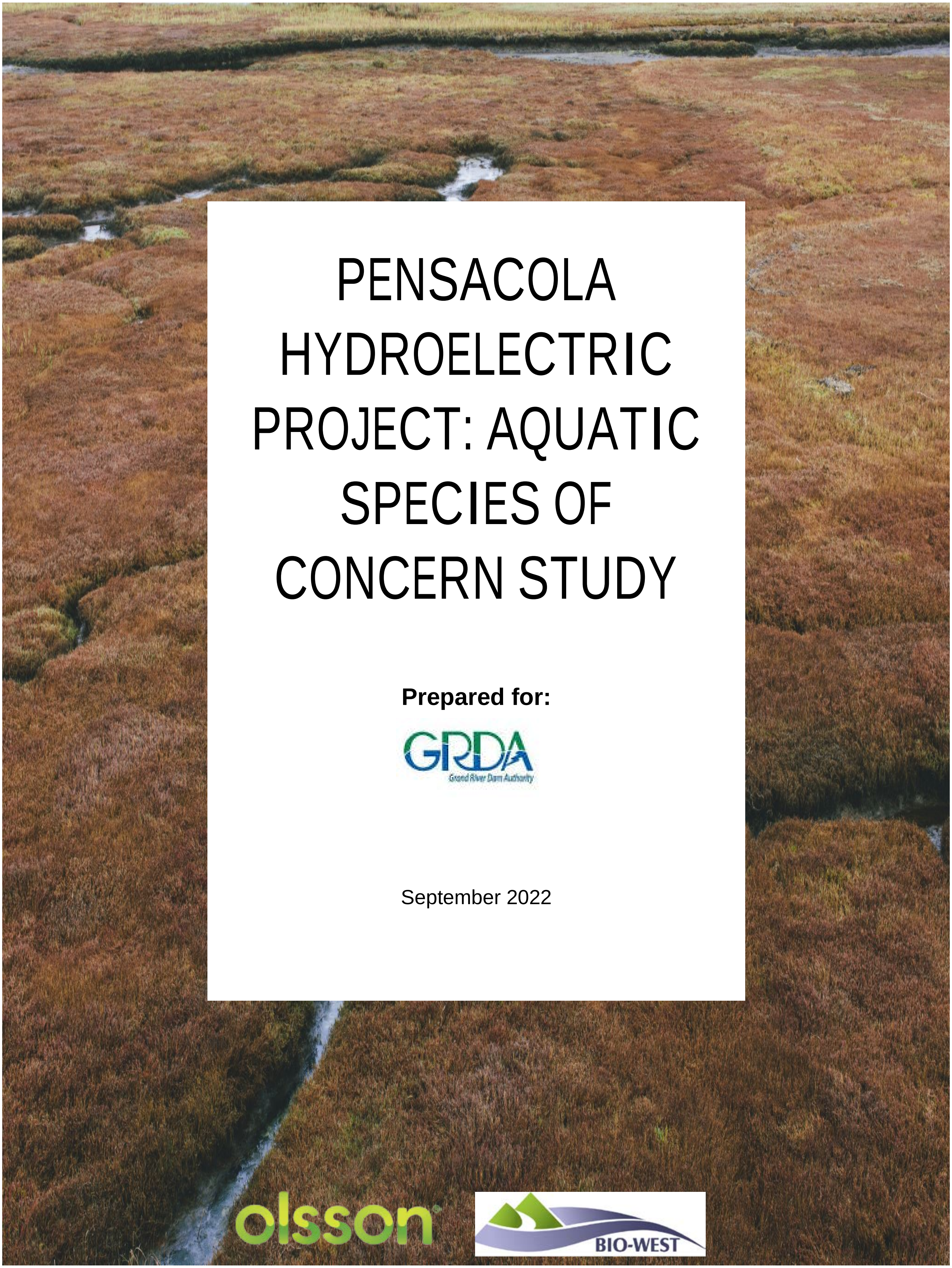

PENSACOLA HYDROELECTRIC PROJECT: AQUATIC SPECIES OF CONCERN STUDY

Prepared for:

GRDA
Grand River Dam Authority

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BIO-WEST

ACRONYMS AND ABBREVIATIONS

CHM	Comprehensive Hydraulic Model
CFR	Code of Federal Regulations
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FPA	Federal Power Act
GIS	Geographic Information System
GRDA	Grand River Dam Authority
H&H	Hydrologic and Hydraulic Study
ISR	Initial Study Report
kW	kilowatts
NDAA	National Defense Authorization Act for Fiscal Year 2020
NRHP	National Register of Historic Places
ODWC	Oklahoma Department of Wildlife Conservation
OSU	Oklahoma State University
OWRB	Oklahoma Water Resource Board
PAD	Pre-Application Document
PD	Pensacola Datum
PSP	Proposed Study Plan
RSP	Revised Study Plan
RTE	rare, threatened, and endangered
SMP	Shoreline Management Plan
TCTC	Tar Creek Trustee Council
TSMD	Tri-state Mining District
USACE	U.S. Army Corps of Engineers
USFWS	U. S. Fish and Wildlife Service
USGS	U. S. Geological Survey

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1. INTRODUCTION

As part of the relicensing of the Pensacola Hydroelectric Project (Project; FERC [Federal Energy Regulatory Commission] No. 1494), the Grand River Dam Authority (GRDA) filed a Pre-Application Document (PAD) with FERC on February 1, 2017 (GRDA 2017). The GRDA filed its Proposed Study Plan (PSP) for the relicensing on April 27, 2018 (GRDA 2018a). Also, on April 27, 2018, FERC released its Scoping Document 2 for the relicensing of the Project (FERC 2018). In its PSP, GRDA did not include a specific study to investigate potential Project effects on aquatic resources. Based on comments received from federal and state resource agencies and other stakeholders, GRDA's Revised Study Plan (RSP), filed on September 24, 2018, proposed an Aquatic Species of Concern Study to provide further details regarding how potential impacts to aquatic resources related to changing water levels due to Project operations will be assessed during the relicensing process.

GRDA's Aquatic Species of Concern Study proposed a phased approach to identify and analyze potential Project effects on aquatic species in the study area and focused on six species: Neosho Mucket (*Lampsilis rafinesqueana*); Rabbitsfoot mussel (*Quadrula cylindrical cylindrical*); Winged Mapleleaf mussel (*Quadrula fragosa)*; Neosho Madtom (*Noturus placidus*); Neosho Smallmouth Bass (*Micropterus dolomieu velox*); and Paddlefish (*Polyodon spathula*). In the RSP, GRDA's Aquatic Species of Concern Study Plan generally proposed to use existing information and output from the Comprehensive Hydraulic Model (CHM) to assess potential impacts to these aquatic resources. For the three Neosho River species (Neosho Mucket, Neosho Madtom, and Neosho Smallmouth Bass), GRDA also proposed to conduct field surveys in the second study season to develop rough estimates of species' distribution in relevant reaches, if determined necessary.

FERC issued its Study Plan Determination on November 8, 2018, which recommended the following refinements to GRDA's proposed Aquatic Species of Concern Study:

- For Paddlefish, FERC recommended that GRDA include estimating the proportion of Paddlefish spawning habitat affected by increasing the reservoir elevation, relative to available spawning habitat in the project vicinity. FERC explained that estimating the proportion of spawning habitat affected by increasing the reservoir elevation could be accomplished using GRDA's proposed data gathering methodology.

- For the three Neosho species, FERC recommended that GRDA address the need for species density information by: (1) including a review of existing density estimates in the Project vicinity for each species (for the first season of studies); and (2) including surveys designed to estimate each species' density (in the second season of studies).

The review of existing information required by the FERC-approved Aquatic Species of Concern Study during the first season was summarized in an Initial Study Report (ISR) submitted in September 2021. Following agency comments and GRDA responses on this report, FERC issued a Year 2 Study Plan Determination in February 2022. This determination identified areas to be surveyed for Neosho Mucket and Neosho Madtom during Phase 2 studies in 2022, and directed GRDA to consult with EcoAnalysts, Tar Creek Trustee Council (TCTC), and USFWS on mussel survey design. A proposed mussel survey design was developed, shared with the above entities during spring 2022, and completed during the summer of 2022 (see Appendix). This comprehensive Aquatic Species of Concern Study Report summarizes results of the initial review of existing information and subsequent survey efforts and provides an analysis of the effects of anticipated project operations on each of the aquatic species of concern.

1.1 Purpose of the Study

The purpose of this study is to determine if GRDA's anticipated operation has the potential to affect aquatic species of concern in Grand Lake O' the Cherokees (Grand Lake) and the lower reaches of its tributaries. This study reports on information needed to assess the effects of the Project, if any, on these relevant species identified in the preceding paragraph as part of FERC's analysis for the relicensing of the Project. Specifically, Section 3 summarizes existing and recently collected information on each of the six species identified above and based on that existing information, discusses the potential effects of baseline Project operations versus anticipated Project operations (if any) using hydraulic conditions predicted by the CHM during sensitive life stages.

1.1.1 Species of Concern

The Neosho Mucket, Rabbitsfoot, Winged Mapleleaf, Neosho Madtom, and Neosho Smallmouth Bass have been identified as species of concern that inhabit or have the potential to inhabit the areas affected by the anticipated Project operations. While Paddlefish is not a species of concern, it is an important resource in Grand Lake. Project operations may influence water levels of the surrounding tributaries of the Pensacola Dam. These water level fluctuations have the potential to alter the habitat of the species of concern and Paddlefish. Understanding the spatial and temporal effects, if any, caused by anticipated Project operations on the study area will allow for characterization of potential impacts to these species.

The following list details the dates when the above species were listed by the U.S. Fish and Wildlife Service (USFWS) as threatened or endangered under the federal Endangered Species Act (ESA):

- Neosho Mucket was listed as endangered effective October 17, 2013 – listed wherever found (ECOS 2021a).
- Rabbitsfoot mussel was listed as endangered effective October 17, 2013 – listed wherever found (ECOS 2021b).

- Winged Mapleleaf mussel was listed as endangered effective June 20, 1991, and experimental population, nonessential effective June 14, 2001– Endangered wherever found except where listed as an experimental population (ECOS 2021c).
- Neosho Madtom was listed as threatened effective June 22, 1990 – listed wherever found (ECOS 2021d).

Neosho Smallmouth Bass is not listed under the federal ESA. However, it was identified by Oklahoma Department of Wildlife Conservation (ODWC) in its July 24, 2018, PSP comment letter to FERC as a species of concern in the context of anticipated changes to water level management in Grand Lake.

Paddlefish is not listed under the federal ESA, nor has it been identified by ODWC as a species of concern. Paddlefish use Grand Lake's two primary headwaters (the Neosho River and Spring River) for spawning. However, stocks in Grand Lake and the Neosho and Spring Rivers support a prominent snag fishery, attracting anglers from throughout the United States during the spring spawning run (Jager and Schooley 2016). Although annual catch rates are variable depending on hydrologic conditions, thousands of mature Paddlefish are harvested from Grand Lake stocks during some years (Scarnecchia et al. 2013). Trip expenditures from Paddlefish angling in Oklahoma have an estimated economic impact of $18.2 million (Melstrom and Shideler 2017), much of which is focused on the Grand Lake fishery.

1.2 Project Background

Based on the information in the Shoreline Management Plan (SMP; GRDA 2008) the existing Project consists of the following:

1. A main dam, which has a maximum height of 147 feet (ft) and is comprised of (a) a 53.5-ft-long non-overflow abutment section on the western end, (b) a 4,284-ft long multiple-arch section with a crest elevation of 757-ft Pensacola Datum (PD), (c) an 861-ft long main spillway section, which has a crest elevation of 730-ft PD and is controlled by 21 Taintor gates, each of which is 36-ft long by 25-ft high, (d) a 451-ft long non overflow gravity section on the eastern end, and (e) a 300-ft long non overflow abutment section consisting of a concrete core wall;
2. Two auxiliary spillways with approximate lengths of 464-ft and 422-ft about 1.0 mile east of the main dam, which consist of concrete gravity overflow type spillways with crest elevations of 740-ft PD controlled by a total of 21 Taintor gates, each of which is 37-ft long by 15-ft high;
3. Grand Lake, which has a surface area of 46,500 acres (ac) and a storage volume of 1,680,000 acre-feet at the maximum power pool of 745-ft PD;
4. A 27-ft by 246-ft intake structure;

5. A powerhouse with dimensions of 87.75-ft by 279.0-ft located immediately downstream of the western end of the dam, which contains seven turbine generator units with a total nameplate capacity of 86,900 kilowatts (kW); and
6. Other pertinent equipment and facilities.

Under the Flood Control Act of 1944, the NDAA (National Defense Authorization Act for Fiscal Year 2020), and other federal legislation and regulations, the U.S. Army Corps of Engineers (USACE) has control of the basin wide system of flood control and navigation projects. Flood storage at the Project is when the elevation is expected rise above 745--ft PD.

1.3 Study Area

Grand Lake is located in portions of Craig, Mayes, Delaware, and Ottawa counties, Oklahoma. The study area for the Aquatic Species of Concern review corresponds to those counties associated with the Hydrologic and Hydraulic (H&H) Study (see Section 3 Methodology of the H&H Study Plan: GRDA 2018b). The study area extends upstream from Pensacola Dam along the Neosho River to within approximately 3 miles of the Kansas state line, upstream along the Spring River to within 6.5 miles of the Kansas state line, upstream along the Elk River to the extent dictated by the H&H model, and along Tar Creek to just upstream of the U.S. Geological Survey (USGS) gage at 22nd Avenue Bridge (Figure 1). The study area also encompasses the bays/coves within Grand Lake associated with tributaries flowing into the lake.

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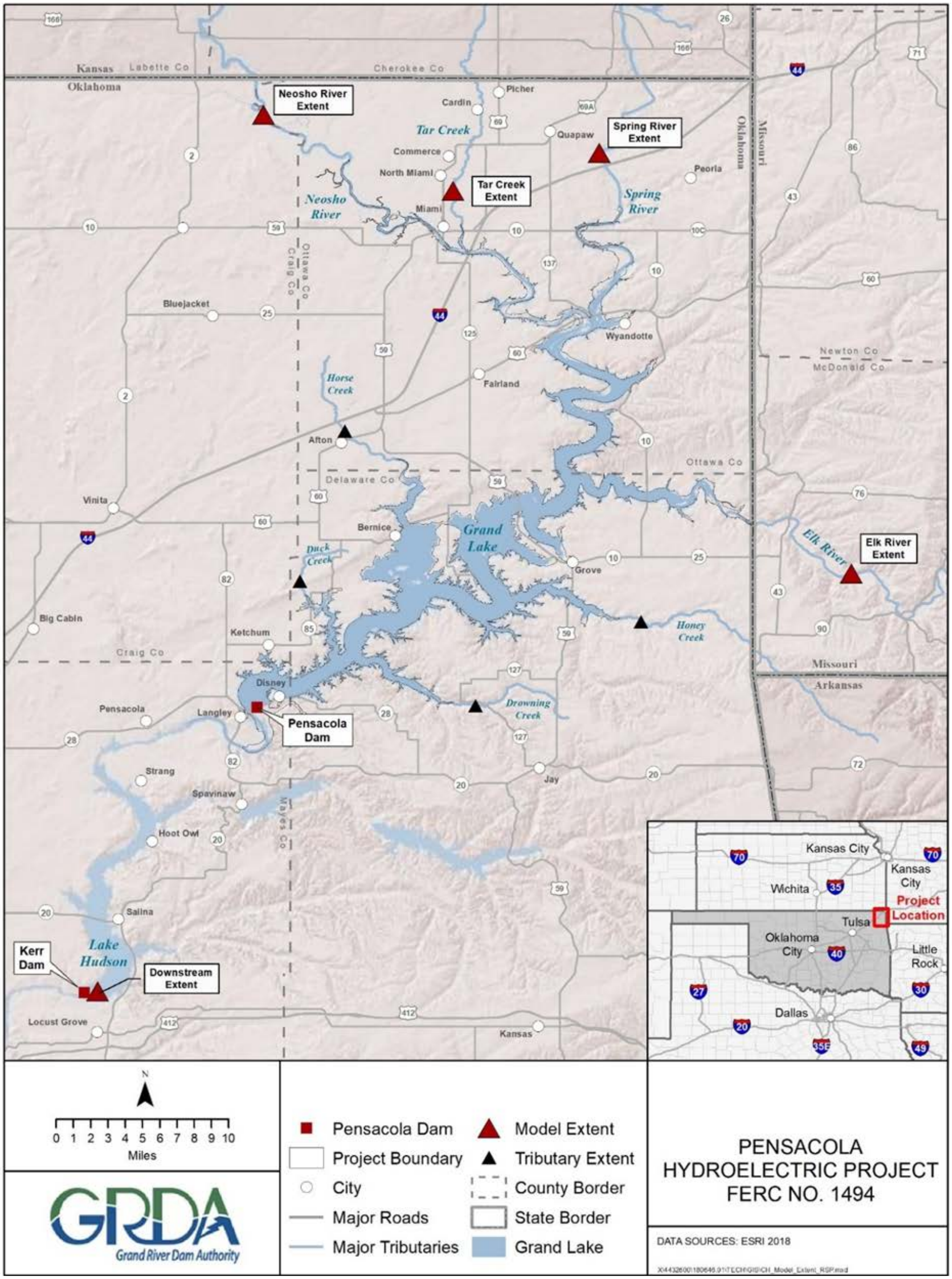
Figure 1. Study Area for the Aquatic Species of Concern



2. PHASES OF STUDY

2.1 Phase I: Review of Existing information

Phase I of this study involved a detailed exploration of existing information, including ODWC reports, peer-reviewed scientific publications, and, to the extent possible, unpublished information gathered by researchers from ODWC, Sam Nobel Museum, OSU invertebrate collection, Oklahoma Water Resource Board, academic institutions, and other entities. As part of the Phase I activities, Olsson coordinated with ODWC to obtain verbal feedback (i.e., documented personal communications) regarding the distributions of the species of interest in reaches that have the potential to be affected by Project operations (study area). Reaches within the study area were identified based on maps generated by the CHM as part of the H&H Study. Habitat preferences for each life-history stage of the species of concern identified in this study report are based on literature review and professional judgment.

