APPENDIX E-13 Additional Published References

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Impact of water-level fluctuations on cyanobacterial blooms: options for management

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Abstract Climate change can promote harmful cyanobacteria blooms in eutrophic waters through increased droughts or flooding. In this paper, we explore how water-level fluctuations affect the occurrence of cyanobacterial blooms, and based on the observations from case studies, we discuss the options and pitfalls to use water-level fluctuations for lake and reservoir management. A drawdown in summer causes an increase in retention time and increased water column nutrient concentrations and temperature of shallow water layers, which may lead to severe cyanobacterial blooms. This effect can potentially be counteracted by the positive response of submerged macrophytes, which compete for nutrients with cyanobacteria, with a higher chance of cyanobacterial blooms under eutrophic conditions. The balance between dominance by submerged macrophytes or cyanobacteria is temperature sensitive with stronger positive effects of drawdown as inhibition of cyanobacterial blooms expected in colder climates. Complete drying out reduces the amount of cyanobacteria in the water column after refilling, with lower water nutrient concentrations, lower fish biomass, lower abundance of cyanobacteria, higher transparency, and higher cover of submerged plants compared to lakes and reservoirs that did not dry out. Water-level rise as response to flooding has contrasting effects on the abundance of cyanobacteria depending on water quality. We conclude that water-level fluctuation management has potential to mitigate cyanobacterial blooms. However, the success will depend strongly on ecosystem properties, including morphometry, sediment type, water retention time, quality of inlet water, presence of submerged vegetation or propagules, abundance of fish, and climate.

Keywords Climate change · Cyanobacteria · Drawdown · Flooding · Lake · Macrophyte · Phytoplankton

Introduction

Aquatic ecosystems are increasingly subject to warming as well as to alterations in rainfall patterns as a consequence of climate change (IPCC 2007). Climate models predict an increase in stochastic events such as

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unpredictable floods and droughts as well as a change in timing or duration of ice cover and snowmelt (IPCC 2007; Wantzen et al. 2008). As a consequence, shallow water bodies will be increasingly prone to prolonged droughts or flooding (Williamson et al. 2009). Particularly in the warmer climates, such as the Mediterranean, shallow water bodies may turn into ephemeral ones during multi-annual droughts (Beklioglu et al. 2007; Romo et al. 2013; Jeppesen et al. 2014).

Indeed, more variation in water levels in non-regulated systems is observed over the last decades (Adrian et al. 2009). Variability in lake hydrology, resulting in fluctuations in the water level, is a key factor affecting the functioning of lake ecosystems (Coops et al. 2003; Beklioglu et al. 2007; Jeppesen et al. 2014). One of the anticipated effects of climate change is the promotion of harmful cyanobacteria blooms in eutrophic waters (Paerl and Huisman 2009; Wagner and Adrian 2009). Increased droughts, increased water retention times, and increased temperatures are demonstrated to contribute to the dominance of cyanobacteria over other algae (Mooij et al. 2005; Paerl and Huisman 2008; O'Farrell et al. 2011; Kosten et al. 2012). In reservoirs, where water is typically removed for human water demand, the rate and extend of water-level fluctuations is mostly larger than in natural shallow lakes. Temporal variations of mean residence times occur not only at seasonal time scales, but also at shorter scales and are closely related to mixing and nutrient transport processes occurring within the reservoir (Rueda et al. 2006). In addition, extensive growth of riparian plants with subsequent nutrient release during rewetting (Kleeberg and Heidenreich 2004) or lacking recolonization of macrophytes after long periods of dry out may occur more frequently than in natural shallow lakes.

Overall, water-level fluctuations in both un-regulated as well as regulated waterbodies may be an important trigger for the promotion of cyanobacterial blooms. Rising of the water level in shallow lakes may result in a transition from the macrophyte-dominated state to the cyanobacteria-dominated state, due to a deterioration of the underwater light climate (Blindow et al. 1993; Havens et al. 2004). This may be of less relevance for deep, stratified lakes. In deep regulated lakes, changing water levels may result in a compressed vertical niche for macrophytes (Rørslett 1984) and consequently reduce their effects on cyanobacteria (Sachse et al. 2014).

On the contrary, lowering of the water table in shallow lakes may result in the opposite, where submerged macrophytes can benefit from the increased light availability and prevent the dominance of cyanobacteria. This knowledge is applied in lake restoration: The controlled lowering of the water level is one of the tools used to improve the water quality in degraded lakes (Coops and Hosper 2002). In deep natural lakes and reservoirs, macrophytes in the littoral zones may rather suffer from declining water levels. In general, more information became available on the effects of water-level fluctuations on the development of submerged and emergent vegetation over the last decade, but still little is known about the possibilities to use water-level fluctuations to mitigate cyanobacterial blooms.

Proposed working mechanisms

Using water-level fluctuations as a management tool to mitigate cyanobacterial blooms can potentially work through several mechanisms. First, there is a direct dilution effect of letting in water. When the outlet is open, this will reduce the water retention time, and the water body gets flushed out. This can lead to fluctuations in water level, but can also be performed while maintaining a stable water level. Lower retention times will reduce the nutrient concentration by reducing the impact of internal nutrient loading or from other external sources (Welch 1981). Furthermore, when cyanobacteria and algae are present, these will partly be washed out, depending on the flushing rate and the quality of the incoming water. The latter parameters determine the occurrence and the threshold levels for shifts between clear and turbid states (Hilt et al. 2011).

Flushing of shallow temperate lakes during the growing season of submerged macrophytes may only bring a turbid lake to a clear water state if the flushed water is relatively clear and the flushing rate is strong enough to induce the shift (Hilt et al. 2011). When the outlet is closed, extra (clearer) water will lead to a rise in water level, which dilutes the phytoplankton suspension, at least temporarily lowering the phytoplankton concentrations and algal blooms. These direct effects of increasing water volume or reducing the retention time on cyanobacterial abundance will be strongly influenced by the quality of the inlet water.

However, when water-level fluctuations are applied as a management tool to improve the ecological conditions and water quality, water managers mostly aim for indirect effects to reduce cyanobacterial blooms. By managing the water level, they aim to restore a macrophyte-dominated clear water state in shallow water bodies (Coops and Hosper 2002). The water level is then regulated such to stimulate the establishment and growth of submerged and emergent macrophytes (Sarneel et al. 2014a). Once established, the macrophytes should then maintain the clear water state and inhibit cyanobacterial blooms (Jeppesen et al. 1998; Scheffer 1998; Kosten et al. 2009; Dong et al. 2014). Macrophytes can do so by capturing nutrients from the water column that are then no longer available for cyanobacterial growth (Van Donk and Van de Bund 2002; Hilt et al. 2010). This is especially true for non-rooted submerged macrophytes (Mjelde and Faafeng 1997). Many macrophyte species also excrete allelopathic substances which can inhibit cyanobacterial growth (Gross 2003; Hilt and Gross 2008). Cyanobacteria species and strains, however, may show a differential sensitivity towards macrophyte allelochemicals (Eigemann et al. 2013; Švanys et al. 2014), but existing studies on the sensitivity of toxic versus non-toxic strains of cyanobacteria were contradictory (Mulderij et al. 2005; Liu et al. 2007; Švanys et al. 2014). In addition, most studies on macrophyte allelopathic effects have been conducted with single cyanobacteria species, and species interactions may reverse the results (Chang et al. 2012). Conclusions concerning the in situ growth inhibition potential of macrophyte allelochemicals (e.g., Shao et al. 2013) should thus be drawn with caution.

Furthermore, macrophyte beds may serve as refugium for zooplankton against predation by fish resulting in a higher grazing pressure on phytoplankton (Schriver et al. 1995; Burks et al. 2001) and periphyton (Mahdy et al. 2015), harbour more macroinvertebrates, and promote piscivorous fish (Blindow et al. 2014 and references therein; Grutters et al. 2015). Together, these properties of macrophytes may reduce cyanobacterial abundance and increase water transparency (Van Donk and Van de Bund 2002; Bakker et al. 2010).

The timescale of direct and indirect measures to reduce cyanobacterial blooms by water-level management is different. Whereas direct measures are aimed at a short-term solution, the switch to a clear water state with macrophytes and without cyanobacterial blooms may require a longer time perspective. In this paper, we explore how water-level fluctuations affect the occurrence of cyanobacterial blooms and what lessons can be learned for the application of water-level management.

Impact of water-level fluctuations on cyanobacteria: case studies

Water-level management has been successfully used to stimulate macrophyte development (Coops et al. 2003; Van Geest et al. 2005; Holm and Clausen 2006; Ejankowski and Solis 2015), but is generally not aimed at reducing cyanobacterial blooms directly. However, water levels in lakes and reservoirs may fluctuate because of usage and extraction of water, drought, or flooding. To evaluate the effect of water-level fluctuations on cyanobacterial blooms, we therefore collected case studies of lakes and reservoirs where water levels fluctuated and where the water bodies contained high densities of cyanobacteria before or after water-level fluctuations. Furthermore, the studies had to report alterations in cyanobacterial abundance in relation to the water-level fluctuations.

We found 13 studies from a wide variety of habitats and ranges of water-level fluctuations from 12 different locations (Table 1). We realize that this list may not be complete, but we want to use these cases as examples to illustrate the important factors to take into account when applying water-level management with the aim to reduce or prevent cyanobacterial blooms.

Response of cyanobacteria to water-level fluctuations

Water-level fluctuations can affect the occurrence of cyanobacterial blooms (Table 1). A drawdown in summer by reducing flow rates causes an increase in retention time and an increase in water column nutrients both through the reduction of water volume as well as an increase in internal nutrient loading by release of nutrients from the sediment (Welch 1981). In deep lakes, water-level drawdown can disrupt the thermal stability of the water body and thus cause the elimination of the thermocline in summer. In shallow lakes, water drawdown can considerably decrease

Table 1 Case studies of the effect of water-level fluctuations (WLF) on cyanobacterial blooms

Type of WLF	Water body	Coordinates	Type/trophy	Maximum depth (m)	Water-level fluctuation/maximum amplitude (interannual)	Effect on cyanobacteria	Mechanism	References
Rise	Lake Kinneret, Israel	32°50′N, 35°35′E	Lake/reservoir/ meso-eutrophic	43	4 m (1991–92), 4.7 m (2002–03)	Blooms	Reduced zooplankton grazing pressure due to increased fish reproduction	Zohary and Ostrovsky (2011)
	Lake Peipsi, Estonia	58°40′N, 27°26′E	Lake/eutrophic	15.3	Water-level rise after year of lowest water level (1996)/1 m	Strong and long-lasting summer or autumn blooms	Potentially increased zooplankton grazing pressure on smaller algae	Kangur et al. (2003)
	Lake Sakadaš, Croatia	45°35′N, 18°51′E	Floodplain lake river Danube/ eutrophic–hypertrophic	4	Extreme flooding with water-level rise in 2006/ ~ 4 m	Strong biomass reduction	Transition from a turbid to a clear state with well-developed macrophyte vegetation; possible stronger allelopathic effects and high zooplankton grazing pressure	Mihaljevic et al. (2010)
	Floodplain lakes lower Rhine, Netherlands	51°51–53′N, 5° 45–55′W	5 floodplain lakes/eutrophic	2–15	Winter flooding by river	Increased phytoplankton biomass and shift from diatoms to chlorophyte and cyanobacteria dominance	Input of nutrients in frequent flooded lakes	Van den Brink et al. (1993)
Oscillating	Lake Võrtsjärv, Estonia	58°17′N, 26°01′E	Lake/eutrophic	6	Mean annual amplitude: 1.4 m, maximum difference 3.2 m, (North Atlantic Oscillation, warmer winter results in higher water level)	Blooms	High water levels: turbid conditions favor shade-tolerant filamentous cyanobacteria, low water levels: lower N/P ratios and higher light conditions favour nitrogen-fixers	Nõges et al. (2003)
	Laguna Grande, Argentina	34°10′–34°17′S; 58°48′–58°53′W	Paraná river floodplain Wetland Reserve Otamendi: shallow lakes and ponds/ hypertrophic	<1	Multi-year natural flood pulse pattern in the Lower Paraná River/ 1 m	Blooms of nitrogen-fixing cyanobacteria during extreme low water levels	Regime shift from a floating plant-dominant state during very high waters to phytoplankton dominance during low water level	O'Farrell et al. (2011)

Table 1 continued

Type of WLF	Water body	Coordinates	Type/trophy	Maximum depth (m)	Water-level fluctuation/maximum amplitude (interannual)	Effect on cyanobacteria	Mechanism	References
	Lake Maggiore, Italy	45°55′N, 8°32′E	Lake/ oligotrophic	372	Drought-induced decreases in lake level, followed by heavy precipitation due to extreme meteorological events/maximum amplitude 3 m	Blooms	Release of nutrients from drying and rewetting of the littoral zone	Callieri et al. (2014)
	Lake Eymir, Turkey	39°57′N, 32°53′E	Lake/ eutrophic	5.5	Drought drawdown followed by rise/maximum amplitude 2 m	Increase in biovolume and proportion	Accumulation of ammonium; increasing anoxia	Beklioglu and Tan (2008)
Draw down	Lake Arancio, Italy	37°38′N, 13°03′E	Reservoir/ hypertrophic	4–15	Water drawdown in summer/11-m amplitude	Blooms	Breaks thermal stability and induces mixing; strong internal loading; long retention times	Naselli-Flores and Barone (2003)
	Lake Võrtsjärv, Estonia	58°17′N, 26°01′E	Lake/ eutrophic	6	Drought-induced winter drawdown/3.2-m amplitude	Strong increase in biovolume	Phosphorus release from resuspended sediments	Nõges and Nõges (1999)
	Lake Xeresa, Spain	39°6′N, 0°12′W	In-lake mesocosms/ mesotrophic	N.a.	Summer drawdown/from 80 to 58 cm and 78 to 26 cm (two years)	No blooms but succession from filamentous to chroococcal cyanobacteria	Improved light conditions for macrophytes; grazing by plant-associated rotifer species	Romo et al. 2004
	Lake Albufera, Spain	39°20′N, 0° 21′W	Coastal Lake/ hypertrophic	1.5	Summer drawdown	Increase in biomass	Higher water retention time	Romo et al. (2013)
Refill after dry out	Northern Ethiopian reservoirs	12° and 15°N and between 37°10′E and 40°10′E	Reservoirs/ eutrophic	1.3–9.5 m	Complete drying out and subsequent refill	Lower biomass	Lower biomass of fish; greater macrophyte cover; lower nutrient concentrations	Teferi et al. (2014)

N.a., Not applicable

water depth, and shallow water layers warm up faster than deeper water.

Under these conditions, both the biomass and relative abundance of cyanobacteria increases, which may lead to severe cyanobacterial blooms. These phenomena have been described in the Mediterranean reservoir Lake Arancio, where a summer water-level drawdown resulted in strong blooms of *Microcystis cf. panniformis* Komárek et al. and *Microcystis aeruginosa* (Kützing) Kützing (Naselli-Flores and Barone 2003; Table 1). Shallow Lake Albufera in Spain responded to lower water levels with one to two orders of magnitude higher biomass of *M. aeruginosa* (Romo et al. 2013; Table 1). A winter water-level drawdown in the shallow Estonian Lake Võrtsjärv induced a three times higher biovolume of nitrogen-fixing cyanobacteria and a mass development of *Cyanonephron styloides* Hickel (Nõges and Nõges 1999; Table 1).

These effects of water-level drawdown can potentially be counteracted by the response of submerged macrophytes to the lowering of the water depth: In Lake Xeresa in Spain, the abundance of charophytes increased when the water level was low, and this prevented cyanobacterial blooms even when extra nutrients were added (up till a threshold) (Romo et al. 2004). Similarly, in Turkish Lake Eymir, spring drawdown of the water level as a result of drought improved underwater light conditions under water and stimulated macrophyte development. Despite increasing cyanobacterial (*M. aeruginosa*, *Oscillatoria* sp. and *Anabaena* sp.) biomass over summer, the macrophyte-dominated state was retained over summer (Beklioglu and Tan 2008; Bucak et al. 2012; Table 1).

However, free floating macrophytes are not able to provide this service: In Laguna Grande, a drawdown broke the dominance of floating plants and induced a shift to cyanobacterial blooms [*Planktolyngbya limnetica* (Lemmermann) Komárková-Legnerová et Cronberg, *Merismopedia minima* Beck, *Arthrospira*, *Anabaenopsis elenkini* Miller, *Sphaerospermum aphanizomenoides* (Forti) Zapomelová Zapomelová, Jezberová, Hrouzek, Hisem, Reháková & Komárková] and disappearance of the macrophytes (O'Farrell et al. 2011). A summer drawdown may thus stimulate the development of both submerged macrophytes and cyanobacteria. Therefore, summer drawdown may result in cyanobacterial blooms, unless the development of submerged macrophytes can prevent this.

The outcome of this interaction between submerged macrophytes and cyanobacteria depends strongly on the trophic state of the water body: The more eutrophic, the more chance that cyanobacteria can dominate. However, also in more oligotrophic lakes, water-level drawdown may result in cyanobacterial blooms as drying and rewetting of littoral areas of oligotrophic Lake Maggiore resulted in nutrient release and subsequent cyanobacteria blooms of *Dolichospermum lemmermannii* (P.G.Richt.) Wacklin, L.Hoffm. & Komárek (Callieri et al. 2014; Table 1).

Furthermore, the balance between macrophyte or cyanobacterial dominance is influenced by temperature and may thus vary with latitude. In the temperate Lakes Peipsi and Võrtsjärv in Estonia and the Swedish Lakes Tåkern and Krankesjön, a lowering of the water level led to dominance of submerged macrophytes, and there was very little algal development (Blindow et al. 1993; Nõges and Nõges 1999; Kangur et al. 2003). In the Mediterranean Lakes, Xeresa and Eymir cyanobacterial biomass increased, but macrophyte development prevented cyanobacterial blooms (Romo et al. 2004; Beklioglu and Tan 2008). In the subtropical floodplain lake, strong cyanobacterial blooms developed during drawdown, whereas no submerged plant development was present and floating macrophytes disappeared (O'Farrell et al. 2011). Whereas latitudinal comparisons of the effect of water drawdown may be confounded by differences in trophic state among lakes of different latitudes, with lower latitudinal lakes being more eutrophic, an increased chance of cyanobacterial blooms at higher temperatures is in general still to be expected.

There is a strong difference between the effect of a drawdown or drying out of lakes and reservoirs. Whereas a drawdown in summer stimulates growth and abundance of cyanobacteria, a complete drying out has the opposite effect. When lakes and reservoirs are refilling after drying out, they have a higher transparency and higher cover of submerged plants, as a result of germination and re-establishment, compared to lakes and reservoirs that did not dry out (Van Geest et al. 2005; Teferi et al. 2014). Northern Ethiopian reservoirs did have lower nutrient concentrations, a lower fish biomass and a lower abundance of cyanobacteria (*Microcystis* sp.) when they had been dry (Table 1).

Drying out does not result in enhanced water column nutrient concentrations as there is no internal loading. In fact, phosphorus binds to the sediment under aerobic conditions, and therefore, there is a net phosphorous retention, instead of release, under completely dry conditions (Smolders et al. 2006; Søndergaard et al. 2013). Rewetted fens, however, show opposite patterns. Elevated levels of P release rates and P concentrations in pore water of up to three orders of magnitude larger than under natural reference conditions were found in rewetted fens whose surface soil layers consisted of highly decomposed peat (Zak et al. 2010). The fish biomass is strongly reduced after drying out, resulting in less sediment disturbance and less predation of zooplankton and thus higher grazing pressure on phytoplankton (Teferi et al. 2014).

Water-level rise as response to flooding has contrasting effects on the abundance of cyanobacteria. Lake Kinneret in Israel experienced its biggest ever bloom of invasive, nitrogen-fixing cyanobacteria in 1994 [*Aphanizomenon ovalisporum* (Forti)] and 2005 [*Cylindrospermopsis raciborskii* (Woloszynska) Seenayya et Subba Raju] after exceptional water-level rises (Zohary and Ostrovsky 2011; Table 1). In the Estonian Lake Peipsi, flooding led to a reduction in light availability and thus in abundance of submerged macrophytes, whereas the biomass of large nitrogen-fixing *Aphanizomenon flos-aquae* (L.) Ralfs increased (Kangur et al. 2003). In the lower Dutch river Rhine, winter flooding with river water high in nutrients resulted in cyanobacterial (*A. flos-aquae)* blooms in floodplain lakes (Van den Brink et al. 1993; Table 1).

On the contrary, shallow Lake Sakadaš in the Danube valley shifted from the turbid to the clear state after extended flooding (Mihaljevic et al. 2010; Table 1). During flooding, macrophytes appeared throughout the entire floodplain, which was associated with clear water and a strong reduction in the biomass of *Limnothrix redekei* (Van Goor) Meffert, *Planktothrix agardhii* (Gom.) Anagn.et Komárek, and *Pseudanabaena limnetica* (Lemm.). In a small eutrophic temperate lake in Germany, flooding resulted in a fivefold increase in dissolved organic carbon and pelagic phytoplankton concentrations due to stronger thermal stratification and anoxia-driven phosphorus release from sediments (Brothers et al. 2014). However, in an Italian reservoir, water-level rise diluted the cyanobacterial biomass and decreased retention times reduced nutrient concentrations as a result of internal loading (Naselli-Flores and Barone 2003). Therefore, the effect of water-level rise depends strongly on the effect of flooding on water nutrient concentrations and transparency.

Shifts in cyanobacteria species composition in response to water-level fluctuations

Apart from affecting the abundance of cyanobacteria, water-level fluctuations also induce shifts in the abundance of functional groups (Nõges and Nõges 1999; Romo et al. 2004). The drivers of these shifts include alterations in the availability of resources for cyanobacteria growth (nutrients and light) as well as the intensity of grazing pressure as a consequence of water-level fluctuations.

During a drawdown, internal phosphorus loading can result in a reduction in the N/P ratio in the water column nutrient concentrations. In several lakes, it has been observed that this led to both an absolute and relative increase in N_2-fixing cyanobacteria, such as *Aphanizomenon skujae* Komárková-Legnerová et Cronberg in the Estonian Lake Võrtsjärv (Nõges and Nõges 1999; Nõges et al. 2003) and *P. limnetica* (Lemmermann) Komárková-Legnerová et Cronberg in the Argentinian Laguna Grande (O'Farrell et al. 2011) during drawdown.

Also, low light availability results in the dominance of shade-tolerant cyanobacteria which would be outcompeted by other phytoplankton groups under high irradiance in clear water conditions (Nõges and Nõges 1999; Nõges et al. 2003). This can be seen when water-level rise reduces light availability in the water column such as in Lake Võrtsjärv which resulted in blooms of the shade-tolerant *L. redekei* (Van Goor) Meffert (Nõges et al. 2003), whereas when water-level rise results in clear water conditions, such as in the Croatian Lake Sakadaš, the same species declines (Mihaljevic et al. 2010).

Furthermore, zooplankton grazing pressure affects the composition of the cyanobacterial community. When fish is (temporary) absent, as a result of fish kills during drawdown in winter or as a result of complete drying out, large zooplankton grazing pressure reduces the amount of unicellular cyanobacteria and phytoplankton and induces dominance by larger filamentous cyanobacteria such as observed in the Estonian Lake Peipsi and Spanish Lake Xeresa (Kangur et al. 2003; Romo et al. 2004). However, partial winter fish kill has also been found to result in a strong reduction in crustacean biomass due to abundant young-of-the-year fish, leading to a strong increase in phytoplankton biomass during the subsequent summer (Hilt et al. 2015).

Using water-level fluctuations to mitigate cyanobacterial blooms

Based on the observations of the effect of water-level fluctuations on cyanobacterial blooms, we can now discuss the options and pitfalls to use water-level fluctuations for lake and reservoir management. We summarized the effect of water-level rise and drawdown on cyanobacteria in Fig. 1 and the main mechanisms responsible for the response of cyanobacteria to water-level fluctuations in Fig. 2.

Water-level rise

Water levels can rise at high precipitation or inflow as well as reduced outflow. Particularly in river floodplains, strong fluctuations of water levels in floodplain lakes are observed as a consequence of the water level in the rivers. Positive effects are the decreased retention time of the water, which is able to reduce and perhaps even flush out cyanobacterial blooms (Verspagen et al. 2006; Romo et al. 2013). Reduced retention times may result in reduced water nutrient concentrations due to the dilution effect and consequently reduces the amount of cyanobacteria (Fig. 2a; Romo et al. 2013). It will depend on the quality of the inlet water as well as the internal loading what the best application of water-level rise is as a management measure. Rørslett and Johansen (1996) reported positive effects of high water levels for macrophyte establishment in a Norwegian reservoir. Often, such reservoirs are devoid of macrophytes due to strong water-level fluctuations and thus lack the beneficial effects of macrophytes in reducing the abundance of cyanobacteria (Sachse et al. 2014).

Several pitfalls may jeopardize the potential positive effects of water-level rise on reducing cyanobacterial blooms. When the water quality of the inlet water is poor, e.g., with high nutrient concentrations, this increases cyanobacteria growth and the chance of blooms (Fig. 2b; Van den Brink et al. 1993). Alternatively, when achieving a water-level rise by reducing the outflow of water, for instance with a sluice, this will increase the retention time, which generally enhances cyanobacterial growth (Romo et al. 2013). Furthermore, at higher water levels, macrophyte growth may be compromised by reduced light availability. Also, in a German reservoir, rising water levels resulted in large areas of inundated plants and led to a very strong year class of roach, a major planktivorous fish, which will eventually lead to turbid conditions (Fig. 2b; Kahl et al. 2008). In tropical lakes and reservoirs, fluctuating water levels enhanced nutrient transfer which positively affected fish yields (Kolding and Van Zwieten 2012).

For application as a management tool, to avoid these pitfalls, a critical evaluation of the quality of the inlet water, the potential internal nutrient loading, and factors controlling the abundance of planktivorous fish is necessary. Also, the timing of water-level rise can influence its effect. In temperate environments with strong seasonality, negative effects of water-level rise on submerged macrophytes can be avoided by applying water-level rise outside the main macrophyte growing season. In contrast, flushing with nutrient-poor water as applied for restoring eutrophic Lake Veluwe in the Netherlands during winter periods (Hosper and Meyer 1986) could probably be more

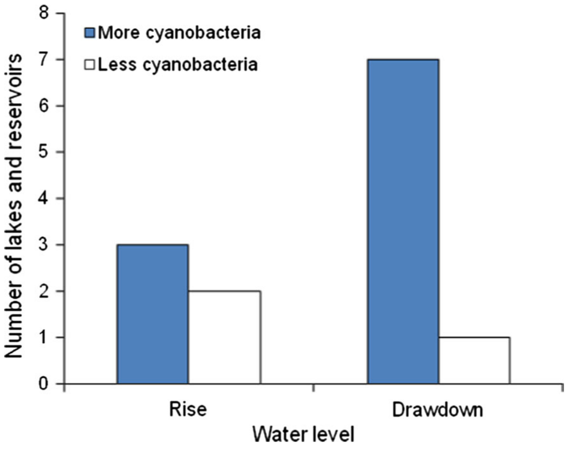

Fig. 1 Number of lakes and reservoirs with more or less cyanobacteria in response to different types of water-level fluctuation. The response of each water body is documented in Table 1

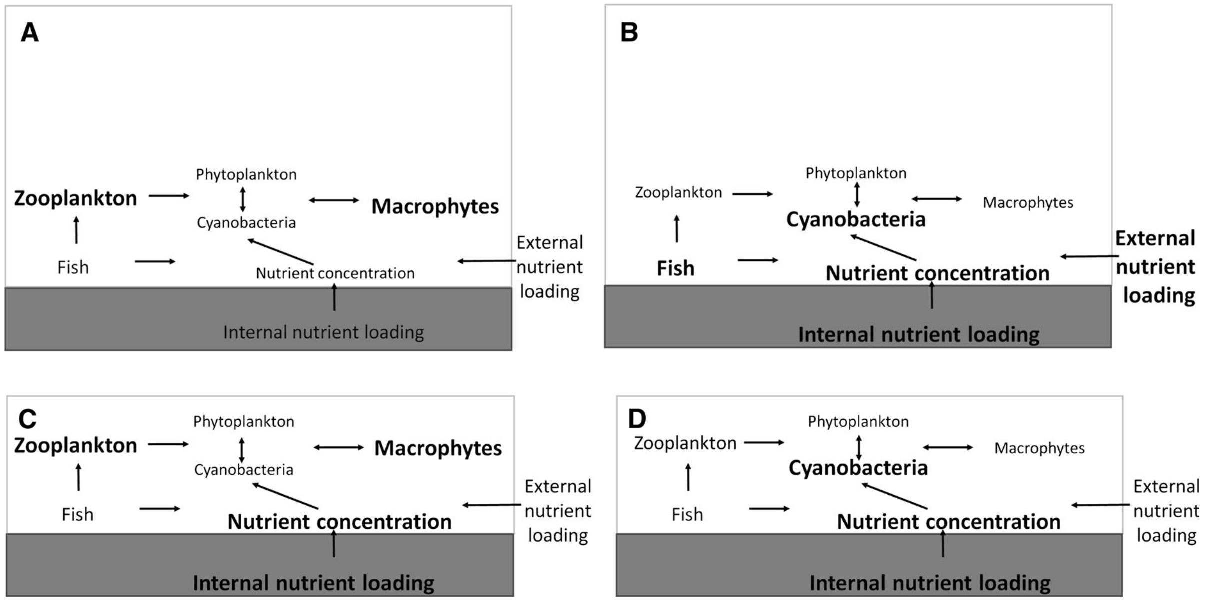

Fig. 2 Effects of water-level rise (**a**, **b**) and drawdown (**c**, **d**) on cyanobacteria abundance in shallow waters. Higher water levels were found to potentially result in lower cyanobacteria abundance due to flushing and increased macrophyte development with subsequent effects on zooplankton (**a**; examples: Lake Sakadaš, Laguna Grande). Opposite effects were found due to increased internal or external nutrient loading (**b**; examples: Lake Peipsi, Dutch floodplain lakes) or increased zooplanktivorous fish abundance (Lake Kinneret). Decreasing water levels increase the importance of internal nutrient loading in shallow waters. Under these conditions, abundant macrophytes and zooplankton may inhibit cyanobacterial blooms, particularly after complete drying out, when fish abundance is low and nutrients are bound in the sediment (**c**; example: Northern Ethiopian reservoirs). In most cases when there is no complete drying out, a drawdown supports cyanobacteria abundance due to increased internal nutrient loading (**d**; examples: Lakes Arancio, Albufera, Maggiore). Due to contrasting effects of water-level fluctuations on the ecosystem properties, it is also possible that the net effect on cyanobacteria is neutral (not depicted in the figure). For more examples, see Table 1. The *size of the text* indicates the abundance of the parameter of interest

effective in spring or summer due to the direct positive influence on the interaction between submerged macrophytes and turbidity in addition to nutrient export (Hilt et al. 2011).

Water-level drawdown

Water-level drawdown occurs when water loss exceeds the inflow. Water loss can occur when the outflow exceeds the inflow, when evaporation exceeds precipitation and when water infiltration exceeds seepage, or a combination of these factors. A drawdown results in an increased retention time and a larger influence of the internal processes. Both will stimulate cyanobacterial growth, and blooms have been reported to occur after drawdowns (Cooke 1980). In addition, drawdowns in deep lakes and reservoirs in summer may reduce their macrophyte-covered area (Rørslett 1984) and consequently reduce their hampering effects on cyanobacteria (Sachse et al. 2014). On the other hand, a positive effect was reported when water levels were decreased shortly after the spawning period of roach in a German reservoir, because it resulted in a total loss of the new roach year class (Kahl et al. 2008). In shallow lakes and reservoirs, the development of submerged macrophytes can be stimulated due to an improved light climate. Overall, it will strongly depend on the lake depth and morphometry, timing and extend of the drawdown, and interaction between the macrophytes and the cyanobacteria if a drawdown leads to reduced or increased cyanobacterial blooms (Fig. 2c, d).

A potential pitfall is that the positive effects of the measure depend strongly on the development of submerged macrophyte vegetation. Therefore, it is important that enough propagules or nearby sanctuaries are present to allow for the macrophytes to develop (Bakker et al. 2013). Planting of macrophytes might be considered in cases of insufficient propagules (Hilt et al. 2006). Timing of drawdown will strongly mitigate its effects: When applied at the start of the macrophyte growing season, the submerged macrophytes can profit optimally from the drawdown, as establishment is a sensitive step in macrophyte development. Drawdown in winter exposes parts of the sediment to both freezing and loss of water which can have strongly negative effects on aquatic plants that have no overwintering structures. It was thus recommended as a management option for nuisance macrophyte growth (Cooke 1980).

Another constraint of the success of drawdown is that the impact of benthivorous fish will increase when water volume is reduced during a drawdown. High fish activity will jeopardize the successful development of submerged vegetation and can enhance nutrient availability in the water column. Water drawdown measures thus may have to be accompanied by a strong reduction in benthic fish through biomanipulation (Meijer et al. 1990).

Also at high sediment nutrient levels, a reduction in water volume may lead to very high nutrient concentrations in the water column, which may favor the development of cyanobacteria over macrophytes as the former are growing faster, and the latter may get covered in dense periphyton layers (Fig. 2d). Furthermore, strong nutrient release of the sediment alters the N/P ratio of available nutrients, as particularly P is released from the sediment. This may stimulate the development of N-fixing cyanobacteria or mat-forming benthic cyanobacteria on sediments with a high P-loading (Nõges et al. 2003).

The success of drawdown as a management measure to mitigate cyanobacterial blooms will also depend strongly on the water temperature. Higher temperatures will favor cyanobacterial growth, and shallower water leads to higher temperatures and potentially increased cyanobacterial growth. Therefore, in warmer regions, drawdown may have less positive effects than in colder regions. Furthermore, during drawdown in Mediterranean regions, the salinity of the water increases, which alters the community composition of the aquatic organisms (Beklioglu et al. 2007).

Temporary drying out

An extreme form of a water drawdown is complete drying out. Temporary drying out for several months has a strong positive effect on reducing or preventing the occurrence of cyanobacterial blooms. The pitfalls that are associated with drawdown are largely avoided with this measure, as complete drying out will lead to fish kills eliminating the negative effects of benthivorous fish on macrophytes due to sediment resuspension and bioturbation. Furthermore, phosphorus is retained under aerobic conditions instead of released, resulting in a net reduction in internal nutrient loading. Furthermore, drying out can stimulate macrophyte recruitment, both of submerged and emergent species (Van Geest et al. 2007; Sarneel et al. 2014a; Van Leeuwen et al. 2014). Altogether, strong positive effects of drying out are documented both on the development of macrophyte vegetation and on the prevention of cyanobacterial blooms in shallow water bodies (Fig. 2c). Furthermore, these effects are prolonged, and the effects last for multiple years (Van Geest et al. 2007; Teferi et al. 2014).

Potential pitfalls are that the results of drying out may depend on the sediment characteristics. Nutrient release from drying and rewetting of lake shores has been associated with increasing cyanobacteria blooms in oligotrophic Lake Maggiore (Callieri et al. 2014). Particularly in organic soils, the biogeochemistry of nutrient exchange between the sediment and water column can be complex, and the resulting nutrient concentrations in the water column after drying out and rewetting on these soils may not be straightforward (Smolders et al. 2006; Lamers et al. 2015). Furthermore, exposure of peaty soil during drawdown or drying out may result in the burning of peat and fast decomposition. This may result in shoreline erosion, particularly when the shores have steep slopes. This would for instance apply to fens that originate from peat excavation activities (Gulati and Van Donk 2002). In contrast, nutrient fluxes from rewetted emergent plants added little to the reservoir-wide internal loading when sufficient iron supply guaranteed an efficient P retention in the sediments (Kleeberg and Heidenreich 2004).

Another potential pitfall is that drying out may eliminate undesirable high densities of benthivorous and planktivorous fish, but also valuable fish species (Beklioglu et al. 2007). In the end, prolonged drying out may cause the aquatic system to be converted to a terrestrial one which has negative effects on purely aquatic vegetation (Veen et al 2013; Sarneel et al 2014b). Furthermore, little is known about the longevity of propagules of submerged macrophytes; hence, the feasibility of germination of submerged vegetation from the propagule bank after prolonged dry conditions is uncertain (Bakker et al. 2013). In deep regulated lakes, drying out of littoral areas may result in a compressed vertical niche for macrophytes, and often, reservoirs lack macrophytes, which reduces the potential benefit of drying out (Rørslett 1984; Rørslett and Johansen 1996).

Morphometry of the water body

The results of water-level fluctuation management will depend strongly on the geometry of the water body. Water-level fluctuations will have a much stronger impact on shallow water bodies then on deep ones, when the range of fluctuations is equal (Sarneel et al 2014b). Also, the slope of the shoreline will strongly mitigate the effect of water-level fluctuations. Shallow water bodies with shallow slopes will experience large impact of water-level fluctuations, whereas deep water bodies with steep shores may be hardly affected (Nowlin et al. 2004).

Furthermore, the lake or reservoir depth can affect whether there is stratification. When water-level fluctuations do not result in mixing of the water layers, then the effect may be limited. However, when water-level fluctuations result in a breaking up of stratification, then the impact can be much stronger due to an increased nutrient availability in the upper part of the water column as a result of mixing of the water layers (Naselli-Flores and Barone 2003; Zohary and Ostrovsky 2011). This in turn may stimulate the growth of cyanobacteria, enhancing the chance of a cyanobacterial bloom. However, mixing can also prevent cyanobacteria blooms (Visser et al. 1996), whereas stronger stratification can also support cyanobacteria blooms (Wagner and Adrian 2009).

Conclusions

Management of water-level fluctuations has not been used yet to particularly mitigate cyanobacterial blooms. Based on our exploration of case studies in the literature, we conclude that it is in principle possible to do this. A water-level drawdown will only reduce cyanobacteria blooms when accompanied by a strong increase in submerged macrophyte abundance, which subsequently compete for nutrients with cyanobacteria or when it leads to a complete drying out. Chances for these effects are likely to be higher in shallow lakes or in reservoirs when fully emptied. In deep lakes and reservoirs, decreasing water levels (without complete drying out) have only been reported to result in cyanobacteria blooms. Water-level rises as response to flooding were found to have contrasting effects on the abundance of cyanobacteria in shallow and deep lakes and reservoirs.

Overall, the outcome of a certain regime of water-level fluctuations will depend strongly on the local conditions, including lake or reservoir depth and morphometry, sediment type, water retention time, quality of inlet water, presence of submerged vegetation or propagules thereof, abundance of benthivorous and planktivorous fish, and climate zone. When these are known, it is possible to estimate the benefits and risks of water-level management as a measure to mitigate cyanobacterial blooms.

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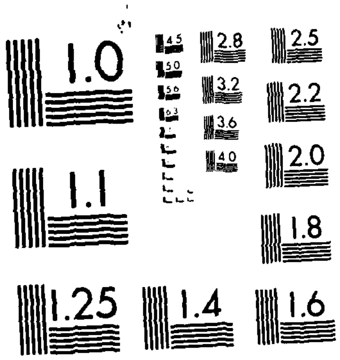

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This report synthesizes and summarizes information gathered from available sources about the physicochemical and biological effects of water-level changes on reservoir ecosystems. It describes how variations in both the physical environment (i.e., basin morphometry, bottom substrates and structures, erosion, turbidity, temperature, and water-retention time) and the chemical

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environment (i.e., nutrients and dissolved oxygen) caused by water-level changes can directly influence a reservoir's production of fish. It also describes the complex ways in which water-level changes affect aquatic plants, zooplankton, and the benthos and how these trophic variations can eventually affect the growth, reproduction, and harvest of fish.

The final part of the report summarizes the effects of drawdown and flooding on reservoir fish populations and recommends ways to manage reservoir fluctuation zones by making controllable variables as favorable as possible for fish survival, spawning, and feeding.

A

PREFACE

This report was prepared by the National Reservoir Research Program (NRRP), Fish and Wildlife Service, for the U. S. Army Engineer Waterways Experiment Station (WES) under Intra-Army Order WESRF-82-24, dated 6 October 1981. The study forms part of the Environmental and Water Quality Operational Studies (EWQOS), Task II.E, "Environmental Effects of Fluctuating Reservoir Water Levels." The EWQOS Program is sponsored by the Office, Chief of Engineers, U. S. Army, and is assigned to WES under the management of the Environmental Laboratory (EL).

This technical report was prepared by Mr. G. R. Ploskey, Fishery Biologist (Research), for the NRRP, of which Mr. R. M. Jenkins was Director. The work was conducted under the direct supervision of Dr. John Nestler, Water Quality Modeling Group, and the general supervision of Mr. D. L. Robey, Chief, Ecosystem Research and Simulation Division, and Dr. J. Harrison, Chief, EL. Dr. J. L. Mahloch was the Program Manager, EWQOS.

Commanders and Directors of WES during the preparation of this report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. The Technical Director was Mr. Fred R. Brown.

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CONTENTS

A REVIEW OF THE EFFECTS OF WATER-LEVEL CHANGES ON RESERVOIR FISHERIES AND RECOMMENDATIONS FOR IMPROVED MANAGEMENT

PART I: INTRODUCTION

1. Effects of water-level changes on reservoir ecosystems have been of concern since the early 1930's when the Tennessee Valley Authority (TVA) began its first extensive studies of large reservoirs. Wood (1951) reviewed most of the literature published before 1950. The importance attached to the effects of water-level changes by agencies responsible for reservoir operations (e.g., TVA, U. S. Army Corps of Engineers, leasing utilities) and for management of fishery resources in reservoirs (State fish and game agencies, U. S. Fish and Wildlife Service) is emphasized by the large volume of literature on the subject (see the extensive annotated bibliographies by Fraser 1972; Triplett et al. 1980; Ploskey 1982).

2. Water-level changes have attracted widespread interest because they affect, or are affected by, virtually every use of reservoirs (water supply, irrigation, flood control, water quality control, hydroelectric power generation, and fishing and other forms of recreation). Water-level fluctuations concern some conservation groups because they may degrade or destroy valuable fish and wildlife habitat or unique plant communities such as bottomland hardwoods. They also may adversely affect fish, wildlife, or reservoir-based recreation. Availability of water often determines water levels and is the primary concern of most reservoir users. A volume of water with sufficient potential energy to permit efficient and timely generation of electricity is the principal concern of associated utilities. Although flood control and water quality control may complement one another (i.e., releases of water during dry periods supplement the flow of water downstream and simultaneously provide

additional capacity for containment of flood waters), needs for water quality control and hydropower generation often conflict.

3. Scheduling models have been developed to help reservoir operators optimize reservoir use and resolve conflicts among competing users (Shane 1981). These models enable the prediction of variation in pool levels, water releases, and hydropower generation for specific project purposes. Performance measures (generation, flood damage, operating constraint violations, and power production) normally accompany basic scheduling data. In present reservoir scheduling models, environmental variables are best described as simple prescriptions for water release to regulate pool levels for such purposes as mosquito control or fish propagation. As multipurpose demands on reservoirs increase, so does the need to evaluate and assign priorities to different uses. Informed, equitable decisions concerning alternative reservoir operations to benefit fish require extensive data on the effects of water-level changes on reservoir ecosystems and fisheries. Current scheduling models rarely address fishery concerns because useful quantitative data on fish, fisheries, and limnology are scarce.

4. While detailed information required to properly manage reservoir ecosystems and enhance fisheries is slowly being accumulated, the demand for quality fisheries is increasing. The Sport Fishing Institute (1977) estimated that 34.3 million freshwater anglers fished about 638 million angler days in 1975. With the number of anglers increasing about 3.2 percent per year (about twice as fast as the U. S. population), the Institute estimated that by 1985 47 million freshwater anglers would be fishing about 871 million days per year. If reservoir fishing continues to account for 26 percent of all freshwater fishing (U. S. Bureau of Sport Fishing and Wildlife 1962) in 1985 and the cost of an angler day--estimated to be $11.50 in 1975 (U. S. Fish and Wildlife Service 1977)--increases an average of 5 percent per year from 1975 to 1985, there will be about 12.2 million anglers on

reservoirs in 1985 fishing an estimated 226 million angler days per year and spending about $4.2 billion for retail goods, services, and fees.

5. This report is a summary and synthesis of information gathered from available literature about the effects of water-level changes on reservoir ecosystems. Recommendations on reservoir operation were either taken directly or synthesized from these sources.

PART II: PHYSICOCHEMICAL SYSTEMS

Introduction

6. This section presents a discussion of how water-level changes affect several physicochemical variables that, in turn, influence the population dynamics, production, or harvest of fish. Such a discussion is warranted because it is essential to an understanding of the effects of water-level changes on fish. Most water-level effects on fish are indirect, mediated by physicochemical changes that alter essential habitat or trophic conditions. These indirect effects are described under the heading "Biological Systems." Among the most important physical variables affecting fish or fisheries are aesthetics, basin morphometry, bottom substrates and structures, erosion, turbidity, temperature, and water-retention time. Important chemical variables include nutrients (carbon, nitrogen, and phosphorus) and dissolved oxygen.

Physical Variables

7. The flooding and exposure of reservoir bottoms and terrestrial vegetation are the most visually obvious effects of water-level fluctuations. Among other reasons why reduced water levels are unpopular is that exposed mud flats and dead, decaying vegetation are not aesthetically pleasing (Davis 1967). Flooding frequently kills trees and other higher terrestrial plants, which then become recurring eyesores whenever water levels are lowered. The early establishment of herbaceous vegetation for aesthetic purposes and erosion control in summer drawdown zones is important (Benson 1976). Drawdown may interfere with boating and recreation by reducing surface area, exposing previously submerged structures that are hazardous to navigation, and by reducing the number of ramps usable by boaters. Marinas and boat docks must be moved or become stranded, and recreation areas (e.g., beaches, picnic sites) may be left considerable distances from the water.

8. A less immediate effect of water-level changes is shoreline modification due to erosion and redeposition of sediments from bank and bottom areas. Waves driven by the wind distribute sediments vertically

according to particle sizes; gravel-sized and larger rocks remain near shore, whereas slightly smaller particles may be displaced somewhat offshore and still smaller particles may be suspended and removed from the shore zone altogether (Zhivago and Lange 1969). Wind and rain also erode substrates exposed by drawdown.

9. The area modified by erosion is largely determined by the magnitude of water-level fluctuations and the morphometry of the basin (Turner 1981). Rates of shoreline changes depend on characteristics of the fluctuation zone--its slope, degree of exposure, and composition. When steep shores of mountain impoundments of Norway were exposed to 6-m fluctuations in water level, they eroded rapidly, leaving a zone of barren rock interspersed with gravel. Although the area of bottom in the fluctuation zone was small because of the steeply sloped basin, an extensive area below the drawdown limit was covered with eroded materials and adversely affected (Grimås 1961). Lowering of mean lake levels in Llyn Tegid, Great Britain, eliminated most of the shallow littoral zone and left behind a steep-sided basin with a mud bottom (Hunt and Jones 1972b). Steeper shores accelerated fallout of organic matter and sediment to greater depths.

10. In contrast to the relatively permanent rapid changes in steep-sided impoundments, Missouri River reservoirs (Benson 1980) and large shallow reservoirs of the USSR (Zhivago and Lange 1969) required over 25 years of erosion and shoreline modification before a dynamic equilibrium was established between erosion and shore building. Alluvial soils in these exposed, wind-swept reservoirs were easily eroded. However, because of the gradual slope of most shores, erosion was slow and involved large areas, even when vertical changes in water levels were small. Rising turbid waters redeposited sediments at higher elevations, and eroded sediments often collected to form terraces in adjacent areas. Terrestrial vegetation that developed in dewatered areas undoubtedly helped to slow erosion, at least temporarily.

11. Aggus (1971) observed that cleared areas of Beaver Reservoir, Arkansas, were subjected to greater and more rapid erosion than areas with vegetation. Breakup and decomposition of flooded herbaceous vegetation resulted in a conspicuous increase in erosion and redeposition. Erosion also was noticeably slowed in several Kansas reservoirs by flooded herbaceous vegetation established during a drawdown in the previous growing season (Groen and Schroeder 1978).

12. Periodic exposure of sediments by reduced water levels may consolidate flocculent sediments and thereby increase reservoir capacity slightly. In experiments with sediments dredged from Lak opka, Florida, Fox et al. (1977) noted that dewatering and dryi for various periods of time shrank bottom sediments; and water used t fill the test containers had the same or lower nutrient concentrat reduced turbidity, and higher dissolved oxygen tensions than water iginally drained from the containers. Reduced water levels and concomitant compaction and aerobic decay of organic matter in Lake Tohopekaliga, Florida, reduced the depth of organic sediments by 50 to 80 percent (Wegener and Williams 1974).

13. Sources of colloidal turbidity in reservoirs include inflowing tributaries, erosion of banks (by waves, wind, and rain), and suspension of bottom sediments by waves or currents. Water-level changes affect the gradient and rate of flow through reservoirs, thereby determining rates and sites of sedimentation (Lara 1973). At low water levels, sediments previously deposited near inflow areas may be sluiced farther down the reservoir. Turbidity from shores and shallow areas is largely controlled by the composition of soils or sediments, rates of erosion, and the extent of mixing of water. Other factors being equal, the more extensive the mixing, the greater the turbidity.

14. Turbidity may increase or decrease as water levels change because fluctuating water levels expose areas of different composition or cover to erosion. Reservoir drawdown may increase turbidity by resuspending previously eroded sediments (Neal 1963; Markosyan 1969).

However, low water levels, in Lake Chautaugua, Illinois, reduced turbidity over that in high-water years because pondweed (Sago sp.) became abundant and reduced turbulence (Starrett and Fritz 1965). Increased water levels often reduce turbidity, especially if inundated areas are covered with terrestrial vegetation or are barren of fine sediments. Vegetation decreases erosion by binding soils and precipitating colloidal clay particles (Irwin 1945). Fluctuating water levels may limit the growth of macrophytes that bind soils and dampen waves in the littoral zone, thereby resulting in increased turbidity (Judd and Taub 1973).

15. Water-level changes that significantly alter depth, area, or fetch may change depth of mixing or patterns of stratification. A shift from stable to fluctuating water levels could reduce the tendency for much of a reservoir to stratify (Turner 1981). This possibility is even more likely if changes in water levels result from selective discharge from the hypolimnion (e.g., see Wiebe 1938) or from rapid rates of discharge--i.e., complete water exchange six or more times a year. Temperatures of inflowing waters tend to dominate the thermal regime of reservoirs as the retention time of water in the basin decreases (Carmack et al. 1979). Cooper (1980) found that high water levels and insignificant drawdowns in late summer prolonged thermal stratification in Grenada Reservoir, Mississippi. Serruya and Pollingher (1977) found that lowering of water levels in Lake Kinneret, Israel, reduced the volume-to-area ratio, which accelerated heat transfer by increasing the input of mechanical energy. The volume of mixed water increased while that in the hypolimnion was reduced (i.e., thermocline depth increased).

Chemical Variable

16. Nutrients enter reservoirs in flowing waters or are leached and physically separated from inundated soils, organic debris, terrestrial vegetation, or drowned animals after water levels increase (Ploskey 1981). Significant annual changes in water levels and inflow have more effect on nutrient levels and productivity in older reservoirs

(> 10 years) than in newer ones. Effects of water-level changes in new reservoirs usually are masked by exceptionally high rates of biological productivity and nutrient cycling. However, as reservoirs age and nutrients are lost to inactive sediments, outflow, or fish harvest (Ellis 1937; Kimsey 1958), the effects of yearly variations in inflow and water levels become more apparent, especially if land use in the watershed changes significantly (e.g., see Mitchell 1975).

17. The quantity of nutrients released from soils after they are inundated by rising waters depends on the organic content, state of decay, and amount of soil involved (Sylvester and Seabloom 1965). Rates of release and use depend on temperature and dissolved oxygen concentration. Soils with organic detritus (e.g., leaves and twigs) provide more food for aquatic detritivores (some bacteria, benthos, zooplankton, and fish) and nutrients for algae than do inert soils.

18. Ball et al. (1975) found that vegetation type influenced the rate and quantity of nutrients released from recently inundated areas in the basin of Palmetto Bend Reservoir, Texas. Grasses and herbage released nutrients faster than trees, contained a greater quantity of nutrients per unit of vegetation weight, and were available in greater quantities (weight per unit area). Similar findings were reported by Denisova (1977). Ball et al. (1975) listed the following conclusions:

a. Effects of inundated terrestrial vegetation on water quality are not necessarily permanent but depend on flushing rates, land use, temperature, and basin morphometry.

b. Decomposition rates of vegetation are largely a function of tissue type, and leaves decompose and release nutrients more rapidly than do bark and wood.

c. Phosphorus is rapidly leached from dead hardwood leaves and particularly from leaves that are damaged or broken.

d. Grasses may be completely decomposed within one year after inundation.

19. Moreover, the type of terrestrial biome (e.g., coniferous forest, grassland, deciduous forest, desert--after Odum 1971) in which a reservoir is located may determine the quality and quantity of nutrients and detritus supplied by changes in water levels. Because herbaceous plants, as in grasslands or deciduous forests, die and decay rapidly after inundation, they are assimilated into the trophic system as high-energy detritus. Though the largest quantities of herbage seldom are as great as the quantity of litter in mature forests, herbaceous plants may be more important per unit of weight than litter, because litter generally contains a greater proportion of indigestible matter--i.e., twigs and wood debris with large amounts of cellulose (Sylvester and Seabloom 1965; Ball et al. 1975). Inundation of a relatively barren fluctuation zone (alpine or desert reservoirs) provides only small quantities of detritus or nutrients.

20. Seasonality of changes in water levels is yet another factor influencing the amount of nutrients and detritus made available. Yount (1975) found nearly constant oven dry weights of needle litter in coniferous forest throughout the year (ca. 1.4×10^4 kg/ha), whereas weights of litter in deciduous forest fluctuated seasonally, with maxima in November and May and minima in September and March. Quantities of phosphorus (P) and nitrogen (N) in coniferous and deciduous forest litter also varied seasonally, generally peaking in winter. More P and N were present when rainfall was below normal because leaching was reduced. Use of nutrients and detritus by aquatic plants and animals is greater if flooding occurs during the growing season than if it occurs in winter.

21. Increased duration of inundation and exposure to waves increases the potential assimilation of nutrients from shoreline areas. Petr (1975) observed that prolonged filling of reservoirs contributes more toward increasing fish production than rapid filling. Short-term fluctuations of water levels (days or weeks) have seldom been related to major changes in water chemistry or biological productivity. By contrast, large seasonal or annual changes have the greatest effect

because low water of sufficient duration provides time for exposed soils to aerate, thereby increasing the availability of nutrients (Birch 1960; Bennett 1962) and time for herbaceous terrestrial plants to colonize exposed sediments (Frey 1967; Groen and Schroeder 1978). When dewatered areas with vegetation are flooded for 3 or more months of the growing season, aquatic animals and plants have enough time to fully colonize the areas and benefit from the nutrients available.

22. In reservoirs with large annual fluctuations in water level, water-exchange rates may vary greatly because of changes in reservoir operation or volume. Water exchange rate and outlet depth influence nutrient retention or "nutrient trap efficiency" (Turner 1981) by determining the amount of nutrient loading and loss, as well as thermal characteristics and mixing of water. If inflow and release of water are constant, a reservoir exchanges water more frequently and retains fewer nutrients when water levels are reduced than when they are high. Nutrient retention and biological production are high as reservoirs fill, because most inflowing nutrients and those from within the basin are retained. By contrast, drawdowns during periods of low inflow flush nutrients downstream. Martin and Arneson (1978) found that a reservoir with a deep outlet released nutrients, whereas a lake with a surface outlet acted as a nutrient trap.

23. The quantity of nutrients retained in a reservoir does not always reflect the amount available for biological production. Jenkins (1973), for example, found that among impoundments with similar concentrations of total dissolved solids (TDS), those with higher rates of water exchange supported larger standing crops of fish, although not necessarily of the desired species. Between TDS concentrations of 100-300 mg ℓ^{-1}, fish crops increased as TDS increased in hydropower mainstream reservoirs; however, total crops remained relatively constant as TDS increased in hydropower storage impoundments. Also, not all nutrients retained in reservoirs are available to biota because many are adsorbed to particulate matter or sediments (Cooper 1967). Fitzgerald (1970) found that aerobic lake muds have a strong affinity for phosphate phosphorus (PO_4) and can sorb as much as 0.125 mg PO_4 per gram of dry

sediment in 30 minutes. Complex interactions among biota and nutrients alter the form and availability of nutrients, as well as major paths of nutrient cycling in reservoirs. Many nutrients occur in several forms (i.e., in different compounds or as living biomass) which are in dynamic equilibrium (Wetzel 1975).

24. Spatial and temporal variations in oxygen concentration may be caused by changes in water levels that inundate areas with varying amounts of organic matter or that alter the amount of surface area exposed to the wind. The greatest oxygen demands result from respiration of microorganisms associated with decay of organic matter in organically rich sediments, herbaceous vegetation, or leaf and grass litter. Inundated inorganic soils and woody vegetation have less effect on biochemical oxygen demand than does readily digestible organic matter (Sylvester and Seabloom 1965; Ball et al. 1975). Vertically, oxygen sources and demands may be separated; demands are greatest in the metalimnion and upper hypolimnion in summer (Lund et al. 1963; Lasenby 1975); whereas primary sources are in the epilimnion, which is reaerated from the atmosphere and by photosynthesis in the euphotic zone. Organic load and water temperature are the major factors controlling oxygen demand at different depths. However, basin morphometry and mixing determine whether the demand for oxygen will exceed the supply.

25. Anoxic conditions may occur throughout the water column if prolonger ice or ice and snow cover prevents diffusion and circulation, or limits light penetration. Such anoxia may cause extensive fish kills (Il´ina and Poddubnyi 1963; Il´ina and Gordeyev 1972). However, without ice cover, concentrations of oxygen are less apt to be low in winter than in summer because temperature is inversely related to the solubility of oxygen in water and directly related to rates of oxygen use by biota.

26. Except in extremely nutrient-rich areas, anoxia is unlikely to occur in shallow water mixed by the wind or in reservoirs where water exchanges rapidly. Stewart (1979) observed that inundated terrestrial vegetation in Rising Sun Lake, New Jersey, lowered oxygen

concentrations (but not below 4 mg ℓ^{-1}) in the epilimnion (areas above a depth of 4.6 m) in summer. In two reservoirs of the Churchill Falls hydroelectric project, Labrador, Canada, no oxygen deficiency was observed in newly flooded areas because of rapid rates of water exchange and mixing of water (Duthie and Ostrofsky 1975).

27. Nutrient loading and oxygen demands in shoreline areas are controlled by the number and characteristics (vegetation and geology) of inundated areas, as influenced by basin slope, height and frequency of water-level fluctuations, and reservoir age (Scully 1972; Denisova 1977). For example, McLachlan (1970b) noted that changes in concentrations of oxygen and nutrients were greater and more rapid over gently sloping shores than over steep rocky ones, because more area was involved and growths of terrestrial vegetation were more dense. As waters rose over gradually shelving areas covered with grasses and animal feces, oxygen concentrations were reduced significantly (McLachlan 1970b, 1974). Anaerobic conditions in sediments can result in release of nutrients. When water levels increased in Lake Apopka, Florida,(a hypereutrophic reservoir) and reflooded nutrient-laden sediments, nutrient concentrations increased and ultimately caused anoxia that killed fish (Fox et al. 1977). By contrast, in nutrient-poor reservoirs or in older impoundments where the upper portion of the fluctuation zone lacks nutrients and vegetation due to years of erosion and water-level fluctuation, increased water levels may have little effect on water chemistry. In Lake Blåsjön, Sweden, Grimås (1961) observed increased crops of zooplankton when 6-m fluctuations were initially implemented; after several years, however, increases in water levels over barren rocky areas did not affect zooplankton populations.

28. Effects of reduced water levels on nutrient concentrations and oxygen demands depend on reservoir age and site-specific characteristics. As aerobic water recedes from shallow areas where a sharp gradient in nutrient concentrations exists across the substrate-water interface, some interstitial water concentrated with nutrients may drain into adjacent surface waters (Turner 1981). Increased nutrient

concentrations and reduced oxygen tensions have been observed in waters receding from marshes (Kadlec 1960; Pazderin 1966; Henson and Potash 1977) or from partly exposed and decaying beds of macrophytes (Geagan 1961). However, in a new African reservoir, McLachlan (1970b) observed no significant changes in the concentrations of nutrients or dissolved oxygen as waters receded from rich, gradually shelving areas. Erosion of exposed beds by rains could increase nutrient levels by washing materials into reservoirs. In older impoundments (> 10 years), where nutrient concentrations at high elevations are lower than at low elevations because of erosion, reduced water levels may increase nutrient concentrations and biochemical oxygen demands by recirculating previously eroded sediments (Markosyan 1969). By contrast, in relatively new reservoirs (< 10 years), where the concentrations of nutrients in sediments usually vary less with elevation than in older reservoirs, reduced water levels probably would not greatly alter the input of nutrients.

PART III: BIOLOGICAL SYSTEMS

Introduction

29. In this report, biological systems are divided into two broad categories: fish-food biota and fish and fisheries. Such a division is useful because it places emphasis on fish and still includes essential information about the effects of water-level changes on plants and invertebrates.

30. Water-level changes affect fish populations most by altering trophic conditions (prey abundance, type, and availability) or habitat. Trophic conditions for fish are affected by changes in the abundance of fish-food biota. Fish respond to altered trophic conditions or habitat by increasing or decreasing growth, reproductive success, and standing crop. Resulting changes in fish populations are ultimately reflected in the annual harvest of fish by anglers.

31. Outstanding in the documented effects of water-level changes on biological systems is the scarcity of quantitative data. This paucity is not surprising, however, given the complexity and variability of biological systems. Although responses of some fish populations to seasonal changes in water levels can be forecasted, actual results may vary because of the effects of unpredictable variables such as temperature, prey availability, or disease. In short, because of multiple variable effects, water-level changes and biological consequences do not have simple cause-effect relations.

Fish-Food Biota

32. Aquatic plants. The three major groups of plants in reservoirs are phytoplankton (microscopic planktonic algae), periphyton (attached microscopic algae), and aquatic macrophytes. The importance of each group as fish food varies among reservoirs because of variations in the productivity of plant communities and in the structure and efficiency of aquatic food webs in different reservoirs. Most of the energy flow from plants to sport fish is indirect, by way of herbivorous zooplankton, benthos, or fish. The net transfer of energy to fish is less efficient in long food chains where energy is transferred several times than in short food chains because about 90 percent of the energy produced at one

level is lost to respiration, egestion, and excretion (Kozlovsky 1968). The species composition and relative abundance of fish may determine the relative use of phytoplankton, periphyton, or macrophytes because of species-specific differences in diets.

33. In addition to serving as food for fish, attached plants often serve other valuable functions in reservoirs. Periphyton and macrophytes provide habitat for invertebrates and fish (e.g., see Cowell and Hudson 1967; Johnson and Stein 1979) and after dying release large quantities of nutrients (Denisova 1977). Macrophytes, like other underwater structures in the littoral zone, may influence productivity and predator-prey relations (Cooper and Crowder 1979). Vegetation of some form (aquatic or terrestrial) is important to the spawning of many species of fish (Lapitskii 1966; Carlander 1969, 1977).

34. Effects of water-level changes on phytoplankton have received little attention (Mitchell 1975), and quantitative data are sparse. Accurate estimates of primary production are difficult to obtain because phytoplankters are highly responsive to changes in their immediate environment and crops turn over rapidly. As suspended algae, phytoplankton production probably is affected more by changes in nutrients, light, temperature, grazing pressure, etc., that result from water-level fluctuations than from the fluctuations directly. An exception is the physical removal of phytoplankton by release of water from the euphotic zone in stratified reservoirs (e.g., see Sreenivasan 1966) or rapid release of water from unstratified mainstream impoundments (Benson and Cowell 1967).

35. Productivity of reservoirs varies greatly seasonally and yearly due to variations in runoff from the drainage basin. High turbidity in inflowing water may limit productivity by reducing light, or if the retention time of water in the euphotic zone is low, phytoplankton populations may not have sufficient time to develop productive densities before being discharged through the dam. According to Wetzel (1975), as the concentrations of phytoplankton increase, the integral photosynthetic efficiencies generally increase until the maximum levels are restricted by self-shading of light.

36. Observations of changes in the abundance, biomass, or production of phytoplankton concomitant with, or after, changes in water levels can almost always be explained by changes in nutrient levels or light, as modified by factors such as temperature, turbidity, or basin morphometry. Guseva (1958) observed that the greatest abundance of littoral phytoplankton in Rybinsk Reservoir, USSR, was associated with high water levels that flooded large areas of terrestrial litter and detritus. Populations in the pelagic zone were less well developed and not influenced by water levels. Similarly, in Lake Mikolajskie, Poland, Pieczyn'ska (1972) found that the biomass of algae was 6 times greater and primary production 11.5 times greater in the fluctuation zone than in the pelagic zone. Pieczyn'ska concluded that the rich fluctuation zone affected total lake productivity and that the extent of the effects depended on the configuration of the shoreline terrace, shoreline development, and water-level fluctuations. Lowering of water levels 10 m in Lake Sevan, USSR, exposed 85 km^2 of bottom area and resuspended previously eroded sediments and nutrients. Although turbidity increased, certain bacteria and phytoplankton populations, which may have been nutrient limited before drawdown, increased exponentially. In Lake Laurel, Georgia, reduced phosphorus concentrations, measured after the lake was drawn down for 6 months and then refilled, helped to explain a post-drawdown decrease in phytoplankton biomass (Barman and Baarda 1978), though flooding of terrestrial plants in the drained zone suggested that phytoplankton biomass would increase.

37. Observations in new reservoirs also suggest that productivity is directly related to nutrient availability and light, as influenced by water levels. Primary production during the first 2 or 3 years of impoundment is high in shallow reservoirs where slight increases in water levels inundate large areas of terrestrial vegetation (Baranov 1961), unless high turbidity limits it (e.g., see Duthie and Ostrofsky 1975). In new deep reservoirs, where nutrients can be limiting, trophic upsurge is uncommon (Baranov 1961), though two- to three-fold increases in phytoplankton crops and production were observed temporarily in

in Lake Ransaren, Sweden, after water levels inundated rich terrestrial areas (Axelson 1961; Rodhe 1964).

38. Increased nutrient availability, resulting from high inflows or changes in water level, has little positive effect on primary productivity during cool months of the year because production is regulated by solar radiation and temperature in temperate waters (Wetzel 1975). In tropical impoundments, nutrients usually are more limiting than temperature, and seasonal changes in primary production are often related to mixing of water or rainy seasons.

39. Mitchell (1971, 1975) conducted the most quantitative study of the effects of water-level changes on phytoplankton productivity. Primary productivity was estimated bimonthly by the uptake of radioactively labeled (^{14}C) bicarbonate during 2-hour incubations taken before and after 1230 hours on sampling days in Lake Mahinerangi, New Zealand. Results of multiple-regression analyses on seasonal productivity trends for 1964-66 suggested that water level and temperature were major factors influencing productivity at near optimal light intensities. Mitchell (1971) explained 78.3 percent of the variability in light-saturated photosynthesis (Y_{est} in mg $C \cdot m^{-3} \cdot hour^{-1}$) in 1964-66 by the following equation:

$$\underline{Y}_{est} = 3.3326 \log_e \underline{X}_1 + 0.1635\ \underline{X}_2 - 0.1381\ \underline{X}_3 - 13.6933$$

where $\underline{X}_1$ is water-level elevation at the dam (ft), $\underline{X}_2$ is temperature (°C), and $\underline{X}_3$ is hours of daylight. Partial regressions of photosynthesis on temperature and water level were significant; day length apparently was the least significant of the three factors. Water levels were more or less continuously rising in 1964-66 when productivity data were used to develop Mitchell's predictive equation, whereas they were higher and more stable in 1968-70 (Mitchell 1975). Productivity in 1968-70 was higher than predicted by Mitchell's (1971) equation, probably because of continuous delayed releases of nutrients from inundated pastures. Other possible responses of phytoplankton were (a) to water level (linear responses as predicted by Mitchell's equation, where nutrients are released from inundated areas at a constant rate and are mineralized and used completely or not at all) or (b) to changes in water levels (where nutrients are released and used rapidly, relative to the time of fluctuations). Mitchell concluded that whatever the response, it is probably modified by variations in the ratio of reservoir volume to the area of land inundated. In stratified reservoirs, the ratio of the epilimnial volume to the area inundated may be more important than the ratio of total volume to that area.

40. Periphyton is affected more directly than phytoplankton by changes in water levels because it is usually attached to fixed substrates (e.g., trees, sediments, rocks, or sand) in the euphotic zone. When water levels decline and expose substrates to the air for more than a few days, attached algae desiccate and die. In Lewis and Clark Lake, South Dakota-Nebraska, where water levels fluctuate little, submerged trees were important substrates for periphyton development. Dense growths (6×10^6 cells cm^{-2}) developed in May, whereas the maximum density on trees in Lake Francis Case--a reservoir upstream where water levels fluctuated 9-11 m annually--was only 6.6×10^3 cells cm^{-2}, about 0.11 percent of that on trees in Lewis and Clark Lake (Benson and Cowell 1967). Winter drawdown in Lake Francis Case apparently destroyed the full development of periphyton communities (Cowell and Hudson 1967; Claflin 1968). Claflin (1968) observed that periphyton growths were heaviest between 3 and 7 m, being limited by wave action in the upper 3 m and by light availability at depths exceeding 7 m. Barman and Baarda (1978) found that periphyton biomass was significantly reduced for almost a year after substrates of Lake Laurel, Georgia, were exposed for 178 days and reflooded. Accrual rates also were below normal in the first summer after treatment. By the second summer, accrual rates were near those observed before the lake was drained.

41. Growth of periphyton is determined by the content and availability of nutrients, required elements (e.g., silica, calcium), and light intensity which attenuates with depth. "Shock events" (Round 1971), such as the breakdown of thermal stratification, intense shading (by turbidity), or water-level changes, may act to regulate species composition and production.

42. The importance of periphyton production to total primary production should not be overlooked, especially in relatively shallow reservoirs or ones with extensive shoreline and littoral development. For example, Pieczyn'ska (1972) showed that periphyton production in the fluctuation zone of Lake Mikolajskie, Poland, amounted to over 40% of the total for that area, whereas phytoplankton production made up only about 10%. Ultimately, the size of the fluctuation zone compared with that of the pelagic zone will determine the relative contribution of algae in each zone to total primary production.

43. From a fisheries standpoint, the presence of some macrophytes is desirable because they increase productivity and diversity of littoral areas. However, at high densities, macrophytes may cause fish kills at night due to oxygen depletion, or limit the surface area available for fishing or boating. Control of overabundant aquatic vegetation often is of more concern to fisheries managers than the absence or scarcity of macrophytes in widely fluctuating reservoirs.

44. Success in regulating densities of macrophytes by manipulating water levels has been inconsistent (Kadlec 1960; Bennett 1962; Holcomb and Wegener 1971; Judd and Taub 1973; Lantz 1974; Lantz et al. 1964). Manipulation effectively controls some species (Hulsey 1958; Nichols 1972, 1974), and it offers a viable alternative to chemical controls that are expensive or detrimental to aquatic animals (Davis 1967). Dunst et al. (1974) listed many accounts of macrophyte control by drawdown. Apparently desiccation, freezing, and soil compaction during drawdowns act to reduce densities of aquatic macrophytes, but drawdown also facilitates mechanical removal. Nichols (1972, 1974), who studied the effects of prolonged winter drawdowns on aquatic macrophytes in Chippewa Flowage, Wisconsin, categorized many species of plants according to their preferences for fluctuating or stable water levels.

45. Increased water levels also may eliminate or reduce the abundance of some species (e.g., Runnström 1951, 1955; Stube 1958; Posey 1962). Merna (1964) found that the construction of a dam on Big Portage Lake, Michigan, which raised lake levels 1 m, reduced the number of species present from 20 (10 of which were common) to two.

46. Aside from species-specific responses, effects of water-level changes on aquatic macrophytes depend on magnitude, duration, and timing. In general, aquatic macrophytes seldom become established in widely fluctuating reservoirs, whereas they commonly are found in reservoirs that fluctuate little (Eschmeyer 1949; Kimsey 1958; Wajdowicz 1964; Grimås 1965; Grimås and Nilsson 1965). Short-term fluctuations (< 3 months) have little effect unless they dry littoral areas and allow them to freeze, or flood them to a depth where plants are limited by light or their ability to reach the atmosphere. Winter drawdowns at below-zero temperatures are more effective than warm-weather drawdowns for controlling aquatic plants. Also, chances of oxygen depletion and fish kills are reduced.

47. Zooplankton. Zooplankton, like phytoplankton, is rarely directly affected by changes in water level because it is suspended in the water column. Direct effects are limited to displacement of zooplankters within reservoirs due to changes in water retention time. Production of zooplankton may be more limited than that of phytoplankton by high rates of water renewal because zooplankton turnover rates are slower (Rodhe 1964). Also, zooplankters with rapid turnover rates such as rotifers, probably are less affected than those with slow rates of turnover (e.g., crustacean zooplankters). Effects are most apparent in mainstream reservoirs where water-retention times are short (< 60 days). Losses of crustacean zooplankton from Lewis and Clark Lake (a mainstream Missouri River reservoir) amounted to 12,619 metric tons (wet weight) in 1963-64 and 29,752 metric tons in 1964-65 (Benson and Cowell 1967). Benson (1973) noted that zooplankton abundance in Lake Sharpe, South Dakota, was higher in 1966-68, when water exchange rates ranged from 26 to 50 days, than it was in 1969, when exchange rates were 18-22 days.

48. Because zooplankton concentrations (numbers and biomass) are highest during the growing season and lowest in winter, the rapid discharge of water is more detrimental during summer than during winter. Increased abundance of zooplankton in Lake Ransaren, Sweden (an impounded natural lake), was the result of low discharge of lake water in summer (Axelson 1961). Rodhe (1964) observed that seasonal regulation of

water levels that resulted in damming from spring to late autumn and discharge during winter favored zooplankton production more than natural regimes of water replacement where highest flushing rates are in spring and summer. Using multivariate analyses, June (1974) found that zooplankton densities in areas near the dam of Lake Oahe, North and South Dakota, were inversely related to discharge rates in summer. Water temperatures and turbidity also were major factors controlling abundance, but both were occasionally influenced by the retention time of water. Similarly, Mayhew (1977) found that flushing rate explained 94 percent of the variation in copepod density in Lake Rathbun, Iowa; temperature explained 74 percent.

49. Outlet depth may determine the amount of zooplankton discharged from a reservoir, because the vertical distribution of plankters varies seasonally and diurnally. Because zooplankton usually is most abundant above a thermocline in summer, discharge from the epilimnion probably would eliminate more biomass than would discharge from greater depths. Rodhe (1964) found that rapid discharge of water from Lake Ransaren removed one third of the epilimnial volume monthly and significantly reduced the volume of zooplankton present in 1958. In 1959, when discharge was reduced, zooplankton volumes were higher than in 1958.

50. Long-term changes in the species composition of zooplankton in old bodies of water have been examined by identifying subfossil remnants of animals in sediments and relating findings to historical oscillations in water levels (Alhonen 1970; Mikulski 1978). Seemingly, high waters favor the development of pelagic plankters such as Bosminidae and Daphnidae, whereas low or receding waters favor littoral plankters such as Chydoridae (Mikulski 1978). The index ILL = Bosminidae + Daphnidae/Chydoridae was directly related to historical water-level changes in Goplo Lake, Poland. Many littoral species were especially abundant when macrophytes were present. Pelagic plankters undoubtedly were favored by the relatively long retention time of water, when water levels were high.

51. With unlimited food and adequate oxygen tensions, temperature regulates zooplankton production by controlling rates of consumption, respiration, growth, and reproduction. Biomass in DeGray Lake, Arkansas, was highest in spring, declined through summer, and was lowest in winter from 1976 to 1981 (unpublished data, Multioutlet Reservoir Study Group, U. S. Fish and Wildlife Service). Changes in water levels have their greatest impact on zooplankton during the growing season primarily because the potential for production is low in winter due to low water temperatures.

52. During the growing season, production of zooplankton probably is most regulated by food availability and quality, both of which can be influenced by water levels or changes therein. Zooplankters eat phytoplankton, bacteria, protozoa, other zooplankton, and suspended detritus. Preferences for different foods vary among species, but increased concentrations of any foods are likely to increase the production of some species. Increased numbers, biomass, or production after impoundment of natural lakes or reservoirs often has been associated with increased food availability after water inundated terrestrial areas. Dahl (1933) observed an increase in the standing crop of Eurycercus lamellatus and other cladocerans after water storage in a Norwegian hydroelectric impoundment. Similar observations of increased abundance after impoundment of natural lakes in Norway or Sweden have been made (Aass 1960; Axelson 1961; Grimås 1961; Lötmarker 1964; Rodhe 1964; Nilsson 1964). Newly impounded lakes probably had higher densities of zooplankton than natural lakes or old reservoirs because the levels of detritus and phytoplankton production were temporarily high (Lötmarker 1964). Increased zooplankton abundance lasted only a few years (Grimås 1961; Nilsson 1964). Rodhe (1964) believed that the two- to three-fold increase in zooplankton volume in Lake Ransaran resulted from increased nutrient and detrital inputs from flooded terrestrial areas. Benson (1968) attributed the increased abundance of rotifers in two Missouri River reservoirs to rising water levels that continually inundated grassy areas. Duthie and Ostrofsky

(1975) noted that zooplankton populations in shallow water increased greatly and changed qualitatively after impoundment of two reservoirs in Labrador, Canada.

53. Observations of zooplankton responding to large-magnitude changes in water levels in old reservoirs parallel those made of zooplankton in new impoundments. Wright (1950 and 1954) observed that production of animals in all trophic levels was low before the draining of Atwood Lake, Ohio. After draining and refilling of the lake in 1947, zooplankton crops increased greatly in response to the inundation of large amounts of organic matter. Standing crops remained high in 1948 but declined in 1949, apparently due to decay and depletion of terrestrial foods. From 1964 to 1966, water levels in Lake Mahinerangi, New Zealand, increased almost linearly, as did phytoplankton production (Mitchell 1975). Although the densities of the three most abundant species of zooplankton did not increase with increased primary productivity, densities of two large-sized but less abundant taxa (Daphnia carinata and cyclopoid copepods) increased significantly.

54. Even falling water levels may increase zooplankton numbers or biomass if they increase food concentrations. For example, Gras and Lucien (1978) observed that the juvenile periods of Moina sp. and Diaphanosoma sp. were shortened by accelerated development and a decrease in the number of instars between 1968 (a high-water year) and 1973 (a low water year). Improved nutritional conditions after the high-water year apparently accelerated development. Zooplankton biomass in July in Lake Sevan, USSR, increased from 0.77 g m^{-3} to 1.36 g m^{-3} between 1947 and 1956 (Markosyan 1969). As water levels declined, primary production increased in response to recirculation of nutrients in sediments.

55. Because zooplankton productivity is mostly related to changes in trophic conditions (primary production and input of detrital foods), it probably is affected little by water-level changes that are small, rapid, or frequent. Zooplankton production should increase when water levels are periodically (every 2-3 years) manipulated to temporarily increase detrital inputs and primary production, while discharge rates

are simultaneously reduced during the growing season. Zooplankton production may be increased substantially by increasing water levels during most of a single growing season and inundating terrestrial vegetation, especially in reservoirs with large fluctuation zones that develop extensive growths of terrestrial vegetation seasonally or every 2 or 3 years.

56. Benthos. Benthic invertebrates are directly and indirectly affected by changes in water levels. Direct effects include (1) exposure and mortality of species that have poor mobility or that lack a diapause or resting mechanism (Aass 1960) and (2) entrainment and loss of benthos from reservoirs during periods of rapid water exchange. Indirect effects result from changes in habitat, food resources, or the chemical environment.

57. Of the direct effects of water-level changes, discharge of benthic invertebrates has been studied the least, though it can be significant in reservoirs with periodically or continuously high flushing rates (Benson 1973). For example, in Lewis and Clark Lake, a Missouri River reservoir with a rapid rate of water exchange, 24 metric tons (wet weight) of Hexagenia nymphs and 20 metric tons of diptera larvae were passed through the turbines of the dam in the spring of 1965 (Swanson 1967; Cowell and Hudson 1967). Most of the discharge occurred at night when insects were most active in the water column. Although densities of benthos in the water column were low (0.5 to 8 m^{-3}), the high rate of discharge of water (about 7.08 m^3 $second^{-1}$ from April to June) resulted in significant numerical losses--e.g., 1.7 x 10^9 Hexagenia nymphs from April to July.

58. The most visually obvious effect of water-level changes on benthos is the exposure and mortality of organisms when water levels are reduced. In Lake Francis Case, a 4-m drawdown in August 1966 stranded up to 6,146 chironomids m^{-2} (Cowell and Hudson 1967). Kaster and Jacobi (1978) observed that annual fluctuations of 7.7 m in a central Wisconsin reservoir exposed 1.8 g m^{-2} (dry weight) of benthos. McLachlan (1974) observed that drawdown in Lake Kariba, Africa, stranded up to 200 mg of benthos m^{-2} and that shorelines receded up to 2 km. Winter

drawdown of Laurel Creek Reservoir, Canada, exposed and killed much of the benthic fauna. Substrates frozen to depths > 20 cm also eliminated burrowing organisms (e.g., oligochaetes, nematodes, chironomids, and mites) that might have survived drawdown if ice or snow had provided a protective cover or if drawdown had occurred during warm weather (Paterson and Fernando 1969). Similar observations were made by Ioffe (1966).

59. Mortality of organisms, due to exposure, undoubtedly reduces populations within the fluctuation zone and may partly explain observations of inverted vertical distributions of benthos in widely fluctuating reservoirs. In bays protected from water-level fluctuations in impounded lakes in Southern Norway, Grimås (1964) noted that the vertical distribution of animals was similar to that in nonfluctuating lakes (i.e., abundance was greater in the littoral zone than at greater depths). Similarly, when water levels of Lake Kariba, Africa, were stable, benthos densities were greatest in shallow areas and decreased rapidly with increasing depth (McLachlan 1970a). However, distributions of benthos were inverted in fluctuating Lake Blåsjön, Sweden (Grimås 1961); densities were greatest just below the drawdown limit. Similar observations have been made in Katta-Kurgan Reservoir, USSR (Stepanova 1966), Barrier Reservoir and Upper and Lower Kananaskis reservoirs, Alberta (Fillion 1967), and in Big Eau Pleine Lake, Wisconsin (Kaster and Jacobi 1978).

60. In addition to losses of organisms in the fluctuation zone due to exposure, the migration of mobile species during drawdown also may concentrate them at or just below the drawdown limit. Engelhardt (1958) observed that many littoral organisms in Lake Walchensee, Germany, descended as waters receded and were concentrated in sublittoral areas. Cowell and Hudson (1967) noted that active migrations by some Hexagenia sp. and chironomids in Lake Francis Case resulted in enormous densities (e.g., 60,620 m^{-2}) at the waters edge, after waters reached minimum levels. Davis and Hughes (1965) observed that increased concentrations of benthos after drawdown caused crowding in Bayou D'Arbonne, Louisiana. Movements to avoid exposure may force

faunas. Grimås (1964) concluded that the shore fauna in Lake Rödungen was diverse because the slow rhythm and restricted amplitude of fluctuations reduced the impact on littoral habitat and insects. Seasonal timing of water-level changes also is important in determining effects. Winter drawdowns can adversely affect survival of burrowing species that remain in drained areas if substrates freeze and do little to improve trophic conditions for fish because predation is reduced in cold water. Flooding terrestrial vegetation in winter does not increase benthos production as much as flooding during the growing season.

64. In addition to effects on numbers and biomass, water-level fluctuations often alter the species composition and reduce the diversity of benthos. Cowell and Hudson (1967) found that chironomids were three times more abundant in fluctuating Lake Francis Case than in Lewis and Clark Lake, which fluctuated little. The dewatered zones of three reservoirs in Alberta, Canada, were dominated by chironomids that survived in drained areas for up to 85 days (Fillion 1967). In Llyn Tegid, North Wales, a dam was constructed in the outlet in 1955, and annual water-level fluctuations increased from 2 to about 5 m. Although total density of bottom organisms increased along shores, many littoral species (e.g., freshwater sponges, flatworms, snails, stoneflies, caddisflies, and amphipods) that were very important as fish foods were reduced in number or completely eliminated. A 42% increase in total density after fluctuations increased resulted almost exclusively from increases in chironomids and oligochaetes (Hynes 1961; Hunt and Jones 1972_a_). In 1967-69, annual fluctuations in water levels of Llyn Tegid were reduced to 2 m. Hunt and Jones (1972_a_) found that all major groups of animals recorded before 1955 were present in 1968-69, and most were fully reestablished. Similar observations of shifts in the species composition of benthos have been made in other impounded natural lakes in Norway and Sweden (see, e.g., Dahl 1933; Aass 1960; Grimas 1961, 1962, 1965).

65. Shifts in species composition and abundance result from changes in environmental conditions and habitat, as a result of water-level fluctuations. Many chironomids and oligochaetes are more tolerant of low oxygen than other aquatic invertebrates, and they also are favored by water-level changes that enhance the deposition of sediments. Hunt and Jones (1972b) observed that reduced water levels increased the fallout of rich organic matter to the profundal zone of Llyn Tegid and increased the abundance of profundal chironomids and oligochaetes. Benson and Hudson (1975) attributed increased abundance of burrowing benthos to reduced water-level fluctuations which caused sediment to be deposited at higher elevations. In impounded lakes in southern Norway, Grimås (1964) noted that the littoral fauna was maintained in areas protected from erosion and that more individuals were present in moss and submerged vegetation than in eroded sediments. He concluded that retention of original forest vegetation helped preserve littoral organisms important to fish.

66. Density of benthos is usually greater in areas with dense vegetation (aquatic or inundated terrestrial) than in other habitats (mud, gravel, rock, or sand), and diversity often varies directly with the diversity of habitat. Areas with vegetation support more benthos (numbers and species) because they provide food as well as structure. The positive influence of vegetation on littoral benthos is exemplified by the high numbers and diversity of benthos in beds of aquatic macrophytes. In Lake Francis Case, for example, invertebrates were twice as abundant in smartweed than in adjacent bottom areas (Cowell and Hudson 1967). During the winter of 1971-72, the density (number m^{-2}) of benthic macroinvertebrates in Lake Tohopekaliga, Florida, was higher in beds of macrophytes (3,272-14,682) than in limnetic areas (1,055-2,626) or in barren areas of the littoral zone (1,658-2,619) during the winter of 1971-72 (Wegener et al. 1974). Diversity also was greater in beds of macrophytes than in littoral or profundal areas. As might be expected, when water levels were high, densities of benthos in the littoral zone and in beds of macrophytes were higher than

densities in deep-water areas. However, when water levels were lowest, benthos was more abundant in profundal areas than in littoral areas with or without vegetation.

67. Periphyton on submerged trees also serves as habitat and food for many benthic invertebrates (Cowell and Hudson 1967; Clafin 1968; Benson 1973). Clafin (1968) found a significant positive correlation between the density of chironomid larvae and the standing crop of periphyton on submerged timber in Lewis and Clark Lake. Cowell and Hudson (1967) observed densities of benthos on tree-based periphyton that were 11 times greater than densities on adjacent bottom areas. In Lake Francis Case, where annual fluctuations of 6 to 13 m exposed the periphyton and tree substrates for 4 to 5 months each year, densities of benthos were only four times greater than on adjacent bottom areas.

68. The importance of habitat that produces food for benthos also is demonstrated by the high density and biomass of benthos that develop in areas of recently submerged herbaceous terrestrial vegetation. During filling of Beaver Lake, Arkansas, Aggus (1971) observed that areas of recently flooded herbaceous plants contained far greater numbers and biomass of benthos than cleared areas or those with woody vegetation only. Presumably, food, substrate, and refuge were provided by the plants. After shrub covered areas of Tsimlyanshoe Reservoir, USSR, were flooded for 2 months, Ioffe (1966) observed densities of benthos as high as 18,000 m^{-2} (wet weight biomass = 315 g m^{-2}). Ioffe also mentioned that biomass on tree substrates in the Rybinsk Reservoir, USSR, was 123 g m^{-2}. In Lake Oahe, North and South Dakota, the densities of benthos were higher in areas where large amounts of terrestrial vegetation had been recently inundated than in barren areas (Jones and Selgeby 1974).

69. McLachlan (1977) divided benthos development in new reservoirs into two phases that also may be used to describe the effects of large seasonal changes in water levels in older impoundments. "Flooding" is a short, productive phase during which water levels rise to cover terrestrial vegetation and when most benthos depends on terrestrial organic matter for food. "Post flooding" is a less productive phase

during which diets of benthic animals shift to include more autochthonous foods (primary production and detritus) after inundated terrestrial foods have been consumed. Biomass of benthos in Lake Chilwa, Africa, for example, declined from 2,967 to 1,051 mg dry weight m^{-2} after the flooding phase had passed. Concomitantly, the percent of allochthonous organic matter in diets of chironomids decreased from 93 to 64. McLachlan (1977) also mentioned similar observations for benthos in Ladyburn Lough, Great Britain, and Lake Kariba, Africa.

70. To date, management of water levels to benefit benthos has dealt mainly with reducing fluctuations (e.g., see Benson and Hudson 1975), or with introducing species (e.g., Mysis sp., Pallasea sp., or Gammaracanthus sp.) capable of surviving extensive fluctuations (Fuerst 1970). Extensive drawdowns, planting of vegetation, and reflooding probably is successful in increasing benthic production for a year or two, inasmuch as the biomass of benthophagous fish usually increases for several years after such a treatment.

Fish and Fisheries

71. Trophic relations and growth. Water-level changes alter trophic relations and growth of fish by regulating the input of allochthonous foods, the productivity or species composition of fish-food biota, or the availability and vulnerability of prey. Changes in water levels that significantly affect fish communities have three characteristics: they are of large magnitude and of long duration and occur during at least part of the growing season. As mentioned in earlier sections on nutrients and fish-food biota, small short-term fluctuation in water level have little effect on nutrients, plants, or invertebrates, and winter fluctuations generally do not increase productivity because low temperatures retard or stop the growth of plants (terrestrial or aquatic) and cold-blooded animals. If areas of the fluctuation zone are barren, even large changes in water level usually have little effect on productivity.

72. Effects of frequent (daily or monthly) fluctuations in water levels on feeding and growth of fish are more subtle than effects related to long-term (1-3 year) cycles of water levels. Although

Hassler (1955) could not correlate changes in water levels to first year growth of sauger (Stizostedion canadense), he did notice a relation between first year growth and a longer cycle of water-level changes. Estes (1971) observed that growth of black basses (Micropterus spp.) and bluegills (Lepomis macrochirus) in Smith Mountain Lake, a pumped storage reservoir in Virginia, was not directly affected by weekly fluctuations of 6 to 8 feet, though reduced reproductive success of gizzard shad (Dorosoma cepedianum) may have reduced growth potential of the basses. In Lake Oahe, North and South Dakota, water-level fluctuations during the growing season had no discernible effect on fish growth unless areas with terrestrial vegetation were flooded (Nelson 1974).

73. Rapidly rising waters that inundate terrestrial areas--especially areas supporting extensive growths of vegetation--temporarily increase supplies of food for opportunistic fish. Areas of flooded herbaceous plants probably provide more food (drowned terrestrial animals, plants, or detritus) than do barren or wooded areas (Dale and Sullivan 1978). Many fish take advantage of temporary increases in food availability during and after increases in water levels. For example, Goodson (1965) observed that white catfish (Ictalurus catus) ate terrestrial plants as waters rose in Pine Flat Lake, California. Diets of black bullheads (Ictalurus melas) in Beaver Lake, Arkansas, changed during flooding to include terrestrial animals, such as earthworms and insects, which made up 56 percent of the volume of stomach contents. When water levels were stable, terrestrial animals composed less than 6 percent of total food volume (Applegate and Mullan 1966). Stomachs of young 4- to 8-inch centrarchids also contained high percentages of terrestrial foods--68 (bluegills), 61 (green sunfish, Lepomis megalotis), 58 (largemouth bass, Micropterus salmoides), and 40 (spotted bass, Micropterus punctulatus--during flooding (Mullan and Applegate 1967).

74. Changes in trophic conditions after waters have flooded areas of vegetation may be inferred from growth rates as well as from changes in diet. Although the changes were only temporary (1 year or less),

consumption of terrestrial animals and growth by brown trout (Salmo trutta) and Arctic char (Salvelinus alpinus) increased after water levels were increased in natural lakes of Norway, Sweden, and England (Huitfeldt-Kaas 1935; Runnström 1951, 1955; Frost 1956; Stube 1958; Aass 1960; Nilsson 1961, 1964). In virtually all studies, growth declined below preimpoundment levels after a year when no additional terrestrial areas were inundated and the staple diet of brown trout (benthic amphipods) was replaced by less desirable chironomids. In Lake Oahe, Nelson (1978) associated the inundation of areas with terrestrial vegetation with increased growth of 13 species of fish (goldeye, Hiodon alosoides; northern pike, Esox lucius; common carp, Cyprinus carpio; river carpsucker, Carpiodes carpio; smallmouth buffalo, Ictiobus cyprinellus; white bass, Morone crysops; white crappie, Pomoxis annularis; black crappie, Pomoxis nigromaculatus; yellow perch, Perca flavescens; sauger; walleye, Stizostedion vitreum; and freshwater drum, Aplodinotus grunniens). Similar observations have been made for spotted bass (Schultz 1966); largemouth bass (Wright 1950; Jackson 1957; Schultz 1966; Aggus and Elliott 1975; Shirley and Andrews 1977); blue sucker, Cycleptus elongatus, and shorthead redhorse, Moxostoma macrolepidotum (Elrod and Hassler 1971); gizzard shad and spotted sucker, Minytrema melanops (Jackson 1957); white crappie (Jackson 1957; Schultz 1966); and for bluegills, yellow perch, and channel catfish, Ictalurus punctatus (Wright 1950).

75. In addition to the terrestrial foods made available by flooding, production of fish-food biota also is increased in newly inundated areas. However, the terrestrial areas must be inundated long enough to enable fish to benefit from this increased production. According to Benson (1973), 25 days of inundation were required for periphyton development on plant stems in Missouri River reservoirs and 40 days for the colonization of epiphyton by aquatic insects.

76. Declining water levels may concentrate prey fish and thereby increase predator foraging and growth (Aggus 1979). Intense predation during periods of low water may selectively cull smaller fishes, provided the drawdown is large enough and occurs when water temperatures are

above 13° C (Bennett 1954, 1962). Jenkins (1970) observed that short drawdowns (2-3 months) seldom produce measurable changes in species composition or abundance of prey fishes. Some authors have observed increased feeding activity or growth by piscivores during or immediately after drawdown--e.g., northern pike (Beard and Snow 1970); smallmouth bass, *Micropterus dolomieui* (Heisey et al. 1980); and largemouth bass (Heman et al. 1969). However, after prolonged drawdown, growth of fish often decreases as concentrations of prey are diminished and the productivity of most invertebrates and small fish is reduced. Growth of large crappies (*Pomoxis* spp.) and flathead catfish (*Pylodictis olivaris*) was inversely correlated with mean annual water levels in Lake Carl Blackwell, Oklahoma (Johnson and Andrews 1973), perhaps because water levels declined progressively for 5 years and continually concentrated prey.

77. Prolonged loss of benthos production from the littoral zone may reduce the production of benthos-feeding fishes or young sport fish. Johnson and Andrews (1973) and Johnson (1974) reported reduced growth of white crappie (age I), channel catfish (ages I, II, and VI), and common carp (ages I and III) as water levels declined in Lake Carl Blackwell, Oklahoma, from 1962 to 1967. Eschmeyer (1949) suggested that food limitations experienced by benthophagous fishes in widely fluctuating reservoirs may account for their low abundance in storage impoundments and that relatively stable water levels may account for their high densities in mainstream reservoirs. Also, low water during or after a spawning period, when food demands by young-of-the-year (YOY) fish are high, may severely reduce survival and annual production of an entire year class of fish (e.g., see Houser and Rainwater 1975). Schultz (1966) noted that growth of white crappies, spotted bass, and largemouth bass in three Mississippi reservoirs was lowest in 1959 and 1963, when water levels were lower than normal in spring. Reduced allochthonous input of nutrients and reduced spawning success in spring by prey fishes probably account for reduced growth.

78. In contrast to spring drawdown, fall drawdown may significantly increase forage for young predators (Benson 1973) and simultaneously reduce populations of small fish (Bennett 1962). Decisions to employ fall drawdown are best made after examining total standing crop and assessing the ratio of available prey to predators--e.g., as determined by the predator-prey model of Jenkins and Morais (1976) or the YOY/Standing Crop (Y/C) ratio of Swingle (1950).

79. Another aspect of predator-prey relations involves changes in the structural complexity of habitat as water levels change. Not only are prey physically concentrated by large drawdowns, but they are often forced to abandon refuge (i.e., aquatic or terrestrial vegetation, artificial structure, or rocks) in the littoral zone. Consequently, prey become more vulnerable to predators (Bennett 1962; Keith 1975). Complex structure not only provides refuge for prey but also reduces the foraging efficiency of predators (Murdock and Oaten 1975). Heman (1965) observed increased growth of largemouth bass (except for YOY) after drawdown of Little Dixie Lake, Missouri, and noted an inverse relation between the amount of inundated vegetation and feeding. Cooper and Crowder (1979) and Crowder and Cooper (1979) concluded that densely structured habitats decrease productivity of predators by reducing their feeding effectiveness and that in barren habitats prey biomass is low due to predation. Water-level manipulation can provide fishery managers with a crude means of regulating structural complexity, and therefore the predator-prey relations of littoral fish in reservoirs, by providing a more complex habitat at high than at low elevations.

80. Changes in the species composition and abundance of prey available to predators as a result of years of water-level fluctuations may alter consumption and growth. Lewis (1967) suggested that food consumption and production of sport fish is limited to a maintenance level by the availability of highly vulnerable foods. Part of the success of drawdowns in improving sport-fish production is a result of an increase in the vulnerability of forage. Aside from increased vulnerability due to concentrating effects or changes in the amount of refuge available, vulnerability and quality of forage vary among species

of prey. Conceivably, water-level changes might be designed to benefit highly vulnerable prey such as threadfin shad (*Dorosoma petenense*), while adversely affecting species such as bluegills, which presumably are less vulnerable to predation. Evidence collected to date does not corroborate or refute such a hypothesis. It does show that certain assemblages of fish are more productive of sport fish than others, though apparently for other reasons. Drawdown of Ridge Lake, Illinois, in 1951 and 1952 significantly reduced populations of small sunfish (Bennett 1954). Bass reproduction and recruitment were much greater in years after sunfish populations were reduced, suggesting that bass production was previously limited by predation on bass eggs and fry by sunfish. Early introductions of threadfin shad in fluctuating California reservoirs were successful in increasing forage of yearling and older black basses, but survival of YOY bass apparently was limited by competition for zooplankton with YOY threadfin shad (von Geldern and Mitchell 1975).

81. Reservoirs with widely fluctuating water levels favor euryphagous fish (i.e., those that eat a wide variety of food). Nilsson (1964) observed that littoral benthos is typically scarce in impounded natural lakes as a result of water-level fluctuations and that brown trout production in these lakes declined significantly when the fish were forced to feed on zooplankton, profundal benthos, or fish. Arctic char were less affected by fluctuating water levels because they fed more on zooplankton than on benthos. Miller and Paetz (1959) noted that increases in weight of lake trout (*Salvelinus namaycush*) usually ceased at about 0.45 kg in three Canadian reservoirs in which littoral benthos was poorly developed. Apparently the fish were prevented from switching from a diet of zooplankton and benthos to one of fish. Grimås (1962) observed that chironomids, which dominated the benthos after water levels fluctuated in impounded natural lakes and inhabited deep waters, were less available as food for brown trout than were the pre-fluctuation species of littoral benthos.

82. Reproduction. Reproduction of fish that spawn in the fluctuation zone of reservoirs is influenced by water levels and by changes in water levels. Adverse effects on reproduction of near-shore spawning fishes are related to (1) a loss of habitat by drawdown or shoreline modification or (2) mortality of eggs or YOY fish by exposure or suffocation with eroded sediments (Hassler 1970). Mortality of eggs or YOY fishes stranded by drawdown has been documented for many species--e.g., salmonids (Aass 1964; Runnström 1951, 1964); sunfishes, *Lepomis* spp. (Heman 1965); walleyes (Priegel 1970); common carp (Shields 1958a; Aronin and Mikheev 1963; Yakovleva 1971); and black basses (Estes 1971). Species of fish that spawn in tributaries (e.g., white bass) or in open-water areas (e.g., goldeye and freshwater drum) generally are not adversely affected (Benson 1973; Gabel 1974). Walburg (1976) observed that the spawning success of channel catfish in Lewis and Clark Lake was unaffected by water levels because they spawned at depths below the drawdown limit. Also, walleyes and saugers that spawned in the Missouri River were unaffected by fluctuations in the lake except indirectly because of adverse effects of water levels on reproduction of forage fish.

83. Control of water levels during spawning is the most practical and inexpensive method of producing fish. Methods to alleviate problems associated with dewatered spawning sites in fluctuation zones have included (1) provision of artificial spawning sites (Ellis 1937, 1942; Martin 1955), (2) construction of nonfluctuating "inlet impoundments" adjoining reservoirs (Ellis 1937; Grimås 1965), (3) artificial propagation of important fish in hatcheries (Il´ina and Gordeyev 1972), and (4) control of water levels during the spawning period. Artificial spawning sites are expensive and impractical for large reservoirs, and inlet impoundments do not make up for the loss of littoral areas, at least in steep-sided, deep reservoirs (Grimås 1965). Although important sport and forage fish are stocked extensively in many reservoirs by State fishery agencies, most of the fish stocks in large reservoirs are produced by natural reproduction.

84. Drawdown has been used to control spawning of rough fish such as squawfish, Ptychocheilus sp. (Jeppson 1957), and common carp (Shields 1958a, 1958b). Although enormous numbers of eggs may be exposed and killed, success in controlling populations varies. Attempts to control common carp spawning in Lake Francis Case in 1956 were not successful; though millions of eggs were destroyed, the 1956 year class made up 78% of the commercial catch of fish in 1959 (Gasaway 1970). Short-term manipulation of water levels to destroy eggs was of limited value because common carp spawned over an extended period of time. Drawdowns combined with selective culling of small fish (e.g., bluegills) has been more consistently effective, at least in small lakes (Bennett 1954).

85. In addition to stranding eggs or young fish, rapidly receding waters may result in desertion of nests, failure of nests, disrupted spawning, or atresia (intraovarian mortality of eggs) in species that build nests along shorelines (black basses, Lepomis sunfishes, and crappies) or spawn in shallow water (yellow perch, northern pike, common carp, buffaloes, and gizzard shad). Walburg (1976) noted that low and variable spring water levels adversely affected spawning success of gizzard shad, emerald shiners (Notropis atherinoides), white bass, white crappies, and yellow perch in Lewis and Clark Lake. June (1970) concluded that a sudden lowering of water levels prevented female northern pike from entering previously used spawning areas and increased the incidence of atresia. Nest desertion (Buck and Cross 1951; Webster 1954) permits sunfish to prey intensively on eggs (Vogele 1975). Poor spawning success of largemouth bass, carpsuckers (Carpiodes sp.), and channel catfish in Lake Carl Blackwell, Oklahoma, was attributed to declining water levels (Johnson 1974). Decreasing or fluctuating water levels can result in the failure or weakening of a year class. For example, year classes of largemouth bass failed when water levels of Lake Nacimiento, California, were lowered excessively (von Geldern 1971).

86. Reproductive success is determined by spawning success and post-spawning survival, as regulated by many factors: temperature, wind, and turbulence (Summerfelt 1975); predatory mortality of eggs, embryos, or larvae (Bennett 1962, 1974); and the amount of food available for

young fish (Hassler 1970; Eipper 1975). Provision of ideal spawning conditions does not always insure a strong year class. Fourt (1978), for example, reported success in producing large numbers of YOY black basses and crappies by flooding terrestrial vegetation on about 7,000 acres of fluctuation zone in Beaver Lake, Arkansas. However, the poor survival of YOY fish after August that resulted from inadequate prey abundance, prevented the development of a strong year class.

87. Although good spawning success may not insure a strong year class, it does increase the chances of producing one, given environmental conditions favorable for survival of the YOY. Good spawning success has often been related to rising waters that flooded terrestrial areas and provided appropriate spawning substrates--e.g., flooding of gravel areas used by walleye (Johnson et al. 1966) or areas of terrestrial vegetation used by yellow perch (Beckman and Elrod 1971), northern pike (Benson 1968; Hassler 1970), buffaloes (Moen 1974), or common carp (Gabel 1974). The importance of spawning habitat cannot be overlooked. Hassler (1970) concluded that rising waters contribute little to the reproductive success of northern pike, unless herbaceous grasses are available. Johnson (1961) found that survival of walleye eggs to the "eyed stage" was high (25%) on gravel but low (0.6%) on mud. Smallmouth bass typically require rock or gravel areas for nesting (Vogele 1981), but other black basses have less specific requirements for nesting habitat.

88. Strong year classes of many freshwater fish have been correlated with rising or high water during and for several months after the spawning season (see LeCren 1965). Other examples include largemouth bass (von Geldern 1971; Summerfelt and Shirley 1978); black basses (Rainwater and Houser 1975); northern pike (Hassler 1970); saugers (Walburg 1972); and common carp, river carpsuckers, smallmouth buffaloes, and bigmouth buffaloes (Gasaway 1970; Elrod and Hassler 1971). Spring water levels and the amount of terrestrial vegetation inundated during spawning explained 79 percent of the variation in year-class strength of yellow perch (Nelson and Walburg 1977). Rainwater and Houser (1975) found that the reproductive success of black basses in Bull Shoals Lake

from 1966 to 1973 was negatively correlated ($P < 0.01$) with fluctuation of water levels during the 3-month spawning season.

89. Rapid exchange rates can affect the survival of young fish (Walburg 1976). In Lewis and Clark Lake, the abundance of YOY fishes was directly related to water-exchange time ($P < 0.02$, $r = 0.73$), as was the catch of young fish in trawls ($P < 0.05$; $r = 0.68$). A reduction in water retention time from 10 days to 4 or 5 days increased the discharge of larval fish through the dam. Year-class strengths of freshwater drum (a pelagic spawner) and channel catfish were correlated with the mean rate of water exchange in July and August (Walburg 1976).

90. The reproductive success of fish that spawn near shores in reservoirs is influenced by the time and duration of flooding and the type of substrate inundated (Aggus 1979). Holčík and Bastl (1976) observed that fish stocks were higher in rivers with flood plains than in rivers without them. Water levels determine available refuge (nursery areas) for young fish by inundating vegetation or receding from it. Survival of YOY fish is enhanced greatly when cover is abundant. Aggus and Elliott (1975) found that the number of YOY largemouth bass in August in Bull Shoals Lake, Arkansas, was directly related to the acre-days of flooding of terrestrial vegetation. Nelson and Walburg (1977) found the abundance of young walleyes to be directly correlated with water levels ($r = 0.62$; $P < 0.01$). Decreasing water levels reduced cover and refuge for larval and juvenile stages of spotted bass (Vogele 1975), and consequently exposes YOY fish (e.g., black basses--Hogue 1972; Aggus and Elliott 1975) to increased predation.

91. Year-class strength of most fishes in reservoirs varies greatly among years (Aggus and Elliott 1975), depending on environmental conditions and predator-prey relations. Strong year classes of one species may suppress future year classes of its own or of other species for several years (1-4) by competing for food (von Geldern 1971) or by preying on eggs, embryos, or larvae (Bennett 1962), or on other YOY fish (Aggus and Elliott 1975). Jenkins (1975) concluded that cannibalism (mostly by yearlings feeding on YOY) and a scarcity of submerged vegetation in some years made it virtually impossible to produce strong

year classes of largemouth bass every year. Swingle and Swingle (1967) noted that weak year classes of crappies occurred when a strong year class of largemouth bass had developed in the previous year.

92. Provision of suitable spawning and nursery areas every year may not be necessary to maintain fish populations because of natural yearly variation in recruitment. Basin-wide management of water levels, where levels of selected reservoirs in a series are manipulated in different years, seems to be the most efficient approach (Neel 1963). Yearly sampling of fish populations to assess species composition, age-class structure, and ratios of prey to predator biomass is necessary to determine which reservoir in a series would benefit most from management.

93. The abundance and species composition of fish changes primarily in response to changes in the quality and quantity of spawning and nursery habitats, as influenced by the long-term effects of water-level changes and waves on the shore zone of reservoirs. The species composition of fish present before shorelines stabilized in Missouri River reservoirs was substantially different from that which finally developed (Benson 1980). The abundance of species that spawned in tributaries or along rocky shores that developed after years of erosion (walleye, sauger, channel catfish, white bass, and river carpsuckers) either remained unchanged or increased as shorelines were modified. Populations of other species that required vegetation or suitable substrates for nest building declined. Walleye reproduction in Ohio reservoirs (Erickson and Stevenson 1972) improved after years of water-level fluctuations had cleaned gravel bars and riprap. Il'ina and Gordeyev (1972) noted that terrestrial vegetation required for reproduction of many fish would not grow in much of the fluctuation zone of the Rybinsk Reservoir, USSR, because years of erosion had removed soils and left a bed of sand.

94. Knowledge of spawning and nursery requirements of fishes is essential for the development of effective strategies for water-level manipulation. Benson (1976) listed spawning and nursery habitats for 16 species of fish. Carlander (1969, 1977) listed temperature and

habitat required for spawning of many sport and commercial fishes. Because time of spawning varies directly with temperature, temperature is more reliable than time of year as an index to spawning, given variations in water temperature with latitude. In reservoirs dominated by warm-water species (black bass, Lepomis sunfishes, catfish, and crappies), virtually all important forage, sport, and commercial fish spawn when temperatures are between 11 and 22°C. In reservoirs dominated by coolwater species (northern pike, walleyes, saugers, and yellow perch), the temperature range for spawning is about 5 to 17°C.

95. Some fishes such as salmonids in cold-water reservoirs spawn in fall. Winter drawdowns in these reservoirs are extremely harmful to reproductive success because spawning and nursery periods are prolonged in cold waters. Aass (1964) found that recruitment of char in Pålsbufjord Lake, Norway, was limited by extreme drawdowns that exposed 75 percent of the bottom area and killed eggs and alevins. In years when the magnitude of drawdown was reduced and water levels were lowered slowly, strong year classes were produced. In Tunhovdfjord Lake, Norway, drawdown occurred in late winter, and although spawning areas were drained, most eggs had hatched and alevins were able to move with the receding waters. Consequently, annual recruitment was less variable in Tunhovdfjord Lake than in Pålsbufjord Lake.

96. Standing Crop and Harvest. The effects of changes in water levels or rates of water exchange on trophic relations, growth, reproduction, and survival of fish are ultimately reflected in fish standing crop. Jenkins (1967) found a significant ($P < 0.005$) negative correlation between the total standing crop of fish and the vertical extent of annual fluctuations in water levels in 70 reservoirs of carbonate-bicarbonate chemical types. Jenkins (1970) found positive correlations between annual water-level fluctuations and standing crops of spotted gar (Lepisosteus osseus), flathead catfish, black bass, and white crappies. Water-level fluctuations were negatively correlated with the biomass of gizzard shad, northern pike, pickerel (Esox spp.), carpsuckers, and sunfish. Aggus and Lewis (1976) found that total standing crop and crops of sunfishes, clupeids, and small fishes

were larger in reservoirs with rapid water exchange (storage ratios < 0.165, as in most mainstream reservoirs) than in those with slow exchanges. Standing crops of fish were more variable in reservoirs with large seasonal changes in inflow and water levels (e.g., storage reservoirs) than in stable mainstream impoundments.

97. Although fish-carrying capacity may be reduced by seasonally fluctuating water levels, large changes that occur every 2 to 4 years can be beneficial. Productivity and carrying capacity can be significantly increased by large water-level changes that are infrequent enough to permit the growth of terrestrial vegetation in dewatered areas. Controlled annual drawdown and reflooding of three Louisiana lakes resulted in a gradual increase in fish standing crop and rapid increases in the biomass of harvestable-size fish in the first 2 or 3 consecutive years of treatment; however, the beneficial effect of annual drawdowns apparently diminished after 4 or 5 consecutive years (Lantz 1974). In Council Grove Reservoir, Kansas, the percent of harvestable-size fish increased from 30.3 to 44.1 percent of the total standing crop, after water levels were managed (Groen and Schroeder 1978). Wegener and Williams (1977) observed a large increase in the total standing crop of fish (from 214 to 510 kg ha^{-1}) within 3 years after water levels of Lake Tohopekaliga, Florida, were manipulated. Drawdown of the lake exposed 50 percent of the bottom for 6 months, and refilling to normal pool required another 6 months. Afterward, high inflows caused water levels to rise and remain above normal pool for the next year. The biomass of black basses alone increased from 39 to 67 kg ha^{-1}.

98. Harvest of fish is affected by many factors, some of which are influenced by water-level changes. Direct effects of water-level fluctuations on angler harvest are rarely documented because of difficulties associated with quantifying short-term responses that are frequently determined by fish behavior. For example, Heman et al. (1969) observed that the harvest of bluegills increased immediately after a midsummer drawdown of Little Dixie Lake, Missouri, and then declined for 2 months. One may speculate that the benthos, the primary food of bluegills, was reduced by drawdown and that this shortage of food

temporarily made bluegills more susceptible to harvest by anglers; however, no conclusive data are available. Harvest of largemouth bass was reduced immediately after the drawdown in August but increased significantly in September and October. Increased predation that the authors concluded reduced the abundance of fry and intermediate-size bluegills also may have increased the vulnerability of bass to anglers. However, other factors probably were involved. Because of the complexity of relations, observed changes in harvest often cannot be readily explained by changes in water level alone. Some other factors that affect harvest are the standing crop; length, frequency distribution, and production of harvestable-size fish (as determined by reproductive success, growth, and recruitment); the local distribution of fish relative to anglers; and environmental conditions such as season and turbidity.

99. Jenkins (1967), who examined relations between nine descriptive variables and the sport and commercial harvest of fish in 127 reservoirs, found that sport-fish harvest per unit area was directly related to total dissolved solids, storage ratio, and shoreline development (shoreline length/ $2\sqrt{\pi \cdot \text{area}}$) and inversely related to reservoir age, area, and mean depth. Consequently, sport-fish harvest should be highest in nutrient-rich, productive reservoirs that entrain water for a year or more and that have a large littoral area relative to the area overlying deep water. Harvest of commercial fishes was inversely related to storage ratio, mean depth, shoreline development, and water-level fluctuation; it was directly related to reservoir age. High commercial harvests are more common from old mainstream reservoirs that are not dendritic, but that are linear and shallow and exchange water rapidly. These reservoirs are generally more productive and easier to fish than deep, dentritic impoundments.

100. Changes in the reproductive success and standing crop of fish ultimately affects harvest. After several natural lakes in Norway were impounded and seasonal water levels began to fluctuate greatly, Aass (1960) observed that catches of brown trout declined while those of Arctic char increased. Trends in harvest of both species paralleled

areas were 10:1 for channel catfish, 61:1 for bluegill, 35:1 for largemouth bass, and 44:1 for white crappie. Structures made from tires concentrated 3.9 times more channel catfish than did control areas without submerged structures and 15, 20, and 14.2 times more bluegills, largemouth bass, and white crappie, respectively.

102. The concentrating effects of natural timber also have been documented. The standing crop of fishes in a cove with standing timber in Tuttle Creek Reservoir, Kansas, was significantly higher than that in a cleared cove (data collected by the Kansas Fish and Game Commission). The biomass of largemouth bass, crappies, buffalofishes, common carp, river carpsuckers, and minnows was significantly less in the cleared than in the wooded cove ($P < 0.05$). The biomass of lepomid sunfishes also was greater in the wooded cove, but not significantly ($P < 0.10$). Mean weights of largemouth bass, crappies, and flathead catfish were generally higher in the wooded than in the cleared cove, suggesting that larger sport fish may be concentrated more than smaller ones. Davis and Hughes (1971), who conducted a 3-year creel survey of anglers in timbered and open-water areas of Bussy Brake Lake, Louisiana, found that trees had no significant effect on the catch (kg hour^{-1}) of black basses, crappies, sunfishes, or catfishes. However, fishing success (the chance of catching at least one fish per trip) was consistently higher in timbered than in cleared areas--90 versus 79 percent in 1960-61, 87 versus 74 percent in 1961-62, and 86 versus 66 percent in 1962-63.

103. In new impoundments where structural habitat in the form of submerged timber, brush, or boulders is present in the fluctuation zone, the construction of artificial structures probably is unjustified. Jensen and Aass (1958) observed that timber in the seasonally drained zone of fluctuating Norwegian lakes was still present after 36 (birch forest) and 51 (fir and juniper forest) years. As reservoirs age, terrestrial vegetation in littoral areas eventually deteriorates, and the use of artificial shelters may become an economically viable management measure for concentrating certain fish and improving harvest.

relative abundance. Abundance was determined by variations in year-class strength that caused single year classes of fish to dominate the creel for several years. Chevalier (1977) correlated the commercial catch of walleyes from Rainy Lake, Minnesota, with water level and its effect on reproductive success 4, 5, and 6 years earlier. Low water during spawning apparently limited year-class strength, which in turn reduced the harvest 4 to 6 years later. Similar observations were made by Johnson et al. (1966) and Derksen (1967). Manipulation of water levels in Lake Tohopekaliga, Florida, nearly quadrupled the harvest of black basses (Wegener and Williams 1974). In Ridge Lake, Illinois, recruitment of largemouth bass was limited by bluegills preying on bass eggs and fry in years of stable water levels. Harvest in these years averaged 19 kg ha^{-1} and the mean weight of bass caught was 0.15 kg (Bennett 1974). Draining of the lake and culling of egg and fry predators such as bluegills allowed the production of strong year classes of bass. Drawdown improved the growth of bass. In years following the years of draining and culling operations, harvest averaged 23 kg ha^{-1}, and the mean weight of bass harvested was 0.35 kg.

101. Drawdown of water levels allows fishery managers to improve the submerged structures in littoral areas or to alter the amount of structure available to fish if structural complexity varies with elevation. Harvest of fish may be significantly increased if fish are concentrated in specific areas that fishermen are aware of or to which they can be directed. Attraction of many sport fishes to structure, because of increased prey availability, refuge, or spawning habitat, improves harvest. Davis and Hughes (1971) found that the presence of submerged trees greatly increased the local abundance of catchable-size largemouth bass and black crappies. Other species--e.g., gars (*Lepisosteus* spp.), buffaloes, and bullheads--were more abundant in open water. In Barkley Lake, Kentucky, Pierce and Hooper (1979) found total standing crops of 2,418 kg ha^{-1} in brush shelters, 998 kg ha^{-1} in tire attractors, and 773 kg ha^{-1} in control areas that lacked structure. It was clear that attracting structures concentrated four species of sport fishes. The ratios of mean standing crop in brush structures to that in control

areas were 10:1 for channel catfish, 61:1 for bluegill, 35:1 for largemouth bass, and 44:1 for white crappie. Structures made from tires concentrated 3.9 times more channel catfish than did control areas without submerged structures and 15, 20, and 14.2 times more bluegills, largemouth bass, and white crappie, respectively.

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104. Although artificial structures are valuable in bringing structure-oriented fish (e.g., black basses, crappies, and sunfishes) and anglers together, problems with placement of structures to avoid exposure during drawdown and periodic maintenance costs have inhibited their use (Jenkins 1973). As Calhoun (1966) stated, "California experience with brush shelters has been generally unsatisfactory... An experimental program at Millerton Lake, a large fluctuating warm-water reservoir, proved expensive and unprofitable."

105. Several authors who have reviewed and contributed to the existing information on the effectiveness of artificial structures in improving sport fisheries have developed valuable references for further information (see, e.g., Brouha and Prince 1973; Wilbur 1974; Prince et al. 1975; and Wilbur 1978). Prince et al. (1975) discussed research on species abundance, biological productivity, spawning, fish movement, and fishing success at artificial reefs. The effectiveness and economics of artificial reefs were examined by Prince and Maughan (1978), and Prince et al. (1979) discussed periphyton production, predator-prey relations, and condition and growth of fish in relation to reef structures. Recent research on fish responses to structure (principally artificial) was presented in a symposium by the North Central Division of the American Fisheries Society (see Johnson and Stein 1979).

106. Seasonal changes in harvest probably result from seasonal changes in the vulnerability of fish to anglers and in the fishing pressure exerted by anglers. It is well established that species spawning along shores are particularly vulnerable to anglers because they are concentrated in particular areas. Parsons (1957) noted that fishing pressure on reservoirs in the southeastern United States was highest in spring as was the harvest of sport fishes. Sixteen years of creel-survey data from Beaver Lake, Arkansas, corroborate Parsons' observations (unpublished data, National Reservoir Research Program). Fluctuating or reduced water levels in spring or early summer may not only be harmful to the reproductive success of fish but also could seriously reduce annual harvest by disrupting concentrations of fish or perhaps by limiting access of anglers to the lake. If drawdowns affect angler

pressure at all, they would have more impact during the growing season (spring, summer, and fall) than in winter, because most anglers fish during the growing season. Seasonal changes in harvest may also result from changes in water levels if turbidity increases greatly. For example, some sport fishes (such as black basses) are primarily sight feeders. Sight impairment may explain why black basses are seldom abundant in turbid impoundments. Kirkland (1963) observed that turbid floodwaters in mid-April greatly reduced the catch of spotted bass in Allatoona Reservoir, Georgia.

PART IV: SUMMARY AND RECOMMENDATIONS

Introduction

107. Increasing demands on reservoirs for water supply, irrigation, flood control, hydroelectric power generation, water quality control, and recreation require that priorities be assigned to these often conflicting uses. Demands for quality fisheries are increasing; fishing pressure on reservoirs is expected to increase 60 million angler days (a total of 36 percent) during the interval 1975-85. The present review was prepared to document the known effects of water-level changes on reservoir ecosystems and biota and to provide recommendations for water-level management to benefit reservoir fish and fisheries.

State-of-the-Art Perspective

108. The findings of this review corroborate the conclusions of a panel of experts who attended a workshop on research needs to have ecological issues considered in basin-level hydropower planning (Hildebrand and Goss 1981). The panel concluded that the capability to quantitatively predict the physical extent of water-level changes was adequate but that the capability to predict biological consequences was not. They also concluded that (1) the theory of bank and bed stability was poorly understood, (2) the capability to predict the effects of water-level changes on aquatic biota in lower trophic levels was poor, and (3) ecologists have not quantified the effects of water-level changes on fish, except to determine optimum or minimum requirements for spawning. The consensus of the panelists was that the ability to address ecosystem-level effects was qualitative at best.

109. After 50 years of studying reservoir biology, biologists have accumulated many observations of physicochemical and biological changes resulting from fluctuations in water levels. Although the observations are sometimes disjunct or contradictory and exceptions to accepted hypotheses are common, enough qualitative information is available so that preliminary recommendations for management of water levels to enhance fisheries can be formulated. However, rigorous quantitative analyses and the development of improved predictive capability must await the

acquisition of appropriate quantitative data and a better understanding of aquatic biology in general. Available information suggests that many of the responses of aquatic biota to water-level changes and their effects are generally predictable. However, almost all reservoir ecosystems have distinct physicochemical and biological characteristics that may cause them to respond differently to similar water-level regimes. Consequently, the guidance presented here is not intended as a broad-brush prescription for enhancing fisheries in all reservoirs. Rather, it is designed as an outline of potentially desirable ingredients for water-level management plans and presents a flexible scheme that can be modified to meet the specific needs of biota in different reservoirs. After all, general management plans are seldom applicable to all reservoirs because operational requirements vary greatly. Water-level regimes required to benefit fishery resources may be completely incompatible with the required operations of some reservoirs (e.g., some hydropower impoundments). By contrast, operational flexibility is possible for many other reservoirs, and water levels can be manipulated to enhance fish production or at least to substantially reduce major adverse effects on fish-food biota and fish communities.

Summary of Effects

110. Drawdown. Drawdown that exposes mudflats, dead and decaying vegetation, benthos, or fish is the most visually obvious type of water-level change. Drawdowns may interfere with fishing and navigation by reducing surface area and exposing previously submerged navigational hazards. It may limit the number of access points available to anglers and other boaters, force marinas and boat docks to be moved, and leave recreational areas such as swimming beaches far from the water. Limitations on access often cause fishing pressure and harvest of fish to decline, especially if drawdown occurs during the spring when harvest is usually highest.

111. Periphyton and benthos which are important sources of food for many littoral fishes, including YOY sport fishes, are adversely affected by drawdowns. Generally, the annual loss of periphyton production is directly related to the magnitude, frequency, and duration

of exposure. Drawdowns in winter presumably have less effect on periphyton than drawdowns during the growing season because of the direct relation between production and water temperature. Benthos associated with periphyton may be more important as food for many fishes than the periphyton itself. The full establishment of benthos associated with periphyton requires about 40 days of inundation and periphyton growth in some reservoirs. Consequently, exposure of these communities during the growing season results in a loss of standing crop throughout the period of exposure and lower biomass for about 40 days thereafter. Winter exposure of the littoral zone reduces the standing crop of benthic insects until late spring or early summer or until the insects have had time to reproduce and recolonize the substrates. During drawdown, standing crops of benthos are generally reduced by exposure or nonpredatory and predatory mortality while animals move to avoid exposure. Many forms survive in the drained zone by burrowing into substrates and entering resting stages. The net result of periodic drawdowns often is an inverted distribution of benthos. Maximum crops occur below the drawdown limit where littoral fish feed infrequently. Also, production of benthos is usually lower in deep water than in shallow water if water temperature diminishes greatly with increasing depth. The species composition of benthos in stable reservoirs usually differs significantly from that in fluctuating reservoirs. Diverse littoral communities of crustaceans and insects (e.g., mayflies, caddisflies, hemipterans, and crustaceans), which are extremely important as food for littoral fishes, are eliminated and replaced by organisms better equipped to survive drawdowns (e.g., chironomids and oligochaetes).

112. As suspended biota, phytoplankton and zooplankton probably are affected less by drawdown than by other changes in the environment, unless flushing rates are high. During the growing season, primary production by phytoplankton generally increases in response to increased nutrients and light until one or both of these factors become limiting. Zooplankton also increases production in response to increased levels

of food, regardless of the cause of the improved trophic conditions, providing other factors are not adverse.

113. Rapid release of water during growing-season drawdowns may adversely affect phytoplankton, zooplankton, some benthos, and larval fishes. Suspended algae, animals, nutrients and detritus in the water column may be flushed downstream. High runoff from the drainage basin may increase turbidity and limit light required for primary production. Concentrations of phytoplankton may not reach sufficient concentrations to fully use available nutrients before being eliminated by discharge. The standing crop of zooplankton also is inversely related to the rates of flow through reservoirs and may be reduced significantly when water retention time is short (e.g., < 30 days). Consequently, in reservoirs where flushing rates are not consistently high, standing crops of phytoplankton, zooplankton, and larval fish may be increased significantly by reducing rates of flushing during warm weather.

114. Most reservoirs that experience large drawdowns seasonally or more frequently do not support extensive growths of aquatic macrophytes. To increase fish production in littoral areas of these reservoirs, man can provide structure by planting and seasonally flooding terrestrial plants, by retaining timber, or by constructing artificial structures.

115. Drawdowns during or within 3 months after the spawning season may limit the reproductive success of fish by reducing survival of eggs, larvae, or fingerlings. Survival is reduced by stranding of eggs or young fish, predation on eggs and YOY fish, or a shortage of food. Reduced standing crops of benthos after drawdown eventually may limit the production and survival of YOY fishes and benthophagous fishes. Severe drawdowns may force fish into anoxic waters in summer, thereby causing mortality by suffocation.

116. Some effects of drawdowns are beneficial. For example, drawdowns have been successfully used to consolidate and aerate sediments. Aeration remineralizes nutrients such as nitrogen and phosphorus and reduces the organic load of sediments by aerobic decay. Consolidation of sediments may reduce turbidity after sediments are reflooded. Inflow

of water when lake elevations are low may move some sediments accumulated in headwater areas downstream, thereby reducing the formation of deltas in upstream areas. Drawdown may disrupt thermal stratification and increase the rate of oxidation and decay of organic matter in sediments at low elevations in the basin by providing oxygen for aerobic metabolism.

117. Drawdowns have also provided the benefit of controlling overabundant aquatic macrophytes that often become established in shallow impoundments with relatively stable water levels. Congested areas have been opened to boats and fishermen. Because the effects of drawdowns on macrophytes are species specific, a review of case-history studies (e.g., see Hulsey 1958; Holcomb and Wegener 1971; Beard 1973; Lantz 1974; Nichols 1972, 1974) is recommended to determine the applicability of drawdown as a control measure. The greatest control by drawdown is usually achieved by winter dewatering in areas where substrates freeze. Short-term drawdowns (< 3 months) during the growing season generally have little effect on macrophytes.

118. Herbaceous terrestrial plants that become established on suitable substrates after drawdown are beneficial. These plants provide excellent spawning and nursery sites for many species of fish when inundated at the appropriate times. They also provide food and refuge for bacteria, zooplankton, benthos, and fish; substrates for attached algae; and nutrients for all aquatic plants.

119. Drawdown provides a chance for fishery managers to plant desirable vegetation, construct or refurbish artificial structures for fish, or to mechanically remove overabundant aquatic macrophytes. Large drawdowns may be used to increase the availability of prey fish for piscivores by concentrating prey and predators or by reducing the amount of refuge available for prey. Benthic invertebrates also may be concentrated by drawdown, and growth rates of many piscivores and benthophagous fishes commonly increase immediately after drawdown. Increased predation may eliminate many egg and fry predators that can limit the reproductive success of some sport fish such as largemouth bass.

120. Drawdowns may help limit the reproductive success of undesirable fishes such as common carp, but few applications have yet been clearly successful in exclusively controlling the abundance of undesirable fishes.

121. Flooding. Flooding of terrestrial areas (especially those with vegetation) often has been associated with increased nutrient and detrital inputs, reduced turbidity, and increased primary and secondary production during the growing season. Flooding may have adverse effects on attached plants such as macrophytes and periphyton if turbidity or depth increase to the point that light becomes limiting. When light is available, phytoplankton production increases if flooding increases nutrient levels. Zooplankton abundance and biomass usually increase if detritus and phytoplankton concentrations increase. Flooding may deposit sediments at higher elevations and thereby enhance the potential of the upper portion of the fluctuation zone to support terrestrial or aquatic plants or burrowing species of benthos. After flooding, many species of benthos and fish rapidly colonize new areas, and fish growth may increase briefly in response to the temporary abundance of drowned terrestrial animals as food. The number and quality of sites available for spawning for many species of fish may change depending on the type of substrate inundated. Benson (1976) listed the spawning requirements of many important sport and commercial fishes, and similar information was provided by Carlander (1969, 1977). Survival of eggs and nests of sport fish such as black bass and crappies may be improved if cover is inundated; nests then are more sheltered from waves, and their defense is facilitated. Increased structural complexity made available by flooding has been associated with improved survival of young littoral fishes. Additional refuge and food account for positive correlations of year-class strength and growth of many fishes with extensive flooding of terrestrial areas.

Water-Level Changes--Effects and Management

122. Management of the fluctuation zone. Intensive management of the fluctuation zone is highly desirable for increasing biological productivity and enhancing fisheries. Because substrates exposed by

drawdown are vulnerable to erosion that may eventually create a barren nutrient-limited fluctuation zone, the early establishment of herbaceous terrestrial vegetation after drawdown is important for erosion control, aesthetic purposes, and nutrient retention. Herbaceous terrestrial plants established during drawdowns increase the availability of nutrients by removing them from sediments to form biomass. Inundated terrestrial plants significantly benefit aquatic plants by providing nutrients or substrates. They provide substrates, refuge, and food for many animals and spawning sites for many species of fish. Herbaceous vegetation also provides nursery habitat that can be expected to increase the survival of YOY sport fishes. When reflooded, vegetation-covered areas also are less apt to contribute to turbidity which is detrimental to spawning and foraging of some fish.

123. Drawdown must occur during the growing season for successful seeding of herbaceous terrestrial plants in fluctuation zones of reservoirs. The time of drawdown should allow for full development of vegetation before winter. Hulsey (1958) recommended drawdown by 15 September in Arkansas for plantings of rye. Groen and Schroeder (1978) also discussed planting of rapidly growing plants such as annual ryegrass, wheat, or rye during September or October after fall drawdowns in Kansas. Ryegrass was usually seeded at 11 kg ha^{-1} and wheat and rye at 34 to 68 kg ha^{-1}. For early drawdowns before August, Japanese millet and hybrid sudan-sorghum were also seeded successfully in fluctuation zones of Arkansas and Kansas reservoirs. Other herbaceous plants may be equally beneficial but have not been used extensively. Species of plants best equipped to grow in fluctuation zones vary with the region of the country, edaphic factors, and climate. In general, plants that grow rapidly and produce lush stands of vegetation within 1 to 3 months are most desirable.

124. Submerged structures (e.g., timber or artificial reefs) have been shown to provide substrates for periphyton and benthos communities and shelter that significantly concentrates fish, thereby increasing angler harvest. The productivity of periphyton-benthos communities on submerged structures increases the availability of food for fish. Structure may modify predator-prey relations of fish by providing refuge

or by decreasing the effectiveness of predator foraging. By manipulating water levels, managers may be able to decrease the structural complexity of shallow-water habitats (by dewatering areas with structure) and thereby increase the use of forage by predators. Conversely, they may be able to increase structural complexity and the survival of YOY sport fishes by inundating upper sections of the fluctuation zone.

125. In new reservoirs, timber should be retained in the fluctuation zone to provide habitat for littoral fish. Stands of timber perpendicular to shorelines and extending vertically through the entire fluctuation zone provide submerged structure at all water levels. Inverted triangular stands of timber or other structures that extend through the fluctuation zone provide more structure at high than at low elevations.

126. In older reservoirs where standing timber has deteriorated, artificial structures or fish attractors should be constructed in the fluctuation zone. Structures can be built or refurbished during drawdowns. They may consist of no more than three or four trees chained together and to the bottom, or they may be more elaborate, such as those described by Brouha and Prince (1973), Wilbur (1974), Prince et al. (1975), Wilbur (1978), Johnson and Stein (1979), and Pierce and Hooper (1979).

127. In large reservoirs where other essential uses prohibit the manipulation of water levels to benefit fishery resources, a potentially valuable alternative is the construction of inlet or subimpoundments of 40 to 200 ha. The idea is not new; subimpoundments were discussed by Ellis (1937) and inlet impoundments were studied by Grimås (1965) in Norway. Subimpoundments can be formed by building flood-control structures across large coves, embayments, or arms of reservoirs. Early views of subimpoundments held that they provided areas of stable water for fish reproduction or feeding. Small subimpoundments preserved some littoral areas but were insufficient mitigation for extensive water-level fluctuations. Subimpoundments do have potential for providing highly productive fisheries in parts of large fluctuating reservoirs where fisheries are limited by extensive fluctuations in water level. Water

levels in subimpoundments could be intensively managed by biologists to benefit fish or waterfowl.

128. Magnitude and frequency of water-level changes. The amount of bottom area affected by changes in water levels is determined by the vertical magnitude of changes and the shape of the reservoir basin. Direct effects of drawdowns on sediments, periphyton, macrophytes, benthos, and littoral fishes are largely a function of the amount of bottom exposed, and consequently, methods to estimate exposed area are valuable. For example, the amount of area exposed annually may be valuable as an independent variable in regression analysis because it can be directly related to changes in elevation or volume, which are important variables in current models for scheduling operations. Hildebrand et al. (1980) developed two methods to estimate the amount of area affected by water-level changes from (1) data on shore slope, (2) the vertical change in water levels, and (3) the length of shore of a given slope. A third method involved a simple geometric model and can be used when no detailed topographic data are available.

