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GRDA Grand River Dam Authority

April 27, 2022

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

Re: Grand River Dam Authority, FERC Project No. 1494-438; Response Comments on Sedimentation Study and Submission of Updated Study Plan for Approval

Dear Secretary Bose:

Pursuant to the Federal Energy Regulatory Commission's (Commission or FERC) Determination on Requests for Study Modifications and New Studies (Determination), issued in the above-referenced proceeding on February 24, 2022, the Grand River Dam Authority (GRDA), owner and licensee of the Pensacola Hydroelectric Project (Project), is pleased to submit its response to comments received on the Sedimentation Study for the relicensing of the Pensacola Hydroelectric Project (FERC No. 1494), coupled with an Updated Study Plan (USP) for the Sedimentation Study for Commission staff's review and approval.

In its February 24 Determination, Commission staff recognized that the Sedimentation Study consists of study methodologies that are "technically complex."[1] Adding to this complexity, Commission staff also recognized that while GRDA during the first study season appeared to have "conducted the study as required in the approved study plan, the first season results were anomalous relative to the initial modeling assumptions."[2]

For these reasons, GRDA in its Sedimentation Study Report filed on December 29, 2021, proposed a different approach for implementing the Sedimentation Study during the second study season, as set forth in its Proposed Modified Study Plan

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[1] Determination on Requests for Study Modifications and New Studies for the Pensacola Hydroelectric Project at B-3, Project No. 1494-438 (issued Feb. 24, 2022) [hereinafter, Determination].

[2] *Id.* Commission staff's comment on "anomalous" results is a reference to the erroneous information submitted by the City of Miami, Oklahoma (City), and relied upon by Commission staff in its October 2018 Study Plan Determination, which inaccurately claimed that the bed of the river/reservoir system consists primarily of sand and that cohesive sediment need not be considered. *See* Sedimentation Study Report § 5.2.3, at p. 100 (filed as Appendix D to Response to Comments on Initial Study Report, Notice of Technical Meeting, and Request for Privileged Treatment of Cultural Resources Information, Project No. 1494-438 (filed Dec. 29, 2021)) [hereinafter, Sedimentation Study Report].

(PMSP).[3] Moreover, recognizing the value of engaging Commission staff and relicensing participants in an iterative process to resolve the complex issues presented by the Sedimentation Study, GRDA convened a voluntary technical meeting on January 14, 2022, to further discuss the first season results of the Sedimentation Study and the PMSP.[4]

In its February 24 Determination, Commission staff recommended a further iterative process for developing an appropriate and technically achievable Sedimentation Study, providing:

> [W]e recommend a 30-day period, from the date of issuance of this determination, for stakeholders to file comments on GRDA's season one Sedimentation Study Report and study modification proposal. We also recommend, as requested by GRDA in this circumstance, providing a 30-day period for GRDA to review and respond to the stakeholder comments. Upon conclusion of the comment and response periods, a determination on the Sedimentation Study modification will be issued within another 30 days.[5]

In response to this further opportunity to provide input on the Sedimentation Study, the City of Miami, Oklahoma (City) filed comments on March 28, 2022.[6]

Throughout this iterative process, GRDA has fully analyzed and deeply considered comments on the Sedimentation Study from Commission staff and the City.[7] In addition, GRDA has challenged its own thinking on this important and complex study plan—all in a good-faith effort to find a compromise methodological solution that would meet the City's expectations and satisfy the goals and objectives established by Commission staff for the Sedimentation Study.

As part of these efforts, GRDA retained WEST Consultants Inc. (WEST) to review the Sedimentation Study report and PMSP and prepare an Independent Technical Review (ITR)—again, in an attempt to better understand potential pathways to a compromise solution. Based on GRDA's review of WEST's ITR, comments submitted by the City, and recommendations from GRDA's long-standing expert consultants, GRDA proposes a different solution than the PMSP proposed in December 2021. Instead, GRDA proposes a new approach that uses the sediment modeling approach (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, while

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3 Response to Comments on Initial Study Report, Notice of Technical Meeting, and Request for Privileged Treatment of Cultural Resources Information, Appendix E, Project No. 1494-438 (filed Dec. 29, 2021).

4 In the Initial Study Report and accompanying meetings held on October 12-14, 2021, GRDA gave a full accounting of its efforts during the first study season to implement the Sedimentation Study. Unfortunately, the City continues to mischaracterize GRDA's efforts as "untimely," *see* Supplemental Comments on GRDA's Untimely Request to Modify Sedimentation Study and Requests for Study Modifications to Conform with Approved Study Plan at 1, Project No. 1494-438 (filed Mar. 28, 2022), despite the fact that the delayed implementation of the Sedimentation Study stems from Commission staff's reliance on inaccurate sedimentation information submitted by the City—and despite the fact that Commission staff has acknowledged the City's error. *See supra* note 2.

5 Determination at B-3.

6 No other relicensing participant raised an objection with the Sedimentation Study.

7 In addition to its comments filed March 28, GRDA filed comments on the Sedimentation Study on January 24, 2022—before Commission staff established a 30-day period for relicensing participants to submit additional comments on the Sedimentation Study. *See* Opposition to GRDA's Untimely Request to Modify Sedimentation Study and Request for Study Modifications to Conform with Approved Study Plan, Project No. 1494-438. GRDA's attached comments are responsive to both sets of comments submitted by the City.

considering through other methodologies the complexities of the silts and clays dominating the system. The specific methods of this compromise proposal are detailed in the attached USP.

To assist relicensing participants' understanding of the USP and inform Commission staff's consideration of it, the following materials are included in this filing:

- ***Attachment 1****—GRDA Response Comments on Sedimentation Study Plan:* This document includes a higher-level overview of sedimentation modeling principles, the challenges of developing a sedimentation model in the Project reach of the Grand/Neosho River, a discussion of the strengths and challenges of each dataset available for a sedimentation model for the Project, and GRDA's rationale for the new methods proposed in the USP. This document also includes a comment/response matrix, which addresses in detail all comments raised by the City.

- ***Attachment 2****—Independent Technical Review of HEC-RAS Sediment Transport Model:* This document contains WEST's ITR of the prior sediment transport model prepared by GRDA's consulting team in furtherance of the Sedimentation Study.

- ***Attachment 3****—Updated Study Plan:* This document, filed as a replacement of GRDA's previously filed PMSP, sets forth GRDA's proposed study plan and methodologies for sediment transport for the second study season.

In developing this compromise proposal set forth in the USP, GRDA acknowledges and appreciates the significant efforts of the City and its consulting team to review and comment on the PMSP. To be sure, there remains significant disagreement between GRDA and the City on many technical aspects of the Sedimentation Study, underlying scientific principles, fieldwork performed, and the reliability of certain datasets—as detailed in Attachment 1. Despite these differences and imperfections in the historical datasets that will limit the proposed STM's predictive capability, GRDA is hopeful that the compromise proposal set forth in the USP will be approved by Commission staff as a technically and scientifically sound compromise solution that will yield important and reliable information on sedimentation in the Project reach of the Grand/Neosho River and its tributaries and as meeting the goals and objectives of the Sedimentation Study.

To allow the important work contemplated in the Sedimentation Study to move forward in a timely manner for reporting in the Updated Study Plan, GRDA respectfully requests Commission staff to approve the USP by May 27, 2022, as contemplated in its February 24 Determination.

If you have any questions, please contact Jacklyn Jaggars at jacklyn.jaggars@grda.com.

Sincerely,

Brian Edwards
Executive Vice President
Lake Operations and Law Enforcement

Attachments

ATTACHMENT 1

GRDA Response Comments on Sedimentation Study Plan

April 2022
Pensacola Hydroelectric Project No. 1494 FERC Relicensing

GRDA Response Comments on Sedimentation Study Plan

Prepared for
Grand River Dam Authority
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TABLE OF CONTENTS

TABLES

FIGURES

ABBREVIATIONS

ADCP	acoustic Doppler current profiler
cfs	cubic feet per second
City	City of Miami, Oklahoma
Cs-137	Cesium-137
EWI	equal-width-increment
FERC	Federal Energy Regulatory Commission
FIS	Flood Insurance Study
GRDA	Grand River Dam Authority
IHO	International Hydrographic Organization
ITR	Independent Technical Review
mm	millimeter
OWRB	Oklahoma Water Resources Board
PD	Pensacola Datum
PMSP	Proposed Modified Study Plan
Project	Pensacola Hydroelectric Project No. 1494
REAS	Real-Estate Adequacy Study
RM	river mile
SEWI	single equal-width-increment
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
USGS	U.S. Geological Survey
USP	Updated Study Plan
WEST	WEST Consultants Inc.
WSE	water surface elevations

1 Introduction

On December 29, 2021, Grand River Dam Authority (GRDA), licensee for the Pensacola Hydroelectric Project No. 1494 (Project), filed with the Federal Energy Regulatory Commission (FERC) and distributed to relicensing participants a final Sedimentation Study that reported on the first season of study and proposed modifications to the FERC-approved plan for the second study season. In the December 2021 final Sedimentation Study report, GRDA's proposed changes were included in a Proposed Modified Study Plan (PMSP). Following its filing and distribution of the Sedimentation Study PMSP, GRDA held a voluntary Technical Meeting in January 2022—which was above the requirements of FERC's Integrated Licensing Process regulations but was important to facilitate review the PMSP and allow an opportunity to address questions from FERC staff and relicensing participants.

On February 24, 2022, FERC issued its Determination on Requests for Study Modification and New Studies for the Pensacola Hydroelectric Project. FERC's February 2022 Determination did not rule on GRDA's PMSP for the Sedimentation Study. Rather, FERC established a 30-day period for relicensing participants to review and comment on the PMSP, followed by a 30-day comment period for GRDA to respond to comments. This GRDA Response Comments on Sedimentation Study Plan (Response), has been prepared as directed by FERC staff in its February 2022 Determination.

GRDA received extensive comments on the PMSP from the City of Miami, Oklahoma (City). The City filed an initial set of comments on January 24, 2022, followed by a supplemental filing on March 28, 2022. No other relicensing participant filed comments on GRDA's PMSP for the Sedimentation Study.

Since filing the Sedimentation Study report in December 2021, GRDA's work on this study has continued. Recognizing the significant complexity of this study—and the varying viewpoints between the experts retained by GRDA and the City, GRDA decided to retain WEST Consultants Inc. (WEST) to review the Sedimentation Study report and PMSP and prepare an Independent Technical Review (ITR). WEST's ITR is being filed with FERC concurrent with this concurrently with this Response. Based on WEST's ITR, the City's comments on the PMSP, and further analysis by GRDA's Sedimentation Study consulting team, GRDA has developed a proposed compromise solution in an effort to resolve the impasse between GRDA and the City while still meeting the FERC-approved objectives of the Sedimentation Study. In lieu of the PMSP, GRDA proposes to use the sediment modeling approach using HEC-RAS, while considering the complexities of the silts and clays dominating the system. The specific methods of this compromise proposal are detailed in the Updated Study Plan (USP), which also is being filed with FERC concurrent with this Response.

At the outset of this Response, GRDA acknowledges the significant efforts of the City and its consulting team to review and comment on the PMSP. As detailed below, there remains significant disagreement between GRDA and the City on many aspects of the Sedimentation Study, underlying scientific principles, field work performed, and the reliability of certain datasets. As a matter of necessity to protect the administrative record and be responsive to FERC's February 2022 Determination, GRDA responds to these issues in this Response, including a detailed comment and response table in Appendix A. Despite the significant differences between GRDA and the City, GRDA has developed the USP in a good-faith effort to find a compromise solution that is intended to yield important and reliable information on sedimentation in the Project reach of the Grand/Neosho River and its tributaries—within the significant limitations of the available datasets.

Overall, the impasse between GRDA and the City can be summarized as follows: The City has expressed a view that the sediment on the Neosho River at the upper end of the reservoir has resulted in increased flood risk for the City. The City has asserted that reservoir operations have led to significant deposition at the upper end of the reservoir and relies heavily on the Grand Lake Real Estate Adequacy Study (REAS) dataset to support its claim that 20 to 30 feet of sand- and gravel-sized sediment deposited in the area during the 11-year period between 1998 and 2009.

For the reasons detailed in this Response filing, GRDA contends that the available evidence does not support the City's claims, and that it is unreasonable to expect that volume of sediment to accumulate in such a short amount of time. After thoroughly reviewing the City's comments and obtaining WEST's ITR, GRDA has concluded that the City's position is fatally flawed in several key respects:

- The City is mistaken in its view that the REAS dataset is valid throughout the study area and specifically in the region of the upper end of the reservoir, where a delta feature has formed.
- The City's criticisms of the 2009 Oklahoma Water Resources Board (OWRB) and 2019 U.S. Geological Survey (USGS) datasets are invalid.
- The City's allegations that GRDA's sediment transport sampling was inadequate are speculative, unsupported by GRDA's reporting, and wholly inaccurate.

These and other issues related to the dataset validity, field work performed, and STM calibration are explained in the sections that follow, with more detailed, technical responses to the City's comments appearing in the Appendix A comment and response table.

2 Typical Sediment Transport Processes

The basis for GRDA's PMSP, as well as certain elements of the proposed compromise solutions in the USP, requires an understanding of standard fluvial and reservoir functions. Water in rivers transports sediment downstream. When conditions such as sediment input or inflow within a stream change, sediment may settle on the streambed or the stream may erode material from the bed and banks and transport it further downstream. These changes influence where sediment is transported or accumulates in the river system.

River confluences, channel expansions, impounded areas, and slope decreases reduce water flow velocities and its kinetic energy. This reduced energy often results in decreased sediment transport capacity and causes sediment to deposit in the river. These natural processes can create bars, mudflats, and other depositional features in the river channel (Simons and Senturk 1992).

Coarser sediment material such as cobbles and gravel require more energy to transport than finer material such as sand, silt, and clay, which means they are deposited first when stream energy decreases. As water flows further into a reservoir or channel expansion, it is common to see deposited material transition from coarse to fine sediments, with silts and clays carried the furthest, as less energy is required to transport these finer-grained particles downstream.

2.1 Sediment Transport

Sediment moves downstream in one of two ways. Finer materials like fine sand, silts, and clays tend to move as suspended load while larger material like cobbles, gravels, and coarse sands skip, slide, or roll on the riverbed and move as bedload.

As particles move, they wear, becoming more rounded and smoother. The sediment in the study area does not fit this description; it is not rounded. Instead, it tends to be angular and sharp, suggesting it has not repeatedly bounced along the riverbed or against other stones and hard materials. That means it is not consistently moving through the system as bedload. Figure 1 displays typical sediment found on riverbeds in the study area.

Figure 1
Typical Sediment on Riverbeds in Study Area

2.2 Typical Delta Formation and Evolution

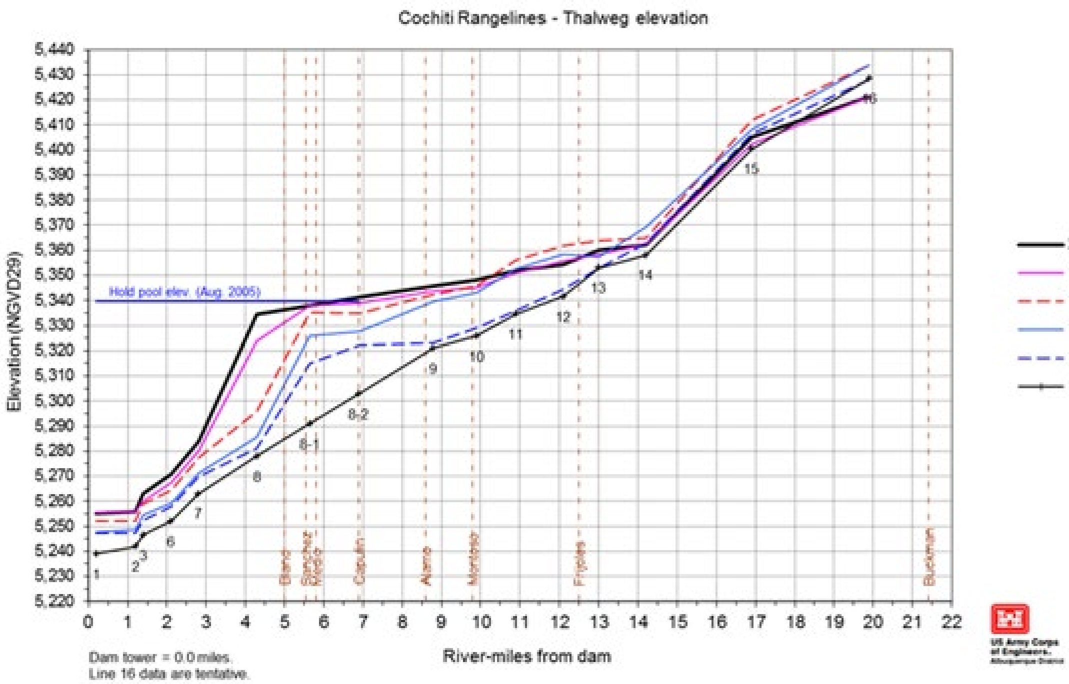
Understanding the reservoir and the associated feature that previously has been referred to as the "hump" from approximately the Twin Bridges area to the confluence of the Elk River is crucial for the sedimentation study. This requires an examination of typical delta formations and how deltas evolve over time. In its comments, the City claims that the delta feature accumulated between 1998 and 2019, despite presenting no evidence of operational changes or sediment loading that would explain 58 years of stable channel geometry resulting in virtually no sedimentation during almost 50 years following dam construction (1940 to 1998), followed by sudden and rapid accumulation of sediment in just 11 years (1998 to 2009). The City's claim contradicts the text of the REAS, defies logic, and ignores the available body of evidence regarding reservoir delta formation and evolution.

Deltas are areas of sediment deposition that tend to accumulate in places where water velocities are reduced and sediment-carrying capacities decrease. The processes that create them can be amplified by river features such as confluences, channel constrictions or expansions, dams, and major changes in depth. As water is constricted and/or impounded, water velocities reduce and the heavier, coarser sediment stops being transported downstream.

Regarding reservoir deltas, as water moves further into the reservoir, flow velocities continue to decrease, allowing gradually finer sediments to settle on the bed. This process creates a reservoir delta and typically begins soon after completion of the impoundment and continues throughout the life of the dam.

As deltas grow in height with continued sediment deposition, the channel flow area decreases, resulting in increased velocities that are more capable of transporting sediment downstream. Based upon changes in inflow and sediment supply, the height of the delta can both increase and decrease over time. Low inflows can allow the delta to grow and begin to reduce the channel cross-sectional area. As the channel cross-sectional area is reduced, the velocity of the flowing water increases and scours an appropriately sized channel cross-section. Similarly, a high inflow event can reduce the size of the delta because it requires a larger channel cross-section to move high inflows through the channel. Then under successive low inflow events it rebuilds itself until the next high inflow event occurs and again reduces its size to make room in the channel to pass the high inflows. Through these natural processes, reservoir deltas are in a continuous state of dynamic equilibrium. In dynamic equilibrium, the river can transport the inflow sediment load without pronounced changes in width, depth, and slope over long time scales. Additional material washes further downstream, depositing on the downstream face of the delta rather than on the top. This textbook pattern is discussed by Vanoni (2006), Morris and Fan (2010), and others, and it is shown in progressive surveys of Cochiti Reservoir in Figure 2.

Figure 2
Typical Reservoir Delta Formation and Evolution—Progressive Bathymetric Surveys of the Cochiti Reservoir Delta, Rio Grande River, New Mexico

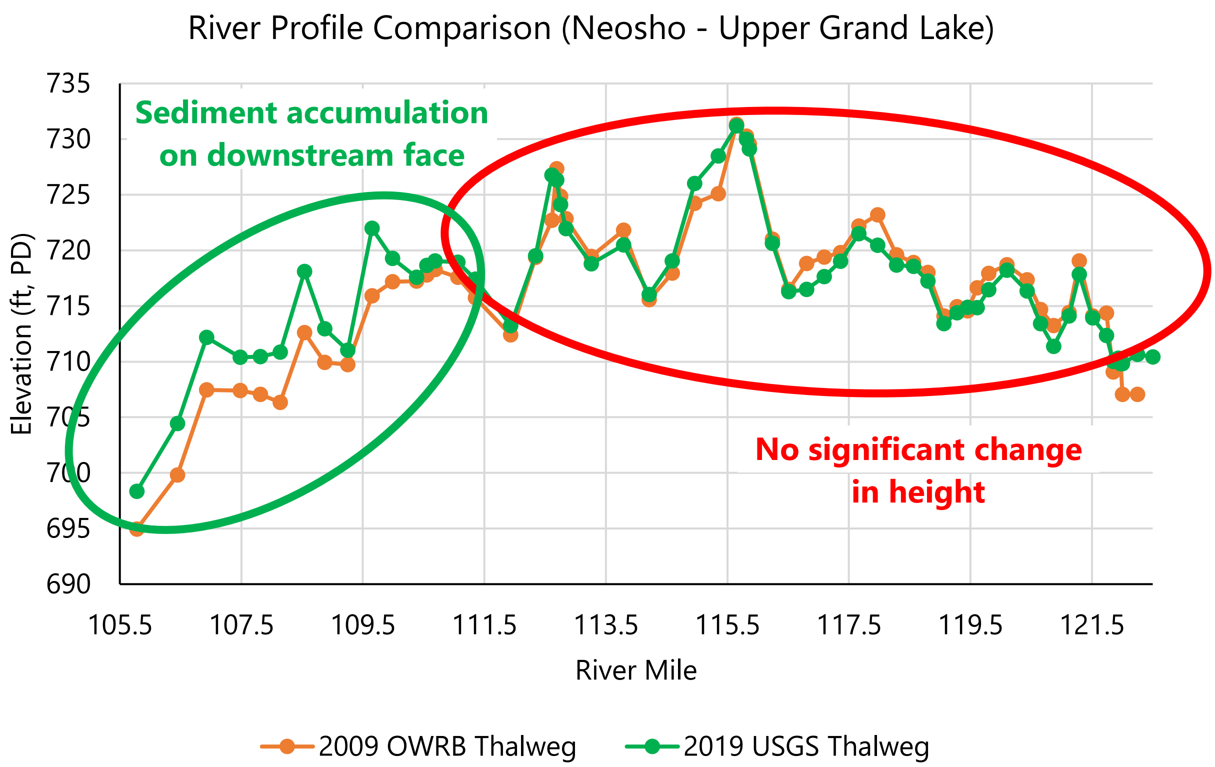


Source: WEST (2012)

Note specifically that the delta height in Cochiti Reservoir remained nearly constant between 1991 and 2005, with sediment accumulating on the downstream face rather than on the top of the delta. This is typical of delta features and what has been shown to occur in many reservoirs.

The Grand Lake bathymetric surveys of 2009 and 2019 in the region of the delta feature at issue here show that sediment is accumulating on the downstream face of the delta feature (Figure 3), extending further into the reservoir, exactly as predicted by normal delta feature evolution (Vanoni 2006; Morris and Fan 2010). The delta feature has not grown appreciably in height over the previous 10 years because the surface sediments have a critical shear stress approximately equal to the bed shear stresses that are present at that location.

Figure 3
Upper Grand Lake Thalweg Comparison



2.3 Reservoir Sedimentation Complexities

The primary objectives of the FERC-approved Sedimentation Study for the Project's relicensing are to develop a sediment transport model (STM) using available historical bathymetry data and sediment information to reasonably match the historical sedimentation patterns in Grand Lake and associated tributaries.

GRDA will develop future flow scenarios to predict future sedimentation patterns that may occur during proposed operations. The predicted sedimentation patterns will then be used to see if any changes to flooding in the reservoir occur with the predicted future sedimentation patterns.

Prior to the first study period, it was believed that the majority of sediment in the reservoir was sand and gravel that does not clump together (non-cohesive sediments). However, in the first study period, field sampling of bed material and sediment transport (suspended and bedload) field measurements showed most of the reservoir sediment was silt and clay that clumps together (cohesive sediments). This finding was not expected based on information provided to FERC by others prior to the first study period. GRDA collected additional field samples and made additional laboratory measurements. The additional laboratory measurements helped explain how the silts and clays behaved when carried downstream and deposited, which is very different from how sands and gravels behave.

Laboratory measurements of the silt and clay (cohesive) samples showed wide variability in the key parameters: sediment density (485% range), critical shear stress (3,000% range), and erosion rate (1,000,000% range). Bed material sizes also cover a range of 5 orders of magnitude or 1,000,000% range.

The cohesive sediment parameterizations used in HEC-RAS only allow selection of two values for critical shear stresses and erosion rates at any point. Selecting just two values from such a wide range of potential parameters overly simplifies transport modeling and decreases confidence in the accuracy of simulation results.

In addition, cohesive sediment transport deep into reservoirs can be dominated by phenomena not accounted for in HEC-RAS. This includes density currents and mud flows, which can transport cohesive material far into a reservoir even with very low bed shear stresses and bed slopes (Lumborg and Vested 2008; van Rijn n.d.; Zavala 2020).

The wide range in properties of the silts and clays and the complex processes regulating their movement within Grand Lake prevented development of an accurate and scientifically defensible STM using HEC-RAS during the first study period. Therefore, GRDA developed and proposed a different approach and submitted the PMSP as part of its December 2021 submittal to FERC.

The approach suggested in the PMSP expanded on the original plan and included the laboratory findings for the properties of silts and clays. Although the PMSP approach did not directly use HEC-RAS to simulate sediment transport, the advantage was it focused on using direct field data comparing sedimentation patterns by using the 2009 to 2019 depth data, historical flow data, sediment rating curves based on the suspended sediment measurements and the hydraulic shear stress distributions from 2009 to 2019 from a HEC-RAS hydraulic model. This approach avoided the problem of representing the wide ranges of sediment properties found in the silts and clays within a model that uses simplistic routines to simulate cohesive sedimentation patterns.

Unfortunately, the City in its comments has strongly objected to the PMSP, instead favoring the STM using HEC-RAS approach approved by FERC in its original November 2018 Study Plan Determination. Recognizing this impasse, GRDA contracted with WEST to prepare an ITR and assist in developing a compromise solution that would entail a STM using HEC-RAS, while still recognizing the significant challenges of modeling cohesive sedimentation patterns, particularly deep into Grand Lake, and recognizing that silts and clays dominate this system.

This has led to the approach defined in the USP that is being filed with FERC concurrent with this Response. A summary of the USP is also provided in Section 7 of this Response.

3 Delta Feature Analysis

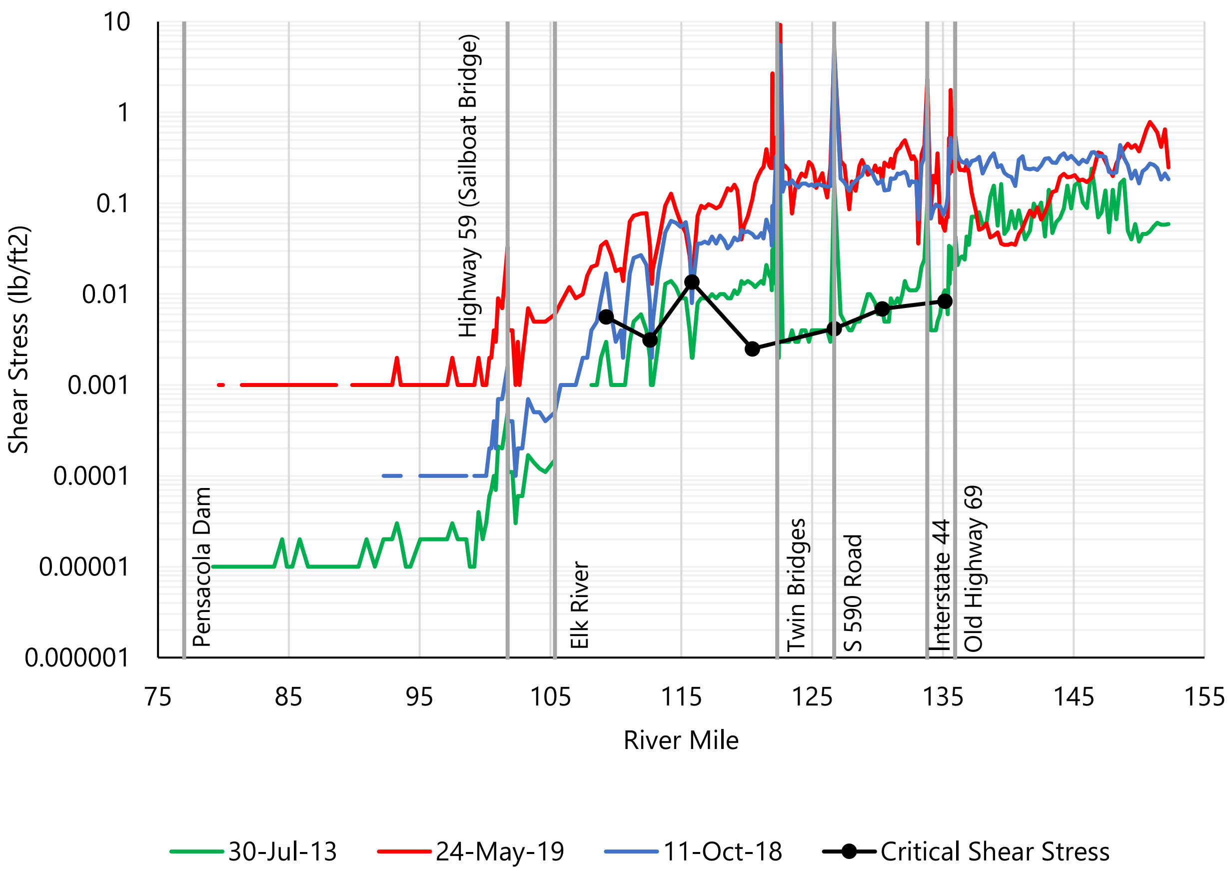
GRDA has performed several analyses of the delta feature formation at issue here and associated sediments. The findings are summarized in Sections 3.1, 3.2, and 3.3 and have demonstrated the delta feature is in a state of dynamic equilibrium and will not substantially increase in height over time.

3.1 Critical Shear Stress Evaluations

As discussed, deltas and other depositional features grow until they reach an equilibrium height. That height is determined by hydraulic shear stresses and the critical shear stress of sediment. When those values are approximately equal, sediment is conveyed over the top of the delta and deposits on the downstream face. GRDA collected sediment samples to evaluate critical shear stress and have STM results that provide bed shear stress information. These results were presented in the December 2021 Sedimentation Study report (see Section 5.2.1) and again at the January 2022 Technical Meeting.

Typical bed shear stresses in the STM are approximately equal to sediment critical shear stresses measured with SEDflume analysis, indicating a dynamic equilibrium state and the sediment being conveyed downstream rather than depositing on top of the delta (Figure 4). This shows the delta has reached that equilibrium height and will extend further into the reservoir rather than increase in height.

Figure 4
Modeled Hydraulic Shear Stress Compared to Critical Shear Stress of Upper Layer of Deposited Sediment



Notes:

Modeled bed shear stresses are shown in green, red, and blue for the 30 JUL 2013 (4,320 cubic feet per second [cfs]), 24 MAY 2019 (90,100 cfs), and 11 OCT 2018 (30,500 cfs) events, respectively. Measured critical shear stresses of sediment samples shown in black.

The green line represents typical flow conditions while the red and blue lines represent higher discharge conditions.

The delta feature is located between Twin Bridges and the Elk River (approximately river mile [RM] 122 and 105, respectively).

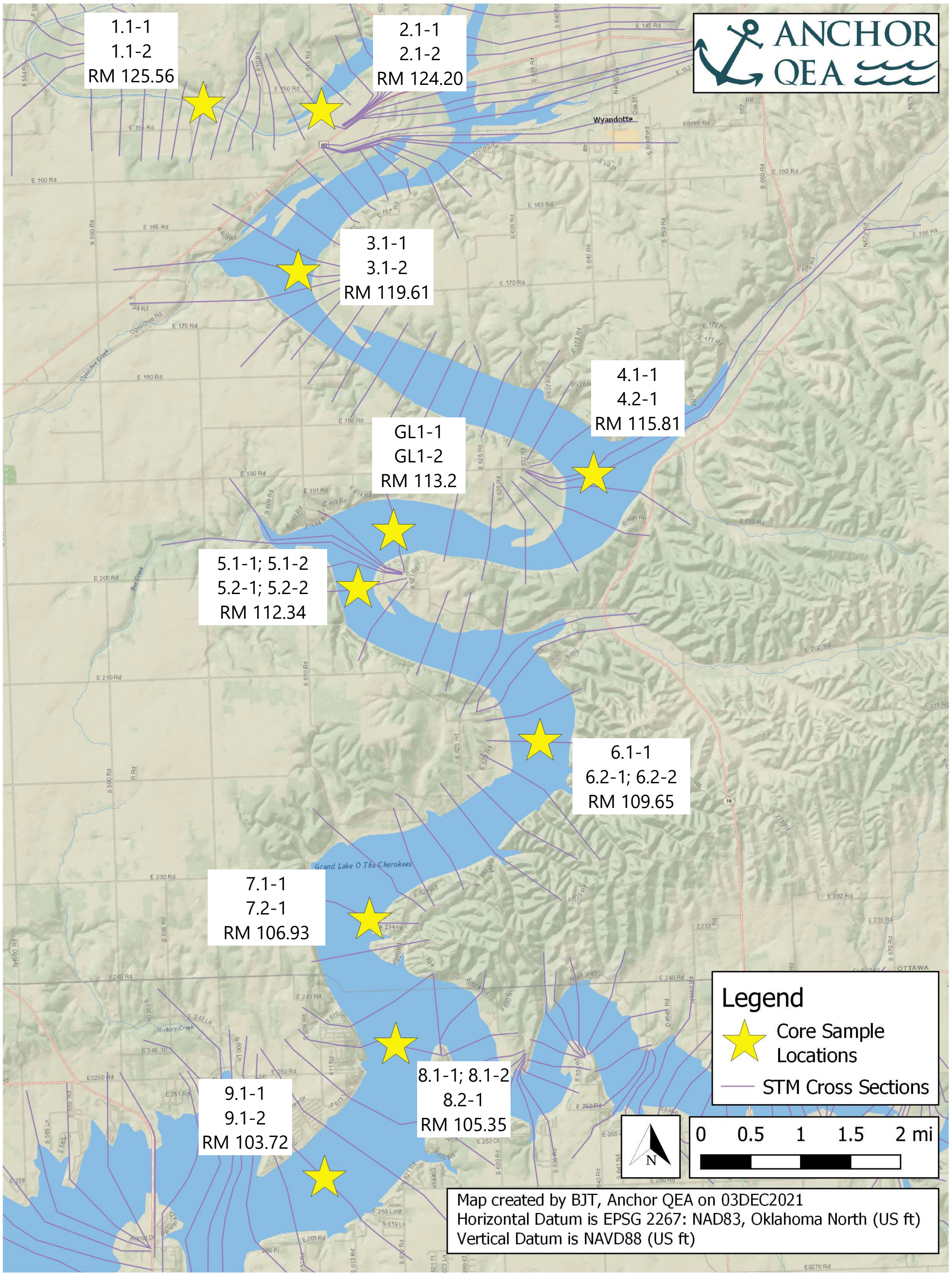
As shown in Figure 4, the modeled bed shear stresses at average conditions (green line) are approximately the same as the measured critical shear stresses (black line). Under lower-flow conditions, the sediments will potentially deposit. Then, during high-flow events (red and blue lines), the modeled bed shear stresses are higher, which means the deposited silts and clays will be eroded and wash downstream.

This matches textbook evolution patterns of reservoir deltas, which state the delta will continue to grow downstream, not vertically, over time (Vanoni 2006; Morris and Fan 2010).

3.2 Cesium-137 Analysis

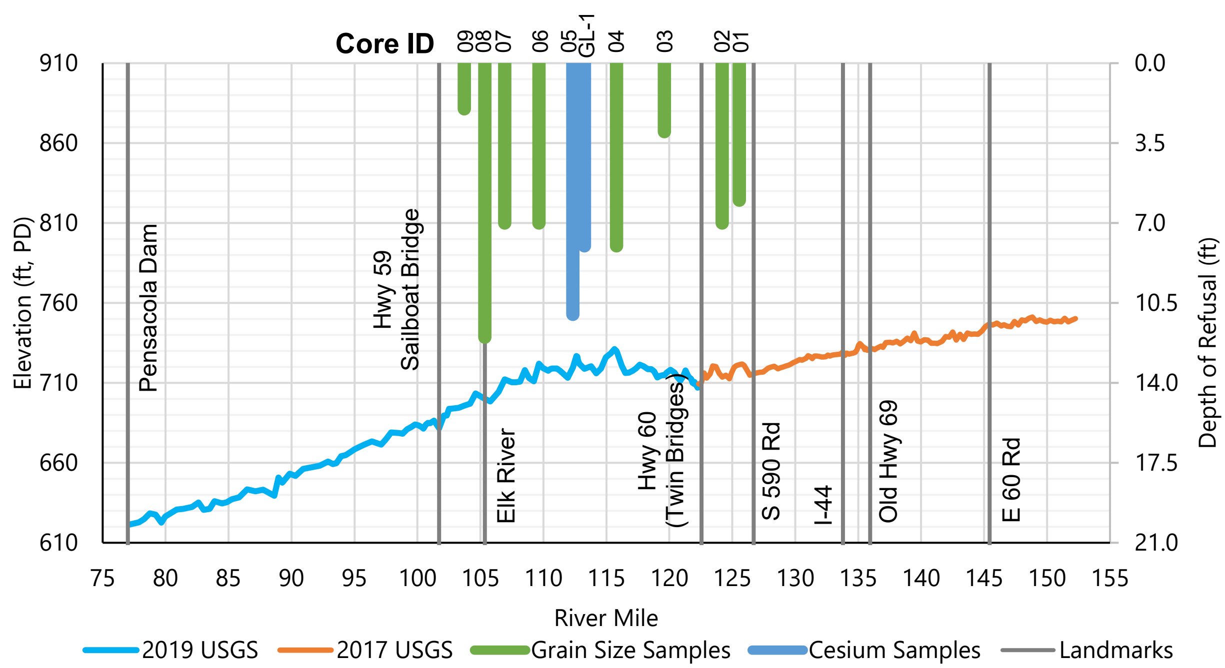
Historical and current coring investigations have shown similar results with regard to the delta feature's evolution. GRDA collected sediment core samples at ten locations within the region of the delta feature using a vibracore (Figure 5). The vibracore pushed core tubes into the riverbed, with a maximum penetration depth of approximately 11 feet in the delta feature region (Figure 6).

Figure 5
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. 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 (river mile [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 6 shows the maximum vibracore penetration depths at each site shown in Figure 5.

Figure 6
Maximum Vibracore Sample Penetration on Neosho River



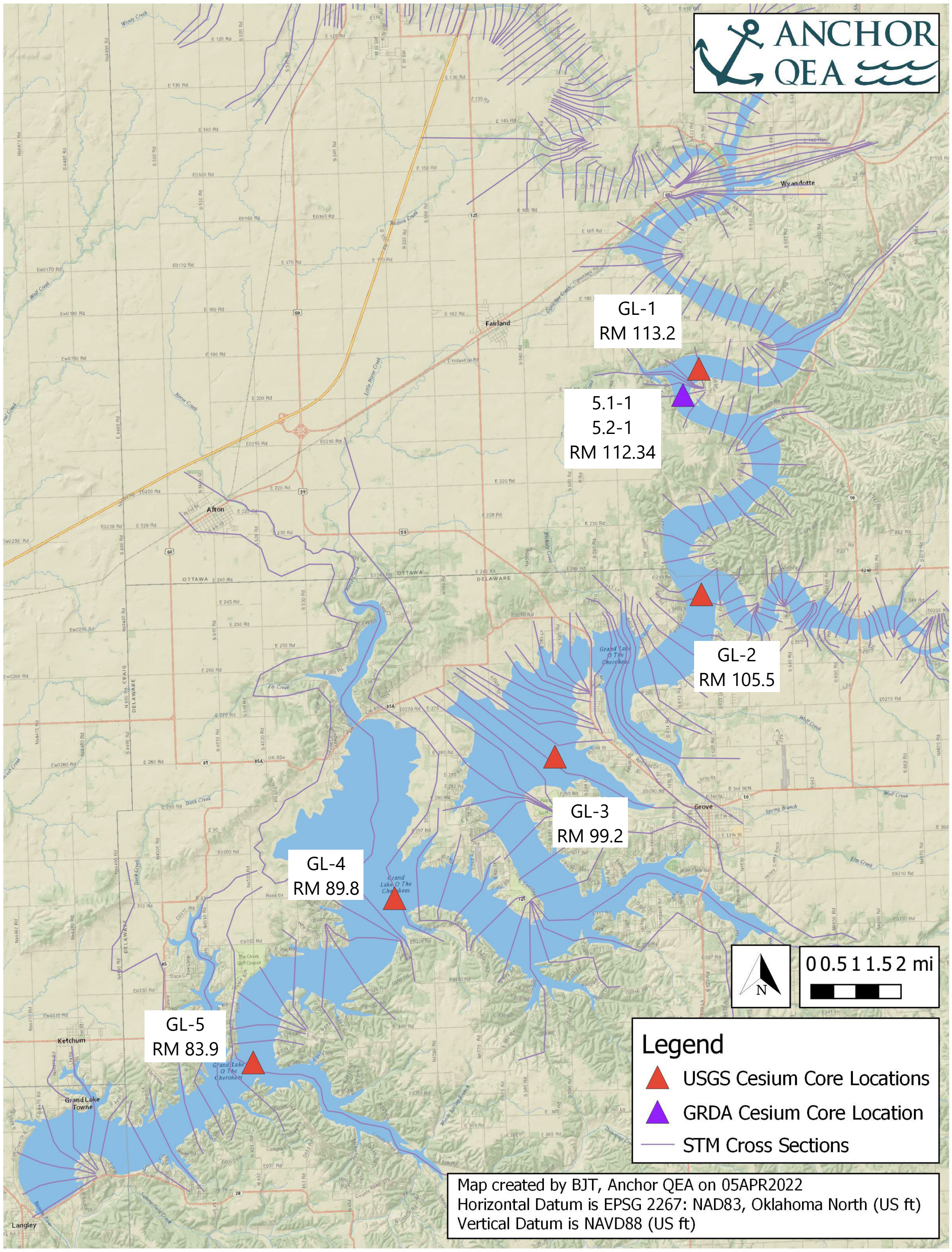
Note: GL-1 sample tested for cesium activity by USGS (Juracek and Becker 2009)

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 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 7).

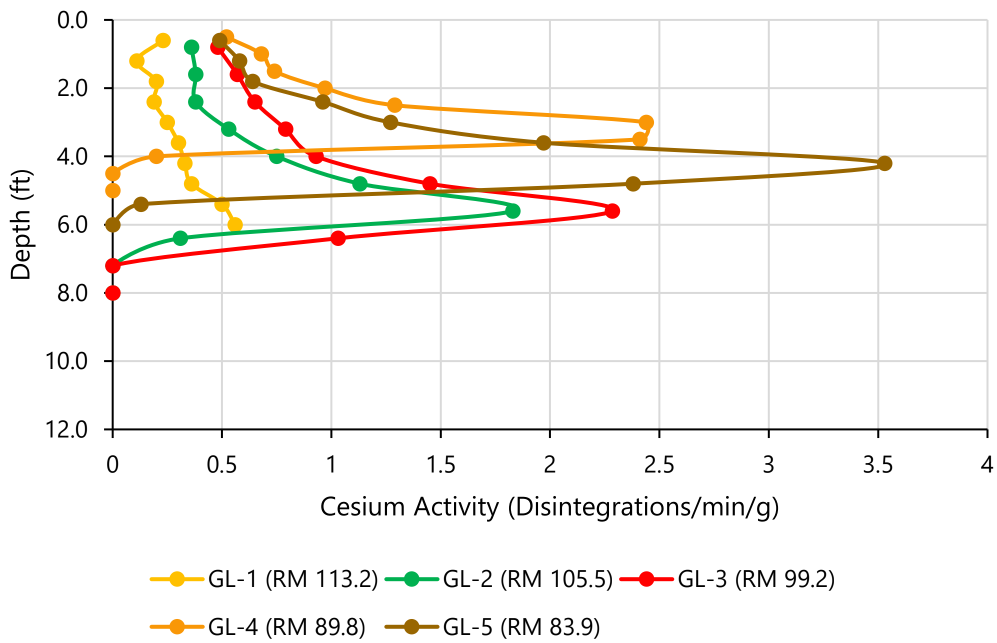
Figure 7
Locations of Sediment Cores Collected for Cesium Analysis



Note: Locations of USGS cores taken from Juracek and Becker (2009)

USGS analysis showed that Cs-137 peaks were located approximately 3 to 6 feet below the bed surface (Figure 8). 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
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.