2.2 Phase II and Phase III: Field Studies to Document Distribution of the Species of Concern and Anticipated Project Effects Discussion

Under GRDA's RSP for the Aquatic Species of Concern Study, if the information gathered during Phase I for any species is of sufficient quality to conduct an effects analysis, then Phase II actions (e.g., fieldwork) were not undertaken for that species. If existing records were inadequate for estimating a species' distribution, the FERC-approved study plan provided for targeted field surveys to be conducted to develop a rough estimate of the species' distribution in the reaches of concern (i.e., reaches of reservoir inundation identified by the CHM). Phase II fieldwork included the following:

1) A review of existing density estimates in the study area for each species and
2) Surveys designed to estimate each species' distribution and density for select species based on the results of the Phase I study.

As stated in the previous section, habitat preferences have been based on information taken from the scientific literature and collaboration with agency experts; no field data was collected during Phase II to characterize habitat use. Phase II data has been analyzed and Phase III incorporated project effects in the discussion sections of this report.

3. EXISTING AND RECENTLY COLLECTED INFORMATION

The following section reviews the habitat preference, distribution, and occurrence of all six species, listed above, that are the subject of this Aquatic Species of Concern Study.

3.1 Neosho Mucket (*Lampsilis rafinesqeana*)

3.1.1Habitat and Conservation Status

The life history for the Neosho Mucket, similar to most freshwater mussels in North America, is not fully understood. In general, freshwater mussels siphon water across gills for respiration and food collection. Mussels are known to forage on detritus, algae, dissolved organic carbon, and other microscopic organisms (Strayer et al. 2004). Adult mussels tend to orient themselves on the surfaces of substrate to take in food and oxygen from the water column (The Neosho Mucket Recovery Team 2018). The Neosho Mucket reproduces with the release of sperm from male mussels into the water column where females can draw it in through their siphon (Barnhart 2003). Reproductive success is often a function of water flow conditions and species density. Neosho muckets spawn in late April and May and female brooding of glochidia occurs through the month of August (Barnhart 2003). It has been demonstrated the Neosho Mucket glochidia are obligate parasites of black bass species, including the Largemouth (*Micropterus salmoides*), Smallmouth (Micropterus dolomieu) and Spotted Bass (*Mocropterus punctulatus*) (Barnhart and Roberts 1997; Service 2005).

Habitat requirements for the Neosho Mucket are not adequately understood and sometimes contradictory depending on the reporting survey and the drainage where found. Previous research has demonstrated an association of Neosho muckets and shallow riffles and runs with moderate to swift-moving water. In Shoal Creek and the Illinois River, Oklahoma, it prefers nearshore areas or areas out of the main current (Oesch 1984; Obermeyer 2000). It is believed the Neosho Mucket does not occur in reservoirs lacking riverine characteristics (Obermeyer et al. 1997). In the Illinois River, Neosho Muckets seem to concentrate in areas outside of the main river channel near the shore (ODWC 2021b), often in mucky and/or slack-water habitats (Olsson 2019).

As of its 5-year status review conducted by USFWS in 2020, the conservation status of the Neosho Mucket remains unchanged and exists in isolated populations with low abundance except in the Spring River critical habitat locations (USFWS 5 Year Review). Threats to conservation vary by river system within the study area. In the Neosho River upstream of Grand Lake, 12 low head dams and 3 federal dams exist, which alter the hydrologic and water quality conditions along the Neosho River North of the project area. Obermeyer (1996) found mussel richness and diversity negatively affected by the presence of low head dams both upstream and downstream on the Neosho River in Kansas. In the Spring River, the historic mining of lead and zinc within the tri-state mining district (TSMD) has caused contamination of waterways within the project area at levels above TSMD sediment quality guidelines in the Spring River (Morrison et. al., 2019). Angelo et al (2007) noted that unionid mussel species richness declined with increasing sediment metals concentrations within the Spring River and TSMD. Overall, threats to the species include impoundment, sedimentation, chemical contaminants, mining, the inadequacy of existing regulatory mechanisms, population fragmentation and isolation, invasive nonindigenous species, and degradation of water quality. Climate change is also likely to have adverse effects on the species because of the alteration of hydrologic cycles of rivers that support Neosho Mucket, but the extent or magnitude of this threat has not been quantified at this time (USFWS 2018).

3.1.2 Distribution and Occurrence

The Neosho Mucket is an endemic and federally endangered freshwater mussel species with a distribution found in the Arkansas River System (Gordon 1981; Harris and Gordon 1987; Mather 1990; Obermeyer 1996). Historically, this species of mussel has been observed in seventeen streams within the Neosho, Illinois, and Verdigris River basins (USFWS 2018). With respect to this relicensing project and discrete study area, rivers within the Neosho River basin with known populations of Neosho Mucket include the Neosho River, Spring River, and Elk River. In a USFWS 5-year review (2020) of the Neosho Mucket, the population status was found to be declining in the Neosho River (Last Observed 2014), and Stable in the Spring and Elk Rivers (Last Observed 2017). While the species is considered endangered wherever found, critical habitat are summarized in Table 1 for the Neosho, Spring and Elk Rivers.

Table 1. Critical habitat for Neosho Mucket

Critical Habitat Unit Number	River	Within Study Area
NM7	Neosho	No
NM5	Spring	No
NM4	Spring	No
NM3	Spring	No
NM2	Elk	Yes

Critical Habitat found within project modeling extent is located on the Elk River with the general description as follows:

Unit NM2 includes 12.6 mi of the Elk River from Missouri Highway 59 at Noel, McDonald County, Missouri, to the confluence of Buffalo Creek immediately downstream of the Oklahoma and Missouri State line, Delaware County, Oklahoma (USFWS 2021).

The occurrence of the Neosho Mucket within the study area has been described as extremely rare in the Oklahoma portions of the Spring and Neosho Rivers (USFWS Biological Opinion 2015). On the Elk River, species occurrences have been documented primarily on the Missouri side of the state line (USFWS 2018). However, some of these locations appear to fall within the study area. While personal contacts with ODWC suggests no formal mussel surveys have been conducted within the Neosho, Spring, and Elk Rivers (Curtis Tacket; Personal Communication) data does exist in various agency reports, primary literature, and communications that is germane to this process. These data are summarized in Table 2.

Table 2. Summary of Neosho Mucket Locations within and adjacent to the Project Area.

River	Date (Years)	Agency/Tribe/Entity	Location/Result	Citation(s)
Neosho	1990	ODWC	4 Sites from Neosho River 3 Miles WNW of Miami to Kansas State Line/8 Relic Shells Found	Mater, C.M. 1990. Status Survey of the Western Fanshell and the Neosho Mucket. Report to the Oklahoma Department of Wildlife Conservation.
	1994-1997	ODWC/OU	Neosho River, State Line to Stepp's Ford Bridge (estimate)/No Live Neosho Muckets/29% of sites had Relic Neosho Mucket Shells	Vaughn CC. Determination of the status and habitat preference of the Neosho Mucket in Oklahoma. Oklahoma City, OK: Oklahoma Biological Survey; 1998. 17 pp.
	2006-2007	Peoria Tribe	Gravel Bars 4, 7, and 8/ Six Relict Shells	USFWS Neosho Mucket 5-year review: Summary and Evaluation.
	2014	Peoria Tribe	Stepp's Ford Bridge/ 1 Live and 1 Relict Shell	USFWS Neosho Mucket 5-year review: Summary and Evaluation USFWS Memorandum, Biological Opinion, May 12, 2015.
	2018	EcoAnaysts, Inc.	19.5 km upstream to 1.5 km downstream of the Interstate 44 Bridge near Miami Oklahoma/No live or Relic Neosho Mucket Found	USFWS Neosho Mucket 5-year review: Summary and Evaluation.
Spring	1990	ODWC	3 Sites North from Devils Promenade Bridge to the State Line/1 relict shell collected	Mater, C.M. 1990. Status Survey of the Western Fanshell and the Neosho Mucket. Report to the Oklahoma Department of Wildlife Conservation
	1994-1997	ODWC/OU	Spring River, E57 Rd Bridge to State Line, 10 Sites, 60% of sites had relic shells. Authors Note Fresh Shells found at 2 sites and may have come down the river from known/healthy populations in Kansas/Missouri.	Vaughn CC. Determination of the status and habitat preference of the Neosho Mucket in Oklahoma. Oklahoma City, OK: Oklahoma Biological Survey; 1998. 17 pp.
	2003/11/05 2006/08/03	KDHE	Spr7: 36.96145, -94.72203, Dead Weathered Neosho Mucket Shell Spr8: 36.93439, -94.74520, Dead (Recent) Neosho Mucket Shell Spr9: 36.87474, -94.76269 None Found	Angelo, R.T., M.S. Cringan, D. L. Chamberlain, A. J. Stahl, S. G. Haslouer, and C. A. Goodrich. 2007. Residual effects of lead and zinc mining on freshwater mussels in the Spring River basin (Kansas, Missouri, and Oklahoma, USA). Science of the Total Environment 384: 467-496.
	2018	EcoAnaysts, Inc.	Found live Neosho Mucket from 8 of 15 sites in Missouri, Kansas, and Oklahoma. They documented changes in in the mussel community since Angelo 2007 with previously inhabited sites uninhabited.	USFWS Neosho Mucket 5-year review: Summary and Evaluation.

River	Date (Years)	Agency/Tribe/Entity	Location/Result	Citation(s)
Elk	1978-1995		23 Neosho Muckets collected in Missouri from two sites. (Location Undisclosed)	USFWS Neosho Mucket 5-year review: Summary and Evaluation.
	1992 & 1998		Reports of Brooding Neosho Mucket Females and Juveniles present at two sites (Location Undisclosed)	USFWS Neosho Mucket 5-year review: Summary and Evaluation.
	2016-2017		45 Live Muckets collected from 4 locations near Noel and HWY DD, McDonald County, MO	USFWS Neosho Mucket 5-year review: Summary and Evaluation.

4. PHASE II STUDY

4.1.1 Study Methodology

Based off historical mussel survey data from 1990-2017, and the 5 year species reviews compiled by USFWS for the Neosho Mucket a data gap was identified in the records regarding the presence or absence of endangered mussel species within the Elk River portion of the GRDA project boundary.

On the Neosho River, the most recent mussel survey completed by Eco Analysts Inc. (2018) in 2017 found no live or relic shells of Neosho Mucket within or upstream of the study area. While one live specimen of Neosho Mucket was found during a bridge construction project in 2014, the body of available data within the Neosho River arm of the project suggests that the Neosho Mucket and other federally listed mussel species are unlikely to occur in the project boundary of the Neosho River arm. On the Spring River, previous surveys from the Kansas/Oklahoma State line to the project boundary have similarly been unable to locate live Neosho Mucket, suggesting that these species are unlikely to occur in this area of the project.

The Elk River portion for the GRDA project boundary was listed in 2015 as critical habitat for the Neosho Mucket. The most recent survey data recounted in the 5 Year Review of the Neosho Mucket status suggests that a population of mussels may exist within the project boundary of Grand Lake as evidenced by recent surveys that recovered live specimens only a few river miles upstream. Per the description in the Code of Federal Regulations (CFR) for critical habitat NM2, a roughly one mile stretch of critical habitat occurs within the current project boundary and no data was identified during the Phase I Study regarding the presence or absence of the Neosho Mucket, or other federally listed unionid species in this area.

Based on the analysis of existing data from Phase 1 Aquatic Studies presented in the ISR along with the subsequent agency comment responses and FERC's study plan determination, Phase 2 mussel surveys were conducted for Neosho Mucket (*Lampsilis rafinesqueana*) in select portions of the Elk, Spring, and Neosho rivers. Specifically, these areas were:

- The portion of the Elk River from the Missouri/Oklahoma state line to the confluence with Buffalo Creek (approximately 1.0 river mile);
- The portion of the Spring River from Warren Branch to the confluence with the Neosho River (approximately 10.5 river miles); and
- The portion of the Neosho River from the City of Miami [Riverview Park] to the confluence with the Spring River (approximately 13 miles).

A three-phase mussel survey methodology was developed by the study team and reviewed by USFWS, EcoAnalysts, and the TCTC. Phase 1 of the methodology included identification and mapping of any potential Neosho Mucket habitat. Phase 2 included qualitative sampling to evaluate the presence of Neosho Mucket in any areas of potential habitat identified. Lastly, Phase 3 included quantitative quadrat sampling to estimate density of Neosho Mucket in any areas where the species was detected.

The initial Phase 1 habitat assessment identified potential habitat consistent with previous mussel survey efforts and habitat descriptions for Neosho Mucket. Freshwater mussels are typically most abundant and diverse within stable fluvial habitats (riffles/runs) of riverine environments (Haag 2012, EcoAnalysts 2018). Specifically, Neosho Muckets have been collected from a variety of habitats but are typically described to have an association with moderately flowing shallow water over gravel or intermixed gravel and sand substrates (McMurray et al. 2012; Oesch 1984) and are not thought to inhabit reservoirs (Obermeyer et al. 1997). Therefore, potential habitat for Neosho Mucket was considered to be flowing water riffles and runs over gravel or intermixed gravel and sand substrates. Limited amounts of potentially suitable Neosho Mucket habitat were identified within the study areas. Therefore, additional mussel survey sites (Community Assessment Sites) were added to characterize the mussel community within other portions of the study area.

Qualitative surveys via timed visual/tactile search methods (hand-grubbing into the top 1-4 inches of substrate to increase detection of more deeply buried mussels) were utilized to efficiently assess occurrence of Neosho Mucket. A qualitative survey approach is an efficient search method to establish a list of taxa, as well as increase the detection probability of rare species (Vaughn et al. 1997; Strayer and Smith 2003). To ensure suitable habitat was adequately sampled, following the same methodology, divers used surface-supplied air from a Brownies Third Lung Hookah Dive System to reach deeper areas. Surveyors conducted a minimum of three person-hours using mask and snorkel (or dive gear, where appropriate). All live mussels were placed in mesh bags and submerged in the stream. If no live mussels were collected by the end of the third person-hour, the site was considered complete. If live mussels were located, an additional two person-hours of search effort were conducted. Since Neosho Mucket (or other listed mussels) were not detected at any point during Phase 2 surveys, Phase 3 quantitative surveys were not necessary (see Section 3.4.2).

Upon completion of surveys at each site, all mussels were identified to species by federally permitted biologists, enumerated, and returned to the approximate location of collection. Voucher photographs were taken of each species collected. At each survey location substrate composition was recorded. Substrate categories included: bedrock, boulder, cobble, gravel, sand, silt, and clay.

4.1.2 Results

Surveys were conducted during the week of July 18th, 2022. Overall, 193 mussels representing 13 species were collected from 13 sites during 57 person-hours of total survey effort (Figure 2). Bluefer (*Potamilus purpuratus*) was the most abundant species, with 108 individuals collected. The next most abundant species was Fragile Papershell (*Leptodea fragilis*), with 23 individuals collected. Threehorn Wartyback (*Obliquaria reflexa*) and Pink Papershell (*Potamilus ohiensis*) were the next most abundant species overall, with nineteen (19) and seventeen (17) individuals collected, respectively. No Neosho Muckets were collected during this study (Table 3).

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Figure 2. Survey Locations.

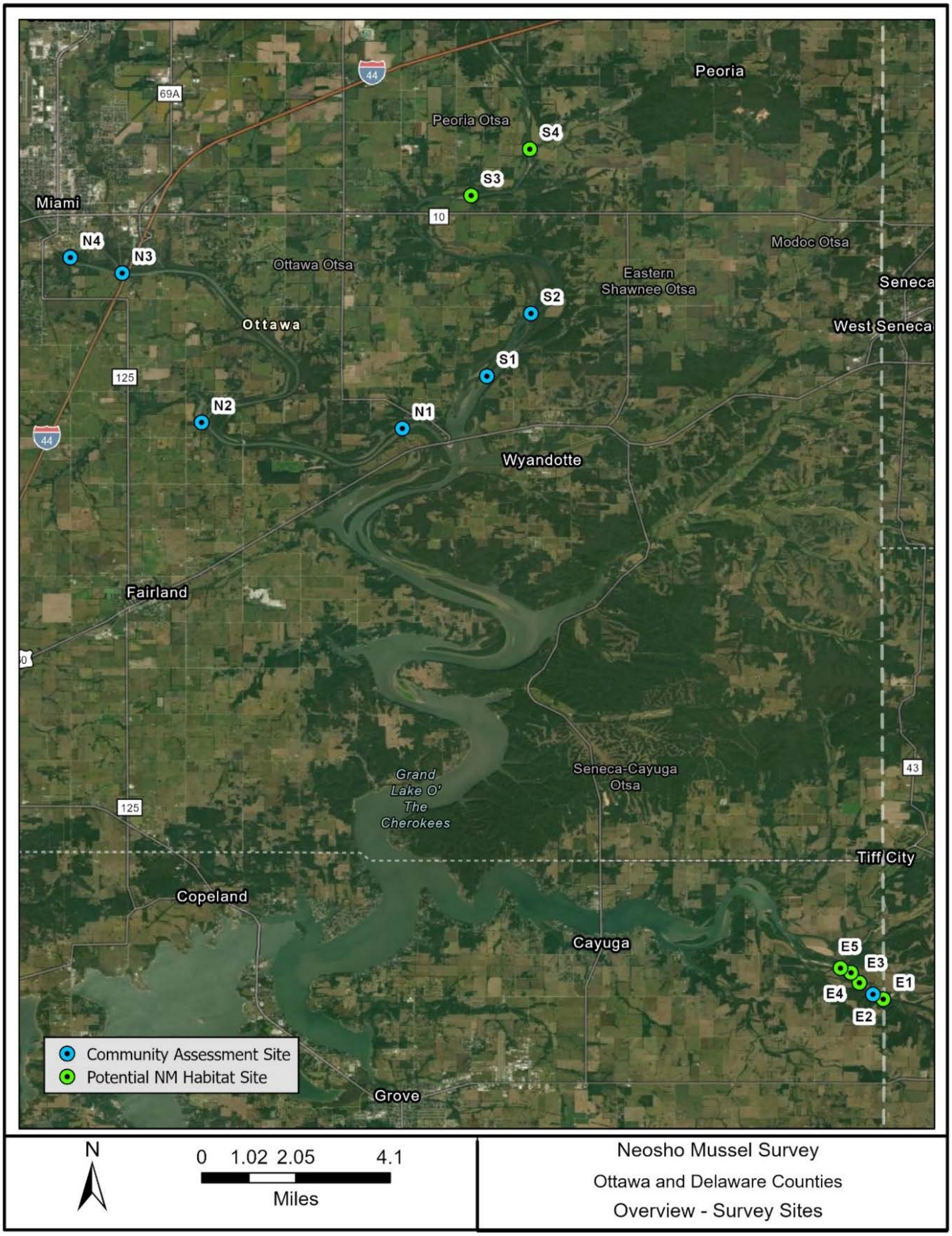

Table 3. Mussel Abundance in the Elk, Spring and Neosho Rivers

Species	Elk		Spring		Neosho		Total	
	Individuals	*Relative abundance*	*Individuals*	*Relative abundance*	*Individuals*	*Relative abundance*	*Individuals*	*Relative abundance*
Anodonta suborbiculata	0	0	5	0.12	0	0	5	0.03
Lampsilis cardium	1	1	4	0.09	0	0	5	0.03
Lampsilis teres	0	0	0	0	3	0.020	3	0.02
Lasmigona complanata	0	0	0	0	1	0.007	1	0.01
Obliquaria reflexa	0	0	5	0.13	14	0.094	19	0.10
Potamilus fragilis	0	0	2	0.05	21	0.141	23	0.12
Potamilus ohiensis	0	0	9	0.24	8	0.054	17	0.09
Potamilus purpuratus	0	0	11	0.29	91	0.611	102	0.53
Quadrula	0	0	1	0.03	0	0	1	0.01
Toxolasma parvum	0	0	0	0	1	0.01	1	0.01
Tritogonia verrucosa	0	0	1	0.03	4	0.03	5	0.03
Utterbackia imbecillis	0	0	0	0	1	0.01	1	0.01
Utterbackiana suborbiculata	0	0	5	0.13	5	0.03	10	0.05
Species Richness	1		9		10		13	
Total Raw Abundance	1		43		149		193	

Elk River Results

On July 18th, three sites of potential Neosho Mucket habitat (E1, E3, and E5) and two additional community assessment sites (E2 and E4) were identified and surveyed on the Elk River for a total of 17 person-hours (Figure 3). Habitats identified and sampled in the Elk River included shallow riffles and runs with a complex substrate mixture of gravel, sand, silt, cobble, and bedrock. The substrate observed at the Elk River sites varied from bedrock to silt. The substrate at sites E1 and E2 varied, ranging from bedrock to silt. The substrate at sites E3, E4, and E5 was predominantly gravel, sand, and silt. All sites were searched for at least three person-hours, except for E-4 which was searched for five person-hours due to the presence of live mussels. Only one live mussel was collected in the Elk River, a Plain Pocketbook (*Lampsilis cardium*) at site E4 (Table 4).