129. A simple index to the amount of littoral area affected by water-level changes is the change in surface area ($\pm$ dA). The index is positive when waters rise and negative when they decline. The index is easy to calculate from readily available data (standard area-capacity curves) and accounts for the effect of basin slope on the productivity of the littoral zone. Littoral areas generally are less well developed and less productive in steep-sided, deep reservoirs than in gently sloping, shallow reservoirs. The effect of a given change in water level on the littoral zone should be directly proportional to the amount of littoral area exposed. In steep-sided, deep reservoirs, the area of bottom exposed by a 2-m drawdown would be small, as would the change in surface area (probably < 5 percent). The littoral zone may be completely eliminated, but the amount of littoral habitat and productivity lost should be low because of the steeply sloped shore areas. A 2-m drawdown in a shallow plains reservoir could reduce surface area by 20-30 percent.

The dA index would be negative and large, reflecting significant losses of productive littoral area. The effect of reflooding these areas should also be related to the index.

130. As discussed above, effects on littoral areas may be related to the amount of bottom area exposed if they result directly from water-level changes. However, if the impacts result indirectly from changes in habitat that accompany water-level changes, factors such as frequency, duration, and timing of water-level changes, as well as edaphic factors, must be considered.

131. Frequent (weekly or monthly) fluctuations in water levels should be avoided because they adversely effect periphyton, benthos, fish reproduction, and the survival of YOY fishes. The fluctuation zone of reservoirs with frequent fluctuations in water levels often become infertile because of erosion. Even long-term (1- to 3-year) changes in water levels would have a little positive effect on nutrients or trophic conditions if the fluctuation zone is infertile or devoid of vegetation. Rapid drawdowns are generally more harmful than slower ones because the time available for benthos or young fish to avoid exposure is shorter. Frequent fluctuations in water levels usually have little beneficial effect on nutrients or trophic conditions, because sediments are not significantly aerated and herbaceous plants do not have time to grow in the fluctuation zone. Flooding of rich stands of herbaceous vegetation can only increase productivity if the duration of flooding extends for 3 or more months of the growing season. Full use of vegetation as food requires time for colonization by bacteria, algae, and invertebrates. Although colonization of newly flooded areas is rapid during the growing season; it is far from immediate in reservoirs with frequent fluctuations, and the full development of algae, zooplankton, and benthos communities would not be complete by the time drawdown would eliminate them. Long periods of flooding (> 3 months) should provide more food and habitat for fish and insure that spawning success is not limited.

132. Drawdowns should last 2 or more months of the growing season (frost-free period) and reduce surface area sufficiently (about 50 percent in reservoirs < 200 ha and at least 20 percent in reservoirs > 200 ha) to improve the growth and condition of sport fishes by concentrating prey. Also, 2 months of low water probably is the minimum time required for predators to have a significant impact on populations of prey fishes (e.g., bluegills), or for lush stands of herbaceous vegetation to become established on suitable substrates in the fluctuation zone. Generally, large drawdowns are more effective than small ones in altering predator-prey interactions and eventually the species composition of fish, but only onsite sampling of fish communities can reveal the optimum magnitude and duration of a drawdown for a specific reservoir.

133. Timing of water-level changes. Drawdowns should be scheduled so that they do not adversely affect the reproductive success of fishes that spawn in littoral areas. In general, provision of high stable water levels during and for a month after the spawning season will not impair reproductive success. Furthermore, water levels should be steady or rising during spring and early summer (April-June) to benefit spring-spawning fishes or in fall (October-January) to benefit fall-spawning salmonids.

134. Evidence from warmwater impoundments suggests that year-class strength is influenced more by survival after spawning than by spawning success. Survival of YOY fishes usually can be improved greatly by maintaining high water levels for as long as possible after spawning is complete, especially if vegetation is present in the fluctuation zone. Because the provision of high water during summer is often restricted by peak demands for water for irrigation, consumptive uses (especially in arid regions), or for generation in hydropower reservoirs, the chances for enhancing the survival of YOY fishes by maintaining high water in summer is remote. However, annual recruitment of many sport fishes in reservoirs is sporadic, suggesting that high water maintained until late summer or fall every 3 to 5 years may be sufficient to produce strong year classes and to maintain quality sport fisheries.

135. Operational flexibility increases where a chain of reservoirs exists. Flexibility generally is directly related to the number of reservoirs in the system, at least for the lower reservoirs in a series. Every 2 years one reservoir in a series could be selected and managed for 1 or 2 years to significantly increase fish production and enhance fisheries. With appropriate scheduling, power and water demands could be made up by releases from other reservoirs. Age structure of fish populations and relations between prey and predator biomass (see methods of Swingle 1950; Jenkins and Morais 1976) should be examined to determine which reservoir would benefit most by intensive management. Impoundments with small populations of mostly older sport fish and few surplus prey would be prime candidates for treatment.

136. A general 2-year plan to manage water levels of non-salmonid reservoirs should include four essential elements:

(1) Drawdown in summer or fall.

(2) Establishment of herbaceous terrestrial vegetation (naturally or by planting) during periods of low water.

(3) Flooding of the drained zone and vegetation in spring.

(4) Maintenance of high water for as much of the growing season as possible.

Variations of this basic plan with regard to magnitude, duration, and time of water-level changes should be adequate to meet the specific needs of most conservation agencies. The Kansas Game and Fish Commission, for example, often limits the extent of drawdown to 10-20 percent of the original area, seeds vegetation extensively, and raises water levels slightly in fall to flood vegetation for waterfowl (Groen and Schroeder 1978). Management of flood-control reservoirs in Arkansas (Hulsey 1958) incorporated extensive drawdowns that reduced surface area by about 80 percent. Drawdowns in most reservoirs are best scheduled for late summer or fall because water temperatures are above 13° C and piscivores are still feeding intensively. Earlier drawdowns are not favorable to the reproductive success of fish that spawn in spring, and drawdown in winter does not permit the establishment of terrestrial vegetation in the drawdown zone.

137. Winter changes in water level have little impact on nutrient levels, oxygen concentrations, or planktonic biota. In winter, low water temperatures reduce rates of nutrient cycling, consumption, respiration, and production of organisms in all trophic levels. Because production is low in winter, rapid releases of water in winter probably would have a negligible effect on phytoplankton or zooplankton production. Inasmuch as feeding by warmwater fish is reduced in water less than about 13° C, significant use of prey by predators is unlikely.

138. Adverse effects of winter changes in water level may occur during that winter or be delayed until the next growing season. Impacts of winter drawdowns probably are most severe on aquatic macrophytes that are exposed and frozen, or on benthos, because the loss of early instars reduces the potential for high production in the next spring and early summer. Winter flooding of terrestrial areas may result in physical separation of detritus and leaching of nutrients, but the use of detritus and nutrients by biota will be low. Vegetation inundated in winter probably will be of less value as spawning and nursery habitat or as food in spring because of physical separation and leaching. Warmwater fish are more susceptible to entrainment and discharge from impoundments in winter than in other seasons because they are less active. In reservoirs with extensive and rapid drawdowns in winter, mortality of fish can be reduced by limiting the rate and extent of drawdown. Survival of eggs or YOY of salmonids spawned in fall may be significantly reduced by drawdown, as a result of stranding or loss of habitat. Development of eggs and fry is slow in cool water; consequently, their vulnerability to potentially adverse conditions is prolonged. The maintenance of stable water levels until YOY fish are able to migrate is essential to the production of strong year classes. If water levels must be lowered, they should be lowered slowly in late winter.

139. There are three primary reasons for intensively managing reservoirs for 1 or 2 years at 3- to 5-year intervals. First, intensive management for 1 or 2 years should do more to increase the primary and secondary production as well as the recruitment of fish than provision of moderately beneficial water levels every year; most reservoir fishes

have evolved boom-and-bust patterns of recruitment, developing strongly during periods of extensive flooding and weakly during periods of drought. Second, by managing water levels every 3-5 years, the necessity of providing water levels suitable for spawning every year is eliminated. Third, improved trophic conditions for invertebrates and fish that result from high inflows and flooding of terrestrial vegetation generally are short-lived because sources of readily available nutrients and detritus are exhausted within 1-2 years. Consequently, even with the most favorable management regime, managers cannot expect to increase fish standing crops for more than 1-2 years.

140. Major perturbations of reservoirs every 3-5 years can be beneficial to sport fish. In unperturbed reservoirs, the biomass of many forage fish is in the form of large fish that are available as food only for large predators. Although high densities of large forage fish require enormous amounts of energy annually, they contribute little to sport-fish production. By perturbing reservoirs with large drawdowns for 3 or more months and then flooding terrestrial areas for 3-5 months of the next growing season, the efficiency of the trophic system can be increased. Populations of larger forage fish should be reduced, and the reproductive success of all fish should be enhanced. Fall drawdowns may force small forage fish from cover and increase the availability of food for YOY and yearling predators at a time when many of the available forage fish have grown too large for them to swallow. Flooding should enhance reproductive success, thereby providing more young fish of a forageable size. Although data are sparse, some evidence suggests that multiple spawnings of gizzard shad (the primary forage fish of most reservoirs) may be produced by brief periodic increases in water levels between June and September (Domermuth and Dowlin 1975; Groen and Schroeder 1978). More research is needed to confirm this phenomenon in other reservoirs, but there is no question that multiple spawns of gizzard shad would be desirable to increase the availability of small forage for young predators late in the growing season.

141. Management plans occasionally are unsuccessful in improving fishery resources because unforeseen factors complicate management of water levels (e.g., excessive drought or flooding). They may fail because the recruitment of fish is poor as a result of stormy weather or low water temperatures during most of the spawning period. The abundance of prey may be low, or large populations of predators may overrun their prey base. Variables such as storms and adverse temperatures are obviously beyond man's control, but provisions of desirable conditions for fish feeding, spawning, and survival should greatly increase the chances of improving fisheries when the uncontrollable variables are favorable.

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DTIC

Grand Lake Management Plan

Background

Grand Lake O' The Cherokees is a 46,500 acre reservoir located in Delaware, Mayes, and Ottawa counties in northeast Oklahoma (Figure 1). The lake is owned and operated by the Grand River Dam Authority (GRDA), an agency of the State of Oklahoma. GRDA operates the Pensacola Project (including Grand Lake) under authorization granted in their 1992 license issued by the Federal Energy Regulatory Commission (FERC). Grand Lake was created by the completion of the Pensacola Dam in 1940, which impounded approximately 53 miles of the Grand River System. The watershed consists of approximately 10,000 square miles of runoff that originate in, and flow across multiple states including Arkansas, Kansas, Missouri, and Oklahoma. The eastern portion of the Grand Lake watershed is made up of the Ozark Plateau. The western portion of the watershed is indicative of the Prairie Plains. Grand Lake's substrate is comprised of limestone, sandstone, chert, and shale. Table 1 contains a list of physical and chemical characteristics of Grand Lake.

GRDA manages Grand Lake elevations in accordance with Article 401 of the 1996 license amendment issued by FERC. The FERC license defines a rule curve or seasonal lake level plan for Grand Lake as follows:

May 1 – Raise elevation from 742 to 744 feet PD
Jun 1 – Elevation 744 feet PD
Aug 1 – Lower elevation from 744 to 743 feet
Aug 16 – Lower elevation from 743 to 741
Sep 1 – Elevation at 741 feet PD
Oct 16 – Raise elevation from 741 to 742 feet PD
Nov 1 – Elevation at 742 feet PD

> Pensacola Datum (PD) is 1.07 feet lower than National Geodetic Vertical Datum, which is a national standard for measuring elevations above sea level.

While elevations outlined in Article 401 are target elevations, Grand Lake can fluctuate greatly due to flood control and hydropower concerns. Since the 1996 rule curve amendment, Grand Lake has fluctuated between 740.5 to 755 feet PD, with five to seven foot deviations from the rule curve being fairly common. Average daily elevations for Grand Lake are presented in Figure 2. Grand Lake is part of the Arkansas River Basin system of flood control and navigation. The United States Army Corps of Engineers (USACOE) has flood control authority when the lake reaches the top of the conservation pool. The flood control pool is between elevations 745 and 755 feet PD.

GRDA is currently in the process of developing a shoreline management plan and updating the recreation management plan for Grand Lake. These plans are expected to be finalized in 2009. Draft copies of these documents can be viewed at http://www.grda.com/Water/SMP/smp.html.

Habitat

Shoreline habitat in Grand Lake is primarily comprised of rock and gravel. Additional habitat includes man-made structures such as rip-rap, brush piles, and boat docks. Very little aquatic vegetation or standing timber exists within the lake. Aquatic vegetation plantings were initiated in 2004 with the goal of determining what plants could be successfully established. This program was a cooperative effort between the ODWC, Oklahoma Water Resources Board (OWRB), Lewisville Aquatic Ecosystems Research Facility and GRDA. A total of 10 founder colonies and 12 acres of aquatic plants have been established and maintained. Evaluation of these sites is still ongoing. A report on this program can be found at http://www.owrb.ok.gov/studies/reports/reports_pdf/GrandLakeRevegProject2007.pdf. The ODWC has established and maintained 13 brush piles on Grand Lake. Locations of the brush piles can be found on the Department's Interactive Digital Wildlife Atlas at http://www.wildlifedepartment.com/wmas2.htm.

Water Quality

Grand Lake is classified as a eutrophic reservoir with high primary productivity. Water quality data collected through the OWRB as part of their Beneficial Use Monitoring Program (BUMP) classifies Grand Lake as supporting or partially supporting the outlined Fish and Wildlife Propagation (FWP) beneficial uses. The complete BUMP report for Grand Lake can be viewed at http://www.owrb.ok.gov/quality/monitoring/bump/pdf_bump/Current/Lakes/grand.pdf. A brief overview of several water quality parameters is included below.

Thermal and Chemical Stratification

The upper portion of Grand Lake (Elk River Arm to Twin Bridges) is well mixed during the fall, winter, and spring. During the summer, up to 43% of the water column will have D.O. values less than 2.0 mg/l. At mid-lake (Elk River Arm downward, including Horse Creek Cove and the Honey Creek Arm), thermal stratification is not present during the fall and winter. The water column during the spring is weakly stratified. Stratification during the summer is more evident with anoxic conditions present for 22-47% of the water column. The lower lake (Horse Creek Cove to Pensacola Dam) is not stratified during the winter, and weakly stratified during the fall and spring. Stratification during the summer is more evident with anoxic conditions present for 47-62% of the water column. All D.O. values meet the Oklahoma Water Quality Standards, partially supporting assigned FWP beneficial use. The thermocline will normally form in June at 30-40 feet below the surface.

Productivity

A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated to measure the lake's productivity. The average TSI was 59, classifying the lake as eutrophic, indicative of variable oxygen concentrations, nutrient rich conditions, and limited benthic species diversity. This value is similar to that calculated in 2004 (TSI=57) and 2001 (TSI=59), placing the lake within the same trophic category. Chlorophyll-a values varied by site and season at Grand Lake. The TSI values ranged from oligotrophic (2%) to hypereutrophic (33%), although most values were in the mesotrophic (21%) or eutrophic categories (44%). The lowest TSI average was at the lower end of the lake and the most productive sites were in the tributary arms, Honey Creek and Spring/Neosho River arm.

Conductivity

Specific conductivity ranged from 264 µS/cm to 374 µS/cm, indicating low to moderate concentrations of ionized salts in Grand Lake.

pH

The pH values ranged from 7.07 to 8.68 representing a neutral to slightly alkaline system. All values are within the acceptable range, supporting the beneficial use based on pH.

Tailrace

Anoxic water from beneath the chemocline is released downstream into the tailrace during generation. Low D.O. values are typical below most hydropower dams in Oklahoma. Grand River Dam Authority is currently working with the Tennessee Valley Authority and other appropriate resource agencies to prevent any negative impacts to aquatic communities in the tailrace.

Fishery

The major sportfish in Grand Lake include largemouth bass, spotted bass, white bass, hybrid striped bass, white crappie, black crappie, blue catfish, channel catfish, flathead catfish, and paddlefish. The primary forage species include threadfin and gizzard shad. Special fishing regulations which apply to Grand Lake, all tributaries upstream to the state line, and below Pensacola Dam downstream to the SH 82 bridge include: 1) all species of black bass have a minimum size limit of 14 inches and a creel limit of six combined per day; 2) all crappie have a minimum size limit of 10 inches and a creel limit of 15 per day; 3) striped bass hybrids and/or white bass have a creel limit of 20 combined per day, of which only five may be 20 inches or longer.

The fish stocking history for Grand Lake is included in Table 2.

Black Bass

Grand Lake is one of the best black bass lakes in the state and region. Tournament results for Grand Lake are summarized in Table 3. Grand Lake contains three species of black bass; largemouth bass (*Micropterus salmoides*), spotted bass (*M. punctulatus*), and smallmouth bass (*M. dolomieu*).

Largemouth Bass

The largemouth bass is the dominant black bass species in Grand Lake. Catch rates and size structure of largemouth bass are included in Table 4 and Figures 3 and 4, respectfully. Largemouth bass from Grand Lake were tested for Largemouth Bass Virus (LMBV) from 2000 through 2003. These results indicated that approximately one-third of the population carried LMBV. LMBV test results from Grand Lake are listed in Table 5. Fish kills resulting from LMBV were never confirmed at Grand Lake; however fishing success did decline from 2000 to 2003. Since 2003, the largemouth population has maintained consistently high recruitment and fishing success has remained above average. Otoliths were collected from largemouth bass during the 2008 sample. These otoliths will be evaluated to determine a baseline for age and growth in Grand Lake.

Spotted Bass

Spotted bass make up a small portion of the black bass population at Grand Lake. Size structure of the spotted bass population is listed in Figures 5-6. Otoliths were collected from spotted bass during the 2008 sample. These otoliths will be evaluated to determine a baseline for age and growth in Grand Lake.

Smallmouth Bass

Smallmouth bass abundance in Grand Lake is unknown. Few smallmouth are caught in the lake, with most of these reports coming from the upper reaches of the tributaries. Smallmouth bass are native to the Grand Lake watershed. A genetic survey across the natural range of smallmouth bass conducted in the 1990s demonstrated that the native populations in eastern Oklahoma represent the two most divergent lineages of the species (referred to as the Ouachita and Neosho smallmouth basses). The genetic uniqueness of these populations along with the desire to protect against contamination of their genetic diversity, led the ODWC to place a moratorium on the stocking of non-native smallmouth bass in watersheds containing these native strains.

Temperate Bass

White Bass

White Bass (*Morone chrysops*) are an important portion of the Grand Lake recreational fishery. They are abundant in number and support numerous, year-round guides on Grand Lake. White bass also create a popular spring fishery in the upper portions of Grand Lake and its tributaries during their spawning run. Catch rates and size structure of the Grand Lake white bass fishery are included in Table 6 and Figures 7 and 8, respectfully.

Hybrid Striped Bass

Hybrid striped bass (F_1: male *Morone chrysops* x female *M. saxatilis*) were first stocked in Grand Lake in 1981 and additional stocking records are included in Table 7. Historically, stocking rates and frequency have not been at the desired levels to produce a quality hybrid striped bass fishery in Grand Lake. However, years following increased stocking efforts have resulted in increased fishing success. Hybrids also pass through the dam during hydropower and floodwater releases to create a recreational tailrace fishery below Pensacola Dam as well as other reservoirs and tailraces located downstream. Hybrid striped bass reach large sizes within and below Grand Lake. A former state record hybrid was caught in the Pensacola Dam tailrace (19.2 lbs) while another was caught in the upper portion of the lake (22.2 lbs.). Catch rates and size structure of the Grand Lake hybrid striped bass fishery are included in Table 7 and Figures 9 and 10, respectfully.

Crappie

Grand Lake contains both white crappie (*Pomoxis annularis*) and black crappie (*P. nigromaculatus*). White crappie is the more prevalent of the two species, accounting for approximately 95% of the population. Over the past five years, the Grand Lake crappie population has declined due to several consecutive years of below average rainfall. Low inflows reduce the abundance of essential nutrients that drive plankton production. Young-of-the-year crappie feed on plankton until they reach approximately 5 inches long. The high inflows experienced in 2007, resulted in a relatively large year class of young crappie. Crappie catch rates, growth rates, and size structure from fall 2007 trapnetting are presented in Tables 8 and 9 and Figures 11, 12 and 13.

The daily creel limit is 15, white and black crappie combined, with a 10-inch minimum length limit.

Catfish

Blue Catfish

The development of the Grand Lake blue catfish (*Ictalurus furcatus*) fishery has steadily increased over the past 10 years. Blue catfish have become an important and commonly sought after sportfish at Grand Lake. The current blue catfish Grand Lake record was caught in 2008 using rod and reel near Sailboat Bridge (43.0 lbs.). Catch rates and size structure of the Grand Lake blue catfish fishery are included in Table 10 and Figures 14 and 15.

Channel Catfish

Channel Catfish **(***Ictalurus punctatus***)** are omnivorous, feeding on a wide variety of organic matter, dead and alive. Some of the more common foods are fish, mussels, snails, insects and crayfish. Catch rates and size structure of the Grand Lake channel catfish fishery are included in Table 11 and Figures 16 and 17.

Flathead Catfish

Adult Flathead Catfish **(***Pylodictis olivaris***)** are found near cover in larger pools and deep holes. They like old brushy tangles, submerged logs and undercut banks. Most are taken while trotlining, juglining, limblining or noodling. A former state record was caught from Grand Lake in 1968, using rod and reel near Big Hollow (44 lbs.). Catch rates and size structure of the Grand Lake flathead catfish fishery are included in Table 12 and Figures 18 and 19.

Paddlefish

Paddlefish (*Polyodon spathula*) have a large historical range in Oklahoma. Grand Lake had population estimates for both 2003 and 2004 (n = 80,808 and n = 55,404, respectively). The spawning migration into Grand Lake's tributaries congregates a large number of fish each year from March – April. Anglers can snag paddlefish over 50 lbs during this period. In the past, paddlefish in the Grand River System were also harvested by commercial fishermen. The threat of overexploitation exists due to heavy fishing pressure and low recruitment. Paddlefish are susceptible to problems with habitat disruption, and low water dams. ODWC recently opened the Paddlefish Research and Processing Center (RPC) at Twin Bridges State Park to learn more about this valuable resource. The center was open during snagging season for anglers to have their fish safely cleaned and packaged free of charge. The RPC opened for the first time on February 20, 2008 and processed 4,221 paddlefish through April 30, 2008. Carcasses and remains from processed fish were recycled into heating oil. Biological data, including length and weight, dentary bones for age analysis, and gonad data was gathered from the fish brought to the RPC. A total of 147 paddlefish jaws were collected during the winters of 2003-2004 from netting mortalities (Sampling mortality was 4.04% during these two years; mortalities increase when water temperatures exceed 10°C). Both male and female age distribution show a spike at age 5 (62% for male and 38% female). Thirty-three percent of males were age 6 or older, while 54% of females were age 8 or older (Tables 13 and 14, Figures 20 and 21). With the help of anglers, the ODWC was able to collect 4,221 paddlefish jaws during the 2008 spawning migration. An ultrasonic telemetry study was initiated during the winter of 2007 to identify migration routes and spawning areas that will need protection in the future. Success of spawning paddlefish in Grand Lake may affect the paddlefish populations in downstream impoundments. As angler interest grows and exploitation increases, it will be necessary to closely monitor paddlefish populations in Grand Lake. Catch rates and size structure of the Grand Lake paddlefish fishery are included in Figure 22. ODWC is currently working with the U.S. Fish and Wildlife Service to obtain 2,000 juvenile paddlefish each year. These fish will be marked with coded wire tags, indicating the year in which they are stocked. These stockings will be valuable in determining known age fish from the Grand Lake population. Fish brought to the RPC will be scanned for the presence of coded wire tags in the future.

Shad

Gizzard Shad

Gizzard Shad *(Dorosoma cepedianum)* provide forage for most game species. The species is often used by anglers as bait for other fish species. Catch rates and size structure of the Grand Lake gizzard shad fishery are included in Table 15 and Figures 23 and 24.

Threadfin Shad

Threadfin Shad *(Dorosoma petenense)* are quite temperature sensitive, with die-offs reported at temperatures below 45°F. They have been introduced as forage fish in Grand Lake. Adults are considerably smaller than gizzard shad adults, rarely exceeding 6 inches in length. The species is often used by anglers as bait for other fish species. Catch rates and size structure of the Grand Lake threadfin shad fishery are included in Table 16 and Figures 25 and 26.

Fish Consumption Advisories

Fish consumption advisories are issued by the Oklahoma Department of Environmental Quality (ODEQ) and can be viewed at www.deq.state.ok.us/mainlinks/press.htm. The most recent advisory at the time of this document was issued on March 12, 2008. That advisory cautioned against the exposure to lead from consumption of fish from waters impacted by the Tar Creek Superfund site and the Tri-State Mining District.
A 2007 study conducted by ODEQ titled “Fish Tissue Metals Analysis in the Tri-State Mining Area Follow-up Study” can be viewed at www.deq.state.ok.us/csdnew/2007TCFishReport.pdf

Threats to the Fishery

Aquatic Nuisance Species

Zebra Mussels

Adult zebra mussels (*Dreissena polymorphawere*) first confirmed in Grand Lake in February of 2005 at the Disney State Park boat ramp. An additional confirmed zebra mussel was found in Ketchum Cove in July of 2006. Since this time, no other reports of zebra mussels have been confirmed at Grand Lake. Zebra mussels will continue to be a threat to Grand Lake and the entire Grand River Watershed. Monitoring of zebra mussels in Grand Lake should be coordinated with efforts of GRDA and other appropriate agencies and universities.

Bighead Carp

Adult bighead carp (*Hypophthalmichthys nobilis*) have been confirmed in Grand Lake. The most recent, confirmed bighead carp was snagged at Miami Park, in the Neosho River in May of 2008. Bighead carp are invasive fish that feed on plankton and compete for food with larval fishes and mussels. Documenting Asian carp sightings will be critical to monitoring their expansion.

Pacu

Sightings of pacu occur in Grand Lake, however they are rare. They are commonly misidentified as piranha, and occasionally receive unwarranted media attention. Pacu are readily available from pet stores and are likely released into Grand Lake once they have outgrown their aquaria. They are classified under a number of genera, but the most common species found in pet stores include the Black Pacu (*Colossoma macropomumand*) and the Red-bellied Pacu (*C. brachypomum*). Pacu are native to South America and are not believed to survive the low temperatures experienced during winters in Oklahoma. They are mainly herbivores, but will also eat small fish, insects, and meat on fishing lures. Their teeth, which may resemble human teeth, are used to cut through vegetation and crush seeds that fall into the water. Pacu and piranha are distinguished from each other by their teeth and jaw alignments; piranha have pointed, razor-sharp teeth in a pronounced underbite, whereas pacu have square, straight teeth in a less severe underbite, or a slight overbite. Pacu are not believed to pose a serious threat to native species at Grand Lake, however they do cause unwanted fear and concern from the general public. Documenting pacu sightings will be critical to monitoring their survival and population increase.

Pollution

Tar Creek Superfund Site and the Tri-State Mining District.

The Tar Creek Superfund Site is a 40 square-mile site that is part of the Tri-State Mining District, which includes northeastern Oklahoma, southeastern Kansas, and southwestern Missouri. Specifically, the site includes the Old Picher Field lead and zinc mining area located in northeastern Ottawa County. The population in the surrounding area is approximately 19,556 people. The Site consists of five mining cities, Picher, Cardin, Quapaw, Commerce, and North Miami, and other areas within Ottawa County. Mining occurred there from the early 20th Century until the 1960's-1970's. The milling process for lead and zinc ore produced waste mile tailings, also known as chat. Chat piles are located throughout the site. In addition to chat, another by-product of the mining operation is highly acidic mine water. The principal pollutants are lead, cadmium, and zinc. When the lead and zinc mines were abandoned, they began filling with water. In the late 1970's, acid mine drainage containing high concentrations of heavy metals began discharging into Tar Creek from natural springs, boreholes, and open mine shafts. Heavy metal contamination in this region has resulted in fish consumption advisories being issued by the ODEQ. Information on fish consumption advisories is discussed in the previous section of this plan. Efforts to monitor and evaluate heavy metal contamination at Grand Lake should be coordinated with the appropriate agencies and universities.

Management Objectives

Goals

- Collect SSP trend data on the major sportfish and forage species.
- Conduct creel survey to determine angling pressure, success, harvest, satisfaction, and regional economic impact of the fishery.
- Protect and enhance aquatic habitat.
- Work with GRDA and other appropriate agencies to improve water quality in the tailrace.
- Work with GRDA and other appropriate entities to enhance boating and/or fishing access.
- Conduct public outreach and solicit feedback regarding fisheries management issues.
- Coordinate and assist with the documentation and monitoring of aquatic nuisance species.
- Coordinate and assist with the monitoring and evaluation of heavy metal contamination.

Strategies

1. Sampling goals for the major sportfish and forage species will be as follows:
    a. Largemouth Bass - Conduct Standardized Sampling Protocol (SSP) spring electrofishing for largemouth bass every other year to determine catch rates by size groups and relative weights. Age and growth data will be collected every three years. Bass tournament results will be monitored annually to evaluate overall trends. Largemouth bass will be tested for LMBV if it is believed to be the cause of a fish kill.
    b. Spotted Bass – Conduct SSP spring electrofishing for spotted bass every other year to determine catch rates by size groups and relative weights. Age and growth data will be collected every three years.
    c. Smallmouth Bass – Conduct SSP spring electrofishing for smallmouth bass every other year to determine if a reservoir population exists, the catch rates by size groups and relative weights. Tissue samples for genetic analysis and age and growth data will be obtained from each smallmouth bass collected.
    d. White Bass – Conduct SSP fall gillnetting for white bass every other year to determine catch rates by size groups and relative weights.
    e. Hybrid Striped Bass – Conduct SSP fall gillnetting for hybrid striped bass every other year to determine catch rates by size groups and relative weights. Age and growth data will be obtained from each hybrid striped bass collected.
    f. White Crappie – Conduct SSP fall trapnetting for white crappie annually to determine catch rates by size groups and relative weights. Age and growth data will be collected each year.
    g. Black Crappie – Conduct SSP fall trapnetting for black crappie annually to determine catch rates by size groups and relative weights. Age and growth data will be collected each year.
    h. Blue Catfish – Conduct electrofishing surveys annually in accordance with findings from ongoing study to optimize sample size and timing. Conduct SSP fall gillnetting for blue catfish every other year to determine catch rates by size groups and relative weights.
    i. Channel Catfish – Conduct SSP fall gillnetting for channel catfish every other year to determine catch rates by size groups and relative weights.

   j. Flathead Catfish – Conduct SSP fall gillnetting for flathead catfish every other year to determine catch rates by size groups and relative weights.
   k. Paddlefish – Conduct mark and recapture population estimate over a two year period. Utilize telemetry techniques to identify the migration routes and spawning sites of paddlefish in the Neosho and Spring Rivers. Collect biological data annually at the Research and Processing Center. Collect known age fish with coded wire tags for age and growth verification. Conduct mail survey to paddlefish permit holders to determine angler attitudes, effort and harvest.
   l. Gizzard Shad – Conduct SSP fall gillnetting for gizzard shad every other year to determine catch rates by size groups.
   m. Threadfin Shad – Conduct SSP fall gillnetting for threadfin shad every other year to determine catch rates by size groups.

2. Design, implement, and analyze a creel survey that will determine angling pressure, success, harvest, satisfaction, and regional economic impact of the fishery. Every effort should be made to coordinate with GRDA to ensure both agencies' needs are addressed, and effort is distributed appropriately between ODWC and GRDA. This survey should begin in 2009.

3. Aquatic habitat will be protected and enhanced in the following ways:
   a. Oppose habitat degradation and shoreline development that does not comply with the Grand Lake Shoreline Management Plan and does not require adequate mitigation. ODWC will propose adequate and reasonable mitigation measures when necessary.
   b. Maintain a minimum of eight (8) aquatic vegetation founder colonies. Maintenance and evaluations of these sites will be conducted during the spring, summer, and fall of each year. A final report on the feasibility of establishing aquatic vegetation in Grand Lake will be prepared at the conclusion of this lake management plan.
   c. Maintain twelve (12) brush piles utilizing natural and artificial materials. Brush piles constructed of natural materials will be recharged at least twice during this lake management plan. Brush piles constructed of artificial materials will be recharged once during this lake management plan.

4. Monitor and assess water quality in the forebay and the tailrace of Pensacola Dam during the summer period annually. Results from each year will be summarized, provided to GRDA and other appropriate resource agencies. Continue to provide technical assistance to GRDA and other resource agencies with the goal of increasing water quality in the Grand Lake tailrace.

5. Develop and/or maintain two (2) boating and fishing access projects at Grand Lake. This will be accomplished through the solicitation of appropriate agencies and entities willing to cooperate on access development or maintenance. A minimum of one (1) boating and fishing access project will be conducted annually with the City of Miami.

6. Conduct one (1) public meeting per year to present agency efforts regarding fisheries management and solicit public feedback.

7. Investigate and report all sightings of aquatic nuisance species to the ODWC Aquatic Nuisance Species biologist, GRDA, other resource agencies, and the media when appropriate.

8. Coordinate the efforts of other agencies and assist, when requested, with the monitoring and evaluation of heavy metal contamination.

Tables

Table 1. Physical and chemical characteristics of Grand Lake O' The Cherokees.

Operating Agencies:	
Hydropower, Lake Patrol	Grand River Dam Authority
Flood Control	U.S. Army Corps of Engineers
Impoundment Date	1940
Surface Area	46,500 acres
Shoreline	1,300 miles
Shoreline Development Index	1.74
Mean Depth	36
Maximum Depth	140
Water Exchange Rate	3.2
Watershed	10,000 square miles
Secchi Disk	36 inches
Conductivity	264 to 374 µS/cm
pH	7.07 to 8.68
Carlson's Trophic State Index (chlorophyll a)	59, Eutrophic

Table 2. Stocking Record for Grand Lake.

Species	N	Size(inches)
Largemouth Bass		
1974 (Florida)	11,000	Fry
1975 (Hybrid)	75,000	Fry
1975 (Florida)	1,500	Fingerlings
1981-83 (Florida)	269,938	1 1/2-3
1986 (Florida)	1,716	3 1/2-8 3/4
1989 (Florida)	1,258	4-6 1/2
1993 (Florida)	51,516	3
1994 (Florida)	34,710	2 1/2-3
1995 (Florida)	30,280	3
Walleye		
1968-72	2,968,487	Fry
1989	464,900	1 1/4
1990	324,755	1 1/4
2001	264,540	1 1/2
Striped Bass		
1973	2,700,000	Advanced Fry
1975-78	9,400,000	Advanced Fry
Hybrid Striped Bass		
1981-83	12,717,000	Advanced Fry
1982	232,000	1 1/2
1984-87	1,472,576	1-2
1989	122,300	1 1/4-1 1/2
1991	404,940	1-1 3/8
1994	3,780,000	Fry
1997	102,000	1 1/4
1998	98,000	1 3/4
2001	150,000	1
2005 (Reciprocal)	690,000	Fry
2007	104,960	1-2
Threadfin Shad		
1976	16,600	Spawning adults
2000	400	Spawning adults

Table 3. Grand Lake Tournament Results. Ranking of Lakes Statewide from which 10 or more Tournament Reports were Received. Ranked According to Quality Fishing Indicators. Grand Lake Ranking listed in parentheses.

Year	Number of Reports	Total Number of Anglers	Number of Bass Caught	Number of Bass Weighed In per 8-Hour Day		Bass/ Tourn	Bass Weighed In/Angler	Percent Successful Anglers		Average Weight per Bass (lbs.)		Number of Bass Weighing In Over 5 lbs.	Angler-Hours per Bass Weighing In Over 5 lbs.	Number of Bass Weighing In Over 8 lbs.	Avg. Big Bass	Avg. 1st Place Weight (lbs.)		Overall Rank
1994	47	2880	4723	1.5	(# 9)	100.5	1.6	72	(# 5)	2.8	(# 1)	215	(# 2)	4	8.5	19.2	(# 1)	# 2
1995	58	3043	5718	1.4	(# 6)	98.6	1.9	75	(# 5)	2.4	(# 7)	167	(# 2*)	0	7.8	17.6	(# 1)	# 1
1996	63	3902	6416	1.5	(# 6)	101.8	1.6	71	(# 6)	2.5	(# 7)	211	(# 6)	2	8.2	17.7	(# 1)	# 2
1997	69	4295	6377	1.0	(# 14)	92.4	1.5	74	(# 5)	2.8	(# 5)	334	(# 13)	3	8.9	18.2	(# 1)	# 3*
1998	53	3821	6308	1.0	(# 17)	119.0	1.7	70	(# 6)	2.6	(# 7)	244	(# 15)	2	9.1	17.3	(# 1)	# 3
1999	45	3718	6308	1.2	(# 12)	140.2	1.7	73	(# 4)	2.7	(# 4)	267	(# 16)	0	9.0	20.1	(# 1)	# 4
2000	49	4537	7147	1.2	(# 10)	145.9	1.6	76	(# 7)	2.5	(# 11)	142	(# 18)	1	8.3	17.5	(# 2)	# 7
2001	51	5363	7253	1.0	(# 12)	142.2	1.4	72	(# 3)	2.3	(# 7)	79	(# 13)	0	7.1	14.5	(# 2)	# 4
2002	45	4968	5041	0.7	(# 13)	112.0	1.0	64	(# 7)	2.4	(# 6)	64	(# 13)	0	7.1	13.2	(# 2)	# 6
2003	77	8986	7242	1.1	(# 18)	94.1	0.8	63	(# 12)	2.3	(# 9)	79	(# 21)	1	8.4	12.5	(# 7)	# 15
2004	38	6415	6738	1.1	(# 12)	177.3	1.1	63	(# 13)	2.5	(# 4)	185	(# 19)	0	7.8	9.7	(#15)	# 15
2005	56	5887	7339	1.7	(# 9)	131.1	1.2	69	(# 11)	2.3	(# 8)	133	(# 13)	2	9.9	13.2	(# 8)	# 3
2006	23	3508	4209	1.2	(# 16)	183.0	1.2	77	(# 5)	2.2	(# 12)	64	(# 19)	0	5.5	15.1	(# 2)	# 12
Avg	**52**	**4717**	**6217**	**1.2**	**11.8**	**126.0**	**1.4**	**71**	**6.8**	**2.5**	**6.8**	**168**	**13.1**	**1**	**8.1**	**15.8**	**3.4**	**5.9**

*Values were tied with other lake(s) for that indicator.

Table 4. Total Number (No.), Catch Rates (C/f), and Relative Weights (W_r) by Size Groups of Largemouth Bass Collected by Spring Electrofishing from Grand Lake Reservoir. Numbers in Parentheses Represent Acceptable C/f Values for a Quality Fishery. Acceptable W_r Values are ≥90.

Total (≥40)			<7.9 In. <200 mm (15-45)		7.9–11.8 In. 200-299mm (15-30)		≥11.8 In. ≥300 mm (≥15)		≥14 In. ≥356 mm (≥10)	
Year	No.	C/f	C/f	W_r	C/f	W_r	C/f	W_r	C/f	W_r
1996	300	100	15.3	93	15.7	95	69	104	41	105
1998	286	95.3	8	104	22.3	102	65	102	43.3	103
2000	290	145	13	98	33.5	94	98.5	96	55.5	95
2001	279	223	30.4	92	58.4	93	134	96	99	95
2002	286	114	14.4	95	28	96	72	104	48.5	105
2003*	1013	168.8	45.3	93	48.5	96	79.8	103	45.8	105
2005	731	121.8	20.8	103	27.3	100	74.8	98	37.5	98

* Denotes Changed Electrofishing SSP

Table 5. Year, sample size, number of fish testing positive, and percent of the sample testing positive for Largemouth Bass Virus from Grand Lake.

Year	Sample size	No. Positive	% Positive
2000	38	14	37
2001	36	12	33
2002	36	10	28
2003	36	12	33

Table 6. Total Number (No.), Fish Per Net Night (C/f), and Relative Weights (Wr) by Size Groups of White Bass Collected by Gill Netting from Grand Lake.

Total			< 8 in. < 200 mm		≥ 8 in. ≥ 200 mm		8 – 12 in. 200 – 299 mm		≥ 12 in. ≥ 300 mm	
Year	No.	C/f	C/f	Wr	C/f	Wr	C/f	Wr	C/f	Wr
1998	279	0.775	.056	90	0.719	93	0.231	95	0.489	92
2000	192	0.533	.158	96	0.375	94	0.131	91	0.244	96
2003	231	0.642	.056	92	0.586	94	0.217	94	0.369	94
2007	139	0.4	0.1	118	0.3	102	0.1	110	0.3	100

Table 7. Total Number (No.), Fish Per Net Night (C/f), and Relative Weights (Wr) by Size Groups of Hybrid Striped Bass Collected by Gill Netting from Grand Lake.

Total			< 12 in. < 300 mm		12 – 20 in. 300 – 499 mm		≥ 20 in. ≥ 500 mm	
Year	No.	C/f	C/f	Wr	C/f	Wr	C/f	Wr
1998	0							
2000	2	0.006					0.006	92
2003	1	0.003			0.003	91		
2007	4	0.013	0.010	88	0.003	92		

Table 8. Total Number (No.), Fish Per Net Night (C/f), and Relative Weights (Wr) by Size Groups of All Crappie Collected by Trap Netting from Grand Lake. Numbers in Parentheses Represent Acceptable C/f Values for a Quality Fishery.

	Total (≥25)		<5" (≥5)		≥5" (10-40)		≥8" (≥10)		≥10" (≥4)	
Year	No.	C/f	C/f	Wr	C/f	Wr	C/f	Wr	C/f	Wr
1999	367	18.4	0.8	104	17.5	92	16.8	101	8.4	101
2001	286	11.4	0.5	93	11.0	89	9.7	90	5.2	90
2003	429	20.4	0.3	83	20.1	98	19.3	98	13.4	96
2007	175	4.2	2.6	109	1.8	104	1.3	104	0.9	101

Table 9. Mean length at Age of Crappie Collected by Trap Netting from Grand Lake. Numbers in Parentheses Represent Values for Acceptable Growth Rates.

	Age 1	Age 2	Age 3	Age 4
Year	(≥ 6.3 in.)	(≥ 7.9 in.)	(≥ 8.9 in.)	(≥ 9.8 in.)
1990	7.2	9.9	10.4	
1991	8.4	9.6	10.9	12.6
1992	7.2	10.0	11.7	8.3
1993	7.3	9.6	11.4	13.2
1995	7.7	9.7	12.1	12.3
1996	7.7	9.9	10.4	13.2
1997	8.6	10.2	11.4	
1998	8.4	10.3	11.4	
1999	8.8	10.7	12.3	12.5
2001	8.1	10.2	11.2	11.9
2003	8.0	10.7	12.0	12.6
2007	9.6	11.8	12.5	14.2

Table 10. Total Number (No.), Fish Per Net Night (C/f), and Relative Weights (Wr) by Size Groups of Blue Catfish Collected by Gill Netting from Grand Lake.

	Total		< 12 in. < 300 mm		12 – 16 in. 200 - 399 mm		≥ 12 in. ≥ 300 mm		≥ 16 in. ≥ 400 mm	
Year	No.	C/f	C/f	Wr	C/f	Wr	C/f	Wr	C/f	Wr
1998	24	0.067	.019	114	0.028	111	0.047	106	0.031	109
2000	18	0.050	.031	103	0.028	85	0.019	85	0.011	91
2003	11	0.031	.003	92	0.008	85	0.028	92	0.022	86
2007	26	0.072	.008	79	0.014	78	0.063	81	0.058	81

Table 11. Total Number (No.), Fish Per Net Night (C/f), and Relative Weights (Wr) by Size Groups of Channel Catfish Collected by Gill Netting from Grand Lake.

	Total		< 12 in. < 300 mm		12 – 16 in. 200 - 399 mm		≥ 12 in. ≥ 300 mm		≥ 16 in. ≥ 400 mm	
Year	No.	C/f	C/f	Wr	C/f	Wr	C/f	Wr	C/f	Wr
1998	113	0.314	.069	89	0.203	85	0.244	89	0.103	96
2000	206	0.572	.333	86	0.383	82	0.239	85	0.117	91
2003	118	0.328	.120	88	0.219	86	0.208	86	0.083	92
2007	209	0.565	.240	87	0.461	85	0.325	84	0.075	88

Table 12. Total Number (No.), Fish Per Net Night (C/f), and Relative Weights (Wr) by Size Groups of Flathead Catfish Collected by Gill Netting from Grand Lake.

	Total		≥ 12 in.		≥ 20 in.		≥ 24 in.		≥ 28 in.	
			≥ 300 mm		≥ 500 mm		≥ 600 mm		≥ 700 mm	
Year	No.	C/f	C/f	Wr	C/f	Wr	C/f	Wr	C/f	Wr
1998	4	0.011	0.006	120	0.003	118				
2000	5	0.014	0.014	106	0.011	101	0.008	105	0.003	102
2003	2	0.006	0.006	103	0.006	103	0.003	101		
2007	2	0.006	0.006	91	0.006	91				

Table 13. Age and Length data for male aged paddlefish in Grand Lake 2004

Age (Years)	N	Mean Length (mm)	Length Group (mm)
4	3	750.6	726-750
5	34	818.8	801-825
6	3	777.3	776-800
7	2	945.5	926-950
8	2	961	951-975
9	6	1033.3	1026-150
10	1	965	951-975
11	0	----	----
12	0	----	----
13	0	----	----
14	1	1007	1001-1025
15	0	----	----
16	0	----	----
17	0	----	----
18	1	1116	1101-1125
19	0	----	----

Table 14. Age and length data for female aged paddlefish in Grand Lake 2004

Age (Years)	N	Mean Length (mm)	Length Group (mm)
4	3	789.6	776-800
5	14	793.7	776-800
6	0	----	----
7	0	----	----
8	5	1034.8	1026-1050
9	5	1073.4	1051-1075
10	3	1072	1051-1075
11	1	1153	1151-1175
12	2	1054.5	1051-1075
13	1	1040	1026-1050
14	0	----	----
15	2	1084	1076-1100
16	0	----	----
17	0	----	----
18	0	----	----
19	1	1270	1251-1275

Table 15. Total Number (No.), Fish Per Net Night (C/f), and Relative Weights (Wr) by Size Groups of Gizzard Shad Collected by Gill Netting from Grand Lake.

	Total		< 6 in. < 150 mm	≥ 6 in. ≥ 150 mm
Year	No.	C/f	C/f	C/f
2003	250	4.531	4.006	0.525
2007	395	1.956	1.013	0.943

Table 16. Total Number (No.), Fish Per Net Night (C/f), and Relative Weights (Wr) by Size Groups of Threadfin Shad Collected by Gill Netting from Grand Lake.

	Total		< 5 in. < 125 mm	≥ 5 in. ≥ 125 mm
Year	No.	C/f	C/f	C/f
2003	150	4.989	4.989	.
2007	444	8.051	7.842	0.209

Figures

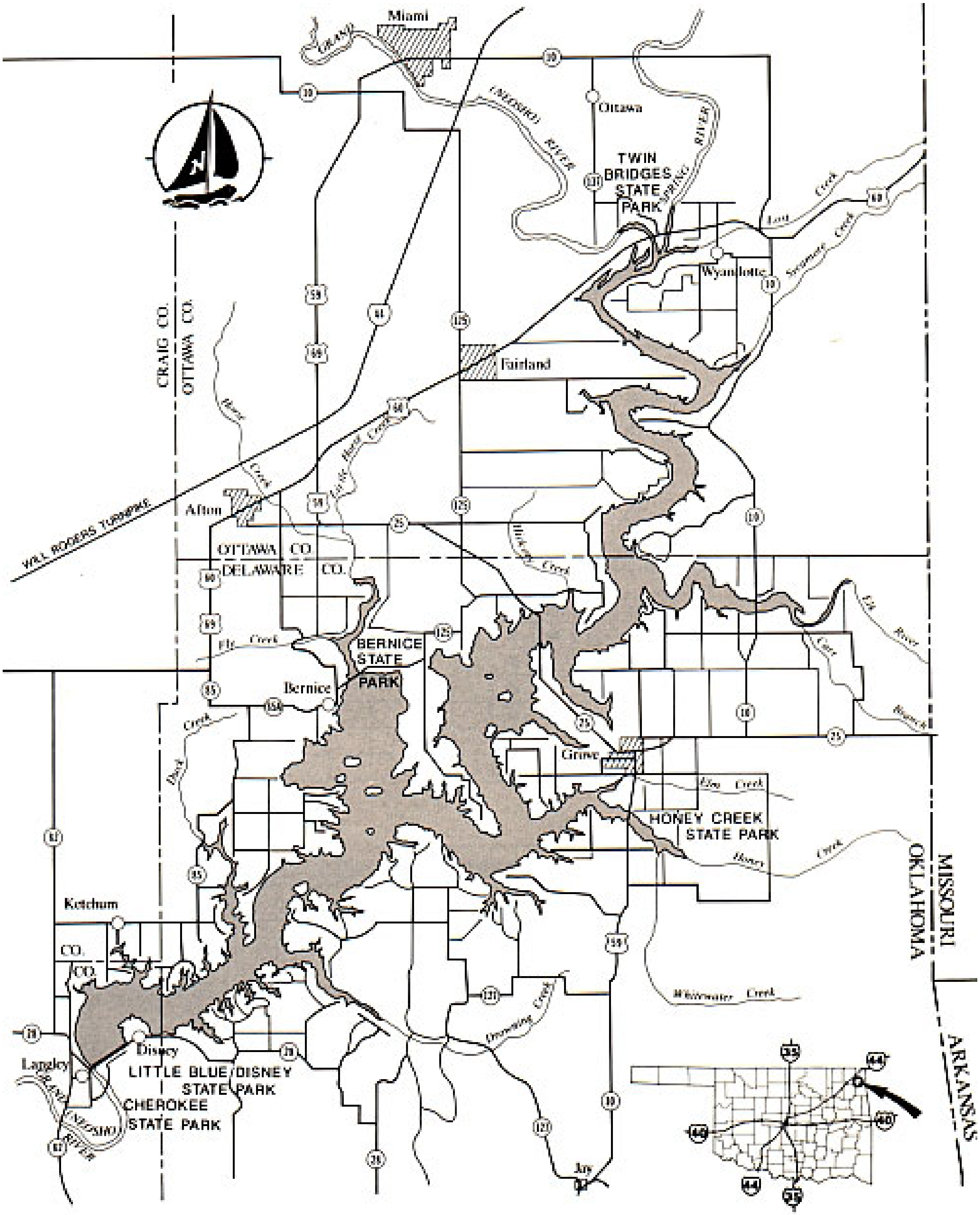

Figure 1. Map of Grand Lake and vicinity.

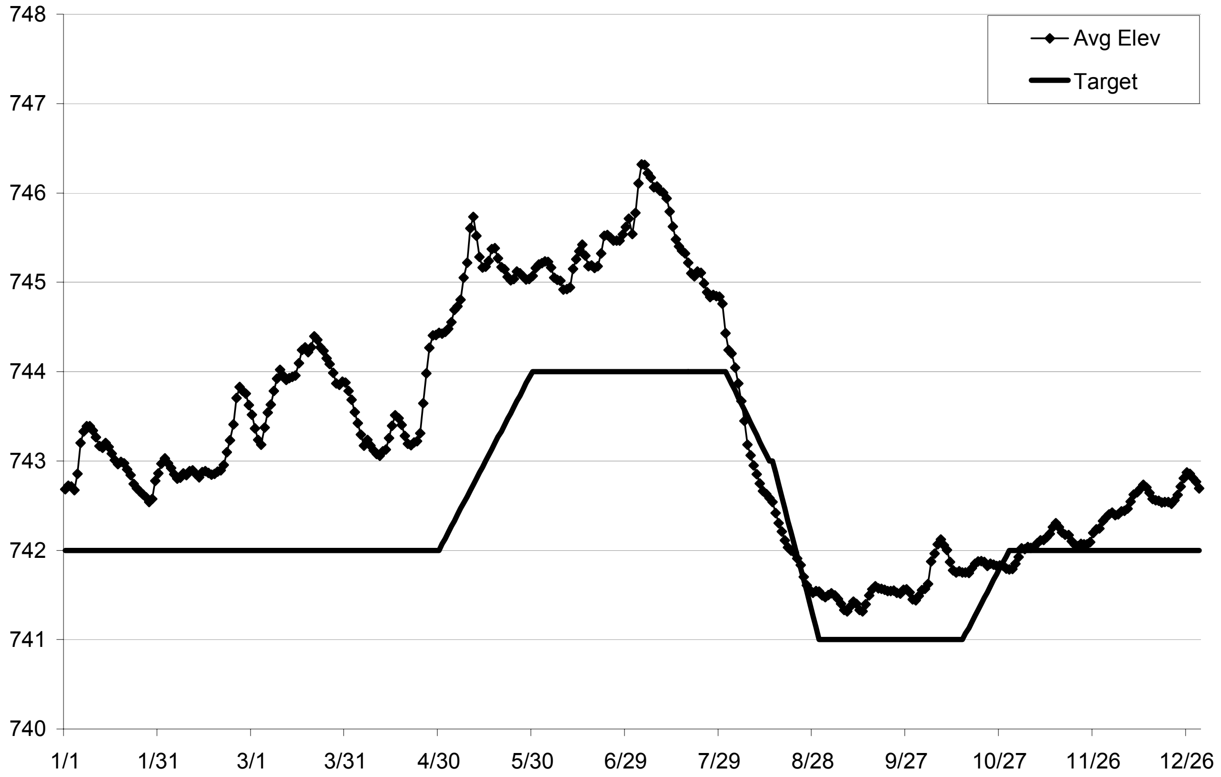

Figure 2. Mean surface elevations for Grand Lake from 1997 through 2007, and target elevations as defined in Article 401 of the 1996 rule curve amendment.

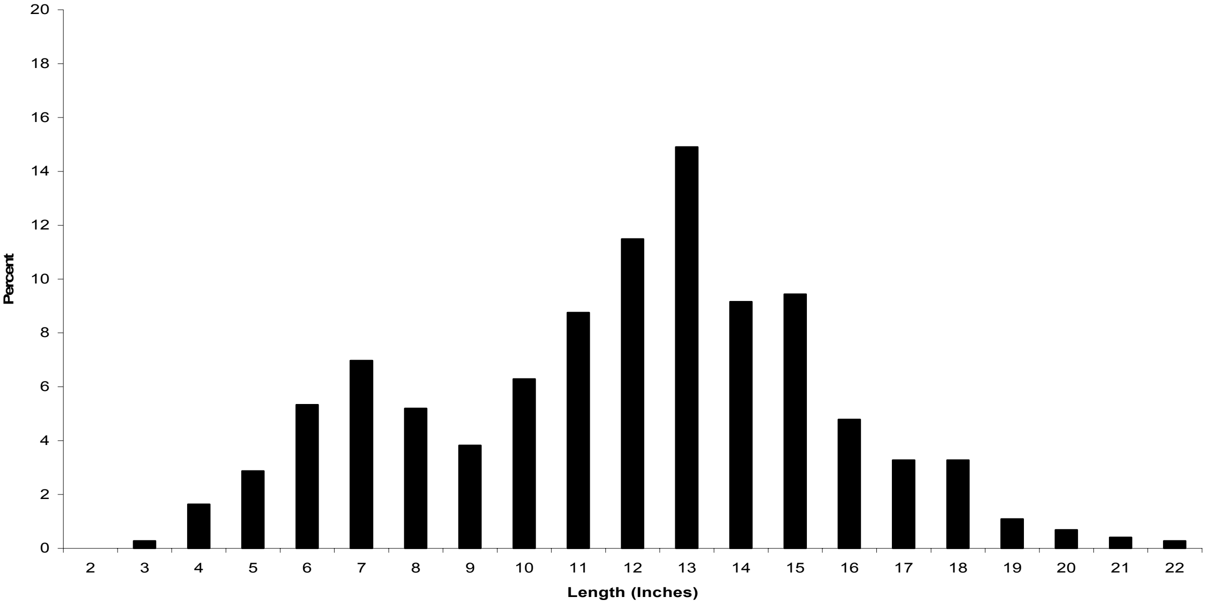

Figure 3. 2005 Electrofishing at Grand Lake. Length Frequency Distribution for Largemouth Bass, N = 731.

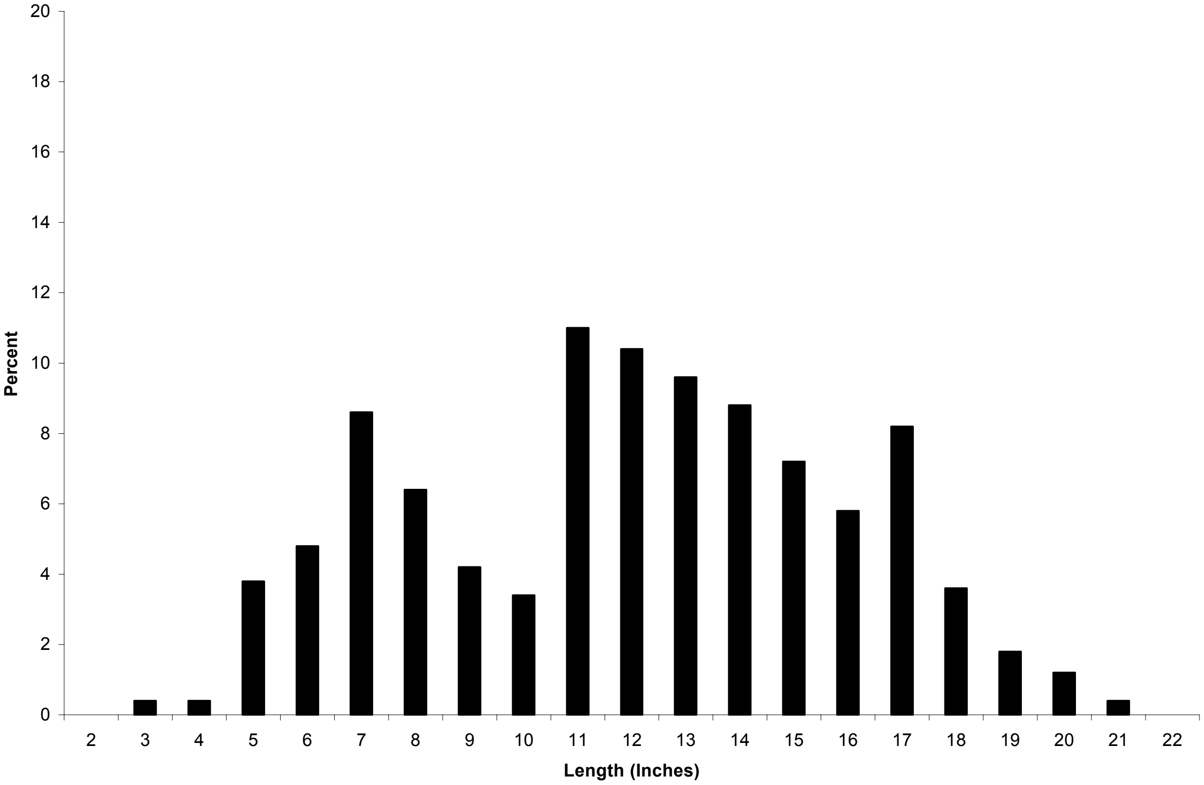

Figure 4. 2008 Electrofishing at Grand Lake. Length Frequency Distribution for Largemouth Bass, N = 500.

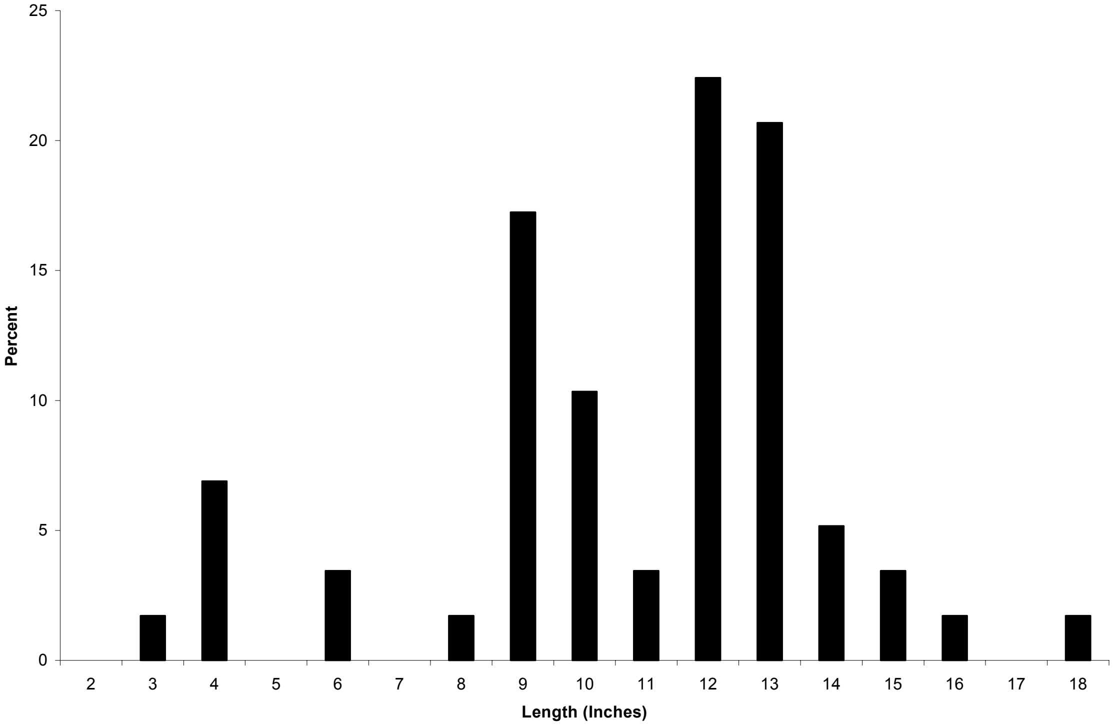

Figure 5. 2005 Electrofishing at Grand Lake. Length Frequency Distribution for Spotted Bass, N = 58.

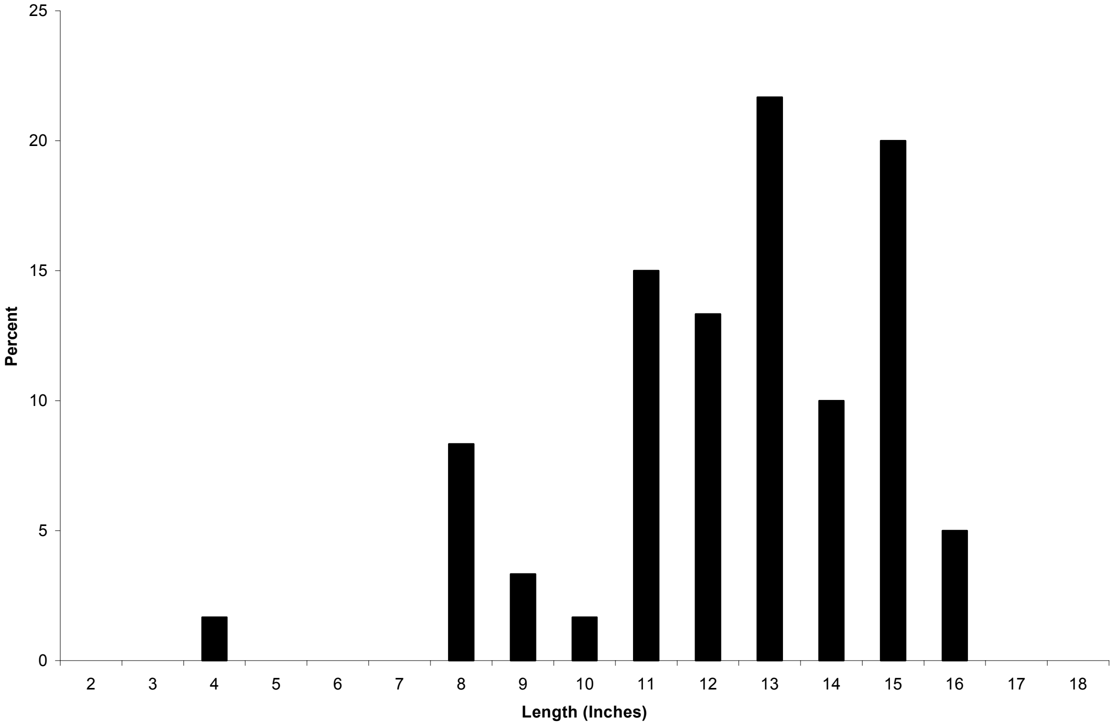

Figure 6. 2008 Electrofishing at Grand Lake. Length Frequency Distribution for Spotted Bass, N = 60.

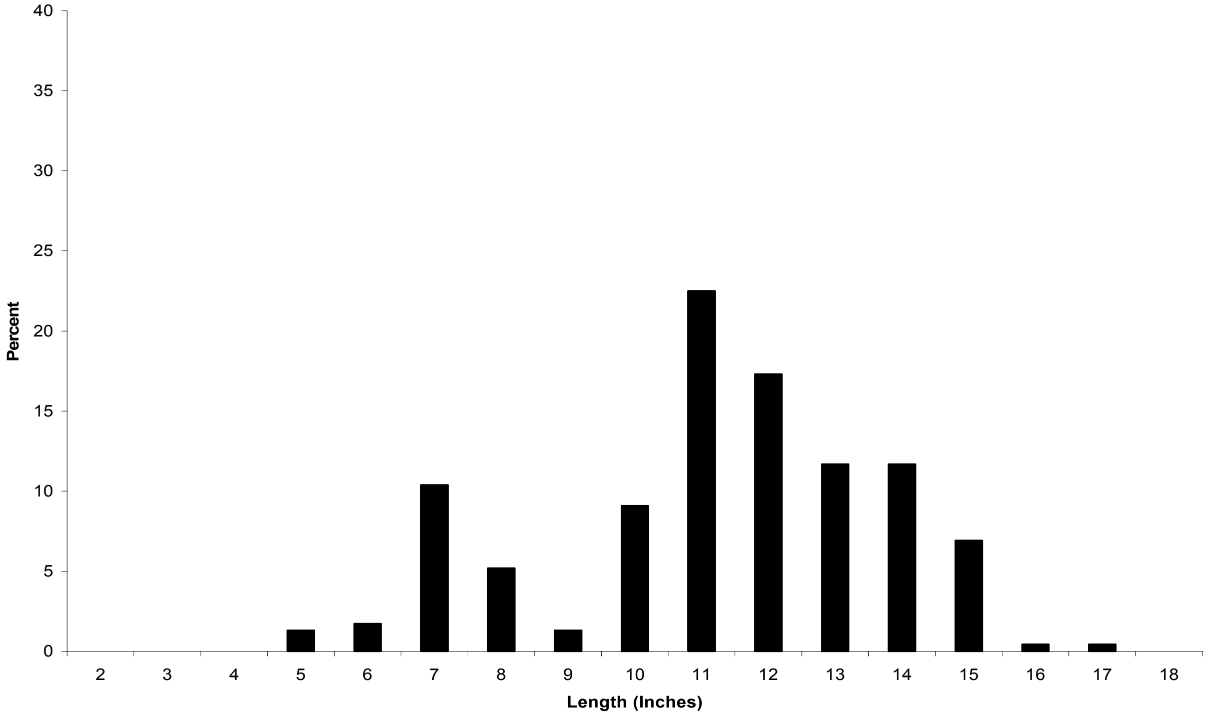

Figure 7. 2003 Gill Netting at Grand Lake. Length Frequency Distribution for White Bass, N = 231.

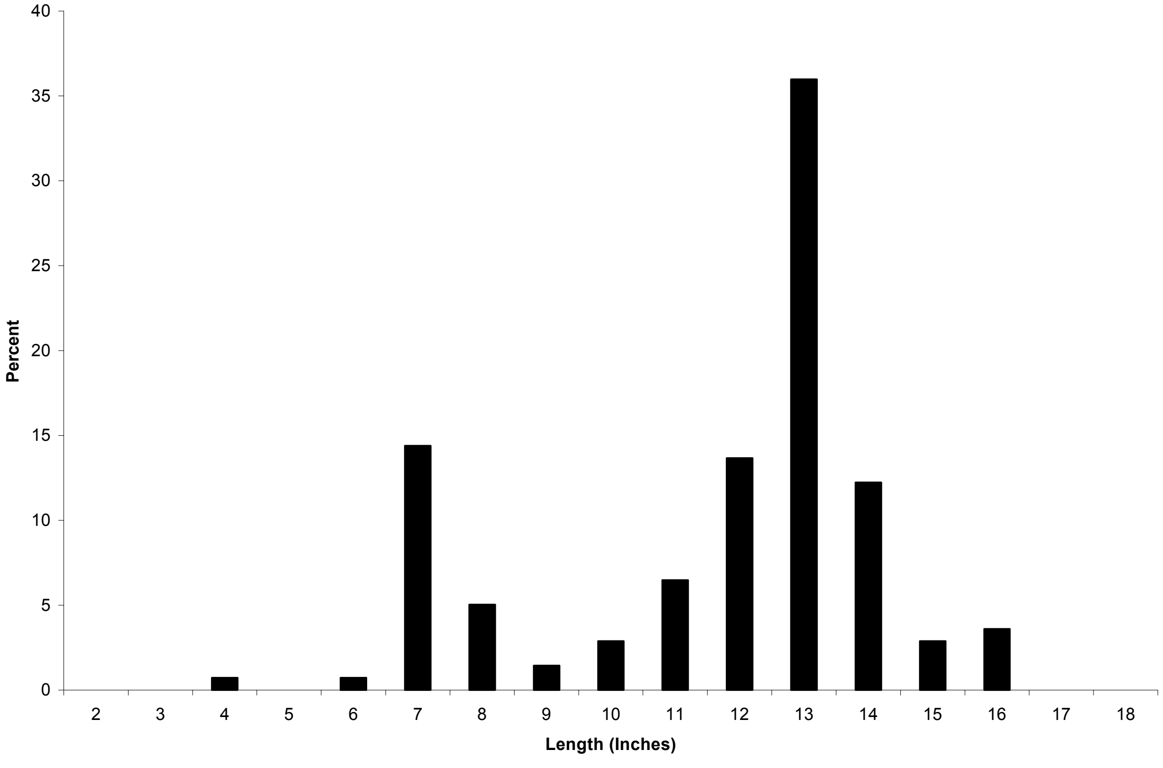

Figure 8. 2007 Gill Netting at Grand Lake. Length Frequency Distribution for White Bass, N = 139.

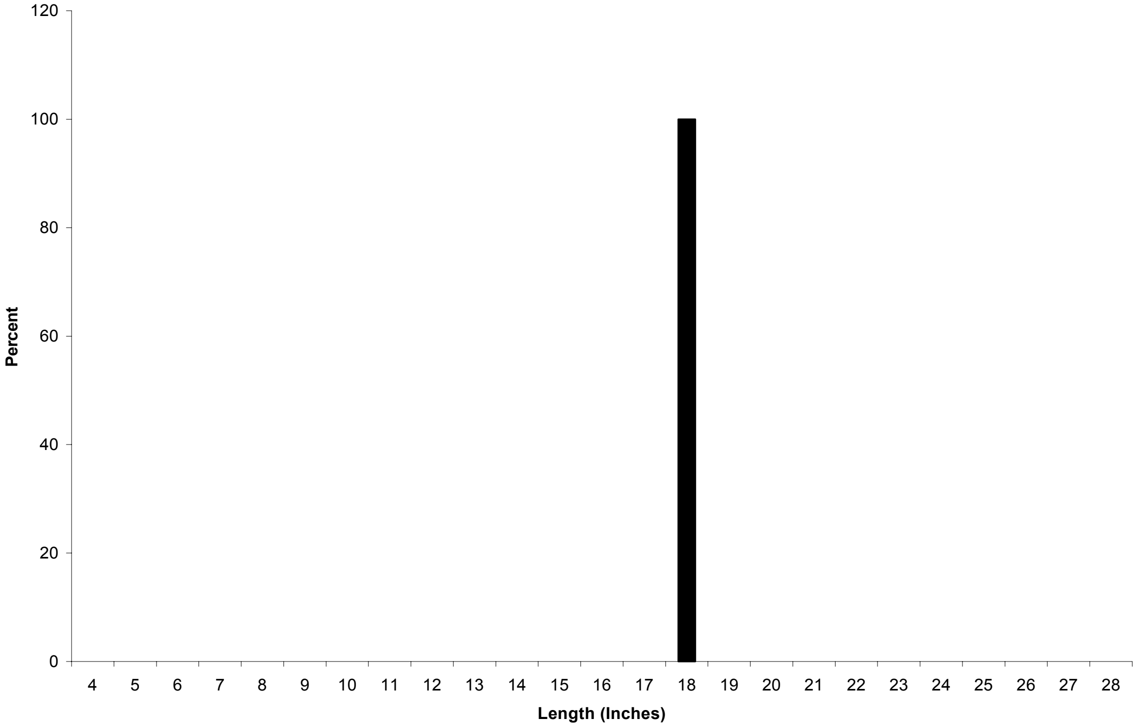

Figure 9. 2003 Gill Netting at Grand Lake. Length Frequency Distribution for Striped Bass Hybrids, N = 1.

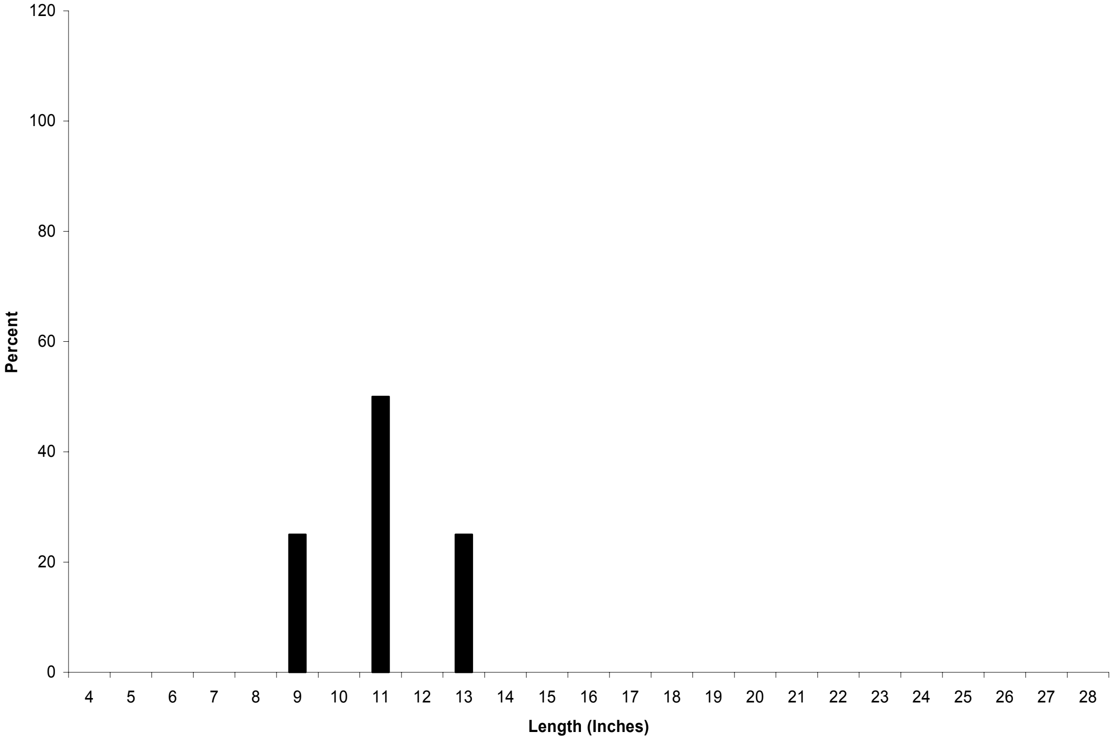

Figure 10. 2007 Gill Netting at Grand Lake. Length Frequency Distribution for Striped Bass Hybrids, N = 4.

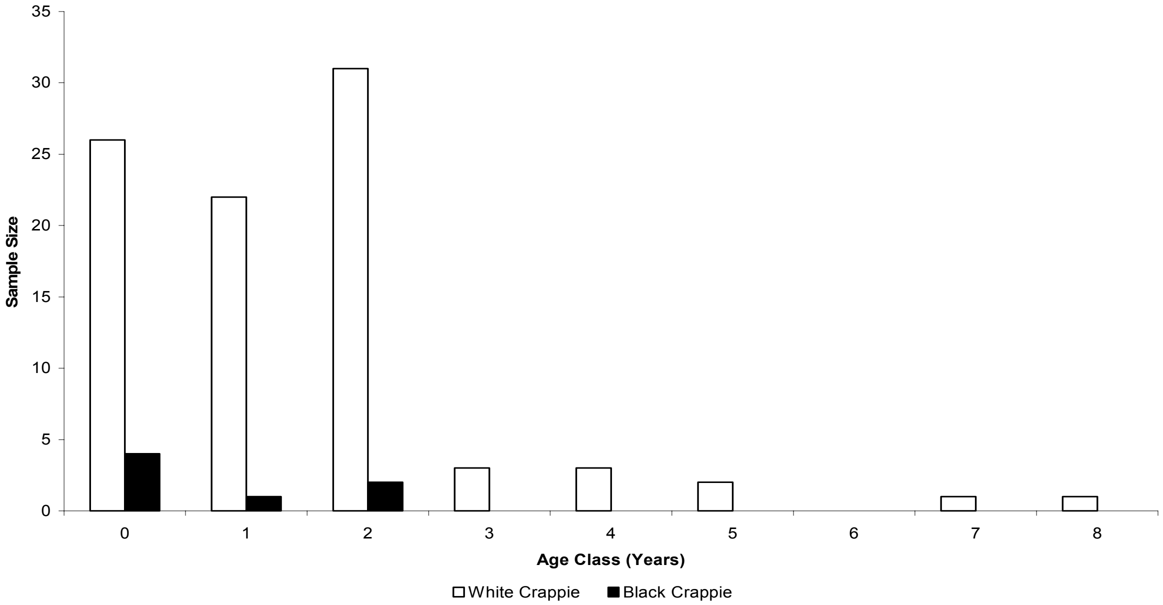

Figure 11. 2007 Trap Netting at Grand Lake. Sample Size by Age of White Crappie and Black Crappie from Otolith Data.

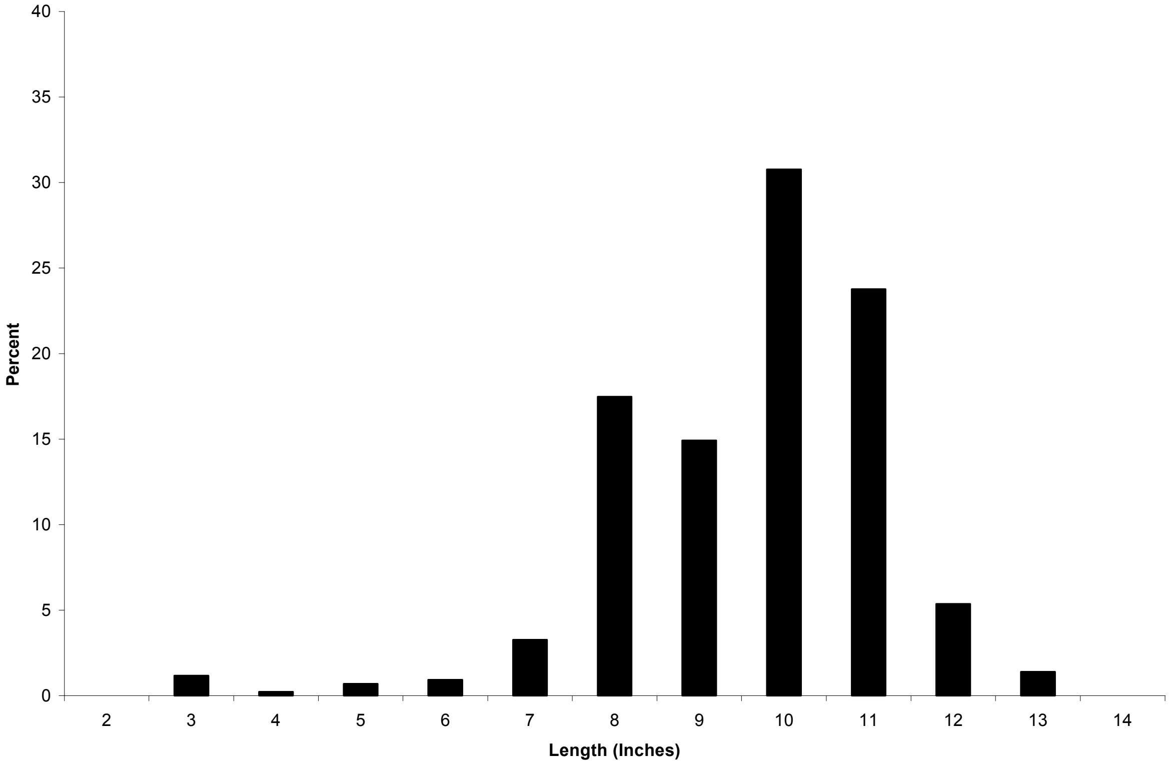

Figure 12. 2003 Trap Netting at Grand Lake. Length Frequency Distribution, All Crappie Combined, N = 429.

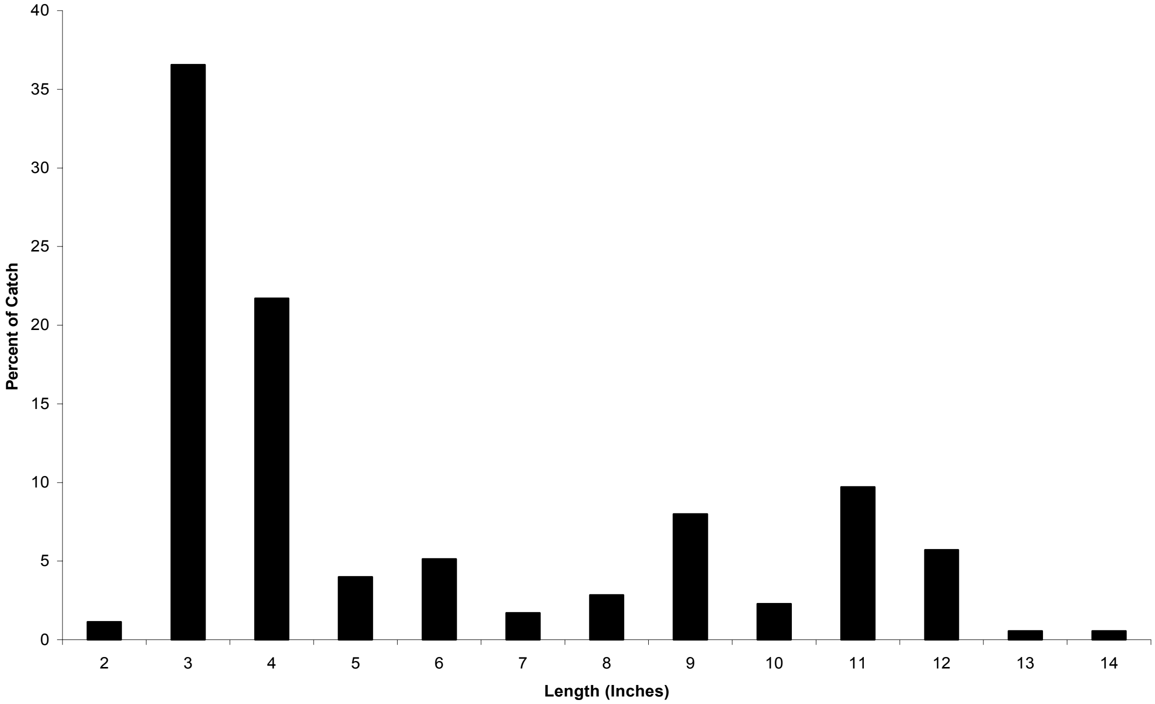

Figure 13. 2007 Trap Netting at Grand Lake. Length Frequency Distribution, All Crappie Combined, N = 175.

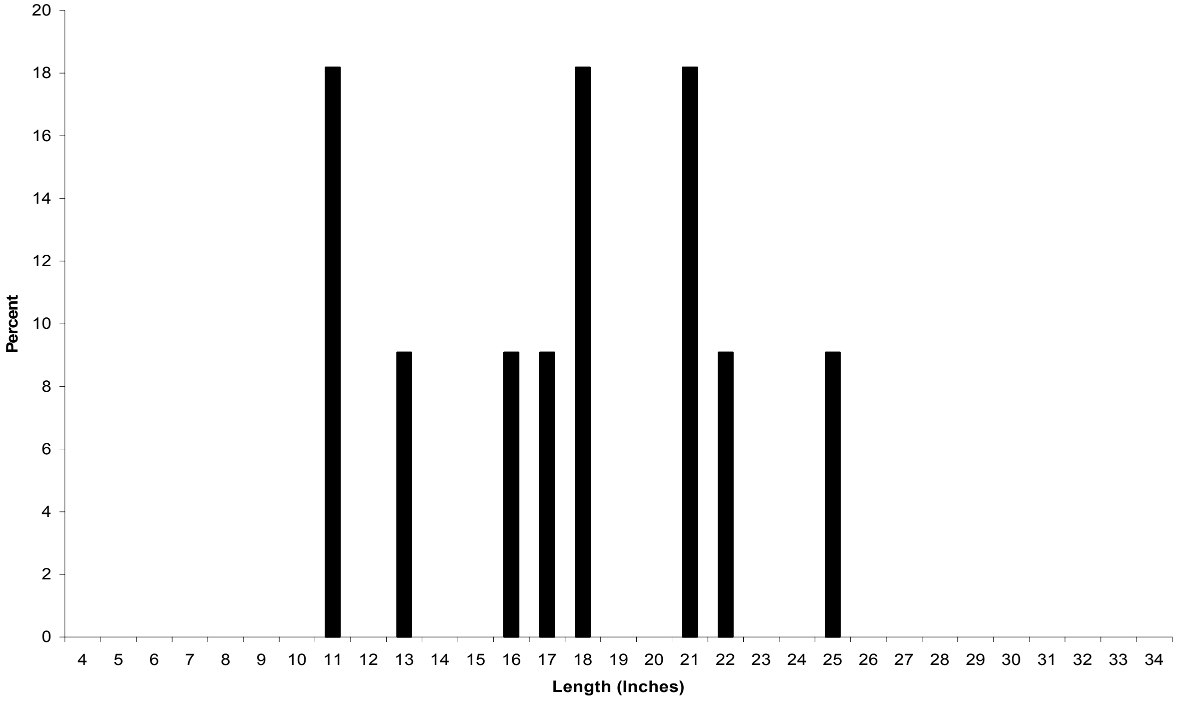

Figure 14. 2003 Gill Netting at Grand Lake. Length Frequency Distribution for Blue Catfish, N = 11.

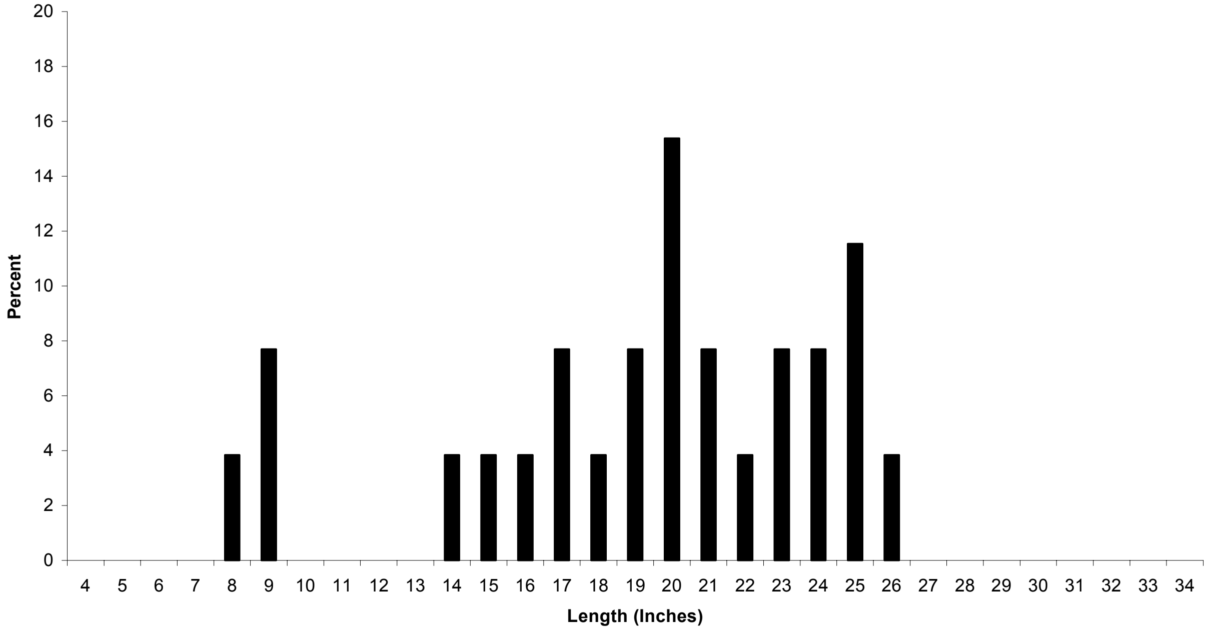

Figure 15. 2007 Gill Netting at Grand Lake. Length Frequency Distribution for Blue Catfish, N = 26.

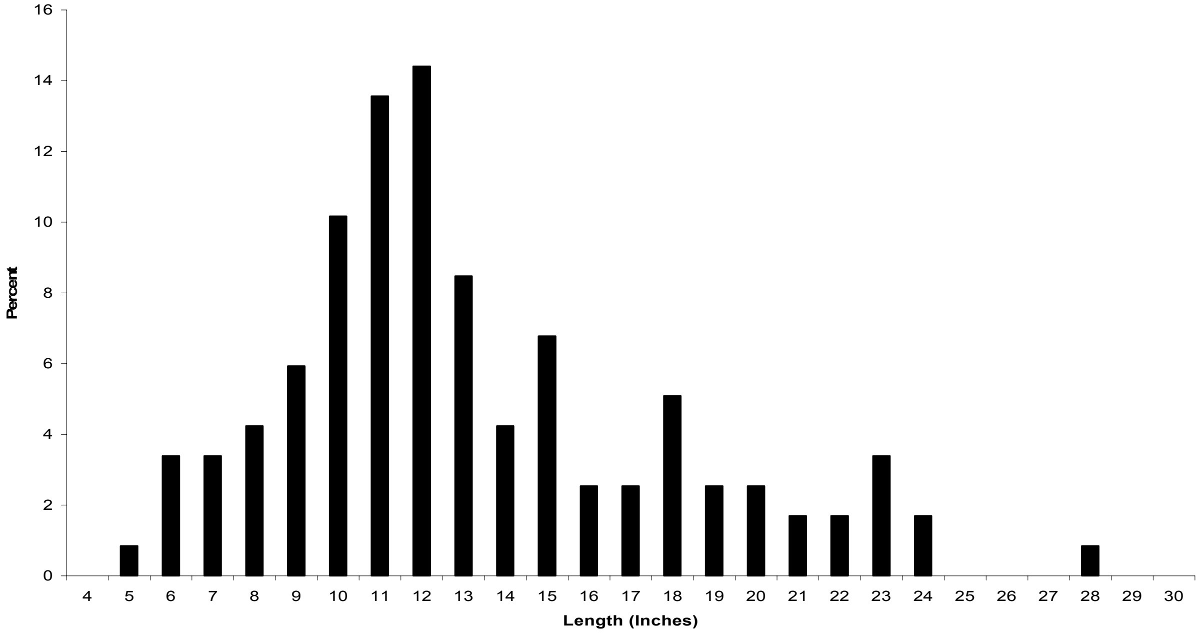

Figure 16. 2003 Gill Netting at Grand Lake. Length Frequency Distribution for Channel Catfish, N = 118.

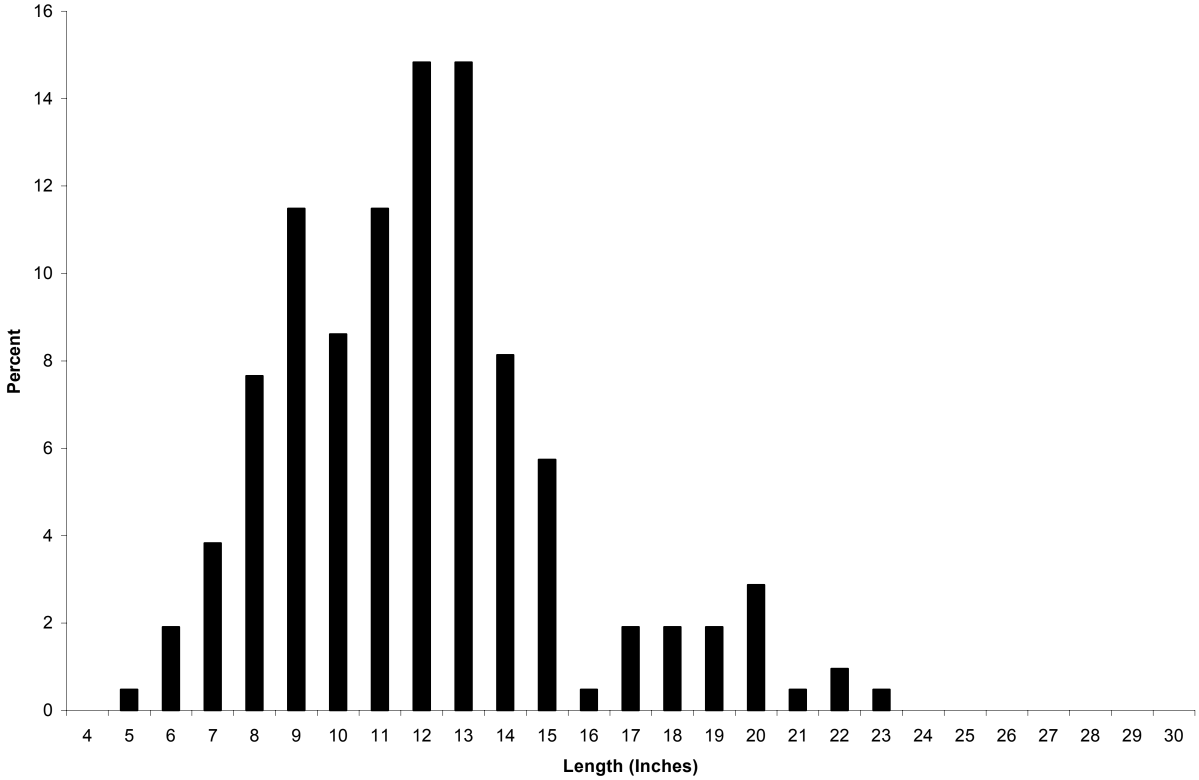

Figure 17. 2007 Gill Netting at Grand Lake. Length Frequency Distribution for Channel Catfish, N = 209.

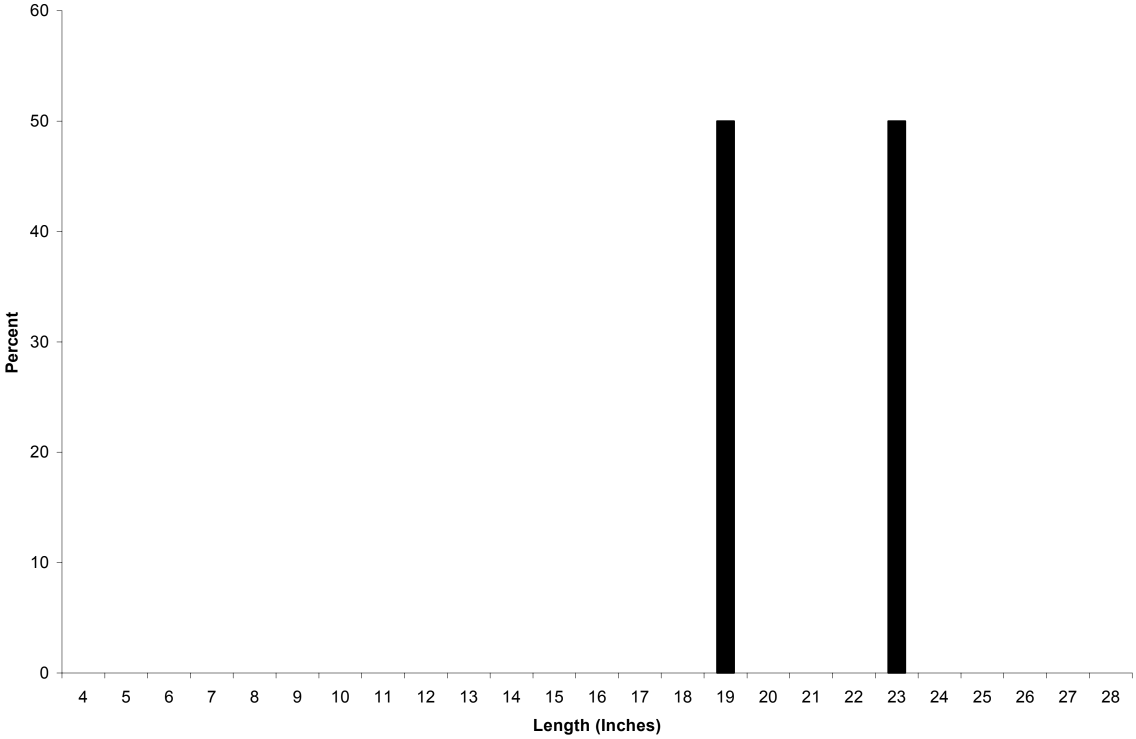

Figure 18. 2003 Gill Netting at Grand Lake. Length Frequency Distribution for Flathead Catfish, N = 2.

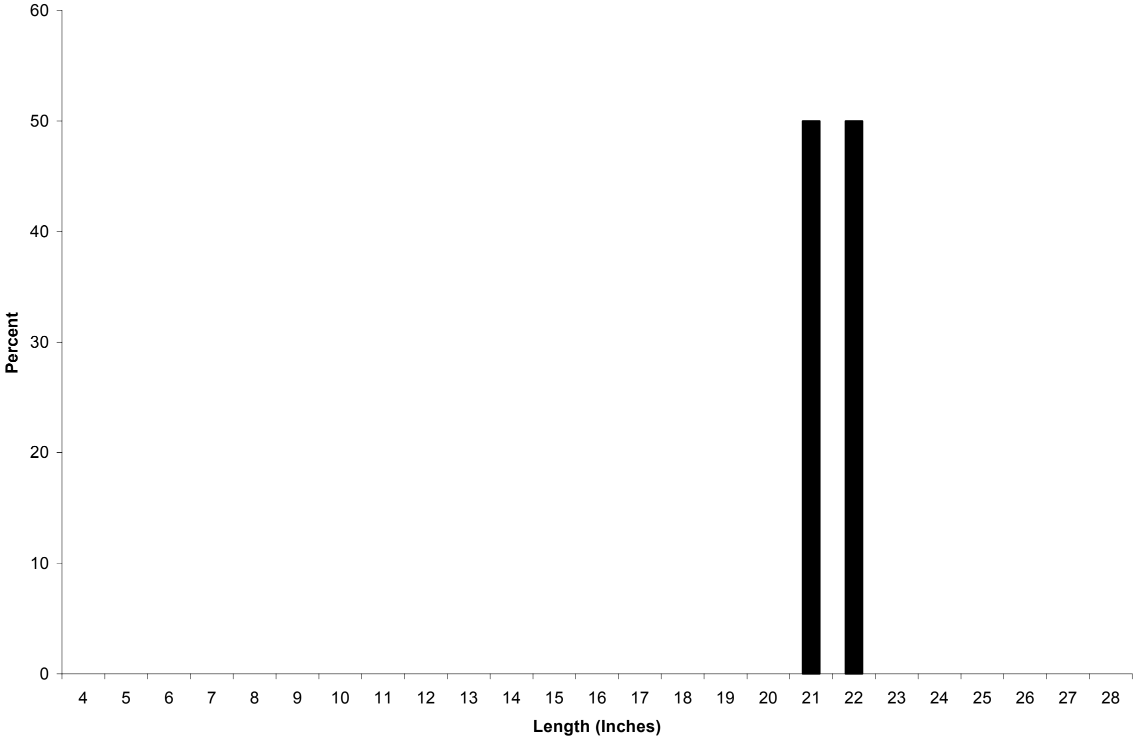

Figure 19. 2007 Gill Netting at Grand Lake. Length Frequency Distribution for Flathead Catfish, N = 2.

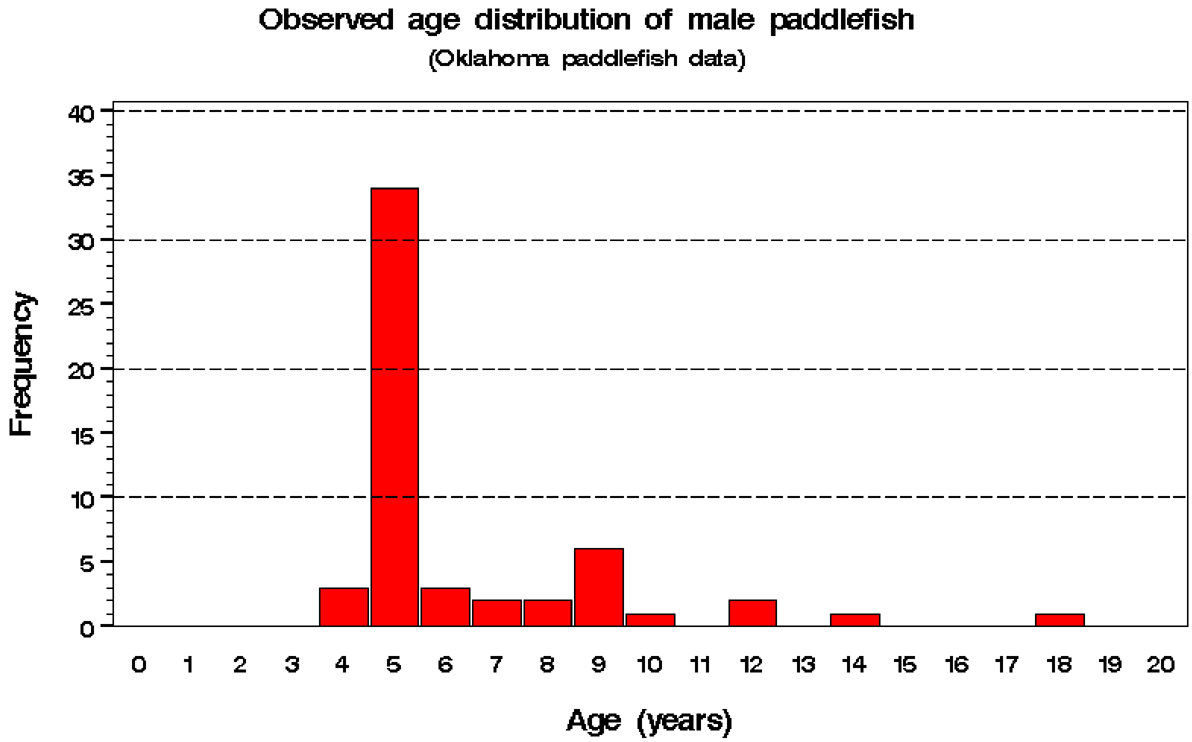

Figure 20. Age distribution of male paddlefish collected from Grand Lake 2003 and 2004.

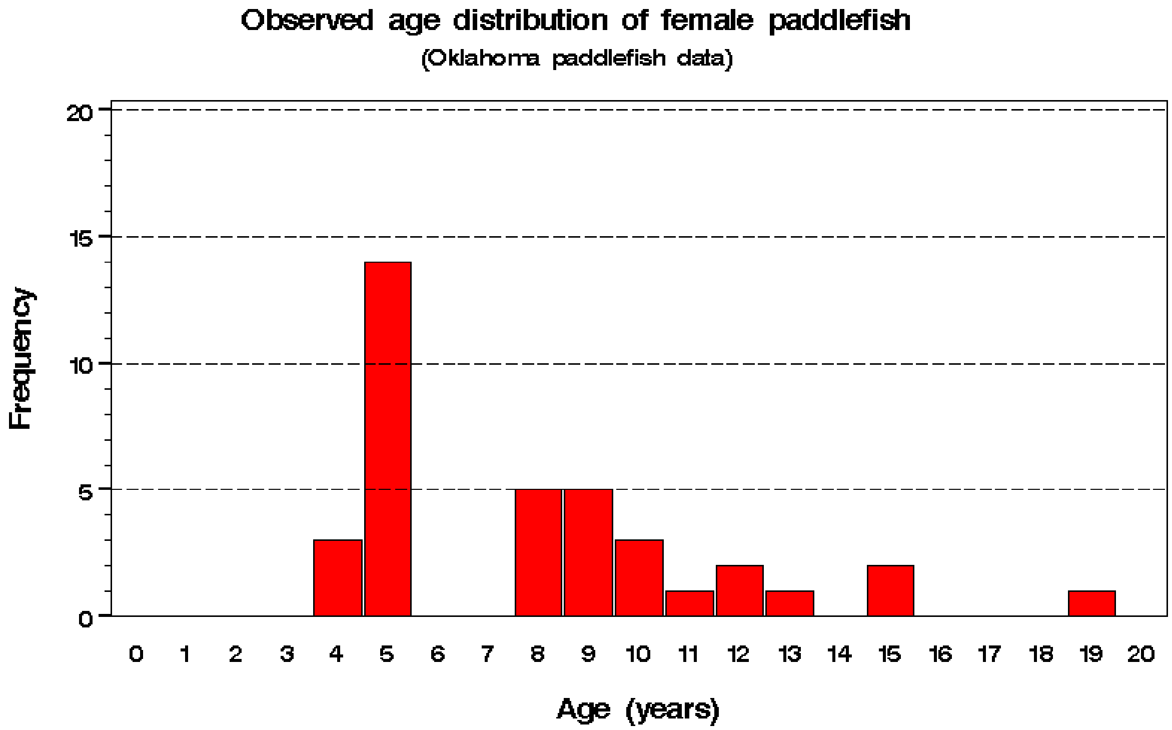

Figure 21. Age distribution of female paddlefish collected from Grand Lake 2003 and 2004

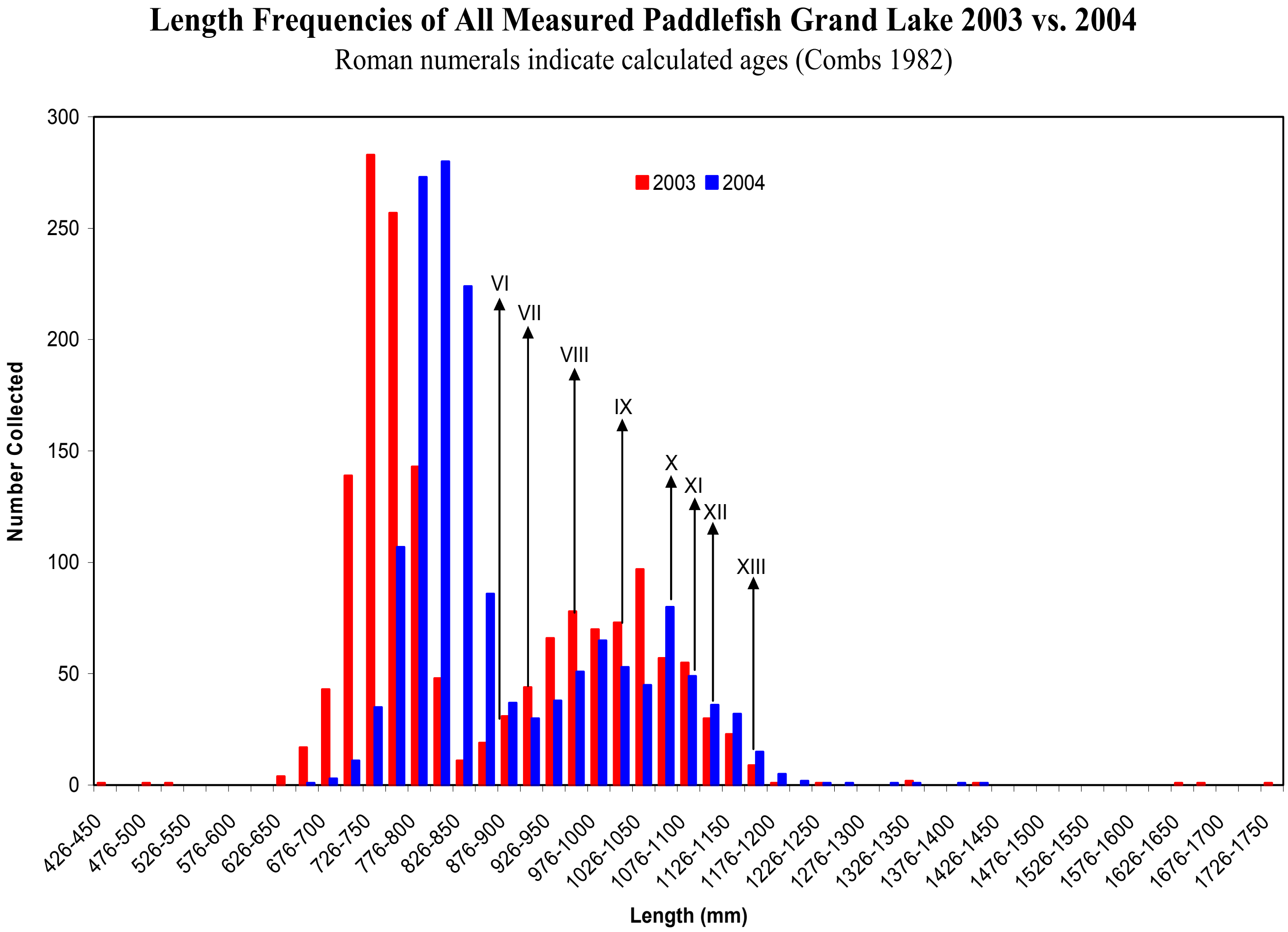

Figure 22. A comparison of length frequencies of all paddlefish collected in Grand Lake from 2003 and 2004.

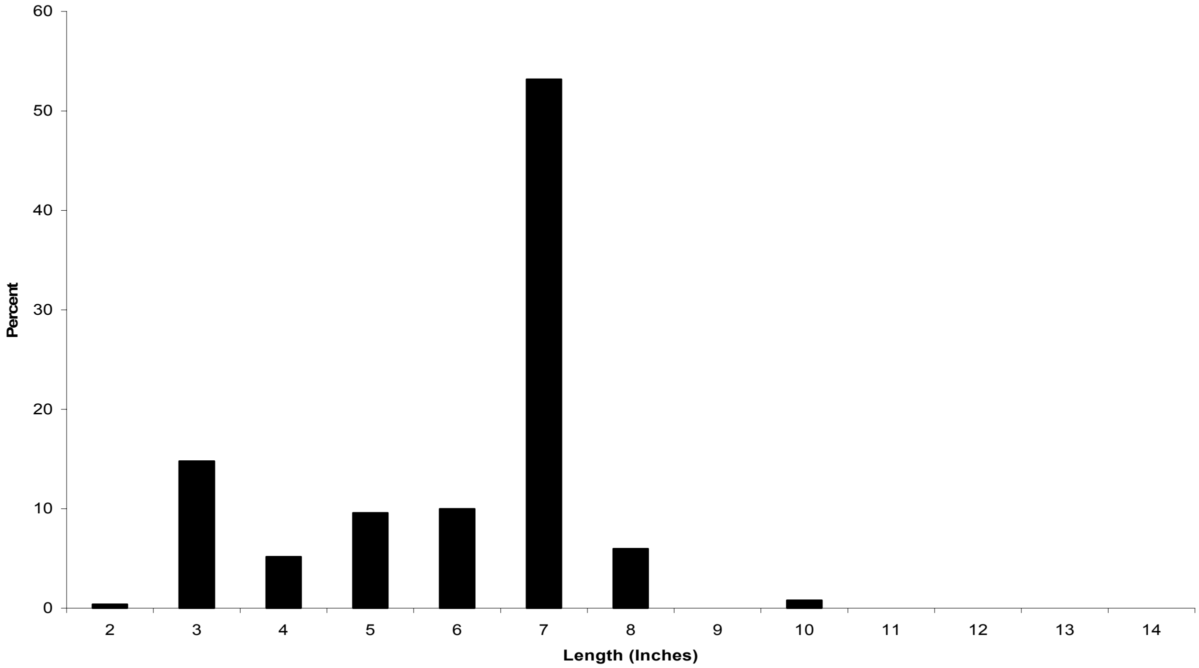

Figure 23. 2003 Gill Netting at Grand Lake. Length Frequency Distribution for Gizzard Shad, N = 250.

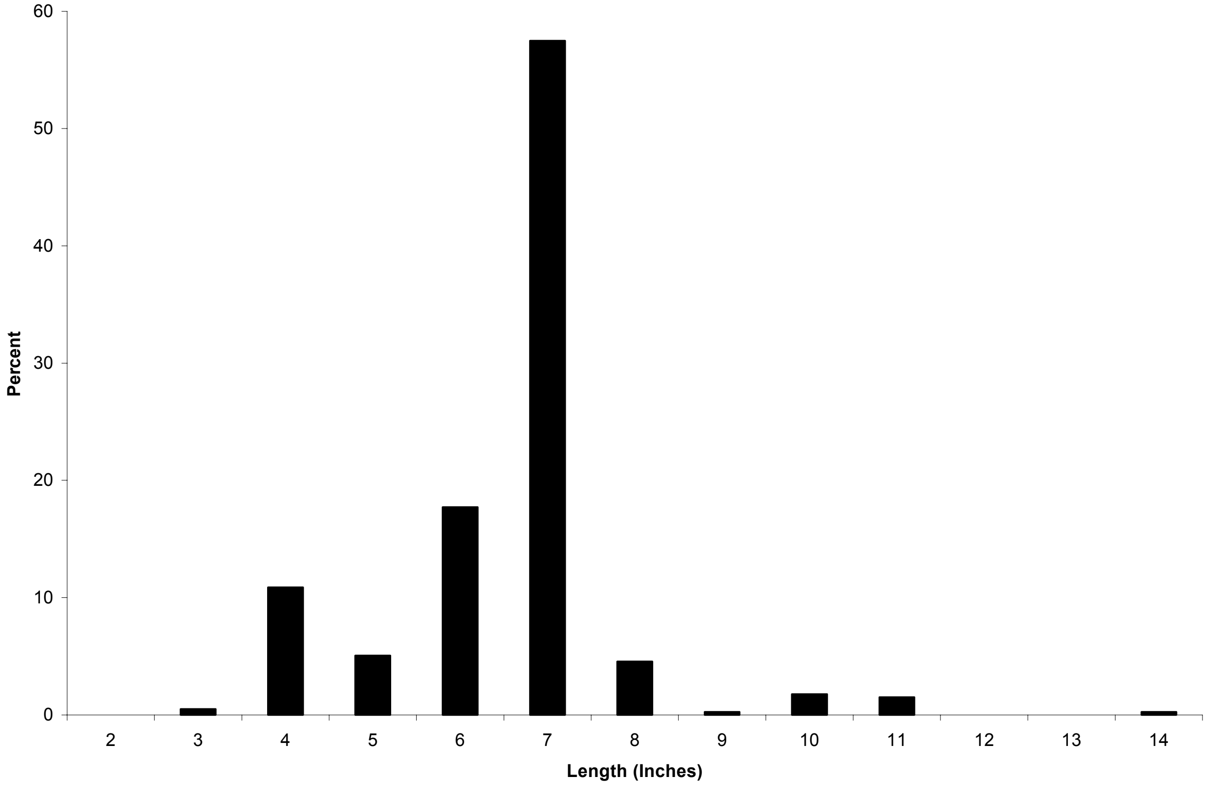

Figure 24. 2007 Gill Netting at Grand Lake. Length Frequency Distribution for Gizzard Shad, N = 395.

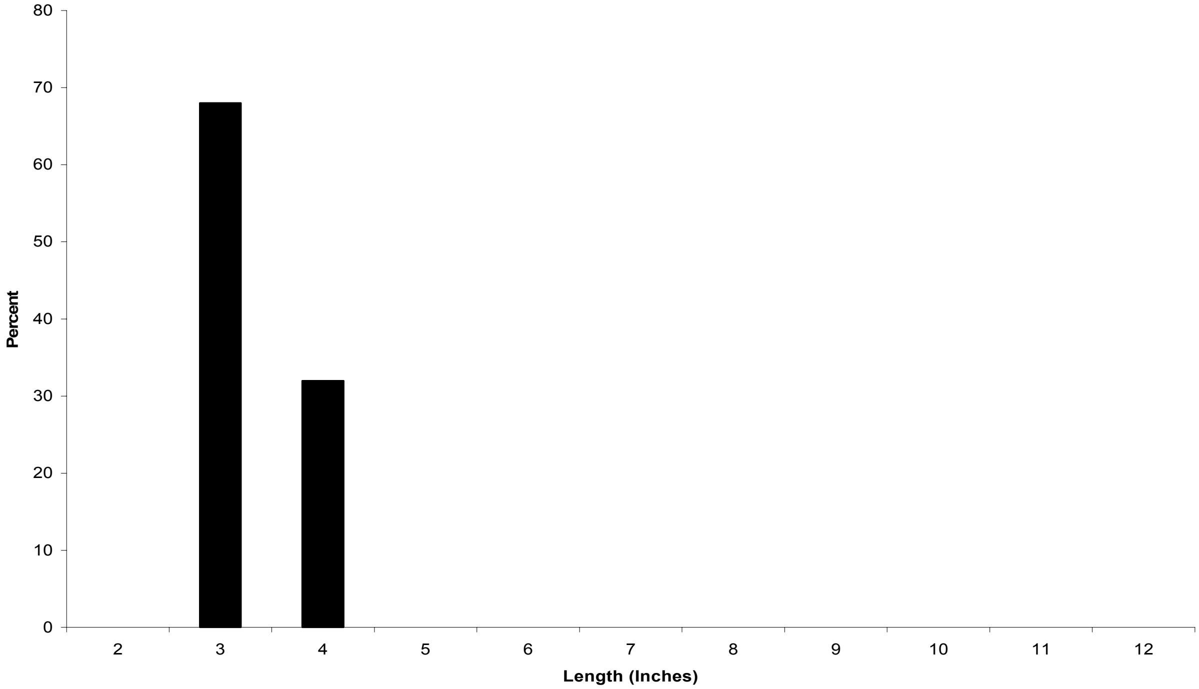

Figure 25. 2003 Gill Netting at Grand Lake. Length Frequency Distribution for Threadfin Shad, N = 150.

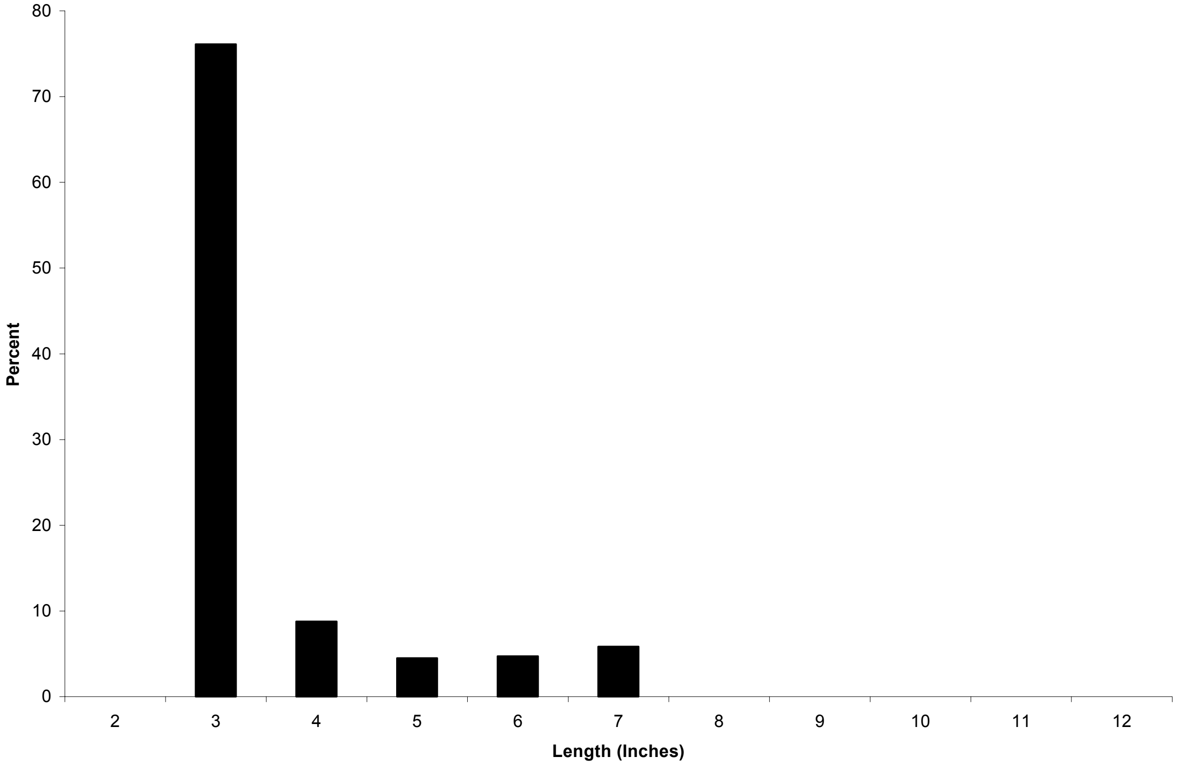

Figure 26. 2007 Gill Netting at Grand Lake. Length Frequency Distribution for Threadfin Shad, N = 444.

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EFFECTS OF ACID MINE DRAINAGES FROM TAR CREEK ON FISHES AND BENTHIC MACROINVERTEBRATES IN GRAND LAKE, OKLAHOMA

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Prepared For:

TAR CREEK ENVIRONMENTAL EFFECTS SUBCOMMITTEE

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L. R. Aggus, L. E. Vogele,
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ABSTRACT

Fish and benthos communities were sampled to determine the effects of acid mine water discharges from Tar Creek on the aquatic biota of Grand Lake and to describe the status of the fish community in the Grand Lake area. Fish and benthos populations were severely stressed in Tar Creek, but populations of fish in the Neosho River showed no significant effect of acid mine water pollution. Cove rotenone samples in Grand Lake in 1982 yielded an average total fish standing crop of 465.3 pounds per acre. This was near the long-term average of 444.8 pounds per acre for the lake, and more than 2 times a national average based on data from 200 large U.S. reservoirs.

Although heavy metals are highly concentrated in Tar Creek, the Neosho River and Spring River also contribute large quantities of heavy metals to the Grand Lake System. These major tributaries to Grand Lake have high water hardness, which contributes to rapid precipitation of metals. Samples of plankton and coarse particulate matter indicated that these materials provided active sites for the uptake of heavy metals. Particulate matter from the Neosho River and Spring River is rapidly precipitated in the upper reaches of Grand Lake. These sediments provide a long-term sink for heavy metals, effectively removing them from many biological processes. The present level of heavy metals loading is not considered a serious threat to fish and benthos communities in Grand Lake.

Program, a fisheries-community survey was developed to identify impacts of discharges from Tar Creek on the aquatic biota. Objectives of these studies were 1) to assess the status of existing fish and macroinvertebrate communities; and 2) to address short-term and long-term biological effects of metals from mine discharge on the Grand Lake aquatic community in northeast Oklahoma.

SAMPLING LOCATIONS

Upper Grand Lake Area

Sampling on the upper Grand Lake area was designed to provide comparisons of fish and benthic invertebrate abundance, distribution, and physiological characteristics in Tar Creek and Fourmile Creek, a morphologically similar stream not receiving heavy metals. In addition, uplake reaches of Grand Lake in the Neosho River and Spring River arms were sampled at several locations, extending downstream to approximately one mile below the mouth of Ogeechee Bay on Grand Lake. Location of sampling stations are shown in Figure 1.

Station 0, Neosho River above low-water dam at Miami, Oklahoma

Located approximately 0.33 mile upstream of the highway 68-59 bridge in Miami, downstream to the low-water dam at Miami (factors for converting measurements from U. S. to metric are given in Appendix I). This site is above the confluence of Tar Creek and the Neosho River. Maximum depth of water was about 5 feet. Shorelines are steep and mostly of clay-silt substrates. Woody vegetation was abundant along both shorelines.

Station 1, Neosho River below low-water dam at Miami, Oklahoma

Located down-stream of the low-water dam at Miami, Oklahoma, to approximately 0.5 mile above U. S. 44 bridge. The site is above the confluence of Tar Creek. Maximum depth of water was about 8 feet. The stream bed is a mixed gravel and sand substrate which was covered with silt at the time of sampling. Shorelines were steep sided with abundant stands of woody vegetation.

Station 2, Neosho River below Tar Creek

Located between 1.8 and 2.5 miles downstream from the mouth of Tar Creek. Maximum depth of water was approximately 10 feet. The stream bed is a mixture of clay, sand, and gravel, overlaid by silt for a depth of two to three inches. One shoreline is steep sided with abundant woody vegetation, while the other is a rock bluff.

Station 3, Neosho River at Conner's Bridge

From Conner's bridge downstream for a distance of approximately 0.75 mile (Mudeater Bend area). Maximum depth of water was 17 feet. The stream bed was a clay-silt mixture of undetermined depth. Shorelines were steep. One side of the stream channel was mud, and the other was broken rock. Woody vegetation was abundant along the mud shoreline.

Station 4, Spring River above U. S. Highway 60 Bridge

From approximately 1.5 to 2.5 miles upstream of the U. S. Highway 60 bridge on Spring River. The streambed was a clay-silt mixture. One shoreline was steep and rocky, and the other was a mud flat. Woody vegetation was abundant along the steep shoreline.

Station 5, Grand River at Ogeechee Bay

Located 2 miles downstream from the U. S. Highway 60 bridge. This station extends 0.5 mile below the mouth of the bay. Maximum depth

Woodard Hollow Cove

Located on the north side of Woodard Hollow, approximately midway in the arm. The cove was blocked off at the mouth to include a surface area of 1.5 acres. Mean and maximum depths were 12.5 and 25 feet, respectively. The cove is narrow and steep-sided, and the shoreline substrates are mostly angular chert.

Boy Scout Cove

Located approximately 2.5 miles upstream from Paradise Point on the Grand River arm of the lake. The 20-acre cove is adjacent to the Cherokee Area Boy Scout Camp. The sample was collected in the back of the cove, where a 2.9-acre area was blocked-off. Mean and maximum depths of this site were 6.3 and 14.0 feet, respectively. Substrates include coarse angular chert and shale along the sides of the cove and silt in the extreme back end of the cove.

Wildcat Hollow Cove

Located approximately 1 mile downlake from Aspenwall Cove and directly across from the mouth of Wilson's Point. The entire 1.9-acre cove was sampled. Mean and maximum depths were 8.0 and 16.0 feet respectively. Shoreline substrates are mostly angular chert, and there were substantial quantities of driftwood in the cove.

METHODS AND MATERIALS

Field sampling procedures were designed to 1) determine if discharges from Tar Creek are producing measurable effects on fish and invertebrate communities in the Tar Creek area; 2) define the extent of the effect outside the Tar Creek area; and 3) describe the current status of the fish community in Grand Lake. Unfortunately, there is no which was connected to a Smith-Root Mark VI "brain box". A setting of 400 pulsed d.c. volts and 6 amps was used on all transects. A three-man crew, consisting of a driver and two people to dip fish, shocked in a downstream direction; the total time spent shocking was recorded for each transect. Fish were placed in a live well supplied with fresh water. When the transect was completed the fish were sorted to species, measured, weighed, and released. If numerous fish of one species were collected, a subsample was taken for lengths and weights, and total lengths were obtained on the remainder.

Experimental gill netting

Three experimental multifilament nylon gill nets, 6 feet deep and 150 feet long, and consisting of six panels each 25 feet in length and including mesh sizes of 1, 1.5, 2, 2.5, 3, and 3.5 inch mesh (bar measure) were set perpendicular to the shore and were fished overnight at stations 1-5. The nets were set randomly as to whether the small-mesh or the large-mesh panels were onshore or offshore. Fish were removed from the nets and sorted to species, and individual lengths and weights were taken. Gills were removed from up to 20 gizzard shad per sample site and were preserved in 10% formalin. The nets were then reset at the next station downstream. Gill samples were shipped to the Tulsa District Corps of Engineers where they were examined for lesions on the gills.

Cove rotenone

Three coves in Grand Lake -- Woodard Hollow (1.5 acre), Boy Scout Cove (2.8 acres), and Wildcat Hollow (1.9 acres) -- were sampled with rotenone from September 8 to 17, 1982. In sampling, each cove was first blocked-off with a 0.6 inch mesh net (bar measure) to prevent fish from entering or leaving the cove. Scuba divers swam the lead lines to ensure magnifier-illuminator. Macroinvertebrates were identified to major taxa, counted, and preserved in vials of 70% ethanol.

Plankton Sampling

Composite plankton samples were taken at station 1-5 on the Neosho River and Spring River. An unmetered Miller sampler was fitted with a No. 20 net (= 80 micron mesh) and towed at mid-depth to obtain a composite sample of at least 10 mg wet weight from each station. Samples were stored in ice and transferred to the Tulsa District, Corps of Engineers, where analysis for heavy metals was conducted.

Statistical Procedures

Sampling of fish and benthic macroinvertebrates at stations on upper Grand Lake (Tar Creek, Fourmile Creek, Neosho River, and Spring River) was designed to detect differences in selected community attributes during a single collection period. Three replicated samples were taken with each type of gear at stations on Tar Creek, Fourmile Creek, the Neosho River, and Spring River. We used the Statistical Analysis System (SAS) of Barr et al. (1979) and conducted one-way analysis of variance to compare population attributes as indicated by each gear type. When significant differences were indicated at the $\alpha = 0.05$ level, a Duncan's Multiple Range test was used to compare means. In tests involving estimates of abundance, the SAS-Rank procedure was applied to raw data. The previously described statistical tests were then conducted on these transformed data.

RESULTS

Fish Community - Upper Grand Lake

Tar Creek and Fourmile Creek

As anticipated, the fish community in Tar Creek was severely reduced compared to that of Fourmile Creek (Table 1). No fish were collected at

Station 8, while 12 species were collected at Station 9. The forms present at this station were present in relatively low densities, as the average catch per seine haul was only 25.7 fish (common and scientific names of fishes used in this report are listed in Appendix II).

Seining at Station 6 on Fourmile Creek yielded 19 species of fish and an average catch per seine haul of 83.3 fish. Small bluegills were most abundant. Only 10 species were captured at Station 7; however, collections included large numbers of red shiners and ghost shiners which were not present at Station 9 on Tar Creek. The average catch per seine haul (249.3 fish) was about 10 times that of Station 9 on lower Tar Creek.

Neosho River and Spring River

Sampling in these major tributaries to Grand Lake permitted an evaluation of effects of discharges from Tar Creek on the fish community in the upstream reaches of Grand Lake. We were concerned with both acute and chronic effects of heavy metals. Under extreme conditions, populations of fish might be reduced or eliminated completely. This would result in changes in species composition, abundance, and species diversity. Chronic effects could alter physiological processes and result in fish being in poor condition; this would ultimately influence length-weight distributions of certain species.

Species composition and abundance: Twenty-six species of fish were collected by experimental gill netting and electroshocking at stations on the Neosho River and Spring River. Twelve species occurred at all sites. The total number of species collected at various stations ranged between 17 and 21, indicating that most taxa were found at more than one station (Table 2). Electroshocking yielded the greater number of species, but did not effectively sample gars. Gill nets were not effective in sampling most centrarchids. With the equal sampling effort applied at each station, we feel that the

Table 3. Average number of each fish species captured per experimental gill net set at sampling locations on the Neosho River, Grand River and Spring River, October 11-15, 1982. Values suffixed by the same letter do not differ significantly at the α = 0.05 lead.

	Neosho River				Spring River
Species	Station 1	Station 2	Station 3	Station 5	Station 4
Spotted gar	-	-	-	-	12.0
Longnose gar	-	13.7	10.0	-	-
Shortnose gar	-	1.0	4.5	1.0	-
Gizzard shad[1/]	5.3 b	5.7 b	1.5 c	15.3 a	20.7 a
Carp[1/]	1.0 b	4.3 a	3.3 a	5.0 a	2.0 b
River carpsucker	3.3	3.7	3.3	3.7	1.5
Smallmouth buffalo	5.0	2.0	2.7	2.0	1.0
Bigmouth buffalo	-	1.0	1.0	-	-
Shorthead redhorse	1.0	-	-	-	-
Channel catfish	2.0	2.0	2.0	2.0	2.0
Flathead catfish	1.0	1.0	1.5	1.0	2.0
White bass	2.0	3.0	1.0	2.0	1.0
White crappie	1.0	1.0	1.0	2.5	1.0
Freshwater drum	1.5	3.3	3.5	2.3	1.3
TOTAL	23.1 b	41.7 a	35.3 a	36.8 a	44.5 a

[1/] Means with the same letter superscript are not significantly different at α = 0.05.

Table 4. Average number of species of fish captured by electrofishing in 500-yard transects at fish sampling stations on the Neosho River, Grand River, and Spring River, October 11-15, 1982. Values suffixed by the same letter do not differ significantly at the α = 0.05 lead.