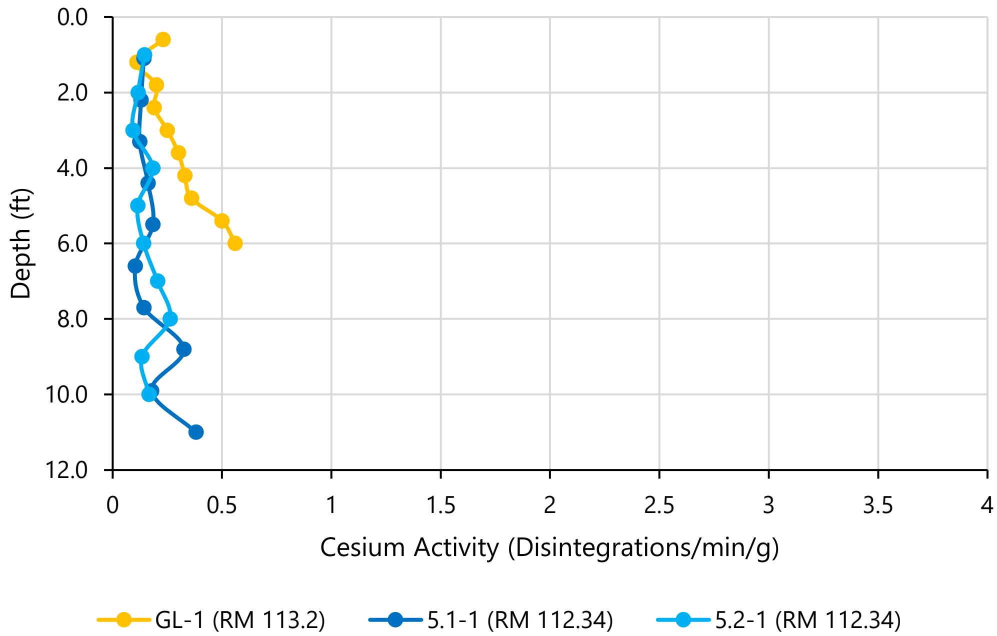
Source: Figure adapted from Juracek and Becker (2009).

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 7.

GRDA sent ten 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 9).

Figure 9
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.

3.3 Grain Size Analysis

The vibracores that were not submitted for CS-137 analysis were divided into 1-foot increments and sent to a laboratory for grain size distribution analysis. This consists of two primary assessments. The first is a hydrometer analysis; it determines the portion of each sample that falls into sand, silt, or clay size ranges. The second is a sieve test where the sediment samples pass through progressively finer meshes. The sieve test provides information about grain sizes in the non-cohesive range (gravels and sands).

Vibracore samples were evaluated using the hydrometer method (Bouyoucos 1962) to determine the percentage of samples that consisted of cohesive material (silt and clay). Preliminary results for this test have been completed and are presented in Appendix C. They showed that samples were on average approximately 50% silt and 39% clay, with just 11% of the total being sand. This confirms GRDA's other data collection demonstrating that much of the material deposited in the delta feature is fine, cohesive material, which may limit the accuracy of HEC-RAS for sediment transport modeling in this reach.

The large portion of cohesive material in this area contributes to uncertainty of STM predictions. However, the primary concerns with the limited cohesive sediment parameterizations in HEC-RAS are density currents and other phenomena that are more important in the wide portions of the lower reservoir. GRDA believes that an STM can be used to simulate sediment transport in the more confined reaches above RM 105. As discussed in Section 7 of this Response and in the USP, sensitivity analyses will bound potential sedimentation outcomes to address model uncertainty.

The final results of the sieve assessment are not available at this time as this is an ongoing analysis, but they will be provided with the USR.

4 Available Datasets

Multiple datasets are available for potential use in this analysis. The earliest data are pre-dam information from circa-1940. The most recent dataset was collected in 2019. All datasets considered for the study are discussed below in chronological order.

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. If, for example, 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.

4.1 Circa-1940 Data

The circa-1940 dataset is comprised of three available data sources:

1. 1938 U.S. Army Corps of Engineers (USACE) topographic maps with 5-foot contours
2. 1941 USACE Pensacola Reservoir Envelope Curve computation folder
3. 1942 USACE Pensacola Reservoir Revised Envelope Curve computation folder

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.

Since the ***known date*** of the data collection can be established, these three data sources will be 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 pre-dam conditions and proposes to use it as the basis for model development in the USP.

4.2 1969 USACE Data

During the Sedimentation Study Technical Meeting, the 1988 Flood Insurance Study (FIS) was mentioned as a potential source for historical bathymetric information. GRDA reviewed the FIS and found that the bathymetry came from a 1969 USACE study. 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 are too small for use in STM calibration and validation.

4.3 1996 Expert Report

The 1998 Real Estate Adequacy Study (REAS) states that modeling data (i.e., bathymetry) from Pensacola Dam to Twin Bridges State Park was 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 from USACE. There were three presentations of bathymetric data 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. Results of the comparison are displayed in Figure 10. The 1998 REAS claims that data below Twin Bridges was 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.

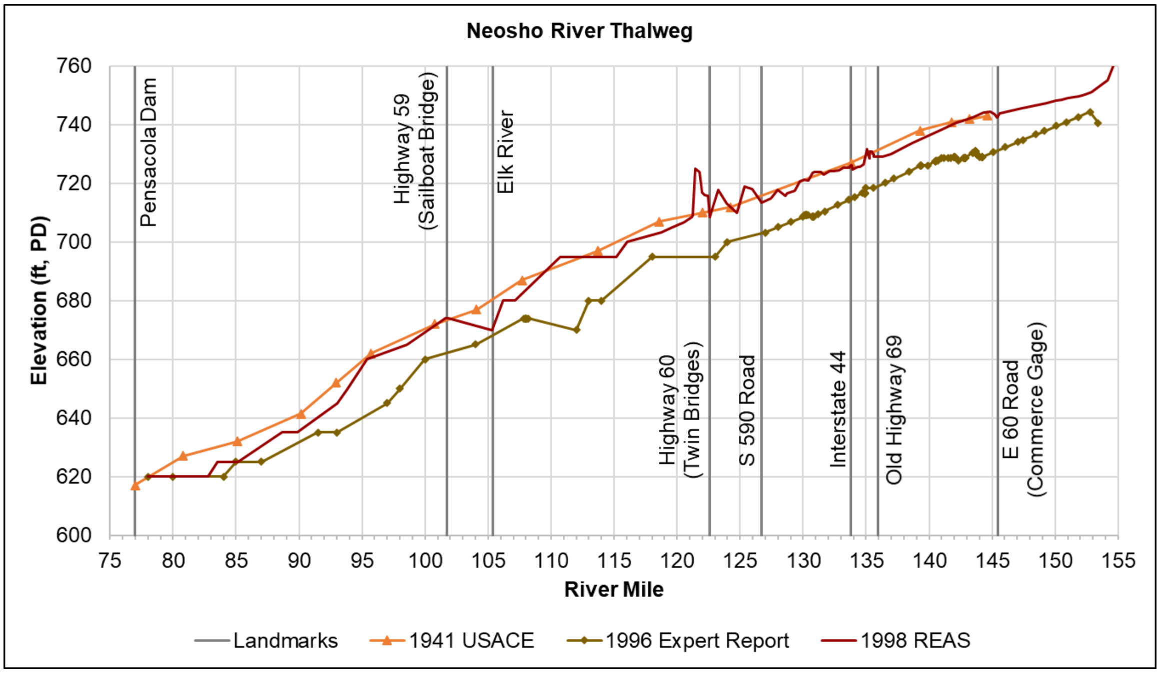
The 1996 Expert Report profile was also compared to the 1941 Envelope Curve profile to see if the 1996 data originated from the 1941 data. The 1941 profile is also displayed in Figure 10. The 1996 and 1941 data are significantly different from each other. Furthermore, the 1996 Expert Report thalweg is 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.

In 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, 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 data 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 must discard the 1996 Expert Report Data.

Figure 10
1996 Expert Report Thalweg Comparison



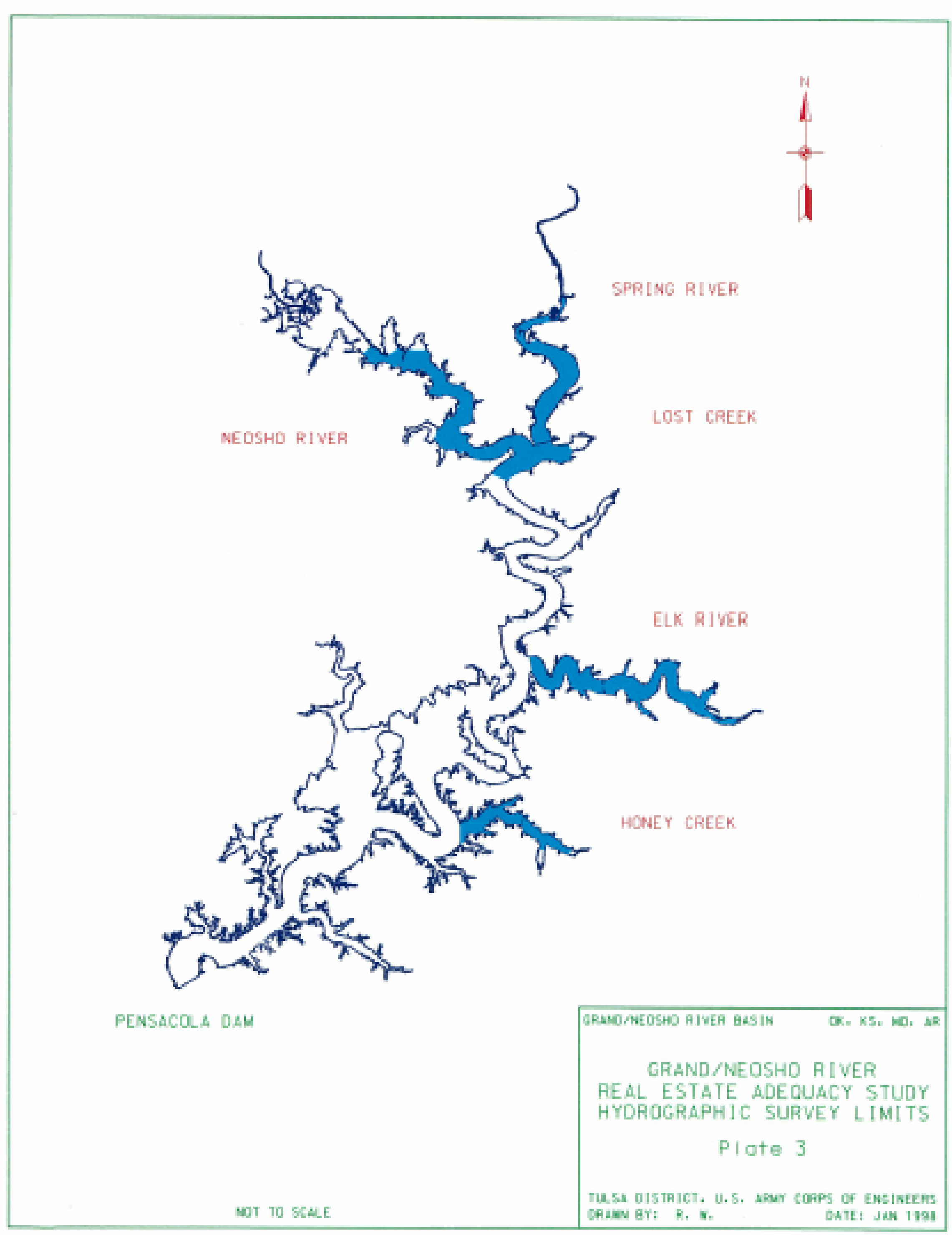
4.4 1998 Real Estate Adequacy Study Data

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

4.4.1 Grand/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 11.

Figure 11
Hydrographic Survey Limits for REAS



Source: USACE (1998)

As discussed in Section 4.3, the 1998 REAS claim that the downstream data came from the 1996 Expert Report has been invalidated by comparing the two datasets. This fact calls the validity of the REAS downstream data into question. Furthermore, that means that 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 typical reservoir sedimentation patterns.

In 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. For the downstream REAS data to be valid, unrealistic erosion would have had to occur.
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 must discard the downstream portion of the REAS data.

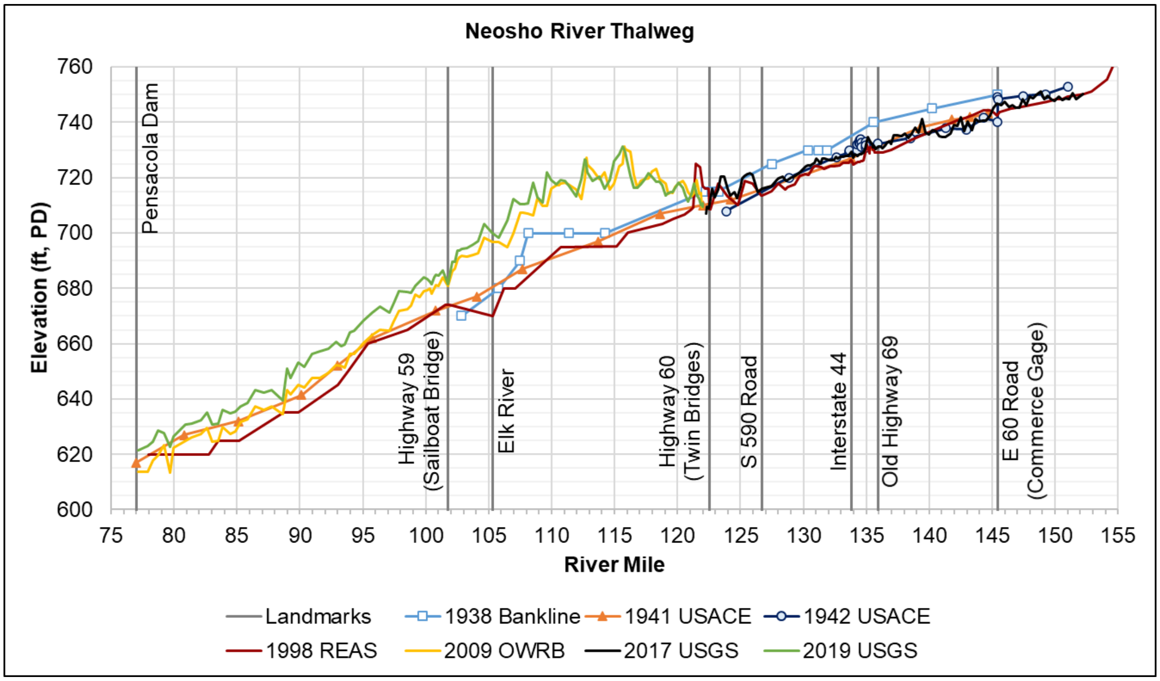
4.4.1.1 The City's Claims Regarding the Downstream Data

The City of Miami has used the downstream portion of the REAS data to make unsubstantiated claims regarding sedimentation rates and patterns in the study area. The City claims that "comparison of the pre-dam river profile with recent bathymetric surveys indicates significant sediment deposition near the head of Grand Lake," and then jumps 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 covers Grand Lake and extends upstream to RM 120.1. As discussed in Section 4.4.1, 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 has investigated the City's claims regarding sediment deposition in the study area.

Figure 12 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 since the dam was constructed in ways that cannot be explained solely by the construction of the dam or Project operations.

Figure 12
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 12, 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 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:

1. From 1940 to 1998, sediment tended to erode in the delta feature region and tended to erode 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 about 11 years.
3. From 2009 to 2019, virtually no sediment deposited on the top of the delta feature. Some sediment deposited on the downstream face of the delta feature and deposited further downstream in the reservoir.

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 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 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, 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 if the City's assumptions are correct.

In 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 a presumed (but demonstrably erroneous) 1998 date of the downstream REAS data, which covers Grand Lake and extends up to RM 120.1.
3. The REAS explicitly states that the downstream data are not from 1998.
4. Comparison of the thalweg profiles show the flaws in the City's assumptions.
5. Comparison of sediment delivery to deposition thickness show the flaws in the City's assumptions.
6. The City has offered no scientific explanation for their assumptions.

For these reasons, GRDA cannot accept the City's claim that the downstream portion of the REAS data are from 1998.

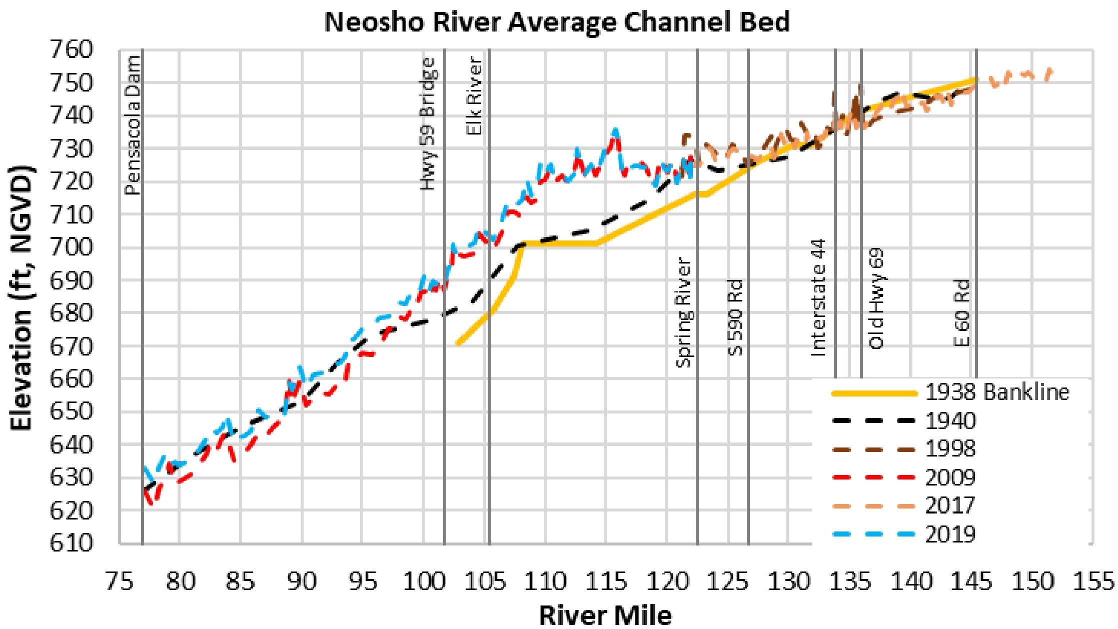
4.4.2 Neosho/Spring Upstream Data

As displayed in Figure 11, 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 used the average channel bed profile to compare several datasets against each other, including the REAS geometry (Figure 13). This method of analysis is more representative of overall channel geometries than the simple thalweg profile, as 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 agrees 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 4.4.4). Thus, there is a significant amount of uncertainty regarding this dataset, which will impact 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. While the upstream REAS dataset meet 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 proposes to use the upstream REAS data for STM calibration and validation.

Figure 13
Historical Neosho River Average Channel Bed Comparison



Source Taken from WEST's ITR.

4.4.2.1 The City's Recommendations Regarding the Upstream Data

Regarding the upstream REAS data, the City states:

> 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 proposes to discard the upstream REAS data, which is at least documented in some form, while keeping the least reliable, incorrectly documented data within the REAS: the downstream data that covers Grand Lake. ***The City proposes 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 prevent GRDA from performing calibration and validation of the STM in the upstream reach. Implementing the City's proposal would result in an STM with less predictive capability.

GRDA rejects the City's proposal to discard the documented upstream portion of the REAS dataset.

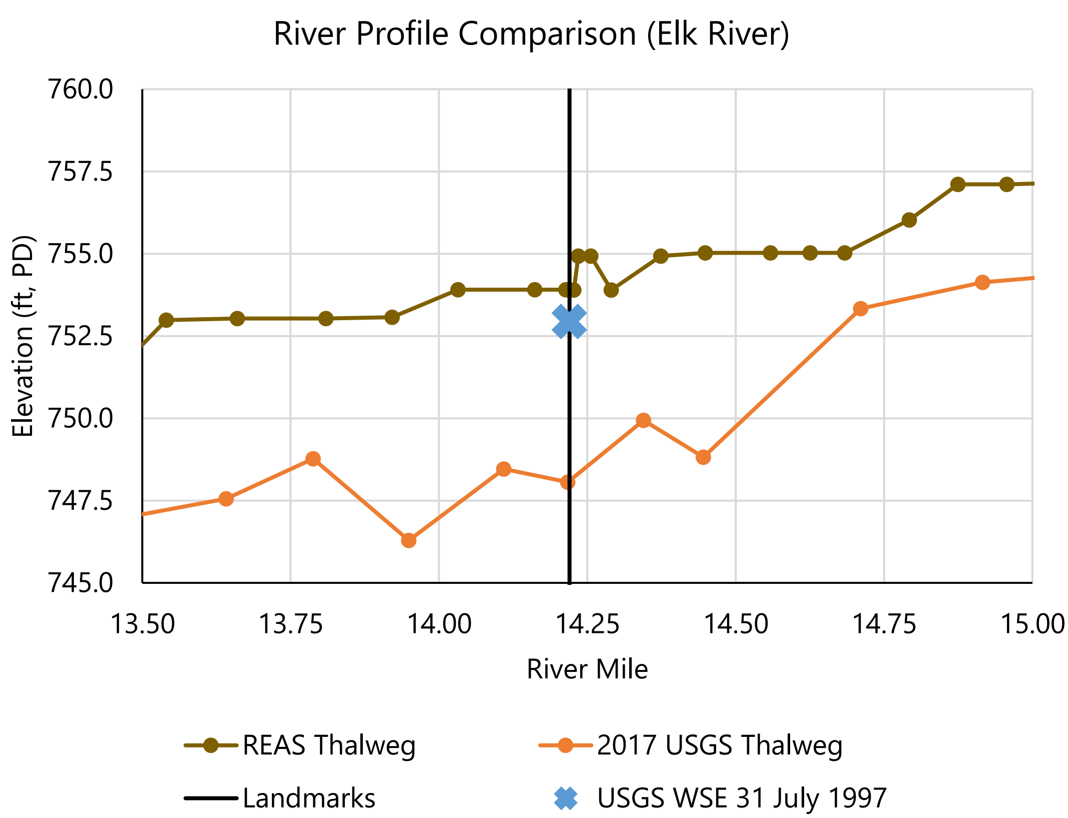
4.4.3 Elk River Data

As displayed in Figure 11, bathymetry on the Elk River was collected as part of the REAS hydrographic survey. However, there are clearly issues with the collected data.

A USGS gaging station (07189000 Elk River near Tiff City, USGS 2021) 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 Pensacola Datum (PD). This is implausible, as that invert elevation is higher than water surface elevations (WSEs) recorded by the USGS. REAS documentation states that the survey was performed in July 1997. The USGS recorded WSEs 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 14). This is clearly an impossible result, as 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.

While the ***known date*** of the data collection has been established, the data itself are not reliable. For these reasons, GRDA cannot use the Elk River REAS data in the STM.

Figure 14
Elk River Thalweg Comparison and WSE Measurement



4.4.4 USACE Stance on Reliability

Given the concerns with the REAS dataset below RM 120.1, GRDA contacted the USACE to discuss the REAS data. David Williams, PhD, PE, CFPM, D.WRE of the Tulsa District stated:

> 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.

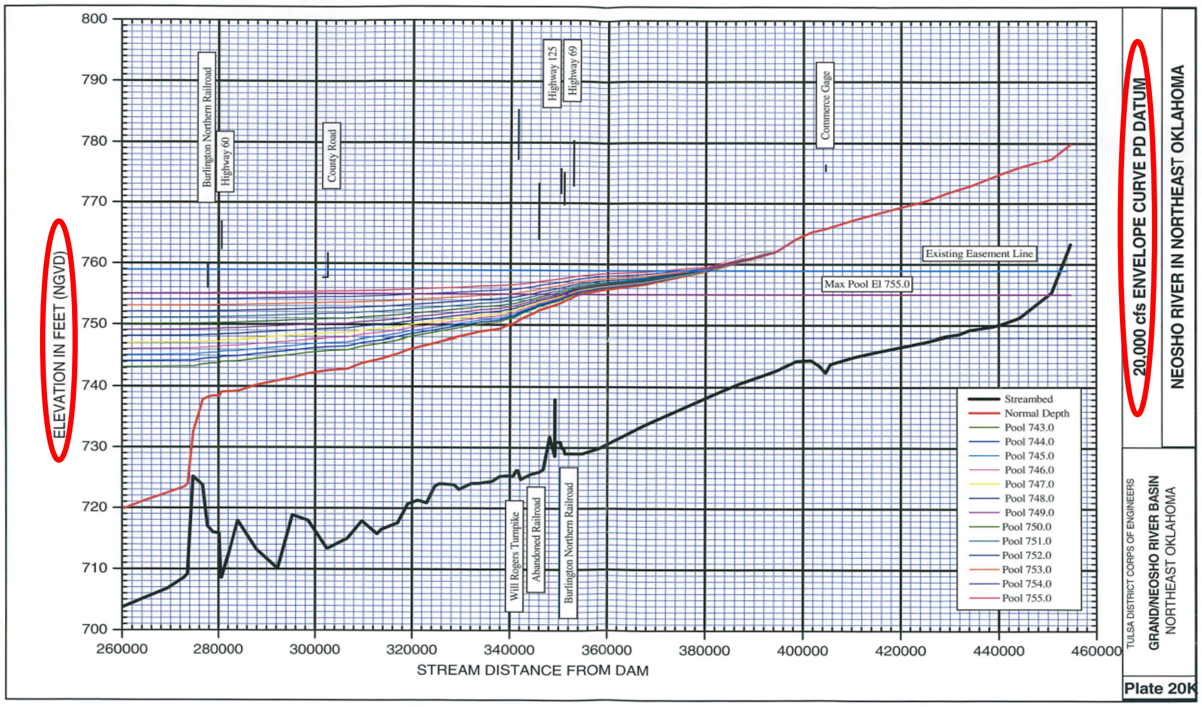
His stated reasons were as follows:

> 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 acknowledges there are problems with the data, suggesting that the datum shift may have been incorrectly applied. In their March 2022 comment submission, the City writes, "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 states that if that issue is resolved, "the REAS dataset probably may be reliable." The City provides 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 agrees that a datum shift is likely one problem with the data, as evidenced by a plot provided by the USACE (Figure 15). 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 that the vertical datum of the displayed data are PD. This type of error (listing two datums on 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 that the City lacks confidence in its own assertion).

Figure 15
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 does not rely on technical criteria. The City cites 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 for legal purposes in the past has no bearing on whether the dataset is reliable or useful for the purposes of this study. The City claims the delta feature was formed in an 11-year span between 1998 and 2009 but, as discussed in Section 4.4.1, 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 asserts that REAS data in the reservoir should be treated as representative of 1998 conditions, completely 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.

In 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 acknowledges that there are issues with the REAS yet provides 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 4.4.1 and the information in this section, GRDA must discard the downstream portion of the REAS data.

4.4.5 Conclusion on 1998 Real Estate Adequacy Study Data Reliability

Portions of the 1998 REAS dataset are usable while other portions are unusable. In summary:

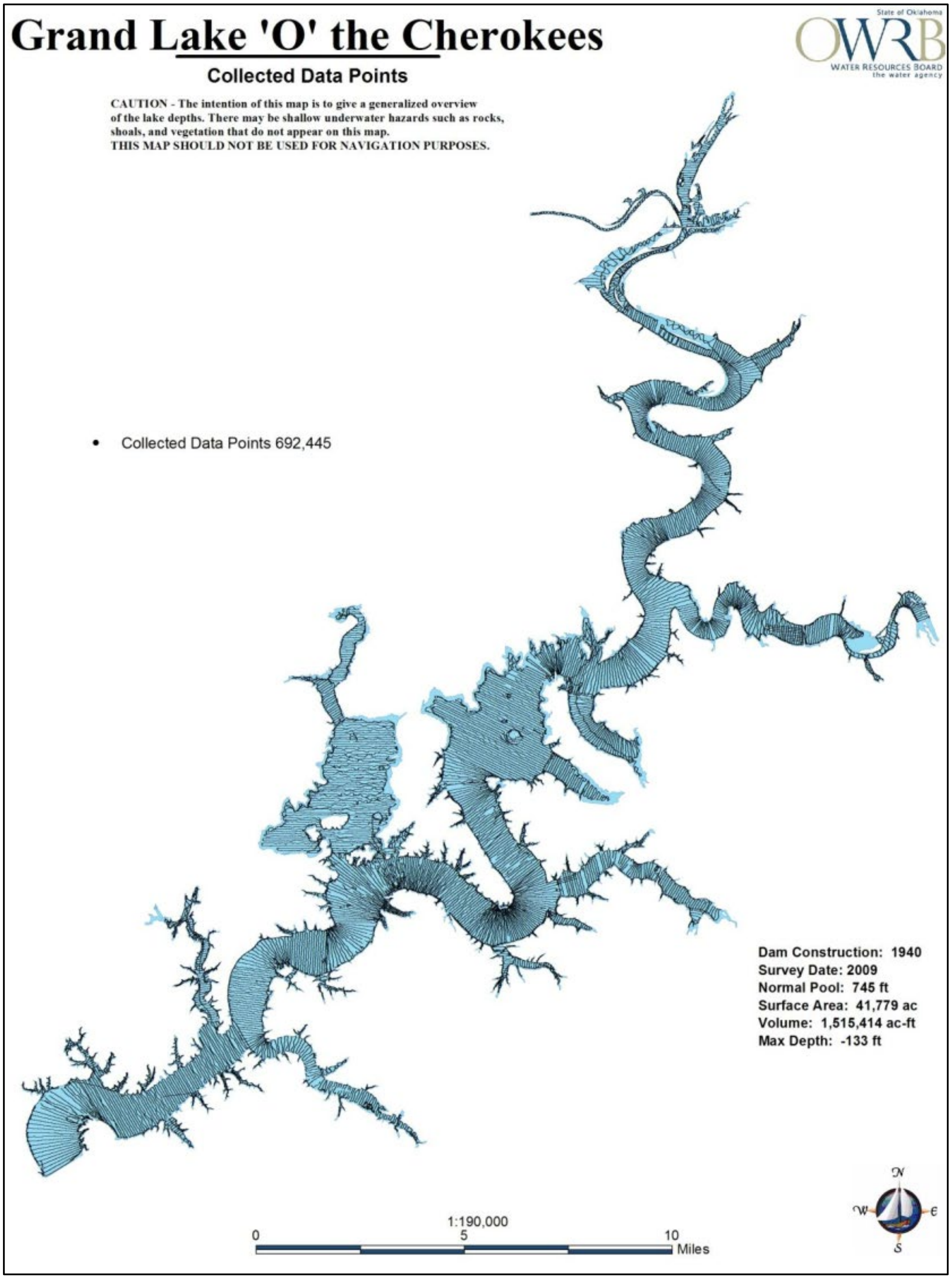
4. The downstream data, which covers Grand Lake and is below RM 120.1, is not usable and must be discarded for the purposes of this study.
5. The upstream data, which covers the Neosho River above RM 120.1 and the Spring River, is usable for this study.
6. The Elk River data are not usable and must be 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. 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 proposes to use the upstream REAS data for STM calibration and validation.

4.5 2009 Oklahoma Water Resources Board Survey

The 2009 Grand Lake bathymetry was collected using a single beam echosounder by the OWRB. 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 16. 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).

Figure 16
Data Density and Survey Track Lines Provided by OWRB in Grand Lake Survey Report



While the City supports the use of the least reliable, incorrectly documented portions of the REAS dataset, they simultaneously argue the 2009 OWRB survey is inaccurate. The reasoning for this conclusion, presented by the City's consultant during the recent Technical Meeting, is that depositional patterns between 2009 and 2019 do not match the City's expectations. The City has not provided evidentiary, technical, or quantifiable reasoning for this conclusion.

A review of typical reservoir deposition and siltation patterns shows that fine sediments can wash 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, 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 in which he states that incoming flows can transfer large volumes of sediment even without steep bed slopes.

The City conducted an oversimplified evaluation of the deposition measured in the downstream areas of Grand Lake in an attempt to prove the 2009 dataset is unreliable. The City suggested that thalweg measurements in the lower reaches showed deposition rates of 0.42 feet/year between 2008 and 2019 and argued it was an unrealistic aggradation rate, particularly near the dam. Not only is deposition in this area explained by density currents and other phenomena discussed in Section 2.3 (Lumborg and Vested 2008; van Rijn n.d., Zavala 2020), but the City's calculated aggradation rate of 0.42 feet/year rests on a gross oversimplification: that a difference in thalweg elevation at a select location is representative of a difference in volume in a large reservoir. To properly calculate aggradation rates in Grand Lake, total storage must be considered. Using the measured changes in storage volume between 2009 and 2019, the reduction was approximately 116,000 acre-feet. Given the overall surface area of the reservoir (approximately 46,500 acres), that amounts to an average depth of accumulation of just 2.5 feet, or 0.25 feet/year—an entirely reasonable rate of deposition. The City's rate of accumulation is nearly 170% of the rate GRDA calculated because of the rudimentary calculation technique the City used.

Because the dataset has documented quality control and there is a ***known date*** of data collection, GRDA can use the 2009 data for calibration and validation.

4.6 2017 USGS Upstream Survey

The 2017 USGS upstream survey data covers the Neosho, Spring, and Elk Rivers. The 2017 USGS upstream survey data went through a thorough quality control process and, as a result, is 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 feet 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.

4.7 2019 USGS Grand Lake Survey

As part of the FERC Study Plan Determination (SPD), the 2019 USGS Grand Lake bathymetry was collected using a multi-beam echosounder by USGS. The 2019 USGS survey data went through the highest levels of quality assurance and, as a result, is 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 uncertainly estimations (using total propagated uncertainty, or TPU). USGS reported that more than 95% of the TPU values were less than 0.30 feet, which is within the most stringent specifications for an International Hydrographic Organization (IHO) Special Order survey (IHO 2008).

Yet the City finds 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 concluded that the aggradation rates were unrealistic, indicating that the datasets are not accurate (City of Miami 2022). However, the City's calculation rests on a gross oversimplification: that a difference in thalweg elevation at a select location is representative of a difference in volume in a large reservoir. To properly calculate aggradation rates in Grand Lake, total storage must be considered. Total storage in Grand Lake from 2009 to 2019 decreased approximately 116,000 acre-feet, a reduction of approximately 7%. This figure is reasonable given the sediment loading to the reservoir during that time period. Given the overall surface area of the reservoir (approximately 46,500 acres), that amounts to an average depth of accumulation of just 2.5 feet, or 0.25 feet/year—an entirely reasonable rate of change.

The City also argues 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, mud flows, 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 2009 and 2019 datasets. Rather, the rudimentary calculation and disregard for documented reservoir sediment transport phenomena demonstrate that the City misunderstands basic principles of sediment transport.

Because the dataset has documented quality control and there is a ***known date*** of data collection, GRDA can use the 2019 USGS data for STM calibration and validation.

5 Bedload Sediment Transport Measurements

The City claims that bedload sediment transport measurements in the vicinity of bridges are misleading due to the presence of bedrock at those locations. The City claims there is no sediment moving through these locations because there is no local source material to be entrained. This is an illogical claim. If bedrock is exposed at a bridge, it indicates that sediment washed away from the bedrock, so sediment must be mobile at that location. Despite the City's claims, any sediment entering the system from upstream can certainly move across this bedrock platform. That sediment would have been sampled by GRDA during bedload transport measurements had it been present.

Further, only one sampling site has exposed bedrock. All other sampling sites have gravel or other sediments as the predominant substrate present. So even if the City's claim—that the presence of bedrock means that no upstream material can be entrained—was valid, this claim only applies to one sampling location.

If, as the City posits, non-cohesive sediment is indeed a major component of the system's sediment transport, that non-cohesive sediment must originate somewhere upstream of the dam. If it is not entering from the upper extents of the study area, one would expect significant bed scour or other sources of sediment within the study area. GRDA has not found any indication that such a sediment source exists, and the City has provided no evidence to support their claim.

Gravel and cobbles transported by streams as bedload tend to be rounded, smooth stones. They wear as they slide, bounce, and roll down the streambed, gradually becoming less angular. However, gravel found in the study area is composed of sharp, jagged stones, which indicates that they are not transported with any regularity and rounded stones are not at all prominent. If they were consistently moving downstream as bedload (Figure 17), they would exhibit the typical shapes found in streams that consistently move large, non-cohesive material.

Figure 17
Typical Angular Sediment on Riverbeds in Study Area

The City speculates that GRDA did not adequately measure bedload sediment transport during sampling events. GRDA followed the FERC-approved study plan, which adopted USGS guidelines when collecting bedload sediment transport measurements. As stated in the Sedimentation Study report (December 2021), GRDA followed standard USGS guidelines for bedload sediment collection (Edwards and Glysson 1999). Laura Rozumalski, PE trained the field team. She is a former USGS employee who was specifically trained in USGS sampling protocols and methodologies. During her time with USGS, she was responsible for field sampling for several years and is exceedingly familiar with USGS stream sampling requirements and data gathering.

The collected measurements show that bedload transport does not play a significant role in sediment movement throughout the study area. If there were significant bedload transport, GRDA's repeated field measurements would have collected appreciable samples to support that claim.

Sampling events took place in August 2019; May and July 2020; and April, May, and July 2021 (Table 2).

Table 2
Sampling Dates and Discharge Measurements, per USGS Gaging Station Records

Date	Discharge (cfs)			
	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

Upon arrival at the site, the Helley-Smith sampler was attached to a collapsible crane equipped with a winch and steel cable (Figure 18). The sampler was fitted with a 0.250 millimeters (mm) mesh bag that fit snugly around the opening on the sampler.

Figure 18
Bedload Transport Measurements Collected Using the Helley-Smith Sampler

Stream velocity was measured with an acoustic Doppler current profiler (ADCP) or by timing a floating object as it was transported downstream along a known length of flagging tape as suggested by USGS (2006). When using the ADCP, the stream was traversed a minimum of four times and the composite data was used to determine the location of highest velocity. This location was expected to be the point of highest bedload transport potential and was used to determine the amount of time the sampler needed to be on the bed.

The sampler was deployed at the point of highest velocity. Deployment involved lowering the Helley-Smith sampler off the bridge with the winch, allowing the tail to contact the water and spin the mouth of the sampler to the upstream direction. The sampler was then lowered further until the crane operator felt the sampler tail contact the bottom. It was raised slightly, then lowered again to confirm contact with the bed. Once contact was confirmed, the sampler was lowered slowly to prevent stirring bed sediment until tension on the cable was released, indicating that the sampler mouth was resting on the streambed.

Several sample attempts were made with measured sampling time ranges from 1 to 10 minutes at each location, following guidance by Edwards and Glysson (1999). They state that, "[g]enerally, a sampling time that does not exceed 60 seconds is preferred," but such a short sampling time produced no measurable volume of sediment. Repeated efforts to collect sediment in this way produced only a few individual grains of sand and occasionally a small amount of organic debris (Figure 19). In rare instances, a piece of gravel was collected. The bag remained clear, with no tears or signs of clogged mesh that would reduce sampling efficiency. Even after several minutes of sampling in the expected highest transport potential vertical, there was no indication of significant bedload transport.

Figure 19
Typical Bedload Transport Captured Using the Helley-Smith Sampler

Note: Photograph taken August 14, 2019, at E 60 Road on the Neosho River; USGS-reported discharge of 15,500 cfs.

During the test sampling runs, a measurement of the stream width was recorded, and the stream was divided into 20 equally sized segments (an exception to this was Tar Creek, where under some flow conditions, the stream width was less than 20 feet; Edwards and Glysson [1999] state that "[f]or narrow cross sections, sampling stations need not be closer than 1 foot apart") using the single equal-width-increment (SEWI) method. Measured stream widths were less than 1,000 feet, which meant all proposed sampling stations were within 50 feet of each other as required by USGS guidance (Edwards and Glysson 1999). GRDA sampled at the midpoint of each segment, but again, despite multiple-minute sampling times at multiple locations, no measurable sediment volumes were collected. Sample collection of 10 or fewer sand grains and occasionally a single piece of gravel was consistent throughout the sampling efforts with no indication that the mesh was damaged or clogged or that the sampler had otherwise malfunctioned. A lack of measurable sediment collection at multiple locations within the streams and with attempted collection times of up to 10 minutes indicated that there was no significant bedload transport.

After traversing the bridge using the method described above, GRDA sampled 20 additional times. No collection attempts yielded sufficient material for analysis. Following guidance from Edwards and Glysson (1999), GRDA performed collection of four samples each from five segments using the multiple equal-width-increment method. As stated previously, no sampling efforts produced a measurable volume of sediment.

Performing this exercise at each bridge and flow event listed above repeatedly produced no measurable volume of sediment in any of the sampling efforts at any segment, leading to GRDA's conclusion that bedload transport does not play a major role in this system.

It is also noteworthy that GRDA used a Helley-Smith style bedload sediment sampler. This sampler design has a reported sampling efficiency ranging from approximately 100% (Helley and Smith 1971) to 160% (Emmett 1980), meaning it captures as much or more sediment moving through the mouth of the sampler than would otherwise move through that area of the streambed. For the sand and small gravel size range, the efficiency is approximately 150% (Hubbell et al. 1985), which means it over-reports bedload sediment transport by 50%. Even without compensating for the sampling efficiency, GRDA did not find measurable amount of bedload sediment moving through the system.

If bedload truly were a significant contributor to the sediment transport processes within the study area, repeated efforts would have resulted in measurable sample volumes. Collection of just a few individual grains of sand with an occasional piece of gravel during all the trips to the study area, over a range of discharges, and in all the streams sampled, indicates that bedload transport is simply not a major component of the system.

6 Suspended Sediment Concentration Measurement

During the same sampling trips used to collect bedload transport measurements, GRDA collected suspended sediment concentration (SSC) measurements. This sampling process also followed USGS guidance (USGS 2006) for equal-width-increment (EWI) sampling using a D-74 isokinetic depth-integrating water sampler (Figure 20).

Figure 20
Sampling Equipment Used During SSC Sampling Efforts

The process for collecting the samples was similar to the process described above for SEWI sampling of bedload sediment transport. After arrival at the site, the stream width was measured and divided into 10 increments of equal width. Velocity measurements were made either by measuring the time taken for a floating object to travel along a known length of flagging tape or with an ADCP. If using the ADCP, four measurements across the stream were collected and the magnitude and location of maximum stream velocities were estimated. Calculations based on nozzle size were performed to determine transit rate of the sampler according to the figure in Edwards and Glysson (1999; presented here as Figure 21).

Figure 21
Example Suspended Sediment Concentration Sampling Transit Rate Determination Figure

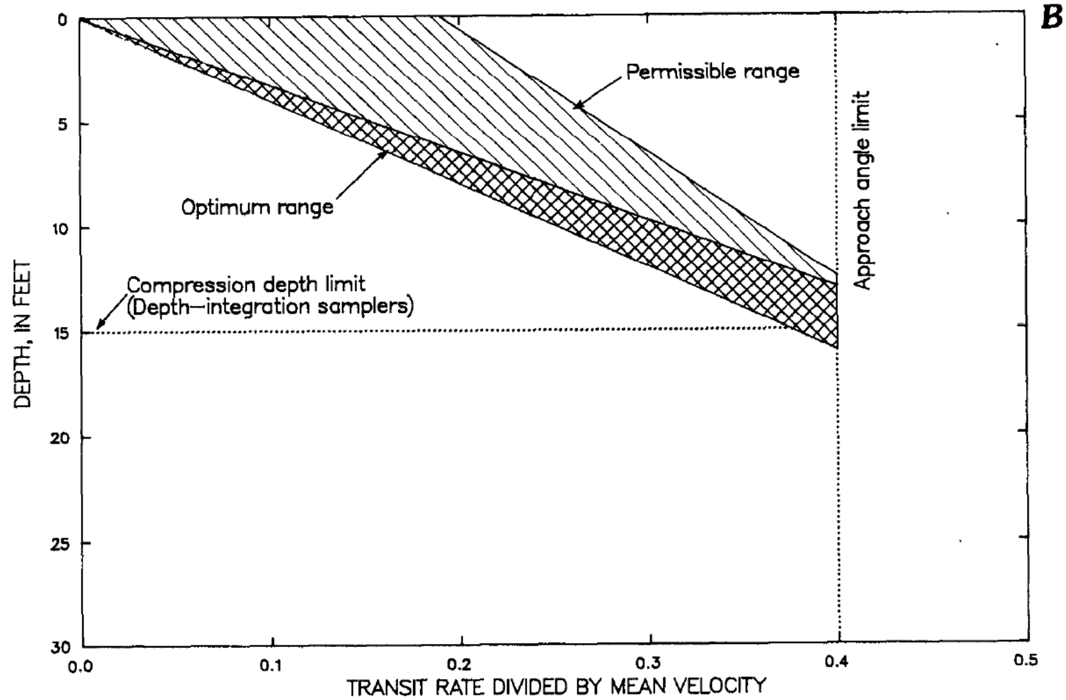


Figure 39. Variation of range of transit rate to mean velocity ratio versus depth relative to nozzle size for pint-size sample container. *A*, 1/8-inch nozzle. *B*, 3/16-inch nozzle. *C*, 1/4-inch nozzle.

Source: Taken from Edwards and Glysson (1999), Figure 39.

