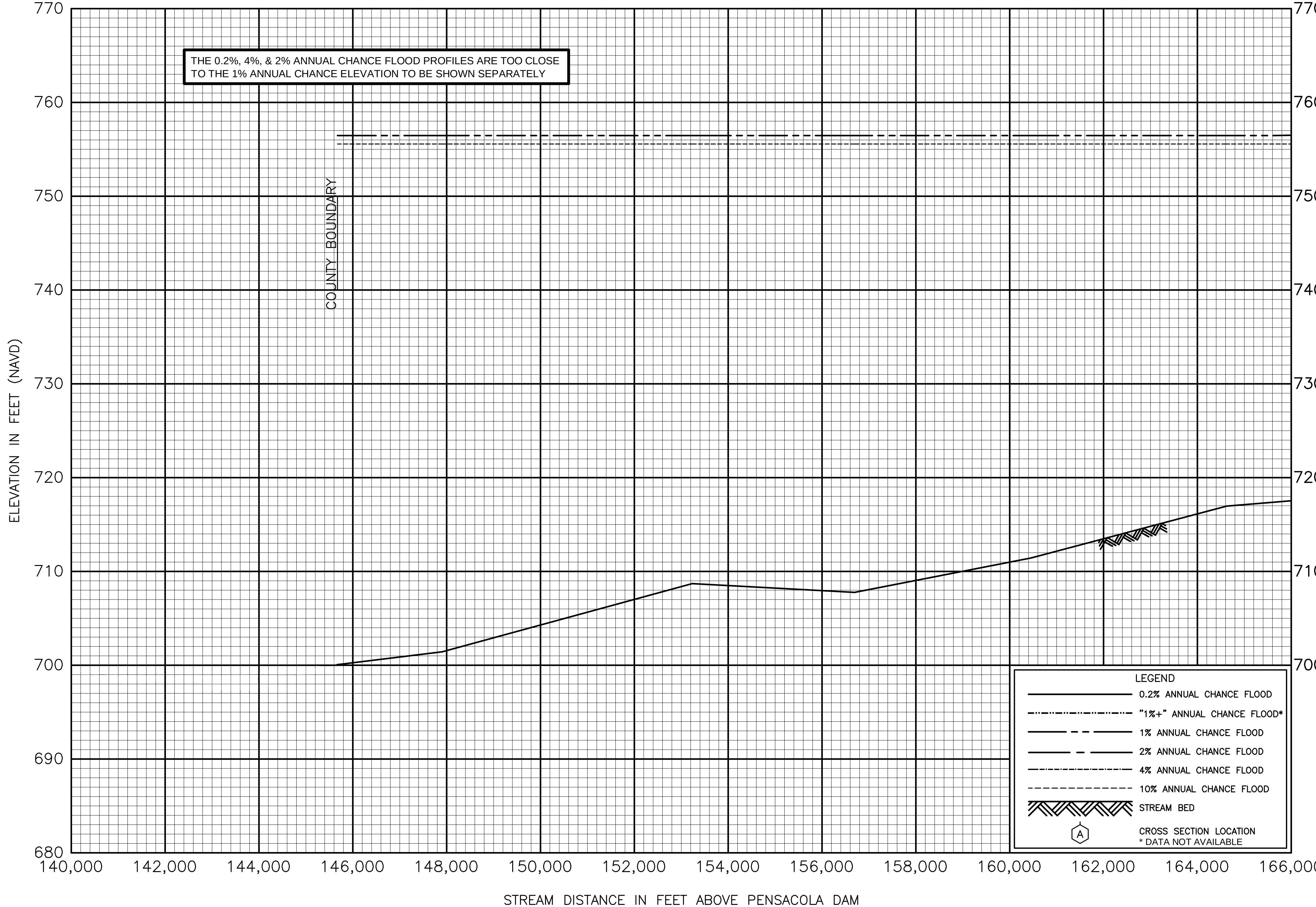
FLOOD PROFILES

LOST CREEK (UPPER REACH)