	Neosho River					Spring River
Species	Station 0	Station 1	Station 2	Station 3	Station 5	Station 4
Spotted gar	0.3	-	-	-	-	-
Gizzard shad[1/]	160.7 a	95.0 b	43.0 b	41.7 b	37.3 b	69.7 b
Common carp[1/]	28.7 a	10.3 b	6.7 b,c	2.7 b,c	-	2.7 b,c
River carpsucker	3.7	2.3	-.7	0.3	0.3	0.7
Smallmouth buffalo	5.0	7.3	7.3	2.7	1.0	3.7
Bigmouth buffalo	1.0	-	1.0	-	-	-
Channel catfish	0.7	3.0	5.3	3.7	1.7	3.3
Flathead catfish	1.3	0.3	0.3	0.3	-	-
White bass	1.7	14.7	9.0	5.3	6.0	3.7
Green sunfish	0.3	1.3	1.0	2.0	2.0	9.3
Warmouth	-	2.3	1.0	4.7	5.7	5.3
Orangespotted sunfish	-	1.0	0.7	-	-	-
Bluegill	2.7	14.6	26.0	63.3	60.7	61.3
Longear sunfish	0.3	-	0.3	0.7	1.3	2.0
Redear sunfish	-	0.3	-	0.3	-	-
Spotted bass	0.3	1.3	-	1.0	-	3.7
Largemouth bass[1/]	0.7 b	3.7 b	4.3 b	9.0 b	20.0 a,b	30.0 a
White crappie[1/]	4.0 c	11.3 a,b,c	24.7 a,b	26.3 a	9.0 b,c	4.3 c
Black crappie	-	0.3	-	-	0.3	-
Freshwater drum	8.3	7.3	1.3	0.3	3.0	2.0
Top minnows	-	-	-	0.3	-	-
Brook silverside	3.0	-	-	-	-	-
Logperch	-	-	-	0.3	0.3	0.3
TOTAL	222.7	176.3	133.6	164.9	148.6	202.0

[1/] Means with the same letter superscript are not significantly different at α = 0.05

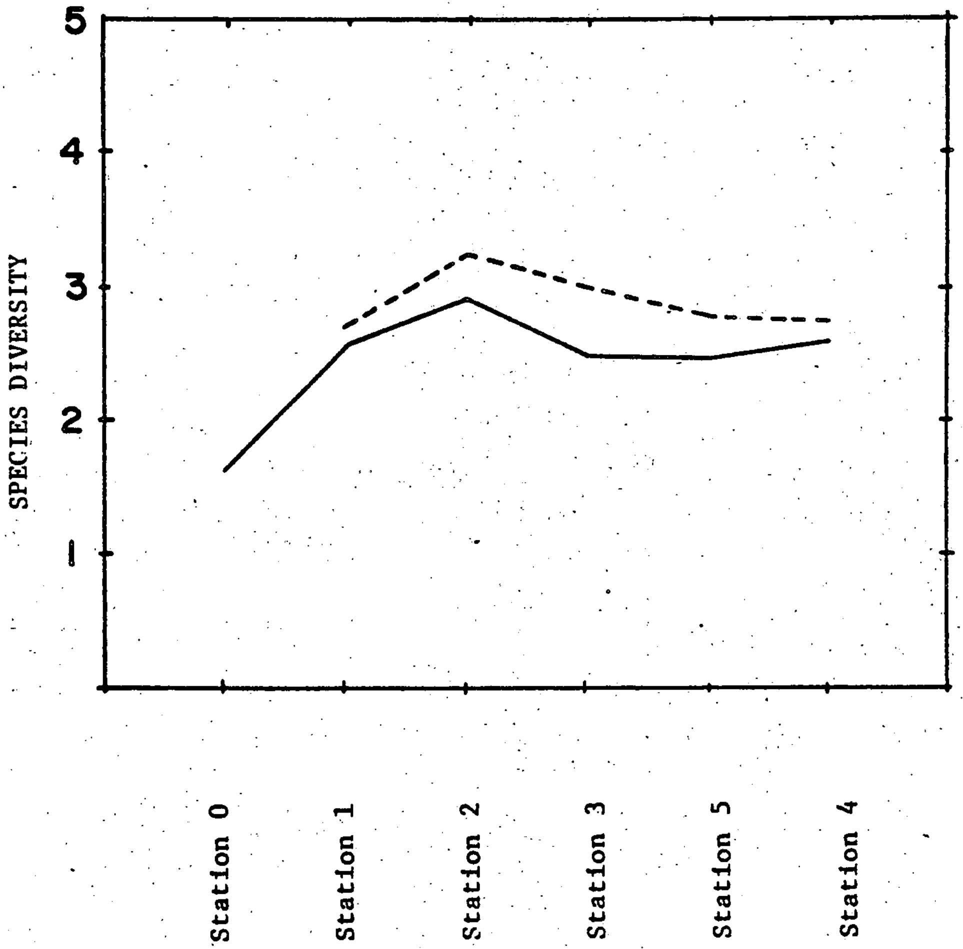

Figure 2. Shannon-Weaver index of species diversity of fishes collected from sampling stations on the Neosho River and Spring River, October 11-15, 1982. Results are from electroshocking (solid line) and electroshocking plus experimental gillnetting (dashed line).

relative conditions of gizzard shad, carp, white bass, bluegill, and white crappie differed significantly between stations. Average relative condition values at stations 3, 4, and 5 were generally lower than those at upstream locations. However, there were noteworthy exceptions among the various species. For example, relative condition of both channel catfish and flathead catfish was highest at Station 3 in contrast to that of other bottom-feeding fishes.

Gill analysis: gross examination of gills extracted from adult gizzard shad during gill net sampling at stations 1 through 5 did not reveal any abnormalities which could be attributed to exposure to heavy metals.

Fish Community - Grand Lake

Species Composition and Standing Crop of Fish

Cove samples have been collected from Grand Lake at irregular intervals since 1949, and these data provided a basis for evaluating the 1982 cove samples. We could not detect definite trends in total standing crop (biomass) as related to discharge from Tar Creek. The total unadjusted standing crop of fish was 465.3 pounds per acre in 1982, compared to an average of 444.8 pounds per acre when all previous years of data were included (Table 6). Gizzard shad, common carp, buffaloes, freshwater drum, and sunfishes made up a substantial part of the total standing crop throughout the period. Crops of common carp, smallmouth buffalo, sunfishes, and white crappie have apparently increased since cove sampling began in 1949, however, these increases in biomass have been gradual and probably reflect long-term effects of reservoir aging.

Standing crops of gizzard shad were lower than expected in the cove samples collected during 1982. Young shad were not collected in large numbers from Boy Scout Cove and Wildcat Hollow Cove, although they were abundant outside these sample areas. We consider the relatively low estimates of shad to be a reflection of a patchy distribution of the young during late summer. (Raw data from cove-rotenone sampling are included in Appendix III).

Prey/Predator Relations

An assessment of availability of prey for piscivorous fishes provides a valuable index to the general health of reservoir fish communities. We used the Available Prey/Predator (AP/P) model of Jenkins and Morais (1976) to define predator-prey relationships in individual coves and for the entire lake. The (AP/P) model uses cove-rotenone data to describe biomass of prey available to predators of various sizes based on the mouth sizes of predators. In determining the adequacy of prey, it is assumed that about 5 pounds of prey will be required annually to produce one pound of predator. Using seasonal estimates of predator and prey production as presented by Jenkins and Morais (1976), the biomass of prey required to maintain predator biomass when samples are collected in mid-September would be about 0.5 pounds of prey per pound of predator (at an available prey/predator ratio of 0.5:1).

There was substantial variation in the total biomass of both available prey and predators at the various sample sites (Figure 3). However, standing crops of prey were deemed adequate to support all sizes of predators. Standing crops of predators and available prey, when adjusted for non-recovery of marked fish and differences in biomass of various fishes between cove and open-water areas, averaged 116 and 367 pounds per acre, respectively. Most of the predator biomass was composed of sport fishes (crappies, catfishes, and black basses), while gizzard shad, sunfishes, small crappies, and freshwater drum were the primary prey fishes. (Results of the Available Prey/Predator analyses are summarized in Appendix IV.)

Trophic Interactions

A measure of major modes of feeding provides valuable insights into how a fish community assimilates various types of food and associated pollutants. We applied the trophic model of Ploskey and Jenkins (1982) to cove-sample data to identify major trophic pathways for fishes in Grand Lake and to obtain estimates of fish production for non-recovery of marked fish and differences in distribution of fishes between coves and open-water areas. The model projected average total standing crop of fish to be 1,052 pounds per acre in Grand Lake (Table 7). Detritus- and benthos-feeding fish (bottom feeders) were the dominant functional groups in the reservoir. There was an estimated 624 pounds per acre of bottom feeders, 268 pounds per acre of planktivores (plant and zooplankton feeders), 149 pounds per acre of piscivores, and only 9 pounds per acre of surface-feeding fish in the lake. Adjusted total standing crops ranged from 434 pounds per acre in the Boy Scout Cove to 1,515 pounds per acre in Woodard Hollow Cove. However, the percentages of standing crop supported by the major food categories were remarkably similar in all study coves, indicating that similar energy sources were being utilized by fishes at each sample location. Estimated annual production of all fishes was 928 pounds per acre or 88 percent of the total standing crop. (Results of the trophic model analysis are presented in Appendix III.)

Heavy-Metals Budget

An estimate of quantity and rate of heavy metals assimilation by the fish community in Grand Lake is important in determining the fate of heavy metals entering the lake. We calculated average concentrations of heavy metals in whole fish samples from collections made during 1980 and 1981 on

Tar Creek, the Neosho River and Spring River (U. S. Fish and Wildlife Service, unpublished). Data were obtained for bottom-feeding fishes and piscivores (Table 8). Unfortunately, no information was available for plankton-feeding fish. These fish were arbitrarily assigned heavy-metals concentrations equal to those for bottom-feeding fish. Surface area of Grand Lake was approximately 41,300 acres at the time of sampling. Using this area, the annual estimates of fish production, and the concentrations of metals in whole fish, the calculated annual budgets (pounds/year) were 5.8 for cadmium, 5.4 for chromium, 38.5 for lead, and 2,313.5 for zinc. These are based on an annual production of 38 million pounds of fish for the entire lake.

Benthos Community - Upper Grand Lake

Tar Creek and Fourmile Creek

Benthos sampling in Tar Creek and Fourmile Creek was designed to provide a comparison of the invertebrate fauna of these morphologically similar streams. Unfortunately, the area around Miami, Oklahoma was extremely dry during late summer of 1982; Fourmile Creek was reduced to a series of intermittent pools, and the flow in Tar Creek was reduced to about 1.0 cfs. In spite of a complete absence of riffle habitat in Fourmile Creek, we collected 13 invertebrate taxa from the upstream Station 6 (Table 9). In contrast, Station 8 in Tar Creek yielded only 5 species, and most were a chironomid species of the *Chironomus plumosus* group. Abundance of macroinvertebrates at Station 8 in Tar Creek was about 3 times that at Station 6 on Fourmile Creek. This difference in invertebrate abundance probably reflected the absence of fish in Tar Creek.

Table 9. Average number of benthic macroinvertebrates per square meter at sampling sites in Fourmile Creek and Tar Creek, Oklahoma, October 19-20, 1982. Numbers are the average of 3 samples.

	Fourmile Creek		Tar Creek	
Taxon	Station 6	Station 7	Station 8	Station 9
Nematoda	7			
Annelida				
Oligochaeta	1,174	307		
Tubificidae	7			
Hirudinea	7			
Amphipoda				
Talifridae	28			
Insecta				
Ephemeroptera				
Baetidae	20			
Unid. Ephemeroptera	7			
Odonata				
Coenagriidae	20			
Cordulidae	47			
Libellulidae				
Hemiptera				
Hydrometridae				7
Corixidae	460	213	20	
Trichoptera				
Hydroptilidae		13		
Coleoptera				
Haliplidae			7	
Unid. Coleoptera		80		
Diptera				
Ceratopogonidae	54			
Chironomidae	80	13	6,007	27
Culicidae				
Chaoborus sp.	80	53	20	1,467
Tabanidae		53		
Unid. Diptera		13		
Gastropoda				
Physidae	54			
Total Organisms	2,045	745	6,061	1,494

Table 10. Average number of benthic macroinvertebrates per square meter at stations on the Neosho River, and Spring River, Oklahoma, October 18-21, 1982. Values suffixed by the same letter do not differ significantly with α = 0.05 level.

	Neosho River				Spring River
Taxon	Station 1	Station 2	Station 3	Station 5	Station 4
Annelida					
Oligochaeta[1]	0	293 c	0	733 b	3,787 a
Tubificidae					13
Insecta					
Ephemeroptera					
Hexagenia sp.[1]	107 a	13 a	0	0	27 a
Chironomidae[1]	0	147 a,b	13 b	333 a	160 a
Culicidae					
Chaoborus sp.[1]	867 b,c	2,280 b	19,320 a	6,160 a	293 c
TOTAL	974	2,733	19,333	7,226	4,280

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[1] Variance of means differed significantly with α = 0.05 level.

Table 11. Concentrations (mg/kg) of cadmium, lead and zinc in composited plankton samples collected at stations 1-5 on the Neosho River and Spring River, October 18-20, 1982.

	Concentration (mg/kg)		
Station	Cadmium	Lead	Zinc
1	2.96	2.0	33.0
2	17.40	115.6	91.7
3	20.92	120.9	84.2
3(Replicate	>120.0	257.3	283.6
4	446.06	481.3	274.6
5	78.96	41.4	192.9

overspread mud flats at stations 4 and 5, and brush habitat was more restricted. A similar habitat preference was exhibited by bluegill, green sunfish, warmouth, and longear sunfish. These forms were most numerous along rocky shorelines, and therefore exhibited patchy distributions in our sampling. This, in part, explains the large apparent differences with no statistical significance in abundance between sampling stations.

Measures of relative condition of fish and gross examination of gill tissues were used to detect subtle physiological responses of certain fishes to heavy metals contamination in the Neosho River and Spring River. Lesions on gill tissues have proven useful as external indications of chronic exposure to lead (Dortman and Whitworth 1969) and zinc (Burks 1976), and relative condition provides a measure of general health of fish. We were unable to detect differences in either of these physiological measures with respect to sampling location, however, tissue analysis indicated differences in heavy metals concentration in some fish.

Analysis of lead and zinc in tissues of fish collected at locations in Tar Creek, in Neosho River, and Spring River by the Oklahoma Department of Health during 1982 indicated that most fishes concentrated greater quantities of lead and zinc in liver tissue than in filets (Tables 12 and 13). Concentrations of heavy metals in fish tissues were highly variable between sampling locations and at different times of the year. In general, detritivores (carp and river carpsucker) and planktivores (gizzard shad) contained higher concentrations of lead and zinc than predators (white crappie and white bass). This distribution of metals in fish indicates that biomagnification of these materials through higher trophic levels is not significant in the fish community of Grand Lake.

Table 13. Concentrations (in parts per million) of lead and zinc in fish fillets collected from the upper Grand Lake area during July, 1982 and (in parentheses) November, 1982 (information supplied by the Oklahoma Department of Health).

		Neosho River		Spring River		Neosho River	
Species	Mouth of Tar Creek	Above Tar Creek	Below Tar Creek	At Hwy.10	At Hwy.60	Ogeechee Bay	Confluence of Sycamore Creek
Lead							
Carp	< 1.0 (< 1.0)	< 1.0 (< 1.0)	< 1.0	(< 1.0)		< 1.0 (< 1.0)	(< 1.0)
White crappie	< 1.0	< 1.0 (< 1.0)	< 1.0 (< 1.0)		< 1.0 (< 1.0)	< 0.5 (< 1.0)	< 1.0 (< 1.0)
River carpsucker					< 1.0 < 1.0		
Channel catfish	< 1.0 (< 1.0)	< 1.0 (< 1.0)	< 1.0 (< 1.0)	(< 1.0)	(< 1.0)	< 1.0 (< 1.0)	(< 1.0)
Gizzard shad			(< 1.0)	< 1.0 (< 1.0)	< 1.0	< 1.0	
Buffaloes				< 1.0	< 1.0		< 1.0
Longnose gar				< 1.0			
White bass						(< 1.0)	
Warmouth	< 1.0						
Zinc							
Carp	16.40 (0.96)	10.20 (4.50)	8.90	(7.90)		7.70 (4.90)	(13.40)
White crappie	7.05	8.05 (6.60)	6.40 (4.50)		7.70 (6.20)	8.80 (9.40)	8.20 (5.80)
River carpsucker					7.60 (4.20)		
Channel catfish	4.30 (4.50)	4.40 (10.50)	4.40 (3.90)	(3.20)	(6.90)	5.70 (8.10)	(4.60)
Gizzard shad			(5.10)	8.70 (13.90)	2.88	22.50	
Buffaloes				12.70	1.08		7.00
Longnose gar				4.50			
White bass						(5.60)	
Warmouth	58.50						

Increases in standing crops of carp, sunfishes, and white crappie which have occurred since 1949 reflect natural aging of the lake

Assessing the long-term or future effects of continued heavy-metals loading on aquatic communities requires an accurate measure of the total quantity of metals entering Grand Lake, and an understanding of the distribution and ultimate disposition of metals once they enter the system. Estimates of heavy-metals loadings are available for Tar Creek, the Neosho River and Spring River. The Oklahoma Water Resources Board has calculated metals loading rates (pounds/day) for Tar Creek based upon data collected between January, 1981 and August, 1982. Average daily loading one mile above the mouth of Tar Creek based upon an average flow of 24.4 mgd, was 6.1 pounds of cadmium, 8.1 pounds of lead and 8,347 pounds of zinc. No chromium was detected. This compares to an average daily loading at the mouth of Tar Creek, based upon an annual average flow of 32.4 mgd, of 2.0 pounds of cadmium and 1,468 pounds of zinc. No lead or chromium was detected. The Neosho River and Spring River also contribute large quantities of heavy metals in the Grand Lake system. Combined daily loadings from the Neosho River and Spring River averaged 48.86 pounds of cadmium, 381.1 pounds of chromium, 359.2 pounds of lead, and 6,020 pounds of zinc during the period 1977 to 1979 (data supplied by U.S. Geological Survey). In spite of a smaller average flow, the Spring River provided about 40 percent of the average annual water inflow of the two tributaries, but 64 percent of cadmium, 36 percent of chromium, 49 percent of lead, and 92 percent of zinc contributed by the two major tributaries. Sampling of heavy metals in the Neosho River and Spring River has continued since 1980. At the time this report was prepared, discharge measurements needed to compute metal budgets were not available. Concentrations of lead and zinc from these samples varied somewhat from the values reported herein. However, they generally substantiate the relative loadings from the two major tributaries.

uplake area of Grand Lake is shallow, and any change in reservoir operation which stabilizes water levels could dramatically increase growth of aquatic macrophytes and patterns of heavy-metals cycling.

Plankton samples from the Neosho River and Spring River indicated that plankton and associated coarse particulate matter provide an important pathway for the uptake of heavy metals in the Grand Lake System. Algae have been identified as important components in concentrating heavy metals (Jackson 1978, Proctor and Sinha 1978, and others). Organic and inorganic particles also provide important mechanisms for the uptake of heavy metals owing to the presence of carbonates, hydroxides, and organic lignins in solutions. Waters of the Neosho River and Spring River are hard (150-300 ppm $CaCO_3$), and both streams contain high dissolved solids and particulate loads. These conditions of high alkalinity also foster rapid precipitation of heavy metals (Jennett and Foil 1979).

Extensive sedimentation occurs along the reaches of the Neosho River and Spring River in the headwaters of Grand Lake. Sediment samples collected by the Oklahoma Department of Health during 1982 from locations in Tar Creek, the Neosho River, and Spring River indicated that large quantities of cadmium, chromium, lead, and zinc are present in sediments from the upper reaches of Grand Lake (Table 14). The accumulation of heavy metals were highest in Tar Creek and in the Spring River where the greatest quantities of metals enter the reservoir. There is a decrease in the concentration of heavy metals downlake from the confluence of the Spring River which suggests that a large percentage of sedimentation occurs in the extreme uplake regions.

Because of the rapid sedimentation, Grand Lake serves as a long-term sink for heavy metals. Studies in the new lead belt in southeast Missouri indicate that reservoirs in that area (Wappapello and Clearwater) also serve as long-term sinks for heavy metals (Proctor and Sinha 1978; and Wixon et al. 1978). Both lakes are considered imperfect sinks because of periodic resuspension of sediments during flooding. In this respect, Grand Lake should be much more efficient, as the mean annual water retention time is 0.32 years as opposed to 0.03 and 0.06 years for Clearwater Lake and Lake Wappapello, respectively.

The ultimate fate of heavy metals, once they are deposited in sediments, is of concern with respect to long-term effects on aquatic communities. Under conditions of high natural water hardness as occurs in Grand Lake, heavy metals are chemically stable. If sediments remain in place and continue to be covered by new material, the metals bound to these substrates should be effectively removed from most biological processes.

Recycling of heavy metals by benthic macroinvertebrates can be significant in lakes where large numbers of burrowing or filter-feeding forms such as midges or tubificids occur (Nicholas and Thomas 1978; Stern and Grant 1981). Substantial numbers of oligochaetes were collected at Station 4, but burrowing macroinvertebrates were generally sparce. Benthos samples from the Neosho River and Spring River contained large numbers of larval Chaoborus sp. These forms inhabit the mud-water interface during daytime and migrate into the water column at night to feed. Recycling of metals in sediments by these macroinvertebrates is therefore limited in Grand Lake.

Periodic flooding of the Neosho River and Spring River produces strong currents for several miles downstream into the lake, and, as demonstrated by Benoit et al. (1968), resuspension of large amounts of sediments during flooding could redistribute sediments for a considerable distance downstream

3) Species composition and standing crops of fish in Grand Lake also showed no effects of heavy metals pollution. Average standing crop of fish (444.8 pounds per acre) is more than twice the National average for similar reservoirs based on a sample of 200 large U.S. reservoirs.

4) Although Tar Creek provides a concentrated source of heavy metals, the Neosho River and Spring River also contribute large quantities of metals. The Spring River loads larger quantities of lead and zinc into Grand Lake than the Neosho River.

5) Plankton and associated coarse particulate matter from samples in the Neosho River and Spring River contained high concentrations of heavy metals. Waters of these rivers are hard, and this contributes to rapid sedimentation. These sediments provide an effective long-term sink for heavy metals.

6) Heavy metals will continue to accumulate in sediments. We do not consider these to be dangerous to fish and other aquatic communities in Grand Lake at present. However, periodic monitoring of water quality, sediments and aquatic communities should be continued to better evaluate long-term biological effects.

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APPENDIX I

CONVERSION FACTORS, U.S. TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this paper can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	25.4	millimeters
feet	0.3048	meters
miles	1.609344	kilometers
yards	0.9144	meters
acres	0.40468	hectares
acres	0.0040468	square kilometers
pounds	453.5923	grams
pounds per acre	1.120851	kilograms per hectare

APPENDIX III

NUMBERS AND POUNDS PER ACRE OF FISHES COLLECTED BY INCH CLASS COVE ROTENONE SAMPLING ON GRAND LAKE, OK, SEPTEMBER 1982.

Boy Scout Cove cont'd

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            BROOK SILVERSIDES    WHITE BASS          GREEN SUNFISH       WARMOUTH            BLUEGILL
    TL      NUMBER   WEIGHT      NUMBER   WEIGHT     NUMBER   WEIGHT     NUMBER   WEIGHT     NUMBER   WEIGHT
     1        0.0     0.0          0.0     0.0         0.0     0.0       52.857    0.083    363.214    0.482
     2      18.929    0.043        0.0     0.0       76.786    0.508     99.286    0.287    225.357    0.698
     3        0.0     0.0          0.357   0.006     12.143    0.268     47.500    1.049     85.714    1.890
     4        0.0     0.0          0.714   0.020     15.714    0.676     13.571    0.572     53.571    2.362
     5        0.0     0.0          0.0     0.0        2.857    0.309     10.357    0.868     23.571    2.079
     6        0.0     0.0          0.0     0.0        0.357    0.049      0.714    0.099      6.429    0.850
 TOTAL      18.929    0.043        1.071   0.026    107.857    1.810    224.285    2.958    757.855    8.361

            LONGEAR SUNFISH      SPOTTED BASS        LARGEMOUTH BASS     WHITE CRAPPIE       LOGPERCH
    TL      NUMBER   WEIGHT      NUMBER   WEIGHT     NUMBER   WEIGHT     NUMBER   WEIGHT     NUMBER   WEIGHT
     2       0.357    0.002        0.0     0.0        0.357    0.002      7.500    0.046      0.0      0.0
     3       1.429    0.031        0.0     0.0        9.643    0.088    113.929    1.180     20.357    0.452
     4       0.0      0.0          0.714   0.016     10.357    0.232      7.143    0.117      0.0      0.0
     5       0.0      0.0          0.0     0.0        6.786    0.329      3.929    0.227      0.0      0.0
     6       0.0      0.0          0.0     0.0        0.357    0.031     13.214    1.173      0.0      0.0
     7       0.0      0.0          0.0     0.0        0.0      0.0        8.214    1.073      0.0      0.0
     8       0.0      0.0          0.0     0.0        0.0      0.0        7.857    1.629      0.0      0.0
     9       0.0      0.0          0.0     0.0        0.714    0.236      1.071    0.366      0.0      0.0
    10       0.0      0.0          0.0     0.0        0.0      0.0        2.857    1.247      0.0      0.0
    11       0.0      0.0          0.0     0.0        0.0      0.0        0.357    0.227      0.0      0.0
    12       0.0      0.0          0.0     0.0        0.0      0.0        0.714    0.657      0.0      0.0
    13       0.0      0.0          0.0     0.0        0.0      0.0        0.357    0.405      0.0      0.0
    14       0.0      0.0          0.0     0.0        0.357    0.499      0.357    0.458      0.0      0.0
 TOTAL       1.786    0.033        0.714   0.016     28.571    1.417    167.499    8.805     20.357    0.452

            DARTERS              FRESHWATER DRUM
    TL      NUMBER   WEIGHT      NUMBER   WEIGHT     NUMBER   WEIGHT     NUMBER   WEIGHT     NUMBER   WEIGHT
     2       2.500    0.004        2.143   0.009      0.0      0.0        0.0      0.0        0.0      0.0
     3       0.0      0.0         50.000   0.739      0.0      0.0        0.0      0.0        0.0      0.0
     4       0.0      0.0        208.214   4.770      0.0      0.0        0.0      0.0        0.0      0.0
     5       0.0      0.0          6.786   0.345      0.0      0.0        0.0      0.0        0.0      0.0
     6       0.0      0.0         39.643   3.328      0.0      0.0        0.0      0.0        0.0      0.0
     7       0.0      0.0          7.500   0.829      0.0      0.0        0.0      0.0        0.0      0.0
     8       0.0      0.0         10.714   2.197      0.0      0.0        0.0      0.0        0.0      0.0
     9       0.0      0.0         13.214   3.773      0.0      0.0        0.0      0.0        0.0      0.0
    10       0.0      0.0          5.000   1.919      0.0      0.0        0.0      0.0        0.0      0.0
    11       0.0      0.0          1.429   0.706      0.0      0.0        0.0      0.0        0.0      0.0
    12       0.0      0.0          0.714   0.477      0.0      0.0        0.0      0.0        0.0      0.0
    18       0.0      0.0          0.357   0.839      0.0      0.0        0.0      0.0        0.0      0.0
 TOTAL       2.500    0.004      345.713  19.931      0.0      0.0        0.0      0.0        0.0      0.0
 TOTALS=  3570.689 FISH WEIGHING   216.566 POUNDS.
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Woodard Hollow Cove cont'd

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            WARMOUTH              BLUEGILL              LONGEAR SUNFISH       SPOTTED BASS          LARGEMOUTH BASS
    TL      NUMBER    WEIGHT      NUMBER    WEIGHT      NUMBER    WEIGHT      NUMBER    WEIGHT      NUMBER    WEIGHT
     1     626.667    0.991     7419.332    9.442        0.0       0.0          0.0       0.0         0.0       0.0
     2     160.000    0.736     2240.667    6.530       68.000     0.450        0.0       0.0         0.0       0.0
     3     109.333    1.373      334.667    5.628      153.333     3.685        3.333     0.034      11.333     0.112
     4      17.333    0.726      177.333    7.834       58.667     2.973        0.667     0.015      18.000     0.413
     5       7.333    0.645       64.000    5.115        8.000     0.600        0.0       0.0        11.333     0.556
     6       3.333    0.461       16.667    2.241        0.0       0.0          1.333     0.121       0.0       0.0
     7       0.667    0.132        0.0      0.0          0.0       0.0         12.000     1.646       0.667     0.097
     8       0.0      0.0          0.0      0.0          0.0       0.0          3.333     0.610       3.333     0.761
     9       0.0      0.0          0.0      0.0          0.0       0.0          2.667     0.833       7.333     2.271
    10       0.0      0.0          0.0      0.0          0.0       0.0          0.0       0.0         2.667     1.270
    11       0.0      0.0          0.0      0.0          0.0       0.0          0.667     0.367       2.667     1.608
    13       0.0      0.0          0.0      0.0          0.0       0.0          0.0       0.0         1.333     1.496
    15       0.0      0.0          0.0      0.0          0.0       0.0          0.0       0.0         0.667     1.176
 TOTAL     924.665    5.064    10252.656   36.790      288.000     7.708       24.000     3.626      59.333     9.760

            WHITE CRAPPIE         LOGPERCH              DARTERS               FRESHWATER DRUM
    TL      NUMBER    WEIGHT      NUMBER    WEIGHT      NUMBER    WEIGHT      NUMBER    WEIGHT      NUMBER    WEIGHT
     2       4.000    0.028        0.0      0.0         26.000     0.028        0.0       0.0         0.0       0.0
     3      94.000    1.116       30.000    0.556        0.0       0.0         44.000     0.514       0.0       0.0
     4      12.000    0.190        0.0      0.0          0.0       0.0         77.333     1.581       0.0       0.0
     5      22.000    1.312        0.0      0.0          0.0       0.0         15.333     0.891       0.0       0.0
     6     184.667   17.283        0.0      0.0          0.0       0.0        131.333    11.330       0.0       0.0
     7     112.000   16.291        0.0      0.0          0.0       0.0         46.667     5.916       0.0       0.0
     8      82.000   17.920        0.0      0.0          0.0       0.0         86.000    17.055       0.0       0.0
     9      19.333    6.411        0.0      0.0          0.0       0.0         50.667    14.953       0.0       0.0
    10       3.333    1.546        0.0      0.0          0.0       0.0         22.000     7.610       0.0       0.0
    11       1.333    0.870        0.0      0.0          0.0       0.0          6.667     3.394       0.0       0.0
    12       0.0      0.0          0.0      0.0          0.0       0.0          3.333     2.119       0.0       0.0
    13       0.0      0.0          0.0      0.0          0.0       0.0          4.000     3.488       0.0       0.0
    14       0.0      0.0          0.0      0.0          0.0       0.0          3.333     3.569       0.0       0.0
    15       0.0      0.0          0.0      0.0          0.0       0.0          3.333     4.661       0.0       0.0
    16       0.0      0.0          0.0      0.0          0.0       0.0          1.333     2.268       0.0       0.0
    17       0.0      0.0          0.0      0.0          0.0       0.0          2.000     4.153       0.0       0.0
    18       0.0      0.0          0.0      0.0          0.0       0.0          1.333     3.183       0.0       0.0
    19       0.0      0.0          0.0      0.0          0.0       0.0          0.700     2.019       0.0       0.0
 TOTAL     534.665   62.967       30.000    0.556       26.000     0.028      499.364    88.704       0.0       0.0
 TOTALS= 16707.855 FISH WEIGHING    650.487 POUNDS.
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Wildcat Hollow Cove Cont'd

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           MOSQUITOFISH-GAMBUSI     BROOK SILVERSIDES        WHITE BASS               GREEN SUNFISH            WARMOUTH
   TL      NUMBER    WEIGHT         NUMBER    WEIGHT         NUMBER    WEIGHT         NUMBER    WEIGHT         NUMBER    WEIGHT
    1         0.0       0.0            0.0       0.0            0.0       0.0            0.0       0.0         38.421     0.073
    2       5.789     0.006          7.368     0.020            0.0       0.0       2101.100     0.445        438.947     1.851
    3         0.0       0.0            0.0       0.0          0.526     0.005         18.900     0.421         44.211     0.936
    4         0.0       0.0            0.0       0.0          3.158     0.052         19.500     0.685         29.474     1.110
    5         0.0       0.0            0.0       0.0            0.0       0.0          9.500     0.784         11.053     1.049
    6         0.0       0.0            0.0       0.0          0.526     0.029          4.200     0.315          7.368     1.512
    7         0.0       0.0            0.0       0.0            0.0       0.0            0.0       0.0          2.105     0.580
    8         0.0       0.0            0.0       0.0            0.0       0.0          0.500     0.139            0.0       0.0
TOTAL       5.789     0.006          7.368     0.020          4.210     0.086       2153.700     2.789        571.579     7.111

           ORANGESPOTTED SUNFIS     BLUEGILL                 LONGEAR SUNFISH          REDEAR SUNFISH           SPOTTED BASS
   TL      NUMBER    WEIGHT         NUMBER    WEIGHT         NUMBER    WEIGHT         NUMBER    WEIGHT         NUMBER    WEIGHT
    1       9.474     0.013       1064.737     1.510          4.737     0.005            0.0       0.0            0.0       0.0
    2       2.632     0.012       1283.684     5.385            0.0       0.0            0.0       0.0            0.0       0.0
    3       1.053     0.012        383.684     9.137         10.526     0.232          0.526     0.009            0.0       0.0
    4         0.0       0.0        496.842    23.000          2.105     0.107            0.0       0.0          3.158     0.070
    5         0.0       0.0        153.684    12.939            0.0       0.0          0.526     0.042          0.526     0.020
    6         0.0       0.0         68.421    11.932            0.0       0.0            0.0       0.0            0.0       0.0
    7         0.0       0.0          8.947     2.130            0.0       0.0            0.0       0.0            0.0       0.0
TOTAL      13.159     0.037       3459.999    66.033         17.368     0.344          1.052     0.051          3.684     0.090

           LARGEMOUTH BASS          WHITE CRAPPIE            LOGPERCH                 FRESHWATER DRUM
   TL      NUMBER    WEIGHT         NUMBER    WEIGHT         NUMBER    WEIGHT         NUMBER    WEIGHT         NUMBER    WEIGHT
    2         0.0       0.0         23.158     0.117            0.0       0.0          1.053     0.005            0.0       0.0
    3       7.368     0.065        110.000     0.968         12.632     0.125          8.421     0.065            0.0       0.0
    4      31.579     0.769         17.895     0.435            0.0       0.0        168.947     4.020            0.0       0.0
    5      13.684     0.693         46.316     2.866            0.0       0.0         14.737     0.471            0.0       0.0
    6       8.947     0.888         77.368     7.197            0.0       0.0          9.474     1.001            0.0       0.0
    7       1.053     0.181         32.632     4.608            0.0       0.0         33.158     3.951            0.0       0.0
    8       0.526     0.118          7.368     1.628            0.0       0.0         11.579     2.525            0.0       0.0
    9       2.105     0.703          9.474     3.279            0.0       0.0         35.789    10.714            0.0       0.0
   10       1.579     0.716         11.053     5.525            0.0       0.0         22.105     7.995            0.0       0.0
   11         0.0       0.0          7.895     5.455            0.0       0.0         10.000     5.202            0.0       0.0
   12         0.0       0.0          5.263     4.604            0.0       0.0          4.211     3.105            0.0       0.0
   13       1.579     1.845          1.053     1.221            0.0       0.0          2.632     2.387            0.0       0.0
   14       1.053     1.652          0.526     0.810            0.0       0.0          2.632     2.814            0.0       0.0
   15       1.579     2.820          0.526     0.822            0.0       0.0          1.579     2.096            0.0       0.0
   16       1.053     2.323            0.0       0.0            0.0       0.0          0.526     0.888            0.0       0.0
   17       1.053     2.673            0.0       0.0            0.0       0.0          0.526     1.035            0.0       0.0
   18       1.053     3.294            0.0       0.0            0.0       0.0          0.526     1.247            0.0       0.0
   19       0.526     1.992            0.0       0.0            0.0       0.0            0.0       0.0            0.0       0.0
TOTAL      74.737    20.732        350.526    39.535         12.632     0.125        327.894    49.521            0.0       0.0
TOTALS=   8555.020 FISH WEIGHING   528.945 POUNDS.
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AVAILABLE PREY-PREDATOR RELATIONSHIP, JENKINS, R. M., AND D. I. MORAIS 1977. U. S. WILDLIFE SERVICE, 100 W. ROCK STREET, FAYETTEVILLE, ARKANSAS 72701.

PERCENT RECAPTURE ADJUSTMENTS BASED ON PREDATOR STOCKING EVALUATION, GRINSTEAD ET AL, 1978.

COVE-OPEN WATER ADJUSTMENTS BASED ON DOUGLAS LAKE ROTENONE STUDY, HAYNE ET AL, 1968.

THE MODEL PRINTS THE FOLLOWING:

1. CUMULATIVE BIOMASS OF ALL PREDATORS (SPRED) BY INCH CLASS.
2. CUMULATIVE BIOMASS OF ALL PREY (SPREY) AND VARIOUS SPECIES AVAILABLE TO PREDATORS HAVING A MOUTH SIZE EQUIVALENT TO A LARGEMOUTH BASS OF THE INCH CLASS IN THE LEFT-MOST COLUMN.
3. CUMULATIVE BIOMASS OF VARIOUS PREDATOR SPECIES BY INCH CLASS.
4. APP RATIO = SPREY/SPRED.
5. C-RATIO = COMPETITION RATIO IS THE RATIO OF THE BIOMASS OF AVAILABLE PREY AT VARIOUS SIZES TO THE BIOMASS OF ALL PREDATORS IN THAT SIZE CLASS AND LARGER. IT INCLUDES ALL PREDATORS WHICH CAN THEORETICALLY COMPETE FOR A PARTICULAR SIZE OF PREY. C-RATIO LESS THAN 1 INDICATE THAT THE BIOMASS OF POTENTIAL PREDATORS EXCEEDS THAT OF POTENTIAL PREY.

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OK.GRAND.SCOUT.82          -------- PREY--------)
INCH  SPRED   SPREY   GSHAD+  TSHAD  SUNF   WBASS  BBASS  CARP  CATF   CRAPP  M+S   CATO  Y PER  DART  DRUM
  2   0.00.1   0.65    0.00   0.0    0.53   0.0    0.00   0.0   0.08   0.00   0.04  0.0   0.0    0.00   0.00
  3   0.09.11  1.73    0.00   0.0    1.31   0.0    0.00   0.0   0.23   0.04   0.10  0.0   0.0    0.02   0.01
  4   0.35     6.19    2.50   0.0    1.88   0.00   0.05   0.0   0.53   0.07   0.10  0.00  0.0    0.61   0.44
  5   0.84    14.35    7.37   0.0    3.07   0.01   0.14   0.0   0.69   0.80   0.10  0.00  0.0    0.91   1.25
  6   1.16    24.75   12.06   0.0    4.30   0.03   0.27   0.0   0.72   1.57   0.10  0.01  0.0    0.91   4.79
  7   6.17    37.45   16.65   0.0    6.28   0.06   0.58   0.0   0.80   2.00   0.10  0.01  0.0    0.91  10.06
  8   9.21    44.59   18.19   0.0    9.01   0.06   0.79   0.0   1.54   2.11   0.10  0.03  0.0    0.91  11.86
  9  12.81    50.00   18.47   0.0   11.73   0.06   0.82   0.0   3.40   2.23   0.10  0.04  0.0    0.91  12.24
 10  21.66    57.90   18.92   0.0   14.19   0.06   0.82   0.02  4.84   2.44   0.10  0.04  0.0    0.91  15.56
 11  26.07    66.39   19.41   0.0   16.66   0.06   0.82   0.05  6.11   2.65   0.10  0.04  0.0    0.91  19.58
 12  28.19    74.06   22.37   0.0   18.18   0.06   0.82   0.05  7.24   3.39   0.10  0.06  0.0    0.91  20.87
 13  31.64    82.37   25.61   0.0   19.10   0.06   0.82   0.05  9.28   4.47   0.10  0.09  0.0    0.91  21.88
 14  38.15   106.10   42.43   0.0   19.88   0.06   0.82   0.05 11.83   5.38   0.10  0.11  0.0    0.91  24.53
 15  41.181  125.96   57.88   0.0   19.88   0.06   0.82   0.05 12.97   5.39   0.10  0.15  0.0    0.91  27.76
 16  41.182  138.11   60.75   0.0   19.88   0.06   0.82   0.05 13.62   5.38   0.10  0.31  0.0    0.91  36.22
 17  41.183  148.27   63.12   0.0   19.88   0.06   0.82   0.05 13.62   5.38   0.10  0.46  0.0    0.91  43.87
 18  41.184  152.99   63.42   0.0   19.88   0.06   0.82   0.05 13.62   5.38   0.10  0.58  0.0    0.91  48.17
 19  41.185  156.45   63.62   0.0   19.88   0.06   0.82   0.18 13.62   5.38   0.10  0.66  0.0    0.91  51.21
 20  41.186  156.90   63.62   0.0   19.88   0.06   0.82   0.62 13.62   5.38   0.10  0.66  0.0    0.91  51.21
 21  41.187  157.28   63.62   0.0   19.88   0.06   0.82   1.01 13.62   5.38   0.10  0.66  0.0    0.91  51.21
 22  41.188  157.58   63.62   0.0   19.88   0.06   0.82   1.31 13.62   5.38   0.10  0.66  0.0    0.91  51.21
 23  41.189  158.06   63.62   0.0   19.88   0.06   0.82   1.79 13.62   5.38   0.10  0.66  0.0    0.91  51.21
 24  41.180  158.73   63.62   0.0   19.88   0.06   0.82   2.46 13.62   5.38   0.10  0.66  0.0    0.91  51.21
 25  41.181  159.01   63.62   0.0   19.88   0.06   0.82   2.74 13.62   5.38   0.10  0.66  0.0    0.91  51.21
 26  41.182  159.011  63.62   0.0   19.88   0.06   0.82   2.74 13.62   5.38   0.10  0.66  0.0    0.91  51.21
 27  41.183  159.48   63.62   0.0   19.88   0.06   0.82   3.21 13.62   5.38   0.10  0.66  0.0    0.91  51.21
 28  41.184  162.51   63.62   0.0   19.88   0.06   0.82   6.24 13.62   5.38   0.10  0.66  0.0    0.91  51.21

------PREDATORS------)
INCH  ESOX   GAR    WALL   TBASS  CRAPPIE  BOWF   FCAT   OCAT   WBASS  STBASS  SKIPJ  BBASS  AP/P RATIO  C-RATIO
  2   0.0    0.0    0.0    0.0     0.0     0.0    0.0    0.0    0.0    0.0     0.0    0.00  390.64      0.02
  3   0.0    0.0    0.0    0.02    0.0     0.0    0.0    0.0    0.02   0.0     0.0    0.08   18.72      0.04
  4   0.0    0.0    0.0    0.06    0.0     0.0    0.0    0.0    0.06   0.0     0.0    0.28   17.93      0.15
  5   0.0    0.0    0.0    0.06    0.0     0.0    0.0    0.0    0.06   0.0     0.0    0.78   17.11      0.35
  6   0.0    0.0    0.0    0.06    0.28    0.0    0.0    0.0    0.06   0.0     0.0    0.82   21.32      0.61
  7   0.0    0.91   0.0    0.06    4.37    0.0    0.0    0.0    0.06   0.0     0.0    0.82    6.07      0.94
  8   0.0    1.03   0.0    0.06    7.29    0.0    0.0    0.0    0.06   0.0     0.0    0.82    4.84      1.27
  9   0.0    1.03   0.0    0.06   10.53    0.0    0.0    0.0    0.06   0.0     0.0    1.18    3.90      1.56
 10   0.0    1.03   0.0    0.06   12.95    0.0    0.0    6.43   0.06   0.0     0.0    1.18    2.67      2.04
 11   0.0    1.03   0.0    0.06   13.33    0.0    0.0   10.47   0.06   0.0     0.0    1.18    2.55      3.40
 12   0.0    1.03   0.0    0.06   13.33    0.0    0.0   12.58   0.06   0.0     0.0    1.18    2.63      4.90
 13   0.0    1.03   0.0    0.06   13.33    0.0    0.19  15.85   0.06   0.0     0.0    1.18    2.60      6.34
 14   0.0    1.03   0.0    0.06   13.33    0.0    0.79  20.65   0.06   0.0     0.0    2.29    2.78     11.12
 15   0.0    1.03   0.0    0.06   13.33    0.0    0.79  23.63   0.06   0.0     0.0    2.29    3.06     41.53
 OK.GRAND.SCOUT.82

STOP         0
*END
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*IN PROCRESS
MAIN   = 011109
015AB8 BYTES USED
EXECUTION BEGINS
PRINT HEADING?   INC RECAPTURE ADJ?   INC COVE-OPEN WATER ADJ?
?
0 1 1
OK:CRAND.B2                 -------- PREY---------}

INCH   SPRED   SPREY  CSHAD+   TSHAD   SUNF    WBASS   BBASS   CARP    CATF    CRAPP   M+S    CATD    Y PER   DART   DRUM
  2     0.00    4.52    0.00   0.0      4.45   0.0     0.00    0.0     0.04    0.00    0.02   0.0     0.0     0.01    0.00
  3     0.10    9.97    0.00   0.0      9.68   0.0     0.00    0.0     0.14    0.06    0.05   0.0     0.0     0.03    0.01
  4     0.59   15.61    2.04   0.0     11.72   0.00    0.06    0.0     0.95    0.16    0.06   0.00    0.0     0.53    0.26
  5     1.46   25.06    6.00   0.0     15.25   0.01    0.21    0.0     1.23    0.77    0.06   0.00    0.0     0.78    0.74
  6     4.64   35.08    9.91   0.0     18.91   0.03    0.49    0.0     1.26    1.48    0.06   0.00    0.0     0.78    3.27
  7    23.23   49.39   11.17   0.0     26.00   0.06    0.98    0.0     1.32    1.95    0.06   0.00    0.0     0.78    7.09
  8    37.15   63.81   12.13   0.0     36.77   0.07    1.42    0.0     1.76    2.19    0.06   0.01    0.0     0.79    9.64
  9    46.94   77.15   12.55   0.0     47.31   0.07    1.75    0.0     2.86    2.47    0.06   0.01    0.0     0.79    9.27
 10    58.09   94.77   15.30   0.0     54.51   0.09    1.32    0.01    3.90    3.82    0.06   0.01    0.0     0.79   14.48
 11    58.14  113.93   19.61   0.0     61.67   0.09    1.82    0.02    4.90    5.18    0.06   0.01    0.0     0.79   20.79
 12    74.29  142.40   29.81   0.0     68.21   0.09    1.82    0.03    5.76   10.53    0.06   0.02    0.0     0.78   25.29
 13    80.79  174.93   41.39   0.0     74.34   0.09    1.82    0.06    7.73   18.43    0.06   0.03    0.0     0.78   29.69
 14    96.75  240.93   84.69   0.0     79.63   0.09    1.82    0.06   10.37   25.06    0.06   0.04    0.0     0.79   38.39
 15    93.54  292.32  123.97   0.0     80.63   0.09    1.82    0.06   11.34   25.06    0.06   0.05    0.0     0.79   48.46
 16    93.85  323.17  131.19   0.0     91.63   0.09    1.82    0.06   11.92   25.06    0.06   0.10    0.0     0.78   70.45
 17   101.67  349.95  137.24   0.0     91.94   0.09    1.82    0.06   11.92   25.06    0.06   0.17    0.0     0.79   90.72
 18   109.49  364.34  138.48   0.0     91.99   0.09    1.82    0.05   11.92   25.06    0.06   0.27    0.0     0.78  103.82
 19   109.97  374.76  139.39   0.0     92.01   0.09    1.92    0.21   11.92   25.06    0.06   0.34    0.0     0.78  113.09
 20   109.97  375.41  139.50   0.0     92.01   0.09    1.92    0.75   11.92   25.06    0.06   0.34    0.0     0.78  113.09
 21   112.10  375.97  139.57   0.0     92.01   0.09    1.82    1.25   11.92   25.06    0.06   0.34    0.0     0.79  113.09
 22   113.73  376.39  139.57   0.0     92.01   0.09    1.92    1.67   11.92   25.06    0.06   0.34    0.0     0.79  113.09
 23   114.76  376.72  139.57   0.0     92.01   0.09    1.92    1.99   11.92   25.06    0.06   0.34    0.0     0.79  113.09
 24   115.63  376.94  139.57   0.0     92.01   0.09    1.82    2.21   11.92   25.06    0.06   0.34    0.0     0.79  113.09
 25   115.63  377.03  139.57   0.0     92.01   0.09    1.82    2.31   11.92   25.06    0.06   0.34    0.0     0.79  113.09
 26   115.63  377.03  139.57   0.0     92.01   0.09    1.92    2.31   11.92   25.06    0.06   0.34    0.0     0.78  113.09
 27   115.63  377.19  139.57   0.0     92.01   0.09    1.82    2.45   11.92   25.06    0.06   0.34    0.0     0.78  113.09
 28   115.63  379.47  139.57   0.0     92.01   0.09    1.92    3.75   11.92   25.06    0.06   0.34    0.0     0.79  113.09

-------PREDATORS-------}
INCH   ESOX     GAR     WALL    TBASS   CRAPPIE  BOWF    FCAT    OCAT    WBASS  STBASS   SKIPJ   BBASS  AP/P RATIO  C-RATIO
  2    0.0      0.0     0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.00 5427.37     0.04
  3    0.0      0.0     0.0     0.01     0.0     0.0     0.0     0.0     0.01    0.0     0.0     0.00   92.90     0.08
  4    0.0      0.01    0.0     0.07     0.0     0.0     0.0     0.0     0.07    0.0     0.0     0.50   26.65     0.14
  5    0.0      0.06    0.0     0.09     0.0     0.0     0.0     0.0     0.09    0.0     0.0     1.31   17.18     0.22
  6    0.0      0.06    0.0     0.09     2.53    0.0     0.0     0.0     0.09    0.0     0.0     1.96    7.56     0.31
  7    0.0      0.50    0.0     0.09    19.79    0.0     0.0     0.0     0.09    0.0     0.0     2.85    2.13     0.45
  8    0.0      0.54    0.0     0.09    32.89    0.0     0.0     0.0     0.09    0.0     0.0     3.64    1.72     0.69
  9    0.0      0.54    0.0     0.09    40.75    0.0     0.0     0.0     0.09    0.0     0.0     5.55    1.64     0.98
 10    0.0      1.03    0.0     0.09    43.40    0.0     0.0     6.44    0.09    0.0     0.0     7.13    1.63     1.29
 11    0.0      1.56    0.0     0.09    44.84    0.0     0.0    13.16    0.09    0.0     0.0     9.50    1.67     1.93
 12    0.0      1.56    0.0     0.09    44.84    0.0     0.0    17.30    0.09    0.0     0.0     9.50    1.92     3.00
 13    0.0      1.56    0.0     0.09    44.84    0.0     0.30   23.01    0.09    0.0     0.0    10.99    2.16     4.23
 14    0.0      1.56    0.0     0.09    44.84    0.0     1.25   26.41    0.09    0.0     0.0    12.59    2.78     6.91
 15    0.0      1.56    0.0     0.09    44.81    0.0     1.26   30.23    0.09    0.0     0.0    15.56    3.13    10.12
 16    0.0      1.56    0.0     0.09    44.81    0.0     1.26   33.91    0.09    0.0     0.0    17.29    3.27    14.53
 17    0.0      1.56    0.0     0.09    44.84    0.0     2.10   33.91    0.09    0.0     0.0    19.29    3.44    20.85
 18    0.0      1.56    0.0     0.09    44.81    0.0     2.10   38.17    0.09    0.0     0.0    21.73    3.36    26.11
 19    0.0      1.56    0.0     0.09    44.84    0.0     2.10   38.17    0.09    0.0     0.0    23.22    3.41    52.50
 20    0.0      1.56    0.0     0.09    44.81    0.0     2.10   38.17    0.09    0.0     0.0    23.22    3.41    66.38
 21    0.0      1.56    0.0     0.09    44.84    0.0     4.22   38.17    0.09    0.0     0.0    23.22    3.35    66.49
 22    0.0      1.56    0.0     0.09    44.84    0.0     5.86   38.17    0.09    0.0     0.0    23.22    3.31   106.52
 23    0.0      1.56    0.0     0.09    44.84    0.0     6.88   38.17    0.09    0.0     0.0    23.22    3.29   198.72
 24    0.0      1.56    0.0     0.09    44.84    0.0     7.75   38.17    0.09    0.0     0.0    23.22    3.26   432.24
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U. S. FISH AND WILDLIFE SERVICE
NATIONAL RESERVOIR RESEARCH PROGRAM

BIOMASS OF FISH SUPPORTED BY SIX MAJOR FOODS (PLOSKEY AND JENKINS 1982) BIOMASS (LBS. PER AC.) IS ADJUSTED FOR NONRECOVERY OF FISH IN ROTENONE SAMPLES USING THE CORRECTIONS OF GRINSTEAD ET AL. (1978). DIFFERENCES IN THE COVE-OPEN WATER DISTRIBUTIONS OF FISH WERE ADJUSTED BY THE DOUGLAS LAKE CORRECTIONS (JENKINS AND MORAIS 1976), AS DERIVED FROM HAYNE ET AL.(1968). THE MODEL PRINTS THE FOLLOWING OUTPUT:

A) COL. 1-- THE BIOMASS OF YOUNG-OF-THE-YEAR FISH (YOY), FISH) YOY, AND THE TOTAL BIOMASS OF EACH TAXON.
B) COLS. 2-7 -- THE BIOMASS OF YOY FISH, FISH) YOY, AND THE TOTAL BIOMASS OF EACH TAXON, AS SUPPORTED BY PLANTS, DETRITUS, BENTHOS, ZOOPLANKTON, FISH (PISCIVORES), AND TERRESTRIAL INVERTEBRATES.
C) THE BIOMASS OF ALL YOY FISH, ALL FISH) YOY, AND THE GRAND TOTAL, AS SUPPORTED BY ALL FOODS OR BY EACH OF THE SIX FOODS. ALTERNATIVELY, THESE TOTALS MAY BE VIEWED AS FUNCTIONAL GROUPS OF FISH BIOMASS, DEFINED ACCORDING TO THE AVERAGE ANNUAL DIET OF THE FISH COMMUNITY.
YOY% REFERS TO THE PERCENT COMPOSITION OF YOY BIOMASS IN THE TOTAL. FOR EXAMPLE, YOY% AT THE BOTTOM OF COL. 5 REFERS TO THE PERCENT OF YOY BIOMASS IN THE TOTAL BIOMASS OF ZOOPLANKTIVORES. COMP % REFERS TO THE PERCENT OF THE TOTAL BIOMASS SUPPORTED BY EACH OF THE SIX FOODS.

ESTIMATES OF PRODUCTION AND CONSUMPTION OF FUNCTIONAL GROUPS OF FISH ARE MADE USING AUGUST CROP DATA AND A NEW UNPUBLISHED MODEL DEVELOPED AT NRRP. ANNUAL PRODUCTION BY FUNCTIONAL GROUPS OF FISH WAS ESTIMATED BY MULTIPLYING THE MEAN BIOMASS OF A FUNCTIONAL GROUP DURING THE GROWING SEASON BY A DAILY TURNOVER RATIO (P/B RATIO) AND BY THE NUMBER OF DAYS IN THE GROWING SEASON (FROST-FREE DAYS). MEAN BIOMASS DURING THE GROWING SEASON WAS CALCULATED USING REGRESSION EQUATIONS THAT RELATE MEAN BIOMASS TO AUGUST BIOMASS. DAILY TURNOVER RATES WERE ASSUMED TO BE 0.0233 FOR YOY FISH AND 0.004186 FOR FISH) AGE 0. THESE RATES CORRESPOND TO ANNUAL P/B RATIOS OF 5.0 AND 0.9, RESPECTIVELY, FOR FISH IN A RESERVOIR WITH A GROWING SEASON OF 215 DAYS.

ANNUAL CONSUMPTION BY FUNCTIONAL GROUPS OF FISH WAS ESTIMATED BY MULTIPLYING ANNUAL PRODUCTION ESTIMATES BY COEFFICIENTS OF FOOD CONVERSION (CONSUMPTION/ PRODUCTION) FOR YOY AND OLDER FISH. COEFFICIENTS WERE WEIGHTED TO ACCOUNT FOR DIFFERENCES IN THE CALORIC CONTENTS OF THE SIX MAJOR FOODS CONSUMED. AS A RESULT, FISH EATING PLANTS AND DETRITUS ARE LESS EFFICIENT THAN PISCIVORES. YOUNG-OF-YEAR FISH ARE ASSUMED TO BE ABOUT 1.5 TIMES MORE EFFICIENT THAN OLDER FISH IN CONVERTING FOODS TO FLESH. ANNUAL MAINTENANCE RATIONS ARE CALCULATED AS 1 % OF THE MEAN BIOMASS OF FISH IN EACH FUNCTIONAL GROUP AND ARE INCLUDED IN THE ESTIMATES OF ANNUAL CONSUMPTION.

PRIMARY PRODUCTION REQUIRED WAS CALCULATED FROM A REGRESSION EQUATION THAT RELATES PRIMARY PRODUCTION AND FISH PRODUCTION. THE EQUATION IS

LOG(PRIMARY PRODUCTION) = 2.4 + 0.68* LOG(FISH PRODUCTION),

WHERE UNITS ARE EXPRESSED IN MG CARBON/M**2/DAY, R**2 = .59 , AND N = 14. MEAN MONTHLY BIOMASS OF BENTHOS WAS CALCULATED BY DIVIDING ANNUAL CONSUMPTION OF BENTHOS BY 10.0 (AN AVERAGE P/B RATIO FOR MULTIVOLTINE BENTHOS). DRY WEIGHT OF BENTHOS IS ASSUMED TO BE 15 % OF ITS WET WEIGHT. MEAN MONTHLY BIOMASS OF ZOOPLANKTON IS CALCULATED BY DIVIDING ANNUAL CONSUMPTION OF ZOOPLANKTON BY 30 (AN AVERAGE P/B RATIO FOR CRUSTACEAN ZOOPLANKTERS). DRY WEIGHT IS ASSUMED TO BE 10 % OF WET WEIGHT. THE MEAN BIOMASS OF PREY FISH REQUIRED IS CALCULATED BY DIVIDING THE THE ESTIMATES OF ANNUAL CONSUMPTION OF FISH BIOMASS BY THE P/B RATIOS FOR YOY AND OLDER PISCIVORES.

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) YOY         41.447      0.0        0.0       11.191       0.0         29.428     0.829
TOTAL         43.267      0.0        0.0       11.755       0.819       29.846     0.847

  YOY          2.708      0.068      0.0        0.731       1.679        0.162     0.068   26 CRAPPIES
) YOY        125.832      0.455      3.320     43.693      19.406       57.700     1.258
TOTAL        128.540      0.523      3.320     44.424      21.085       57.863     1.326

  YOY          8.589      0.0        0.258      5.926       2.405        0.0       0.0     28 FRESHWATER DRUM
) YOY        157.132      1.571      9.428    108.421       6.285       31.426     0.0
TOTAL        165.721      1.571      9.686    114.347       8.690       31.426     0.0

  YOY          0.0        0.0        0.0        0.0         0.0          0.0       0.0     30 DARTERS & LOG PERCH
) YOY          0.250      0.003      0.005      0.230       0.012        0.0       0.0
TOTAL          0.250      0.003      0.005      0.230       0.012        0.0       0.0

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TOTAL YOY     59.536      4.810      8.690     23.241      20.568        1.409     0.818 FUNCTIONAL GROUPS
TOTAL )YOY  1148.241    120.515    249.478    412.251     169.774      181.875    14.347
TOTAL CROP  1207.777    125.325    258.168    435.492     190.342      183.284    15.165
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YOY  %         4.929      3.838      3.366      5.337      10.806        0.769     5.394
COMP %       100.000     10.377     21.375     36.057      15.760       15.175     1.256
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ANNUAL PRODUCTION OF FUNCTIONAL GROUPS OF FISHES
SPECIES      TOTAL CROP  PLANT      DETRITUS    BENTHOS     ZOOPLANKTON     FISH   TERRES. INVERT.
TOTAL YOY    141.187      9.649     15.732     64.819      44.282        4.342     2.361 FUNCTIONAL GROUPS
TOTAL )YOY   872.659    114.415    296.063    264.547     105.961       84.736     6.937
TOTAL CROP  1013.846    124.065    311.796    329.366     150.243       89.078     9.298

ANNUAL CONSUMPTION BY FUNCTIONAL GROUPS (LBS/AC)
TOTAL YOY    507.757     48.528     77.547    222.277     138.567       13.284     7.555 FUNCTIONAL GROUPS
TOTAL )YOY  6952.367   1076.525   2750.108   1848.898     689.692      541.371    45.775
TOTAL CROP  7460.121   1125.053   2827.656   2071.175     828.259      554.655    53.330

PHYTOPLANKTON PRODUCTION =  3086.123 MG CARBON/M**2/DAY    640.086 G C/M**2/YR

MEAN ANNUAL RATE = 4.1-180 G C/M**2/YR (OLIGOTROPHIC),
                    104-310 (MESOTROPHIC), AND
                    300-640 (EUTROPHIC)

MEAN MONTHLY BIOMASS OF BENTHOS REQUIRED=     3.482 G/M**2 DRY WT.  OR  LBS/ACRE WET WEIGHT   460.261

RANGE OF MEAN DRY WEIGHT = 0.12-2.3 G/M**2 IN 12 RESERVOIRS. (PLOSKEY AND JENKINS, 1982.)

MEAN MONTHLY BIOMASS OF ZOOPLANKTON REQUIRED =    69.636 MG/M**3 DRY WT.

  MEAN DRY WT. OF ZOOPLANKTON IN DEGRAY LAKE, AR. RANGED FROM 15 TO 24 MG/M**3 (12 MONTH MEAN) IN 1976, 1977, AND 1978.
THE HIGHEST VALUES OCCURRED IN SPRING (UP TO 71 MG**3).
THE LOWEST OCCURRED IN LATE SUMMER (AS LOW AS .68 MG/M**3).

 BIOMASS OF PREY FISH REQUIRED=  603.577 LBS/ACRE


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  YOY         2.214      0.055      0.0        0.598      1.373      0.133      0.055   26 CRAPPIES
) YOY        25.395      0.063      0.699      8.761      3.489     12.130      0.254
TOTAL        27.609      0.119      0.699      9.359      4.861     12.263      0.309

  YOY        11.588      0.0        0.348      7.996      3.245      0.0        0.0     28 FRESHWATER DRUM
) YOY        40.845      0.408      2.451     28.183      1.634      8.169      0.0
TOTAL        52.432      0.408      2.798     36.178      4.878      8.169      0.0

  YOY         0.008      0.000      0.000      0.007      0.000      0.0        0.0     30 DARTERS & LOG PERCH
) YOY         0.904      0.009      0.018      0.832      0.045      0.0        0.0
TOTAL         0.912      0.009      0.018      0.839      0.046      0.0        0.0

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TOTAL YOY    42.239      3.235      7.188     15.246     15.682      0.498      0.390 FUNCTIONAL GROUPS
TOTAL )YOY  391.964     53.096    103.833    135.438     45.476     52.495      1.627
TOTAL CROP  434.203     56.331    111.020    150.684     61.157     52.993      2.018
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YOY  %        9.728      5.743      6.474     10.118     25.642      0.940     19.343
COMP %      100.000     12.974     25.569     34.704     14.085     12.205      0.465
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ANNUAL PRODUCTION OF FUNCTIONAL GROUPS OF FISHES
SPECIES       TOTAL CROP  PLANT     DETRITUS    BENTHOS    ZOOPLANKTON    FISH   TERRES. INVERT.
TOTAL YOY     98.449      6.490     13.013     42.522     33.762      1.536      1.127 FUNCTIONAL GROUPS
TOTAL )YOY   314.169     50.409    123.221     86.912     28.383     24.457      0.787
TOTAL CROP   412.618     56.899    136.234    129.434     62.145     25.993      1.913

ANNUAL CONSUMPTION BY FUNCTIONAL GROUPS (LBS/AC)
TOTAL YOY    356.547     32.640     64.144    145.814    105.647      4.698      3.604 FUNCTIONAL GROUPS
TOTAL )YOY  2572.494    474.291   1144.593    607.422    184.741    156.256      5.192
TOTAL CROP  2929.041    506.931   1208.736    753.236    290.388    160.954      8.796

PHYTOPLANKTON PRODUCTION =  1799.527 MG CARBON/M**2/DAY    377.901 G C/M**2/YR

MEAN ANNUAL RATE = 4.1-180 G C/M**2/YR (OLIGOTROPHIC),
                   104-310 (MESOTROPHIC), AND
                   300-640 (EUTROPHIC)

MEAN MONTHLY BIOMASS OF BENTHOS REQUIRED=     1.266 G/M**2 DRY WT.  OR  LBS/ACRE WET WEIGHT   167.386

RANGE OF MEAN DRY WEIGHT = 0.12-2.3 G/M**2 IN 12 RESERVOIRS. (PLOSKEY AND JENKINS, 1982.)

MEAN MONTHLY BIOMASS OF ZOOPLANKTON REQUIRED =    24.414 MG/M**3 DRY WT.

  MEAN DRY WT. OF ZOOPLANKTON IN DEGRAY LAKE, AR. RANGED FROM 15 TO 24 MG/M**3 (12 MONTH MEAN) IN 1976, 1977, AND 1978.
THE HIGHEST VALUES OCCURRED IN SPRING (UP TO 71 MG**3).
THE LOWEST OCCURRED IN LATE SUMMER (AS LOW AS .68 MG/M**3).

 BIOMASS OF PREY FISH REQUIRED=   174.383 LBS/ACRE


STANDING CROP OF FISH IN OK.GRAND.WOOD.82                 POUNDS/ACRE
                  1          2          3          4           5           6        7
SPECIES       TOTAL CROP  PLANT     DETRITUS    BENTHOS    ZOOPLANKTON    FISH   TERRES. INVERT.
  YOY         13.776      2.066      4.822      0.413      6.475      0.0        0.0      3 GIZZARD SHAD
) YOY        239.720     62.327    153.421     11.986     11.986      0.0        0.0
TOTAL        253.497     64.394    158.243     12.399     18.461      0.0        0.0
TOTAL            1.168        0.012        0.023        1.075        0.058        0.0          0.0

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TOTAL YOY       75.467        4.357        5.325       42.362       18.922        2.279        2.222  FUNCTIONAL GROUPS
TOTAL )YOY    1439.772      136.343      414.770      457.300      213.571      210.926        6.862
TOTAL CROP    1515.239      140.700      420.094      499.662      232.493      213.205        9.084
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YOY  %           4.981        3.097        1.268        8.478        8.139        1.069       24.458
COMP %         100.000        9.286       27.725       32.976       15.344       14.071        0.599
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ANNUAL PRODUCTION OF FUNCTIONAL GROUPS OF FISHES
SPECIES         TOTAL CROP   PLANT      DETRITUS      BENTHOS     ZOOPLANKTON      FISH    TERRES. INVERT.
TOTAL YOY      190.707        8.741        9.641      118.149       40.738        7.025        6.414  FUNCTIONAL GROUPS
TOTAL )YOY    1150.002      129.442      492.220      293.455      133.296       98.271        3.318
TOTAL CROP    1340.708      138.183      501.860      411.604      174.035      105.296        9.731

ANNUAL CONSUMPTION BY FUNCTIONAL GROUPS (LBS/AC)
TOTAL YOY     1022.665       43.960       47.520      405.153      127.477       21.490       20.519  FUNCTIONAL GROUPS
TOTAL )YOY   11930.871     1217.909     4572.187     2050.935      867.615      627.844       21.893
TOTAL CROP   12953.535     1261.868     4619.707     2456.088      995.092      649.334       42.412

PHYTOPLANKTON PRODUCTION =  3649.474 MG CARBON/M**2/DAY    766.389 G C/M**2/YR

MEAN ANNUAL RATE = 4.1-180 G C/M**2/YR (OLIGOTROPHIC),
                   104-310 (MESOTROPHIC), AND
                   300-640 (EUTROPHIC)

MEAN MONTHLY BIOMASS OF BENTHOS REQUIRED=      4.129 G/M**2 DRY WT.  OR  LBS/ACRE WET WEIGHT   545.797

RANGE OF MEAN DRY WEIGHT = 0.12-2.3 G/M**2 IN 12 RESERVOIRS. (PLOSKEY AND JENKINS, 1982.)

MEAN MONTHLY BIOMASS OF ZOOPLANKTON REQUIRED =     83.662 MG/M**3 DRY WT.

  MEAN DRY WT. OF ZOOPLANKTON IN DEGRAY LAKE, AR. RANGED FROM 15 TO 24 MG/M**3 (12 MONTH MEAN) IN 1976, 1977, AND 1978.
THE HIGHEST VALUES OCCURRED IN SPRING (UP TO 71 MG**3).
THE LOWEST OCCURRED IN LATE SUMMER (AS LOW AS .68 MG/M**3).

 BIOMASS OF PREY FISH REQUIRED=   701.202 LBS/ACRE


STANDING CROP OF FISH IN OK.GRAND.82                       POUNDS/ACRE
                    1          2            3            4            5            6          7
SPECIES         TOTAL CROP   PLANT      DETRITUS      BENTHOS     ZOOPLANKTON      FISH    TERRES. INVERT.
  YOY            0.061        0.0          0.0          0.001        0.0          0.060        0.0        1 GARS
) YOY            1.490        0.0          0.0          0.0          0.0          1.490        0.0
TOTAL            1.550        0.0          0.0          0.001        0.0          1.550        0.0

  YOY           18.881        2.832        6.608        0.566        8.874        0.0          0.0        3 GIZZARD SHAD
) YOY          120.336       31.287       77.015        6.017        6.017        0.0          0.0
TOTAL          139.216       34.119       83.623        6.583       14.891        0.0          0.0

  YOY            0.0          0.0          0.0          0.0          0.0          0.0          0.0        9 CARP & GOLDFISH
) YOY          170.413       35.787       66.461       51.124       15.337        1.704        0.0
TOTAL          170.413       35.787       66.461       51.124       15.337        1.704        0.0

  YOY            0.024        0.002        0.002        0.011        0.008        0.0          0.000     10 MINNOWS
) YOY            0.0          0.0          0.0          0.0          0.0          0.0          0.0
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TOTAL YOY      59.081        4.134        7.068       26.950       18.391          1.395        1.143  FUNCTIONAL GROUPS
TOTAL )YOY    993.315      103.318      256.026      334.990      142.938        148.431        7.612
TOTAL CROP   1052.396      107.452      263.094      361.939      161.329        149.826        8.755
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YOY  %          5.614        3.847        2.686        7.446       11.400          0.931       13.058
COMP %        100.000       10.210       25.000       34.392       15.330         14.237        0.832
=-=-=-=-=-=-

ANNUAL PRODUCTION OF FUNCTIONAL GROUPS OF FISHES
SPECIES      TOTAL CROP   PLANT        DETRITUS     BENTHOS      ZOOPLANKTON        FISH   TERRES. INVERT.
TOTAL YOY     143.448        8.293       12.795       75.163       39.594          4.302        3.300  FUNCTIONAL GROUPS
TOTAL )YOY    778.937       98.089      303.834      214.968       89.212         69.154        3.680
TOTAL CROP    922.385      106.382      316.629      290.131      128.806         73.456        6.981

ANNUAL CONSUMPTION BY FUNCTIONAL GROUPS (LBS/AC)
TOTAL YOY    1532.806       41.708       63.070      257.748      123.896         13.160       10.559  FUNCTIONAL GROUPS
TOTAL )YOY  18225.227      922.910     2822.291     1502.390      580.675        441.820       24.286
TOTAL CROP  19758.031      964.618     2885.361     1760.138      704.572        454.979       34.845

PHYTOPLANKTON PRODUCTION =  2915.931 MG CARBON/M**2/DAY    612.345 G C/M**2/YR

MEAN ANNUAL RATE = 4.1-100 G C/M**2/YR (OLIGOTROPHIC),
                   104-310 (MESOTROPHIC), AND
                   300-640 (EUTROPHIC)

MEAN MONTHLY BIOMASS OF BENTHOS REQUIRED=     2.959 G/M**2 DRY WT.  OR  LBS/ACRE WET WEIGHT   391.142

RANGE OF MEAN DRY WEIGHT = 0.12-2.3 G/M**2 IN 12 RESERVOIRS. (PLOSKEY AND JENKINS, 1982.)

MEAN MONTHLY BIOMASS OF ZOOPLANKTON REQUIRED =    59.237 MG/M**3 DRY WT.

  MEAN DRY WT. OF ZOOPLANKTON IN DEGRAY LAKE, AR. RANGED FROM 15 TO 24 MG/M**3 (12 MONTH MEAN) IN 1976, 1977, AND 1978.
THE HIGHEST VALUES OCCURRED IN SPRING (UP TO 71 MG**3).
THE LOWEST OCCURRED IN LATE SUMMER (AS LOW AS .68 MG/M**3).

 BIOMASS OF PREY FISH REQUIRED=   493.050 LBS/ACRE


STOP         0
*END

*GO
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e3
*CO
e3
*IN PROGRESS
COMPILE =   0.28 SEC



ELECTRO-SHOCKER    SPOTTED GAR              STATION 0  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  334
WT  120

ELECTRO-SHOCKER    GIZZARD SHAD             STATION 0  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  174  234  153  172  169  217  179  175  201  166  176  223  173  293  161  186  200  201  172  180  160  171  120  128  113
WT   43  116   40   43   42   98   56   50   80   49   48  104   52  226   36   54   82   78   46   52   40   44   14   22   12

TL  108  176  139  196  175  166   95  110  130  110  113  125  100  108   96  105   86  122  147  100  109  173  146  101   88
WT   10   56   22   74   58    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL  109  165   94  170  180  116  171   96  172  116  163  113  102  108  172  106  127  120  125  110  166  172  100  101   91
WT    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL  120  127  103  181  119  122  104  113  179  173  185   98  113  111   99  198   91  181  186  111  101  165  164  167  178
WT    0    0    0    0    0    0    0    0    0    0    0    6    0    0    0    0    0    0    0    0    0    0    0    0    0

TL  126  118  120  136  178  170  167  130  118   91  172   93  129   98  165  177  177  140  122  168  180  110  197  106  184
WT    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL  160  197  173  164  115  178  178  135   89  112  170  227  185  175  210   85  105  104  119  118  110  100  103   91  181
WT    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL  100  178  194  110  190  107  112   94   82  101   85  105
WT    0    0    0    0    0    0    0    0    0    0    0    0

ELECTRO-SHOCKER    CARP                     STATION 0  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  450  430  479  562  530  605  415  512  519  523  468  570  543  459  456  443  430  455  505  563  481  448  555  494  480
WT 1135 1063 1544 2270 2134 3495 1135 1061 2043 2179 1453 2270 1907 1317 1453 1000 1010 1453 1600 2724 1507 1271 2043 1498 1634

TL  481  445  494
WT  836 1271 1453

ELECTRO-SHOCKER    FLATHEAD CATFISH         STATION 0  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  362
WT  440

ELECTRO-SHOCKER    WHITE BASS               STATION 0  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  112
WT   16

ELECTRO-SHOCKER    BLUEGILL                 STATION 0  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  136  170  101  100   93  148
WT   44  104   20   18   16   70

ELECTRO-SHOCKER    LARGEMOUTH BASS          STATION 0  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  470
WT 1600
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ELECTRO-SHOCKER    WHITE BASS          STATION 0  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL   90   84  100
WT    6    6    8

ELECTRO-SHOCKER    GREEN SUNFISH       STATION 0  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL   94
WT    8

ELECTRO-SHOCKER    BLUEGILL            STATION 0  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  136   97
WT   50    6

ELECTRO-SHOCKER    LONGEAR SUNFISH     STATION 0  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL   90
WT    6

ELECTRO-SHOCKER    LARGEMOUTH BASS     STATION 0  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  110
WT   12

ELECTRO-SHOCKER    WHITE CRAPPIE       STATION 0  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  151  139
WT   34   24

ELECTRO-SHOCKER    FRESHWATER DRUM     STATION 0  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  274  184  239  284  260  285  265  163  194  244  243  218  120  147  121  200
WT  210   66  160  244  220  270  218   60   80  142  140  124   20   32   18  114

ELECTRO-SHOCKER    GIZZARD SHAD        STATION 0  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  324  294  250  281  297  268  265  212  195  261  280  234  234  246  312  348  240  211  121  103  238  171  200  111  104
WT  340  296  140  206  250  192  172   90   74  160   68  118  118  136  280  396  128   80   18    8  110   42   70    8   10

TL  111  116  111  102  111   80   80  110   82  109   99   86   94  105   93  114  114   99  137  125  276  189  173  189  235
WT   12   12    9    6   10    4    4    0    0    0    0    0    0    0    0    0    0    0    0    0  184   54   44   56  120

TL  275  250  101  108  105   91  134  120  215  104  131   91  226  171  182  211   96  246  237  233  201  191  182  184  161
WT    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL  115  110  186  201  167  176  111   85  109   97   97   99   90   97  107  121  111   86  107   95   90  103  110  121   86
WT    8    8    0   74   54   52    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL  106   95   94  107  107  220  126  130  127  100   89   95   91   99  100  120  101  117  110  100  134  114   94   97   76
WT    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL  171   99  120  111  128  116  100  101  100  103  125  111  130  104   90   91  130  120  108  120  106   84  114  115  117
WT    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL  125  100   95   95  220  116   94  109  120  104  109   95
WT    0    0    0    0    0    0    0    0    0    0    0    0

ELECTRO-SHOCKER    CARP                STATION 0  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  553  514  548  475  475  530  555  460  415  800  461  491  350  521  506  547  626  453  586  491  438  481  505  419  489
WT 2633 1861 2315    0    0    0    0    0    0    0    0    0  544    0    0    0 2724 1271 1952 1861 1180 1816    0  980    0

TL  451  421  398  408  277
WT 1180  930  756  880  260

ELECTRO-SHOCKER    SMALLMOUTH BUFFALO  STATION 0  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  440  342  390  389  418  409  358
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ELECTRO-SHOCKER    LARGEMOUTH BASS       STATION 1  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  105
WT    6

ELECTRO-SHOCKER    WHITE CRAPPIE         STATION 1  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  132  146
WT   22   32

ELECTRO-SHOCKER    FRESHWATER DRUM       STATION 1  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  160  142  170  120  168
WT   48   30   48   16   54

GILLNET            GIZZARD SHAD          STATION 1  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  258  262  245  237
WT  154  176  144  138

GILLNET            CARP                  STATION 1  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  351
WT  556

GILLNET            RIVER CARPSUCKER      STATION 1  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  475  427  407
WT 1317  872  782

GILLNET            SMALLMOUTH BUFFALO    STATION 1  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  387  379  252  366  445  467
WT  896  818  210  658 1407 1453

GILLNET            CHANNEL CATFISH       STATION 1  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  331  282
WT  248  143

GILLNET            WHITE BASS            STATION 1  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  364  400  329  363
WT  712  996  568  822

GILLNET            FRESHWATER DRUM       STATION 1  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  177  156
WT   56   40

ELECTRO-SHOCKER    GIZZARD SHAD          STATION 1  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  171  210  178  205  213  174  206  172  211  161  209  179  171  172  211  202  189  241  167  180  176  170  183  219  210
WT   52   82   60   80   88   50   84   54   90   44   88   52   48   46   86   80   56  124   44    0    0    0    0    0    0

TL  171  176  173  130  180  106  174  118  161  199  131  160  175  120  129  178  212   95  127  200  111  166  119  162  175
WT    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL  183  171  124  164  103  169  178  133  189  136  125  146  165  105  129  183  126  113  178  124  167  170  115   86  155
WT    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL  164  162  114  158  110  111  170  181  121  108  170  175  135  125  148   95  103  182  183  110  116  121  105  174   90
WT    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL  102  100  163  113  111   85  108  122  160  119  174  188  176  148   95   90  162  194  112  116  119  181  103  177  174
WT    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL  114  160  132  108  136  129  174  142  188   96  164  236  207  162  191  156  174  173  231  180  173  208  110  163   97
WT    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL  159  176  175  173  192   98  161  173  110  193  201  173  180  168  220  197  171  128  123
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WT   53

ELECTRO-SHOCKER    GIZZARD SHAD          STATION 1  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  171  185  133  117  168  166  116  126  174  158  177  137  117  140  160   78  123  172  169  170  124  119  154  210  210
WT   50   72   23   20   53   47   22   21   48   39   54   28   18   28   36    2   16   48   50   44   20   18   38   90   96

TL  132  127  187  177  162  193  138  167  206  187  162  173  159  125  127  120  125  119  126  123  140  118  119  120  125
WT   20   20   60   52   38   52   22   38   78   60   34   42   36   20   18   16   20   16   23   18   24   18   16   21   24

TL  123  126  162  128  124  127  141  146  113  160  130  132  125  120  110  120
WT   18   20   38   18   18   20   32   32   12   40   24   24   24   21   18   18

ELECTRO-SHOCKER    CARP                  STATION 1  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  535  510  495  505  540  440  456  622  518  483  485  280  271  451  509  468  470  495  377  355  516
WT 1816 1680 1680 1816 2043  999 1135 2134 1725 1362 1498  260  256 1180 1907 1362  992 1453  662  572 1861

ELECTRO-SHOCKER    RIVER CARPSUCKER      STATION 1  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  317  407
WT    0  792

ELECTRO-SHOCKER    SMALLMOUTH BUFFALO    STATION 1  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  246  410  284  252  215  161  119  134  222  102  136
WT  182  980  334  220  132   53   19   35  158   12   30

ELECTRO-SHOCKER    CHANNEL CATFISH       STATION 1  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  307  335  533  270  423  352  177
WT  200  250 1680  138  565  350   38

ELECTRO-SHOCKER    FLATHEAD CATFISH      STATION 1  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  215
WT   93

ELECTRO-SHOCKER    WHITE BASS            STATION 1  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  348  344  284  201  194  195  212  207  213  216  128  104   95  185  103  123  120  147  164   86  107  103  124  102   99
WT  560  536  314  110   98   98  129  320  124  142   29   14   12   83   10   23   20   37   52    6   17   15   18   16   15

TL  100   94   86  103   83   90  174  106  122   77   78  105   80
WT   12   12   10   14    8   11   63   18   20    6    6   14    4

ELECTRO-SHOCKER    GREEN SUNFISH         STATION 1  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL   65   98  102  100
WT    7   17   16   18

ELECTRO-SHOCKER    WARMOUTH              STATION 1  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  118  117  115   96   88
WT   27   38   34   16   14

ELECTRO-SHOCKER    ORANGESPOTTED SUNFIS  STATION 1  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL   63   62   48
WT    5    4    2

ELECTRO-SHOCKER    BLUEGILL              STATION 1  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  142  110  161  132  126  123  130   99   90  129  105  118  115  148   94  157  108  107  157   85  103  104  114  127  125
WT   58   27   93   53   44   38   50   18   16   39   24   34   28   74   17   92   23   26   92   16   20   20   28   44   48

TL   72   85   89   58
WT    6   11    9    2

ELECTRO-SHOCKER    REDEAR SUNFISH        STATION 1  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  104
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ELECTRO-SHOCKER    SMALLMOUTH BUFFALO     STATION 2  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  265  265  296
WT  248  260  380

ELECTRO-SHOCKER    CHANNEL CATFISH        STATION 2  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  345  410  388
WT  284  480  400

ELECTRO-SHOCKER    WHITE BASS             STATION 2  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  180   80  160  196  165  103   73
WT   82    2   54  110   60   10    6

ELECTRO-SHOCKER    GREEN SUNFISH          STATION 2  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL   58
WT    2

ELECTRO-SHOCKER    WARMOUTH               STATION 2  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  160
WT  100

ELECTRO-SHOCKER    BLUEGILL               STATION 2  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  162  108  132  134  104  106   88   80   98   55   88
WT   88   20   46   44   22   26   10    8   20    2   12

ELECTRO-SHOCKER    LARGEMOUTH BASS        STATION 2  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  365  176  303  130   75
WT  744   70  410   30    5

ELECTRO-SHOCKER    WHITE CRAPPIE          STATION 2  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  310  265  308  350  155  302  228  230  150  222  150  155  270  146  140  210  140  143   75   70  242
WT  450  270  440  618   40  382  160  164   36  152   40   40  332   32   32  110   30   30    3    2  202

GILLNET            LONGNOSE GAR           STATION 2  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL 1190  882 1035 1040  813  897  700  930
WT 5221 1680 2996 3269 1226 1771  999 2270

GILLNET            SHORTNOSE GAR          STATION 2  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  592
WT 1044

GILLNET            GIZZARD SHAD           STATION 2  TRANSECT 1, GRAND LAKE - TAR CREEK STUDY.
TL  261  280  248  259  273  168  166
WT  156  206  136  152  200   44   46

GILLNET            CARP                   STATION 2  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  515  472  460  492  490  463
WT 1680 1226 1135 1407 1453 1135

GILLNET            RIVER CARPSUCKER       STATION 2  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  407
WT  756

GILLNET            BIGMOUTH BUFFALO       STATION 2  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  516
WT 2452

GILLNET            FLATHEAD CATFISH       STATION 2  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  452
WT 1180
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TL  714
WT 1362

GILLNET             GIZZARD SHAD          STATION 2  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  252  353
WT  128  406

GILLNET             CARP                  STATION 2  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  497  478  472  466
WT 1634 1317 1226 1453

GILLNET             RIVER CARPSUCKER      STATION 2  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  387
WT  776

GILLNET             SMALLMOUTH BUFFALO    STATION 2  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  262
WT  238

GILLNET             WHITE BASS            STATION 2  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  375  372  383
WT  858  802  878

GILLNET             WHITE CRAPPIE         STATION 2  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  300
WT  426

GILLNET             FRESHWATER DRUM       STATION 2  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  248  175  107
WT  160   60   16

ELECTRO-SHOCKER     GIZZARD SHAD          STATION 2  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  120  161  180  185  166  215  196  194  170  260  180  178  191  163  116  121  177  125  158  170  163  162  182  114  130
WT   20   42   50   62   43   90   70   70   48  150   52   52   70   46   18   16   52   21   34   48   44   42   56   15   21

TL  118  110
WT   17   10

ELECTRO-SHOCKER     CARP                  STATION 2  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  412  460  450  461  433  372  450
WT  817 1135 1226 1180 1090  620 1090

ELECTRO-SHOCKER     RIVER CARPSUCKER      STATION 2  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  400  395
WT  746  702

ELECTRO-SHOCKER     SMALLMOUTH BUFFALO    STATION 2  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  455  302  276  282  330  308  355  258  267  172  135  262  290
WT 1453  340  262  290  514  400  584  240  250   63   34  238  336

ELECTRO-SHOCKER     CHANNEL CATFISH       STATION 2  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  342  351  380  335  280  340  270  430  256
WT  280  300  414  254  150  296  138  499  123

ELECTRO-SHOCKER     WHITE BASS            STATION 2  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  358  275  272  200  190  257  260  205  282  245  200   68   78  105
WT  672  280  276  110   90  224  218  116  300  200  112    2    3   12

ELECTRO-SHOCKER     GREEN SUNFISH         STATION 2  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL   70   36
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GILLNET             CHANNEL CATFISH       STATION 2  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  447  392
WT  672  428

GILLNET             FLATHEAD CATFISH      STATION 2  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  615
WT 3133

GILLNET             FRESHWATER DRUM       STATION 2  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  270  264  207  176
WT  152  196   86   54

ELECTRO-SHOCKER     GIZZARD SHAD          STATION 3  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  104  110   79   86   77  209  196  217  172  114  105   93  127
WT    6   14    3    5    4   84   80   96   48   14   12    4   16

ELECTRO-SHOCKER     CARP                  STATION 3  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  444  365  501  428
WT 1008  644 1589 1078

ELECTRO-SHOCKER     SMALLMOUTH BUFFALO    STATION 3  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  295
WT  348

ELECTRO-SHOCKER     CHANNEL CATFISH       STATION 3  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  300  236
WT  174   90

ELECTRO-SHOCKER     WHITE BASS            STATION 3  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL   94   90  110  120  100
WT    6    6   14   12    5

ELECTRO-SHOCKER     GREEN SUNFISH         STATION 3  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  101   83   86   71   85
WT   16    8   10    6   12

ELECTRO-SHOCKER     WARMOUTH              STATION 3  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  104  105  116  152  113  112   84   91
WT   20   20   28   72   28   28   10   10

ELECTRO-SHOCKER     BLUEGILL              STATION 3  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  113  133   95  137  122   94  122  114   93  129   90   91  112  117  122   94   91  160  165  149  113  131   90  120  131
WT   30   44   18   48   36   14   36   28   14   34   12   13   26   30   32   16   14   72   84   60   28   42   12   30   42

TL  118  105   83  112   83   96  155   87  104  166  110   92   93   86  105  109   81  141   81  165  141   85  138  113  120
WT   32   28   10   26   10   12   80    8   18   84   24   12   12   10   16   18    6   28    4   74   56    6   46   24   32

TL  109  110  133   76  105  109  108   92   99  155  112  137  108   85   90   93  111  161  107   48  105  110  103   76  110
WT   20   16   40    4   16   22   20   12   14   58   24   48   20    8   10   12   24   76   22    1   20   24   20    8   22

TL   91   95  120  120   84  100   95  110   84   95  103  108
WT   14   16   28   32    8   16   14   24    8    8   20   22

ELECTRO-SHOCKER     LONGEAR SUNFISH       STATION 3  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL   83   89
WT    8   10

ELECTRO-SHOCKER     REDEAR SUNFISH        STATION 3  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  115
WT   26
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TL  242
WT  232

ELECTRO-SHOCKER    KILLIFISHES-TOPMINNO   STATION 3  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL   54
WT    0

ELECTRO-SHOCKER    WHITE BASS             STATION 3  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  122  120
WT   16   16

ELECTRO-SHOCKER    WARMOUTH               STATION 3  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  116
WT   32

ELECTRO-SHOCKER    BLUEGILL               STATION 3  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  161  172   95  121   71   91   90  134   98   87   81  122  150   99   88   74  141  102  110   80  106  111  136  150   44
WT   90   92   10   28    4   10   10   48   12    8    6   30   52   16   10    6   54   16   22    8   18   18   48   60    0

TL   50   76   75   52   38
WT    0    0    0    0    0

ELECTRO-SHOCKER    LARGEMOUTH BASS        STATION 3  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  122   85   80   89
WT   16    5    4    6

ELECTRO-SHOCKER    WHITE CRAPPIE          STATION 3  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  275  231  286  190  155  171  212  236  205  144  197  232  219  263  281  272  271  153  222  228  260  151  135  138  159
WT  304  168  354   80   40   50  132  160  108   34   82  136  110  242  318  282  216   40  132  120  260   34   20   32   44

TL  219   80
WT  124    0

ELECTRO-SHOCKER    FRESHWATER DRUM        STATION 3  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL   96
WT    5

GILLNET            LONGNOSE GAR           STATION 3  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL 1154 1005 1275 1067  930  935  824 1065  975 1132  785  894
WT 6492 3360 7264 4449 2633 2270 1816 3223 3269 4949 1317 2361

GILLNET            GIZZARD SHAD           STATION 3  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  182
WT   50

GILLNET            CARP                   STATION 3  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  564  497
WT 2179 1680

GILLNET            RIVER CARPSUCKER       STATION 3  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  428  416  416  421  425
WT  888  868  836  856  922

GILLNET            SMALLMOUTH BUFFALO     STATION 3  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  541
WT 2315

GILLNET            BIGMOUTH BUFFALO       STATION 3  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  520
WT 2815
WT    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    9    0

ELECTRO-SHOCKER    LARGEMOUTH BASS        STATION 3  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  369  518  436  400  235  361  282  115   93   76
WT  744 2270 1271 1135  170  740  350   12    6    0

ELECTRO-SHOCKER    WHITE CRAPPIE          STATION 3  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  240  261  155  210  165  141  240  128  148  267  155  275  264  291  231  235  161  175  214  171  130  160  165  143  216
WT  210  280   36  120   50   40  206   20   28  256   36  322  296  380  164  174    0    0    0    0    0    0    0    0    0

TL  256  132  125  128  143  144  152  154  133  134   99   90  125  141   76  129
WT    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

GILLNET            LONGNOSE GAR           STATION 3  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL 1325 1265 1165 1175 1255  933 1102  830 1010  998  997 1060  977  930  760  935 1028
WT 8853 6356 5312 5312 7264 2769 4994 1589 2951 2724 2815 3768 2679 2724 1044 2497 3632

GILLNET            SHORTNOSE GAR          STATION 3  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  670  710  705  651
WT 1090 1589 1544 1180

GILLNET            GIZZARD SHAD           STATION 3  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  342  407
WT  406  660

GILLNET            CARP                   STATION 3  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  488  490  457  498  485
WT 1226 1090 1226 1498 1453

GILLNET            RIVER CARPSUCKER       STATION 3  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  466  442  400
WT  990  970  700

GILLNET            SMALLMOUTH BUFFALO     STATION 3  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  432  447  453  465  393  465
WT 1180 1453 1271 1271  842 1680

GILLNET            FLATHEAD CATFISH       STATION 3  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  648  408
WT 3223  680

GILLNET            WHITE CRAPPIE          STATION 3  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  280
WT  360

ELECTRO-SHOCKER    GIZZARD SHAD           STATION 4  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  150  146  131  140  150  139  145  110  126  134  141  140  146  158  176  141  149  136
WT   36   32   20   28   32   28   32   12   18   22   28   28   32   44   46   26   30   20

ELECTRO-SHOCKER    CARP                   STATION 4  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  525  501  469  468  534
WT 2134 1907 1407 1589 2179

ELECTRO-SHOCKER    RIVER CARPSUCKER       STATION 4  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  378  381
WT  638  600

ELECTRO-SHOCKER    SMALLMOUTH BUFFALO     STATION 4  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  209
WT  130
WT    0

ELECTRO-SHOCKER    FRESHWATER DRUM         STATION 4  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  350
WT  404

GILLNET            SPOTTED GAR             STATION 4  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  441  462  451  583  498  452  578  518  541  567  620  698  630  638  760  700
WT  358  370  370  818  580  394  800  622  844  680 1044 1317 1180 1135 2361 1407

GILLNET            GIZZARD SHAD            STATION 4  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  330  237  170  240  231  181  285  177  180  260  172  200  176  172  194  175  186
WT  352  124   40  114  112   48  230   42   52  138   42   70   42   44   62   43   54

GILLNET            RIVER CARPSUCKER        STATION 4  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  370  395
WT  560  700

GILLNET            CHANNEL CATFISH         STATION 4  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  602  312
WT 2633  214

GILLNET            WHITE BASS              STATION 4  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  318
WT  380

GILLNET            FRESHWATER DRUM         STATION 4  TRANSECT 1  GRAND LAKE - TAR CREEK STUDY.
TL  200
WT   73

ELECTRO-SHOCKER    GIZZARD SHAD            STATION 4  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  214  186  139  182  193  229  171  220  115  195  202  210  215  225  195  179  185  144  132  139  126  111  130  111  114
WT  104   60   21   52   60  102   52  104   10   84   88   92  100  110   72   60   58   30   28   22   20   10   20   12   16

TL  114  102  108  121  104   95   89  107  135   91  110  115  111  101  108  103  100  108  117  115   92  114  114  111  112
WT   12    8   10   16    8    0    0    0    0    0    0    8   10    0    0    0    0    0    0    0    0    0    0    0    0

TL   81   90  129  152  117   98  115  121  120  124  112   95  105  108  127  105  100  110  107  110  114  116  117  119  110
WT    0    8    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL  110   80  128  104  119  104  111  120  100  116  108   97   95  122   82  105  102
WT    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

ELECTRO-SHOCKER    WHITE BASS              STATION 4  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  140  102   89  115  130  101  120
WT   24    8    4    0    0    0    0

ELECTRO-SHOCKER    BLUEGILL                STATION 4  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  178  105  131
WT  114   18    0

ELECTRO-SHOCKER    LARGEMOUTH BASS         STATION 4  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL   81   84   89   79   80   95   81   74   71   82
WT    0    0    0    0    0    0    0    0    0    0

GILLNET            SPOTTED GAR             STATION 4  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL  710  725  620  560  468  580  635  418
WT 1816 1907 1180  772  342  808 1044  292

GILLNET            GIZZARD SHAD            STATION 4  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
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TL  110   93
WT    0    0

ELECTRO-SHOCKER    GREEN SUNFISH          STATION 4  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  133
WT    0

ELECTRO-SHOCKER    WARMOUTH               STATION 4  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  113   56
WT    0    0

ELECTRO-SHOCKER    BLUEGILL               STATION 4  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  159  125  154  166  153  112   91  114  116   90   75  121   72  170  154  145  120  104  109   50  114  153   87  121   93
WT   86   34   76   94   56   24    8   20    0    0    0    0    0  100   70   58   34    0    0    0    0    0    0    0    0

TL   95   89  121   52   88  119   98   77   86   91   94   82   55   83   48   44   43   57   86   40  101   65   40   43   56
WT    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL   79
WT    0

ELECTRO-SHOCKER    LARGEMOUTH BASS        STATION 4  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  245  470  365  251  350  295  250  215  261  258  230  271  377  254  241  238  260  275  230  240  231  236   85  124  275
WT  200 1771  770  248  632  302  218  130  248  280  176  244  934  244  176  174  280  320  140  176  160  188    0   20  280

TL  105  171  219  119   98   96   77   74   70  113  150   36  108   80   78   90  115   87  126   93   78   69  103
WT    0   66  124    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

ELECTRO-SHOCKER    WHITE CRAPPIE          STATION 4  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  306  254  315  232  301  271  272  225  159  171  155  137
WT  450  250  518  155  428  340  294  148   50   52   40    0

ELECTRO-SHOCKER    FRESHWATER DRUM        STATION 4  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  155  209  156  145  110
WT   36  104   50   28    0

GILLNET            SPOTTED GAR            STATION 4  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  648  600  667  576  504  580  745  598  750  738  825  440
WT 1188 1044 1362  898  530  870 1907  908 2225 2088 3178  298

GILLNET            SHORTNOSE GAR          STATION 4  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  805
WT 2452

GILLNET            GIZZARD SHAD           STATION 4  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  247  277  251  180  184  272  178  242  176  182  178  226  170
WT  128  170  138   50   50  162   46  120   42   47   44   94   39

GILLNET            SMALLMOUTH BUFFALO     STATION 4  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  420
WT 1271

GILLNET            CHANNEL CATFISH        STATION 4  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  180
WT   43

GILLNET            WHITE BASS             STATION 4  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  366
WT  762
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TL  270  436  355  260
WT  144  680  318  134

ELECTRO-SHOCKER    WHITE BASS              STATION 5  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL    89   95  105   91   81  106  107   99  100  165   90  100  385  312  213  189
WT     4    0    0    0    0   10   12    6    6   60   12    0  720  360  132   88

ELECTRO-SHOCKER    GREEN SUNFISH           STATION 5  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL    96  100  112  106  121  108
WT     0    0   28   20   32   20

ELECTRO-SHOCKER    WARMOUTH                STATION 5  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL    85   90   86   64   48  106  104   91   80   50  170
WT     0    0    0    0    0   20   18   14    8    0  104

ELECTRO-SHOCKER    BLUEGILL                STATION 5  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL    97   83  105  109  120  116  100  101   88   94   79   60  114   94  106   91   93   81  111   73   83   94   73   90   92
WT     8    8    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL   111  122  106   88   91   89   87  103  110   97   65  119  101  125  117  111  124  101  129   93   85   97   82   82   59
WT     0   32    0    0    0    0    0    0    0    0    0   32   18   32   28   22   30   14   34    0    0    0    0    0    0

TL    61   89   93   82  103   84   93   80  100  107  105  110   86   70   52   83   92   87   75   72  111  112  110   96   85
WT     0    0    0    0    0    0    0    4   12   24   24   22    0    0    0    0    0    0    0    0   23   24   24   14    0

TL    83   92   84   84   55  101  104  117  114   96  169  103  148  186  141  170   76  127  129   93  127   88   82   94  131
WT     0    0    0    0    0    0    0   28    0    0   92   18   60  112   56   92    4   40   44    7   36   10    8   10   40

TL   137  101  110   93  119  107  109   96  114  111  110  103  103   97   81   78   90   84  156   79   94   82   53   83   74
WT    60   14   15   12   34   20   21   18   26   24   24   18   18   16    8    4    8    7   68    0    0    0    0    0    0

TL   103   78   85   92  101
WT     0    0    0    0    0

ELECTRO-SHOCKER    LONGEAR SUNFISH         STATION 5  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL    74   76   78   86
WT     0    0    4    8

ELECTRO-SHOCKER    LARGEMOUTH BASS         STATION 5  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL    93  256  151  142  183  111  200  227  243  188  220  280  214  258  260  241  336  458  224  330  315  428  429  234  242
WT     4  244   44   38   76   16  100  150  196   90  140  304  114  252  264  204  580 1453  160  584  460 1180 1180  174  224

TL   234  245  235  358  221  218  242  215  197  310  331  260  245  251  245
WT   164  200  188  750  154  140  170  132  114  480  408  252  210  232  198

ELECTRO-SHOCKER    WHITE CRAPPIE           STATION 5  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL    82  305  254  265  219  231  215  231  261  139  221  119  201  179
WT     0  460  260  284  160  174  142  160  282   30  130   16  120   56

ELECTRO-SHOCKER    BLACK CRAPPIE           STATION 5  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL   200
WT    98

ELECTRO-SHOCKER    LOGPERCH                STATION 5  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL    94
WT     6

ELECTRO-SHOCKER    FRESHWATER DRUM         STATION 5  TRANSECT 2  GRAND LAKE - TAR CREEK STUDY.
TL   115
WT    16
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TL  126   89  112   40
WT   32   10   20    0

ELECTRO-SHOCKER    BLUEGILL                STATION 5  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL   96  119  110   94  165  160  133   85   90   55   48   55  117   75   87   48   75   60   48   60  106  100   89   88   78
WT   14   18   16    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

TL   80  156   76  103   82   86   50   50   50   56
WT    0    0    0    0    0    0    0    0    0    0

ELECTRO-SHOCKER    LARGEMOUTH BASS         STATION 5  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  323  266  255  101  100  371  371  324  254  240  154
WT  470  272  212    0    0  800  872  520  236  184   48

ELECTRO-SHOCKER    WHITE CRAPPIE           STATION 5  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  267  242  289   69  262  252  275  251
WT  280  220  390    0  250  244  296  220

ELECTRO-SHOCKER    FRESHWATER DRUM         STATION 5  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  250  102   98  120  109  117  104  105
WT  160   10   10   16   12   20   12   10

GILLNET            GIZZARD SHAD            STATION 5  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  408  325  260  350  250  330  268  235  350  355  298  292
WT  658  364  130  430  134  394  178  120  438  445  321  202

GILLNET            CARP                    STATION 5  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  530  568  450  522  552
WT 1816 2134 1135 1816 1998

GILLNET            RIVER CARPSUCKER        STATION 5  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  415  407  418  422
WT  856  786  857  860

GILLNET            CHANNEL CATFISH         STATION 5  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  386  410  185
WT  410  512   32

GILLNET            FLATHEAD CATFISH        STATION 5  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  490
WT 1180

GILLNET            WHITE BASS              STATION 5  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  418  251
WT 1044  212

GILLNET            WHITE CRAPPIE           STATION 5  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  173
WT   61

GILLNET            FRESHWATER DRUM         STATION 5  TRANSECT 3  GRAND LAKE - TAR CREEK STUDY.
TL  232  112
WT  140   13

EXEC =    1.75 SEC
*END

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Fishes of the Neosho River System in Oklahoma

Author(s): Branley A. Branson

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Fishes of the Neosho River System in Oklahoma

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ABSTRACT: One hundred and three species of fishes, or 66% of the species known to occur in Oklahoma, are reported from the Neosho River and its tributaries. Notes on the habitat and habits of the various species, and some theoretical considerations as to how certain species may have entered the system by means of stream-capture from the White River System are included.

The Neosho River, known as the Grand downstream from the mouth of the Spring River, rises in the Flint Hills region of Morris Co., near Parkerville, east-central Kansas. From its source, the stream flows in a southeasterly direction for about 478 miles to its confluence with the Arkansas River near Fort Gibson, Oklahoma, 0.9 mi downstream from the mouth of the Verdigris River. The Neosho and its tributaries flow across gently westward-dipping, successively older geological formations (Cretaceous, Permian, Pennsylvanian). The general topography varies from rolling prairies in the extreme upper portion, to rugged and broken terrain in the Flint Hills. The elevation above mean sea level at the headwaters is about 1500 ft (460 m), falling to 477 ft (145 m) in Arkansas. The channel of the main stream is tortuous and well-defined, and its banks are generally stable. The bed is in gravel and boulders, except where excessive siltation has occurred. Many of the smaller streams, once clear, are turbid as a result of strip mining and improper soil-tilling practices. The upland watershed has only a light covering of topsoil, which supports substantial growths of native grasses, elm, cottonwood, willows and sycamores. In the more or less broken terrain of Oklahoma, Missouri, and Arkansas, the soil thickness varies greatly and timber growths, principally oaks, pines, hickories, elms, cottonwoods and willows, are abundant.

The Neosho watershed includes an area of approximately 12,660 square miles, 6,285 of which are in Kansas, 2,965 in Oklahoma, 2,995 in Missouri and 415 in Arkansas. The drainage basin has a width of about 30 miles in its upper reaches, about 70 near its center, and a maximum of about 90 near the Kansas-Oklahoma state line. The watershed is bounded on the north by the Kansas and Osage, on the east by the White and Illinois, and on the west by the Arkansas and Verdigris watersheds.

There are three major tributaries to the Neosho. The Cottonwood River heads in eastern McPherson Co., Kansas, and extends 383 miles to its mouth near Emporia, Kansas. Spring River, the Neosho's largest feeder, arises near Aurora, Lawrence Co., Missouri, and empties into the Pensacola Reservoir about 6 mi N of Wyandotte, Oklahoma. Elk River, locally called Cowskin Creek, is formed by Big Sugar and Little Sugar creeks near Pineville, Missouri, and empties into the Neosho near the Oklahoma-Missouri state line. These three tributaries drain 43% of the entire watershed.

There are few natural lakes or swamps in the watershed, as the water derived from approximately 40 inches of annual rainfall quickly percolates into the very rocky soil. Winters are moderate and the summers long with relatively high temperatures. This and most of the introductory material above was gleaned from U. S. House Document 442 (1948) of the 80th Congress.

The following report is based upon collections made by Dr. Allan D. Linder, now of Idaho State University, Messrs. R. M. Sutton, W. G. Greer, G. H. Wallen, the author, and from collections made over the years by various interested parties from the University of Oklahoma and Oklahoma State University under the direction of Drs. C. D. Riggs and G. A. Moore, respectively. Professor W. C. Gibson made the collections at Northeastern Oklahoma A. and M. College, Miami, Oklahoma, available.

Collecting Localities

A 1. 24:VI:1955; Little Cabin Creek, 3 mi E of Vinita, U. S. 66, Craig Co.
A 2. 24:VI:1955; Horse Creek, 3 mi SE of Afton, Ottawa Co.
A 3. 25:VI:1955; Lost Creek, T 27N, R 24E, S 22, near Wyandotte, Ottawa Co.
A 4. 25:VI:1955; Sycamore Creek, T 27N, R 24E, S 35, Ottawa Co.
A 5. 25:VI:1955; Honey Creek, 3 mi E of State Highway 10, near Grove, Delaware Co.
A 6. 25:VI:1955; Spavinaw Creek, 5.2 mi N of Colcord, Delaware Co.
A 7. 12:VIII:1955; Coal Creek, T 27N, R 22E, S 21, 1 mi W of Narcissa, Ottawa Co.
A 8. 12:VIII:1955; Tar Creek, T 28N, R 22E, S 30, at Miami, Ottawa Co.
A 9. 12:VIII:1955; Elm Creek, T 28N, R 23E, S 28, 1 mi E of Miami, Ottawa Co.
A10. 12:VIII:1955; Birch Creek, T 28N, R 22E, S 15, North Miami, Ottawa Co.
A11. 13:VIII:1955; Neosho River, T 28N, R 21E, S 9, 5 mi W of Commerce, Ottawa Co.
A12. 13:VIII:1955; Lytle Creek, T 29N, R 23E, S 21, 1 mi E of Pitcher, Ottawa Co.
A13. 14:VIII:1955; Warren Branch (trib. Spring River), T 28N, R 24E, S 14 and 15, 9 mi E, 2 mi W of Miami, Ottawa Co.
A14. 2:IX:1955; Lost Creek, T 27N, R 24E, S 28, Ottawa Co.
A15. 2:IX:1955; unnamed spring-fed stream (trib. Neosho River), T 27N, R 24E, S 19, just off State Highway 10, 10 mi NE of Miami, Ottawa Co.
A16. 3:IX:1955; Neosho River, T 29N, R 21E, S 1, Ottawa Co.
A17. 3:IX:1955; Squaw Creek, T 29N, R 21E, S 22, 1 mi W of Solid South, Ottawa Co.
A18. 23:XII:1955; Russel Creek, T 29N, R 20E, S 19 and 24, 1 mi S of Kansas-Oklahoma state line, Craig Co.
A19. 23:XII:1955; Middle Creek, T 27N, R 19E, S 26 and 35, 2 mi W of West Point, Craig Co.
A20. 24:XII:1955; Beer Creek, T 27N, R 20E, S 9 and 16, 2 mi N, 1.5 mi W of Pyramid, Craig Co.
A21. 24:XII:1955; Pecan Creek, T 25N, R 19E, S 22, Craig Co.

A22. 26:XII:1955; Mustang Creek, T 24N, R 21E, S 27 and 28, 1 mi N of Ketchum, Craig Co.
A23. 26:XII:1955; White Oak Creek, T 24N, R 19E, S 1 and 2, 4 mi W of Hulwe, Craig Co.
A24. 26:XII:1955; Rock Creek, T 24N, R 19E, S 21 and 28, 3.5 mi. W of Big Cabin, Craig Co.
A25. 26:XII:1955; Little Cabin Creek, T 28N, R 21N, S 31, at Welch, Craig Co.
B 1. 30:III:1956; Neosho River, low-water dam, Municipal Park, Miami, Ottawa Co.
B 2. 30:III:1956; Elk River (Cowskin Creek), T 25N, R 25E, S 20, Delaware Co.
B 3. 31:III:1956; small unnamed stream, T 24N, R 25E, S 16 and 17, 2 mi S of Dodge, Delaware Co.
B 4. 31:III:1956; Honey Creek, T 24N, R 25E, S 20 and 21, 2.4 mi S of Dodge, Delaware Co.
B 5. 31:III:1956; Snail Creek, T 24N, R 24E, S 21 and 28, 3 mi S, 2 mi E of Grove, Delaware Co.
C 1. 12:V:1956; Spring Creek, below Cedar Crest Lake Club, Mayes Co.
C 2. 12:V:1956; Spring Creek, 3 mi above Cedar Crest Lake Club, Mayes Co.
C 3. 12:V:1956; Little Spring Creek, 0.25 mi below U. S 82 Bridge, Mayes Co.
C 4. 12:V:1956; Saline Creek, U. S. 82 crossing, Mayes Co.
C 5. 12:V:1956; Salt Branch of Saline Creek, Mayes Co.
C 6. 12:V:1956; Little Saline Creek, 8 mi E of Salina, Mayes Co.
C 7. 12:V:1956; Spavinaw Creek, near mouth, Mayes Co.
54. Spavinaw Creek, 7 mi S of Jay, Delaware Co. (Hubbs and Ortenburger, 1929).
55. Elk River, 7 mi N of Grove, Delaware Co. (Hubbs and Ortenburger, 1929).
56. Little Cabin Creek, 3 mi E of Vinita, Craig Co. (Hubbs and Ortenburger, 1929).
57. Pryor Creek, 1 mi NE of Chelsea, Rogers Co. (Hubbs and Ortenburger, 1929).
J 1. 21:IV:1955; Sycamore Creek, 8 mi E of Fairland, U.S. 60, 2 mi N on State 10, Ottawa Co. (N. E. O. A. and M.).
J 2. 2:VIII:1955; Spavinaw Creek, 6 mi S and 2.2 mi E of Jay, Delaware Co. (N. E. O. A. and M.).
J 3. Black Hollow, Lower Spavinaw Lake, Delaware Co. (Jackson, 1954).
J 4. 28:VIII:1954; 5 mi S of Miami, Ottawa Co. (N. E. O. A. and M.).
J 5. Lake Eucha, Delaware Co. (Jackson, 1958).
J 6. Lake Spavinaw, Delaware Co. (Jackson, 1958).
J 7. Grand Lake (Elkin, 1958).
J 8. Grand Lake (Hall, 1951).
J 9. 24:IV:1955; power pool, Grand River Dam, Mayes Co. (N. E. O. A. and M.).
J10. 15:IX:1953; low-water dam, Neosho River, Miami, Ottawa Co. (N. E. O. A. and M.).
J11. 10:III:1954; Tar Creek, 0.5 mi S of Miami, Ottawa Co. (N. E. O. A. and M.).
J12. 23:IV:1955; Neosho River Dam, Mayes Co. (N. E. O. A. and M.).
J13. 18:IV:1955; Pryor Creek, Pryor, Mays Co. N. E. O. A. and M.).

J14. 2:X:1954; Lost Creek, State 10, Ottawa Co. (N. E. O. A. and M.).

J15. 18:IV:1955; Neosho River, S of Pryor, Mayes Co. (N. E. O. A. and M.).

J16. 4:V:1955; Spring River, 5 mi S Miami, Ottawa Co. (N. E. O. A. and M.).

J17. 14:VIII:1955; Warren Branch, near State 10 Bridge, N of Miami, Ottawa Co. (N. E. O. A. and M.).

ANNOTATED LIST

PETROMYZONTIDAE

Ichthyomyzon castaneus Girard. Chestnut Lamprey

LOCALITIES: below Ft. Gibson Dam, Muskogee Co. (Hall and Moore, 1954).

The only known record for this small, parasitic lamprey in the Neosho River System. Scars are observed infrequently on various suckers, catfishes, carp, buffalofish and the freshwater drum by commercial fishermen.

Ichthyomyzon gagei Hubbs and Trautman. Southern Brook Lamprey

LOCALITIES: St. Louis Double Spring (trib. Neosho River), NE Hulbert, Cherokee Co.; Big Spring Creek, 5 mi S of Locust Grove, Mayes Co.; Spavinaw Creek, between Spavinaw and Upper Spavinaw Lakes and in Spavinaw Lake, Delaware Co. (Hall and Moore, 1954); Elk River, Ottawa Co. (Hubbs and Trautman, 1937).

POLYODONTIDAE

Polyodon spathula (Walbaum). Paddlefish

LOCALITIES: confluence of Spring and Neosho rivers, Ottawa Co., and below Lake Spavinaw Dam, Mayes Co. (Riggs and Moore, 1951); numerous large specimens from Grand Lake (Elkin, 1958); mouth of Spring River, Ottawa Co. (Branson, personal observation).

Commercial fishermen often take "spoonbills" from their nets in Grand Lake and sell them with catfishes. They are restricted to the deeper waters and impoundments of the Neosho and its larger tributaries.

AMIIDAE

Amia calva Linnaeus. Bowfin

We have not seen specimens from the upper Neosho Drainage. Although once relatively common in the Ft. Gibson Reservoir and, from the description of natives, probably also in Lake Spavinaw, the species is apparently now common only in southeastern Oklahoma.

LEPISOSTEIDAE

Lepisosteus spatula (Lacépède). Alligator Garfish

LOCALITIES: The only record is taken from a picture printed in the Muskogee *Daily Phoenix,* 28:VI:1956. The fish was captured by a fisherman from Ft. Gibson Reservoir.

Lepisosteus oculatus (Rafinesque). Spotted Garfish

LOCALITIES: J8; 26:IX:1955, North Bay, Ft. Gibson Reservoir, Muskogee Co. (Mr. W. R. Heard). No other extant records in the Neosho. However, sight records are not uncommon, and Branson and Hartmann (1963) reported it from Spring River in Kansas.

Lepisosteus platostomus Rafinesque. Shortnose Garfish
LOCALITIES: J10.

Relatively common in the Neosho in Kansas (Deacon, 1961); many specimens seen in the water at Miami, Ottawa Co., and near the Pensacola Dam in Mayes Co.

Lepisosteus osseus (Linnaeus). Longnose Garfish
LOCALITIES: A1, A2; 55; J10.

Although only a few specimens were found at each of the above stations, it is common in all of the larger streams and impoundments in the Neosho River System.

CLUPEIDAE

Alosa chrysochloris (Rafinesque). Skipjack Herring
LOCALITIES: 26:IX:1955, below Ft. Gibson Dam, Wagoner Co. (W. R. Heard).

According to Mr. Heard the skipjack is relatively common in this area. However, the species apparently subtracted from the fauna northward, as the author has not seen specimens from the Pensacola Reservoir or its tributaries.

Dorosoma cepedianum (LeSueur). Gizzard Shad
LOCALITIES: A1, A8, B1, C1; J3, J15.

Numerous adults were secured at all stations; much more widespread than records indicate, especially in impounded areas.

Dorosoma petenense (Günther). Threadfin Shad
LOCALITIES: J13; sight records Ft. Gibson, Wagoner Co. (W. R. Heard).

Wherever the last two species occur, especially in reservoirs, they produce prodigious numbers of young. An exceedingly important species in the economy of the white bass. In old impoundments shad numbers may be tremendous, hence the importance of maintaining a predator fauna, *i.e.,* garfishes and others, to hold down their numbers (personal observations, made at Lake Texoma, southern Oklahoma).

SALMONIDAE

Salmo gairdneri Richardson. Rainbow Trout
LOCALITIES: Spavinaw Lake, Delaware Co. (Hall, 1956).

This is the only extant record for the Neosho in Oklahoma. However, I captured one specimen from Elm Creek, a tributary to Shoal Creek, near Neosho, Missouri. The latter doubtless escaped from the nearby Neosho trout hatchery. There are no native trouts or chars now living in the system.

HIODONTIDAE

Hiodon alosoides (Rafinesque). Goldeye
LOCALITIES: 3 adults, 26:IX:1955, below the Ft. Gibson Dam, Wagoner Co. (W. R. Heard).

This species should also be present in the Pensacola Reservoir, but no specimens were seen.

CHARARCIDAE

Astyanax fasciatus (Cuvier). Banded Tetra
LOCALITIES: Lake Spavinaw, Delaware Co. (Hall, 1956).

The species was first recorded from Oklahoma in Lake Texoma by Riggs (1954). Both of the above records are considered as "bait-bucket" introductions; neither have apparently been successful in establishing the species.

CATOSTOMIDAE

Cycleptus elongatus (LeSueur). Blue Sucker

LOCALITIES: Carey Bay, Grand Lake, Delaware Co. (Moore and Cross, 1950).

This is the only record in the Neosho River in Oklahoma. It is occasionally taken from deep riffles in Kansas (Deacon, 1961) and is relatively common in Lake Texoma in the Red River Drainage. Very little is known concerning the biology of this species. Most of the summer and fall months are spent in deep water and streams are ascended in mid-February for the purpose of spawning. This very primitive species is adapted for living near the bottom in swift streams.

Ictiobus cyprinellus (Valenciennes). Bigmouth Buffalofish
Ictiobus niger (Rafinesque). Black Buffalofish
Ictiobus bubalus (Rafinesque). Smallmouth Buffalofish

The buffalofishes form a rather difficult taxonomic group. All three species are present in various waters of the Neosho system but there are few published records from the Oklahoma segment of the stream. I have taken *I. bubalus* and *I. niger* at Miami, Oklahoma, and my students collected a few specimens of all three from Spring River in Kansas. Mr. W. R. Heard observed numerous specimens of all three at Duncan Cove, 9:VIII:1955, Ft. Gibson Reservoir, and Hall (1951) from Grand Lake. The largemouth buffalofish prefers quiet backwaters, oxbows and deeper waters, whereas the other two are often taken in midstream. Buffalofishes consistently compose a large percentage of the take by commercial fishermen in Grand Lake (Elkin, 1958).

Carpiodes carpio (Rafinesque). River Carpsucker

LOCALITIES: A11, A16; J7, J11, J10, J2, J8.

Only one or two young adults were taken at each locality except by Elkin (1958), who recorded hundreds of individuals in several year-classes. This species is often confused with the smallmouth buffalofish by commercial fishermen and is sold as that species.

Carpiodes velifer (Rafinesque). Highfin Carpsucker

LOCALITIES: 26:XI:1955, Long Bay, Ft. Gibson Reservoir (W. R. Heard).

Although abundant at this one locality, I have not seen specimens from any of the other reservoirs in this drainage.

Moxostoma carinatum (Cope). River Redhorse

LOCALITIES: J3.

Nearly restricted to the clear tributaries of the Neosho. It was not found by Deacon (1961) in Kansas. This is the largest of Neosho redhorses and is an excellent food fish.

Moxostoma macrolepidotum pisolabrum Trautman and Martin. Pealip Sucker

LOCALITIES: A14; Neosho River, Muskogee Co.; Grand Lake, Delaware Co.; Elk River, near Oklahoma in Arkansas (Trautman and Martin, 1951); J8.

Although there are few published records in Oklahoma, this fish is common in the Neosho River during periods of drought in Kansas (Deacon, 1961). It extends westward to at least Sumner Co., Kansas, and Kay Co., Oklahoma, in the Chikaskia River Drainage. Moore recently took one adult specimen from the Red River near the Lake Texoma Dam, Grayson Co., Texas (Riggs and Moore, 1963).

Moxostoma duquesnei (LeSueur). Black Redhorse

LOCALITIES: 54, 55.

Not common in the Neosho proper, being a fish of the eastern tributaries. It is found in quiet backwater situations of 2-10 feet in depth.

Moxostoma erythrurum (Rafinesque). Golden Redhorse

LOCALITIES: A4, C1; 54, 55; J9, J3.

This common redhorse of the Neosho Drainage in Kansas (Deacon, 1961) and Oklahoma is a fish of running water, often collected from deep pools and riffles.

Minytrema melanops (Rafinesque). Spotted Sucker

LOCALITIES: A2, A23; J3.

Sometimes locally abundant in backwater situations, and considerably more tolerant of suspended silt than most other suckers in the system.

Catostomus commersoni (Lacépède). White Sucker

LOCALITIES: A6, A13, C3; 55.

All of the above specimens were young of the year. An uncommon species in the Neosho Drainage, usually in clear, cool pools.

Hypentelium nigricans (LeSueur). Hog Sucker

LOCALITIES: A3, A4, A5, C1, C2; 55; J2, J10.

Fairly common in the clear eastern tributaries, this species becomes progressively scarcer in the upper Neosho (Deacon, 1961). The young seem to prefer well-vegetated areas. Mating and reproduction occur in late April to mid-May.

CYPRINIDAE

Cyprinus carpio Linnaeus. Common Carp

LOCALITIES: A2, A10, C1; 55, 56; J3; 1 adult, 8:III:1953, Horse Creek, 0.5 mi NW of Afton, Ottawa Co. (N. E. O. A. and M.).

Carassius auratus (Linnaeus). Goldfish

LOCALITIES: 3 half-grown, Duncan Cove, 9:X:1955, Ft. Gibson Reservoir (W. R. Heard); Gravel pits between Salina and Locust Grove, State 82, Mayes Co. (Moore and Cross, 1950); 8:V:1955, small unnamed stream, 9 mi N, 1.25 mi W of Vinita, Craig Co. (N. E. O. A. and M.).

This species has been widely utilized as a bait minnow and may become widespread in the state. The only other sites definitely known in Oklahoma are in Payne and Cimarron counties (Moore and Cross, 1950).

Notemigonus crysoleucas (Mitchill). Golden Shiner

LOCALITIES: A2, A7, A10, A17, A18, A19, A22, A24, B1; 57; J1; 12 adul s Horse Creek, 1.5 mi NE of Afton, Ottawa Co. (N. E. O. A. and M.).

Numerous immature and adult specimens were collected from backwater areas and intermittent pools. Attains sizes up to nearly 12 inches in length.

Semotilus atromaculatus (Mitchill). Creek Chub

LOCALITIES: A3, A4, A5, A6, A13, B2, B5, C2, C6; 54; 55; J14, J17; 1 adult, 26:XI:1955, Long Bay, Ft. Gibson Reservoir, Muskogee Co. (W. R. Heard).

This species occupies the clear to moderately turbid eastern tributaries. We have not taken it from the main body of the Neosho, or its western tributaries. It prefers quiet waters and attains lengths up to a foot.

Chrosomus erythrogaster Rafinesque. Redbellied Dace

LOCALITIES: A3, A4, A5, A6, A13, A14, C1, C3, C7, J2, J17.

Restricted to cold, well-vegetated tributaries where it often becomes very abundant. It has been reported from only a few localities in Oklahoma.

Hybopsis biguttata (Kirtland). Hornyhead Chub

LOCALITIES: A4, A5, A6, A13, B2, B3, C1, C2, C3, C6, C7; 54; 55; J1, J3, J17.

The hornyhead chub is very abundant in most of the eastern clear tributaries but is absent from the main stream.

Hybopsis amblops (Rafinesque). Bigeye Chub

LOCALITIES: 55.

The few specimens reported by Hubbs and Ortenburger (1929) represent the only published record for this form in the Neosho System, although it is fairly common in other parts of the Arkansas Drainage.

Hybopsis x-punctata Hubbs and Crowe. Gravel Chub

LOCALITIES: A11; "Grand River, northeastern Oklahoma," (Hubbs and Crowe, 1956); 3 adults, 9:X:1955, Duncan Cove, Ft. Gibson Reservoir, Muskogee Co. (W. R. Heard).

A single adult specimen was collected at station A11. This is usual when attempting to secure gravel chubs with a seine. It lives in the fastest part of the stream under stones, somewhat like a darter. When collected with rotenone or electrical-shocking equipment numerous individuals are often taken. The species is more common in the Illinois River System.

Phenacobius mirabilis (Girard). Suckermouth Minnow

LOCALITIES: A9, A12, A16.

Although only 11 adults were taken from quiet backwater pools, the suckermouth minnow is widespread in the Neosho Drainage. Deacon (1961) found it common over small gravel and clean sand below riffles in Kansas and I have collected it from similar Shoal Creek situations in Missouri and Kansas.

Notropis percobromus Cope. Plains Shiner

LOCALITIES: A12.

A single small specimen was taken from a riffle habitat. This is the only record of this species in the Neosho. The records (stations 54, 55) of Hubbs and Ortenburger (1929) were based upon *N. rubellus* (Hubbs, 1945). *Notropis percobromus* is a relatively common fish in southern and western parts of the Arkansas System.

Notropis rubellus (Agassiz). Rosyface Shiner

LOCALITIES: A3, A18, A19; 55; J3.

A total of 40 immature, young and adult specimens were taken at the first three stations. The habitat preference seems to be clear to moderately turbid pools rather than rapidly flowing water.

Notropis pilsbryi Fowler. Arkansas Bleeding Shiner

LOCALITIES: A3, A4, A5, A6, A13, A14, B3, B4, B5, C1, C2, C3, C4, C5, C6, C7, C8; 54, 55; J1; numerous localities (Hubbs and Moore, 1940).

This is the most common cyprinid in the eastern tributaries. However, we have not seen it from the main stream. It occupies riffles with swiftly flowing water during the breeding season and is probably the most important forage fish in the upland streams.

Notropis boops Gilbert. Bigeye Shiner

LOCALITIES: A13, C1, C5, C8; 55.

This species, fairly abundant at the above stations, is probably present in all of the clear eastern tributaries.

Notropis whipplei (Girard). Steelcolor Shiner

LOCALITIES: 55.

This is the only record of the steelcolor shiner in the Neosho River in Oklahoma. However, a single specimen was taken from Shoal Creek in Missouri.

Notropis camurus (Jordan and Meek). Bluntface Shiner

LOCALITIES: C1, C7, C8, C5.

Notropis camurus is common in several of the clear tributaries of the Neosho in Kansas, but less so in the southern ones. It is rare in the main stream.

Notropis lutrensis (Baird and Girard). Plains Red Shiner

LOCALITIES: A1, A2, A3, A4, A5, A8, A9, A11, A12, A14, A16, A17, A19, A20, A21, A24, B1, B5, C1, C6; 54, 55, 57; J2, J12.

The red shiner is the dominant minnow in the quiet waters of the main stream and in western tributaries. It is also found in clear eastern streams, but populations there never attain the size of those seen in the western ones. A very important bait minnow, locally called the "redhorse minnow."

Notropis greenei Hubbs and Ortenburger. Wedgespot Shiner

LOCALITIES: C1, C5, C8,; 55 (type locality).

Only a few individuals were found at the first three stations. The author, accompanied by Mr. G. H. Wallen, Oklahoma Fish and Wildlife Service, visited the type locality in 1955 without taking a single specimen. The species is, however, common in the clear tributaries of the Illinois River, notably Big and Little Lee creeks, Adair County. The raising of the water level during the formation of Grand Lake, followed by an extensive drought, may have greatly reduced the species' numbers in the Neosho Drainage. This species also possibly represents a faunal exchange with the Illinois.

Notropis volucellus (Cope). Mimic Shiner
LOCALITIES: 55.

Although Deacon (1961) found this species sparingly in the main stream in Kansas, I have not seen it, either from the river or its tributaries, in Oklahoma. The only published record is that of Hubbs and Ortenburger (1929).

Notropis buchanani Meek. Ghost Shiner
LOCALITIES: A1, A11, A16, B1.

The ghost shiner is abundant in the Neosho and its turbid tributaries, where it occupies habitats at the sides of riffles and in the more sluggishly flowing parts of the streams. I have not seen it from the clear eastern streams.

Notropis stramineus (Cope). Sand Shiner
LOCALITIES: A12, A21, C1; J1.

The sand shiner was not abundant at any of the localities. It frequents sandy-bottomed areas in running water, both in turbid and clear streams.

Hybognathus placita Girard. Plains Minnow
LOCALITIES: B3.

Five adult specimens represent the only known record for this species in the Neosho drainage. This probably represents a relict population of a fish that is common in other parts of the Arkansas System.

Dionda nubila (Forbes). Ozark Minnow
LOCALITIES: A4, A5, B2, C1, C2, C3, C8; 54, 55; J1.

Only five to 12 specimens of *D. nubila* were secured from each of the above stations. However, there is a definite and progressive increase in numbers as one moves from the lowlands toward headwater situations in any Ozarkian stream. In Shoal Creek, *Dionda* sometimes becomes numerous enough to compete with *Notropis pilsbryi* and *Campostoma.*

Pimephales tenellus (Girard). Slim Minnow
LOCALITIES: A19; several localities in the drainage (Hubbs and Black, 1947).

Seldom found in direct stream flow. More often than not, it frequents backwaters in clear streams. The species seems to attain much larger sizes in headwater situations (pools) than in similar areas downstream. The fins have a very definite yellowish coloration in life, which has not been noted in related species.

Pimephales vigilax (Baird and Girard). Bullhead Minnow

LOCALITIES: A1, A2, A11, A12, B2; 55.

Only moderately abundant; 15 to 20 specimens at each station. It prefers sluggishly moving water over a muddy substrate.

Pimephales notatus (Rafinesque). Bluntnose Minnow

LOCALITIES: A1, A2, A19, A21, C1; 55, 56; J2, J3.

The most common *Pimephales* in tributary streams, especially at the base of riffles flowing over gravel, but also taken from riffles and quiet backwater areas in reduced numbers.

Pimephales promelas Rafinesque. Fathead Minnow

LOCALITIES: A9, A21, A24; 3 adults, 8:V:1955, Elm Creek, near Pensacola, Oklahoma State Highway 28, Mayes Co. (N. E. O. A. and M.).

This species doubtless occurs naturally in the Neosho River System, but it is difficult to determine its native range since it is sold by nearly every bait dealer in the entire drainage. It is common practice for fishermen to empty their bait buckets into the nearest stream at the end of a fishing trip. The commonly observed habitat was quiet backwaters in both turbid and clear streams.

Campostoma anomalum (Rafinesque). Stoneroller

LOCALITIES: A2, A3, A4, A5, A6, A13, A14, A21, B3, B4, B5, C1, C3, C4, C7, C8; 54, 55, 57; J1, J17.

The stoneroller is second in abundance only to *Notropis pilsbryi* in the eastern clear tributaries. It is adapted for life in swift riffle situations, but is often found in quiet springs and on wave-swept shores.

Campostoma anomalum X *Chrosomus erythrogaster.*

LOCALITIES: Spring Creek, State 33, at Kansas, Delaware Co., Oklahoma (Hubbs and Bailey, 1952).

This hybrid combination, described as *Oxygeneum pulverulentum* Forbes, is known in Oklahoma only from one location. However, the author secured several specimens from a small spring-fed tributary of Shoal Creek in Jasper Co., Missouri. The two parental species often occupy nearly identical spawning grounds.

ICTALURIDAE

Ictalurus punctatus (Rafinesque). Channel Catfish

LOCALITIES: A8, A11, A16; J3, J5, J6, J7, J8, J9, J11.

Channel catfish numbers were greatly reduced during the recent drought period, the strongest year-class up to 1961 (Deacon) was 1957. However, this species is the most common of the larger catfishes in all of the continuously flowing streams in the Neosho Basin, except in the very turbid ones where it is replaced by the black bullhead. Large adult males, 25 to 30 pounds in weight, are often called "blue cats" by local fishermen, but *I. furcatus* is not known from the upper Arkansas drainage in Oklahoma.

Ictalurus natalis (LeSueur). Yellow Bullhead

LOCALITIES: A18, C7, C8; J2, J3; 1 immature, Little Cabin Creek, Vinita, Craig Co. (N. E. O. A. and M.).

The yellow bullhead, lumped by local fishermen with *I. melas* and *Noturus flavus* as "mud cats," is seldom found in very shallow, turbid pools; it seems to prefer the quieter parts of streams and deep ponds and lakes. The species is never as abundant as the black bullhead. Its maximum weight is about two pounds.

Ictalurus melas (Rafinesque). Black Bullhead

LOCALITIES: A2, A7, A8, A9, A10, A14, A17, A18, A20, A23, A24, B1, B3; J3, J4, J6, J7, J10; 1 adult 28:III:1953, Cow Creek, 5 mi W of Miami, Ottawa Co. (N. E. O. A. and M.); 3 immature, 31:IV:1955, small unnamed stream, 3 mi W of Ketchum, Craig Co. (N. E. O. A. and M.).

The black bullhead is characteristically a fish of mud-bottomed backwaters and ponds. However, it is occasionally secured from clear, running streams. It is one of the most widely distributed fishes in Oklahoma.

Plyodictus olivaris (Rafinesque). Flathead Catfish

LOCALITIES: A11, A16; J3, J5, J6.

The largest food fish in the Neosho Drainage, often attaining weights in excess of 60 pounds, and 80- to 90-pound individuals are sometimes taken. Mating and egg deposition usually take place in recesses under banks or under large rocks. After hatching, the young enter the stream in large numbers where they lead a retiring life under rocks in relatively shallow water. As the fish attains larger size it moves downstream to deeper waters. In 1955, at station A 11, flathead young were extremely numerous on deep riffles. Most of the catfishes caught and sold from the larger impoundments of the Neosho by commercial fishermen are of this species.

Noturus flavus Rafinesque. Stonecat

LOCALITIES: 55.

The record from Elk River is the only published account of this species in the Neosho in Oklahoma. However, Deacon (1961) found it common in Kansas. The paucity of records is doubtless correlated with the inefficiency of a seine in taking such secretive species. The stonecat lives under stones and rocks in riffle areas.

Noturus exilis (Nelson). Slender Madtom

LOCALITIES: A3, A5, A6, B4, C1, C2, C3, C4, C6, C7, C8.

Abundant at all of the clear stations, especially in shallow riffles with abundant vegetation. Madtoms, although not extensively used for this purpose, are excellent bait for smallmouth bass.

ANGUILLIDAE

Anguilla rostrata (LeSueur). American Eel

No specimens of the eel were secured from the Neosho during the study period. However, the author caught a large specimen on a bank-line set in Horse Creek, about 6 mi E of Afton, Ottawa Co., and George Moore (personal communication) took a specimen by hook and line from the Neosho several years ago.

AMBLYOPSIDAE

Typhlichthys subterraneus Girard. Small Blindfish

LOCALITIES: Cave Springs a tributary of Warren's Branch of Spring River, 1 mi S of Peoria, Ottawa Co.

The single specimen reported by Hall (1956) is the only known record for any blind fish in Oklahoma. However, its presence in the very numerous caves of northeastern Oklahoma is expected.

CYPRINODONTIDAE

Fundulus catenatus (Storer). Northern Studfish

LOCALITIES: A4; 7 specimens, Spavinaw Creek, 1.5 mi above State 10, Delaware Co.; 31 specimens, Buffalo Creek, just above mouth of Elk River, Ottawa Co.; 1 specimen, Woodward Hollow, Grand Lake, Delaware Co. (Hall, 1956).

Eleven large adults were taken at station A4. The habits and habitat of this species are unlike those of any other *Fundulus* in Oklahoma. They are found along the edges of shallow to moderately deep riffles over mixtures of gravel and mud where they swim about midway between the bottom and surface. There are no other records of the species in Oklahoma.

Fundulus sciadicus Cope. Plains Topminnow

LOCALITIES: C2, C3, C4; 54.

The first three collections represent the first published records for this species in Oklahoma since 1929. *Fundulus sciadicus* is nowhere common in Oklahoma but is fairly abundant in small spring-fed tributaries of Spring Creek in Missouri. It occupies very clear, heavily vegetated waters with little or no current and is usually found under dead leaves or growing aquatic plants. It appears to enjoy approximately the same habitat conditions as *Etheostoma microperca,* with which it is often found.

Fundulus kansae Garman. Plains Killifish

LOCALITIES: C5; Salt Branch of Saline Creek, 1 mi S of Salina, Mays Co. (Heard, 1958); Grand Lake (Hall, 1951).

This species is common in western and southern parts of the Arkansas System, but the above localities are the only records from the Neosho Drainage and are probably relicts of a once much greater distribution. Saline Creek, and its small tributary, Salt Branch, have retained ecological conditions somewhat similar to those found in southwestern and south-central Oklahoma.