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Figure 3. Elk River Survey Sites

Table 4. Mussel Abundance at Elk River Sites

Species	Common Name	Elk River 1	Elk River 2*	Elk River 3	Elk River 4	Elk River 5*	Total
Lampsilis cardium	Plain Pocketbook	-	-	-	1	-	**1**
Total		**0**	**0**	**0**	**1**	**0**	**1**

*Community Assessment Site

Spring River Results

At the Spring River on July 19th, two sites of potential Neosho Mucket habitat were identified and sampled, and two additional community assessment sites were surveyed to evaluate the mussel community within lentic habitats of the study area (Figure 4). All sites on the Spring River were searched for 5 person-hours due to the presence of live mussels at each site. Habitat at the two most-upstream Spring River sites (S3 and S4) was characterized by shallow runs and riffles with complex substrates composed of gravel, sand, bedrock, and silt. Hence, these areas were identified as potential Neosho Mucket habitat. The remainder of the study area was characterized by deeper, slower moving water with silt and clay substrates. Two sites were conducted within these areas (S1 and S2) to characterize the mussel community within lentic portions of the study area.

In the Spring River, 20 person-hours of total survey time resulted in collection of 43 individuals belonging to 9 species. The most abundant species was the Bluefer, with 11 individuals. Pink Papershell was the next most abundant species collected, with 9 individuals (Table 5).

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Figure 4. Spring River Survey Sites

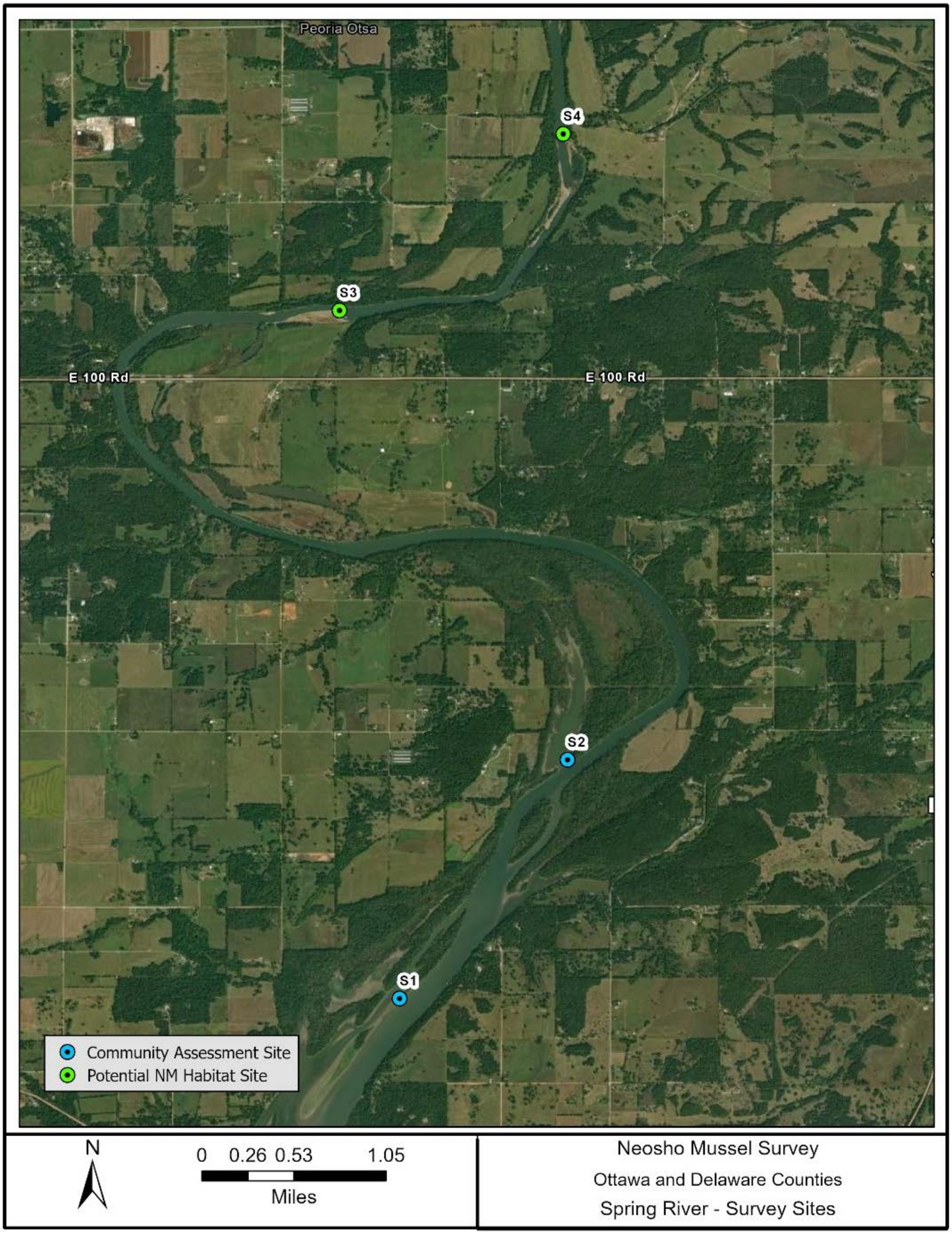

Table 5. Mussel Abundance at Spring River Sites

Species	Spring River – 1*		Spring River – 2*		Spring River - 3		Spring River - 4		Total	
	Individuals	*Relative abundance*	*Individuals*	*Relative abundance*	*Individuals*	*Relative abundance*	*Individuals*	*Relative abundance*	*Individuals*	*Relative abundance*
Anodonta suborbiculata	0	0	5	0.5	0	0	0	0	5	0.12
Lampsilis cardium	0	0	0	0	1	0.07	3	0.43	4	0.09
Obliquaria reflexa	0	0	0	0	4	0.29	1	0.14	5	0.12
Potamilus fragilis	0	0	0	0	2	0.14	0	0	2	0.05
Potamilus ohiensis	9	0.75	0	0	0	0	0	0	9	0.21
Potamilus purpuratus	2	0.17	0	0	6	0.43	3	0.43	11	0.26
Quadrula quadrula	1	0.08	0	0	0	0	0	0	1	0.02
Tritogonia verrucosa	0	0	0	0	1	0.07	0	0	1	0.02
Utterbackiana suborbiculata	0	0	5	0.5	0	0	0	0	5	0.12
Species Richness	3		2		5		2		8	
Total Raw Abundance	12		10		14		7		43	

*Community Assessment Site

Neosho River Results

On July 20, the habitat assessment identified no potentially suitable habitat for Neosho Mucket within the Neosho River study area. No shallow rifles or runs were present within this area. Instead, the habitat was dominated by deep slow-moving lentic waters. However, to characterize the mussel community present, four community assessment sites were surveyed within the Neosho River study area (Figure 5). All the sites were searched for five person-hours, as live mussels were detected at each site. Substrates at N1 and N2 were 100% silt. At N3, there was 10% cobble, 20% gravel, 50% silt, and 20% clay with rip-rap present associated with a bridge crossing. Finally, at N4, the substrate was 50% silt and 30% clay with minor amounts of gravel (15%) and cobble (5%).

During 20 person-hours of survey effort in the Neosho River, 149 individuals were collected belonging to 10 species. The most abundant species was the Bluefer, with 91 individuals. The next two most abundant species were the Fragile Papershell and the Threehorn Wartyback, represented by 21 and 14 individuals, respectively (Table 6).

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Figure 5. Neosho River Survey Sites

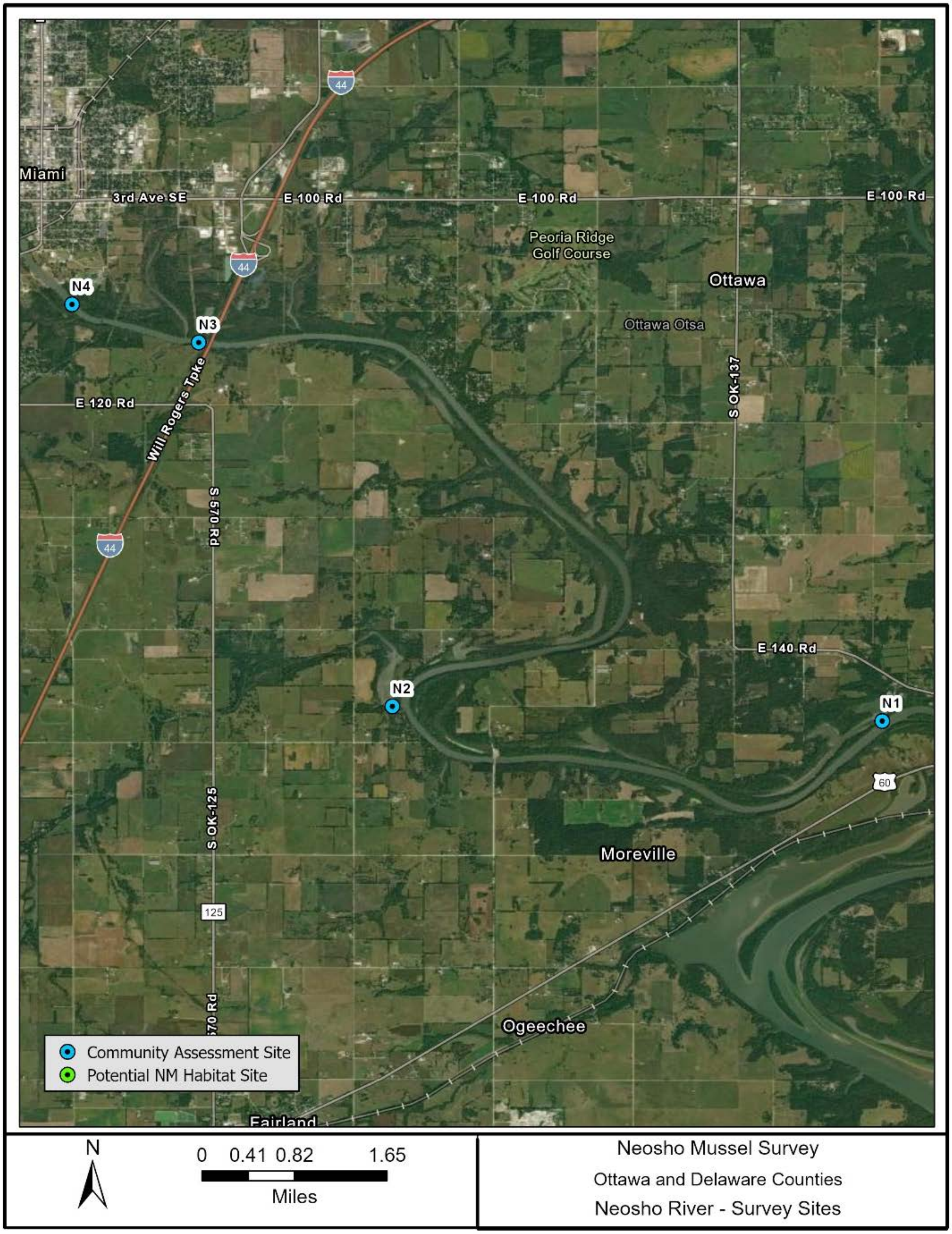

Table 6. Mussel Abundance at Neosho River Sites

Species	Neosho River – 1*		Neosho River – 2*		Neosho River – 3*		Neosho River – 4*		Total	
	Individuals	*Relative abundance*	*Individuals*	*Relative abundance*	*Individuals*	*Relative abundance*	*Individuals*	*Relative abundance*	*Individuals*	*Relative abundance*
Lampsilis teres	1	0.020	0	0	2	0.05	0	0	3	0.02
Lasmigona complanata	0	0	0	0	0	0	1	0.02	1	0.01
Obliquaria reflexa	7	0.14	0	0	3	0.08	4	0.07	14	0.09
Potamilus fragilis	0	0	0	0	18	0.46	3	0.05	21	0.14
Potamilus ohiensis	6	0.12	0	0	0	0	2	0.04	8	0.05
Potamilus purpuratus	33	0.67	0	0	14	0.36	44	0.79	91	0.61
Toxolasma parvum	1	0.02	0	0	0	0	0	0	1	0.01
Tritogonia verrucosa	0	0	0	0	2	0.05	2	0.04	4	0.03
Utterbackia imbecillis	1	0.02	0	0	0	0	0	0	1	0.01
Utterbackiana suborbiculata	0	0	5	1	0	0	0	0	5	0.03
Species Richness	6		1		5		6		10	
Total Raw Abundance	49		5		39		56		149	

*Community Assessment Site

4.1.3 Discussion

Overall, the habitat assessment identified potentially suitable Neosho Mucket habitat in the Elk River study area and upper portions of the Spring River study area. However, large portions of the Spring River study area and the entire Neosho River study area were dominated by deep lentic reservoir areas. Mussel surveys were targeted to areas identified as potential Neosho Mucket habitat but were also conducted in other portions of the study areas to document the community present and confirm suspected habitat associations. These targeted habitat-specific surveys and additional community assessment surveys within the study areas of the Elk, Spring, and Neosho Rivers documented 188 individual mussels of 12 species during 57 person-hours of total survey effort at 13 locations. Of these species collected, the majority were generalist or lentic-adapted species such as the Bleufer, Fragile Papershell, Threehorn Wartyback, Pink Papershell, and Flat Floater (*Anodonta suborbiculata*). Flat Floater was not documented by previous surveys which focused on riverine habitats upstream. No Neosho Muckets were observed.

Based on habitat descriptions for Neosho Mucket from the literature discussed in section 3.1.2, Phase 2 mussel surveys identified limited potentially suitable habitat within the study area. Three areas of potentially suitable habitat were identified and surveyed by the study team in the Elk River study area and two areas of potentially suitable habitat were identified and surveyed within the Spring River study area. No potentially suitable habitat was identified within the Neosho River study area. Despite the lack of potentially suitable Neosho Mucket habitat within the Neosho River study area and the lower Spring River study area (downstream of Hwy 10 bridge), additional surveys were conducted in these lentic areas to provide a more complete characterization of the mussel community present.

Using hydraulic models developed as part of the relicensing project, section-averaged velocities were calculated for cross-sections extracted at each mussel sampling location under both the baseline Project operations and anticipated Project operations scenarios (Table 7). The difference in section-averaged velocity at these cross-sections ranged from 0.00 to -0.22 ft/s (average = -0.06 ft/s).

Additionally, lentic/lotic maps were generated from the CHM to evaluate changes to inundation relative to Project operations. These maps demonstrate a minor increase in inundation under the anticipated project operations that is expected to have minimal, if any, impact to freshwater mussels in the study areas.

Given that no Neosho Muckets were observed in the project area, minor changes in inundation are expected, and the relatively minimal change in velocity predicted to occur, no impacts to Neosho Mucket populations are expected to occur due to anticipated changes in Project operations.

Table 7. Baseline and Anticipated Operation Velocities at Mussel Survey Locations

Site	Latitude	Longitude	RM	1D or 2D	Section-averaged velocity (ft/s)		Difference in Velocity (ft/s)
					Previous Operations	Proposed Operations	
Elk 1	36.624261	-94.617709	12.03	1D	1.06	1.05	-0.01
Elk 2	36.625842	-94.621131	11.81	1D	0.61	0.61	0.00
Elk 3	36.629460	-94.625396	11.41	1D	0.53	0.52	-0.01
Elk 4	36.632643	-94.628038	11.24	1D	0.55	0.54	-0.01
Elk 5	36.634090	-94.631331	11.01	1D	1.22	1.00	-0.22
Neosho 1	36.803739	-94.769177	123.46	1D	0.62	0.58	-0.04
Neosho 2	36.805637	-94.832343	127.47	1D	1.14	1.10	-0.04
Neosho 3	36.852565	-94.857317	133.88	2D	1.77	1.72	-0.05
Neosho 4	36.857480	-94.873648	134.92	1D	2.07	1.98	-0.09
Spring 1	36.820170	-94.742590	2.26	1D	0.21	0.20	-0.01
Spring 2	36.839876	-94.728731	3.79	1D	0.26	0.26	0.00
Spring 3	36.876963	-94.747551	9.30	1D	0.59	0.56	-0.03
Spring 4	36.891539	-94.729085	10.94	1D	1.65	1.43	-0.22

4.2 Rabbitsfoot (*Quadrula cylindrica*)

4.2.1 Habitat and Conservation Status

The Rabbitsfoot is a freshwater mussel typically found in small-to-medium-sized rivers that have a moderate current and clear, relatively shallow water. It prefers river bottoms that are a mixture of sand and gravel substrates (Watters 1988). The Rabbitsfoot spawns from May to June (Yeager and Neves 1986). Six species of minnows have been determined to be suitable hosts for the Rabbitsfoot larval stage: blacktail shiner (*Cyprinella venusta*), red shiner (*Cyprinella lutrensis*), bluntface shiner (*Cyprinella camura*), cardinal shiner (*Luxilus cardinalis*), whitetail shiner (*Cyprinella galctura*), spotfin shiner (*Cyprinella spiloptera*), and bigeyed chub (*Hybopsis amblops*). Based on records received from the OWRB, none of the host species have been present at sampling events in the Neosho, Spring, and Elk rivers draining into the project area from 2003-2018.