GRDA selected the largest nozzle (1/8-inch, 3/16-inch, or 1/4-inch) that would be permitted with given field conditions, per guidance offered by Edwards and Glysson (1999). As they state:

> Possible errors caused by using too small a nozzle are usually minor when dealing with fine material (less than 0.062 mm), but tend to increase in importance with increasing particle size. Small nozzles also are more likely than large ones to plug with organic material, sediment, and ice particles.

The sampler was then attached to the crane with the largest appropriate nozzle and sampling bottle installed. The crane was moved to the center of one of the EWI increments before being lowered toward the water surface and held in place. A stopwatch was used to time the transit with a gage on the winch used to determine the amount of line let out (Figure 22). Once the stopwatch started, the crane operator lowered the sampler to the bed. Upon contact, the operator immediately raised the sampler at the same rate.

Figure 22
Gage on Winch Used to Determine Length of Cable Let Out during Sampling

Source: Photograph taken August 15, 2019, at E 57 Road on the Spring River; USGS-reported discharge of 1,240 cfs.

The bottles were occasionally rejected, field rinsed, reinstalled, and the vertical was resampled. This occurred only if the time taken to cover the transit distance indicated that transit speed was too fast or too slow, the sample bottle was over- or under-filled, or if the sampler made heavy contact with the bed (which would raise the risk of entraining bed sediment in the collection bottle).

Bottles were then sealed and placed in storage for transport to the laboratory for SSC analysis.

7 Proposed Sedimentation Modeling in Updated Study Plan

The STM developed by GRDA per the Sedimentation Study and provided at the time of the Technical Meeting cannot accurately reflect sediment transport in the study area. GRDA took the City's comments under consideration and made modifications to the STM. These included adjusting the cross sections to have fewer station-elevation points and providing sediment definition files that reflect the actual sediment beds. Upon completion of those modifications, GRDA retained the services of WEST to perform an ITR of the modeling efforts to date.

WEST specializes in hydrology, hydraulics, sediment transport, fluvial geomorphology, and water quality. They brought to the ITR their extensive experience with sediment transport modeling in HEC-RAS. WEST was tasked with evaluating the current STM and providing an expert opinion of the feasibility of using HEC-RAS for sediment transport modeling within the study area. After completion of the ITR, the findings were presented to GRDA.

WEST found that the model can likely be calibrated to provide reasonable estimations of sediment deposition and erosion in the study area upstream of the confluence with the Elk River. Despite simplified parameterization of cohesive sediments, WEST agrees with the City that HEC-RAS is capable of simulating the transport of those constituents and predicting the ongoing deposition patterns both at the delta feature and in the upper reaches of the relevant tributaries. GRDA therefore proposes to use the STM to directly predict sediment transport and deposition patterns and developed the following approach with input from WEST.

7.1 Sediment Transport Model Development Overview

GRDA proposes to use HEC-RAS to develop a truncated version of the STM. The model will simulate sediment transport and deposition on the Neosho River, Spring River, Tar Creek, and Elk River upstream of RM 105. This area includes the portions of the study area that have the potential to affect upstream water levels, which is the focus for evaluating reservoir operations with the STM. The area downstream of RM 105 will not be explicitly modeled in the STM because it is dominated with cohesive sediments. The City of Miami is correct when it stated:

> [T]he total quantities of cohesive sediment entering the reservoir mainly inform the reduction in storage capacity due to sedimentation. They displace the same amount of water regardless of where in the reservoir they settle, meaning that their spatial distribution in the reservoir is largely irrelevant to the hydraulics of the tributaries and upstream flooding.

GRDA agrees that fine, cohesive sediment inflow to and deposition in the areas downstream of the STM limit do not affect the upstream areas. Thus, it is not critical to precisely determine the final location of the sediment downstream of the STM limit. However, the total mass of sediment moving past the delta feature will still be evaluated to determine the effects on the power pool and storage volume in the reservoir.

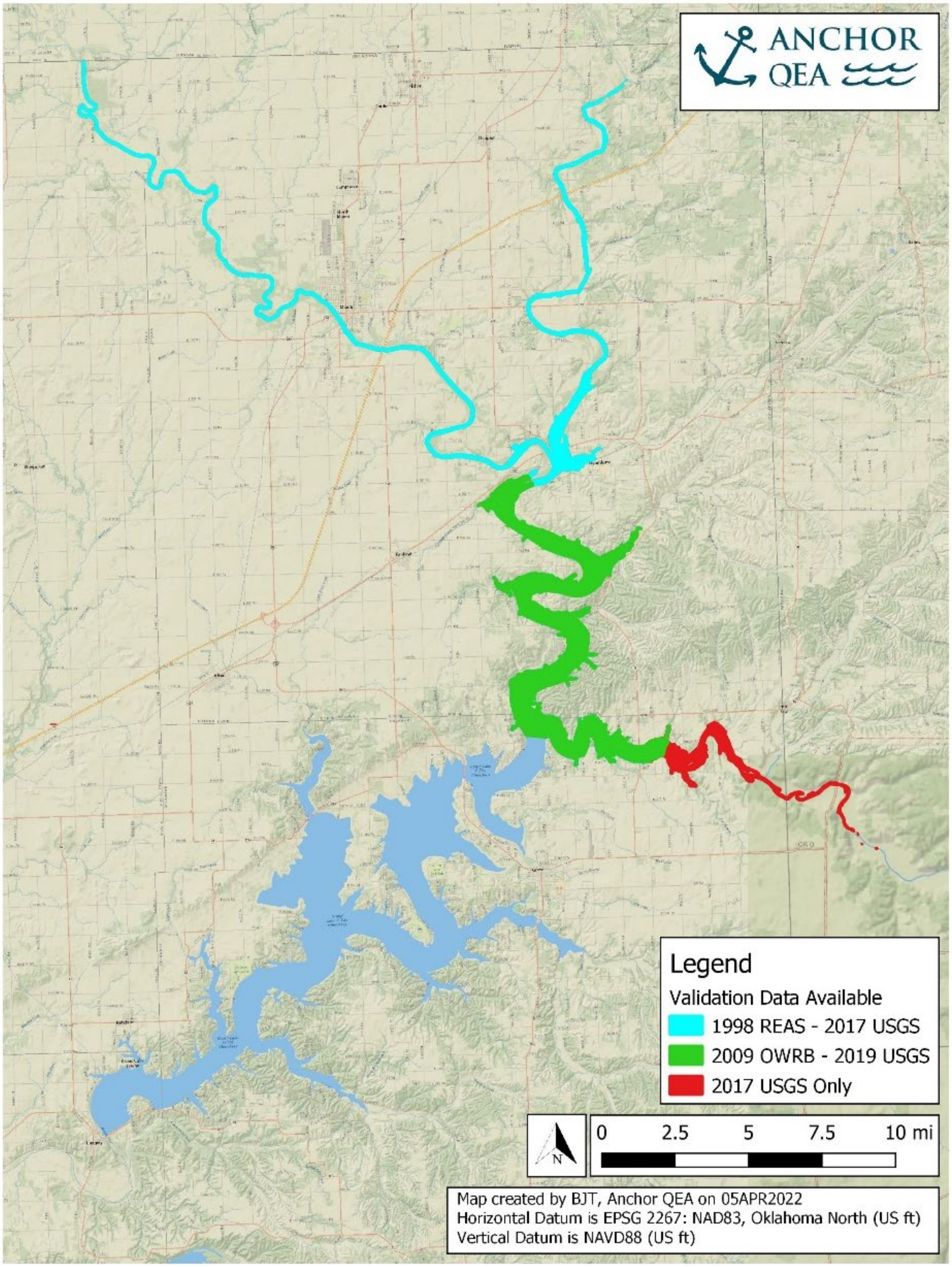
7.2 Geometry

While the STM will be truncated below RM 105, the upper areas of the reservoir, including the delta feature and upstream reaches of the major tributaries will continue to be part of the STM. The geometry sources for calibration will include circa-1940 topographic maps and channel data, the upper portion of the REAS data, the 2009 OWRB survey of Grand Lake, 2017 USGS surveys of upstream areas, and the 2019 USGS Grand Lake survey (Figure 23).

Several of these datasets are far from perfect but represent the best available data. Model results are only as good as the available input data, so the uncertainty with the terrain information means model predictions will be necessarily imprecise. This is the case with any long-term sedimentation model but will be exacerbated in this case by the significant limitations of the available data. To address this, GRDA will perform sensitivity analyses to bound future sedimentation outcomes. Inputs such as sediment loading, critical shear stress and erodibility parameters, and other relevant data will be varied within plausible ranges to evaluate their effects on sediment deposition. GRDA will present all data used to develop those parameters and any assumptions made in the USR.

Based upon the discussion of geometry datasets included in Section 4, the following datasets are incorporated into the STM.

Figure 23
Model Geometries used for Calibration and Validation



Note: All starting geometry will be based on circa-1940 data.

7.2.1 Circa-1940 Dataset

Section 4.1 discusses the circa-1940 dataset. Because these sources will be merged and do not represent one cohesive dataset, there will be uncertainty associated with the circa-1940 terrain.

The imprecise, limited nature of this dataset poses challenges for STM development and model accuracy. Because this geometry will be derived from a combination of 5-foot contour maps and old channel information, it will necessarily come with significant uncertainty. That does not mean it cannot be used for analysis, but it does mean that the model predictions cannot be considered a guarantee of future sedimentation.

7.2.2 1998 Real Estate Adequacy Study Dataset

Section 4.4 discusses the 1998 REAS dataset. One of the main contentions coming from the Initial Study Report and associated Technical Meeting was the topic of the REAS dataset. The City has asserted that the dataset should be used in its entirety with potential modifications for datum shifts, then suggested that data upstream of Miami could be thrown out.

Multiple datasets are presented in the 1998 REAS. GRDA analyzed the data and determined that the data upstream of RM 120.1 on the Neosho River and the data on the Spring River are usable for this study.

Given the quality control issues noted in Section 4.4, there is a significant amount of uncertainty regarding the usable data. Nevertheless, GRDA and WEST believe the upstream section of data can be used for STM calibration purposes. The extent of the upstream REAS data are shown in light blue in Figure 23.

7.2.3 2009 OWRB Dataset

Given the thorough quality control documentation and data density of the 2009 OWRB survey, GRDA proposes to continue using it as a baseline for STM calibration. This dataset will be used from approximately two miles downstream of the Spring River (RM 120.1) to the downstream extent of the STM (RM 105) as shown in green in Figure 23.

7.2.4 2017 USGS Upstream Dataset

The 2017 USGS upstream survey data went through a thorough quality control process and, as a result, is of high quality. The 2017 USGS upstream survey will continue to be used for the upstream geometries. The 2017 data are shown in red in Figure 23 where it is the only data available and is shown in light blue where upstream REAS data also exists.

7.2.5 2019 USGS Grand Lake Dataset

The 2019 USGS Grand Lake bathymetry has also been through a thorough quality control process and is considered a reliable data source. The 2019 USGS survey covers the delta feature (RM 120.1 to RM 105) and will continue to be used for model calibration and as a baseline for future projections. The 2019 USGS data are shown in green in Figure 23.

7.3 Calibration

The STM will be calibrated using 1940 site conditions as a starting point. The known stream discharges and calculated sediment rating curves will inform model inputs between 1940 and the calibration survey for each portion of the study area (Table 3). Calibration for the model will focus on matching sediment accumulation and erosion patterns in the modeled reaches using HEC-RAS.

Table 3
Model Reaches and Available Survey Data Calibration and Validation

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 105)	Circa-1940 USACE	2009 OWRB	2019 USGS
Elk River (above RM 5.47)	Circa-1940 USACE	2017 USGS	
Reservoir (below RM 105)	Circa-1940 USACE	2009 OWRB	2019 USGS

Following calibration runs, the model will simulate additional time to the validation survey (also listed in Table 3). The modeled results will be compared to surveyed bathymetry to validate the model calibration.

Model calibration will also be evaluated based on comparison with the other quality assurance components of the three-level approach using the qualitative geomorphic and quantitative geomorphic and engineering analyses described in the USP. The quantitative geomorphic and engineering analyses are similar to those proposed as part of GRDA's PMSP and rely on measured field data. They will provide additional validation of the model and ensure higher confidence in STM outputs.

After calibration, the model will be used to predict future sediment transport patterns in the truncated study area resulting from a range of Project operations.

7.4 Future Simulations

Future simulations using the STM will be based on the latest available geometry. As in previous documents, this geometry will be referred to as the 2019 dataset for simplicity but will consist of the 2019 USGS survey of Grand Lake and the 2017 USGS survey for the upper reaches of the tributaries.

7.4.1 Hydrology Development

GRDA will begin future simulations by evaluating past hydrology of the region and creating a synthetic 50-year hydrograph as discussed in the USP.

7.5 Evaluation of Sedimentation Effects

7.5.1 Modeled Area

GRDA will use the STM to simulate the 50-year relicensing period under expected operational scenarios as were required by FERC for the H&H Study. These scenarios will cover a range of starting WSEs at the dam and allow evaluation of the impact of Project operations on sedimentation patterns in the study area.

Following STM simulation of the 50-year period, GRDA will import the predicted model geometry from each of the operational scenarios to the 1D Upstream Hydraulic Model (UHM). The UHM will then simulate specific events and compare the results to simulation results that used the baseline 2019 geometry to determine the impacts of predicted sedimentation on water levels in the study area. These results will be included in a final report submitted as part of the USR.

7.5.2 Lower Reservoir

GRDA will also evaluate sedimentation within the lower portions of the reservoir that lie outside the proposed STM domain (below RM 105). As stated by the City and agreed upon by both WEST and GRDA, it is reasonable to evaluate sediment deposition within the reservoir itself as it relates to storage and the power pool. Cohesive sediments are deposited in the lower reservoir and do not dynamically impact upstream water levels. GRDA will evaluate the volume of sediment moving into the reservoir to meet their requirements under FERC's SPD.

Deposition quantities in the lower reservoir will rely on the Project's trapping efficiency using the relationships discussed by the USACE in EM 1110-2-4000 (1995). Trapping efficiency is simply the ratio of sediment flowing into the reservoir to sediment deposited in the reservoir. The modeled sediment outflow from the STM will provide inflow sediment quantities to the lower reservoir, from which the total mass of sediment deposited during the simulation can be calculated. Relationships between sediment density and total mass can be used to quantify the total change in storage volume and its impact on the power pool.

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Appendix A: Comment Response Matrix

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
2			4, 1	**Suspended sediment and bed material grab samples.** Suspended sediment measurements taken by GRDA at the same time as the bedload measurements suggest significant sand transport higher in the water column: sand made up an average of 18% of all suspended sediments collected. For some sampling events, Tetra Tech calculates well over 1,000 tons per day of sand transported in suspension. The Helley-Smith sampler used by GRDA should have collected not only bedload sediment, but also some sediment in suspension.	The City's comment is misleading because the sediment rating curve for the Neosho River shows suspended sediment transport of 34,000 tons per day at a flow of 15,500 cfs and a suspended sediment transport of 100,000 tons per day at 37,500 cfs. The 1,000 tons per day calculated by the City's consultant is a small fraction (1% to 3%) of the overall sediment load, which consists primarily of finer materials (silt and clay). At lower discharges, the fraction of coarse material will only decrease. The City's comment is inaccurate because they suggest that the bedload sampler should have collected suspended and bedload sand. The very fine sands pass through the 250-microgram (µm) mesh of the bedload sampler bag, but the overall tonnage of suspended sediment is accounted for by using the total flow at a section and converting the suspended sediment concentration to tons per day. That the bedload sampler collected virtually no sediment (see GRDA's response to Comment No. 1) demonstrates that no coarse bedload was being transported and no suspended sediment coarser than 0.25 millimeters (mm) was being transported to any significant degree. The findings of the bedload sampling efforts do not contradict the suspended sediment sampling results. The fact that some fine sand is being transported in suspension through the entire water column does not mean that significant quantities of coarse material are being transported in the 3-inch layer of flow above the bed being sampled by the Helley-Smith bedload sampler. The City's computed transport rates are significantly less than the suspended sediment transport values from the sediment rating curve based on the suspended sediment sampling. The City's argument also relies on an uncalibrated Meyer-Peter and Müller (MPM) equation that was then compared to the measured bedload data which shows essentially no transport. At many bed material sample locations, the samples include a significant amount of gravel-sized material, which tends to armor the bed and limit the transport of the finer sized sediment, which supports GRDA's findings and discredits the City's.
3			4, 2	The grab samples likewise show significant quantities of sand in the bed materials. In the Neosho River, two grab samples collected at river mile 145.5 near the Commerce Gage (the closest grab samples to the bedload sampling location) contained roughly 15% and 30% sand. The upstream-most Spring River grab sample likewise included about 18% sand, with more occurring in samples farther downstream. Given that GRDA collected significant non-cohesive sediments in suspension and the bed material in the channels is sand and gravel, GRDA does not explain how properly-conducted bedload sampling could have failed to capture any noncohesive sediment.	Please see GRDA's response to Comment No. 1. The City's comment is misleading because it relates only to the upper sections of the reservoir and focuses on only one portion of the objectives of the Sedimentation Study while ignoring deposition in the lower reservoir. The full objective of the Sedimentation Study as outlined in the Study Plan Determination (SPD) is to "assess the effects of current project operation between reservoir elevations 740 feet and 745 feet PD, and any potential changes to project operation, on sediment erosion, transport, and deposition in the lower reaches of the tributaries to Grand Lake (i.e., on the Neosho, Spring, and Elk Rivers, and Tar Creek), and to characterize the impact that sedimentation has on flooding upstream of Pensacola Dam" and any "observed or predicted effects of project operation on sedimentation of the power pool." The City's comment also ignores the distinction between sediment that exists on the bed and sediment that is being actively transported. GRDA has acknowledged there is significant coarse, non-cohesive material present on the streambeds. That does not mean that material is being carried downstream. Sampling efforts have shown that transport is dominated by fine, cohesive material; the presence of coarser sediment on the beds indicates natural "armoring" which occurs over time as fine materials are washed downstream, leaving coarser armor layers that do not move consistently. GRDA's assessment of the significance of non-cohesive sediments accurately reflects the sediment composition in the reservoir as a whole and specifically in the lower reservoir and on the delta feature.

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					All 14 of the samples collected for SEDFLUME analyses consisted primarily of silt and clay-sized sediment. The incoming sediment load, as shown by field data, consists primarily of silt and clay materials transported in suspension. The fine, non-cohesive sediment that flows into the bedload sampler passes through the sampler bag if it is smaller than the 0.25 mm mesh of the bag, as discussed in GRDA's response to Comment No. 2. This small quantity of sediment that is not sampled in bedload sampling is largely accounted for when computing the suspended sediment transport in terms of tons per day because the total value of flow, including the flow above the lowest depth that the suspended sediment sampling nozzle reaches (from 3 inches above the bed to the water surface) and the flow that occurs below the nozzle depth (from the bed surface to the level of the nozzle) is applied to the suspended sediment concentration. Given that the suspended sediment sizes in the non-cohesive size range are still quite fine, their concentration is more uniform in the vertical than that of the significantly coarser sediment typically transported as bedload. Again, in this sampling effort no transport of the coarser bed materials was captured because, as the data show, these sizes were not being transported (see GRDA's response to Comment No. 1). Laboratory analysis of the recently-collected vibracore samples, which cover the delta feature between Twin Bridges and the Elk River confluence (the primary area of concern regarding sedimentation and potential upstream effects) has shown that approximately 90% of all sediment in this area consists of cohesive silt and clay material. Although this has been referred to as the "hump," the technically accurate term is "delta feature." A delta feature is present in all fluvial systems where water slows, whether that slowing occurs near a confluence, upstream of a hydraulic constriction like that found at Twin Bridges, where hydraulic bed roughness increases, where channels expand, at the headwaters of a reservoir, or where bed slopes become less steep (Simons and Senturk 1992; Vanoni 2006; Morris and Fan 2010). Sediment deposits in these areas, with coarser material settling first and finer material being carried farther downstream (see Response Comment of GRDA Section 2).
4			4, 3	**Bedload transport estimates.** The bedload transport estimation equation suggested by GRDA indicates that bedload transport should be occurring at the reported flows, which further calls into question GRDA's reported bedload transport results. In the PMSSP, GRDA suggests using the Meyer-Peter Müller ("MPM") equation, which is "well-suited to modeling sediment transport in non-cohesive systems." GRDA predicted that the MPM equation "will show limited, if any, sediment transport." In preparing these comments, Tetra Tech estimated bedload transport by applying the MPM sediment-transport equation suggested by GRDA, hydraulic output from the comprehensive hydraulic model ("CHM"), and reported bed material data. But the MPM equation found the opposite of what GRDA expected: the MPM equation predicts significant bedload transport (over 1,400 tons per day on the Neosho River at flows of 15,500 and 39,500 cfs). Thus, the MPM equation suggested by GRDA indicates that significant bedload transport likely does occur. Although the December Sedimentation Report states that "in the model," GRDA will use other data and calculations "to develop a more complete understanding of the relative contribution of bedload transport," GRDA would presumably not pursue that inquiry if the Commission approves the PMSSP, allowing GRDA to abandon the sediment transport model ("STM") entirely.	The City's statement is incorrect because Tetra Tech uses an uncalibrated MPM sediment transport equation to calculate bedload transport and then compares the results to measured field data. The MPM equation is one of the standard bedload transport equations used in HEC-RAS. This approach demonstrates a fundamental misunderstanding of the sediment transport modeling process. Demonstrating the dangerous and inaccurate approach advocated by Tetra Tech in this comment, consider the idea of using an uncalibrated hydraulic model to calculate water-surface elevations, then comparing the calculations to measured high-water marks and claiming that the measured high-water marks are incorrect because the uncalibrated model could not recreate the measured field data. That parallel example shows how Tetra Tech misunderstands the sediment transport modeling process. As discussed in GRDA's response to Comment No. 2, the total sediment loading of the system at their reported flow rates is 34,000 tons/day and 100,000 tons/day at 15,500 and 37,500 cfs, respectively. Their value represents just 1% to 3% of total sediment transport. The Updated Study Plan (USP) proposed by GRDA uses the STM and a quantitative sediment transport evaluation to compare hydraulic shear stress to measured sediment critical shear stress. There is no plan to abandon evaluation of bedload sediment transportation despite the City's unfounded presumptions.

<table>
<tr><th>Comment No.</th><th colspan="2">Section</th><th>Page No. Paragraph</th><th>Tetra Tech Observation</th><th>GRDA Response</th></tr>
<tr><td>5</td><td></td><td>B</td><td>4, 4</td><td>B. GRDA has not provided the model and related files created in its failed attempt to calibrate the sediment transport components of its model.

Second, GRDA refuses to provide the modeling files from its failed sediment transport calibration efforts. The December Sedimentation Report details GRDA's lack of success in calibrating the sediment transport components of the STM. But GRDA refuses to share the modeling files documenting those efforts, thereby preventing the Commission and stakeholders from evaluating GRDA's claims or attempting to resolve issues with the model. Because GRDA will not allow review of its efforts under the approved study plan, it has failed to justify departing from that plan and the Commission should reject the PMSSP.</td><td>Contrary to the City's claim, the FERC-approved study plan did not require GRDA to produce any modeling files associated with unsuccessful efforts to calibrate the STM. Instead, GRDA gave a full reporting of these efforts in the ISR written report and in the associated ISR meetings, where the City had a full and fair opportunity to ask questions and better understand the challenges GRDA encountered in attempting to calibrate the STM. If the City does not believe GRDA's reporting, the City is free to attempt to calibrate the STM model itself; GRDA has fully disclosed all the information needed to make such an attempt.

When responding to the City's request for files from the failed sediment transport calibration, GRDA explained that the requested model files are not considered a final product and so were not provided. Such files are never provided for sedimentation studies, and it is extremely atypical for the City's consultants to ask for this type of information. Much of the work of calibrating a model involves trial and error, with engineers making changes to the model to ensure results match measured outcomes. It is not realistic to provide the City's consultants with every draft file as GRDA refines the model.

Moreover, in the Updated ISR, GRDA fully explained why the model could not be calibrated. In Section 5.2, page 80, GRDA explained the problems discovered with the REAS dataset that prevented effective hydraulic calibration. GRDA also stated on page 80 that "limitations in HEC-RAS with regard to cohesive sediment transport modeling curtail the ability of the STM to produce meaningful predictions for deposition and erosion patterns in the future."

GRDA repeatedly highlighted the wide range of cohesive sediment parameters discovered in the study area. Table 22 of the Updated ISR (reproduced below) shows the wide range and the difficulty of selecting appropriate values for the sediment parameters.

<table>
<tr><th>Calibration Factor</th><th>Hydraulic Model</th><th>Cohesive Sediment Model</th></tr>
<tr><td>Resistance to Flow</td><td>Manning's n
Range: 0.015 – 0.045 in channel
300%</td><td>Manning's n
Range: 0.015 – 0.045 in channel
300%</td></tr>
<tr><td>Bed Material</td><td>n/a</td><td>Bi-model distribution covering 5 orders of magnitude
1,000,000%</td></tr>
<tr><td>Critical Shear Stress</td><td>n/a</td><td>Range: 3,000%</td></tr>
<tr><td>Erosion Rate</td><td>n/a</td><td>Range: 5 orders of magnitude
1,000,000%</td></tr>
<tr><td>Bulk Density</td><td>n/a</td><td>Range 485%</td></tr>
</table>

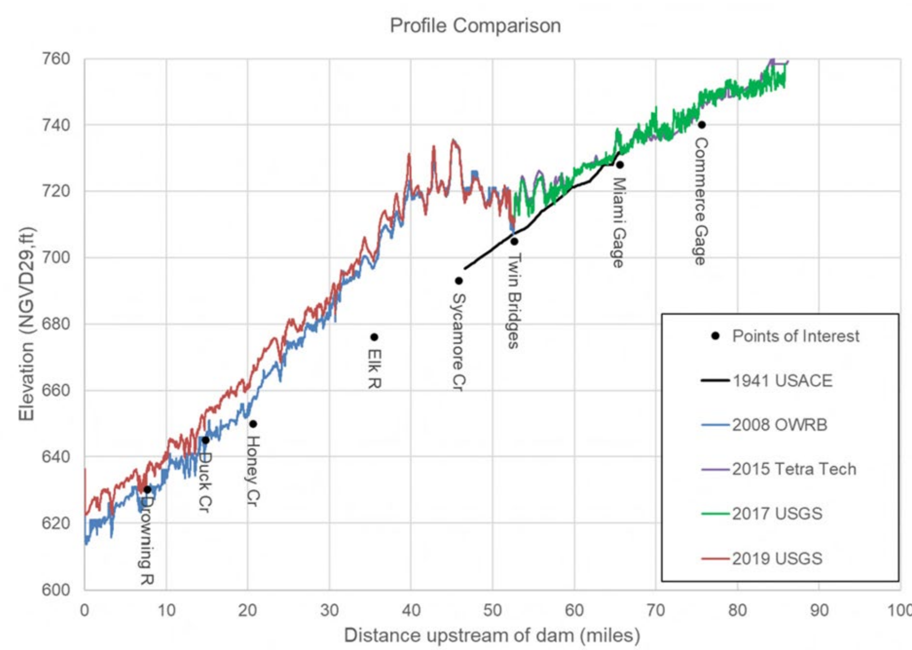
GRDA also discussed, on page 94, the limitations of modeling cohesive sediment given the wide variation of density, citing the HEC-RAS User's Manual (USACE 2016): "When calibrating a depositional cohesive model to volume change computed from repeated cross-sections, cohesive density will be a very sensitive</td></tr>
</table>

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					parameter." The model only allows selection of one value for silt and one value for clay densities, which vary across a range of 485%, so choosing the correct value is nearly impossible. Consolidation of cohesive sediments is also cited as a problem on page 94 of the Updated ISR. USACE (2020) states that a single consolidation curve is used to model the entire model domain. Selecting a singular, defensible consolidation curve for such variable sediments as those highlighted in the table above is virtually impossible. For all these reasons, the model could not be calibrated as-built. GRDA was very clear about that in the Updated ISR, and it is unreasonable for the City's consultants to expect draft versions of the model and input files.
6		C	6, 3	**C. HEC-RAS is an appropriate tool for modeling the non-cohesive sediment that dominates the Project's sediment-related contribution to flooding.** Finally, as the City previously explained, HEC-RAS remains an appropriate tool for modeling sedimentation in this system, even if silt- and clay-sized particles transported in suspension were dominant as GRDA claims. In further support, Tetra Tech indicates that precisely modeling the fate of cohesive sediments deep into the reservoir is far less important than the need to understand deposition of the sand and gravel (non-cohesive) sediments that contribute to backwater flooding—particularly the hump. Thus, the total quantities of cohesive sediment entering the reservoir mainly inform the reduction in storage capacity due to sedimentation. They displace the same amount of water regardless of where in the reservoir they settle, meaning that their spatial distribution in the reservoir is largely irrelevant to the hydraulics of the tributaries and upstream flooding. By contrast, a useful sedimentation study for this relicensing requires accurately modeling the dynamics of the coarser, non-cohesive sediments in the tributaries, which dominate the interaction between sediment transport and Project hydraulics—especially the hump and backwater flooding.	The City's statement that HEC-RAS is an appropriate tool to model **non-cohesive** sediment is correct, but it ignores the significant role played by **cohesive** sediment within the study area. The Sedimentation Study has an objective to "characterize the impact that sedimentation has on flooding upstream of Pensacola Dam." It is important to note that in their comment the City does not state HEC-RAS is an appropriate tool for modeling non-cohesive sediment **AND** cohesive sediment. The City attempts to downplay the importance of the cohesive sediment in the system and jumps to the conclusion that HEC-RAS is appropriate to meet the required objective of the study. This is not true. The City continues to state that "precisely modeling the fate of cohesive sediments deep into the reservoir is far less important than the need to understand deposition of the sand and gravel (non-cohesive) sediments" when field data collected in 2021 demonstrate the importance and dominance of cohesive sediments in the transport system. Moreover, the City's comment continues to advance the unsupported narrative of "backwater flooding." Despite having numerous opportunities in this relicensing process, the City has failed to provide any adequate evidence to conclude backwater flooding occurs as a result of Project operation. Instead, the City merely continues to make unsupported claims with the hope that the Commission and other decision-makers in this process will accept them. In contrast, GRDA's Hydrologic and Hydraulic (H&H) Study showed that the impact from nature-driven inflow events is 70 times greater than the impact of the Project starting pool elevation, as discussed in Section 4.5.1 of GRDA's Response to Comments on Initial Study Report (2021). Similarly, the City also states, without providing evidence, that the Project produces sedimentation that has contributed substantially to flooding. Again, the City has provided no technical defense of this position, which represents pure speculation on the part of the City. In the same light, the City ignores FERC's Study Plan Determination (SPD), which requires GRDA to use the sediment transport model to "address how operations affect sedimentation rates, including sedimentation of the power pool." By stating that "precisely modeling the fate of cohesive sediments deep into the reservoir is far less important than the need to understand deposition of the sand and gravel (non-cohesive) sediments," the City ignores the dominant issue that will provide information on sedimentation effects on the power pool and reservoir storage, which FERC required GRDA to address. GRDA attempted to fulfill FERC's requirements by developing and calibrating one single HEC-RAS model that incorporates the cohesive sediment dominance below River Mile (RM) 105, the middle portion of the

Comment No.	Section	Page No. Paragraph	Tetra Tech Observation	GRDA Response
				reservoir dominated with cohesive sediments with some non-cohesive sediments up to RM 120.1 (approximately 2 miles downstream of the Spring River confluence), and the upper portion of the reservoir dominated by cohesive sediments and some non-cohesive sediments. Calibrating one single model for all three parts of the system was not possible. The City recommends a solution to ignore cohesive sediment in the system and FERC's requirement for understanding the effect of sedimentation on the power pool. The City's approach is disingenuous because it is obviously being made as a matter of convenience, with a strong bias to improperly influence the results to support their unsupported (and ever-changing) claims. To obtain a fresh and objective perspective on these complex issues, GRDA recently retained WEST Consultants (WEST) to perform an independent technical review (ITR) of the STM development process. WEST concluded that HEC-RAS can be an appropriate tool when excluding the lower portion of the reservoir (downstream of RM 105 and the Elk River confluence) where cohesive sediments are dominant. Under this approach, the sedimentation effects on the entire power pool can be addressed through a separate analysis of changes to storage. WEST also confirmed that the U.S. Army Corps of Engineers' (USACE's) Grand Lake Real Estate Adequacy Study (REAS) dataset below RM 120.1, which covers the delta feature, relied on existing surveys; WEST's comparisons of the Grand Lake REAS thalweg and the circa 1940 USACE thalweg indicate that the REAS data below RM 120.1 were likely based on surveys performed circa 1940 and do not represent 1998 conditions (see Section 5.2 of the ITR report). A review of the REAS documentation confirmed that hydrographic surveys were not performed in the area of the delta feature. GRDA has developed and presented a USP as part of this submittal. The USP proposes to explicitly model the sediment transport and deposition patterns upstream of the Elk River confluence at RM 105. This truncated model will cover the study area from there to the upper reaches of the Neosho River, Spring River, Elk River, and Tar Creek (see the USP included with this submission for more detail). It is important to note that several of the available geometry datasets contain significant uncertainty. This is covered in the USP and in the Response Comment (Section 4). Model predictions are only as good as the input information; however, the data GRDA proposes to use are the best available for each time period, and an imperfect model is better than blind speculation. GRDA will perform sensitivity analyses to bound potential sedimentation quantities and will document relevant assumptions and findings as part of the USR.
7		8, 1	**11. GRDA should be required to report its bedload transport sampling methods and results to allow evaluation of whether GRDA performed the study in accordance with the study plan requirements and the methodology GRDA says it followed.**	GRDA reports on its sampling methods in Section 3.1.2.4 of the December 2021 Sedimentation Study Report, in the Response Comment (Section 5), and in their response to Comment No. 1.
8		8, 1	**12. GRDA should be required to share all files from its attempts to calibrate the STM, not just what it subjectively considers to be a final product, especially given its request through the PMSSP not to develop that final product.**	Please see GRDA's response to Comment No. 5.

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
9	Attach 1	1	11, 2	A key purpose of the sedimentation study from the City's perspective is to evaluate: (1) the sedimentation processes along the tributaries and Grand Lake, (2) the impact of the dam and operations on sedimentation and associated flooding in and in the vicinity of Miami, and (3) alternatives for mitigating the impacts. Comparison of the pre-dam river profile with recent bathymetric surveys indicates significant sediment deposition near the head of Grand Lake, with up to 30 feet in the reach between Twin Bridges and the Elk River confluence (Figure A), which increases the upstream flooding along the Neosho and Spring Rivers. Sediment sampling by GRDA indicates that bed material in the rivers is mostly sand and gravel and the lakebed is mostly clay and silt. A critical area of interest is the sediment deposition (which has been referred to by GRDA's consultants as the "hump") near the upper end of the lake, with the greatest deposition in the area between Twin Bridges and Sycamore Creek (Figure A, below; see also Figure 69, December Sedimentation Report). The GRDA bed-material sampling indicates that this "hump" consists of sand-sized material. GRDA's suspended sediment-transport measurements indicate that the Neosho and Spring Rivers are transporting a range of material from clay to sand-sized, and the bed-load measurements show no sediment transport.  A key question of the study is, what are the future aggradation/degradation patterns in the area between Twin Bridges and Elk River, and how does this impact upstream flooding? Based on historic patterns, the sand will continue to deposit near the head of Grand Lake, primarily on the upstream limb of the "hump", and may further increase upstream flooding, while the finer silt and clay sized material will deposit farther downstream in lower energy areas. The finer silt- and clay-sized material will deposit farther downstream of the hump in lower velocity (energy) areas that are probably depositional over the full range of flows and reservoir levels. The	The City's stated purposes of the Sedimentation Study do not align with those provided by FERC. Specifically, FERC's SPD did not require GRDA to evaluate alternatives to eliminate dam-related sedimentation and related flooding effects (if any) over the license period. As explained in Section 4.2.6 of GRDA's Response to Comments on Initial Study Report (ISR Response), filed with FERC on December 29, 2021, GRDA's relicensing application will identify and analyze any appropriate protection, mitigation, and enhancement (PM&E) measures across all resources at the Project. It is premature to identify potential PM&E measures at this study phase of the relicensing effort. The City's comment is also misleading. First, they have not proved that there have been 30 feet of deposition in this area. The only available field data on the depth of sediment was collected in early 2022, when GRDA used 16-foot vibracore tubes to collect samples. Maximum depth of refusal on the delta feature was 11 feet, which does not offer proof of a 30-foot layer of sediment. The City's claim relies on comparing 2019 thalweg peaks to uncertain, low-resolution circa 1940 data that artificially smooths the thalweg profile. Second, based on typical fluvial reservoir deposition patterns, any sediment accumulation in this reach will continue expanding downstream rather than significantly increase the height of the delta feature. As discussed by Vanoni (2006), sediments transported into an impoundment settle in the headwaters of the reservoir. This can be accentuated by river confluences, channel constrictions or expansions, and changes to bed slopes (Simons and Senturk 1992), but it tends to begin with coarser sediments at the upstream end with finer materials settling farther downstream, gradually forming a delta feature. As discussed in the Response Comment (Section 2.2), the top elevation of the delta feature will not continue to grow indefinitely and potentially increase backwater elevations. Although aggradation will likely continue, the top elevation of the delta feature will remain largely static in the future. Typical delta feature formation results in early vertical growth of relatively coarser sediment deposits (in the case of the study area, fine sands), reducing flow area of the stream. As the flow area is reduced, the water velocities increase, resulting in higher transport capacity. Eventually, the delta feature reaches an equilibrium elevation and grows in length with limited increases in height (Response Comment Section 2.2, Figure 2). These delta features do not grow infinitely tall; instead, they grow until bed shear stresses are equal to sediment critical shear stress, resulting in additional material washing farther into the reservoir. It is unreasonable to assume, as the City falsely asserts, that the delta feature at the headwaters of Grand Lake would be an exception to this textbook pattern. A review of average channel bed profiles shows the average bed profiles in 2009 and 2019 represent typical delta features (Response Comment Section 4.4.2, Figure 13; ITR Section 5.1, Figure 6). The average bed channel is a more representative measure than simply using the thalweg, as it accounts for areas in the channel outside of the thalweg. Between 2009 and 2019, deposition occurred on the downstream face rather than on top of the delta feature, as expected by Vanoni (2006) and Morris and Fan (2010). Further, the dam has been in place for more than 80 years, and surveys completed in 2009 and 2019 indicate that the delta feature is not growing significantly taller, but rather extending farther into the reservoir (Response Comment Section 2.2, Figure 3). These surveys indicate that the delta feature has reached an equilibrium height and is now behaving in textbook fashion, with additional sediment washing deeper into

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
				PMSSP is critically flawed because it will not answer these questions that can only be answered with a well-developed sediment transport model. GRDA has not provided sufficient documentation or discussion in the reports or a working sediment-transport model to support or independently evaluate its claim that HEC-RAS is not appropriate for this study. For example, they do not provide the bed-material gradations applied in the model, nor did they provide comparisons between the bed material gradations and the gradation of the sediment in transport. Further, they recognize that the rivers convey suspended sediment, however, they only discuss a bedload equation, neglecting the suspended bed material and fine sediment loads. GRDA has indicated it wants to discontinue the HEC-RAS sediment-transport modelling, and instead perform the PMSSP, which Tetra Tech summarizes into the following steps: 1. Evaluate the erosion/deposition patterns in Grand Lake and tributaries based on the 10-year period between the 2009 and 2018/2019 bathymetric surveys (but no other available channel geometry data). 2. Develop a 50-year mean-daily flow record at each tributary (Neosho, Spring, Elk Rivers and Tar Creek). 3. Develop sediment-transport rating curves for the non-cohesive sediment based on the flow data and bed-material measurements. It is not clear how sediment load for the cohesive material will be computed. 4. Compute the sediment inflow volumes to Grand Lake by integrating the flow and sediment-transport rating curves over the 10-year period between the surveys. 5. Validate the sediment-transport rating curves by comparing the predicted inflow sediment volumes with the measured difference in lake volume between 2009 and 2019. 6. Run the HEC-RAS model and use the hydraulic output to develop spatial relationships between bed shear and the measured erosion/deposition patterns. 7. Predict the future erosion/deposition by: a. Computing the inflowing sediment volume based on the sediment rating curves and future flow conditions b. Estimating the vertical change in lake-bed elevation at selected cross-sections for the 50-year period by distributing the incoming sediment volume along Grand Lake based on the developed relationship between bed shear and erosion/deposition patterns. c. Adjusting the cross-sections in the HEC-RAS model to represent the erosion/deposition d. Re-running the hydraulic component of the HEC-RAS model over a series of floods and comparing the difference in maximum water-surface elevation between 2019 and future channel conditions. Our review identifies flaws in Steps 1, 3, 4, 5, 6 and 7 (excludes Step 2) and we do not believe the PMSSP will provide meaningful results. As such, we strongly oppose the proposed modified sedimentation study plan.	the reservoir rather than accumulating on top of the delta feature, which matches the expected patterns reported by Vanoni (2006) and Morris and Fan (2010).