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



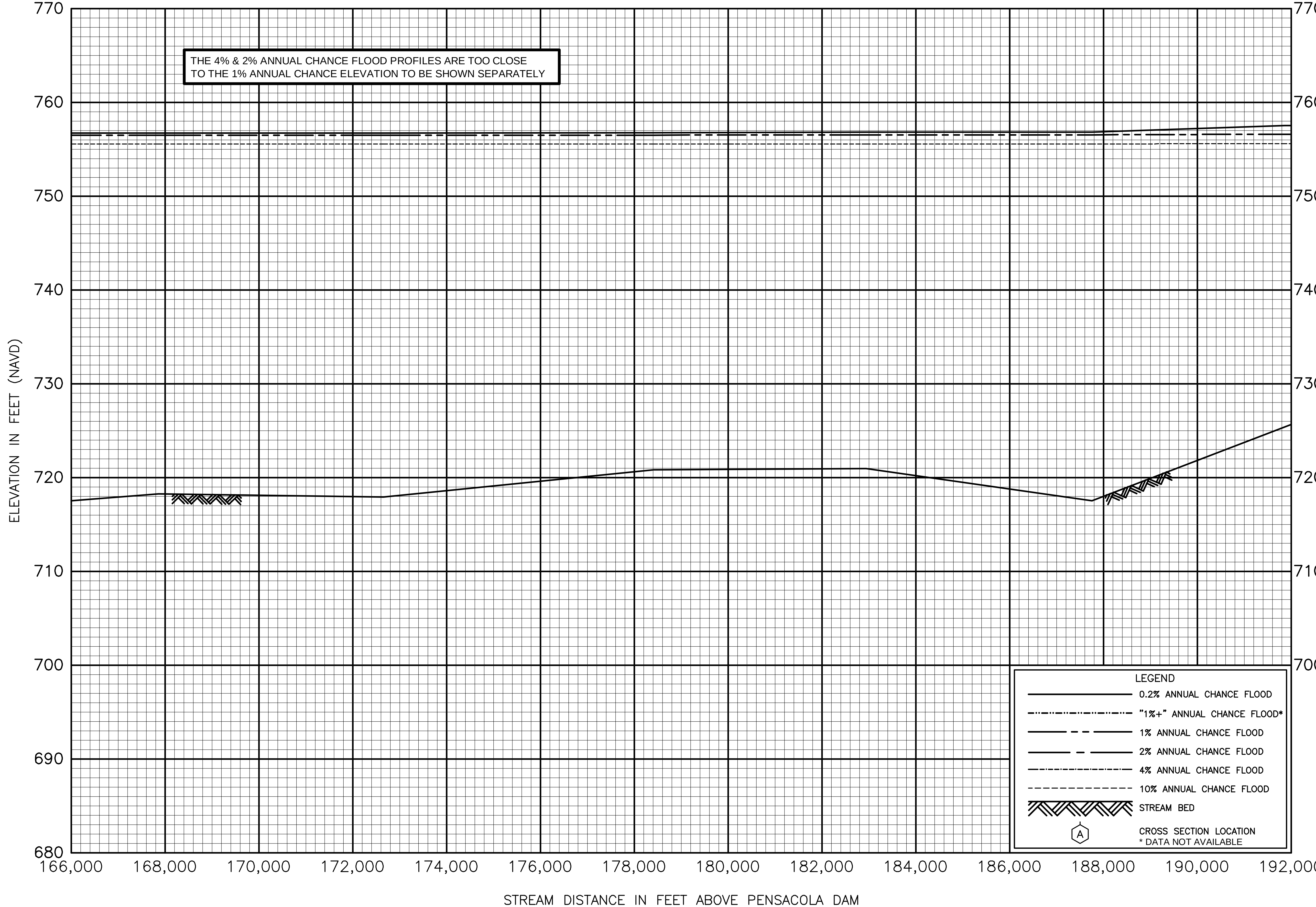
FLOOD PROFILES

NEOSHO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



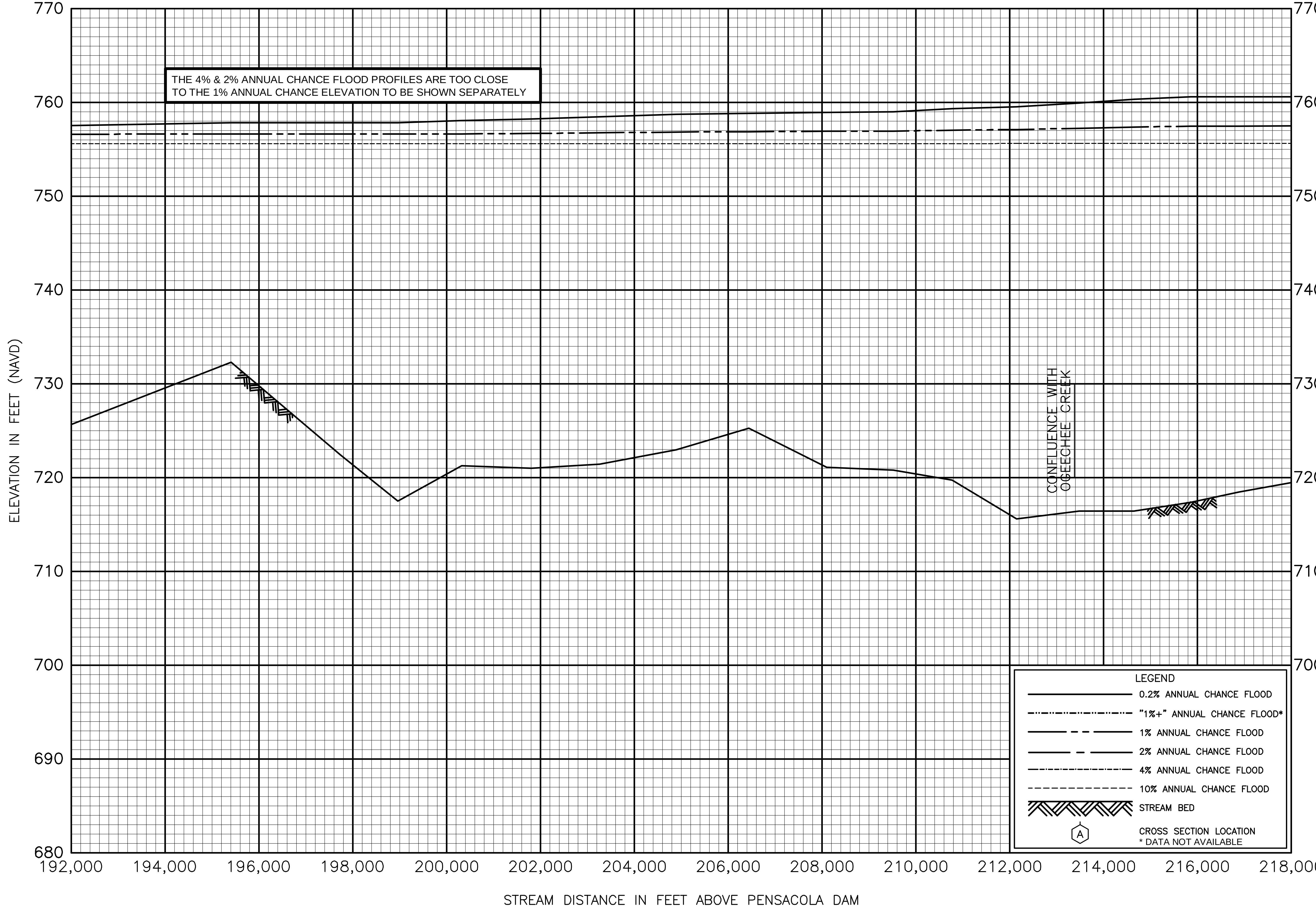
FLOOD PROFILES

NEOSHO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



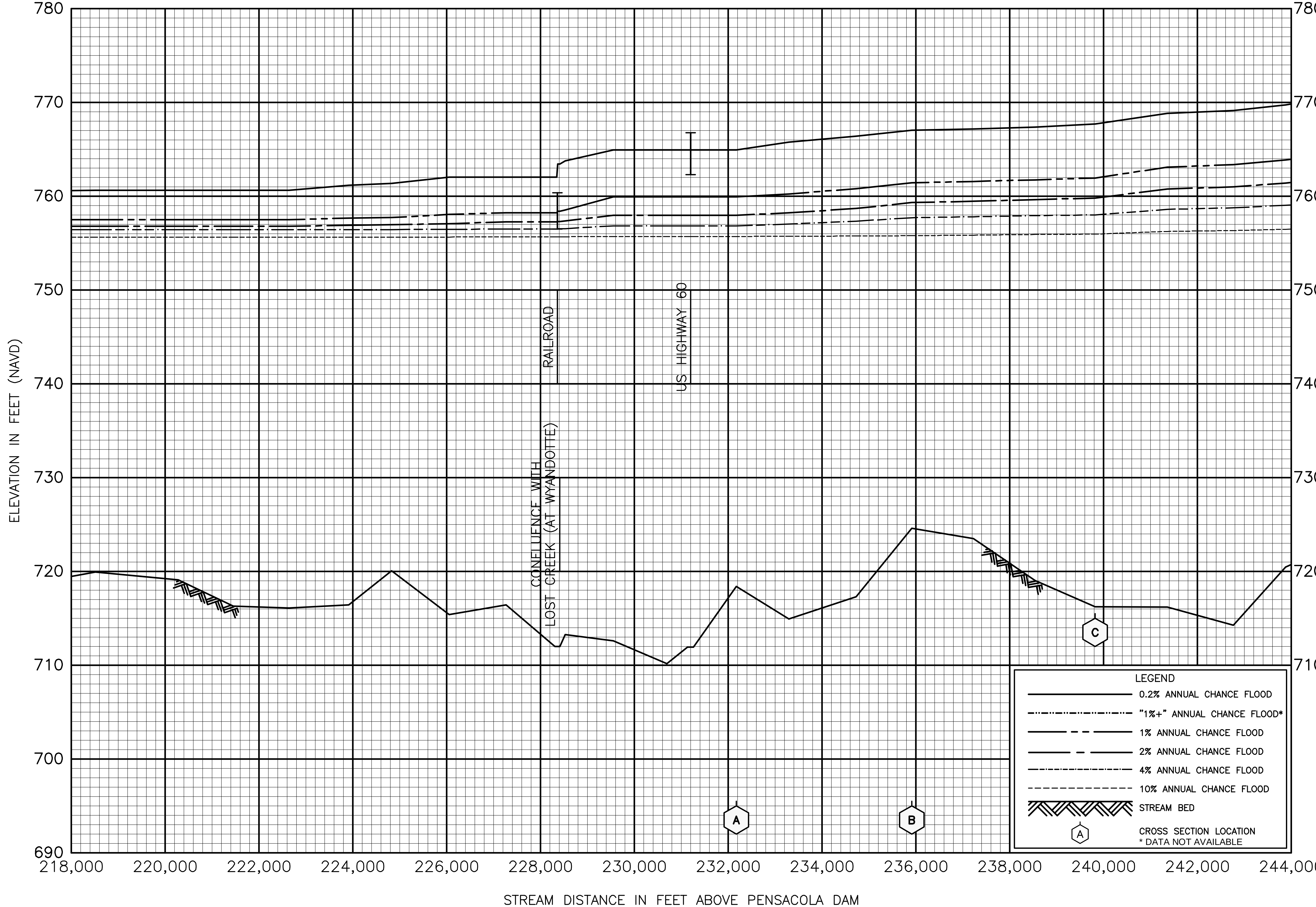
FLOOD PROFILES

NEOSHO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