As with other headwater-inhabiting species of mussel, the combination of river impoundments and the ecological requirements of the Rabbitsfoot predict a series of isolated populations in the headwater streams throughout the species range. Because adults do not typically burrow into sediment but rather lie horizontally on the streambed surface (Watters 1988), flow refuges may decrease the likelihood of displacement into unsuitable habitat. The primary cause of population declines of the Rabbitsfoot is the construction of reservoirs and impoundments throughout its range (USFWS 2009). Direct disturbance by human recreational activities also can have a negative impact on the species. Metal pollution in the Spring River was the consequence of metal inputs from the Tri-State Mining District, where extensive mining for Pb and Zn occurred during the mid-1800s through the 1950s (Barks 1986; Wildhaber et al. 1999b; 2000a; Brumbaugh et al. 2005)

4.2.2 Distribution and Occurrence

The Rabbitsfoot was historically found in the Verdigris, Neosho, Spring, Illinois, Blue, and Little rivers in Oklahoma. Populations currently remain in the Verdigris, Illinois, and Little rivers. Though Rabbitsfoot still exist in the Spring and Neosho rivers, they are considered very rare or extirpated in the Oklahoma portion (Curtis Tacket; personal communication; USWFS 2020b). Relic shells indicate that Rabbitsfoot formerly occurred extensively in the Verdigris, Fall, Cottonwood, Neosho, and Spring rivers in Kansas, and Spring River and Shoal Creek in Missouri, but recent records only identify a few individuals from a handful of sites in the Spring and Neosho rivers (EcoAnalysts 2018, Obermeyer et al. 1997). In 2016 and 2017, biologists surveyed 15 sites extending from 500 meters downstream of the confluence with the North Fork of the Spring River in Jasper County, Missouri, to 7.45 miles upstream of the confluence with the Neosho River in Ottawa County, Oklahoma (USFWS 2020b). Based on the five-year review (USFWC 2020b), two live specimens from two sites in Missouri and two live specimens from two sites in Kansas were reported but no specimens were found in Oklahoma during this survey period. This species is considered endangered wherever found with the closest critical habitat in Missouri 25 miles upstream (Table 8).

Table 8. Critical habitat for Rabbitsfoot

Critical Habitat Unit Number	River	Within Study Area
RF1	Spring	No

4.2.3 Discussion

Through personal contact and data received from the Sam Nobel Museum, OSU invertebrate collection department, and ODWC suggest that no Rabbitsfoot mussel surveys have been conducted within the drainages leading up to the reservoir. The closet critical habitat is located 25 miles upstream from the Project area in Jasper County Missouri on the Spring River. No live specimens have been found in Oklahoma segment of the river (EcoAnalysts 2018). The five-year review (USFWS 2020b) acknowledges the Oklahoma segment of the river as historic range with no extant population. Therefore, based on the literature and data available, it is not likely that a population would occur within the study area. Rabbitsfoot mussels have not been found in any surveys, including the 2022 survey.

4.3 Winged Mapleleaf (*Quadrula fragosa*)

4.3.1 Habitat and Conservation Status

The Winged Mapleleaf is a freshwater mussel found in areas that have high water quality in stream beds varying from sand, cobble, or rubble (USFWS 2011, ODWC 2021c). The Winged Mapleleaf is often found in dense and diverse mussel beds where the large number of mussel species may stabilize the riverbed and improve the habitat for rare mussel species (Allen and Vaughn 2008).

The Winged Mapleleaf has been found to be a fall tachytictic or short-term brooder (Heath et al. 2000). Habitat degradation is the primary cause of this species decline. Dams, channelization, and dredging increase siltation, physically alter habitat conditions, and block the movements of fish hosts (ODWC 2021c). Other factors could include narrow range, sparse population and low reproduction, and the probability of inbreeding, which could weaken the species genetically (Hornbach et al.1996). Of the five remaining populations, three are subject to threats from restricted populations and isolation from other populations. The low flows associated with droughts have been found to pose a high degree of threat to the Little River population (Hove et al. 2012).

4.3.2 Distribution and Occurrence

Historically, the Winged Mapleleaf is known to occur in the Boggy, Kiamichi, Neosho, and Little rivers of Oklahoma. The only known population to still occur in Oklahoma is found in the Little River, though its status in other river systems is generally unknown (USWFS 2011).

Winged Mapleleaf is known to exist in Missouri, Wisconsin, Arkansas, and Oklahoma. Known populations closest to the Project include those in the Bourbeuse River in Missouri, the Ouachita River in Arkansas, the Saline River in Arkansas, and the Little River in Arkansas and Oklahoma. In the Little River, the Winged Mapleleaf has been found in 12 sites since 2005 (Galbraith et al. 2008). In 2008 (Allen and Vaughn 2008), sampled six mussel beds and located Winged Mapleleaf in four of those beds. No critical habitat is currently designated for this species.

4.3.3 Discussion

Personal contact with the Sam Nobel Museum, OSU invertebrate collection department and ODWC indicate that no Winged Mapleleaf specimens have been previously found within the Neosho, Spring, and Elk Rivers or surrounding drainages leading up to the Project reservoir. The only recognized population in Oklahoma is within the Little River which is 175 miles from the study area. It is not likely that there is a population within the study area. Winged Mapleleaf mussels have not been found in any surveys, including the 2022 survey.

4.4 Neosho Madtom (Noturus placidus)

4.4.1 Habitat and Conservation Status

Neosho Madtoms have been found in the highest numbers during daylight in riffles in late summer and early fall, after young of the year are estimated to have recruited to the population (Moss 1983; Luttrell et al. 1992; Fuselier and Edds 1994). Neosho Madtoms prefer the interstitial spaces of unconsolidated pebbles and gravel, moderate-to-slow flows, and depths averaging 0.23 meter (Wildhaber et al. 2000). Adults hide in the interstices of loose gravel riffles during the day and feed nocturnally on the aquatic insects (Cross and Collins 1995). Young of the year are said to inhabit slower flowing waters downstream from riffles and use pools and backwaters as nursery areas (Fuselier and Edds 1994). Where contamination has occurred, Neosho Madtoms seem to be limited primarily by the presence of contaminants associated with the Spring River acting directly (via mortality or avoidance) or indirectly (by suppressing and/or contaminating) on the benthic invertebrate food base (Cross and Collins 1995).

4.4.2 Distribution and Occurrence

The Neosho Madtom is a small catfish commonly 1.75–2.75 inches long; the maximum is about 3 inches long (Wenke 1991). This species is native to the Illinois River in Oklahoma, the Neosho River (Kansas & Oklahoma), the Cottonwood River (Kansas), and the Spring River (Kansas, Oklahoma, and Missouri), where it inhabits riffles and bar habitats with loose pebble and gravel substrate, moderate to high water velocities, and relatively shallow depths (Ernsting et al. 1989; Wilkinson et al. 1996; Wilkinson and Fuselier 1997; Wildhaber et al. 2000). The density of Neosho Madtom populations is much greater in the Neosho system (i.e., the Neosho and Cottonwood rivers combined) than in the Spring River (Moss 1983; Wilkinson et al. 1996). The Tar Creek superfund site is located with portions of the range of the Neosho Madtom within the Neosho and Spring rivers watersheds and the superfund site is a known source of heavy metal contamination (lead, cadmium, and zinc). Where metals contamination is minimal, Neosho Madtom densities seem to be limited primarily by physical and chemical habitat quality and availability. Extant Oklahoma populations of the Neosho Madtom are restricted to the Neosho River upstream from Grand Lake. A population documented in 1946 in the lower Illinois River is now presumed to be extirpated (Moss 1981).

4.4.3 Phase II and Phase III Recommendations

Neosho madtoms have been found in the drainages of the study area from 1969-2007; the last sampling attempts near the project area occurred in 2016 and were conducted by the OWRB (Figure 6). The closest collection point within the study area was conducted in 2007. Because of the five-year data gap, it is proposed that sampling efforts take place within the Neosho River branch of the study area including sampling select locations upstream to determine habitat quality. Determining habitat quality outside of the project area will allow for appropriate mitigation if management practices limit suitable habitat within the study area. All previous madtom locations have been within this branch of the river and it is the most likely area to have a stable population.

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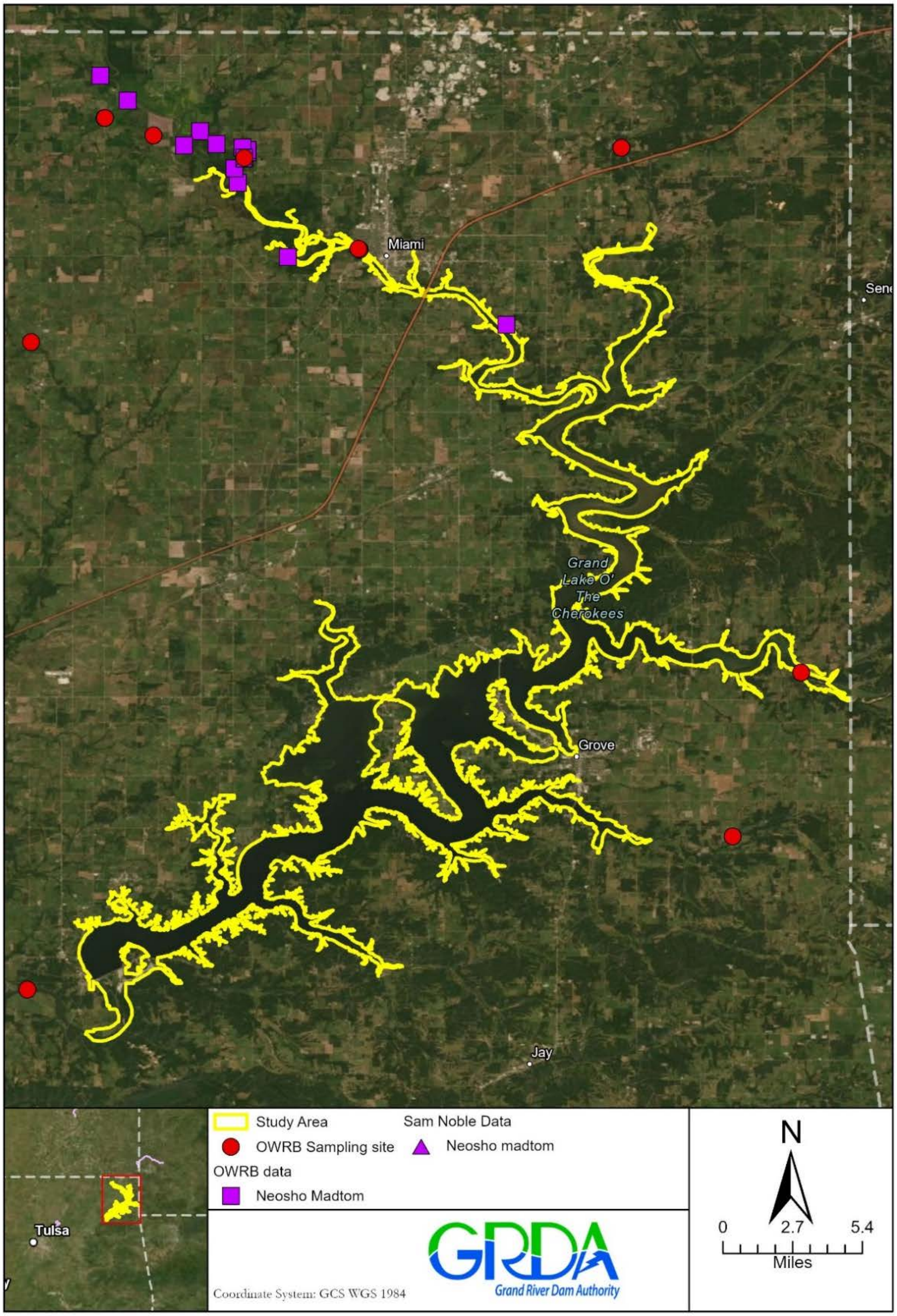
Figure 6. Known Locations of Neosho Madtom – data provided by OWRB and Sam Noble Museum.



Based on the Phase 1 literature review, agency comments, and the subsequent FERC Study Plan Determinations (2018 and 2022) the need for Phase 2 Neosho Madtom surveys were identified in select portions of the Spring and Neosho rivers. In the Neosho River, surveys were conducted from the Craig/Ottawa County border south to near the Hwy 60 bridge. In the Spring River, surveys were conducted from the I44 bridge downstream to the Hwy 10 bridge. Surveys were limited to areas with potential suitable habitat. Madtom sampling was conducted in July and August of 2022 at selected sites where riffles and gravel bars were identified during the time of surveys.

At each site, five points were surveyed by kick-seining (4.6 m x 1.8 m seine with 3.2 mm mesh) where at least two surveyors thoroughly disturbed the substrate beginning at least four meters upstream from a stationary seine and then kicked in a downstream direction to the seine's lead line. All fishes captured were identified to species, measured for total length (TL) to the nearest millimeter, and enumerated.

Lastly, substrate and mean water-column velocity were quantified to characterize habitat conditions at each site and were measured near the center of each sampling point. Substrate samples were collected and sieved using a series of sieves (38 mm, 19 mm, 9.5 mm, and 2 mm) to determine the particle size distribution. Sites where substrates were not compacted and contained over 50% of gravel 8-16 mm in diameter were considered high quality habitat for Neosho Madtom as defined by Moss (1981).

Spring River surveys were completed on July 19th, 2022 at a discharge of 605 cubic feet per second (cfs) according to the USGS Spring River near Quapaw Oklahoma gage. Median discharge for this date is about 725 cfs.

Neosho River surveys were initiated on July 20, 2022 at flows of 2,190 cfs (according to the USGS Commerce Oklahoma gage. Median flows for this time of year and location were expected to be about 1,100 cfs. These elevated flows inundated much of the appropriate Neosho Madtom habitat with swift flowing water and made sampling swift flowing riffles difficult. As a result, the study team made the decision to postpone sampling until flow conditions were more appropriate for sampling using the kick seining method. Surveys were completed on August 16, 2022 when flows reached 171 cfs at the Commerce gage.

4.4.3.1 Results

Twenty-eight fish species were collected from 11 riffle/gravel bars in the Neosho and Spring Rivers (Figure 7). Neosho Madtoms were collected at five of the seven sites on the Neosho River and were not observed in the four sites sampled on Spring River (Table 9).

4.4.3.1.1 Neosho River

A total of twenty-one species of fish were collected at the Neosho River survey sites with the Red Shiner (*Cyprinella lutrensis*), Emerald Shiner (*Notropis atherinoides*), and White Bass

(*Morone chrysops*) being the most abundant species (421, 246, and 119 individuals, respectively) accounting for 73% of the individuals collected (Figure 8, Table 9). Neosho Madtoms were collected from five of nine sites surveyed, N1, N2, N3, N4, and N6 (Table 9) and were more abundant at sites within the upstream portions of the study area. Average velocity for all the survey sites in the Neosho River was 1.7 ft/s and ranged from 0.6 to 3.4 ft/s. Sites with Neosho Madtoms had an average flow of 1.9 ft/s (Table 10).

On the Neosho River, the substrate composition varied from a relatively even mixture of substrates to those with predominantly larger particles having smaller average substrate size farther downstream. The largest particles sizes (38 mm and 19 mm) comprised greater that 40% in the upstream most sites (Neosho 1 and Neosho 2) and less than 5% of the samples in the remaining sites and being completely absent in the 2 farthest downstream sites (Neosho 6 and Neosho 7). (Table 11).