Fundulus notatus (Rafinesque). Blackstripe Topminnow

LOCALITIES: A1, A2, A3, A4, A5, A6, A7, A12, A14, A15, A17, A18, A19, A20, A23, A25, B1, C1, C5, C7, C8; 55, 56, 57; J1, J11, J12, J13, 21:V:1955, Spring River, State 10, N of Miami, Ottawa Co. (N. E. O. A. and M.).

Although widespread in the Neosho System it seldom produces very large populations. The largest number of individuals collected was 22 at station J1. The fish characteristically occupies quiet areas in both turbid and clear backwaters, usually in bisexual pairs.

Fundulus olivaceus (Storer). Blackspotted Topminnow

LOCALITIES: J8.

This is the only record in the Neosho River and its tributaries; it is a species characteristic of the Illinois River System. However, several of the Neosho tributaries head very near to some small streams flowing into the Illinois River in Delaware County. It is likely that, during flood stages, some faunal exchange occurs between the two systems.

POECILIIDAE

Gambusia affinis (Baird and Girard). Gambusia or Mosquitofish

LOCALITIES: A1, A2, A3, A4, A5, A8, A9, A10, A11, A12, A14, A16, A17, A21, A22, A23, A24, A25, B1, B4, B5, C1, C4, C5, C7; J1, J3, J11, J12, J14; Salt Branch of Saline Creek, 1 mi S of Salina, Mayes Co. (Heard, 1958).

Much more abundant in backwaters and along stream margins where the current is reduced in western tributaries than in the clear eastern tributaries. It characteristically swims near the surface in small groups and enjoys the widest distribution of any species in Oklahoma.

ATHERINIDAE

Labidesthes sicculus (Cope). Brook Silversides

LOCALITIES: A1, A2, A3, A7, A13, A14, A17, A19, A24, B5, C1, C5, C7; J1, J2, J3, J10, J14, J15; 54, 55.

The brook silversides occupies much the same habitat as *Fundulus notatus* and *Gambusia,* often being taken with them. It usually does not form large populations in streams, but occasionally becomes abundant in protected lacustrine situations.

SERRANIDAE

Roccus chrysops (Rafinesque). White Bass

LOCALITIES: A11, J3, J6, J7, J9, J10, J13, J16.

Only one or two individuals were taken at each station, since the white bass is primarily a lake fish. This species is often incorrectly referred to as the "striped bass."

CENTRARCHIDAE

Micropterus salmoides (Lacépède). Largemouth Bass

LOCALITIES: A1, A2, A3, A4, A5, A8, A10, A13, A14, A15, A20, B2, B4, B5, C1, C5, C7; 54, 55; J3, J4, J5, J7, J13.

Of the three blackbasses, the largemouth occupies a much wider spectrum of ecological conditions than the other two. It is found in both turbid and clear streams, but prefers quiet waters. Growth is rapid, following spawning, and in some ponds in the area weights of two to two and one-half pounds are attained in two years.

Micropterus dolomieui Lacépède. Smallmouth Bass

LOCALITIES: A4, C2, C3, C7; J1, J5, J14, 54, 55; Elk River, Turkey Ford, Delaware Co., 13:IX:1935 (type locality for *M. dolomieui velox* Hubbs and Bailey); Lost Creek, just N of Wyandotte, Ottawa Co., 13:IX:1935; Grand River, 4 mi E of Choteau, Mayes Co., 12:IX:1935; Spavinaw Creek, just above Spavinaw Lake, Delaware Co., 12:IX:1936; Spring Creek, about 8 mi N of Moody, Cherokee Co., 31:VIII:1936; Saline Creek, Mayes Co.; Spring Creek, Camp Garland, 5 mi S of Locust Grove, Mayes Co.; Spavinaw Creek, 7 mi S of Jay, Delaware Co., 10:VII:1927; Elk River, 7 mi N of Grove; Neosho River, 5 mi SE of Wagoner, Wagoner Co., 12:VII:1929 (Hubbs and Bailey, 1940).

Nearly always found in the clear waters of eastern tributaries. It appears to prefer pools at the base of riffles, or shoals in clear portions of lakes. Spawning occurs when the water temperature reaches 60 F and continues into late July. Nests are constructed of gravel and rocks in sheltered areas; the fry and young, including yearlings, remain in tributaries near the shore. The food consists mostly of small to moderately large fishes, crayfishes, and some insects. Growth is much slower than in either of the other blackbasses.

Micropterus punctulatus (Rafinesque). Spotted Bass

LOCALITIES: A11, B1, B4, C7; 55; J3, J4, J17.

Somewhat similar to the smallmouth in habitat requirements and is often taken with that species, both as adults and as young. In the western clear tributaries of Kansas the spotted bass completely replaces *M. dolomieui.*

Chaenobryttus gulosus (Cuvier). Warmouth

LOCALITIES: A1, A2, A3, A10, A17, A23, A25, B2, C8; J4.

The warmouth, often confused by fishermen with the rockbass, is a species with a distinct preference for mud-bottomed, vegetated backwaters in both clear and turbid streams, ponds and lakes. It is nowhere very abundant, but is a good pan fish, attaining weights of nearly one-half pound.

Lepomis cyanellus Rafinesque. Green Sunfish

LOCALITIES: A1, A2, A3, A4, A7, A8, A9, A10, A11, A12, A13, A14, A15, A16, A17, A18, A19, A20, A22, A23, A24, B1, B2, B3, B5, C1, C2, C3, C4, C5, C7; 54, 55, 56, 57; J2, J3, J6.

The green sunfish is universally distributed in the Arkansas River System but is most abundant in ponds and lakes or in pools of streams. It builds nests in gravel and small rocks near the shore.

Lepomis microlophus (Günter). Redear Sunfish

LOCALITIES: A19; J3, J4; Duncan Cove, 9:X:1955, Ft. Gibson Reservoir Cherokee Co. (W. R. Heard, pers. comm.).

Not native to Oklahoma, but has been widely planted. It is somewhat similar to the bluegill in breeding habits. Its food consists of insects, small fishes, crustaceans, snails and small clams.

Lepomis megalotis (Rafinesque). Longear Sunfish

LOCALITIES: A1, A2, A3, A4, A5, A6, A8, A13, A16, A17, A19, A20, A21, A22, A23, A24, A25, B1, B2, B3, B4, B5, C1, C2, C3, C4, C5, C7; 54, 55; J1, J3, J6.

Nearly as widely distributed as *L. cyanellus.* Its nest is constructed in running water about 12 inches deep.

The longear sunfish of the northeastern part of the Arkansas River

Drainage is a very distinctive form and is doubtless an undescribed race. The very long, broadly spatulated earflap extends well beyond the middle of the spinous dorsal in adult males. The color pattern differs strikingly from that of *L. megalotis* in other systems. During the height of breeding activity a median brick-red stripe extends from the origin of the dorsal fin to about the level of the eyes. The distribution of this form needs to be analyzed and the color pattern adequately described.

Lepomis humilis (Girard). Orangespotted Sunfish

LOCALITIES: A1, A2, A4, A7, A10, A12, A14, A15, A17, A18, A19, A20, A21, A22, A23, A24, B1; 55, 56, 57; Horse Creek, 3 mi E of Afton, 25:I:1955, Ottawa Co. (Branson and Moore, 1962).

The smallest species in the Neosho Drainage, it is distinctly modified for living in turbid streams (Moore, 1956). It is decidedly more abundant in western tributary backwaters over muddy bottoms than in similar situations in clear eastern ones. As in other *Lepomis,* a nest is constructed in rocks and gravel.

Lepomis macrochirus Rafinesque. Bluegill Sunfish

LOCALITIES: A1, A2, A3, A4, A7, A10, A11, A12, A13, A15, A18, A20, A22, A23, A24, B1, B2, B4, B5, C1, C2, C3, C5, C7; 55, 56; J3, J4, J6, J10.

Large populations are not maintained in streams, this fish is predominantly a pond and a lake form.

Lepomis macrochirus X *Lepomis megalotis.*

LOCALITIES: A20.

Lepomis macrochirus X *Lepomis cyanellus*

LOCALITIES: A18.

Lepomis macrochirus X *Lepomis humilis*

LOCALITIES: A1.

It will be noted that all of these hybrids occurred in small turbid and sluggish streams which stand in intermittent pools through most of the year. This means that several kinds of fishes may be trapped together in a nearly homogeneous habitat. Such conditions may trigger natural hybridization in many of the Great Plains streams. The same phenomenon occurs, but on a much larger scale, when several species are placed together in farm ponds. Hybridization in sunfishes needs to be thoroughly investigated in such situations; for it seems that introgression is occurring in some populations, such as those that exist in Kansas and Oklahoma strip-mine pits. Various combinations between the redear, orangespotted and green sunfishs should be attempted in order to ascertain whether certain of the offspring exhibit fertility.

Ambloplites rupestris Rafinesque. Rockbass

LOCALITIES: A3, A4, A6, C2, C3, C4, C6, C7; 55; Spring Creek, 4:V:1957, Mayes Co. (Branson and Moore, 1962).

The rockbass, sometimes confused with the warmouth, is restricted to the eastern clear tributaries. It is a nocturnal form, hiding during the day under overhanging ledges, logs and rocks. It feeds primarily upon crayfish, a few insects and small fishes. During twilight hours *A. rupestris* is the dominant sunfish in Spavinaw Creek.

Pomoxis nigromaculatus LeSueur. Black Crappie

LOCALITIES: A17; J5, J6, J10.

The black crappie is nowhere very abundant in the Neosho drainage, except in isolated situations. It prefers relatively clear ponds and lakes, reproduction usually occurring in saucer-shaped nests or at the base of plants in 2-3 ft of water. The food is mainly insects, crayfishes and small fishes.

Pomoxis annularis Rafinesque. White Crappie

LOCALITIES: A1, A2, A4, A9, A10, A11, A24, B1; 55; J3, J5, J6, J7, J10; Grand Lake (Jenkins, 1953).

The white crappie is somewhat similar to the black in habits but is often found in very turbid situations. When the two occur together, the black crappie does not fare well, doubtless because of a lack of efficiency in habitat utilization in comparison to *P. annularis.*

PERCIDAE

Stizostedion canadense (Smith). Pikeperch or Sauger

LOCALITIES: J4.

This is the only locality known for the sauger in the Neosho River drainage in Oklahoma, but the species is probably native here (Moore, 1954). The specimen is a very large, partially decayed head and anterior trunk collected by Branson and Gibson. The species is not large, rarely attaining four pounds and has a preference for deep water (Harlan and Speaker, 1956). It is occasionally captured by hook and line, local fishermen calling the fish "jack salmon."

Stizostedion vitreum (Mitchill). Walleye Pike

LOCALITIES: Grand Lake (Hall, 1956).

The walleye is not a native species, occupying more northern latitudes. However, the walleye has been widely planted and is being raised and studied, both in Kansas and Oklahoma (Robert Hartmann, Kansas Fish and Wildlife Service, pers. comm.). Occasional specimens are taken up to 25 pounds in weight (Niemuth *et al.,* 1959), but the average adult weight in Kansas is seldom more than 8 to 10 pounds. Like the sauger, this is a species of deep waters except at crepuscular periods, when it comes to shoals and deep riffles for the purpose of feeding.

Percina phoxocephala (Nelson). Slenderhead Darter

LOCALITIES: A11, A14, A16, B1, B2, C1, C5, C7; 3 localities in Ottawa, 2 in Delaware, 1 in Craig, 5 in Mayes and 2 in Wagoner counties (Blair, 1959).

Inhabits deep riffles where the current is sufficiently strong to prevent siltation of the gravel and sand. It is seldom taken from smaller tributaries.

Percina caprodes (Rafinesque). Logperch

LOCALITIES: A1, A2, A3, A4, A14, A16, B2, C1, C5, C7; 55; J3; 4 localities in Ottawa, 3 in Craig, 3 in Delaware, 9 in Mayes and 5 in Wagoner counties (Blair, 1959).

Taken from both deep and shallow riffles in large and small streams, but it seems to prefer water of about two feet in depth.

Percina shumardi (Girard). River Darter

LOCALITIES: B1, B2; 2 localities in Ottawa, 1 in Mayes, 1 in Wagoner and 2 in Delaware counties (Blair, 1959).

Found in riffles three or more feet in depth and consequently not often secured by general collecting. This accounts in part for the paucity of records for the species in Oklahoma.

Percina copelandi (Jordan). Channel Darter

LOCALITIES: B2, C1, C5, C7; 1 locality in Ottawa, 1 in Delaware, 3 in Craig and 4 localities in Mayes counties (Blair, 1959).

Seldom found in swiftly flowing riffles, but at times becomes abundant over sand in sluggish ones. It overwinters in quiet backwaters that are filled with decaying leaves and other organic debris. The leaves possibly afford protection from low winter temperatures and provide cover lacking in the main channel. In early April the darter begins to move back into the channels and is seldom found in backwater situations by late May. It is more common in the smaller tributaries of the Neosho than in the main channel.

Etheostoma stigmaeum (Jordan). Speckled Darter

LOCALITIES: A1, A14, B2, C1, C5; 55; 1 locality each in Ottawa, Delaware, Wagoner and Mayes counties (Blair, 1959).

Nearly always found in rapidly flowing riffles of 1-2 ft in depth over clean sand. During the breeding season it bears several brilliantly iridescent turquoise blotches along the side. In off-breeding season, this species is often confused with *E. nigrum* because of its long slender shape and blunt snout, but it differs from that species in color pattern and in having two anal spines.

Etheostoma chloresomum (Hay). Bluntnose Darter

LOCALITIES: A1, A7, A19, A24; J4; 1 locality in Ottawa, 1 in Wagoner, 2 in Craig and 3 in Mayes counties (Blair, 1959).

Always associated with quiet backwaters or stagnant pools with mud bottoms. When taken from very turbid waters its flesh is nearly transparent.

Etheostoma zonale (Cope). Banded Darter

LOCALITIES: A3, A14, B2, C1, C5, C7, C8; 1 locality in Ottawa, 1 in Delaware, 6 in Mayes and 4 in Wagoner counties (Blair, 1959).

Lives in riffle situations in clear eastern tributaries of the Neosho.

Etheostoma blennioides Rafinesque. Greenside Darter

LOCALITIES: B2, C2, C5, C8; 1 in Ottawa, 2 localities in Delaware, 5 in Mayes and 2 in Wagoner counties (Blair, 1959).

The male greenside darter is a very dark shade of green during the reproductive period and the female is a somewhat lighter shade. Sexual dimorphism is marked even in the off-breeding season. Although occasional specimens are taken elsewhere, *E. blennioides* is collected in abundance only from torrential waters flowing through heavy vegetation.

Etheostoma whipplei (Girard). Redfin Darter

LOCALITIES: A19; 4 localities in lower Neosho Drainage (Hubbs and Black, 1941); 2 localities in Ottawa, 11 in Craig, 12 in Mayes and 9 in Wagoner counties (Blair, 1959); Earbeb, Crutchfield and Spavinaw creeks (Blair and Windle, 1961).

Primarily characteristic of streams tributary to the Arkansas and Verdigris rivers, but it does range into some of the western tributaries of the Neosho and a few eastern ones. It is a riffle fish.

Etheostoma punctulatum (Agassiz). Stipple Darter

LOCALITIES: A3, A4, A5, A6, A13, A14, B4, C1, C2, C3, C4, C5, C6, C7; 55; 5 localities in Ottawa, 4 in Delaware, 7 in Mayes and 5 in Wagoner counties (Blair, 1959); 1 mi E of Turkey Ford, Elk River, Delaware Co. (Moore and Cross, 1950).

This large species is restricted to clear Ozarkian streams where it has a preference for heavily vegetated, shallow riffles and vegetation in quiet side pools and backwaters. It becomes especially abundant in cold, headwater springs.

Etheostoma craigini Gilbert. Arkansas Darter

LOCALITIES: C3; Elk River, 1 mi E of Turkey Ford, Delaware Co.; gravel pit between Salina and Locust Grove; Little Spring Creek, 4 mi S of Locust Grove, Mayes Co. (Moore and Cross, 1950); 1 locality in Ottawa, 1 in Delaware and 4 in Mayes counties (Blair, 1959); 3 specimens, 24:IX:1961, small tributary of Spavinaw Creek, near mouth, Delaware Co.; small tributary to Little Spring Creek, near State 82, S of Locust Grove (Blair and Windle, 1961).

This beautiful little darter is poorly known in Oklahoma. Blair and Windle (1961) listed its only darter associates as *E. microperca* and *E. whipplei.* However, the author has taken it numerous times with *E. spectabile, E. punctulatum* and *Percina copelandi.* We have found it in two kinds of habitats, all in clear, cool water and always over mud bottoms. One of these is in very slowly flowing water with copious watercress and algae. The fish were not particularly abundant in such situations. The second type was areas where dead leaves were abundant with little or no current. At one Shoal Creek locality in Missouri, 12 breeding adults were collected in two hauls with a 6-ft habitat seine. The Oklahoma localities listed above are at the westernmost limits of the species' known distribution in that state. It is much more numerous in Missouri and Arkansas.

Etheostoma spectabile (Agassiz). Orangethroat Darter

LOCALITIES: A2, A3, A4, A5, A6, A13, A14, A19, A21, B2, B3, B4, B5, C1, C2, C3, C4, C5, C6, C7; 55; J1, J2, J10, 9 localities in Ottawa, 14 in Delaware, 8 in Craig, 19 in Mayes and 10 in Wagoner counties (Blair, 1959).

The orangethroat darter is by far the most widespread and variable percid in the Neosho River Basin. It is found in both turbid and clear running water, in riffles and in backwaters. In heavily vegetated, upland, eastern tributaries it is somewhat replaced by the next species.

Etheostoma flabellare Rafinesque. Fantail Darter

LOCALITIES: A4, A5, A6, A13, B2, B3, C2, C3, C4, C6, C7; J2; 1 locality in Craig, 6 in Ottawa, 15 in Delaware, 7 in Mayes and 8 in Wagoner counties (Blair, 1959).

Seldom found in the main river (Deacon, 1961), being primarily a fish of riffles in small clear eastern tributaries. In upland areas large populations are produced.

Etheostoma gracile (Girard). Slough Darter

LOCALITIES: A7, A23; 2 localities in Ottawa, 2 in Craig, 3 in Mayes, 1 in Rogers and 5 in Wagoner counties (Blair, 1959).

This small darter is adapted for turbid and intermittently stagnant streams, and is seldom found elsewhere. Its favorite habitat is in vegetation near the shore over a mud bottom.

Etheostoma microperca Jordan and Gilbert. Least Darter

LOCALITIES: A4, A13, C2, C6; 2 localities in Ottawa, 1 in Delaware, 1 in Wagoner and 4 in Mayes counties (Blair, 1959); "abundant," 25:I: and 14:IV:1961, Little Spring Creek, State 82 Bridge, S of Locust Grove, Mayes Co. (Blair and Windle, 1961).

In the spring and summer, the least darter is always associated with heavily vegetated, spring-fed backwaters, and in the winter with leaf-filled backwaters. Mating and reproduction occur in and on upright vegetation. Sexual dimorphism is marked, the male possessing greatly enlarged pectoral fins.

SCIAENIDAE

Aplodinotus grunniens Rafinesque. Freshwater Drum

LOCALITIES: A2, A16, B1; J3, J6, J7, J9.

The freshwater drum is seldom taken in small tributaries or headwater situations. It is very abundant in the Neosho and Spring rivers, and their impoundments where a large size is attained. Its food consists mainly of crayfish, small clams and snails.

COTTIDAE

Cottus carolinae (Gill). Banded Sculpin

LOCALITIES: A4, A5, A6, A13, B3, C2, C3, C6; 54, 55; J17.

This species is not found in any of the turbid streams, and seldom in the Neosho proper. Its food consists of insects, crayfish and small fishes. Spawning occurs in early to middle May.

OTHER SPECIES EXPECTED

In addition to the 103 species herein listed from the Oklahoma portion of the Neosho River Drainage, several others should be sought. These are briefly discussed below.

Chrosomus eos Cope. Northern Redbellied Dace

Four specimens of this northern species were found on 13 May

1956 in a bait dealer's tanks at Ft. Gibson, Wagoner County, and five on 7:VI:1956 in another dealer's tanks, derived from brooder ponds near Choteau (Heard, 1959). Since many of the clear streams of the Ozarkian region approximate conditions known in the native range of this species it is possible that it could become habituated to Oklahoma waters.

Hybopsis storeriana (Kirtland). Silver Chub

This species is often found in more western stretches of the Arkansas River drainage (Moore and Buck, 1953). Deacon (1961) and Wallen (1958) took one specimen each from the Marais des Cygnes and Verdigris rivers, respectively. Since the Neosho empties into the Arkansas only about one mile downstream from the Verdigris, it is quite likely that this species also occurs in the Neosho.

Notropis chrysocephalus Rafinesque. Arkansas Common Shiner

This is the species until recently called *N. cornutus* in Oklahoma. However, Gilbert (1961) has shown *N. cornutus* to be separable from its western counterpart, *N. chrysocephalus.* The author and his students have collected several specimens from Shoal Creek (Grand Falls, south of Joplin) and Spring River. Since these streams are major tributaries of the Neosho, it may also occasionally be found in the Neosho.

Ictalurus nebulosus (LeSueur). Brown Bullhead Catfish

The only locality known for *I. nebulosus* in Oklahoma is in the Little River System of McCurtain Co. However, the species has been planted in many of the strip-mine pits adjacent to Oklahoma in Kansas and Missouri, and one relatively large specimen was secured from Shoal Creek in Missouri. During flood stage, these pits often discharge waters into nearby Neosho tributaries.

Noturus miurus Jordan. Brindled Madtom

This small catfish doubtless occurs in the waters of the Neosho, since the author took three specimens from Shoal Creek in April of 1962 and numerous ones from Spring River in March of 1964. Wallen (1958) reported seven specimens from a tributary of the Verdigris River. This species lives in quiet waters over a muddy substrate, primarily along the shore line.

Noturus nocturnus Jordan and Gilbert. Freckled Madtom

The freckled madtom is primarily a species of small streams. However, Deacon (1961) found it in the Neosho River in Kansas, and Wallen (1958) took 78 specimens from the Verdigris in Oklahoma. A diligent search will probably disclose the species in the waters of the Neosho River in Oklahoma.

Noturus species. Neosho Madtom

The Neosho madtom (mss., W. Ralph Taylor, U. S. Nat. Mus.) is fairly common in the Neosho River in Kansas (Deacon, 1961). It is found mostly in moderate riffles over clean sand or gravel and has a color pattern somewhat like that of *N. miurus.*

Eucalia inconstans (Kirtland). Brook Stickleback

In the same minnow vats with *Chrosomus eos* (discussed above) Heard (1959) found six specimens of the brook stickleback, another northern species. It is hoped this form does not become established in the Oklahoma fish fauna, and that proper measures are taken to militate against the indiscriminate introduction of exotic fishes anywhere, preferably by legislation.

Amblyopsis rosae (Eigenmann). Rosa's Blindfish

This small blindfish is rather commonly taken from caves in southwestern Missouri. Since there are numerous caves with running water in adjacent Oklahoma, this form doubtless occurs there.

Perca flavescens (Mitchill). Yellow Perch

The yellow perch, a third northern species, has been widely planted in Kansas and Missouri and is sporadically collected from strip pits in those areas. It could easily escape into the Neosho.

Ammocrypta clara Jordan and Meek. Western Sand Darter

This species is widespread from southern Minnesota to Texas and may also occur in the Neosho Drainage.

Percina nasuta (Bailey). Longnose Darter

This form, very closely resembling *P. phoxocephala,* is common in the swift riffles of the Illinois River System. During the rainy season, water and fishes may be exchanged by those two rivers, so it is possible that the longnose darter may eventually be found in the Neosho.

Etheostoma nigrum Rafinesque. Johnny Darter

This widespread form doubtless occurs in the Neosho Drainage, especially in the lower reaches. The author found it abundant in Cow Creek, a tributary of Spring River in Kansas.

DISCUSSION

The Neosho River, in Oklahoma, is a meeting place between eastern and western faunas. Table 1 demonstrates that 23 species of fishes are restricted to the clear eastern tributaries, whereas only two species are found in the western ones and not elsewhere. Twenty-nine species are found in both eastern and western tributaries and in the main channel, but only 12 species are restricted to the channel. Eleven species are shared, to the exclusion of western tributaries, by the main channel and eastern tributaries, and six by the channel and western tributaries to the exclusion of eastern ones. Only one species occurs in both kinds of tributaries but not in the main channel. From the above, it appears that the Neosho River is very definitely acting as a barrier against east to west, and, to a degree, west to east dispersal. *Etheostoma whipplei* apparently has been able to barely penetrate from the west into a few of the eastern tributaries and the peculiar form of *Lepomis megalotis* has been able to cross the river into several western streams.

The few instances of isolated populations are doubtless special cases. The small population of *Hybognathus placita* and of *Fundulus kansae,* both being representatives of the larger Arkansas River Drainage, are either relicts of a once much wider range, or an example of species seeking out proper environments. The Neosho may have changed its course and captured these two small streams from the Arkansas, thus isolating their faunas. The possibility of faunal exchange between the Illinois and Neosho rivers has been mentioned in an attempt to explain the occurrence of *Fundulus olivaceus* in the latter. The single locality record for *Typhlichthys subterraneus* is probably due to the lack of a complete survey of the caves in the region.

The White River drainage of Arkansas possesses large populations of *Notropis rubellus, N. chrysocephalus* and *Fundulus catenatus,* all species which are relatively rare in the Neosho River drainage of Oklahoma. The headwaters of Shoal Creek, of Missouri and Kansas, and those of Elk River of Arkansas and Oklahoma, both lie in very close proximity to the headwaters of several White River tributaries. Hall (1956) is of the opinion that the *F. catenatus* found in Oklahoma represent bait-bucket imports. A better explanation perhaps is that faunal exchange, either by headwater stream capture or by flood exchange, has occurred between the White River and Shoal Creek or Elk River, or both. Since Elk River is tributary directly to the Neosho and Shoal Creek to Spring River, I assume an exchange likely occurred through the Elk. Near Noel, Missouri, only a few miles from Oklahoma, *F. catenatus* is exceedingly abundant. However, the small tributaries of Shoal Creek lie within ½-mile of some of those to the White System. Even though the exchange route would be considerably longer, it is not a particularly untenable one. Shoal Creek is typically Ozarkian in its fish and bottom fauna, in water chemistry and in terrestrial fauna and flora. There are many Ozarkian insects, mollusks and plants which just barely get into Kansas along this stream. Furthermore, Spring River and the Neosho, during periods of drought, assume characteristics of smaller tributaries. During the 5-year period from 1952 through 1956, the longest dry period on record occurred (Garrett, 1958). During this period, Deacon (1961) found several typically small tributary fishes in the Neosho River, which was clear and creek-like at that time. One factor which influenced the movement of small stream fishes into the river, of course, was the drying of the tributaries. It was also during this period that *Fundulus catenatus* was first discovered in Oklahoma. It is assumed that during such periods as these that small-creek forms could utilize the river as an escape route to areas farther south. *F. catenatus* should be sought in the Illinois River System.

ORIGIN OF THE NEOSHO RIVER FAUNA

Hydrographically, Oklahoma is drained by two river systems: the Arkansas in the north, and the Red in the south. The headwaters of the Neosho River, lying as they do in Morris and Morrison counties, are east of the central Kansas uplift (see Moore *et al.,* 1951), and the river flows for a greater part of its length along the old Nemaha anticline, roughly demarked by interfaces of Permian (on the west) and Pennsylvanian rocks on the east. The stream flows in a southeasterly direction, avoiding the Forest City Basin, and enters the Mississippian depression, termed the Cherokee Basin, in Ottawa Co., Oklahoma. The Spring River Drainage, as well as that of the Elk, empties into the Cherokee Basin.

Shoal Creek heads at about the 94th longitude in Missouri, the distance between them and one of the main branches of the James River, a tributary of the White, is approximately three miles. However, when the numerous small creeks in each system are investigated the separating distance is less than a mile. This same type of relationship is true between the Elk and White rivers (Fig. 1).

It is hypothesized here that the Neosho River during the past geologic history of Kansas and Oklahoma flowed through a different channel than at present. Seevers and Jungmann (1963) found considerable evidence for lateral movement of the channel previous to and during the Pleistocene, and slightly west of the present drainage are found the outlines of an old valley system, now beveled by erosion;

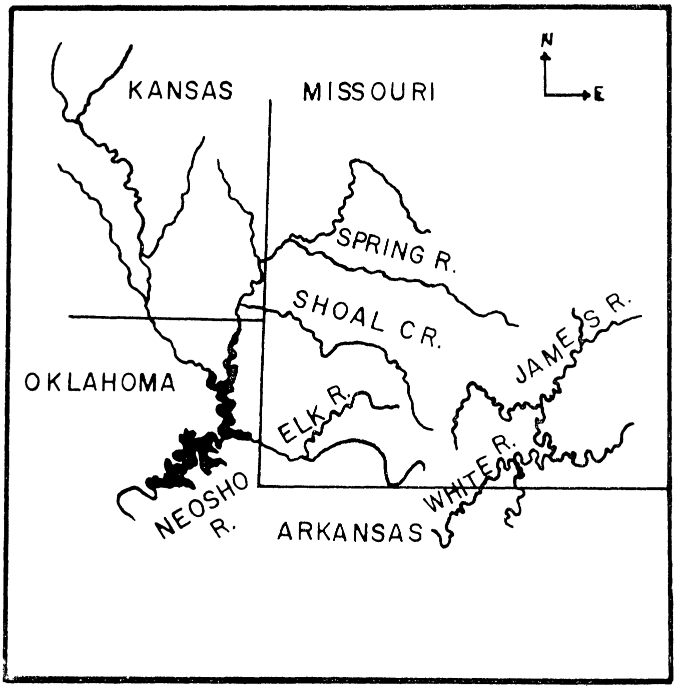

Fig. 1.—Diagram showing the close approximation of the Neosho and White river drainages in Missouri, Oklahoma and Arkansas.

and considerable erosion also took place previous to the Pennsylvanian above the drainage. At the same time the Central Kansas Uplift formed, correlated with a formation of a definite tilting of the anticline toward the southeast, there was considerable uplifting taking place in the Ozarks, and the subsequent tilting of some drainages into the old depression of the Cherokee Basin. It is known that the relief in eastern Kansas near the end of the Kansas Pleistocene was considerably less than now (Jewett, 1963), being raised subsequently. Moreover, as the Kansas ice accumulated in the north, advancing eventually as far south as the Kansas River Basin, considerable climatic changes were felt in this region, primarily a wetter climate, and various channel deepening and stream capturing occurred (Bayne and Fent, 1963). As the ice began melting, causing isostatic adjustment in the earth's crust (Heim and Howe, 1963), additional rearrangement in channels occurred. It is thought, then, that the Neosho was forced gradually to change its course, and that Spring and Elk rivers, possibly at one time a single continuous stream, were captured from the White System. The present loop-pattern is also highly suggestive.

The biological evidence for such stream pirating, although not yet overwhelming, is considerable. Smith (1956) reported two specimens of *Cryptobranchus alleganiensis* (Daudin), one from the Neosho River in Labette Co., and one from Spring River in Cherokee Co., Kansas. These specimens are typical *alleganiensis* rather than being like those from southwestern Missouri. Branson (1963) gave additional evidence based on gastropod mollusks.

Some of the fishes herein discussed (Table 1) are much later arrivals in the Neosho River than are others. The primary influence in the system has been from the Arkansas River, flowing as it does into the faunistically rich Mississippi River Valley.

Catostomus commersoni, although common in headwater springs and pools of Shoal Creek and Elk River, is scarce in Oklahoma. The white sucker is abundant in Big and Little Sugar creeks and in James River in Arkansas.

In Oklahoma, *Etheostoma craigini* has been found only in some spring-fed pools and a few creeks in the Neosho Drainage, no farther south than Mayes Co. This darter is abundant in headwaters springs and cold, clear backwaters in Shoal Creek and Elk River, becoming progressively scarcer downstream. It is rare in Spring River.

The specimens of *Etheostoma nigrum* from the Cherokee Basin of southeastern Kansas are structurally unlike those of the Missouri-Kansas basins as regards cheek and nape squamation, and are also unlike those from the southern parts of the Arkansas River drainage in Oklahoma and Arkansas. They are quite similar to the form known from White River and its tributaries.

Fundulus catenatus entered the Neosho system by means of the Elk River, and possibly to a lesser degree via Shoal Creek, being more abundant in James and Elk rivers.

TABLE 1.—Origin and relative distribution of fishes in the Neosho River system of Oklahoma (single records and introduced species excluded). 1, Arkansas River drainage; 2, White River drainage by stream capture

Species	Eastern tributaries	Main channel	Western tributaries	Origin
Ichthyomyzon gagei	+	—	—	1
Ichthyomyzon castaneus	—	+	—	1
Polyodon spathula	—	+	—	1
Amia calva	—	+	—	1, 2
Lepisosteus spatula	—	+	—	1
Lepisosteus platostomus	—	+	+	1
Lepisosteus oculatus	—	+	—	1
Lepisosteus osseus	—	+	+	1
Alosa chrysochloris	—	+	—	1, 2
Dorosoma cepedianum	+	+	+	1
Dorosoma petenense	—	+	+	1
Hiodon alosoides	—	+	—	1
Cycleptus elongatus	—	+	—	1
Ictiobus (3 species)	—	+	—	1
Carpiodes carpio	+ (rare)	+	—	1
Carpiodes velifer	—	+	—	1
Moxostoma carinatum	+	+ (rare)	—	2
Moxostoma macrolepidotum	+	+ (rare)	—	1, 2
Moxostoma duquesnei	+	+ (rare)	—	1, 2
Moxostoma erythrurum	+	+ (rare)	—	1
Minytrema melanops	+	+ (rare)	+ (rare)	1
Catostomus commersoni	+	—	—	2
Hypentelium nigricans	+	+ (rare)	—	1, 2
Notemigonus crysoleucas	+	+	+	1
Semotilus atromaculatus	+	—	—	1, 2
Chrosomus erythrogaster	+	—	—	1, 2
Hybopsis biguttata	+	—	—	1, 2
Hybopsis x-punctatus	+	+	—	1
Phenacobius mirabilis	+	+	+ (rare)	1
Notropis rubellus	+	—	—	2
Notropis pilsbryi	+	—	—	1
Notropis boops	+	—	—	1
Notropis camurus	+	—	—	1
Notropis lutrensis	+ (scarce)	+	+	1
Notropis greenei	+	—	—	1
Notropis buchanani	—	+	+	1
Notropis stramineus	+	+	+	1
Dionda nubila	+	—	—	1, 2
Pimephales tenellus	+	+ (rare)	+	1
Pimephales vigilax	+ (scarce)	+	+	1, 2
Pimephales notatus	+	+	+	1
Pimephales promelas	+ (scarce)	+ (scarce)	+ (scarce)	1
Campostoma anomalum	+	+ (rare)	+ (rare)	1, 2
Ictalurus punctatus	+	+	+	1, 2
Ictalurus natalis	+	+	+	1
Ictalurus melas	+ (scarce)	+	+	1
Pylodictus olivaris	—	+	—	1
Noturus flavus	+	+	—	1

TABLE 1.—(continued)

Species	Eastern tributaries	Main channel	Western tributaries	Origin
Noturus exilis	+	+ (rare)	—	1, 2
Anguilla rostrata	—	+	+	1
Fundulus catenatus	+	—	—	2
Fundulus sciadicus	+	—	—	1, 2
Fundulus notatus	+	+	+	1
Gambusia affinis	+	+	+	1, 2
Labidesthes sicculus	+	+	+	1
Roccus chrysops	—	+	+	1
Micropterus salmoides	+	+	+	1, 2
Micropterus dolomieui	+	—	—	1, 2
Micropterus punctatus	+	+	+	1, 2
Chaenobryttus gulosus	+	+	+	1, 2
Lepomis cyanellus	+	+	+	1, 2
Lepomis megalotis	+	+	+	2
Lepomis humilis	+	+	+	1, 2
Lepomis macrochirus	+	+	+	1, 2
Ambloplites rupestris	+	—	—	1, 2
Pomoxis nigromaculatus	+	+	+	1, 2
Pomoxis annularis	+	+	+	1, 2
Stizostedion canadense	—	+	—	2
Percina phoxocephala	+	+	—	1
Percina caprodes	+	+	+	1, 2
Percina shumardi	+	+	—	1
Percina copelandi	+	+	—	1
Etheostoma stigmaeum	+	—	—	1, 2
Etheostoma chlorosomum	—	—	+	1
Etheostoma zonale	+	+	—	1, 2
Etheostoma blennioides	+	+	—	1, 2
Etheostoma whipplei	+ (scarce)	—	+	1
Etheostoma punctulatum	+	—	—	1, 2
Etheostoma craigini	+	—	—	2
Etheostoma spectabile	+	+	+	1, 2
Etheostoma flabellare	+	—	—	1, 2
Etheostoma gracile	—	—	+	1
Etheostoma microperca	+	—	—	1, 2
Aplodinotus grunniens	—	+	+	1
Cottus caroliniae	+	—	—	1, 2

Additional study may bring to light more information on this interesting problem. The author is presently attempting to complete a comprehensive study on the Spring River Drainage.

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EFFECTS OF THE PENSACOLA HYDROPOWER PROJECT ON THE FISHERY RESOURCE OF THE GRAND RIVER

Component C

Effects on Fisheries of Establishment of a Riverine Environment in the Headwaters of Lake Hudson

by

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Introduction

Tailwaters below dams frequently support productive fisheries and afford excellent opportunities for angling (Miller and Chance 1954; Fry 1962; Pfitzer 1967; Moser and Hicks 1970; Summers 1978; Peters 1986). Fish concentrate in tailwaters because of the abundant forage, preferred temperatures, and current often present there (Walburg et al. 1971), as well as the tendency of many species to migrate upstream to spawn; dams typically impose a barrier to upstream migration and ascending fish become concentrated below them (Eschmeyer and Smith 1943; Eschmeyer 1944; Hall 1951; Walburg et al. 1971). In addition, fish moving downstream past dams (over spillways or through turbines) often remain in tailwaters, at least temporarily (Clark 1942; Louder 1958; Elser 1960; Nelson 1969; Siefert 1969; Walburg et al. 1971; Jacobs and Swink 1983; Jernejcic 1986).

Productive fisheries for salmonids have developed below some high dams with hypolimnetic releases during summer (Pfitzer 1967; Ruane et al. 1986). Summer discharges maintain low water temperatures in these tailwaters conducive to the survival of coldwater fishes. However, the low temperatures also preclude the maintenance of warmwater fish assemblages. At the other extreme, excellent warmwater fisheries typically develop below mainstream low-head dams discharging unstratified waters (Pfitzer 1967; Ruane et al. 1986). Conditions conducive to neither warmwater or coldwater species exist at reservoirs which discharge cold hypolimnetic water directly into a downstream reservoir (where lack of a riverine reach precludes adequate oxygenation for trout and water temperatures are too cold for warmwater species; Pfitzer 1967) and at reservoirs with especially heterogenous annual flows (where water too cold for warmwater species may be released during high-flow years, but temperatures reach levels detrimental to salmonids during low-flow years; Hickman and Hevel 1986).

Many tailwaters conform to none of the extremes presented above but rather exhibit intermediate characteristics. Reservoir stratification and the vertical location of intakes are the primary factors influencing the quality and temporal variability of tailwater fisheries in such systems (Peters 1986). Physicochemical properties of hypolimnetic releases from stratified reservoirs with long retention times are often less than optimal and can influence abundances and health of tailwater fishes (Hannan and Young 1974; Ruane et al. 1986). Dissolved oxygen concentrations can be depressed (resulting in low feeding and growth rates, impaired reproduction, or death) and dissolved iron, manganese, hydrogen sulfide, and ammonia can reach stressful levels (Ruane et al. 1986; Edwards 1978). Water temperatures in tailwaters are often lower in summer and higher in autumn than normal, and undergo slower rates of warming and cooling in spring and autumn, respectively (Edwards 1978; Ruane et al. 1986). During spring and early summer, discharges may be too cold for reproduction and growth of warmwater species (Dendy and Stroud 1949; Pfitzer 1967; Ruane et al. 1986) and can reduce abundances and diversities of fish assemblages (Edwards 1978). Erratic flows associated with peaking hydropower releases can result in extreme and rapid physicochemical fluctuations stressful to fish (Ruane et al. 1986), streambed exposure (Pfitzer 1967), and depressed abundances of species preferring riverine environments (Brown et al. 1968; Jacobs and Swink 1983).

The Pensacola Dam tailwater is inhabited by warmwater fishes and seasonally receives effluents of hypolimnetic origin solely through temporally heterogenous hydropower discharges withdrawn at an intermediate depth from a reservoir with a long retention time. Accordingly, it is potentially subject to many of the deleterious effects described above. To evaluate the effects of hydroelectric generation on the tailwater fishery, we compared fish assemblages and water quality in the Pensacola Dam tailwater and in the lacustrine headwaters of Lake Hudson downstream from the area directly affected by discharges (Fig. C.1).

Methods

The fish assemblage inhabiting the Pensacola Dam tailwater was sampled at about monthly intervals from January 1988 to July 1989 using three gear types (gill nets, trap nets, and electrofishing). Sampling was conducted during daylight and no turbine discharge occurred during sampling to preclude net displacement.

The tailwater study area extended from the generating station downstream about 1 km to the power-plant access bridge (Fig. C.2). The area was divided into 26 sampling stations, each about 100 m long and 40 m wide (Fig. C.2). Two sampling stations encompassed the stilling basin above the cable. The remaining stations were arranged in three columns along the east and west banks and in midstream (Fig. C.2).

Seven monofilament-nylon experimental gill nets were set on each sampling date. The nets were 2.4 m deep, 91.4 m long, and included six 15.2-m panels with bar mesh sizes of 3.81, 5.08, 6.35, 7.62, 8.89, and 10.16 cm. A stratified-random sampling design was used to select net locations. Two gill nets were set at randomly-selected stations in each of the three columns (east and west banks and midstream). The seventh net was randomly assigned to one of the two stations above the cable. The nets were set parallel to the shoreline and fished for about two hours. All captured fish were removed, identified, weighed (g), measured (mm total length), and released. Total catches (numeric and biomass) of each species in each net were divided by the duration of the net set (in minutes) and multiplied by 60 to derive catch-per-unit-effort values standardized to one net-hour.

Thirteen trap nets were set in the tailwater on each sampling date. The nets were constructed of tarred 1.3-cm nylon mesh stretched over two 1.8x0.9-m frames and four 0.76-m diameter hoops; a single 12.7-m lead extended perpendicularly from the mouth of each net. Four trap nets were set at randomly-selected stations in each of the three columns (east and west banks and midstream). The thirteenth net was randomly assigned to one of the two stations above the cable. The trap nets set in the bank columns were set perpendicular to the shore with their leads extending towards the shore. Midstream nets were set parallel to shore with their leads extending upstream. Trap nets were fished for about 6 hours. All captured fish were removed, identified, weighed, measured, and released. Total catches (numeric and biomass) of each species in each net were divided by the duration of the net set (in minutes) and multiplied by 60 to derive catch-per-unit-effort values standardized to one net-hour.

A commercially-produced 6.1-m aluminum electrofishing boat was used to complete 13 standardized electrofishing transects on each sampling date. Direct current (300 volts, 6-8 amperes, 60% pulse-width, 80 pulses/second) was applied in 100-m linear transects parallel to shore. Four transects were completed at randomly-selected stations in each of the three columns. The thirteenth was randomly assigned to one of the two stations above the cable. All captured fish were identified, weighed, measured, and released. Total catches (numeric and biomass) of each species in each transect constituted catch-per-unit-effort rates (i.e., number or biomass per transect).

The Hudson Lake study area extended from the Strang Bridge to the mouth of the cove leading to the Strang boat ramp (Fig. C.2). The area was partitioned into 241 100x40-m sampling stations (Fig. C.2). Sampling in the Hudson study area duplicated that in the tailwater except that three gill-net sets, five trap-net sets, and five electrofishing transects were completed at non-shoreline sampling stations. As in the tailwater, two gill-net sets, four trap-net sets, and four electrofishing transects were completed at sampling stations along each of the shorelines.

Water temperature, dissolved oxygen concentration, pH, and conductivity were measured at 12 stations between Pensacola Dam and the Hudson study area with a Hydrolab Surveyor II in association with fish sampling. Water quality stations 1 to 3 were located in the tailwater study area at the cable, opposite the boat ramp, and under the bridge (Fig. C.2). Stations 4 to 9 were located at 3.2-km intervals between the two study areas (Fig. C.1). Stations 10 to 12 were located at the Strang Bridge and at the center and downstream border of the Hudson study area (Fig. C.2). At all sites, measurements were made at a depth of about 1 m. Grand River Dam Authority personnel provided discharge data.

Mean catch-per-unit-effort rates (by gear) of all species in aggregate and of species composing >1% of total catch were plotted over time to assess seasonal trends in abundance at the study sites. A catch index value combining the three gear types was calculated for each sampling date to facilitate evaluation of seasonal trends in abundance of major species; the index incorporated the relative magnitude of gear-specific catch rates by date and treated each gear equally. Analysis of variance was used to test whether significant differences existed in mean catch-per-unit-effort rates of all species among sampling dates.

Length-frequency distributions were constructed for species composing >1% of total catch to document sizes present at each site. Monthly species richnesses at both sites were quantified to compare the fish assemblages present at each. Correlation analyses (Pearson product-moment) were used to evaluate linear relationships between water quality variables (temperature, dissolved oxygen concentration, pH, conductivity, and mean weekly discharge) and log-transformed catch-per-unit-effort rates in the tailwater study area.

To enhance the tractability of tables presented in this section, we employed three-letter codes identifying each species. The codes and common and scientific names for each species are listed in Table C.1.

Results

The tailwater study area harbored a speciose fish assemblage. A total of 38 species and 8,818 individuals was collected in the tailwater with all three gear types from January 1988 to July 1989 (Table C.2). Numerically, the gizzard shad was the most abundant species collected (30.4%) followed by white bass (14.2%) and white crappie (12.3%); 13 species individually composed >1% of the total catch (Fig. C.3) and 94.7% in aggregate (Table C.2).

The white bass was numerically the most abundant (30.0%; Fig. C.4) of the 29 species in the gill net catch (Table C.2), followed by smallmouth buffalo (12.7%) and gizzard shad (10.6%). Eleven species individually composed >1% of the gill-net catch (Fig. C.4) and 94.0% in aggregate (Table C.2). White crappie (39.9%) and bluegill (32.8%) dominated the trap-net catch in the tailwater (Table C.2). Eight of the 27 species collected with trap nets individually composed >1% of the catch (Fig. C.5) and 97.1% in aggregate (Table C.2). The electrofishing catch was dominated by gizzard shad (64.7%; Fig C.6 and Table C.2). Brook silversides composed 14.8% of the electrofishing catch and 5 other species individually contributed at least 1% (Fig. C.6). In aggregate, these 7 species (out of 23) composed 95.6% of the electrofishing catch (Table C.2).

Gear-specific catch rates of all species in aggregate and most species individually fluctuated appreciably in the tailwater during the study period (Tables C.3 to C.20). Catch rates of all species in aggregate for all gear types were low in winter, high in spring, and declined through summer and autumn (Fig. C.7). The anomalous peak in electrofishing catch rates in December 1988 resulted from the ephemeral appearance of an abundance of brook silversides (Table C.13). Significant differences existed among monthly mean catch rates of all species in aggregate for all three gear types (Table C.21).

Trends in catch rates of most major species present in the tailwater (i.e., species which composed >1% of the total catch) followed a similar seasonal trend as for all species in aggregate (Figs. C.8-C.20). This was especially true for gizzard shad (Fig. C.8), smallmouth buffalo (Fig. C.13), longnose gar (Fig. C.17), and freshwater drum (Fig. C.20). White bass (Fig. C.9), white crappie (Fig. C.10), hybrid striped bass (Fig. C.15), and river carpsuckers (Fig. C.16) were especially abundant during spring and present in low abundances or absent during other seasons. Bluegill (Fig. C.11), channel catfish (Fig. C.14), longear sunfish (Fig. C.18), and paddlefish (Fig. C.19) tended to decline in abundance less sharply during summer and autumn than the aforementioned species. Brook silversides were present only during winter (Fig. C.12). Significant differences in mean catch rates of all of these species existed among months for (at least) the gear type most effective for each (Table C.21). For gill nets, trap nets, and electrofishing, significant differences existed among monthly catch rates for 16 of 29 (55.2%), 12 of 27 (44.4%), and 12 of 23 (52.2%) species collected, respectively (Table C.21). Of the 14 species for which significant differences among monthly catch rates did not exist for at least one gear type (Table C.21), only one (blue catfish) was represented by more than 16 individuals during the entire study (Table C.2).

Most gizzard shad collected in the tailwater were adults ranging in total length (TL) from about 150 to 300 mm (Fig. C.21). Very few young-of-the-year gizzard shad were captured in the tailwater. White bass (Fig. C.21), white crappie (Fig. C.22), channel catfish (Fig. C.24), and hybrid striped bass (Fig. C.24) were represented by wide size ranges of individuals including multiple age classes and catchable-sized individuals. Conversely, length-frequency distributions of bluegill (Fig. C.22), brook silversides (Fig. C.23), smallmouth buffalo (Fig. C.23), river carpsuckers (Fig. C.25), longnose gar (Fig. C.25), longear sunfish (Fig. C.26), paddlefish (Fig. C.26), and freshwater drum (Fig. C.27) captured in the tailwater were largely unimodal.

Relative abundances of biomasses of fishes collected in the tailwater (Figs. C.28 to C.31) differed appreciably from the numeric distributions (Figs. C.3 to C.6), largely as a function of average species weight. Considering all gear types together (Table C.22), paddlefish biomass ranked highest (23.4%), followed by longnose gar (14.4%), smallmouth buffalo (12.8%), hybrid striped bass (12.3%), and white bass (10.0%). Ten species individually composed >1% of the total biomass collected (Fig. C.28) and 94.1% in aggregate (Table C.22). Despite the difference between rank orders of numbers and biomasses of species collected, overlap of species that composed >1% of the total catch in both rankings was high (gizzard shad, white bass, white crappie, smallmouth buffalo, channel catfish, hybrid striped bass, river carpsucker, longnose gar, and paddlefish; Figs. C.3 and C.28). Exceptions were bluegill, brook silversides, longear sunfish, and freshwater drum which were relatively abundant numerically (Fig. C.3), but because of their small individual sizes composed only a small fraction of the biomass collected. The inverse was true for common carp (Fig. C.28). Considering each gear type separately, relationships in species composition and rank between numeric (Figs. C.4 to C.6) and biomass (Figs. C.29 to C.31) abundances were similar to that for all gear types combined (i.e., general overlap in species composition but with reordering of ranks) except that white crappie and gizzard shad ranked first in both categories in trap-net and electrofishing collections, respectively.

Temporal trends in catch rates of biomasses of all species in aggregate and of individual species (Tables C.23 to C.40, Figs. C.32 to C.42) closely reflected the seasonal trends in numeric catch rates observed (Tables C.3 to C.20, Figs. C.7 to C.20). In general, biomass catch rates were low in winter, high in spring, and declined through summer and autumn (Fig. C.32). Significant differences existed among mean monthly biomass catch rates of all species in aggregate for all three gear types and for many individual species/gear combinations (Table C.41). In general, species/gear combinations that exhibited significant temporal differences in mean numerical catch rates (Table C.21) also showed significant temporal differences in mean biomass catch rates (Table C.41).

Fewer species were collected in the Hudson study area (25; Table C.42) than in the tailwater (38; Table C.2). Only two fishes (flathead catfish and warmouth) were collected exclusively in Hudson, whereas 15 were collected only in the tailwater. However, most of these species were rare in all samples. Only four species collected in appreciable numbers in the tailwater (paddlefish, 146; yellow bullhead, 39; walleye, 26; black bullhead, 18) were absent from Hudson samples.

Monthly species richnesses in the tailwater were typically higher than in Hudson, but exhibited greater temporal variability (Fig. C.43). Minimum species richnesses in the tailwater occurred in late winter and early spring and maxima were achieved in late spring and early summer; richnesses declined through summer and autumn. In the Hudson study area, species richnesses were minimal in mid-winter and remained relatively constant throughout the remainder of the year (Fig. C.43).

The gizzard shad was the most abundant species collected in Hudson samples (22.3% of total catch; Fig. C.44) followed by bluegill (13.4%), brook silversides (12.7%), and white bass (12.4%); 11 species individually composed >1% of the total catch (Fig. C.44) and 96.5% in aggregate (Table C.42). The white bass was the most abundant (27.6%; Fig. C.45) of the 17 species caught in gill nets (Table C.42), followed by smallmouth buffalo (17.5%), channel catfish (17.2%), and gizzard shad (12.9%). Nine species individually composed >1% of the gill-net catch (Fig. C.45) and 97.0% in aggregate (Table C.42). Bluegill (46.8%) and white crappie (29.1%) dominated the trap-net catch (Table C.42). Eight of the 14 species collected with trap nets individually composed >1% of the total catch (Fig. C.46) and 97.0% in aggregate (Table C.42). The electrofishing catch (Fig. C.47) was dominated by gizzard shad (45.4%) and brook silversides (39.2%); smallmouth buffalo (5.5%), largemouth bass (3.2%), and common carp (2.5%) were caught in lesser but appreciable numbers by electrofishing (Table C.42, Fig. C.47).

Catch rates of fishes in the Hudson study area (Tables C.43 to C.54) were relatively stable temporally compared to tailwater values. For all species in aggregate, catch rates for all three gear types were low in winter and moderate throughout the remainder of the year (Fig. C.48). Catch rates in Hudson were generally lower than in the tailwater but exhibited greater stability (Fig. C.49). Trends in catch rates of individual species (Figs. C.50 to C.60) typically fluctuated more than those of all species in aggregate, but showed few discernable seasonal trends; most were relatively stable from spring through autumn for the gear type most effective for each species. Exceptions were brook silversides which were collected only in late autumn and winter (Fig. C.52) and white bass which were caught at very low rates during spring (Fig. C.53) when they were abundant in the tailwater (Fig. C.9).

Significant differences existed among monthly mean catch rates of fishes in aggregate in the Hudson study area only in trap-net samples (Table C.55). No significant difference existed among monthly aggregate catch rates in gill-net or electrofishing samples (Table C.55). Similarly, significant differences among monthly catch rates existed for only 2 of 17 (11.8%), 3 of 14 (21.4%), and 3 of 15 (20.0%) species collected in gill nets, trap nets, and by electrofishing, respectively, in the Hudson study area (Table C.55).

Comparisons of length-frequency distributions of fishes collected in the Hudson (Figs. C.61 to C.66) and tailwater (Figs. C.21 to C.27) study areas showed dissimilarities in age and size structures for some species. Small, young-of-the-year gizzard shad and bluegill were present in Hudson but absent in the tailwater. Small brook silversides and large channel catfish were more common in Hudson than in the tailwater. Length-frequency distributions of white bass, freshwater drum, smallmouth buffalo, white crappie, and river carpsuckers were similar in both areas.

Water quality measurements in the tailwater (Table C.56, Figs. C.67 and C.68) fluctuated seasonally and corresponded closely to values recorded at the depth of the intakes in Grand Lake (Section A.3). Fluctuations in water temperature and dissolved oxygen concentration were appreciable (Fig. C.67) whereas seasonal changes in pH and conductivity were small and encompassed ranges unlikely to affect fish (Fig. C.68). Mean water temperatures and dissolved oxygen concentrations in the tailwater ranged from 3.3 to 23.2 C and 3.2 to 12.5 mg/L (Table C.56). Water temperatures and dissolved oxygen concentrations in the tailwater and Hudson study areas were similar from late autumn through late spring, but deviated during the warmer months when Grand Lake was stratified (Fig. C.69). Values of both variables were higher in the Hudson study area than in the tailwater during summer (Fig. C.69). Mean water temperatures and dissolved oxygen concentrations in the Hudson study area ranged from 3.1 to 30.8 C and 7.2 to 12.3 mg/L (Table C.56).

Temperature data collected by GRDA personnel at Station 3 were similar to values we recorded. However, their dissolved oxygen concentration readings were frequently lower than ours during summer and early fall. The disparity probably resulted from the time of day when measurements were made (Gary Hunt, personal communication); we typically measured water quality in the afternoon whereas GRDA collected their data at dawn.

Longitudinally, both temperature and dissolved oxygen concentration increased rapidly within the tailwater during summer but then remained relatively constant until Station 6 about 10 km downstream from the dam (Fig. C.70). Temperature and dissolved oxygen concentration then gradually increased downstream and stabilized in the Hudson study area (Fig. C.70).

Turbine discharge varied considerably during the study period (Fig. C.71). Low discharges occurred from late spring through early autumn in 1988 when drought conditions existed. Nevertheless, absence of at least some discharge each day was rare and occurred on only 22 days from January 1988 through July 1989. Spillway discharge was infrequent and occurred only in January (7 days), March (2 days), and April (22 days) 1988.

Aggregate numerical catch rates of fishes in the tailwater were positively and significantly correlated with water temperatures for all gear types (Table C.57). Gill net catches of individual species were all positively correlated with water temperatures, and many of the relationships were significant (Table C.57). The same was true for electrofishing samples, except brook silverside catch rates were negatively correlated with water temperatures (Table C.57); this species was abundant only in winter samples. Negative correlations existed between water temperatures and trap net catch rates of many species (Table C.57), but the relationships were positive (though not all significant) for species abundant in trap net collections (white crappie, bluegill, longear sunfish, white bass, and gizzard shad; Fig. C.5). The positive correlations between catch rates and temperatures reflected the general seasonal abundances of fishes in the tailwater (i.e., low in winter, moderate or high during other seasons).

Significant negative correlations existed between aggregate catch rates and pH values in the tailwater for all gear types (Table C.58). Most species/gear combinations also exhibited this relationship. It is probable that these correlations merely reflected the positive association typically observed between pH and dissolved oxygen concentration in stratified reservoirs (Wetzel 1975). Correlations between aggregate catch rates and dissolved oxygen concentrations were negative and significant for all gear types (Table C.59). Most species/gear combinations also exhibited this relationship. It is improbable that these correlations were biologically significant; rather, they primarily reflected low catch rates in winter (when dissolved oxygen concentrations were high). Deleting January, February, and March samples from this analysis substantially weakened the negative correlations between catch rates and dissolved oxygen concentrations (Table C.60). However, the presence of moderate abundances of fish in the tailwater during mid-summer when dissolved oxygen concentrations reached their minimum, followed by a lack of increase in abundance in autumn when dissolved oxygen concentrations increased, suggests that this variable did not influence tailwater fish abundances as overtly as expected.

Significant negative correlations existed between aggregate gill-net and trap-net catch rates and conductivity in the tailwater (Table C.61). Aggregate electrofishing catch rate was not significantly correlated with conductivity. These correlations, as well as those for individual species/gear combinations, suggested no biologically relevant trends. Rather, they appeared to reflect the general increase in conductivity associated with the drought of 1988 (Fig. C.68) in combination with decreasing fish abundances in the tailwater following the spring of 1988.

No significant correlation existed between aggregate gill-net or trap-net catch rates and mean turbine discharges during the week before sampling (Table C.62). A significant negative correlation existed between aggregate electrofishing catch rates and discharges (Table (C.62). Most individual species/gear combinations were negatively correlated with discharge but positive associations were also evident (Table (C.62). This lack of consistency probably resulted from the variability in discharges present during spring fish samples when fish abundances in the tailwater were high (Fig. C.71).

Discussion

Although more species of fish were collected in the tailwater study area than in Hudson, overall fish assemblage composition in both study areas was similar. Most species collected exclusively at one site were rare and probably inhabited both areas at least temporarily; their capture in only one of the areas probably reflected their greater density there.

Conversely, temporal dynamics of the fish assemblages at the two sites differed dramatically. In the Hudson study area, fish abundances and species richnesses were low in winter but moderate and relatively constant throughout the remainder of the year. In the tailwater, both abundances and species richnesses peaked at high levels in spring and early summer, slowly declined through summer and autumn, and were depressed in winter. Similarly, Jacobs and Swink (1983) observed a more abundant, but less stable, fish assemblage in a tailwater than at a downstream control site. Fish abundances in tailwaters are typically enhanced during spring and when upstream reservoirs are not stratified, but are depressed during winter (Walburg et al. 1971; Jacobs and Swink 1983; Jackson and Davies 1988).

The high spring abundances in the tailwater probably resulted from upstream migration associated with reproductive cycles, coupled with the barrier to further upstream migration imposed by the dam. Fish were attracted to the tailwater by the presence of current resulting from dam discharges and concentrated there because they were blocked from ascending any farther (Walburg et al. 1971). Following the peak period of reproductive activity, fish dispersed downstream and were unlikely to return to the tailwater because water temperatures and dissolved oxygen concentrations were more favorable for warmwater fishes in downstream reaches during summer and autumn. During winter, fish apparently retreated to deep areas in lower sections of Hudson Lake and abundances were depressed at both study sites.

Although water temperatures in the Pensacola Dam tailwater and the Hudson study area were distinct during periods when Grand Lake was stratified (late spring through early fall; Section A.3), it is unlikely that the temperatures in the tailwater were overtly deleterious to warmwater fishes. The difference was slight relative to the tolerances of warmwater fishes. Even at the depressed temperatures available in the tailwater, growth and reproduction of warmwater fishes were probably possible (though not optimized). Furthermore, water temperatures in the tailwater did not fluctuate widely over short periods, as is often the case when hypolimnetic discharges are made intermittently (Pfitzer 1967; Ruane et al. 1986), and thereby precluded temperature shock stress. Frequent or continuous discharges, coupled with relatively high hypolimnetic water temperatures (compared to high-head dams) probably averted extreme temperature fluctuations. Nevertheless, preferred water temperatures were available downstream and fish were unlikely to resist this thermal gradient.

The difference in dissolved oxygen concentration between the study areas was more pronounced. Concentrations in the tailwater reached low levels in July and August 1988 and June 1989 but did not precipitate mass exodus of fishes from the tailwater as expected. Rather, fish abundances declined slowly during this period and continued to decline in autumn when dissolved oxygen concentrations improved. Fish may have acclimated to the depressed dissolved oxygen concentrations as the concentrations gradually declined.

Variations in discharge, although appreciable, apparently did not influence fish abundances in the tailwater. For example, discharges associated with individual spring sampling periods varied greatly during both years without concurrent changes in fish abundances. Relatively low discharges were apparently sufficient to attract or retain fishes moving upstream. The paucity of days when no discharge occurred probably detracted from the significance of this commonly influential variable (Pfitzer 1967; Ruane et al. 1986).

Presence of forage entrained from the reservoir (Walburg et al. 1971) did not appear to be a major cause of fish concentration (at least of piscivorous species) in the tailwater because most entrainment of young-of-the-year gizzard shad (which composed the majority of turbine-entrained fishes; Section A.2) occurred in mid-winter when fish abundances in the tailwater were low. However, entrained invertebrates (zooplankton and insects) were probably important forages during periods when discharges were drawn from the epilimnion of Grand Lake (Walburg et al. 1971). It also appeared unlikely that a majority of the fish concentrated in the tailwater originated in the upstream reservoir (Clark 1942; Louder 1958; Elser 1960; Nelson 1969; Siefert 1969; Walburg et al. 1971; Jacobs and Swink 1983; Jernejcic 1986) because young-of-the-year gizzard shad were rare in tailwater samples and spillway discharge was brief in 1988 and absent in 1989. However, it is noteworthy that spring tailwater fish abundances in 1988 exceeded those in 1989; fish leaving Grand Lake over the spillways may have migrated to the tailwater and supplemented abundances. Conversely, the higher and more sustained total discharges from Grand Lake in spring 1988 may have better elicited upstream movement of fishes residing in Hudson Lake.

The Pensacola Dam tailwater differs from many other tailwaters in Oklahoma because it is situated in close proximity to a downstream reservoir, does not receive spillway discharges, and possesses a small, narrow stilling basin. Typically, Oklahoma tailwaters include large, deep stilling basins to accomodate spillway discharges and are situated above long stretches of shallow prairie rivers. During summer and winter, such tailwaters offer thermal refuge to fishes from extreme temperatures present in riverine reaches and are therefore inhabited by abundant fish assemblages throughout much of the year. Conversely, fish residing below Grand Lake are afforded thermal refuge in Hudson Lake and can vacate the tailwater. Unfortunately, the tendency for fish abundances to decline in summer, when angling pressure is high, reduces the recreational potential of the Pensacola Dam tailwater. Implementation of strategies designed to enhance summer water quality in the tailwater, and thereby reduce the rate of downstream emigration, may be useful in enhancing the recreational value of the tailwater. Possible techniques include hypolimnetic aeration, destratification, hydroturbine aeration, tailrace aeration, and multi-level intakes (Ruane et al. 1986); however, it is unlikely that these methods would be cost-effective in the Pensacola Dam tailwater.

In summary, the Pensacola Dam tailwater is seasonally inhabited by an abundant and speciose fish assemblage which concentrates in the tailwater in response to annual reproductive cycles coupled with the barrier to upstream migration imposed by the dam. Operation of the hydroelectric facility imposes no overt deleterious effects on the fishery, but discharge of cool, poorly oxygenated, hypolimnetic water during summer reduces the suitability of the tailwater compared to downstream reaches. Fishes which disperse from the tailwater following the spawning season are therefore unlikely to return until the following spring. Improved summer water quality would probably enhance the recreational value of this tailwater.

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Table C.1. Species codes, common names, and scientific names of fishes collected in the Pensacola Dam tailwaters and headwaters of Hudson Lake, January 1988 to July 1989.

Code	Common name	Scientific name
BBF	Bigmouth buffalo	*Ictiobus cyprinellus*
BBH	Black bullhead	*Ictalurus melas*
BCF	Blue catfish	*Ictalurus furcatus*
BLC	Black crappie	*Pomoxis nigromaculatus*
BLG	Bluegill	*Lepomis macrochirus*
BLS	Blue sucker	*Cycleptus elongatus*
BSS	Brook silverside	*Labidesthes sicculus*
CCF	Channel catfish	*Ictalurus punctatus*
CRP	Common carp	*Cyprinus carpio*
CSH	Common shiner	*Notropis cornutus*
DRM	Freshwater drum	*Aplodinotus grunniens*
FCF	Flathead catfish	*Pylodictis olivaris*
GRS	Green sunfish	*Lepomis cyanellus*
GSH	Golden shiner	*Notemigonus crysoleucas*
GZS	Gizzard shad	*Dorosoma cepedianum*
HFC	Highfin carpsucker	*Carpiodes velifer*
HYB	Hybrid striped bass	*Morone saxatilis x M. chrysops*
HYS	Hybrid sunfish	*Lepomis* sp.
LES	Longear sunfish	*Lepomis megalotis*
LGP	Logperch	*Percina caprodes*
LMB	Largemouth bass	*Micropterus salmoides*
LNG	Longnose gar	*Lepisosteus osseus*
MSS	Mississippi silverside	*Menidia audens*
OSS	Orangespotted sunfish	*Lepomis humilis*
PDF	Paddlefish	*Polyodon spathula*
QBS	Quillback	*Carpiodes cyprinus*
RBT	Rainbow trout	*Oncorhynchus mykiss*
RCS	River carpsucker	*Carpiodes carpio*
RRH	River redhorse	*Moxostoma carinatum*
SBF	Smallmouth buffalo	*Ictiobus bubalus*
SNG	Shortnose gar	*Lepisosteus platostomus*
SPB	Spotted bass	*Micropterus punctulatus*
SPG	Spotted gar	*Lepisosteus oculatus*
SRH	Shorthead redhorse	*Moxostoma macrolepidotum*
WHB	White bass	*Morone chrysops*
WHC	White crappie	*Pomoxis annularis*
WHS	White sucker	*Catostomus commersoni*
WLY	Walleye	*Stizostedion vitreum*
WRM	Warmouth	*Lepomis gulosus*
YBH	Yellow bullhead	*Ictalurus natalis*

Table C.2. Total catches (N) and relative abundances (%) of fishes captured with gill nets, trap nets, and by electrofishing in the Pensacola Dam tailwaters, January 1988 to July 1989.

	Gill net		Trap net		Electrofishing		Combined	
Sp.	N	%	N	%	N	%	N	%
BBF	4	0.141	0	0.000	0	0.000	4	0.045
BBH	2	0.070	16	0.646	0	0.000	18	0.204
BCF	60	2.114	2	0.081	10	0.285	72	0.816
BLC	6	0.211	0	0.000	0	0.000	6	0.068
BLG	22	0.775	812	32.808	43	1.227	877	9.945
BLS	1	0.035	0	0.000	0	0.000	1	0.011
BSS	0	0.000	0	0.000	520	14.835	520	5.897
CCF	177	6.237	87	3.515	74	2.111	338	3.833
CRP	31	1.092	3	0.121	29	0.827	63	0.714
CSH	0	0.000	1	0.040	0	0.000	1	0.011
DRM	18	0.634	8	0.323	79	2.254	105	1.191
GZS	302	10.641	112	4.525	2268	64.707	2682	30.415
GRS	5	0.176	75	3.030	1	0.028	81	0.918
GSH	0	0.000	1	0.040	0	0.000	1	0.011
HFC	3	0.106	0	0.000	0	0.000	3	0.034
HYB	271	9.549	2	0.081	21	0.599	294	3.334
HYS	2	0.070	4	0.162	0	0.000	6	0.068
LES	0	0.000	151	6.101	6	0.171	157	1.780
LGP	0	0.000	2	0.081	9	0.257	11	0.125
LMB	28	0.987	1	0.040	11	0.314	40	0.454
LNG	166	5.849	14	0.566	2	0.057	182	2.064
MSS	0	0.000	0	0.000	3	0.085	3	0.034
OSS	0	0.000	2	0.081	0	0.000	2	0.023
PDF	142	5.004	0	0.000	4	0.114	146	1.656
QBS	8	0.282	0	0.000	0	0.000	8	0.091
RBT	4	0.141	0	0.000	0	0.000	4	0.045
RCS	222	7.822	5	0.202	12	0.342	239	2.710
RRH	10	0.352	0	0.000	9	0.257	19	0.215
SBF	360	12.684	2	0.081	103	2.939	465	5.273
SNG	0	0.000	1	0.040	0	0.000	1	0.011
SPB	17	0.599	3	0.121	11	0.314	31	0.352
SPG	7	0.247	0	0.000	0	0.000	7	0.079
SRH	7	0.247	1	0.040	8	0.228	16	0.181
WHB	853	30.056	141	5.697	263	7.504	1257	14.254
WHC	84	2.960	987	39.878	18	0.514	1089	12.349
WHS	2	0.070	1	0.040	0	0.000	3	0.034
WLY	24	0.846	1	0.040	1	0.028	26	0.295
YBH	0	0.000	39	1.576	0	0.000	39	0.442
TOTAL	2838		2475		3505		8818	

Table C.3. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 15 January 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	1	0.036	0.094	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	2	0.026	0.063	0	0.000	0.000
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	4	0.308	1.109
CCF	63	2.250	2.350	0	0.000	0.000	0	0.000	0.000
CRP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	0	0.000	0.000	0	0.000	0.000	7	0.538	1.941
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	3	0.107	0.134	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	1	0.013	0.046	0	0.000	0.000
LMB	2	0.071	0.189	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	3	0.107	0.197	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	5	0.179	0.238	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	1	0.036	0.094	0	0.000	0.000	0	0.000	0.000
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	1	0.036	0.094	1	0.013	0.046	0	0.000	0.000
WHC	3	0.107	0.134	62	0.795	0.431	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	1	0.036	0.094	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	1	0.013	0.046	0	0.000	0.000
TOTAL	83	2.964	2.559	67	0.859	0.476	11	0.846	2.154

Table C.4. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 4 February 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	2	0.129	0.221	0	0.000	0.000	0	0.000	0.000
BLC	1	0.071	0.189	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	1	0.014	0.050	0	0.000	0.000
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	30	2.308	4.289
CCF	2	0.095	0.162	0	0.000	0.000	1	0.077	0.277
CRP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	23	1.307	0.986	1	0.014	0.050	2	0.154	0.376
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	1	0.071	0.189	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	1	0.055	0.146	0	0.000	0.000	0	0.000	0.000
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHC	0	0.000	0.000	7	0.099	0.179	1	0.077	0.277
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	1	1.071	0.189	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	31	1.800	0.979	9	0.127	0.175	34	2.615	4.556

Table C.5. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 2 May 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	4	0.032	0.066	0	0.000	0.000
BCF	17	0.687	0.333	2	0.016	0.057	1	0.077	0.277
BLC	3	0.106	0.196	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	28	0.221	0.250	1	0.077	0.277
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	5	0.385	1.121
CCF	25	1.170	1.192	72	0.573	1.053	1	0.077	0.277
CRP	16	0.625	0.760	1	0.008	0.028	1	0.077	0.277
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	100	4.268	4.430	79	0.609	1.475	280	21.538	22.868
GRS	2	0.090	0.239	9	0.070	0.104	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	147	6.117	8.152	1	0.008	0.028	3	0.231	0.439
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	6	0.223	0.225	0	0.000	0.000	2	0.154	0.376
LNG	34	1.397	1.195	4	0.031	0.064	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	1	0.008	0.028	0	0.000	0.000
PDF	65	2.671	2.251	0	0.000	0.000	1	0.077	0.277
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	37	1.537	0.997	3	0.024	0.086	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	26	1.137	0.923	0	0.000	0.000	1	0.077	0.277
SNG	0	0.000	0.000	1	0.008	0.028	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	2	0.093	0.164	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	132	6.007	4.995	99	0.772	1.570	10	0.769	0.927
WHC	41	1.695	0.849	574	4.520	3.444	3	0.231	0.439
WHS	1	0.045	0.119	1	0.008	0.029	0	0.000	0.000
WLY	3	0.103	0.129	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	38	0.299	0.555	0	0.000	0.000
TOTAL	657	27.972	16.000	917	7.206	6.100	309	23.769	22.643

Table C.6. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 24 May 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	2	0.122	0.212	12	0.122	0.222	0	0.000	0.000
BCF	3	0.214	0.567	0	0.000	0.000	0	0.000	0.000
BLC	1	0.071	0.189	0	0.000	0.000	0	0.000	0.000
BLG	5	0.364	0.750	188	1.913	2.300	4	0.308	0.480
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	4	0.308	0.630
CCF	4	0.286	0.488	5	0.046	0.114	7	0.538	0.877
CRP	2	0.143	0.378	0	0.000	0.000	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	8	0.513	0.441	4	0.039	0.062	20	1.538	2.402
GZS	3	0.172	0.300	3	0.028	0.053	327	25.154	17.776
GRS	0	0.000	0.000	21	0.202	0.226	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	53	3.750	8.934	0	0.000	0.000	9	0.692	1.437
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	40	0.391	0.472	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	3	0.164	0.207	0	0.000	0.000	2	0.154	0.376
LNG	44	3.077	4.888	2	0.018	0.044	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	6	0.464	0.497	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	70	4.524	2.219	1	0.009	0.033	6	0.462	0.660
RRH	2	0.122	0.212	0	0.000	0.000	0	0.000	0.000
SBF	59	3.851	3.078	1	0.010	0.037	15	1.154	2.544
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	3	0.214	0.567	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	38	2.730	2.837	21	0.193	0.570	46	3.538	4.484
WHC	21	1.455	2.260	141	1.484	1.483	4	0.308	0.855
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	1	0.086	0.227	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	328	22.323	19.159	439	4.456	4.706	444	34.154	20.412

Table C.7. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 23 June 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	1	0.067	0.179	0	0.000	0.000	5	0.385	1.121
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	1	0.057	0.151	40	0.482	0.772	4	0.308	1.109
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	5	0.323	0.358	2	0.028	0.100	0	0.000	0.000
CRP	3	0.202	0.536	0	0.000	0.000	2	0.154	0.555
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	1	0.067	0.179	0	0.000	0.000	6	0.462	1.391
GZS	12	0.784	1.544	0	0.000	0.000	162	12.462	8.130
GRS	0	0.000	0.000	3	0.037	0.071	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	6	0.387	0.691	0	0.000	0.000	0	0.000	0.000
HYS	1	0.067	0.179	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	4	0.053	0.153	2	0.154	0.376
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	1	0.067	0.179	0	0.000	0.000	1	0.077	0.277
LNG	19	1.244	1.591	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	13	0.861	1.718	0	0.000	0.000	0	0.000	0.000
QBS	2	0.126	0.216	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	9	0.585	0.468	0	0.000	0.000	0	0.000	0.000
RRH	1	0.067	0.179	0	0.000	0.000	1	0.077	0.277
SBF	71	4.381	2.708	0	0.000	0.000	17	1.308	2.720
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	2	0.143	0.378	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	11	0.712	0.875	6	0.070	0.100	21	1.615	3.776
WHC	2	0.116	0.202	77	1.017	2.325	6	0.462	1.391
WHS	1	0.067	0.179	0	0.000	0.000	0	0.000	0.000
WLY	0	0.000	0.000	1	0.014	0.050	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	162	10.327	9.885	133	1.701	2.836	228	17.538	10.063

Table C.8. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 21 July 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	1	0.071	0.189	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	3	0.213	0.392	92	1.143	1.711	7	0.538	0.967
BLS	1	0.070	0.186	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	20	1.372	1.066	1	0.013	0.046	3	0.231	0.599
CRP	3	0.204	0.255	0	0.000	0.000	2	0.154	0.555
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	3	0.202	0.364	0	0.000	0.000	21	1.615	3.042
GZS	57	3.817	5.707	5	0.064	0.127	178	13.692	8.107
GRS	1	0.072	0.191	17	0.206	0.600	0	0.000	0.000
GSH	0	0.000	0.000	1	0.013	0.046	0	0.000	0.000
HFC	2	0.136	0.232	0	0.000	0.000	0	0.000	0.000
HYB	3	0.214	0.567	0	0.000	0.000	0	0.000	0.000
HYS	1	0.070	0.186	3	0.036	0.130	0	0.000	0.000
LES	0	0.000	0.000	27	0.328	0.837	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	7	0.481	0.275	0	0.000	0.000	2	0.154	0.376
LNG	7	0.483	0.391	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	21	1.461	0.803	0	0.000	0.000	1	0.077	0.277
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	18	1.236	0.825	0	0.000	0.000	0	0.000	0.000
RRH	1	0.070	0.186	0	0.000	0.000	5	0.385	0.768
SBF	21	1.436	0.728	0	0.000	0.000	1	0.077	0.277
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	7	0.492	0.753	0	0.000	0.000	1	0.077	0.277
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	6	0.410	0.427	9	0.108	0.390	25	1.923	2.362
WHC	1	0.065	0.172	107	1.315	2.079	2	0.154	0.376
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	8	0.559	0.588	0	0.000	0.000	1	0.077	0.277
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	192	13.135	7.899	262	3.226	5.001	249	19.154	10.946

Table C.9. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 18 August 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	28	1.951	5.162	0	0.000	0.000	1	0.077	0.277
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	20	0.266	0.605	2	0.154	0.376
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	7	0.498	0.749	0	0.000	0.000	9	0.692	0.855
CRP	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	1	0.070	0.184	0	0.000	0.000	15	1.154	1.573
GZS	28	2.013	2.758	3	0.039	0.075	154	11.846	7.647
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	1	0.013	0.047	1	0.077	0.277
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	1	0.070	0.184	0	0.000	0.000	3	0.231	0.599
LNG	1	0.060	0.157	0	0.000	0.000	1	0.077	0.277
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	1	0.070	0.184	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	2	0.132	0.226	0	0.000	0.000	0	0.000	0.000
RRH	1	0.079	0.208	0	0.000	0.000	0	0.000	0.000
SBF	30	2.087	3.240	0	0.000	0.000	1	0.077	0.277
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	1	0.060	0.157	0	0.000	0.000	2	0.154	0.376
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	3	0.231	0.832
WHB	4	0.248	0.556	0	0.000	0.000	18	1.385	4.134
WHC	9	0.627	1.659	3	0.040	0.103	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	1	0.070	0.184	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	115	8.068	11.654	27	0.358	0.680	211	16.231	8.258

Table C.10. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 17 September 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	1	0.080	0.212	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	8	0.100	0.318	1	0.077	0.277
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	4	0.242	0.324	0	0.000	0.000	0	0.000	0.000
CRP	0	0.000	0.000	0	0.000	0.000	6	0.462	1.664
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	34	2.094	2.158	11	0.131	0.166	67	5.154	4.845
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	3	0.213	0.379	0	0.000	0.000	3	0.231	0.832
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	1	0.067	0.179	1	0.012	0.045	0	0.000	0.000
LNG	3	0.208	0.263	2	0.025	0.060	1	0.077	0.277
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	7	0.487	0.618	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	5	0.369	0.617	0	0.000	0.000	24	1.846	4.981
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	2	0.125	0.214	0	0.000	0.000	1	0.077	0.277
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	3	0.214	0.269	0	0.000	0.000	0	0.000	0.000
WHC	0	0.000	0.000	1	0.013	0.046	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	2	0.140	0.243	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	65	4.240	2.029	23	0.281	0.349	103	7.923	5.530

Table C.11. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 16 October 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	1	0.080	0.212	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	9	0.117	0.143	3	0.231	0.599
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	7	0.513	0.708	0	0.000	0.000	1	0.077	0.277
CRP	1	0.080	0.212	0	0.000	0.000	2	0.154	0.376
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	3	0.042	0.109	0	0.000	0.000
GZS	26	1.965	2.729	1	0.013	0.046	102	7.846	7.175
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	1	0.080	0.212	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	4	0.051	0.184	1	0.077	0.277
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	5	0.401	1.060	0	0.000	0.000	1	0.077	0.277
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	4	0.318	0.635	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	11	0.836	0.624	0	0.000	0.000	18	1.385	2.815
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	2	0.026	0.062	2	0.154	0.376
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	1	0.080	0.212	0	0.000	0.000	2	0.154	0.555
WHB	3	0.232	0.434	0	0.000	0.000	6	0.462	1.391
WHC	0	0.000	0.000	1	0.013	0.046	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	60	4.585	4.090	20	0.261	0.342	138	10.615	7.124

Table C.12. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 19 November 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	5	0.064	0.108	0	0.000	0.000
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	25	1.923	3.499
CCF	4	0.286	0.567	0	0.000	0.000	0	0.000	0.000
CRP	0	0.000	0.000	1	0.013	0.046	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
GZS	6	0.429	0.732	1	0.013	0.046	85	6.538	9.938
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	2	0.026	0.092	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	2	0.154	0.376
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	22	1.571	1.592	0	0.000	0.000	1	0.077	0.277
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	1	0.071	0.189	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	4	0.286	0.393	0	0.000	0.000	1	0.077	0.277
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	2	0.143	0.244	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	43	3.071	7.694	0	0.000	0.000	17	1.308	4.131
WHC	0	0.000	0.000	3	0.038	0.100	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	1	0.071	0.189	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	83	5.929	8.648	12	0.154	0.209	132	10.154	12.928

Table C.13. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 9 December 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	1	0.071	0.189	8	0.103	0.145	2	0.154	0.555
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	437	33.615	56.342
CCF	7	0.432	0.559	0	0.000	0.000	29	2.231	5.372
CRP	0	0.000	0.000	1	0.012	0.044	1	0.077	0.277
CSH	0	0.000	0.000	1	0.013	0.046	0	0.000	0.000
DRM	1	0.071	0.189	0	0.000	0.000	0	0.000	0.000
GZS	0	0.000	0.000	2	0.023	0.057	41	3.154	5.871
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	1	0.071	0.189	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	1	0.071	0.189	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	26	1.848	4.700	0	0.000	0.000	8	0.615	2.219
WHC	0	0.000	0.000	1	0.013	0.046	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	1	0.071	0.189	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	38	2.637	5.490	13	0.164	0.180	518	39.846	57.283

Table C.14. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 29 January 1989.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	2	0.129	0.221	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	6	0.409	0.702	0	0.000	0.000	3	0.231	0.832
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	6	0.079	0.151	8	0.615	1.660
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	10	0.769	2.242
CCF	10	0.642	0.952	1	0.013	0.048	6	0.462	1.127
CRP	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
CSH	0	0.000	0.000	1	0.013	0.048	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	2	0.154	0.376
GZS	0	0.000	0.000	1	0.013	0.048	11	0.846	2.304
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	1	0.013	0.048	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	2	0.137	0.234	0	0.000	0.000	0	0.000	0.000
QBS	1	0.063	0.168	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	8	0.517	0.485	1	0.077	0.277	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	28	1.827	1.398	0	0.000	0.000	3	0.231	0.832
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	1	0.066	0.174	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	1	0.067	0.177	0	0.000	0.000	0	0.000	0.000
WHB	17	1.098	1.255	0	0.000	0.000	4	0.308	0.855
WHC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	4	0.260	0.244	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	80	5.216	2.679	10	0.132	0.235	49	3.769	4.833

Table C.15. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 26 February 1989.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	3	0.231	0.599
CCF	0	0.000	0.000	0	0.000	0.000	2	0.154	0.555
CRP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
GZS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	1	0.080	0.212	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	6	0.440	0.345	0	0.000	0.000	1	0.077	0.277
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	2	0.147	0.251	0	0.000	0.000	0	0.000	0.000
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	1	0.075	0.197	1	0.013	0.046	1	0.077	0.277
WHC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	10	0.742	0.585	1	0.013	0.046	8	0.615	0.961

Table C.16. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 11 March 1989.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	2	0.154	0.555
CCF	0	0.000	0.000	3	0.038	0.099	0	0.000	0.000
CRP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	0	0.000	0.000	1	0.013	0.047	0	0.000	0.000
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	3	0.189	0.343	0	0.000	0.000	1	0.077	0.277
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	1	0.060	0.159	1	0.013	0.047	6	0.462	1.198
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	1	0.066	0.174	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	5	0.315	0.424	5	0.065	0.162	9	0.692	1.494

Table C.17. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 25 April 1989.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	4	0.050	0.103	6	0.462	0.776
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	0	0.000	0.000	1	0.013	0.045	0	0.000	0.000
CRP	1	0.060	0.157	0	0.000	0.000	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	8	0.515	0.848	0	0.000	0.000	226	17.385	0.998
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	25	1.675	2.781	0	0.000	0.000	2	0.154	0.555
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	1	0.013	0.045	3	0.231	0.599
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	5	0.273	0.496	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	36	1.785	1.672	0	0.000	0.000	5	0.385	0.870
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	1	0.047	0.125	0	0.000	0.000	1	0.077	0.277
WHB	396	24.150	21.285	4	0.050	0.103	91	7.000	9.256
WHC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	472	28.503	22.670	10	0.125	0.165	334	25.692	22.205

Table C.18. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 12 May 1989.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	7	0.094	0.153	1	0.077	0.277
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	1	0.062	0.164	0	0.000	0.000	0	0.000	0.000
CRP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	3	0.231	0.439
GZS	14	0.881	1.756	0	0.000	0.000	322	24.769	38.668
GRS	0	0.000	0.000	2	0.027	0.096	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	4	0.248	0.657	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	15	0.202	0.319	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	5	0.385	0.870
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	2	0.132	0.225	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
SBF	13	0.807	2.136	0	0.000	0.000	2	0.154	0.555
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	1	0.013	0.048	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	1	0.066	0.174	0	0.000	0.000	0	0.000	0.000
WHB	153	9.503	25.143	0	0.000	0.000	7	0.538	1.330
WHC	2	0.124	0.329	0	0.000	0.000	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	190	11.824	30.064	25	0.336	0.381	341	26.231	38.584

Table C.19. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 9 June 1989.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	1	0.054	0.142	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	1	0.055	0.144	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	11	0.649	1.212	182	2.005	3.327	4	0.308	0.480
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	16	0.867	1.667	2	0.022	0.078	9	0.692	1.109
CRP	3	0.146	0.251	0	0.000	0.000	1	0.077	0.277
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	3	0.164	0.433	0	0.000	0.000	9	0.692	0.947
GZS	5	0.277	0.573	1	0.011	0.039	205	15.769	3.242
GRS	2	0.109	0.289	12	0.147	0.264	1	0.077	0.277
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	1	0.067	0.179	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	1	0.011	0.041	0	0.000	0.000
LES	0	0.000	0.000	40	0.487	0.982	1	0.077	0.277
LGP	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
LMB	1	0.039	0.105	0	0.000	0.000	0	0.000	0.000
LNG	56	2.989	4.482	6	0.066	0.111	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	4	0.220	0.214	0	0.000	0.000	1	0.077	0.277
QBS	5	0.227	0.227	0	0.000	0.000	0	0.000	0.000
RBT	4	0.203	0.428	0	0.000	0.000	0	0.000	0.000
RCS	45	2.660	2.239	1	0.010	0.038	3	0.231	0.599
RRH	2	0.079	0.209	0	0.000	0.000	2	0.154	0.555
SBF	25	1.316	0.649	0	0.000	0.000	2	0.154	0.555
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	1	0.054	0.142	0	0.000	0.000	0	0.000	0.000
SPG	3	0.148	0.164	0	0.000	0.000	0	0.000	0.000
SRH	1	0.040	0.105	0	0.000	0.000	0	0.000	0.000
WHB	19	1.021	1.965	0	0.000	0.000	8	0.615	0.961
WHC	5	0.258	0.570	7	0.083	0.160	1	0.077	0.277
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	214	11.642	10.682	252	2.842	4.096	248	19.077	13.684

Table C.20. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Pensacola Dam tailwaters, 25 July 1989.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	1	0.058	0.154	212	2.460	3.708	0	0.000	0.000
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	2	0.119	0.203	0	0.000	0.000	6	0.462	0.877
CRP	2	0.126	0.333	0	0.000	0.000	12	0.923	1.706
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	1	0.056	0.149	1	0.011	0.040	1	0.077	0.277
GZS	9	0.540	0.764	4	0.045	0.071	101	7.769	7.886
GRS	0	0.000	0.000	11	0.132	0.319	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	1	0.063	0.167	0	0.000	0.000	2	0.154	0.555
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	17	0.196	0.380	1	0.077	0.277
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	1	0.056	0.149	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	1	0.011	0.041	0	0.000	0.000
PDF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	4	0.222	0.208	0	0.000	0.000	0	0.000	0.000
RRH	3	0.169	0.448	0	0.000	0.000	0	0.000	0.000
SBF	26	1.573	2.514	0	0.000	0.000	7	0.538	0.776
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	1	0.054	0.142	0	0.000	0.000	5	0.385	0.650
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	2	0.112	0.193	1	0.012	0.042	2	0.154	0.376
WHB	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
WHC	0	0.000	0.000	3	0.034	0.088	1	0.077	0.277
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	53	3.150	2.811	250	2.901	4.306	139	10.692	7.642

Table C.21. Probability values of analyses of variance testing whether differences exist among monthly mean numeric catch-per-unit-effort rates, by gear, of fishes collected in the Pensacola Dam tailwaters, January 1988 to July 1989. Asterisks denote statistically significant probability values (alpha=0.05).

Species	Gill net	Trap net	Electrofishing
BBF	0.1121	--	--
BBH	0.0051*	0.0001*	--
BCF	0.4497	0.4595	0.2831
BLC	0.4171	--	--
BLG	0.0678	0.0001*	0.1788
BLS	0.4642	--	--
BSS	--	--	0.0001*
CCF	0.0002*	0.0001*	0.0141*
CRP	0.0062*	0.5868	0.0301*
CSH	--	0.5263	--
DRM	0.0001*	0.0027*	0.0001*
GRS	0.5902	0.0085*	0.4595
GSH	--	0.4595	--
GZS	0.0007*	0.0082*	0.0001*
HFC	0.0588	--	--
HYB	0.0103*	0.5161	0.0191*
HYS	0.5287	0.4973	--
LES	--	0.0009*	0.3658
LGP	--	0.5264	0.0086*
LMB	0.0495*	0.4595	0.1304
LNG	0.0013*	0.0001*	0.5264
MSS	--	--	0.0478*
OSS	--	0.5214	--
PDF	0.0001*	--	0.6650
QBS	0.0001*	--	--
RBT	0.0834	--	--
RCS	0.0001*	0.5594	0.0001*
RRH	0.6214	--	0.0099*
SBF	0.0001*	0.5246	0.0875
SNG	--	0.4595	--
SPB	0.0203*	0.0526	0.0005*
SPG	0.2373	--	--
SRH	0.5002	0.4595	0.4978
WHB	0.0001*	0.0006*	0.0001*
WHC	0.0001*	0.0001*	0.2205
WHS	0.5238	0.4595	--
WLY	0.0001*	0.4595	0.4595
YBH	--	0.0001*	--
TOTAL	0.0001*	0.0001*	0.0001*

Table C.22. Total catches (g) and relative abundances (%) of biomasses of fishes captured with gill nets, trap nets, and by electrofishing in the Pensacola Dam tailwaters, January 1988 to July 1989.

	Gill net		Trap net		Electrofishing		Combined	
Sp.	g	%	g	%	g	%	g	%
BBF	13900	0.384	0	0.000	0	0.000	13900	0.310
BBH	114	0.003	1086	0.371	0	0.000	1200	0.027
BCF	24403	0.674	388	0.133	3320	0.575	28111	0.626
BLC	1122	0.031	0	0.000	0	0.000	1122	0.025
BLG	2142	0.059	32710	11.171	1172	0.307	36624	0.816
BLS	476	0.013	0	0.000	0	0.000	476	0.011
BSS	0	0.000	0	0.000	459	0.079	459	0.010
CCF	152965	4.226	13628	4.654	15821	2.740	182414	4.063
CRP	53053	1.466	3500	1.195	50843	8.807	107396	2.392
CSH	0	0.000	25	0.009	0	0.000	25	0.001
DRM	14204	0.392	677	0.231	18366	3.181	33247	0.741
GZS	26357	0.728	3839	1.311	172187	29.824	202383	4.508
GRS	463	0.013	3493	1.193	52	0.009	4008	0.089
GSH	0	0.000	3	0.001	0	0.000	3	<0.001
HFC	1095	0.030	0	0.000	0	0.000	1095	0.024
HYB	507391	14.019	3300	1.127	40770	7.062	551461	12.284
HYS	0	0.000	196	0.067	0	0.000	196	0.004
LES	0	0.000	4783	1.633	145	0.025	4928	0.110
LGP	0	0.000	29	0.010	158	0.027	187	0.004
LMB	23775	0.657	120	0.041	8195	1.419	32090	0.715
LNG	590387	16.312	47507	16.225	6764	1.172	644658	14.360
MSS	0	0.000	0	0.000	14	0.002	14	<0.001
OSS	0	0.000	38	0.013	0	0.000	38	0.001
PDF	1017049	28.101	0	0.000	31750	5.499	1048799	23.362
QBS	4579	0.127	0	0.000	0	0.000	4579	0.102
RBT	1042	0.029	0	0.000	0	0.000	1042	0.023
RCS	278679	7.700	5654	1.931	15147	2.624	299480	6.671
RRH	3628	0.100	0	0.000	2531	0.438	6159	0.137
SBF	453454	12.529	1651	0.564	121824	21.101	576929	12.851
SNG	0	0.000	1200	0.410	0	0.000	1200	0.027
SPB	10968	0.303	143	0.049	4098	0.710	15209	0.339
SPG	16385	0.453	0	0.000	0	0.000	16385	0.365
SRH	6345	0.175	415	0.142	11000	1.905	17760	0.396
WHB	362807	10.024	22504	7.686	66262	11.477	451573	10.059
WHC	17973	0.497	139442	47.623	3009	0.521	160424	3.573
WHS	920	0.025	0	0.000	0	0.000	920	0.020
WLY	33580	0.928	1400	0.478	2850	0.494	37830	0.843
YBH	0	0.000	5075	1.733	0	0.000	5075	0.113
TOTAL	3619256		292807		577336		4489399	

Table C.23. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 15 January 1988.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	500	17.857	47.246	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	17	0.218	0.583	0	0.000	0.000
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	8	0.615	2.219
CCF	52011	1857.536	2716.783	0	0.000	0.000	0	0.000	0.000
CRP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	0	0.000	0.000	0	0.000	0.000	68	5.231	18.860
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	2370	84.643	106.580	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	13	0.167	0.601	0	0.000	0.000
LMB	1778	63.500	168.005	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	32099	1146.393	2070.601	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	4728	168.857	361.998	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	280	10.000	26.458	0	0.000	0.000	0	0.000	0.000
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	110	3.929	10.394	127	1.628	5.871	0	0.000	0.000
WHC	512	18.286	23.115	7118	91.256	92.703	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	2280	81.429	215.440	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	50	0.641	2.311	0	0.000	0.000
TOTAL	96668	3452.430	5946.620	7325	93.910	102.069	76	5.846	21.079

Table C.24. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 4 February 1988.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	565	39.043	88.144	0	0.000	0.000	0	0.000	0.000
BLC	137	9.786	25.891	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	69	0.965	3.479	0	0.000	0.000
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	84	6.538	12.122
CCF	3902	177.591	418.508	0	0.000	0.000	550	42.308	152.543
CRP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	16745	910.855	835.703	175	2.426	8.745	1418	109.077	266.324
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	1150	82.143	217.330	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	1500	107.143	283.473	0	0.000	0.000	0	0.000	0.000
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHC	0	0.000	0.000	1395	19.722	41.816	218	16.769	60.462
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	775	55.357	146.461	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	24774	1381.918	2015.510	1639	23.113	54.040	2270	174.692	491.451

Table C.25. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 2 May 1988.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	236	1.864	3.925	0	0.000	0.000
BCF	7325	313.051	262.657	388	3.088	11.132	940	72.308	260.709
BLC	750	26.571	56.056	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	1385	10.871	16.484	75	5.769	20.801
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	22	1.692	5.266
CCF	38868	1837.721	1970.216	10900	85.592	150.171	38	2.923	10.539
CRP	23378	943.306	1432.398	1350	10.385	37.442	1422	109.385	394.392
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	8337	354.522	326.773	1717	13.275	30.952	19980	1536.923	1264.848
GRS	108	4.872	12.891	358	2.793	4.019	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	266275	11094.398	15162.572	3125	24.038	86.672	3502	269.385	807.724
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	5200	200.095	229.571	0	0.000	0.000	1750	134.615	485.363
LNG	108940	4513.581	4223.485	11355	89.173	176.501	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	8	0.062	0.222	0	0.000	0.000
PDF	406606	16740.286	14048.982	0	0.000	0.000	6400	492.308	1775.041
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	37531	1546.403	1023.878	3131	25.001	90.144	0	0.000	0.000
RRH	110	5.238	13.859	0	0.000	0.000	0	0.000	0.000
SBF	31420	1379.551	1140.234	0	0.000	0.000	820	63.077	227.427
SNG	0	0.000	0.000	1200	9.231	33.282	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	3935	182.857	324.074	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	51737	2321.791	1775.981	16238	126.536	234.397	1029	79.154	132.980
WHC	10787	465.364	245.360	106532	387.892	698.379	337	25.923	75.638
WHS	300	12.124	20.901	0	0.000	0.000	0	0.000	0.000
WLY	2300	78.681	103.537	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	5025	39.610	62.725	0	0.000	0.000
TOTAL	1003907	42020.412	42373.425	162948	1307.203	1636.447	36315	2793.462	5460.728

Table C.26. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 24 May 1988.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	114	6.588	11.389	850	8.714	15.194	0	0.000	0.000
BCF	3550	253.571	670.887	0	0.000	0.000	0	0.000	0.000
BLC	100	7.143	18.898	0	0.000	0.000	0	0.000	0.000
BLG	404	29.260	63.760	7135	71.850	97.911	246	18.923	35.231
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	16	1.231	2.522
CCF	3020	215.714	484.488	321	2.936	7.186	1520	116.923	216.560
CRP	3000	214.286	566.947	0	0.000	0.000	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	7802	488.398	704.673	436	4.074	8.688	3528	271.385	543.762
GZS	242	13.966	24.181	200	1.838	3.530	22105	1700.308	972.368
GRS	0	0.000	0.000	1206	11.675	12.098	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	119200	8535.906	21066.070	0	0.000	0.000	14250	1096.154	2702.966
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	1326	13.126	15.649	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	3500	188.235	236.468	0	0.000	0.000	1428	109.846	346.088
LNG	147979	10317.680	17927.998	15750	146.338	315.305	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	33000	2536.494	2986.659	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	97800	6304.433	3469.441	1250	11.538	41.603	7400	569.231	816.889
RRH	800	42.437	92.134	0	0.000	0.000	0	0.000	0.000
SBF	72250	4783.838	3965.619	850	8.776	31.644	17250	1326.923	3064.760
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	7800	557.143	1474.061	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	11922	868.924	799.690	2438	22.453	71.547	5393	414.846	586.140
WHC	3724	257.003	334.143	10816	116.110	111.843	1302	100.154	356.330
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	875	75.000	198.431	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	517082	35696.019	55095.937	42578	419.428	732.198	74438	5725.924	9643.616

Table C.27. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 23 June 1988.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	710	47.919	126.782	0	0.000	0.000	1647	126.692	443.742
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	95	5.429	14.363	1704	20.572	32.949	109	8.385	30.231
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	1088	67.571	84.321	135	1.877	6.767	0	0.000	0.000
CRP	6100	411.699	1089.252	0	0.000	0.000	1675	128.846	464.561
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRH	58	4.143	10.961	0	0.000	0.000	338	26.000	77.511
GZS	1049	69.141	145.991	0	0.000	0.000	14410	1108.462	689.827
GRS	0	0.000	0.000	159	1.890	4.137	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	18975	1256.328	2515.832	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	137	1.803	4.867	43	3.308	9.141
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	74	4.994	13.214	0	0.000	0.000	2750	211.538	762.713
LNG	64622	4177.312	5936.724	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	5	0.385	1.387
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	86200	5730.833	12126.049	0	0.000	0.000	0	0.000	0.000
QBS	1045	67.600	127.717	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	9998	636.422	452.044	0	0.000	0.000	0	0.000	0.000
RRH	650	43.870	116.068	0	0.000	0.000	60	4.615	16.641
SBF	76910	4738.209	3245.749	0	0.000	0.000	18432	1417.846	2661.337
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	1790	127.857	338.278	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	2844	182.300	195.340	520	6.051	8.062	2483	191.000	342.694
WHC	331	18.813	32.179	6877	88.028	122.589	710	54.615	157.407
WHS	620	41.845	110.711	0	0.000	0.000	0	0.000	0.000
WLY	0	0.000	0.000	1400	19.462	70.173	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	273159	17632.235	26681.575	10932	139.683	249.544	42662	3281.692	5657.192

Table C.28. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 21 July 1988.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	3000	214.286	566.947	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	316	22.448	41.371	3041	37.851	55.980	245	18.846	31.709
BLS	476	33.443	88.481	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	17800	1237.965	1632.627	70	0.897	3.236	236	18.154	44.381
CRP	6425	445.609	676.551	0	0.000	0.000	3825	294.231	1060.864
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	1745	125.016	312.136	0	0.000	0.000	1726	132.769	205.333
GZS	4411	296.369	384.675	241	3.083	7.909	13728	1055.923	555.327
GRS	70	5.042	13.340	577	7.062	15.238	0	0.000	0.000
GSH	0	0.000	0.000	3	0.038	0.138	0	0.000	0.000
HFC	1095	74.490	142.994	0	0.000	0.000	0	0.000	0.000
HYB	11015	780.141	1332.801	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	76	0.913	3.294	0	0.000	0.000
LES	0	0.000	0.000	844	10.259	26.232	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	4891	334.346	371.526	0	0.000	0.000	827	63.615	155.354
LNG	20350	1401.925	1163.065	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	135200	9382.991	4775.154	0	0.000	0.000	4150	319.231	1151.003
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	20293	1398.778	853.424	0	0.000	0.000	0	0.000	0.000
RRH	156	10.960	28.998	0	0.000	0.000	1741	133.923	369.992
SBF	30573	2101.130	618.770	0	0.000	0.000	920	70.769	255.162
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	2310	162.613	298.861	0	0.000	0.000	244	18.769	67.673
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	2189	149.086	178.080	530	6.370	22.968	2057	158.231	173.650
WHC	170	11.039	29.206	4210	52.270	63.285	286	22.000	65.299
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	10190	716.004	783.845	0	0.000	0.000	2850	219.231	790.448
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	272675	18903.681	14292.852	9592	118.743	198.280	32835	2525.692	4926.195

Table C.29. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 18 August 1988.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	9098	634.007	1677.425	0	0.000	0.000	71	5.462	19.692
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	726	9.663	21.956	62	4.769	11.649
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	2598	187.034	237.751	0	0.000	0.000	670	51.538	73.477
CRP	0	0.000	0.000	0	0.000	0.000	8800	676.923	2440.681
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	160	11.150	29.500	0	0.000	0.000	7214	554.923	1504.393
GZS	1866	134.590	208.895	234	3.073	5.995	12671	974.692	618.771
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	38	0.495	1.786	34	2.615	9.430
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	865	60.279	159.483	0	0.000	0.000	1030	79.231	197.578
LNG	5625	334.821	885.854	0	0.000	0.000	3564	274.154	988.476
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	9100	634.146	1677.794	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	1662	106.832	185.218	0	0.000	0.000	0	0.000	0.000
RRH	465	36.566	96.745	0	0.000	0.000	0	0.000	0.000
SBF	33335	2310.722	4319.010	0	0.000	0.000	890	68.462	246.842
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	350	20.833	55.120	0	0.000	0.000	140	10.769	38.829
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	6750	519.231	1872.113
WHB	384	27.530	48.804	0	0.000	0.000	1010	77.692	201.428
WHC	807	56.237	148.789	345	4.581	13.526	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	1200	83.624	221.247	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	67515	4638.371	9951.635	1343	17.812	43.263	42906	2745.538	8223.359

Table C.30. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 17 September 1988.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	830	66.489	175.912	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	424	5.334	17.902	28	2.154	7.766
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	2985	180.675	401.140	0	0.000	0.000	0	0.000	0.000
CRP	0	0.000	0.000	0	0.000	0.000	9050	696.154	2510.018
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	2812	176.768	146.852	779	9.272	11.573	5481	421.615	430.638
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	8850	631.074	1107.617	0	0.000	0.000	6800	523.077	1885.981
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	475	32.058	84.819	120	1.485	5.354	0	0.000	0.000
LNG	9230	666.300	1071.661	4710	58.210	178.604	3200	246.154	887.520
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	7775	535.374	611.669	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	5845	439.026	811.008	0	0.000	0.000	28975	2228.846	5888.565
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	993	59.723	110.355	0	0.000	0.000	1000	76.923	277.350
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	850	61.369	80.636	0	0.000	0.000	0	0.000	0.000
WHC	0	0.000	0.000	25	0.316	1.140	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	3800	274.156	505.529	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	44445	3123.012	5107.198	6058	74.617	214.573	54534	4194.923	11887.838

Table C.31. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 16 October 1988.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	135	10.814	28.612	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	398	5.117	6.510	60	4.615	11.266
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	4284	310.475	678.025	0	0.000	0.000	628	48.308	174.176
CRP	3250	260.347	688.814	0	0.000	0.000	3400	261.538	658.962
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	145	2.032	5.397	0	0.000	0.000
GZS	1805	136.819	164.265	5	0.064	0.231	7728	594.462	500.159
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	3550	284.379	752.397	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	106	1.351	4.873	30	2.308	8.321
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	5620	450.200	1191.118	0	0.000	0.000	410	31.538	113.714
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	28400	2263.236	4815.906	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	13790	1056.634	940.487	0	0.000	0.000	20130	1548.462	3041.304
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	135	1.730	5.758	774	59.538	152.980
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	780	62.483	165.315	0	0.000	0.000	1320	101.538	366.102
WHB	1041	77.547	147.233	0	0.000	0.000	914	70.308	184.665
WHC	0	0.000	0.000	180	2.308	8.321	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	62655	4912.934	9572.172	969	12.602	31.090	35394	2722.615	5211.649

Table C.32. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 19 November 1988.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	226	2.897	6.330	0	0.000	0.000
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	209	16.077	35.082
CCF	335	23.929	63.309	0	0.000	0.000	0	0.000	0.000
CRP	0	0.000	0.000	750	9.615	34.669	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	90	6.923	24.962
GZS	260	18.571	49.135	80	1.026	3.698	5494	422.615	628.693
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	45	0.577	2.080	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	9	0.692	1.797
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	199750	14267.857	13949.774	0	0.000	0.000	6500	500.000	1802.776
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	4800	342.857	447.613	0	0.000	0.000	1100	84.615	305.085
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	1770	126.429	262.150	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	4839	345.643	789.380	0	0.000	0.000	1987	152.846	444.142
WHC	0	0.000	0.000	455	5.833	14.248	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	1400	100.000	264.575	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	213154	15225.286	15825.936	1556	29.182	61.025	15389	1183.768	3242.537

Table C.33. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 9 December 1988.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	125	8.929	23.623	293	3.756	6.053	61	4.692	16.918
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	89	6.846	8.444
CCF	3632	225.130	369.551	0	0.000	0.000	5907	454.385	1425.344
CRP	0	0.000	0.000	1400	17.004	61.309	1250	96.154	346.688
CSH	0	0.000	0.000	11	0.141	0.508	0	0.000	0.000
DRM	174	12.429	32.883	0	0.000	0.000	198	15.231	54.915
GZS	0	0.000	0.000	122	1.452	4.060	3035	233.462	420.353
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	10400	742.857	1965.415	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	7429	529.916	1387.130	0	0.000	0.000	803	61.769	222.712
WHC	0	0.000	0.000	81	1.038	3.744	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	2250	160.714	425.210	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	24010	1679.975	4203.812	1907	32.733	75.674	11343	872.539	2495.374

Table C.34. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 29 January 1989.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	7350	474.036	812.378	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	1515	103.166	164.861	0	0.000	0.000	662	50.923	183.606
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	251	3.297	5.707	391	30.077	82.116
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	18	1.385	3.754
CCF	12226	785.417	1310.475	645	8.554	30.843	3302	254.000	575.346
CRP	0	0.000	0.000	0	0.000	0.000	1350	103.846	374.423
CSH	0	0.000	0.000	14	0.187	0.675	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	200	15.385	46.700
GZS	0	0.000	0.000	74	0.981	3.539	1060	81.538	217.693
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	26	0.345	1.243	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	17994	1233.874	2225.772	0	0.000	0.000	0	0.000	0.000
QBS	700	44.444	117.589	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	12424	796.399	756.504	0	0.000	0.000	1300	100.000	360.555
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	39021	2541.191	1890.410	0	0.000	0.000	4050	311.538	1123.268
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	755	49.780	131.706	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	1500	100.446	265.756	0	0.000	0.000	0	0.000	0.000
WHB	8014	515.380	598.851	0	0.000	0.000	292	22.462	62.998
WHC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	7550	496.047	525.998	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	109049	7140.180	8800.300	1010	13.364	42.007	12625	971.154	3030.459

Table C.35. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 26 February 1989.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	5	0.385	0.961
CCF	0	0.000	0.000	0	0.000	0.000	358	27.538	99.291
CRP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	250	19.231	69.338
GZS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
QBS	450	36.048	95.374	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	7600	555.568	462.808	0	0.000	0.000	1175	90.385	325.886
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	2300	170.375	304.199	0	0.000	0.000	0	0.000	0.000
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	400	29.814	78.880	65	0.836	3.013	64	4.923	17.750
WHC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	10750	791.805	941.261	65	0.836	3.013	1852	142.462	513.226

Table C.36. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 11 March 1989.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	7	0.538	1.941
CCF	0	0.000	0.000	116	1.489	3.746	0	0.000	0.000
CRP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	0	0.000	0.000	6	0.078	0.282	0	0.000	0.000
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	3420	216.657	378.160	0	0.000	0.000	1200	92.308	332.820
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	1450	86.913	229.950	801	10.443	37.654	9850	757.692	1926.984
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	960	63.297	167.467	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	5830	366.867	775.577	923	12.010	41.682	11057	850.538	2261.745

Table C.37. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 25 April 1989.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	253	3.170	6.454	319	24.538	41.001
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	0	0.000	0.000	81	1.019	3.673	0	0.000	0.000
CRP	1200	71.429	188.982	0	0.000	0.000	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	1241	80.026	132.044	0	0.000	0.000	30873	2374.846	2833.562
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	35510	2331.586	4734.284	0	0.000	0.000	7800	600.000	2163.331
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	16	0.202	0.727	68	5.231	14.342
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	4489	237.114	405.365	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	52109	2649.716	2510.784	0	0.000	0.000	6610	508.462	1084.864
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	727	34.239	90.587	0	0.000	0.000	852	65.538	236.302
WHB	184742	11065.928	7388.736	2587	32.419	67.216	46007	3539.000	5029.803
WHC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	280018	16470.038	15450.782	2937	36.810	78.070	92529	7117.615	11403.205

Table C.38. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 12 May 1989.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	184	2.476	4.511	48	3.692	13.313
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CRP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	0	0.000	0.000	0	0.000	0.000	1113	85.615	247.951
GZS	2437	152.769	332.653	0	0.000	0.000	12933	994.846	1079.640
GRS	0	0.000	0.000	85	1.134	4.088	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	16300	1012.422	2678.618	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	373	5.033	8.941	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	68	5.231	10.505
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	2544	167.736	290.364	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	730	56.154	202.466
SBF	16077	998.571	2641.972	0	0.000	0.000	2272	174.769	630.139
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	8	0.107	0.385	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	868	57.231	151.418	0	0.000	0.000	0	0.000	0.000
WHB	74733	4641.801	12281.052	0	0.000	0.000	2448	188.308	542.111
WHC	457	28.385	75.100	0	0.000	0.000	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	113416	7058.915	18451.177	650	8.750	17.925	19612	1508.615	2726.125

Table C.39. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 9 June 1989.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	3550	190.179	503.165	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCP	310	16.924	44.778	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	1114	65.549	120.780	6369	71.205	114.639	128	9.846	18.316
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	9736	497.538	697.564	1360	14.735	53.126	1160	89.231	135.032
CRP	5500	267.361	459.686	0	0.000	0.000	1021	78.538	283.174
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	4183	228.371	604.214	0	0.000	0.000	2930	225.385	585.664
GZS	804	44.581	93.211	90	0.984	3.549	14163	1089.462	842.090
GRS	285	15.560	41.167	533	6.344	9.290	52	4.000	14.422
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	3500	236.220	624.981	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	120	1.357	4.894	0	0.000	0.000
LES	0	0.000	0.000	1357	16.489	33.547	21	1.615	5.824
LGP	0	0.000	0.000	0	0.000	0.000	22	1.692	6.102
LMB	222	8.769	23.200	0	0.000	0.000	0	0.000	0.000
LNG	224590	12191.144	18424.960	15692	172.130	272.496	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
PDF	58300	2863.290	3348.409	0	0.000	0.000	14700	1130.769	4077.046
QBS	2384	117.632	142.719	0	0.000	0.000	0	0.000	0.000
RBT	1042	53.039	112.353	0	0.000	0.000	0	0.000	0.000
RCS	62690	3784.848	3647.812	1273	13.323	48.036	4072	313.231	922.429
RRH	230	9.085	24.036	0	0.000	0.000	0	0.000	0.000
SBF	41795	2241.173	932.613	0	0.000	0.000	2245	172.692	622.651
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	1400	75.000	198.431	0	0.000	0.000	0	0.000	0.000
SPG	4650	337.612	474.666	0	0.000	0.000	0	0.000	0.000
SRH	820	32.540	86.092	0	0.000	0.000	803	61.769	222.712
WHB	11573	636.041	976.381	0	0.000	0.000	1675	128.846	241.736
WHC	1185	61.713	140.315	1117	12.043	21.435	0	0.000	0.000
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	439863	23974.169	31721.533	27911	308.610	561.012	42992	3307.076	7977.198

Table C.40. Total biomass (g), biomass catch-per-unit-effort (CPUE) values, and standard deviations (SD) of biomass CPUE by species and gear, Pensacola Dam tailwaters, 25 July 1989.

	Gill net			Trap net			Electrofishing		
Sp.	g	CPUE	SD	g	CPUE	SD	g	CPUE	SD
BBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	88	5.131	13.576	10236	118.665	185.988	0	0.000	0.000
BLS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	480	28.534	48.865	0	0.000	0.000	1452	111.692	195.391
CRP	4200	264.706	700.346	0	0.000	0.000	19050	1465.385	2611.863
CSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	82	4.621	12.234	96	1.065	3.840	779	59.923	216.056
GZS	1093	65.885	95.420	291	3.275	5.319	8458	650.615	621.215
GRS	0	0.000	0.000	575	6.949	17.724	0	0.000	0.000
GSH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HFC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	5100	321.429	850.420	0	0.000	0.000	7000	538.462	1941.451
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	531	6.114	12.615	17	1.308	4.715
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	9050	510.338	1350.228	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
OSS	0	0.000	0.000	30	0.342	1.233	0	0.000	0.000
PDF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
QBS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RBT	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	5725	332.607	319.633	0	0.000	0.000	0	0.000	0.000
RRH	1217	68.628	181.572	0	0.000	0.000	0	0.000	0.000
SBF	30000	1812.306	2816.170	0	0.000	0.000	8280	636.923	975.546
SNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	1600	85.714	226.779	0	0.000	0.000	1940	149.231	336.703
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	1650	91.149	157.581	415	4.788	17.265	1275	98.077	251.095
WHB	0	0.000	0.000	0	0.000	0.000	100	7.692	27.735
WHC	0	0.000	0.000	292	3.300	8.720	156	12.000	43.267
WHS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WLY	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
YBH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	60285	3591.051	6772.824	12466	144.498	252.704	48507	3731.308	7225.037

Table C.41. Probability values of analyses of variance testing whether differences exist among monthly mean biomass catch-per-unit-effort rates, by gear, of fishes collected in the Pensacola Dam tailwaters, January 1988 to July 1989. Asterisks denote statistically significant probability values (alpha=0.05).

Species	Gill net	Trap net	Electrofishing
BBF	0.0808	--	--
BBH	0.0044*	0.0001*	--
BCF	0.4670	0.4595	0.5352
BLC	0.2790	--	--
BLG	0.0633	0.0001*	0.0821
BLS	0.4642	--	--
BSS	--	--	0.0007*
CCF	0.0011*	0.0001*	0.2268
CRP	0.1084	0.5815	0.0713
CSH	--	0.5237	--
DRM	0.0149*	0.0053*	0.0720
GRS	0.5439	0.0001*	0.4595
GSH	--	0.4595	--
GZS	0.0009*	0.0027*	0.0001*
HFC	0.0253*	--	--
HYB	0.0532	0.4726	0.3151
HYS	--	0.5214	--
LES	--	0.0007*	0.5185
LGP	--	0.5252	0.0174*
LMB	0.2594	0.4595	0.6079
LNG	0.0037*	0.0002*	0.5260
MSS	--	--	0.0953
OSS	--	0.4824	--
PDF	0.0001*	--	0.6084
QBS	0.0075*	--	--
RBT	0.0880	--	--
RCS	0.0001*	0.5717	0.0004*
RRH	0.6542	--	0.1083
SBF	0.0001*	0.5254	0.0827
SNG	--	0.4595	--
SPB	0.5263	0.2959	0.0499*
SPG	0.3058	--	--
SRH	0.5610	0.4595	0.5368
WHB	0.0001*	0.0001*	0.0001*
WHC	0.0001*	0.0001*	0.5091
WHS	0.4496	--	--
WLY	0.0003*	0.4595	0.4595
YBH	--	0.0001*	--
TOTAL	0.0001*	0.0001*	0.0001*

Table C.42. Total catches (N) and relative abundances (%) of fishes captured with gill nets, trap nets, and by electrofishing in the headwaters of Hudson Lake, January to December 1988.

	Gill net		Trap net		Electrofishing		Combined	
Sp.	N	%	N	%	N	%	N	%
BCF	1	0.145	0	0.000	0	0.000	1	0.058
BLG	2	0.289	225	46.778	5	0.886	232	13.364
BSS	0	0.000	0	0.000	221	39.184	221	12.730
CCF	119	17.221	14	2.911	3	0.532	136	7.834
CRP	40	5.789	1	0.208	14	2.482	55	3.168
DRM	55	7.959	7	1.455	2	0.355	64	3.687
FCF	3	0.434	0	0.000	2	0.355	5	0.288
GZS	89	12.880	42	8.732	256	45.390	387	22.293
GRS	0	0.000	4	0.832	4	0.709	8	0.461
HYB	4	0.579	0	0.000	0	0.000	4	0.230
HYS	0	0.000	1	0.208	0	0.000	1	0.058
LES	0	0.000	9	1.871	3	0.532	12	0.691
LGP	0	0.000	0	0.000	1	0.177	1	0.058
LMB	17	2.460	2	0.416	18	3.191	37	2.131
LNG	8	1.158	0	0.000	0	0.000	8	0.461
MSS	0	0.000	0	0.000	2	0.355	2	0.115
RCS	30	4.342	4	0.832	0	0.000	34	1.958
RRH	2	0.289	0	0.000	1	0.177	3	0.173
SBF	121	17.511	0	0.000	31	5.496	152	8.756
SPB	0	0.000	0	0.000	1	0.177	1	0.058
SPG	2	0.289	2	0.416	0	0.000	4	0.230
SRH	5	0.724	0	0.000	0	0.000	5	0.288
WHB	191	27.641	25	5.198	0	0.000	216	12.442
WHC	2	0.289	140	29.106	0	0.000	142	8.180
WRM	0	0.000	5	1.040	0	0.000	5	0.288
TOTAL	691		481		564		1736	

Table C.43. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Hudson Lake headwaters, 14 January 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CRP	10	0.429	0.596	0	0.000	0.000	1	0.077	0.277
DRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
FCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	1	0.042	0.111	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	11	0.470	0.571	0	0.000	0.000	1	0.077	0.277

Table C.44. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Hudson Lake headwaters, 5 February 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	5	0.330	0.872	0	0.000	0.000	0	0.000	0.000
CRP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
DRM	1	0.066	0.174	0	0.000	0.000	0	0.000	0.000
FCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	1	0.059	0.156	0	0.000	0.000	0	0.000	0.000
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	1	0.066	0.174	0	0.000	0.000	1	0.077	0.277
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	8	0.504	0.888	0	0.000	0.000	0	0.000	0.000
WHC	0	0.000	0.000	1	0.012	0.043	0	0.000	0.000
WRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	16	1.025	1.766	1	0.012	0.043	1	0.077	0.277

Table C.45. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Hudson Lake headwaters, 4 March 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	45	0.577	0.706	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	7	0.500	0.913	1	0.013	0.046	0	0.000	0.000
CRP	6	0.429	0.932	1	0.012	0.045	1	0.077	0.277
DRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
FCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	17	1.214	1.822	6	0.077	0.277	17	1.308	2.626
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	3	0.214	0.267	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	2	0.026	0.092	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	2	0.143	0.244	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
RCS	1	0.071	0.189	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	4	0.286	0.267	0	0.000	0.000	9	0.692	1.702
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	1	0.071	0.189	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	46	3.286	3.988	0	0.000	0.000	0	0.000	0.000
WHC	0	0.000	0.000	9	0.112	0.405	0	0.000	0.000
WRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	87	6.214	5.522	64	0.817	0.736	28	2.154	3.579

Table C.46. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Hudson Lake headwaters, 28 April 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	25	0.369	0.303	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
CCF	11	0.756	0.961	6	0.090	0.172	0	0.000	0.000
CRP	2	0.138	0.236	0	0.000	0.000	3	0.231	0.599
DRM	4	0.286	0.567	0	0.000	0.000	0	0.000	0.000
FCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	27	1.919	3.412	6	0.091	0.327	46	3.538	4.136
GRS	0	0.000	0.000	1	0.015	0.054	1	0.077	0.277
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	2	0.030	0.074	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	4	0.276	0.373	0	0.000	0.000	7	0.538	0.967
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	2	0.143	0.244	1	0.015	0.055	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	2	0.143	0.378	0	0.000	0.000	0	0.000	0.000
WHC	0	0.000	0.000	48	0.704	0.929	0	0.000	0.000
WRM	0	0.000	0.000	1	0.015	0.055	0	0.000	0.000
TOTAL	52	3.659	3.962	90	1.330	1.062	58	4.462	5.174

Table C.47. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Hudson Lake headwaters, 25 May 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	32	0.410	0.555	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	16	0.552	0.571	0	0.000	0.000	0	0.000	0.000
CRP	12	0.406	0.398	0	0.000	0.000	1	0.077	0.277
DRM	5	0.172	0.261	2	0.026	0.063	0	0.000	0.000
FCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	20	0.687	0.391	5	0.064	0.231	38	2.923	2.139
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	1	0.013	0.046	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	5	0.172	0.233	0	0.000	0.000	0	0.000	0.000
LNG	1	0.034	0.091	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
RCS	9	0.307	0.265	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	41	1.413	1.071	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	1	0.034	0.091	2	0.026	0.092	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	6	0.200	0.278	0	0.000	0.000	0	0.000	0.000
WHC	0	0.000	0.000	13	0.167	0.333	0	0.000	0.000
WRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	116	3.977	1.844	55	0.705	0.916	40	3.077	2.216

Table C.48. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Hudson Lake headwaters, 24 June 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BCF	1	0.066	0.174	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	12	0.154	0.259	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	35	2.153	4.358	0	0.000	0.000	0	0.000	0.000
CRP	3	0.166	0.210	0	0.000	0.000	0	0.000	0.000
DRM	26	1.682	4.146	3	0.038	0.139	0	0.000	0.000
FCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	3	0.143	0.378	0	0.000	0.000	12	0.923	1.382
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	1	0.013	0.046	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
LNG	2	0.095	0.163	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	5	0.276	0.586	3	0.038	0.100	0	0.000	0.000
RRH	1	0.045	0.119	0	0.000	0.000	0	0.000	0.000
SBF	26	1.473	0.869	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	7	0.333	0.745	0	0.000	0.000	0	0.000	0.000
WHC	0	0.000	0.000	7	0.090	0.161	0	0.000	0.000
WRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	109	6.432	8.637	26	0.333	0.385	13	1.000	1.581

Table C.49. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Hudson Lake headwaters, 20 July 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	1	0.054	0.142	16	0.205	0.282	2	0.154	0.376
BSS	0	0.000	0.000	0	0.000	0.000	2	0.154	0.376
CCF	11	0.644	0.583	0	0.000	0.000	0	0.000	0.000
CRP	1	0.055	0.146	0	0.000	0.000	1	0.077	0.277
DRM	3	0.161	0.425	2	0.026	0.063	1	0.077	0.277
FCF	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
GZS	10	0.552	1.099	14	0.179	0.443	53	4.077	7.365
GRS	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	1	0.013	0.046	0	0.000	0.000
LES	0	0.000	0.000	2	0.026	0.092	1	0.077	0.277
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	1	0.066	0.174	2	0.026	0.092	3	0.231	0.438
LNG	1	0.071	0.189	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	3	0.193	0.243	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
SBF	12	0.782	0.934	0	0.000	0.000	3	0.231	0.438
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	29	1.554	4.110	3	0.037	0.134	0	0.000	0.000
WHC	0	0.000	0.000	14	0.179	0.382	0	0.000	0.000
WRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	72	4.131	4.334	54	0.691	0.739	69	5.308	8.169

Table C.50. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Hudson Lake headwaters, 17 August 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	1	0.071	0.189	4	0.051	0.125	1	0.077	0.277
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	14	0.981	0.485	0	0.000	0.000	3	0.231	0.599
CRP	1	0.075	0.197	0	0.000	0.000	0	0.000	0.000
DRM	4	0.278	0.261	0	0.000	0.000	0	0.000	0.000
FCF	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
GZS	5	0.363	0.390	6	0.077	0.277	12	0.923	1.320
GRS	0	0.000	0.000	1	0.013	0.046	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	1	0.013	0.046	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	1	0.066	0.174	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	5	0.366	0.647	0	0.000	0.000	0	0.000	0.000
RRH	1	0.066	0.174	0	0.000	0.000	0	0.000	0.000
SBF	4	0.275	0.371	0	0.000	0.000	1	0.077	0.277
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHB	6	0.429	0.607	17	0.218	0.692	0	0.000	0.000
WHC	1	0.071	0.189	7	0.090	0.277	0	0.000	0.000
WRM	0	0.000	0.000	2	0.026	0.092	0	0.000	0.000
TOTAL	43	3.041	0.844	38	0.487	0.878	18	1.385	1.557

Table C.51. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Hudson Lake headwaters, 18 September 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	44	0.591	0.678	2	0.154	0.376
BSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
CCF	4	0.243	0.485	7	0.088	0.223	0	0.000	0.000
CRP	1	0.061	0.162	0	0.000	0.000	1	0.077	0.277
DRM	9	0.535	0.325	0	0.000	0.000	0	0.000	0.000
FCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	2	0.122	0.324	5	0.064	0.161	54	4.154	4.845
GRS	0	0.000	0.000	2	0.027	0.067	2	0.154	0.376
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	2	0.154	0.376
LGP	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
LMB	2	0.120	0.206	0	0.000	0.000	1	0.077	0.277
LNG	4	0.239	0.470	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	3	0.179	0.327	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	11	0.665	0.890	0	0.000	0.000	3	0.231	0.438
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	1	0.059	0.156	0	0.000	0.000	0	0.000	0.000
WHB	40	2.387	2.357	5	0.064	0.128	0	0.000	0.000
WHC	0	0.000	0.000	30	0.387	0.604	0	0.000	0.000
WRM	0	0.000	0.000	1	0.014	0.049	0	0.000	0.000
TOTAL	77	4.611	3.099	94	1.245	0.983	66	5.077	4.924

Table C.52. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Hudson Lake headwaters, 15 October 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	26	0.346	0.636	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	116	8.923	19.670
CCF	4	0.314	0.445	0	0.000	0.000	0	0.000	0.000
CRP	1	0.079	0.208	0	0.000	0.000	0	0.000	0.000
DRM	2	0.142	0.375	0	0.000	0.000	0	0.000	0.000
FCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	3	0.234	0.618	0	0.000	0.000	10	0.770	1.092
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	0	0.000	0.000	0	0.000	0.000	3	0.231	0.438
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	2	0.150	0.257	0	0.000	0.000	9	0.692	1.494
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	1	0.071	0.189	0	0.000	0.000	0	0.000	0.000
WHB	9	0.694	1.629	0	0.000	0.000	0	0.000	0.000
WHC	0	0.000	0.000	11	0.151	0.543	0	0.000	0.000
WRM	0	0.000	0.000	1	0.014	0.049	0	0.000	0.000
TOTAL	22	1.684	2.236	38	0.511	0.795	138	10.615	21.274

Table C.53. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Hudson Lake headwaters, 18 November 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	12	0.154	0.300	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	26	2.000	5.492
CCF	10	0.695	0.812	0	0.000	0.000	0	0.000	0.000
CRP	3	0.210	0.263	0	0.000	0.000	5	0.385	0.650
DRM	1	0.067	0.179	0	0.000	0.000	0	0.000	0.000
FCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
GZS	1	0.067	0.179	0	0.000	0.000	5	0.385	0.870
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	1	0.071	0.189	0	0.000	0.000	3	0.231	0.438
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	4	0.282	0.565	0	0.000	0.000	0	0.000	0.000
SPB	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	1	0.067	0.179	0	0.000	0.000	0	0.000	0.000
WHB	38	2.620	4.321	0	0.000	0.000	0	0.000	0.000
WHC	1	0.067	0.179	0	0.000	0.000	0	0.000	0.000
WRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	60	4.148	5.784	12	0.154	0.300	40	3.077	5.894

Table C.54. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE by species and gear, Hudson Lake headwaters, 11 December 1988.

	Gill net			Trap net			Electrofishing		
Sp.	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
BCF	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
BLG	0	0.000	0.000	9	0.150	0.204	0	0.000	0.000
BSS	0	0.000	0.000	0	0.000	0.000	76	5.846	20.186
CCF	2	0.134	0.354	0	0.000	0.000	0	0.000	0.000
CRP	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
DRM	0	0.000	0.000	0	0.000	0.000	1	0.077	0.277
FCF	3	0.206	0.544	0	0.000	0.000	0	0.000	0.000
GZS	0	0.000	0.000	0	0.000	0.000	9	0.692	1.797
GRS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
HYS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LES	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LGP	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
LMB	1	0.067	0.177	0	0.000	0.000	0	0.000	0.000
LNG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
MSS	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
RCS	2	0.159	0.420	0	0.000	0.000	0	0.000	0.000
RRH	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SBF	16	1.206	1.664	0	0.000	0.000	5	0.385	0.768
SPB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SPG	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
SRH	2	0.137	0.363	0	0.000	0.000	0	0.000	0.000
WHB	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WHC	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
WRM	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
TOTAL	26	1.908	1.987	9	0.150	0.204	92	7.077	21.681

Table C.55. Probability values of analyses of variance testing whether differences exist among monthly mean numeric catch-per-unit-effort rates, by gear, of fishes collected in the Hudson Lake headwaters, January to December 1988. Asterisks denote statistically significant probability values (alpha=0.05).

Species	Gill net	Trap net	Electrofishing
BCF	0.4551	--	--
BLG	0.5329	0.0006*	0.0997
BSS	--	--	0.1011
CCF	0.3592	0.0146*	0.0402*
CRP	0.2275	0.4494	0.1054
DRM	0.4455	0.3557	0.5334
FCF	0.4551	--	0.5334
GRS	--	0.2184	0.2146
GZS	0.0964	0.5165	0.0004*
HYB	0.0002*	--	--
HYS	--	0.4494	--
LES	--	0.6926	0.0944
LGP	--	--	0.4494
LMB	0.1834	0.4494	0.0053*
LNG	0.1613	--	--
MSS	--	--	0.5334
RCS	0.3615	0.1020	--
RRH	0.5306	--	0.4494
SBF	0.0004*	--	0.0783
SPB	--	--	0.4494
SPG	0.5180	0.4494	--
SRH	0.6670	--	--
WHB	0.0688	0.2723	--
WHC	0.5362	0.0006*	--
WRM	--	0.6831	--
TOTAL	0.1441	0.0001*	0.1918

Table C.56. Water quality conditions in the Pensacola Dam tailwaters and headwaters of Hudson Lake, January 1988 to July 1989.

Date	Station	Temperature (C)	pH	D.O. (mg/l)	Conductivity (umhos/cm)
22 JAN 88	1	3.31	8.07	11.95	251
	2	3.35	7.85	11.65	250
	3	3.36	7.73	11.64	251
	4	3.43	7.82	11.65	252
	5	3.55	7.79	11.63	251
	6	3.60	7.77	11.58	251
	7	4.49	7.72	11.66	252
	8	3.32	7.69	11.55	251
	9	3.25	7.67	11.62	254
	10	3.29	7.64	11.64	257
	11	3.27	7.68	11.63	254
	12	3.27	7.70	11.57	256
4-5 FEB 88	1	3.70	8.25	13.04	272
	2	3.68	8.04	12.42	273
	3	3.51	7.92	12.12	269
	4	3.41	7.96	12.77	262
	5	3.39	7.99	12.40	264
	6	3.21	8.03	12.31	264
	7	2.84	7.81	12.53	264
	8	2.99	7.81	12.29	265
	9	3.00	7.75	12.32	269
	10	3.01	7.80	12.32	273
	11	3.06	7.79	12.28	280
	12	3.13	7.80	12.29	292
28-29 MAR 88	1	8.90	7.96	10.72	345
	2	8.87	7.94	10.70	345
	3	8.83	7.93	10.73	345
	4	8.84	--	10.73	347
	5	8.90	--	10.69	348
	6	8.93	7.82	10.59	347
	7	8.99	7.78	10.63	346
	8	9.05	--	10.72	347
	9	9.25	--	10.62	348
	10	9.34	7.65	10.58	348
	11	9.23	7.62	10.56	348
	12	9.37	7.96	10.43	347

Table C.56. (Continued).