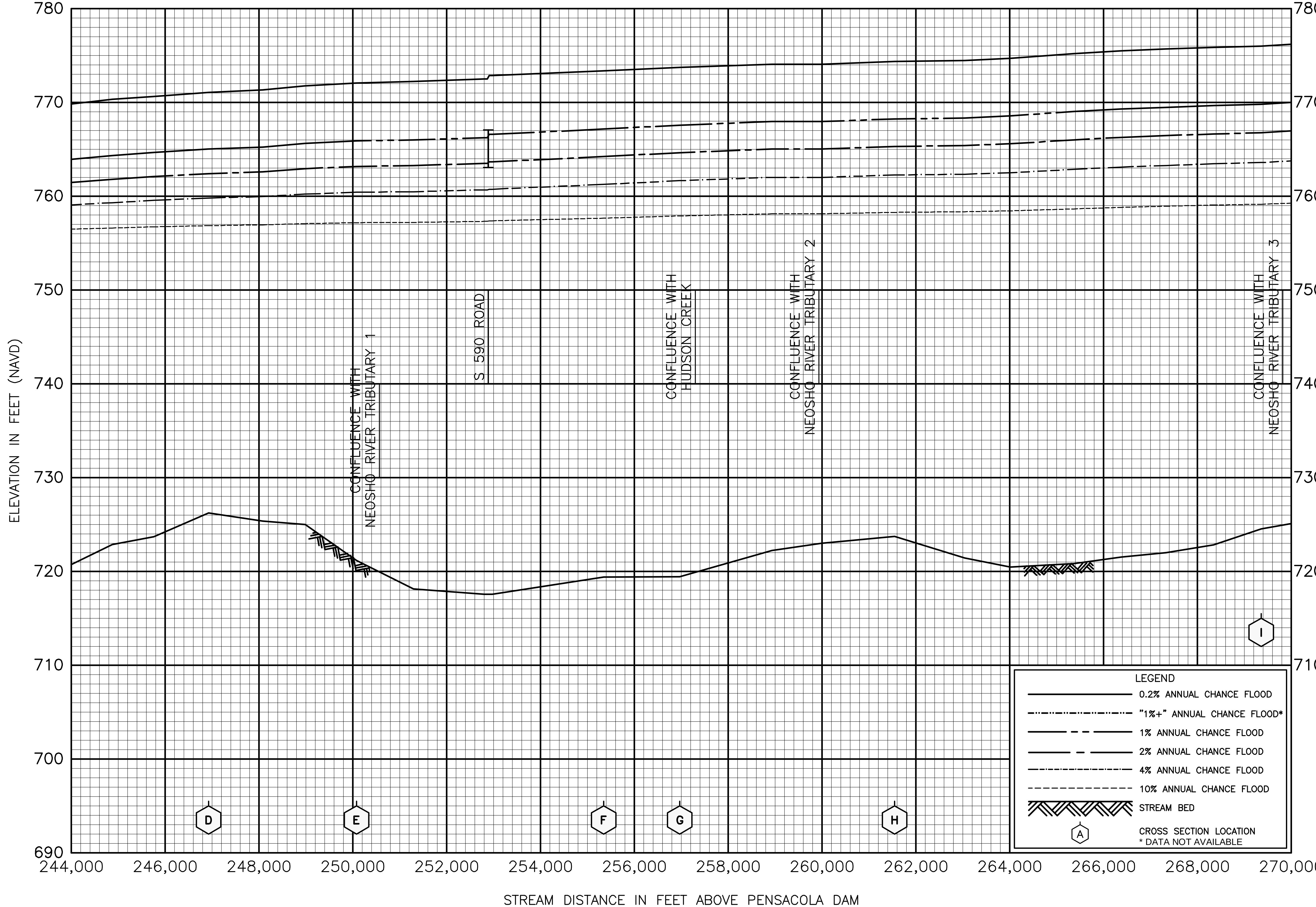
FLOOD PROFILES

NEOSHO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



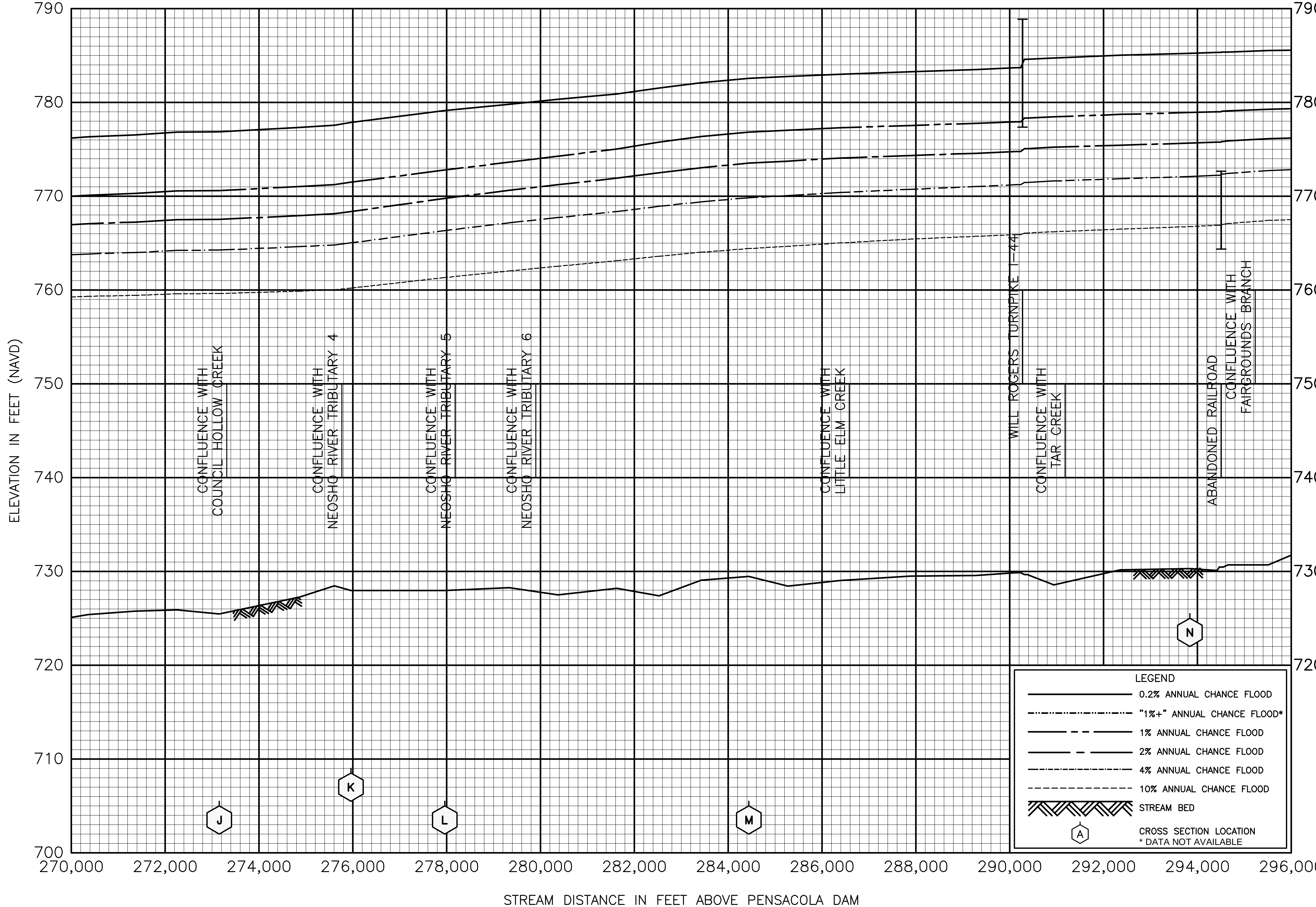
FLOOD PROFILES

NEOSHO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



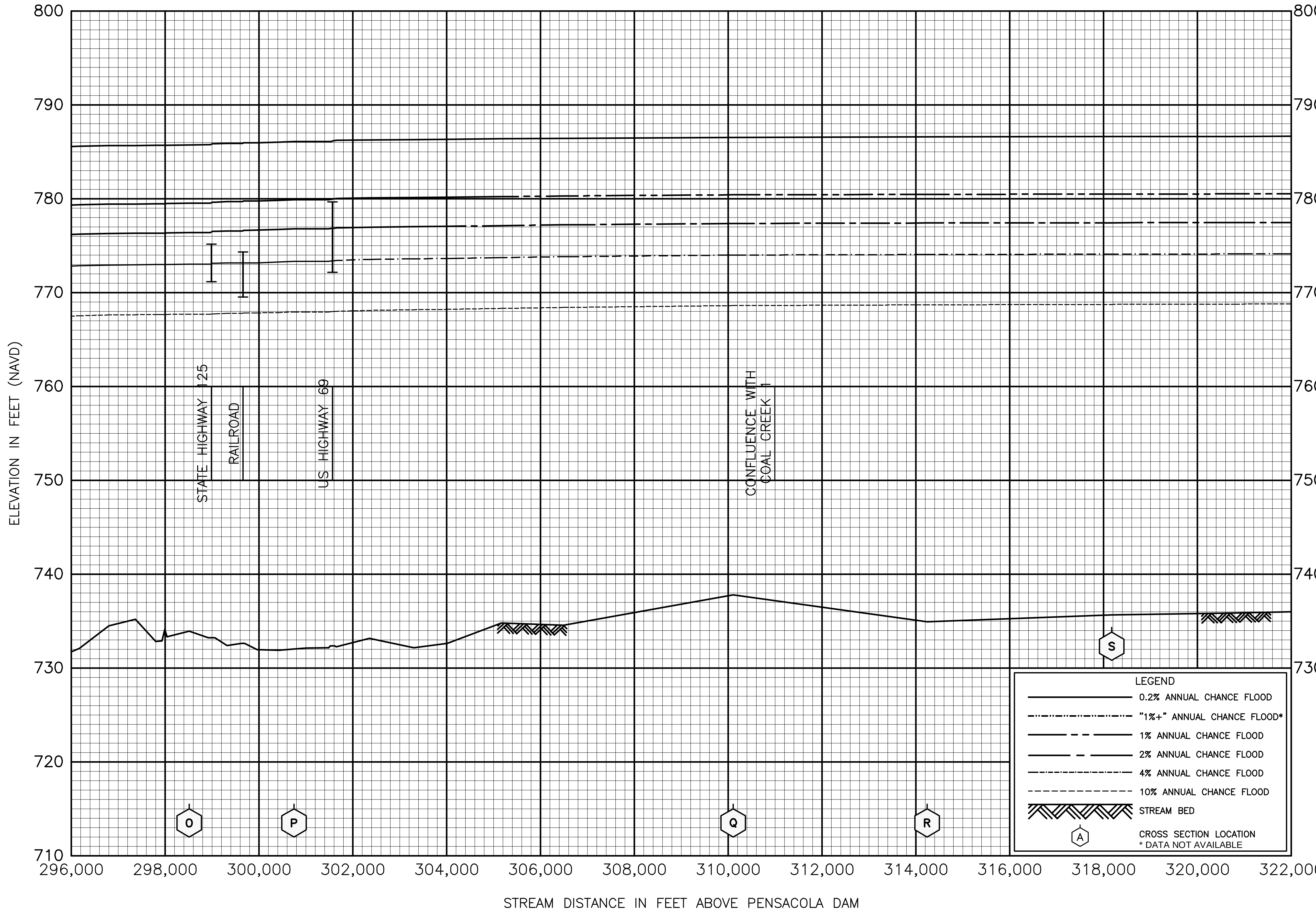
FLOOD PROFILES

NEOSHO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