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
				Tetra Tech previously reviewed review of GRDA's sediment transport model and noted numerous deficiencies in the model geometry. Because of these deficiencies, the model will not provide meaningful results for modelling non-cohesive sediments. That review lists changes that should be made to the model. We recommend implementing the changes in a technically defensible way and submitting an updated sediment- transport report to FERC that provides detailed analysis and findings.	
10		2	12, 1	The PMSSP indicates "As a result of the findings during the first study period, GRDA proposes to conduct a modified Sedimentation Study in the second study period to determine whether operation of the Project influences sediment transport and sedimentation within the Neosho River/Grand Lake upstream and within Grand Lake to assess the effects of Project operations on sediment erosion, transport, and deposition in the lower reaches of the tributaries to Grand Lake and to characterize the impact that sedimentation has on flooding upstream of Pensacola Dam and the conservation pool." The PMSSP changes both the study approach and study goals, which the City strongly opposes. FERC's Study Plan Determination in 2018 directed GRDA to "adopt the City of Miami's proposed methodology for conducting its sedimentation study…" The study goals and objectives under the City's methodology are to: 1. Evaluate the historic changes in channel bathymetry by comparing existing and historic survey data, including longitudinal bed profiles and cross sections. 2. Evaluate the cumulative sedimentation impacts of past Project operations on flooding in local communities and Tribal Lands along the Neosho, Spring, Elk Rivers and Tar Creek by: (1) modifying the Existing conditions comprehensive hydraulic model (CHM) to represent the historic cross-sections, (2) running the models over a range of historic flood events, and (3) comparing the differences in maximum water-surface elevation. 3. Develop a comprehensive sediment transport model of Grand Lake, Tar Creek and the Neosho, Spring and Elk Rivers, calibrate the model to historic conditions, and use the calibrated model to predict potential changes in bed elevation over the duration of the potential 30- to 50-year license period. 4. Determine potential alternatives to eliminate or mitigate the dam-related sedimentation and related flooding effects over the license period. (Tetra Tech 2018, Sedimentation Study Plan, Attachment 5 to City of Miami Comments on GRDA's Proposed Study Plan, filed July 26, 2018).	Once again, the City's comment is misleading in several important ways. First, contrary to the City's comment, FERC's SPD did not require GRDA to adopt the City's goals and objectives for the sedimentation study. Rather, the SPD only recommended that GRDA adopt the City's "proposed methodology" for the sedimentation study. Second, the City's quote from FERC's SPD conveniently drops an important qualification from FERC staff regarding the specific method that they recommended GRDA adopt. The full quote from FERC's SPD states: "Therefore, we recommend that GRDA adopt the City of Miami's proposed methodology for conducting its sedimentation study, **specifically the use of HEC-RAS for the sediment transport model**." In addition to this attempt to misrepresent FERC's SPD, the City's comment is completely counter to its prior position on the goals and objectives of the sedimentation study. When commenting on GRDA's Revised Study Plan, they stated unequivocally: "The City of Miami agrees with the goals and objectives of GRDA's proposed study, but does not agree that the proposed methodology will comprehensively address GRDA's goals and objectives." As GRDA is working diligently and in good faith with the City in an effort to find a compromise solution to this highly complex and technical matter, it is both inappropriate and discouraging that the City has chosen to arbitrarily move the goalposts, backtrack on prior progress, and make resolution even more challenging. Regardless, GRDA appreciates the City's recent comments on the heightened importance of the delta feature in understanding sedimentation processes and of the value of using HEC-RAS in aiding our understanding of these processes. Based on the City's comments, as well as WEST's ITR of the STM, GRDA is proposing a compromise solution in its USP. See also GRDA's response to Comment No. 6.
11			13, 1	The PMSSP does not make any reference to evaluating alternatives to eliminate or mitigate the dam-related sedimentation and related flooding effects over the license period, and instead, limits the study *to assess the effects of Project operations on sediment erosion, transport, and deposition in the lower reaches of the tributaries to Grand Lake and to characterize the impact that sedimentation has on flooding upstream of Pensacola Dam and the conservation poo*l.	FERC's SPD did not require GRDA to evaluate alternatives to eliminate dam-related sedimentation and related flooding effects (if any) over the license period. As explained in Section 4.2.6 of GRDA's Response to Comments on Initial Study Report, filed with FERC on December 29, 2021 (ISR Response), GRDA's relicensing application will identify any appropriate protection, mitigation, and enhancement (PM&E) measures, which

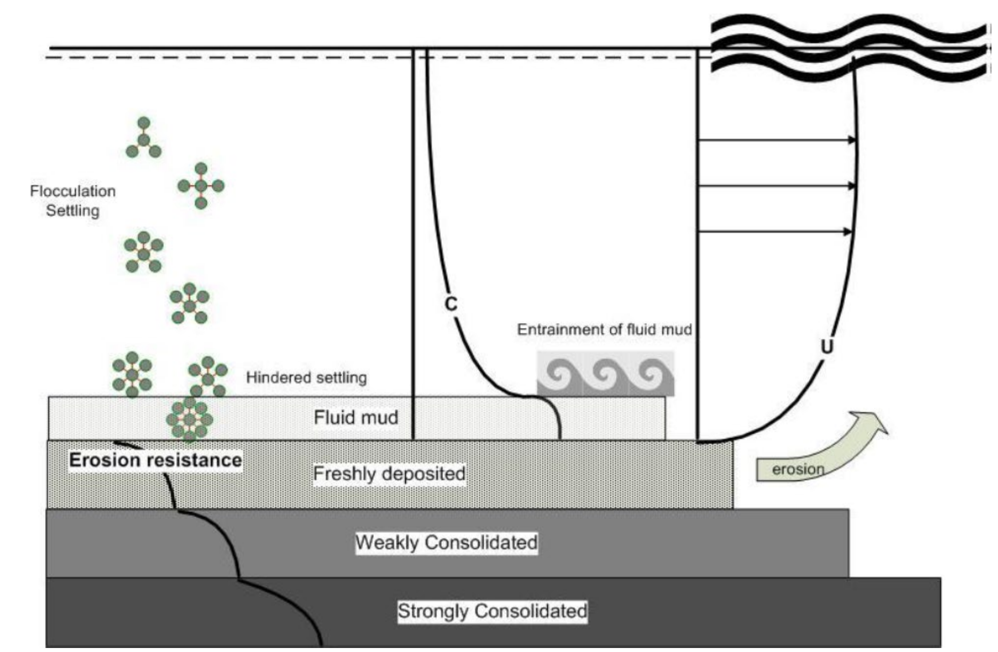
Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					will be identified and analyzed across all resources at the Project. It is premature to identify potential PM&E measures at this study phase of the relicensing effort.
12				…it appears that GRDA plans to assess the impacts of Project operation only within GRDA's limited range, not the full range of elevations the Project has historically been operated at (and reasonably could be again). This is a critical departure from the approved FERC study plan. The City requests that GRDA evaluate alternatives for mitigating the dam-related sedimentation and related flooding effects over the license period, including performing model scenarios with starting water-surface elevations beginning at 734-feet PD, the same as requested by FERC for the Comprehensive Hydraulic Model.	FERC's SPD did not require GRDA to evaluate effects associated with a starting water-surface elevation of 734 feet PD. Moreover, there is no basis for the City's speculative comment that the Project could again operate at such low reservoir elevations. Such an analysis would not in any way inform Project effects in the future because 1) neither the Commission nor any other regulatory agency has any authority to impose conditions affecting Project water-surface elevations and 2) GRDA has clearly established its intent, on the record of this relicensing, to operate within the range of 742 to 745 feet PD. These points are expressed in more detail in Sections 1.6, 4.2.1, 4.2.2, 4.2.3, and 4.2.4 of GRDA's ISR Response.
13			13, 2	The PMSSP indicates "*Specifically, there is a discrepancy between the City's assertions that sediment was primarily composed of non-cohesive materials such as sand and gravel and actual conditions.*" The December Sedimentation Report states that "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." Based on this statement, cohesive sediment- transport modeling is not needed to evaluate the impacts of sedimentation at the head of Grand Lake on upstream flooding. A sediment-transport model could be run to predict the bedload, suspended load, and wash load and the resulting aggradation/degradation patterns for the non-cohesive sediments. The model would likely predict the sands and gravels will deposit near the head of Grand Lake, while the washload component (silts and clays) would deposit farther down the lake and would be unlikely to re-mobilized. The deposition of the silts and clay would reduce the lake volume, but since they are likely deposited downstream of the hump (unlike most of the sand and gravel), they would likely have negligible impact on backwater flooding. The December Sedimentation Report includes the results of the grab samples and core sediment sampling. Specifically, the reported bed-material gradations along the Neosho River indicate sand from just upstream of the City of Miami (Figure 41, RM134.6-135.267) and downstream of Tar Creek (Figure 42, RM130.37) to just upstream of Sycamore Creek (Figure 44, RM 115.65). The sediment gradations are discussed and presented in the City of Miami's January 2022 comments. The approximate location of the grab samples is shown in the December Sedimentation Report at Figure 6 (page 15). Due to the scale of the mapping, it is not possible to identify the locations of the grab samples in the channel and to compare with the core samples (for which GRDA does report precise coordinates, in December Sedimentation Report, Appendix C, pages 1-1 to 1-2). The locations of each sediment core sample are reported in Table 1 of the SEDflume study by Integral Consulting, 2020, Appendix C to the December Sedimentation Report. Figure B, below, shows the locations of GRDA's core sediment samples by plotting the coordinates reported by	The City's comment falsely accuses GRDA of deliberately skewing sample locations to obtain favorable results. In so doing, the City demonstrates a profound misunderstanding of the purpose of this sampling effort. To understand the critical shear stress of cohesive sediment in the project area, it is necessary to collect cores from areas of cohesive sediment. Targeting areas that were both accessible by the push core used in collection and that contained cohesive sediment resulted in a need to sample from the boundaries of the stream. The City's critique that "the core sample locations were deliberately chosen to investigate cohesive sediments" is precisely what was done because that was the information needed to evaluate said cohesive sediments. It should also be noted that the cohesive sediment collected is representative of the cohesive sediment in those reaches and to imply otherwise is misleading. Critical shear stresses of non-cohesive material are well understood based on measurable properties such as grain size and density, so there was no need to collect non-cohesive material cores.

Comment No.	Section	Page No. Paragraph	Tetra Tech Observation	GRDA Response
			GRDA; Figure C shows close ups of the three core sample locations along the Neosho River and one sample collected downstream of Twin Bridges. Mapping those coordinates reveals that the Neosho River core samples were collected near the base of the left bank, and therefore likely represent fine-grained deposits along the margins of the bank or floodplain deposits that have been exposed due to minor bank erosion. Most of the larger rivers and creeks in the Midwest have a significant washload and have fine-grained floodplain deposits. None of the core samples appear to come from the main channel of the Neosho River where the sand and gravel bed material occurs. The December Sedimentation Report states that "[c]ohesive sediment cores were collected," seemingly indicating that the core sample locations were deliberately chosen to investigate cohesive sediments, not to be representative of the reaches where they were taken (page 16).	
14			The Sedimentation Study reports "This wide range of sediment types and sizes may be due to fine sediment being transported down river and deposited in the reservoir during certain events or seasons and then may be flushed farther downstream under other flow and reservoir conditions." A more likely hypothesis is that silt to gravel size material is transported during flood events, and finer silt-clay sized material is deposited on the receding limb of the hydrograph and under low (energy) flow conditions. The HEC-RAS sediment-transport model will provide valuable information for addressing this, but the PMSSP cannot.	Bedload sampling shows essentially no coarse sediment being transported through approximately 99% of the flow regime (see GRDA's response to Comments No. 1 and 2, and Response Comment Section 5). This is further supported by the comparison of channel bed profiles that show only small changes in the bed elevation from 1940 to 2019, as confirmed by the City (see Comment No. 31). If there is very little coarse material being transported into the upstream reaches and little erosion of the channel bed, the coarse materials must not be moving through the system in significant quantities. It is also unclear what the City is using as a basis for claiming that their unsupported hypothesis is "more likely" than the conclusions reached by GRDA from measured field data and interpretation of those results. Regardless, to accommodate the City's desire for a HEC-RAS STM, GRDA has proposed a compromise solution in its USP to develop a truncated HEC-RAS STM that covers the region of the delta feature. See GRDA's response to Comment No. 6.
15		14, 2	Similar to the approved Sedimentation Study Plan, GRDA proposes to perform a Bathymetric Change Analysis. The data for this analysis has been available since 2019, is relied on for the PMSSP, and the analysis should have been completed and presented as part of the ISR. Tetra Tech submitted (via the City of Miami filing on June 21, 2021) the following points in response to GRDA's 6-month Model Input Status Report for the H&H; they have been slightly modified for this review.	As discussed prior (see PMSP, USP, discussion at January 2022 Technical Meeting), GRDA will complete this work as part of the upcoming study period and will present results as part of the USR.
16			Bed elevations from the 2015 Tetra Tech and 2017 USGS surveys along the centerline of the channel between Twin Bridges and Miami are in good agreement (Figure A).	The 2015 Tetra Tech survey occurred just 2 years before the USGS 2017 survey. Sedimentation studies need datasets spanning an extended time period, as the City's consultant themselves state, arguing that "unless the Commission requires the City's requested changes, GRDA will extrapolate half a century of sediment transport from a single 10-year period." Using that same logic, the 2-year period between the Tetra Tech and USGS surveys will provide no useful comparisons. If surveys are performed too close together in time, it is difficult to tell whether measured changes reflect measurement uncertainty and errors or are due to actual changes. Evaluating changes over a longer period provides better certainty that measured changes are real thus, are reliable for calibration. Regardless, GRDA proposes using the REAS dataset upstream of RM 120.1 as discussed in the USP and in the Response Comment (Sections 4 and 7).

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
17				The 2008 OWRB and 2019 USGS surveys show similar amounts of aggradation between about the Elk River and Twin Bridges; however, elevations from the 2019 USGS surveys are typically higher.	The 2009 OWRB and 2019 USGS surveys show expected, textbook delta feature formation and evolution patterns as discussed in GRDA's Narrative Section 2.2. The City suggests that aggradation is similar between the 2009 and 2019 surveys, but the data show very limited vertical growth at the top of the delta feature and additional sediment deposition on the downstream face, as expected in textbook deposition patterns (see Narrative, Section 2.2, Figures 2 and 3). These surveys indicate that the delta feature has reached an equilibrium height and is now behaving in textbook fashion, with additional sediment washing deeper into the reservoir rather than accumulating on top of the delta feature. Please see also GRDA's response to Comment No. 9.
18				From Pensacola Dam to about 30 miles upstream, the 2019 USGS survey is 5 to 8 feet higher than 2008 OWRB survey. Conservatively, this represents an aggradation rate of 0.42 feet/year (5 feet from over 12-year period from 2008 to 2019). Based on this rate, there would have been about 28-feet of aggradation at the dam from 1940-2008, which has clearly not happened. Further, it does not seem physically reasonable that the silts and clays would be transported approximately 40 miles from the Neosho and Spring Rivers to the dam.	The City's calculated aggradation rate of 0.42 feet per year rests on a gross oversimplification: that a difference in thalweg elevation at a select location is representative of a difference in volume in a large reservoir. To properly calculate aggradation rates in Grand Lake, total storage must be considered. Total storage in Grand Lake from 2009 to 2019 decreased approximately 116,000 acre-feet, a reduction of approximately 7%. This figure is reasonable given the sediment loading to the reservoir during that period. Given the overall surface area of the reservoir (approximately 46,500 acres), that amounts to an average depth of accumulation of just 2.5 feet, or 0.25 feet/year—an entirely reasonable rate of change. Further, the City's comment demonstrates a profound lack of understanding of basic principles of sediment transport. The results of the 2019 USGS survey are not at all surprising and are easily understood by textbook deposition patterns discussed by Vanoni (2006) and Morris and Fan (2010); these processes are discussed in the Narrative document (see Section 2.2). Sediment can also be transported or flow long distances into the reservoir with some material depositing in the vicinity of the dam. The City claims that the 2009 to 2019 bathymetric data, which show significant sedimentation in the vicinity of the dam, do not make sense because of the low values of hydraulic shear stress of water flowing through the reservoir as it approaches the dam. They are apparently unaware of the phenomenon of fluid mud or turbidity or density currents, which can result in sediment moving long distances in a reservoir. Leo C. van Rijn (n.d.) states, *"The inflow of a current with a certain density into stagnant reservoir water of a slightly different density may proceed as a plume or jet like current. Driven by the density differences between the sediment-laden inflow and the clear water in the reservoir, the turbidity current plunges beneath the clear water and moves towards the dam as a submerged current."* Furthermore, he states that *"low-velocity turbidity currents are capable of carrying large amounts of fine sediment into the deeper parts of the reservoir."* In discussing hyperpycnal flows, Carlos Zavala (2020) states, *"A hyperpycnal flow forms when a relatively dense land-derived gravity flow enters into a marine or lacustrine water reservoir."* He then states that *"long-lived Newtonian subcritical flows are capable of transferring huge volumes of sediment, freshwater and organic matter far from the coast even along gentle or flat slopes."* Following on this line of thought, he states that *"no steep slopes are necessary"* for "muddy" sediment flow and that *"flow can travel for long distances since the flow is sustained by the river discharge."*

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					The following figure from "The Methods of Coastal Models" Modelling of Cohesive Sediment Dynamics by Ulrik Lumborg and Hans Jacob Vested (2008) shows the various stages and characteristics of sediment as it deposits on the bed of the reservoir.  Suspended sediment forms flocs that deposit at the bed. With increasing currents, the loose 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 are eroded. From Lumborg and Vested (2008). They 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 collecting the samples observed the following (Integral Consulting 2020): *"In general, sediment consisted of silt and clay with a surface layer of*

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					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 the development of a fluid mud layer would be forming and flowing on a seasonal basis. Based on the presence of a layer of unconsolidated sediment or fluff or fluid mud, this component of sediment 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 towards the dam, as indicated by the 2009 and 2019 bathymetry and as discussed in the scientific literature.
19				The nearby upstream tributaries are relatively small and likely do not contribute enough sediment to cause this amount of aggradation. We would expect only minor aggradation in this area since construction of the dam, therefore, the differences are likely due to differences in surveying equipment and methods, an error in one (or both) of the surveys, or a combination of the two.	The City's assertion here again implies that they are either unfamiliar with density flows, discussed by Lumborg and Vested (2008), van Rijn (n.d.), and Zavala (2020), or they are misleading FERC. Please see GRDA's response to Comment No. 18.
20				Tetra Tech also developed a comparison of the 2008 OWRB and 2019 USGS digital elevation models (surfaces) of Grand Lake, which shows that: The differences are larger at the downstream end of the reservoir (near Pensacola Dam) compared to upstream (Figure D); this is consistent with the centerline profiles in Figure A but is an unexpected result. A more typical deposition pattern would show relatively little difference between the surveys near Pensacola Dam (and miles away from the tributaries, which are the major source of sediment inputs) and larger differences near Twin Bridges due to sedimentation at the head of Grand Lake where there is a significant reduction in sediment transport capacity.	The City's assertion here again implies that they are either unfamiliar with density flows, discussed by Lumborg and Vested (2008), van Rijn (n.d.), and Zavala (2020), or they are misleading FERC. Please see GRDA's response to Comment No, 18.
21				The USGS (2019) report presents an elevation-volume rating curve (Figure 11) that indicates a reduction in volume at the dam crest elevation (755 feet) of about 10 percent between 2008 and 2019 and about 17 percent between 1940 and 2019 (USGS Figure 5). The USGS (2019) attributes the difference to survey methods and equipment but does not provide either profile or planform comparisons of the two surveys to allow independent evaluation of this conclusion. It does not make physical sense that storage volumes experienced only a 7-percent decline over the 68-year period from 1940 to 2008, but a 10 percent decline over the 11-year period from 2008 to 2019.	The City seems to be comfortable evaluating a full record of measured data when it suits their interests and discarding data that go against their favored narrative. They argue that it is unreasonable to believe there was a 17% decrease in storage over an 80-year period when the first 70 years showed only a 10% loss to attempt to discredit the thoroughly quality controlled and well-documented 2009 survey. In the exact same document, they argue that the entire REAS dataset seems perfectly reasonable despite suggesting stable bathymetry near the delta feature from approximately 1940 to 1998, massive increases in deposition from 1998 to 2009, and then minimal deposition from 2009 to 2019. GRDA does not dispute the fact that deposition patterns suggested by the circa 1940 dataset are imperfect. That does not negate the fact that they represent the best available information. GRDA has discussed the

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					shortcomings of the circa 1940 data—and the REAS information—in their submissions (see USP, Response Comment Section 4.1 and 4.4). They recognize that there are concerns and are open about those flaws. Regarding those shortcomings, the circa 1940 stage-storage curves are based on relatively few cross-sectional surveys and topographic maps. Clearly the accuracy, resolution, and coverage of the surveys performed in 2009 and 2019 are better than the pre-dam surveys', and it is far more likely the volume estimates from circa 1940 would have significant uncertainty. Using coarse evaluations for the circa 1940 storage does not have any impact on whether the 2009 or 2019 surveys are valid. Moreover, the USGS reviewed the 2009 OWRB survey and did not find any major issues with the resulting bathymetric dataset. The documented quality control (QC) procedures include the use of standard USACE surveying guidance (USACE 2002). The OWRB used a DIGIBAR-Pro Profiling Sound Velocimeter to calibrate the SyQuest Bathy 1500 Echo Sounder to account for changes in sound velocity in water at various depths during the survey. Quality assurance crossline checks were performed to evaluate the repeatability of the survey measurements at a given location. This was done within HYPACK software, a widely used hydrographic surveying package. A total of 111 cross-section points were used to evaluate errors; the results showed a mean difference of 0.5 foot, which meets USACE (2002) requirements, and a standard deviation of 0.43 foot. Depth accuracy at the 95% confidence level was calculated to be +/- 1.3 feet, which is better than the minimum performance standards defined by USACE (2002) of +/- 2.0 feet. Position information was provided by differential GPS. The settings used for the system and latency testing were provided as part of the OWRB (2009) report as well. In summary, the City has not presented any valid reason to believe this dataset, which includes a reported 692,445 data points (coverage and track lines shown below) and meets USACE (2002) guidance for hydrographic surveys, is at all suspect. The City instead argues that it should be thrown out simply because the documented changes between 2009 and 2019 do not match the City's biased expectations-which, again, run counter to textbook principles of sediment transport. With regard to the 2019 dataset, the City has not provided any evidence supporting its vague, easily dismissed assertion that the results are not what they expected. The QC procedures are well-documented and have shown the survey to be of high quality.

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
22				In summary, there are significant and unexpected differences between the 2009 and 2019 hydrographic surveys that have not been explained by GRDA. The PMSSP relies heavily on these surveys (and discards all other available channel geometry data), including for estimating the incoming sediment volume and the areas of erosion/degradation over historic and future conditions. We conclude that the PMSSP is an unworkable method that will not produce reliable results.	Although the City is obviously not pleased with the results of the 2009 and 2019 hydrographic surveys, it provides no valid scientific or technical basis for questioning them. The City's speculative concerns run afoul of basic sediment transport principles and are easily dismissed. See GRDA's response to Comment No. 18. See also GRDA's response to Comment No. 21. The City changes their views on long-term sedimentation patterns depending on the situation and offers no explanation for changes that are unfavorable for their preferred outcome. Regarding the claim that GRDA is refusing to consider past bathymetric information, GRDA is not opposed to using past data and is in fact proposing to use historical datasets to build the STM (see USP, Response Comment Section 7). The datasets will produce a circa 1940 geometry, include portions of the REAS geometry that were surveyed circa 1998 (despite concerns raised at the October 2021 ISR Technical Conference and associated report, in the Updated ISR, at the January 2022 Technical Meeting, and again in the USP and Response Comment Section 4.4), the 2009 OWRB survey of Grand Lake, and USGS surveys from 2017 and 2019. See also GRDA's response to Comment No. 6.
23			15, 5	**Sediment Transport Rate Measurements -** Tetra Tech agrees with this approach and supports the continued collection of sediment transport data, particularly under high-flow conditions. We also recommend collecting bed material samples at these locations, and further, collecting bedload and suspended load samples near the City of Miami and at Connor's Bridge to validate the HEC-RAS sediment transport model.	GRDA's USP does not propose further collection of bedload or suspended load samples. As pointed out by the City's consultant in reference to suspended sediment concentration (SSC) sampling efforts in GRDA's Proposed Study Plan (Tetra Tech 2018), "Coupled with the very limited number of existing samples and the limited ability to collect sufficient additional samples during the study period, the relationships suggested here will have extremely high uncertainty and will be of little or no value in meeting study objectives." The City's consultants are once again changing their position, suggesting that having a small number of sediment transport measurements *is* useful with no explanation for the change of position. Regardless of the City's shifting viewpoint, the presence of USGS gaging stations at the locations GRDA already measured enabled GRDA to supplement known datasets; locations near the City of Miami and Connors Bridge will not have those data points and are therefore not capable of providing useful calibration or validation measurements. The existing USGS and GRDA datasets provide sufficient information for model development, and additional efforts will not appreciably aid STM development. The City's proposal also requires GRDA to time sampling efforts to capture specific extreme flows that cannot be easily predicted or guaranteed in the remaining time allotted for the study. The cost of sending field crews to the site on short notice is simply not justified by the minimally useful data that might be obtained.

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
24				Suspended sediment measurements were collected at the new Stepp's Ford Bridge across the Neosho River near Commerce Gage at intermediate flows of about 15,500 cfs and 37,500 cfs. For reference, the reported bankfull discharge at the Commerce Gage is about 20,000 cfs. The sampling site is located in a very wide section of the floodplain that conveys a significant amount of the flood flows. The suspended-sediment measurements indicate the concentration of the sediment greater than 0.0625 mm (i.e sand fraction) is about 18 mg/l at 15,500 cfs which equates to 751 tons/day, and 16 mg/l at 39,500 cfs, which equates to 1,614 tons/day. This clearly shows that sand is being transport in suspension along the Neosho River, and therefore, bedload transport must be occurring as well.	Please see GRDA's response to Comment No. 2. The City's calculated bedload transport comprises just 1% to 3% of total sediment transport in the system at the flow rates described; at lower discharges, the non-cohesive material will be even less significant.
25				The December Sedimentation Report provides little detail on how the suspended transport material samples were collected, except to indicate they followed USGS procedures. (December Sedimentation Report at 21-22.) For example, the report does not specify the mesh size of the bag, the number of samples at each site or the sampling time. The December Sedimentation Report provides no information on how the bed load measurements were collected.	GRDA followed the USGS guidance (USGS 2006) for equal-width-increment (EWI) sampling using a D-74 isokinetic depth-integrating water sampler. A description of the process followed is included in the Narrative document submitted with this response (see Section 6).
26				In addition, it is not clear what the grab samples represent. For example, two sediment gradations were collected at River Mile 145.5 (1-NR60SS and 13-NR60S). The information does not specify whether this site is at the Stepps Ford Bridge or further upstream, nor does it indicate the geomorphic features the samples represent. The 1-NR60SS sample has a median (D50) size of about 5mm and 13- NR60S has a median size of 10mm, indicating that they are made up of gravel with a lesser amount of sand.	GRDA has provided the locations of the grab samples and accompanying field notes in Appendix B. This information was *not* required under the FERC-approved SPD but has been provided here as a good-faith effort to be responsive to the City's requests.
27				Tetra Tech performed sediment transport capacity calculations at comparable discharges to those at the time of the suspended sediment measurements. The hydraulic data were obtained from the CHM and converted to cross-sectionally averaged values. At 15,500 cfs, the model predicts an average main channel depth of 12.7 feet, velocity of 4.7 ft/s and the energy slope of 0.00021. At 39,500 cfs, the main channel flow is approximately 26,710 cfs, the average velocity is approximately 4.7 ft/s, the average depth is 18.4 ft and the energy slope is 0.000184. The model output indicates backwater conditions at higher flows, likely caused by the downstream channel contraction and bedrock outcrop in the channel bed. The sediment transport capacities were computed for these two discharges using the USACE's SAMwin software by applying the Meyer-Peter Müller (1948) sediment transport equation with the hydraulic conditions listed above and the coarser bed material gradation, Sample 13-NR60S. The predicted bedload at 15,500 cfs is 34 mg/l or 1,448 tons/day, and the predicted bedload at 39,500 cfs is 20 mg/l or 1,426 tons/day. These predicted rates are consistent with expectations from the suspended sediment measurements and indicate that substantial sand and fine gravel is transported at the gage site. A correctly developed HEC-RAS model is appropriate for modelling these sediment transport conditions.	Please see GRDA's response to Comment No. 2. These sediment transport rates are an exceedingly small portion of total sediment loading to the reservoir despite the City's claims.

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
28			16, 2	**Sediment Samples –** During GRDA's sedimentation study conference on January 14, 2022, GRDA indicated it intends to collect additional vibracore samples in Grand Lake. The location and depth should be recorded, and a gradation analysis should be performed on the samples. It is recommended to keep the samples for chemical analysis for the requested contaminated sediment transport study. During the conference, GRDA reported that the vibracore sampling will vibrate 16- foot tubes into the sediment bed. As shown in Figure A, the sediment depths are up to 30 feet between Twin Bridges and Elk River, and therefore, the vibracores will not be long enough.	The City has shown no credible evidence that the sediment deposition is up to 30 feet (see GRDA's response to Comment No. 9). GRDA has already collected these samples, and location and depth were recorded for each. Grain size evaluations indicated largely silt and clay materials in all cores on the delta feature (see Response Comment, Section 3.3 and Appendix C). The USGS (Juracek and Becker 2009) collected several gravity core samples and analyzed them at equal intervals for various contaminants as well as Cesium 137 (Cs-137) to give approximate deposition dates. They collected several samples, including one on the delta feature at approximately RM 113. This core, named GL-1 in their study, represented approximately 6 feet of sediment. Their testing found no 1963 peak in Cs-137 activity, indicating that their collected sample had been deposited after 1963. They suggested that deposition was not continual at this location, but that sediment was deposited and washed away regularly. Because sample GL-1 was relatively short, GRDA analyzed deeper cores for Cs-137 in this area. GRDA collected two separate cores at approximately RM 112.34 (5.1-1 and 5.2-1) and divided the cores into 4-cm increments and sealed them in glass sample jars with labels indicating core collection time and date, depth range of the sample, and core identification number. Material along the edge of a core tube is disturbed during coring and some mixing occurs at that boundary. Therefore, care was taken to avoid collecting materials from the area within 1.5 cm of the core tube. Ten samples were selected at equal intervals from each core for Cs-137 analysis. The results showed that there was again no obvious peak of Cs-137 activity (see Response Comment Section 3.2). A more detailed report will be provided as part of the USR. However, it should be noted that these findings lend further support to the USGS (Juracek and Becker 2009) statement that the area is not continually depositional. As they explicitly stated, the water in that area is shallow, and sediments are therefore prone to wave disturbance, which would move sediment. As stated in the Response Comment (Section 3.2), Cs-137 analysis requires areas of continual deposition to provide useful information about sediment deposition dates, and both USGS (Juracek and Becker 2009) and GRDA findings indicate that the delta feature is not purely depositional. Given typical behavior of delta features, this is to be expected, as the deposited sediments move downstream rather than continually settle on the top of the delta feature (Vanoni 2006, Morris and Fan 2010; discussed also in Section 2.2 of GRDA's Response Comment). There is no value in further testing of the sediment cores. The USGS findings (Juracek and Becker 2009) have been confirmed with GRDA's efforts. As stated by Juracek and Becker (2009), trends in sediment constituents in this area are not reliable indicators. They also analyzed a range of constituents in their core samples that are publicly available for review should the City or others wish to evaluate the USGS data.
29			16, 4	**Proposed Field Work –** The PMSSP states "As presented in the ISR, GRDA's consultants have analysed the 1998 REAS bathymetric dataset and found the dataset to be unreliable for the purposes of the Sedimentation Study." GRDA should clearly explain the basis for this statement. This data set has been used extensively including for litigation purposes. GRDA have only	Please see GRDA's response to Comment No. 22, the attached Response Comment Section 4.4 and 7, and the USP for a discussion of the portions of the REAS dataset that will be used in future efforts and the rationale for discounting other portions.

Comment No.	Section	Page No. Paragraph	Tetra Tech Observation	GRDA Response
			highlighted specific areas that they deem unreliable. GRDA must provide a comparison along the full length of the available data, and show which parts of are unreliable and why, and which parts can be used with confidence.	
30			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 difference between PD and NGVD29 is 1.07 feet. (For example, 745 feed PD is 746.07 feet NGVD.) Applying the datum adjustment in the wrong direction would have resulted in a difference of 2.14 feet (2 times 1.07 feet). GRDA should investigate the datum shift and to determine if the adjustment was applied incorrectly, in which case the REAS dataset probably may be reliable.	The City's argument seems to be that there was poor quality control for this dataset, but nevertheless, it "probably may be reliable." This only further supports the USACE's (and GRDA's) statement that the data did not undergo sufficient review and are clearly unreliable. GRDA already evaluated the REAS dataset and concluded there is likely a discrepancy with the datums used (see Response Comment, Section 4.4.4). It is unclear which surveys or cross-sections Tetra Tech is comparing the REAS thalweg against. The circa 1940 USACE data shows it is lower than the REAS thalweg in some locations and higher in other locations. The 2017 USGS survey is also lower than the REAS thalweg in some locations and higher in other locations. The time difference between the 2015 Tetra Tech survey and the 2017 USGS survey of the Neosho River is so short that it is not a useful dataset for the purposes of this study. Please see GRDA's response to Comment No. 16. In any event, as detailed in GRDA's response to Comment No. 22, the USP, and Section 4.4 of the Response Comment, most of the REAS data are completely unreliable, and GRDA will not be using these unreliable portions in carrying out the USP. The portions collected circa 1998 (above RM 120.1) will be used for the USP with the understanding that this is the best available information despite being a flawed dataset.
31			Further, 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 survey data for the reach upstream of the City.	The City is proposing replacement only of areas actually surveyed as part of the 1998 REAS study. The quality control for this area is suspect (as confirmed by the USACE, GRDA [response to Comment No. 22, USP, and Section 4.4.4 of the Response Comment], and the City [Comment No. 30]), but this reach will be used during STM calibration. The concerns about datum applications (see Comment No. 30 and GRDA's response to Comment No. 22) highlight the shortcomings, but GRDA also recognizes that this is the best available data covering that portion of the river between 1940 and 2017 and proposes using it in the USP.
32		17, 1	**Sub-Bottom Profiling -** Tetra Tech supports the use of sub-bottom profiling to determine the depth of sediments in the reservoir, and in particular, along the historic channel alignment. This information should be compared with the historic bed elevation profiles.	A summary of the subbottom profiling efforts completed in January 2022 will be provided with the USR.
33		17, 2	**Non-cohesive sediments –** The PMSSP proposes to use a representative sediment transport equation to predict sediment transport rates. Tetra Tech agrees with GRDA that these equations are not appropriate for modelling the cohesive materials. Back-water conditions in Grand Lake and its tributaries create looped (hysteresis effect) hydraulic rating curves and the sediment rating curves will, therefore, also be looped. The PMSSP does not acknowledge, nor explain how looped sediment rating curves would be developed and applied. This is a significant flaw in the study, which will lead to incorrect estimates of the sediment loads.	Given that both the STM and quantitative sediment transport evaluation approaches use daily flow in a quasi-unsteady model and the single value sediment rating curves, neither the City's method nor the PMSP would directly account for any looped relationships. Concerns raised about this issue by the City are either misleading or represent a misunderstanding of how the STM will calculate sediment transport. Regarding hysteresis and backwater, looped sediment rating curves occur on both impounded and unimpounded streams. HEC-RAS can be used to model impounded and unimpounded systems. The City's comment is another attempt to advance the unsupported narrative where backwater from the Project is assumed without scientific proof. In contrast, GRDA's H&H Study showed that the impact from nature-driven inflow events is 70 times greater than the impact of the Project starting pool elevation, as discussed in Section 4.5.1 of GRDA's Response to Comments on Initial Study Report (GRDA 2021).

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					However, after considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.
34			17, 3	**Cohesive sediments –** The PMSSP indicates that "Erosion rates will be determined for specific scenarios and compared with field observations, SSC measurements, and bathymetric changes." Assuming that the channel bed is cohesive, there is no discussion of how the erosion rates will be determined. The previous comment regarding the looped-rating curve applies here. Further, the repeat surveys of Grand Lake indicate it is depositional.	Please see GRDA's response to Comment No. 33. The simulated movement of sediment through the reservoir is dictated by the comparison of changes in bathymetric data and the incoming sediment load and the distribution of hydraulic shear stresses. This movement of sediment may result in transport, erosion, or deposition of sediment as the change in bathymetric data indicate. The PMSP would not explicitly use the erosion rate parameter developed from SEDflume. The rate of erosion, in this context, is derived from changes in bathymetry compared to the incoming load. GRDA agrees that the repeated surveys of Grand Lake indicate it is a depositional area. That is well-established behavior of impoundments and not something that is surprising in the least. That does not mean there is no erosion elsewhere in the system. It is unclear what the City is suggesting. However, after considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.
35			17, 4	**Evaluation of Sediment Loading -** The PMSSP indicates that "There is a direct relationship between the hydraulic shear stress and the transport or deposition of cohesive sediment as it flows down the rivers and into the reservoir." This highly generalized statement is overly simplified, and potentially incorrect, depending on how the analysis is actually implemented. The fine sediment (i.e., silts and clays) load (also referred to as the wash load) is not directly related to the local bed shear stress, but rather depends on the supply from upstream sources (mostly beyond the study area). As a result, the anticipated quantities can only be estimated from suspended sediment measurements. The coarser fraction of the sediment load (i.e., sand and gravel) is carried at the hydraulic capacity based on a combination of the local bed shear stress, vertical velocity profiles, and the bed material size. The sand- to gravel-sized material will continue to deposit near the head of Grand Lake, while the silts and clays will settle out of suspension further into the lake at a rate and	It is accepted that hydraulic shear stress is a primary driving force for the transport of sediment and/or deposition (Simons and Senturk 1992). Other factors include the settling velocity and the extent to which fluid mud or turbidity/density currents may play a role in the transport of sediment through the reservoir (see GRDA's response to Comment No. 18). Further, the upstream loading has already been evaluated through field measurements (see GRDA's response to Comment No. 25; and Response Comment Section 6), which, as the City states, defines the cohesive sediment loading. There is nothing in the City's comment that suggests GRDA does not already have sufficient information to perform the analysis that was proposed in the PMSP. However, after considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
				spatial distribution controlled by the settling characteristics of the sediment, local hydraulic conditions and reservoir depths.	are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.
36				Figures 64 to 68 in Section 5.2.1 in the December Sedimentation Report compare the modelled hydraulic shear stress (though it is not clear if this is the maximum shear stress over the hydrograph) against the “critical shear stress for upper layers of deposited sediment” at 4,320 cfs (low flow), 30,500 cfs (intermediate flow) and 90,100 cfs (high flow). Figures E and F (below) reproduce GRDA’s Figures 68 and 69, respectively. At the modelled flows, the hydraulic shear stress is near or exceeds the critical shear stress, indicating that cohesive sediments eroded in the reach from the City of Miami to well downstream of Twin Bridges. This explains why the channel is composed of sand and gravel. Further, the cohesive sediment samples appear to have been collected near the banks or in areas of low velocity, and do not appear to be representative of sediment-transport conditions in the main channel. GRDA indicates that [t]hese hydraulic shear stresses cause cohesive sediment to be transported farther downstream into the reservoir. These same hydraulic shear stresses experienced during this flow event are great enough to erode some of the existing non-cohesive deposits and move them further downstream along with cohesive sediments in suspension (p. 84 of the December Sedimentation Report). In the discussion for the 30,500 cfs flow, GRDA states, [d]ownstream from Sycamore Creek, hydraulic shear stresses experienced are similar to the critical shear stresses at the deposited sediment surface in the region where samples were collected. Farther downstream in the reservoir the hydraulic shear stresses continue to decrease to zero which would cause cohesive sediment in suspension to deposit. Figure 69 in Section 5.2.1 in the December Sedimentation Report shows a distinct hump where the primary non-cohesive sediment deposits are located in the reservoir (Figure 69). The pattern of hydraulic shear stress with respect to critical shear stress and settling properties of the cohesive sediment dictate where the suspended sediment deposits. These shear stress figures in the December Sedimentation Report support the need for HEC-RAS sediment transport modelling (see Figure E below). GRDA reports that non-cohesive sediments deposit at the hump and cohesive sediments deposit downstream of the hump where they do not influence backwater flooding. An appropriately developed HEC-RAS model will predict the erosion and deposition patterns in and potentially upstream from the “hump” over a range of flood events. The PMSSP will not.	As the City points out in their comments, the modeled shear stresses predict that cohesive sediments would have eroded from Miami to downstream of Twin Bridges. As a result, the channel has become naturally armored, leaving the less erodible, less mobile material (sand and gravel) on the bed. GRDA has never claimed that there is no non-cohesive material on the riverbed, only that it does not appear to play a significant role in overall sediment transport within the system, as confirmed by comparisons of cohesive sediment transport. Cohesive sediments represent approximately 97% to 99% of the total sediment load during large flow events and likely a greater portion during lower discharge events. The shear stress figures referenced by the City (Response Comment Section 3.1, Figure 4) indicate that the cohesive sediment continues to move downstream. The City also does not explain how the referenced figure (Response Comment Section 3.1, Figure 4) supports the need for HEC-RAS modeling. The HEC-RAS model using hydraulic outputs to determine the deposition patterns of the system. The PMSP would also have used hydraulic outputs from a HEC-RAS model to determine the deposition patterns of the system. GRDA’s initial bed shear stress findings (December 2021 Updated ISR and Response Comment Section 3.1) indicate that sedimentation occurs exactly as predicted by textbook delta evolution patterns. The City implies, again without proof or any supporting evidence and disregarding survey data showing otherwise, that the delta feature in question would somehow be an anomaly to normal sedimentation. Although samples from the upper portions of the study area contain a significant quantity of non-cohesive material, those collected in the region of the delta feature contain significant quantities of silt and clay. For example, samples GS-W3, GS-W4, and GS-W5 were collected between RM 114.21 and 115.86 (on the delta feature) and show 30% to 45% cohesive material contents, a significant portion that will impact sediment transport characteristics as seen in HEC-RAS documentation (USACE 2016b), stating, “Additionally, mixing and armoring algorithms in both the main sediment model and BSTEM compute a ‘% cohesive’ and take different approaches based on the percentage of the bed material [that is cohesive].” The HEC-RAS reference manual (USACE 2016a) clarifies, saying “if more than 20% of the active layer is cohesive, then the model considers the sediment ‘matrix supported,’ assuming cohesive sediment is abundant enough to fill the voids and regulate the erosion rate of all particles.” The City's evaluation of how the PMSP would have worked is not valid. The PMSP would have computed hydraulic shear stress on a daily basis using HEC-RAS over the 50-year time period, not on a 5-year increment. This approach is based on the relationships developed between sedimentation patterns and hydraulic shear based on bathymetric changes. The PMSP would not rely on distinguishing between sand to gravel or clay-to-silt sizes of material as the sedimentation pattern includes any and all types of sediments in the system. It does not matter whether the sediment is of one type or another, the relationship relates sedimentation patterns (whether it is of one type of sediment or another) to the distribution of hydraulic shear stress. Again, the PMSP approach would have avoided the complex issues of sediment modeling and would have directly uses data and basic hydraulic modeling information. Hydraulic shear related to erosion or deposition patterns are applicable in upstream reaches as this is the primary driving force for sediment

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					transport and either erosion or deposition of sediment. These relationships have not yet been developed because FERC has not yet decided which approach to follow pending the City's comments and GRDA's responses to the comments. Regardless, after considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.
37			18, 2	The PMSSP states that "At a number of locations along the river and reservoir, a hydraulic shear-duration curve will be developed over the 2009 to 2019 time period, similar to a flow duration curve (One set of curves will be developed based on the 2009 data and another set on the 2019 data so the change in shear distribution will be determined at the various locations along the river and reservoir). Based on the incoming sediment load and sediment deposition patterns from the change in crosssections or bathymetry, the quantity of sediment being deposited between key locations or passing farther downstream will be calculated. This will establish the historic deposition of sediment at various locations along the river and reservoir and the corresponding distribution of hydraulic shear stresses that caused the sediment to deposit where it did over this time period." This method does not make sense for the following reasons. 1. As previously noted, sediment deposition/settling (especially the fine sediment component) is only tangentially correlated with bed shear stress. The lowest shear stresses will be in the deepest part of the lake. In reality, the coarse sediment will fall out at the head of the lake and the finer sediments will preferentially settle in downstream areas within the reservoir based on how long it takes to fall out of suspension. The PMSSP would assume that the greatest deposition will occur in areas with the lowest shear stress, which will predict that the bulk of the deposition will occur well downstream in the reservoir. The PMSSP would then inaccurately show there is no deposition on the upstream limb of the "hump" nor any continued impacts that would increase the backwater effects.	The correlation between hydraulic shear stress from HEC-RAS with the quantities of sediment deposited in the delta feature based on changes in bathymetry, as well as sediment settling concepts, as well as the concept of fluid mud or density currents, which may account for the fact that the bathymetric data show significant sediment deposition in the lower reservoir, were considered in the PMSP and discussed in GRDA's response to Comment No. 18. This is also discussed in the USP. The City states that, "The PMSSP [*sic*] would then inaccurately show there is no deposition on the upstream limb of the 'hump' nor any continued impacts that would increase the backwater effects," without explaining why such a finding would be inaccurate. They seem to be claiming that the PMSP will find deposition to occur where bed shear stress is the lowest. Not only is that exactly the expected location of sediment deposition, but it also indicates that the City has determined the bed shear at the top of the delta feature is high enough to wash sediment downstream and is only low enough to result in deposition on the downstream face of the delta feature. This conclusion in fact matches the exact textbook expectations of delta feature formation and evolution as detailed by Vanoni (2006) and Morris and Fan (2010). If the PMSP were to find that to be the case, it would be far from an atypical result. See GRDA's response to Comments No. 9 and 36. Regardless, after considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
38				2. The hydraulic shear-duration curves are developed at a "number of locations along the river and reservoir..." The selection of these locations is subjective and the spacing between the locations is not defined. In comparison, a hydraulic model has significantly more resolution for predicting bed elevation changes. The PMSSP does not indicate how the hydraulic shear-duration curves will account for the looped sediment-transport conditions, in fact it may not be possible to develop hydraulic shear duration curves due to the non-unique shear versus sediment transport relationships.	The same cross-sections developed for the STM are available for the hydraulic shear-duration curves so any of these may be analyzed. It is intended that the analysis focus on key locations along the reservoir where significant changes occur in the shear-duration curves. Given that both the STM and hydraulic shear-duration approaches use daily flow in a quasi-unsteady model and the single value sediment rating curves, neither the City's method nor the PMSP would directly account for any looped relationships. Concerns raised about this issue by the City are either misleading or represent a misunderstanding of how the STM will calculate sediment transport. Nevertheless, after considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed an USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence, combined with the other two components of the three-level approach which include qualitative geomorphic and quantitative engineering and geomorphic approaches as outlined in the USP.
39				3. The PMSSP does not quantify how GRDA will calculate the incoming sediment loads to the upstream boundaries. For example, it does not specify if sediment rating curves will be developed, and if so, whether they will be developed based on measured values or based on sediment transport capacity.	The incoming sediment loads are based on the sediment rating curves that were presented in the Updated ISR filed in December 2021 (see Section 3.1.4.1.1 for the specific curves). These sediment rating curves are based on data collected by the USGS and GRDA.
40				4. As indicated in comments to Section 2.1 above, there are discrepancies between the 2009 and 2018/19 surveys that do not makes sense, particularly downstream of Elk River. Therefore, it is not reasonable to develop a method that relies exclusively on changes between the 2009 and 2018/19 surveys.	GRDA does not agree with the City's speculative comment of discrepancies between the 2009 and 2019 datasets. Please see GRDA's responses to Comments No. 18 and 21.
41				The PMSSP states that "[r]elationships will then be developed for the distribution of hydraulic shear and how it varies in the downstream direction correlated to the amount of sediment deposited between each successive location. These relationships define the historic pattern of sedimentation as dictated by hydraulic shear stress and how it varies along the river and reservoir as compared to the quantity of incoming sediment load based on the historic hydrology and sediment rating curves applied to that hydrology." To predict future rates, the PMSSP proposes to start with the 2019 geometry, determine the sediment input over a 50-year period and distribute the sediment along the reservoir based on predicted shear patterns. This will be done on about a 5-year increment. As discussed previously, this method (1) is based on inaccurate sediment volume estimates, and (2) does not account for the physical processes of sand-togravel sized sediments being deposited near the head of the lake and clay-to-silt sized material being flushed farther downstream into the reservoir. The PMSSP states that "[t]his approach focuses on key data and direct physical relationships between hydraulic shear stress and sedimentation patterns. This approach does not have to rely on the complexities of cohesive sediment characteristics as previously discussed regarding modeling issues because the simple relationship between hydraulic shear stress and sedimentation already integrates and explains these complexities without having to delve directly into them through use of an overly simplistic sediment transport modeling approach."	As discussed in GRDA's response to Comment No. 37, hydraulic shear stress is absolutely one of the most important drivers of sedimentation. The City's allegation that "[t]he shear stress and sedimentation data are available, and it would have been relatively easy to demonstrate an example of the relationship," conveniently disregards the figure comparing measured sediment critical shear stress and modeled hydraulic bed shear stress that the City references in Comment No. 36 (it is also provided in the attached Response Comment Section 3.1, Figure 4). GRDA performed the exact analysis the City is asking for and found that the critical shear stress of the sediment shows that sediment will continue moving downstream rather than depositing on the top of the delta feature. This is again typical behavior for such features when their heights are in dynamic equilibrium (see GRDA's response to Comment No. 9 and the Response Comment Section 2.2). It is also unclear what the City believes drives sediment transport if bed shear stress and inflow loading compared to bathymetric change are not reliable indicators of the primary driving force and resulting pattern of sedimentation. These sets of information include all sizes of sediment being transport into and deposited in the reservoir. If they have alternative theories, they have not presented them to date or cited any scientific literature that disputes GRDA's position. Further, the City's evaluation of how the PMSP would have worked is not valid. The PMSP proposed to compute hydraulic shear stress on a daily basis using HEC-RAS over the 50-year time period, not on a 5-year increment. This approach was based on the relationships developed between sedimentation patterns and hydraulic shear based on bathymetric changes. The PMSP would not rely on distinguishing between sand to

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
				GRDA has not demonstrated there is a "direct physical relationships between hydraulic shear stress and sedimentation patterns", particularly with respect to the fine-grained sediment. The shear stress and sedimentation data are available, and it would have been relatively easy to demonstrate an example of the relationship.	gravel or clay-to-silt sizes of material as the sedimentation pattern includes any and all types of sediments in the system. It does not matter whether the sediment is of one type or another, the relationship relates sedimentation patterns (whether it is of one type of sediment or another) to the distribution of hydraulic shear stress. Again, this approach would have avoided the complex issues of sediment modeling and directly used data and basic hydraulic modeling information. Regardless, after considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed an USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.
42				GRDA provides no documentation or working model to support their claim that HECRAS is not an appropriate model, other than general statements in the PMSSP and at the Technical Conference. The information it has provided is not sufficient to permit an independent check of their conclusions—in particular because it appears that GRDA provided only HEC-RAS modeling files from the hydraulic calibration, not the reported attempts at calibrating the sediment transport components of the model).	Please see GRDA's response to Comment No. 5.
43				Non-cohesive and cohesive sediment transport routines were available in the USACE HEC-6 software since at least the early 1990's. The routines were incorporated and updated in HEC-RAS 5.0 in 2017. They are well tested and have been used extensively in similar settings. GRDA offers no justification (and we see none) for concluding that HEC-RAS is inappropriate for this application.	The date that cohesive sediment transport routines were first incorporated to USACE HEC software is irrelevant. The issue at hand is whether those routines are sufficient to accurately model cohesive sediment transport. GRDA has presented evidence supporting their findings that the cohesive sediment parameterization used by HEC-RAS is overly simplistic and limits the software's accuracy when dealing with silt and clay material (see GRDA's response to Comment No. 6, Updated ISR Section 5.2). By truncating the model below RM 105, GRDA is proposing a solution that will use HEC-RAS to explicitly model sedimentation in the upper reaches of the study area where the model is most capable of predicting sediment transport. It also removes the lower reaches of the reservoir where the model is least able to simulate and where precise location of sediment deposition is unimportant (see Comment No. 6, where the City states, regarding cohesive materials flowing into the lower portions of the reservoir, "…their spatial distribution in the reservoir is largely irrelevant to the hydraulics of the tributaries and upstream flooding"). The trapping efficiency and incoming sediment load analysis will still allow GRDA to predict changes to reservoir storage volume and evaluate impacts to the power pool as required by FERC's SPD. Statements from the U.S. Society on Dams (USSD), referring to modeling sedimentation in impounded reservoirs, stated in 2015 that: • 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.