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Figure 7. Neosho Madtom Survey Sites

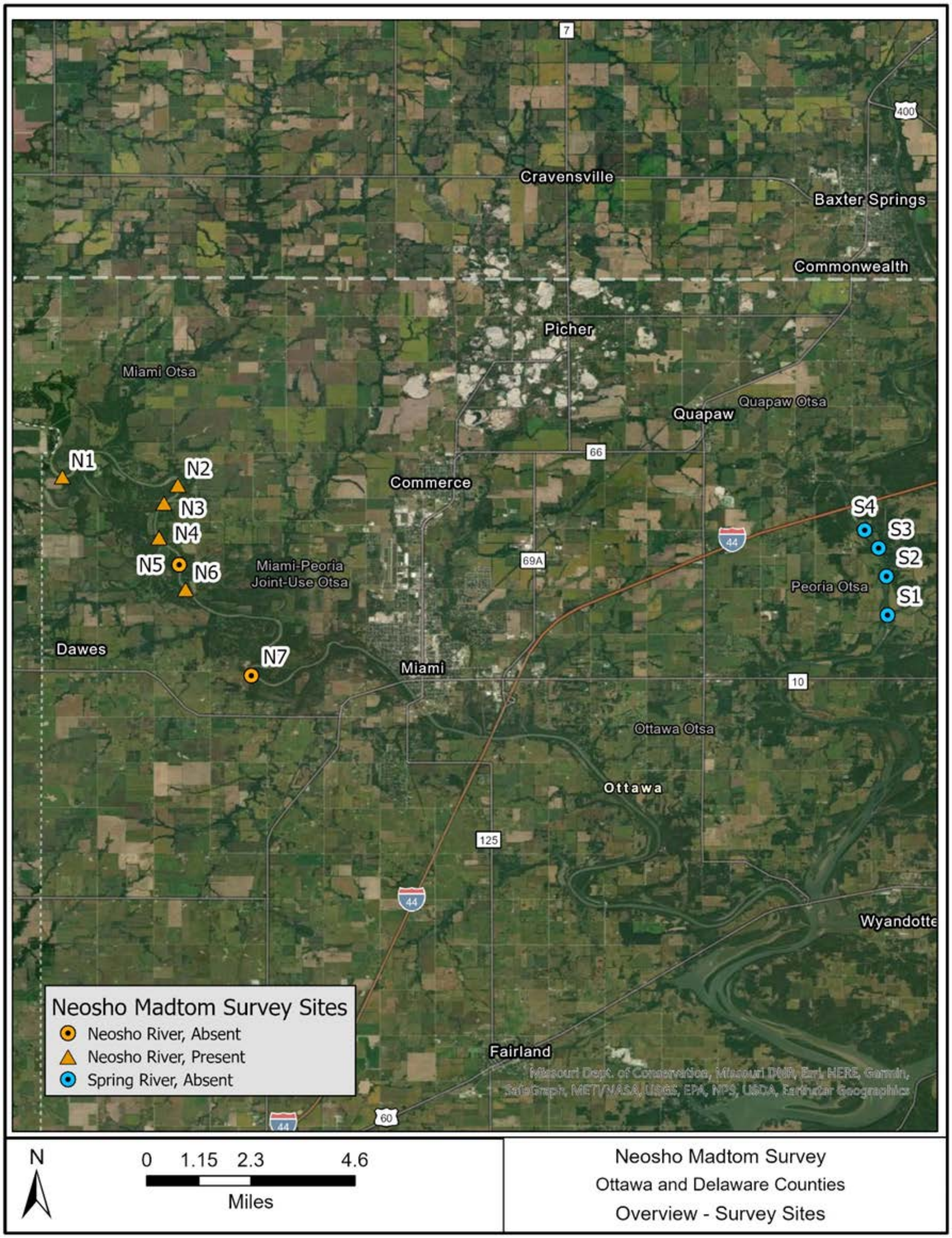

Table 9. Overall Survey Results

Species		Survey Sites												
Scientific Name	**Common Name**	**N1**	**N2**	**N3**	**N4**	**N5**	**N6**	**N7**	**S1**	**S2**	**S3**	**S4**	**Total**	**Relative Abundance**
Dorosoma petense	Threadfin Shad	0	0	0	0	0	0	0	1	0	0	0	1	<0.01
Campastoma anomalum	Central Stoneroller	1	0	0	0	0	0	0	2	0	0	0	3	<0.01
Cyprinella lutrensis	Red Shiner	50	11	34	8	32	46	28	27	47	12	7	302	0.33
Erimystax x-punctatus	Gravel Chub	2	0	1	3	0	0	0	4	19	1	6	36	0.04
Luxilus cardinalis	Cardinal Shiner	0	0	0	0	0	0	0	7	4	4	1	16	0.02
Notropis athernoides	Emerald Shiner	20	52	30	9	12	18	44	35	13	2	1	236	0.26
Notropis buchanani	Ghost Shiner	0	0	0	0	1	0	0	0	0	0	0	1	<0.01
Notropis percobromus	Carmine Shiner	0	0	0	0	0	0	0	0	2	0	3	5	<0.01
Notropis vollucellus	Mimic Shiner	0	0	0	0	0	0	0	0	0	0	1	1	<0.01
Phenocobius mirabilis	Suckermouth Minnow	0	1	0	8	0	1	2	0	0	0	0	12	0.01
Pimephales notatus	Bluntnose Minnow	0	1	0	2	0	0	0	0	0	0	0	3	<0.01
Ictalurus furcatus	Blue Catfish	0	0	33	0	1	0	0	0	0	0	0	34	<0.04
Ictalurus punctatus	Channel Catfish	13	0	22	8	0	6	0	1	0	0	0	50	<0.05
Noturus flavus	Stonecat	2	0	1	0	0	1	0	0	0	0	1	5	0.01
Noturus miurus	Brindled Madtom	0	0	0	0	0	1	0	0	0	0	0	1	<0.01
Noturus placidus	Neosho Madtom	4	1	3	2	0	3	0	0	0	0	0	13	0.01
Plyodictus olivaris	Flathead Catfish	0	0	0	0	0	0	0	0	0	1	0	1	<0.01
Menidia audens	Mississippi Silverside	0	0	0	1	1	3	0	0	5	0	0	10	0.01
Morone chrysops	White Bass	0	2	1	5	0	1	0	1	27	15	64	116	0.13
Lepomis cyanellus	Green Sunfish	0	0	0	0	0	1	0	0	0	0	0	1	<0.01
Lepomis macrochirus	Bluegill	0	0	0	1	0	0	0	0	0	0	0	1	<0.01
Micropterus punctatus	Spotted Bass	0	0	0	0	0	0	0	0	0	0	1	1	<0.01
Etheostoma whipplei	Redfin Darter	1	0	0	0	0	0	0	0	0	0	0	1	<0.01
Percina caprodes	Logperch	1	1	0	0	0	0	0	0	1	0	0	3	<0.01
Percina phoxocephala	Slenderhead Darter	3	2	1	0	1	4	3	7	0	0	0	21	0.02
Percina shumardi	River Darter	0	0	2	2	0	6	9	10	3	0	7	39	0.04
Aplodinotus grunniens	Freshwater Drum	0	0	0	4	0	1	0	0	0	0	0	5	0.01
Species Richness		**10**	**8**	**10**	**12**	**6**	**13**	**5**	**10**	**9**	**6**	**10**	**27**	**-**
Total Abundance		**97**	**71**	**128**	**53**	**48**	**92**	**86**	**95**	**121**	**35**	**92**	**918**	**-**

Table 10. Substrate/Habitat Results (%) and Velocity (ft/s)

	Site										
Mesh size (mm)	Spring 1	Spring 2	Spring 3	Spring 4	Neosho 1	Neosho 2	Neosho 3	Neosho 4	Neosho 5	Neosho 6	Neosho 7
38	25	25	15	5	40	60	5	5	5	0	0
19	25	30	45	40	20	20	65	15	35	50	5
9.5	25	20	10	20	15	10	15	10	30	30	50
2	25	25	30	35	25	10	15	70	30	20	45
Velocity (ft/s)	2.0	3.2	3.1	2.6	1.8	1.9	1.5	1.3	0.6	3.4	1.4

Figure 8. Neosho River Survey Sites

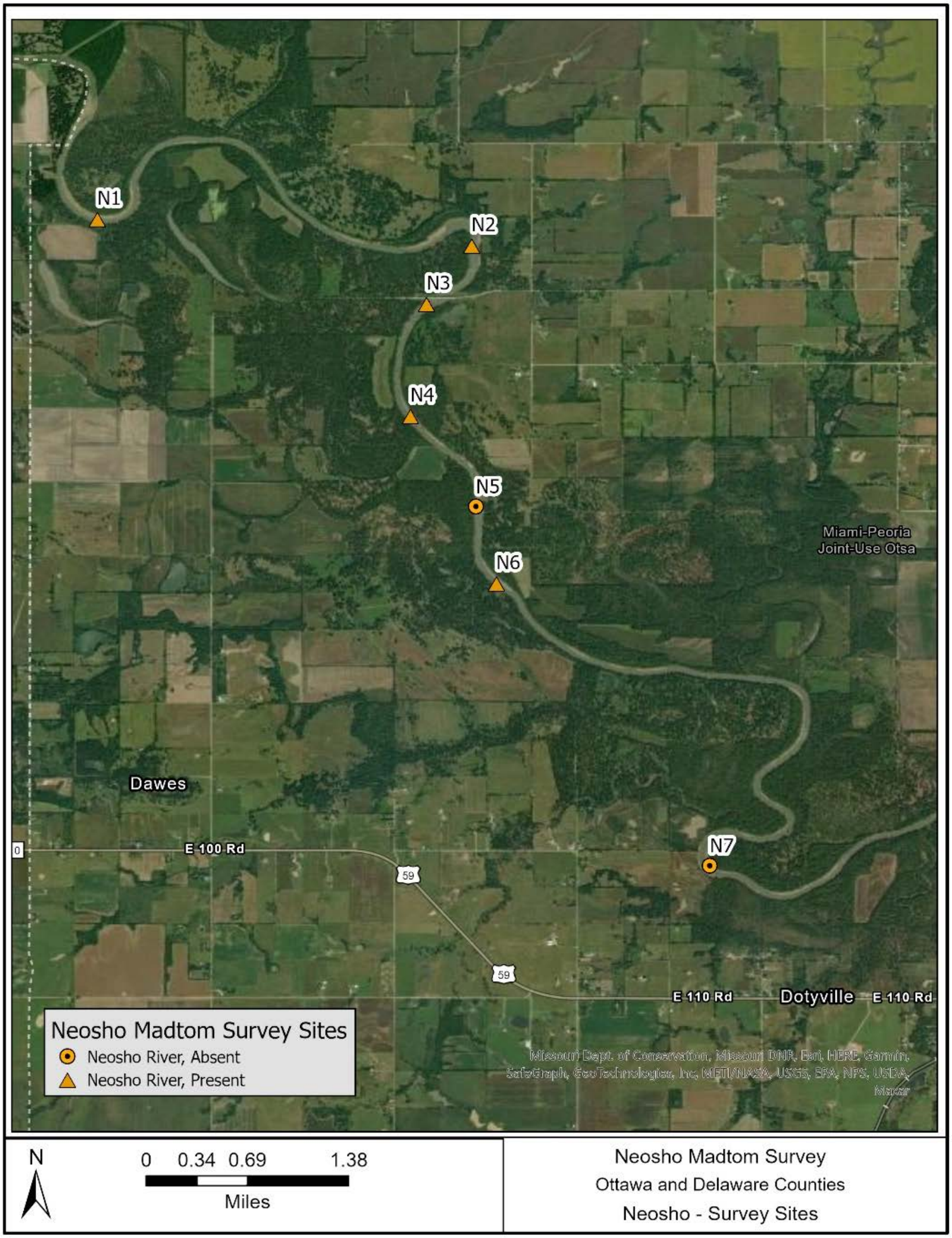

Table 11. Neosho River Site Results

Species		Survey Sites									
Scientific Name	**Common Name**	**N1**	**N2**	**N3**	**N4**	**N5**	**N6**	**N7**	**Total**	**Relative Abundance**	**CPUE**
Campastoma anomalum	Central Stoneroller	1	0	0	0	0	0	0	1	0.00	0.02
Cyprinella lutrensis	Red Shiner	50	11	34	8	32	46	28	209	0.36	3.80
Erimystax x-punctatus	Gravel Chub	2	0	1	3	0	0	0	6	0.01	0.11
Notropis athernoides	Emerald Shiner	20	52	30	9	12	18	44	185	0.32	3.36
Notropis buchanani	Ghost Shiner	0	0	0	0	1	0	0	1	0.00	0.02
Phenocobius mirabilis	Suckermouth Minnow	0	1	0	8	0	1	2	12	0.02	0.22
Pimephales notatus	Bluntnose Minnow	0	1	0	2	0	0	0	3	0.01	0.05
Ictalurus furcatus	Blue Catfish	0	0	33	0	1	0	0	34	0.06	0.62
Ictalurus punctatus	Channel Catfish	13	0	22	8	0	6	0	49	0.09	0.89
Noturus flavus	Stonecat	2	0	1	0	0	1	0	4	0.01	0.07
Noturus miurus	Brindled Madtom	0	0	0	0	0	1	0	1	0.00	0.02
Noturus placidus	Neosho Madtom	4	1	3	2	0	3	0	13	0.02	0.24
Menidia audens	Mississippi Silverside	0	0	0	1	1	3	0	5	0.01	0.09
Morone chrysops	White Bass	0	2	1	5	0	1	0	9	0.02	0.16
Lepomis cyanellus	Green Sunfish	0	0	0	0	0	1	0	1	0.00	0.02
Lepomis macrochirus	Bluegill	0	0	0	1	0	0	0	1	0.00	0.02
Etheostoma whipplei	Redfin Darter	1	0	0	0	0	0	0	1	0.00	0.02
Percina caprodes	Logperch	1	1	0	0	0	0	0	2	0.00	0.04
Percina phoxocephala	Slenderhead Darter	3	2	1	0	1	4	3	14	0.02	0.25
Percina shumardi	River Darter	0	0	2	2	0	6	9	19	0.03	0.35
Aplodinotus grunniens	Freshwater Drum	0	0	0	4	0	1	0	5	0.01	0.09
Species Richness		10	8	10	12	6	13	5	21		
Total Abundance		97	71	128	53	48	92	86	575		
Catch Per Unit Effort (CPUE)		19.40	14.20	25.60	10.60	9.60	18.40	17.20	16.43		

4.4.3.1.2 Spring River Results

Seventeen species of fish were collected from four sites in the Spring River (Figure 9). Neosho Madtoms were not observed (Table 12). The average velocity at survey sites in the Spring River was 2.7 ft/s and ranged from 2 to 3.1 ft/s (Table 13). The substrate size distribution ranged from 5% to 40% with a trend for a more even distribution of particle sized in downstream sites (Table 10).

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Figure 9. Spring River Survey Sites

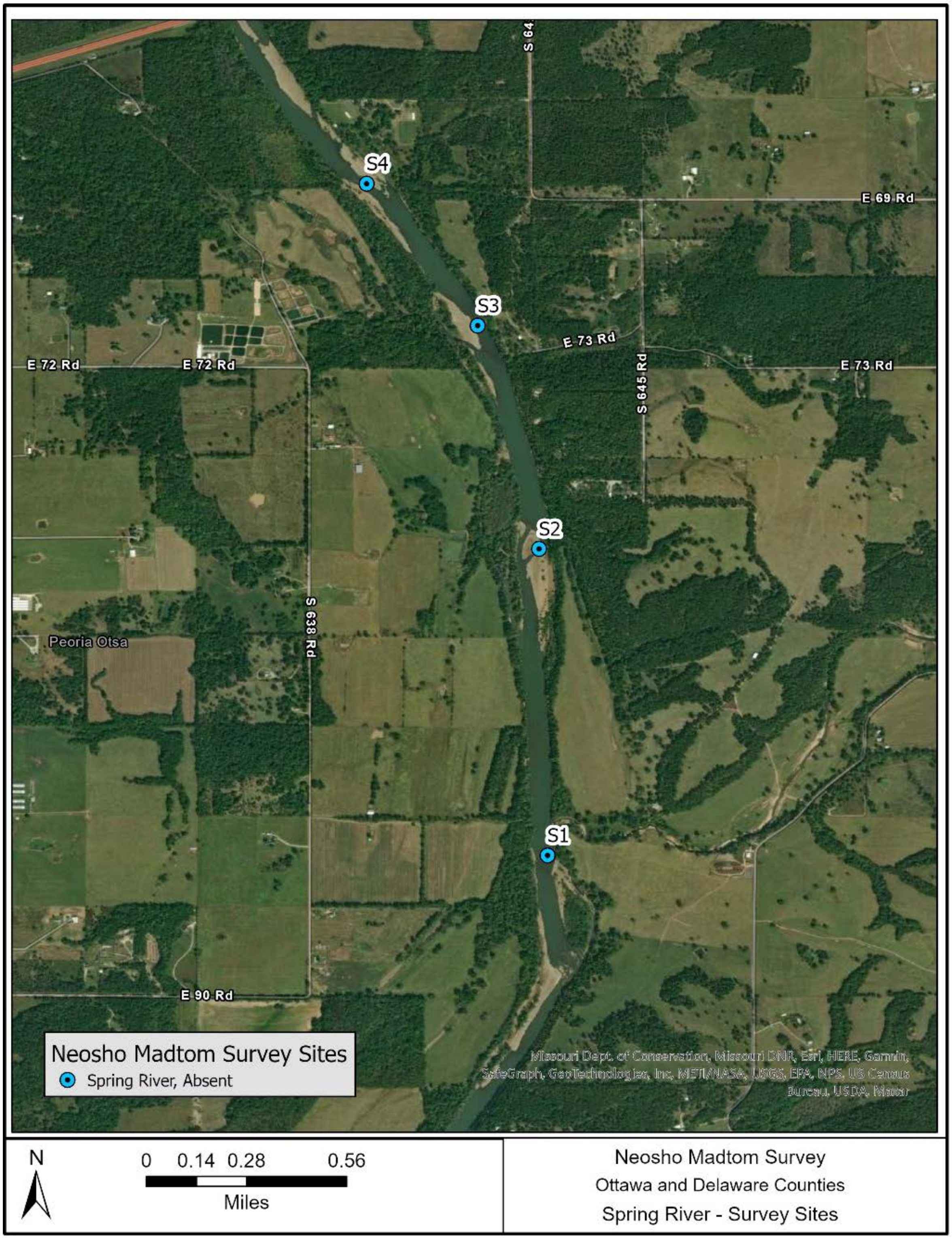

Table 12. Spring River Results

Species		Survey Sites						
Scientific Name	**Common Name**	**S1**	**S2**	**S3**	**S4**	**Total**	**Relative Abundance**	**CPUE**
Dorosoma petense	Threadfin Shad	1	0	0	0	1	0.003	0.05
Campastoma anomalum	Central Stoneroller	2	0	0	0	2	0.006	0.10
Cyprinella lutrensis	Red Shiner	27	47	12	7	93	0.271	4.65
Erimystax x-punctatus	Gravel Chub	4	19	1	6	30	0.087	1.50
Luxilus cardinalis	Cardinal Shiner	7	4	4	1	16	0.047	0.80
Notropis athernoides	Emerald Shiner	35	13	2	1	51	0.149	2.55
Notropis percobromus	Carmine Shiner	0	2	0	3	5	0.015	0.25
Notropis vollucellus	Mimic Shiner	0	0	0	1	1	0.003	0.05
Ictalurus punctatus	Channel Catfish	1	0	0	0	1	0.003	0.05
Noturus flavus	Stonecat	0	0	0	1	1	0.003	0.05
Noturus miurus	Brindled Madtom	0	0	0	0	0	0.000	0.00
Noturus placidus	Neosho Madtom	0	0	0	0	0	0.000	0.00
Plyodictus olivaris	Flathead Catfish	0	0	1	0	1	0.003	0.05
Menidia audens	Mississippi Silverside	0	5	0	0	5	0.015	0.25
Morone chrysops	White Bass	1	27	15	64	107	0.312	5.35
Micropterus punctatus	Spotted Bass	0	0	0	1	1	0.003	0.05
Percina caprodes	Logperch	0	1	0	0	1	0.003	0.05
Percina phoxocephala	Slenderhead Darter	7	0	0	0	7	0.020	00.35
Percina shumardi	River Darter	10	3	0	7	20	0.058	1.00
Species Richness		**10**	**9**	**6**	**10**	**17**		
Total Abundance		**95**	**121**	**35**	**92**	**343**		
Catch Per Unit Effort (CPUE)		**19.00**	**24.20**	**7.00**	**18.40**	**17.15**		

4.4.3.2 Discussion

As documented during previous surveys (see Section 3.4.1), Neosho Madtom were found within the Neosho River study area but were not located in the Spring River study area of Oklahoma. Within the Neosho River study area, they were most common at upstream sites near the Craig/Ottawa County line, and occurrence decreased at downstream sites. Substrate particle size also decreased from upstream to downstream, suggesting a potential relationship between larger particle sizes and Neosho Madtom occurrence. Also, it should be noted that velocities documented at sampling sites in the Neosho River were similar to those reported in the literature for Neosho Madtom (Moss 1983), whereas velocities documented at Spring River sites were generally lower.