Date	Station	Temperature (C)	pH	D.O. (mg/l)	Conductivity (umhos/cm)
28 APR 88	1	14.90	7.31	7.30	269
	2	14.90	7.34	7.32	270
	3	14.92	7.35	7.28	271
	4	14.98	7.47	7.31	268
	5	15.07	7.47	7.31	269
	6	15.24	7.41	7.28	268
	7	15.49	7.46	7.20	266
	8	15.82	7.54	7.26	265
	9	15.60	7.43	7.26	265
	10	15.54	7.61	7.25	267
	11	15.48	7.45	7.21	267
	12	16.60	7.42	7.21	266
2 MAY 88	1	14.61	7.19	7.17	304
	2	15.89	7.39	6.93	281
	3	15.30	7.37	7.08	275
24-25 MAY 88	1	16.90	7.38	7.03	288
	2	19.01	7.54	7.06	289
	3	18.90	7.51	7.09	289
	4	18.79	7.58	7.42	288
	5	18.51	7.41	7.15	287
	6	19.63	7.51	7.21	287
	7	18.00	--	--	--
	8	18.50	--	--	--
	9	20.00	--	--	--
	10	22.00	--	--	--
	11	20.50	--	--	--
	12	22.00	--	--	--
23 JUN 88	1	18.63	7.28	5.92	297
	2	20.83	7.42	7.20	296
	3	22.05	7.26	5.50	299
	4	20.20	7.33	5.10	299
	5	21.40	7.38	6.63	300
	6	--	--	--	--
	7	--	--	--	--
	8	--	--	--	--
	9	--	--	--	--
	10	--	--	--	--
	11	--	--	--	--
	12	--	--	--	--

Table C.56. (Continued).

Date	Station	Temperature (C)	pH	D.O. (mg/l)	Conductivity (umhos/cm)
20 JUL 88	1	22.26	7.39	4.28	298
	2	22.21	7.34	4.44	298
	3	22.26	7.27	4.18	295
	4	21.94	7.49	4.09	299
	5	22.10	7.21	4.22	298
	6	22.23	7.15	4.25	299
	7	22.08	6.87	4.33	300
	8	22.08	7.11	5.50	306
	9	26.51	8.28	8.53	287
	10	27.20	8.29	9.16	286
	11	26.88	7.94	7.80	287
	12	27.50	8.40	8.88	283
17-18 AUG 88	1	18.44	7.15	1.98	325
	2	21.77	7.21	4.36	321
	3	22.99	7.22	3.26	320
	4	23.59	7.32	4.20	318
	5	22.91	7.14	3.45	316
	6	23.20	6.78	4.02	315
	7	25.98	7.03	6.55	307
	8	29.03	7.81	8.75	292
	9	30.96	7.65	9.90	287
	10	31.21	8.74	8.32	286
	11	30.39	8.50	7.80	293
	12	30.77	8.53	8.71	290
16 SEP 88	1	22.10	7.48	5.15	336
	2	22.63	7.49	5.34	336
	3	22.55	7.49	5.13	336
	4	22.45	7.42	5.03	334
	5	22.42	7.22	4.94	335
	6	22.28	7.45	4.94	333
	7	23.13	7.50	5.65	333
	8	24.05	7.67	6.15	332
	9	24.66	7.82	7.18	332
	10	25.00	8.30	8.58	328
	11	25.53	8.29	8.28	329
	12	25.15	8.33	8.17	327

Table C.56. (Continued).

Date	Station	Temperature (C)	pH	D.O. (mg/l)	Conductivity (umhos/cm)
15 OCT 88	1	18.62	7.25	6.15	387
	2	18.73	7.34	6.41	386
	3	18.79	7.34	6.96	387
	4	18.66	7.31	4.95	389
	5	18.48	7.30	5.33	386
	6	18.60	6.84	5.16	386
	7	18.60	6.95	6.48	385
	8	18.76	7.44	6.64	382
	9	18.76	7.55	7.83	382
	10	18.70	7.58	8.01	382
	11	18.58	7.64	8.34	382
	12	18.26	7.73	8.82	381
19 NOV 88	1	14.65	--	8.80	394
	2	14.48	--	8.88	394
	3	14.45	--	8.11	395
	4	14.31	--	8.60	395
	5	14.70	--	8.60	393
	6	14.32	--	8.33	394
	7	14.32	--	8.75	393
	8	14.42	7.24	8.55	395
	9	14.11	8.04	8.47	396
	10	13.81	6.99	8.50	396
	11	13.74	7.29	8.79	398
	12	13.55	7.79	9.45	398
9 DEC 88	1	10.86	7.52	9.46	345
	2	10.83	7.43	9.87	344
	3	10.83	7.48	9.93	343
	4	10.67	7.44	9.55	342
	5	10.80	7.44	9.48	342
	6	10.63	7.40	9.90	343
	7	10.29	6.97	9.75	340
	8	10.38	--	9.54	342
	9	10.44	--	9.63	342
	10	10.57	7.08	9.90	340
	11	10.67	7.40	9.78	341
	12	10.59	7.62	9.75	343
29 JAN 89	1	7.24	7.38	11.06	363
	2	7.32	7.96	12.56	358
	3	7.09	7.78	11.86	362
26 FEB 89	1	5.34	7.47	11.60	365
	2	5.34	7.62	11.13	357
	3	5.05	7.59	11.40	358

Table C.56. (Concluded).

Date	Station	Temperature (C)	pH	D.O. (mg/l)	Conductivity (umhos/cm)
11 MAR 89	1	6.36	7.46	9.72	360
	2	6.30	7.60	11.03	347
	3	5.65	7.58	11.20	345
25 APR 89	1	12.00	7.51	10.30	342
	2	12.75	7.69	11.73	338
	3	12.83	7.50	10.57	339
15 MAY 89	1	14.88	7.83	8.81	308
	2	15.29	7.95	8.30	309
	3	15.65	8.00	8.33	307
9 JUN 89	1	18.79	7.62	7.04	315
	2	20.13	7.97	7.62	312
	3	19.87	7.97	7.27	312
25 JUL 89	1	22.85	7.24	4.72	340
	2	23.49	7.37	4.48	334
	3	23.30	7.39	4.47	333

Table C.57. Correlation coefficients (CC) and probability values (P) of correlation analyses testing for significant relationships between log-transformed numeric catch-per-unit-effort rates and water temperatures, by gear, in the Pensacola Dam tailwaters, January 1988 to July 1989. Asterisks denote statistically significant probability values (alpha=0.05).

	Gill net		Trap net		Electrofishing	
Species	CC	P	CC	P	CC	P
BBF	0.2083	0.0193*	--	--	--	--
BBH	0.2563	0.0038*	-0.0778	0.2361	--	--
BCF	0.1126	0.2095	-0.2459	0.0001*	0.0296	0.6521
BLC	0.2096	0.0185*	--	--	--	--
BLG	0.2795	0.0015*	0.4059	0.0001*	0.1018	0.1203
BLS	0.2612	0.0031*	--	--	--	--
BSS	--	--	--	--	-0.1997	0.0021*
CCF	0.0425	0.6366	-0.0485	0.4605	0.0950	0.1474
CRP	0.2987	0.0007*	-0.2560	0.0001*	0.2120	0.0011*
CSH	--	--	-0.2726	0.0001*	--	--
DRM	0.3108	0.0004*	-0.1076	0.1005	0.2602	0.0001*
GRS	0.2573	0.0036*	0.1800	0.0058*	0.0505	0.4423
GSH	--	--	-0.2318	0.0004*	--	--
GZS	0.4807	0.0001*	0.1012	0.1227	0.6456	0.0001*
HFC	0.2331	0.0086*	--	--	--	--
HYB	0.0062	0.9451	-0.2886	0.0001*	0.0711	0.2785
HYS	0.2706	0.0022*	-0.1384	0.0343*	--	--
LES	--	--	0.1934	0.0030*	0.1492	0.0225*
LGP	--	--	-0.2812	0.0001*	0.0082	0.9002
LMB	0.2954	0.0008*	-0.2321	0.0003*	0.1523	0.0197*
LNG	0.4103	0.0001*	-0.0536	0.4146	0.1014	0.1221
MSS	--	--	--	--	0.0353	0.5906
OSS	--	--	-0.2341	0.0003*	--	--
PDF	0.2632	0.0029*	--	--	0.0683	0.2982
QBS	0.3017	0.0006*	--	--	--	--
RBT	0.2631	0.0029*	--	--	--	--
RCS	0.3157	0.0003*	-0.1929	0.0030*	0.0340	0.6050
RRH	0.3312	0.0002*	--	--	0.1433	0.0284*
SBF	0.4538	0.0001*	-0.2635	0.0001*	0.1976	0.0024*
SNG	--	--	-0.2748	0.0001*	--	--
SPB	0.3220	0.0002*	-0.2034	0.0018*	0.2250	0.0005*
SPG	0.2667	0.0025*	--	--	--	--
SRH	0.2637	0.0028*	-0.2321	0.0003*	0.1100	0.0932
WHB	0.0971	0.2795	0.0075	0.9090	0.1706	0.0089*
WHC	0.2083	0.0193*	0.0660	0.3144	0.1156	0.0778
WHS	0.2579	0.0036*	-0.2732	0.0001*	--	--
WLY	0.1896	0.0334*	-0.2341	0.0003*	0.0763	0.2449
YBH	--	--	-0.1080	0.0992	--	--
TOTAL	0.3997	0.0001*	0.3260	0.0001*	0.6163	0.0001*

Table C.58. Correlation coefficients (CC) and probability values (P) of correlation analyses testing for significant relationships between log-transformed numeric catch-per-unit-effort rates and pH, by gear, in the Pensacola Dam tailwaters, January 1988 to July 1989. Asterisks denote statistically significant probability values (alpha=0.05).

	Gill net		Trap net		Electrofishing	
Species	CC	P	CC	P	CC	P
BBF	-0.1780	0.0528	--	--	--	--
BBH	-0.2450	0.0072*	0.0861	0.2024	--	--
BCF	-0.2376	0.0093*	0.2423	0.0003*	-0.0702	0.2991
BLC	-0.2538	0.0054*	--	--	--	--
BLG	-0.0895	0.3332	-0.1796	0.0074*	-0.0602	0.3727
BLS	-0.2573	0.0047*	--	--	--	--
BSS	--	--	--	--	0.0853	0.2064
CCF	-0.0683	0.4605	-0.0583	0.3885	-0.0820	0.2244
CRP	-0.3312	0.0002*	0.2678	0.0001*	-0.1540	0.0220*
CSH	--	--	0.2775	0.0001*	--	--
DRM	-0.2122	0.0205*	0.1376	0.0411*	-0.1345	0.0458*
GRS	-0.2056	0.0249*	-0.0085	0.8999	0.0813	0.2285
GSH	--	--	0.2685	0.0001*	--	--
GZS	-0.4475	0.0001*	-0.1112	0.0992	-0.3799	0.0001*
HFC	-0.2523	0.0056*	--	--	--	--
HYB	-0.0581	0.5303	0.3142	0.0001*	-0.0339	0.6160
HYS	-0.2679	0.0032*	0.2060	0.0021*	--	--
LES	--	--	0.0720	0.2864	-0.1110	0.0999
LGP	--	--	0.3012	0.0001*	0.1500	0.0258*
LMB	-0.3129	0.0005*	0.2836	0.0001*	-0.2003	0.0028*
LNG	-0.1805	0.0494*	0.2416	0.0003*	-0.0815	0.2277
MSS	--	--	--	--	-0.0629	0.3518
OSS	--	--	0.2570	0.0001*	--	--
PDF	-0.3728	0.0001*	--	--	-0.0242	0.7201
QBS	-0.1028	0.2658	--	--	--	--
RBT	-0.1132	0.2203	--	--	--	--
RCS	-0.1508	0.1016	0.2222	0.0009*	0.0441	0.5145
RRH	-0.2394	0.0087*	--	--	-0.0256	0.7051
SBF	-0.3488	0.0001*	0.2732	0.0001*	-0.1556	0.0207*
SNG	--	--	0.2902	0.0001*	--	--
SPB	-0.2636	0.0038*	0.2495	0.0002*	-0.1996	0.0029*
SPG	-0.1694	0.0655	--	--	--	--
SRH	-0.1910	0.0374*	0.2725	0.0001*	-0.1364	0.0429*
WHB	-0.1405	0.1275	-0.1036	0.1247	-0.1442	0.0321*
WHC	-0.2729	0.0027*	-0.1484	0.0275*	-0.0945	0.1615
WHS	-0.2809	0.0020*	0.2885	0.0001*	--	--
WLY	-0.2265	0.0133*	0.2641	0.0001*	-0.0602	0.3731
YBH	--	--	-0.0228	0.7365	--	--
TOTAL	-0.2522	0.0056*	-0.1699	0.0114*	-0.3860	0.0001*

Table C.59. Correlation coefficients (CC) and probability values (P) of correlation analyses testing for significant relationships between log-transformed numeric catch-per-unit-effort rates and dissolved oxygen concentration, by gear, in the Pensacola Dam tailwaters, January 1988 to July 1989. Asterisks denote statistically significant probability values (alpha=0.05).

	Gill net		Trap net		Electrofishing	
Species	CC	P	CC	P	CC	P
BBF	-0.1722	0.0538	--	--	--	--
BBH	-0.2251	0.0113*	0.0794	0.2265	--	--
BCF	-0.1684	0.0594	0.2266	0.0005*	-0.0246	0.7076
BLC	-0.2028	0.0227*	--	--	--	--
BLG	-0.2238	0.0117*	-0.3653	0.0001*	-0.0547	0.4052
BLS	-0.2426	0.0062*	--	--	--	--
BSS	--	--	--	--	0.1999	0.0021*
CCF	-0.1115	0.2138	0.0166	0.8004	-0.1081	0.0989
CRP	-0.2974	0.0007*	0.2462	0.0001*	-0.2076	0.0014*
CSH	--	--	0.2695	0.0001*	--	--
DRM	-0.2776	0.0016*	0.1151	0.0790	-0.2838	0.0001*
GRS	-0.2341	0.0083*	-0.1522	0.0199*	-0.0202	0.7580
GSH	--	--	0.2192	0.0007*	--	--
GZS	-0.5187	0.0001*	-0.1364	0.0370*	-0.5843	0.0001*
HFC	-0.2259	0.0110*	--	--	--	--
HYB	-0.0031	0.9727	0.2732	0.0001*	-0.0486	0.4598
HYS	-0.2482	0.0051*	0.1306	0.0459*	--	--
LES	--	--	-0.1436	0.0281*	-0.1447	0.0269*
LGP	--	--	0.2789	0.0001*	0.0524	0.4249
LMB	-0.3268	0.0002*	0.2268	0.0005*	-0.2024	0.0019*
LNG	-0.3482	0.0001*	0.0820	0.2114	-0.1310	0.0454*
MSS	--	--	--	--	-0.0153	0.8162
OSS	--	--	0.2203	0.0007*	--	--
PDF	-0.2889	0.0010*	--	--	-0.0638	0.3312
QBS	-0.2199	0.0133*	--	--	--	--
RBT	-0.2081	0.0194*	--	--	--	--
RCS	-0.2648	0.0027*	0.1844	0.0046*	-0.0001	0.9983
RRH	-0.3043	0.0005*	--	--	-0.1382	0.0345*
SBF	-0.3742	0.0001*	0.2506	0.0001*	-0.1552	0.0175*
SNG	--	--	0.2597	0.0001*	--	--
SPB	-0.3128	0.0004*	0.2020	0.0019*	-0.2512	0.0001*
SPG	-0.2231	0.0120*	--	--	--	--
SRH	-0.2084	0.0192*	0.2244	0.0005*	-0.1314	0.0446*
WHB	0.0277	0.7578	-0.0240	0.7152	-0.0838	0.2016
WHC	-0.2513	0.0045*	-0.1314	0.0446*	-0.1070	0.1026
WHS	-0.2360	0.0078*	0.2582	0.0001*	--	--
WLY	-0.2111	0.0176*	0.2303	0.0004*	-0.0902	0.1690
YBH	--	--	0.0544	0.4079	--	--
TOTAL	-0.3083	0.0004*	-0.3312	0.0001*	-0.5290	0.0001*

Table C.60. Correlation coefficients (CC) and probability values (P) of correlation analyses testing for significant relationships between log-transformed catch rates and dissolved oxygen concentration, by gear, in the Pensacola Dam tailwaters, April to December 1988 and April to July 1989. Asterisks denote statistically significant probability values (alpha=0.05).

	Gill net		Trap net		Electrofishing	
Species	CC	P	CC	P	CC	P
BBF	-0.1966	0.0619	--	--	--	--
BBH	-0.1581	0.1346	0.0164	0.8325	--	--
BCF	-0.1839	0.0810	0.0014	0.9858	-0.0635	0.4120
BLC	-0.1478	0.1622	--	--	--	--
BLG	-0.1020	0.3361	-0.2216	0.0038*	0.0295	0.7038
BLS	-0.2104	0.0453*	--	--	--	--
BSS	--	--	--	--	0.2821	0.0002*
CCF	-0.2189	0.0371*	0.0235	0.7613	-0.0670	0.3864
CRP	-0.1257	0.2351	0.0533	0.4910	-0.1860	0.0155*
CSH	--	--	0.0318	0.6812	--	--
DRM	-0.1570	0.1373	-0.0253	0.7444	-0.2358	0.0020*
GRS	-0.1500	0.1559	-0.0957	0.2157	0.0165	0.8316
GSH	--	--	-0.0349	0.6523	--	--
GZS	-0.3344	0.0012*	-0.1404	0.0687	-0.1597	0.0381*
HFC	-0.2377	0.0233*	--	--	--	--
HYB	0.1020	0.3360	-0.0012	0.9878	0.0082	0.9161
HYS	-0.2075	0.0485*	-0.0600	0.4387	--	--
LES	--	--	-0.0630	0.4157	-0.1072	0.1655
LGP	--	--	0.0457	0.5555	0.1910	0.0128*
LMB	-0.2837	0.0064*	-0.0239	0.7581	-0.1676	0.0294*
LNG	-0.1130	0.2863	0.0031	0.9682	-0.1363	0.0772
MSS	--	--	--	--	0.0599	0.4393
OSS	--	--	-0.0302	0.6964	--	--
PDF	-0.0992	0.3496	--	--	-0.0028	0.9715
QBS	-0.1347	0.2030	--	--	--	--
RBT	-0.1181	0.2649	--	--	--	--
RCS	-0.1276	0.2282	0.0093	0.9043	0.0265	0.7326
RRH	-0.2385	0.0228*	--	--	-0.1033	0.1814
SBF	-0.1973	0.0608	-0.0011	0.9884	-0.0732	0.3439
SNG	--	--	-0.0012	0.9878	--	--
SPB	-0.2757	0.0082*	0.0069	0.9290	-0.2442	0.0014*
SPG	-0.0984	0.3535	--	--	--	--
SRH	-0.1321	0.2121	-0.0322	0.6773	-0.1060	0.1700
WHB	0.4396	0.0001*	0.0232	0.7645	0.2038	0.0079*
WHC	-0.0796	0.4535	-0.1280	0.0971	-0.0602	0.4369
WHS	-0.1763	0.0946	-0.0012	0.9878	--	--
WLY	-0.2818	0.0068*	-0.0113	0.8837	-0.0926	0.2309
YBH	--	--	0.0179	0.8177	--	--
TOTAL	-0.0329	0.7570	-0.2076	0.0067*	-0.0103	0.8940

Table C.61. Correlation coefficients (CC) and probability values (P) of correlation analyses testing for significant relationships between log-transformed numeric catch-per-unit-effort rates and conductivity, by gear, in the Pensacola Dam tailwaters, January 1988 to July 1989. Asterisks denote statistically significant probability values (alpha=0.05).

	Gill net		Trap net		Electrofishing	
Species	CC	P	CC	P	CC	P
BBF	0.4742	0.0001*	--	--	--	--
BBH	0.4475	0.0001*	-0.0102	0.8761	--	--
BCF	0.0306	0.7342	0.2036	0.0017*	-0.0230	0.7262
BLC	0.3712	0.0001*	--	--	--	--
BLG	0.1616	0.0705	-0.1495	0.0221*	0.0039	0.9528
BLS	0.4823	0.0001*	--	--	--	--
BSS	--	--	--	--	0.0661	0.3141
CCF	-0.2146	0.0158*	-0.0926	0.1580	0.0067	0.9188
CRP	0.0638	0.4780	0.2687	0.0001*	0.0415	0.5272
CSH	--	--	0.2634	0.0001*	--	--
DRM	0.1467	0.1011	0.2141	0.0010*	-0.1509	0.0209*
GRS	0.3571	0.0001*	-0.1401	0.0322*	-0.0202	0.7586
GSH	--	--	0.2342	0.0003*	--	--
GZS	0.0480	0.5937	-0.0001	0.9999	-0.1433	0.0284*
HFC	0.4431	0.0001*	--	--	--	--
HYB	-0.2776	0.0016*	0.1998	0.0021*	-0.1162	0.0761
HYS	0.4455	0.0001*	0.1591	0.0148*	--	--
LES	--	--	-0.0688	0.2949	0.0029	0.9653
LGP	--	--	0.2058	0.0016*	-0.0192	0.7704
LMB	0.0910	0.3108	0.2568	0.0001*	-0.0857	0.1912
LNG	-0.2217	0.0126*	0.0716	0.2754	0.0106	0.8715
MSS	--	--	--	--	0.1114	0.0890
OSS	--	--	0.2432	0.0002*	--	--
PDF	0.0043	0.9617	--	--	-0.0067	0.9190
QBS	0.3986	0.0001*	--	--	--	--
RBT	0.4169	0.0001*	--	--	--	--
RCS	-0.2258	0.0110*	0.1476	0.0239*	-0.0665	0.3110
RRH	0.3121	0.0004*	--	--	-0.0930	0.1563
SBF	-0.0328	0.7153	0.2373	0.0002*	0.0658	0.3163
SNG	--	--	0.2478	0.0001*	--	--
SPB	0.2856	0.0012*	0.2771	0.0001*	0.0781	0.2341
SPG	0.3030	0.0006*	--	--	--	--
SRH	0.4995	0.0001*	0.2595	0.0001*	0.0734	0.2633
WHB	0.0155	0.8634	-0.1402	0.0320*	-0.0762	0.2455
WHC	-0.2037	0.0221*	-0.5431	0.0001*	-0.1573	0.0161*
WHS	0.4587	0.0001*	0.2463	0.0001*	--	--
WLY	0.2182	0.0141*	0.2311	0.0004*	-0.0479	0.4658
YBH	--	--	-0.0760	0.2471	--	--
TOTAL	-0.2132	0.0165*	-0.4183	0.0001*	-0.0689	0.2941

Table C.62. Correlation coefficients (CC) and probability values (P) of correlation analyses testing for significant relationships between log-transformed numeric catch-per-unit-effort rates and mean weekly discharges, by gear, in the Pensacola Dam tailwaters, January 1988 to July 1989. Asterisks denote statistically significant probability values (alpha=0.05).

	Gill net		Trap net		Electrofishing	
Species	CC	P	CC	P	CC	P
BBF	-0.4748	0.0001*	--	--	--	--
BBH	-0.5436	0.0001*	-0.1764	0.0068*	--	--
BCF	0.0041	0.9635	-0.2098	0.0012*	-0.0573	0.3826
BLC	-0.3424	0.0001*	--	--	--	--
BLG	-0.3225	0.0002*	-0.1138	0.0824	-0.1624	0.0128*
BLS	-0.5298	0.0001*	--	--	--	--
BSS	--	--	--	--	0.0370	0.5733
CCF	0.0843	0.3481	0.1508	0.0210*	-0.0884	0.1779
CRP	-0.0523	0.5610	-0.2501	0.0001*	-0.0012	0.9857
CSH	--	--	-0.2920	0.0001*	--	--
DRM	-0.4450	0.0001*	-0.2992	0.0001*	-0.2291	0.0004*
GRS	-0.3584	0.0001*	-0.0938	0.9408	0.0226	0.7305
GSH	--	--	-0.3116	0.1528	--	--
GZS	-0.1804	0.0433*	-0.0049	0.0001*	-0.3535	0.0001*
HFC	-0.4736	0.0001*	--	--	--	--
HYB	0.2040	0.0220*	-0.2293	0.0004*	0.0025	0.9698
HYS	-0.5337	0.0001*	-0.2583	0.0001*	--	--
LES	--	--	-0.1993	0.0022*	-0.0786	0.2313
LGP	--	--	-0.2574	0.0001*	-0.1187	0.0700
LMB	-0.2538	0.0041*	-0.3145	0.0001*	-0.0842	0.1995
LNG	-0.1098	0.2211	-0.1158	0.0772	-0.0912	0.1644
MSS	--	--	--	--	-0.0005	0.9935
OSS	--	--	-0.2463	0.0001*	--	--
PDF	0.0666	0.4590	--	--	0.0683	0.2981
QBS	-0.4636	0.0001*	--	--	--	--
RBT	-0.4247	0.0001*	--	--	--	--
RCS	-0.0610	0.4973	-0.1757	0.0071*	-0.0480	0.4652
RRH	-0.4131	0.0001*	--	--	-0.0959	0.1434
SBF	-0.3436	0.0001*	-0.3012	0.0001*	-0.1798	0.0058*
SNG	--	--	-0.2760	0.0001*	--	--
SPB	-0.4074	0.0001*	-0.3114	0.0001*	-0.0206	0.7541
SPG	-0.3645	0.0001*	--	--	--	--
SRH	-0.4595	0.0001*	-0.2826	0.0001*	-0.0541	0.4103
WHB	-0.0921	0.3050	0.0802	0.2214	-0.2210	0.0007*
WHC	0.0783	0.3836	0.2304	0.0004*	-0.0191	0.7712
WHS	-0.4930	0.0001*	-0.2744	0.0001*	--	--
WLY	-0.3124	0.0004*	-0.3153	0.0001*	-0.0513	0.4348
YBH	--	--	0.2122	0.0011*	--	--
TOTAL	-0.0949	0.2907	0.1044	0.1113	-0.4146	0.0001*

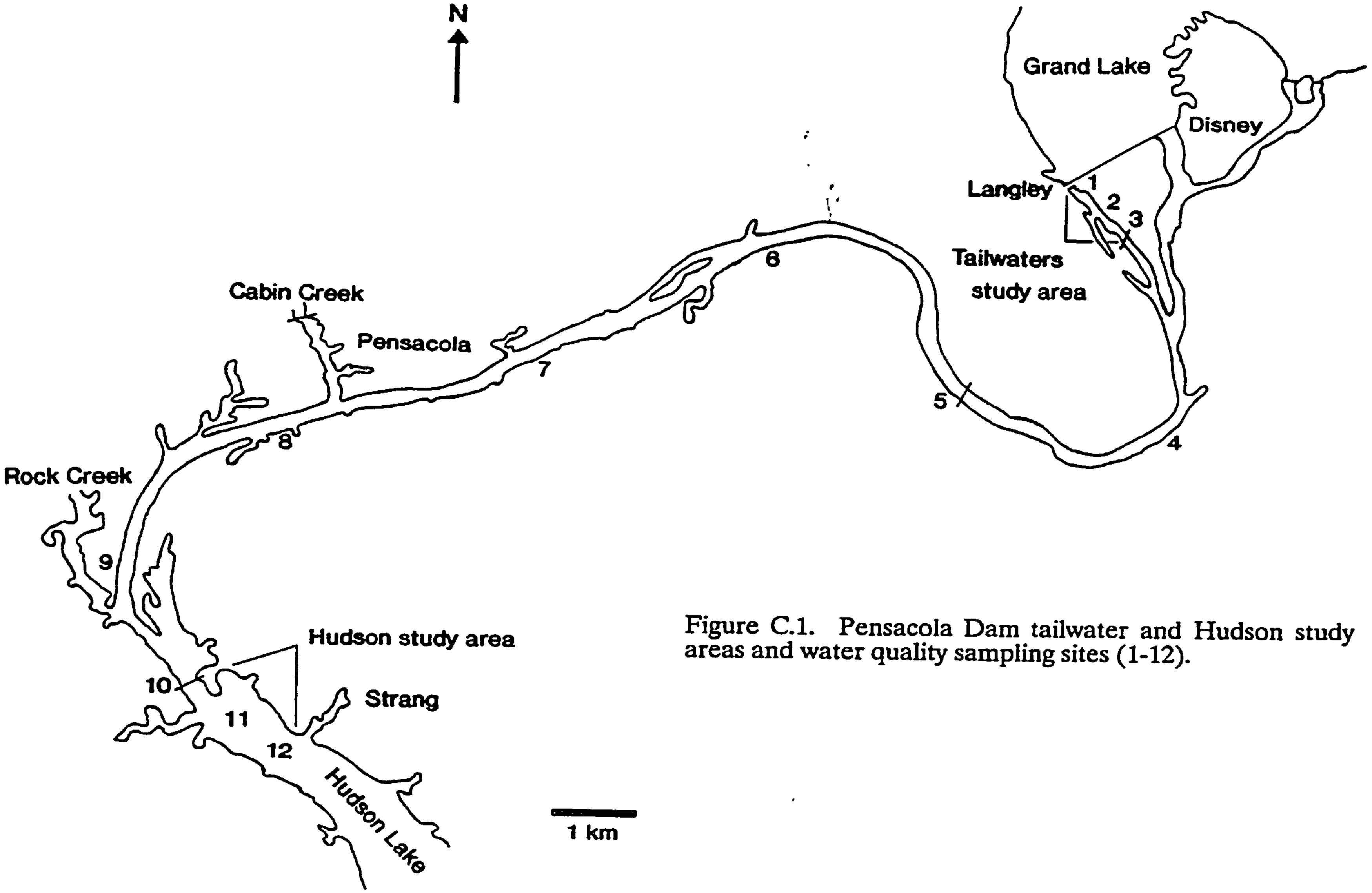

Figure C.1. Pensacola Dam tailwater and Hudson study areas and water quality sampling sites (1-12).

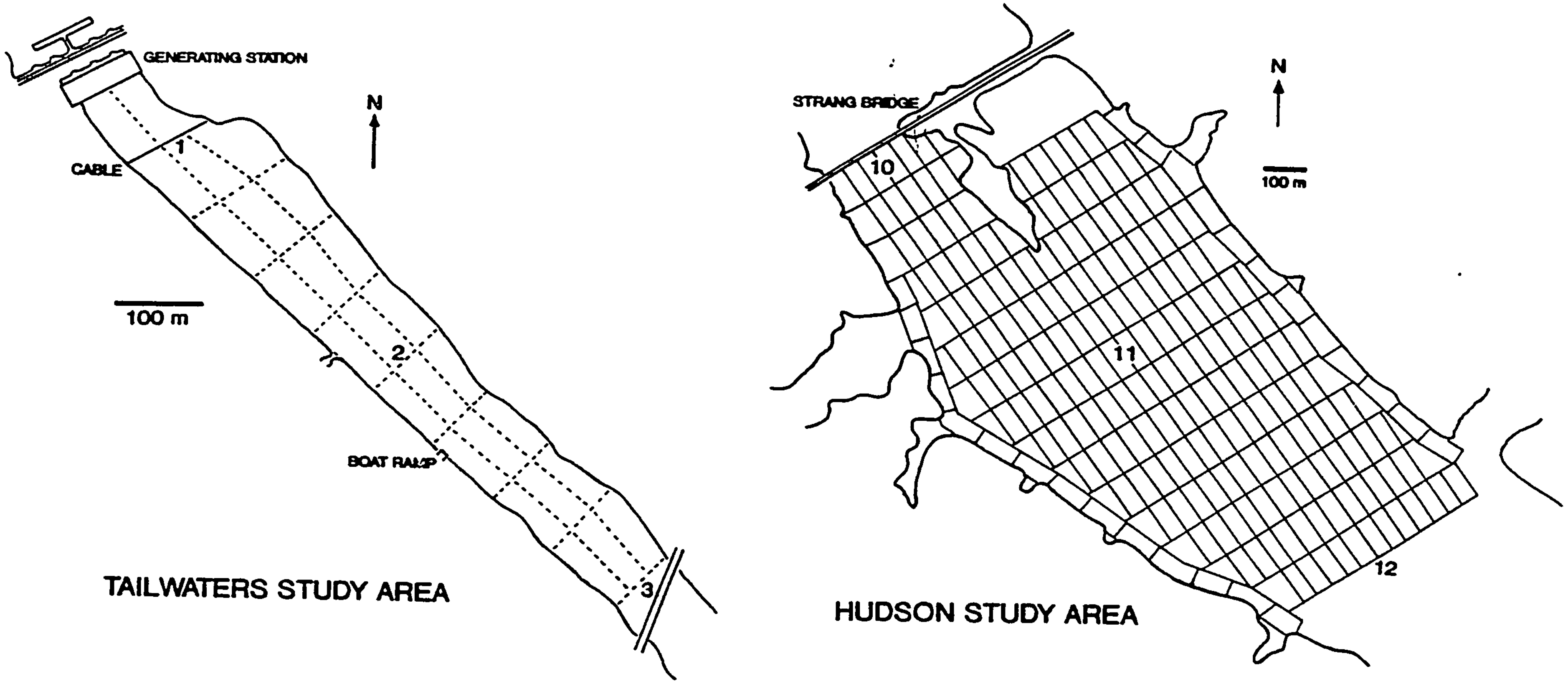

Figure C.2. Fish sampling grids and water quality sampling sites in the Pensacola Dam tailwater and Hudson study areas.

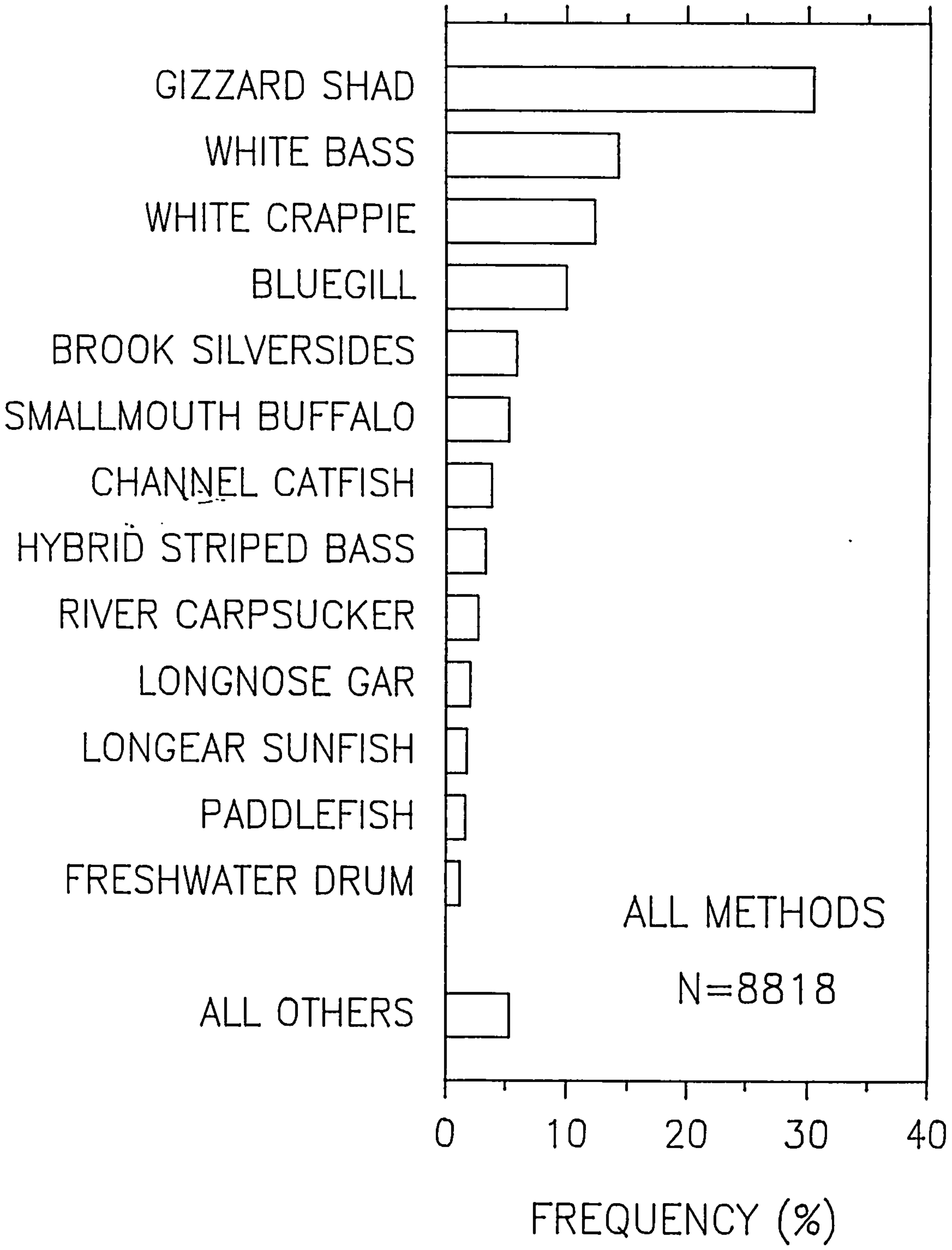

Figure C.3. Relative numeric abundances (%) of fishes constituting >1% of the total catch captured using all gear types in the Pensacola Dam tailwater, January 1988 to July 1989.

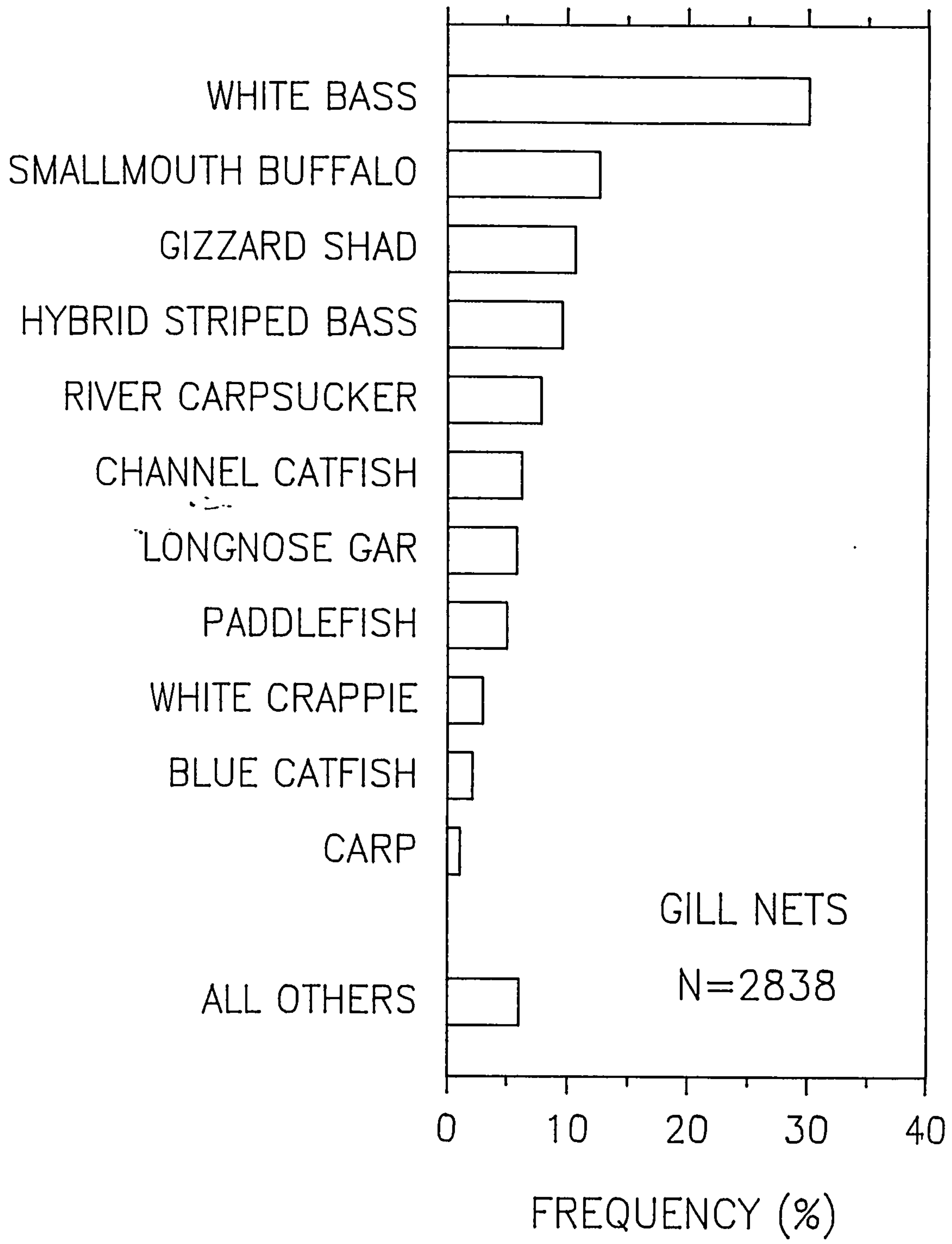

Figure C.4. Relative numeric abundances (%) of fishes constituting >1% of the gill-net catch in the Pensacola Dam tailwater, January 1988 to July 1989.

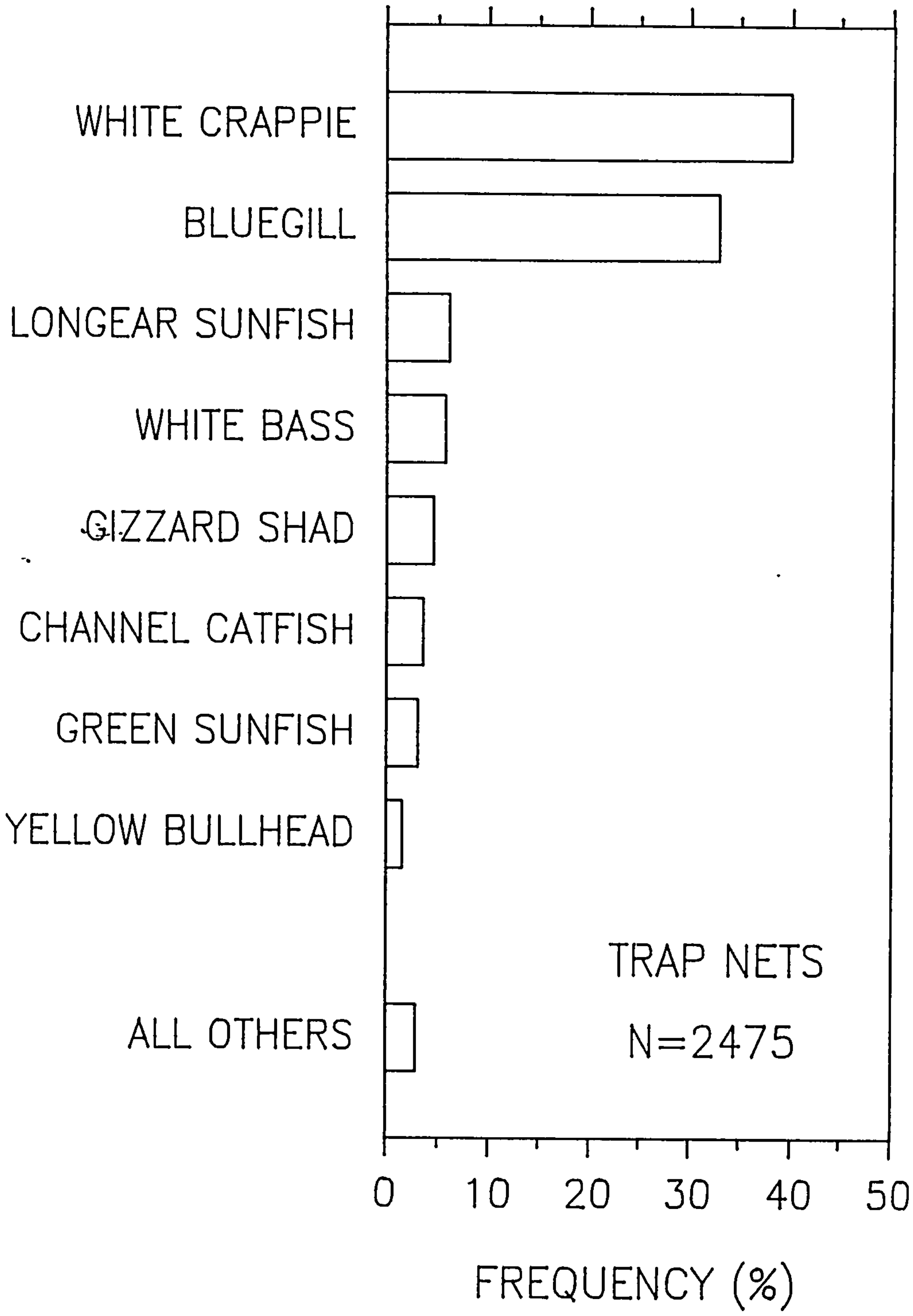

Figure C.5. Relative numeric abundances (%) of fishes constituting >1% of the trap-net catch in the Pensacola Dam tailwater, January 1988 to July 1989.

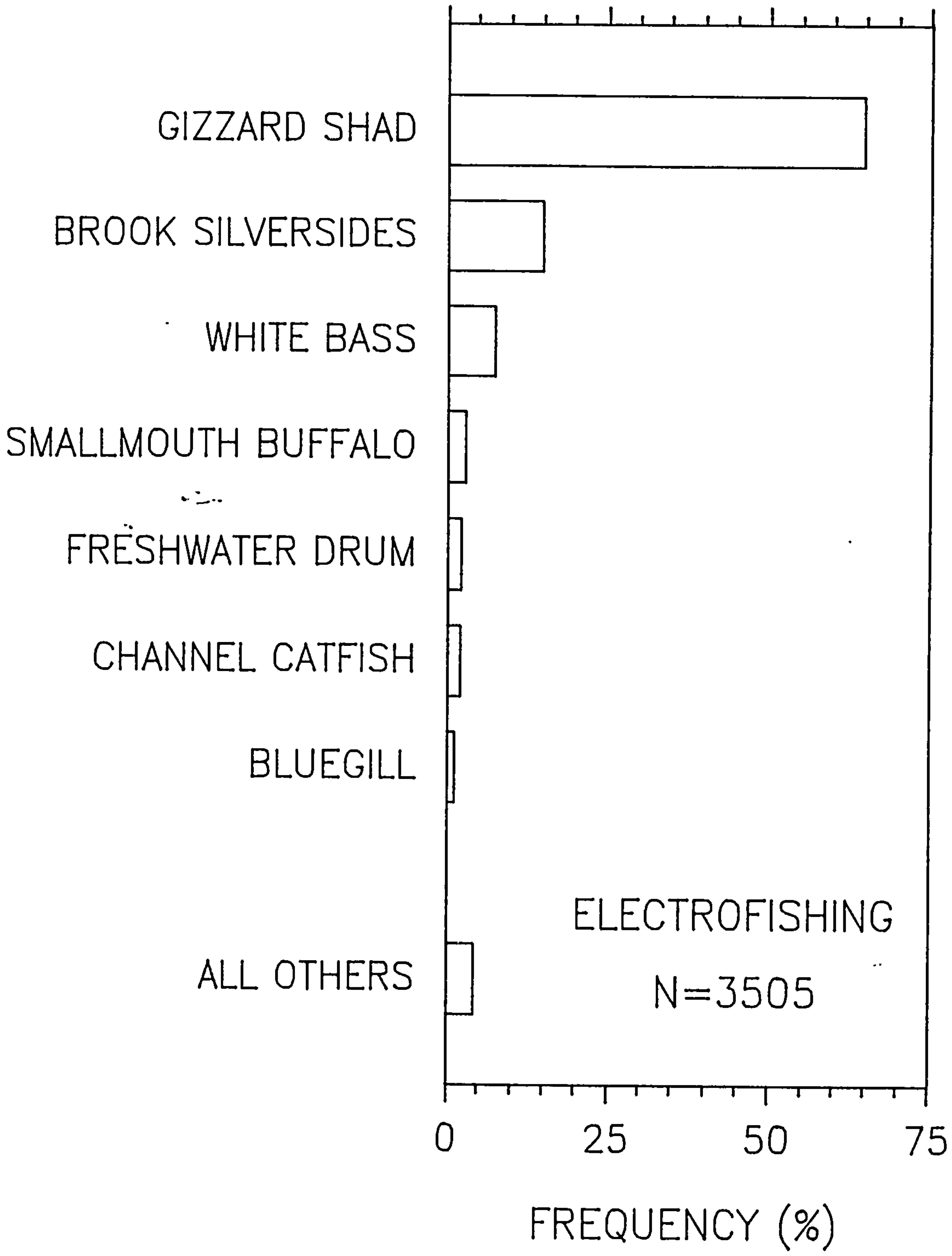

Figure C.6. Relative numeric abundances (%) of fishes constituting >1% of the electrofishing catch in the Pensacola Dam tailwater, January 1988 to July 1989.

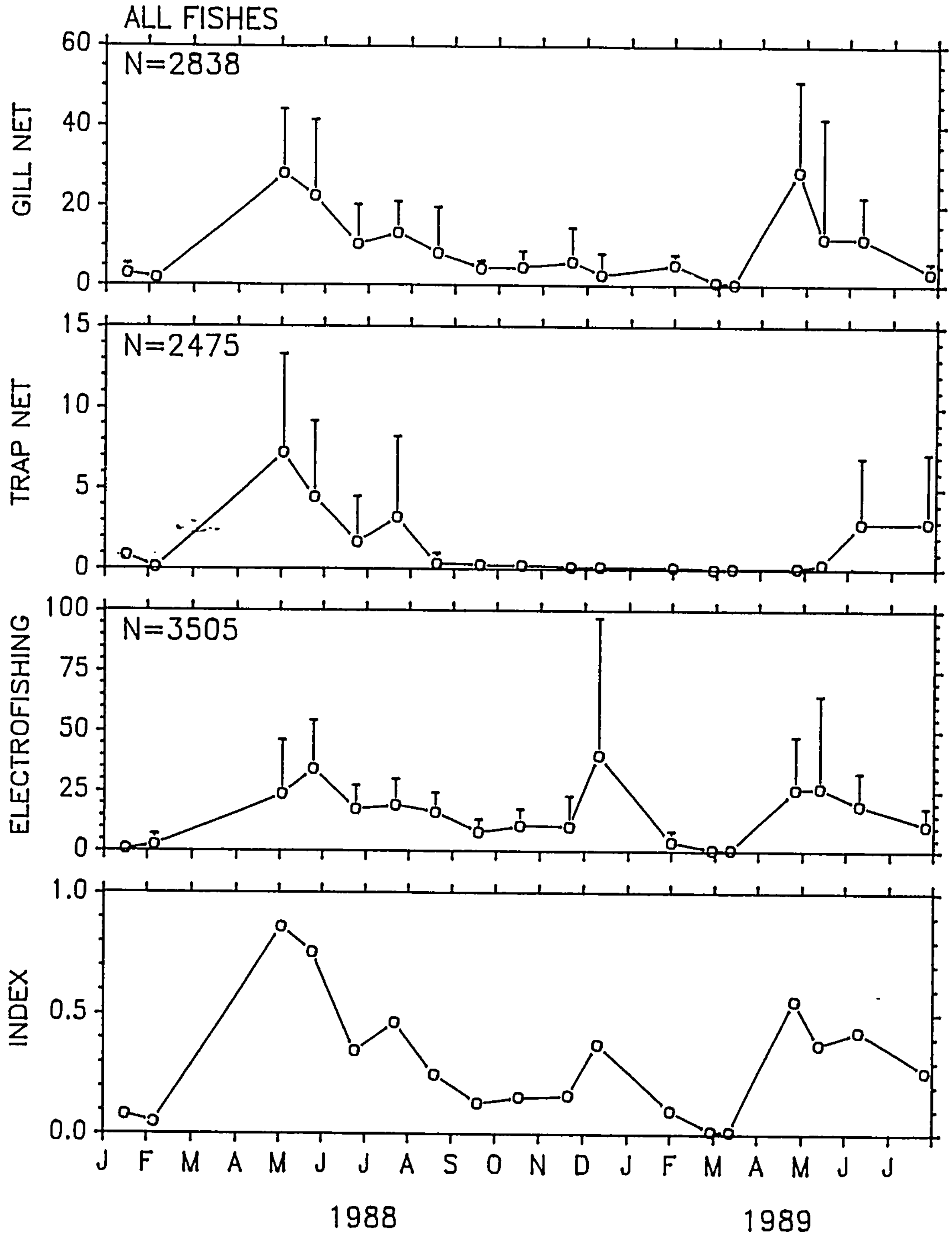

Figure C.7. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of all fishes in aggregate, Pensacola Dam tailwater, January 1988 to July 1989.

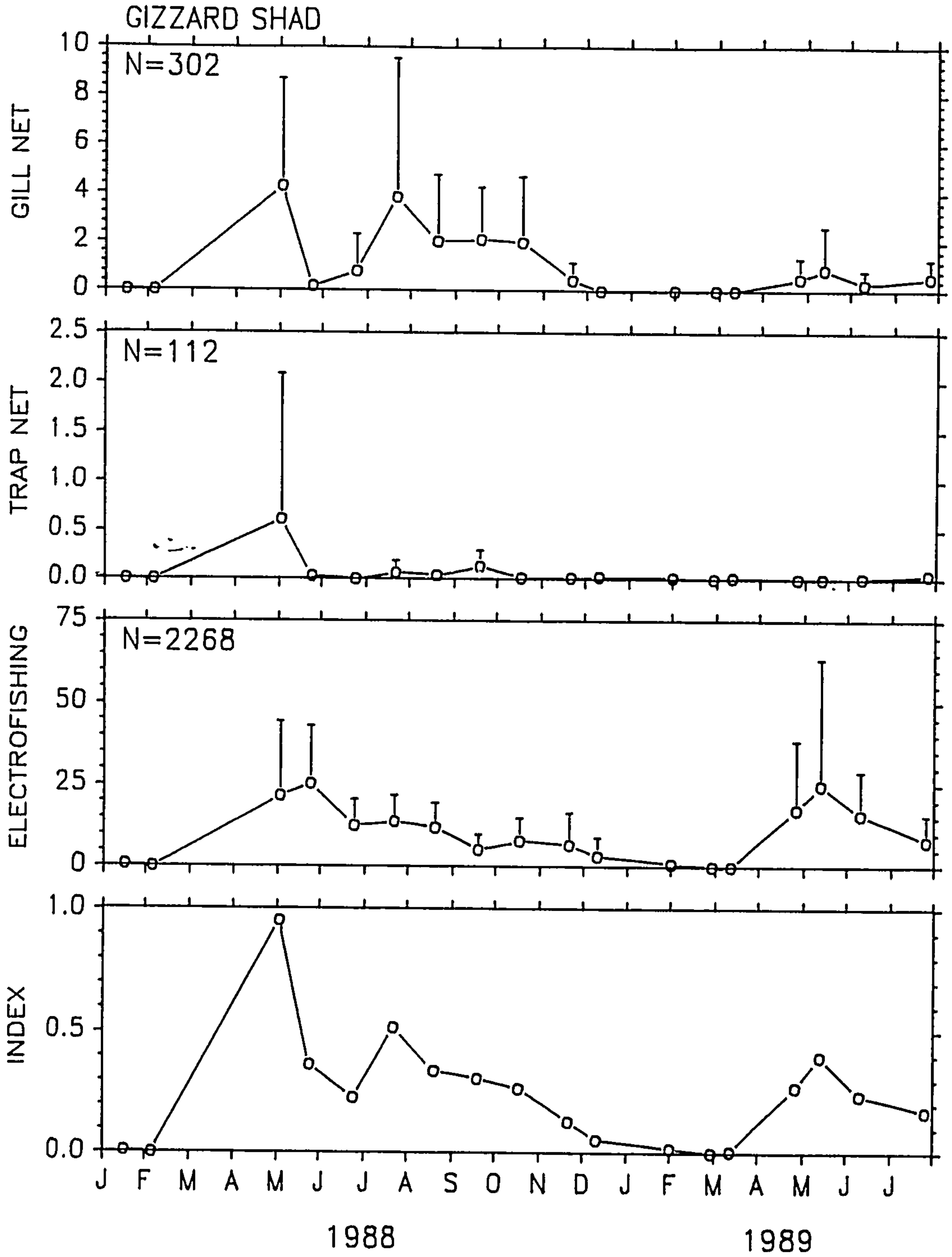

Figure C.8. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of gizzard shad, Pensacola Dam tailwater, January 1988 to July 1989.

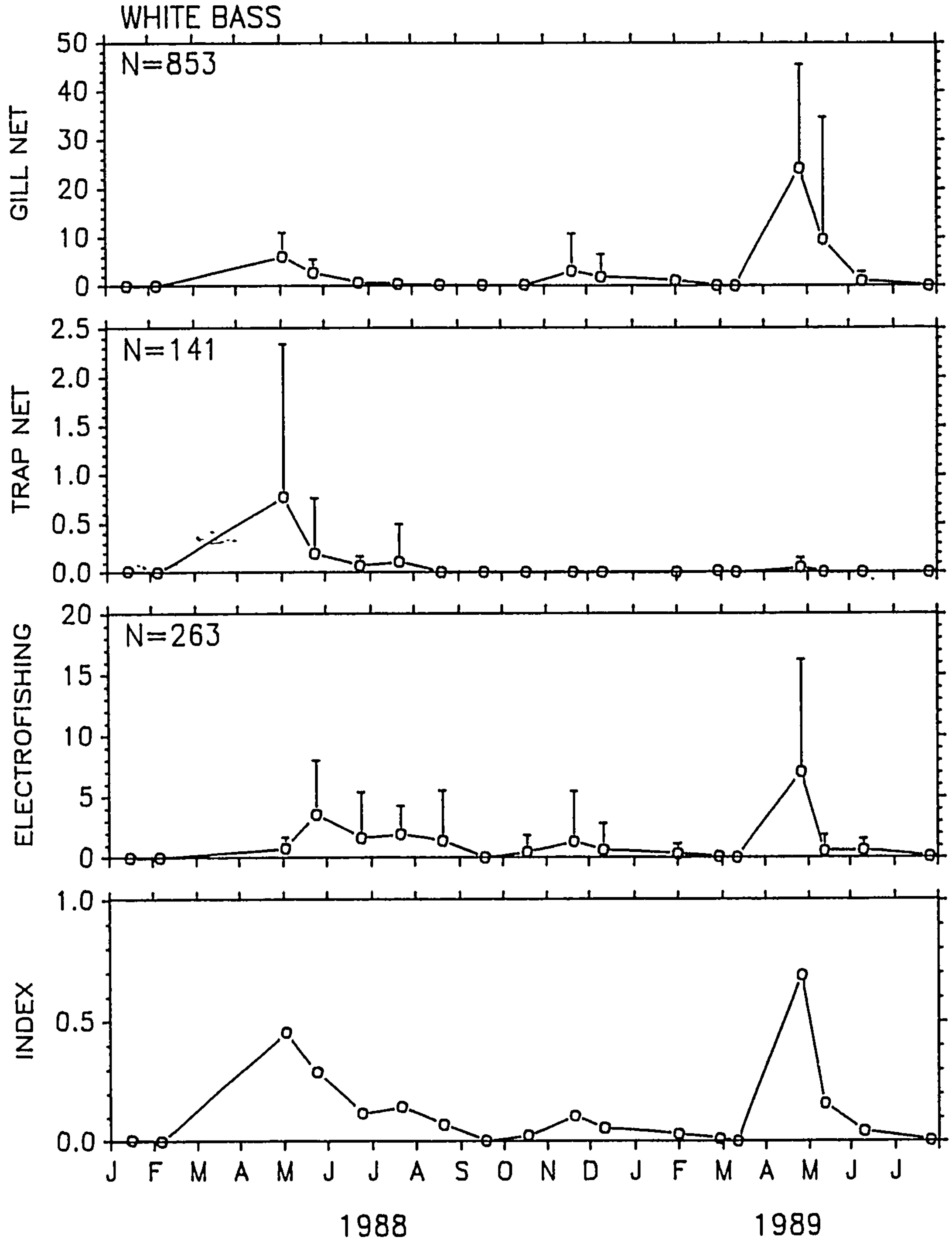

Figure C.9. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of white bass, Pensacola Dam tailwater, January 1988 to July 1989.

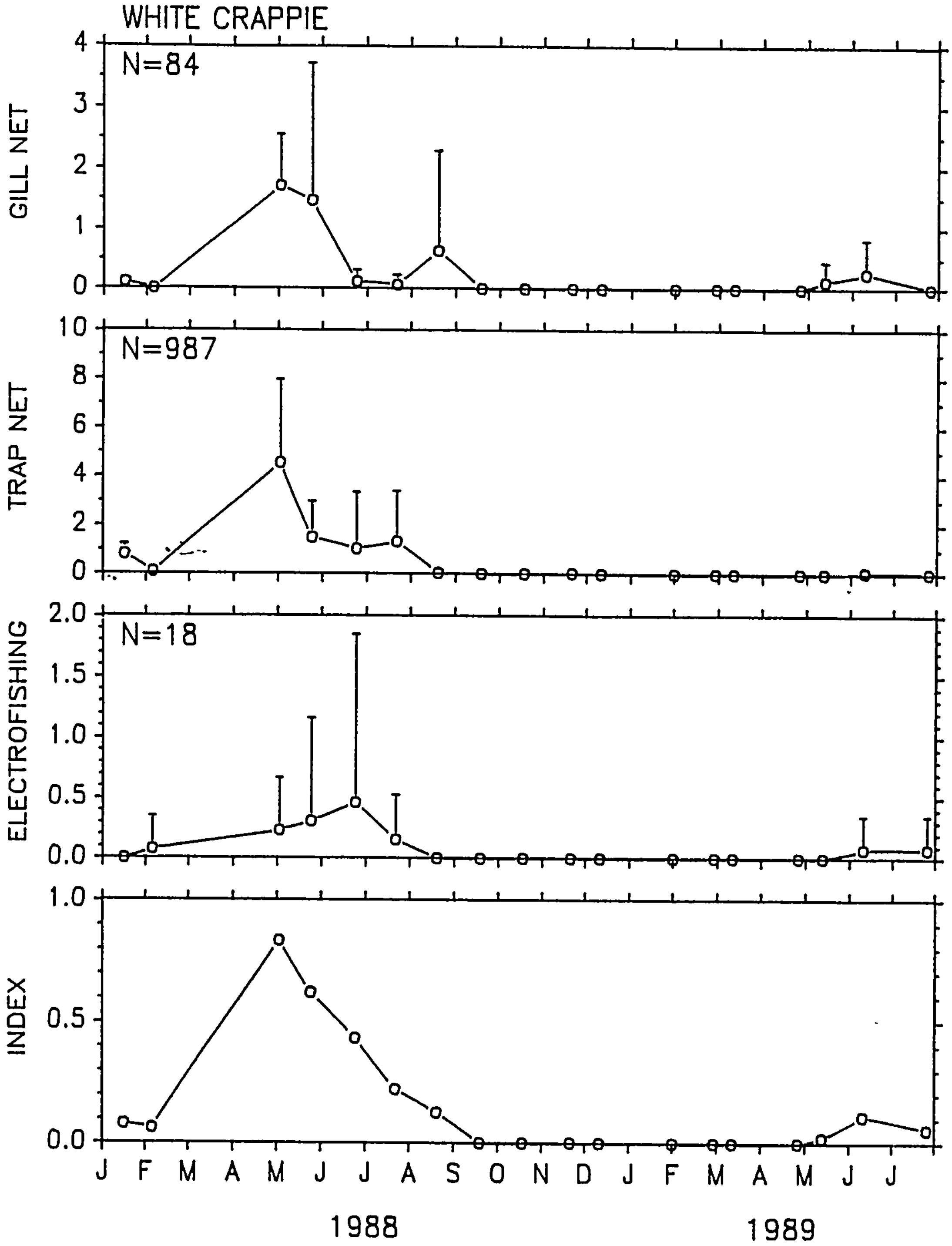

Figure C.10. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of white crappie, Pensacola Dam tailwater, January 1988 to July 1989.

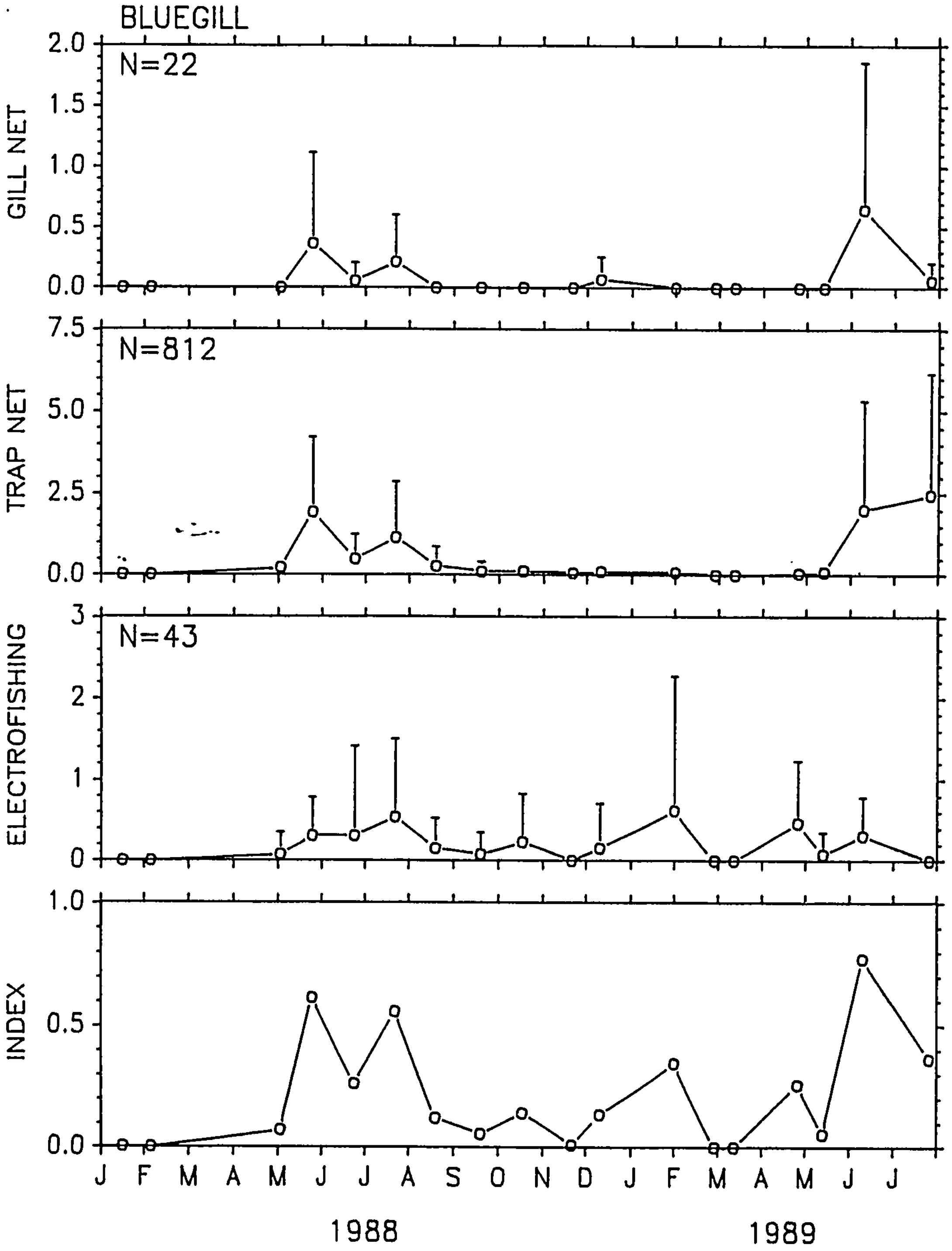

Figure C.11. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of bluegill, Pensacola Dam tailwater, January 1988 to July 1989.

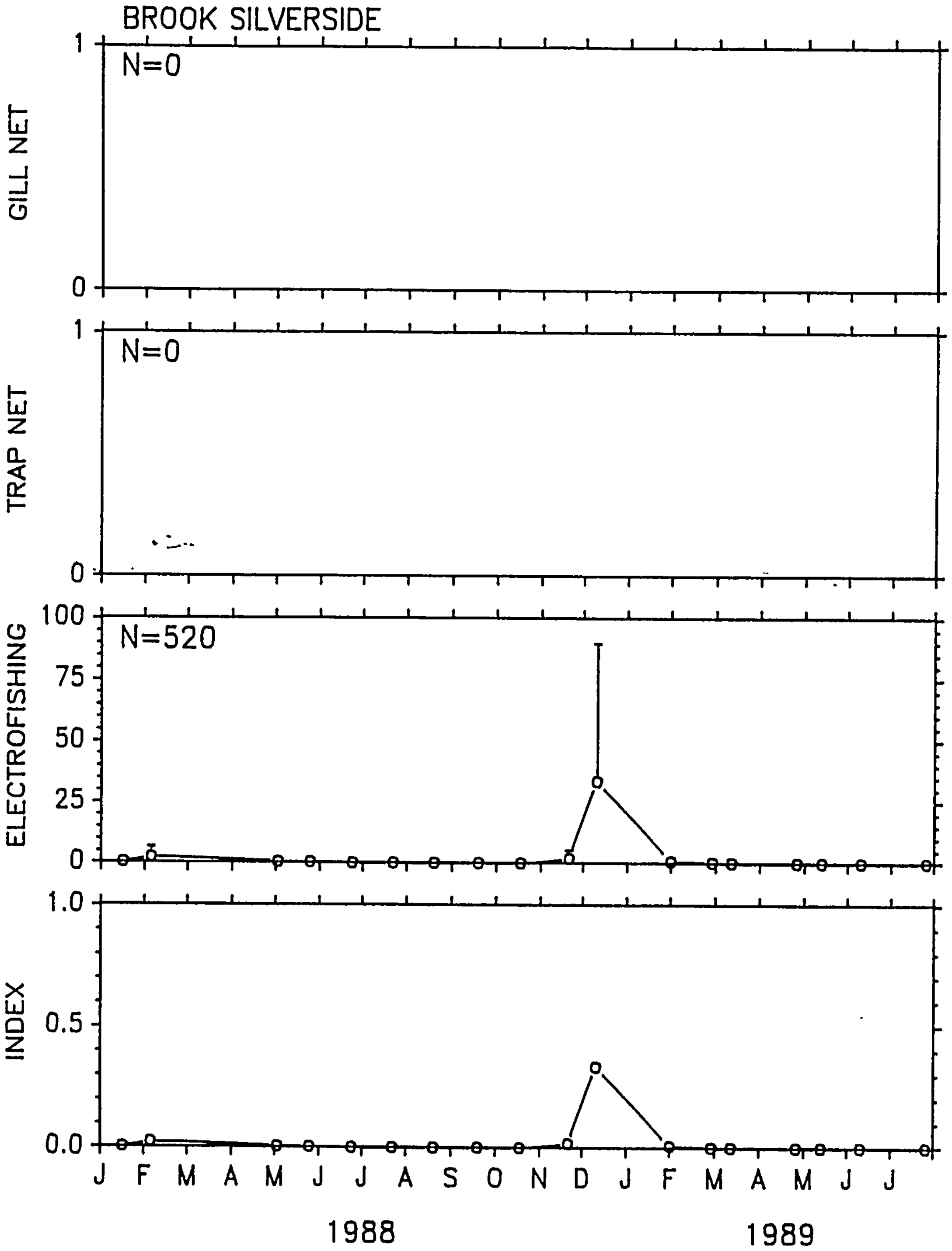

Figure C.12. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of brook silversides, Pensacola Dam tailwater, January 1988 to July 1989.

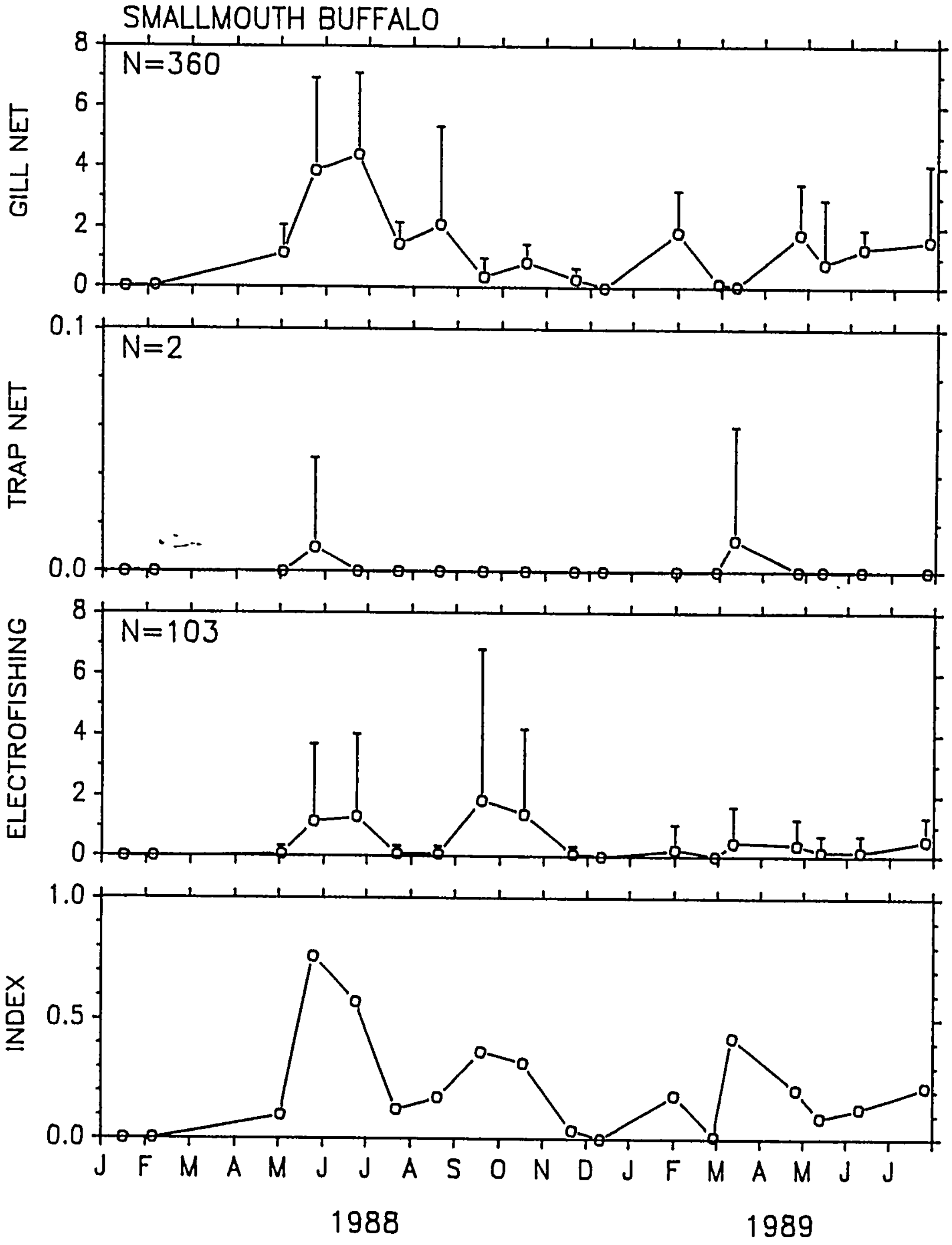

Figure C.13. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of smallmouth buffalo, Pensacola Dam tailwater, January 1988 to July 1989.

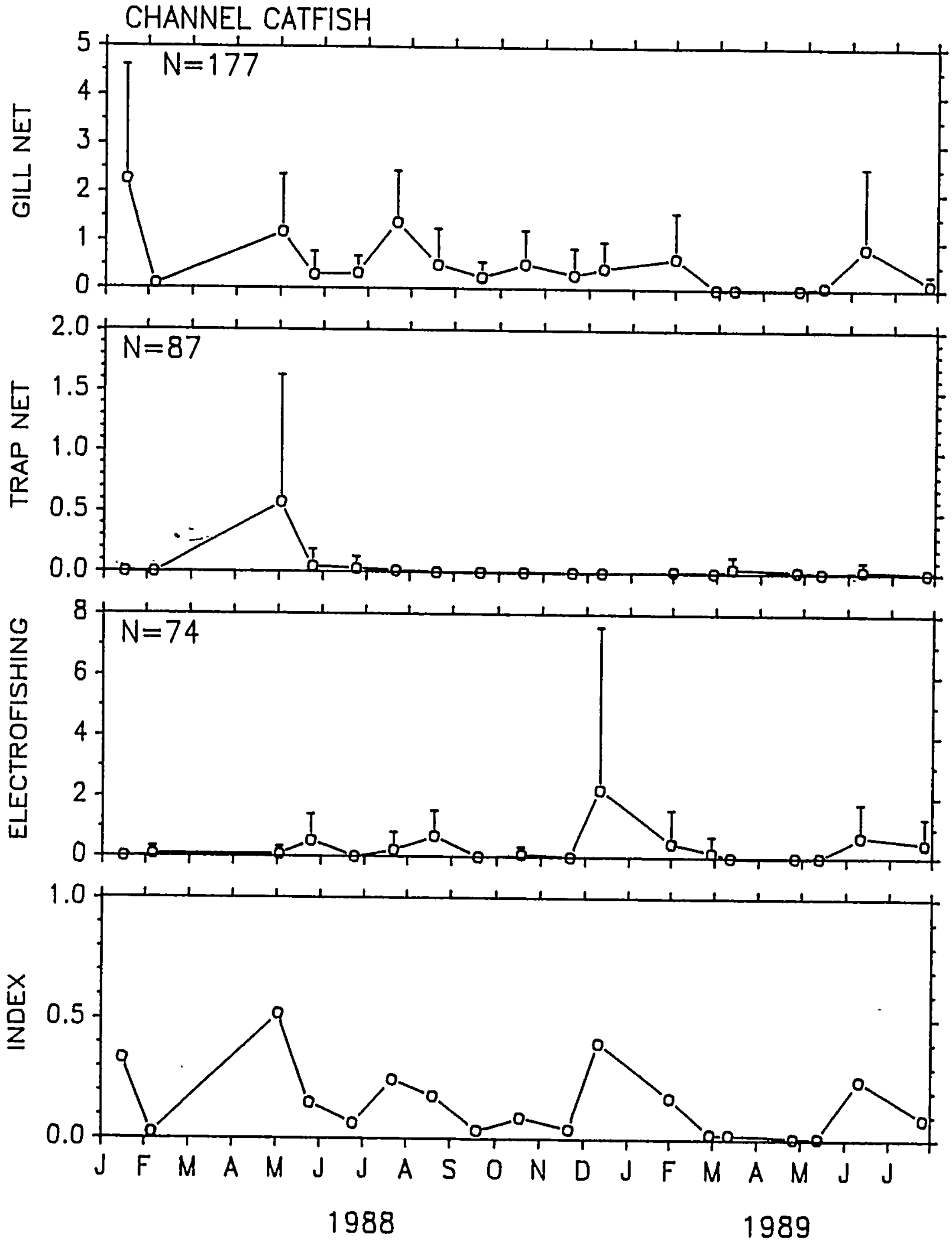

Figure C.14. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of channel catfish, Pensacola Dam tailwater, January 1988 to July 1989.

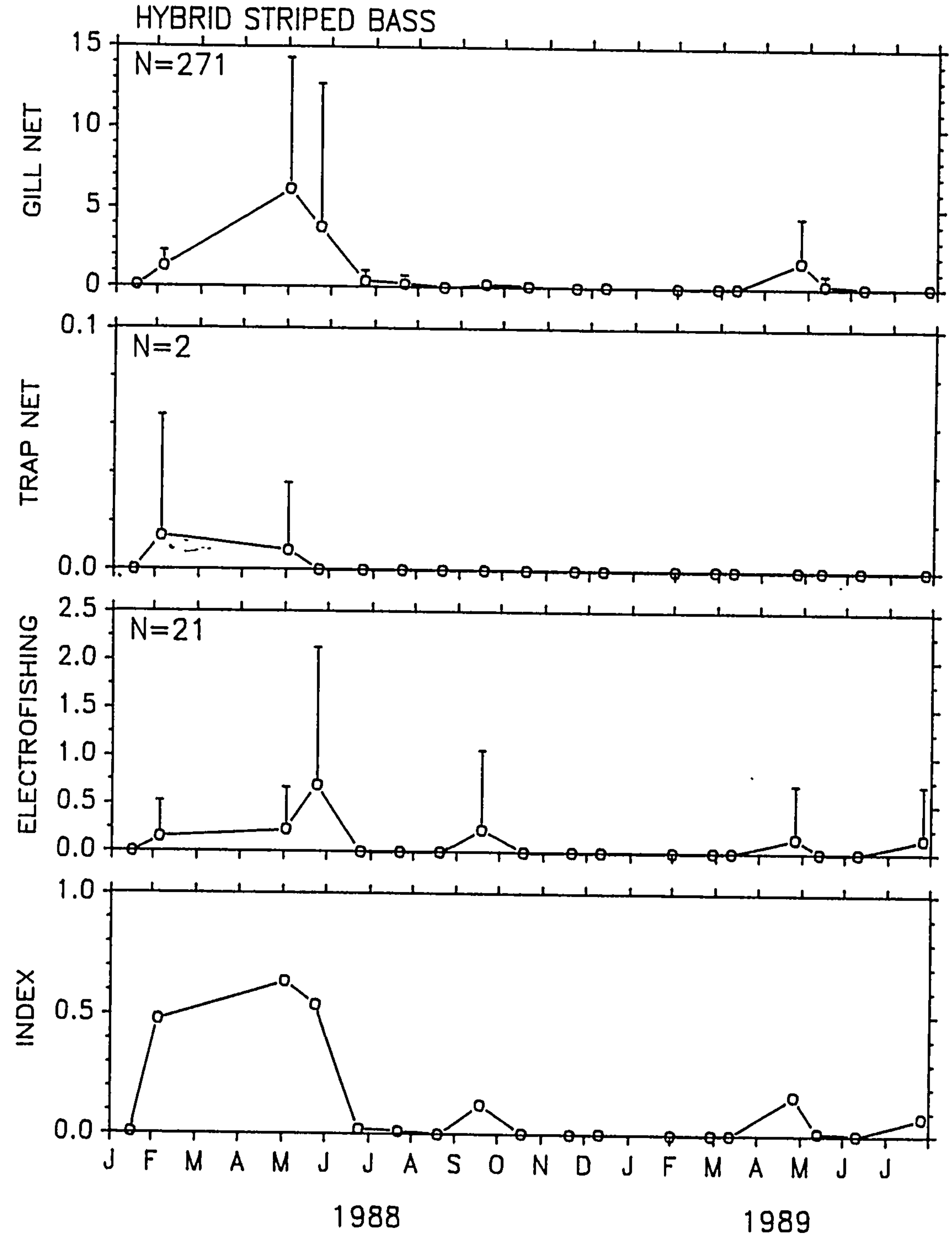

Figure C.15. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of hybrid striped bass, Pensacola Dam tailwater, January 1988 to July 1989.

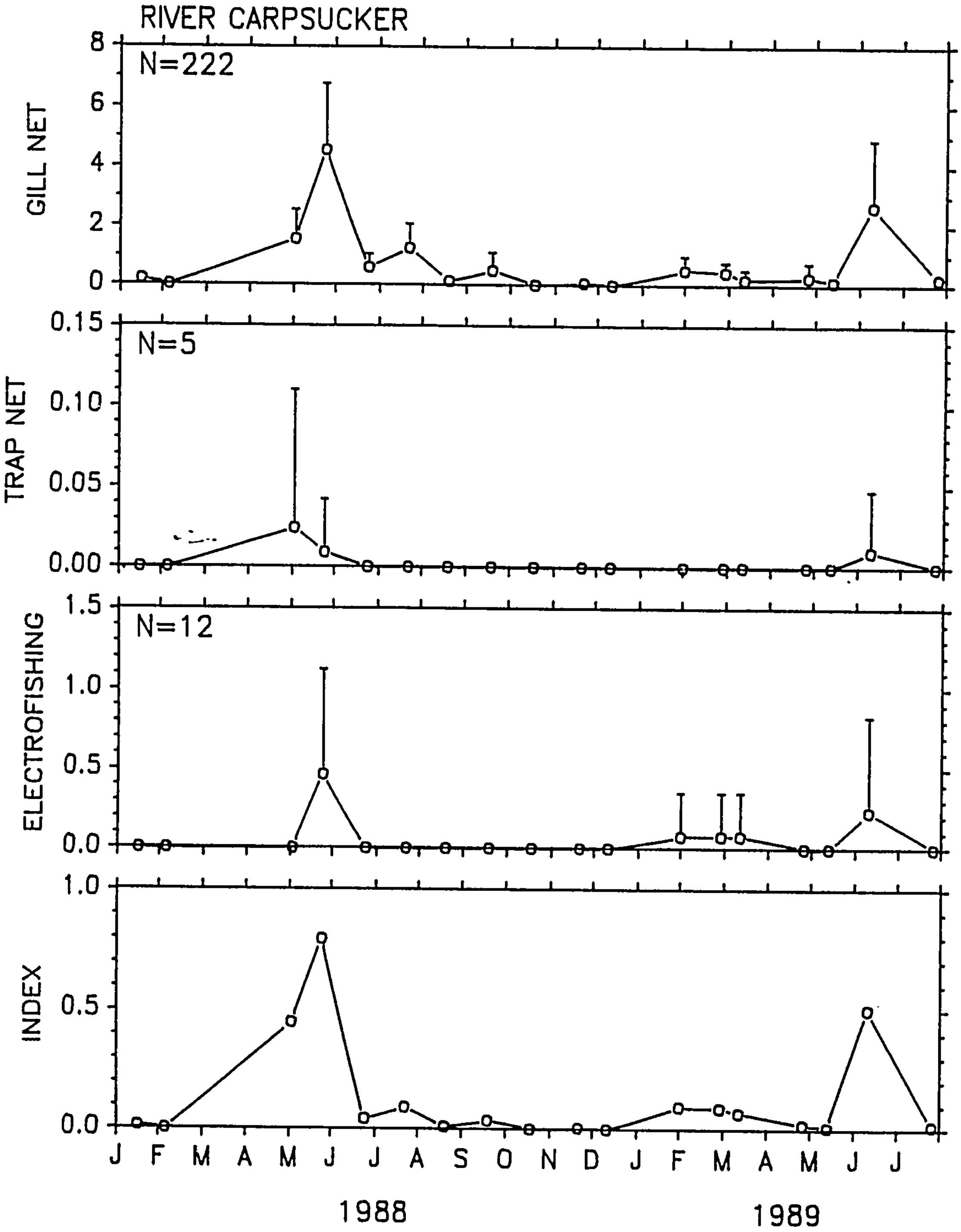

Figure C.16. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of river carpsucker, Pensacola Dam tailwater, January 1988 to July 1989.

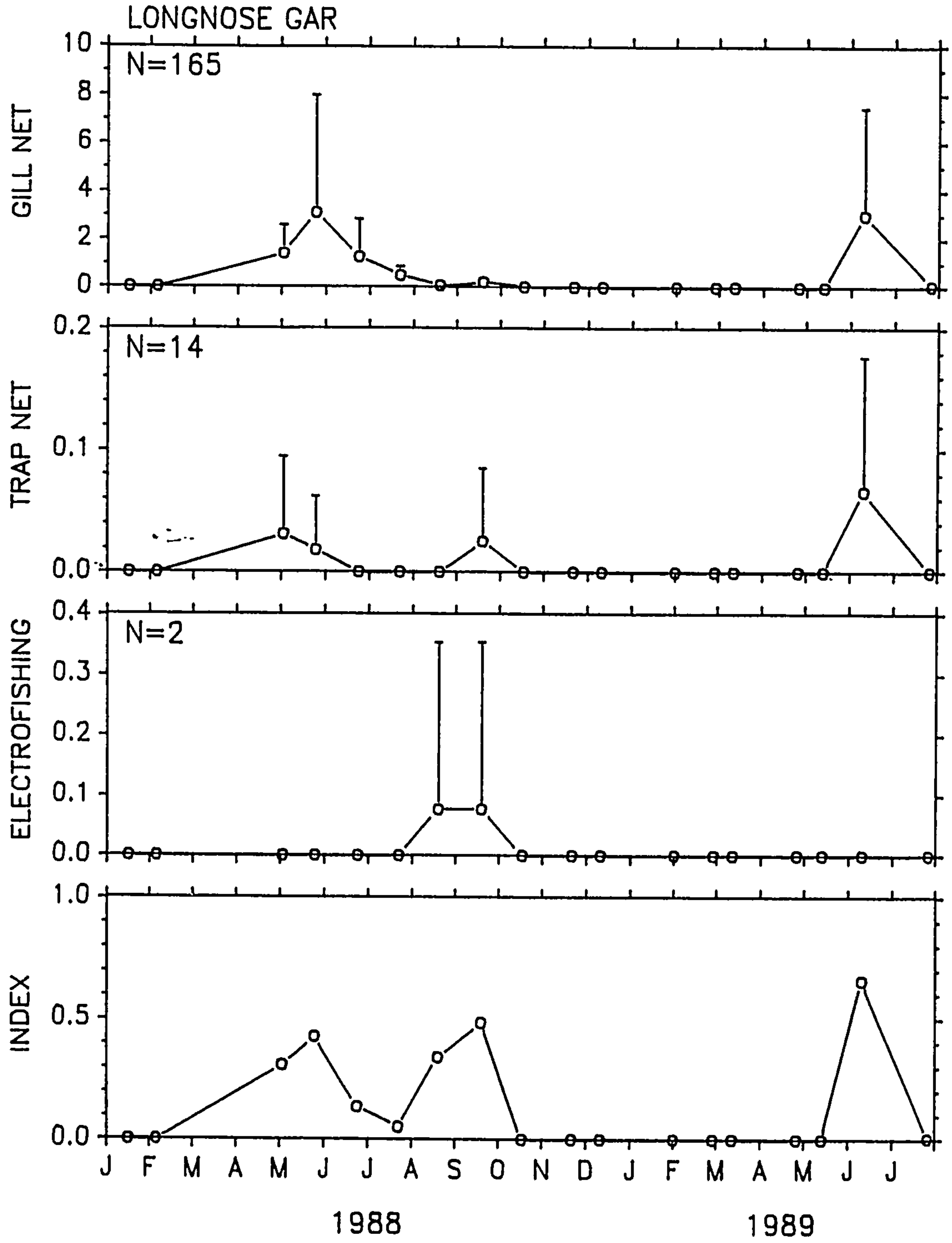

Figure C.17. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of longnose gar, Pensacola Dam tailwater, January 1988 to July 1989.

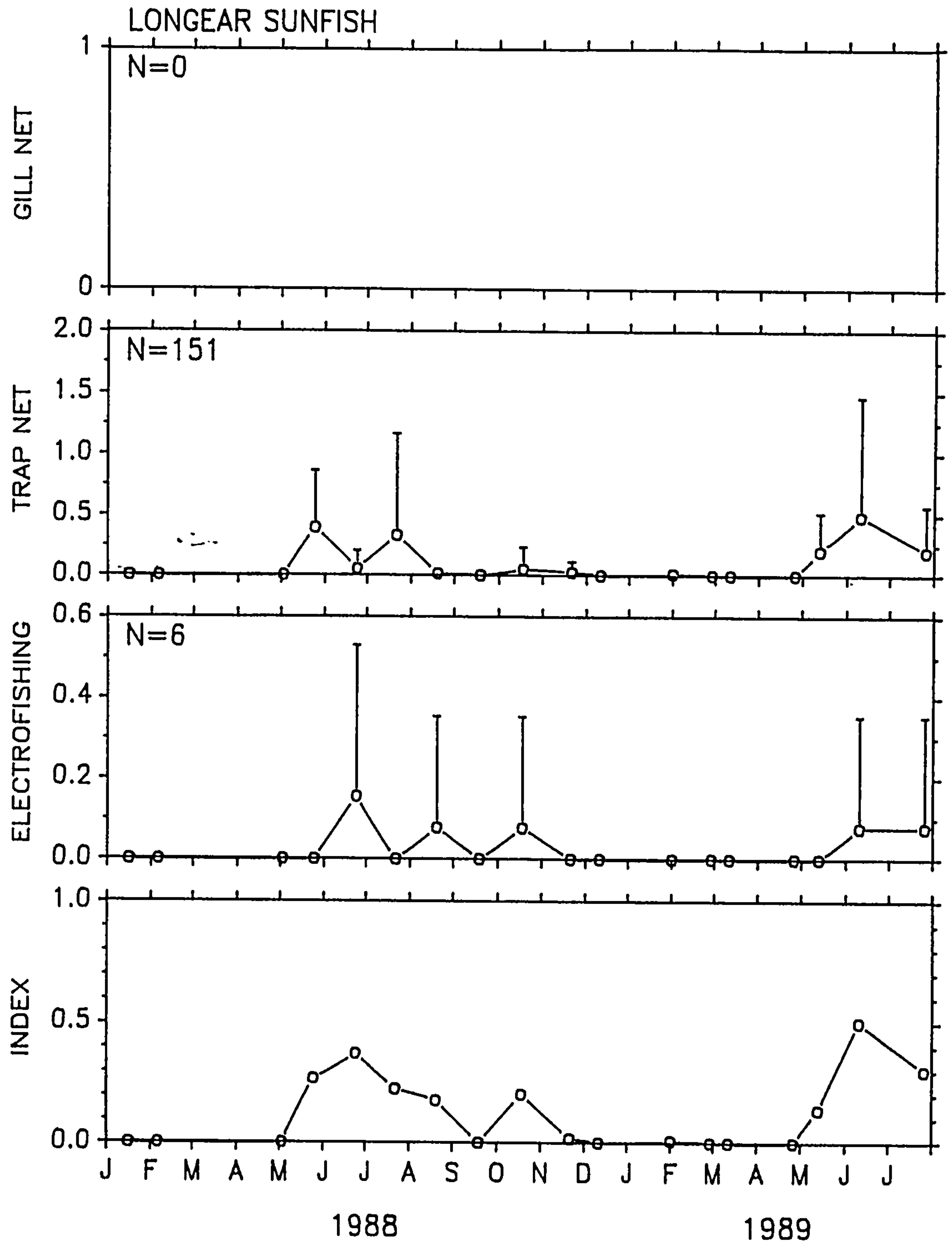

Figure C.18. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of longear sunfish, Pensacola Dam tailwater, January 1988 to July 1989.

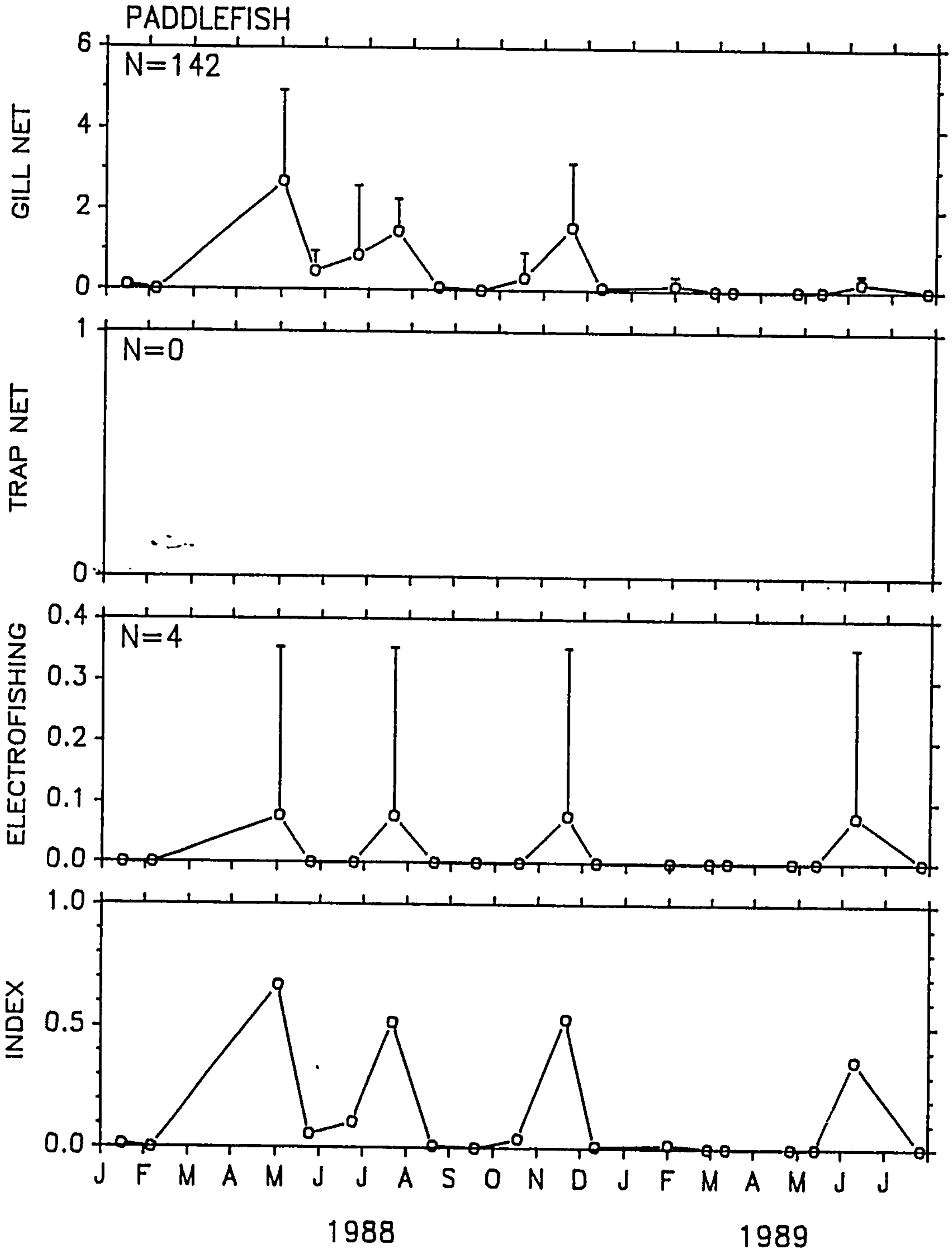

Figure C.19. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of paddlefish, Pensacola Dam tailwater, January 1988 to July 1989.

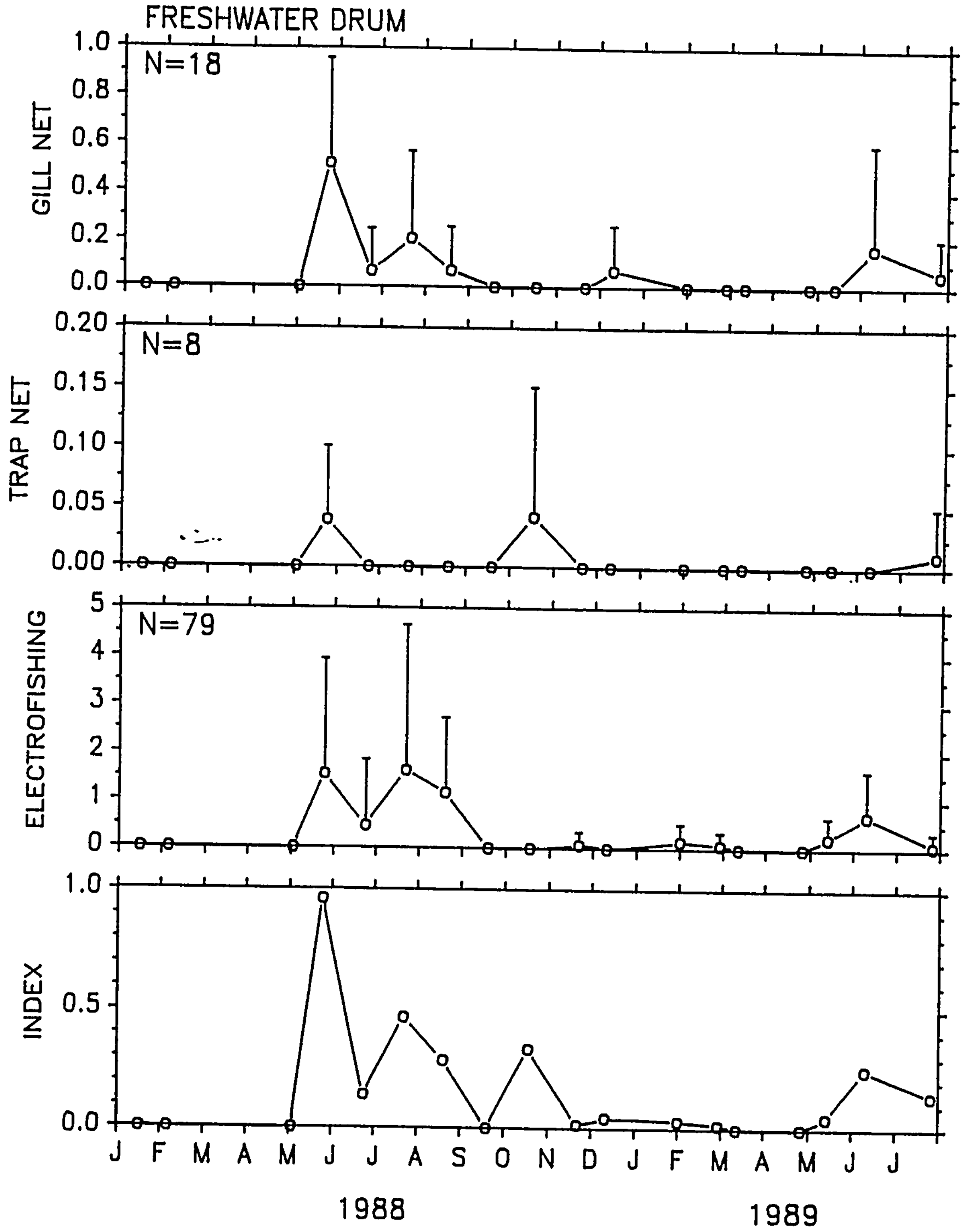

Figure C.20. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of freshwater drum, Pensacola Dam tailwater, January 1988 to July 1989.

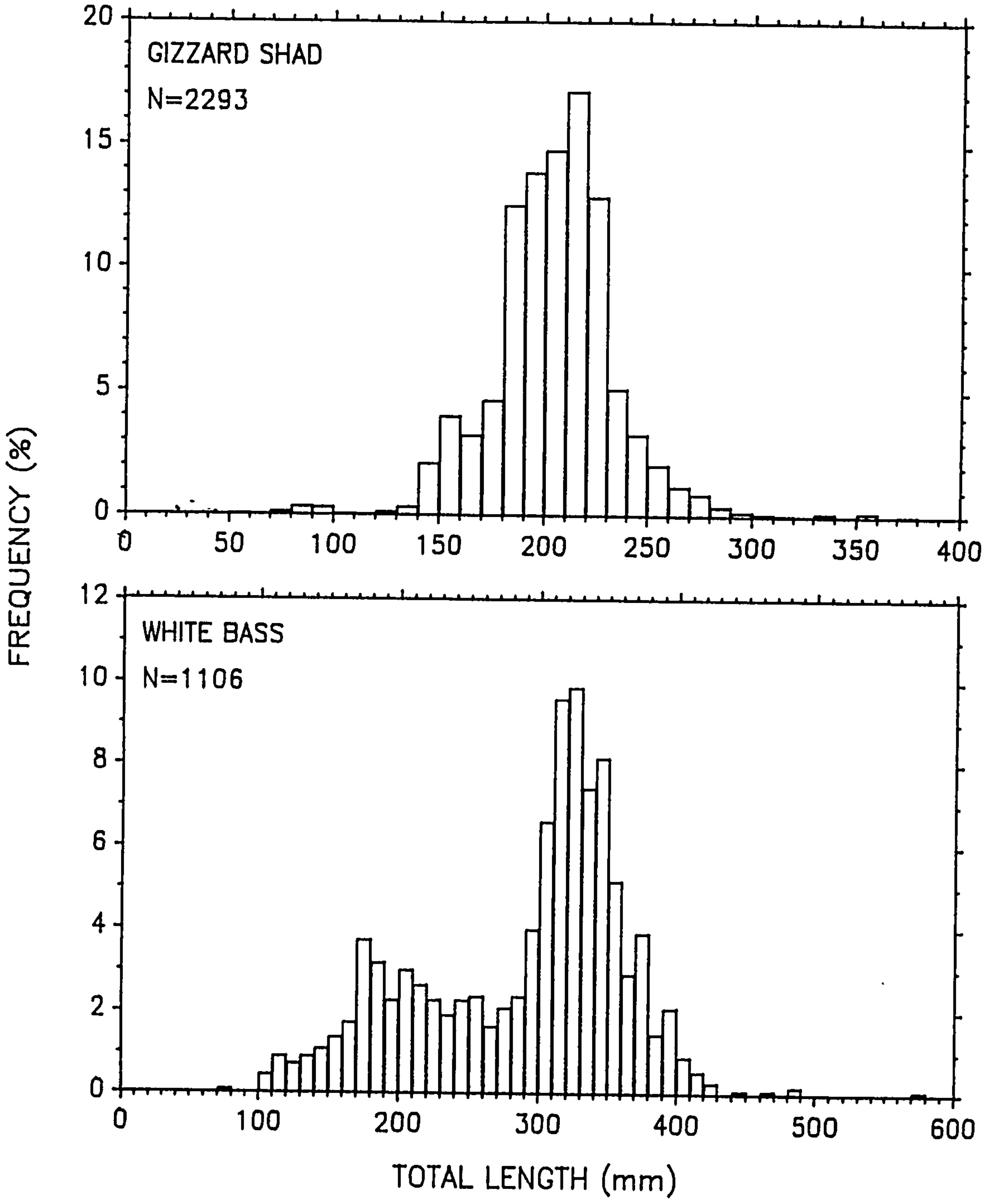

Figure C.21. Length-frequency distributions of gizzard shad and white bass collected in the Pensacola Dam tailwater, January 1988 to July 1989.

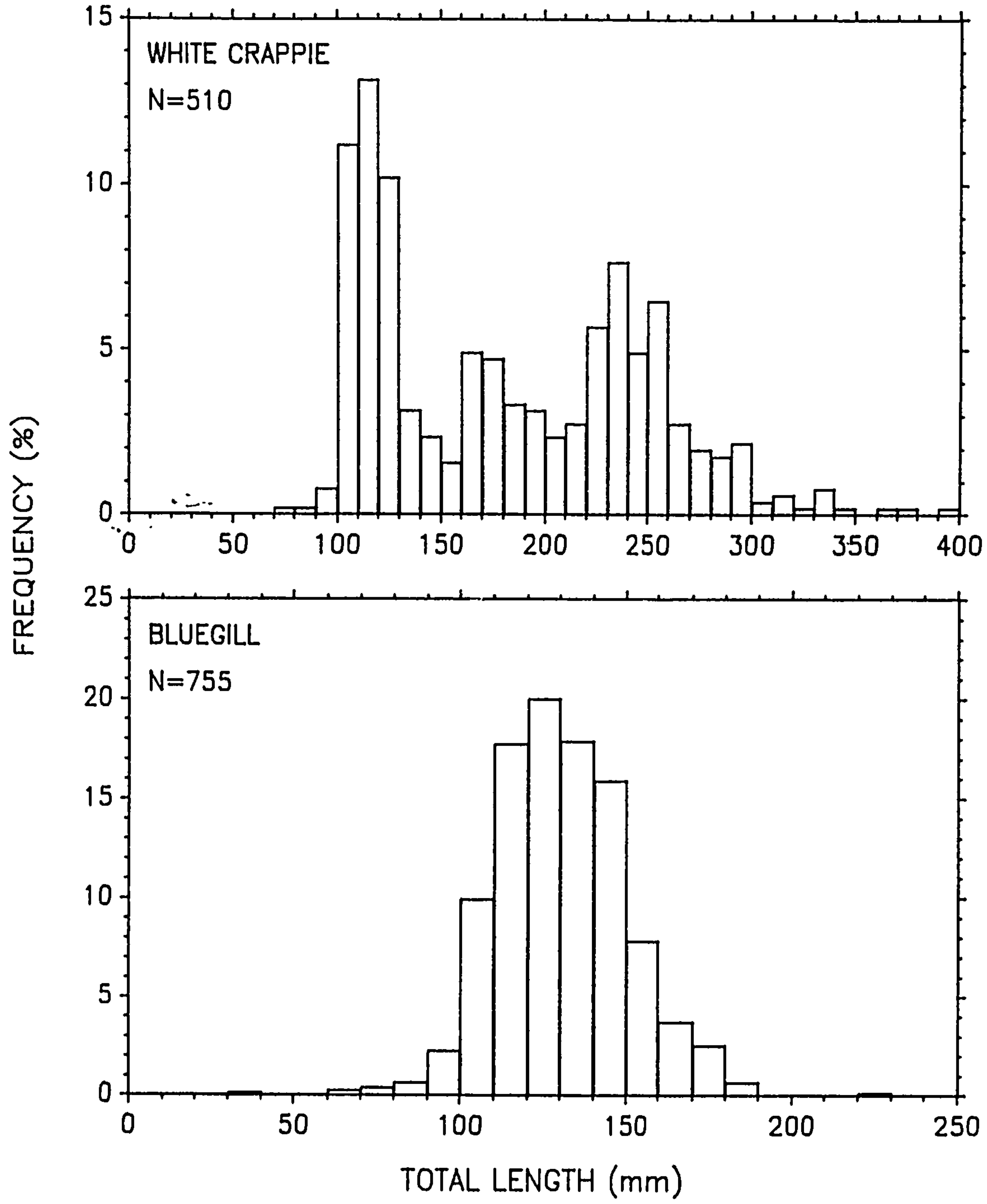

Figure C.22. Length-frequency distributions of white crappie and bluegill collected in the Pensacola Dam tailwater, January 1988 to July 1989.

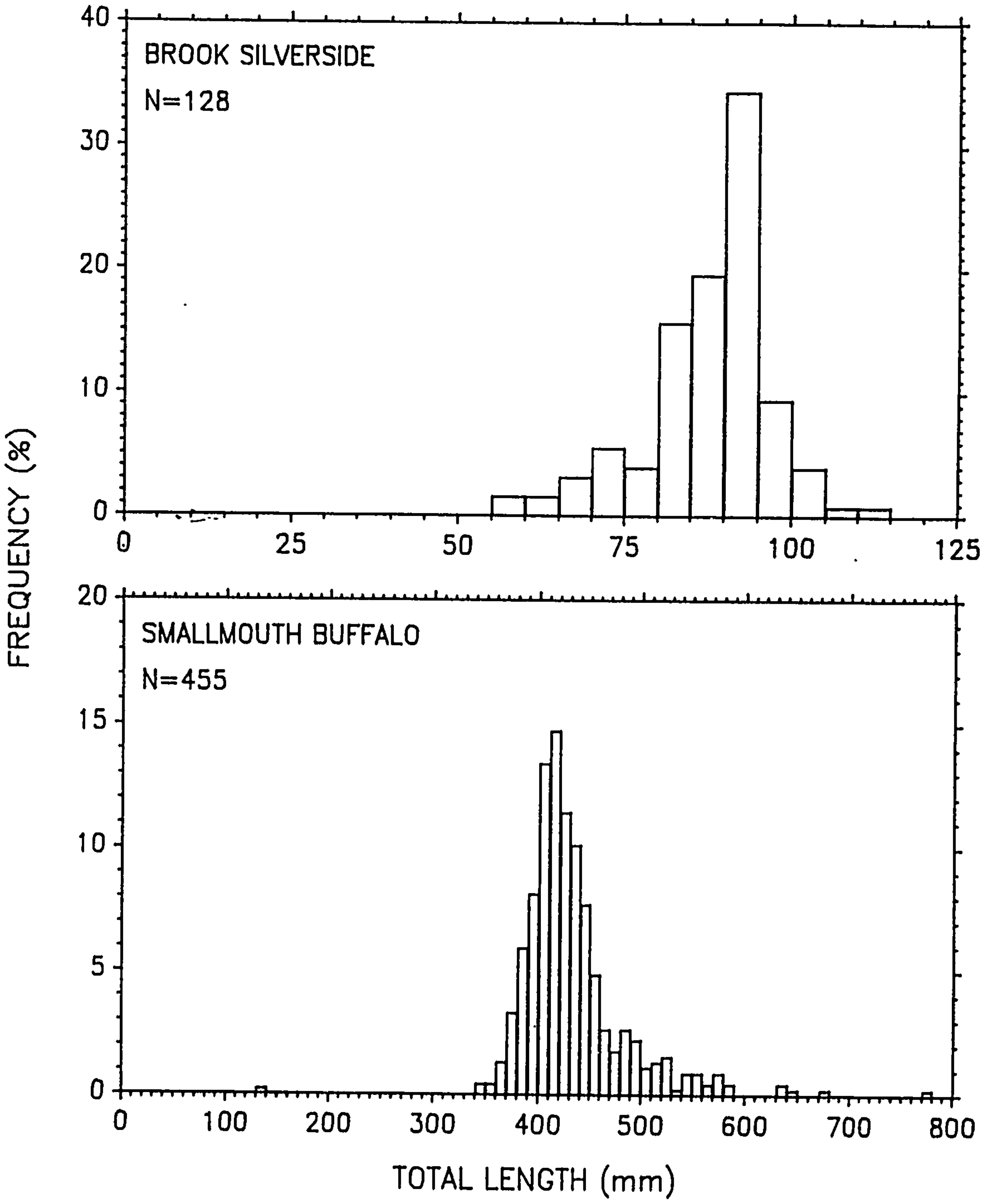

Figure C.23. Length-frequency distributions of brook silversides and smallmouth buffalo collected in the Pensacola Dam tailwater, January 1988 to July 1989.

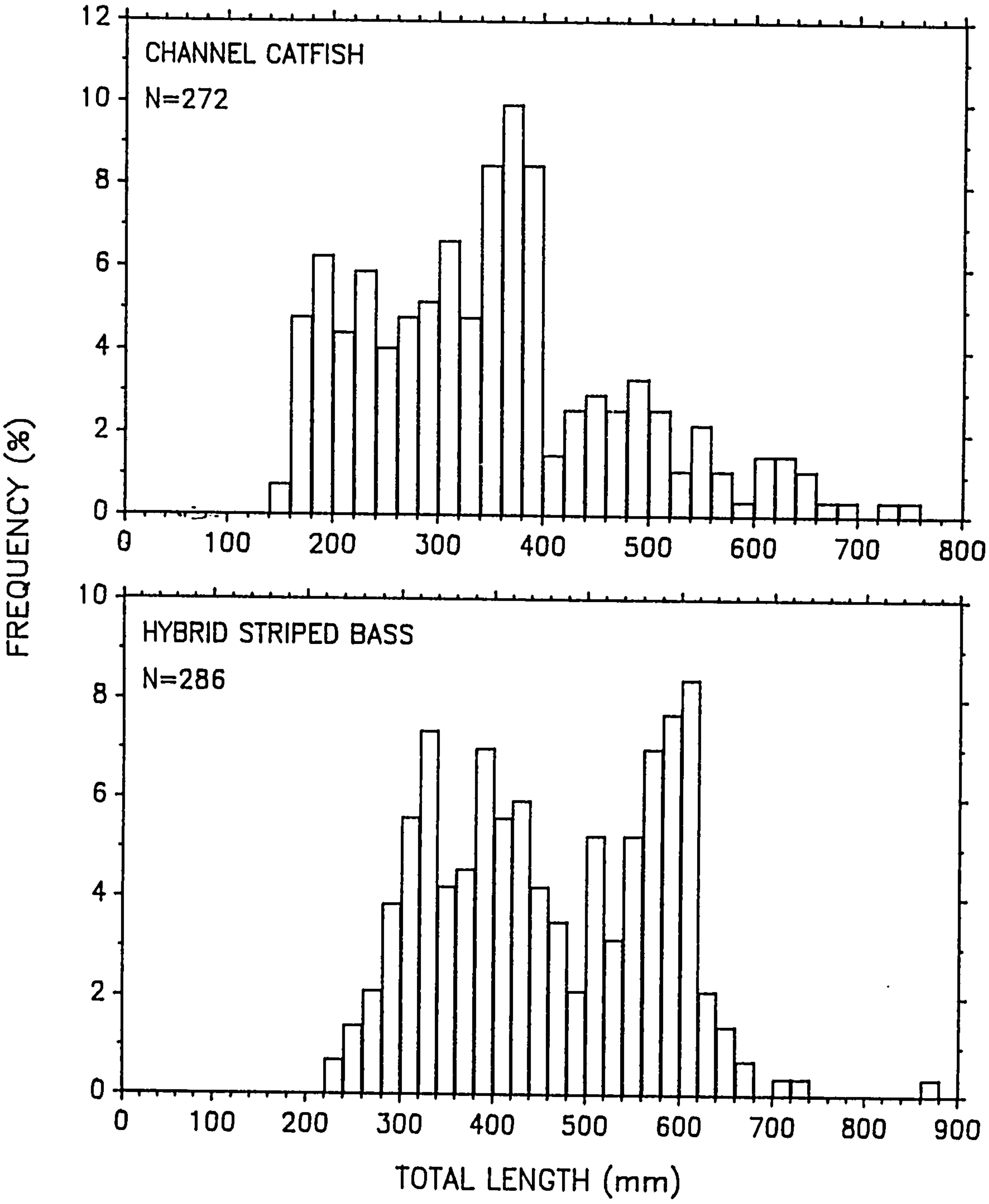

Figure C.24. Length-frequency distributions of channel catfish and hybrid striped bass collected in the Pensacola Dam tailwater, January 1988 to July 1989.

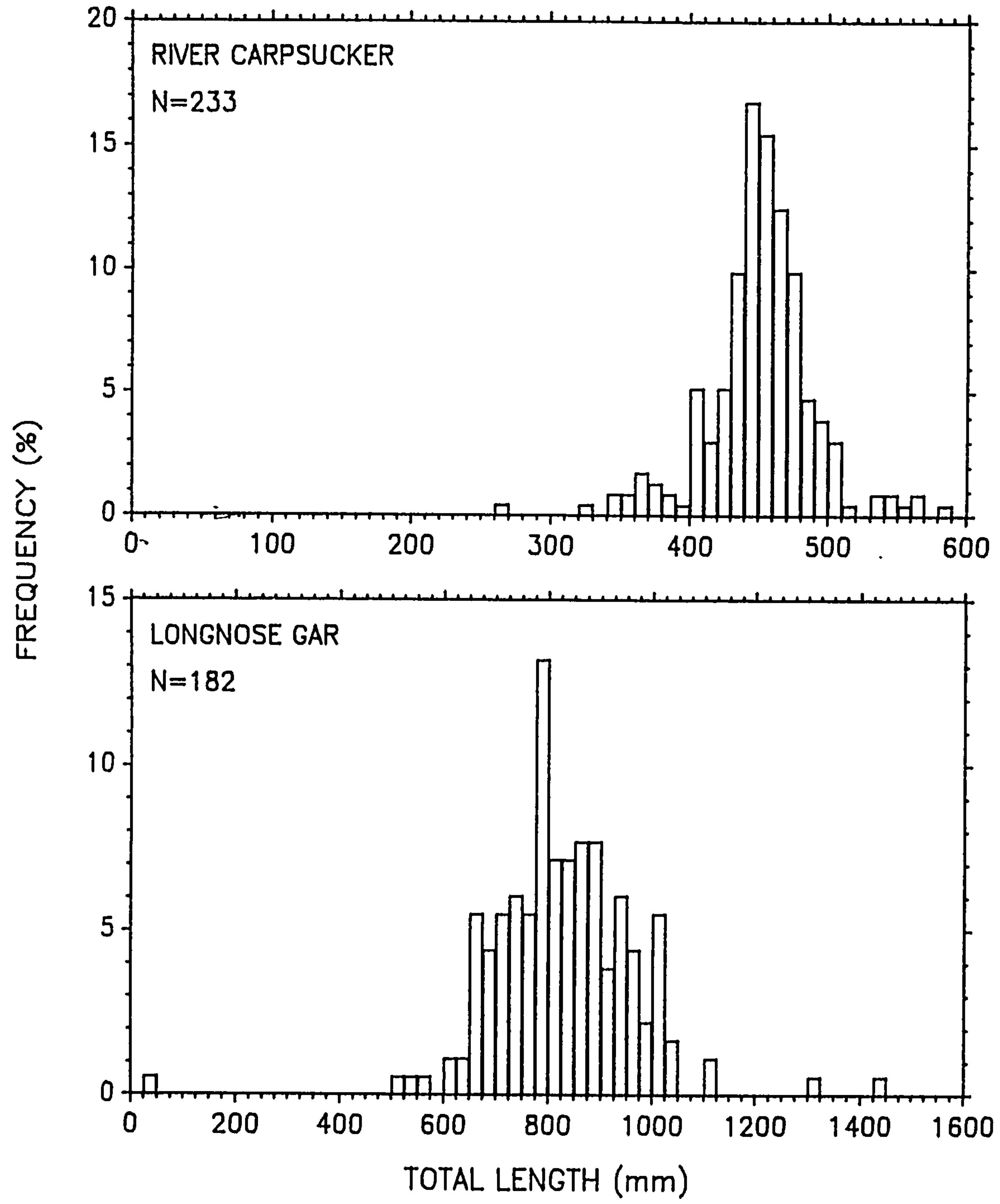

Figure C.25. Length-frequency distributions of river carpsuckers and longnose gar collected in the Pensacola Dam tailwater, January 1988 to July 1989.

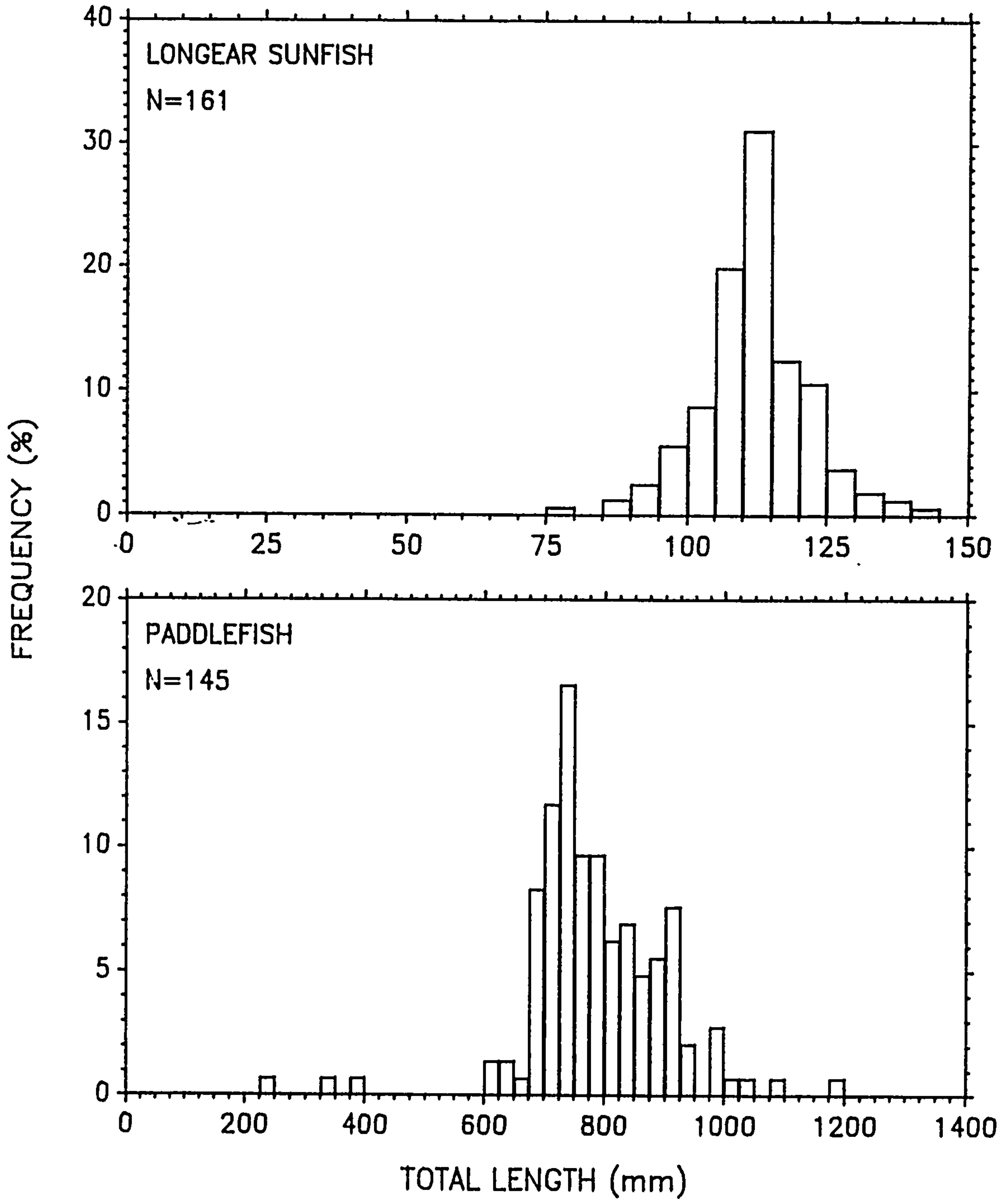

Figure C.26. Length-frequency distributions of longear sunfish and paddlefish collected in the Pensacola Dam tailwater, January 1988 to July 1989.

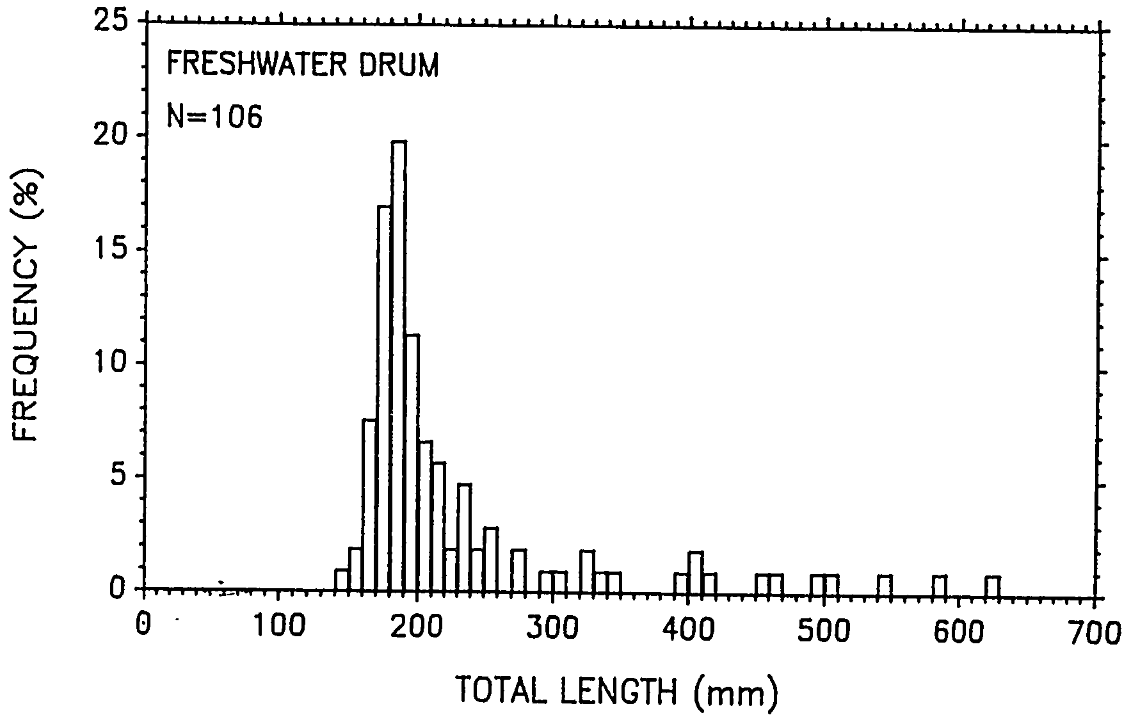

Figure C.27. Length-frequency distribution of freshwater drum collected in the Pensacola Dam tailwater, January 1988 to July 1989.

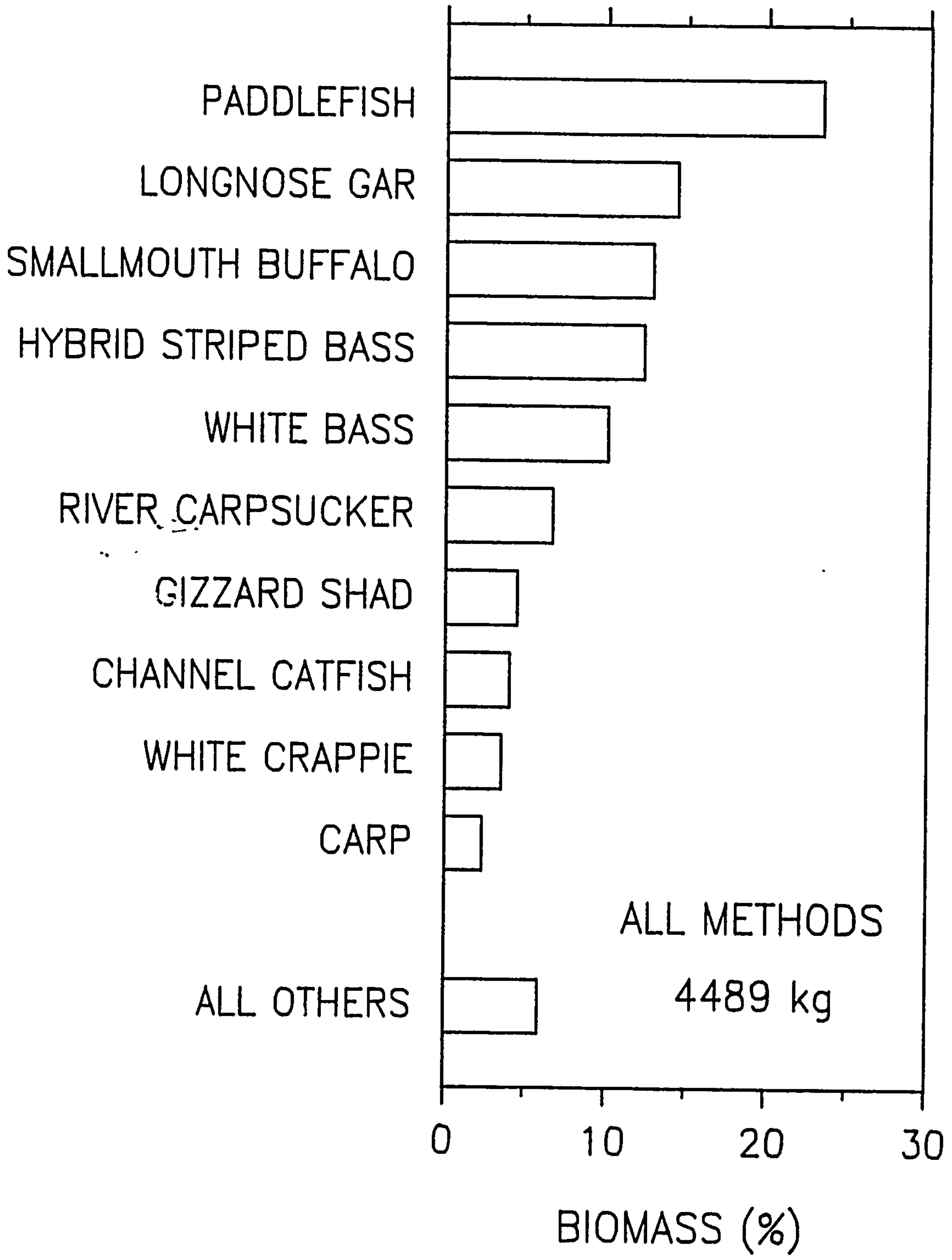

Figure C.28. Relative abundances (%) of biomasses of fishes constituting >1% of the total biomass collected using all gear types in the Pensacola Dam tailwater, January 1988 to July 1989.

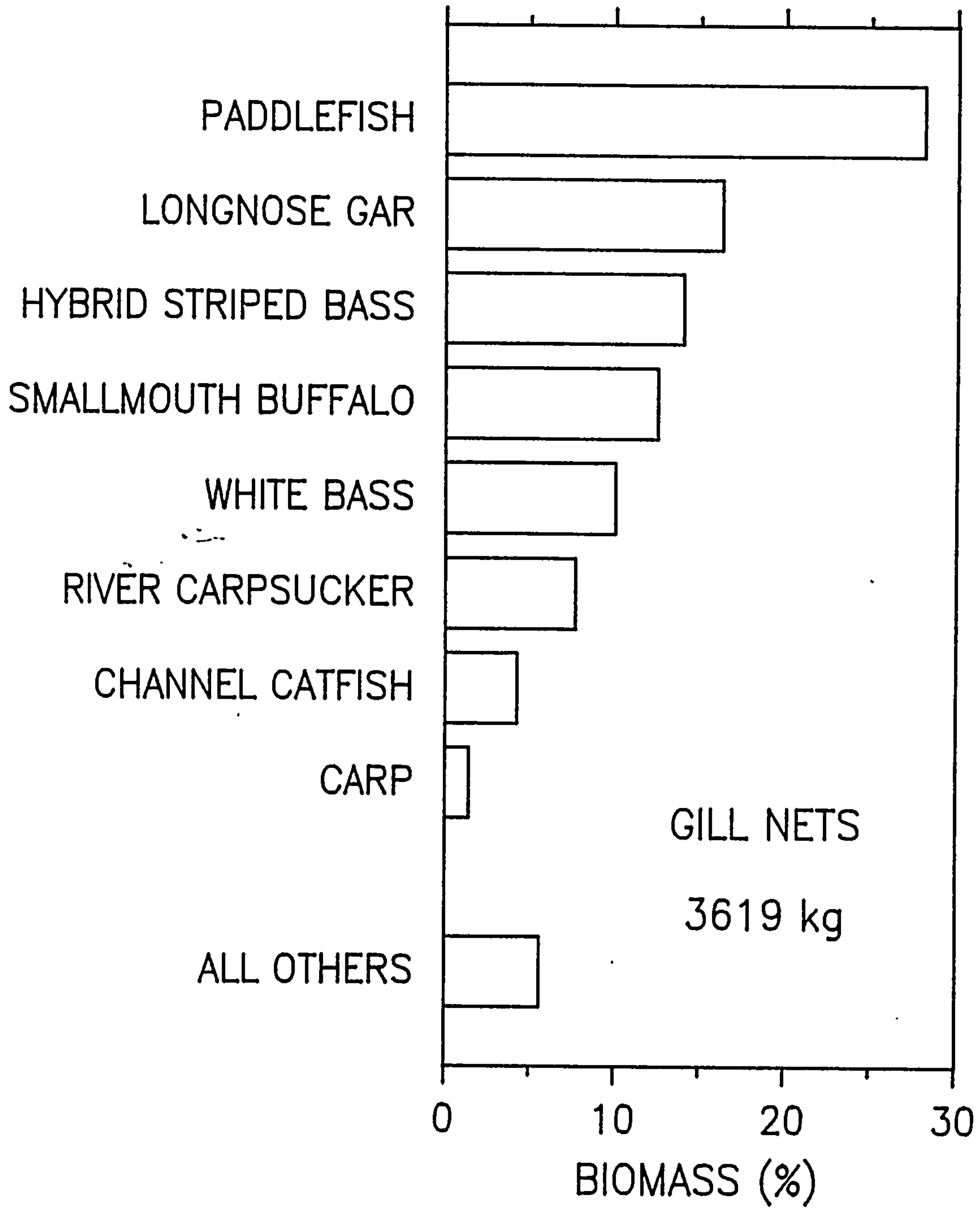

Figure C.29. Relative abundances (%) of biomasses of fishes constituting >1% of the total biomass collected using gill nets in the Pensacola Dam tailwater, January 1988 to July 1989.