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					• These deposited sediments present a sediment transport challenge because of the difficulty in characterizing the erodibility of cohesive materials since erodibility will vary as a function of time, depth, consolidation, reservoir operations, and other factors. • 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. GRDA also addresses processes not captured by HEC-RAS in their response to Comment No. 18. Density currents and other phenomena that transport sediment deep into reservoirs despite low shear stress are not uncommon, but HEC-RAS is not designed to simulate such occurrences. Even if HEC-RAS were developed to handle those phenomena, it still does not have the ability to simulate the wide range of sediment parameters measured in the study area (see Updated ISR Section 5.2.2, Table 22). Density varies by 485%, critical shear stress by 3,000%, and both grain size and erosion rate by 1,000,000%. HEC-RAS uses routines that do not begin to capture that level of complexity, even without considering temporal changes as a result of cohesive sediment consolidation. In making the SPD, FERC relied on data from the City that suggested non-cohesive sediment dominated the system, and cohesive materials were unimportant to the overall study. GRDA's field measurements repeatedly showed that was not the case, and as a result, the data-gathering and modeling efforts became significantly more complex and required more time. Because the cohesive sediment routines in HEC-RAS are limited and simplified, GRDA determined it was not a viable option for the modeling efforts. GRDA stands behind the technical basis for the PMSP, and the City's criticisms of the methodology are unfounded (see GRDA's response to Comments No. 33, 35, 36, 37, 38, and 41). Despite that, after considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.
44	January Memo	Intro	1, 1	As detailed below, the Commission should reject GRDA's attempt to modify the Sedimentation Study Plan for three reasons: the request comes three months late, GRDA has failed to show good cause to depart from the approved study plan, and GRDA's proposed alternative will not answer the most important sediment related questions posed by this relicensing.	GRDA presented their reasons for the modification requests multiple times, including within the PMSP and in the December 2021 ISR filing (see Section 5.2.2) and January 2022 Technical Meeting. In making the SPD, FERC relied on data from the City that suggested non-cohesive sediment dominated the system, and cohesive materials were unimportant to the overall study. GRDA's field measurements

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					repeatedly showed that was not the case, and as a result, the data-gathering and modeling efforts became significantly more complex and required more time. Because the cohesive sediment routines in HEC-RAS are limited and simplified, GRDA determined it was not a viable option for the modeling efforts. GRDA stands behind the technical basis for the PMSP, and the City's criticisms of the methodology are unfounded (see GRDA's response to Comments No. 33, 35, 36, 37, 38, 41, and 43). Despite this unfounded criticism, after considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
45		I	4, 2	Critically, GRDA's main change would jettison a key element of the study that GRDA has always opposed: the use of computer sediment transport modeling to understand and predict the Project's effects on sediment transport, and particularly the extent to which it exacerbates backwater flooding. The City advocated this approach, and the Commission noted in its November 8, 2018 Study Plan Determination ("SPD") that "the City of Miami's proposal provides a more clear, comprehensive, and standardized approach to collecting and analyzing the data necessary to adequately understand the potential effects of the project on sediment transport processes upstream." … Accordingly, the SPD required GRDA to "adopt the City of Miami's proposed methodology for conducting the sedimentation study," including sediment transport modeling with HEC-RAS.	The City's comment misleadingly states the FERC-required methodology for this study. See GRDA's response to Comment No. 10. The City's claim that sediment transport exacerbates backwater flooding is another attempt to advance the unsupported narrative of "backwater flooding" and presumes a conclusion without supporting information. GRDA's H&H Study showed that the impact from nature-driven inflow events is 70 times greater than the impact of the Project starting pool elevation, as discussed in Section 4.5.1 of GRDA's Response to Comments on Initial Study Report (2021). GRDA has not proposed to abandon HEC-RAS despite what the City argues. The PMSP instead proposed using the hydraulic outputs of the model to quantify sediment transport and deposition. Dr. Robert Simons, a member of GRDA's consultant team was involved in a project in which he performed quantitative analysis of sediment transport and deposition on a system dominated by cohesive sediment and reviewed results of analyses on the Hudson and Ashtabula rivers without a separate sediment transport model, instead relying on a hydraulic model and known sediment parameters (Simons and Simons 1996). *In situations where computer models are used, it is critical that professional judgement is used to ensure reliability of results. FERC itself stated in a 1988 report that a "[computer model] cannot be a substitute for professional experience." The same article stated "While models are highly useful tools, they can also be a source of misinformation for users and project reviewers who do not understand all the assumptions, capabilities and limitations of a particular computer model. Such is the case with computerized sedimentation models."* As stated by Simons and Simons (1996), "Using a computer model to analyze and predict sediment transport only works when the analyst considers the model's limitations and the physical processes involved, and conducts adequate calibration and verification." When GRDA began the sediment transport modeling process, they originally planned to calibrate sediment transport between the REAS and 2009 datasets, then validate the calibration using the 2019 terrain. As they worked on that process, they found that the REAS dataset was unreliable. As a result, they were only able to calibrate the model, not validate the calibration, which meant the predictive capability of the STM would be suspect. Following the PMSP would have allowed GRDA to achieve the goals of the study with increased confidence in the final results. Regardless, after considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

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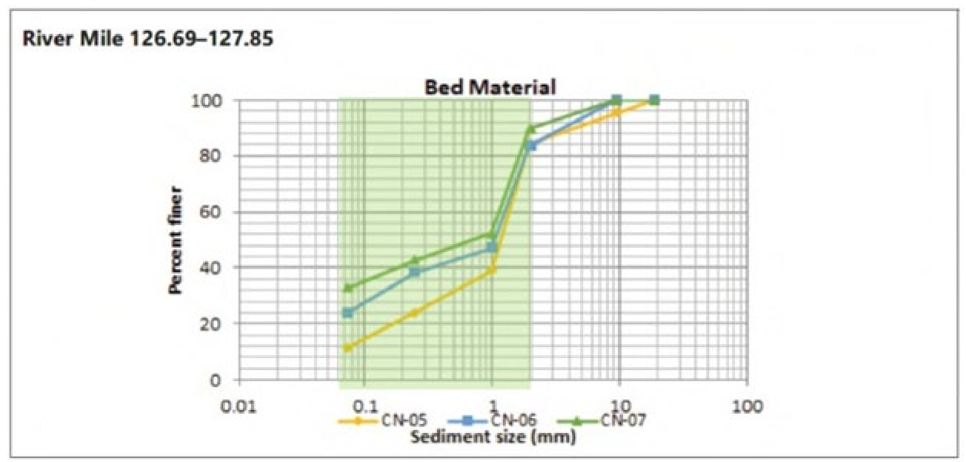
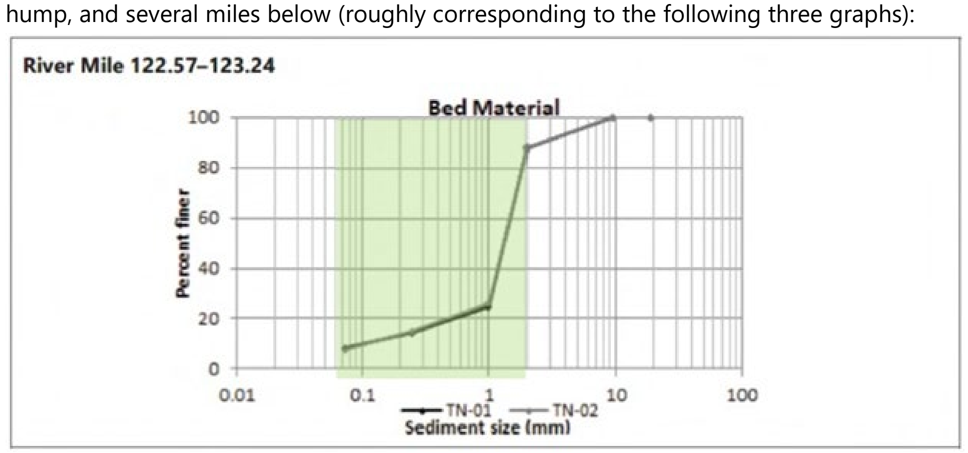
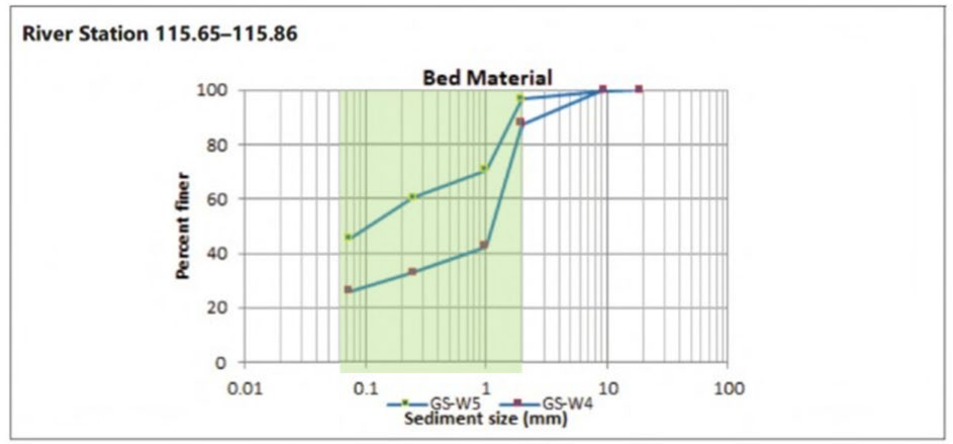
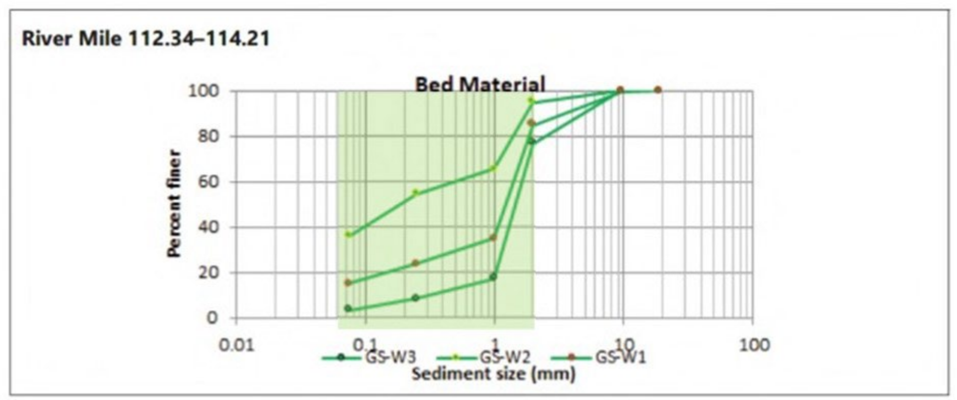
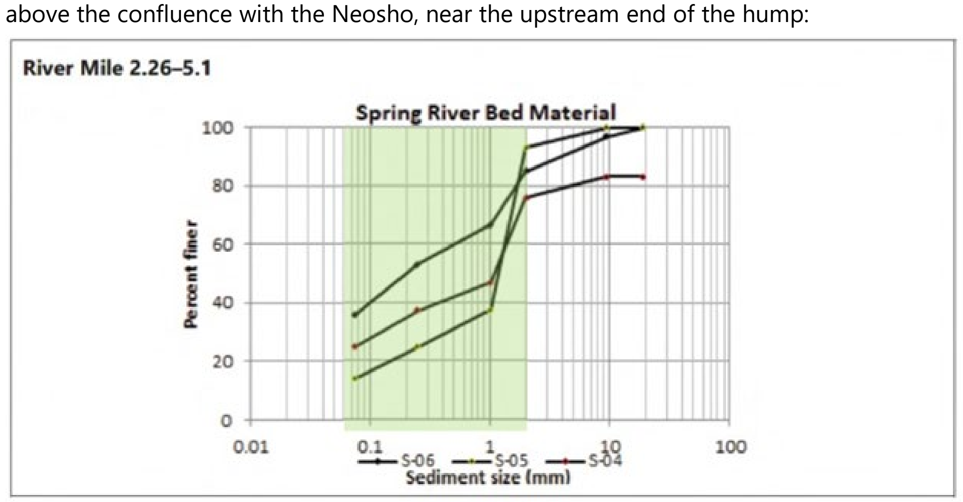
46			4, 3	The Commission should reject GRDA's request for three reasons. First, the Commission should not reward GRDA's inexcusable delay in requesting a modification to the study. Second, GRDA has not shown that HEC-RAS cannot work. Rather, GRDA's own December Sedimentation Study undercuts the GRDA's factual arguments for the request, and GRDA's consultants committed fundamental errors in setting up the model. Finally, GRDA has not shown good cause for its proposed alternative, a mashup of estimation techniques that do not represent the physical sediment transport processes and invites bias into the study's conclusions.	GRDA stands behind the technical basis for its PMSP, and the City's criticisms in its comment are unsubstantiated and untrue. See GRDA's response to Comments No. 33, 35, 36, 37, 38, 41, and 43. Regardless, after considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.
47		I A	4, 4	The Commission should reject GRDA's untimely request because it undermines the Commission's ability to develop a clear, rigorous basis for any conditions it later imposes in this relicensing process. Moreover, GRDA misled the Commission and stakeholders in its ISR. GRDA claimed that "[t]he Sedimentation Study was completed in accordance with the [Revised Study Plan ("RSP")], as modified by the Commission [S]taff in the [Study Plan Determination], except for one variance in schedule." But instead of a mere adjustment to the schedule, GRDA requested major changes to the substance of the study. On top of that, GRDA had the audacity to oppose providing stakeholders with an opportunity to comment on those major changes. The Commission should not condone such cavalier treatment of stakeholders or the ILP process.	GRDA did not mislead the stakeholders in the ISR. The study was performed according to the SPD with the schedule variance. GRDA is astounded by the City's allegation that GRDA somehow misled the Commission in this process. As the City is quite aware, the reason that the Sedimentation Study Report remained a work-in-progress at the time of the ISR is not due to GRDA's tardiness. Rather, it was attributable to the Commission's mistaken reliance on the City's representations of non-cohesive sediments—representations that were proven to be highly inaccurate, and which required GRDA to consider other options to meet the goals and objectives of the Sedimentation Study. These baseless allegations from the City are completely unproductive, because they distract from the rigorous, good-faith efforts by GRDA to resolve an extraordinarily complex study program. At every stage of relicensing, FERC's ILP regulations are intentionally iterative, to allow experts to exchange information and ideas, and in this case, Commission staff have allowed a full second round of engagement—beyond what is required in its regulations—to facilitate resolution. And while the City's unfounded attacks are distracting and unproductive, GRDA appreciates the City's detailed comments on the PMSP. While GRDA does not agree with the City on much of its substantive claims, after further review and collaboration, it does see the merits of revising the PMSP to rely on HEC-RAS modeling of sediment transport at and above the Elk River confluence.
48		I B	5, 4	GRDA seeks to modify the Sedimentation Study on the grounds that cohesive sediments (silt and clay) dominate Grand Lake and its tributaries, and that HEC-RAS is inappropriate for modeling sediment transport in systems dominated by cohesive sediment. GRDA is wrong on both points. Its own data show that the tributaries to Grand Lake transport sand (a non-cohesive sediment) in significant quantities	As shown in GRDA's responses to Comments No. 1 and 2, the transport of fine sediment in the silt and clay range is much greater than the transport of sand in this system, with cohesive sediments making up 97% to 99% of total sediment loading. See also the PMSP, December 2021 Sedimentation Study Report (Section 5.2).
49				...sand appears to make up most of the sediment "hump" that has accumulated at the head of the reservoir. In effect, the hump appears to act like a submerged earthen dam, increasing the extent to which the Project backs floodwaters up into the City and surrounding areas. The question then becomes: Did the hump accumulate as a result of dam operations, and how will operation of the dam affect it over the term of a new license? Pre-dam surveys, engineering principles, common sense, and much of the data in the December Sedimentation Report suggest that the hump's existence is a Project impact and that dam operations likely govern its behavior.	The City states that the delta feature acts as a "submerged earthen dam, increasing the extent to which the Project backs floodwaters up into the City and surrounding areas," but they have offered no proof of this claim. One of the goals of the Sedimentation Study is to determine whether Project operations have any effect on the upstream water levels, but the City has already jumped to the conclusion that it does before the study has been completed. They have no technical basis for these claims. They wish to answer questions about the delta feature's origin and expected future evolution without studying it. GRDA is investigating sediment transport right now, and it is too early in the process to make baseless accusations. The City provides no evidence supporting their speculation about potential impacts of operating at lower water levels before indicating the delta feature "might" partially erode under those conditions. They also

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
				For example, if the reservoir were operated at lower levels, especially during high-flow events, the hump might partially erode, thereby reducing upstream flooding. Flooding is therefore a Project impact that might be mitigated in a new license by operating the Project so as to affect the hump. Nowhere does GRDA dispute that HEC-RAS is well-suited for modeling the movement of sand. Because GRDA's own data shows that sand predominates in the vicinity of the hump, HEC-RAS is well-suited to this study, as explained in the next section. The subsequent section then explains why GRDA is also wrong methodologically and that HEC-RAS remains appropriate even if cohesive sediment were the primary issue in the study. GRDA's pitch for discarding HEC-RAS relies on its assertion that cohesive sediments dominate the Grand Lake system, which supposedly makes HEC-RAS incapable of representing that system. Thus, trying to abandon HEC-RAS, GRDA claims that sediment samples "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." GRDA claims to have found "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." In particular, it asserts that "the streambeds consist of gravel with limited sand[.]"	then claim that "[f]looding is therefore a Project impact that might be mitigated in a new license by operating the Project so as to affect the [delta feature]," but this is again purely speculative. They have produced no evidence that this is the case, and they jump to conclusions without allowing for a full, scientific study. Although samples from the upper portions of the study area contain a significant quantity of non-cohesive material, those collected in the region of the delta feature contain significant quantities of silt and clay. For example, samples GS-W3, GS-W4, and GS-W5 were collected between RM 114.21 and 115.86 (on the delta feature) and show 30% to 45% cohesive material contents. Vibracore samples show large proportions of cohesive material as well (see GRDA's Response Comment, Section 3.3 and Appendix C). Even the comparatively low percentages measured at GS-W3, GS-W4, and GS-W5 are significant portions that will impact sediment transport characteristics as seen in HEC-RAS documentation (USACE 2016b), stating, "Additionally, mixing and armoring algorithms in both the main sediment model and BSTEM compute a '% cohesive' and take different approaches based on the percentage of the bed material [that is cohesive]." The HEC-RAS reference manual (USACE 2016a) clarifies, saying "if more than 20% of the active layer is cohesive, then the model considers the sediment 'matrix supported,' assuming cohesive sediment is abundant enough to fill the voids and regulate the erosion rate of all particles." The incoming sediment load, as shown by the data, consists primarily of silt and clay materials transported in suspension. Laboratory analysis of the recently collected core samples, which cover much of the area of the delta feature (the primary area of concern regarding sedimentation and potential upstream effects) also show that they are largely composed of silts and clays (see GRDA's Response Comment, Section 3.3 and Appendix C). The idea that cohesive material is irrelevant to the study is not founded on measured data; GRDA has shown cohesive sediment to comprise 97% to 99% of total sediment loading (see GRDA's response to Comments No. 1 and 2).
50		I B 1	6, 2	GRDA's own data, however, directly contradict that assertion and reveal that sand dominates the riverbed for some 15 miles in the crucial transition from river to reservoir. This sandy reach spans at least from the downstream side of the hump (the farthest-downstream grab sample reported) up into both the Neosho and Spring Rivers several miles above where they combine near the upstream end of the hump. Further, the cohesive samples reported by GRDA along the Neosho River all appear to be collected along the base of the left bank and, therefore, it appears they represent bank material and not bed material.	Please see GRDA's responses to Comments No. 13, 36, and 49.

Comment Response Table

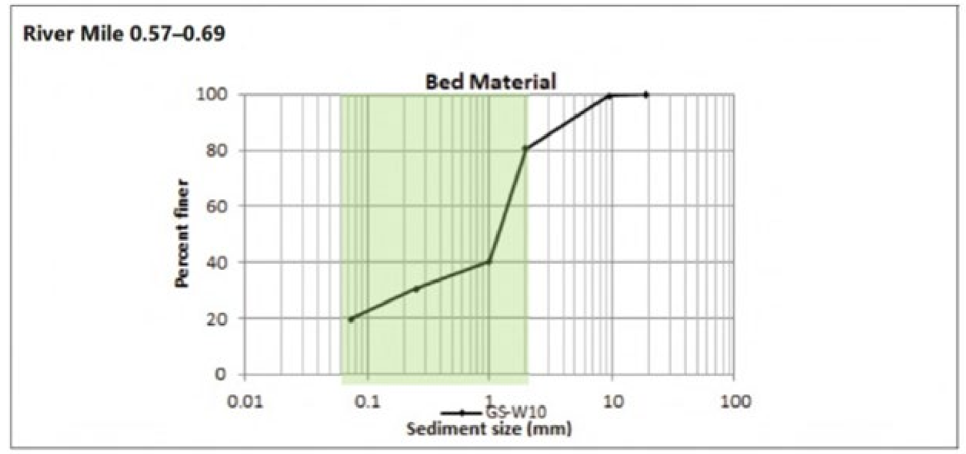
Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section	Page No. Paragraph	Tetra Tech Observation	GRDA Response
51		6, 3	The figures below are taken straight from the December Sedimentation Report; they show GRDA's grab sample data, with each curve representing the proportions of different sediment sizes in an individual sample. To each, the City has added a green box spanning the range of sediment sizes considered to be sand (including by GRDA). The percentage of sand in a sample is the difference in the curve's height from one side of that box to the other. For example, in the first graph below, subtracting the values on the left side of the box from the values on the right side shows that sand makes up roughly 55% (sample CN-07) to 70% (sample CN-05) of the samples. The sample data show that sand dominates the Neosho River bed starting about four to six miles above Twin Bridges and the start of the hump.  This holds true moving downstream, as11 of the remaining 13 grab samples from lower in the Neosho River contain about 50% to 80% sand. Those samples span Twin Bridges, the peak of the hump, and several miles below (roughly corresponding to the following three graphs): 	Samples CN-05 through CN-07 were collected at RM 126.69 to 127.85. These locations are approximately 4 to 5 miles upstream of the upper end of the delta feature. The non-cohesive material upstream of the delta feature is typical of the non-cohesive sediment found in the riverine reaches upstream. These samples do not represent the finer sediment forming the delta feature. On the delta feature, cohesive silts and clays form a significant portion of the sediment (see GRDA's Response Comment, Section 3.3 and Appendix C) which decrease the suitability of the cohesive sediment transport routines used by HEC-RAS. Regardless, after considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach. Please see GRDA's response to Comments No. 36 and 49.

Comment No.	Section	Page No. Paragraph	Tetra Tech Observation	GRDA Response
				
52		9, 1	The Spring River tells a similar story. Sand dominates all four grab samples in the five miles just above the confluence with the Neosho, near the upstream end of the hump: 	The City is again asserting that the sediment in the delta feature region is primarily non-cohesive, but as discussed in GRDA's Response Comment, Section 3.3 and in their response to Comment No. 49, much of the sediment in that location is cohesive. Regarding the full scope of the study, FERC's SPD required GRDA to evaluate the impacts of sedimentation on the power pool and storage volume as well. The limited parameterizations used by HEC-RAS for cohesive sediment transport are not capable of accurately simulating cohesive deposition in the lower reaches of the reservoir. GRDA's USP proposes a compromise solution that would rely on explicit modeling in upstream areas and a separate analysis in the lower reservoir to address this issue. Please see GRDA's responses to Comments No. 3 and 6.

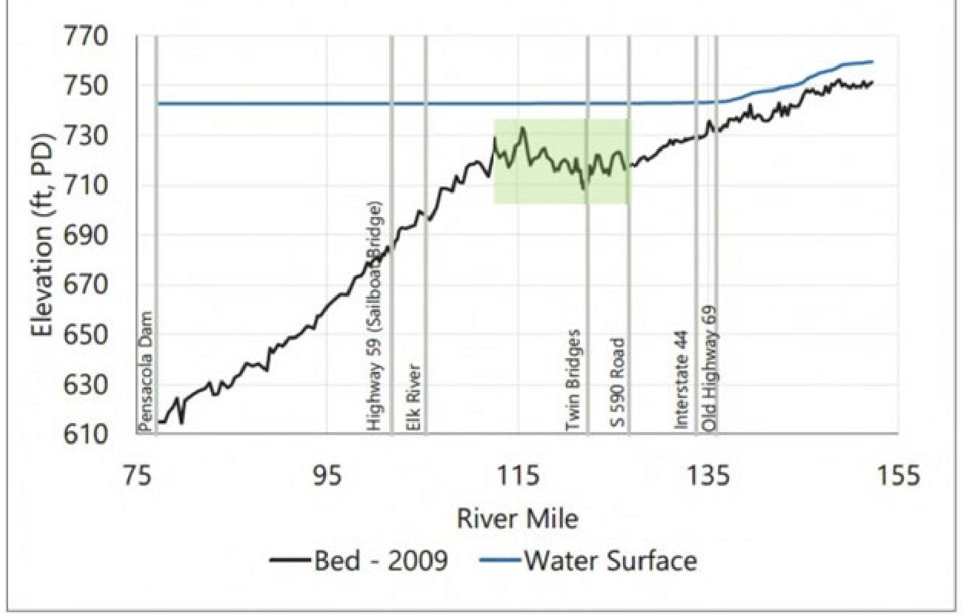
Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
				 These results show remarkable agreement that non-cohesive sands dominate the bed for 15 critical miles where the tributaries meet the reservoir. Deep in its report, GRDA acknowledges this: "The profile of the riverbed shows a distinct hump where the primary non- cohesive sediment deposits are located in the reservoir[.]" GRDA's data (presented above) show that sand dominates those deposits, so GRDA's statement about the hump appears irreconcilable with another statement in the same report: "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[.]" Because that latter factual representation is the linchpin to GRDA's entire argument against HEC-RAS, the graphs above lay that argument to rest.	
53			10, 1	It is also important which 15 miles of bed the sand dominates—and it turns out to be the reach with the most important impacts on upstream flooding, and also the reach where Project operations have the greatest effect on sedimentation, by controlling the location of the river-reservoir transition. The next figure is GRDA's representation of the Grand Lake / Neosho River bed profile, included in the December Sedimentation Report to show the location of the hump (centered around River Mile 115 under GRDA's numbering).27 The City has added a green box showing the reach of the river where sand predominates, as indicated by the graphs above. (Sand could remain prevalent downstream from that reach, but GRDA has not reported any grab samples from the Neosho downstream from the green box.)	Please see GRDA's response to Comment No. 49.

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section	Page No. Paragraph	Tetra Tech Observation	GRDA Response
			Figure 69 **Neosho River Thalweg and Water Surface Profiles** 	
54		10, 2	Moreover, GRDA's sediment transport sampling shows that sand is not stationary in the tributaries, but moves in significant quantities. For example, based on GRDA's suspended sediment sample results, Tetra Tech calculated that the Neosho River at Commerce Gage (well upstream of the City) carries roughly 1,000 tons per day of sand as suspended sediment at flows of about 20,000 cfs, and roughly 1,600 tons per day of suspended sand at about 40,000 cfs.	As shown in GRDA's response to Comment No. 1, the transport of fine sediment in the silt and clay range is much greater than the transport of sand in this system. The tonnages of cohesive material estimated at the same flows are approximately 34,000 tons per day and 100,000 tons per day, respectively. According to the calculations that the City is relying on, the non-cohesive materials make up as much as 3% or as little as 1% of the total load under these flows. At lower flows with decreased bed shear, the percentage of material carried in suspension will be higher.
55		11, 1	In sum, GRDA's actual data (as distinct from its self-serving conclusions) support what it concedes is the City's "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[.]" Sand dominates the bed of the hump and both tributaries for several miles upstream. GRDA's field data suggest that the rivers have sufficient energy to move that sand downstream to the hump, but not enough to move it into the reservoir. Presumably, this happens because the river's energy dissipates as soon as it meets the reservoir, meaning that the level at which GRDA maintains the reservoir under the new license critically impacts the hump and its contribution to upstream flooding.	Please see GRDA's response to Comment No. 1.
56		11, 2	In short, the fate of sand in the tributaries is the most important question in the Sedimentation Study, and HEC-RAS remains the best tool to answer that question. The Commission should deny GRDA's request to abandon HEC-RAS on that basis alone…	Please see GRDA's response to Comments No. 1, 49, and 54. The fate of sand is clearly not the most important question in the Sedimentation Study as demonstrated by the dominance of the actual source of sediment being primarily suspended sediment consisting of silt and clay transported by the rivers and deposited in the reservoir. However, after considering comments received from the City and others following the January 2022

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					Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.
57		I B 2	11, 3	GRDA's argument for abandoning HEC-RAS (and computer modeling of sediment transport altogether) relies on its incorrect claim that HEC-RAS cannot adequately represent cohesive sediment transport in Grand Lake and its tributaries. In fact, the HEC-RAS sediment transport modeling files provided to the City reveal fundamental errors in the construction of the model, which would have failed to accurately represent the system regardless of sediment makeup.	Please see GRDA's response to Comments No. 43 and 75 to 81. After considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and remove those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. The USP includes a qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.
58			11, 4	Moreover, GRDA's arguments against using HEC-RAS here apply to any other river system with significant cohesive sediments. In effect, GRDA argues that HEC-RAS is never an appropriate tool for modeling cohesive sediment transport—a position inconsistent with the successful use of HEC-RAS to represent such systems for decades. GRDA's contrary arguments, aiming to invalidate HEC-RAS as a viable approach to sediment transport modeling, do not follow from its study efforts to date. GRDA observes that after attempting to set up the HEC-RAS sediment transport model, "tests were performed, and the results were erroneous[.]" This "lead[s]" GRDA "to the conclusion that the model is unreliable as a predictive tool for sedimentation." However, the unreliability of GRDA's model does not show that HEC-RAS cannot be used to produce reliable results. It shows that GRDA constructed the model incorrectly. Tetra Tech's review suggests that failures in model setup are indeed one shortcoming of GRDA's model. Even without the complexities of cohesive sediment (the primary basis for GRDA's request to change horses midstream), GRDA's model as constructed would likely not calibrate successfully nor be a useful tool for predicting sedimentation. Any failure in calibration results therefore derives from user error in constructing the model, not the presence of cohesive sediment.	Please see GRDA's response to Comments No. 43 and 75 to 81. The USSD (2015) states that: *"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."* Furthermore they state: *"Most 1D sediment transport models, and transport functions, are designed for non-cohesive sediment transport. Models often include the addition of simple cohesive sediment computational procedures to enhance model capability."* Such is the case with HEC-RAS. They conclude by stating: *"For many areas, one-dimensional mathematical models are still often used with success for long-term sediment deposition predictions. However, for detailed studies two-dimensional or quasi-3D models are increasingly used, incorporating a fully hydrodynamic approach (quasi-steady for long-term simulations), and modules for erosion and deposition in cohesive and non-cohesive sediments, to be able to simulate storage, sluicing or flushing reservoir operations. Where density currents form in a reservoir, Navier-Stokes 2D vertical or 3D models should be used to describe the formation, movement and sediment transport of the density current. These models should be calibrated on local reservoir field data, especially when dealing with cohesive sediments."*

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					For these reasons, the USP focuses the modeling effort to be upstream of the Elk River confluence in the area of the delta feature and upstream reaches and does not explicitly model downstream areas of the reservoir where even more complex sediment dynamics exist and where the deposition of sediment does not influence any potential for upstream flooding. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and remove those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system.
59			12, 3	Finally, even if GRDA's consultants are unable to correctly construct the HEC-RAS model, that is no reason to abandon sediment transport modeling. The Commission should reject GRDA's attempt to avoid modeling now for the same reasons it did in the SPD. If HEC-RAS still does not work after GRDA's consultants correct the setup problems and calibrate the model, the Commission should simply require GRDA to proceed with the Sedimentation Study using a model with functionality more specifically designed for the issues GRDA raises. One such model is the Environmental Fluid Dynamics Code ("EFDC"), a public-domain, three-dimensional modeling program that has successfully been used by Tetra Tech to model Grand Lake and its tributaries. The City and Tetra Tech also understand that GRDA's consultant Anchor QEA has used EFDC in other studies. Moreover, EFDC would have a significant side benefit: it would reduce the burden of preparing the City's requested Contaminated Sediment Transport Study 34 because the same model could be used for both the sedimentation and contaminated sediment transport studies.	The City proposes using EFDC for the modeling effort, partially because it would streamline work on their requested Contaminated Sediment Transport Study—a study request that has been repeatedly denied by FERC. EFDC, while a powerful model that can be used for evaluating cohesive sediments is not a workable solution. The development time frame for the model would be 9-12 months, which is not feasible within the time constraints of the study. The model is also designed to evaluate single events; it is poorly suited to simulation of a 50-year relicensing period. GRDA has also evaluated Delft3D as a potential option for this study, but again, the model cannot be developed quickly enough for the purposes of this study, and it is also not designed for years-long simulations. After considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.
60		I C	13, 1	GRDA's methodology would ignore the impact of backwater effects on sediment transport, even though such effects have long been demonstrated as a result of the Project (including as a key contributor to upstream flooding).	This is simply not true. The PMSP evaluates the hydraulic bed shear stress to determine sedimentation patterns within the entire study area. The reason any backwater could impact sediment transport is because of the decreased hydraulic bed shear stress, which is exactly what the PMSP would evaluate. These effects are in no way ignored in the PMSP, and it is unclear what basis the City is using to make these false assertions. Furthermore, GRDA's H&H study has shown that operations of the dam do not contribute to flooding in upstream areas. Water-surface elevations upstream of the dam are a function of incoming flow event volume, not Project operations. As discussed in Section 4.5.1 of GRDA's Response to Comments on Initial Study Report (December 29, 2021), the impact of nature-driven inflow events is 70 times greater than the impact of the Project starting pool elevation. It is disingenuous of the City to presume a conclusion regarding backwater effects when scientific analysis has already proven otherwise. After considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.
61			13, 2	The PMSSP does not explain how GRDA would determine erosion rates for cohesive sediments, so even if GRDA were correct that cohesive sediments cause a problem with the existing study, the PMSSP contains no proposed solution.	The PMSP would have developed the relationship between the quantity of sediment being transported down the rivers (based on flow data and the sediment rating curves based on data) and into the reservoir to the quantity of sediment that would either have been deposited at a given location and the amount of sediment that would have been transported further downstream from that given location (based on the change in bathymetric data over time). These relationships would have been based on data. This approach did not rely on determination or application of the erosion rate parameter, which as the data show varies by 5 orders of magnitude. The beauty of the PMSP was that it relied on very direct analysis of the change in bed elevation at a given location compared to the quantity of sediment being delivered (based on the flow and sediment rating curves), and the computed distribution of hydraulic shear stress from the STM. This method avoided the tremendous issues of the wide range of erosion rates that is a key parameter in the modeling process. GRDA agrees that one benefit of HEC-RAS would be to determine erosion rates, which is one of the reasons GRDA has decided to propose the USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence along with qualitative geomorphic and quantitative geomorphic analyses as part of the three-level approach.
62			13, 3	The PMSSP relies heavily on professional judgment, reducing transparency and avoiding production of a tool (the model) that others could use for apples-to apples comparisons of different operating conditions or scenarios. Stakeholders and Commission Staff have been appropriately wary of allowing GRDA to rely too much on professional judgment in related contexts.	The City's comment is both nonsensical and unproductive. Any environmental studies—and particularly modeling work—rely on professional judgment, and Commission staff have not expressed or demonstrated any wariness of GRDA's professional judgment. To the contrary, Commission staff are considerably satisfied with all the environmental and technical studies conducted by GRDA to date. While the sedimentation study has proven to be complex and acrimonious, GRDA has sought to be collaborative, transparent, and forthcoming in attempting to find resolution. In fact, the PMSP relied primarily on the analysis of data and less on professional judgment. The key elements of this approach were again the flow data, sediment rating curves based on data, bathymetric change based on data, and the computed distribution of hydraulic shear stress based on the STM. As noted by FERC in a 1988 article that a "[computer model] cannot be a substitute for professional experience." The same article stated "While models are highly useful tools, they can also be a source of misinformation for users and project reviewers who do not understand all the assumptions, capabilities and limitations of a particular computer model. Such is the case with computerized sedimentation models." Using the STM and the extremely wide range of a number of parameters requires much more professional judgment than the approach in the PMSP. The fact that the City of Miami's consultants think that not much professional judgment is required when using the STM demonstrates a serious lack of understanding of the modeling process, particularly in light of the tremendously wide range of parameters required to be used and the simplifications associated with the model.
63			13, 4	Abandoning sediment transport modeling would omit one of the three elements of GRDA's own methodological framework for the study, returning to a "two legged stool" approach like the one previously criticized by the City.	GRDA does not agree that the PMSP would have reverted to the "two legged stool" approach, as fully explained in the PMSP, GRDA proposed to continue to use HEC-RAS for the key element of computation of hydraulic shear stresses over a range of flow and reservoir operation conditions.

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					Regardless, after considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.
64			13, 5	The PMSSP would ignore all possible Project operations outside a very narrow range of reservoir elevations, between 742 and 745 feet Pensacola datum ("PD") at the dam. GRDA can argue that it is free to operate the reservoir only at high levels, but it is not free from the obligation to understand and mitigate the impacts of its operations. Doing so requires studying the sediment impacts of the full range of reasonable reservoir operating levels (such as lower levels that prevailed for much of the 20th century).	The City's comment is nonsensical. GRDA should not be required to study an operational scheme that will not be implemented during the new license term. GRDA has not regularly operated the Project below elevation 741 PD since FERC approved a rule curve modification since 1996—over 25 years ago. Those past operations are not part of the environmental baseline for this relicensing. See ISR Response Sections 1.6, 4.2.1, 4.2.2, 4.2.3, and 4.2.4.
65		II	14, 2	The discussion at GRDA's January 14, 2022 technical conference of the large sediment hump downstream of Twin Bridges shows the need for GRDA to evaluate past sedimentation trends over more than a 10-year period in order to determine the impacts of Project operations on sediment transport. GRDA notes that the hump is "where the primary non-cohesive sediment deposits are located in the reservoir[.]" A U.S. Army Corps of Engineers survey from the time of dam construction indicates that the hump consists of as much as 30 feet of sediment deposited in the last 80 years.	Please see GRDA's response to Comments No. 21 and 22. There is no credible evidence that there has been 30 feet of deposition in this area (see GRDA's response to Comment No. 9). While the presence of the delta feature is not being debated, the time frame of its development as presented by the City is unrealistic. Without the actual survey dates used to create the REAS geometry downstream of RM 120.1, there is no way to confidently calibrate the model (see Response Comment Section 4.4). The City would have GRDA ignore that and proceed as though it was surveyed at the same time as the upper portions of the study area despite clear evidence that is not the case. Simply put, it is impossible to develop a reasonable calibration using the REAS dataset at the delta feature. GRDA proposes to use the REAS dataset above RM 120.1 for calibration during STM development since it was surveyed in approximately 1998. However, the poor quality control introduces significant uncertainty. GRDA does not plan to use the undated portion of the data below RM 120.1 (see USP).
66			14, 3	GRDA does not try to explain the location of the hump, despite its importance to upstream flooding. Moreover, GRDA appears to reject the obvious explanation that the hump developed where the backwater effect from the reservoir is most pronounced, artificially slowing the Spring and Neosho Rivers to the point that they can no longer transport these sediments. GRDA rejects that hypothesis on the assumption that these rivers simply do not transport sand and gravel. That assumption is based, in turn, on the limited bedload transport sampling performed at one location each on the Spring and Neosho Rivers. The flow conditions represented in those samples include some high flows, but not extraordinary ones that would be expected to mobilize much greater quantities of these relatively large sediments. GRDA does not address the possibility that its sampling does not accurately capture non-cohesive sediment transport (and ignores the significant sand volumes in suspended sediment samples) before jumping to the conclusion that no such sediments are transported.	The City seems to have already decided that the presence of the delta feature has caused upstream flooding. To GRDA's knowledge, the City has not released a study showing this to be true, and they are jumping to conclusions without proof of their claims. The City's presumption regarding backwater effects continues to advance an unsupported narrative without scientific proof. In contrast, GRDA's H&H Study showed that the impact from nature-driven inflow events is 70 times greater than the impact of the Project starting pool elevation, as discussed in Section 4.5.1 of GRDA's Response to Comments on Initial Study Report (2021). The delta feature is a textbook example and is likely in dynamic equilibrium with respect to its vertical growth. GRDA's conclusions regarding the quantity of non-cohesive sediment transport within the system are based on extensive time spent measuring bedload and suspended load transport. The City would like to convince the Commission that the amount of non-cohesive sediment transported by the Neosho River is a large amount, but within the context of total sediment loading to the stream, it is small (see GRDA's response to Comments No. 1 and 2). The location of the delta feature is not in dispute or the fact that relatively lower hydraulic shear stresses result in some of the incoming sediment load to deposit in this reach

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					of the reservoir. The delta feature is the result of deposition of a portion of the incoming sediment load, which primarily consists of cohesive sediment (silt and clay) that is transported almost exclusively as suspended sediment load by the upstream rivers. As the data clearly show, there is very little non-cohesive sediment transport occurring in these rivers as documented by the dominance of these finer sizes of sediment and the very low quantities of non-cohesive sediment being transported. Also, after considering comments received from the City and others following the January 2022 Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transport at and above the Elk River confluence. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system. In addition to sediment transport modeling the USP includes qualitative geomorphic and quantitative engineering and geomorphic analyses as part of the three-level approach.
67			14, 4	GRDA also inappropriately discards all bathymetry and channel profile information collected before 2009 in developing its model. As a result, GRDA seeks (under both the existing and proposed new study plans) to model sediment transport over the potential 50-year life of a license based only on changes in bathymetry that occurred from 2009 to 2019, and without any quantitative modeling of the system's overall dynamics. This limited period plainly fails to capture historic trends in sediment transport, both because reservoir operating levels stayed higher during that period than they did historically (and could again), and also because ten years is simply too short a period to characterize sediment transport, which can often be dominated by a small number of very high-flow events. Indeed, that particular 10-year period includes only one very high flow event on the Spring River (December 2015) and one or none on the Neosho (depending on when during its April to July 2019 bathymetry survey the USGS surveyed the area below Twin Bridges in relation to peak flows during the disastrous May 2019 flood).	GRDA is discarding portions of datasets collected before 2009 that exhibit critical shortcomings. The failings of the REAS data have been discussed in the Response Comment Section 4.4, the USP, and in the December 2021 Updated ISR (Section 5.1.3.1): • Unknown date of surveys comprising the REAS data below RM 120.1 as confirmed by the REAS documentation • Unrealistic apparent changes in deposition patterns from 1940-1998, 1998-2009, and 2009-2019 with no explanation based on sediment loading, project operations, or other defensible evidence • Thalweg elevations below recorded water levels on the Elk River • Poor quality control throughout the study area The limitations with the circa-1940 USACE data include the following: • Limited cross-section survey data • No original station-elevation data in the region of the delta feature The 1969 USACE data: • Covers only four cross-sections near Miami Despite the shortcomings of the REAS and circa-1940 datasets, GRDA is proposing to use portions in their USP. GRDA recognizes that these flawed datasets nevertheless represent the best available survey data and are making good-faith efforts to produce reliable predictions of future sedimentation. Sensitivity analyses will help GRDA bound predicted deposition quantities and improve the understanding of potential future outcomes (see USP). It should also be noted that the City's speculation that GRDA will maintain higher water levels is baseless. Please see ISR Response Section 1.6.
68			15, 1	GRDA's treatment of the sediment hump below Twin Bridges shows how this willful blindness to historical data undermines the reliability of the study overall. Noting that the hump showed little change from 2009 to 2019, it appears that GRDA intends to simply proceed as though that hump	The City has asserted without evidence that the delta feature "exacerbates backwater flooding upstream." If there is proof of this happening, the City has not presented it.