Using hydraulic models developed as part of the relicensing project, section-averaged velocities were calculated for cross-sections extracted at each madtom sampling location under both the baseline operations and anticipated operations scenarios (Table 13). The difference in section-averaged velocity at these cross-sections ranged from -0.01 to -0.22 ft/s (average = -0.05 ft/s). The average velocity changes at Neosho Madtoms sites were -0.02 ft/s and ranged from -0.01 to -0.04 ft/s (Table 13).

Additionally, lentic/lotic maps were generated from the CHM to evaluate changes to inundation relative to Project operations. These maps demonstrate a slight increase in inundation during the period of May 15 to July 8, with most of this change occurring in areas of close proximity to the reservoir. There is essentially no discernable change to inundation in the sections of the mainstem Neosho River occupied by Neosho Madtoms under the two scenarios.

While Neosho Madtoms were observed at five of the eleven survey sites, no material impacts to Neosho Madtoms populations are expected to occur due to changes in project operations. Anticipated changes to inundation will have minimal, if any, influence on upstream areas of the Neosho River mainstem where Neosho Madtom were most common. Additionally, the change in the velocity predicted to occur is relatively minimal (-0.02 ft/s) compared to the range of velocities predicted at occupied sites (max:3.4 ft/s, min: 1.3, range: - 2.1 ft/s; Table 13).

Table 13. Previous and Anticipated Velocities at Neosho Madtom Sampling Locations

Site	Latitude	Longitude	RM	1D or 2D	Section-averaged velocity (ft/s)		Difference in velocity (ft/s)
					Previous Operations	Proposed Operations	
Spring 1	36.891539	-94.729085	10.94	1D	1.65	1.43	-0.22
Spring 2	36.903907	-94.72943	11.83	1D	1.46	1.40	-0.06
Spring 3	36.912914	-94.731908	12.43	1D	2.98	2.91	-0.07
Spring 4	36.891539	-94.729085	10.94	1D	1.65	1.43	-0.22
Neosho 1	36.93597	-94.99258	148.72	2D	3.87	3.86	-0.01
Neosho 2	36.93336	-94.95569	145.79	2D	4.47	4.46	-0.01
Neosho 3	36.92761	-94.96014	145.26	2D	3.65	3.63	-0.02
Neosho 4	36.91657	-94.96173	144.45	2D	3.65	3.63	-0.02
Neosho 5	36.90761	-94.95527	143.69	2D	3.43	3.41	-0.02
Neosho 6	36.90008	-94.953251	143.13	2D	3.02	2.99	-0.04
Neosho 7	36.87222	-94.93223	139.47	2D	3.92	3.81	-0.10

4.5 Neosho Smallmouth Bass

4.5.1 Habitat and Conservation Status

The Neosho Smallmouth Bass is found in streams that have watersheds with coarse-textured soils (Brewer et al. 2007, Brewer and Long 2015, Dauwalter et al 2007) within the Ozark and Boston Mountain ecoregions. Generally, smallmouth bass are found in clear streams, but the Neosho Smallmouth Bass can persist in some streams that are often spring fed and have relatively high sediment loads (Nigh and Shroeder 2002; Brewer and Long 2015). Though Neosho Smallmouth Bass are found in pool habitats, larger streams that have various channel units, including runs and riffles, are necessary for abundant populations (Dauwalter et al. 2007, Brewer 2013).

Spawning habitat for the Neosho Smallmouth Bass consists of low-velocity, nearshore waters that are close to cover. The Neosho Smallmouth Bass also prefers to construct nests in areas that have fine sediment substrates and avoids areas that have thick layers or silts and clays (Dauwalter et al. 2007). In years that have low stream flows, low water velocity at the nest site was found to be important for nest success (Dauwalter et al. 2007). In years that have elevated discharge events, nest success was influenced by streamflow, temperature, and distance to shore (Dauwalter et al. 2007).

However, available biology and ecology data suggest that Neosho Smallmouth Bass possess local adaptations to warmer climates and intermittent stream flows (Brewer and Long 2015). Moreover, the Neosho Smallmouth Bass inhabits stream systems but lack impact to impoundment fisheries (Stark and Echelle 1998; Malloy 2001), underscoring the unique fluvial ecology of this subspecies compared with nonnative Smallmouth Bass that thrive in impoundments following stocking. Conservation of the Neosho Smallmouth Bass subspecies, and the population-level diversity within the subspecies, would thus provide a “diversified portfolio” that would contribute to maintaining the overall adapt-ability of Smallmouth Bass to future climate change or habitat-related stressors (Schindler et al. 2010). Nonnative black bass are typically stocked in impoundments to bolster sportfishing opportunities, and native congeners often experience introgression, widespread admixture, or complete replacement within impoundments (Avise et al. 1997; Barwick et al. 2006).

4.5.2 Distribution and Occurrence

The Neosho Smallmouth Bass is a genetically distinct subspecies of smallmouth bass (Stark and Echelle 1998, Tayler et al. 2018). The Neosho Smallmouth Bass is found in the western extent of the Ozark Highlands ecoregion (Nigh and Schroeder 2002) and is known to occur in the Spring River, the Elk River, the Neosho River, Spavinaw Creek, Spring Creek, the Illinois River, Baron Fork, Sallisaw Creek, Lee Creek, Clear Creek, the Mulberry River, Big Piney Creek, and the Illinois Bayou (Brewer and Long 2015). Taylor et al. (2018) identified Neosho

Smallmouth Bass in Sycamore Creek, the Elk River, and Honey Creek all which feed into Grand Lake.

4.5.3 Discussion

Several records show that a smallmouth bass population is present within the drainages of the study area (Figure 10), but during the sampling there was no determination that the Neosho subspecies was identified. It is likely that all records of smallmouth bass from OWRB and the Sam Nobel Museum are not of the Neosho strain (Curtis Tacket; personal communication) because the smallmouth bass that may occur within Grand Lake and the stretches of the Neosho, Spring, and Elk rivers in Oklahoma are likely to be reservoir-strain fish. ODWC sampling efforts (locations not disclosed), which looked for both the Neosho and reservoir subspecies, did not detect the Neosho subspecies of the smallmouth bass within this project area or surrounding drainages; the latest surveys occurred in 2019 (Curtis Tacket; personal communication). Based on these data indicating that the Neosho Smallmouth Bass does not occur within the study area, no additional surveys for Neosho Smallmouth Bass occurred in 2022. Furthermore, due to their absence within the study area, Project Operations should not impact the Neosho Smallmouth Bass

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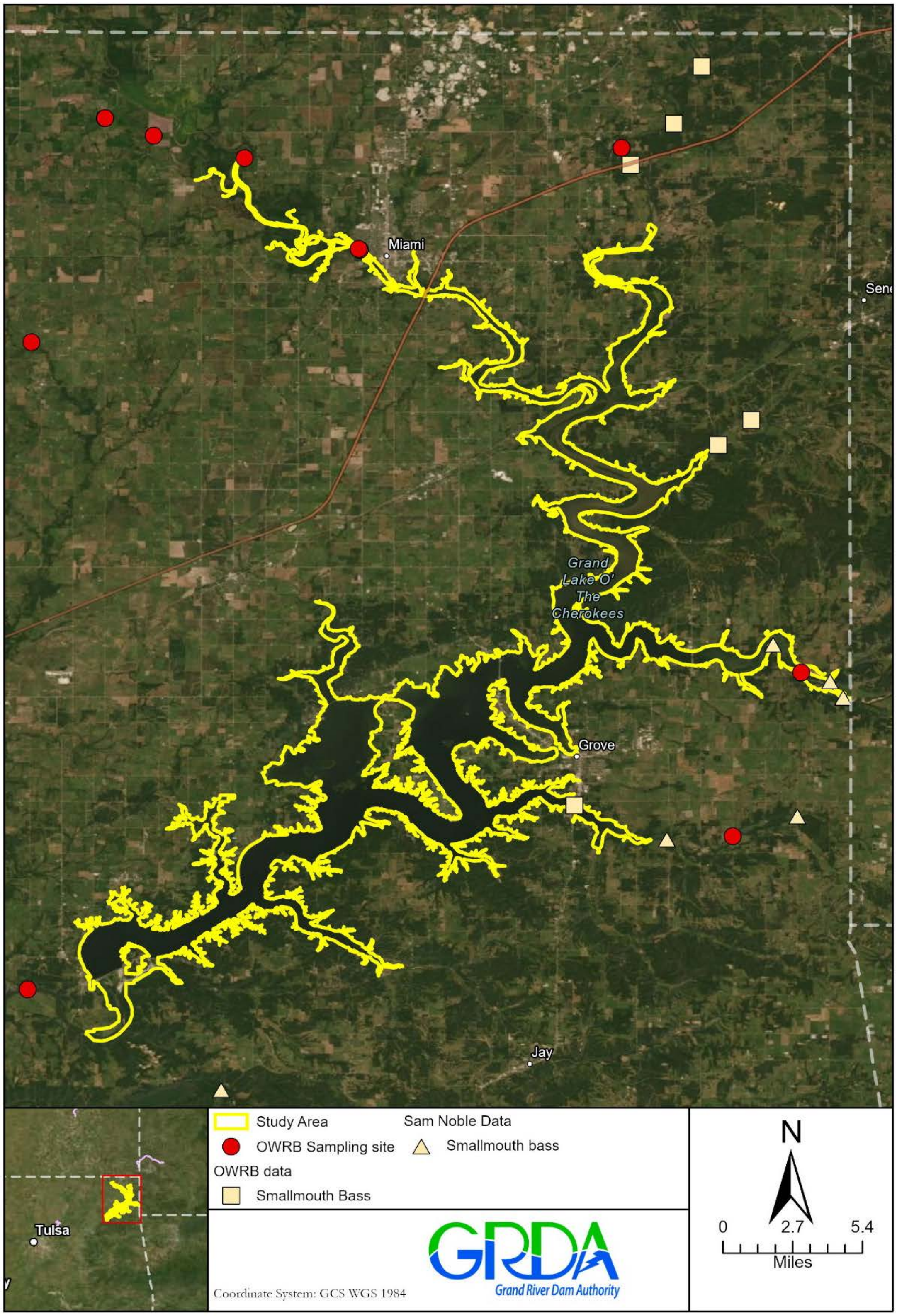
Figure 10. Known Locations of Neosho Smallmouth Bass – data provided by OWRB and Sam Noble Museum.



4.6 Paddlefish

4.6.1 Habitat and Conservation Status

Adult Paddlefish inhabit deep slow-moving pools of large rivers and associated lakes and reservoirs, where they use special electrical receptors on their rostrum to detect zooplankton that are filtered from the water with specialized gill rakers (Jennings and Zigler 2009). They typically inhabit areas with depths greater than 9.8 ft and current velocities below 1.6 feet per second (ft/s) in reservoirs (Rosen et al. 1982; Zigler et al. 2003). Appropriate spawning habitats are more specific and require riverine habitats. Paddlefish spawning occurs in aggregations over hard substrates such as washed cobble within river environments during March – June, depending on latitude (Jennings and Zigler 2009; Schooley and O'Donnell 2016). In Oklahoma, spawning peaks in late March and early April (Scarnecchia et al. 2013). Spawning appears to be episodic, often initiated by rising water levels and occurring during periods of high flow, and year-class recruitment is often highest in years that have extended high flow conditions during the spring spawning period (O'Keefe et al. 2007; Jennings and Zigler 2009; Scarnecchia et al. 2013). Paddlefish spawn demersal eggs that become adhesive upon fertilization and stick to the substrate (Purkett 1961; Yeager and Wallus 1982). Hard substrates such as gravel and cobble are key to spawning success because eggs that fall on sand or silt may have reduced survival (Schooley and O'Donnell 2016).

Previous research by ODWC biologists has quantified the amount of hard spawning substrates within the Neosho and Spring rivers upstream of Grand Lake to the first migration barriers and evaluated how changes in flows influence the availability of spawning habitat in these rivers (Schooley and O'Donnnel 2016; Schooley and Neely 2018). Because changes to reservoir elevations could potentially influence the availability of spawning substrates, Phase I of this study included compilation of this data and development of maps to evaluate the amount and spatial distribution of Paddlefish spawning substrate within the Project area.

To perform this evaluation, spatially explicit depth and hardness data from the above studies provided by Jason Schooley (ODWC Senior Biologist, Paddlefish Research Center) and Ben Neely (Kansas Department of Wildlife, Parks, and Tourism) were compiled and formatted into a geographic information system (GIS) platform. Details on data collection and analysis used to generate this dataset and differentiate substrate types are provided in Schooley and O'Donnell (2016) and Schooley and Neely (2018). The study area for this dataset includes 38.5 miles of the Neosho River upstream to a dam at Chetopa, Kansas, and 22.4 miles of the Spring River upstream to a barrier at Baxter Springs, Kansas. Within this study area, the amount of usable spawning substrate changes with flow in each system because higher flows generally inundate more usable substrate. At the maximum flows evaluated, a total of approximately 2,647 ac of potential habitat occurs, of which 1,701 ac (64 percent) consist of hard substrates presumably suitable for Paddlefish spawning (Table 14). Specifically, 997 ac of Paddlefish spawning substrates (69 percent of available) were identified within the Neosho River and 704 ac (59 percent of available) were identified in the Spring River. The availability of hard substrates generally increases moving upstream from the river/reservoir interface. Within the project boundary, approximately 696 ac of Paddlefish spawning substrate was identified within the Neosho River and 493 ac of spawning substrate was observed within the Spring River (Table 14; Figures 11-13). Therefore, 70 percent of the available spawning substrate within both the Neosho River and the Spring River falls within the Project boundary.

Due to hydrology differences between the two river systems, modeling of proportional habitat availability under varying flow rates suggests that the Neosho River has greater value for Paddlefish reproduction than the Spring River (Schooley and Neely 2018). Additionally, studies using dentary bone microchemistry to identify natal river found that 87% of fish analyzed were of Neosho River origin, whereas only 7% were of Spring River origin (Whitledge and Schooley 2019). Taken together, this demonstrates that the Neosho River has much greater value to Paddlefish reproduction than the Spring River.

Table 14. Area of Paddlefish Spawning Substrate in Acres (ac) as Quantified by Schooley and O'Donnell (2016) in Relation to their Study Area and the Project.

	Neosho River	Spring River	Overall
Study Area (ac)	1,444	1,203	2,647
Paddlefish Spawning Habitat (ac)	997	704	1,701
Paddlefish Spawning Habitat within Project (ac)	696	493	1,189
Percent of Paddlefish Spawning Habitat within Project	70%	70%	70%

The area below the confluence of the two rivers, in the Grand River near the river/reservoir interface, was not evaluated for spawning habitat. Spawning activity in this section is unlikely because this area is a transitional zone used by staging Paddlefish in the late winter and early spring as they wait for high-flow pulses to move upriver into the Spring or Neosho rivers and begin spawning (Schooley and O'Donnell 2016). Occurrence of such high-flow pulses which stimulate upstream migration within the spring spawning period are the major determinant of Paddlefish spawning success, and likely have a much greater influence on Paddlefish recruitment than reservoir levels.

Figure 11. Potential Paddlefish Spawning Substrate as Defined by Schooley and O'Donnell (2016) within the Project Boundary on the Neosho River downstream of Miami, OK.

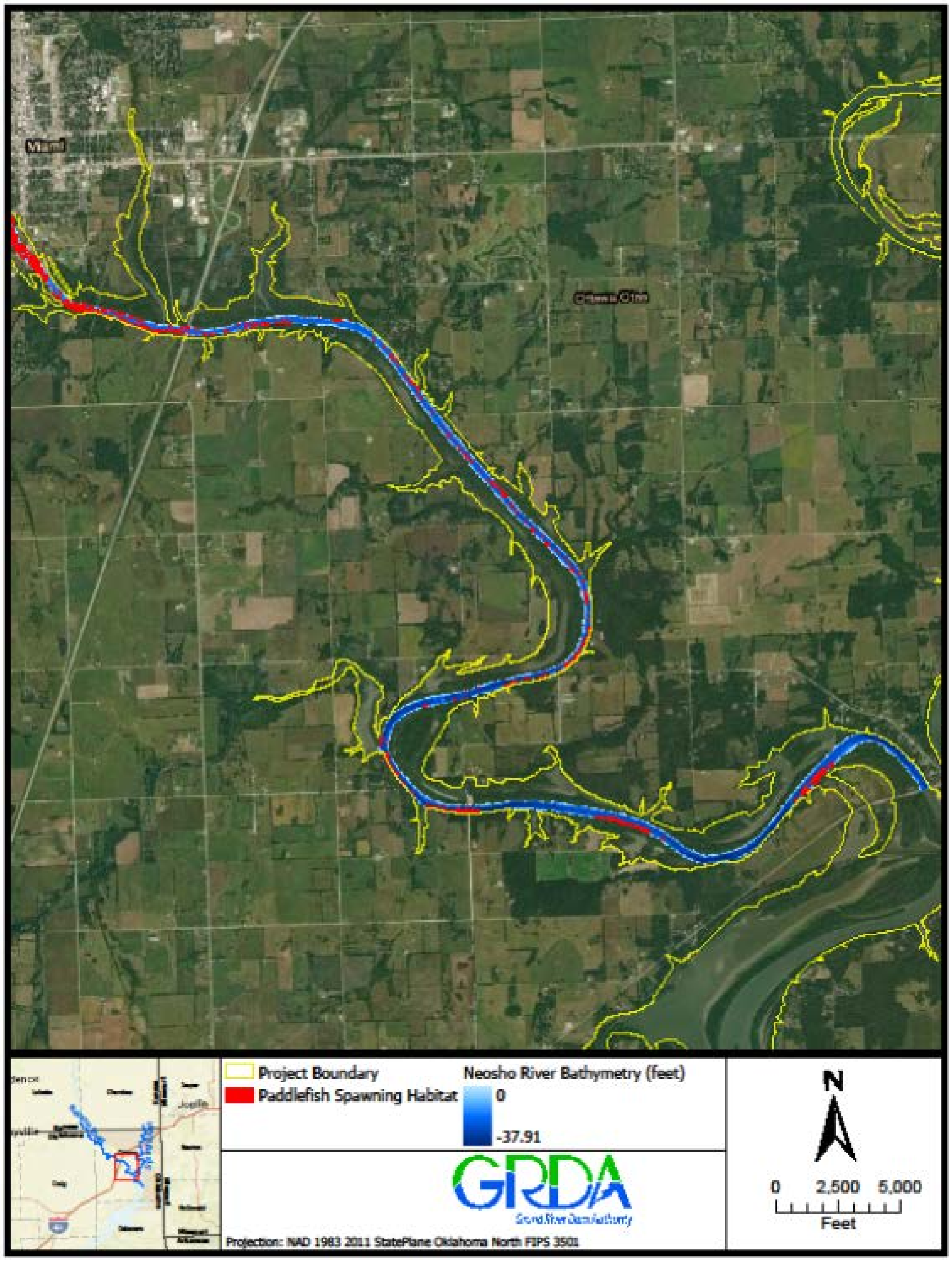


Figure 12. Potential Paddlefish Spawning Substrate as Defined by Schooley and O'Donnell (2016) within the Project Boundary on the Neosho River upstream of Miami, Oklahoma.