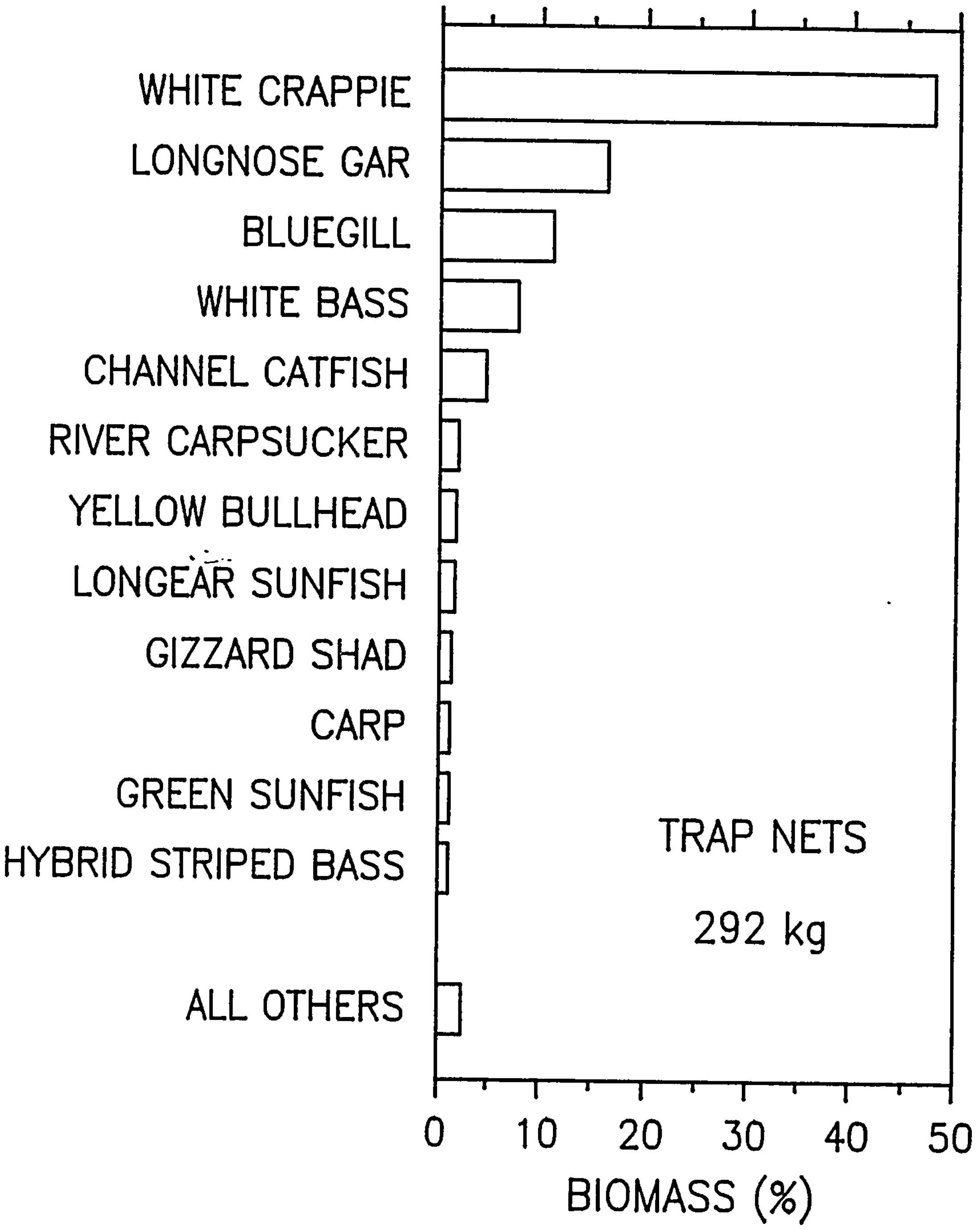

Figure C.30. Relative abundances (%) of biomasses of fishes constituting >1% of the total biomass collected using trap nets in the Pensacola Dam tailwater, January 1988 to July 1989.

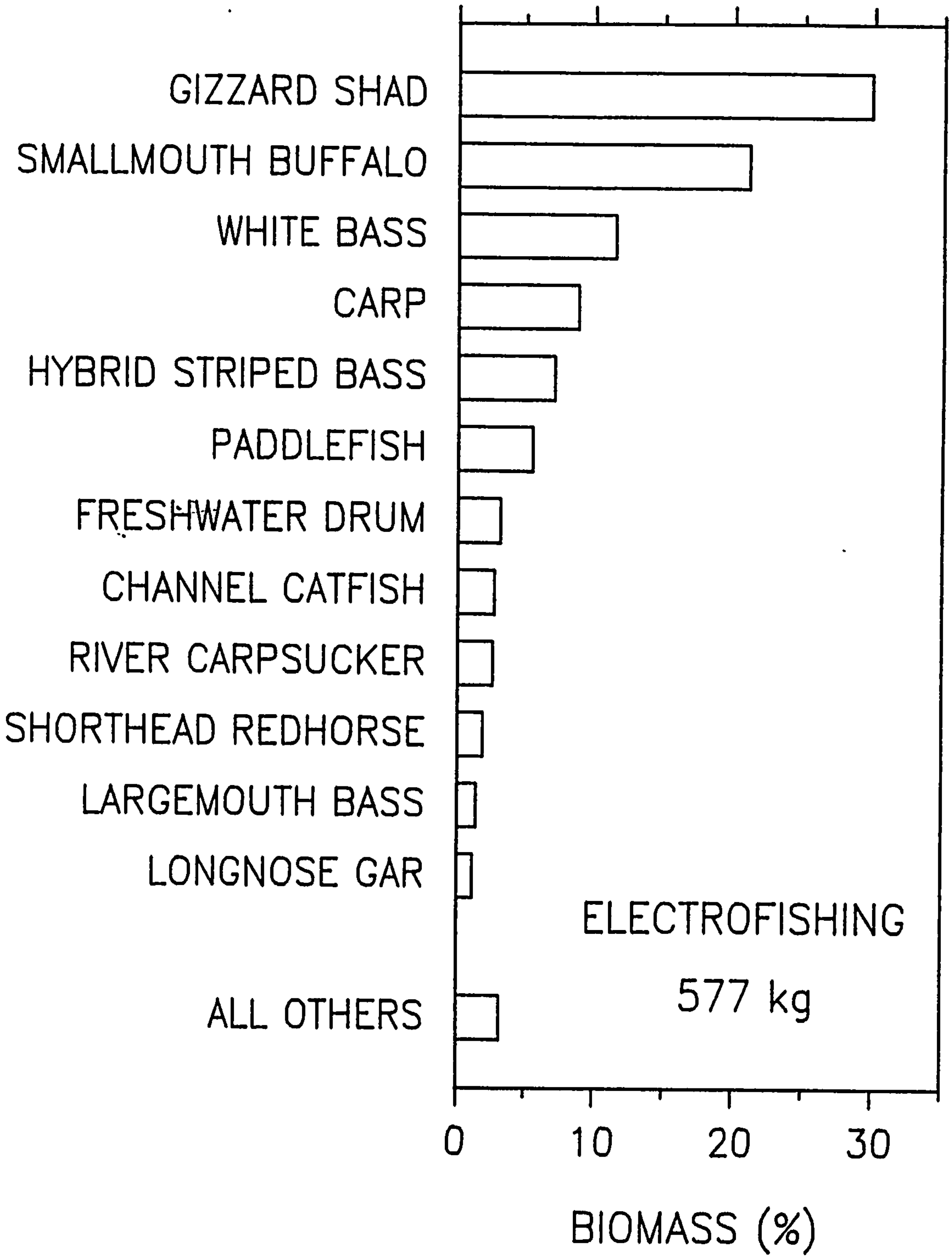

Figure C.31. Relative abundances (%) of biomasses of fishes constituting >1% of the total biomass collected by electrofishing in the Pensacola Dam tailwater, January 1988 to July 1989.

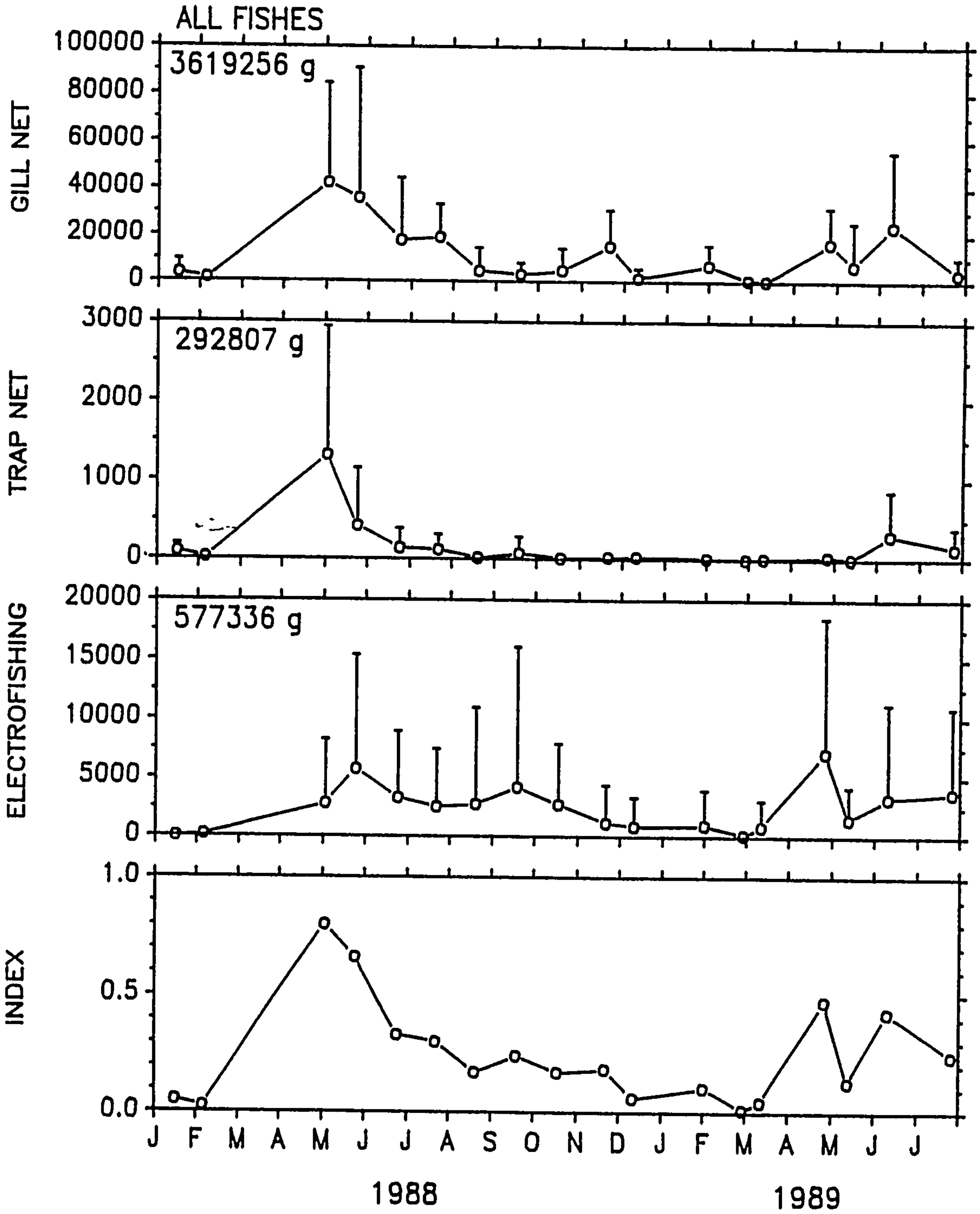

Figure C.32. Biomass catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of all fishes in aggregate, Pensacola Dam tailwater, January 1988 to July 1989.

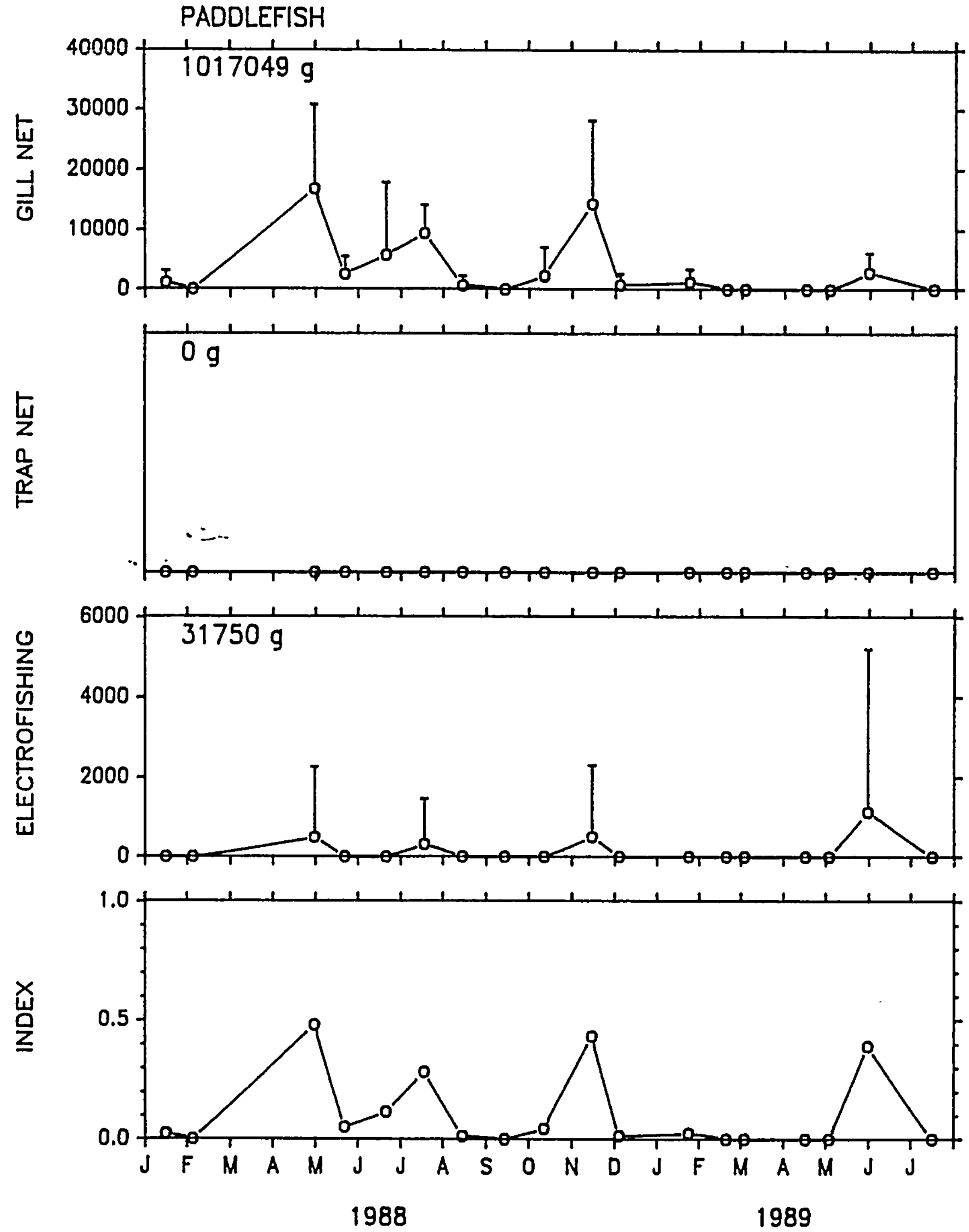

Figure C.33. Biomass catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of paddlefish, Pensacola Dam tailwater, January 1988 to July 1989.

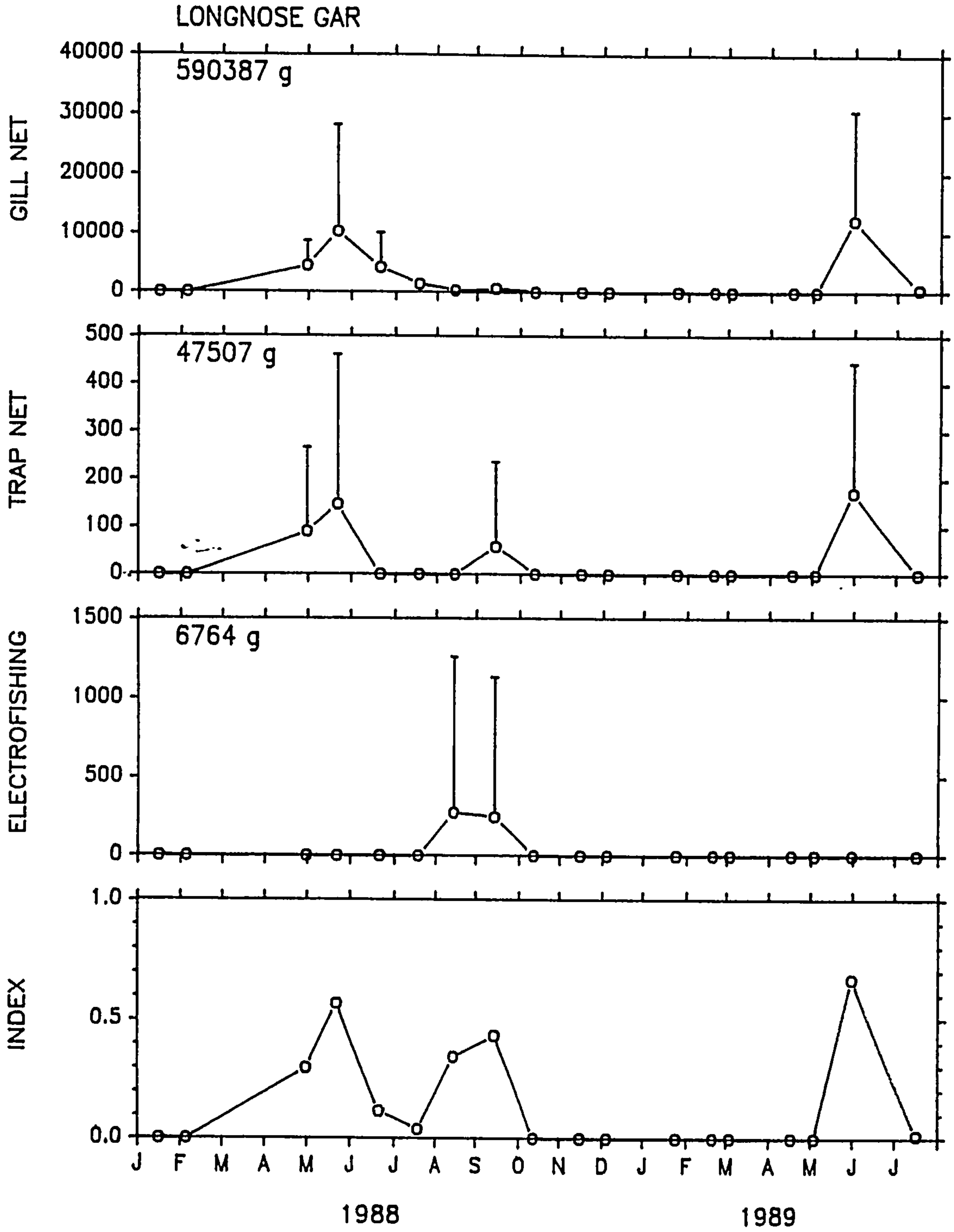

Figure C.34. Biomass catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of longnose gar, Pensacola Dam tailwater, January 1988 to July 1989.

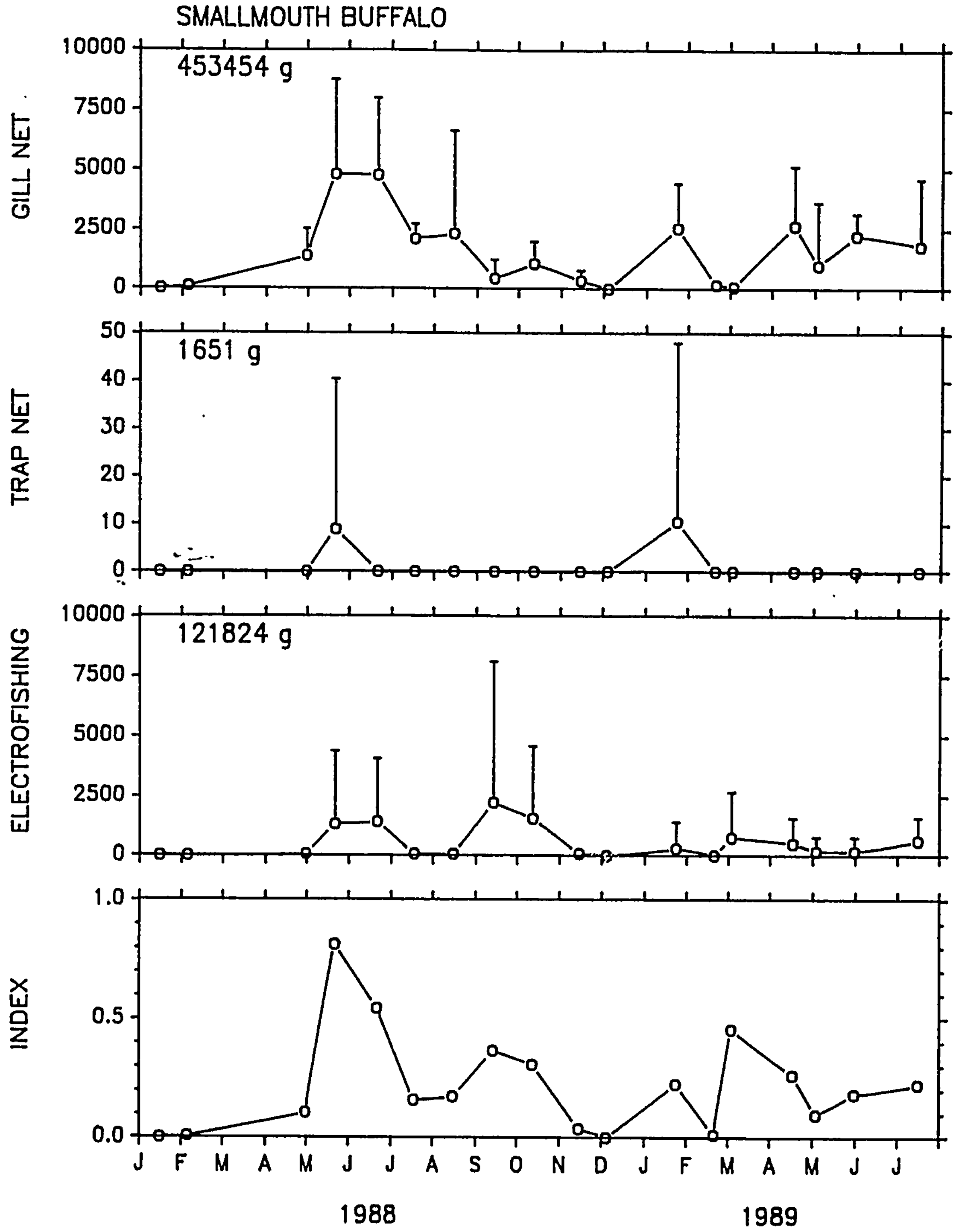

Figure C.35. Biomass catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of smallmouth buffalo, Pensacola Dam tailwater, January 1988 to July 1989.

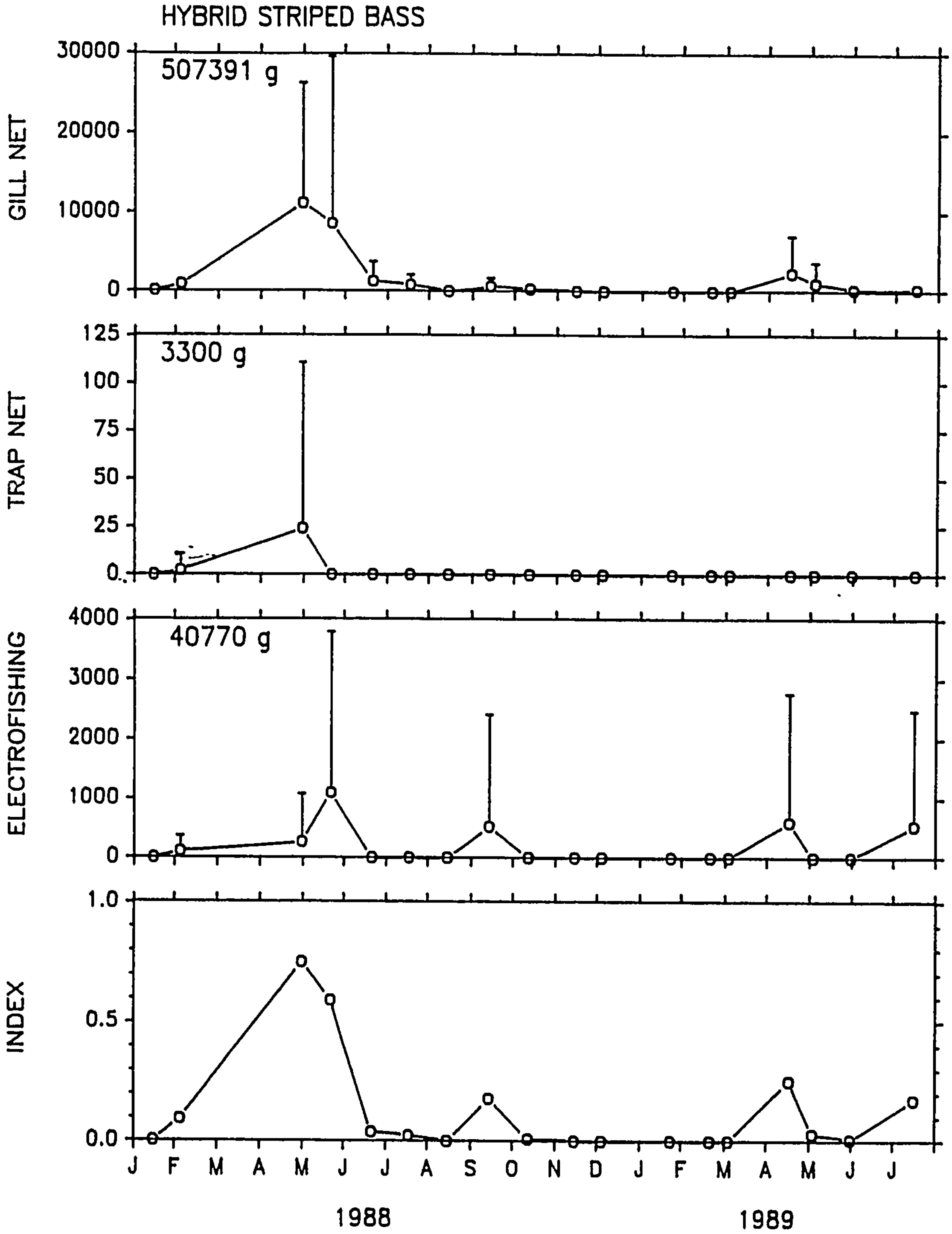

Figure C.36. Biomass catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of hybrid striped bass, Pensacola Dam tailwater, January 1988 to July 1989.

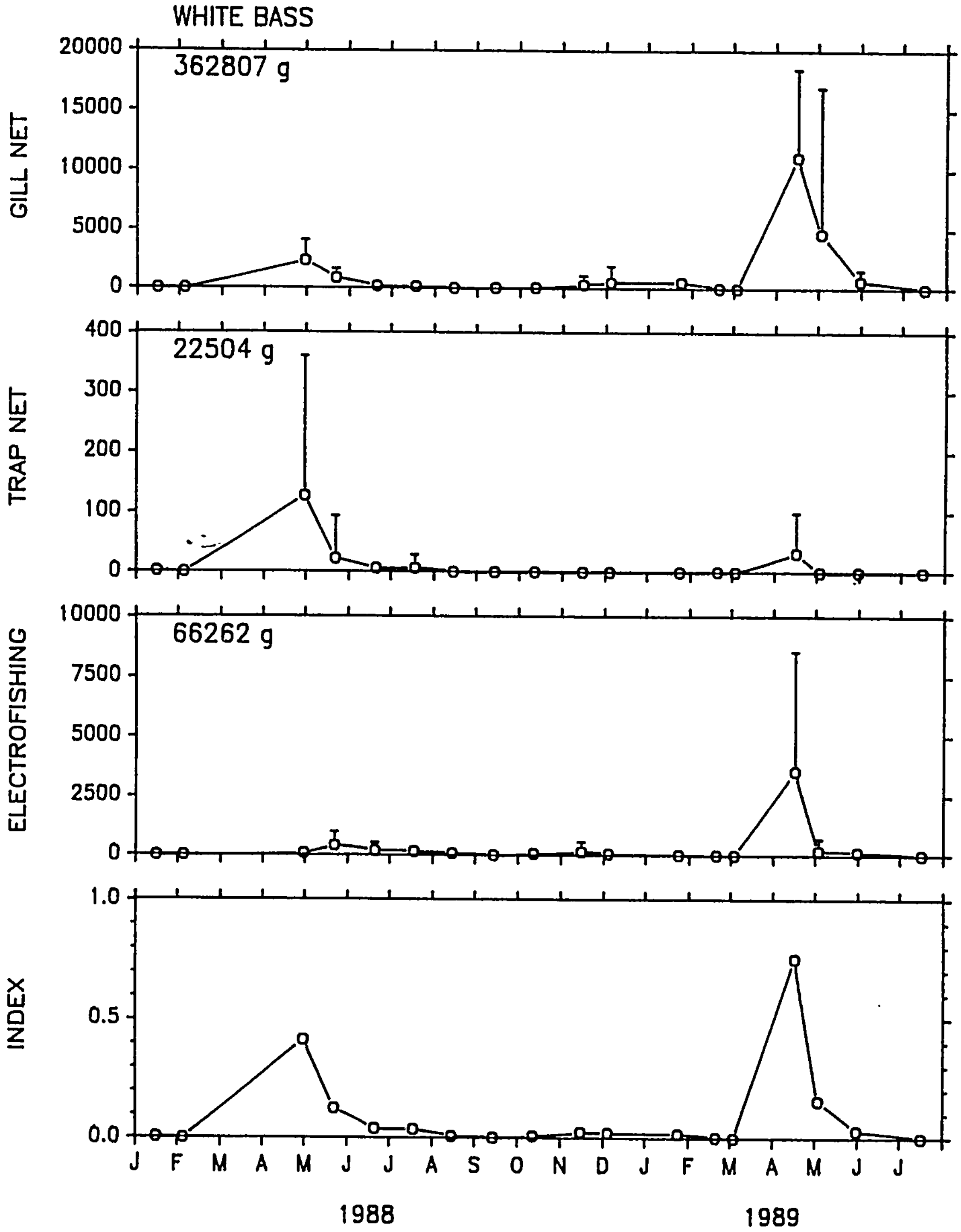

Figure C.37. Biomass catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of white bass, Pensacola Dam tailwater, January 1988 to July 1989.

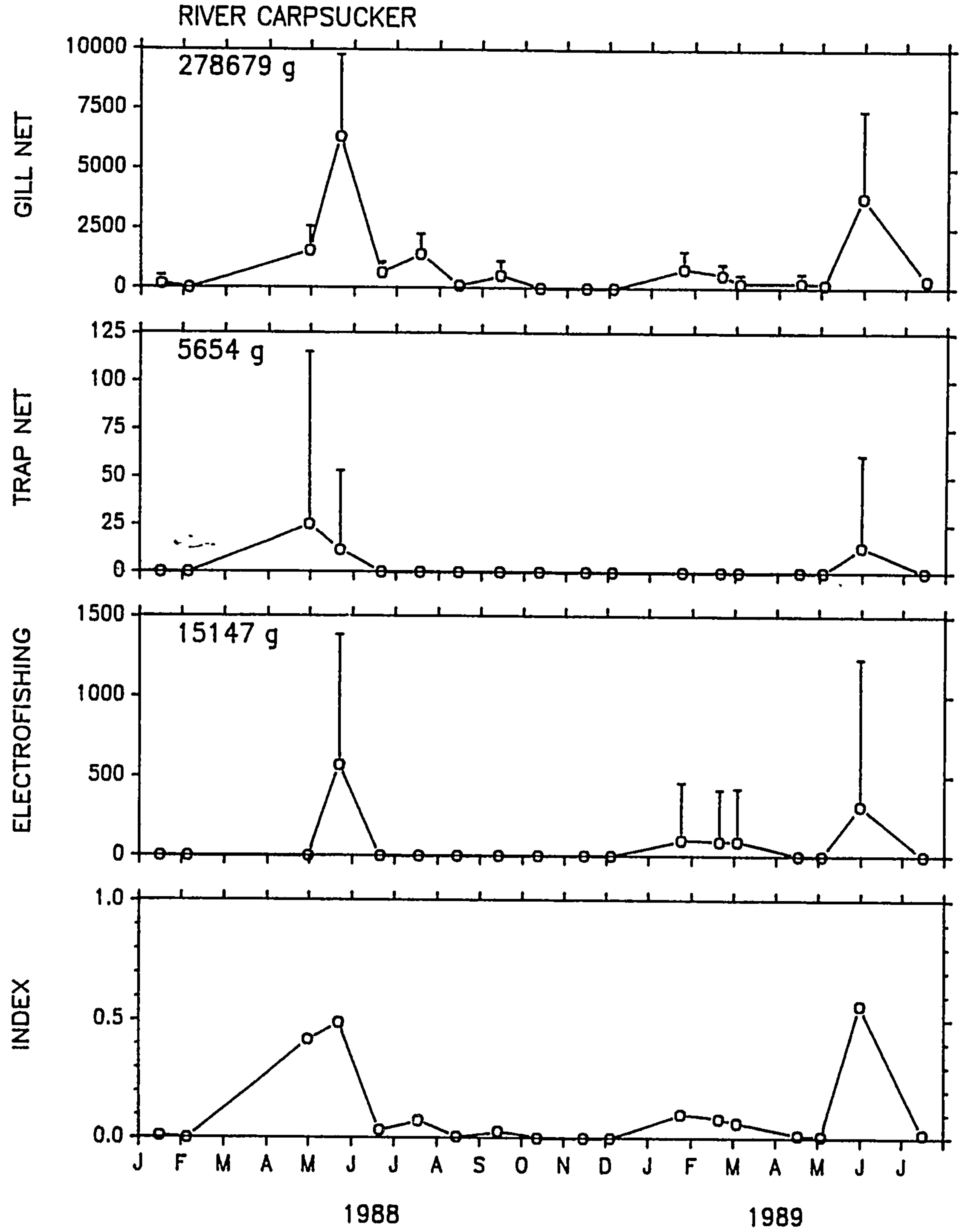

Figure C.38. Biomass catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of river carpsucker, Pensacola Dam tailwater, January 1988 to July 1989.

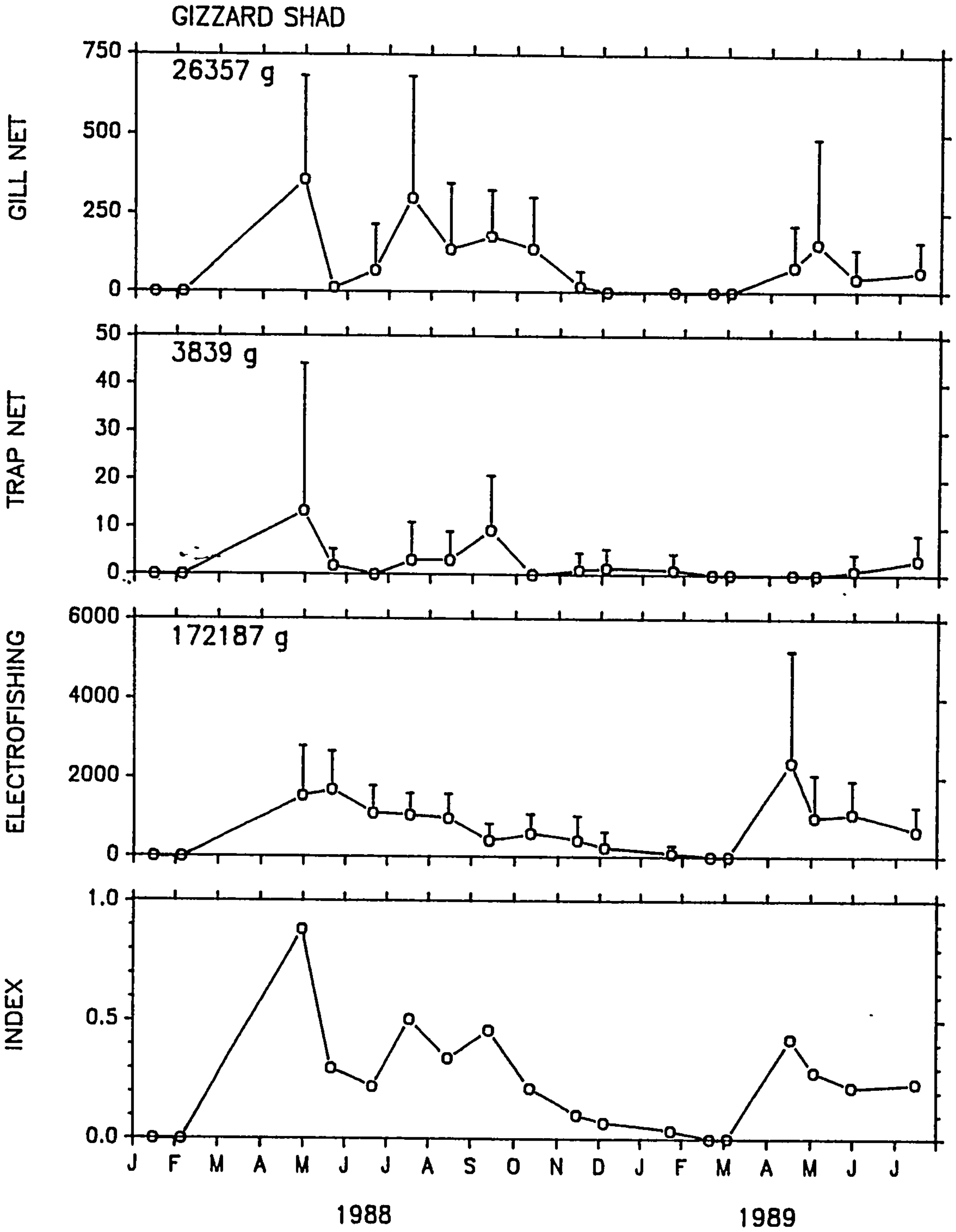

Figure C.39. Biomass catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of gizzard shad, Pensacola Dam tailwater, January 1988 to July 1989.

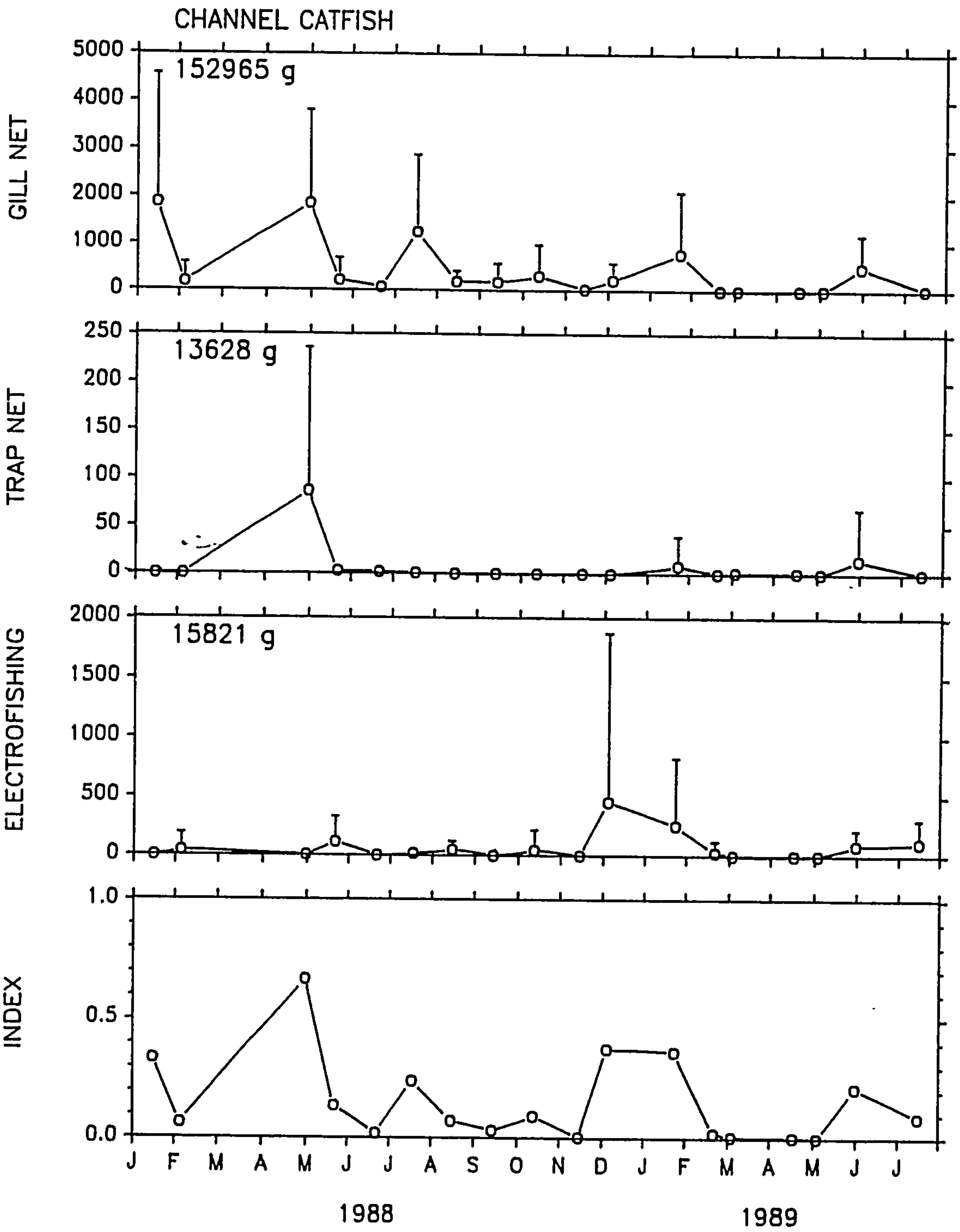

Figure C.40. Biomass catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of channel catfish, Pensacola Dam tailwater, January 1988 to July 1989.

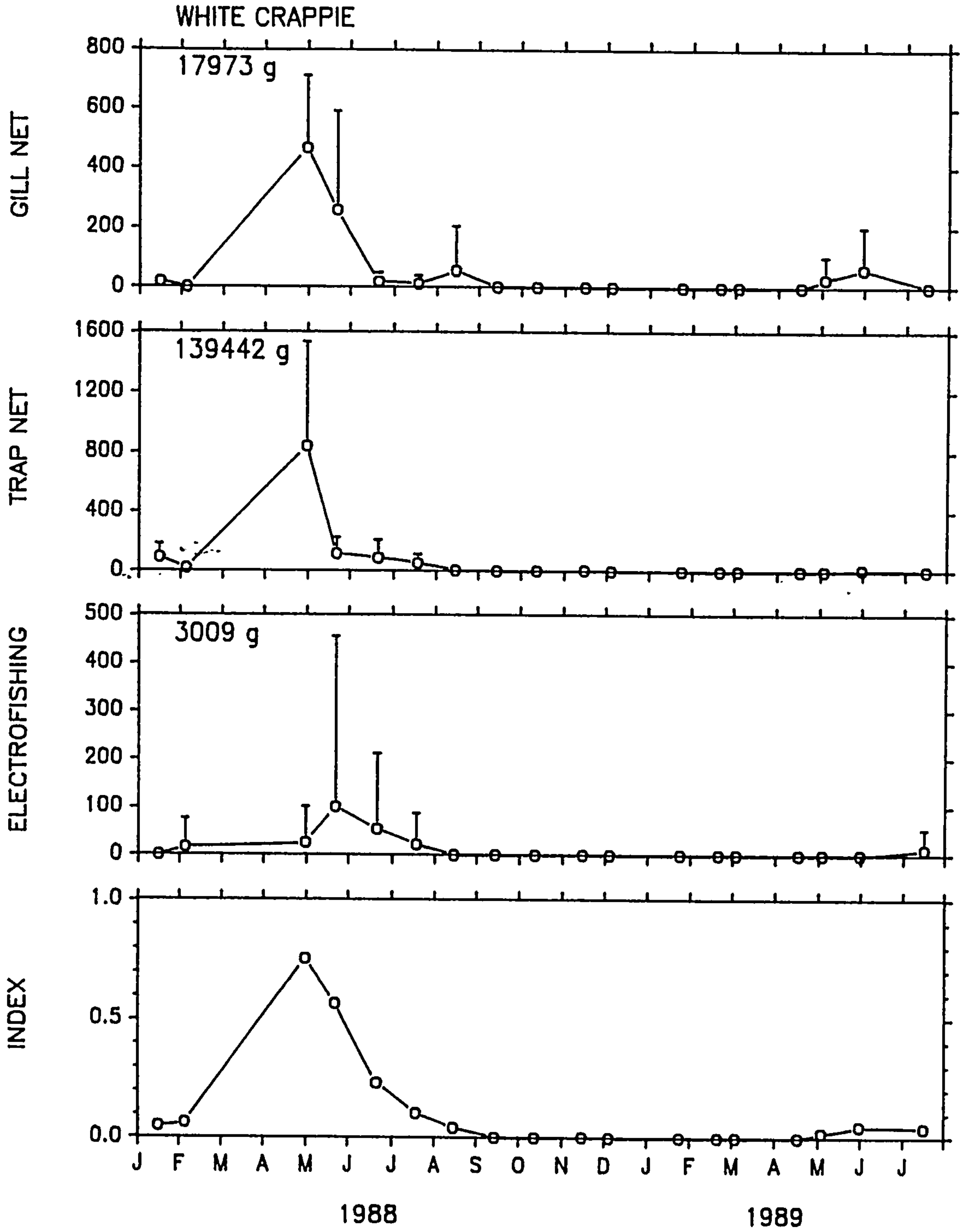

Figure C.41. Biomass catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of white crappie, Pensacola Dam tailwater, January 1988 to July 1989.

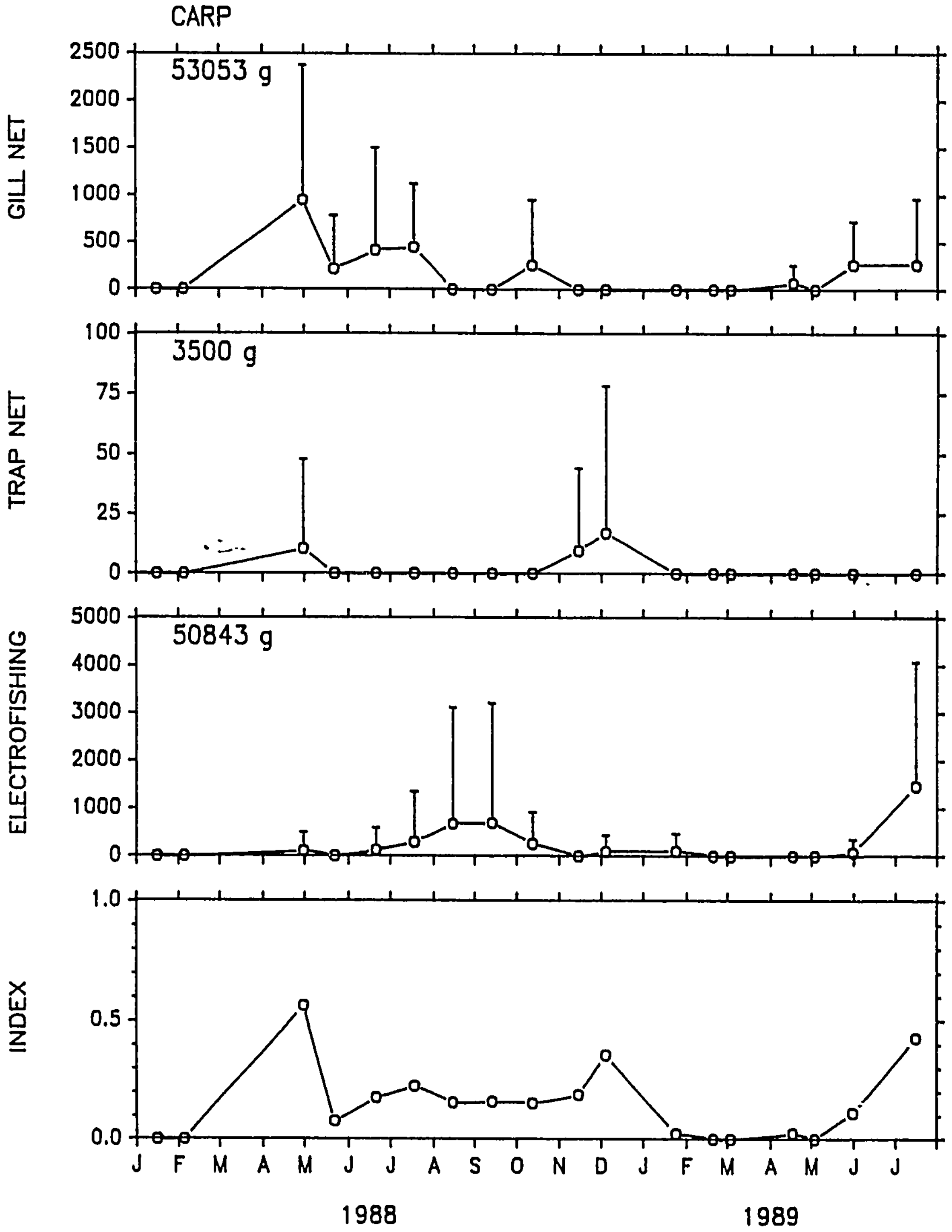

Figure C.42. Biomass catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of common carp, Pensacola Dam tailwater, January 1988 to July 1989.

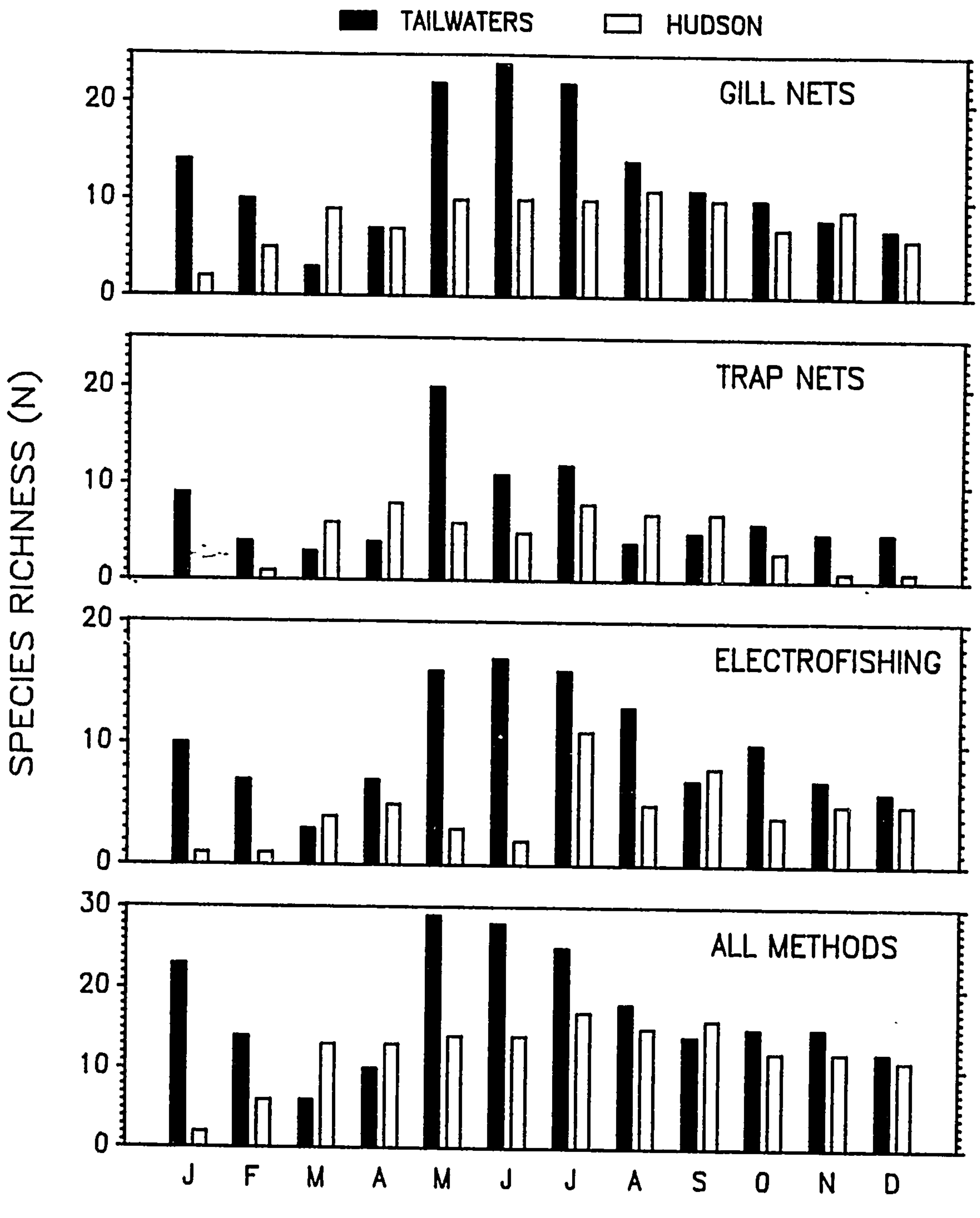

Figure C.43. Monthly species richnesses of gill-net, trap-net, electrofishing, and combined-gear fish collections in the Pensacola Dam tailwater and Hudson study areas.

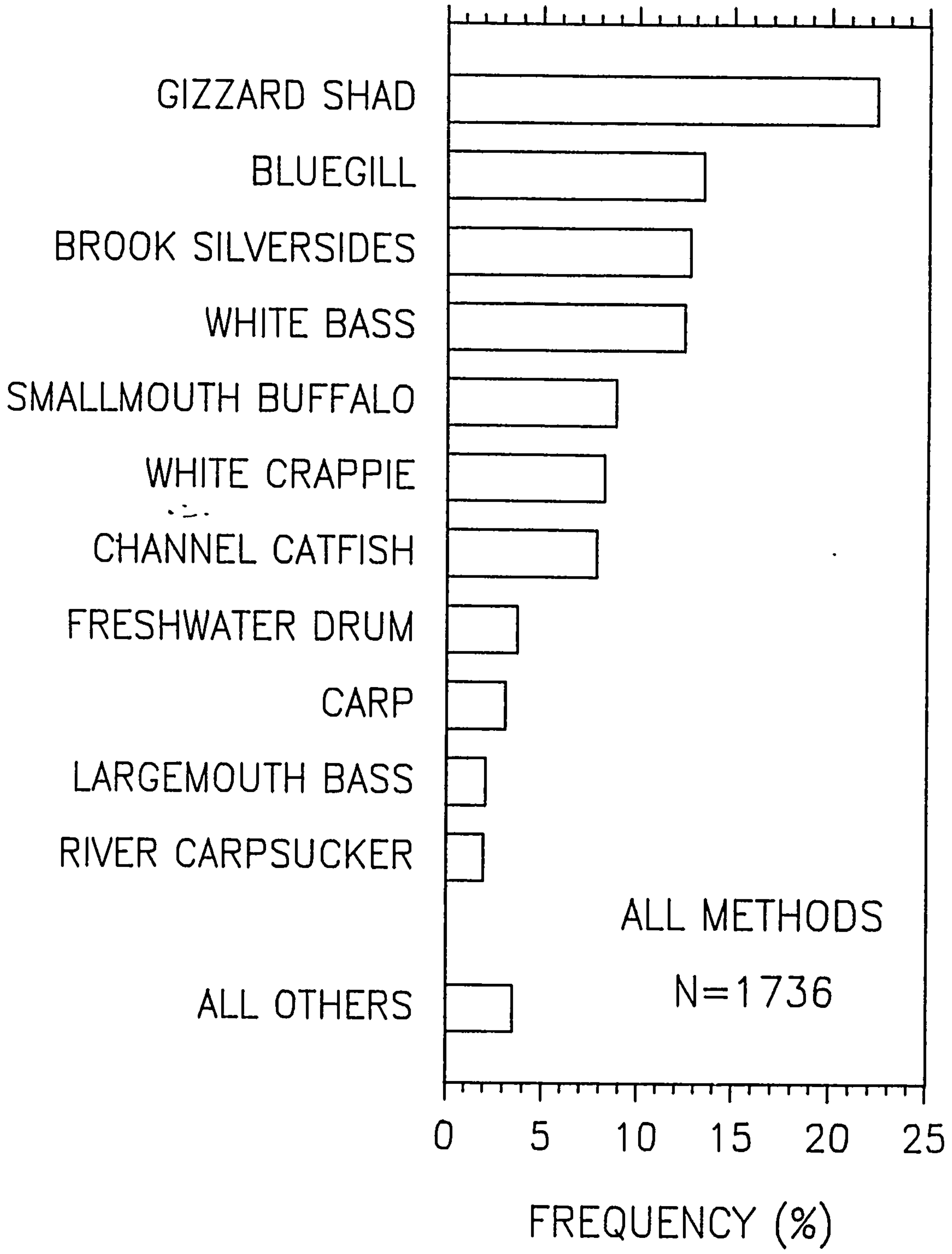

Figure C.44. Relative numeric abundances (%) of fishes constituting >1% of the total catch captured using all gear types in the Hudson study area, January to December 1988.

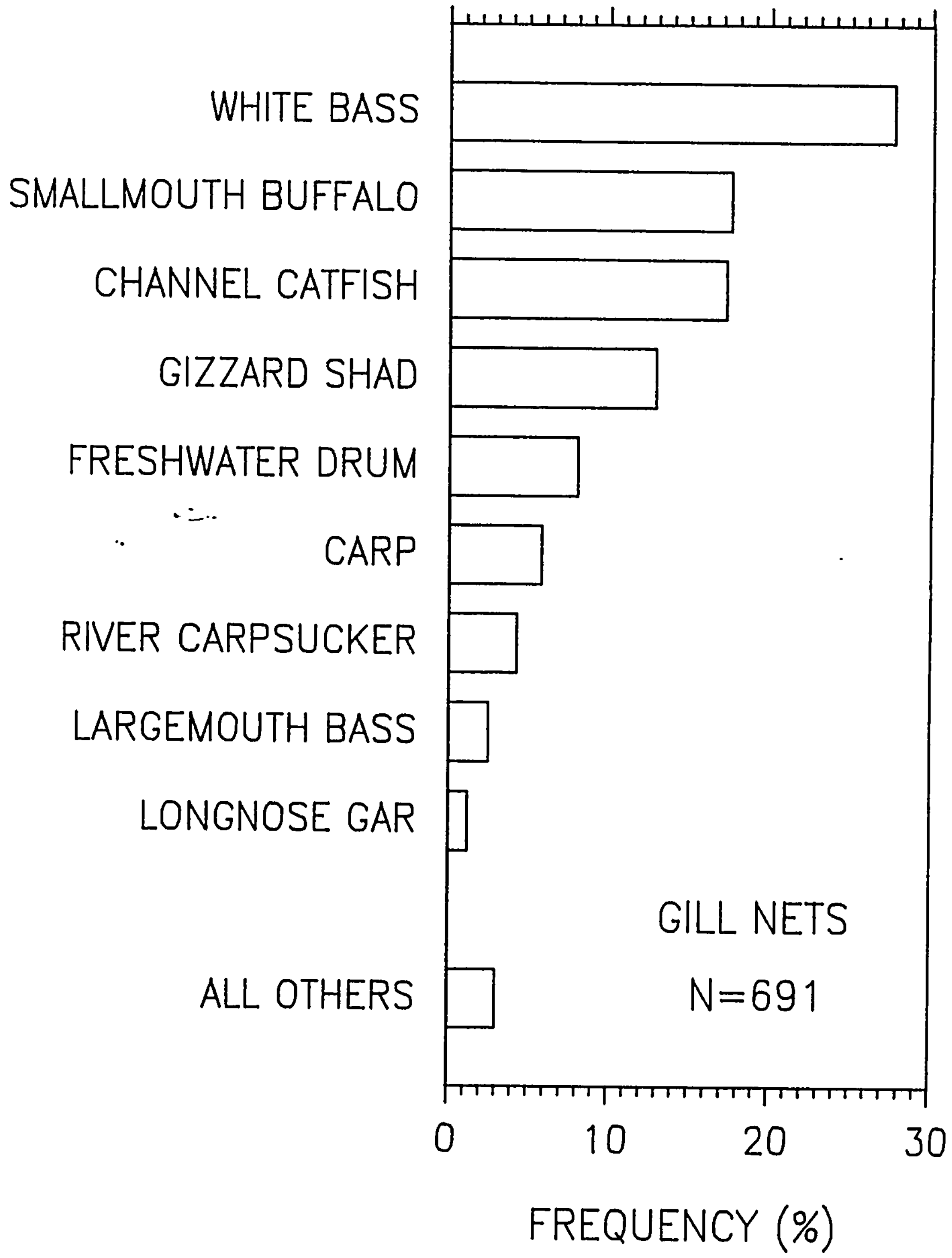

Figure C.45. Relative numeric abundances (%) of fishes constituting >1% of the gill-net catch in the Hudson study area, January to December 1988.

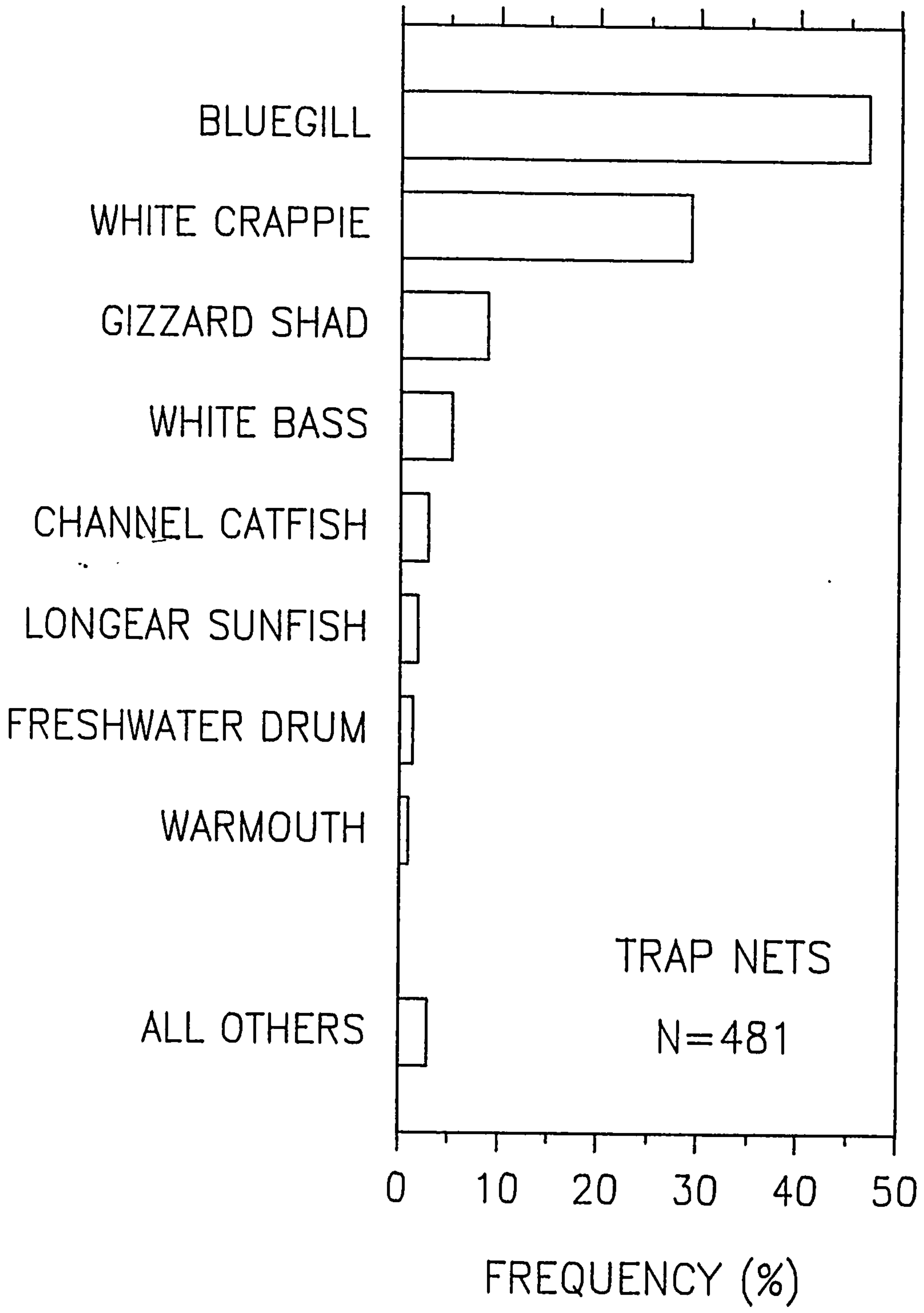

Figure C.46. Relative numeric abundances (%) of fishes constituting >1% of the trap-net catch in the Hudson study area, January to December 1988.

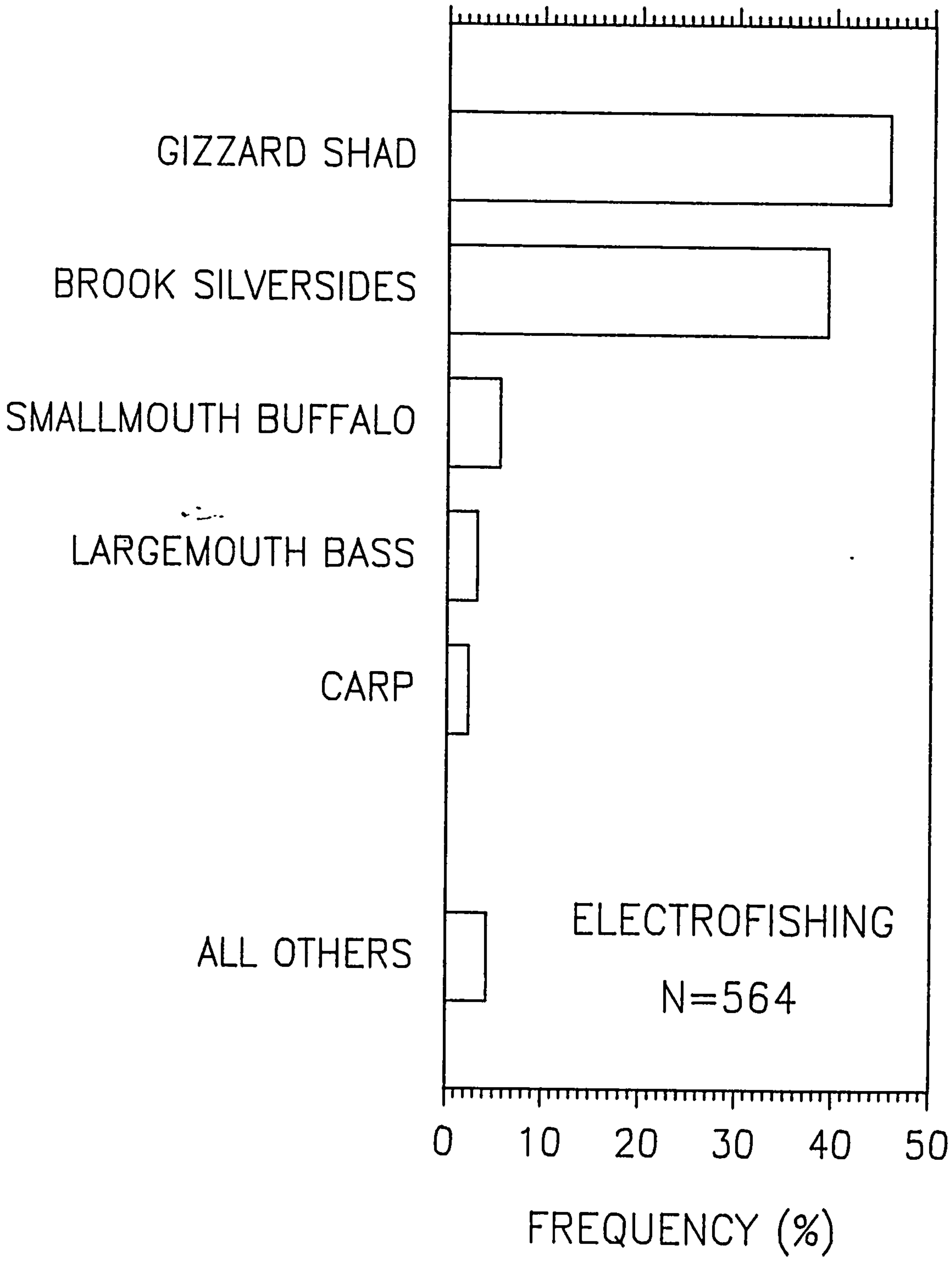

Figure C.47. Relative numeric abundances (%) of fishes constituting >1% of the electrofishing catch in the Hudson study area, January to December 1988.

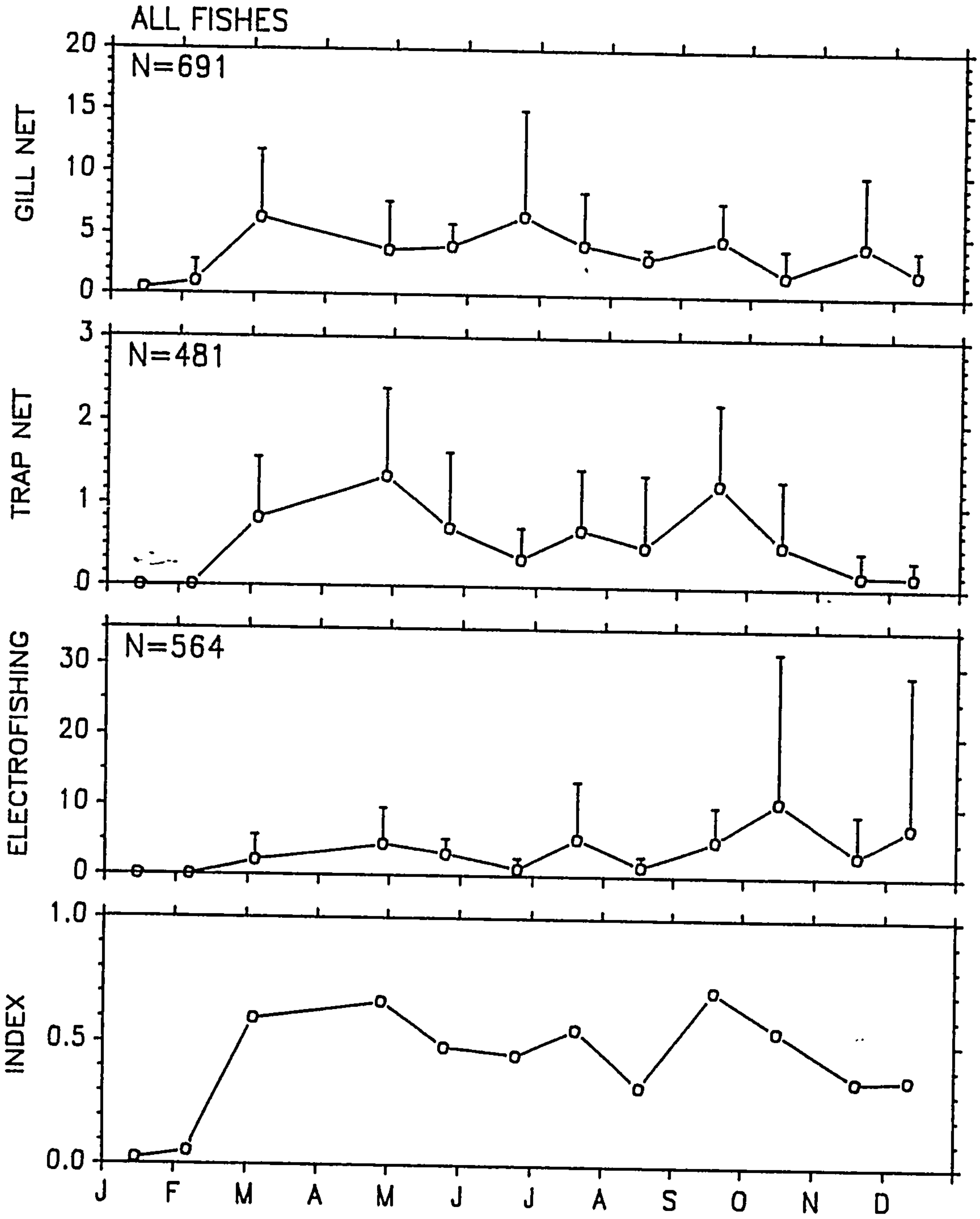

Figure C.48. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of all fishes in aggregate, Hudson study area, January to December 1988.

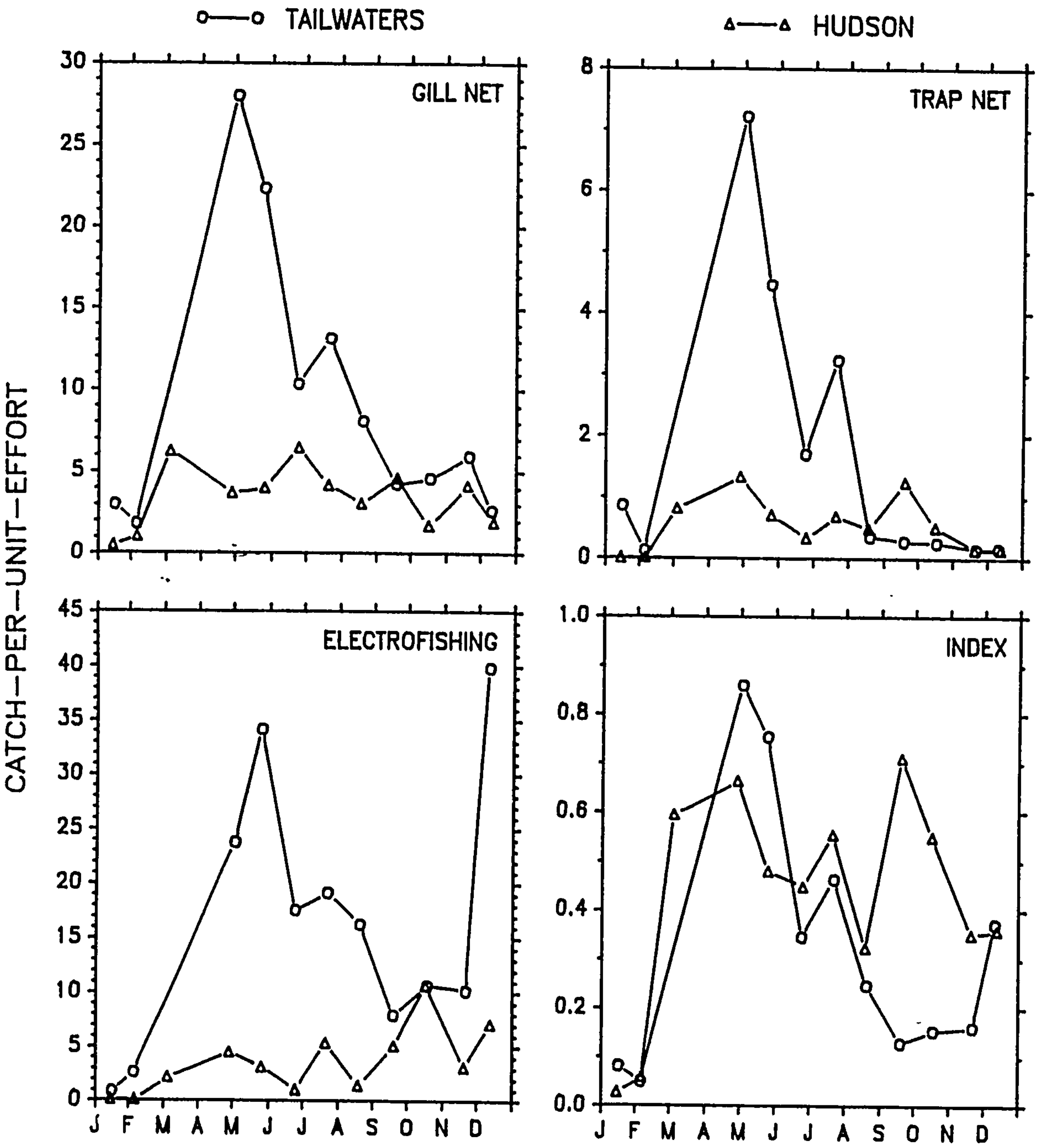

Figure C.49. Numeric catch-per-unit-effort rates by gear and combined-gear catch index values of all fishes in aggregate, Pensacola Dam tailwater and Hudson study areas, January to December 1988.

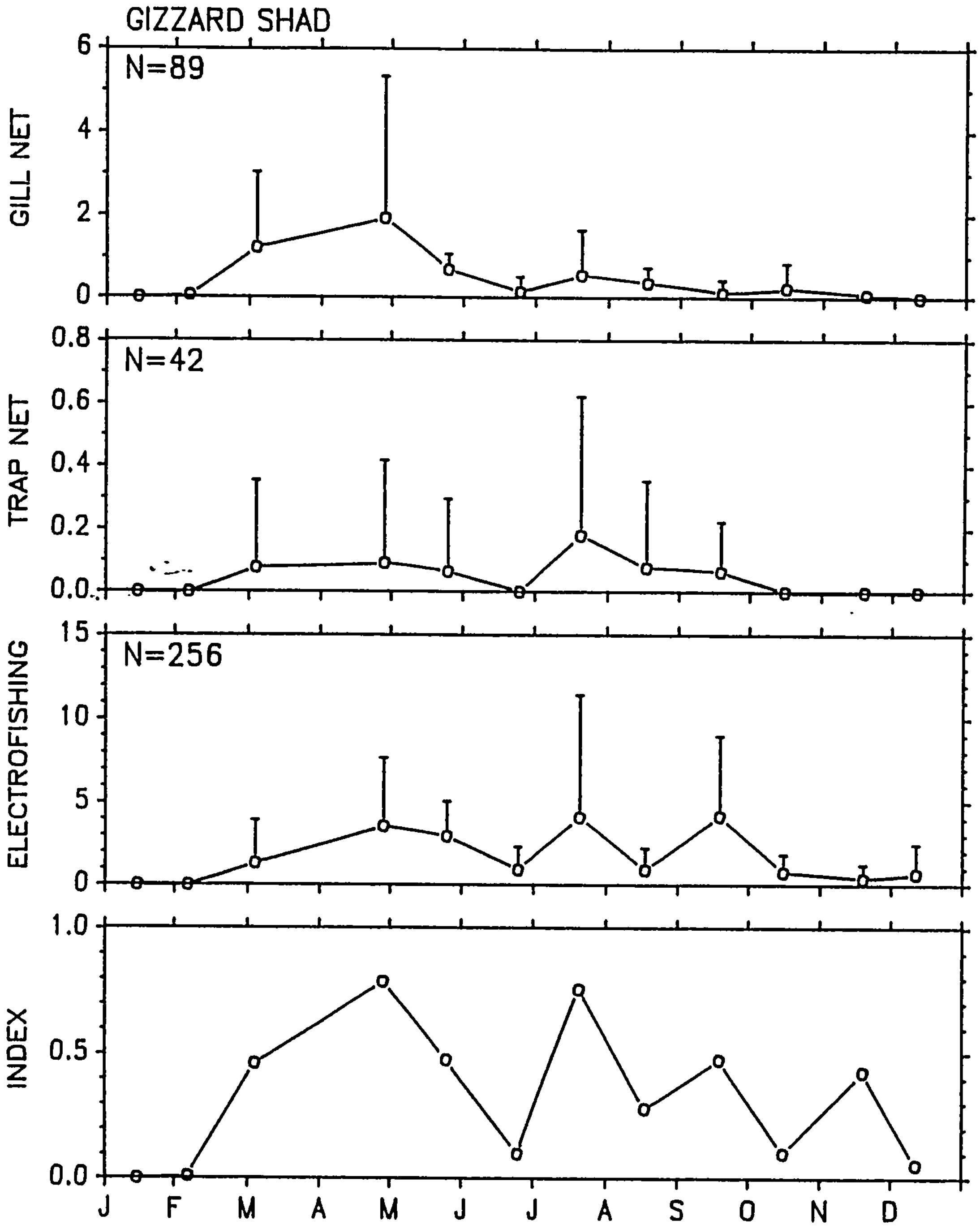

Figure C.50. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of gizzard shad, Hudson study area, January to December 1988.

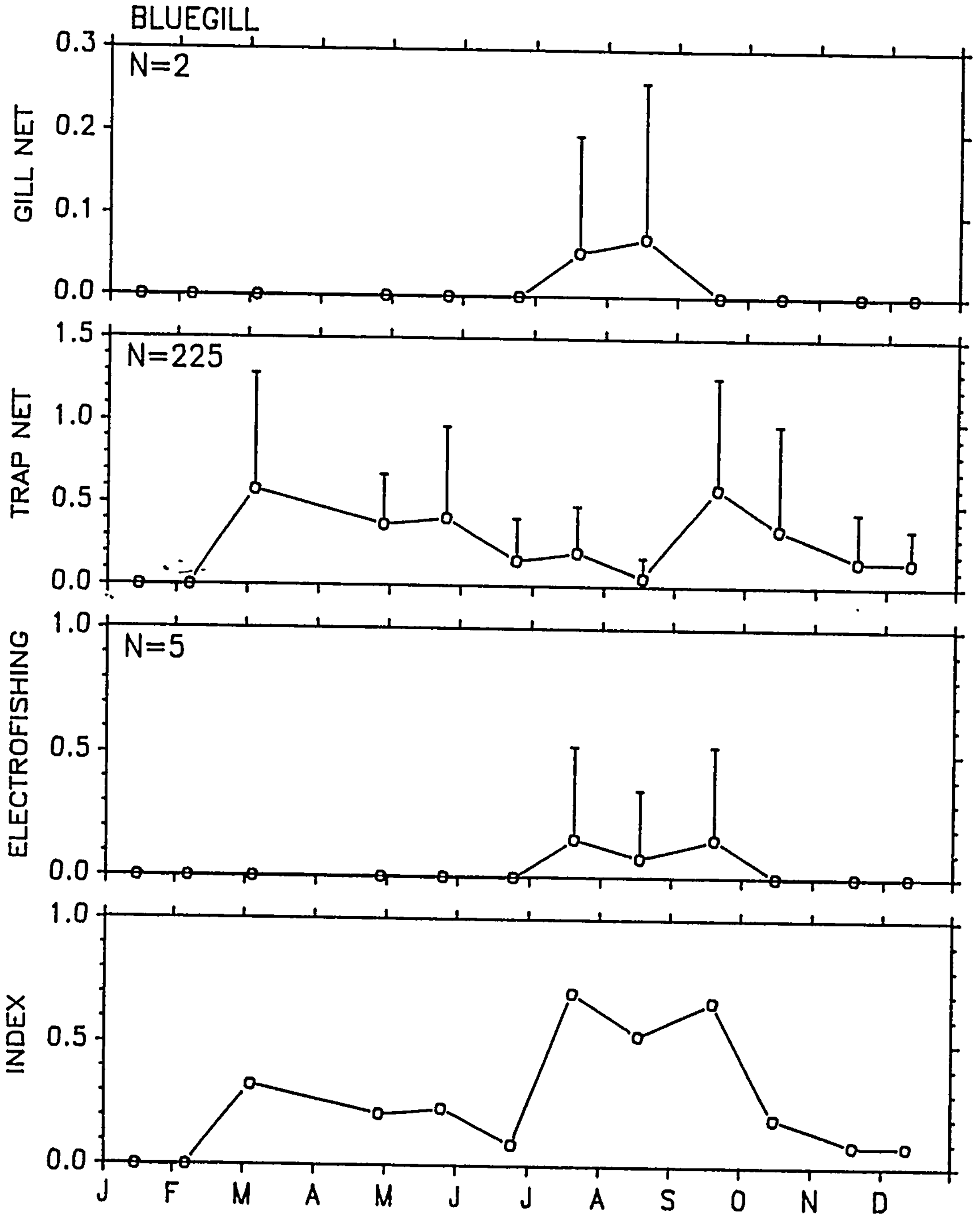

Figure C.51. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of bluegill, Hudson study area, January to December 1988.

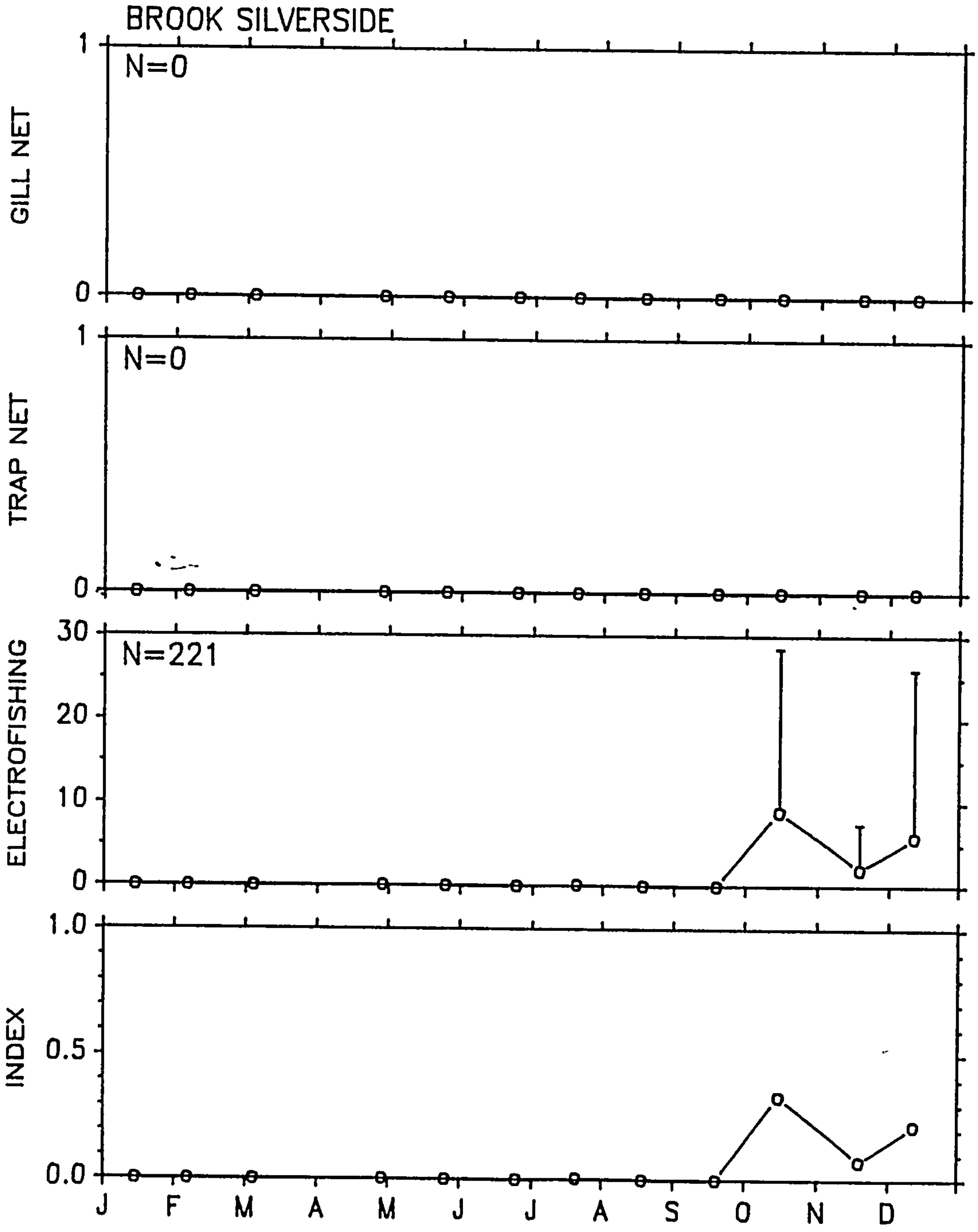

Figure C.52. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of brook silversides, Hudson study area, January to December 1988.

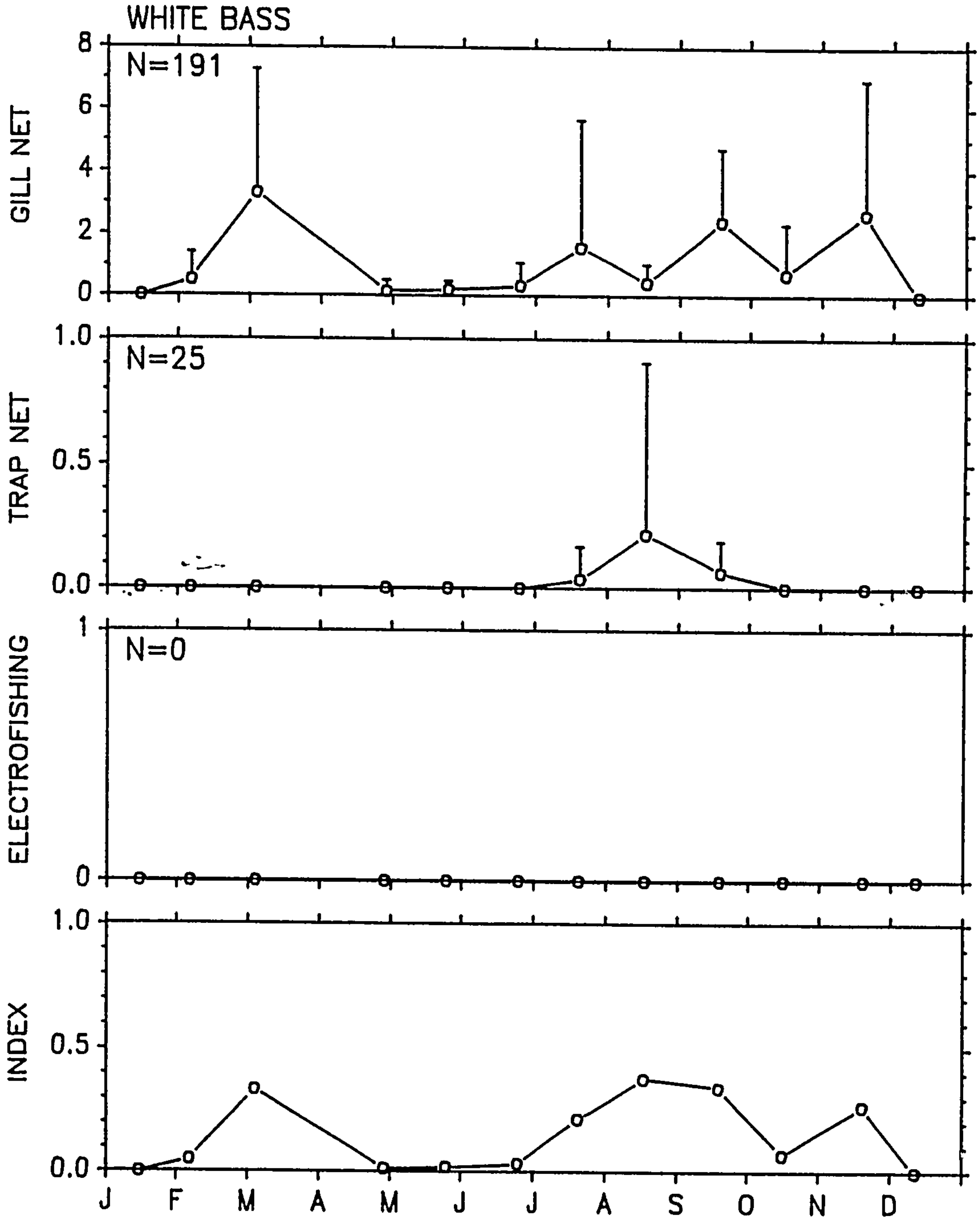

Figure C.53. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of white bass, Hudson study area, January to December 1988.

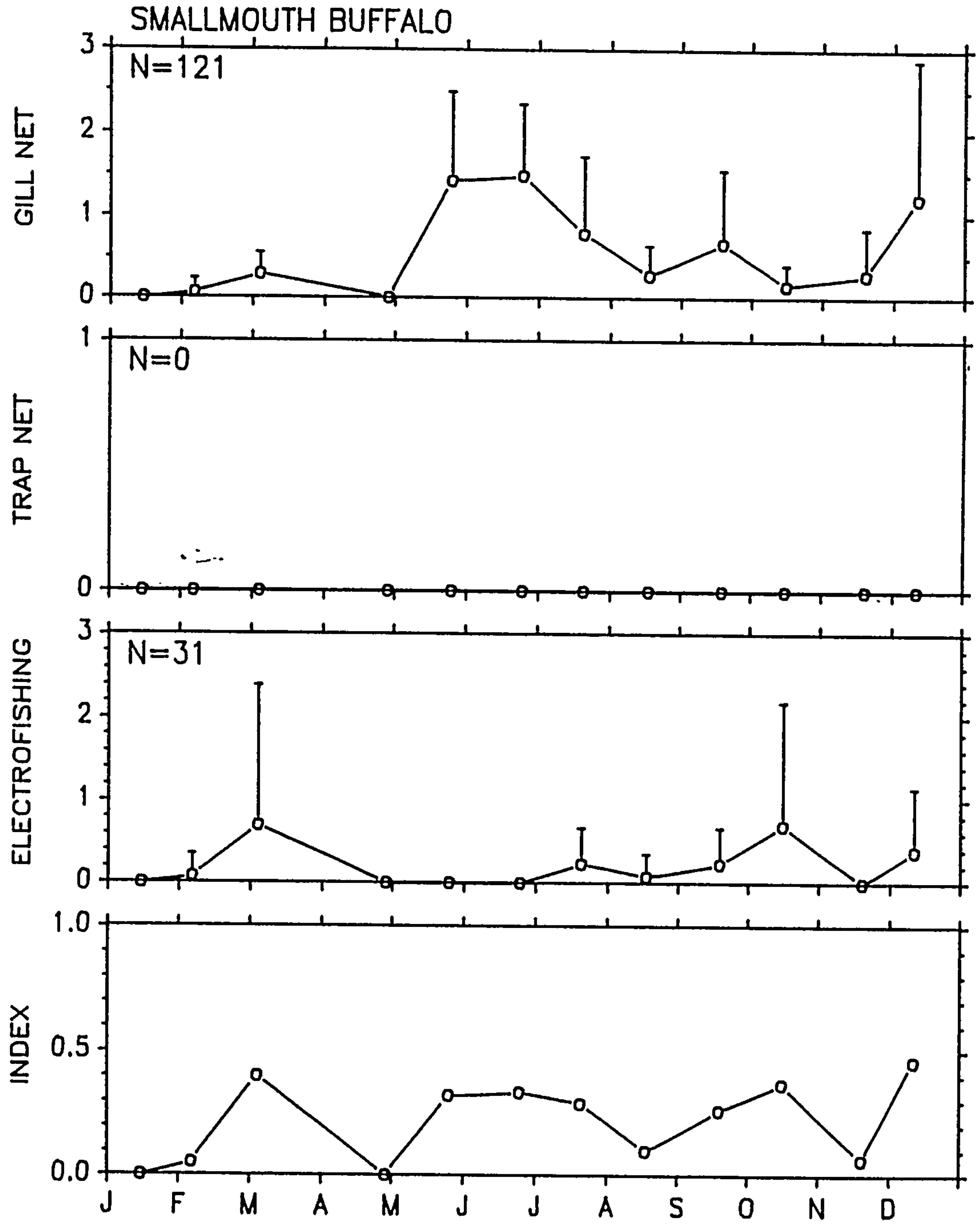

Figure C.54. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of smallmouth buffalo, Hudson study area, January to December 1988.

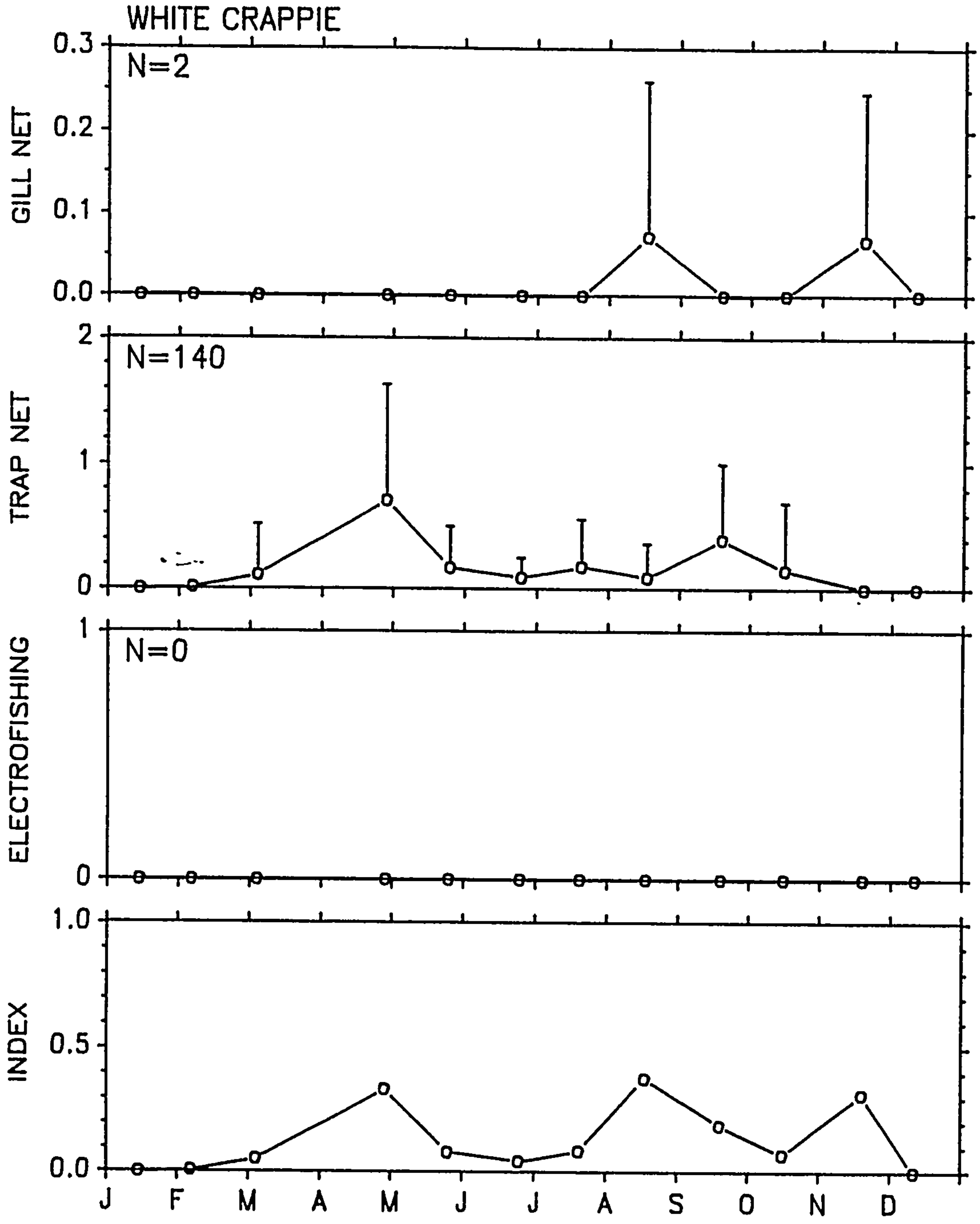

Figure C.55. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of white crappie, Hudson study area, January to December 1988.

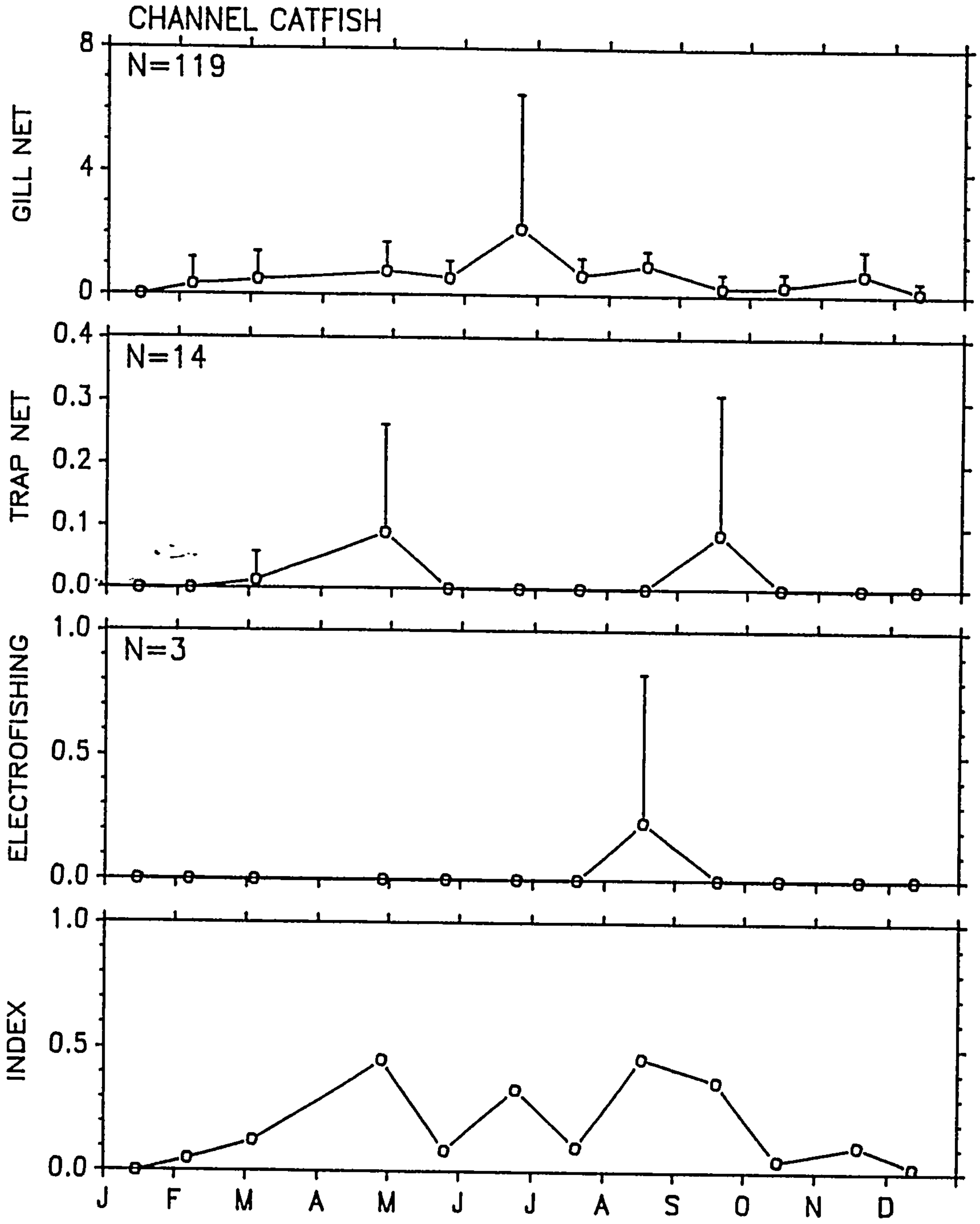

Figure C.56. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of channel catfish, Hudson study area, January to December 1988.

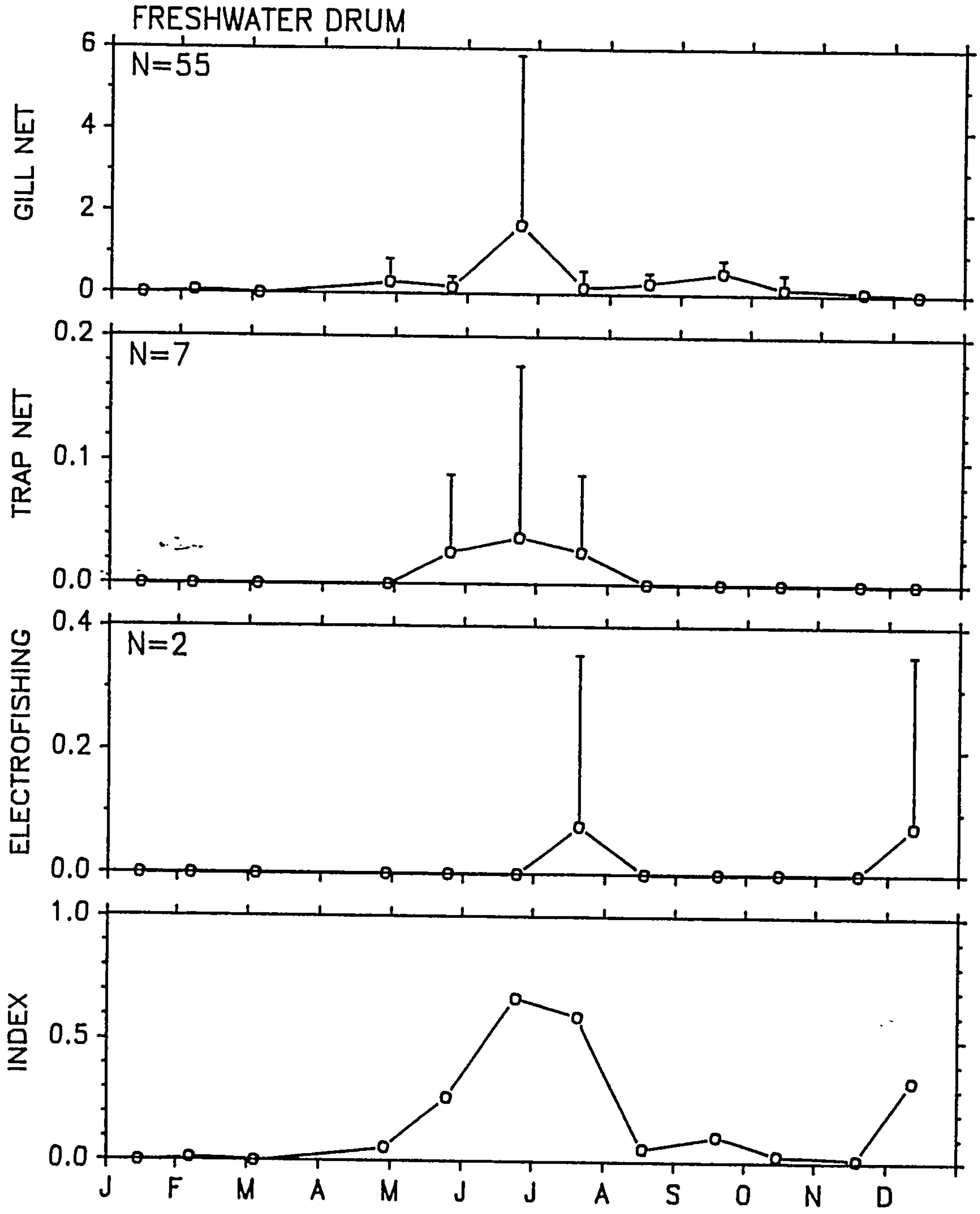

Figure C.57. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of freshwater drum, Hudson study area, January to December 1988.

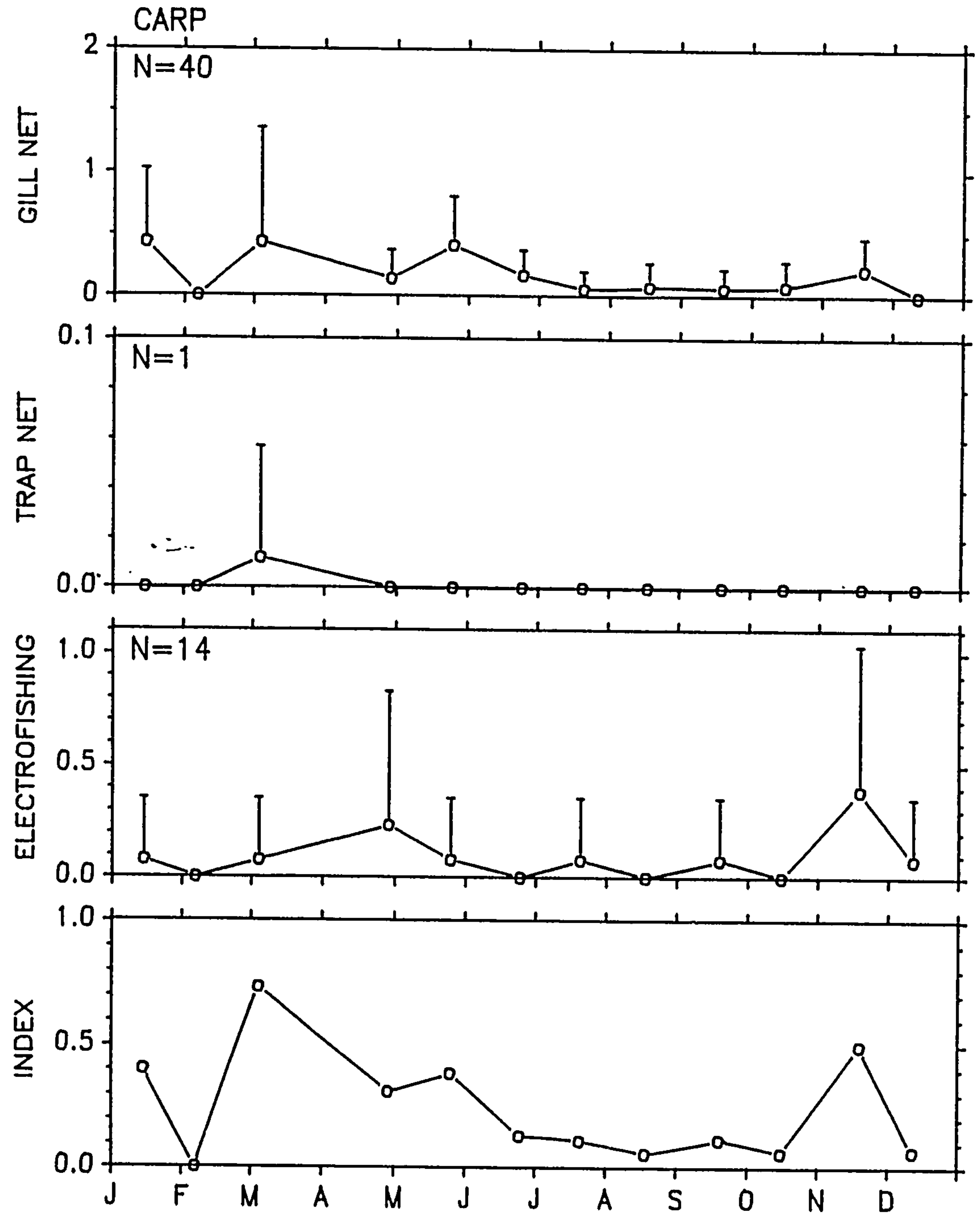

Figure C.58. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of common carp, Hudson study area, January to December 1988.

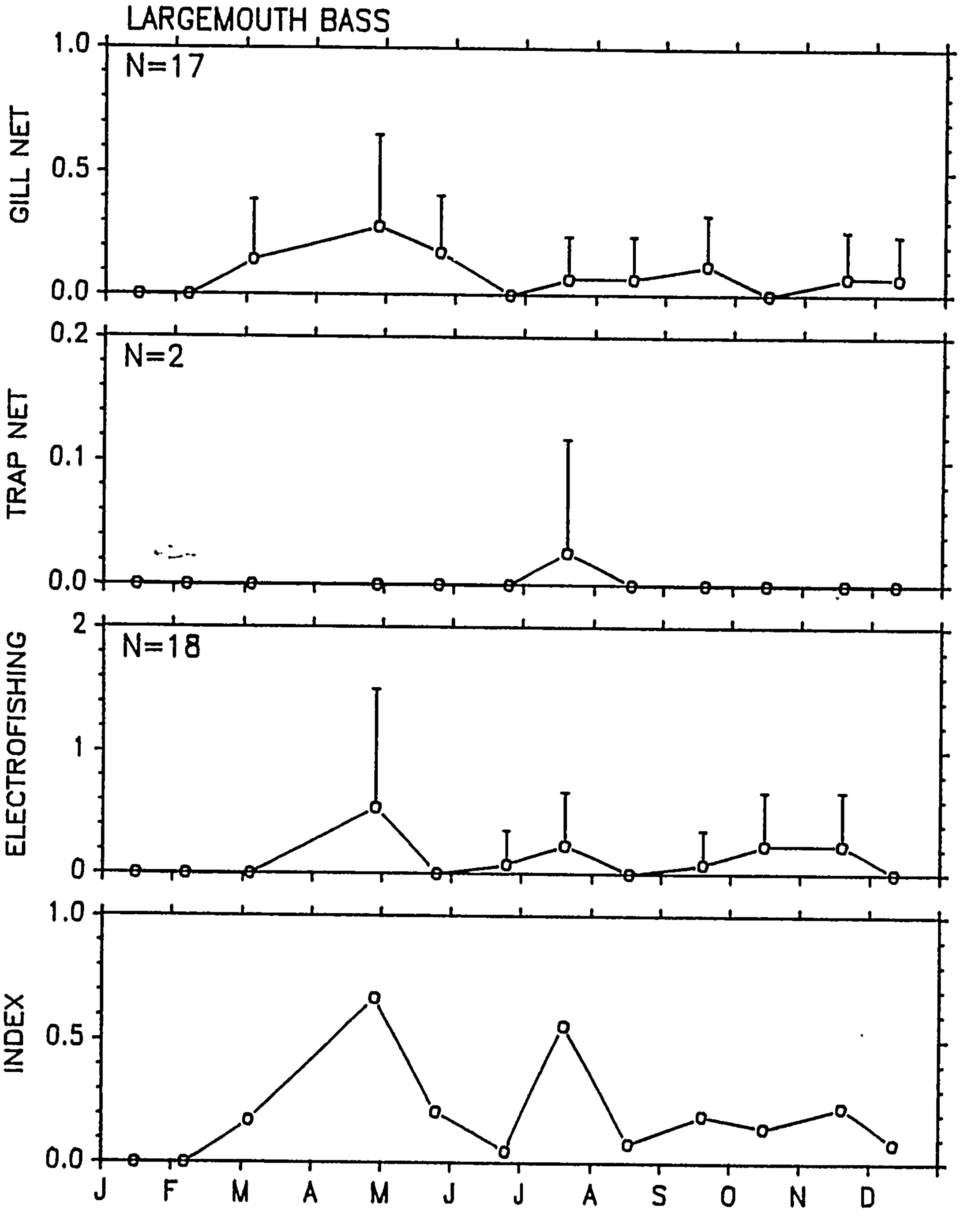

Figure C.59. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of largemouth bass, Hudson study area, January to December 1988.

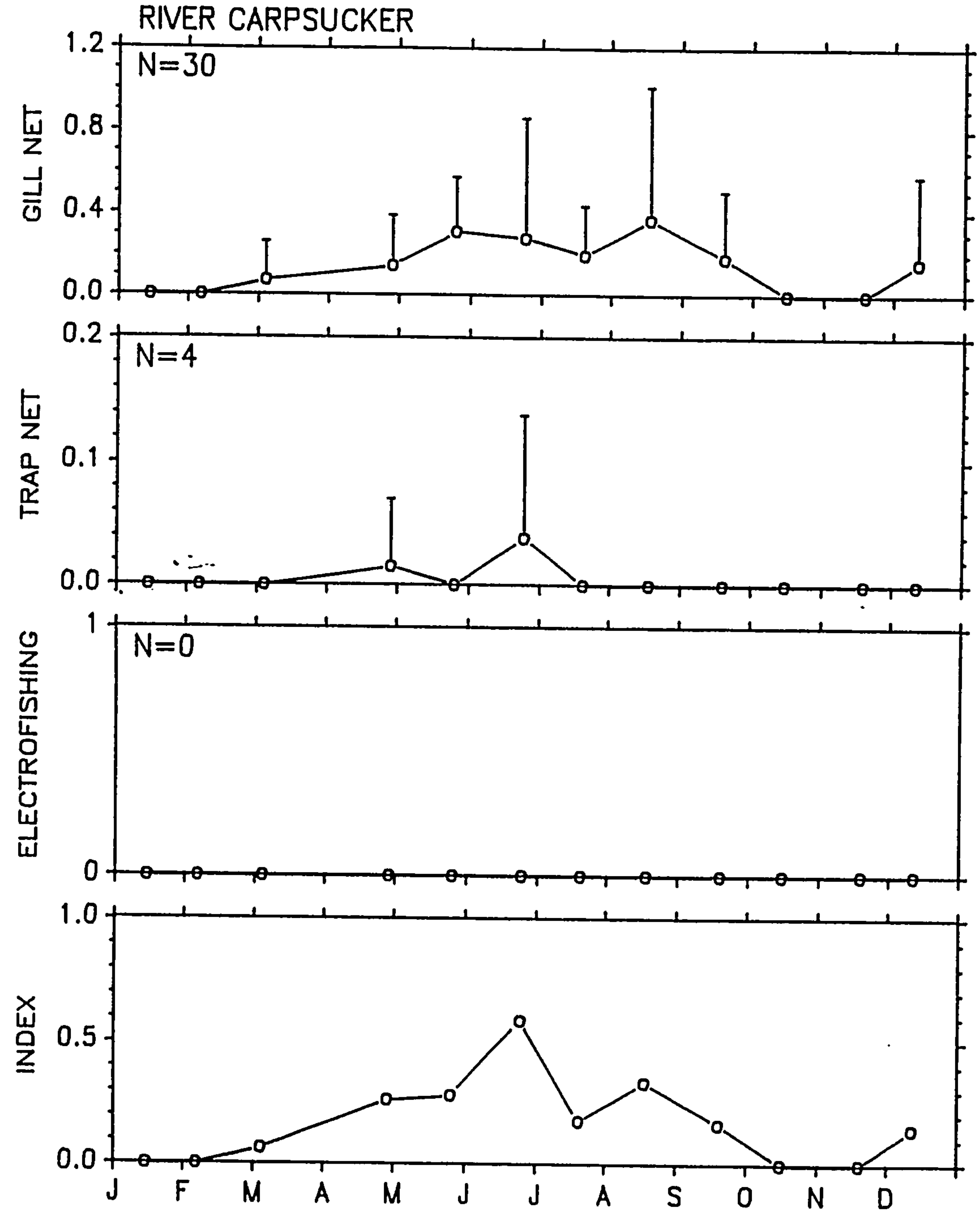

Figure C.60. Numeric catch-per-unit-effort rates (+1 SD) by gear and combined-gear catch index values of river carpsucker, Hudson study area, January to December 1988.

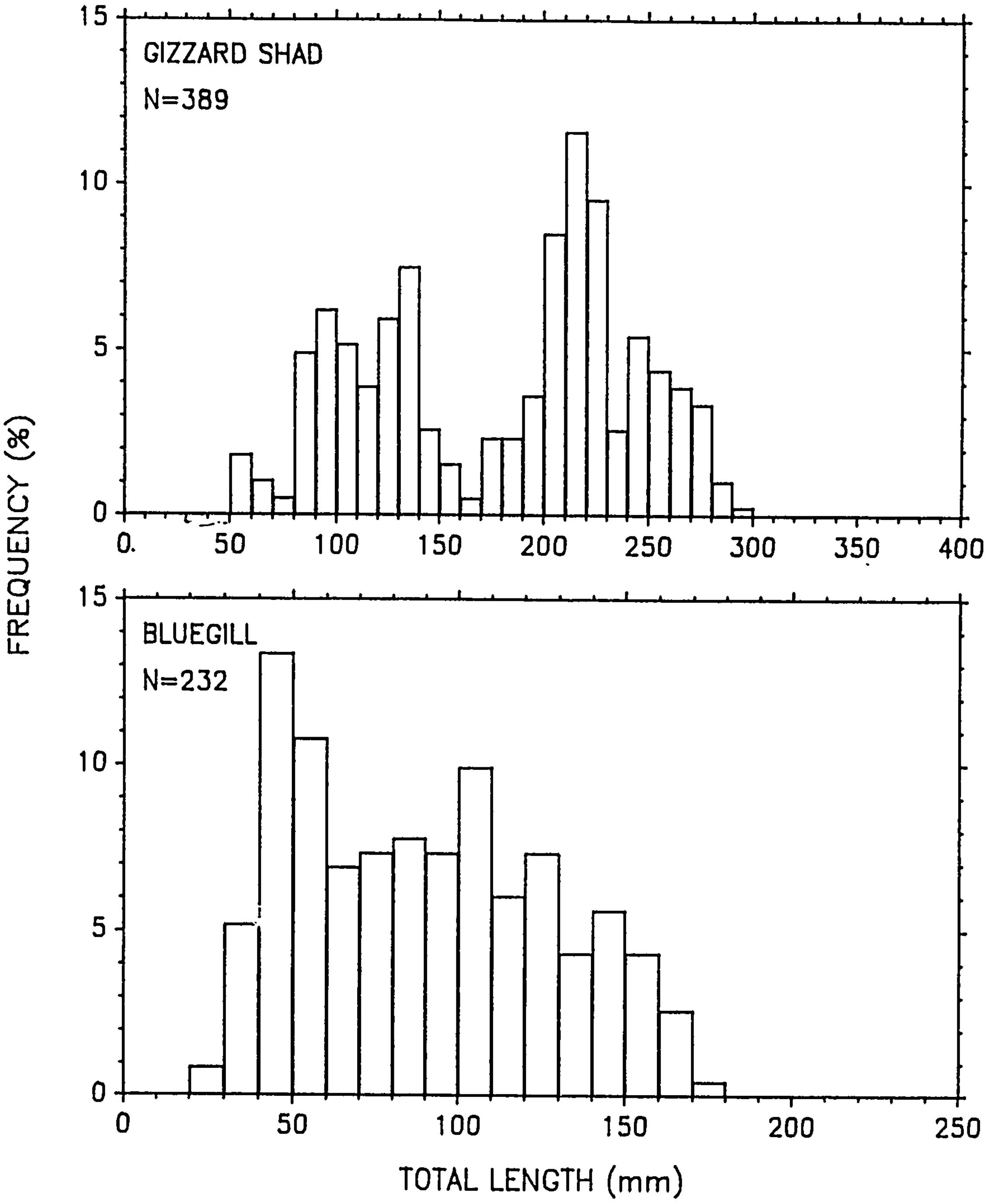

Figure C.61. Length-frequency distributions of gizzard shad and bluegill collected in the Hudson study area, January to December 1988.

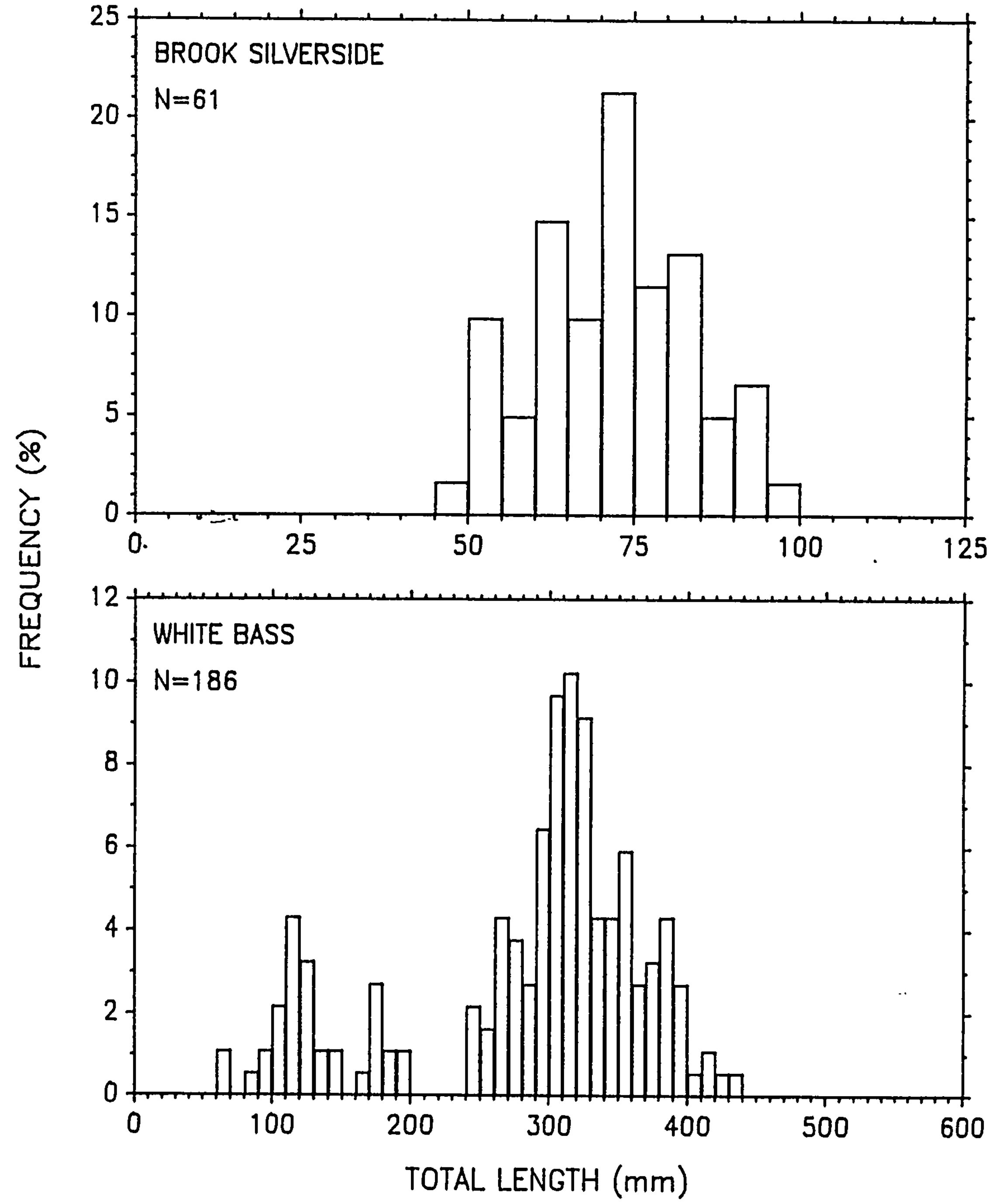

Figure C.62. Length-frequency distributions of brook silversides and white bass collected in the Hudson study area, January to December 1988.

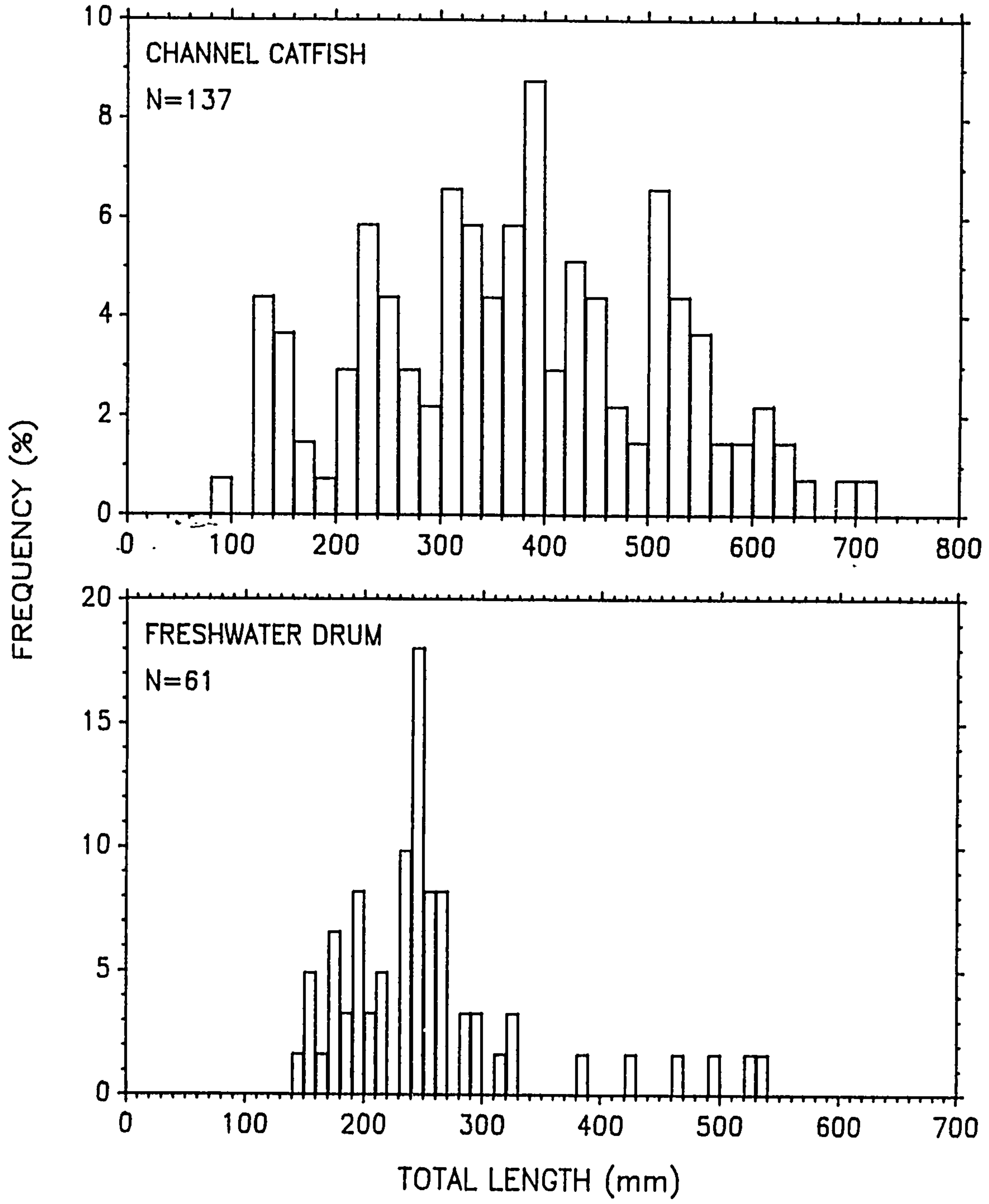

Figure C.63. Length-frequency distributions of channel catfish and freshwater drum collected in the Hudson study area, January to December 1988.

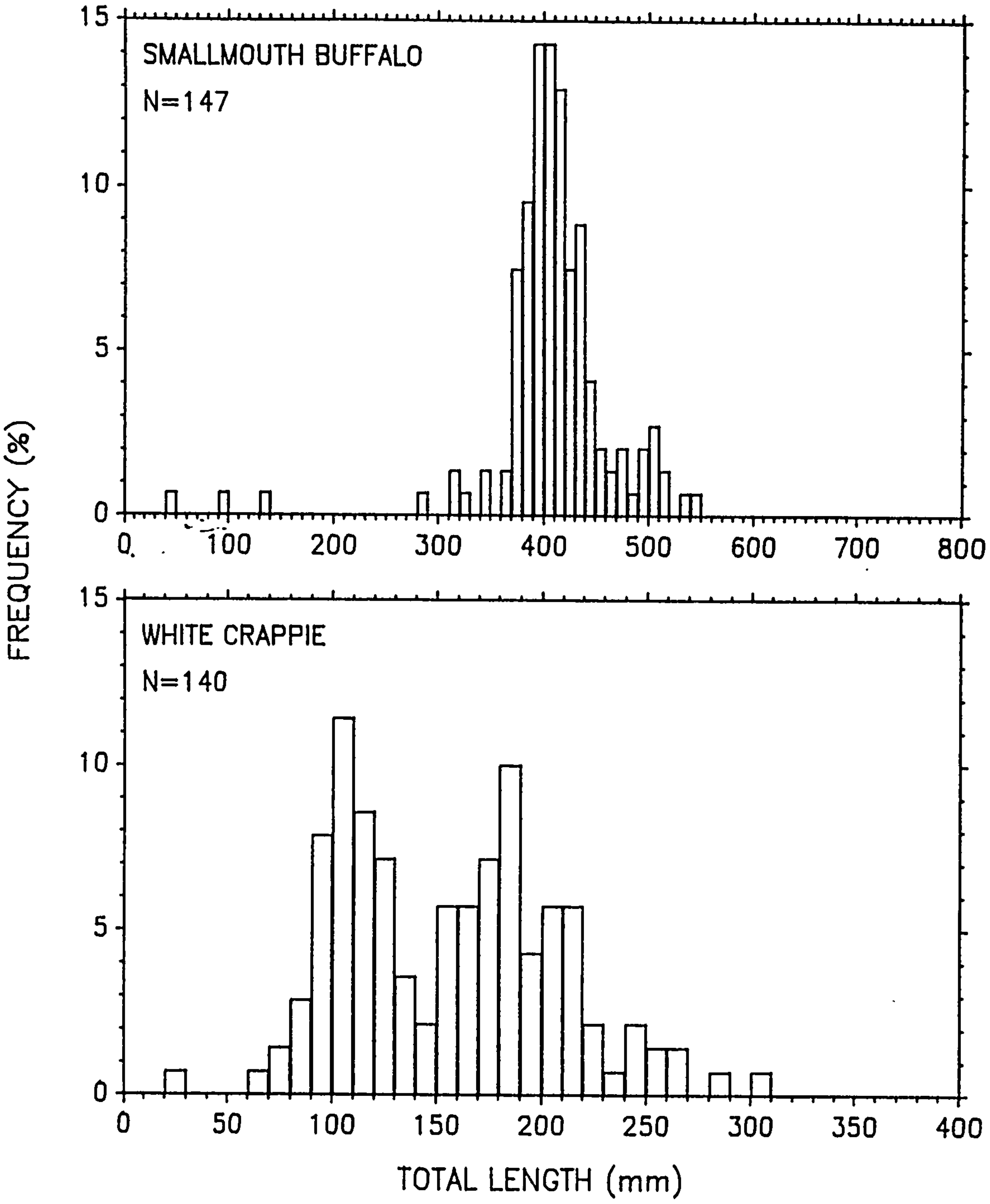

Figure C.64. Length-frequency distributions of smallmouth buffalo and white crappie collected in the Hudson study area, January to December 1988.

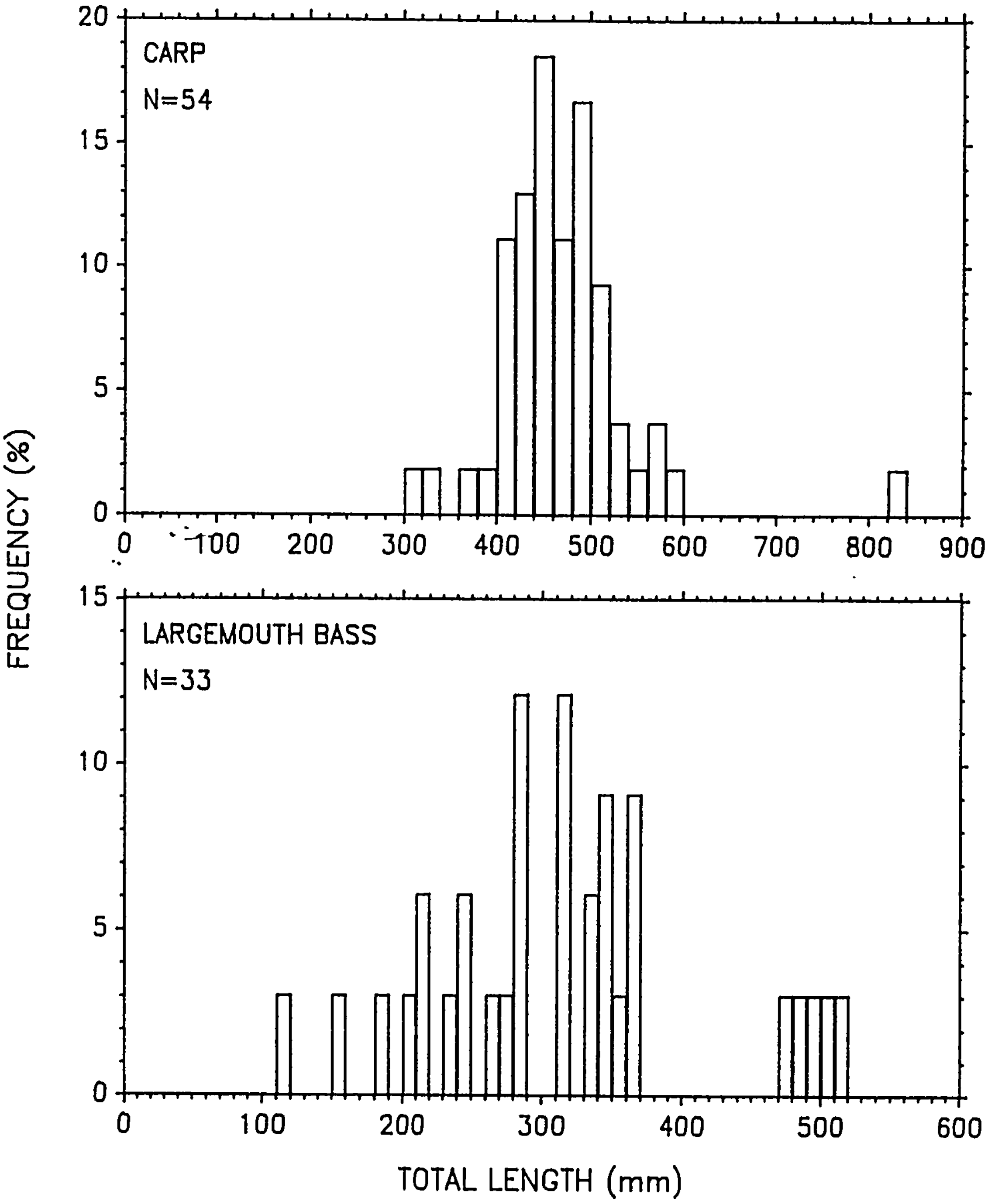

Figure C.65. Length-frequency distributions of common carp and largemouth bass collected in the Hudson study area, January to December 1988.