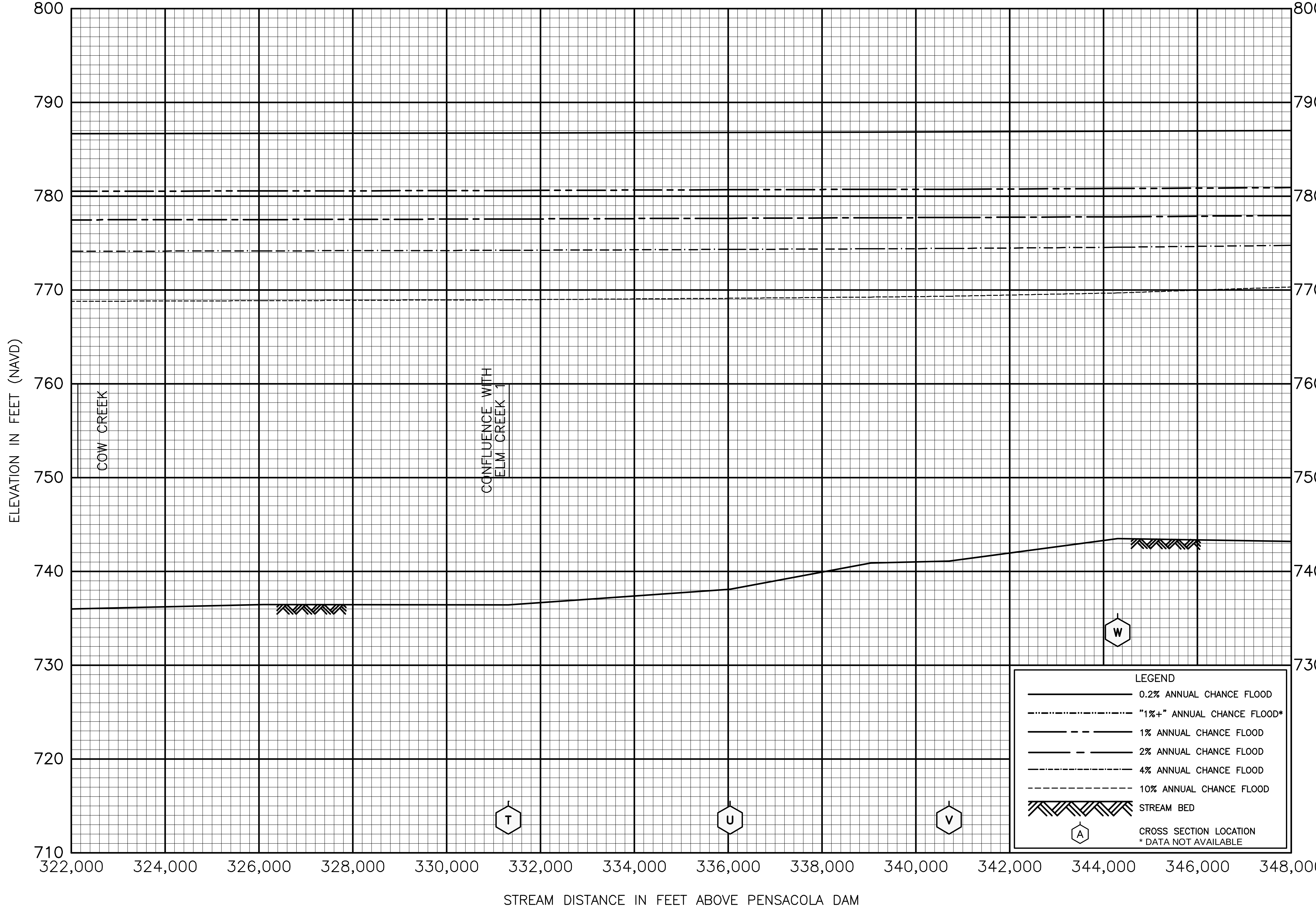
FLOOD PROFILES

NEOSHO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



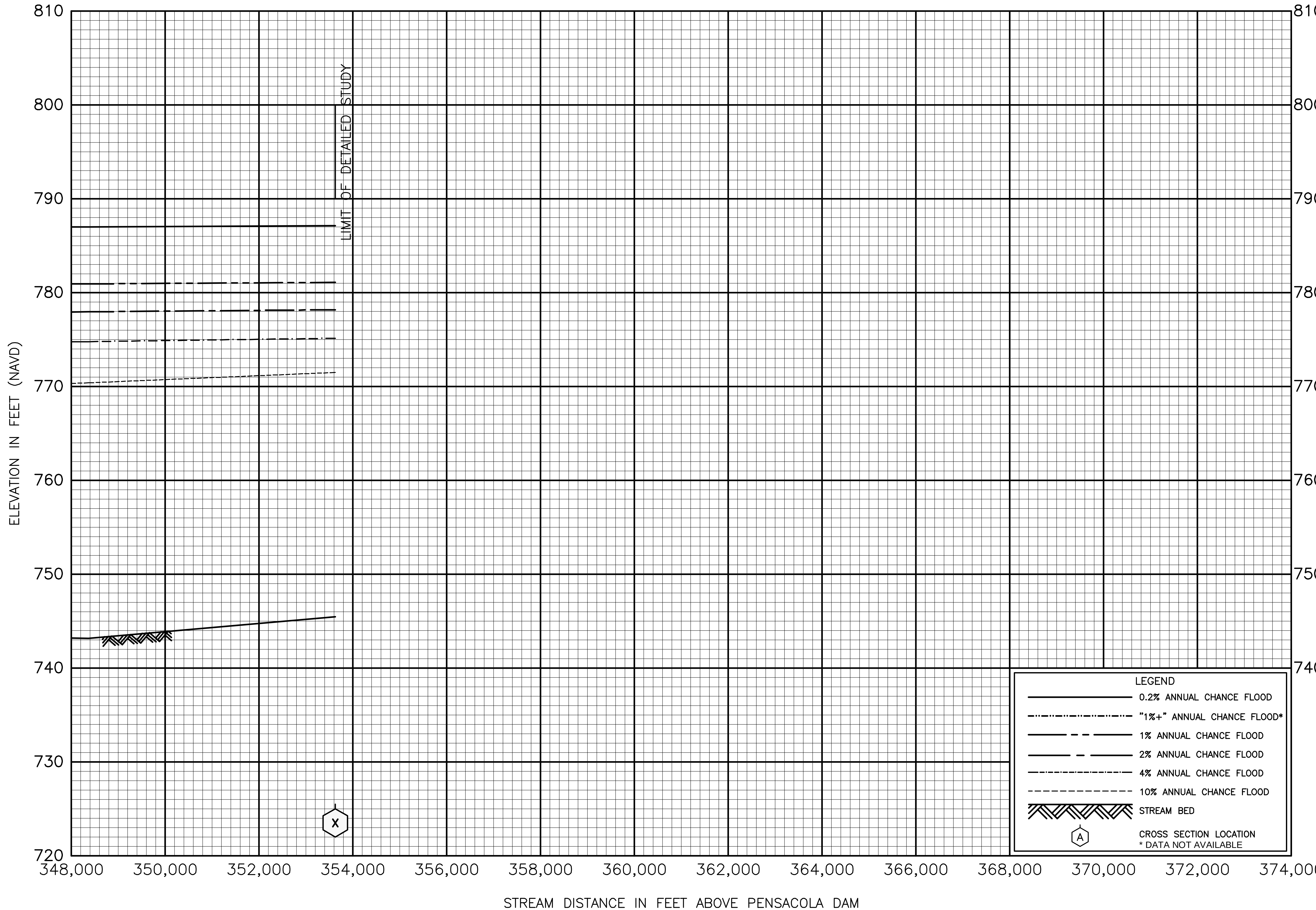
FLOOD PROFILES

NEOSHO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



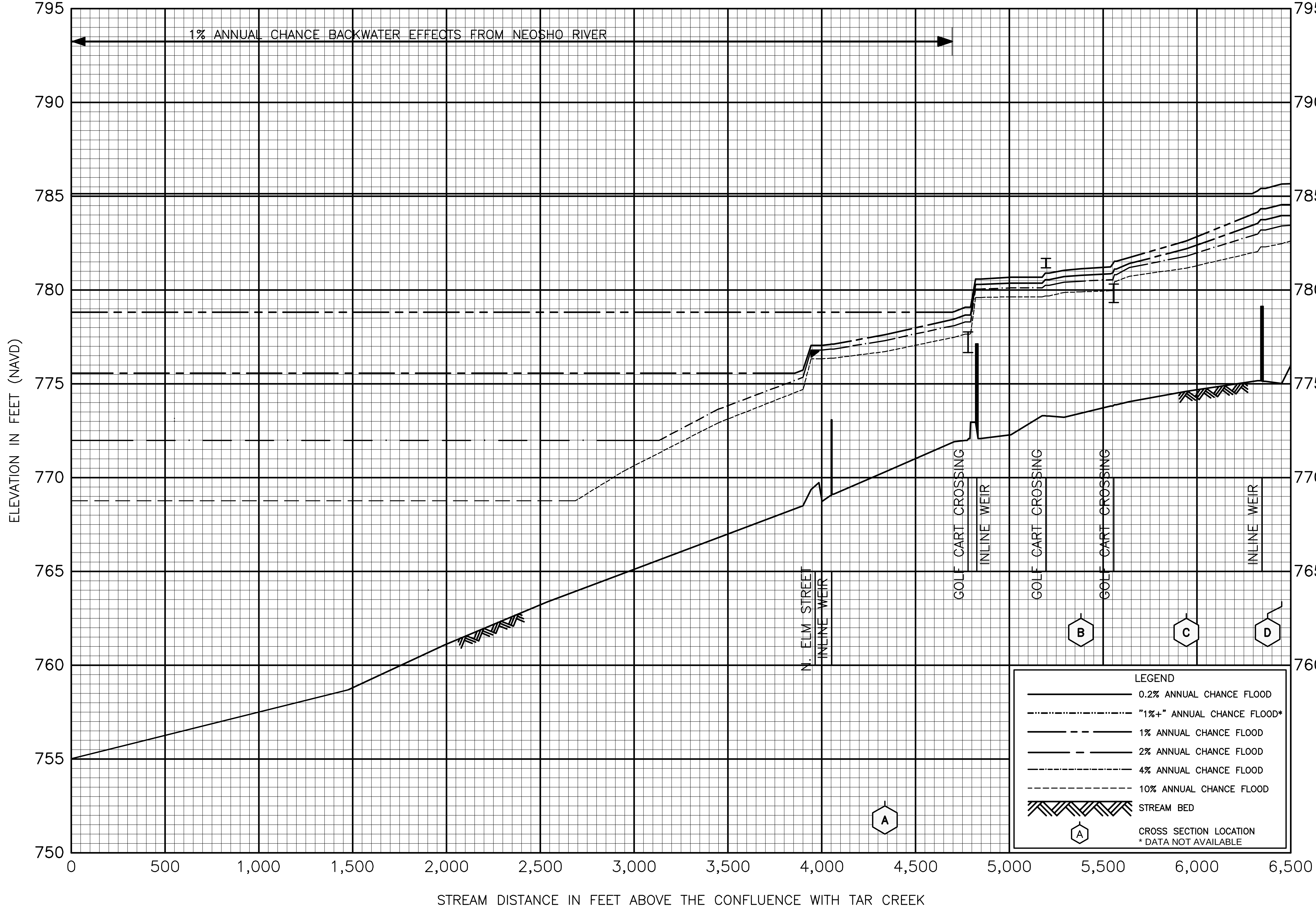
FLOOD PROFILES

NEOSHO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



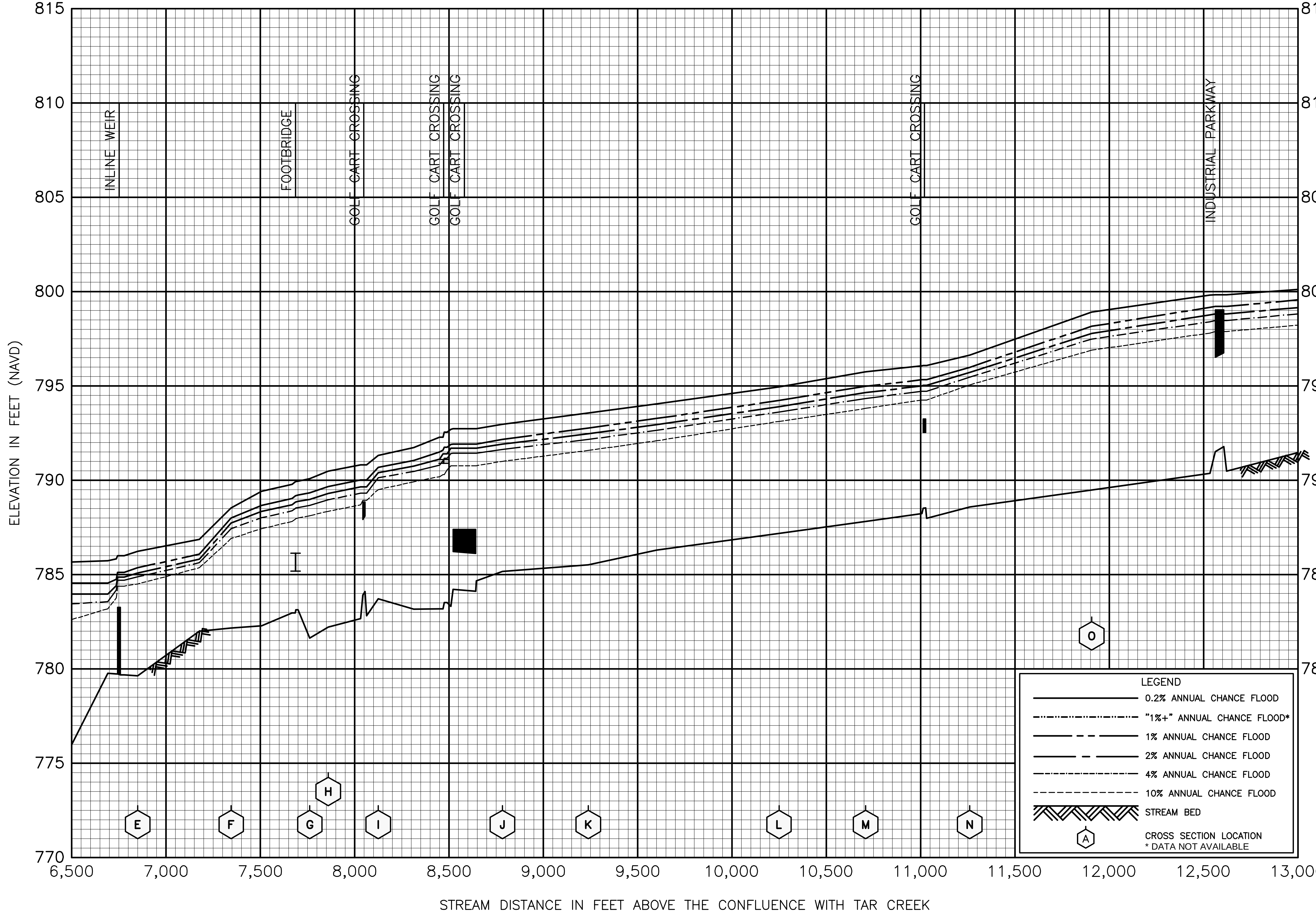
FLOOD PROFILES