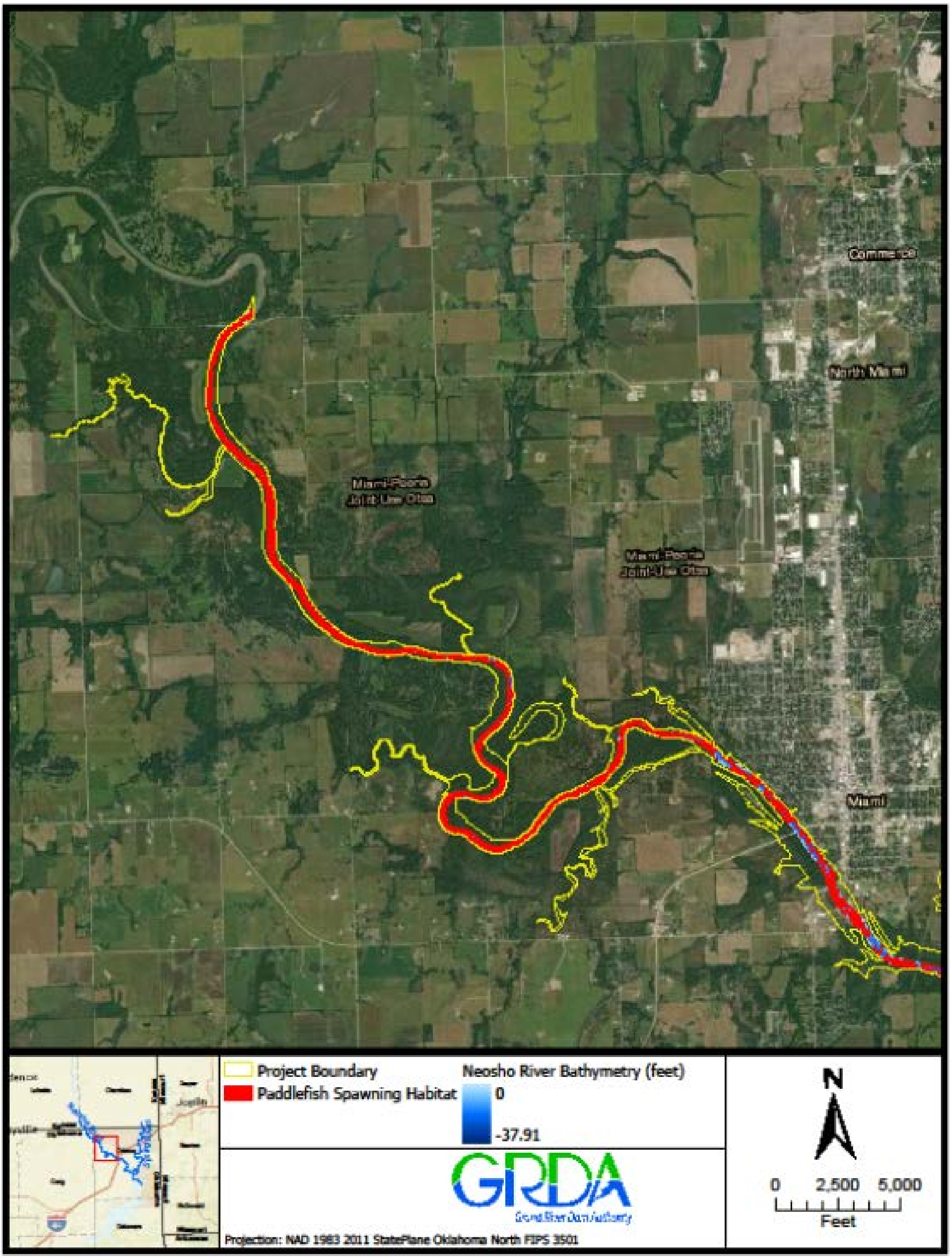
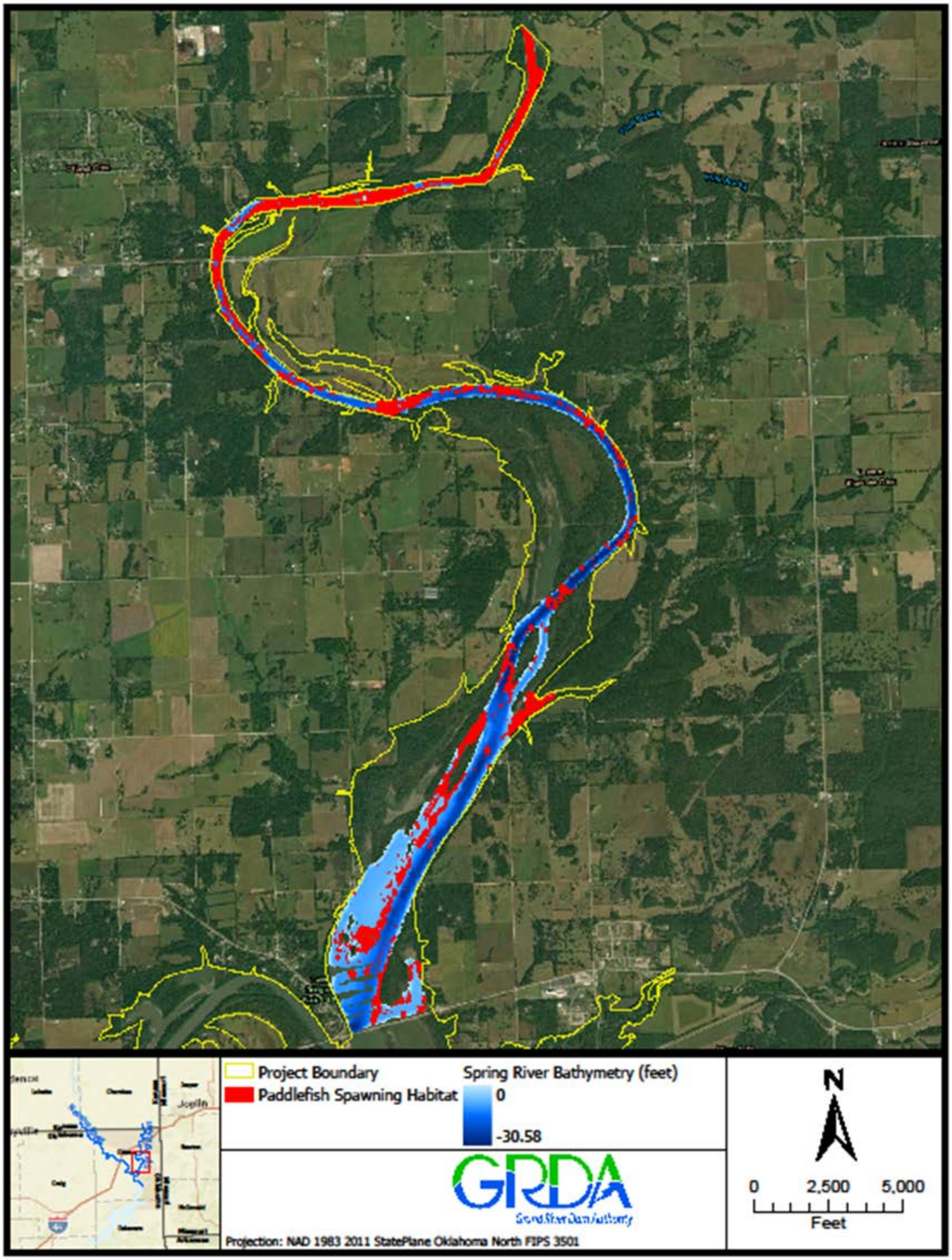


Figure 13. Potential Paddlefish Spawning Substrate as Defined by Schooley and O'Donnell (2016) within the Project Boundary on the Spring River.



4.6.2 Distribution and Occurrence

Paddlefish are native to large rivers and lakes of the Mississippi River drainage and nearby gulf slope drainages from the San Jacinto River in the southwest to the Tombigbee and Alabama rivers in the southeast. At the northern extent of their range, Paddlefish extend as far west as the Missouri and Yellowstone rivers of Montana to the Ohio and Allegheny rivers of the northeast (Jennings and Zigler 2009). In Oklahoma, Paddlefish were originally present in most large rivers of the Arkansas system including the Neosho and Grand rivers, the Little River, and the Red River (Miller and Robison 2004).

Paddlefish stocks in Grand Lake and the Neosho and Spring rivers support a prominent snag fishery, attracting anglers from throughout the United States during the spring spawning run (Jager and Schooley 2016). Although annual catch rates are variable depending on hydrologic conditions, thousands of mature Paddlefish are harvested from Grand Lake stocks during some years (Scarnecchia et al. 2013). Trip expenditures from Paddlefish angling in Oklahoma have an estimated economic impact of 18.2 million dollars (Melstrom and Shideler 2017), much of which is focused on the Grand Lake fishery. Since 2015, good water years (years with extended high springtime flows) have resulted in good Paddlefish recruitment in the Neosho watershed. The impacts of a large recruitment event in 2015 are now being realized as the males have reached sexual maturity and the females will in 2022-2023 (personal communication via email on Sep. 13, 2021, Jason Schooley, ODWC Paddlefish Research Center).

4.6.3 Discussion

As documented above, a large percentage of available Paddlefish spawning habitat occurs within upstream portions of the Project area in the Neosho and Spring Rivers. However, inundation maps from the CHM demonstrate a non-discernable change in inundation of upstream Paddlefish spawning areas under anticipated operations. Regardless of the anticipated future operation of the Project, the magnitude and timing of inflow events will continue to be the main determinant of hydraulic conditions necessary to facilitate successful Paddlefish spawning. Therefore, based on the abundance of potential spawning substrates available in upstream areas, the anticipated change in Project operations is not expected to adversely impact Paddlefish.

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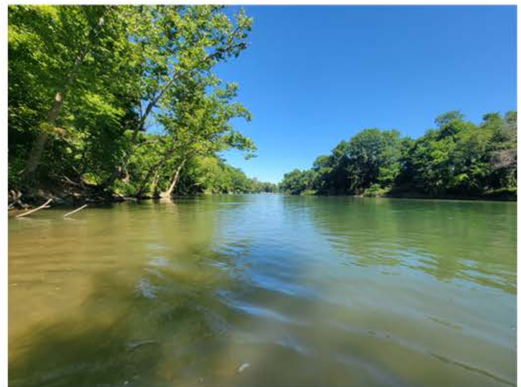
APPENDIX A

Photo log

1. Elk 1 mussel site.



2. Elk 2 mussel site.

3. Elk 3 mussel site.

4. Elk 4 mussel site.

5. Elk 4 mussels collected.

5. Elk 5 mussel site.


7. Spring 1 mussel site.


8. Spring 1 mussels collected.


9. Spring 2 mussel site.


10. Spring 2 mussels collected.


11. Spring 3 mussel site.


12. Spring 3 mussels collected.

13. Spring 4 mussel site.

14. Spring 4 mussels collected.

15. Neosho 1 mussel site.

16. Neosho 1 mussels collected

17. Neosho 2 mussel site.

18. Neosho 2 results

19. Neosho 3 mussel site.

20. Neosho 3 mussels collected.

21. Neosho 4 mussel site.

22. Neosho 4 mussels collected.

23. Neosho 1 Madtom Site.

24. Neosho 2 Madtom Site.

25. Neosho 3 Madtom Site.

26. Neosho 4 Madtom Site.

27. Neosho 5 Madtom Site.

28. Neosho 6 Madtom Site.

29. Neosho 7 Madtom Site.

30. Spring 1 Madtom Site.

31. Spring 2 Madtom Site.

32. Spring 3 Madtom Site.

33. Spring 4 Madtom Survey.

APPENDIX B

Mussel Survey Plan and Comments

Aquatic Species of Concern Study

Phase 2 Freshwater Mussel Sampling Protocols

6. INTRODUCTION

The Grand River Dam Authority (GRDA) is relicensing the Pensacola Hydroelectric Project following the Integrated Licensing Process (ILP) as designated by the Federal Energy Regulatory Commission (FERC). One component of this process is an Aquatic Species of Concern Study to gather information on multiple potential aquatic species of concern and assess any potential effects of the Project on these species. As outlined in the Revised Study Plan, this study included three phases. Phase 1 (completed in 2021) consisted of a review of existing information to determine if further evaluation was needed; Phase 2 included potential field surveys to document distribution and density of the species of concern; and Phase 3 was an assessment of potential impacts of project operation, if any, for relevant species. The Phase 1 review of existing information was summarized in the Initial Study Report (ISR) filed by GRDA on September 30, 2021 and proposed 2022 Phase 2 surveys for Neosho Mucket (*Lampsilis rafinesqueana*) in the Elk River portion of the study area, among other tasks. Both FERC and United States Fish and Wildlife Service (USFWS) provided comments on GRDA's proposed Phase 2 study plan related to Neosho Mucket and GRDA filed an official Response to Comments with FERC on December 29, 2021. On February 24, 2022, FERC released a Study Plan Determination on Study Year 2. This Study Plan Determination recommended that GRDA conduct targeted freshwater mussel surveys for Neosho Mucket in USFWS-recommended portions of the Spring River and Neosho River, after consultation with USFWS, EcoAnalysts, and the Tar Creek Trustee Council (TCTC) on survey design.

This document describes the proposed survey design for conducting Phase 2 targeted mussel surveys for Neosho Mucket in recommended portions of the Elk River, Spring River, and Neosho River. It aggregates survey locations and methods proposed by GRDA in the September 2021 ISR, modifications associated with the December 2021 Response to Comments, as well as FERC recommendations in the February 2022 Study Plan Determination. Goals of these surveys are to provide the information needed to determine whether Neosho Mucket are present and to provide habitat information to assess the potential effects of project operation on Neosho Mucket that are present within the targeted survey locations.

7. SURVEY AREAS

As defined by the process described above, three areas have been identified for targeted mussel surveys to assess the distribution and site-specific density of Neosho Mucket in the Project vicinity. These areas are:

- the portion of the Elk River from the Missouri/Oklahoma state line to the confluence with Buffalo Creek[1] (approximately 1.0 river mile);
- the portion of the Spring River from Warren Branch to the confluence with the Neosho River[2] (approximately 10.5 river miles); and
- the portion of the Neosho River from the City of Miami [Riverview Park] to the confluence with the Spring River[3] (approximately 13 miles).

8. SURVEY METHODOLOGY

Within each of the three survey reaches outlined above, the following three-phase survey methodology will be implemented. These surveys are planned for June-August 2022 with exact timing depending upon appropriate flow and weather conditions. The surveys will be conducted under the supervision of qualified personnel with appropriate permits and knowledge of mussel survey methods and procedures for handling endangered mussel species. Resumes of key team members are provided.

8.1 Phase 1 – Identify and Map Any Potential Neosho Mucket Habitat

Surveys are intended to target Neosho Mucket. Phase 1 of surveys will involve identifying and mapping appropriate habitat for this species within the previously defined survey reaches. To do this, experienced malacologists will traverse the entire study area by boat and/or canoe/kayak to examine habitat conditions. Any areas of potential Neosho Mucket habitat will be georeferenced by creating polygons around areas of potential habitat with a GPS.

Potential habitat will be identified consistent with previous mussel survey efforts and habitat descriptions for Neosho Mucket. Freshwater mussels are typically most abundant and diverse within stable fluvial habitats (riffles/runs) of riverine environments (Haag 2012, EcoAnalysts 2018). Specifically, Neosho Muckets have been collected from a variety of habitats but are typically described to have an association with moderately flowing shallow water over gravel or intermixed gravel and sand substrates (McMurray et al. 2012; Oesch 1984) and are not thought to inhabit reservoirs (Obermeyer et al. 1997). Therefore, potential habitat for Neosho Mucket will be considered flowing water riffles and runs over gravel or intermixed gravel and sand

[1] As outlined in the Initial Study Report submitted September 30, 2021.
[2] Requested modification in FERC Study Plan Determination-Season II-02242022.
[3] Requested modification in FERC Study Plan Determination-Season II-02242022.

substrates[4]. Depth, benthic current velocity, and percent substrate composition (visually classified based on the modified Wentworth scale) will be recorded at each area of potential habitat delineated and reference photographs will be taken.