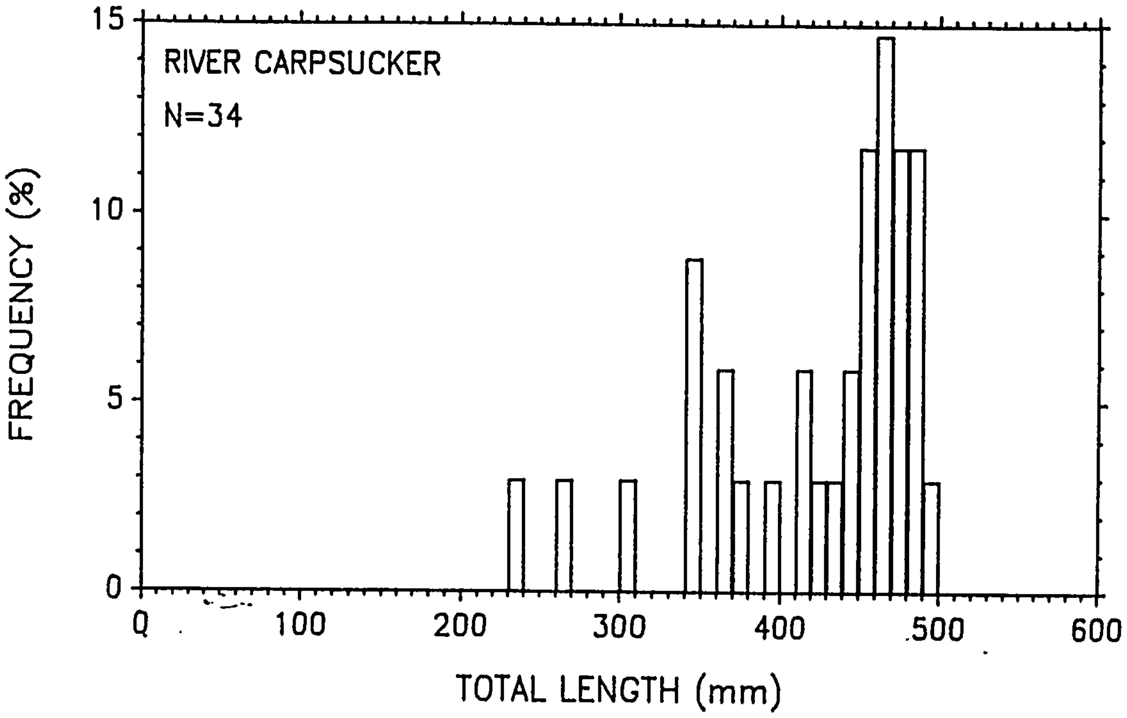

Figure C.66. Length-frequency distribution of river carpsuckers collected in the Hudson study area, January to December 1988.

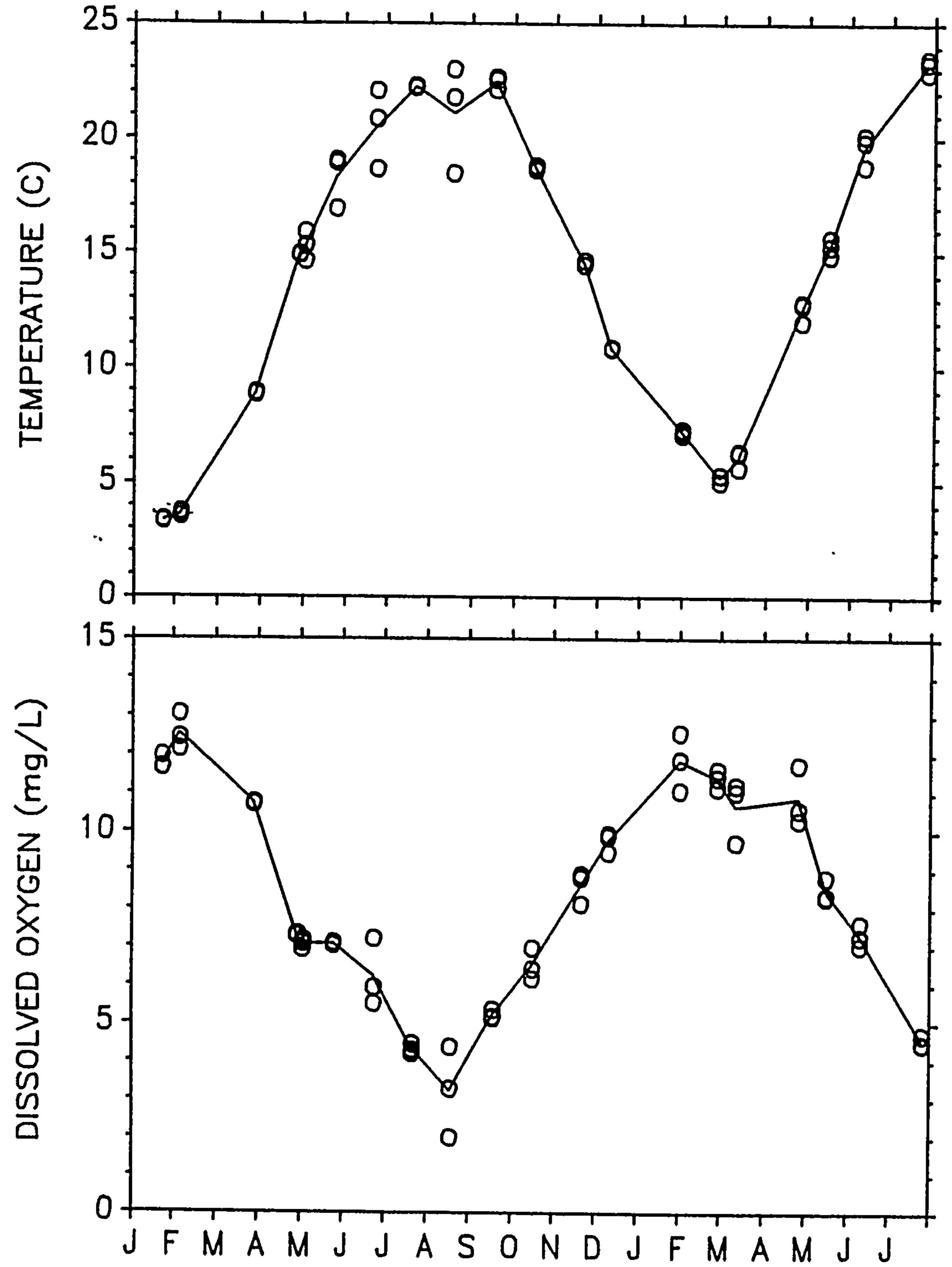

Figure C.67. Water temperatures and dissolved oxygen concentrations recorded in conjunction with fish sampling in the Pensacola Dam tailwater (stations 1-3), January 1988 to July 1989.

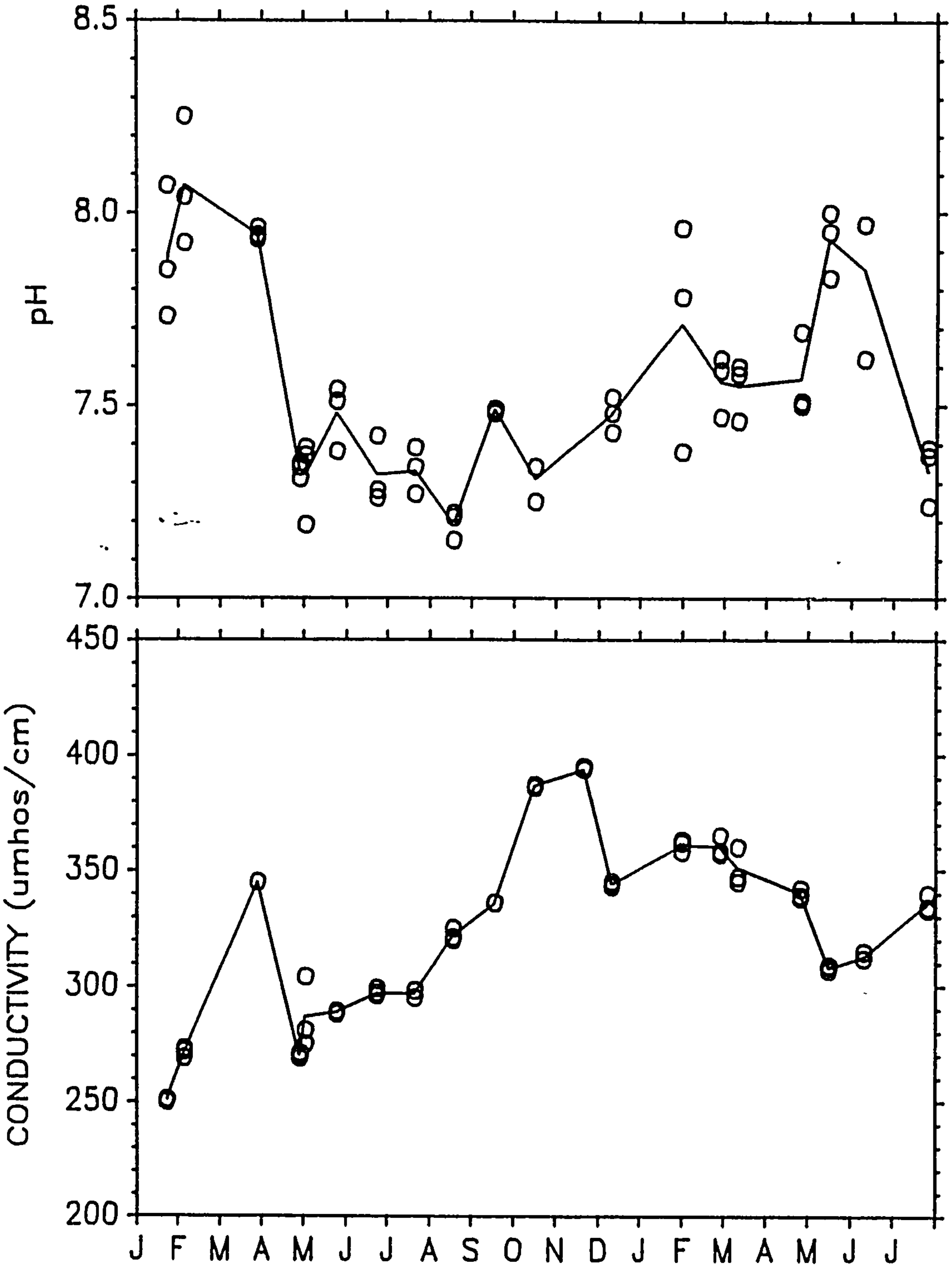

Figure C.68. Conductivity and pH values recorded in conjunction with fish sampling in the Pensacola Dam tailwater (stations 1-3), January 1988 to July 1989.

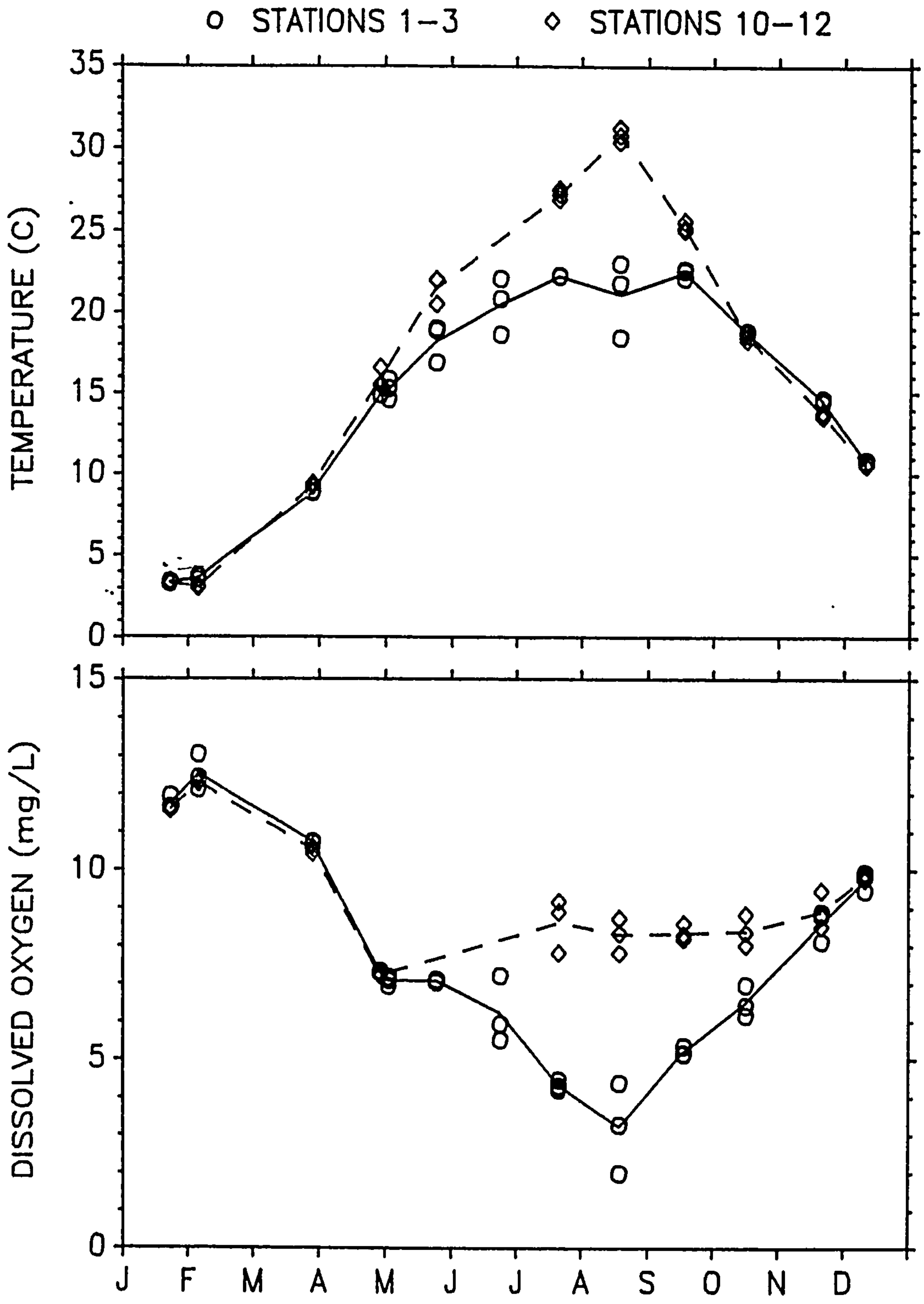

Figure C.69. Water temperatures and dissolved oxygen concentrations recorded in conjunction with fish sampling in the Pensacola Dam tailwater (stations 1-3) and Hudson (stations 10-12) study areas, January to December 1988.

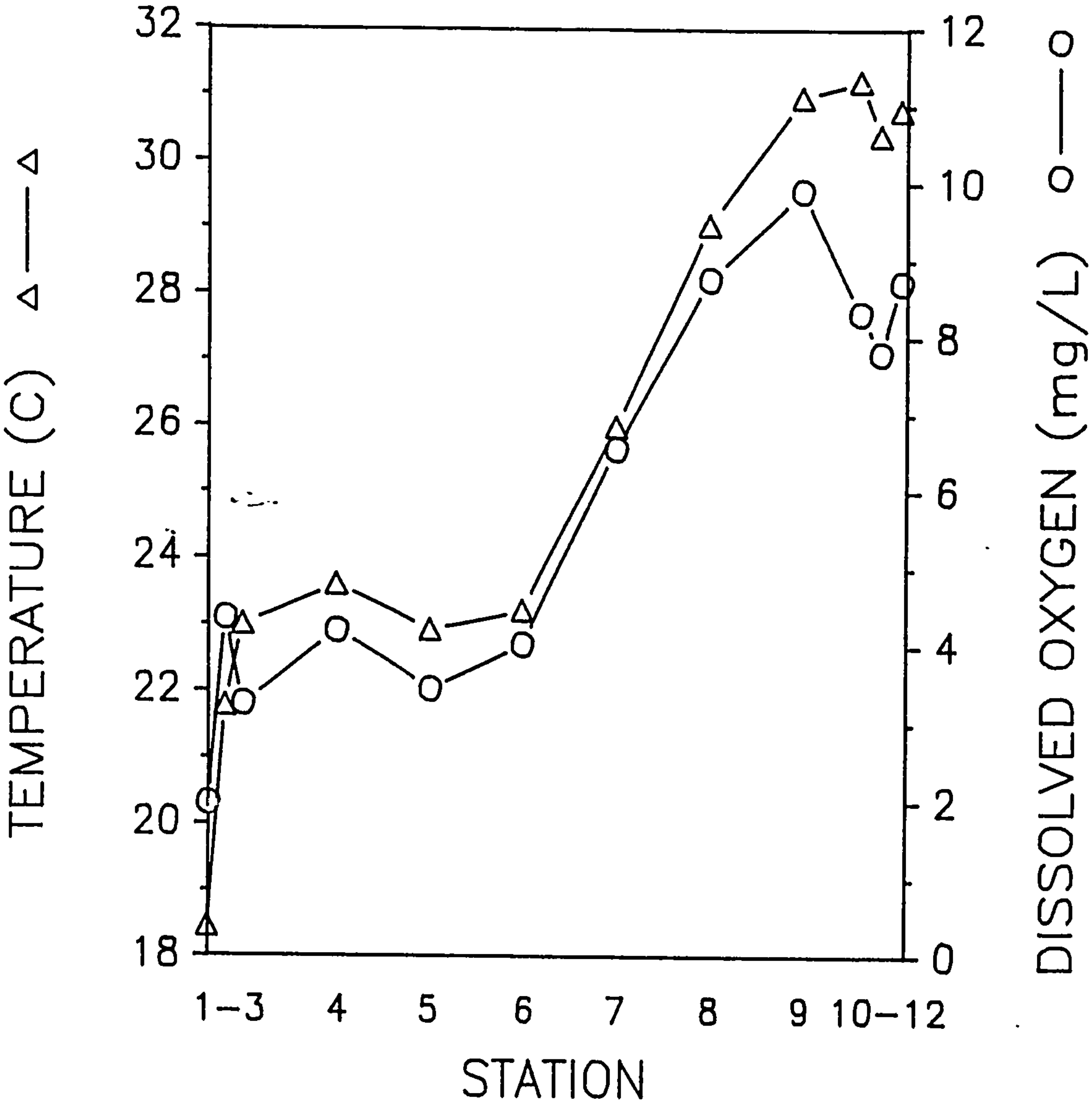

Figure C.70. Water temperatures and dissolved oxygen concentrations recorded at water quality stations 1 to 12, 17-18 August 1988.

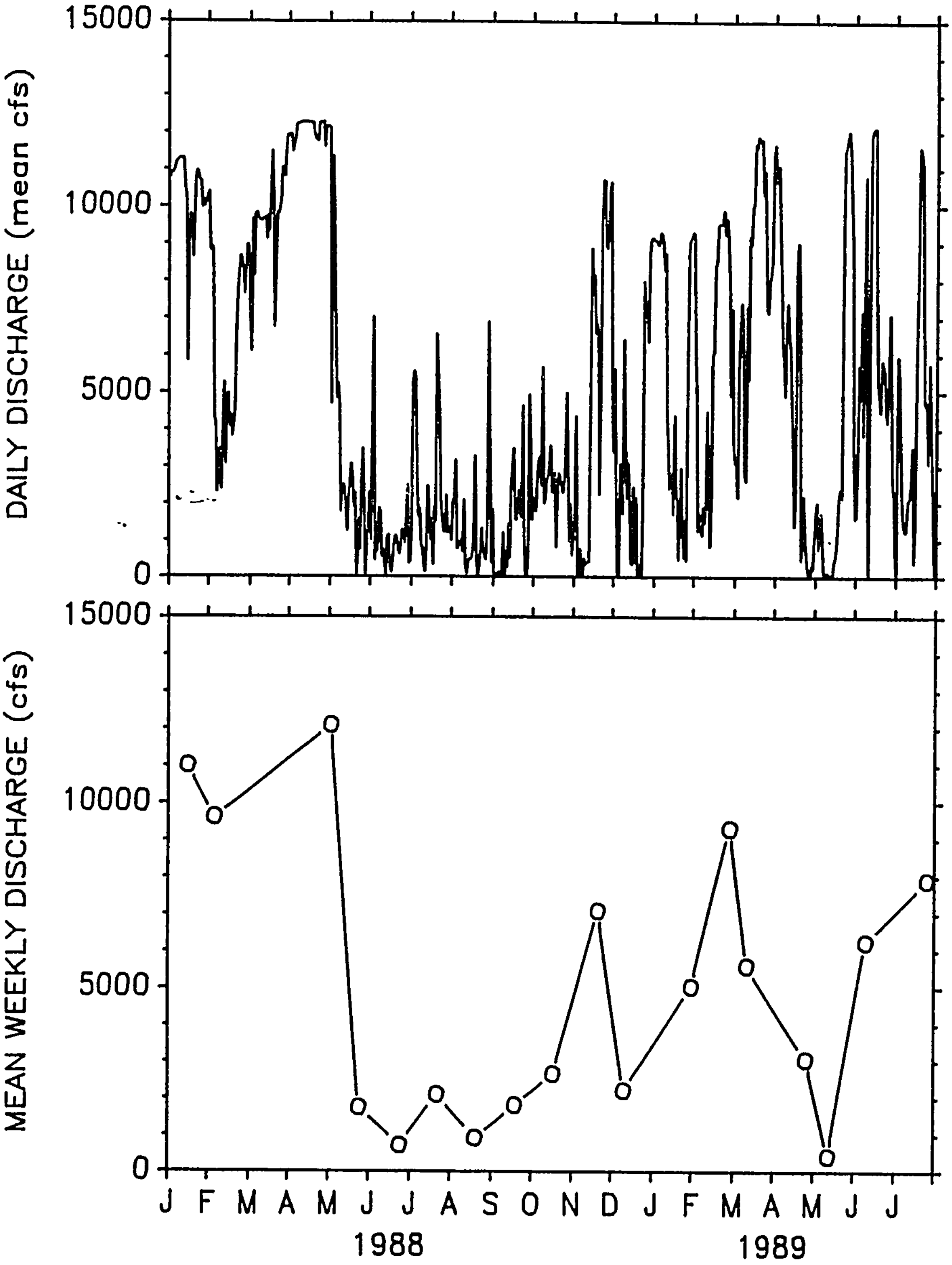

Figure C.71. Mean daily discharges, January 1988 through July 1989, and mean weekly discharges associated with fish sampling in the Pensacola Dam tailwater, January 1988 to July 1989, from the Pensacola Dam hydroelectric facility.

APPENDIX E-14 Dissolved Oxygen Mitigation Plan

Introduction

To improve dissolved oxygen (DO) in the tailraces of the Pensacola Dam, GRDA has adopted an adaptive mitigation plan in conjunction with the Oklahoma Water Resources Board (OWRB). This plan was adapted after multi-year studies into the causes and extent of low DO in this area, as well as the effectiveness of mitigation scenarios.

Pensacola Adaptive Mitigation Plan (AMP)

Three multi-parameter sondes with dissolved oxygen (DO) probes will continue to be installed on the county road bridge, aka Langley Bridge, approximately 1000 meters downstream of the Pensacola Dam. The probes are located near the right and left edges of water as well as midstream. These probes will continue to be used to manage the Pensacola AMP, with any individual probe on the bridge capable of activating a mitigation response.

To facilitate the response process, an e-mail alert system has been set up to notify both operators and other interested parties. When any individual probe indicates a DO mg/L reading below any of the action limits listed below, the software sends out an alarm email to all necessary personnel at Grand River Dam Authority (GRDA), Oklahoma Department of Wildlife Conservation (ODWC), United States Fish and Wildlife Service (USFWS), and the OWRB. This email indicates the most recently measured DO concentration and states the appropriate response according to the Pensacola AMP. Once measurements rise above the action limit, the system sends out an alert notification indicating the target value has been achieved.

In the event status emails are not received or the reporting system is not working during the months of April-October, GRDA operators will notify OWRB and GRDA staff and begin mitigation releases until a resolution email is received. During the months of November through March, OWRB and GRDA staff are still contacted about readings below the action limit. However, based upon current environmental conditions, the decision to begin mitigation is left to the professional judgment of the respective GRDA and OWRB staff. Based on historical data, dissolved oxygen concentrations at the penstock during this time-period are typically high enough to not cause a significant concern for environmental impacts.[1]

The action limit is set at 6.5 mg/L from 10/16 through 6/15 and at 5.5 mg/L from 6/16 through 10/15. Once the action limit is reached, according to any one of the Langley Bridge DO probes, one turbine will begin running at 20% wicket gate (~320 cfs) with full aeration. Once a release is started, it continues until the average DO value exceeds the criterion. Depending on lake level conditions in Grand Lake and Lake Hudson, it continues for three to eight hours. A second action limit is set at 4.5 mg/L. If the second action limit is reached, the first turbine release is increased to 25% wicket gate (~430 cfs) and will continue for a minimum of 2 hours. This operational plan continues year-round.[2]

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[1] The email protocol was changed per the OWRB recommendation in GRDA's April 1, 2019 annual report for dissolved oxygen-Accession # 20190401-5512.

[2] Action limits were increased to these levels per the OWRB recommendation in GRDA's April 2, 2018 annual report for dissolved oxygen-Accession # 20180402-5302.

Example Email Alarm and Alert Notifications:
First Action Limit Email:
ODO (mg/L) at Langley bridge is at 5.25. Open one turbine to a 20% wicket gate position and run for a minimum of 6 hours. If after 6 hours no additional alarms have been received, the turbine may be closed. Note: it is likely you will receive emails from the other probes below Pensacola dam, do not open additional turbines. Only one turbine is used for the first stage of the mitigation plan. If you have any questions, please call Lance Phillips (Work 405-xxx-xxxx Cell 405-530-xxxx) or Monty Porter (Work 405-530-xxxx Cell 405-xxx-xxxx).

Second Action Limit Email:
ODO (mg/L) at Langley bridge is at 3.65. Open the turbine from 20% wicket gate to a 25% wicket gate position and run for a minimum of 2 hours. If after 2 hours, no additional alarms have been received, the turbine may be reset to 20% wicket gate position. Note: it is likely you will receive emails from the other probes below Pensacola dam, do not open additional turbines. Only one turbine is used for the first stage of the mitigation plan. If you have any questions please call Lance Phillips (Work 405-530-xxxx Cell 405-xxx-xxxx) or Monty Porter (Work 405-530-xxxx Cell 405-xxx-xxxx).

Resolution Email:
ODO (mg/L) at Langley bridge is at 5.51. This value indicates that dissolved oxygen (DO) is currently meeting WQ standards. Continue mitigation plan outlined in the last alarm email.

Reporting

On an annual basis, prior to April 1st of the year following the monitoring, GRDA will provide a report to the Commission. The report shall describe the sampling methodology, results of the monitoring; any actions taken based on the results; any proposed changes in the monitoring provisions for the next cycle; and a proposed sampling/monitoring schedule for the next cycle.

GRDA will prepare the report in consultation with the U.S. Fish and Wildlife Service, ODWC, OWRB, and the Oklahoma Department of Environmental Quality. GRDA will include with the report documentation of consultation, copies of comments and recommendations on the report after it has been prepared and provided to the agencies, and specific descriptions of how the agencies' comments are accommodated by the plan. GRDA will allow a minimum of 30 days for the agencies to comment and to make recommendations before filing the report with the Commission. If GRDA does not adopt a recommendation, the filing must include GRDA's reasons, based on project-specific information.

References

Dennis, A. Floodplain Analysis of the Neosho River Associated with Proposed Rule Curve Modifications for Grand Lake O' the Cherokees. Master's thesis, University of Oklahoma, 2014.

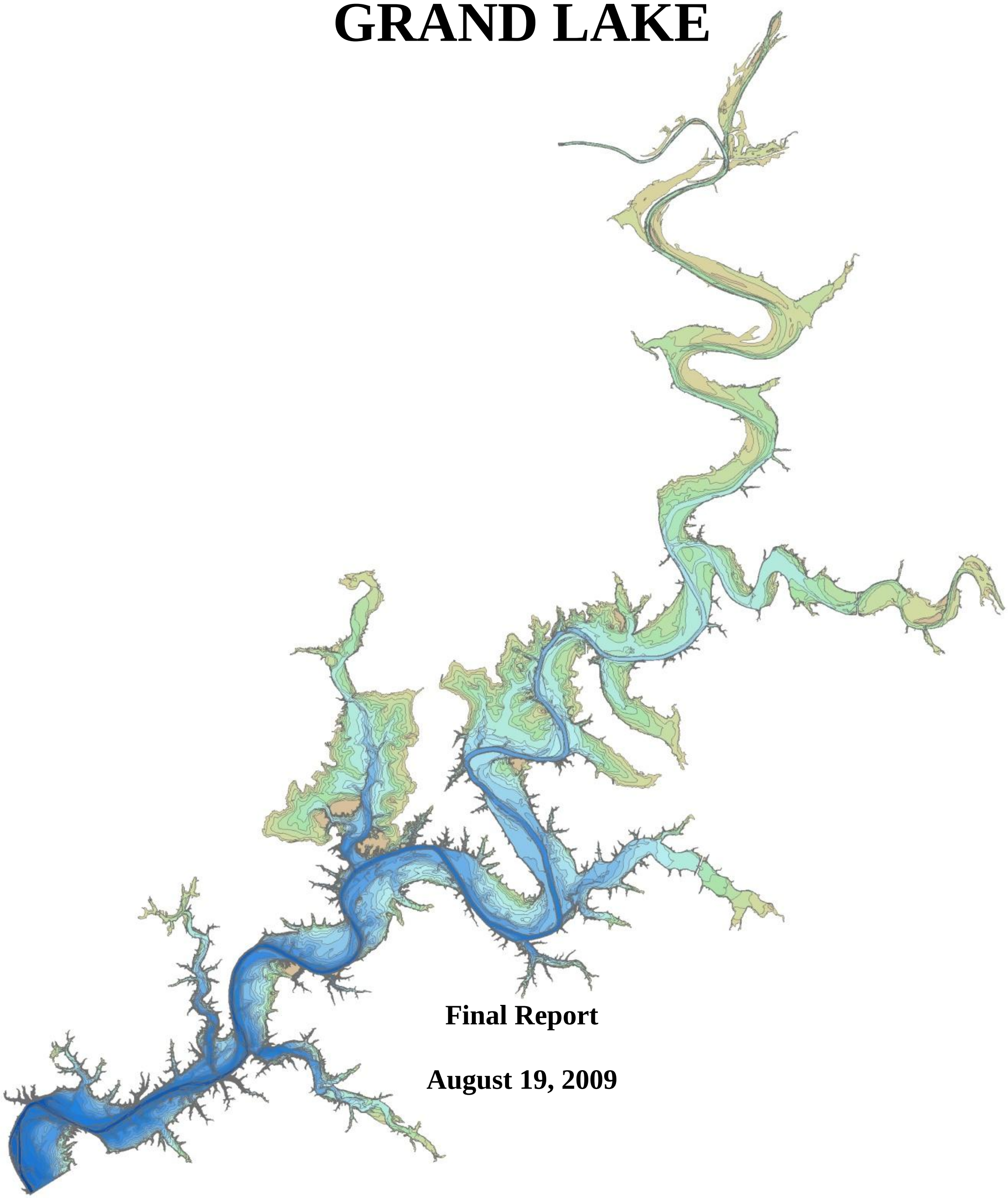
Oklahoma Water Resource Board. 2012. Sample Years 2006-2011 Reports: “Dissolved Oxygen Monitoring Below Pensacola Dam (Grand Lake) and Kerr Dam (Hudson Lake) for the Grand River Dam Authority (GRDA) Federal Energy Regulatory Commission (FERC) Permit". Oklahoma City, OK.

Oklahoma Water Resources Board. 2015. Pensacola Mitigation Testing Report 2014. Oklahoma City, OK.

Oklahoma Water Resources Board. 2018. Pensacola Mitigation Testing Report 2017. Oklahoma City, OK.

APPENDIX E-15 2009 OWRB 2011 Hydrographic Survey

HYDROGRAPHIC SURVEY of GRAND LAKE



Final Report

August 19, 2009

Prepared by:

State of Oklahoma
OWRB
WATER RESOURCES BOARD
the water agency

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GRAND LAKE
HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

The Oklahoma Water Resources Board (OWRB) conducted a hydrographic survey of Grand Lake beginning in April of 2008 and ending in January of 2009. The purpose of this survey was to produce a new elevation-area-capacity table for Grand Lake that would aid in a dependable yield determination conducted by the United States Army Corps of Engineers (USACE).

LAKE BACKGROUND

Grand Lake is located on Grand River, which is formed by the junction of the Neosho and Spring Rivers, ten miles southeast of Miami, OK (**Figure 1**). It was created in 1940 with the completion of the Pensacola Dam. The lake is located in Ottawa, Delaware, Mayes, and Craig counties. Grand Lake's original purposes were hydropower and flood control.

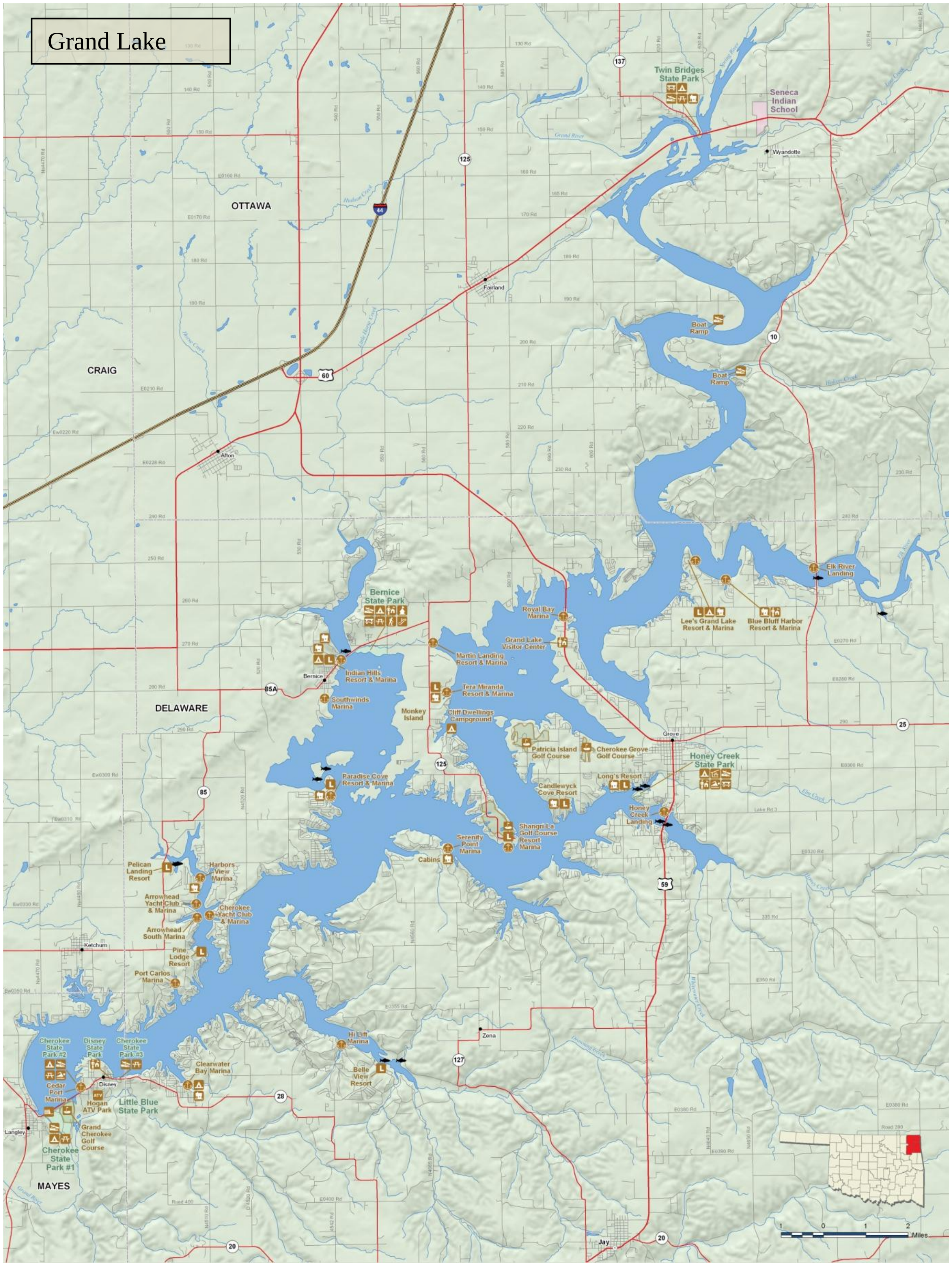


Figure 1: Location map for Grand Lake.

HYDROGRAPHIC SURVEYING PROCEDURES

The process of surveying a reservoir uses a combination of Geographic Positioning System (GPS) and acoustic depth sounding technologies that are incorporated into a hydrographic survey vessel. As the survey vessel travels across the lake's surface, the echosounder gathers multiple depth readings every second. The depth readings are stored on the survey vessel's on-board computer along with the positional data generated from the vessel's GPS receiver. The collected data files are downloaded daily from the computer and brought to the office for editing after the survey is completed. During editing, data "noise" is removed or corrected, and average depths are converted to elevation readings based on the daily-recorded lake level elevation on the day the survey was performed. Accurate estimates of area-capacity can then be determined for the lake by building a 3-D model of the reservoir from the corrected data. The process of completing a hydrographic survey includes four steps: pre-survey planning, field survey, data processing, and GIS application.

Pre-survey Planning

Boundary File

The boundary file for Grand was on-screen digitized from the 2006 color digital orthoimagery quarter quadrangle (DOQQ) mosaic of Mayes, Delaware, and Ottawa counties in Oklahoma. The screen scale was set to 1:1,500. The digitized line is to represent the shoreline as closely as possible. Due to the photography being a summer photo, it was difficult to determine the actual shoreline when there are trees and other vegetation hanging over the lake. The 1995 DOQQs of the lakes were used as back ground reference. The reservoir boundaries were digitized in North American Datum (NAD) 1983 State Plane Coordinates (Oklahoma North-3501).

Set-up

HYPACK software from Hypack, Inc. was used to assign geodetic parameters, import background files, and create virtual track lines (transects). The geodetic parameters assigned were State Plane NAD 83 Zone OK-3501 Oklahoma North with distance units and depth as US Survey Feet. The survey transects were spaced according to the accuracy required for the project. The survey transects within the digitized reservoir boundary were at 300 ft increments and ran perpendicular to the original stream channels and tributaries. Approximately 1,680 virtual transects were created for the Grand Lake.

Field Survey

Lake Elevation Acquisition

The lake elevation for Grand Lake was retrieved from the USACE website (http://www.swt-wc.usace.army.mil/PENS.lakepage.html). The USACE post hourly lake elevation to this website.

Method

The procedures followed by the OWRB during the hydrographic survey adhere to U.S. Army Corps of Engineers (USACE) standards (USACE, 2002). The quality control and quality assurance procedures for equipment calibration and operation, field survey, data processing, and accuracy standards are presented in the following sections.

Technology

The Hydro-survey vessel is an 18-ft aluminum Silverstreak hull with cabin, powered by a single 115-Horsepower Mercury outboard motor. Equipment used to conduct the survey included: a ruggedized notebook computer; Syqwest Bathy 1500 Echo Sounder, with a depth resolution of 0.1 ft; Trimble Navigation, Inc. Pro XR GPS receiver with differential global positioning system (DGPS) correction; and an Odom Hydrographics, Inc, DIGIBAR-Pro Profiling Sound Velocimeter. The software used was HYPACK.

Survey

A two-man survey crew was used during the project. Data collection for Grand Lake occurred in the spring, fall, and winter of 2008 as well as the first two months of 2009. The survey crew followed the parallel transects created during the pre-survey planning while collecting depth soundings and positional data. Data was also collected along a path parallel to the shoreline at a distance that was determined by the depth of the water and the draft of the boat – generally, two to three feet deep. Areas with depths less than this were avoided.

Quality Control/Quality Assurance

While on board the Hydro-survey vessel, the Syqwest Bathy 1500 Echo Sounder was calibrated using A DIGIBAR-Pro Profiling Sound Velocimeter, by Odom Hydrographics. The sound velocimeter measures the speed of sound at incremental depths throughout the water column. The factors that influence the speed of sound—depth, temperature, and salinity—are all taken into account. Deploying the unit involved lowering the probe, which measures the speed of sound, into the water to the calibration depth mark to allow for acclimation and calibration of the depth sensor. The unit was then gradually lowered at a controlled speed to a depth just above the lake bottom, and then was raised to the surface. The unit collected sound velocity measurements in feet/seconds (ft/sec) at 1 ft increments on both the deployment and retrieval phases. The data was then reviewed for any erroneous readings, which were then edited out of the sample. The sound velocity corrections were then applied to the raw depth readings.

A quality assurance cross-line check was performed on intersecting transect lines and channel track lines to assess the estimated accuracy of the survey measurements. The overall accuracy of an observed bottom elevation or depth reading is dependent on random and systematic errors that are present in the measurement process. Depth measurements contain both random errors and systematic bias. Biases are often referred to as systematic errors and are often due to observational errors. Examples of bias include a bar check calibration error, tidal errors, or incorrect squat corrections. Bias, however, does not affect the repeatability, or precision, of results. The precision of depth readings is affected by random errors. These are errors present in the measurement system that cannot be easily reduced by further calibration. Examples of random error include uneven bottom topography, bottom vegetation, positioning error, extreme listing of survey vessel, and speed of sound variation in the water column. An assessment of the accuracy of an individual depth or bottom elevation must fully consider all the error components contained in the observations that were used to determine that measurement. Therefore, the ultimate accuracy must be estimated (thus the use of the term “estimated accuracy”) using statistical estimating measures (USACE, 2002).

The depth accuracy estimate is determined by comparing depth readings taken at the intersection of two lines and computing the difference. This is done on multiple intersections. The mean difference of all intersection points is used to calculate the mean difference (MD). The mean difference represents the bias present in the survey. The standard deviation (SD), representing the random error in the survey, is also calculated. The mean difference and the standard deviation are then used to calculate the Root Mean Square (RMS) error. The RMS error estimate is used to compare relative accuracies of estimates that differ substantially in bias and precision (USACE, 2002). According the USACE standards, the RMS at the 95% confidence level should not exceed a tolerance of ± 2.0 ft for this type of survey. This simply means that on average, 19 of every 20 observed depths will fall within the specified accuracy tolerance.

HYPACK Cross Statistics program was used to assess vertical accuracy and confidence measures of acoustically recorded depths. The program computes the sounding difference between intersecting lines of single beam data. The program provides a report that shows the standard deviation and mean difference. A total of 111 cross-sections points at Grand Lake were used to compute error estimates. A mean difference of 0.5 ft and a standard deviation of 0.43 ft were computed from intersections. The following formulas were used to determine the depth accuracy at the 95% confidence level.

$$RMS = \sqrt{\sigma^2{}_{Random\ error} + \sigma^2{}_{Bias}}$$

where:

Random error = Standard deviation
Bias = Mean difference
RMS = root mean square error (68% confidence level)

and:

$$RMS\ (95\%)\ depth\ accuracy = 1.96 \times RMS\,(68\%)$$

An RMS of ± 1.3 ft with a 95% confidence level is less than the USACE's minimum performance standard of ± 2.0 ft for this type of survey. A mean difference, or bias, of 0.5 ft is equal to the USACE's standard maximum allowable bias of ± 0.5 ft for this type of survey.

The GPS system is an advanced high performance geographic data-acquisition tool that uses DGPS to provide sub-meter positional accuracy on a second-by-second basis. Potential errors are reduced with differential GPS because additional data from a reference GPS receiver at a known position are used to correct positions obtained during the survey. Before the survey, Trimble's Pathfinder Controller software was used to configure the GPS receiver. To maximize the accuracy of the horizontal positioning, the horizontal mask setting was set to 15 degrees and the Position Dilution of Precision (PDOP) limit was set to 6. The position interval was set to 1 second and the Signal to Noise Ratio (SNR) mask was set to 4. The United States Coast Guard reference station used in the survey is located near Sallisaw, Oklahoma. The reference beacon system transmitted corrected signals in real time, so no post-processing corrections of position data were needed.

A latency test was performed to determine the fixed delay time between the GPS and single beam echo sounder. The timing delay was determined by running reciprocal survey lines over a channel bank. The raw data files were downloaded into HYPACK, LATENCY TEST program. The program varies the time delay to determine the "best fit" setting. A position latency of 0.1 seconds was produced and adjustments were applied to the raw data in the EDIT program.

Data Processing

The collected data was transferred from the field computer onto an OWRB desktop computer. After downloading the data, each raw data file was reviewed using the EDIT program within HYPACK. The EDIT program allowed the user to assign transducer offsets, latency corrections, tide corrections, display the raw data profile, and review/edit all raw depth information. Raw data files are checked for gross inaccuracies that occur during data collection.

Offset correction values of 3.2 ft. starboard, 6.6 ft. forward, and -1.1 ft. vertical were applied to all raw data along with a latency correction factor of 0.1 seconds. The speed of sound corrections were applied during editing of raw data.

A correction file was produced using the HYPACK TIDES program to account for the variance in lake elevation at the time of data collection. Within the EDIT program, the corrected depths were subtracted from the elevation reading to convert the depth in feet to an elevation.

After editing the data for errors and correcting the spatial attributes (offsets and tide corrections), a data reduction scheme was needed. To accomplish this, the corrected data was resampled spatially at a 10 ft interval using the Sounding Selection program in HYPACK. The resultant data was saved and exported out as a xyz.txt file. The HYPACK raw and corrected data files for Grand Lake are located on the DVD entitled *Grand HYPACK/GIS Metadata.*

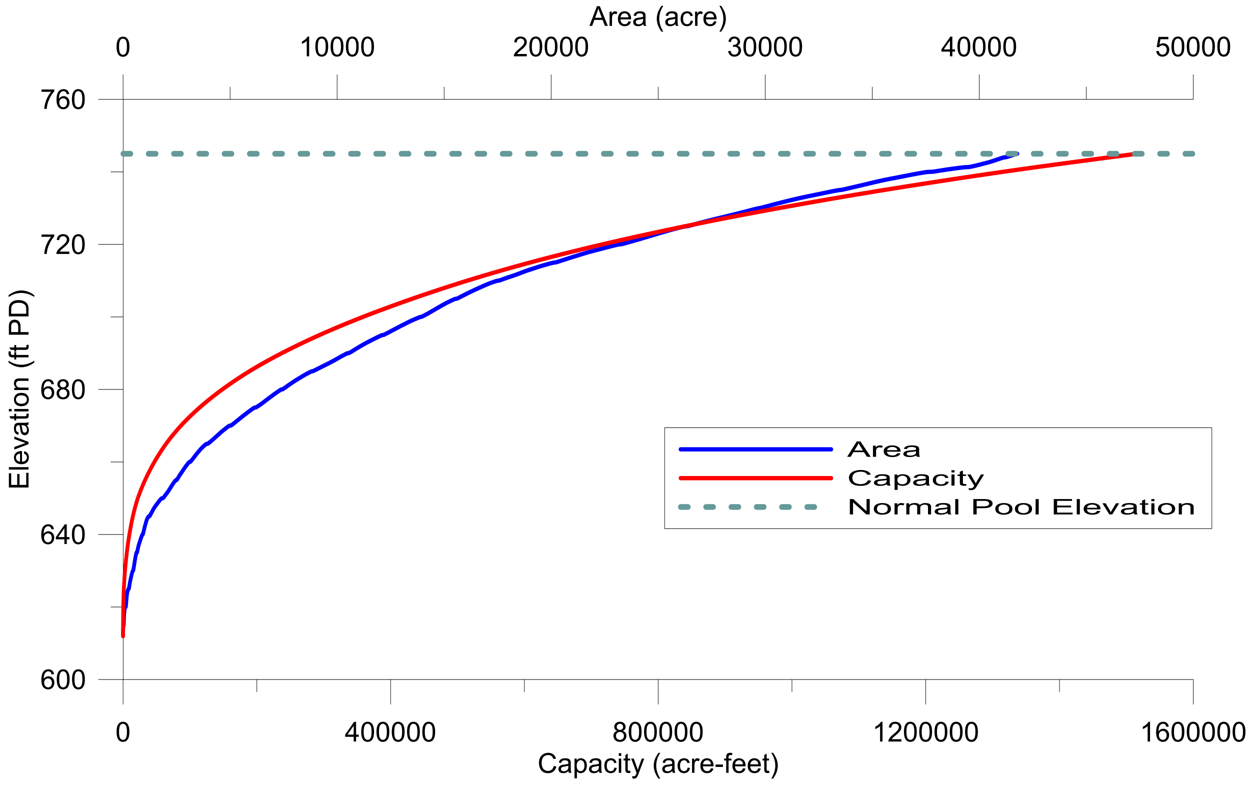
GIS Application

Geographic Information System (GIS) software was used to process the edited XYZ data collected from the survey. The GIS software used was ArcGIS Desktop and ArcMap, version 9.2, from Environmental System Research Institute (ESRI). All of the GIS datasets created are in Oklahoma State Plane North Coordinate System referenced to the North American Datum 1983. Horizontal and vertical units are in feet. The edited data points in XYZ text file format were converted into ArcMap point coverage format. The point coverage contains the X and Y horizontal coordinates and the elevation and depth values associated with each collected point.

Volumetric and area calculations were derived using a Triangulated Irregular Network (TIN) surface model. The TIN model was created in ArcMap, using the collected survey data points and the lake boundary inputs. The TIN consists of connected data points that form a network of triangles representing the bottom surface of the lake. The lake volume was calculated by slicing the TIN horizontally into planes 0.1 ft thick. The cumulative volume and area of each slice are shown in **APPENDIX A: Area-Capacity Data.**

Contours, depth ranges, and the shaded relief map were derived from a constructed digital elevation model grid. This grid was created using the ArcMap Topo to Raster Tool and had a spatial resolution of five feet. A low pass 3x3 filter was run to lightly smooth the grid to improve contour generation. The contours were created at a 5-ft interval using the ArcMap Contour Tool. The contour lines were edited to allow for polygon topology and to improve accuracy and general smoothness of the lines. The contours were then converted to a polygon coverage and attributed to show 5-ft depth ranges across the lake. The bathymetric maps of the lakes are shown with 5-ft contour intervals in

Grand Lake
Area-Capacity by Elevation
2008/2009 Survey



APPENDIX B: Grand Lake Maps.

All geographic datasets derived from the survey contain Federal Geographic Data Committee (FGDC) compliant metadata documentation. The metadata describes the procedures and commands used to create the datasets. The GIS metadata file for both lakes is located on the DVD entitled *Grand HYPACK/GIS Metadata.*

RESULTS

Results from the 2008/2009 OWRB survey indicate that Grand Lake encompasses 41,779.01 acres and contains a cumulative capacity of 1,515,415.52 ac-ft at the normal pool elevation (745 ft Pensacola Datum (PD)). The average depth for Grand Lake was 36.3ft.

SUMMARY and COMPARISON

Table 1 is comparison of area and volume changes of Grand Lake at the normal pool elevation. Based on the design specifications, Grand Lake had an area of 46,500 acres and cumulative volume of 1,672,000 acre-feet of water at normal pool elevation (745 ft PD). The surface area of the lake has had a decrease of 4,721 acres or approximately 10.1%. The 2008/2009 survey shows that Grand Lake had a decrease in capacity of 9.3% or approximately 156,588 acre-feet. Caution should be used, however, when directly comparing between the design specifications and the 2008/2009 survey conducted by the OWRB because different methods were used to collect the data and extrapolate capacity and area figures. It is the recommendation of the OWRB that another survey using the same method used in the 2008/2009 survey be conducted in 10-15 years. By using the new survey figures as a baseline, a future survey would allow an accurate sedimentation rate to be obtained.

Table 1: Area and Volume Comparisons of Grand Lake at normal pool (745 ft PD).

Feature	Survey Year

	1940 Design Specifications	2008/2009
Area (acres)	46,500	41,779
Cumulative Volume (acre-feet)	1,672,000	1,515,415
Mean depth (ft)	36.0	36.3
Maximum Depth (ft)		133

REFERENCES

U.S. Army Corps of Engineers (USACE). 2002. Engineering and Design - Hydrographic Surveying, Publication EM 1110-2-1003, 3rd version.

Oklahoma Water Resources Board (OWRB). 2008. Oklahoma Water Atlas.

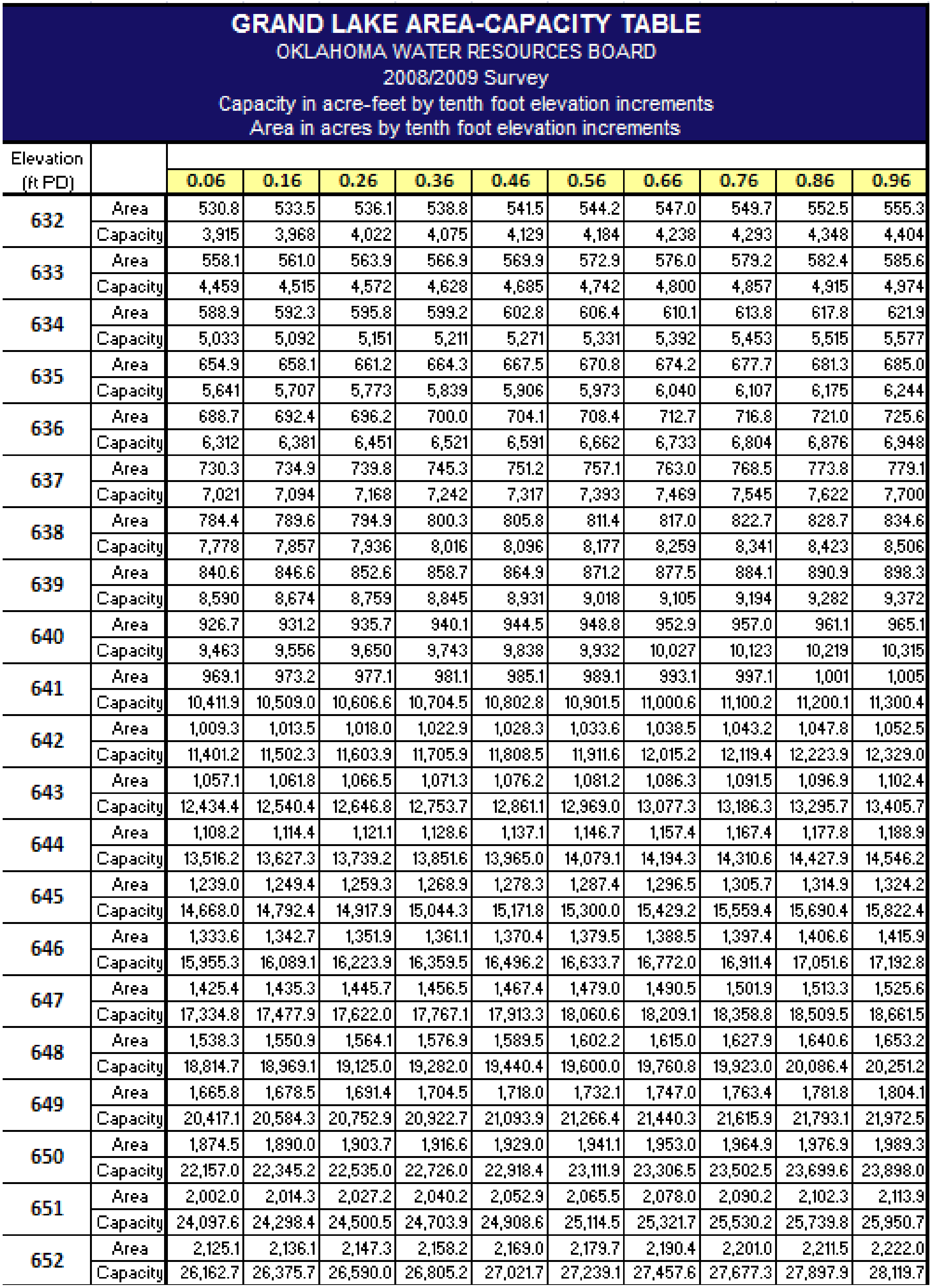
APPENDIX A: Area-Capacity Data

Table A. 1: Grand Lake Capacity/Area by 0.1-ft Increments.

GRAND LAKE AREA-CAPACITY TABLE
OKLAHOMA WATER RESOURCES BOARD
2008/2009 Survey
Capacity in acre-feet by tenth foot elevation increments
Area in acres by tenth foot elevation increments

Elevation (ft PD)		0.06	0.16	0.26	0.36	0.46	0.56	0.66	0.76	0.86	0.96
611	Area										0.0000
	Capacity										0.0000
612	Area	0.0003	0.0149	0.0405	0.0819	0.1359	0.2026	0.2912	0.4399	0.6588	0.8749
	Capacity	0.0000	0.0006	0.0033	0.0093	0.0201	0.0369	0.0613	0.0970	0.1520	0.2284
613	Area	1.151	1.533	1.934	2.358	2.832	3.351	3.937	4.584	5.276	6.018
	Capacity	0.3290	0.4620	0.6357	0.8499	1.109	1.418	1.782	2.207	2.700	3.265
614	Area	6.810	7.649	8.534	9.474	10.48	11.54	12.68	13.97	15.46	17.15
	Capacity	3.905	4.628	5.437	6.337	7.334	8.435	9.646	10.98	12.45	14.08
615	Area	30.83	31.42	31.96	32.47	32.97	33.47	33.97	34.47	34.98	35.49
	Capacity	16.62	19.73	22.90	26.12	29.39	32.72	36.09	39.51	42.98	46.51
616	Area	36.01	36.53	37.08	37.63	38.19	38.78	39.40	40.05	40.71	41.40
	Capacity	50.08	53.71	57.39	61.12	64.92	68.77	72.67	76.65	80.69	84.79
617	Area	42.11	42.85	43.61	44.41	45.26	46.15	47.07	48.03	49.04	50.13
	Capacity	88.97	93.22	97.54	101.9	106.4	111.0	115.7	120.4	125.3	130.2
618	Area	51.29	52.53	53.83	55.21	56.68	58.24	59.89	61.66	63.54	65.55
	Capacity	135.3	140.5	145.8	151.3	156.9	162.6	168.5	174.6	180.8	187.3
619	Area	67.65	69.87	72.20	74.64	77.22	80.00	83.06	86.31	89.84	93.97
	Capacity	194.0	200.8	207.9	215.3	222.9	230.7	238.9	247.4	256.2	265.3
620	Area	129.4	131.4	133.1	134.7	136.3	137.7	139.1	140.5	141.9	143.3
	Capacity	276.9	289.9	303.1	316.5	330.1	343.8	357.6	371.6	385.7	400.0
621	Area	144.6	146.0	147.4	148.7	150.1	151.4	152.8	154.2	155.6	157.0
	Capacity	414.4	428.9	443.6	458.4	473.3	488.4	503.6	519.0	534.5	550.1
622	Area	158.4	159.9	161.5	163.2	164.9	166.5	168.1	169.8	171.5	173.2
	Capacity	565.9	581.8	597.9	614.1	630.5	647.1	663.8	680.7	697.8	715.0
623	Area	175.1	176.9	178.8	180.6	182.5	184.4	186.5	188.7	191.3	194.3
	Capacity	732.4	750.0	767.8	785.8	803.9	822.3	840.8	859.6	878.6	897.9
624	Area	198.3	202.5	207.1	212.0	217.0	222.2	227.6	233.5	240.2	248.8
	Capacity	917.5	937.5	958.0	978.9	1,000	1,022	1,045	1,068	1,092	1,116
625	Area	271.7	275.2	278.3	281.2	283.9	286.5	289.0	291.5	294.0	296.6
	Capacity	1,142	1,170	1,197	1,225	1,254	1,282	1,311	1,340	1,369	1,399
626	Area	299.4	302.3	305.2	307.9	310.8	314.1	317.6	321.2	324.4	327.6
	Capacity	1,429	1,459	1,489	1,520	1,551	1,582	1,613	1,645	1,678	1,710
627	Area	330.7	333.9	337.3	341.0	344.6	348.2	351.9	355.6	359.4	363.2
	Capacity	1,743	1,776	1,810	1,844	1,878	1,913	1,948	1,983	2,019	2,055
628	Area	366.9	370.4	374.0	377.6	381.2	385.0	388.8	392.7	396.6	400.8
	Capacity	2,092	2,128	2,166	2,203	2,241	2,280	2,318	2,357	2,397	2,437
629	Area	405.0	409.3	413.7	418.2	422.8	427.5	432.7	438.3	444.7	452.4
	Capacity	2,477	2,518	2,559	2,600	2,643	2,685	2,728	2,772	2,816	2,861
630	Area	474.7	478.1	481.3	484.3	487.2	490.2	493.2	496.0	498.8	501.6
	Capacity	2,907	2,955	3,003	3,051	3,100	3,149	3,198	3,247	3,297	3,347
631	Area	504.3	507.0	509.7	512.4	515.0	517.7	520.3	523.0	525.6	528.2
	Capacity	3,397	3,448	3,499	3,550	3,601	3,653	3,705	3,757	3,809	3,862

Table A. 2: Grand Lake Capacity/Area by 0.1-ft Increments (cont).



GRAND LAKE AREA-CAPACITY TABLE

OKLAHOMA WATER RESOURCES BOARD

2008/2009 Survey

Capacity in acre-feet by tenth foot elevation increments

Area in acres by tenth foot elevation increments

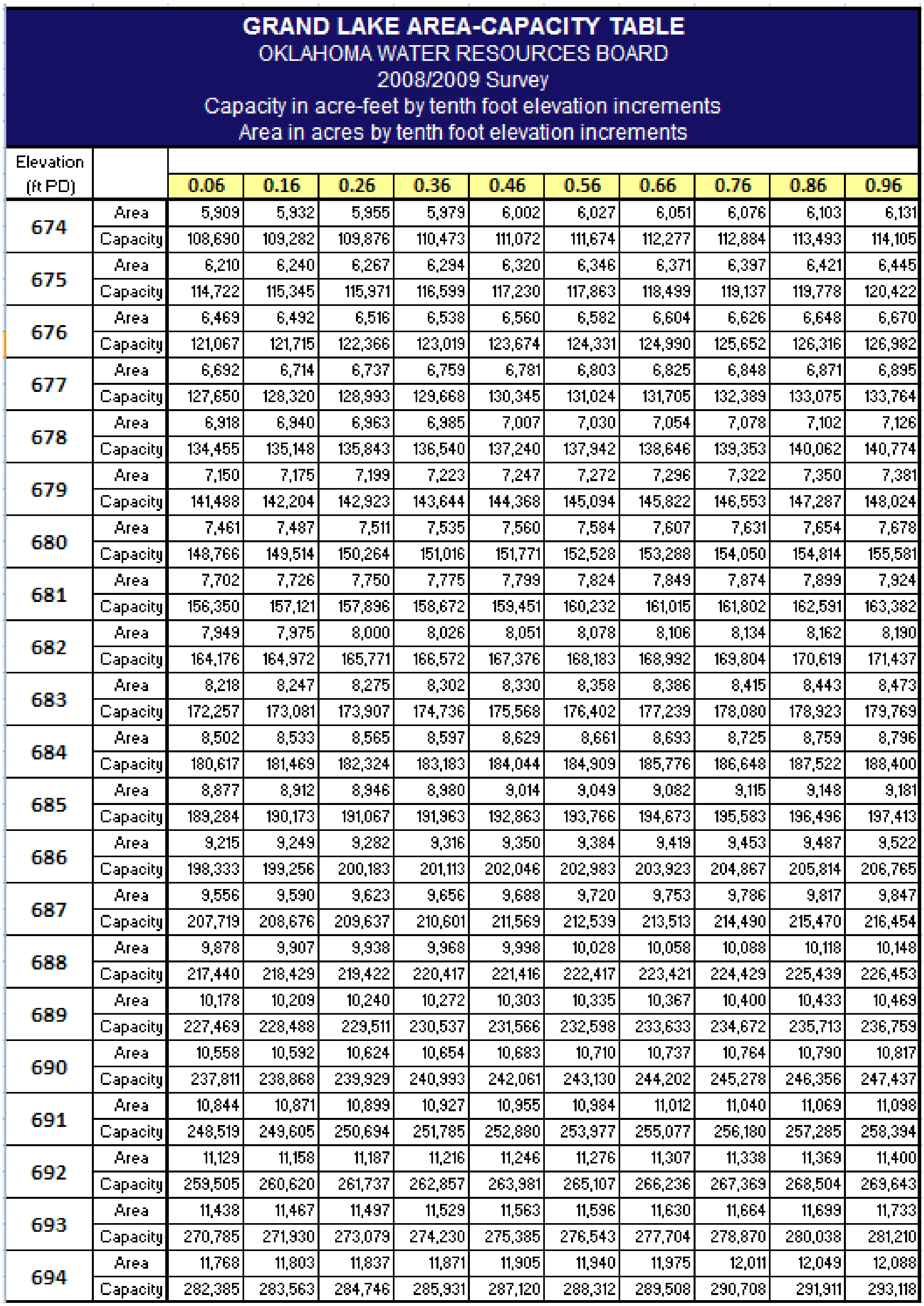
Elevation (ft PD)		0.06	0.16	0.26	0.36	0.46	0.56	0.66	0.76	0.86	0.96
632	Area	530.8	533.5	536.1	538.8	541.5	544.2	547.0	549.7	552.5	555.3
	Capacity	3,915	3,968	4,022	4,075	4,129	4,184	4,238	4,293	4,348	4,404
633	Area	558.1	561.0	563.9	566.9	569.9	572.9	576.0	579.2	582.4	585.6
	Capacity	4,459	4,515	4,572	4,628	4,685	4,742	4,800	4,857	4,915	4,974
634	Area	588.9	592.3	595.8	599.2	602.8	606.4	610.1	613.8	617.8	621.9
	Capacity	5,033	5,092	5,151	5,211	5,271	5,331	5,392	5,453	5,515	5,577
635	Area	654.9	658.1	661.2	664.3	667.5	670.8	674.2	677.7	681.3	685.0
	Capacity	5,641	5,707	5,773	5,839	5,906	5,973	6,040	6,107	6,175	6,244
636	Area	688.7	692.4	696.2	700.0	704.1	708.4	712.7	716.8	721.0	725.6
	Capacity	6,312	6,381	6,451	6,521	6,591	6,662	6,733	6,804	6,876	6,948
637	Area	730.3	734.9	739.8	745.3	751.2	757.1	763.0	768.5	773.8	779.1
	Capacity	7,021	7,094	7,168	7,242	7,317	7,393	7,469	7,545	7,622	7,700
638	Area	784.4	789.6	794.9	800.3	805.8	811.4	817.0	822.7	828.7	834.6
	Capacity	7,778	7,857	7,936	8,016	8,096	8,177	8,259	8,341	8,423	8,506
639	Area	840.6	846.6	852.6	858.7	864.9	871.2	877.5	884.1	890.9	898.3
	Capacity	8,590	8,674	8,759	8,845	8,931	9,018	9,105	9,194	9,282	9,372
640	Area	926.7	931.2	935.7	940.1	944.5	948.8	952.9	957.0	961.1	965.1
	Capacity	9,463	9,556	9,650	9,743	9,838	9,932	10,027	10,123	10,219	10,315
641	Area	969.1	973.2	977.1	981.1	985.1	989.1	993.1	997.1	1,001	1,005
	Capacity	10,411.9	10,509.0	10,606.6	10,704.5	10,802.8	10,901.5	11,000.6	11,100.2	11,200.1	11,300.4
642	Area	1,009.3	1,013.5	1,018.0	1,022.9	1,028.3	1,033.6	1,038.5	1,043.2	1,047.8	1,052.5
	Capacity	11,401.2	11,502.3	11,603.9	11,705.9	11,808.5	11,911.6	12,015.2	12,119.4	12,223.9	12,329.0
643	Area	1,057.1	1,061.8	1,066.5	1,071.3	1,076.2	1,081.2	1,086.3	1,091.5	1,096.9	1,102.4
	Capacity	12,434.4	12,540.4	12,646.8	12,753.7	12,861.1	12,969.0	13,077.3	13,186.3	13,295.7	13,405.7
644	Area	1,108.2	1,114.4	1,121.1	1,128.6	1,137.1	1,146.7	1,157.4	1,167.4	1,177.8	1,188.9
	Capacity	13,516.2	13,627.3	13,739.2	13,851.6	13,965.0	14,079.1	14,194.3	14,310.6	14,427.9	14,546.2
645	Area	1,239.0	1,249.4	1,259.3	1,268.9	1,278.3	1,287.4	1,296.5	1,305.7	1,314.9	1,324.2
	Capacity	14,668.0	14,792.4	14,917.9	15,044.3	15,171.8	15,300.0	15,429.2	15,559.4	15,690.4	15,822.4
646	Area	1,333.6	1,342.7	1,351.9	1,361.1	1,370.4	1,379.5	1,388.5	1,397.4	1,406.6	1,415.9
	Capacity	15,955.3	16,089.1	16,223.9	16,359.5	16,496.2	16,633.7	16,772.0	16,911.4	17,051.6	17,192.8
647	Area	1,425.4	1,435.3	1,445.7	1,456.5	1,467.4	1,479.0	1,490.5	1,501.9	1,513.3	1,525.6
	Capacity	17,334.8	17,477.9	17,622.0	17,767.1	17,913.3	18,060.6	18,209.1	18,358.8	18,509.5	18,661.5
648	Area	1,538.3	1,550.9	1,564.1	1,576.9	1,589.5	1,602.2	1,615.0	1,627.9	1,640.6	1,653.2
	Capacity	18,814.7	18,969.1	19,125.0	19,282.0	19,440.4	19,600.0	19,760.8	19,923.0	20,086.4	20,251.2
649	Area	1,665.8	1,678.5	1,691.4	1,704.5	1,718.0	1,732.1	1,747.0	1,763.4	1,781.8	1,804.1
	Capacity	20,417.1	20,584.3	20,752.9	20,922.7	21,093.9	21,266.4	21,440.3	21,615.9	21,793.1	21,972.5
650	Area	1,874.5	1,890.0	1,903.7	1,916.6	1,929.0	1,941.1	1,953.0	1,964.9	1,976.9	1,989.3
	Capacity	22,157.0	22,345.2	22,535.0	22,726.0	22,918.4	23,111.9	23,306.5	23,502.5	23,699.6	23,898.0
651	Area	2,002.0	2,014.3	2,027.2	2,040.2	2,052.9	2,065.5	2,078.0	2,090.2	2,102.3	2,113.9
	Capacity	24,097.6	24,298.4	24,500.5	24,703.9	24,908.6	25,114.5	25,321.7	25,530.2	25,739.8	25,950.7
652	Area	2,125.1	2,136.1	2,147.3	2,158.2	2,169.0	2,179.7	2,190.4	2,201.0	2,211.5	2,222.0
	Capacity	26,162.7	26,375.7	26,590.0	26,805.2	27,021.7	27,239.1	27,457.6	27,677.3	27,897.9	28,119.7

Table A. 3: Grand Lake Capacity/Area by 0.1-ft Increments (cont).

GRAND LAKE AREA-CAPACITY TABLE
OKLAHOMA WATER RESOURCES BOARD
2008/2009 Survey
Capacity in acre-feet by tenth foot elevation increments
Area in acres by tenth foot elevation increments

Elevation (ft PD)		0.06	0.16	0.26	0.36	0.46	0.56	0.66	0.76	0.86	0.96
653	Area	2,232	2,243	2,253	2,264	2,275	2,286	2,297	2,308	2,319	2,330
	Capacity	28,342	28,566	28,791	29,017	29,244	29,472	29,701	29,931	30,163	30,395
654	Area	2,342	2,353	2,365	2,377	2,389	2,402	2,414	2,428	2,441	2,456
	Capacity	30,629	30,864	31,100	31,337	31,575	31,815	32,055	32,298	32,541	32,786
655	Area	2,508	2,520	2,531	2,542	2,553	2,563	2,574	2,584	2,594	2,604
	Capacity	33,035	33,286	33,539	33,792	34,047	34,303	34,560	34,818	35,077	35,337
656	Area	2,614	2,625	2,635	2,646	2,657	2,669	2,681	2,693	2,705	2,716
	Capacity	35,598	35,860	36,123	36,387	36,652	36,918	37,186	37,455	37,725	37,996
657	Area	2,728	2,739	2,751	2,762	2,773	2,784	2,796	2,807	2,818	2,830
	Capacity	38,268	38,541	38,816	39,092	39,369	39,646	39,925	40,206	40,487	40,769
658	Area	2,841	2,853	2,865	2,876	2,888	2,900	2,912	2,923	2,935	2,947
	Capacity	41,053	41,337	41,623	41,910	42,199	42,488	42,779	43,071	43,364	43,658
659	Area	2,964	2,977	2,989	3,002	3,015	3,028	3,042	3,056	3,071	3,087
	Capacity	43,953	44,250	44,549	44,848	45,149	45,452	45,755	46,060	46,366	46,674
660	Area	3,147	3,163	3,177	3,191	3,205	3,219	3,232	3,245	3,259	3,272
	Capacity	46,987	47,302	47,619	47,938	48,258	48,579	48,901	49,225	49,551	49,877
661	Area	3,285	3,298	3,311	3,324	3,337	3,349	3,362	3,375	3,388	3,402
	Capacity	50,205	50,534	50,865	51,196	51,530	51,864	52,199	52,537	52,875	53,214
662	Area	3,415	3,428	3,442	3,456	3,470	3,483	3,497	3,510	3,524	3,538
	Capacity	53,555	53,897	54,241	54,586	54,932	55,280	55,629	55,979	56,331	56,684
663	Area	3,553	3,568	3,582	3,597	3,612	3,627	3,643	3,659	3,676	3,692
	Capacity	57,039	57,395	57,752	58,111	58,472	58,834	59,197	59,563	59,929	60,298
664	Area	3,710	3,727	3,745	3,763	3,782	3,801	3,821	3,842	3,863	3,886
	Capacity	60,668	61,040	61,414	61,789	62,167	62,546	62,927	63,310	63,695	64,083
665	Area	3,969	3,991	4,012	4,033	4,054	4,074	4,094	4,113	4,133	4,152
	Capacity	64,476	64,874	65,275	65,677	66,081	66,488	66,896	67,307	67,719	68,133
666	Area	4,172	4,191	4,210	4,229	4,248	4,267	4,286	4,305	4,323	4,342
	Capacity	68,550	68,968	69,388	69,810	70,234	70,660	71,087	71,517	71,948	72,382
667	Area	4,361	4,380	4,398	4,417	4,436	4,454	4,473	4,492	4,511	4,529
	Capacity	72,817	73,254	73,693	74,134	74,577	75,021	75,467	75,916	76,366	76,818
668	Area	4,548	4,567	4,586	4,605	4,625	4,646	4,668	4,690	4,712	4,733
	Capacity	77,272	77,728	78,186	78,645	79,107	79,570	80,036	80,504	80,974	81,447
669	Area	4,754	4,775	4,795	4,816	4,838	4,860	4,882	4,906	4,931	4,958
	Capacity	81,921	82,397	82,876	83,356	83,839	84,324	84,811	85,301	85,793	86,287
670	Area	5,044	5,068	5,091	5,114	5,136	5,157	5,178	5,199	5,220	5,241
	Capacity	86,788	87,294	87,802	88,312	88,825	89,340	89,856	90,375	90,896	91,420
671	Area	5,261	5,282	5,303	5,324	5,345	5,367	5,388	5,409	5,429	5,451
	Capacity	91,945	92,472	93,001	93,533	94,066	94,602	95,140	95,680	96,221	96,766
672	Area	5,472	5,493	5,514	5,535	5,556	5,577	5,599	5,621	5,643	5,665
	Capacity	97,312	97,860	98,411	98,963	99,518	100,074	100,633	101,194	101,757	102,323
673	Area	5,688	5,710	5,731	5,753	5,776	5,798	5,820	5,842	5,865	5,887
	Capacity	102,891	103,461	104,033	104,607	105,184	105,762	106,343	106,927	107,512	108,100

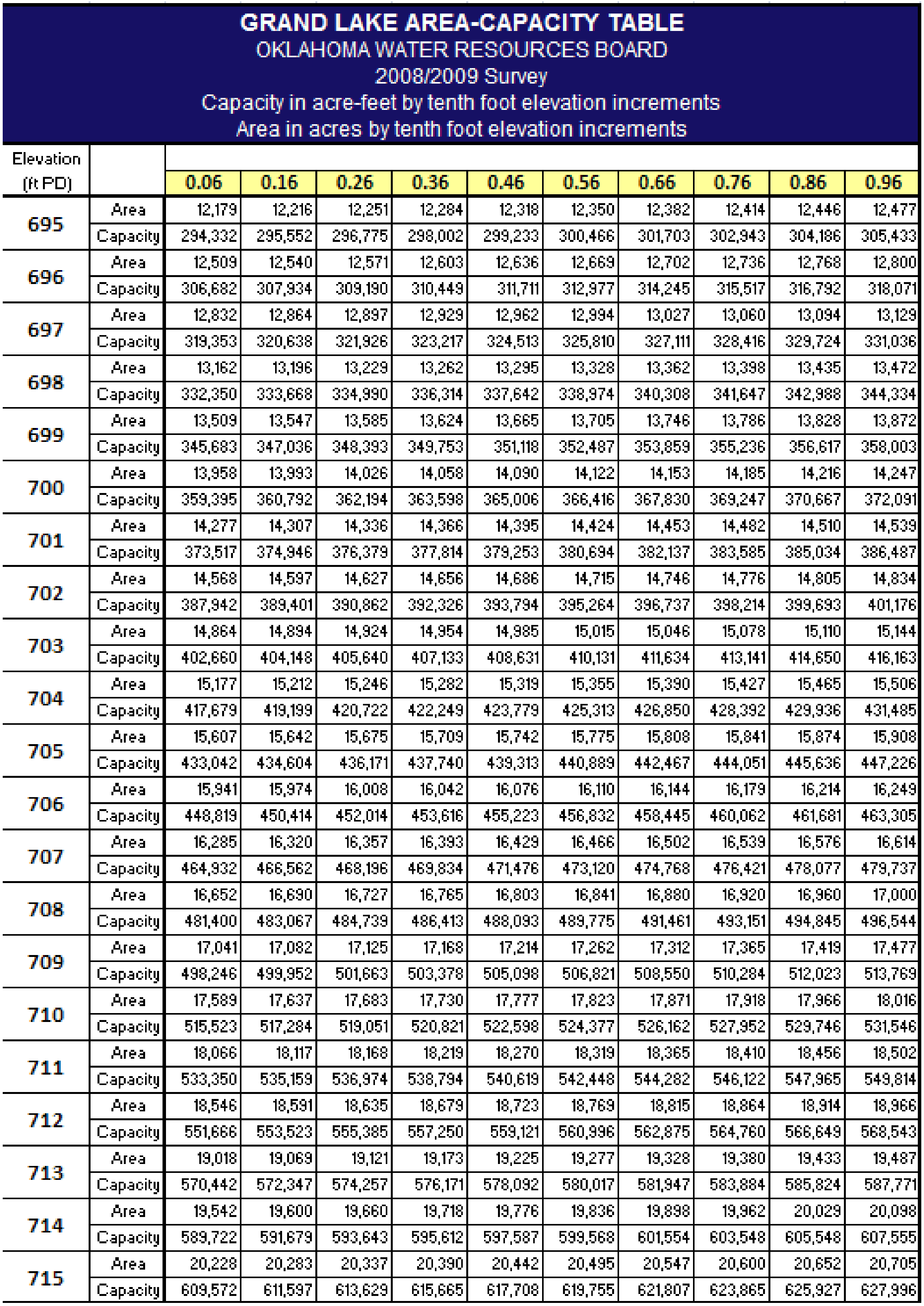
Table A. 4: Grand Lake Capacity/Area by 0.1-ft Increments (cont).



GRAND LAKE AREA-CAPACITY TABLE
OKLAHOMA WATER RESOURCES BOARD
2008/2009 Survey
Capacity in acre-feet by tenth foot elevation increments
Area in acres by tenth foot elevation increments

Elevation (ft PD)		0.06	0.16	0.26	0.36	0.46	0.56	0.66	0.76	0.86	0.96
674	Area	5,909	5,932	5,955	5,979	6,002	6,027	6,051	6,076	6,103	6,131
	Capacity	108,690	109,282	109,876	110,473	111,072	111,674	112,277	112,884	113,493	114,105
675	Area	6,210	6,240	6,267	6,294	6,320	6,346	6,371	6,397	6,421	6,445
	Capacity	114,722	115,345	115,971	116,599	117,230	117,863	118,499	119,137	119,778	120,422
676	Area	6,469	6,492	6,516	6,538	6,560	6,582	6,604	6,626	6,648	6,670
	Capacity	121,067	121,715	122,366	123,019	123,674	124,331	124,990	125,652	126,316	126,982
677	Area	6,692	6,714	6,737	6,759	6,781	6,803	6,825	6,848	6,871	6,895
	Capacity	127,650	128,320	128,993	129,668	130,345	131,024	131,705	132,389	133,075	133,764
678	Area	6,918	6,940	6,963	6,985	7,007	7,030	7,054	7,078	7,102	7,126
	Capacity	134,455	135,148	135,843	136,540	137,240	137,942	138,646	139,353	140,062	140,774
679	Area	7,150	7,175	7,199	7,223	7,247	7,272	7,296	7,322	7,350	7,381
	Capacity	141,488	142,204	142,923	143,644	144,368	145,094	145,822	146,553	147,287	148,024
680	Area	7,461	7,487	7,511	7,535	7,560	7,584	7,607	7,631	7,654	7,678
	Capacity	148,766	149,514	150,264	151,016	151,771	152,528	153,288	154,050	154,814	155,581
681	Area	7,702	7,726	7,750	7,775	7,799	7,824	7,849	7,874	7,899	7,924
	Capacity	156,350	157,121	157,896	158,672	159,451	160,232	161,015	161,802	162,591	163,382
682	Area	7,949	7,975	8,000	8,026	8,051	8,078	8,106	8,134	8,162	8,190
	Capacity	164,176	164,972	165,771	166,572	167,376	168,183	168,992	169,804	170,619	171,437
683	Area	8,218	8,247	8,275	8,302	8,330	8,358	8,386	8,415	8,443	8,473
	Capacity	172,257	173,081	173,907	174,736	175,568	176,402	177,239	178,080	178,923	179,769
684	Area	8,502	8,533	8,565	8,597	8,629	8,661	8,693	8,725	8,759	8,796
	Capacity	180,617	181,469	182,324	183,183	184,044	184,909	185,776	186,648	187,522	188,400
685	Area	8,877	8,912	8,946	8,980	9,014	9,049	9,082	9,115	9,148	9,181
	Capacity	189,284	190,173	191,067	191,963	192,863	193,766	194,673	195,583	196,496	197,413
686	Area	9,215	9,249	9,282	9,316	9,350	9,384	9,419	9,453	9,487	9,522
	Capacity	198,333	199,256	200,183	201,113	202,046	202,983	203,923	204,867	205,814	206,765
687	Area	9,556	9,590	9,623	9,656	9,688	9,720	9,753	9,786	9,817	9,847
	Capacity	207,719	208,676	209,637	210,601	211,569	212,539	213,513	214,490	215,470	216,454
688	Area	9,878	9,907	9,938	9,968	9,998	10,028	10,058	10,088	10,118	10,148
	Capacity	217,440	218,429	219,422	220,417	221,416	222,417	223,421	224,429	225,439	226,453
689	Area	10,178	10,209	10,240	10,272	10,303	10,335	10,367	10,400	10,433	10,469
	Capacity	227,469	228,488	229,511	230,537	231,566	232,598	233,633	234,672	235,713	236,759
690	Area	10,558	10,592	10,624	10,654	10,683	10,710	10,737	10,764	10,790	10,817
	Capacity	237,811	238,868	239,929	240,993	242,061	243,130	244,202	245,278	246,356	247,437
691	Area	10,844	10,871	10,899	10,927	10,955	10,984	11,012	11,040	11,069	11,098
	Capacity	248,519	249,605	250,694	251,785	252,880	253,977	255,077	256,180	257,285	258,394
692	Area	11,129	11,158	11,187	11,216	11,246	11,276	11,307	11,338	11,369	11,400
	Capacity	259,505	260,620	261,737	262,857	263,981	265,107	266,236	267,369	268,504	269,643
693	Area	11,438	11,467	11,497	11,529	11,563	11,596	11,630	11,664	11,699	11,733
	Capacity	270,785	271,930	273,079	274,230	275,385	276,543	277,704	278,870	280,038	281,210
694	Area	11,768	11,803	11,837	11,871	11,905	11,940	11,975	12,011	12,049	12,088
	Capacity	282,385	283,563	284,746	285,931	287,120	288,312	289,508	290,708	291,911	293,118

Table A. 5: Grand Lake Capacity/Area by 0.1-ft Increments (cont).



GRAND LAKE AREA-CAPACITY TABLE
OKLAHOMA WATER RESOURCES BOARD
2008/2009 Survey
Capacity in acre-feet by tenth foot elevation increments
Area in acres by tenth foot elevation increments

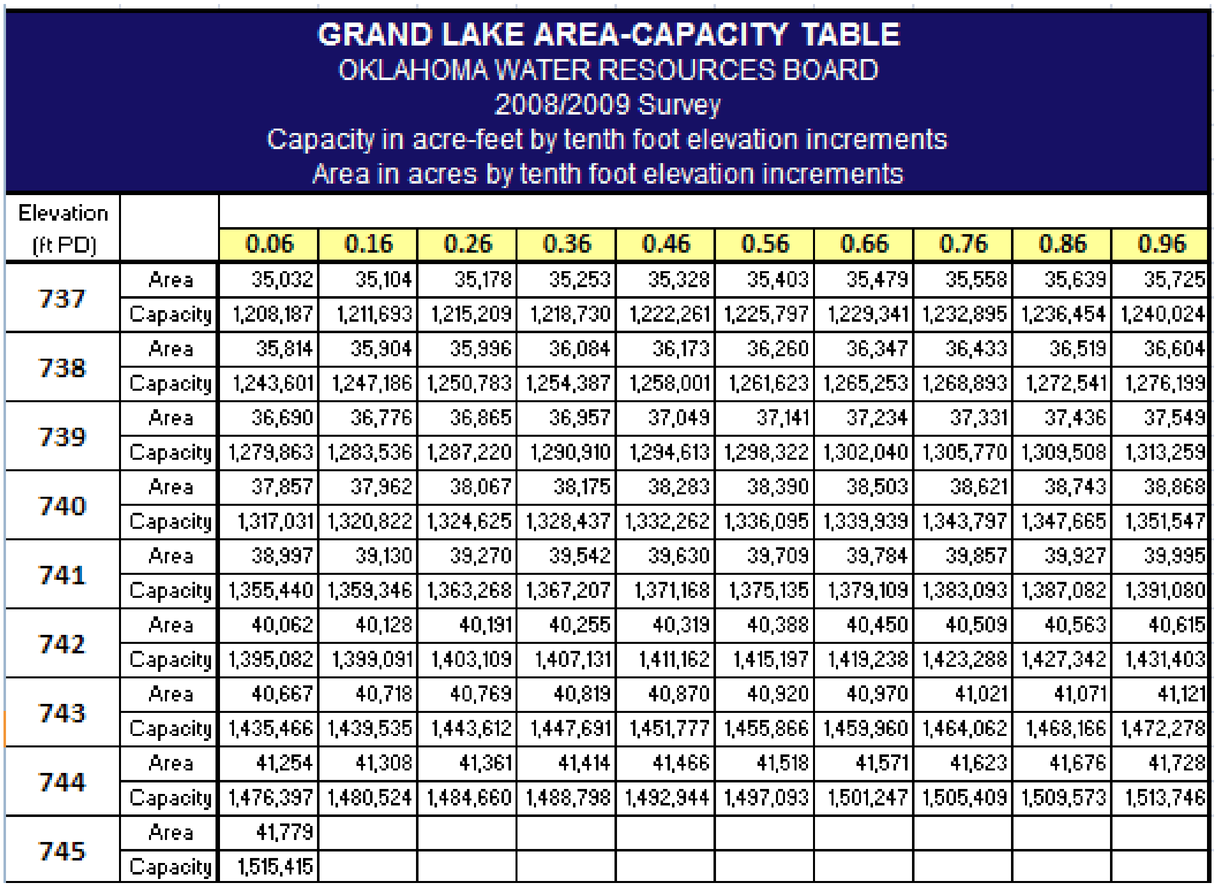
Elevation (ft PD)		0.06	0.16	0.26	0.36	0.46	0.56	0.66	0.76	0.86	0.96
695	Area	12,179	12,216	12,251	12,284	12,318	12,350	12,382	12,414	12,446	12,477
	Capacity	294,332	295,552	296,775	298,002	299,233	300,466	301,703	302,943	304,186	305,433
696	Area	12,509	12,540	12,571	12,603	12,636	12,669	12,702	12,736	12,768	12,800
	Capacity	306,682	307,934	309,190	310,449	311,711	312,977	314,245	315,517	316,792	318,071
697	Area	12,832	12,864	12,897	12,929	12,962	12,994	13,027	13,060	13,094	13,129
	Capacity	319,353	320,638	321,926	323,217	324,513	325,810	327,111	328,416	329,724	331,036
698	Area	13,162	13,196	13,229	13,262	13,295	13,328	13,362	13,398	13,435	13,472
	Capacity	332,350	333,668	334,990	336,314	337,642	338,974	340,308	341,647	342,988	344,334
699	Area	13,509	13,547	13,585	13,624	13,665	13,705	13,746	13,786	13,828	13,872
	Capacity	345,683	347,036	348,393	349,753	351,118	352,487	353,859	355,236	356,617	358,003
700	Area	13,958	13,993	14,026	14,058	14,090	14,122	14,153	14,185	14,216	14,247
	Capacity	359,395	360,792	362,194	363,598	365,006	366,416	367,830	369,247	370,667	372,091
701	Area	14,277	14,307	14,336	14,366	14,395	14,424	14,453	14,482	14,510	14,539
	Capacity	373,517	374,946	376,379	377,814	379,253	380,694	382,137	383,585	385,034	386,487
702	Area	14,568	14,597	14,627	14,656	14,686	14,715	14,746	14,776	14,805	14,834
	Capacity	387,942	389,401	390,862	392,326	393,794	395,264	396,737	398,214	399,693	401,176
703	Area	14,864	14,894	14,924	14,954	14,985	15,015	15,046	15,078	15,110	15,144
	Capacity	402,660	404,148	405,640	407,133	408,631	410,131	411,634	413,141	414,650	416,163
704	Area	15,177	15,212	15,246	15,282	15,319	15,355	15,390	15,427	15,465	15,506
	Capacity	417,679	419,199	420,722	422,249	423,779	425,313	426,850	428,392	429,936	431,485
705	Area	15,607	15,642	15,675	15,709	15,742	15,775	15,808	15,841	15,874	15,908
	Capacity	433,042	434,604	436,171	437,740	439,313	440,889	442,467	444,051	445,636	447,226
706	Area	15,941	15,974	16,008	16,042	16,076	16,110	16,144	16,179	16,214	16,249
	Capacity	448,819	450,414	452,014	453,616	455,223	456,832	458,445	460,062	461,681	463,305
707	Area	16,285	16,320	16,357	16,393	16,429	16,466	16,502	16,539	16,576	16,614
	Capacity	464,932	466,562	468,196	469,834	471,476	473,120	474,768	476,421	478,077	479,737
708	Area	16,652	16,690	16,727	16,765	16,803	16,841	16,880	16,920	16,960	17,000
	Capacity	481,400	483,067	484,739	486,413	488,093	489,775	491,461	493,151	494,845	496,544
709	Area	17,041	17,082	17,125	17,168	17,214	17,262	17,312	17,365	17,419	17,477
	Capacity	498,246	499,952	501,663	503,378	505,098	506,821	508,550	510,284	512,023	513,769
710	Area	17,589	17,637	17,683	17,730	17,777	17,823	17,871	17,918	17,966	18,016
	Capacity	515,523	517,284	519,051	520,821	522,598	524,377	526,162	527,952	529,746	531,546
711	Area	18,066	18,117	18,168	18,219	18,270	18,319	18,365	18,410	18,456	18,502
	Capacity	533,350	535,159	536,974	538,794	540,619	542,448	544,282	546,122	547,965	549,814
712	Area	18,546	18,591	18,635	18,679	18,723	18,769	18,815	18,864	18,914	18,966
	Capacity	551,666	553,523	555,385	557,250	559,121	560,996	562,875	564,760	566,649	568,543
713	Area	19,018	19,069	19,121	19,173	19,225	19,277	19,328	19,380	19,433	19,487
	Capacity	570,442	572,347	574,257	576,171	578,092	580,017	581,947	583,884	585,824	587,771
714	Area	19,542	19,600	19,660	19,718	19,776	19,836	19,898	19,962	20,029	20,098
	Capacity	589,722	591,679	593,643	595,612	597,587	599,568	601,554	603,548	605,548	607,555
715	Area	20,228	20,283	20,337	20,390	20,442	20,495	20,547	20,600	20,652	20,705
	Capacity	609,572	611,597	613,629	615,665	617,708	619,755	621,807	623,865	625,927	627,996

Table A. 6: Grand Lake Capacity/Area by 0.1-ft Increments (cont).

GRAND LAKE AREA-CAPACITY TABLE
OKLAHOMA WATER RESOURCES BOARD
2008/2009 Survey
Capacity in acre-feet by tenth foot elevation increments
Area in acres by tenth foot elevation increments

Elevation (ft PD)		0.06	0.16	0.26	0.36	0.46	0.56	0.66	0.76	0.86	0.96
716	Area	20,757	20,810	20,864	20,918	20,972	21,025	21,079	21,132	21,186	21,240
	Capacity	630,069	632,147	634,232	636,321	638,416	640,516	642,621	644,733	646,848	648,971
717	Area	21,295	21,350	21,405	21,460	21,516	21,572	21,628	21,686	21,744	21,805
	Capacity	651,097	653,229	655,368	657,511	659,661	661,815	663,975	666,142	668,313	670,492
718	Area	21,869	21,934	21,998	22,062	22,127	22,192	22,257	22,323	22,388	22,452
	Capacity	672,675	674,865	677,063	679,265	681,476	683,692	685,914	688,144	690,379	692,623
719	Area	22,516	22,580	22,645	22,711	22,777	22,844	22,912	22,982	23,055	23,133
	Capacity	694,871	697,125	699,388	701,655	703,931	706,212	708,499	710,795	713,097	715,407
720	Area	23,288	23,353	23,416	23,478	23,540	23,600	23,659	23,719	23,778	23,836
	Capacity	717,729	720,061	722,400	724,745	727,097	729,454	731,816	734,187	736,561	738,943
721	Area	23,895	23,955	24,015	24,074	24,133	24,192	24,250	24,307	24,364	24,421
	Capacity	741,329	743,721	746,121	748,525	750,937	753,353	755,775	758,204	760,637	763,078
722	Area	24,477	24,533	24,589	24,645	24,701	24,757	24,813	24,870	24,927	24,984
	Capacity	765,522	767,972	770,430	772,891	775,360	777,832	780,311	782,796	785,286	787,782
723	Area	25,041	25,098	25,155	25,212	25,270	25,328	25,387	25,447	25,507	25,567
	Capacity	790,283	792,790	795,304	797,822	800,347	802,877	805,413	807,955	810,503	813,058
724	Area	25,629	25,691	25,755	25,820	25,885	25,954	26,025	26,098	26,173	26,252
	Capacity	815,617	818,183	820,757	823,335	825,922	828,513	831,112	833,720	836,333	838,955
725	Area	26,397	26,461	26,524	26,586	26,649	26,711	26,774	26,838	26,901	26,966
	Capacity	841,588	844,231	846,882	849,537	852,200	854,868	857,541	860,224	862,910	865,605
726	Area	27,030	27,096	27,162	27,227	27,292	27,357	27,423	27,490	27,558	27,627
	Capacity	868,304	871,010	873,725	876,444	879,171	881,903	884,642	887,389	890,141	892,902
727	Area	27,698	27,769	27,841	27,912	27,986	28,056	28,123	28,192	28,264	28,332
	Capacity	895,668	898,441	901,222	904,010	906,806	909,608	912,417	915,234	918,056	920,888
728	Area	28,399	28,470	28,542	28,611	28,680	28,747	28,813	28,879	28,945	29,010
	Capacity	923,724	926,567	929,419	932,276	935,142	938,013	940,891	943,777	946,668	949,567
729	Area	29,074	29,139	29,205	29,271	29,336	29,402	29,468	29,535	29,605	29,678
	Capacity	952,471	955,382	958,300	961,224	964,155	967,092	970,035	972,987	975,944	978,909
730	Area	29,787	29,852	29,916	29,979	30,043	30,107	30,171	30,234	30,297	30,360
	Capacity	981,883	984,864	987,854	990,848	993,851	996,858	999,872	1,002,894	1,005,920	1,008,954
731	Area	30,424	30,488	30,553	30,620	30,688	30,756	30,823	30,889	30,956	31,024
	Capacity	1,011,993	1,015,038	1,018,092	1,021,150	1,024,217	1,027,289	1,030,368	1,033,455	1,036,547	1,039,647
732	Area	31,093	31,163	31,234	31,305	31,378	31,451	31,526	31,602	31,679	31,757
	Capacity	1,042,753	1,045,865	1,048,987	1,052,113	1,055,249	1,058,390	1,061,539	1,064,697	1,067,860	1,071,034
733	Area	31,836	31,916	31,998	32,079	32,161	32,242	32,324	32,407	32,491	32,574
	Capacity	1,074,213	1,077,400	1,080,598	1,083,801	1,087,015	1,090,234	1,093,462	1,096,701	1,099,945	1,103,200
734	Area	32,656	32,736	32,817	32,900	32,983	33,066	33,152	33,241	33,332	33,429
	Capacity	1,106,461	1,109,730	1,113,010	1,116,295	1,119,591	1,122,893	1,126,204	1,129,525	1,132,853	1,136,193
735	Area	33,583	33,661	33,737	33,810	33,882	33,954	34,028	34,102	34,175	34,246
	Capacity	1,139,544	1,142,906	1,146,277	1,149,654	1,153,041	1,156,432	1,159,831	1,163,239	1,166,653	1,170,075
736	Area	34,319	34,391	34,465	34,539	34,611	34,682	34,752	34,821	34,891	34,961
	Capacity	1,173,503	1,176,938	1,180,383	1,183,833	1,187,292	1,190,756	1,194,228	1,197,708	1,201,193	1,204,688

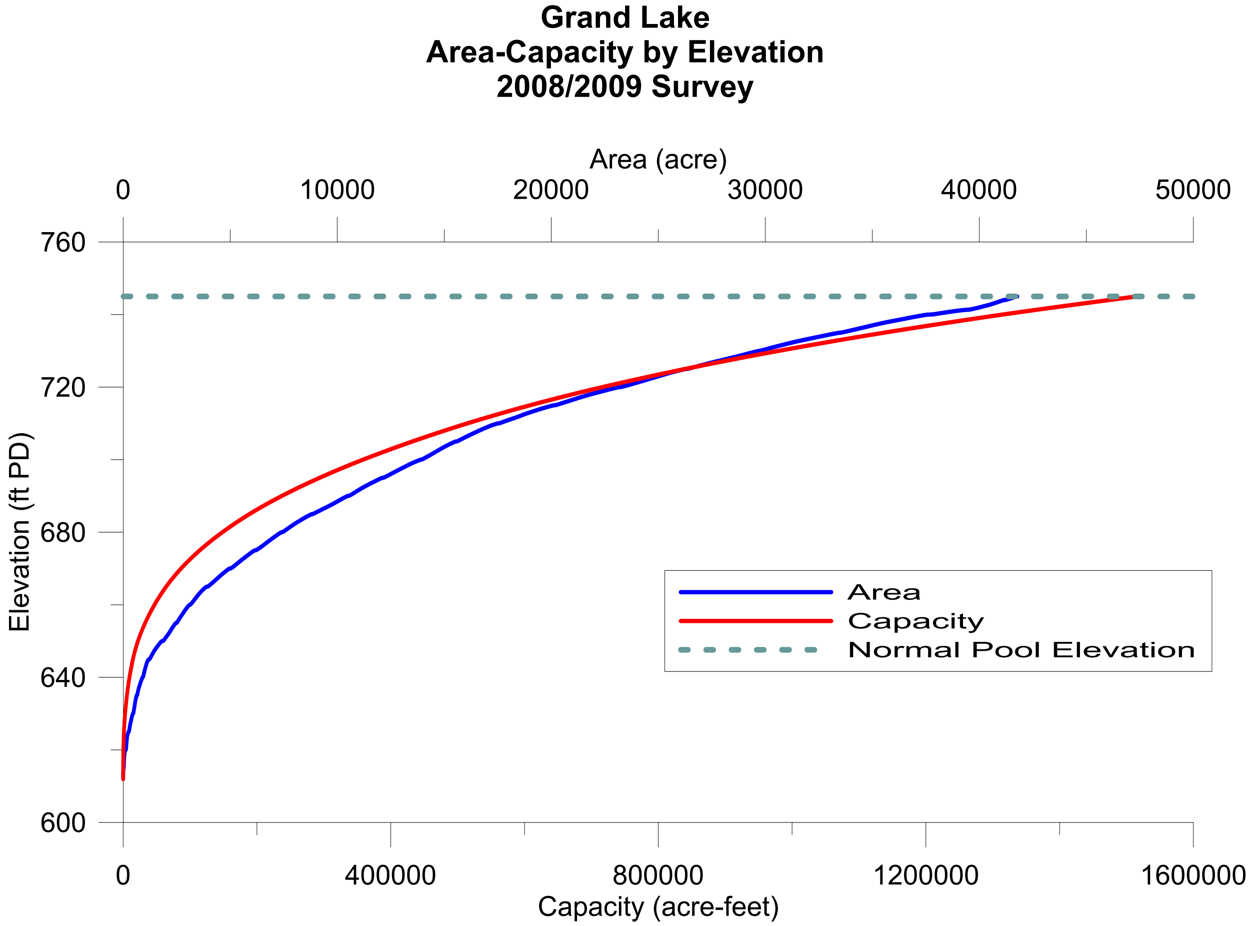
Table A. 7: Grand Lake Capacity/Area by 0.1-ft Increments (cont).



GRAND LAKE AREA-CAPACITY TABLE
OKLAHOMA WATER RESOURCES BOARD
2008/2009 Survey
Capacity in acre-feet by tenth foot elevation increments
Area in acres by tenth foot elevation increments

Elevation (ft PD)		0.06	0.16	0.26	0.36	0.46	0.56	0.66	0.76	0.86	0.96
737	Area	35,032	35,104	35,178	35,253	35,328	35,403	35,479	35,558	35,639	35,725
	Capacity	1,208,187	1,211,693	1,215,209	1,218,730	1,222,261	1,225,797	1,229,341	1,232,895	1,236,454	1,240,024
738	Area	35,814	35,904	35,996	36,084	36,173	36,260	36,347	36,433	36,519	36,604
	Capacity	1,243,601	1,247,186	1,250,783	1,254,387	1,258,001	1,261,623	1,265,253	1,268,893	1,272,541	1,276,199
739	Area	36,690	36,776	36,865	36,957	37,049	37,141	37,234	37,331	37,436	37,549
	Capacity	1,279,863	1,283,536	1,287,220	1,290,910	1,294,613	1,298,322	1,302,040	1,305,770	1,309,508	1,313,259
740	Area	37,857	37,962	38,067	38,175	38,283	38,390	38,503	38,621	38,743	38,868
	Capacity	1,317,031	1,320,822	1,324,625	1,328,437	1,332,262	1,336,095	1,339,939	1,343,797	1,347,665	1,351,547
741	Area	38,997	39,130	39,270	39,542	39,630	39,709	39,784	39,857	39,927	39,995
	Capacity	1,355,440	1,359,346	1,363,268	1,367,207	1,371,168	1,375,135	1,379,109	1,383,093	1,387,082	1,391,080
742	Area	40,062	40,128	40,191	40,255	40,319	40,388	40,450	40,509	40,563	40,615
	Capacity	1,395,082	1,399,091	1,403,109	1,407,131	1,411,162	1,415,197	1,419,238	1,423,288	1,427,342	1,431,403
743	Area	40,667	40,718	40,769	40,819	40,870	40,920	40,970	41,021	41,071	41,121
	Capacity	1,435,466	1,439,535	1,443,612	1,447,691	1,451,777	1,455,866	1,459,960	1,464,062	1,468,166	1,472,278
744	Area	41,254	41,308	41,361	41,414	41,466	41,518	41,571	41,623	41,676	41,728
	Capacity	1,476,397	1,480,524	1,484,660	1,488,798	1,492,944	1,497,093	1,501,247	1,505,409	1,509,573	1,513,746
745	Area	41,779									
	Capacity	1,515,415									

Figure A. 1. Area-Capacity Curve for Grand Lake



APPENDIX B: Grand Lake Maps

Figure B. 1: Grand Lake Bathymetric Map with 5-foot Contour Intervals.

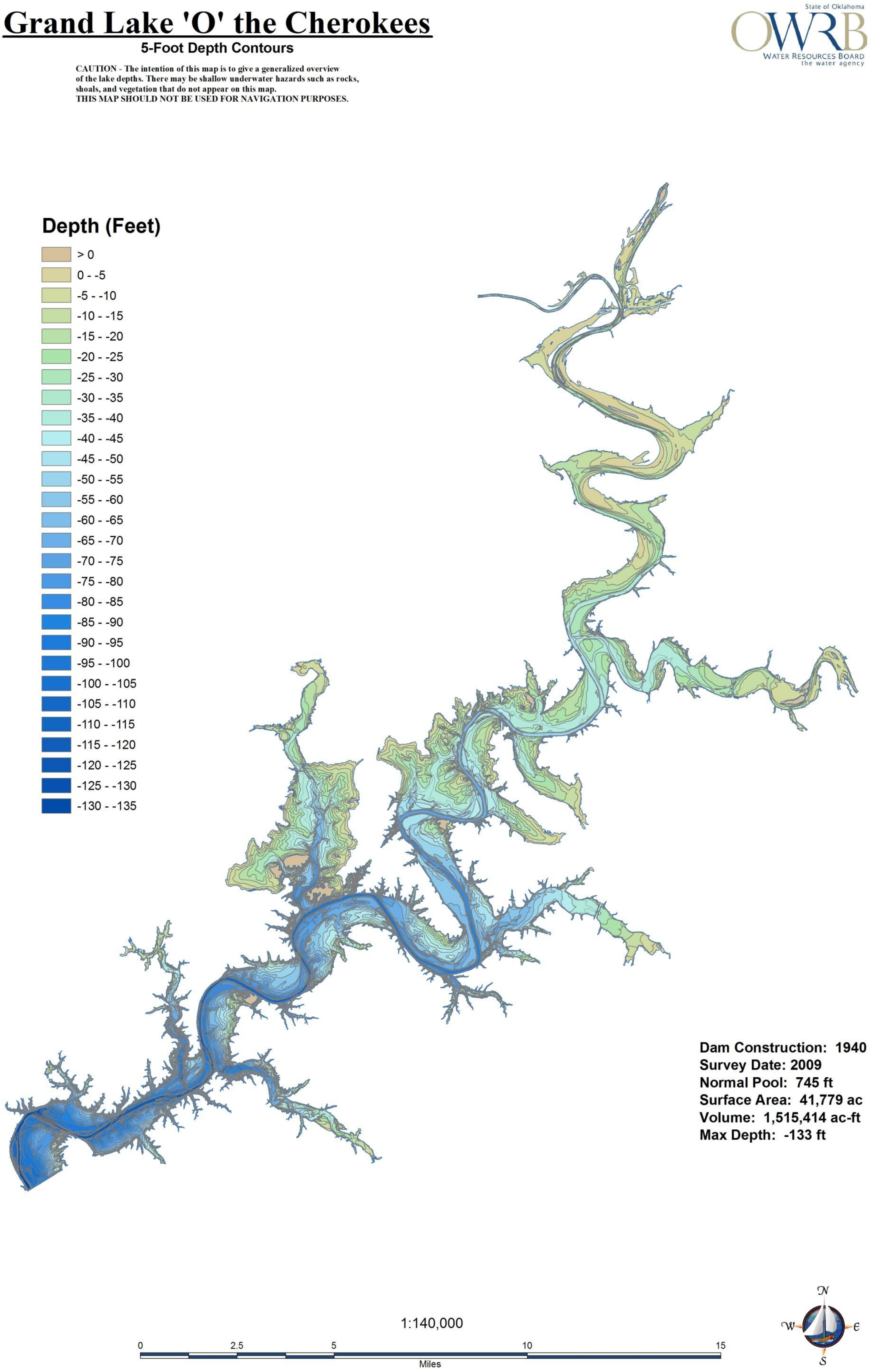


Figure B. 2: Grand Lake Shaded Relief Bathymetric Map.

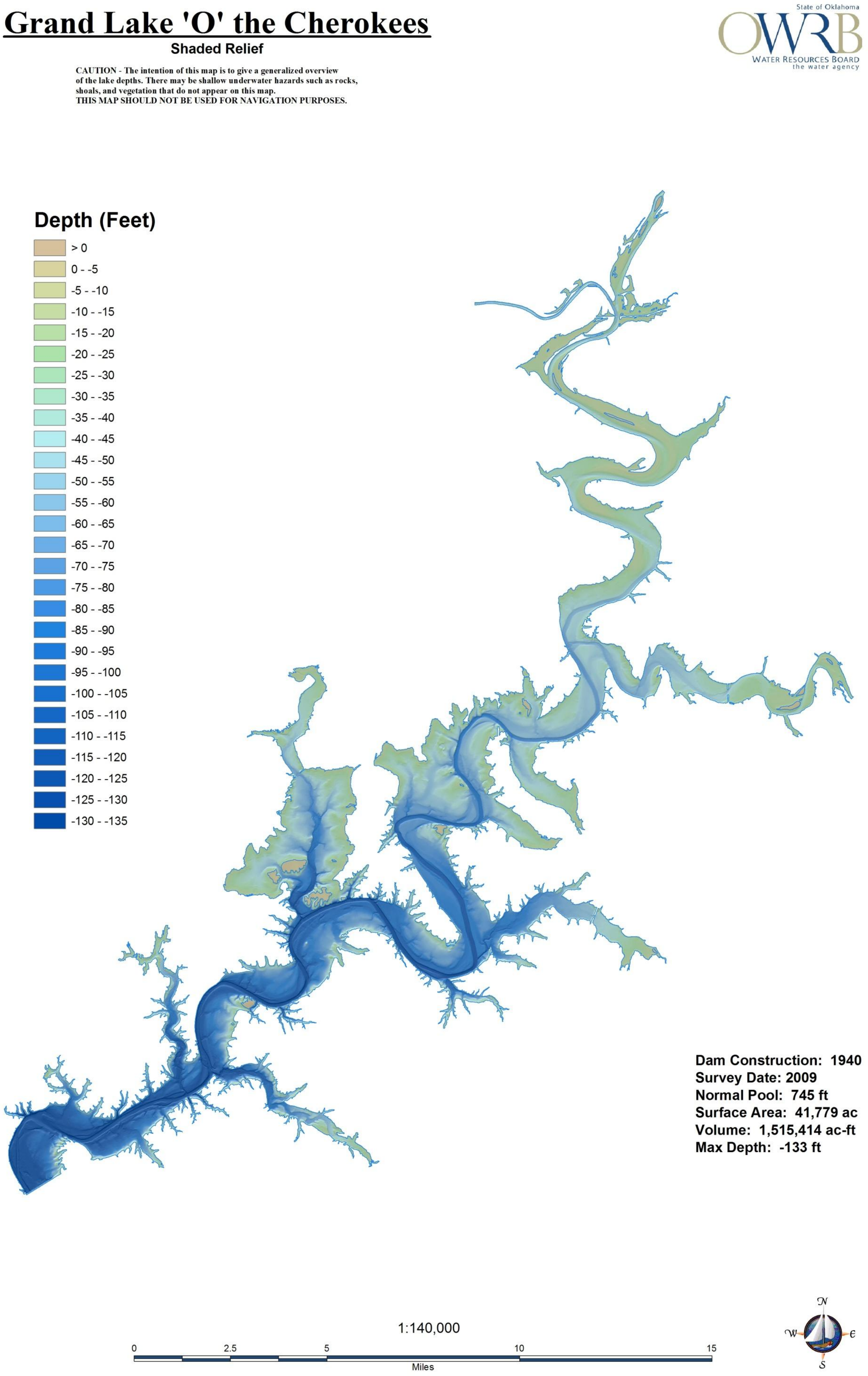
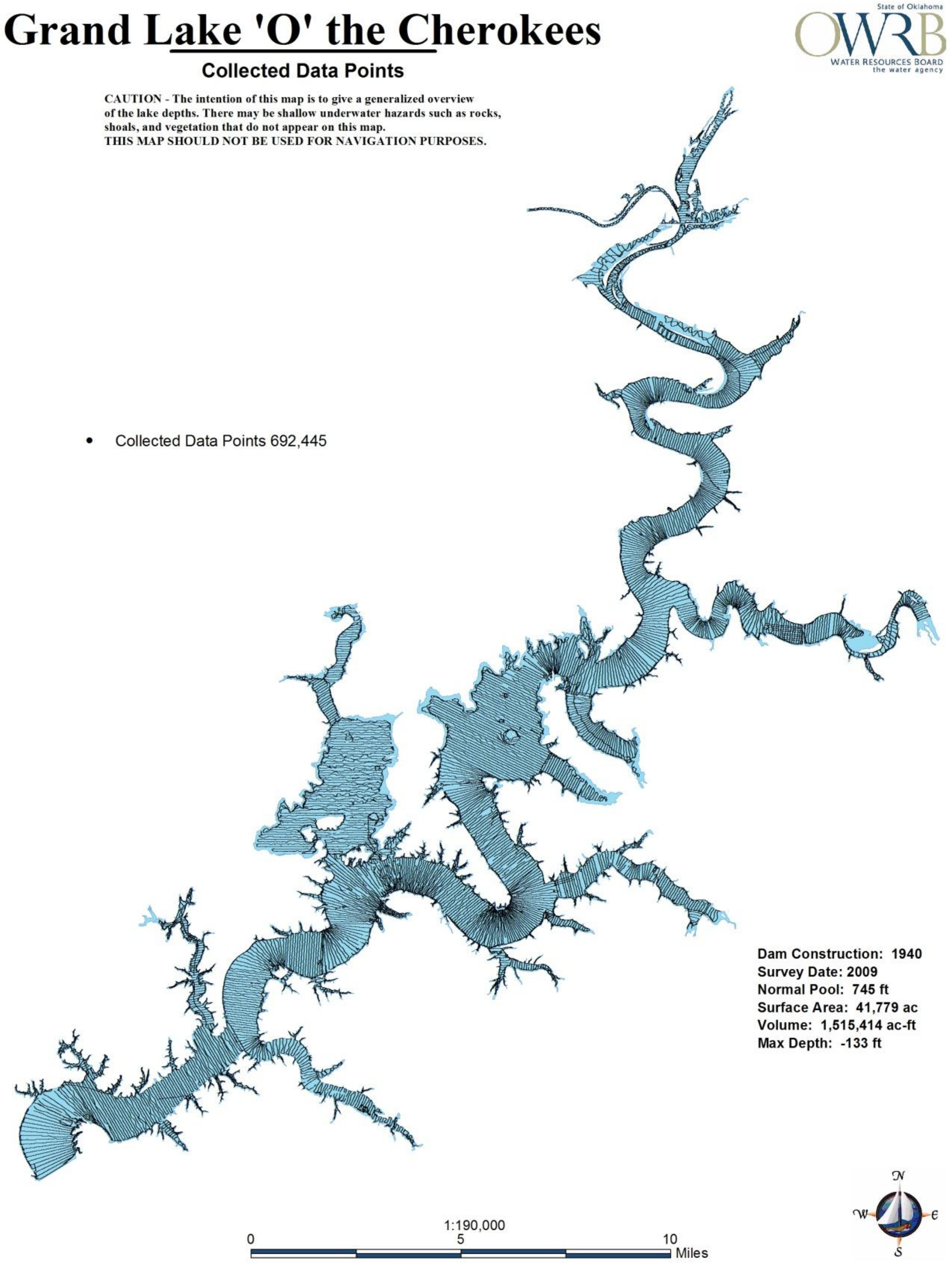


Figure B. 3: Grand Lake Collected Data Points.



Grand Lake 'O' the Cherokees

Collected Data Points

CAUTION - The intention of this map is to give a generalized overview of the lake depths. There may be shallow underwater hazards such as rocks, shoals, and vegetation that do not appear on this map.
THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.

Dam Construction: 1940
Survey Date: 2009
Normal Pool: 745 ft
Surface Area: 41,779 ac
Volume: 1,515,414 ac-ft
Max Depth: -133 ft

APPENDIX E-16 OWRB 2011 Hydrographic Survey of Tailraces

HYDROGRAPHIC SURVEY of GRDA TAILRACES

Draft Report
October 5, 2011

Prepared by:

State of Oklahoma
OWRB
WATER RESOURCES BOARD
the water agency

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GRDA TAILRACES
HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

The Oklahoma Water Resources Board (OWRB) conducted a hydrographic survey of the tailraces of the Pensacola Dam, Kerr Dam, and the Holway Pumpback Station at Saline Creek. The purpose of these surveys was to produce bathymetric maps of the surveyed areas.

SURVEY PLAN

The survey area extended 1,000 feet below each dam. The number of survey transects was divided into two levels. Level 1 areas had a greater distance between survey lines. In Level 1 areas, the lines ran parallel to the dam and were spaced 50 ft apart. The first 100 ft of survey area out from the dam was denoted as Level 2. These areas required a greater degree of detail. Survey lines in Level 2 areas were spaced approximately 10 feet apart parallel with the dam. Also in Level 2 areas, another set of lines ran perpendicular to the dam and were spaced at 10 ft intervals. In both areas, the lines extended as near to the shore as safety and equipment limitations permit (Note – The presence of sand/gravel bars, boulders, and/or rocks limited where depth data was collected).

SURVEY AREAS

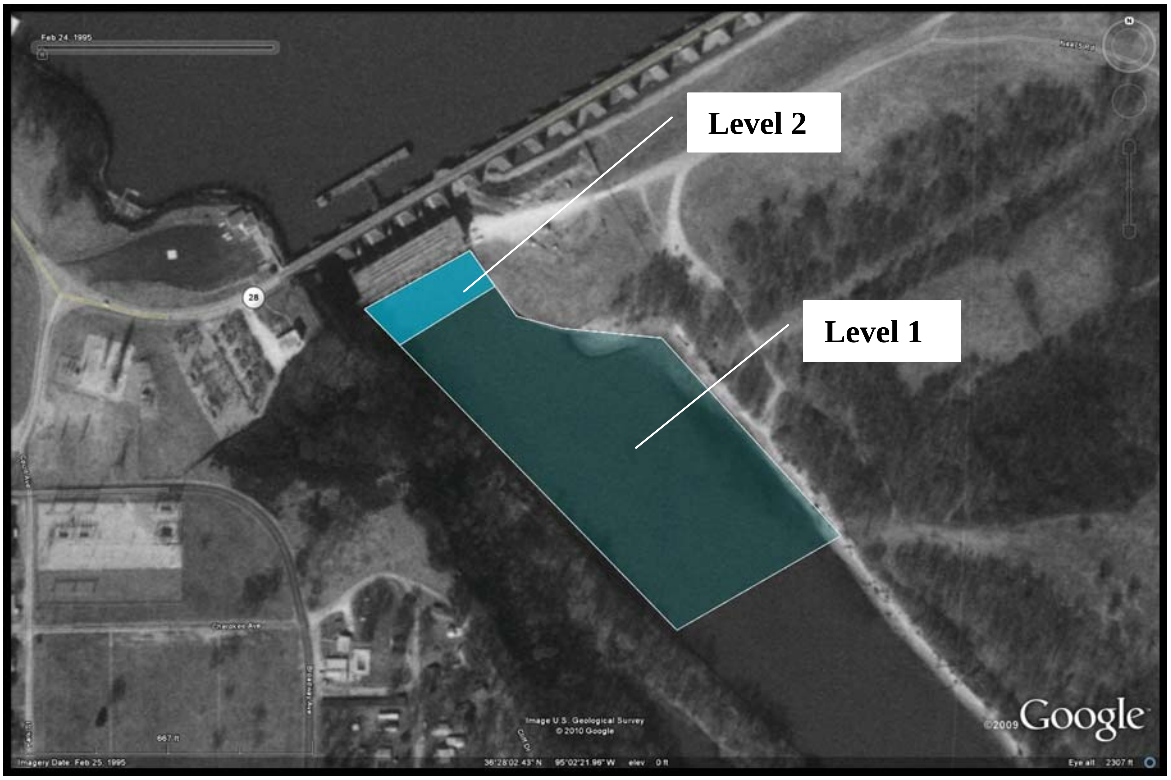


Figure 1: Survey area below Pensacola Dam.

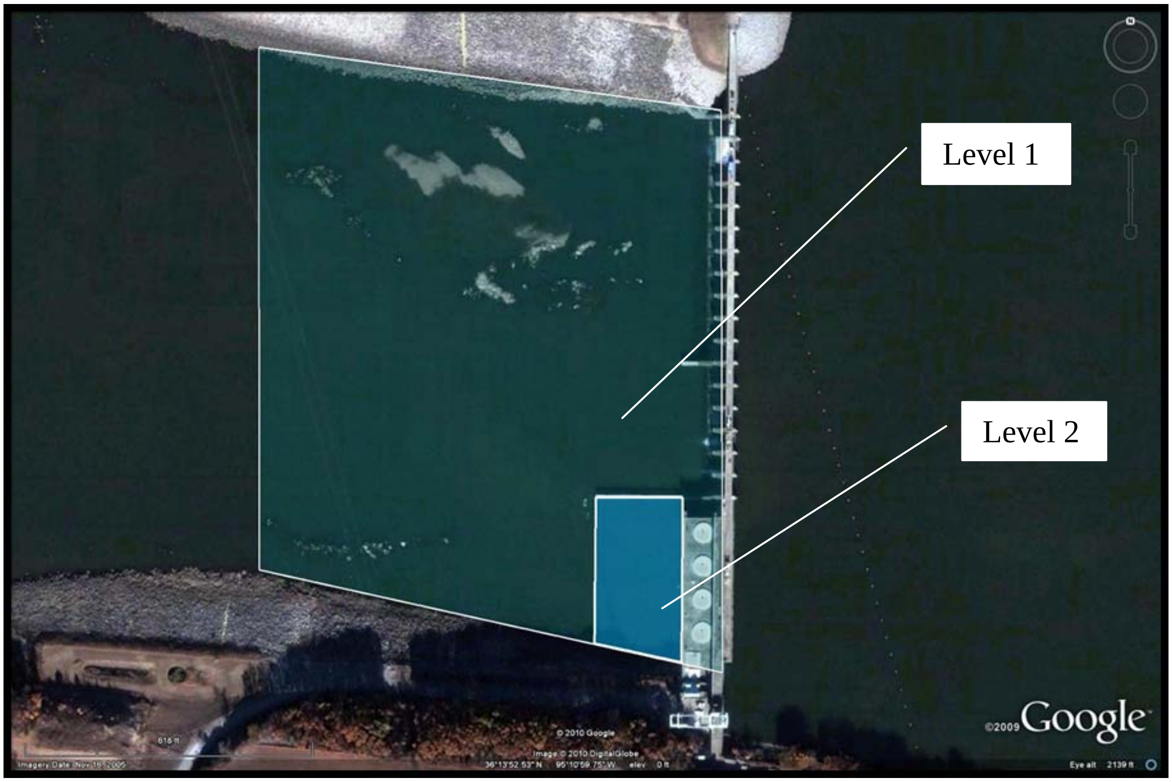


Figure 2: Survey area below Kerr Dam

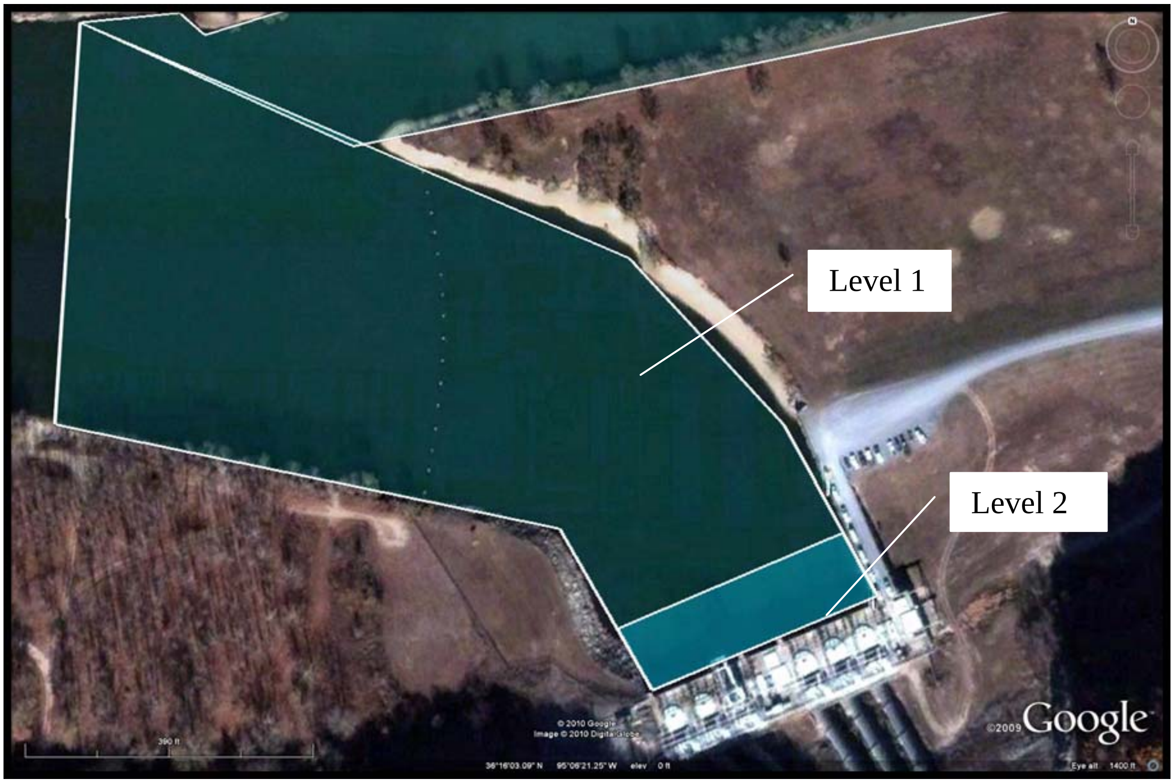


Figure 3: Survey area below Holway Pumpback Station

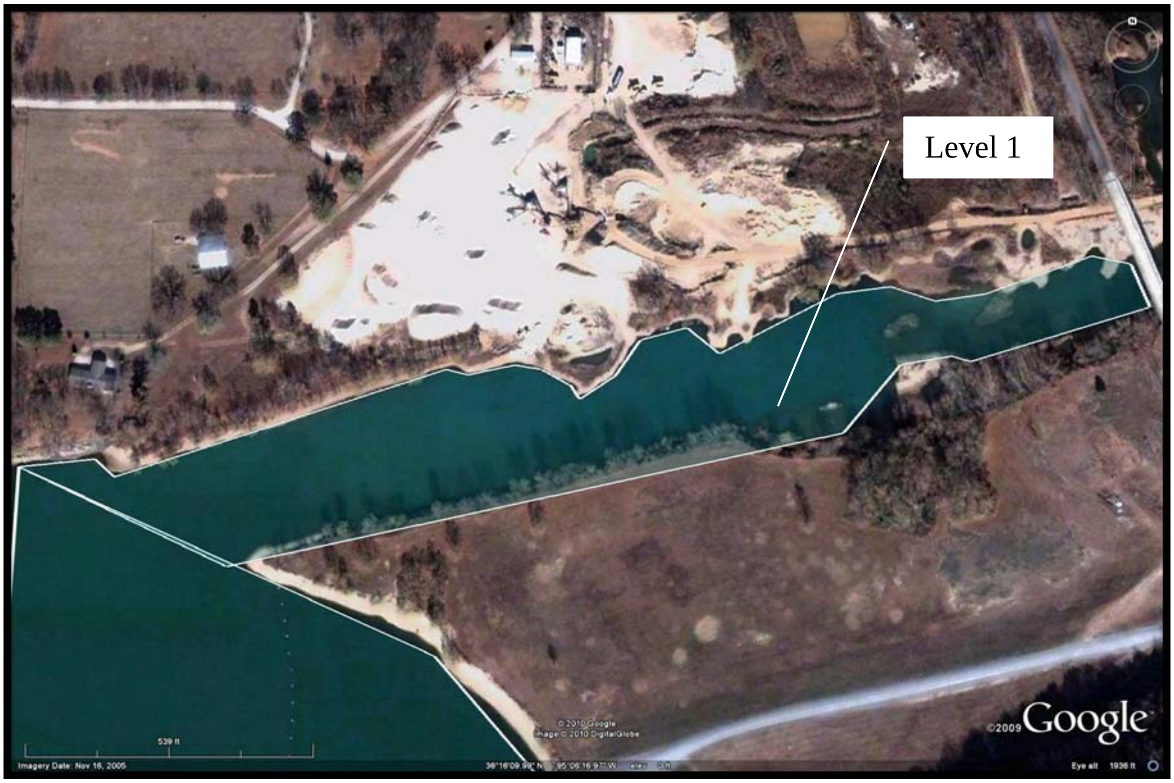


Figure 4: Survey area below Hwy 20 Bridge at Saline Creek

HYDROGRAPHIC SURVEYING PROCEDURES

The process of surveying a reservoir uses a combination of Geographic Positioning System (GPS) and acoustic depth sounding technologies that are incorporated into a hydrographic survey vessel. As the survey vessel travels across the lake's surface, the echosounder gathers multiple depth readings every second. The depth readings are stored on the survey vessel's on-board computer along with the positional data generated from the vessel's GPS receiver. The collected data files are downloaded daily from the computer and brought to the office for editing. During editing, data "noise" is removed or corrected, and average depths are converted to elevation readings based on the daily-recorded lake level elevation on the day the survey was performed. Accurate estimates of area-capacity can then be determined for the lake by building a 3-D model of the reservoir from the corrected data. The process of completing a hydrographic survey includes four steps: pre-survey planning, field survey, data processing, and GIS application.

Pre-survey Planning

Boundary File

The boundary file for reach area was on-screen digitized from the 2006 color digital orthoimagery quarter quadrangle (DOQQ) mosaic. The screen scale was set to 1:1,500. A line was to represent the shoreline as closely as possible. Due to the photography being a summer photo, it was difficult to determine the actual shoreline when there are trees and other vegetation hanging over the lake. The 1995 DOQQs of the lakes were used as back ground reference. The reservoir boundaries were digitized in NAD 1983 State Plane Coordinates (Oklahoma North-3501).

Set-up

HYPACK software from Hypack, Inc. was used to assign geodetic parameters, import background files, and create virtual track lines (transects). The geodetic parameters assigned were State Plane NAD 83 Zone OK-3501 Oklahoma North with distance units and depth as US Survey Feet. The survey transects were spaced according to the accuracy required for the project. The survey area extended 1,000 feet below each dam. The number of survey transects was divided into two levels. Level 1 areas had a greater distance between survey lines. In Level 1 areas, the lines ran parallel to the dam and were spaced 50 ft apart. The first 100 ft of survey area out from the dam was denoted as Level 2. These areas required a greater degree of detail. Survey lines in Level 2 areas were spaced approximately 10 feet apart parallel with the dam. Also in Level 2 areas, another set of lines ran perpendicular to the dam and were spaced at 10 ft intervals. In both areas, the lines extended as near to the shore as safety and equipment limitations permit (Note – The presence of sand/gravel bars, boulders, and/or rocks limited where depth data was collected).

Field Survey

Lake Elevation Acquisition

The lake elevation for each area was obtained by collecting positional data over a period of 20+ minutes. This data was then uploaded to the On-line Positioning Users Service-Rapid Static (OPUS-RS) website. The National Geodetic Survey (NGS) operates the OPUS as a means to provide GPS users easier access to the National Spatial Reference System (NSRS).

OPUS-RS allows users to submit their GPS data files to NGS, where the data is processed to determine a position using NGS computers and software. Each data file that is submitted is processed with respect to at least three Continuously Operating Reference Stations (CORS).

Method

The procedures followed by the OWRB during the hydrographic survey adhere to U.S. Army Corps of Engineers (USACE) standards (USACE, 2002). The quality control and quality assurance procedures for equipment calibration and operation, field survey, data processing, and accuracy standards are presented in the following sections.

Technology

The Hydro-survey vessel is an 18-ft aluminum Silverstreak hull with cabin, powered by a single 115-Horsepower Mercury outboard motor. Equipment used to conduct the survey included: a ruggedized notebook computer; Innerspace 456XPe Echo Sounder, with a depth resolution of 0.1 ft; Trimble Navigation, Inc. Pro XR GPS receiver with differential global positioning system (DGPS) correction; and an Odom Hydrographics, Inc, DIGIBAR-Pro Profiling Sound Velocimeter. The software used was HYPACK.

Survey

A two-man survey crew was used during the project. The survey crew followed the parallel transects created during the pre-survey planning while collecting depth soundings and positional data. Data was also collected along a path parallel to the shoreline at a distance that was determined by the depth of the water and the draft of the boat – generally, two to three feet deep. Areas with depths less than this were avoided.

Quality Control/Quality Assurance

While on board the Hydro-survey vessel, the Innerspace 456XPe Echo Sounder was calibrated using A DIGIBAR-Pro Profiling Sound Velocimeter, by Odom Hydrographics. The sound velocimeter measures the speed of sound at incremental depths throughout the water column. The factors that influence the speed of sound—depth, temperature, and salinity—are all taken into account. Deploying the unit involved lowering the probe, which measures the speed of sound, into the water to the calibration depth mark to allow for acclimation and calibration of the depth sensor. The unit was then gradually lowered at a controlled speed to a depth just above the lake bottom, and then was raised to the surface. The unit collected sound velocity measurements in feet/seconds (ft/sec) at 1 ft increments on both the deployment and retrieval phases. The data was then reviewed for any erroneous readings, which were then edited out of the sample. The sound velocity corrections were then applied to the to the raw depth readings.

The GPS system is an advanced high performance geographic data-acquisition tool that uses DGPS to provide sub-meter positional accuracy on a second-by-second basis. Potential errors are reduced with differential GPS because additional data from a reference GPS receiver at a known position are used to correct positions obtained during the survey. Before the survey, Trimble's Pathfinder Controller software was used to configure the GPS receiver. To maximize the accuracy of the horizontal positioning, the horizontal mask setting was set to 15 degrees and the Position Dilution of Precision (PDOP) limit was set to 6. The position interval was set to 1 second and the Signal to Noise Ratio (SNR) mask was set to 4. The

United States Coast Guard reference station used in the survey is located near Sallisaw, Oklahoma.