QUAIL CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



FLOOD PROFILES

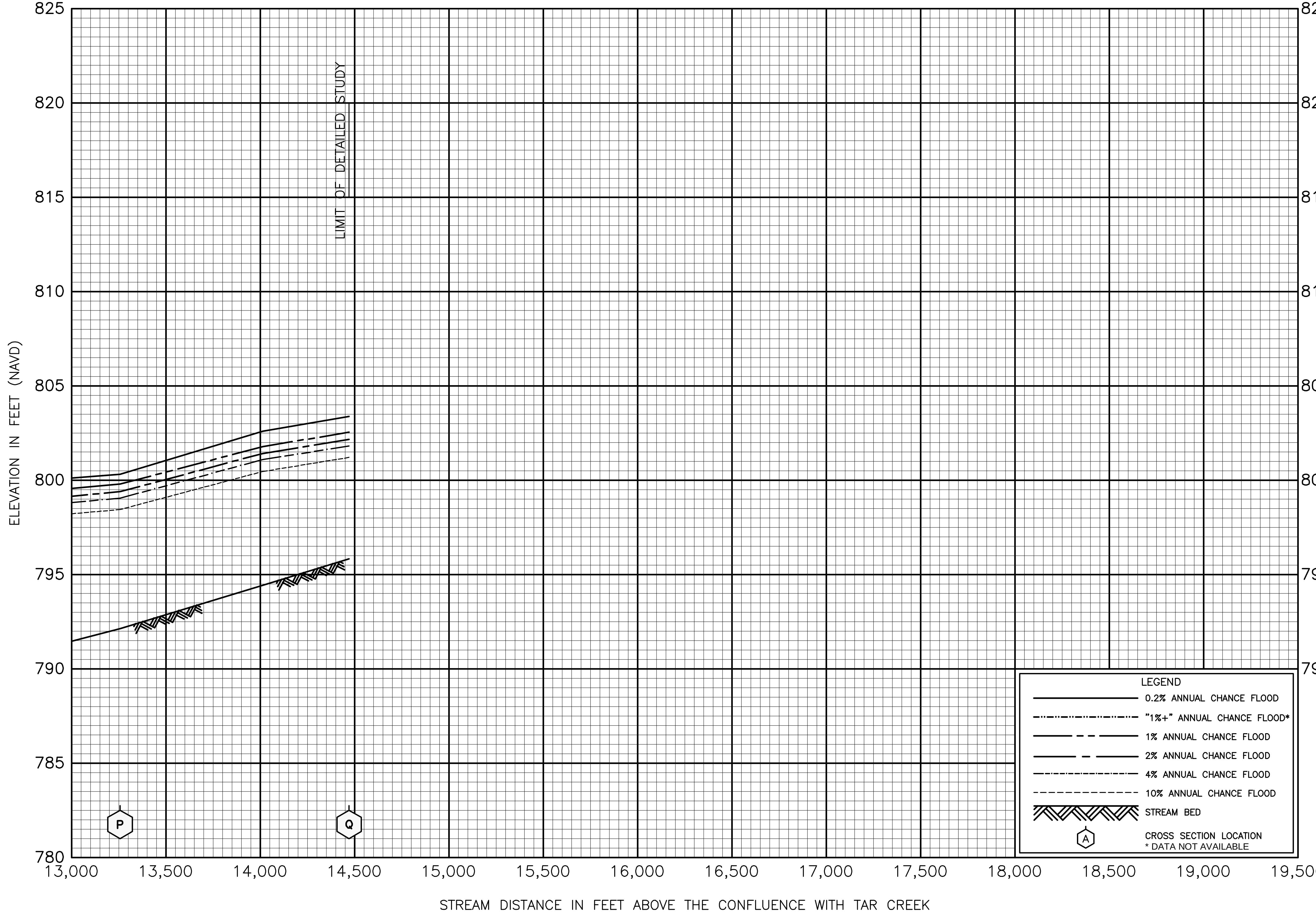
QUAIL CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS

32P



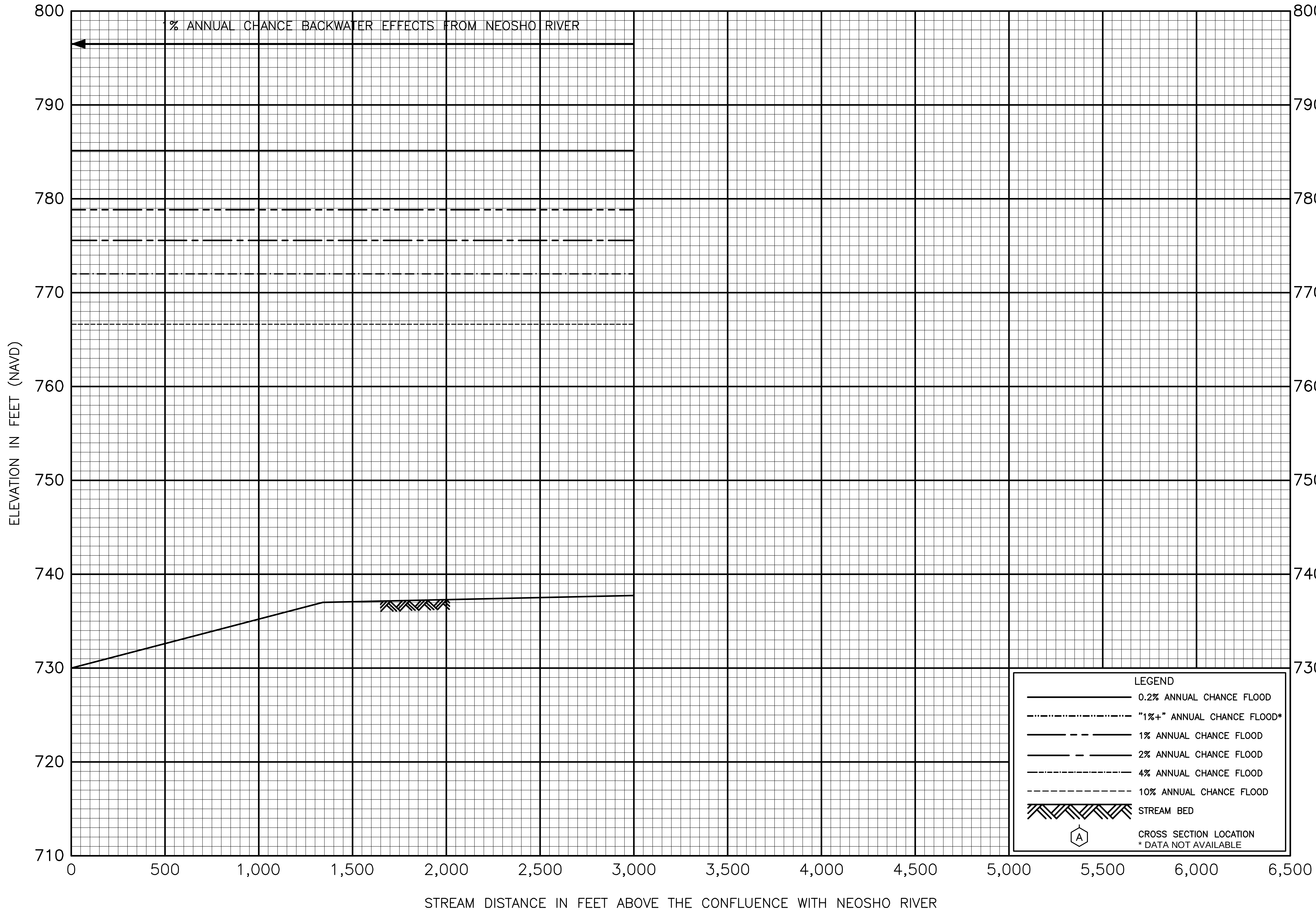
FLOOD PROFILES

QUAIL CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



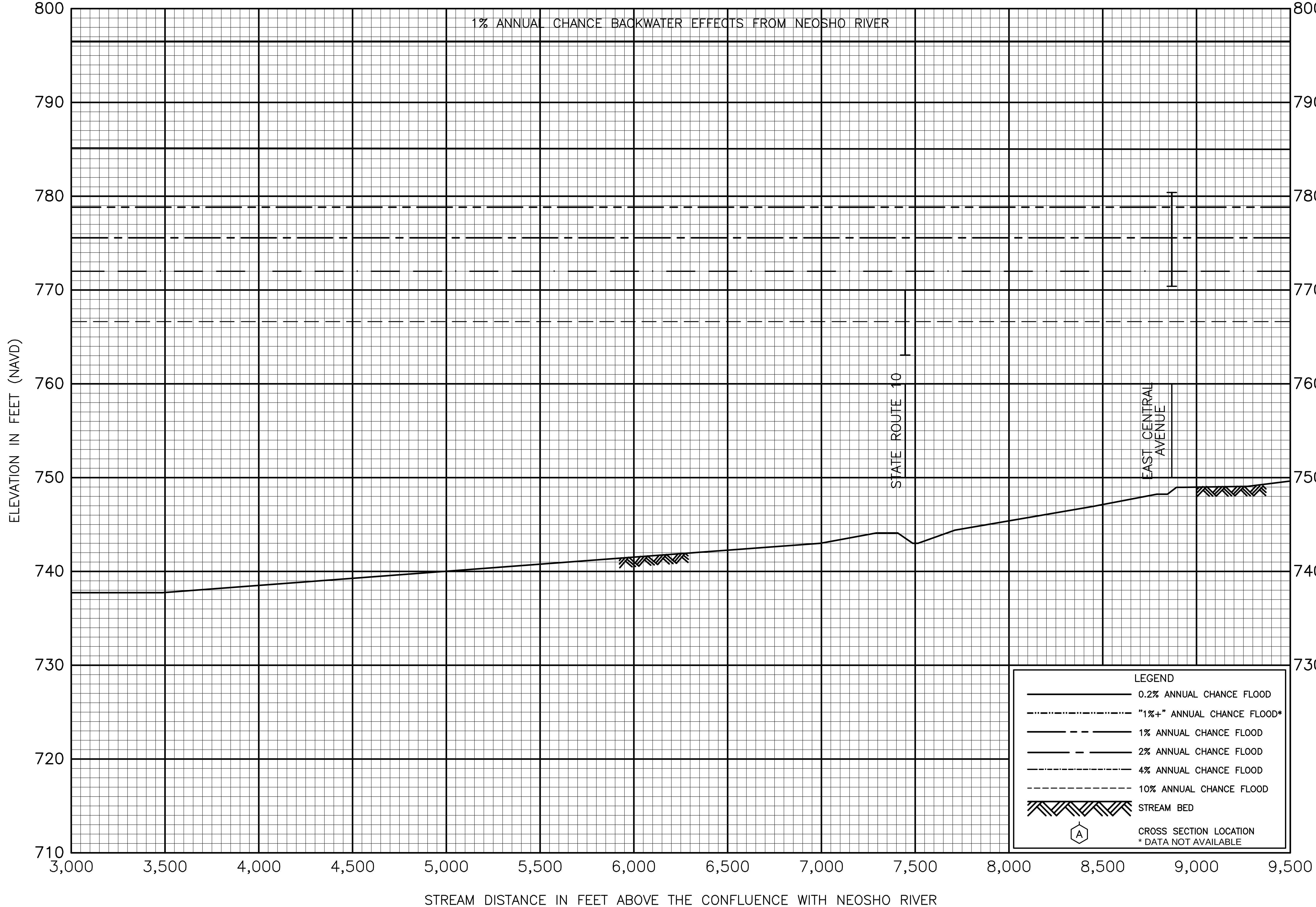
FLOOD PROFILES

TAR CREEK (AT MIAMI)