8.2 Phase 2 – Qualitative Surveys

Within each delineated area of potential habitat, qualitative surveys via timed visual/tactile search methods (hand-grubbing into the top 1-4 inches of substrate to increase detection of more-deeply buried mussels) will be utilized to efficiently assess occurrence of Neosho Mucket. A qualitative survey approach is an efficient search method to establish a list of taxa, as well as increase the detection probability of rare species (Vaughn et al. 1997; Strayer and Smith 2003). Surveyors will select a shoreline and begin searching from downstream to upstream moving back and forth across the stream, ensuring that all the delineated search area of potential habitat is sufficiently covered. Surveyors will conduct a minimum of three one-person-hour searches using mask and snorkel. All live mussels and shell material will be collected, placed in mesh bags submerged in the stream, and aggregated by person-hour. If no live mussels are collected by the end of the third person-hour, the site will be considered complete. If live mussels are located, an additional two person-hours of search effort will be conducted. If a previously undetected mussel species is collected in the fifth person-hour, additional one-person-hour searches will be conducted until no new species are collected. If Neosho Mucket (or other listed mussels) are detected at any point during Phase 2 surveys, qualitative methods will immediately cease, and sampling will immediately transition to Phase 3 quantitative surveys.

Upon completion of qualitative surveys, all mussels will be identified to species by a qualified malacologist, enumerated, and returned to the approximate location of collection. Voucher photographs will be taken of each species collected. Shell material will also be collected, identified to species (when possible), and classified as fresh dead (FD; intact periostracum and lustrous nacre), weathered dead (WD; intact periostracum, weathered and chalky nacre); or subfossil (SF; shell chalky, no periostracum).

8.3 Phase 3 – Quantitative Surveys

Phase 3 quantitative surveys will be conducted at all sites where Neosho Mucket are located during Phase 2 qualitative surveys. A single 100 m^2 quantitative sampling area will be delineated encompassing the area where Neosho Mucket were located. Within this 100 m^2 quantitative sampling area, systematic sampling will be incorporated using three random starts with a minimum of 10 0.25 m^2 quadrats conducted at each 100 m^2 site (Strayer and Smith 2003). Visual/tactile search methods will be used to remove larger mussels and each quadrat

[4] In the initial study report, it was stated *"Additional, randomly selected quadrat points will be available to replace locations that do not provide mussel habitat (e.g., too close to shore, water depth, poor substrate)."* Such areas are now being excluded from the 100 m^2 sampling area. Therefore, additional randomly selected quadrat points are no longer necessary.

will then be excavated to a depth of 20 cm and sieved, as this increases the likelihood of detecting juvenile mussels. Data will be used to generate an estimate of Neosho Mucket density within each 100 m^2 site with each random start serving as an independent replicate.

Upon completion of quantitative surveys, all mussels will be identified to species by a qualified malacologist, enumerated, and returned to the approximate location of collection. All Neosho Mucket collected will also be measured to the nearest millimeter shell length. Shell material will also be collected, identified to species (when possible), and classified as fresh dead (FD; intact periostracum and lustrous nacre), weathered dead (WD; intact periostracum, weathered and chalky nacre); or subfossil (SF; shell chalky, no periostracum).

9. SUMMARY

The above three-phase survey methodology addresses the goals of the project by identifying and mapping any potentially appropriate habitat for Neosho Mucket within the proposed survey areas, using qualitative timed searches to most-efficiently evaluate occurrence of the target species, and using quantitative surveys to provide an estimate of site-specific density of Neosho Mucket in the areas where it is detected.

10. REFERENCES

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Response Table:

USFWS	Comment	Response
1	The Protocol identifies three principal areas for the surveys. These reflect prior input provided by the Service, which recommended making use of existing information collected on mussel resources of the Project area. We agree largely with the three identified areas, although we recommend expansion of the Elk River area. Presently, the Protocol proposes surveying a 1.0-mile portion of the Elk River between the Missouri/Oklahoma state line and the confluence with Buffalo Creek. Although sensitive mussel species such as the Neosho mucket are not likely to occur much farther downstream than Buffalo Creek, it is plausible that they could occur upstream of the state line. Future management actions that may be taken by the GRDA include scenarios in which lentic (pooled) waters would inundate presently flowing habitats, including extending pooled waters upstream of the state line. Such change may impact the Neosho mucket and other sensitive mussels. It creates a justification for expanding the Elk River survey area, minimally to include the extent of river habitat likely to be affected by future pool changes.	The project boundary extends to approximately the Oklahoma/Missouri state line, so the proposed survey area includes all habitats within the influence of the project. This proposed survey area was included in the ISR and received no comments in FERC's Study Plan Determination.
2	The qualitative survey procedure states that surveyors will conduct a minimum of three one-person-hour searches (of each survey area), using mask and snorkel. The quantitative survey procedure states that surveyors will sample a minimum of ten 0.25 m2 quadrats (within each survey area), without specifying surveyor gear. GRDA surveyors need to be prepared to dive using SCUBA or surface-supplied air to complete the surveys. While it is correct that typical Neosho mucket habitat is often described as flowing riffles and runs over gravel or gravel/sand substrates, Neosho muckets can occupy greater depths than cannot be surveyed efficiently by snorkeling. Potential habitats that will be encountered by the surveyors in the survey areas include extensive areas that are too deep to survey by snorkeling, even at base flows. We recommend that the Protocol state SCUBA or hookah diving will be employed in the surveys to sample deeper habitats.	We will add divers using surface-supplied-air to sample deeper habitats.
3	The qualitative survey procedure states that if Neosho muckets or other listed mussels are detected at any point of surveying, qualitative methods will immediately cease, and sampling will transition to quantitative methods. This provision disregards the greater effectiveness of qualitative searches for detecting the variety of species present, including rare species. Under the proposed Protocol, a random encounter with a listed mussel very early in qualitative sampling could result in under-detection of an area's mussel species. We recommend that the Protocol be revised to state that detection of a listed species will result in a transition to quantitative surveying, after which qualitative surveying will be completed.	As stated, the only reason to continue qualitative surveys is to document mussel assemblage composition, which is not the goal of this study. The goal of this study is to document if Neosho Mucket occur in the survey area, and if so, to estimate their densities in specific occupied habitats. The downside of additional qualitative sampling is that mussels collected/disturbed during qualitative surveys will influence density calculations from subsequent quantitative surveys. Given this, and the specific goals of the study, it is best to initiate quantitative

		sampling immediately upon detection of the target species. Other mussel protocols usually use a similar qualitative/quantitative transition.
4	The qualitative survey procedure states that voucher photographs will be taken of each species collected. The quantitative survey procedure does not address photo-documentation but does state that shell length of all Neosho muckets collected will be recorded in millimeters. We recommend that the Protocol be revised to state that voucher photographs/images shall be taken of all specimens of all listed mussel species collected and of at least one specimen of all other mussel species collected. The photographs/images must be of sufficient quality to support expert confirmation of species identifications. In addition, we recommend that the Protocol be revised to state that shell lengths of all listed mussel specimens collected shall be recorded in millimeters. We also recommend that for non-listed mussel species collected, the range of shell lengths be recorded and reported to demonstrate population recruitment.	We will take individual photos and length measurements of all listed mussels collected. For non-listed mussels, we will record min and max length and measure a subset of individuals.
5	The Protocol proposes to accomplish quantitative surveying using systematic sampling, as described by Strayer and Smith (2003). Sampling is to be performed within 100 m2 sampling areas using 3 random starts and a minimum of ten 0.25 m2 quadrats. The target minimum of ten sampling units would provide a relatively data-poor sample, especially with the use of 0.25 m2 quadrats. Length and width of the sampling area are not specified, and perhaps are to be varied to fit site habitats, but in most configurations will call for more than ten quadrats. We believe that setting/completing a higher target, such as a minimum of 15 sampling units, would result in better quantitative assessments.	We will revise protocols to include 15 0.25 m2 quadrats per quantitative sampling area.
6	The Protocol does not describe how the data collected are to be analyzed or presented, but we assume reports will be produced and made available to the Service, which include logical compilations and analyses of all pertinent data. Data on any occurrences of the Neosho mucket or other federally-listed species are most important, but data on other mussel species dependent on high quality lotic habitats also will be pertinent to assessing Project impacts. We recommend that plans for data analysis and reporting be described.	Data analysis will be presented in the USR.
7	Recommendations for sampling locations were based on assumptions that information from past surveys (the Service assisted in identifying this for the GRDA) will be used in composing an overall picture of mussel resources in the Project area. The Protocol does not describe if previously collected information was found to be sufficient for the relicensing analysis or would need to be supplemented in various respects. We recommend that this be addressed prior to conduct of the Phase 2 surveying.	Previous data was summarized and addressed in the ISR and this sampling plan was developed in response to that.
EcoAnalysts	Comment	Response
1	In Phase 1- working in this basin, we found many of the mussels in back channels or in outside bends of pools. So, I would suggest that although unionids are typically in shallow runs above and below riffles (not in riffles), they can also be in flowing parts of pools and secondary channels. In the Spring River in particular, we found the main part of the channel to be high energy and unstable. Most of the mussels we found were in secondary channels, along the edges	We will sample flowing-water areas in main-channel and side-channel areas and look for areas with the complex substrate (sand/gravel/cobble/clay mix) that is described here.

	of islands. If substrate was “spongy” (sand/gravel/cobble over a clay base) there were typically mussels. In the Neosho in particular, more mussels were found in cracks in the bedrock or in silt/clay substrate along banks.	
2	Phase 2 mentions using mask and snorkel. Even during low water, we had to dive many of the areas with Neosho mucket.	We will add divers using surface-supplied-air to sample deeper habitats.
3	Phase 3- 10 quantitative samples may be insufficient if the objective is to obtain a density estimate of Neosho mucket. 10 samples can be used as a pilot to estimate density and standard deviation from which an adequate sample size can be calculated. An error objective should be established (+/- x% of the mean). I typically use a 25 to 30% precision unless this is a long-term monitoring that you want to compare over time, then you might want a more precise estimate. However, as precision increases, sample size increases substantially.	Based on input from USFWS, we will increase to 15 quadrat samples per quantitative sampling area.
TCTC	Comment	Response
1	In general, the Council recommends the sampling plan be revised to follow the U.S. Fish and WildHfe Service and Texas Parks and Wildlife Department, Texas Freshwater Mussel Sampling Protocol (October 2021) - https://www. fws.govllibrary/collections/texas-freshwater-mussel-sampling-protocol.	The Texas Freshwater Mussel Sampling Protocols referenced are designed for mussel relocation projects in Texas. Their goal is to collect mussels and relocate them from areas of direct impact related to instream construction projects. Our goals are different, and therefore, we should follow a protocol designed specifically to address these goals. Specifically, our goals are to identify if Neosho Mucket occur in the proposed sampling areas, and if so, at what approximate densities. Therefore, we should focus our efforts specifically in areas of potential Neosho Mucket habitat, initially use qualitative searches which are best at identifying the presence of rare species (Neosho Mucket) and follow with quantitative surveys in areas where the target species is detected. Others (Heidi Dunn with EcoAnalysts) have confirmed the appropriateness of this three-phase sampling approach. The protocols referenced in this comment are designed for construction projects in Texas and are not appropriate for the specific goals of our study.
2	Increase the amount of qualitative survey hours	A minimum of 5 person-hours of qualitative survey effort will be conducted

		at each sampling location. This will provide a thorough search effort which is comparable to or greater than most other previous survey efforts. Qualitative survey effort during previous surveys in the study area (EcoAnalyst 2018) ranged from 0.5 - 6.0 person-hours per site and averaged less than 1.5 person-hours per site.
3	Identify the maximum effort at a given location (minimum identified currently)	As described in the survey protocol, a minimum of 5 person-hours of qualitative survey will be conducted at each location. If new species are found on the last person-hour, additional 1 person-hr searches will be conducted until no new species are encountered. Although this leaves the maximum amount of effort somewhat undetermined, it ensures that the team samples until no new species are being collected.
4	Include dive teams to ensure that all habitats are surveys and reduce sampling bias	We will add divers using surface-supplied-air to sample deeper habitats.
5	Increase number of quadrats to increase statistical strength	Based on input from USFWS, we will increase to 15 quadrat samples per quantitative sampling area.
6	Take photos of all individual muckets that are found, and any other sensitive/rare species found	We will photograph each individual listed mussel encountered.
7	Include a description of how the data will be presented and how previous studies will be included	Data analysis will be presented in the USR.
8	In the final report, include sized classes of all mussels found to help determine reproduction at each location	We will include at least the minimum and maximum size of each species collected in the final report. We will include size class distributions for listed species.

USFWS COMMENTS:

The U. S. Fish and Wildlife Service (Service) has reviewed the proposed Phase 2, Freshwater Mussel Sampling Protocol (Protocol) prepared by the Grand River Dam Authority (GRDA) in regard to ongoing relicensing of the Pensacola Hydroelectric Project (Project). We submit the following comments for your consideration.

1. The Protocol identifies three principal areas for the surveys. These reflect prior input provided by the Service, which recommended making use of existing information collected on mussel resources of the Project area. We agree largely with the three identified areas, although we recommend expansion of the Elk River area. Presently, the Protocol proposes surveying a 1.0-mile portion of the Elk River between the Missouri/Oklahoma state line and the confluence with Buffalo Creek. Although sensitive mussel species such as the Neosho mucket are not likely to occur much farther downstream than Buffalo Creek, it is plausible that they could occur upstream of the state line. Future management actions that may be taken by the GRDA include scenarios in which lentic (pooled) waters would inundate presently flowing habitats, including extending pooled waters upstream of the state line. Such change may impact the Neosho mucket and other sensitive mussels. It creates a justification for expanding the Elk River survey area, minimally to include the extent of river habitat likely to be affected by future pool changes.
2. Response: Survey area expanded to include all suitable mussel habitat downstream of the Kansas State line.
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3. The qualitative survey procedure states that surveyors will conduct a minimum of three one-person-hour searches (of each survey area), using mask and snorkel. The quantitative survey procedure states that surveyors will sample a minimum of ten 0.25 m^2 quadrats (within each survey area), without specifying surveyor gear. GRDA surveyors need to be prepared to dive using SCUBA or surface-supplied air to complete the surveys. While it is correct that typical Neosho mucket habitat is often described as flowing riffles and runs over gravel or gravel/sand substrates, Neosho muckets can occupy greater depths than cannot be surveyed efficiently by snorkeling. Potential habitats that will be encountered by the surveyors in the survey areas include extensive areas that are too deep to survey by snorkeling, even at base flows. We recommend that the Protocol state SCUBA or hookah diving will be employed in the surveys to sample deeper habitats.
4. The qualitative survey procedure states that if Neosho muckets or other listed mussels are detected at any point of surveying, qualitative methods will immediately cease, and sampling will transition to quantitative methods. This provision disregards the greater effectiveness of qualitative searches for detecting the variety of species present, including rare species. Under the

proposed Protocol, a random encounter with a listed mussel very early in qualitative sampling could result in under-detection of an area's mussel species. We recommend that the Protocol be revised to state that detection of a listed species will result in a transition to quantitative surveying, after which qualitative surveying will be completed.

5. The qualitative survey procedure states that voucher photographs will be taken of each species collected. The quantitative survey procedure does not address photo-documentation but does state that shell length of all Neosho muckets collected will be recorded in millimeters. We recommend that the Protocol be revised to state that voucher photographs/images shall be taken of all specimens of all listed mussel species collected and of at least one specimen of all other mussel species collected. The photographs/images must be of sufficient quality to support expert confirmation of species identifications. In addition, we recommend that the Protocol be revised to state that shell lengths of all listed mussel specimens collected shall be recorded in millimeters. We also recommend that for non-listed mussel species collected, the range of shell lengths be recorded and reported to demonstrate population recruitment.
6. The Protocol proposes to accomplish quantitative surveying using systematic sampling, as described by Strayer and Smith (2003). Sampling is to be performed within 100 m^2 sampling areas using 3 random starts and a minimum of ten 0.25 m^2 quadrats. The target minimum of ten sampling units would provide a relatively data-poor sample, especially with the use of 0.25 m^2 quadrats. Length and width of the sampling area are not specified, and perhaps are to be varied to fit site habitats, but in most configurations will call for more than ten quadrats. We believe that setting/completing a higher target, such as a minimum of 15 sampling units, would result in better quantitative assessments.
7. The Protocol does not describe how the data collected are to be analyzed or presented, but we assume reports will be produced and made available to the Service, which include logical compilations and analyses of all pertinent data. Data on any occurrences of the Neosho mucket or other federally-listed species are most important, but data on other mussel species dependent on high quality lotic habitats also will be pertinent to assessing Project impacts. We recommend that plans for data analysis and reporting be described.
8. Recommendations for sampling locations were based on assumptions that information from past surveys (the Service assisted in identifying this for the GRDA) will be used in composing an overall picture of mussel resources in the Project area. The Protocol does not describe if previously collected information was found to be sufficient for the relicensing analysis or would need to be supplemented in various respects. We recommend that this be addressed prior to conduct of the Phase 2 surveying.

Scott A. Thompson
Executive Director

OKLAHOMA Environmental Quality

Kevin Stitt
Governor

May 6, 2022

Darrell E. Townsend II, Ph.D.
Vice President, Ecosystems & Watershed Management
Grand River Dam Authority
P.O. Box 70
Langley, OK 74350-0070

RE: Tar Creek Trustee Council's Comments on Proposed Phase 2, Freshwater Mussel Sampling Protocol

Dear Dr. Townsend:

As designated Tar Creek Trustee Council (Council) Lead Administrative Trustee, I received your certified letter requesting Council comment on the GRDA's proposed Phase 2, Freshwater Mussel Sampling Protocol on April 8, 2022. The request was circulated to the Council trustees and discussed during our April 12th meeting.

In general, the Council recommends the sampling plan be revised to follow the U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department, *Texas Freshwater Mussel Sampling Protocol* (October 2021) - https://www.fws.gov/library/collections/texas-freshwater-mussel-sampling-protocol. More specific recommendations are:

a) increase the amount of qualitative survey hours,
b) identify the maximum effort at a given location (minimum identified currently),
c) include dive teams to ensure that all habitats are surveys and reduce sampling bias,
d) increase number of quadrats to increase statistical strength,
e) take photos of all individual muckets that are found and any other sensitive/rare species found,
f) include a description of how the data will be presented and how previous studies will be included, and
g) in the final report, include sized classes of all mussels found to help determine reproduction at each location.

The Council welcomes the opportunity to provide constructive feedback on this protocol as we prepare to implement selected restoration projects detailed in the Council's Phase 1 Restoration Plan and Environmental Assessment Plan.

If you have any questions for the Council, you can contact me at susan.mensik@deq.ok.gov or at (405) 702-9145.

Sincerely,

Susan Mensik

Susan Mensik, Lead Administrative Trustee Representative
Tar Creek Trustee Council

PENSACOLA HYDROELECTIC PROJECT: AQUATIC SPECIES OF CONCERN STUDY

September 2022