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section	Page No. Paragraph	Tetra Tech Observation	GRDA Response
			has never changed, and therefore will not change over the next 50 years. By assuming that the hump is stable and stationary, GRDA avoids responding to what it concedes is Tetra Tech's "logical proposition" that the hump accumulated near the head of the reservoir because that is where the Project's operations cause the greatest decrease in hydraulic conditions (e.g. shear stress and flow velocities). Unless the Commission requires the City's requested changes, GRDA will extrapolate half a century of sediment transport from a single 10-year period. Worse, it will do so without acknowledging the logical conclusion that where Project operations slow tributary flows, the resulting sediment hump exacerbates backwater flooding upstream.	Further, GRDA has no intention of ignoring the presence of the delta feature. The STM includes the delta feature in its geometry, sediment properties in the area of the delta feature have been defined by GRDA's field work, and it is included in the USP. It should also be noted that GRDA is not opposed to using a longer period of record to evaluate sediment transport and is in fact proposing exactly that in the USP. GRDA has evaluated the 1969 USACE data that was referenced by a FERC consultant in the January 2022 Technical Meeting. Unfortunately, the 1969 USACE data consists of just four cross-sections covering 2.3 river miles in the vicinity of Miami. GRDA has also reviewed circa-1940 USACE data, which is limited but will be used in the USP. As discussed in GRDA's response to Comment No. 67 and in the Response Comment (Section 4.4.1), the REAS dataset is not reliable below RM 120.1.
69		15, 2	Finally, GRDA has indicated that it intends to gather additional sediment cores in the study area. At the January 14, 2022 technical conference, the U.S. Fish and Wildlife Service suggested that the presence and concentration of heavy metals at various depths in those cores could be used as a marker for whether or not the sediment at a given depth was deposited within the historic period (i.e., since activities at the Tri-State Mining District began generating significant heavy metal inputs into the system's sediment). This method could provide new data to corroborate or question the historical bathymetry data that GRDA simply discards, including the 1940 pre-dam survey by the Corps. If GRDA does not perform such testing, at a minimum, the Commission should require GRDA to retain the sediment cores collected, keeping depth information intact, to allow such testing in the future.	GRDA has already collected these samples, and location and depth were recorded for each. Grain size evaluations indicated largely silt and clay materials in the cores throughout the region of the delta feature. GRDA collected sediment cores for Cs-137 testing. These approximately 10-foot cores were divided into 4-cm increments, and 10 of each were evaluated for Cs-137 activity. Results support the USGS (Juracek and Becker 2009) study suggesting the delta feature is not continuously depositional (see GRDA's response to Comment No. 28 and Response Comment Section 3.2). Additional testing will not provide useful information for this study. The USGS study (Juracek and Becker 2009) evaluated sediment constituents in multiple locations already, and that information is publicly available for review should the City or any other stakeholder wish to review their findings.
70		16, 1	**6. GRDA should be required to design and run its sediment transport model to determine the Project's historical and ongoing role in creating the sediment hump where the reservoir slows the flows from its tributaries**	The delta feature will be included in any evaluation of sediment transport in the study area. GRDA reassures the City that it has no plans to ignore parts of the stream geometry.
71		16, 2	**7. GRDA should be required to study the impact of a wide range of reservoir operating levels on the size and location of the hump over the term of a new license**	Please see GRDA's response to Comment No. 70. GRDA will be studying the impact over the range of operating levels it anticipates operating under during the new license term. Any other study parameters would be unreasonable and would not produce information relevant to the Commission's environmental analysis. See ISR Response Sections 1.6, 4.2.1, 4.2.2, and 4.2.3.
72		16, 3	**8. Based on the conclusions derived from the preceding requirement, GRDA should be required to model the contribution of Project sediment effects - particularly the hump - to flooding in and around the City of Miami over the term of a new license**	Please see GRDA's response to Comment No. 70.
73		16, 4	**9. GRDA should not be allowed to discard all pre-2009 channel geometry data, but instead should be required to use all available historical data in calibrating its model, except where it can show that data in specific locations are unreliable**	Please see GRDA's response to Comments No. 67 and 68.

Comment Response Table

Grand Lake Sedimentation Study, Initial Study Report and January 2022 Technical Meeting

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
74			16, 5	**10. GRDA should be required to test new sediment cores for heavy metals at different depths, or at least preserve the samples to allow for such future testing, as evidence of historical deposition.**	Please see GRDA's response to Comments No. 28 and 69 and Response Comment Section 3.2.
75	Attach 1	Table	19, 1	With respect to cohesive sediments, GRDA has not presented any argument as to why HEC-RAS is less well suited to modelling cohesive sediment transport in the Grand Lake system than anywhere else. Rather, GRDA's criticisms could be applied any time significant cohesive sediment is present. Thus, GRDA's criticism appears to amount to a general claim that HEC-RAS is unsuited to cohesive sediment modelling—despite the fact that the cohesive sediment modelling functionality of HEC-RAS has been widely used since at least the early 1990s. Cross-section spacing varies widely between adjacent sections in parts of the model. For example, the cross-section spacing in the "Neosho River / Above Tar" reach ranges from 736 ft to 1712 ft to 899 ft between RS 131.01, RS 130.87 and RS 130.54. The "Elk River / Elk River" Reach has lengths that range from 523 ft to 2429 ft to 760 ft between RS 19.59, RS 19.49 and RS 19.03. Cross-section spacing in a sediment transport model should be as uniform as possible to ensure proper aggradation and degradation effects for similar volumes of sediment. Widely varying cross-section spacing can cause unreasonable aggradation/degradation patterns over the simulation and lead to numerical instability.	While there are a few locations with larger differences in cross-section spacing, the model is generally evenly spaced. Where the stream is particularly sinuous or incoming tributaries are present, spacing varies more widely to accurately capture the stream conditions, but it is simply not the case that the model alternates between close and far spacing throughout as implied by the City. GRDA followed standard practices when developing this model. WEST Consultants did not indicate that cross-section spacing was problematic during their independent technical review of the STM.
76			19, 2	Cross-sections throughout the model generally have the near maximum number of allowable points to define the topography. This is common when basing the geometry on digital terrain models and presents no issue for hydraulic modelling. However, when modelling a mobile bed, the high number of points can lead to an exaggerated "sawtooth" pattern of erosion and deposition across the channel. This can create a cross-section with a far larger wetted perimeter than appropriate which can negatively influence the hydraulics and sediment transport computations. The common way to deal with this is to simplify the cross-section geometry by reducing the number of cross-section points that are at risk becoming dry as the cross-section evolves. Care must be taken during the simplification process to ensure the hydraulic properties of the cross-section are not significantly altered. In the absence of these adjustments, it is likely that long-term sediment transport simulation results will not be reasonable.	The model has been updated to use fewer station-elevation points.
77			19, 3	All cross-sections throughout the model use the same bed material sediment gradation, where the all the bed material is in the range from 0.0625 to 2mm. This is unexpected because the model includes channels from three different river systems, at least two of which are reported to have median (D50) bed material size larger than 2 mm (Neosho River - Figure 41) and Spring River - Figure 49), and well as in Grand Lake as far downstream as Sycamore Creek. The sedimentation study in the September 2021 ISR reports in Section 3.1.3.2 that the "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."	While the model was hydraulically calibrated, the sediment transport components of this model were not finalized for reasons explained in the December 2021 report. These settings were provided as dummy input parameters to allow the model to run, but GRDA recognizes that they do not reflect the conditions present in the study area. The STM will be updated with comments received from WEST Consultants in the ITR. WEST suggested re-evaluation of the hydraulic calibration on the STM. This focuses specifically on differences between the UHM and STM at several locations.

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					WEST also recommended simulating temperature differences in the model, as the current version used a constant temperature throughout the simulation. Temperature measurements have been recorded at various locations throughout the study area, and average seasonal variations will be used to define this. Sediment rating curves used in the model currently do not fully account for the amount of sediment entering the system. Specifically, it showed insufficient sediment supply to match the deposition in the downstream reaches (below the Elk River). A review of the curves will be incorporated into the next steps, with potential for a power relationship used to define the rating curves and increase sediment loading to match the recorded deposition. WEST also recommended using Krone-Partheniades relationships to define cohesive sediment erosion parameters, which had not been done in the version submitted for technical review. The uncalibrated version of the model showed that a similar weight of sediment was deposited in the entire region of the delta feature between RM 105 (Elk River confluence) and RM 122 (Twin Bridges), but that the distribution within the reach did not match well with the measured spatial distribution.
78			19, 4	The prescribed sediment transport function is the MPM equation which is a bedload transport function suitable for coarse-grained systems. GRDA reports significant amounts of suspended sediment transport. The current model will, therefore, likely significantly underestimate the transported mass under all conditions.	See GRDA's response to Comment No. 77.
79			19, 5	Bridges in the model are coded within the cross-section geometry and lids. This may be an acceptable configuration for bridge decks that do not interact with the flow; however, many bridges overtop or experience pressure flow under certain flow conditions. The bridge coding should be modified to permit pressure flow and overtopping computations.	USACE guidance (USACE 2016) indicates that the use of lidded cross-sections is recommended for sediment transport evaluations, as stated in GRDA's most recent ISR. The suggestion to model them otherwise would go against the City's own recommendation to maintain consistent cross-section spacing. WEST confirmed this is a valid approach during the ITR and did not recommend using bridge routines for the STM.
80			19, 6	All cross-sections in the model are configured to prevent erosion below the initial condition elevation. Even though the reach in the backwater zone from the reservoir will primarily be deposition, the inability for cross sections to in the non-backwatered part of the reach to erode will likely undermine the quality of the final results. This would also prevent evaluating alternative scenarios such as simulating conditions with starting water-surface elevation at 734-feet PD and evaluating the change in bed elevation downstream of Twin Bridges and the subsequent impact on flooding.	See GRDA's response to Comment No. 77. As explained in GRDA's response to Comment No. 71, GRDA will be studying the impact over the range of operating levels it anticipates operating under during the new license term. Any other study parameters would be unreasonable and would not produce information relevant to the Commission's environmental analysis. See ISR Response Sections 1.6, 4.2.1, 4.2.2, and 4.2.3.
81				Review of the model output for the June 2007 flood (June 10, 2007 to July 10, 2007) indicates that the simulation appears to significantly underestimate the amount of sediment transported. According to the ISR, the measured sediment load at the Neosho River at Commerce gage is about 40,000 tons/day at a flow of 20,000 cfs. The model reports a total sediment load of 18,000 tons for the 30-day period, where the flow is above 20,000 cfs for approximately 14 days. This indicates that the model is underestimating the sediment load by several orders of magnitude.	As described previously (see the December 2021 ISR filing, January 2022 Technical Meeting), the model could not be calibrated for sediment transport. The sediment distributions and several other inputs included in it were dummy parameters to allow the model to run (see GRDA's response to Comment No. 77). The fact that results of an uncalibrated model do not reflect real-world measurements should not be a surprise. GRDA developed the PMSP so that the study area could be evaluated while considering the significant contribution of cohesive materials to the system. However, after considering comments received from the City and others following the Technical Meeting, GRDA has re-evaluated the data and has proposed a USP that relies on HEC-RAS modeling of sediment transportation at and above the Elk River confluence. The USP includes qualitative geomorphic and

Comment No.	Section		Page No. Paragraph	Tetra Tech Observation	GRDA Response
					quantitative engineering and geomorphic analyses as part of the three-level approach. This compromise allows GRDA to explicitly model the upper portions of the study area (including the critical reach containing the delta feature) and separately evaluate those portions where the limited cohesive sediment capabilities of HEC-RAS are unable to accurately simulate the complex system.

Appendix B: Grab Sampling

FRESHWATER ENGINEERING

Sediment Grab Sampling

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

FreshWater Engineering

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

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

FRESHWATER ENGINEERING

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

FRESHWATER ENGINEERING

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

FRESHWATER ENGINEERING

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

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

Sediment Grab Sampling

FRESHWATER ENGINEERING

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

FreshWater Engineering

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

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

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

FreshWater Engineering

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

FRESHWATER ENGINEERING

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

FRESHWATER ENGINEERING

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

FRESHWATER ENGINEERING

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

FRESHWATER ENGINEERING

Sediment Grab Sampling

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

FRESHWATER ENGINEERING

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

FRESHWATER ENGINEERING

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

FreshWater Engineering

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

FRESHWATER ENGINEERING

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

FRESHWATER ENGINEERING

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

FRESHWATER ENGINEERING

Date: 16 DEC 2019

Staff: TK, BT, BD

Weather: 29F, cloudy, breezy

Stream Name: Neosho (North of Spring & Tar)

Station No: NM-02

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

FreshWater Engineering

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

FRESHWATER ENGINEERING

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

FRESHWATER ENGINEERING

Date: 16 DEC 2019

Staff: TK, BT, BD

Weather: 30F cloudy, windy

Stream Name: Tar Creek

Station No: TCBWS

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

Locations of sediment grab samples are provided separately in GrabSampleLocations.csv

Appendix C: Preliminary Vibracore 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	04.2-1	0 - 12	26.0	54.0	20	Silt Loam

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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
72		72 - 81	0.8	58.0	41	Silty Clay

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Comments

Soil Texture Analysis

Sample Number	Sample Name Core	Depth (in)	SAND %	SILT %	Clay %	Soil Type
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 D: SSC and Bedload

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, Bridge ~10 feet below gage

158, 173, 188*, 203, 218, 250, 260, 270*, 280, 290

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

FRESHWATER ENGINEERING

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, 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; 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

FRESHWATER ENGINEERING

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

FRESHWATER ENGINEERING

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

FRESHWATER ENGINEERING

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

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, 137, 150, 163*, 176, 189, 202, 215, 228*, 241, 254   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: 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, Bridge ~10 feet below gage

147, 161, 175*, 189, 203, 217, 231, 245*, 259, 268

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,   Bridge   ~10 feet below gage

92, 100*, 108, 116, 124, 132, 140*, 148, 156

Notes:

(SEWI, *=MEWI x 5)

Sample times 1-10 min; No measurable sample, nothing collected in bag

General Remarks:

SSC/Bedload Sampling

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,   Bridge   ~10 feet below gage

158, 173, 188*, 203, 218, 233, 248, 263*, 278, 293

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:

ATTACHMENT 2

Independent Technical Review of HEC-RAS Sediment Transport Model

Technical Memorandum

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To: Mead and Hunt

From: Chris Bahner, P.E., D.WRE

Date: April 15, 2022

Subject: Independent Technical Review of HEC-RAS Sediment Transport Model

1. Introduction

The Pensacola Hydroelectric Project is located in Mayes County, Oklahoma, on the Grand-Neosho River. Pensacola Dam, which was constructed in 1940, impounds Grand Lake. Grand River Dam Authority (GRDA) owns and operates the dam, and the Federal Energy Regulatory Commission (FERC) regulates its licensure. The U.S. Army Corps of Engineers (USACE) takes over operations of the dam during flood control operations.

Mead & Hunt is assisting GRDA with the FERC relicensing. In support of this effort, Mead & Hunt have completed a hydrologic and hydraulic (H&H) study of the Grand-Neosho River in the vicinity of the dam. The hydraulic analyses include the development of a Hydrologic Engineering Center’s River Analysis System (HEC-RAS) model Version 5.0.7 (USACE, 2019) of the project reach located upstream of the dam. Information about the H&H analyses for the reach upstream of the dam is documented in *Initial Study Report, Hydrologic and Hydraulic Modeling: Upstream Hydraulic Model, Pensacola Dam Hydroelectric Project, Project No. 1494* (Mead & Hunt, 2021). This memorandum refers to the hydraulic model for the upstream reach as UHM (upstream hydraulic model).

Mead & Hunt also subcontracted with Anchor QEA and Simons & Associates to obtain sediment data and conduct a sedimentation analysis of Grand Lake and associated tributaries. Data collected included bed gradations, SEDflume samples and testing, suspended sediment concentrations, and bedload sediment transport measurements. The sedimentation analysis involves the development of an HEC-RAS sediment transport model (STM) of the reach upstream of the dam. Information about the data collected and sediment transport analyses is documented in *Initial Study Report*, *Grand Lake Sedimentation Study* (Anchor QEA, LLC, and Simons & Associates, 2021).

Mead & Hunt retained WEST Consultants, Inc. (WEST) to perform an independent technical review (ITR) of the STM. Attachment 1 provides information on the STM provided to WEST.

All elevation data in this memorandum has a referenced vertical datum of either:

(1) A local datum referred to as the Pensacola Datum (PD).
(2) National Geodetic Vertical Datum of 1929 (NGVD).
(3) North American Vertical Datum of 1988 (NAVD).

The conversion factor from PD to NGVD is +1.07, i.e., an elevation of 100 ft PD corresponds to an elevation of 101.07 ft NGVD. The conversion factor from PD to NAVD is +1.40, i.e., an elevation of 100 ft PD corresponds to an elevation of 101.40 ft NAVD.

2. Level I Sedimentation Analyses

Prior to reviewing the STM, WEST performed some Level I type sediment transport computations to obtain general information about the performance of the reservoir and to evaluate the HEC-RAS STM. The following paragraphs discuss the analyses.

2.1. Reservoir Trap Efficiency

Reservoir trap efficiency is the ratio of the deposited sediment to the total sediment inflow (USBR, 2006). It depends on the inflowing sediment load size and fall velocity, flow rate, and flow velocity through the reservoir. The trap efficiency analysis was completed using the following two methods documented in Engineering Manual (EM) 1110-2-4000 (USACE, 1995):

(1) Brown with a median value for the K coefficient that is dependent on retention time, grain size, and reservoir operations related to sluicing.

(2) Brune with modifications by Dendy.

The data needed for the calculations include the storage capacity and average annual flow. The average annual flow relationship was derived from the daily flow data available from the U.S. Geological Survey (USGS) gages on the Neosho, Elk, and Spring Rivers (Tar Creek was not included since the daily data is not available for the period between 1940 and July 2004). The calculations were performed on an annual basis with the assumption that the storage loss is linear between the provided 1940, 2009, and 2019 storage capacity curves. The average trap efficiency was then computed for the period between: (1) 1940 and 2009, and (2) 2009 and 2019.

Table 1 provides the trap efficiency results.

Table 1. Trap Efficiency Results

Method	Trap Efficiency (%)	
	1940 - 2009	2009 – 2019
Brown	93	94
Brune/Dendy	93	93

The results indicate the following:

(1) The trap efficiency is similar for the two methods and time periods considered.

(2) The trap efficiency based on Brown's method is about 93 percent (7 percent of inflowing sediment load passing the dam) for the period between 1940 and 2009 and about 94 percent (6 percent passing) for the period between 2009 and 2019.

(3) The trap efficiency based on Brune/Dendy is about 93 percent (or 7 percent passing) for both periods.

2.2. Additional Bed Profiles

An excel file with the historic thalweg profiles was provided by Mead & Hunt. WEST developed two additional profiles using information provided in the Pensacola reservoir backwater study (USACE, 1941) and geometry files for the 2009 and 2019 terrain: (1) average channel bed elevation, and (2) average section elevation. For sediment transport studies, changes in average bed elevation are more insightful than changes in thalweg elevations. Thalweg profile comparison could indicate that a reach has degraded while the reach has actually aggraded. For the 2009 and 2019 datasets, the average channel and section elevations were determined using basic hydraulic results from the HEC-RAS model. Steady flow models were developed for both terrain datasets. The models were run with a constant reservoir elevation set to the top of dam (757.00 ft PD/758.07 ft NGVD). The average bed elevation was then determined by subtracting the hydraulic (or average) depth from the water surface elevation.

The profiles for the 1940 conditions were determined using the information provided in the 1941 Pensacola reservoir backwater study (USACE, 1941). The information included either tabular or graphical results of the area and hydraulic radius relationships with depths for the channel and overbank area. Using a similar vertical reference (top of dam) as the 2009 and 2019 data, the channel/overbank area and hydraulic radius were obtained at each cross section considered in developing the 1940 storage capacity curve. The following was computed for both the channel and overbank areas: (1) average width by dividing the area by the hydraulic radius (similar to hydraulic depth for wide channels), and (2) average bed elevation by subtracting the hydraulic radius from the reference vertical elevation. The average bed elevation for the section was then estimated using a width-weighted average for the channel and overbank areas.

Figure 1 shows the various profiles of the historic data (1940, 1998, 2009, 2017, and 2019) for the Neosho River from river mile (RM) 77 to RM 155. This figure also includes the 1938 bankline for reference. The following conclusions can be drawn from reviewing the plots:

(1) Average channel bed profile is similar to the thalweg, but the magnitude of the change is less.

(2) Thalweg and average channel bed profiles show no significant change in the elevation for the reach upstream of about RM 135.

(3) The deposition pattern for the average section elevation is different than that of the average channel and thalweg profiles, with more material depositing within the reservoir.

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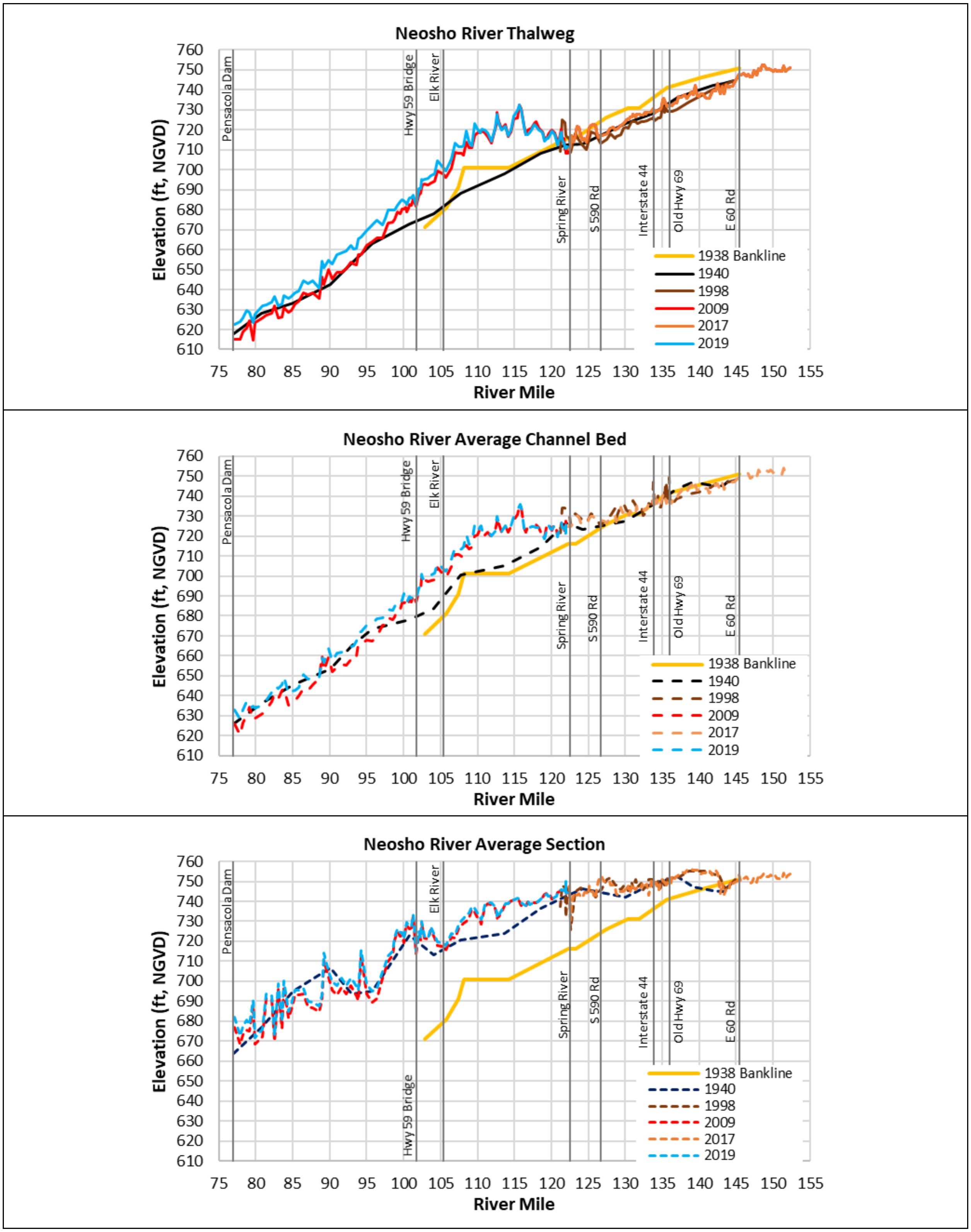


Figure 1. Bed Profiles along Neosho River

2.3. Volume and Weight of Sediment Deposits

The volume of deposition was estimated using two approaches. The first approach was based on the changes in the storage capacity curves for the years 1940, 2009, and 2019. The volume of deposition for the period between 1940 and 2009 was estimated by subtracting the volume at the upper conversation pool level (745 ft, PD) (extracted from the 2009 storage capacity curve) from the volume extracted at the same level from the 1940 storage capacity curve. A similar approach was applied to the 2009 and 2019 periods.

The conversion from volume to weight was accomplished by multiplying the volume of each sediment type (clay, silt, and sand) by the estimated average dry unit weight of each sediment type for each period considered and summing the results. The average dry unit weight for each period differs due to compaction that results from natural settlement over time. This using was estimated using Miller's method documented in ASCE Manual 54 (ASCE, 1977) and the following information as derived from the SEDflume results for the locations within the reservoir:

Reach between Elk River and Spring River (based on average for SED NR 164, SED NR 202, SED NR SC, and SED NR SB) based on the following:

Material Type	Unit Weight (lbs/ft^3)	Fraction of Total
Clay	28	0.274
Silt	65	0.668
Sand	93	0.058

The initial uncompacted dry unit weight of 52.3 lbs/ft^3 was estimated to have compacted average dry unit weight of 64.0 lbs/ft^3 for the 1940 and 2009 period and 57.9 lbs/ft^3 for the 2009 to 2019 period.

Reach downstream of Elk River (based on SED NR SC) based on the following:

Material Type	Unit Weight (lbs/ft^3)	Fraction of Total
Clay	28	0.284
Silt	65	0.692
Sand	93	0.024

The initial uncompacted dry unit weight of 45.5 lbs/ft^3 was estimated to have compacted average dry unit weight of 57.7 lbs/ft^3 for the 1940 and 2009 period and 51.2 lbs/ft^3 for the 2009 to 2019 period.

A representative dry unit weight for the storage capacity curve method was based on a length-weighted average. The representative dry unit weight of 60.2 lbs/ft^3 was determined for the 1940 and 2009 period and 53.6 lbs/ft^3 for the 2009 to 2019 period. Table 2 provides the volume and weight of the sediment deposited within the reservoir based on the change in storage capacity.

Table 2. Estimated Volume and Weight of Deposition for Storage Capacity Curve Method

Period	Volume (ac-ft)[(1)]	Dry Unit Weight (lbs/ft^3)	Weight (million tons)
1940 - 2009	169,300	60.2	221.9
2009 - 2019	115,600	53.6	135.0

Notes:

(1) Based on the capacity data referenced to the upper conservation pool elevation of 745 ft, PD.

The second approach was based on evaluating the changes in cross sectional data. The sediment deposition volume for the period between 1940 and 2009 was estimated using an average-area-end method, with the change in area at each cross section being computed using the change in the average section elevation and movable bed widths determined from the 2009 and 2019 data. The sediment deposition volume for the period between 2009 and 2019 was estimated using HEC-RAS model results. The steady flow simulations previously mentioned were used to extract the cross section area below the top of dam level at each cross section. The volume between cross sections was then calculated using the control volume concept used by the HEC-RAS sediment transport module, which calculates the volume between two points that are half-way between the cross section of interest and the bounding upstream and downstream cross sections. The change in volume was then determined by subtracting the control volume determined for the 2019 data by the volume determined for the 2009 data. The volume and weight of sediment deposition for this approach were estimated for two reaches: (1) from the dam to Elk River confluence near RM 105.35, and (2) from the Elk River confluence to the Spring River confluence near RM 122.25. Table 3 summarizes the volume and weight estimated using the cross section approach.

Table 3. Estimated Volume and Weight of Deposition for Cross Section Approach

Period	Reach	Volume (ac-ft)	Dry Unit Weight (lbs/ft^3)	Weight (million tons)
1940 - 2009	RM 77 – RM 105.35	116,000	57.9	146.3
	RM 105.35 – RM 122.25	50,100	64.0	69.8
	Dam to RM 122.25	166,100	60.2	216.1
2009 - 2019	RM 77 – RM 105.35	93,110	51.2	103.8
	RM 105.35 – RM 122.25	6,860	57.7	8.6
	Dam to RM 122.25	100,000	53.6	112.4

A review of the data in Table 2 and Table 3 indicates the following:

(1) The results for the two methods are similar. Although there is a greater difference (~17%) for the 2009 to 2019 period compared to the 1940 to 2009 period (~3%).

(2) More than 60% of the sediment deposited within the reservoir is downstream of the Elk River confluence (RM 105.35).

(3) The calculated deposition rate is higher during the 2009 – 2019 period than during the 1940 – 2009 period. However, it should be noted this general conclusion of increased deposition rate has not occurred in the reach between RM 105.35 and RM 122.25 where it has

decreased slightly from about 1 ft/yr to 0.9 ft/yr. Calculated differences could be attributed to actual difference or perceived differences:

a. Differences in calculated depositional rates could be associated with the data sources, including data density (e.g., the sparse 1940 data) and/or accuracy.

b. Differences in calculated depositional rates could be due to real differences associated with the occurrence of extreme flood events or man-made causes such as changes in watershed management.

2.4. Sediment Budget

A basic sediment budget analysis was completed for the new calibration period between 2009 and 2019. The sediment budget is based on the concept that the inflow sediment load minus the outflow sediment load equals the change in sediment storage. For this analysis, the inflow sediment load computed from the sediment budget approach was compared to the inflow sediment load estimated from the HEC-RAS inflowing sediment relationship (referred to HEC-RAS total sediment load). This check was performed to ensure that the HEC-RAS inflowing sediment load relationship can provide the same amount of sediment that has deposited in the reservoir.

The inflowing sediment load based on the sediment budget concept was estimated to be the summation of the amount of the sediment deposited in the reservoir and the amount of sediment that bypassed the reservoir, estimated using the trap efficiency based on the Brown method with a median K coefficient. For the HEC-RAS total sediment load, the daily sediment load for Neosho, Spring, and Elk Rivers, and Tar Creek was estimated using the daily discharges measured at the USGS gages and the suspended sediment discharge rating curve provided in the HEC-RAS STM. The total sediment load was then estimated by summing the daily sediment loads for the 2009 to 2019 period. Table 4 summarizes the HEC-RAS total sediment load for the Neosho River and significant tributaries to the reservoir. The HEC-RAS STM total sediment load to Grand Lakes reservoir is about 45.2 million tons. Table 5 summarizes the comparison of this sediment load to the inflow sediment load estimated from the sediment budget approach. This comparison indicates a significant deficit in the sediment load to the Grand Lake. As a result, the current HEC-RAS model will not be able to simulate the total sediment deposition that has occurred within the reservoir.

Table 4. HEC-RAS Total Sediment Load for the 2009 – 2019 Period

System	Weight (million tons)	Percent of Total Load
Neosho River	36.74	81.3
Spring River	4.91	0.1
Elk River	3.51	10.9
Tar Creek	0.06	7.8
Grand Lake	45.22	-

Table 5. Sediment Budget Results

Period	Weight of Sediment (million tons)				
	Deposited within Reservoir	Bypassing Dam	Inflowing Sediment Load		
			Summation of Sediment Deposited and Bypassing Dam	Estimated from Sediment Rating Curves	Difference
2009 - 2019	112.4	7.0	119.4	45.2	-74.2

3. Initial Sedimentation Study Report Comments

The initial sediment study report (ISSR) was reviewed to obtain a better understanding of the development, calibration, and parameter selection used in the HEC-RAS model. Attachment 2 includes general comments on the initial report are applicable to the next version of the study report. The three key comments on the report are as follows:

(1) **Model Parameters**. The final report should include graphical and tabular information on all model parameters used in the STM. The report lacks several key parameters, including water temperature, settling velocity, movable bed boundaries, bed exchange iterations (SPI), bed change options, and routing method.

(2) **Bedload Transport**. The bedload measurements indicate that there was no bedload transport measured for the flows with a maximum discharge of 41,600 cfs for Neosho River, 750 cfs for Tar Creek, 23,400 cfs for Spring River, and 4,940 cfs for Elk River. These flows are considered low flow events, and it is possible that bedload could contribute sediment to the reservoir for higher flow events. Some bed load will occur at higher flow events, but it will be a relatively small amount to the total sediment load. If no further field work will be conducted, some additional analysis (e.g., stable bed analysis) should be conducted to determine the estimated quantity and size for the bed load portion.

(3) **Inflowing Sediment Load Relationship**. As presented in the previous section, the weight of sediment delivered to the reservoir is significantly smaller than the weight of sediment deposited in the reservoir. There is a high level of uncertainty in this relationship due to the high natural variability in sediment transport from variations in water temperature, stream slope, bed sediment size distributions, and measurement errors for discharge and sediment concentrations. The high variability is reflected in large scatter of data in the logarithmic plots commonly used for defining sediment discharge rating curves which are often represented by a power function. More discussion is provided in the next section of the memorandum.

4. Sediment Transport HEC-RAS Model Comments

Attachment 3 contains specific comments on the HEC-RAS STM. The six key comments on the STM are as follows:

(1) **Hydraulic Calibration**. The hydraulic calibration may have been completed using the geometry file based on the 1998 terrain data; the 1998 terrain data is the current geometry associated with the plans for the fixed bed calibration events (April 2017, January 2017, December 2015, October 2009, July 2007, and May 2019) mentioned in the ISSR. However, there are two steady-state model runs (Calibration-2009 and Calibration-2019) with the appropriate geometry files that could have been used for hydraulic calibration. Unfortunately, no information related to hydraulic calibration was provided. Therefore, the hydraulic calibration should be revisited for the new base geometry condition used for the model calibration if the same events documented in the ISSR are being considered. Otherwise, the next sedimentation report should document the hydraulic calibration efforts of the STM. Special attention should also be given to differences related to the model results from the hydraulic analysis. This could be important near bridges. Figure 2 compares the water surface elevation at RS 122.75 (just upstream of Hwy 60 bridge at the Twin Bridges State Park) calculated using the STM and UHM for the October 2009 event. This figure shows that there are noticeable differences in the water surface elevations computed between the two models.

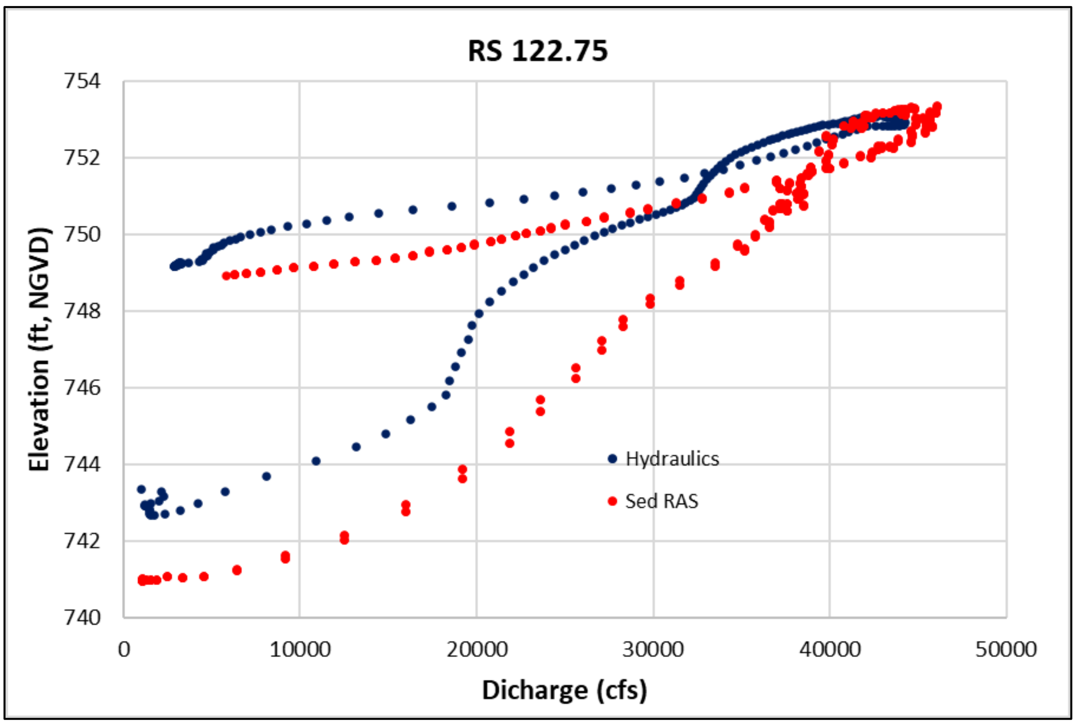


Figure 2. Comparison of water surface elevations at RS 122.75 from STM and UHM for the October 2009 event

(2) **Temperature Data.** The water temperature in the STM is simulated at a constant 60°F. The temperature simulated in the model should be based on measured data or average seasonal variation defined by measured data.

(3) **Inflowing Sediment Load**. As previously stated, the sediment budget evaluation indicates that the inflowing sediment load is not sufficient to produce the amount of sediment estimated to have deposited within the reservoir between 2009 to 2019. Therefore, it is recommended that sediment discharge rating curves be modified, and additional sediment load contributions be considered for the ungaged drainage area to the reservoir. Also mentioned earlier, a power function (straight line on logarithmic scale) is commonly used to define the sediment discharge rating curve. This approach can be considered, potentially emphasizing the upper limit of the relationship. Figure 3 illustrates this approach. The final relationships can be derived using the sediment budget concept to ensure enough sediment is being introduced into the reservoir.

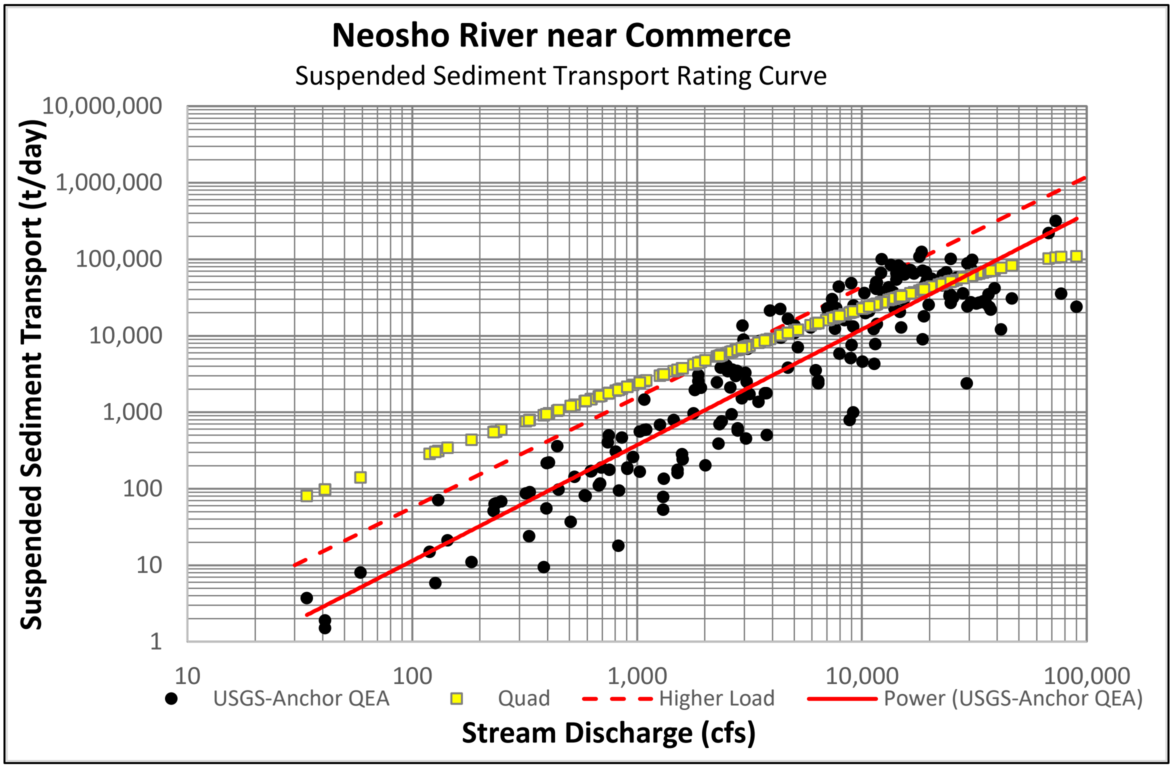


Figure 3. Suspended sediment load versus discharge relationships

In regards the sediment composition, the HEC-RAS sediment inflow relationship is composed of 35% clay, 63% silt, and 2% very fine sand (VFS) sized material. This does not match the information measured at the SEDflume data for the locations within the reservoir, where the deposition material, on average, consists of 27% clay, 67% silt, and 6% VFS.

(4) **Cohesive Transport**. The Cohesive Option selected in the STM is "Use Selected Transport Functions for All Grain Sizes." It is recommended that the "Use Krone/Partheniades for Clay and Silt Size Fractions" be used because of the large silt and clay load flowing into the reservoir. Also, it is recommended that the Sediment Routing Method be changed from the Continuity approach to the "Limit to Water Velocity" approach. Finally, different silt/clay parameters can be defined spatially if desired.

(5) **Downstream Boundary**. There is a potential discrepancy at the downstream boundary (Figure 4). Figure 4 shows the 1940, 2009, and 2019 storage capacity curves. It also shows the storage capacity (light blue markers) curve developed using data obtained from the USGS website. The USGS data after January 1, 2021, matches the 2019 relationship, while the data prior to 2021 matches the relationship that is 1.07 ft above the 2019 relationship. The USGS website indicates that these data are referenced to the PD datum. The Pensacola reservoir backwater study (USACE, 1941) indicates that the USGS changed benchmark elevations, and the maps used for their analysis are from an old base line that is 1.072 ft lower than the corrected base line. It appears the USGS has not applied this adjustment to the data on their website, and the reported elevations are referenced to the NGVD and not PD datum. If correct, then the downstream water surface elevations in the model are consistent with the geometry data. If not, then the downstream water surface elevations would have to be adjusted.