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



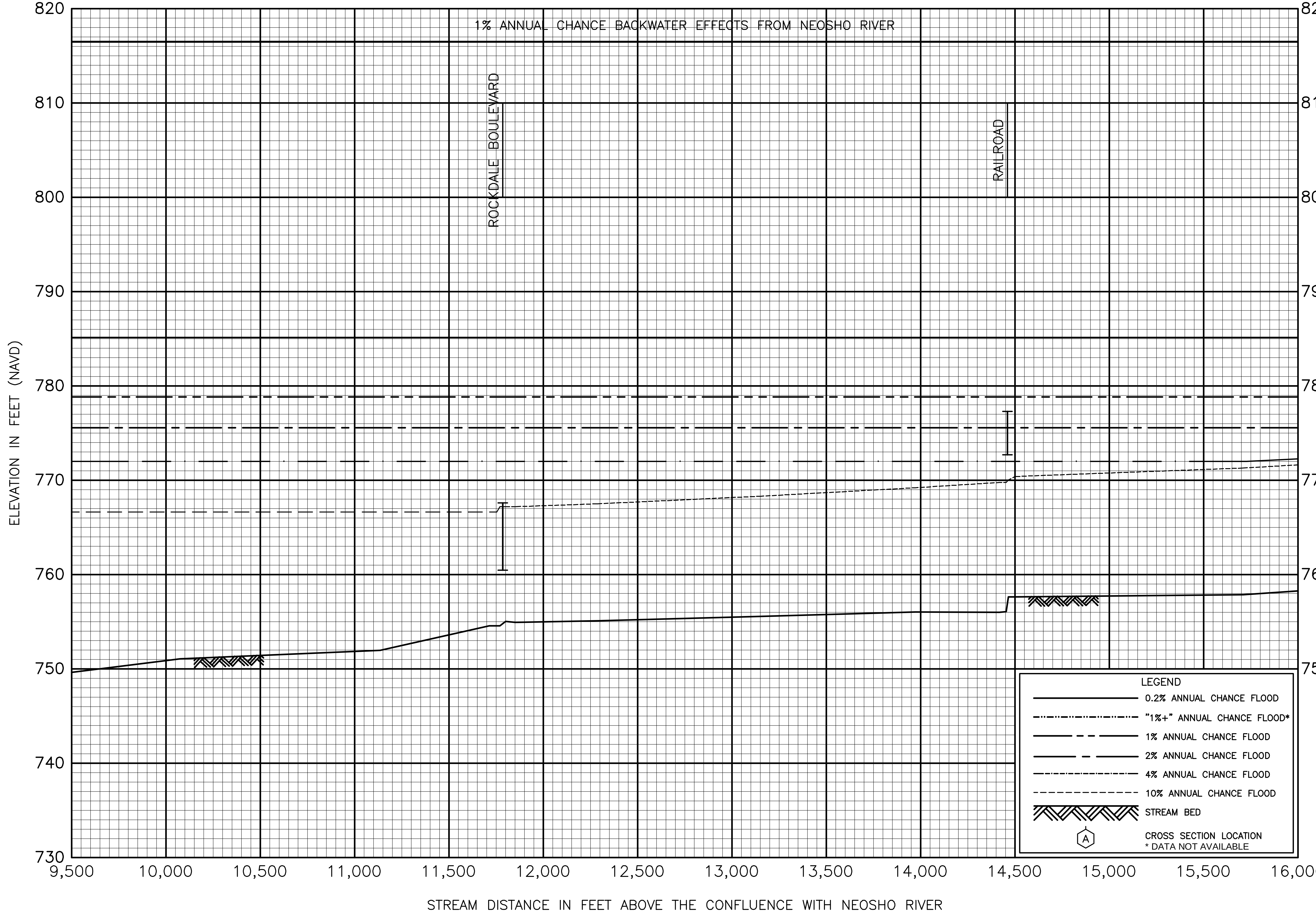
FLOOD PROFILES

TAR CREEK (AT MIAMI)

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



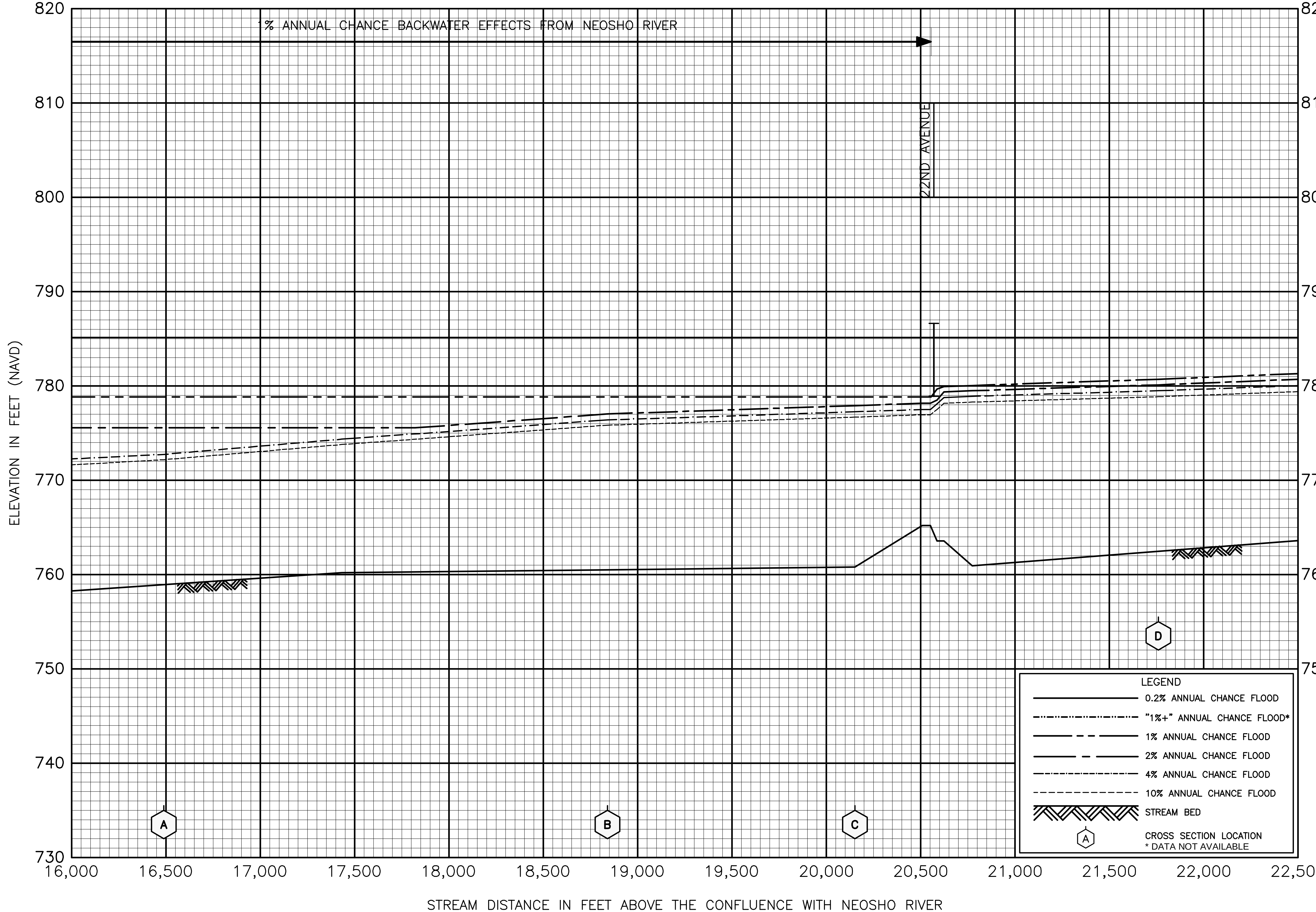
FLOOD PROFILES

TAR CREEK (AT MIAMI)

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS

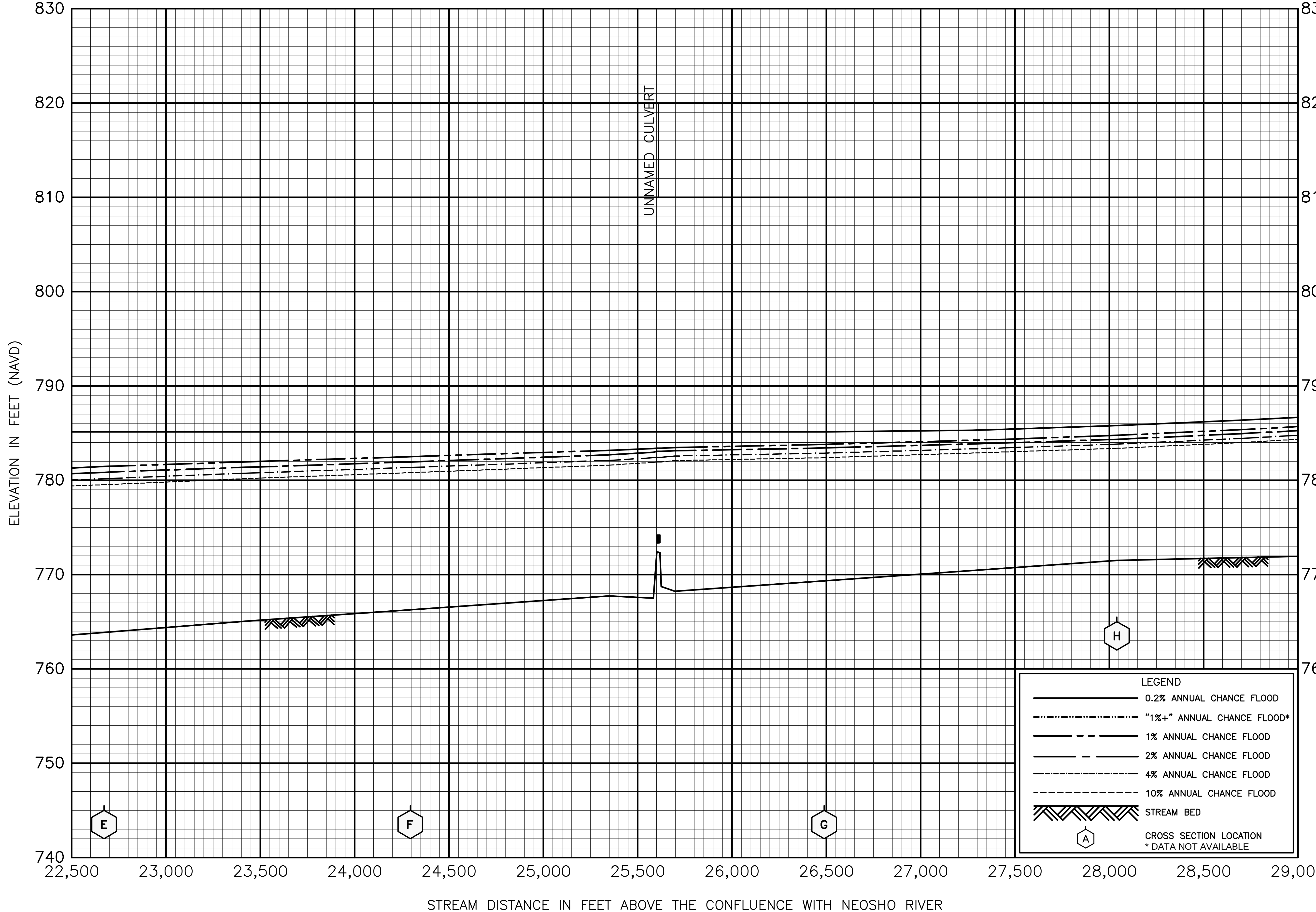


FLOOD PROFILES

TAR CREEK (AT MIAMI)

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS



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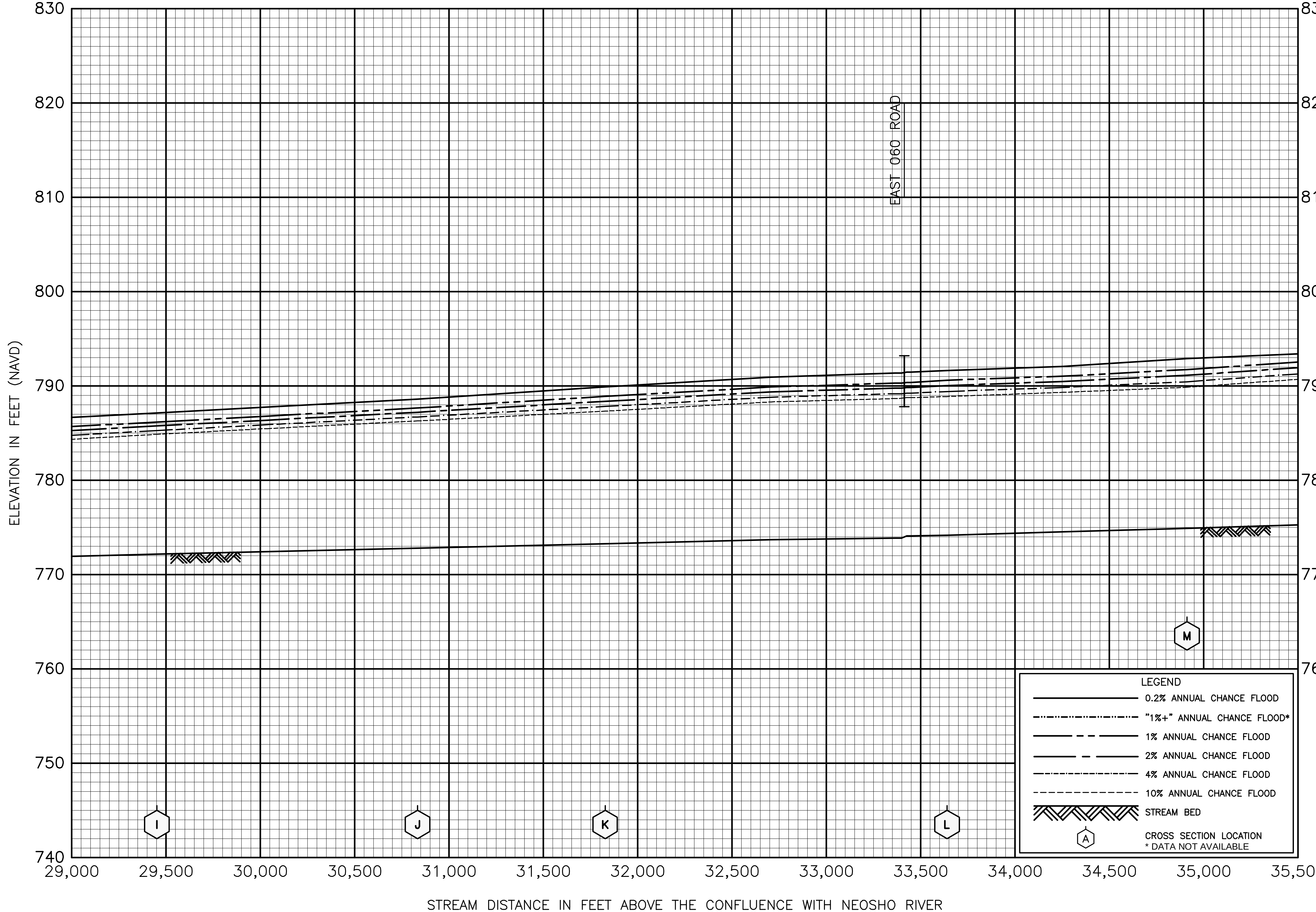
TAR CREEK (AT MIAMI)

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



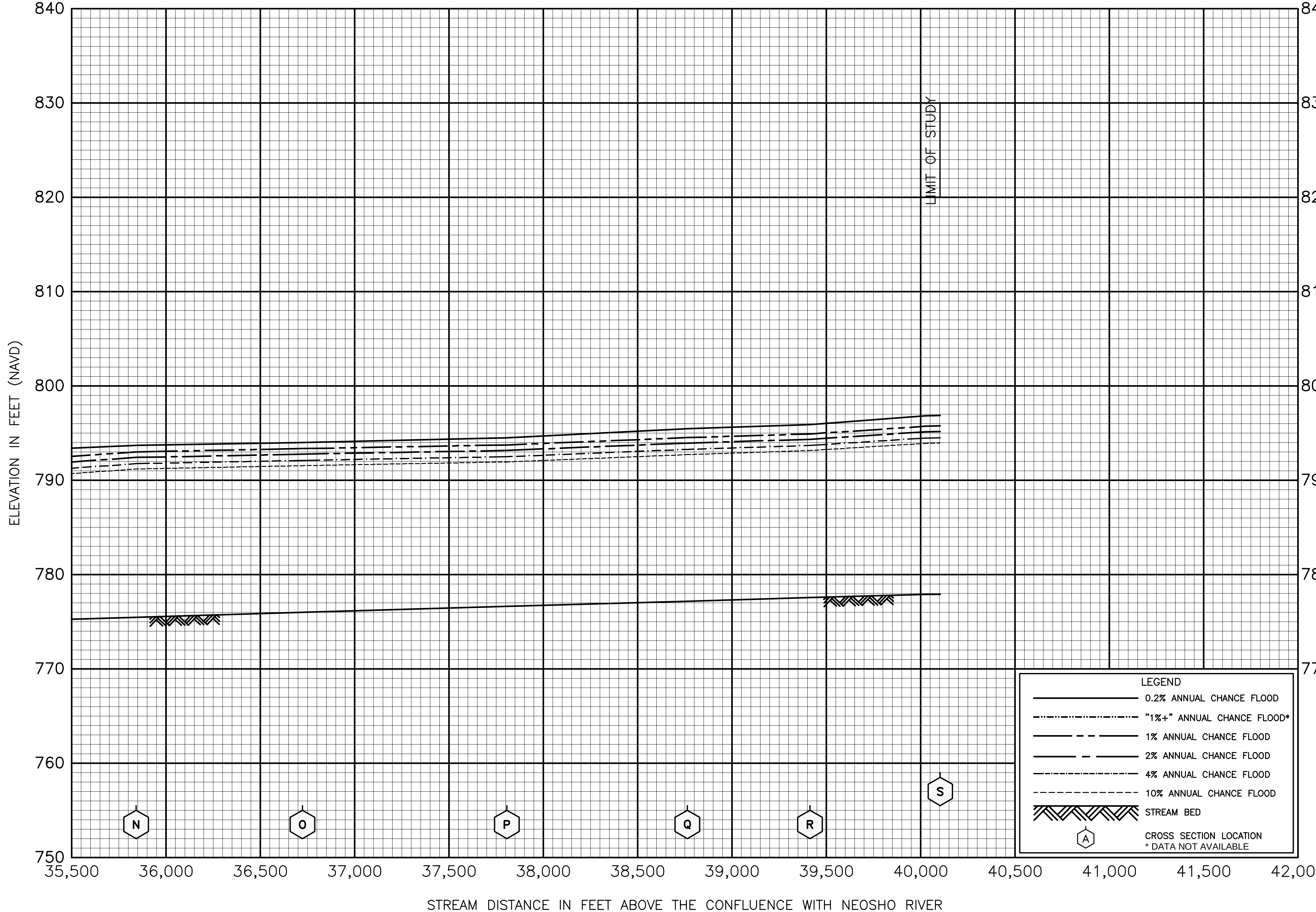
FLOOD PROFILES

TAR CREEK (AT MIAMI)