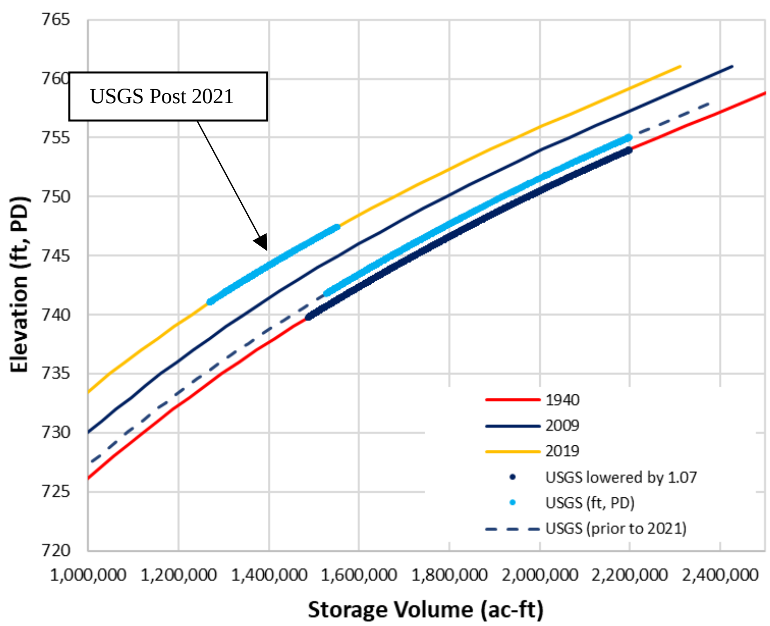
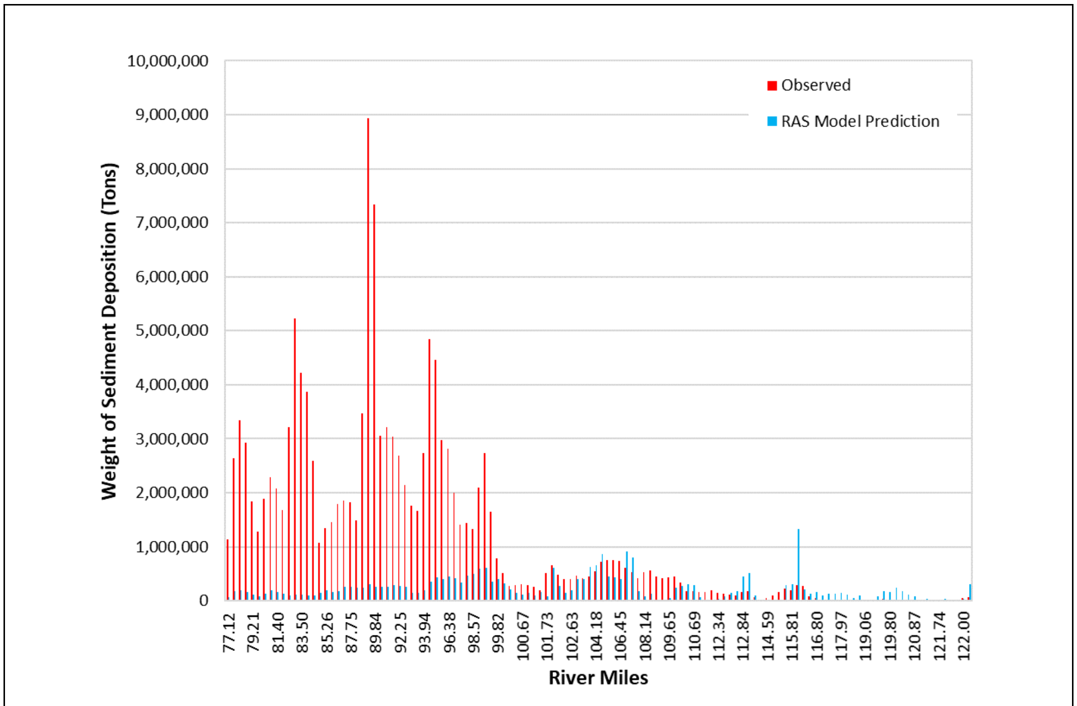


Figure 4. Elevation versus storage volume relationship for Grand Lake reservoir

(6) **Sediment Transport Calibration Results**. The model results were evaluated in terms of the weight of sediment deposition within the reservoir downstream of where Spring River flows into the Neosho River. Figure 5 shows the simulated weight of deposition from the STM compared to the measured weight of deposition. The results indicate that the model: (1) underpredicts the weight of depositions below RM 105.25, and (2) has a similar amount of weight sediment depositions within the reach between RM 105.25 and RM 122.25, but it does not accurately simulate the spatial distribution within the reach.



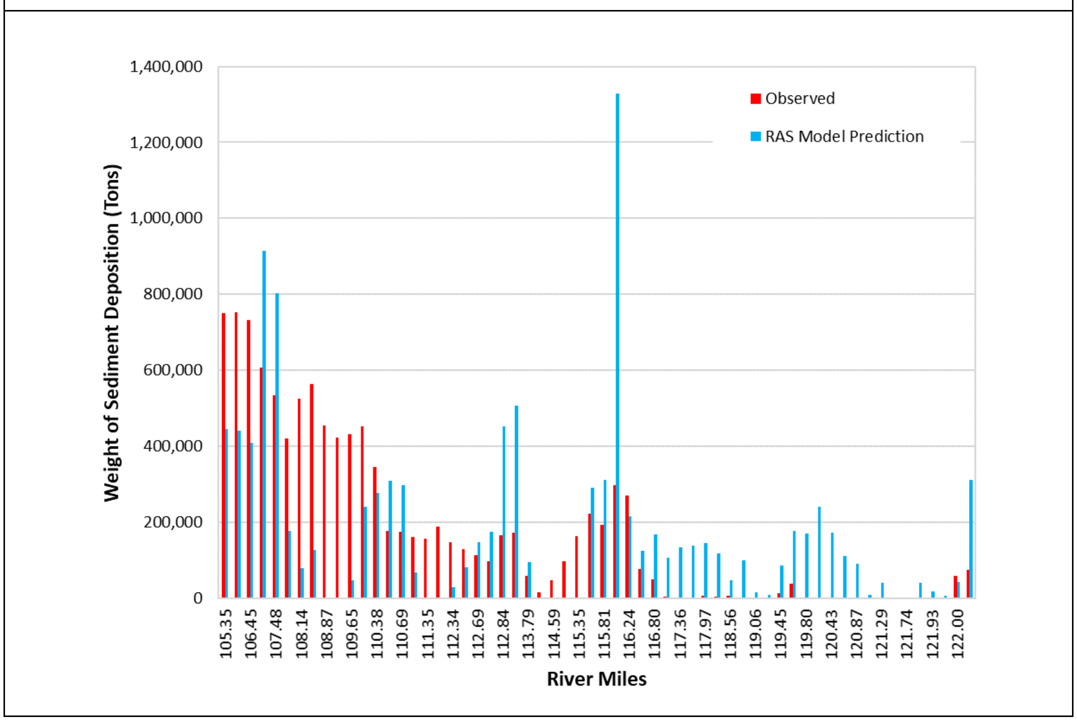


Figure 5. Observed versus HEC-RAS simulated weight of sediment deposition

5. Special Items

This section of the memorandum addresses special items mentioned during the initial meeting between Mead & Hunt, Anchor QEA, Simons & Associates, and WEST held on March 9, 2022.

5.1. The "Hump"

The historic thalweg profiles of Neosho River show that the thalweg profile has been relatively stable for the reach upstream of the S 590 Road bridge (RM 126.7) and the deposition within the reservoir has created what has been referred to as a "hump" within the reach between the Spring River confluence (RM 122.5) and the Elk River confluence (RM 105.35). Figure 6 shows the hump in the thalweg profile. This figure also includes the average channel bed profile. A review of this profile shows that the average bed profile resembles a typical delta formation within a reservoir (Figure 7) where there is a flattening of the bed slope due to the deposition, followed by a steepening of the bed slope.

Another contributing factor to the formation of the hump pattern in the thalweg formation is associated with the hump reach having narrower deposition limits compared to the downstream reach. The average width of the deposition limits for the hump reach is about 3,490 ft, while the average width in the downstream reach is about 8,590 ft.

It should be noted that deposition near confluences and upstream of channel constrictions is common response in a river system. So, some of the deposition within the upstream end of the hump reach could be attributed to the various bridge structures and Spring River confluence.

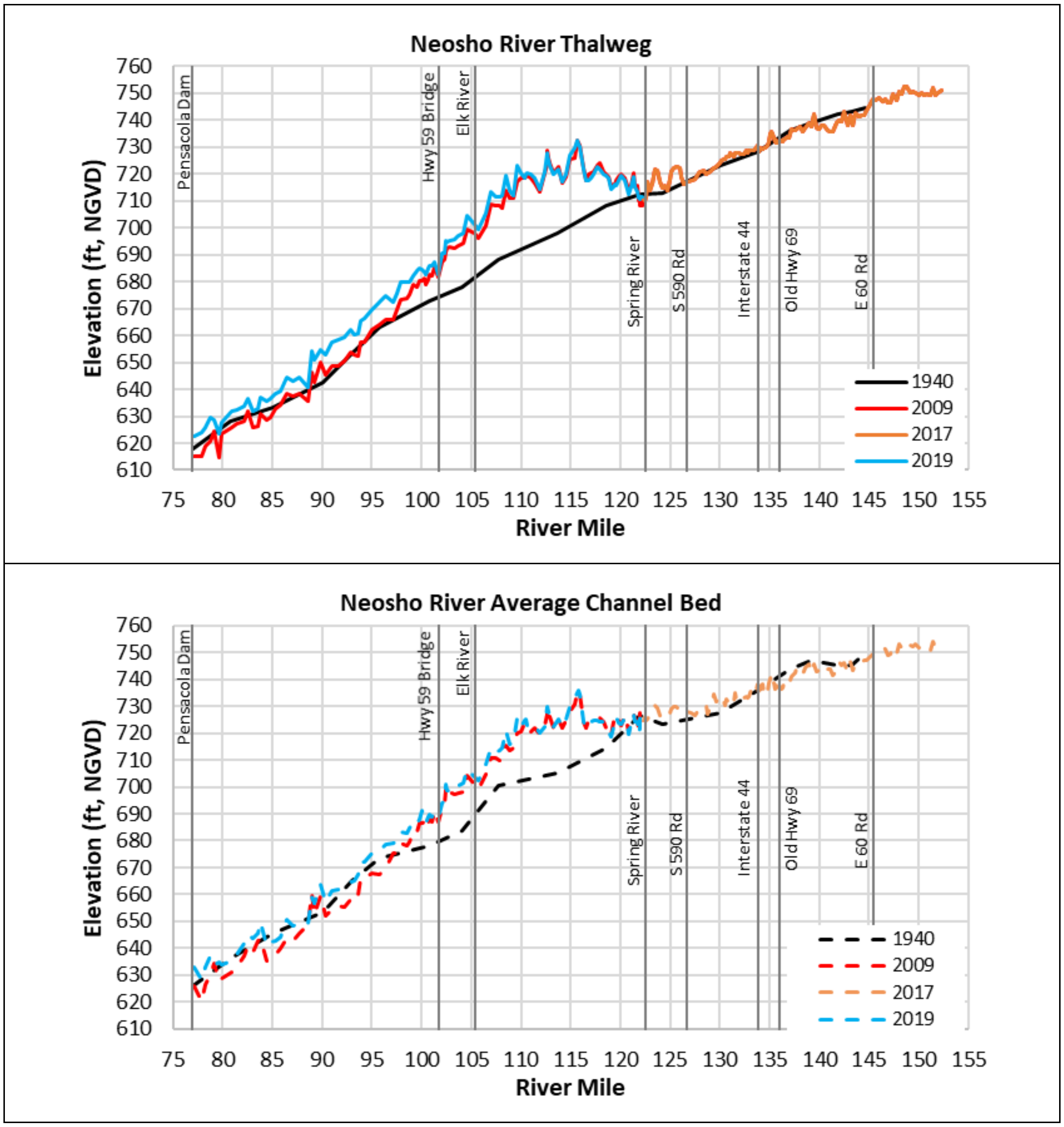


Figure 6. Bed profiles of Neosho River

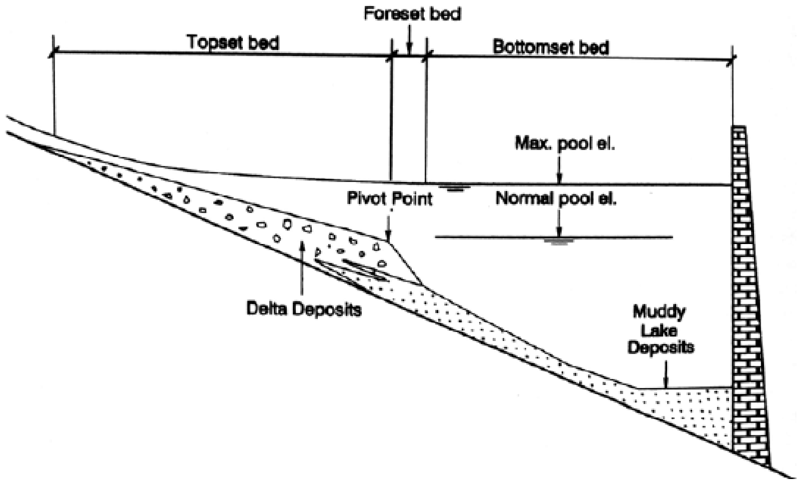


Figure 7. Typical reservoir delta bed profile (Morris and Fan, 2010)

5.2. 1998 Data

It was mentioned during the initial meeting that there were some concerns related to the 1998 REAS profile reflected in the historic thalweg comparison plot. Figure 8 shows the comparison plot of the 1940 and 1998 REAS thalweg profiles. This plot shows that, in many locations, the 1998 REAS thalweg profile is at a lower elevation than the 1940 thalweg profile, which is extremely unlikely due to the backwater influences from Pensacola Dam.

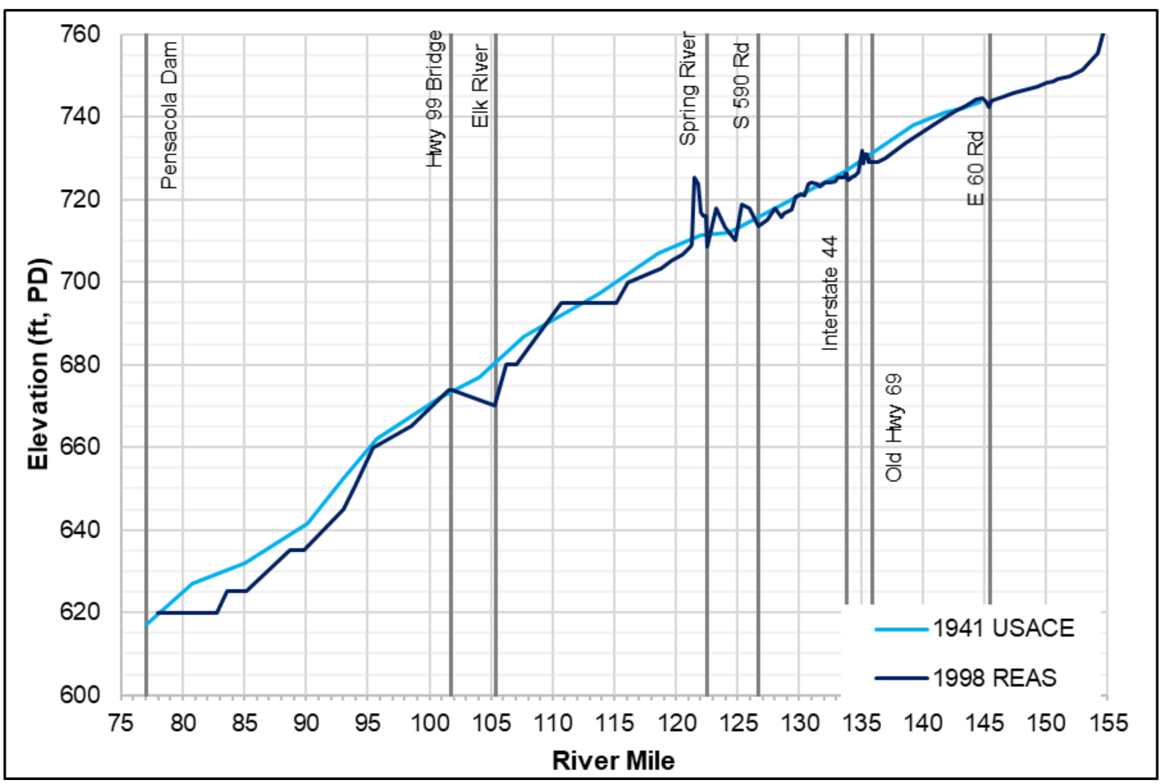


Figure 8. Comparison of 1941 USACE and 1998 REAS

The purpose of the 1998 REAS study was to define the guide taking line for real estate easements between elevation 750 and 757 ft PD at the dam. The hydraulic documentation indicates that the hydrographic survey was limited to the upper portion of the reservoir, with the limits being shown in Plate 3 of the report. Figure 9 shows Plate 3, and as expected, there were no hydrographic surveys within the reservoir for the 1998 REAS study. Therefore, the thalweg profile shown in the 1998 report most likely reflects the 1940 conditions, with the differences shown in Figure 8 being associated with the different data sources.

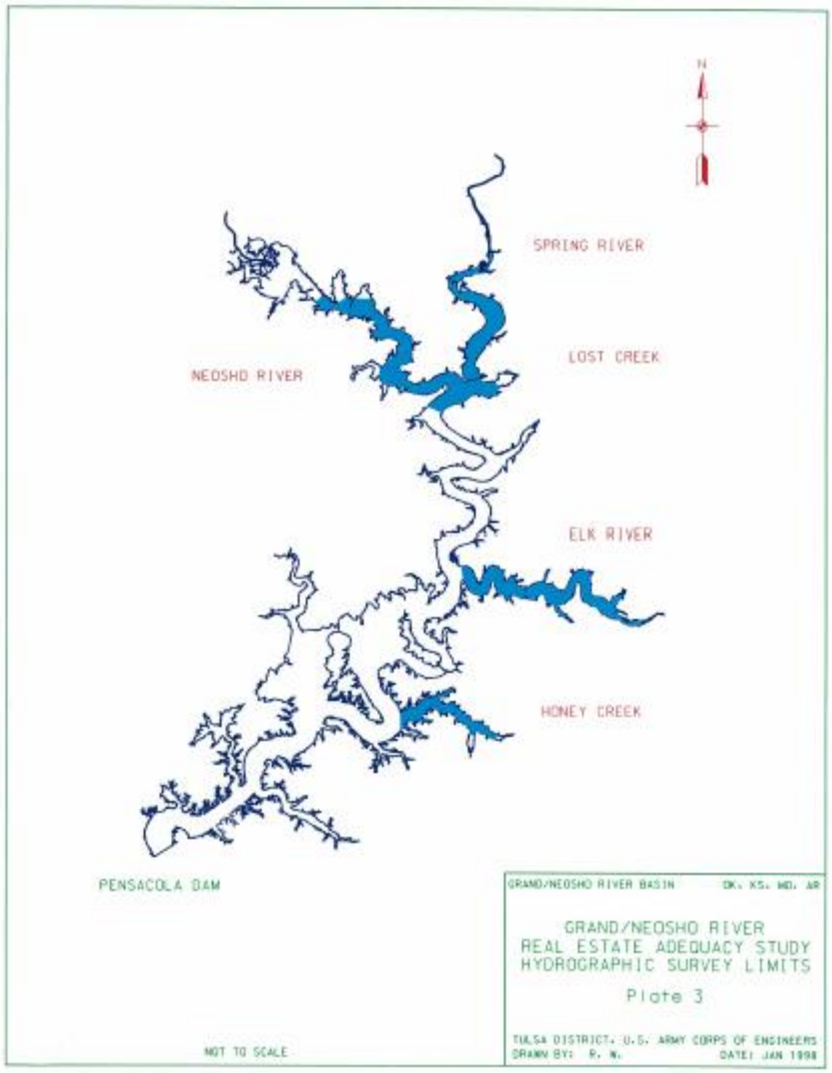


Figure 9. Hyrdrographic survey limits for 1998 REAS (USACE, 1998)

5.3. STM Calibration Period

The initial plan involved calibration of the STM using the period between 1998 and 2009 and validation using the period between 2009 and 2019. This approach is applicable for the reach upstream of RM 121 because no bathymetry data exists downstream of RM 121 for the year 1998.

Tetra Tech, a City of Miami consultant, states that the STM model should be calibrated for the period between 1940 and 2009. Tetra Tech's discussions in *Hydraulic Analysis of the Effects of Proposed Rule Changes at Pensacola Dam on the Neosho River Flooding in the Vicinity of Miami, Oklahoma* related to changes focuses on the reach upstream of Twin Bridges/U.S. Highway 60 (around RM 122.5):

> "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 ft, with over 10 ft of aggradation in some locations in the 6- to 7-mile reach upstream from Twin Bridges/U.S. Highway 60 (Figure 4.6). Based on the elevations along the tops of the channel banks, a similar amount of aggradation has occurred in the overbanks along this portion of the reach."

Figure 10 shows Figure 4.6 from Tetra Tech's report. The figure shows more cross section locations used in defining the 1940 profile than other profile plots provided as part of this ITR. However, it does not mention the source of the data. Their reference sections indicate two possible sources: (1) *Pensacola Reservoir Computation Folder for the revised envelope curve of water surface in Reservoir* (USACE, 1942), and (2) *Pensacola Reservoir topographic mapping, 36"x48" sheets* (USACE, 1940). If cross section data exist within this reach, then calibration of the model could be considered for the between 1940 and 2009, with an emphasis on simulating the changes upstream of RM 122.5.

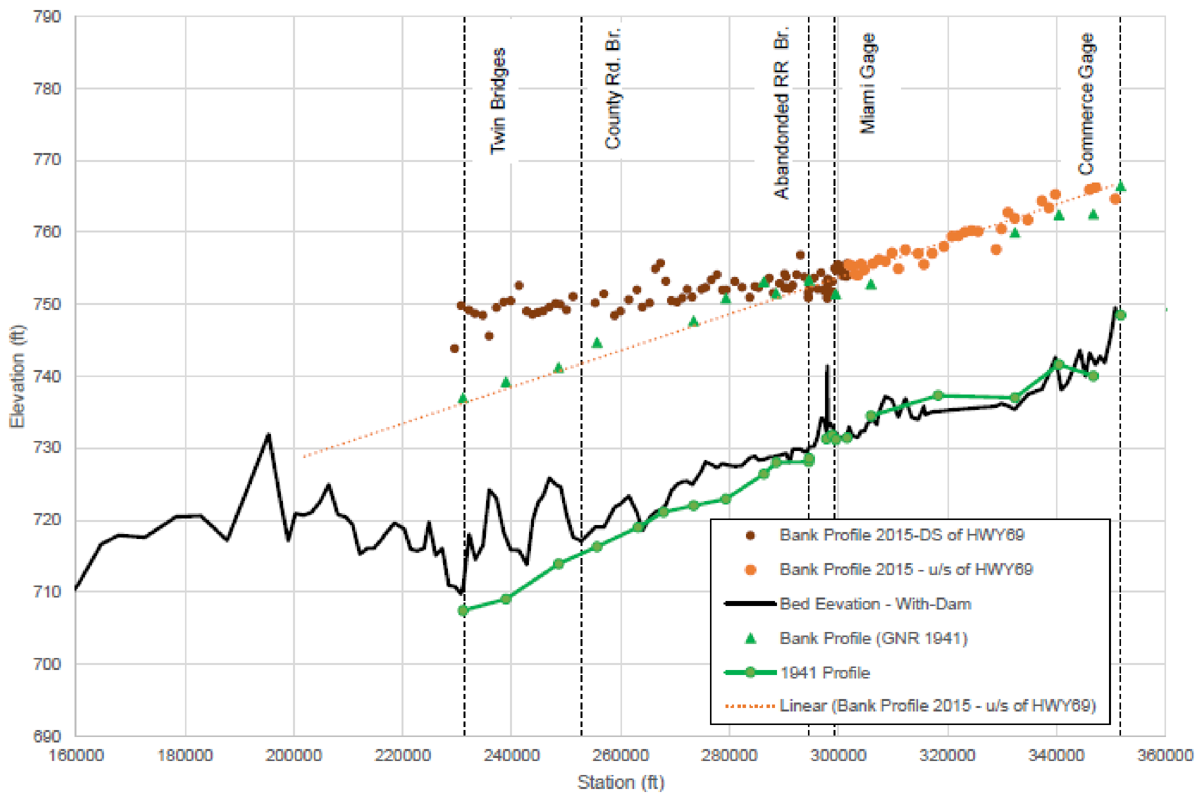


Figure 4.6. Comparison of the 1940 and 2015 thalweg profiles.

Figure 10. Comparison of 1940 and 2015 thalweg profiles (Tetra Tech, 2016)

A potential concern with using 2009 to 2019 for the calibration period is that the overbank cross section geometry for the reach of interest mentioned by Tetra Tech is the same for both datasets.

6. Summary of Recommendations

Mead & Hunt is assisting GRDA in the relicensing efforts for Pensacola Hydroelectric Project with FERC. In support of this effort, WEST was retained to perform an ITR of the sedimentation analysis of Grand Lake and associated tributaries. The main comments/recommendations are as follows:

- **Documentation.** The final report should include graphical and tabular information on all model parameters used in the STM. It should also document the final calibration (hydraulics and sediment) of the model.
- **Bedload Transport**. Additional evaluation (e.g., stable bed analysis) should be performed on the potential magnitude and sediment size of bedload transport contributing to the total sediment load during higher flow events.
- **Hydraulic Calibration**. The hydraulic calibration of the STM should possibly be re-evaluated if the calibration period changes, or the same approach documented in the ISSR

is being used for the STM. Special attention should also be given to difference related to the model results from the hydraulic analysis and within reaches immediately upstream of bridge structures.

- **Downstream Boundary Condition**. USGS data used for the downstream water surface elevations in the model should be reviewed to ensure that the USGS data are in the same datum as the model.
- **Inflowing Sediment Load**. The inflowing sediment load and distribution should be adjusted to match the amount and size distribution of the sediment deposited within the reservoir downstream of RM 122.5. This should be based more on the SEDflume data than the grab samples data since the SEDflume data more closely resembles the suspended sediment measured at the upstream locations and the small contributions from bedload. The required adjustments can be determined by the amount of sediment deposited within the reservoir as determined from a sediment budget approach.
- **Cohesive Transport**. The STM should use the cohesive sediment transport option with the “Limit to Water Velocity” sediment routing method to simulate the deposition and erosion of the clay and silt material within the reservoir. The model parameters at specific SEDflume locations should be based on depth-averaged values. Determination of cohesive parameters should be documented in the final report.
- **Historic Data**. The consultant team should seek out additional cross section data from 1938 or the 1940’s.
- **Sediment Transport Calibration**. HEC-RAS can be used to model the system. Ideally, the STM should be calibrated and validated to two different events. Tetra Tech has indicated that the calibration should be performed for the period from 1940 to 2009. This can be accomplished if cross section data circa 1940 are available. The cross sections for the reach downstream can defined by using the 2009 cross section data and adjusting by the change in average section elevation determined using the 1941 area-hydraulic relationships provided in the Pensacola reservoir backwater study (USACE, 1941). Because Tetra Tech has emphasized the bed changes of the Neosho River immediately upstream of RM 122.5. the emphasis of the calibration/validation effort should be on the same reach. In general, the best data available that covers the longest period of record to evaluate changes should be used.

- **Sensitivity Analysis.** The evaluation of future responses within the reservoir should be based on a sensitivity analysis of the various model parameters to account for the high level of uncertainties in sediment transport. Uncertainties can be divided into two categories. The first is aleatory (or inherent), which corresponds to variability or randomness that naturally exists in nature. This uncertainty can’t be reduced. The second is epistemic (or knowledge-based) that is associated with the state of knowledge of a physical system (our estimation of reality), our ability to measure it, and the inaccuracies in our predictions of the physical system. Model calibration and validation efforts will reduce this uncertainty, but not eliminate it.

- **Simplified HEC-RAS STM**. A simpler HEC-RAS model should be created to address Tetra Tech’s concerns. This model would extend from RM 105.25 at the downstream end and to the gaging stations at the upstream end (RM 145.44 on Neosho River, RM 14.16 on Spring River, and RM 7.6 on Tar Creek).

- **Bed Profiles**. Historic bed profile plots should consider both the thalweg and average bed elevations.
- **1998 REAS Data**. The Neosho 1998 profile data are only applicable for the reach upstream of RM 122.5 since no bathymetry data were obtained from the reservoir downstream of this location. The Neosho data surveyed circa 1998 can be used for calibration or validation.

7. References

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ATTACHMENT 3

Updated Study Plan

Pensacola Hydroelectric Project, FERC No. 1494

Updated Study Plan

Sedimentation Study

Prepared for

Grand River Dam Authority

Prepared by

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April 2022

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ADCP........................ Acoustic Doppler Current Profiler
BIA............................ Bureau of Indian Affairs
FERC........................ Federal Energy Regulatory Commission
GRDA .... Grand River Dam Authority
ISR............................ Initial Study Report
ITR............................ Independent Technical Review
OWRB .... Oklahoma Water Resources Board
PD............................. Pensacola Datum
Project .... Pensacola Hydroelectric Project
PSMP .... Proposed Modified Study Plan
REAS........................ Real Estate Adequacy Study
RM .... River Mile
RSP .... Revised Study Plan
SPD .... Study Plan Determination
SSC .... Suspended Sediment Concentration
STM .... Sediment Transport Model
UHM .... Upstream Hydraulic Model
USACE .... U.S. Army Corps of Engineers
USGS .... U.S. Geological Survey
USP .... Updated Study Plan
USR .... Updated Study Report
WEST .... WEST Consultants
WSE .... Water Surface Elevation

1.0 INTRODUCTION

Grand River Dam Authority (GRDA) submitted their final Sedimentation Study report on the first study period, together with a Proposed Modified Study Plan (PMSP), in December 2021 and held a Technical Meeting in January 2022.

GRDA received comments in response to the Sedimentation Study report and PMSP and has re-evaluated the existing data and the modeling efforts to date.

The majority of comments received on the ISR and PMSP can be grouped into two main categories:

1) Differences in opinion on calibration of the Sediment Transport Model (STM), and
2) Differences in opinion on which datasets to utilize in future analyses.

To develop a solution and offer a compromise, GRDA retained the services of WEST Consultants (WEST) in performing an Independent Technical Review (ITR) of the STM and existing datasets. Based upon information provided in the ITR, GRDA believes that with modifications to the original extent of the STM, careful consideration of the use of datasets for calibration and validation, and implementation of additional quality assurance methods, it can be possible to predict sediment transport patterns and deposition using HEC-RAS modeling software.

This Updated Study Plan (USP) replaces the PMSP. The USP moves forward in a bifurcated approach composed of two branches.

1. The first branch utilizes HEC-RAS to directly model sediment transport and deposition as required by FERC in the Study Plan Determination (SPD). This approach is possible provided the model extends downstream to River Mile (RM) 105 and not beyond RM 105 (the confluence of the Elk River) downstream to the Pensacola Dam.
2. The second branch evaluates total sediment loading downstream of RM 105 to Pensacola Dam where cohesive sediments are dominant with a combination of model outputs and USACE (1995) calculations.

The first branch includes analysis of sedimentation using the STM. GRDA will use the U.S. Army Corps of Engineers' (USACE's) Grand Lake Real Estate Adequacy Study (REAS; USACE 1998) dataset in the upper reaches of the Spring and Neosho Rivers. GRDA has reviewed the documentation provided with the REAS, and they have found that survey data upstream of RM 120.1 (approximately 2 miles downstream of the Spring River confluence) were collected in 1998. Below that location, the data are based on older surveys that do not reflect the conditions present in 1998. REAS data in Elk River are still considered invalid, as the US Geological Survey (USGS) gaging station (07189000 Elk River near Tiff City, MO; USGS 2021) reports water surface elevations below the lowest point of the REAS channel geometry.

It is important to note that the STM results will not provide exact information about future sediment deposition. The results of any model are only as good as the input data, and input data available to GRDA have significant limitations. GRDA will use the available data to create a prediction of future conditions through calibration and validation, but the results will be a limited approximation of future conditions. Sensitivity analyses will be performed to provide a potential range in the model results.

The second branch of the Sedimentation Study will analyze the effect of sedimentation on the power pool. In the SPD, at the request of the Bureau of Indian Affairs (BIA), the STM was expanded to include an evaluation on how sedimentation affects the power pool and whether sedimentation reduces the capacity for power generation. GRDA's bifurcated approach is a compromise solution that meets the objectives of the SPD. Work completed as part of the first study period determined sedimentation in the power pool downstream of the RM 105 unexpectedly dominates the volume of sediment in the reservoir and this sediment is almost entirely cohesive, thereby significantly complicating calibration of the STM.[1]

This bifurcated approach with two branches allows for a much more representative STM without sacrificing the accuracy of both the STM and the power pool analysis. This strategy will use HEC-RAS to model sedimentation in the upper reaches of the study area, where the specific locations of sediment aggradation and degradation are more crucial to the overall assessment of sedimentation, while also simplifying modeling efforts in the lower portions of Grand Lake where the specific locations of sediment deposition are less critical. Using USACE (1995) trapping efficiency calculations allows quantification of sediment deposited in the lower reservoir and evaluation of impacts to the power pool and reservoir storage as required by the SPD.

In an effort to implement additional quality assurance methods for inputs to the STM, GRDA will also perform a quantitative evaluation of sediment transport within the study area. This is a key component of the three-level approach discussed by GRDA in previous documents. The quantitative analysis relies on measured field data to assess sediment transport and will help validate the STM results. This will also allow a more detailed evaluation of the cohesive sediment transport processes than is possible with the limited parameterization of cohesive materials used by HEC-RAS. This validation is similar to the approach suggested by GRDA in the PMSP and is described in more detail below.

2.0 STUDY PLAN ELEMENTS

2.1 Study Goals and Objectives

Consistent with the SPD, the goal of the Sedimentation Study is 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. To do this, the USP will use the STM developed in HEC-RAS that is truncated below the Elk River confluence (RM 105). This strategy allows GRDA to use HEC-RAS to evaluate sediment transport above the Elk River, where it is better suited, while relying on USACE (1995) trapping efficiency and sediment inflows to evaluate the lower reservoir.

[1] A sediment transport model that incorporates sediments that are dominated by cohesive sediments significantly increases the range and complexity of potential input parameters and can easily lead to unreliable and misleading results.

Specific Tasks
The following tasks are considered part of this USP:

Bathymetric Change Analysis

- Continue to compare spatial and temporal changes associated with previously collected bathymetry survey data in the study area.
- Continue to analyze sediment bed changes relative to velocities from USGS-collected Acoustic Doppler Current Profiler (ADCP) and GRDA-collected ADCP data.
- Define areas of deposition and erosion.
- Continue to conduct specific gage analyses at USGS gages to understand trends in stage over time due to changes in cross-sectional area.
- Continue to develop spatial and temporal understanding of geomorphological changes and rate of change.

Sediment Transport Modeling

- Calibrate the STM for sediment deposition and transport patterns observed between hydrographic surveys within the study area.
- Evaluate sediment transport at key locations in the study area using the STM under selected future operations scenarios.
- Determine the amount of sediment transported into the lower reaches of the study area using STM outputs and calculated trapping efficiencies of the lower reservoir.

Characterization of Sedimentation Impacts on Flooding

- Use the STM to simulate new channel and overbank geometry with synthetic 50-year hydrographs and selected Project operation scenarios.
- Evaluate changes to flood extent using STM channel and overbank changes considering Project operations.

Data Synthesis and Reporting

- Synthesize findings of bathymetric change analysis and sediment transport evaluation to inform hydraulic modeling efforts.
- Provide an understanding of the effects of Project operations on sediment transport characteristics and projected distribution of sediment related to flood extent and duration in the study area.
- Use the STM to estimate future sedimentation considering modified Project operation scenarios.
- Summarize study results and conclusions in the Updated Study Report (USR).

2.2 Agency and Native American Tribe Resource Management Goals

The Sedimentation Study results can inform separate analyses to assess Project effects on resources such as geology and soils, water resources, fisheries and aquatic resources, terrestrial resources, threatened and endangered resources, and cultural resources. Such analyses, in turn, can inform agency decision-making pursuant to statutory obligations.

2.3 Background and Existing Information

The primary sources of data are provided by USGS stream gage monitoring stations located throughout the watershed, supported by periodic surveying and bathymetric mapping of Grand Lake and its tributaries. Previous studies have also evaluated sediment within the Neosho and Spring rivers.

Background Data and Literature Review

Relevant previous reports and historical sediment sampling investigations known to have been conducted within the basin have been reviewed. GRDA will continue to develop an organized database to store the data collected as a part of the existing data review and analysis. These data will be fully documented. This information will be provided in the USR describing the type and quality of data available.

Data gaps identified as part of the effort in the first study period have been filled by initial development of the STM and by an initial evaluation of sediment transport and are documented in the ISR. Sediment concentration, channel sediment properties, and flow velocity within the river channel are three pieces of information necessary for sediment analysis in the Grand Lake watershed which were collected in the initial study period. Suspended sediment concentration (SSC) measurements allow estimation of sediment transport through a given point in the system. Sediment grab and core sampling provide information about material properties of bed sediments. Current velocity profiles were used in conjunction with the SSC measurements and the sediment properties to calculate sediment flux at sampling locations on the rivers.

In addition to previous studies performed by the USGS and others, GRDA completed significant data collection efforts as part of the first study period.

Water Surface Elevation Monitoring

GRDA has maintained water level monitors throughout the study area since December 2016. The water surface elevations have been recorded by HOBO pressure loggers and were used to calibrate both the Upstream Hydraulic Model (UHM) and STM. More information is available in the Sedimentation Study ISR.

Sediment Transport Rate Measurements

Sediment transport rate measurements provide important insights into sediment movement along streams. These are grouped into SSC and bedload measurements.

GRDA-collected SSC and bedload samples using a D-74 SSC sampler and Helley-Smith bedload sampler, respectively, suspended from bridges at the locations of the following USGS gages:

- 07185000 Neosho River near Commerce, Oklahoma
- 07185090 Tar Creek near Commerce, Oklahoma
- 07188000 Spring River near Quapaw, Oklahoma
- 07189000 Elk River near Tiff City, Missouri

SSC measurements were supplemented with USGS records. Sampling trips were planned around specific targeted flow events to fill gaps in the USGS datasets. Once all samplings were collected, GRDA was able to relate sediment discharge to stream flow rates for use in model development.

Bedload transport was found to be negligible during the sampling events (Response Comment of GRDA, Section 5; Appendix A, Response to Comment No. 1). As discussed in the Sedimentation Study ISR (Section 3.1.2.4), the sampling efforts covered a wide range of discharge rates and produced no measurable bedload transport. This is an important set of data because it demonstrates the lack of transport of non-cohesive sediment in the sand and gravel size range.

Sediment Samples

Substrate properties are an important variable in determining sediment transport rates. Sediment grab and core samples were analyzed to determine bulk density, grain size, composition, and critical shear stress (the minimum bed shear necessary to initiate sediment grain motion).

A total of 62 sediment grab samples were collected and analyzed to parameterize sediment characteristics within the river system. Sampling occurred in the Neosho, Spring, and Elk rivers as well as Tar, Sycamore, and Horse creeks.

GRDA-collected samples distributed according to Table 2.6-1.

Table 2.6-1. Sediment grab sample locations.

Location	Number of Samples Collected		
	Grab	**SEDflume Core**	**Vibracore**
Neosho Upstream of Miami	3		
Neosho Miami – Wyandotte	17	3	4
Neosho Downstream of Wyandotte	9	4	20
Tar Creek	13	2	
Spring River	10	3	
Sycamore Creek	1		
Elk River	8	2	
Horse Creek	1		
Total	**62**	**14**	**24**

Where grab samples showed substantial cohesive sediments, core samples were taken for additional analysis. Core samples were tested using SEDflume by Integral Consulting (2020) following procedures developed by McNeil et al. (1996). Testing determined critical shear stress, an important parameter for analysis of cohesive sediment transport in fluvial systems as a function of depth in the sediment column.

Grab samples that showed predominantly sand or gravel did not require additional core sampling. Where sediment was non-cohesive, the above geotechnical testing results provided sufficient information for sediment transport calculations.

GRDA continued to collect field data to ensure a more accurate understanding of sediment transport in the study area. This effort was developed in response to perceived discrepancies between bathymetric datasets used in the Pensacola Dam relicensing study. Between Twin Bridges and the Elk River, the available datasets showed approximately 30 feet of deposition between the REAS (USACE 1998) and 2009 Oklahoma Water Resources Board (OWRB) surveys (OWRB 2009), with just a few feet of deposition between 2009 and the 2019 USGS survey (see Sedimentation Study ISR for more information). Coupled with sediment loading estimates, this raised questions about the validity of the REAS survey in this river reach. As presented in the Response Comment of GRDA (Section 4.4) and Appendix A (Response to Comment No. 6) accompanying this submittal, GRDA has analyzed the REAS bathymetric dataset and found the dataset to be unreliable below RM 120.1 for the purposes of the Sedimentation Study. GRDA does plan to use the data above RM 120.1 as a calibration dataset during STM development.

There are two common ways to evaluate sediment layer thicknesses that GRDA used to support this study. The first was sub-bottom profiling, and the second was vibracore sampling.

Sub-Bottom Profiling

GRDA used a sub-bottom profiler (SBP) to measure sediment layer thicknesses along cross-sections where vibracore samples were also collected. SBPs use sonar technology to locate the transitions between different layers of sediment. Outputs can readily distinguish silt and clay layers from sandy or rocky material, allowing for estimates of layer thicknesses. Data from these systems are frequently used to calculate sediment volumes. A full report documenting the findings will be included with the USR.

Vibracore Sampling

GRDA collected vibracore samples at the locations shown in Figure 2.3-1:

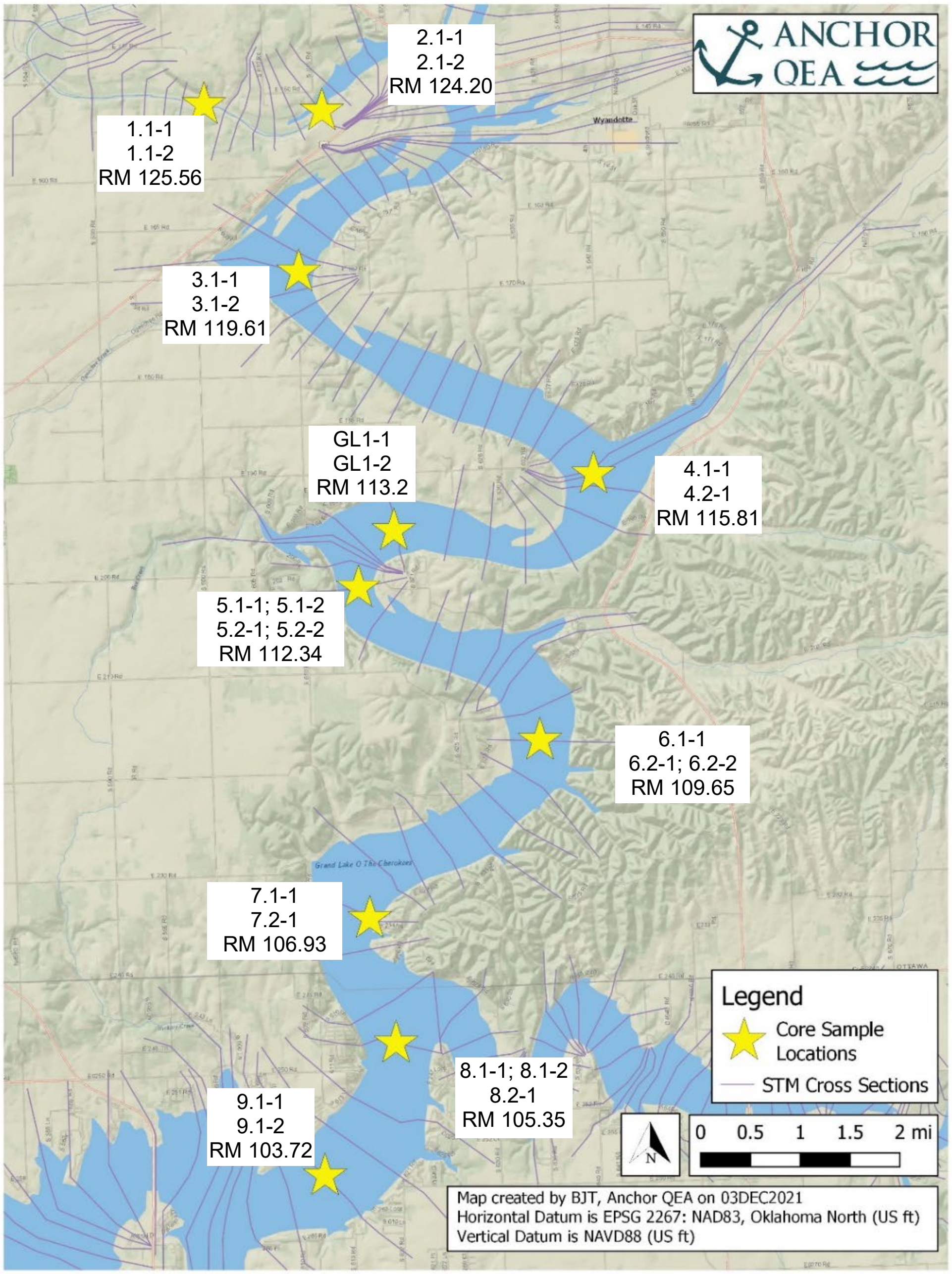

Figure 2.3-1. Vibracore sampling locations.

Vibracoring allowed GRDA to collect sediment cores for analysis to determine the depth of accumulation at sample sites. A vibracore rig can collect samples through soft sediments and sand; rocky soils typically stop the sampler. Sampling efforts using 16-foot core tubes produced a maximum core length of approximately 11 feet (Response Comment of GRDA) (Section 3.2) and Appendix A (Response to Comment No. 28).

GRDA selected ten locations for core sampling. Nine locations were along a transect that was measured with the SBP. Areas of particular interest were those in the reach covering the delta feature (approximately Twin Bridges at RM 122 to the Elk River confluence at approximately RM 105). The samples were taken at specific river cross-sections, with at least two cores at each cross-section. An additional location was the site of USGS samples collected as part of the sediment study presented by Juracek and Becker (2009) where GRDA collected samples GL1-1 and GL1-2.

The cores were analyzed for several purposes. The first was a simple sediment size gradation, which showed that the bulk of sediment was composed of cohesive silts and clays (Response Comment of GRDA Section 3.3). This is consistent with GRDA's SEDflume samples and findings presented as part of the ISR.

The second was a cesium 137 (Cs-137) analysis to estimate the approximate date of sediment deposition. A more detailed summary of the results is provided in the Response Comment of GRDA (Section 3.2) and Appendix A (Response to Comment No. 28) included with the USP, and a full report will be included with the USR.

2.4 Nexus between Project Operations and Effects on Resources

The operation of the Pensacola Project affects the elevations of Grand Lake. The Sedimentation Study will allow relicensing participants to understand the relationship between Project operations and sedimentation pertaining to the extent and duration of inundation.

The Sedimentation Study will also provide an understanding of the magnitude and extent of sedimentation and subsequent sediment transport associated with Project operations on upstream flooding.

2.5 Study Area

This Sedimentation Study will have extents similar to those of the existing hydrologic and hydraulic modeling study. It includes Grand Lake/Neosho River from Pensacola Dam to approximately the Kansas state line, the Spring River from its confluence with the Neosho to approximately the Kansas state line, and upstream along the Elk River. The study area encompasses the lower reaches of the Neosho, Spring, and Elk rivers where interactions between the reservoir and tributaries are likely greatest. The study area will also include a portion of Tar Creek.

2.6 Methodology

Bathymetric Change Analysis

Bathymetric changes can provide valuable information about sedimentation and erosion. Reaches or cross-sections where sediment has accumulated or eroded over time are apparent when looking at bathymetric changes from one survey to the next. The extent and rate of change may indicate areas where sediment deposition or erosion is likely to have some effect on flood duration and severity.

Bathymetric Comparisons

Bathymetric comparisons will be performed based on the type of data available. The 2017 survey performed by the USGS and the 2008/2009 survey performed by the OWRB overlap in the lowest 3 to 5 river miles of the Neosho, Spring, and Elk rivers. Survey data will be compared using surface differencing to evaluate erosion and deposition in those reaches.

Elsewhere, channel survey data are limited to cross-sections surveyed infrequently since the construction of Pensacola Dam in 1940. The long-term range of the data will permit broader analysis regarding channel aggradation, erosion, or migration. Where data are limited to cross-sections, bathymetric changes at each cross-section will be analyzed (see example in Figure 2.6-1), then volumetric changes between cross-sections will be computed to find the volume of sediment accreted or eroded.

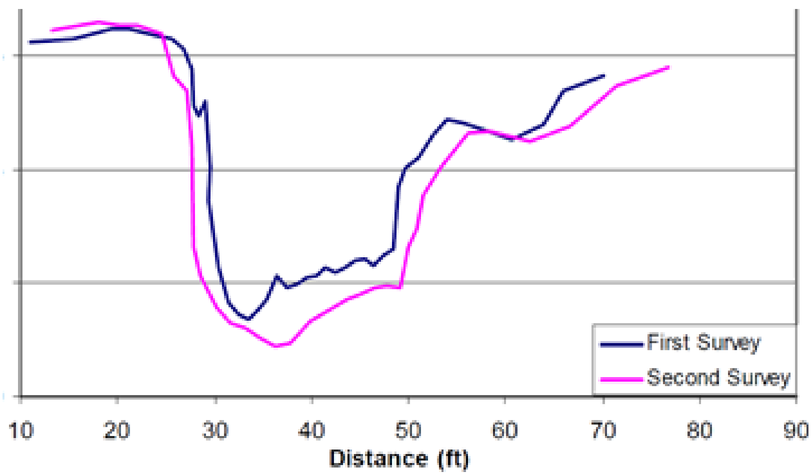

Figure 2.6-1. Example: Bathymetric cross-section comparison.

Additionally, ADCP surveys conducted by the USGS at the four gaging stations in the study area have collected bathymetry data across each channel cross-section. These surveys have been repeated between 5 and 25 times, depending on the site. These channel cross-sections will be analyzed based on the accompanying flow data for volume changes, channel migration, and effects on flood events.

Stage and flow volume measurements will also be used during bathymetric change analysis. The relationship between water surface elevation and flow rate through time will be analyzed and related to observed bathymetric changes. This evaluation will provide an indication of the effects of sedimentation and erosion on water levels in the specified reach.

Synthesis

The bathymetric comparison analysis will be synthesized into the USR detailing the temporal and spatial sedimentation patterns. Volume changes will be reported on a reach and cross-section scale. Reaches with significant changes will be highlighted as potential areas of interest for further investigation.

Proposed Field Work

At this time, there is no proposal for additional fieldwork. The collection of additional SSC and bedload sediment transport samples at sites not monitored by the USGS will not provide statistically sufficient data points to produce meaningful relationships that could be used for STM development. GRDA has also collected more than twice the number of sediment grab samples requested by the City of Miami (City) and has fully characterized the river and lakebeds based on work already completed. Sediment core samples have been collected and analyzed; further work would provide redundant information and cannot be accommodated under the current USR schedule.

STM Development

GRDA will continue to use the three-level approach to evaluate sediment transport within the study area. As requested by the City and others, GRDA will develop an STM within HEC-RAS. They will also produce a quantitative analysis using the methodology that relies on measured field data and documented relationships between hydraulic bed shear stress, sediment erodibility data, and bathymetric surveys.

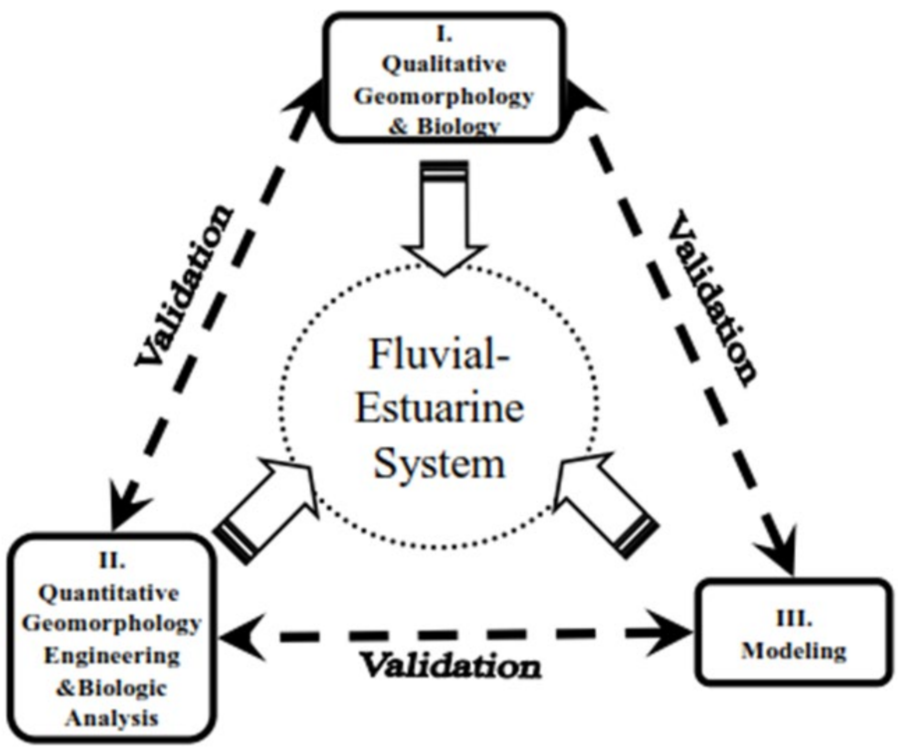

Figure 2.6-2. A conceptual schematic of the three-level approach for analyzing geomorphic, sediment transport, and sedimentation processes. Validation must occur between all three levels to ensure that reasonable results have been achieved.

Sediment Transport Model

An STM will be used to evaluate sediment transport and deposition patterns within the study area. HEC-RAS sediment transport modeling will explicitly determine the fate of sediment above the

Elk River (RM 105). Although most of the sediment being transported by the system is cohesive (silt and clay), the system does carry some volume of non-cohesive material (sand). Over time, this sediment can accumulate in the headwater of the reservoir and contribute to delta feature formation as sediment is deposited where stream velocities decrease. Coarser materials (in this case, sands) tend to deposit first, with gradually finer materials (silts and clays) dropping out of suspension further into the reservoir.

Bathymetry data indicate that the Grand Lake delta feature is located between RM 122 (approximately Twin Bridges) and RM 105 (approximately the Elk River confluence). HEC-RAS is more capable of modeling the accumulation associated with the relatively well-understood sediment transport process of delta feature formation.

Downstream of RM 105, deposition consists almost entirely of cohesive sediment (silt and clay). HEC-RAS uses a simplified parameterization of cohesive sediment transport to predict deposition and erosion of silt and clay and is therefore less well-suited to explicitly model sediment transport below this point.

It is far more challenging to model and understand the transport of cohesive sediment than it is to model and understand the transport of non-cohesive sediment. The main issue is variability of sediment characteristics within the soil column. As cohesive sediment rests, it consolidates and becomes more compressed. This results in changing resistance to erosion; surface sediments erode far more easily than the material underneath them. The density of the material also changes, with lower portions of the column having a higher density. Erodibility parameters measured in Grand Lake cover a range of approximately 1,000,000%, and density covers a range of 485%. The cohesive sediment characterization in HEC-RAS allows for only one set of erodibility parameters per sample location, regardless of how deep in the soil column it is buried. HEC-RAS also only allows for a single, global density change factor over time even though the silts and clays may feature very different consolidation rates from one location to the next.

Because of the complexity of modeling cohesive sediment transport and the wide range of measured sediment characteristics, the simplified cohesive parameterization that HEC-RAS uses is unable to accurately model the precise fate of silts and clays. This has led to the decision to truncate the STM at RM 105. Material carried in the wash load beyond that point is almost exclusively the fine silts and clays that pose significant challenges to accurately model. Below this point, the precise location of sediment deposition is less critical than the quantity of sediment deposited. As the City stated in their March 2022 comments to FERC:

> *[T]he total quantities of cohesive sediment entering the reservoir mainly inform the reduction in storage capacity due to sedimentation. They displace the same amount of water regardless of where in the reservoir they settle, meaning that their spatial distribution in the reservoir is largely irrelevant to the hydraulics of the tributaries and upstream flooding.*

Therefore, modeling the precise location of deposition in the reservoir is unnecessary. GRDA need only determine the quantity of sediment washing into it.

Below the Elk River (RM 105), the model outputs will be used to determine the quantity of sediment moving into the lower reservoir. The USACE has developed a method of calculating sediment trapping efficiency for impounded rivers (USACE 1995). The sediment trapping efficiency is the ratio of sediment held in the reservoir compared to the total amount entering the reservoir; sediment inflow and the trapping efficiency can therefore be used to determine the total quantity of sediment held. That information will allow evaluation of sediment impacts on the power pool and total storage.

By truncating the STM at RM 105, the locations of sediment deposition can be accurately modeled in the region of the delta feature and upstream tributaries where HEC-RAS is well-suited, while still quantifying the cohesive sediment washing into the lower reaches of the study area without relying on the limited cohesive sediment parameterization that HEC-RAS uses. This will enable GRDA to meet the objectives of the study.

Model Development

The STM was the subject of an ITR performed by WEST. The findings of the ITR suggest that HEC-RAS may be a suitable tool for sediment transport modeling above the Elk River confluence at approximately RM 105.

WEST suggested a re-evaluation of hydraulics in the STM, specifically focusing on simulation result differences between the UHM and the STM at several locations. WEST also recommended incorporating measured seasonal water temperature differences into the STM. Water temperatures have been recorded at various locations throughout the study area, and average seasonal variations will be included as part of future model development.

Sediment rating curves used in the model currently do not fully account for the amount of sediment entering the system. Specifically, the rating curves show insufficient sediment supply to match the deposition in the downstream reaches below the Elk River. A review of the curves will be incorporated into the next steps, with potential for a power relationship used to define the rating curves and increase sediment loading to match the recorded deposition.

WEST also recommended using Krone-Partheniades relationships to define cohesive sediment erosion parameters, which had not been done in the version submitted for the ITR.

After reviewing the STM and making necessary updates, the model will be truncated at RM 105 (just below the Elk River confluence). The upper region of the study area will be explicitly modeled with HEC-RAS and will contain the entire system from the Elk River confluence and above. The lower region is everything below the Elk River; this region will be evaluated using reservoir trapping efficiency and modeled sediment outflows. GRDA proposes this compromise so that HEC-RAS can be used to evaluate sediment deposition on the delta feature and the upper reaches of the Grand Lake tributaries, where it is more well-suited to the analysis, while simultaneously addressing the limited parameterizations used to model cohesive sediment transport within HEC-RAS.

The upper region includes the delta feature and will allow GRDA to evaluate the locations of sediment aggradation and degradation over time. The STM will simulate the evolution and the dynamics of the delta feature and answer questions about the impact of sedimentation on upstream water levels.

The lower region covers the bulk of the reservoir. As discussed in the Response Comment of GRDA (Section 7.5.2) and Appendix A (Comment No. 6), the exact location of sediment deposition within the reservoir is relatively unimportant to upstream water levels. Quantifying the changes to the stage-storage curve over time is sufficient to assess sedimentation’s impact on the power pool and storage. Therefore, this region of the study area does not need to be explicitly modeled in HEC-RAS or rely on simplified cohesive sediment parameterizations, and a separate analysis can be used instead.

Analysis of the lower region will use STM outputs. Sediment outflow quantities will be used in conjunction with the calculated reservoir trapping efficiencies to calculate the total amount of sediment retained in the basin. GRDA can then quantify any impacts to the power pool and reservoir storage.

Model Inputs

Model inputs will be based largely on GRDA's field efforts and publicly available information published by the USGS. These can be grouped into three main categories:

- Hydrology
- Sediment Bed
- Sediment Loading

Hydrology

The discharge information for the model will be developed from USGS gaging station information. These include the following gages, where daily discharge measurements have been recorded since approximately 1940:

Table 2.6-2. USGS datasets available for STM development

USGS Gage	Datasets	Period of Record
07185000 – Neosho River near Commerce, OK	Discharge	1939 – Present
07185090 – Tar Creek near Commerce, OK	Discharge	2004 – Present
07185095 – Tar Creek at 22nd St Bridge at Miami, OK	Discharge	1984 – Present
07188000 – Spring River near Quapaw, OK	Discharge	1939 – Present
07189000 – Elk River near Tiff City, MO	Discharge	1939 – Present
07190000 – Lake O' the Cherokees at Langley, OK	Reservoir Storage	1940 – Present

Several stations offer hourly discharge and stage datasets and periodic SSC data, as shown in Table 2.6-3.

Table 2.6-3. USGS hourly datasets available for STM development

USGS Gage	Period of Record		
	Discharge	Stage	SSC
07185000 – Neosho River near Commerce, OK	1990 - present	2007- present	1944 - 2016
07185080 – Neosho River at Miami, OK	N/A	2007- present	N/A
07185090 – Tar Creek near Commerce, OK	2007 - present	2007- present	2004 - 2016
07185095 – Tar Creek at 22nd St Bridge at Miami, OK	1989 - present	2007- present	1988 - 2006
07188000 – Spring River near Quapaw, OK	1989 - present	2007- present	1944 - present
07189000 – Elk River near Tiff City, MO	1990 - present	2007- present	1993-2009

In addition, the USGS has hourly records of the stage at 07190000 – Lake O' the Cherokees at Langley, OK dating back to 2007.

These datasets will provide the necessary information for hydraulic boundary conditions. Inflows will be based on the recorded discharges, and the downstream boundary will be set with the water levels at Pensacola Dam.

Sediment Bed

GRDA has collected numerous bed samples to define the sediment present in the system. This is separate from the sediment that is actively moving through the study area; it simply describes what has settled onto the streambeds and lakebeds. A brief discussion was presented earlier in this document.

Sediment Loading

Sediment loading will be another key STM boundary condition. Table 2.6-3 provides the period of record for SSC measurements provided by the USGS. These are sporadic measures taken at specific instances in time rather than continuous records, and they have been supplemented by GRDA fieldwork during the initial phase of the Sedimentation Study. Sediment rating curves (relating stream discharge to sediment loading) will be refined based on the available data and input from WEST in the ITR.

Fieldwork by GRDA has also measured bedload transport. The bedload transport collection efforts produced no measurable quantities of bedload. The calculated bedload values show that it is a much smaller portion of total sediment transport than the suspended fraction. However, this will be considered during model development and calibration. Adjustments to the sediment rating curves to ensure proper calibration may require inclusion of small amounts of coarser sediments for extreme events.

Sediment Transport Model Parameters

Non-Cohesive Sediment

Non-cohesive sediments will be modeled using the Meyer-Peter Müller (1948) or “MPM” sediment transport equation modified with Toffaleti’s suspended sediment equation (Toffaleti 1968). This is applicable for bedload transport of the sands and gravels present in the study area, and the Toffaleti equation covers suspended transport. Both are based on empirical relationships developed with non-cohesive materials.

Cohesive Sediment

Cohesive sediments will be modeled based on hydraulic shear stress and sediment critical shear stress values. Hydraulic shear stress is a measure of the drag force on a streambed caused by water flowing across it. Sediment critical shear stress is the bed shear stress at which material first starts moving. The sediment critical shear stress values to be used in the STM were obtained from SEDflume laboratory analyses completed as part of the first study year (Integral Consulting 2020). The critical shear measurements will then be used to determine erosion and deposition.

Erosion rates of cohesive sediments were determined by fitting SEDflume erosion rates to applied shear stress using the formula given by Ariathurai (1974):

$$Q_{se} = \begin{cases} M_{se} \dfrac{\tau - \tau_{se}^{c}}{\tau_{se}^{c}}, & \tau \geq \tau_{se}^{c} \\ 0, & \tau < \tau_{se}^{c} \end{cases}$$

where Q_{se} = surface erosion rate,
τ and τ_{se}^{c} = bed shear stress and critical surface erosion shear stress, respectively, and
M_{se} = surface erosion rate constant.

The quantity $\tau - \tau_c$ is known as excess shear stress and primarily influences the amount of erosion at a given bed shear stress. The surface erosion rate constant, M_{se}, is determined from SEDflume laboratory analysis and is illustrated in Figure 2.6-3.

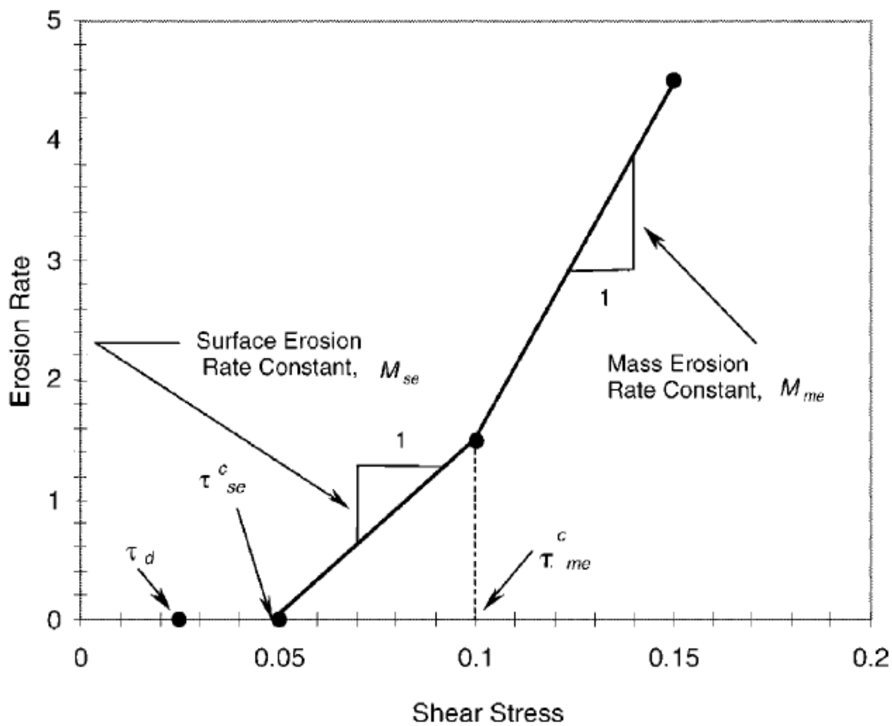

Figure 2.6-3. Determination of M_{se} from graphical analysis.

This analysis provides the parameters needed for the Krone-Partheniades transport relationship that will be used to simulate cohesive sediment transport.

Sediment transport results will be compared with measured SSC data to evaluate their accuracy. Agreement between measured and calculated values of sediment loads will be evaluated across a range of flows and sediment fluxes to determine their suitability.

Model Geometries

There have been several surveys of the study area that will be used for this analysis. The earliest geometry was collected circa 1940, and the most recent survey was completed in 2019. These will be used for model development and calibration as described below.

Circa 1940 Surveys

The circa 1940 terrain will be based on information available from pre-dam conditions. This includes a 1938 topographic map of the area, circa 1940 channel data, and thalweg profile information provided by the USACE (1938, 1941, 1942).

These products represent the best available information for pre-dam conditions, but they are imperfect. The overbank geometry will be derived from a 5-foot contour map of the study area. Bathymetry will come from channel data that were derived from USACE bathymetric surveys. The original bathymetric source data are not available.

As a result, the representation of the circa 1940 topography and bathymetry contains significant uncertainty. The 5-foot contours limit the resolution of cross-sectional geometry, and this information must be paired with bathymetric surveys completed at a different time. Therefore, GRDA will be forced to use professional judgment to develop a full terrain (bathymetry and topography) dataset for use in model development. These limitations mean that model results will necessarily be imprecise. All assumptions, datasets, and supporting rationale will be documented and presented as part of the USR.

1998 REAS Surveys

The USACE surveyed the upper reaches of the Neosho River and Spring River as part of the REAS (USACE 1998). This useable portion of this dataset covers the reach upstream of RM 120.1 (approximately 2 miles downstream of the Spring River confluence).

This information for the reach upstream of RM 120.1 is the best circa 1998 data available, but it is also imperfect. The USACE has indicated that the quality control procedures used at the time of the surveys were flawed, and GRDA's review of the data has confirmed that assessment as discussed in the ITR report, Response Comment of GRDA (Sections 4 and 7) and Appendix A (Comment No. 6) submitted with this proposal. Questions about vertical datum shifts have been raised by multiple parties, including the City of Miami (2022) whose consultant team stated, "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," (Appendix A, Comment No. 6) and there is limited spatial resolution in the data; these data will therefore also include a significant amount of uncertainty.

Bathymetry from the REAS below RM 120.1 will not be used. The REAS documentation included the following figure, which clearly shows bathymetry in the reach containing the delta feature was not collected during the REAS. Based on reviews of the data in this area discussed in detail in the ITR report (Section 5.2), Response Comment of GRDA (Section 4.4.1) and Appendix A (Response to Comment No. 6) submitted with this proposal, it seems likely that the bathymetry was surveyed circa 1940 and does not represent site conditions at the time of the study.

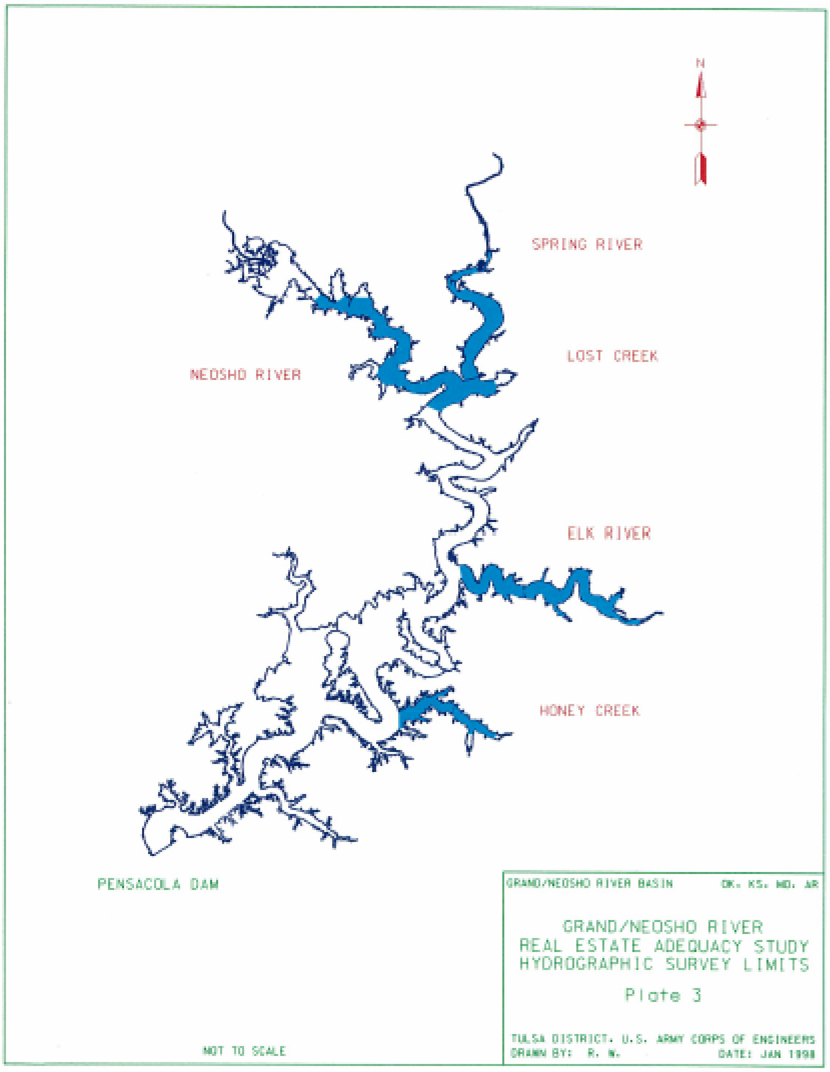

Figure 2.6-4. 1998 REAS hydrographic survey coverage.

The Elk River bathymetry from the REAS will not be used. Water levels recorded by the USGS gage at Highway 43 (USGS Site 07189000 – Elk River near Tiff City, MO) place the water surface below the streambed in this location. Because they are clearly unreliable, these data will not be used for this study.

2017 USGS Upstream Surveys

The USGS surveyed the upstream reaches of the Neosho, Spring, and Elk Rivers in 2017 (Smith et al. 2017). This dataset has been thoroughly reviewed and quality control procedures were well documented. It covers the Neosho and Spring Rivers upstream of Twin Bridges (approximately RM 122) and the Elk River above RM 5.47.

2009 OWRB Grand Lake Survey

In 2009, the OWRB collected single-beam bathymetry for Grand Lake from Pensacola Dam to Twin Bridges (approximately RM 122). This dataset includes thorough quality control documentation and features dense coverage of the reach containing the delta feature (from Twin Bridges to the Elk River confluence).

<u>2019 USGS Grand Lake Survey</u>

The USGS-collected multi-beam hydrographic survey data in Grand Lake in 2019 (USGS 2020). This dataset includes thorough quality control documentation and covers Grand Lake up to Twin Bridges, including the delta feature.

The above data sources will provide the basis for STM development and calibration.

Model Calibration

The STM will be calibrated to measured bed changes based on the historical surveys. Different reaches of the study area have been surveyed at different times (see above); the starting and finishing dates of calibration runs will therefore vary by location (Figure 2.6-5).

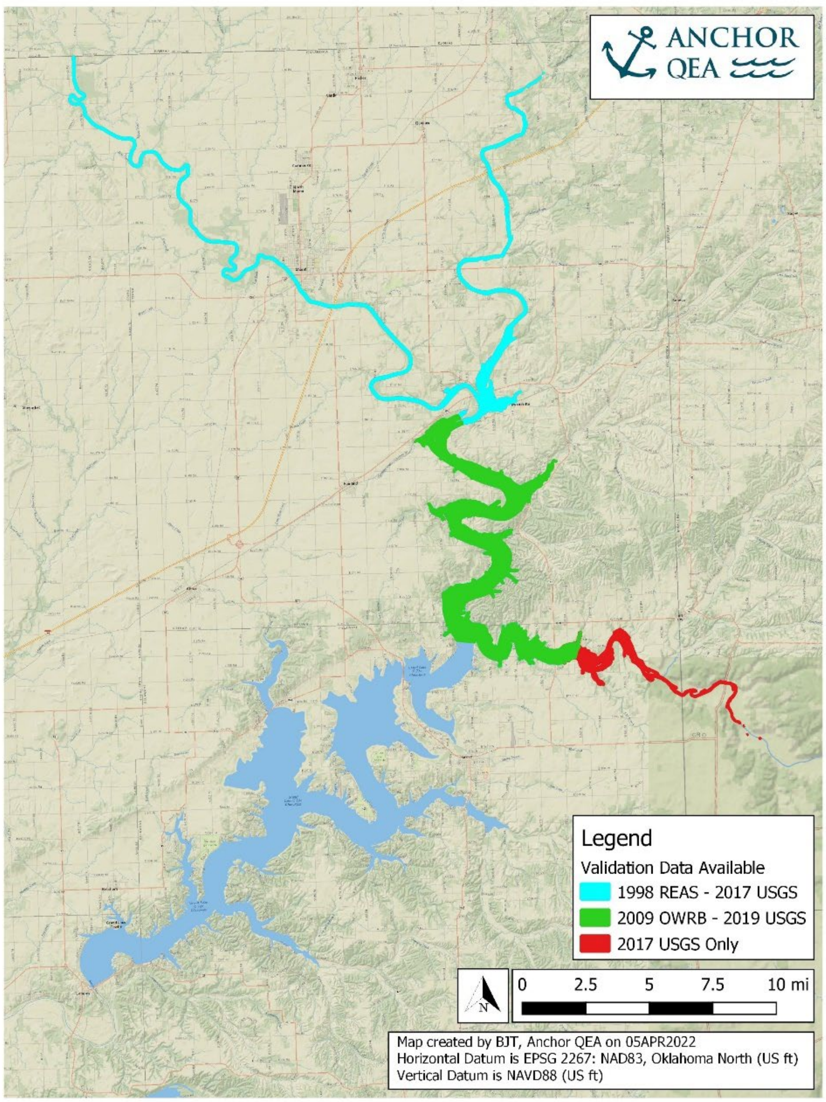

Figure 2.6-5. Model geometries used for calibration and validation by reach. All starting geometry will be based on circa 1940 data.

The study area will be divided into four areas. The first is the upper area and will cover the Neosho River, Spring River, and Tar Creek above RM 120.1 (shown in teal in Figure 2.6-5). The second is the area of the Neosho that contains the delta feature between RM 120.1 and RM 105 (green in Figure 2.6-5). The third area is the Elk River above RM 5.47. Each of these three areas will be calibrated based on the available bathymetric information. The final area is the lower reservoir from RM 105 to RM 77.12 at Pensacola Dam (orange in Figure 2.6-5).

Calibration will start with the circa 1940 bathymetry and terrain and simulate flows and sediment inputs recorded between dam construction and the date of the calibration survey shown in Table 2.6-4. GRDA will then compare the model results to the measured terrain changes (upper, lower, and Elk River reaches) or total calculated deposition (reservoir) and adjust parameters as needed.

Table 2.6-4. 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 105)	Circa 1940 USACE	2009 OWRB	2019 USGS
Elk River (Above RM 5.47)	Circa 1940 USACE	2017 USGS	
Reservoir (Below RM 105)	Circa 1940 USACE	2009 OWRB	2019 USGS

Where a validation survey is available, GRDA will then simulate recorded hydrology and sediment loading and compare final outputs as a validation method. Because only two reliable surveys are available for the Elk River, validation will not be possible for the Elk River reach.

Model Scenarios

Following STM calibration and validation, the model will be used to evaluate reasonable future scenarios. These will use a synthetic 50-year hydrograph based on past hydrology by randomizing the historic flow recordings. Any long-term trends in magnitude will be included in the hydrograph development process by multiplication using a scaling factor. The STM will be used to evaluate the following scenarios:

- Fifty-year period with current rule-curve operating range[2]; predicted channel and overbank geometry will then be used to simulate specific flow events and evaluate effects of simulated sedimentation on water levels.
- Fifty-year periods with adjusted operations covering the operating ranges from 742 to 745 feet PD.

GRDA will adjust model parameters such as sediment loading and erosion parameters of cohesive material within a reasonable range as part of the sensitivity analyses. The specific parameters and range of values used in the sensitivity analyses will be provided with the USR.

The model sensitivity analyses results will bound expected future sedimentation patterns, but no model is capable of perfectly predicting future conditions given the uncertainties in future hydrology. This is particularly true in this case given the limited resolution and lack of georeferenced information for the circa 1940 data and the uncertainties associated with the REAS data. The results of any model are only as good as the input data, and input data available to GRDA have significant limitations. GRDA will use the available data to create a prediction of future

[2] Based on previous analysis for the December 3, 1996, Order Amending License to ensure the Project is operated for balanced multiple uses, including hydropower generation, water supply, public recreation, and wildlife enhancement operation below an elevation of 741 feet PD is not being analyzed because it does not balance multiple uses. (77 FERC ¶ 61,251).

conditions using the STM calibration, validation, and then prediction approach, but the results will be a bounded approximation of future conditions.

Quantitative Sediment Transport Evaluation

In addition to the STM, GRDA will use 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 and upstream water levels. GRDA will use this analysis as a means of validating the model outputs and providing additional confidence in STM results.

Recent evaluations of computer modeling by the U.S. Society on Dams (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:

> *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 non-cohesive 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 and Partheniades are the relationships used in HEC-RAS for cohesive sediment.

The USSD (2015) findings also state:

> *In summary, the sediment transport conditions associated with reservoirs are extremely complex. Detailed analysis of many of these problems lies beyond present knowledges, 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 cohesive reservoir sediment deposition play a significant role in determining the fate of transported sediment (Lumborg and Vested 2008, van Rijn n.d.; Zavala 2020), 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 truncate the STM at RM 105.

For these reasons, GRDA will also perform a quantitative engineering analysis of sediment transport within the study area. This approach will rely on measured field data including sediment transport, erodibility, and grain size distributions; bathymetric surveys; and overbank topographic information.

Specific components of the quantitative sediment transport analysis include the following:

Historic trends in bathymetry and channel cross-sections will be compared over time.

- Compare previously collected bathymetry survey data in the study area to determine past channel/bed changes
- Assess areas of deposition and erosion with respect to geomorphic processes
- Perform specific gage analysis
- Develop spatial and temporal understanding of geomorphological changes and rates of change and correlations between historic hydraulic patterns and historic sedimentation patterns

Sediment transport results will be evaluated:

- Determine site-specific sediment transport mobility criteria (critical shear stress) for locations in the study area
- Estimate sediment transport rates at selected sites using appropriate established formulas for cohesive and non-cohesive sediments
- Evaluate trends in sediment transport over time based on USGS and GRDA-collected field data
- Compare upstream sediment transport (sediment supply) based on the suspended sediment and bedload data to the bathymetric data and associated loss of sediment storage in the reservoir (sedimentation)
- Settling velocity analysis

In addition to the basic engineering and geomorphic analyses described above, analysis will be conducted using the hydraulic component of the STM to compare hydraulic shear stress—the driving force typically affecting sediment transport (and erosion or deposition)—to the sedimentation patterns (based on change in bathymetry between successive surveys) and comparing this information to the incoming sediment load. This analysis will be conducted specifically at the delta feature and in downstream reaches of the reservoir below Elk River that are not included in the STM.

Hydraulic shear stresses will be computed by the STM and can be relied on to reasonably represent the forces which either cause sediment to be transported or deposited along these rivers and in the reservoir. There is a direct relationship between the hydraulic shear stress and the transport or deposition of cohesive sediment as it flows down the rivers and into the reservoir. The analysis of this relationship can be utilized to understand the pattern of historical sedimentation and make projections into the future using any change in the historical distribution of shear stress as it may vary with operational alternatives and changes in sedimentation patterns. This analysis will be utilized to validate STM results.

If there are significant differences between the two methods, further consideration of input parameters will be necessary. This will result in iterative modifications to either the STM or the quantitative analysis to better reproduce measured bathymetric changes as necessary. The purpose of performing the quantitative analysis is to validate STM results and ensure model accuracy. This validation effort will guide adjustment of input parameters for the STM as needed. When both methods produce similar results and reproduce the measured bathymetric changes, it will indicate they are capable of reliable sedimentation predictions. Final inputs and assumptions for both the STM and quantitative approach will be documented and provided as part of the USR.

<u>Circa 1940 to 2009</u>
From circa 1940 to 2009, hydraulic shear stresses are calculated for each day and corresponding flow by the STM. Based on a comparison of the circa 1940 bathymetry to the 2009 bathymetry, the delta feature formed within the reservoir during this period. At a number of locations along the river and reservoir, hydraulic shear-duration curves will be developed over the circa 1940 to 2009 time period, similar to a flow-duration curve (one set of curves will be developed based on the circa 1940 data and another set on the 2009 data to determine the change in shear distribution at various locations along the river and reservoir). Based on the incoming sediment load and sediment deposition patterns from the change in cross-sections or bathymetry, the quantity of sediment being deposited between key locations or passing farther downstream will be calculated. This will establish the historical deposition of sediment at various locations along the river and reservoir and the corresponding distribution of hydraulic shear stresses that caused the sediment to deposit where it did over this period. At each location, the hydraulic shear distribution and the quantity of sediment deposited between any particular location and the next location upstream will be known. The locations will be selected based on significant shifts in the hydraulic shear distributions, historical sedimentation patterns, as well as intermediate locations to develop an adequate set of information to define how the variation in hydraulic shear affects the sedimentation pattern. Relationships will then be developed for the distribution of hydraulic shear and how it varies in the downstream direction correlated to the amount of sediment deposited between each successive location. These relationships will define the historical pattern of sedimentation as affected by hydraulic shear stress and how it varies along the river and reservoir as compared to the quantity of incoming sediment load based on the historical hydrology and sediment rating curves applied to that hydrology.

GRDA will evaluate sediment deposition using the distribution of STM bed shear stress outputs. This will be an iterative process that will use incoming sediment loads, future flows, and proposed Project operations to drive the STM. Bed shear stress distributions will be analyzed to determine locations where sediment is likely to drop out of suspension and where sediment will be transported further downstream. Initial simulations will focus on changes to hydraulic shear stress distributions between the circa 1940 and 2009 channel geometry under historical flow and operational scenarios.

<u>2009 to 2019</u>
The same analysis for circa 1940 to 2009 will be conducted from 2009 to 2019 to analyze the time period when the height of the delta feature is stable and sediment has primarily been transported into the lower portion of the reservoir.

Starting with 2019 cross-sections and bathymetry, the distribution of hydraulic shear stress will be computed at the same locations as the 2009 to 2019 analysis. The new distributions of hydraulic shear will be developed for a specific flow and operation scenario (for example a 50-year time period with reservoir operation as prescribed for the scenario). The incoming sediment load will be computed using the upstream hydrology for the 50-year time period using the sediment transport rating curves. This will define the total quantity of sediment to distribute. Using the starting hydraulic shear stress distribution relationships with sedimentation relationships developed for the 2009 to 2019 period, an initial distribution of the computed amount of sediment will be made. Based on this geometry, updated distributions of hydraulic shear will be developed to refine the initial distribution of the quantity of sediment for the 50-year period. This iteration of refinement will result in the expected distribution of sediment for that particular scenario. With a range of sedimentation patterns based on the proposed operating regime for each scenario, the hydraulic model will then be run to evaluate the flooding potential upstream along the various rivers to show the effects of sedimentation on flooding.

This approach focuses on key data and direct physical relationships between hydraulic shear stress and sedimentation patterns. This approach does not have to rely on the complexities of cohesive sediment characteristics as previously discussed regarding modeling issues, because the simple relationship between hydraulic shear stress and sedimentation already integrates and explains these complexities without having to delve directly into them through use of an overly simplistic sediment transport modeling approach. These results in terms of sedimentation pattern will be compared to and evaluated against the STM results before the hydraulic analysis of upstream flooding is conducted using the UHM.

Characterization of Sedimentation Impacts on Flooding

The impact of Project operations will be evaluated by comparing the starting and ending geometries of each 50-year STM simulation. The predicted channel and overbank geometries will be used to simulate specific flow events and evaluate the effects of sedimentation on upstream water levels for a range of Project operational scenarios. The effects of sedimentation in the reservoir will also be evaluated for a range of Project operational scenarios to provide an understanding of storage change and potential impacts to the power pool.

<u>Data Synthesis and Reporting</u>

The Sedimentation Study will assimilate and synthesize findings from existing data analyses, bathymetric changes, field measurements, sediment transport evaluations, operations impacts, and sediment loading to provide an understanding of the sediment transport trends within the study area.

Findings of the review of existing data will be documented in the USR detailing the types, sources, and quality of data. An organized database of all data will be created and made available.

Results of sediment data measurements, ADCP measurements, suspended sediment measurements, and water levels will be summarized in the USR. ADCP and water level data have already been provided to GRDA for use in UHM calibration and validation. The USR will detail the methods, analysis techniques, and results of field measurements.

Relevant findings will be compared against each other to determine the sediment transport regime in the study area. Bathymetric changes, modeled sediment loading, and calculated sediment transport rates will be analyzed to create a mass balance sediment budget for the study area. This analysis will provide an understanding of sediment movement through the watershed.

Findings of the investigation of sedimentation on flooding will be presented in the USR with maps and figures of simulated flooding extents, profiles, and depths.

Calculated sediment transport rates obtained from field measurement data and hydraulic modeling of Project operations will inform the impacts of Project operations on sedimentation in the study area. The USR will include a description of sediment transport evaluation methods and results. Selected calculations and results will be made available in the USR.

2.7 Executable Model and Model Documentation

Following completion of the USP, GRDA will provide the final STM and supporting documentation within 10 days of receiving a request for said materials. This does not include draft versions of the model and associated files or draft documentation. These files will:

- Allow independent reviewers to evaluate the appropriateness of the STM, including input geometry, model parameters, flow data, sediment information, and calibration and scenario runs
- Allow independent reviewers to evaluate the methods used to develop maximum water surface and bed elevation profiles as well as GIS maps showing predicted inundation depths and extents for various scenarios
- Allow for model use in other studies, as appropriate

The USR will include a technical summary documenting:

- Data sources
- Input hydrology
- Model development process
- Modeling assumptions
- Model calibration
- Model outputs

2.8 Consistency with Generally Accepted Scientific Practice

The Sedimentation Study follows generally accepted scientific practice regarding field data collection, sediment transport analysis, and hydraulic modeling. Truncating the model below the Elk River confluence does not affect the capability of the model to evaluate sedimentation impacts on upstream water levels. Combining model outputs with USACE guidance (1995) for trapping efficiency calculations allows GRDA to evaluate sedimentation impacts on the power pool and reservoir storage.

2.9 Schedule

The schedule of the Sedimentation Study is displayed in Table 2.9-1.

Table 2.9-1. Sedimentation study schedule.

Task	Completion Date
(Technical) Report (USR)	September 30, 2022

2.10 Level of Effort and Cost

The estimated cost for completion of the Sedimentation Study is approximately $1,400,000.

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