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



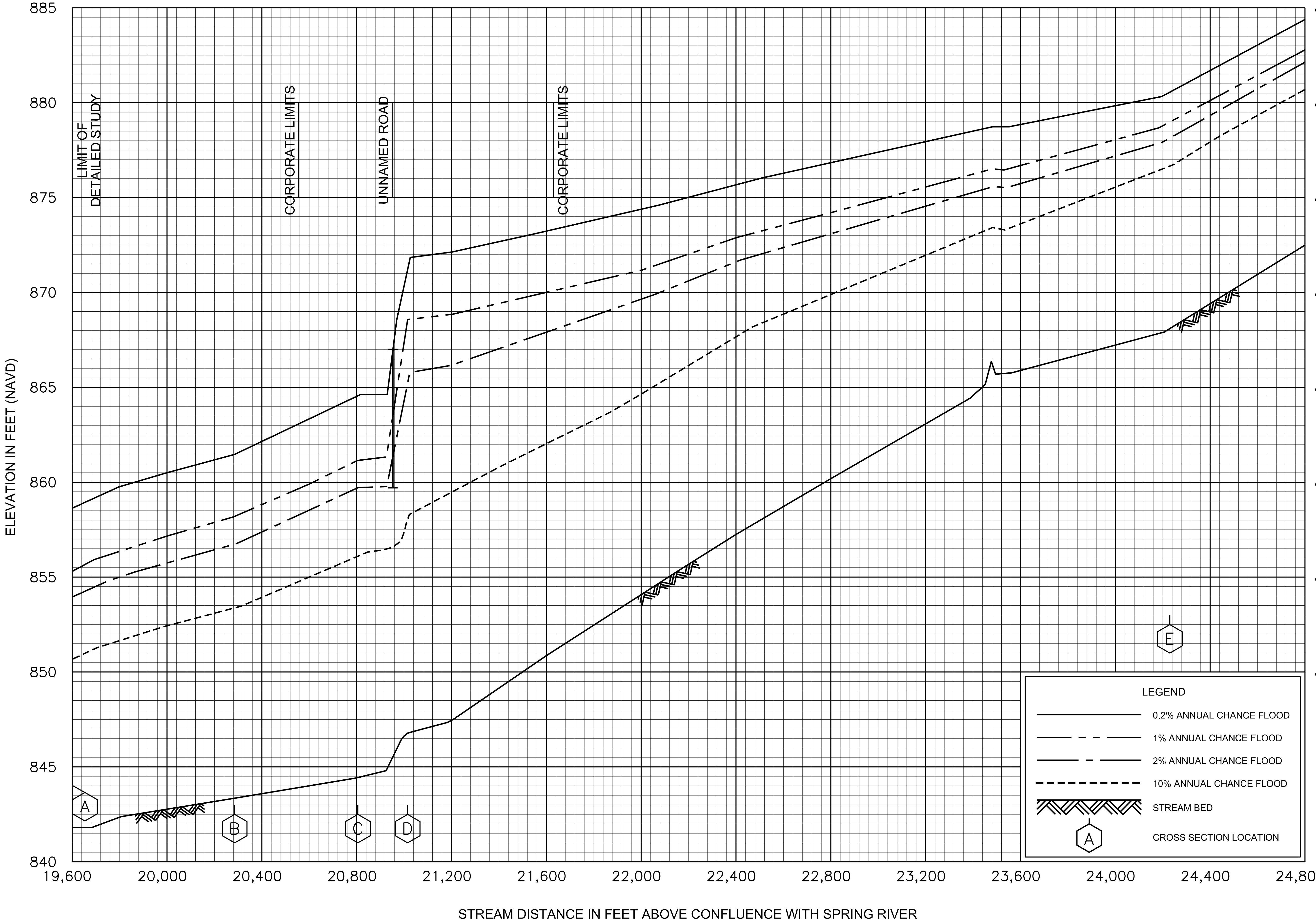
FLOOD PROFILES

TAR CREEK (AT MIAMI)

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS

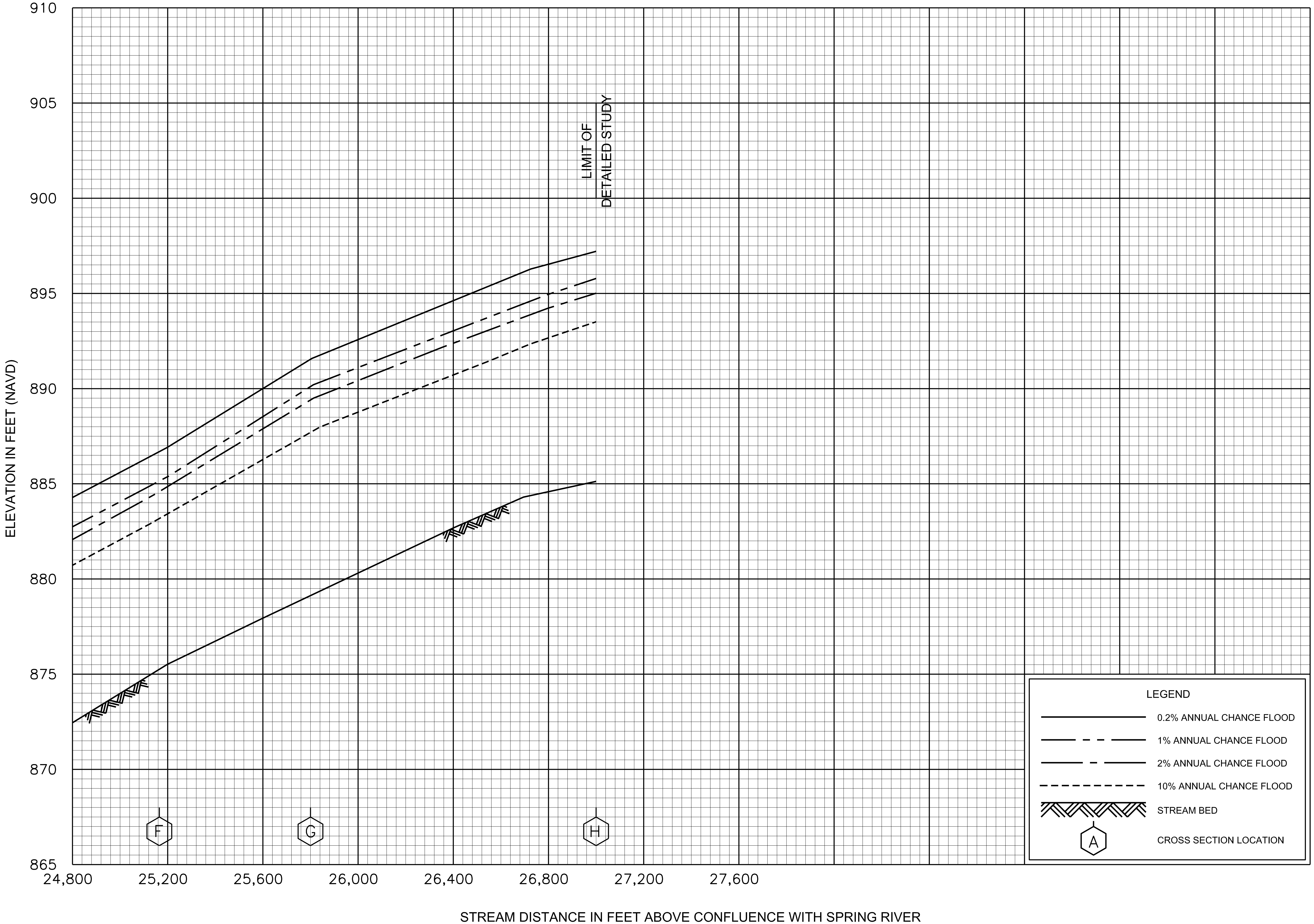


FLOOD PROFILES

WARREN BRANCH

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS



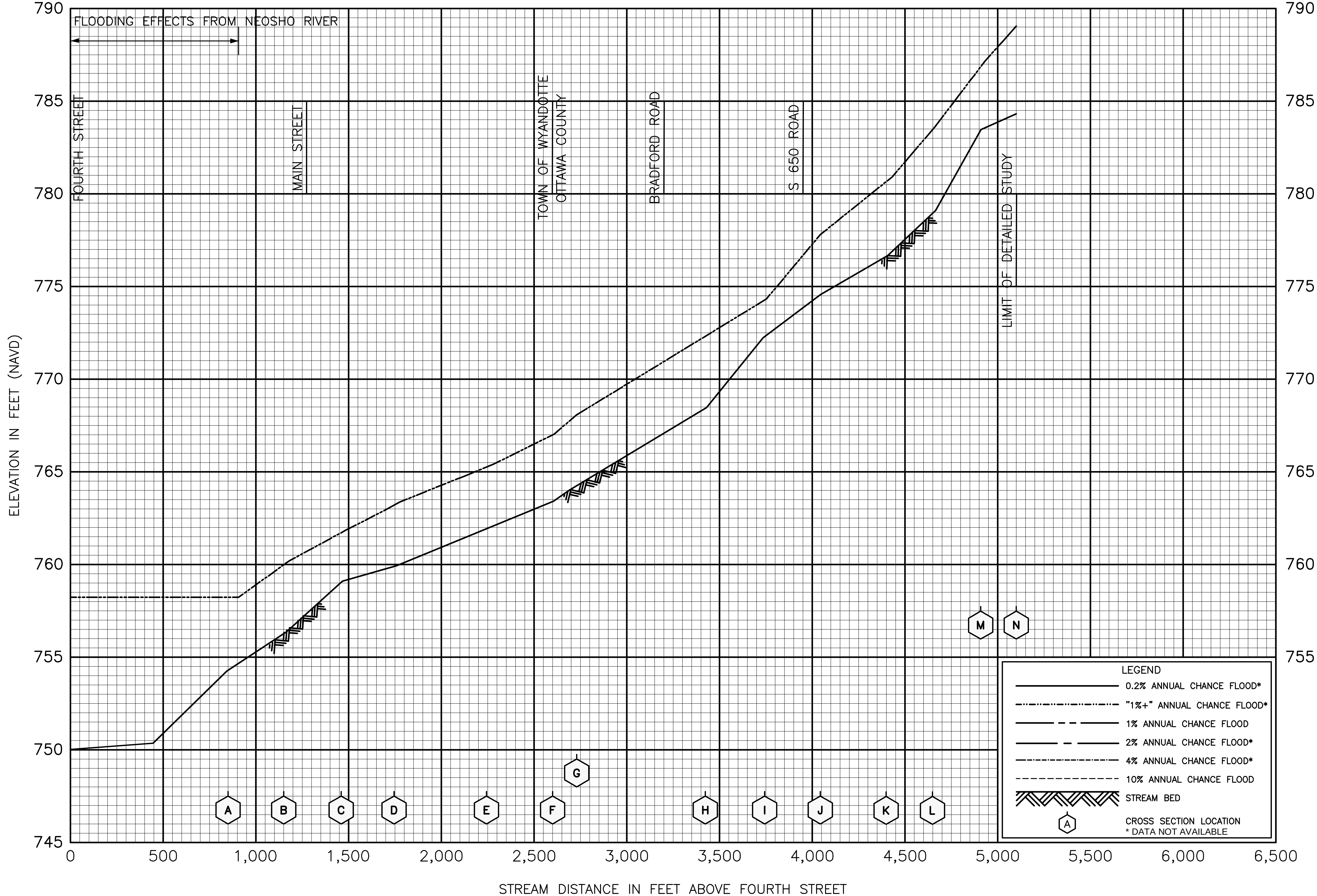
FLOOD PROFILES

WARREN BRANCH

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK

AND INCORPORATED AREAS



FLOOD PROFILES

WYANDOTTE DITCH

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, OK
AND INCORPORATED AREAS