A latency test was performed to determine the fixed delay time between the GPS and single beam echo sounder. The timing delay was determined by running reciprocal survey lines over a channel bank. The raw data files were downloaded into HYPACK - LATENCY TEST program. The program varies the time delay to determine the “best fit” setting. A position latency of 0.1 seconds was produced and adjustments were applied to the raw data in the EDIT program.

Data Processing

The collected data was transferred from the field computer onto an OWRB desktop computer. After downloading the data, each raw data file was reviewed using the EDIT program within HYPACK. The EDIT program allowed the user to assign transducer offsets, latency corrections, tide corrections, display the raw data profile, and review/edit all raw depth information. Raw data files are checked for gross inaccuracies that occur during data collection.

Offset correction values of 3.2 ft. starboard, 6.6 ft. forward, and -1.1 ft. vertical were applied to all raw data along with a latency correction factor of 0.1 seconds. The speed of sound corrections were applied during editing of raw data.

A correction file was produced using the HYPACK TIDES program to account for the variance in lake elevation at the time of data collection. Within the EDIT program, the corrected depths were subtracted from the elevation reading to convert the depth in feet to an elevation.

After editing the data for errors and correcting the spatial attributes (offsets and tide corrections), a data reduction scheme was needed due to the large quantity of collected data.. To accomplish this, the corrected data was resampled spatially at a 5 ft interval using the Sounding Selection program in HYPACK. The resultant data was saved and exported out as a xyz.txt file.

GIS Application

Geographic Information System (GIS) software was used to process the edited XYZ data collected from the survey. The GIS software used was ArcGIS Desktop and ArcMap, version 9.2, from Environmental System Research Institute (ESRI). All of the GIS datasets created are in Oklahoma State Plane North Coordinate System referenced to the North American Datum 1983. Horizontal and vertical units are in feet. The edited data points in XYZ text file format were converted into ArcMap point coverage format. The point coverage contains the X and Y horizontal coordinates and the elevation and depth values associated with each collected point.

Contours, depth ranges, and the shaded relief map were derived from a constructed digital elevation model grid. This grid was created using the ArcMap Topo to Raster Tool and had a spatial resolution of five feet. A low pass 3x3 filter was run to lightly smooth the grid to improve contour generation. The contours were created using the ArcMap Contour Tool. The contour lines were edited to allow for polygon topology and to improve accuracy and general smoothness of the lines. The contours were then converted to a polygon coverage and attributed to show depth ranges across the lake. The bathymetric maps of the lakes are shown in **APPENDIX A: GRDA Tailrace Maps**.

All geographic datasets derived from the survey contain Federal Geographic Data Committee (FGDC) compliant metadata documentation. The metadata describes the procedures and commands used to create the datasets.

RESULTS

The contour maps from the OWRB survey are located in **APPENDIX A: GRDA Tailrace Maps**.

REFERENCES

U.S. Army Corps of Engineers (USACE). 2002. Engineering and Design - Hydrographic Surveying, Publication EM 1110-2-1003, 3rd version.

APPENDIX A: GRDA Tailrace Maps

Figure A. 1: Pensacola Dam Tailrace Bathymetric Map with 3-foot Contour Intervals.

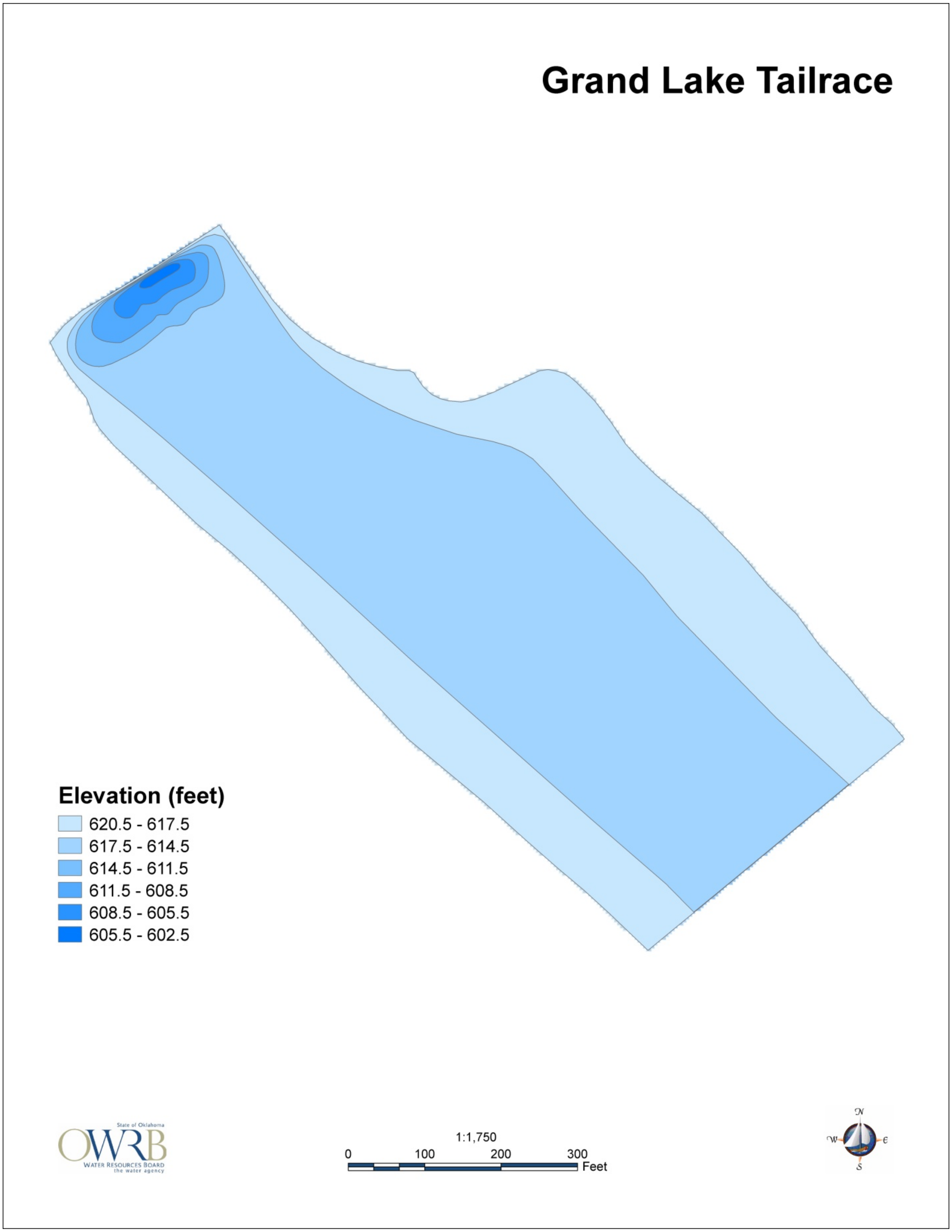


Figure A. 2: Kerr Dam Tailrace Bathymetric Map with 5-foot Contour Intervals.

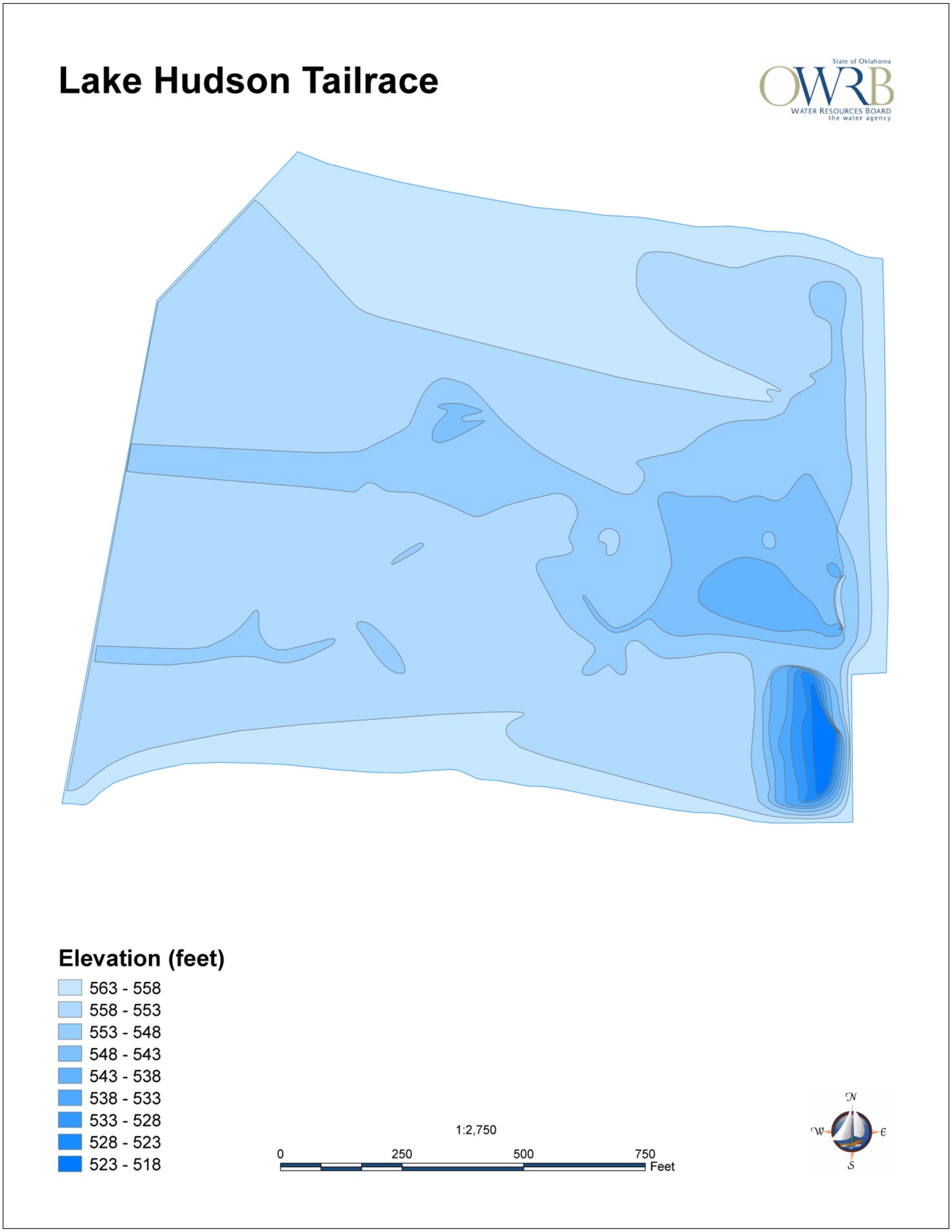
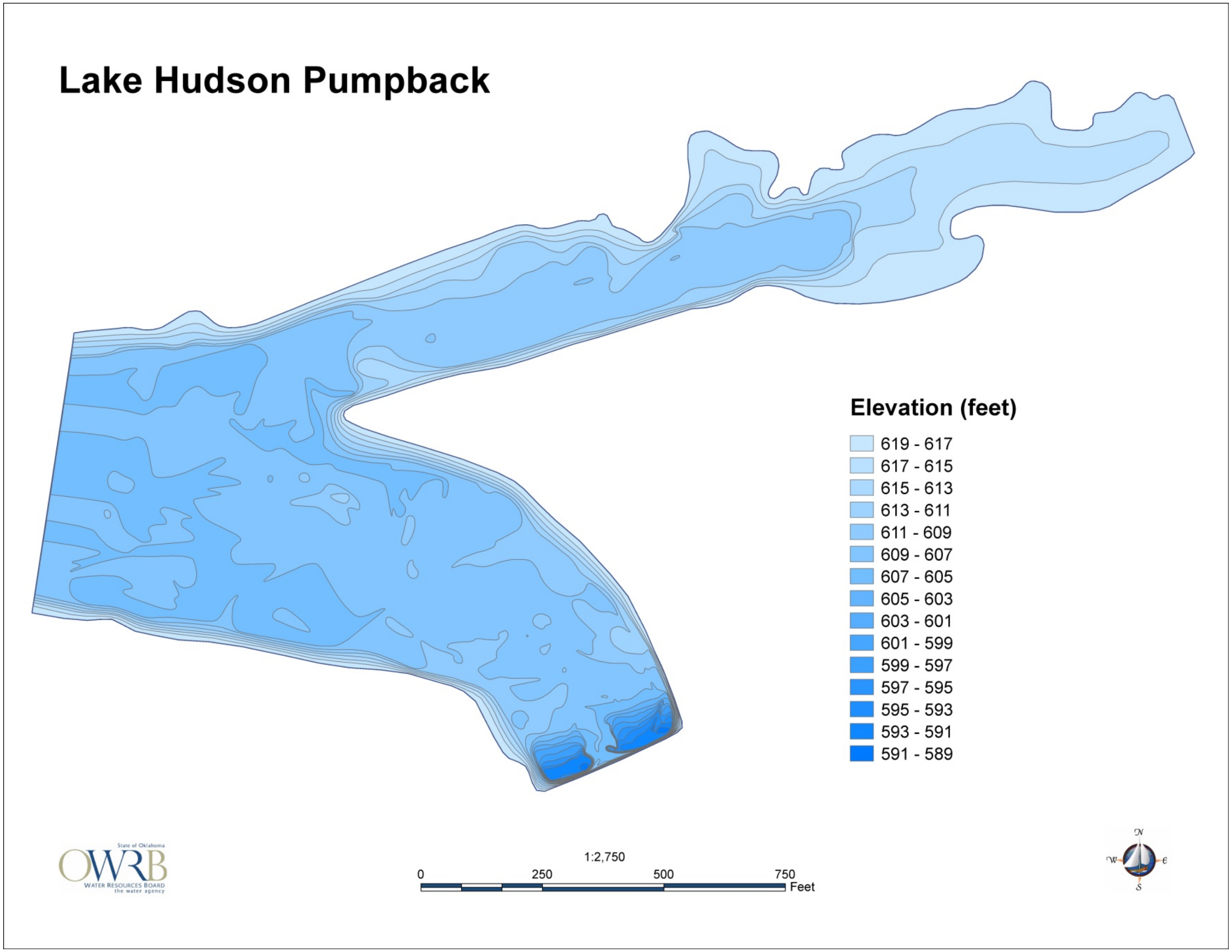


Figure A. 3: Holway Pumpback Tailrace/Saline Creek Bathymetric Map with 2-foot Contour Intervals.



APPENDIX E-17 Wetland and Riparian Habitat Study Report

Wetlands and Riparian Habitat Study for the Pensacola Hydroelectric Project
(FERC Project No. 1494)
Craig, Delaware, Mayes, and Ottawa Counties, Oklahoma

Prepared for:

Grand River Dam Authority

Prepared by:

Horizon Environmental Services, Inc.

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Chapter **Page**

LIST OF TABLES

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ATTACHMENTS

1.0 INTRODUCTION

Horizon conducted an updated Wetlands and Riparian Habitat Study (Study) for the Grand River Dam Authority (GRDA) on the Grand Lake O' the Cherokees (Grand Lake) located in Craig, Delaware, Mayes, and Ottawa counties, Oklahoma, to evaluate the effects of anticipated operations of the Pensacola Hydroelectric Project (Project) operations to wetlands and riparian habitat areas based on the inundation maps generated by the Comprehensive Hydraulic Model (CHM).

Inundation maps generated by the CHM were overlaid onto preliminary base maps that were developed using National Wetlands Inventory and other existing wetlands information and information related to the riparian habitat areas and Wildlife Management Areas (WMAs). The maps delineated the median areas inundated under baseline operations and the median areas to be inundated under anticipated operations during the growing season along with the current Project boundary. Horizon assessed the potential impacts to wetlands, riparian areas, and WMAs by identifying the extent, duration, and seasonality (timing) of inundation occurring in the Project boundary.

2.0 STUDY YEAR TWO ACTIVITIES

2.1 DATABASE CONTENTS

Project operations influence water levels of Grand Lake. These water level fluctuations have the potential to affect aquatic vegetation, wetlands, and riparian habitat, which can be important habitats for fish and wildlife. As such, Horizon was contracted to conduct a wetlands and riparian habitat study to quantify and refine the potential impacts associated with the anticipated change in Project operations under the new Federal Energy Regulatory Commission (FERC) license for the Project. Horizon used the National Wetlands Inventory (NWI) and CHM data to identify, display, and describe the composition of wetland and riparian communities (within the study area) in a geographic information systems (GIS) database. For this study, we utilized the CHM data to determine the median elevation for the baseline operation and the anticipated operation of the project during the growing season (March 30 to November 2) to develop wetland and riparian inundation areas.

GRDA currently operates the Project's conservation pool to target reservoir surface elevations to serve multiple purposes, including hydropower generation, water supply, public recreation, and wildlife enhancement. This operational scheme, referred to as the Project's rule curve, is required by Article 401 of the license. Over the years, the rule curve has been adjusted several times by the FERC. Even during the existing license term, the Article 401 rule curve requirements have been amended several times. As recently as 2015, GRDA was required by the FERC to target a low elevation of 741 feet Pensacola Datum (PD) during the latter part of the growing season beginning September 1 through mid-October of each year. The recent operations of the Project as modified by the FERC from time to time are generally considered in the established baseline operation. Under baseline Project operations, the median elevation as determined by the CHM has been 742.92 feet PD.

Under the Project's new license, GRDA does not anticipate Project operations in accordance with a rule curve. In 2019, Congress enacted the National Defense Authorization Act for Fiscal Year 2020 (NDAA 2020), which, among other things, granted GRDA autonomy in establishing reservoir levels within Grand Lake:

> "(A) IN GENERAL.—Except as may be required by the Secretary [of the Army] to carry out responsibilities under section 7 of the Flood Control Act of 1944 (33 U.S.C. 709),

> the Commission or any other Federal or State agency shall not include in any license for the project any condition or other requirement relating to—
>
> (i) surface elevations of the conservation pool; or
>
> (ii) the flood pool (except to the extent it references flood control requirements prescribed by the Secretary).
>
> (B) EXCEPTION.—Notwithstanding subparagraph (A), the project shall remain subject to the Commission's rules and regulations for project safety and protection of human health."
>
> Pub. L. No. 116-92, § 7612(b)(2), 133 Stat. 1198, 2312 (2019).

Based on authority granted to GRDA under NDAA 2020 and informed by the first season of relicensing studies, GRDA has determined that the following anticipated operational parameters will apply during the new license term:

1. GRDA will no longer utilize a rule curve with seasonal target elevations.
2. GRDA will maintain the conservation pool between elevations 742 and 745 feet PD for purposes of normal hydropower operations. While hydropower operations may occur when water surface elevations are outside this range (e.g., maintenance drawdowns and high-flow events), GRDA expects to generally maintain water surface elevations between 742 and 745 feet PD during normal Project operations.
3. Instead of managing the Project to target a specified seasonal elevation, GRDA's new operations may fluctuate reservoir levels within the elevational range of 742 and 745 feet PD, for purposes of responding to grid demands, market conditions, and the public interest, such as environmental and recreational considerations.
4. GRDA will continue to adhere to the Corps' direction on flood control operations in accordance with the Water Control Manual, with no changes to existing operations.

These anticipated Project operations under the new FERC license will result in a water level fluctuation between 742 to 745 feet PD, with a CHM predicted median elevation of 743.46 ft PD during the growing season.

To meet the objectives of this study, median wetland and riparian inundation levels during baseline operations and anticipated operations were compared to the wetland and habitat types from the NWI database. The NWI database was clipped below the baseline median elevation to remove erroneous areas of open water. The analysis of the wetland acres that may be affected was then assessed between the baseline median and anticipated median inundation levels during the growing season.

To determine the net change (increase) in wetland, riparian habitats, and WMAs between the baseline and anticipated median operational levels, Horizon assessed 160.78 acres of wetland habitat types as defined by the NWI map layer and as reported in Table 1. As provided in Table 2, the study area contains 2.70 acres of riparian habitat types. As reported in Table 3, the study area contains 28.54 acres of WMAs. These data are also displayed graphically in a map set that is included in Attachment A. It should be noted that the wetland and riparian areas that are listed in the tables below and illustrated in Attachment A are difficult to display due to the large geographical scope of the study and the narrow area between the baseline and anticipated operation water line. The majority of the water line difference, in a horizontal direction, between the baseline and anticipated operation ranges between a few to several feet wide along the lake shoreline.

Table 1. Wetland Composition within Study Area

Wetland Habitat Type	Acres Within Study Area
Freshwater Emergent Wetlands	
Palustrine, Emergent, Persistent, Scrub-Shrub, Broad-Leaved Deciduous, Seasonally Flooded, Diked/Impounded (PEM1/SS1Ch)	0.23
Palustrine, Emergent, Persistent, Temporary Flooded (PEM1A)	0.02
Palustrine, Emergent, Persistent, Seasonally Flooded (PEM1C)	3.61
Palustrine, Emergent, Persistent, Seasonally Flooded, Diked/Impounded (PEM1Ch)	2.02
Total Freshwater Emergent Wetlands Acres	**5.88**
Freshwater Forested Wetland	
Palustrine, Forested, Broad-Leaved Deciduous, Emergent, Persistent, Seasonally Flooded, Diked/Impounded (PFO1/EM1Ch)	0.80
Palustrine, Forested, Broad-Leaved Deciduous, Scrub-Shrub, Broad-Leaved Deciduous, Temporary Flooded (PFO1/SS1A)	0.55
Palustrine, Forested, Broad-Leaved Deciduous, Scrub-Shrub, Broad-Leaved Deciduous, Temporary Flooded, Diked/Impounded (PFO1/SS1Ah)	3.33
Palustrine, Forested, Broad-Leaved Deciduous, Scrub-Shrub, Broad-Leaved Deciduous, Seasonally Flooded (PFO1/SS1C)	0.36
Palustrine, Forested, Broad-Leaved Deciduous, Scrub-Shrub, Broad-Leaved Deciduous, Seasonally Flooded, Diked/Impounded (PFO1/SS1Ch)	22.12
Palustrine, Forested, Broad-Leaved Deciduous, Unconsolidated Bottom, Semi-permanently Flooded, Diked/Impounded (PFO1/UBFh)	3.28
Palustrine, Forested, Broad-Leaved Deciduous, Temporary Flooded (PFO1A)	11.32
Palustrine, Forested, Broad-Leaved Deciduous, Temporary Flooded, Diked/Impounded (PFO1Ah)	7.84
Palustrine, Forested, Broad-Leaved Deciduous, Seasonally Flooded (PFO1C)	9.52

Wetland Habitat Type	Acres Within Study Area
Palustrine, Forested, Broad-Leaved Deciduous, Seasonally Flooded, Diked/Impounded (PFO1Ch)	51.31
Palustrine, Forested, Broad-Leaved Deciduous, Semi-permanently Flooded, Diked/Impounded (PFO1Fh)	7.98
Palustrine, Forested, Dead, Broad-Leaved Deciduous, Semi-permanently Flooded, Diked/Impounded (PFO5/1Fh)	0.83
Total Freshwater Forested Wetland Acres	**119.24**
Freshwater Scrub-Shrub Wetlands	
Palustrine, Scrub-Shrub, Broad-Leaved Deciduous, Emergent, Persistent, Temporary Flooded, Ditched (PSS1/EM1Ad)	0.37
Palustrine, Scrub-Shrub, Broad-Leaved Deciduous, Emergent, Persistent, Seasonally Flooded (PSS1/EM1C)	0.73
Palustrine, Scrub-Shrub, Broad-Leaved Deciduous, Emergent, Persistent, Seasonally Flooded, Diked/Impounded (PSS1/EM1Ch)	6.13
Palustrine, Scrub-Shrub, Broad-Leaved Deciduous, Unconsolidated Bottom, Semi-permanently Flooded, Diked/Impounded (PSS1/UBFh)	0.13
Palustrine, Scrub-Shrub, Broad-Leaved Deciduous, Temporary Flooded (PSS1A)	0.59
Palustrine, Scrub-Shrub, Broad-Leaved Deciduous, Temporary Flooded, Diked/Impounded (PSS1Ah)	0.11
Palustrine, Scrub-Shrub, Broad-Leaved Deciduous, Seasonally Flooded (PSS1C)	1.22
Palustrine, Scrub-Shrub, Broad-Leaved Deciduous, Seasonally Flooded, Diked/Impounded (PSS1Ch)	15.13
Palustrine, Scrub-Shrub, Broad-Leaved Deciduous, Semi-permanently Flooded (PSS1F)	0.07
Palustrine, Scrub-Shrub, Broad-Leaved Deciduous, Semi-permanently Flooded, Diked/Impounded (PSS1Fh)	9.21
Total Freshwater Scrub-Shrub Wetlands Acres	**33.69**
Freshwater Open Water	
Palustrine, Unconsolidated Bottom, Permanently Flooded, Diked/Impounded (PUBHh)	1.84
Palustrine, Unconsolidated Bottom, Permanently Flooded, Excavated (PUBHx)	0.13
Total Freshwater Open Water Acres	**1.97**
Total Wetland Acres Within Study Area	**160.78**

Table 2. Riparian Composition within Study Area

Riparian Habitat Type	Acres Within Study Area
Riparian, Lotic, Forested, Deciduous (Rp1FO6)	2.49
Riparian, Lentic, Forested, Deciduous (Rp2FO6)	0.21
Total Riparian Habitat Acres	**2.70**

Table 3. Wildlife Management Areas within Study Area

WMA Name	Acres Within Study Area
Connors Bridge	0.22
Mallard Point	13.4
West Spring River	14.92
Total WMA Acres	**28.54**

2.2 DISCUSSION AND CONCLUSION

According to NWI and GRDA data, 160.78 acres of wetlands, 2.70 acres of riparian habitat, and 28.54 acres of WMAs were identified in the study area and will be periodically inundated more often under the anticipated operations than under the baseline operations (i.e, the median elevation is expected to be slightly higher under the anticipated operations than it is under current, baseline operations).

In some areas of the reservoir far upstream, the stream channel had migrated to one side or the other from the location mapped in the original NWI data. The majority of these areas occur in portions of the reservoir where the median elevation differences are indistinguishable between the baseline and anticipated operations. Therefore, no major deviations from the preliminary wetland cover types required ground-truthing.

Overall, GRDA's anticipated operations under the new license will result in water level fluctuations ranging from 742 to 745 feet PD (or 3 feet), whereas baseline operations have resulted in frequent water level fluctuations ranging from 741 to 745 feet PD (or 4 feet). As a result, fewer overall impacts to wetlands, riparian areas, and WMAs are expected under the anticipated operations than under baseline operations. Additional wetlands will experience permanent inundation between 741 and 742 feet PD under the anticipated operations.

Historically, baseline operations enforced by the rule curve frequently resulted in an operational range between 741 and 745 feet PD (4 feet). In comparison, the median baseline and anticipated reservoir elevations during the growing season (March 30 to November 2) yield elevations of 742.92 feet PD and 743.46 feet PD, respectively. This increase of 0.54 feet is not likely to yield significant changes to wetlands in the affected areas. Furthermore, the comparisons between the baseline and anticipated operations also include the historical and now-abandoned fall drawdown of the reservoir to 741 feet PD to expose mudflats.

Using historical data to represent normal events, including 1-year flood events, the output of the CHM produced a comparison of the median water surface elevation (WSEL) under baseline operations versus the median WSEL under anticipated operations for the growing season (March 30 to November 2). The mapped output when overlaid on other sources of data, including the NWI data, showed very small differences along shorelines that could result in a net increase or conversion to other types of wetlands, because the anticipated operations have a higher median elevation during the growing season than do the baseline operations.

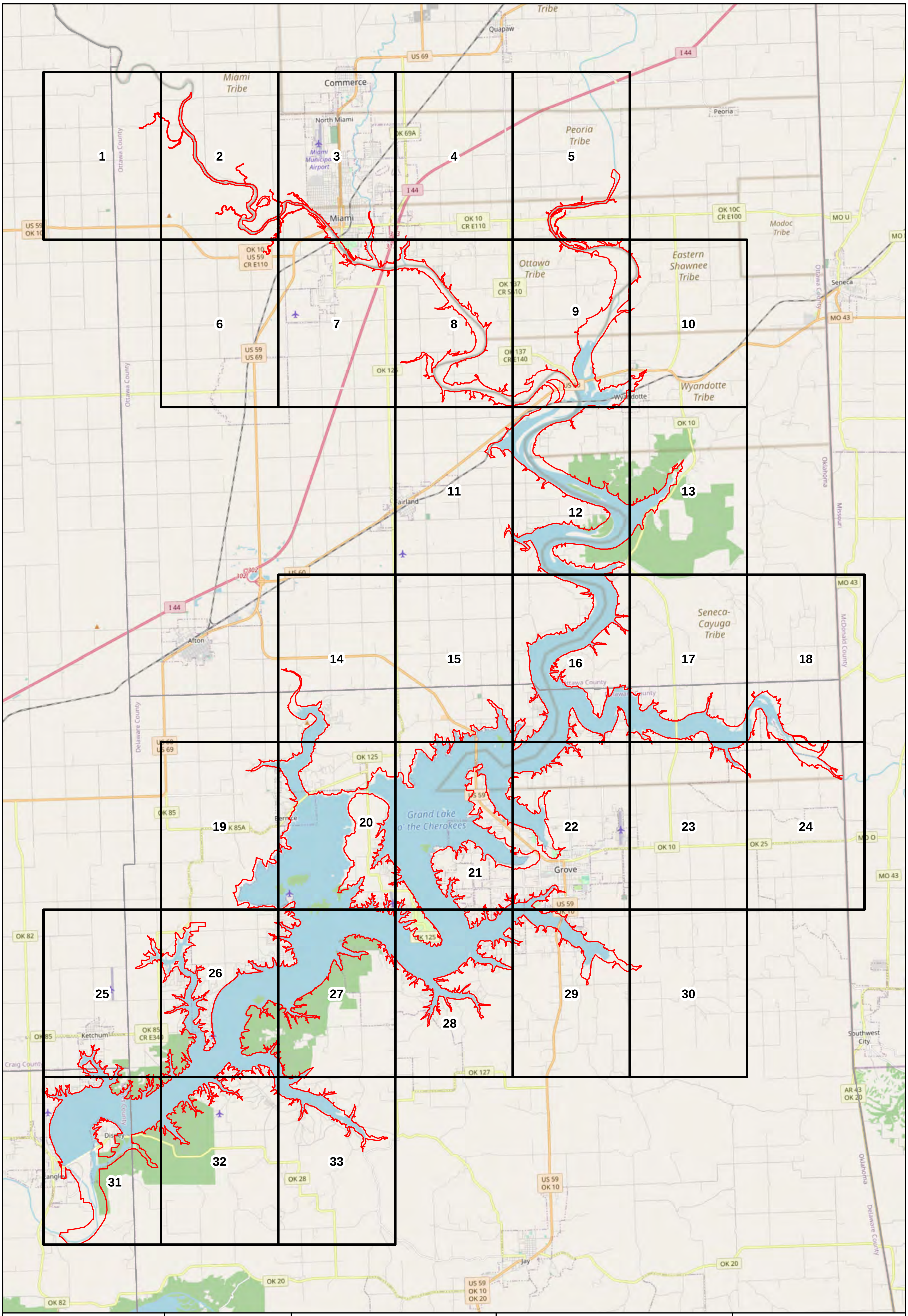
3.0 REFERENCES CITED

Cowardin, L., V. Carter, and E. LaRoe. Classification of Wetlands and Deepwater Habitats of the United States. US Fish and Wildlife Service publication. Published 1979.

(Esri) Environmental Systems Research Institute. World Imagery, <https://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9>. Imagery date 29 March 2021.

ATTACHMENT A

Wetland and Riparian Inundation Changes Map Set



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Source:	OSM, 2022

Wetland & Riparian
Inundation Changes
Overall Map
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

▭	County Boundary
🟥	Project Boundary
▭	1:24,000-scale Map Sheet

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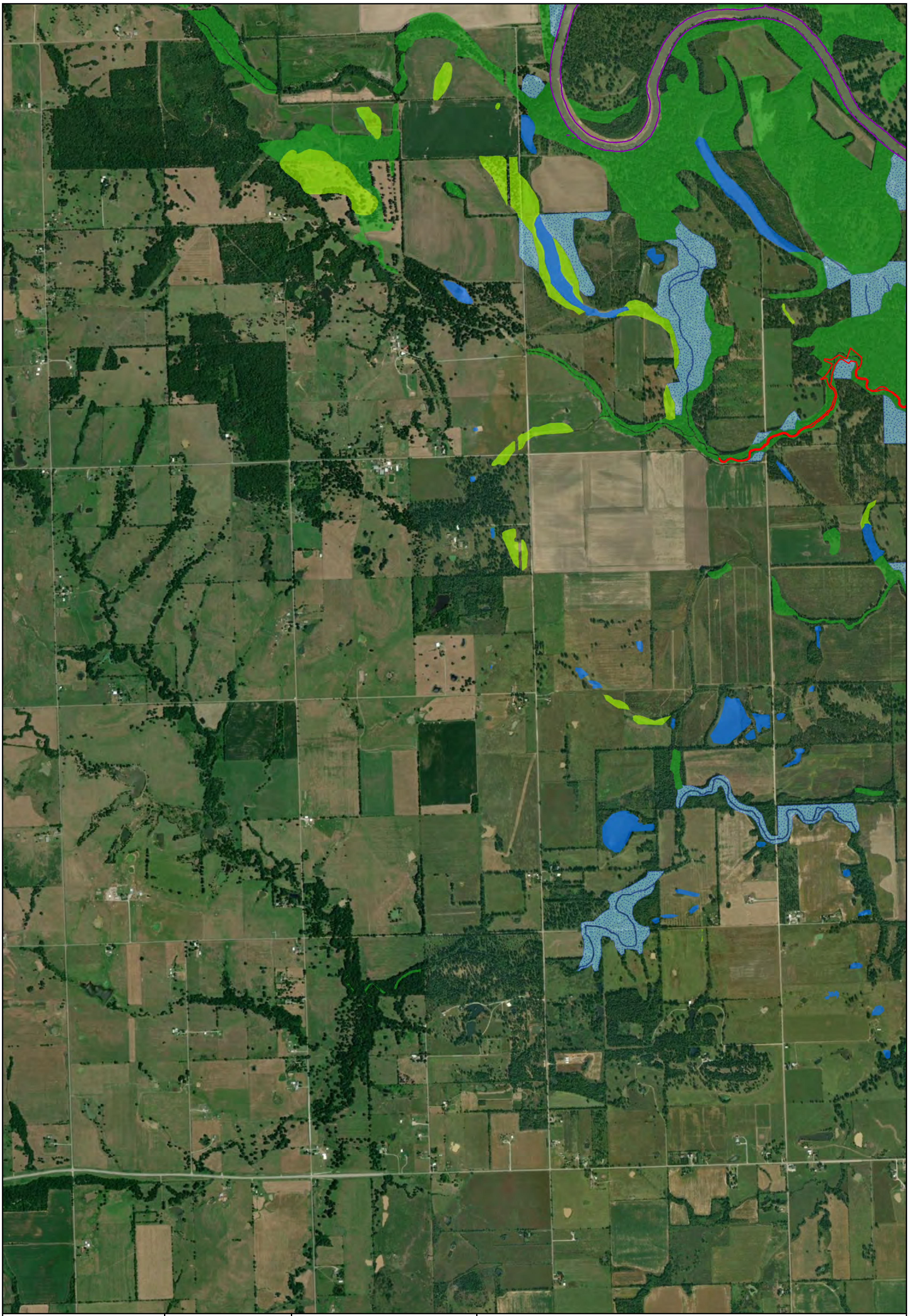

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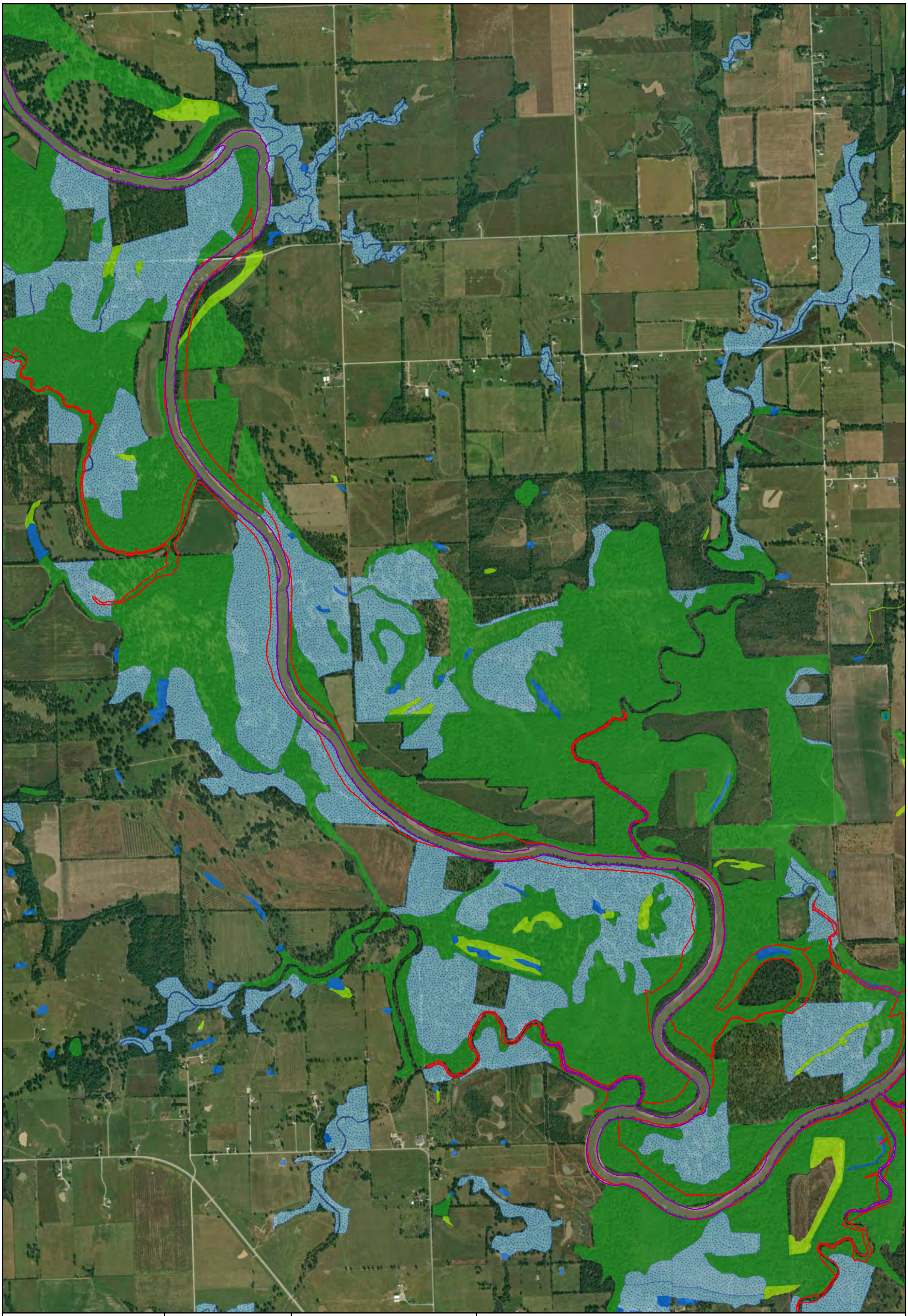
Source:	Esri, 2021

Figure 1

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

▭	Project Boundary
▭	Wetland & Riparian Anticipated Inundation Boundary
▭	Wetland & Riparian Baseline Inundation Boundary
▨	USFWS Riparian Habitat
🟩	Freshwater Emergent Wetland
🟩	Freshwater Forested/Shrub Wetland
🟦	Freshwater Pond



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Source:	Esri, 2021

Figure 2

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

- 🟥 Project Boundary
- 🟪 Wetland & Riparian Anticipated Inundation Boundary
- 🟪 Wetland & Riparian Baseline Inundation Boundary
- 🟦 USFWS Riparian Habitat
- 🟩 Freshwater Emergent Wetland
- 🟩 Freshwater Forested/Shrub Wetland
- 🟦 Freshwater Pond

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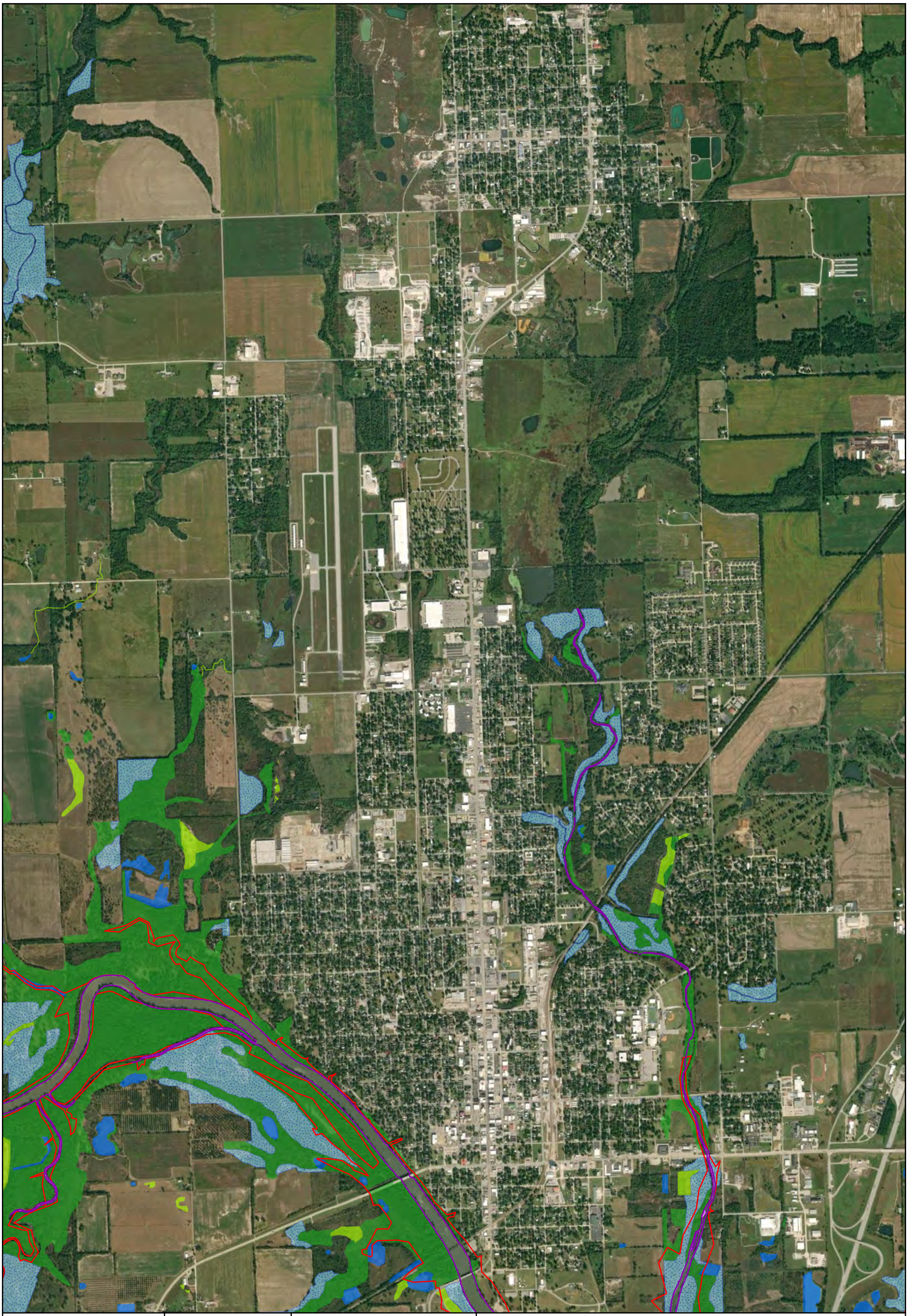

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Feet

Figure 3

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

▭	Project Boundary	▨	USFWS Riparian Habitat
▭	Wetland & Riparian Anticipated Inundation Boundary	🟩	Freshwater Emergent Wetland
▭	Wetland & Riparian Baseline Inundation Boundary	🟩	Freshwater Forested/Shrub Wetland
		🟦	Freshwater Pond

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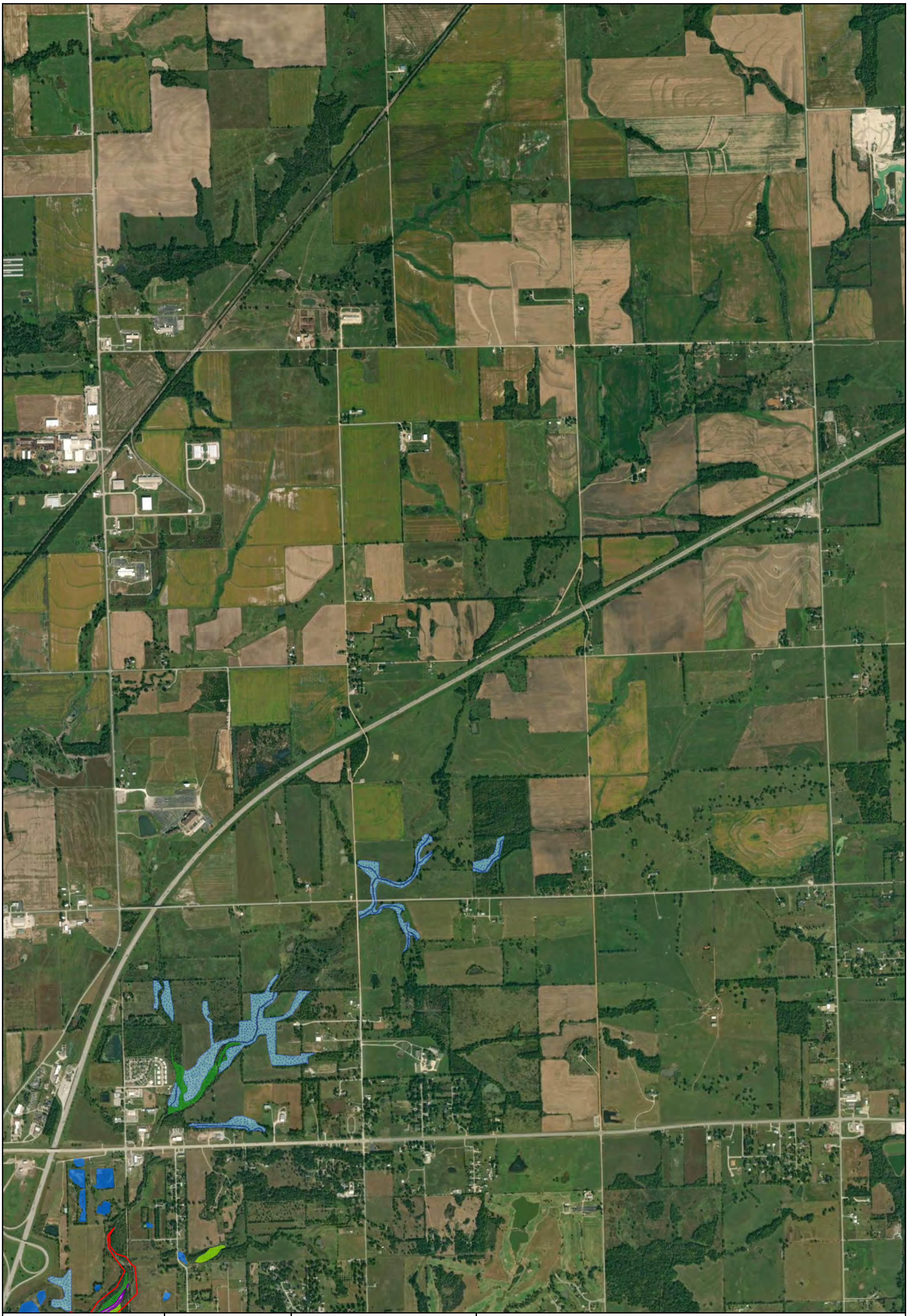

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Feet

Figure 4

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

☐	Project Boundary	▨	USFWS Riparian Habitat
☐	Wetland & Riparian Anticipated Inundation Boundary	🟩	Freshwater Emergent Wetland
☐	Wetland & Riparian Baseline Inundation Boundary	🟩	Freshwater Forested/Shrub Wetland
		🟦	Freshwater Pond

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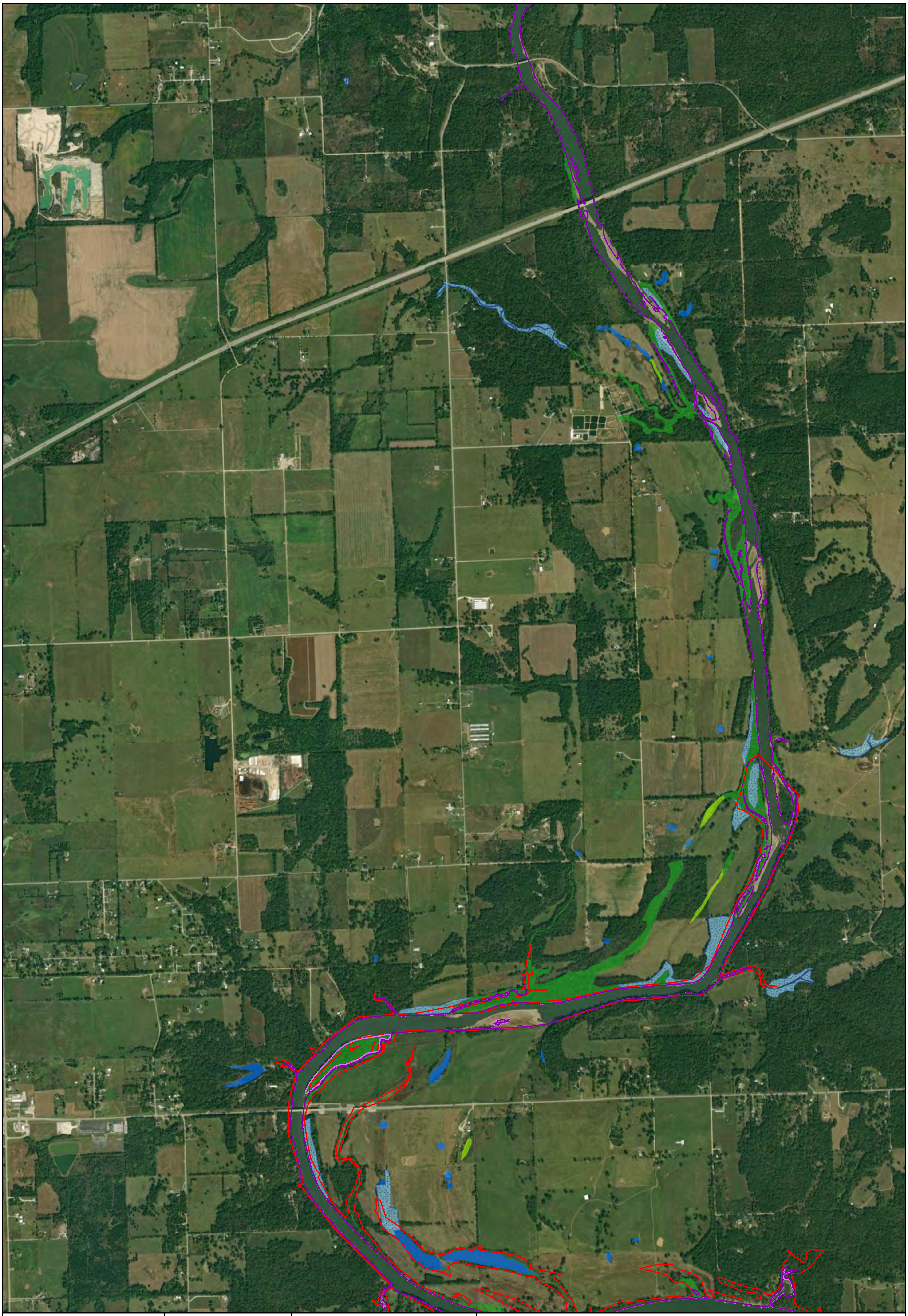

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Figure 5

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

- ▢ Project Boundary
- ▢ Wetland & Riparian Anticipated Inundation Boundary
- ▢ Wetland & Riparian Baseline Inundation Boundary
- ▨ USFWS Riparian Habitat
- 🟩 Freshwater Emergent Wetland
- 🟩 Freshwater Forested/Shrub Wetland
- 🟦 Freshwater Pond

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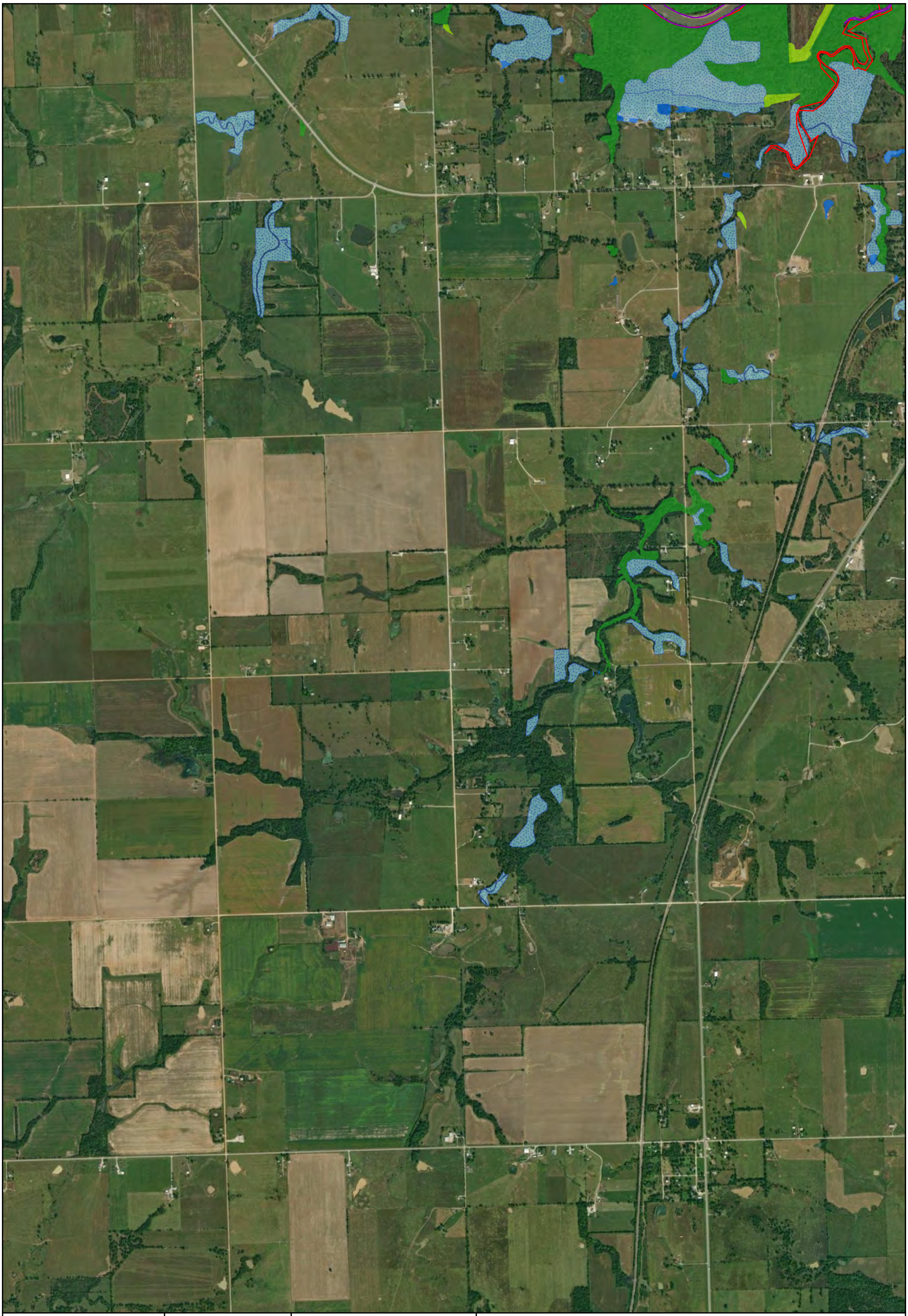

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Environmental Services, Inc.

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Source:	Esri, 2021

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Feet

Figure 6

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

☐	Project Boundary	▨	USFWS Riparian Habitat
☐	Wetland & Riparian Anticipated Inundation Boundary	🟩	Freshwater Emergent Wetland
☐	Wetland & Riparian Baseline Inundation Boundary	🟩	Freshwater Forested/Shrub Wetland
		🟦	Freshwater Pond

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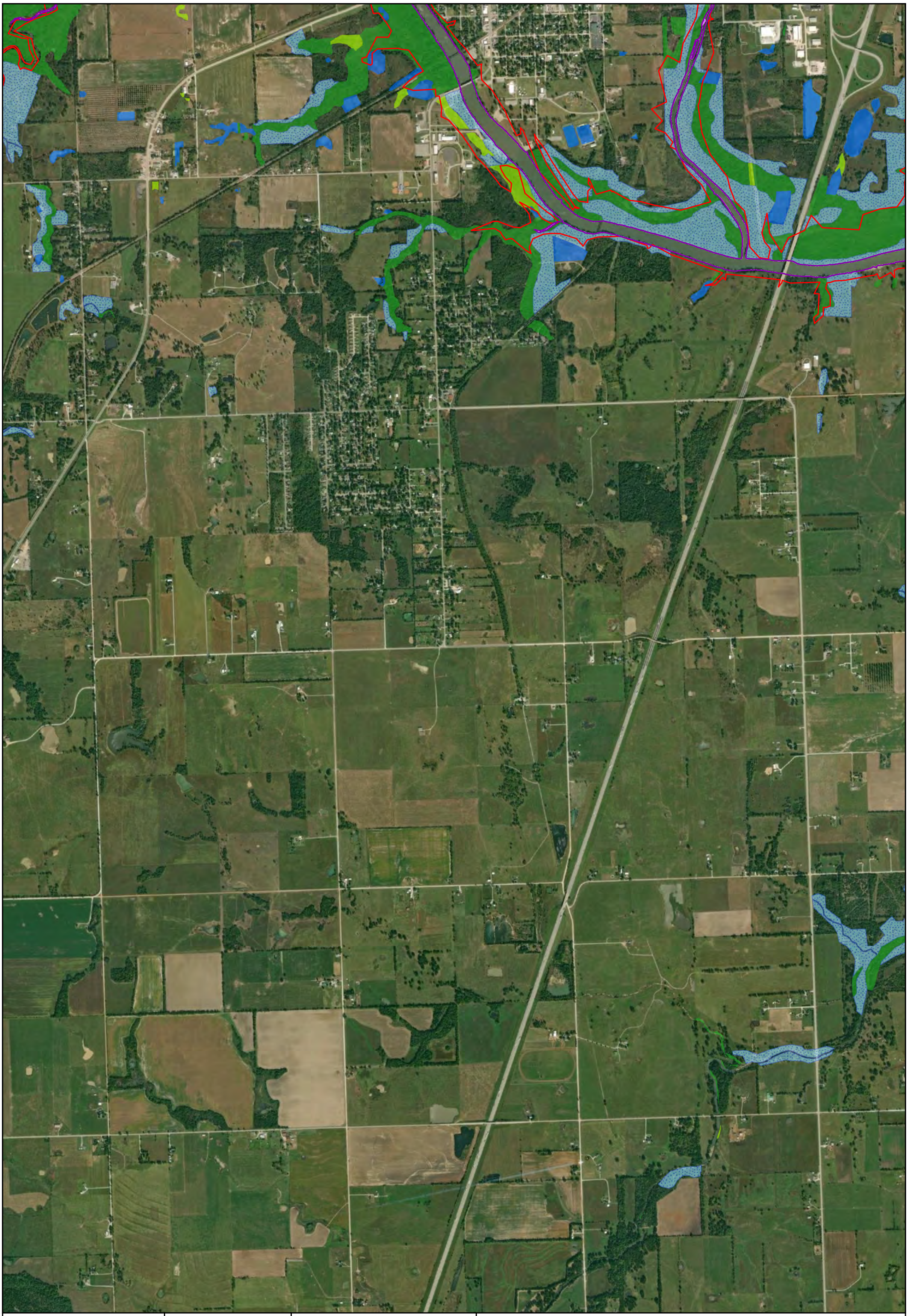

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Environmental Services, Inc.

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Source:	Esri, 2021

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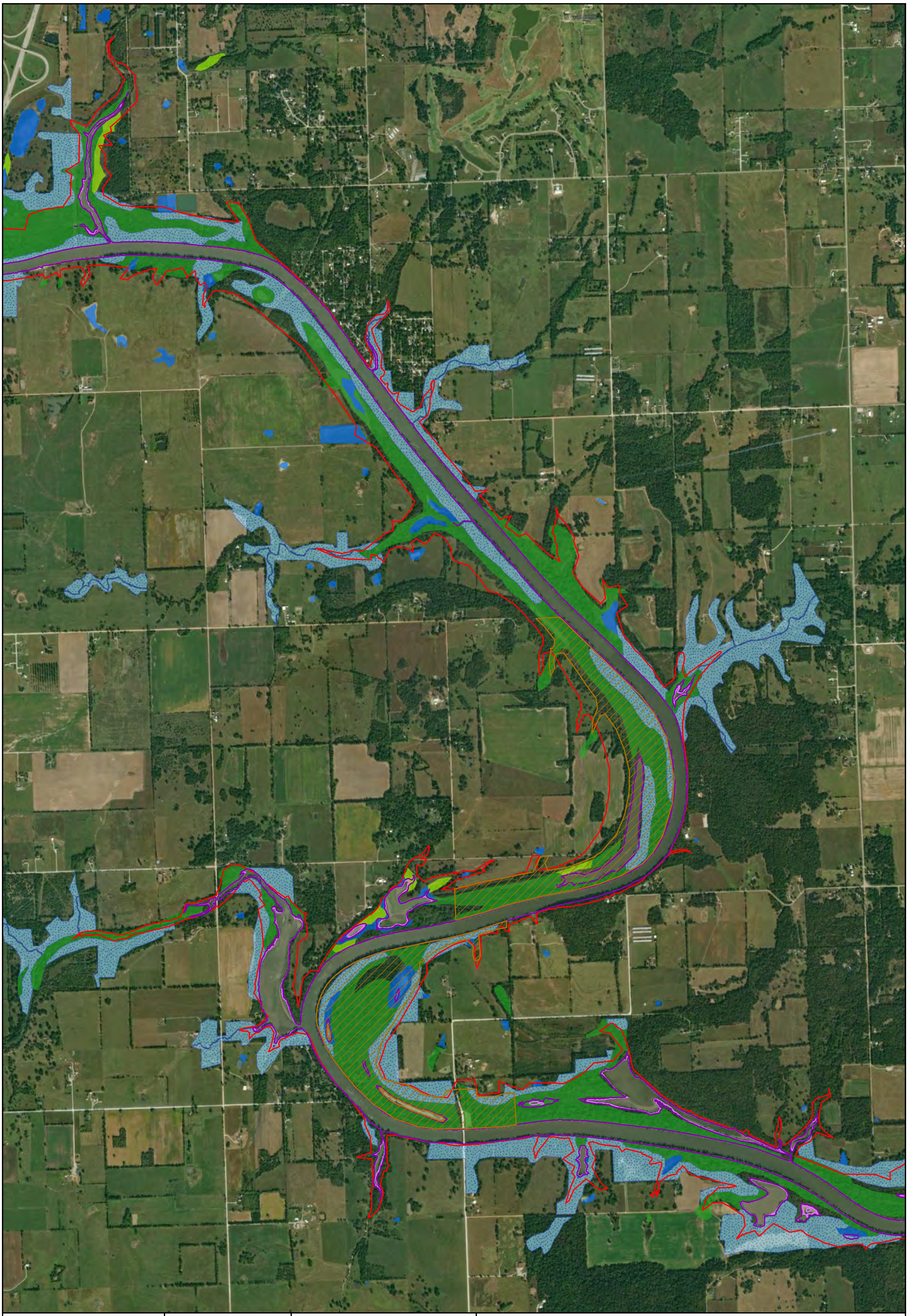
Feet

Figure 7

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

- ▭ Project Boundary
- ▭ Wetland & Riparian Anticipated Inundation Boundary
- ▭ Wetland & Riparian Baseline Inundation Boundary
- ▨ USFWS Riparian Habitat
- ■ Freshwater Emergent Wetland
- ■ Freshwater Forested/Shrub Wetland
- ■ Freshwater Pond



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Environmental Services, Inc.

Date: 09/14/2022
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Source: Esri, 2021

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Figure 8

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

- 🟥 Project Boundary
- 🟪 Wetland & Riparian Anticipated Inundation Boundary
- 🟪 Wetland & Riparian Baseline Inundation Boundary
- ▨ Wildlife Management Area
- 🟦 USFWS Riparian Habitat
- 🟩 Freshwater Emergent Wetland
- 🟩 Freshwater Forested/Shrub Wetland
- 🟦 Freshwater Pond

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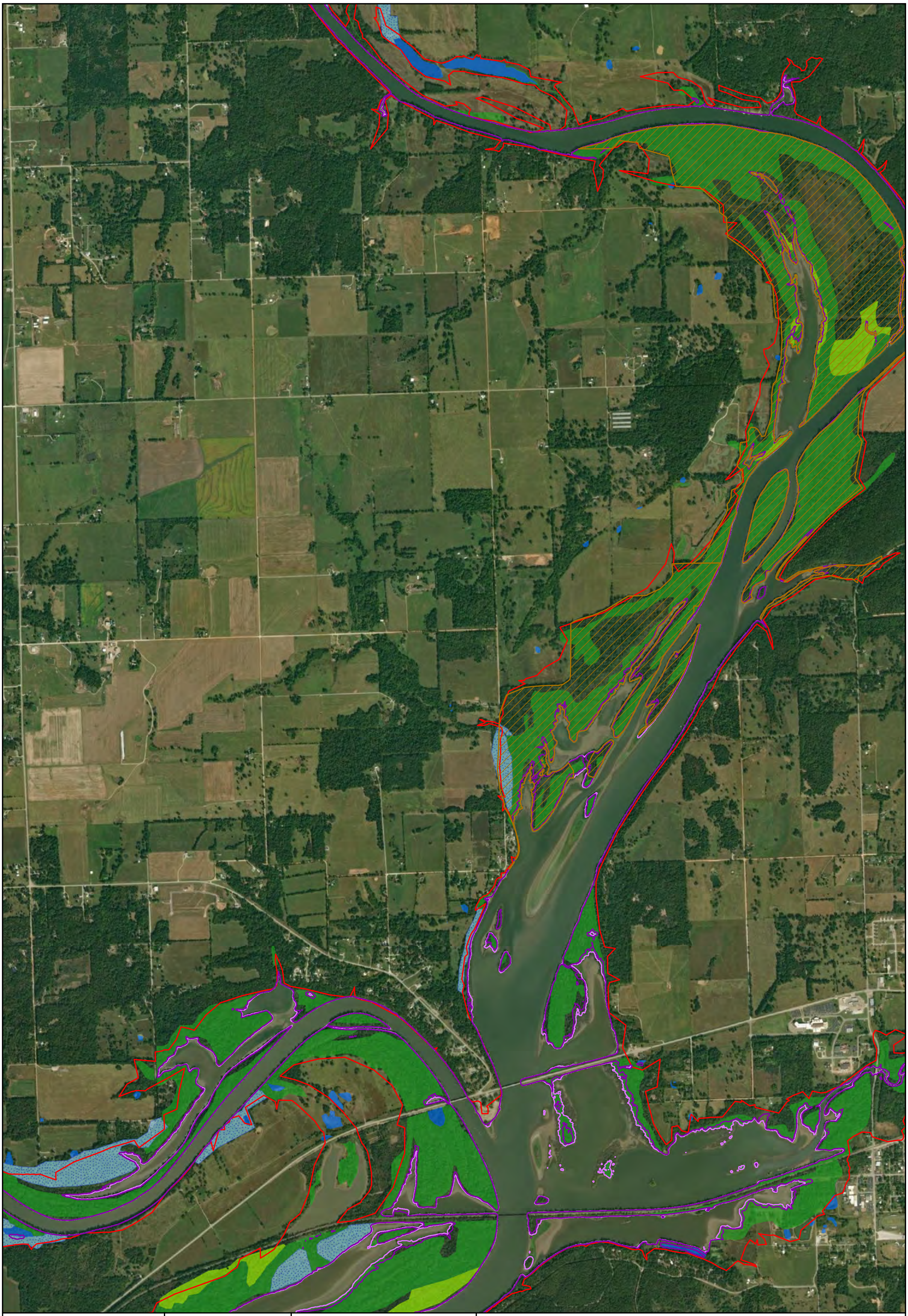

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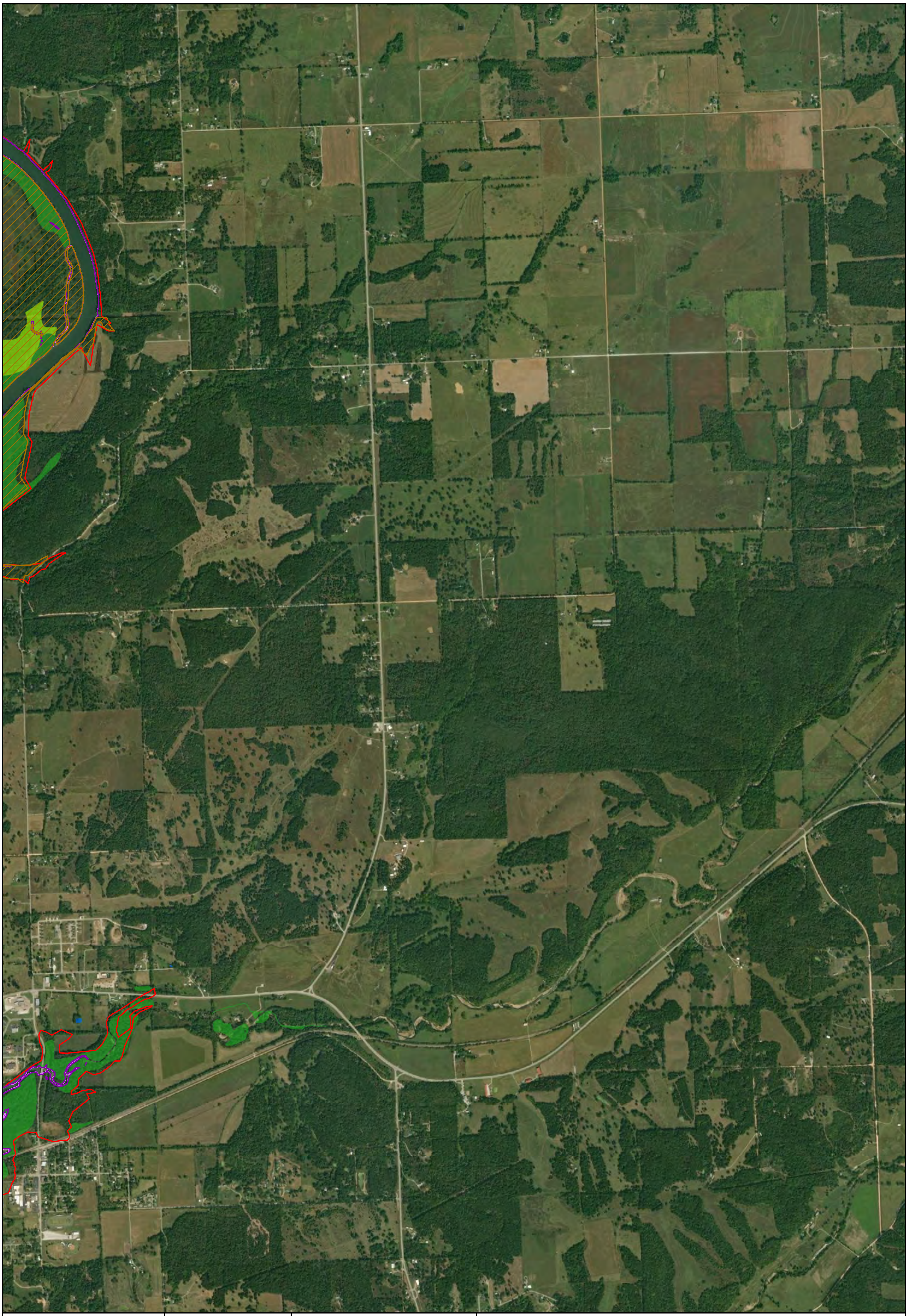
Drawn: KRW
Source: Esri, 2021

Figure 9

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

- □ Project Boundary
- □ Wetland & Riparian Anticipated Inundation Boundary
- □ Wetland & Riparian Baseline Inundation Boundary
- ▨ Wildlife Management Area
- ▨ USFWS Riparian Habitat
- 🟩 Freshwater Emergent Wetland
- 🟩 Freshwater Forested/Shrub Wetland
- 🟦 Freshwater Pond



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Source:	Esri, 2021

Figure 10

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

- ▭ Project Boundary
- ▭ Wetland & Riparian Anticipated Inundation Boundary
- ▭ Wetland & Riparian Baseline Inundation Boundary
- ▨ Wildlife Management Area
- 🟩 Freshwater Emergent Wetland
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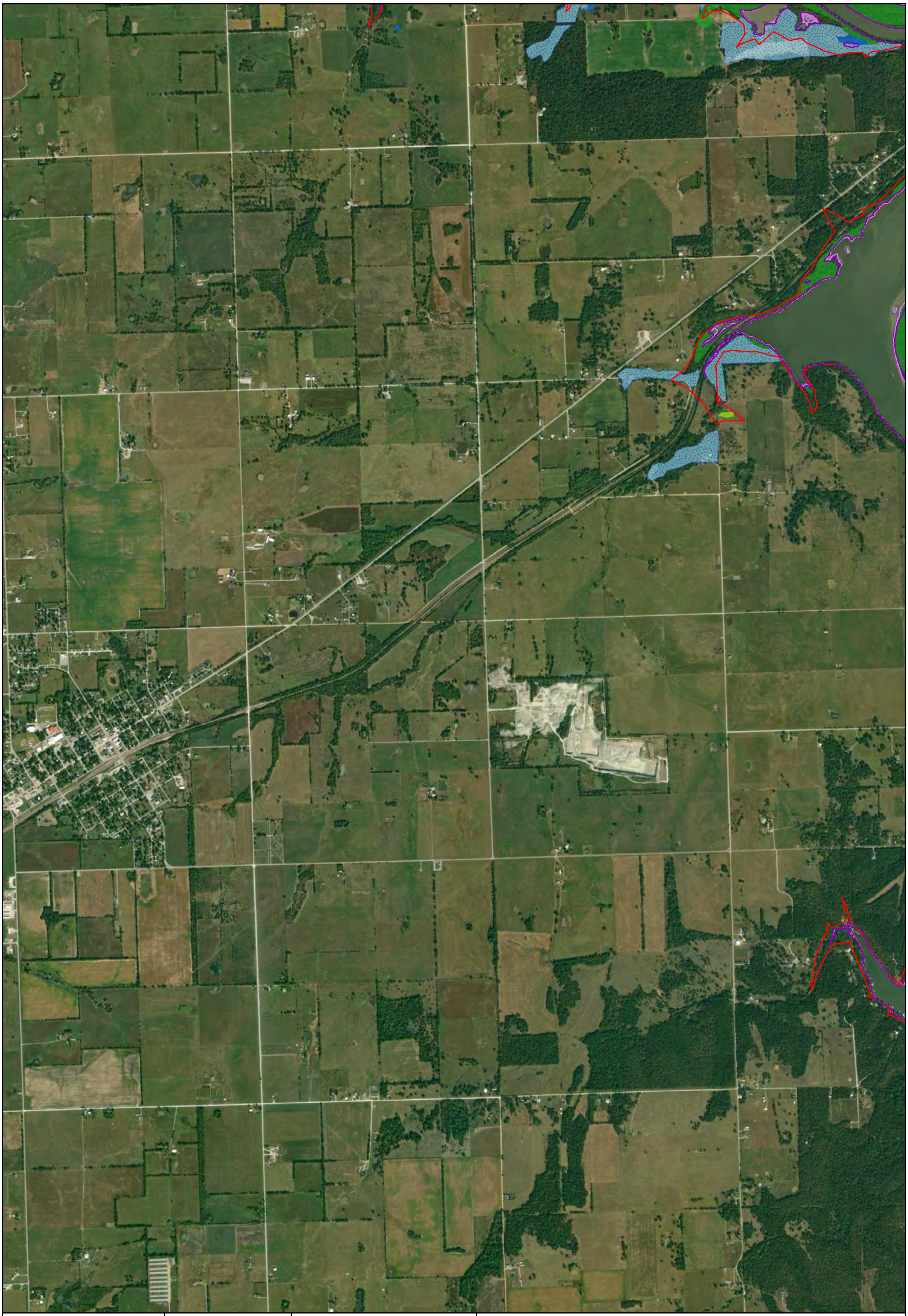

Horizon™
Environmental Services, Inc.

Date:	09/14/2022
Drawn:	KRW
Source:	Esri, 2021

0 1,000 2,000
Feet

Figure 11

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

🟥	Project Boundary
🟪	Wetland & Riparian Anticipated Inundation Boundary
🟪	Wetland & Riparian Baseline Inundation Boundary
▨	USFWS Riparian Habitat
🟩	Freshwater Emergent Wetland
🟩	Freshwater Forested/Shrub Wetland
🟦	Freshwater Pond

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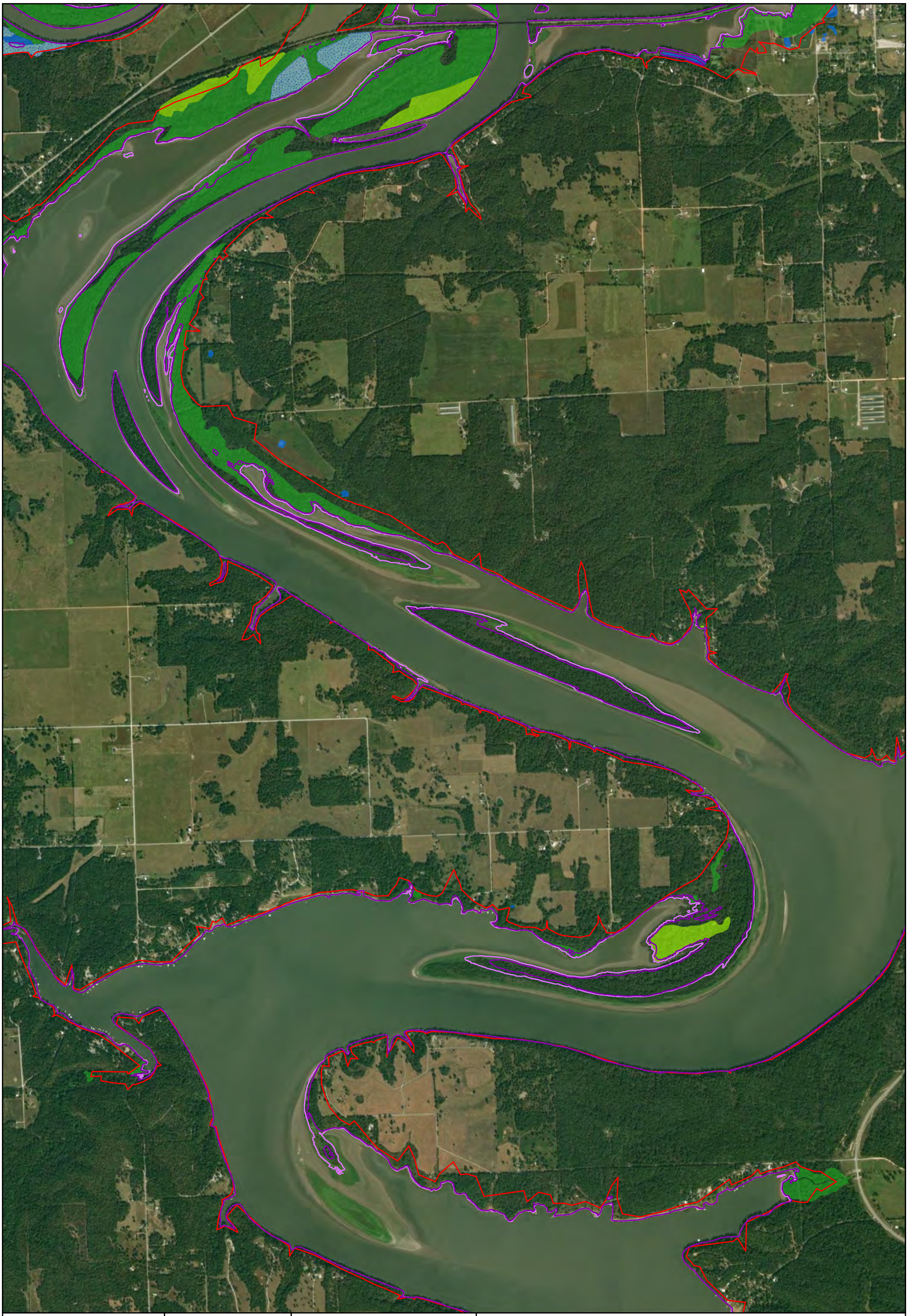

Horizon™
Environmental Services, Inc.

Date:	09/14/2022
Drawn:	KRW
Source:	Esri, 2021

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Feet

Figure 12

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

🟥	Project Boundary
🟪	Wetland & Riparian Anticipated Inundation Boundary
🟪	Wetland & Riparian Baseline Inundation Boundary
▨	USFWS Riparian Habitat
🟩	Freshwater Emergent Wetland
🟩	Freshwater Forested/Shrub Wetland
🟦	Freshwater Pond

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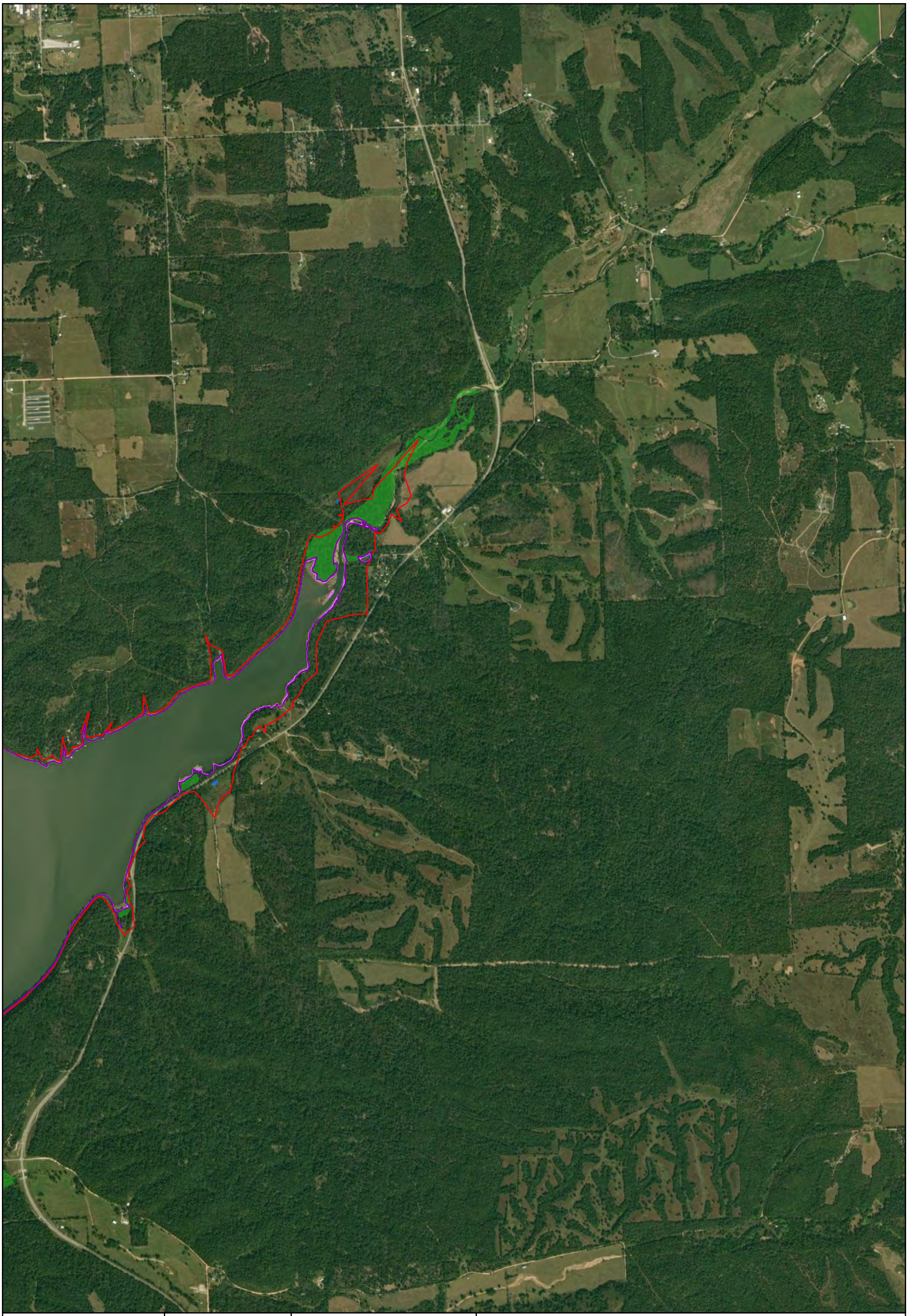

Horizon™
Environmental Services, Inc.

Date:	09/14/2022
Drawn:	KRW
Source:	Esri, 2021

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Feet

Figure 13

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

- 🟥 Project Boundary
- 🟪 Wetland & Riparian Anticipated Inundation Boundary
- 🟪 Wetland & Riparian Baseline Inundation Boundary
- 🟩 Freshwater Emergent Wetland
- 🟩 Freshwater Forested/Shrub Wetland
- 🟦 Freshwater Pond

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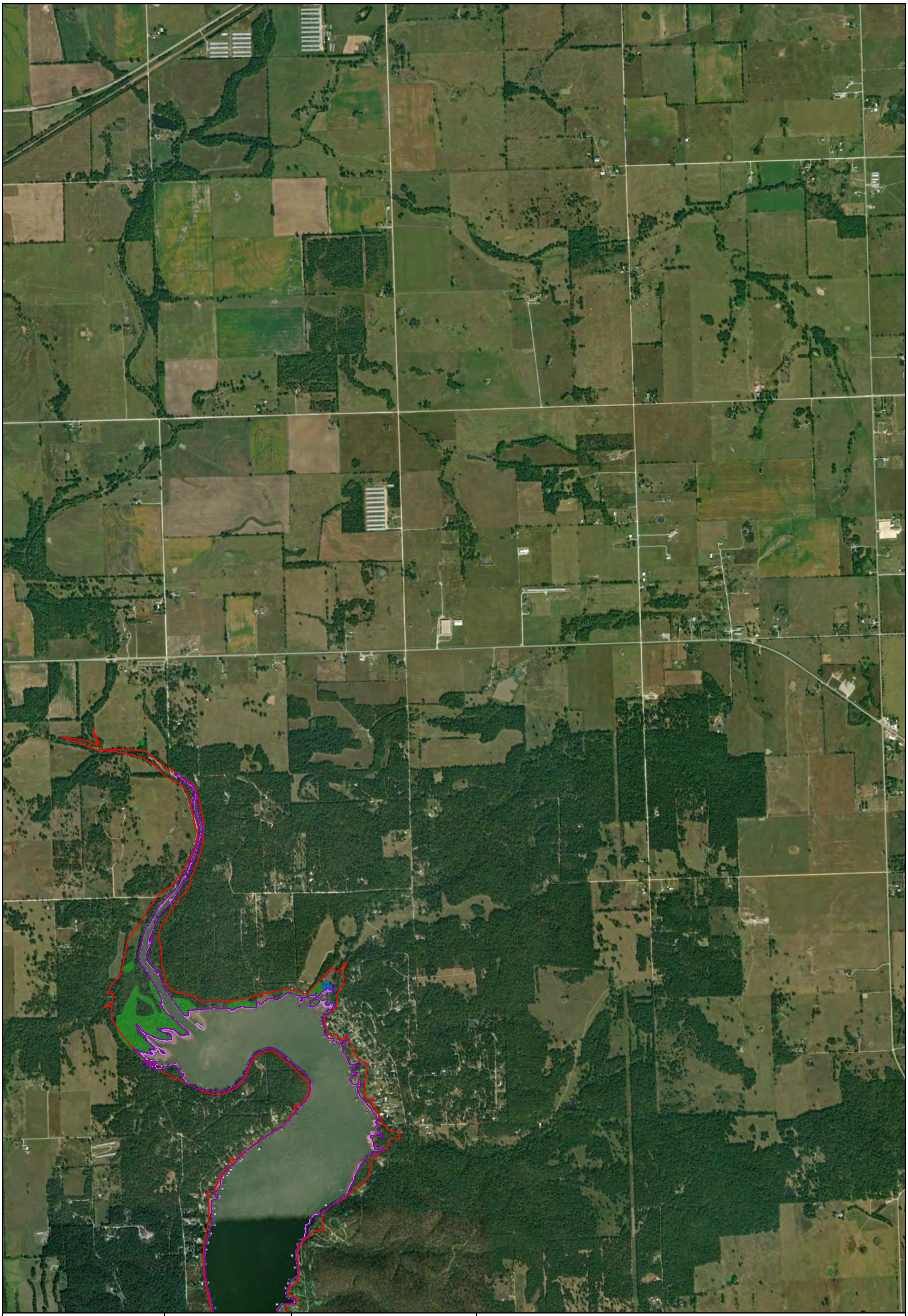

Horizon™
Environmental Services, Inc.

Date: 09/14/2022
Drawn: KRW
Source: Esri, 2021

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Feet

Figure 14

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

□	Project Boundary
□	Wetland & Riparian Anticipated Inundation Boundary
□	Wetland & Riparian Baseline Inundation Boundary
🟩	Freshwater Forested/Shrub Wetland
🟦	Freshwater Pond

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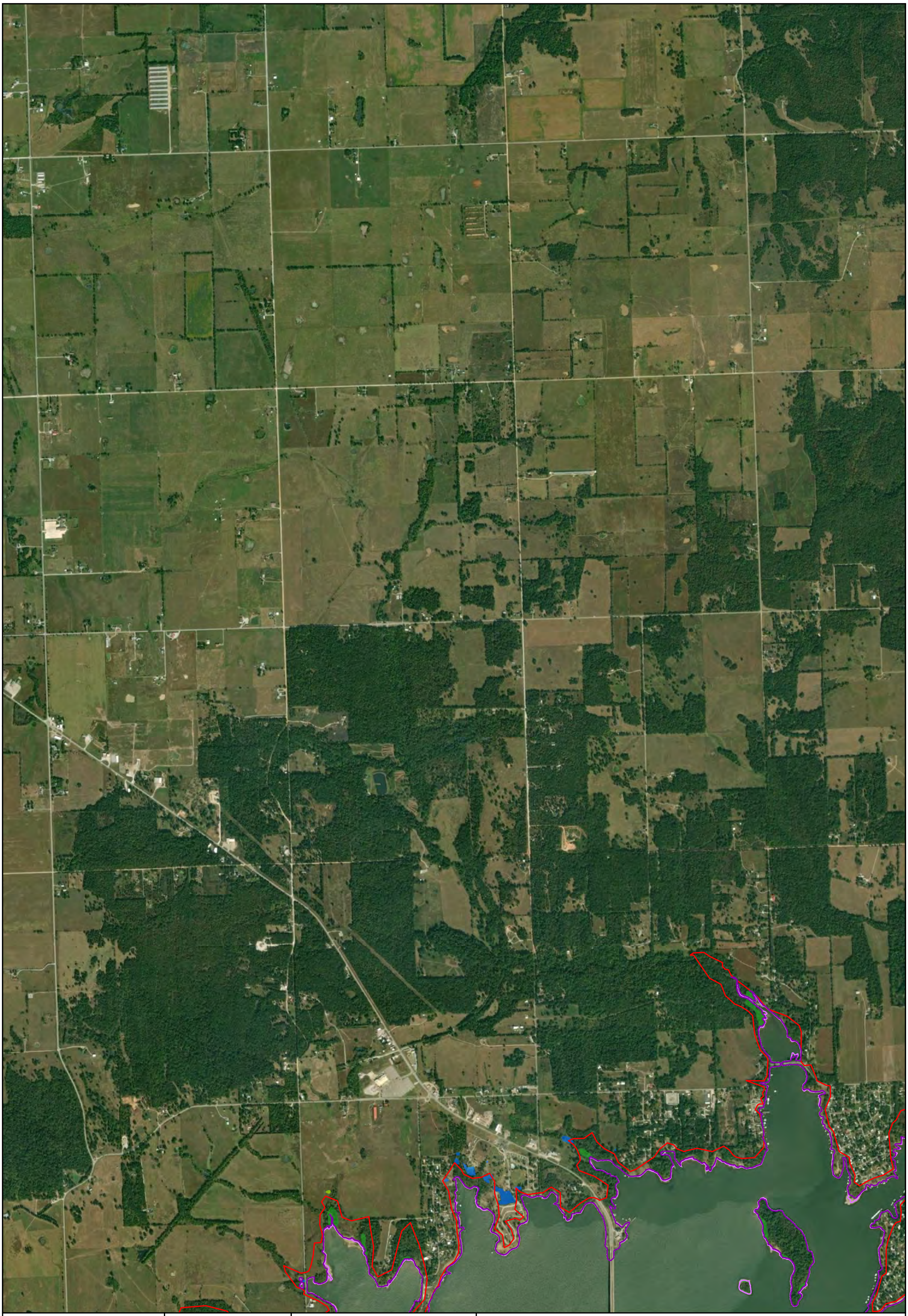

Horizon™ Environmental Services, Inc.

Date:	09/14/2022
Drawn:	KRW
Source:	Esri, 2021

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Feet

Figure 15

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

☐	Project Boundary	🟩	Freshwater Emergent Wetland
☐	Wetland & Riparian Anticipated Inundation Boundary	🟩	Freshwater Forested/Shrub Wetland
☐	Wetland & Riparian Baseline Inundation Boundary	🟦	Freshwater Pond

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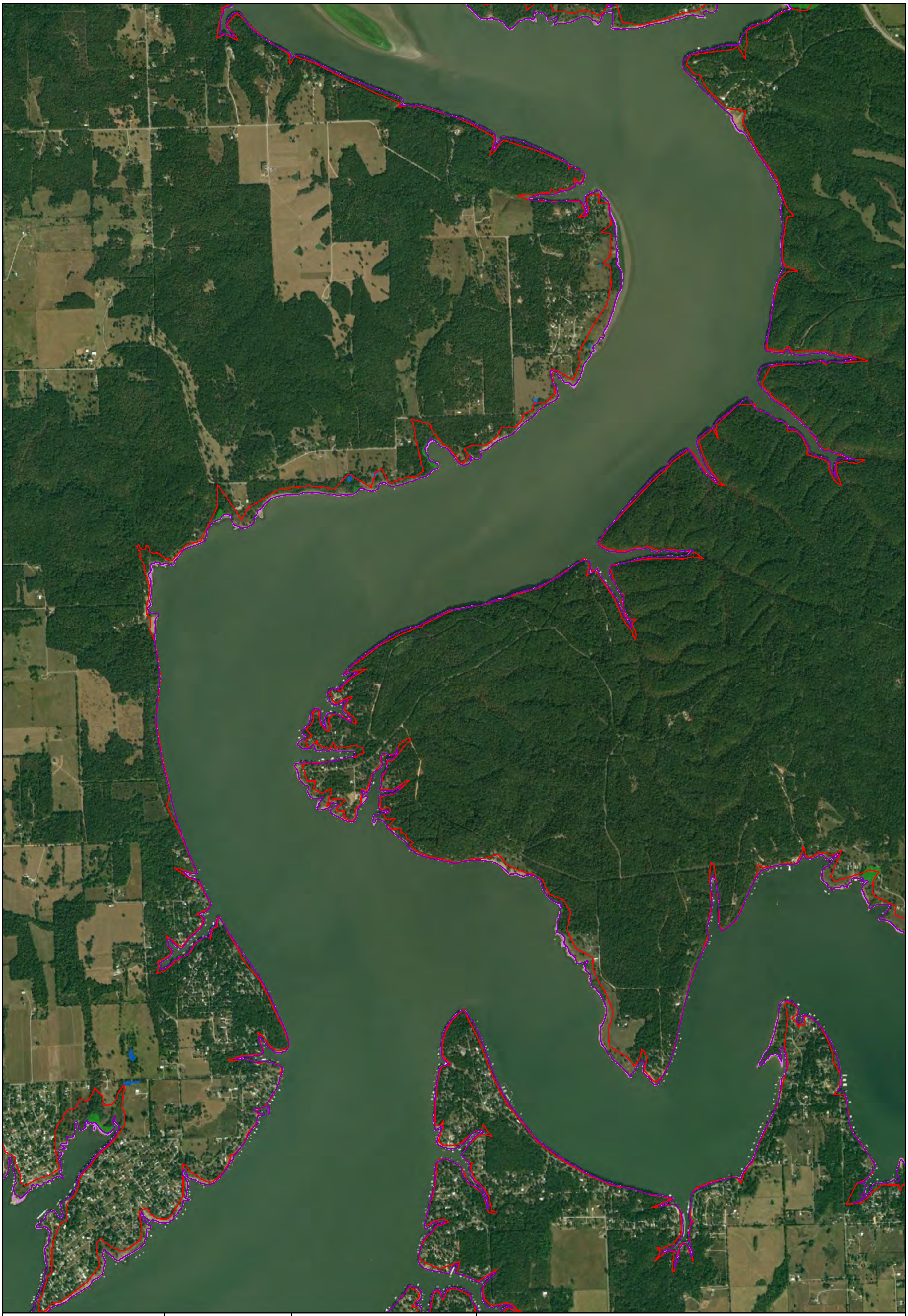

Horizon Environmental Services, Inc.

Date: 09/14/2022
Drawn: KRW
Source: Esri, 2021

Figure 16

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

🟥	Project Boundary
🟪	Wetland & Riparian Anticipated Inundation Boundary
🟪	Wetland & Riparian Baseline Inundation Boundary
🟩	Freshwater Forested/Shrub Wetland
🟦	Freshwater Pond

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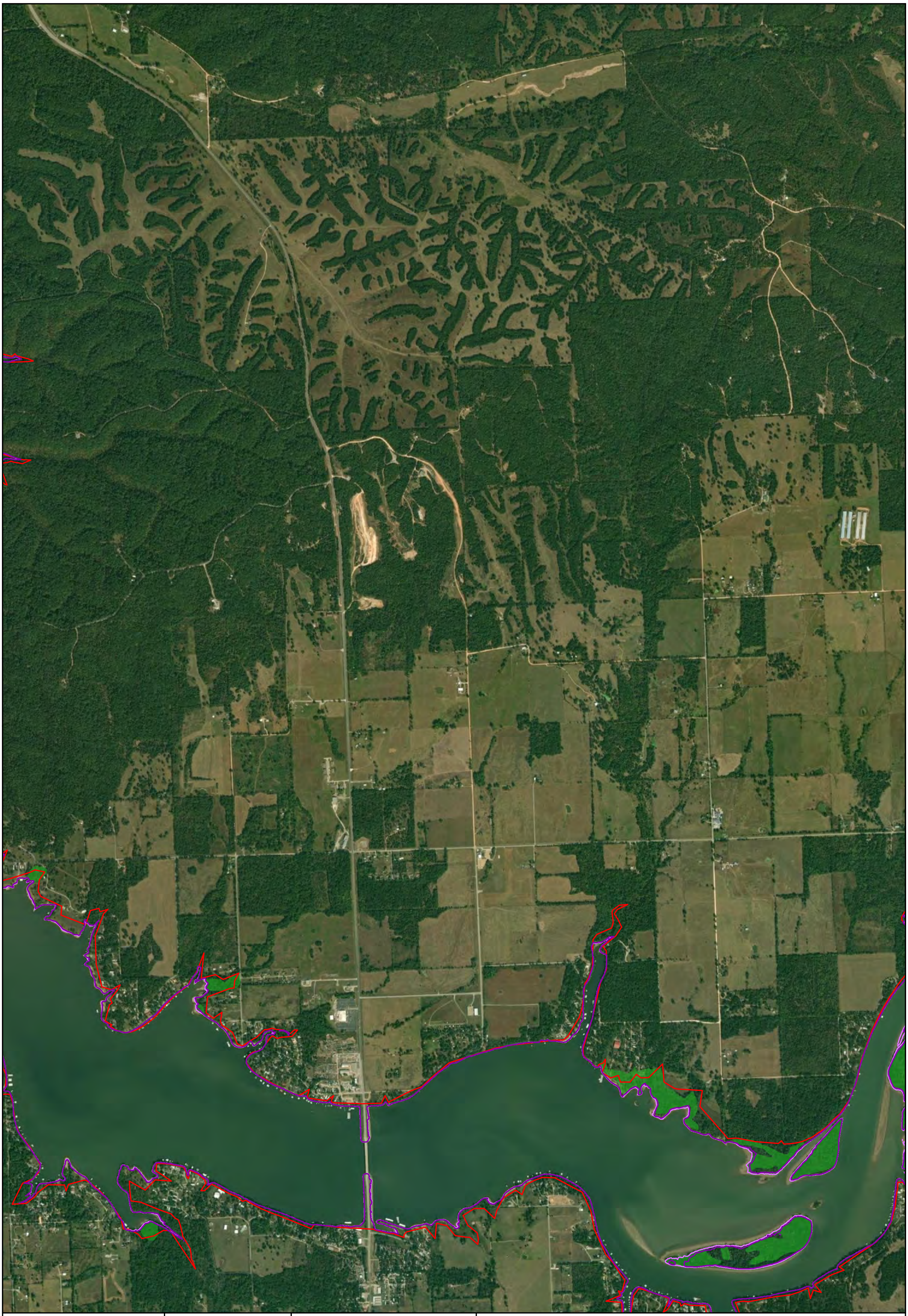


Horizon™
Environmental Services, Inc.

Date:	09/14/2022
Drawn:	KRW
Source:	Esri, 2021

0 1,000 2,000
Feet

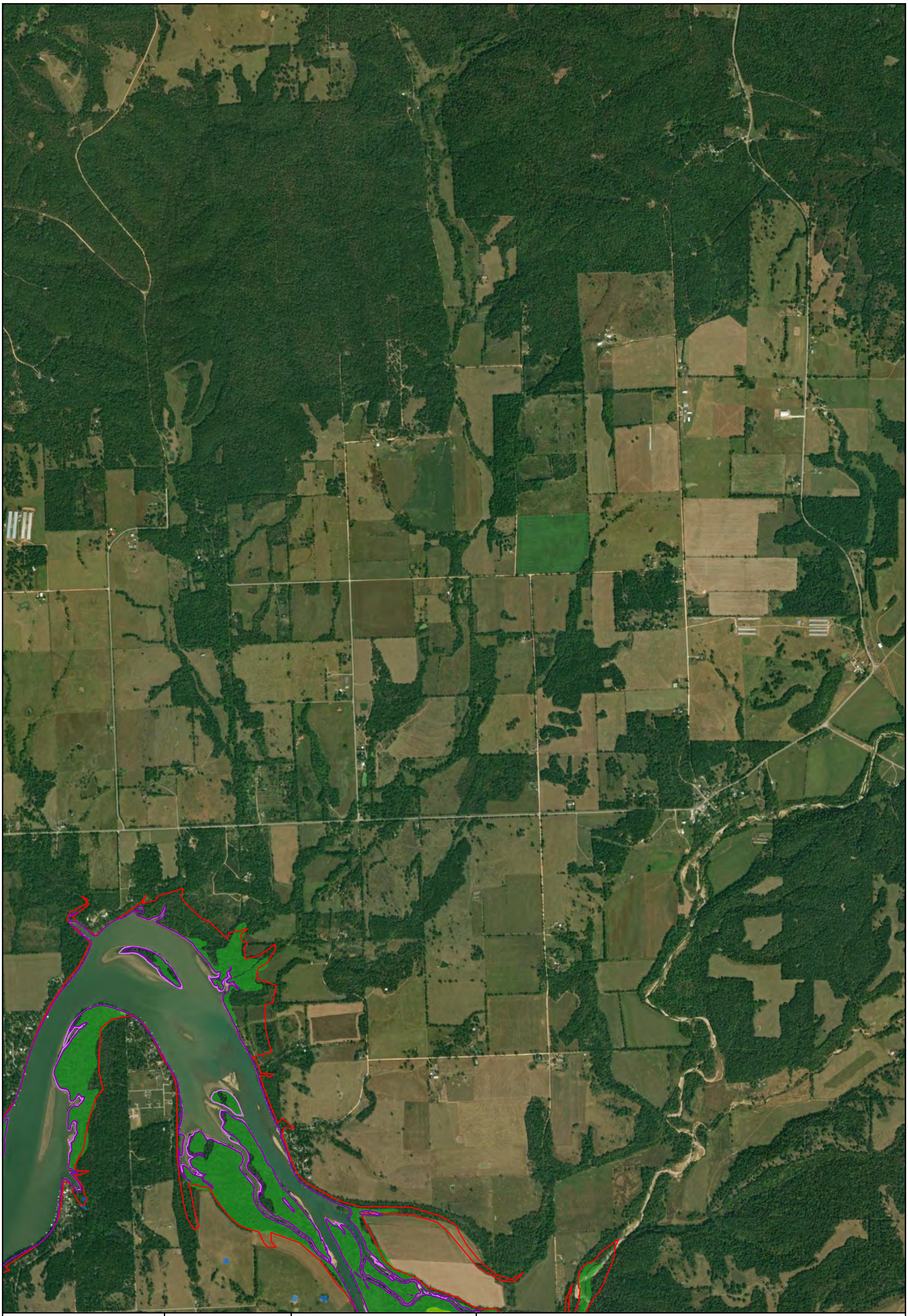
Figure 17

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

□	Project Boundary
□	Wetland & Riparian Anticipated Inundation Boundary
□	Wetland & Riparian Baseline Inundation Boundary
🟩	Freshwater Forested/Shrub Wetland
🟦	Freshwater Pond

21021--GRDA_Pensacola_Project_Relicensing\Graphics\WD_2022\21021-001WD_02A_Wetland_and_Riparian



Horizon™
Environmental Services, Inc.

Date:	09/14/2022
Drawn:	KRW
Source:	Esri, 2021

N

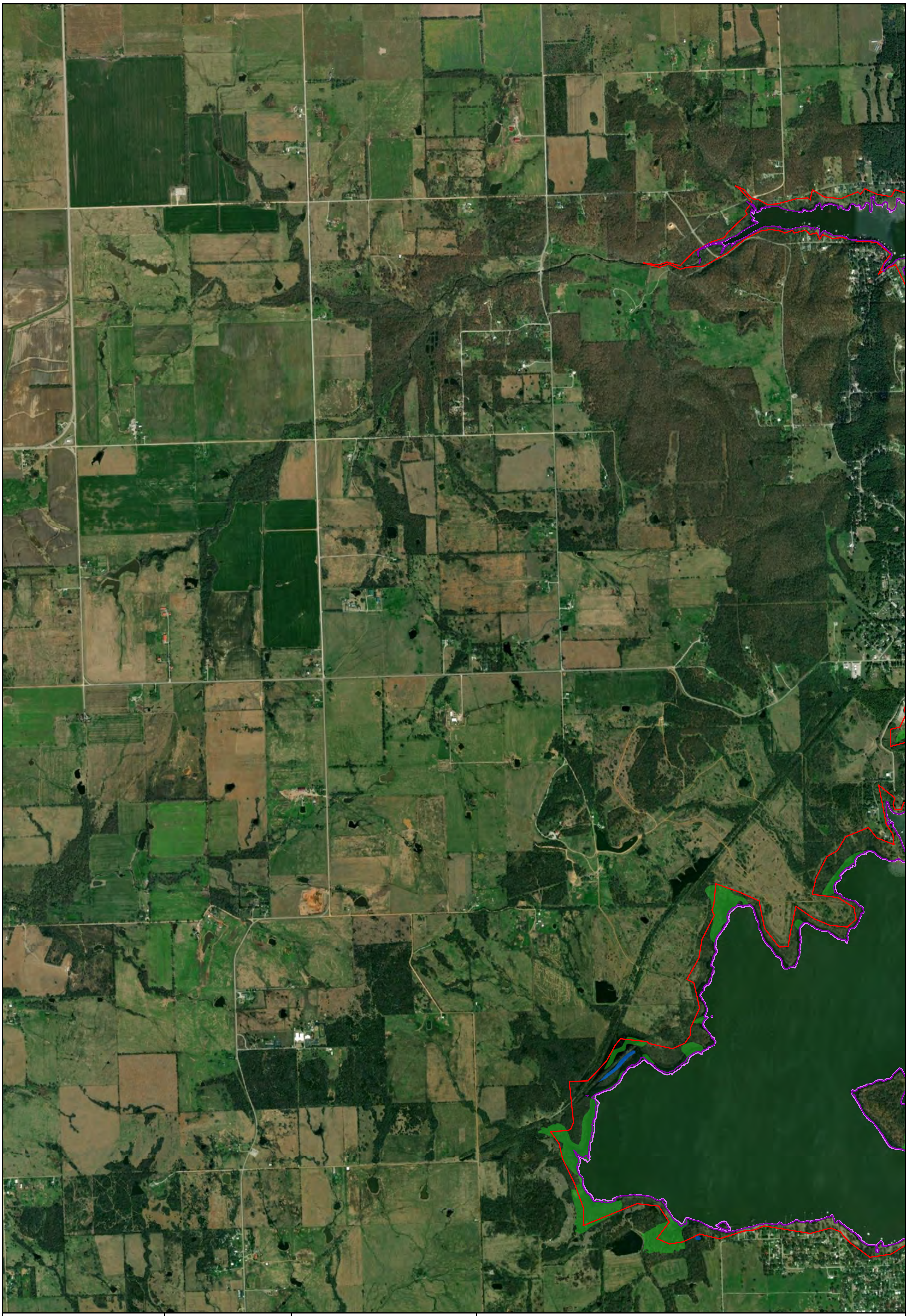
0 1,000 2,000
Feet

Figure 18

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

▭	Project Boundary
▭	Wetland & Riparian Anticipated Inundation Boundary
▭	Wetland & Riparian Baseline Inundation Boundary
🟩	Freshwater Emergent Wetland
🟩	Freshwater Forested/Shrub Wetland
🟦	Freshwater Pond



Horizon™
Environmental Services, Inc.

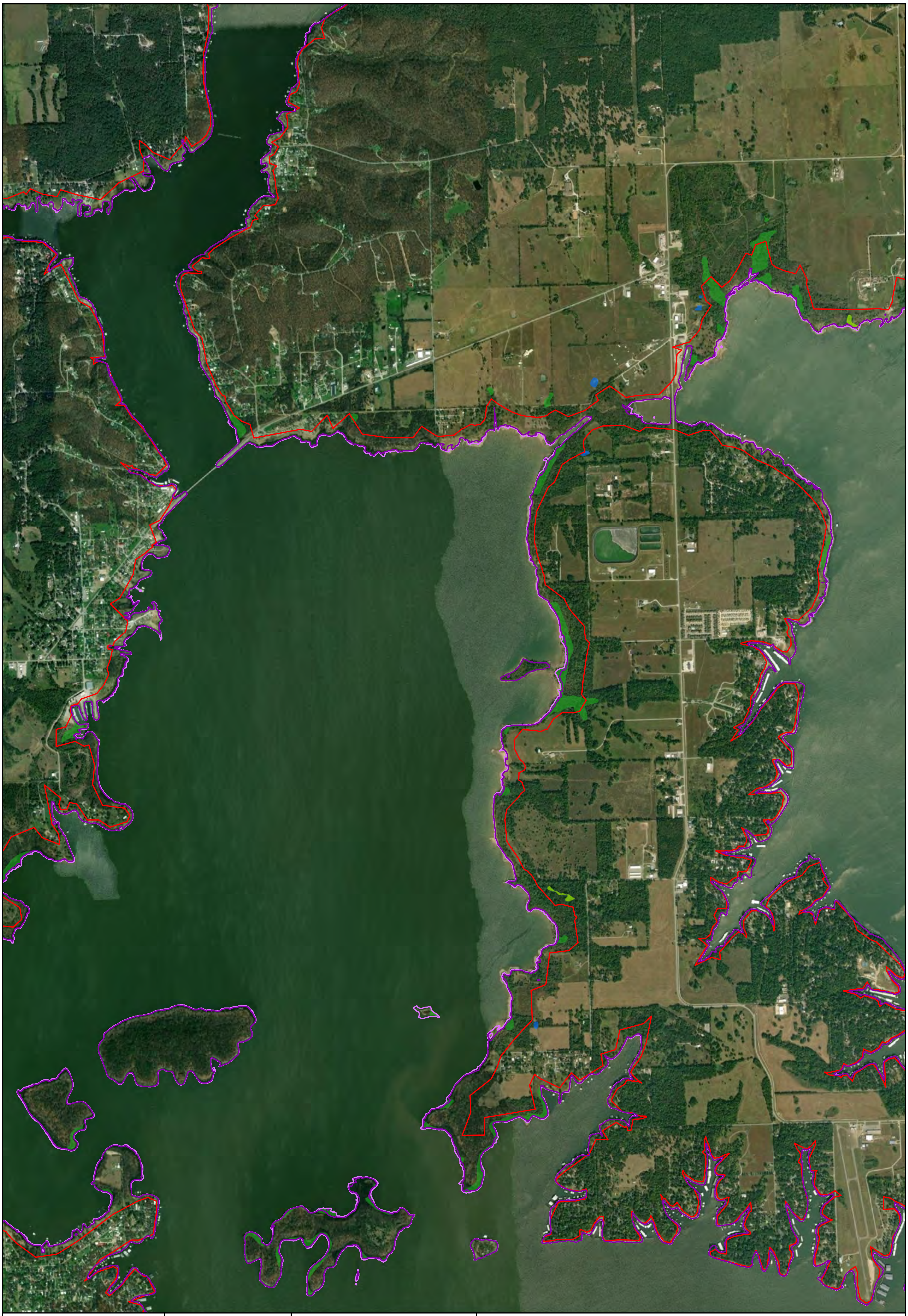
Date:	09/14/2022
Drawn:	KRW
Source:	Esri, 2021

Figure 19

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

- 🟥 Project Boundary
- 🟪 Wetland & Riparian Anticipated Inundation Boundary
- 🟪 Wetland & Riparian Baseline Inundation Boundary
- 🟩 Freshwater Forested/Shrub Wetland
- 🟦 Freshwater Pond



Horizon
Environmental Services, Inc.

Date:	09/14/2022
Drawn:	KRW
Source:	Esri, 2021

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Feet

Figure 20

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

□	Project Boundary	🟩	Freshwater Emergent Wetland
□	Wetland & Riparian Anticipated Inundation Boundary	🟩	Freshwater Forested/Shrub Wetland
□	Wetland & Riparian Baseline Inundation Boundary	🟦	Freshwater Pond

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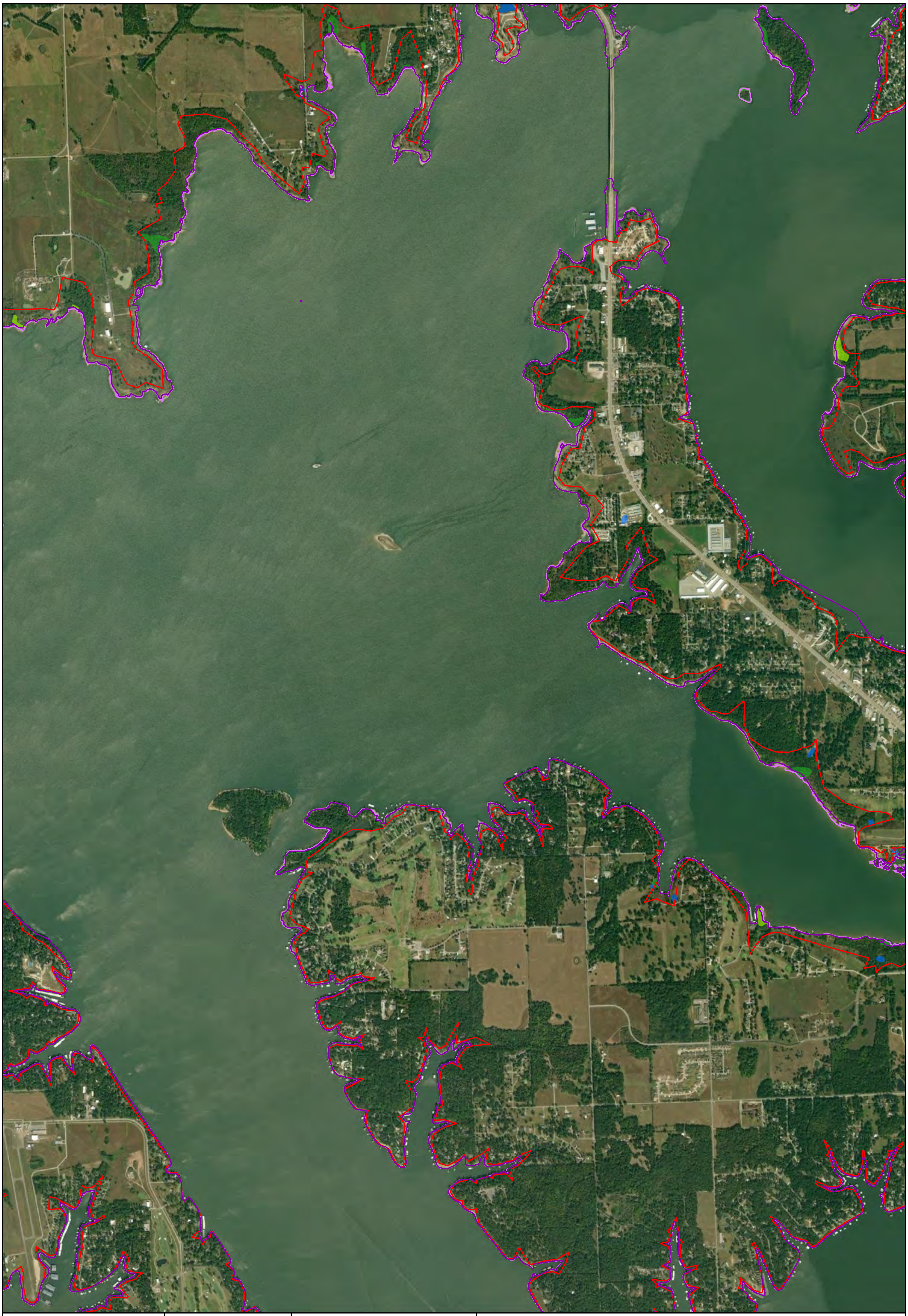


Horizon Environmental Services, Inc.

Date: 09/14/2022
Drawn: KRW
Source: Esri, 2021

0 1,000 2,000
Feet

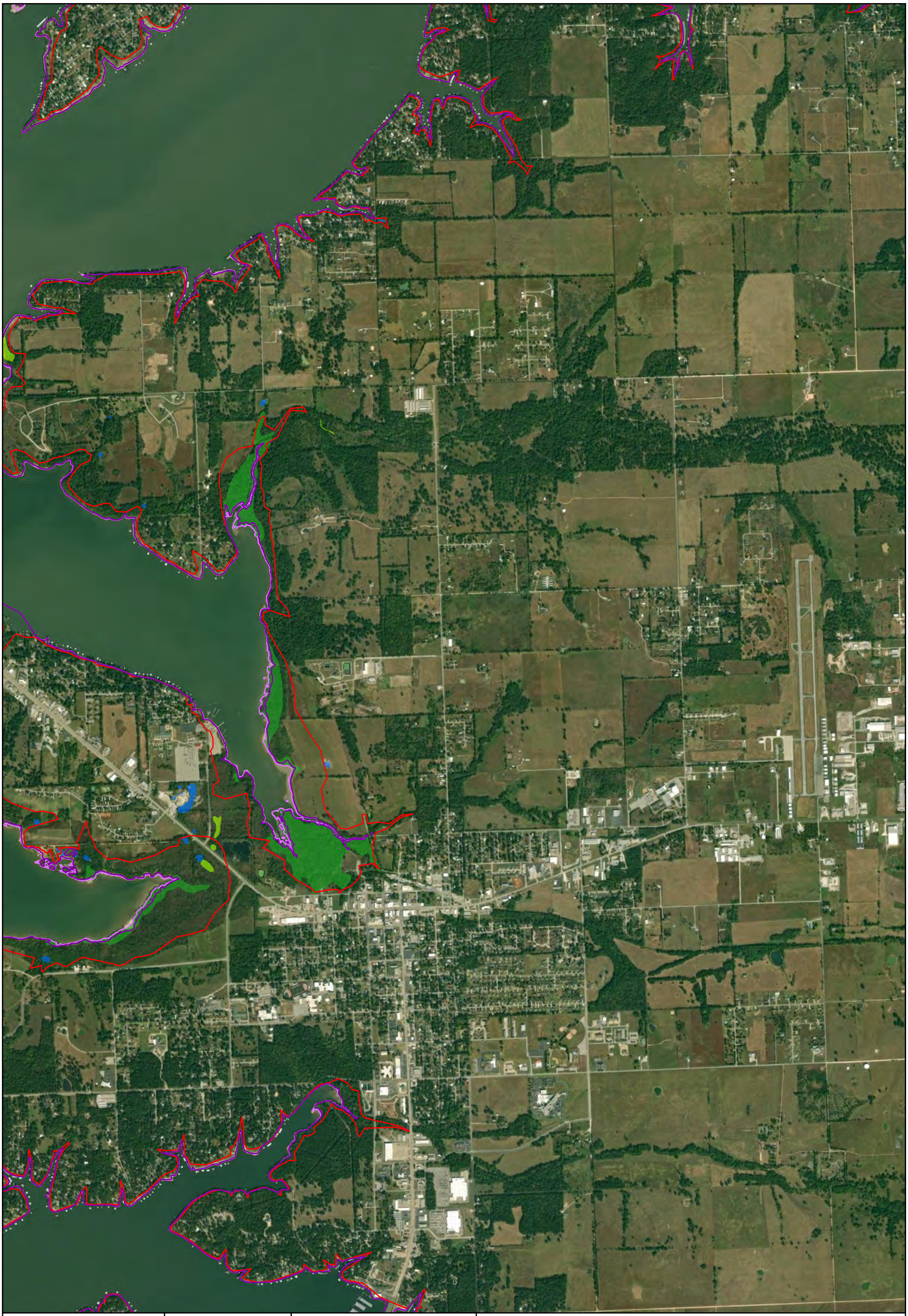
Figure 21

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

□ Project Boundary
□ Wetland & Riparian Anticipated Inundation Boundary
□ Wetland & Riparian Baseline Inundation Boundary
🟩 Freshwater Emergent Wetland
🟩 Freshwater Forested/Shrub Wetland
🟦 Freshwater Pond

21021--GRDA_Pensacola_Project_Relicensing\Graphics\WD_2022\21021-001WD_02A_Wetland_and_Riparian



Horizon™
Environmental Services, Inc.

Date:	09/14/2022
Drawn:	KRW
Source:	Esri, 2021

0 1,000 2,000
Feet

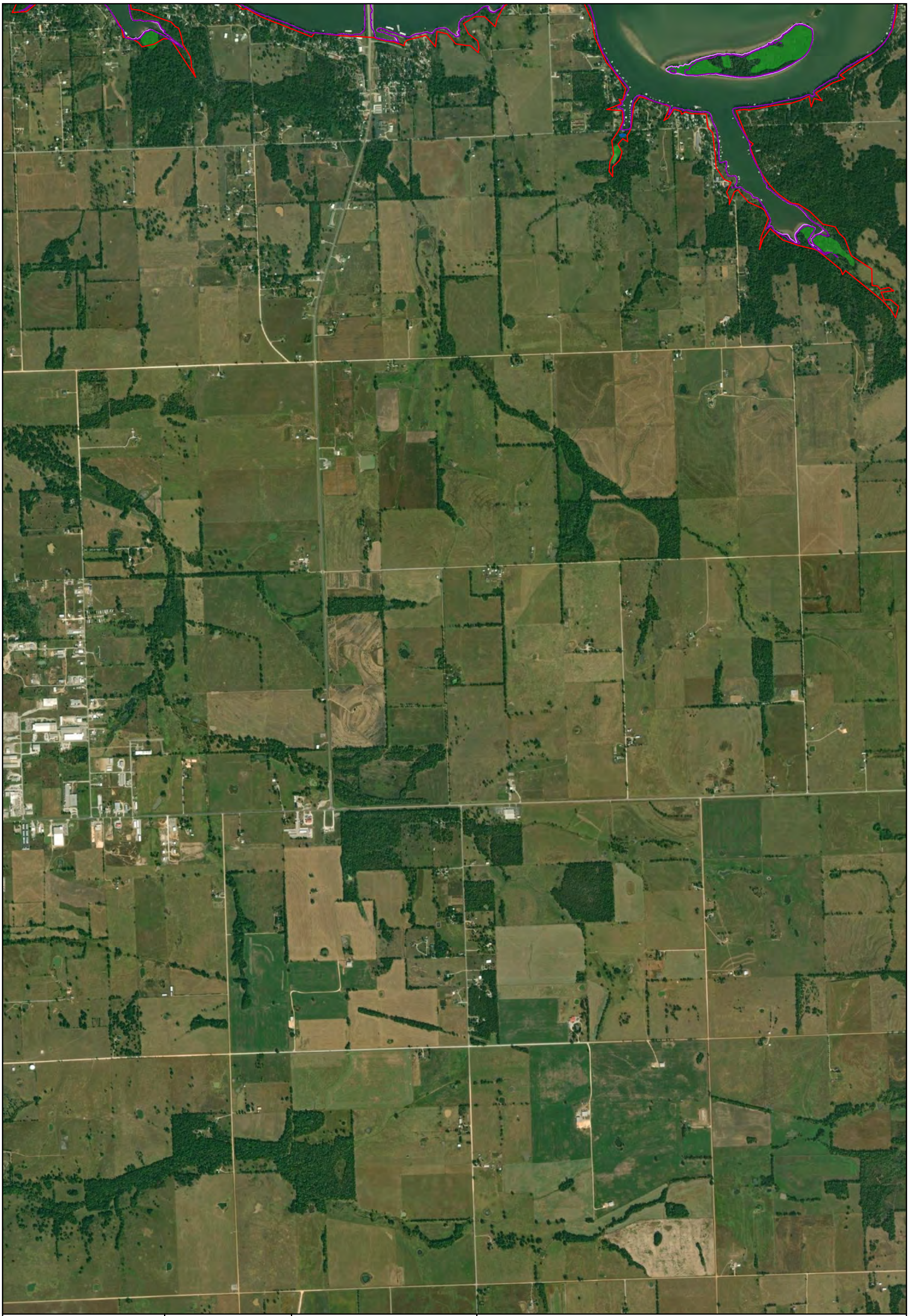
Figure 22

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

🟥	Project Boundary	🟩	Freshwater Emergent Wetland
🟪	Wetland & Riparian Anticipated Inundation Boundary	🟩	Freshwater Forested/Shrub Wetland
🟪	Wetland & Riparian Baseline Inundation Boundary	🟦	Freshwater Pond

21021--GRDA_Pensacola_Project_Relicensing\Graphics\WD_2022\21021-001WD_02A_Wetland_and_Riparian



Horizon™
Environmental Services, Inc.

Date: 09/14/2022
Drawn: KRW
Source: Esri, 2021

N

0 1,000 2,000
Feet

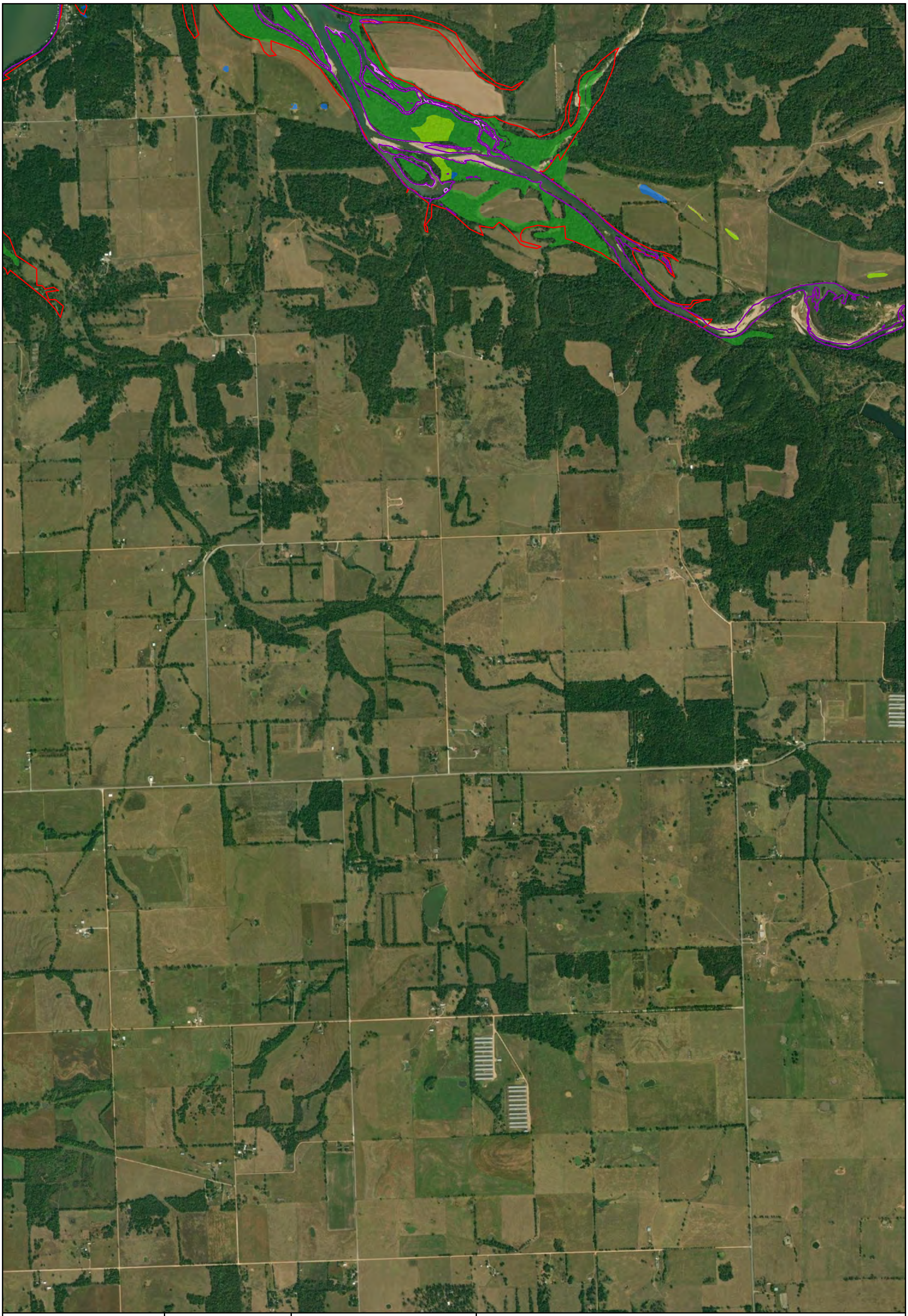
Figure 23

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

- □ Project Boundary
- □ Wetland & Riparian Anticipated Inundation Boundary
- □ Wetland & Riparian Baseline Inundation Boundary
- 🟩 Freshwater Forested/Shrub Wetland
- 🟦 Freshwater Pond

21021--GRDA_Pensacola_Project_Relicensing\Graphics\WD_2022\21021-001WD_02A_Wetland_and_Riparian



Horizon™ Environmental Services, Inc.

Date: 09/14/2022
Drawn: KRW
Source: Esri, 2021

0 1,000 2,000
Feet

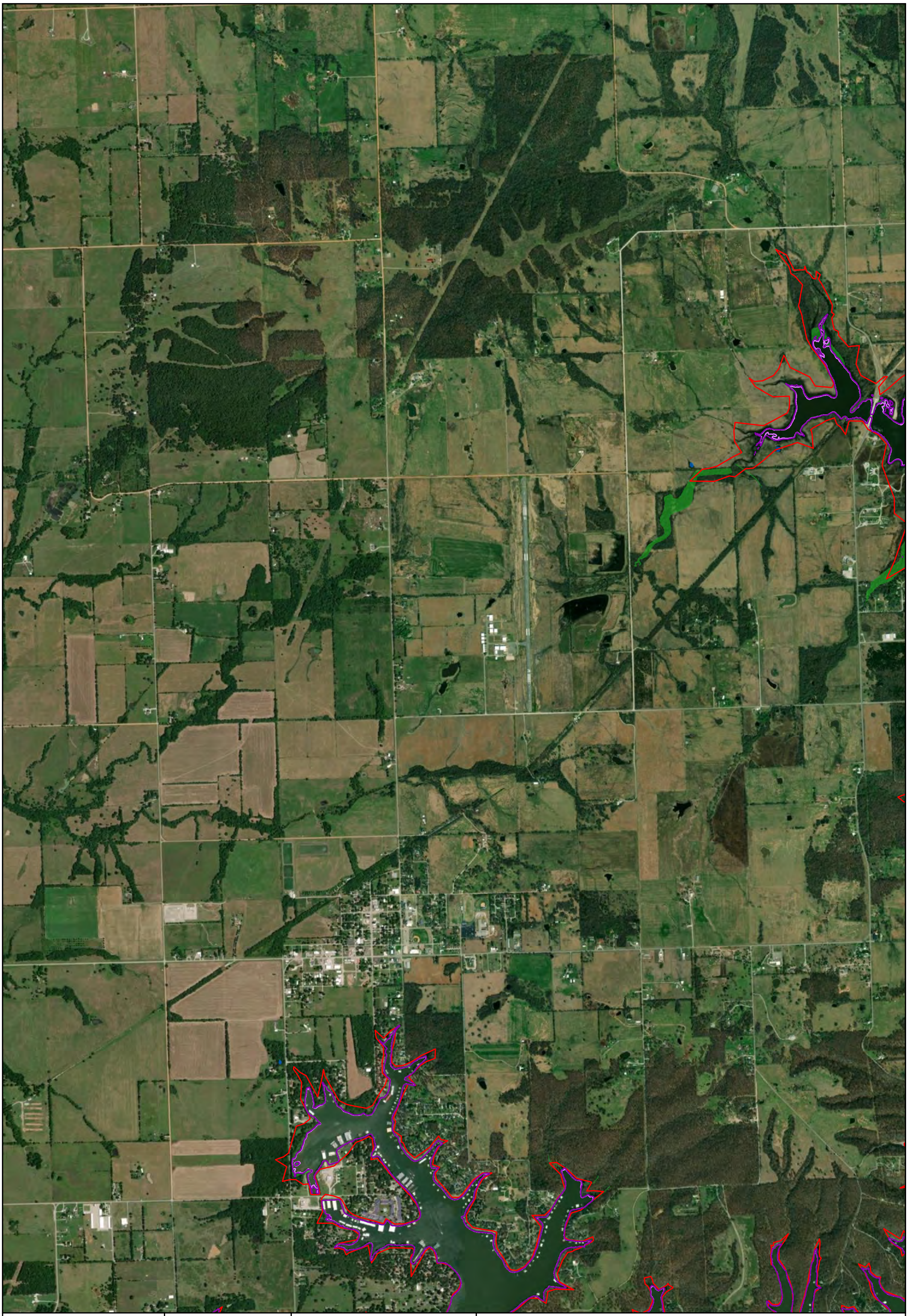
Figure 24

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

🟥	Project Boundary	🟩	Freshwater Emergent Wetland
🟪	Wetland & Riparian Anticipated Inundation Boundary	🟩	Freshwater Forested/Shrub Wetland
🟪	Wetland & Riparian Baseline Inundation Boundary	🟦	Freshwater Pond

21021--GRDA_Pensacola_Project_Relicensing\Graphics\WD_2022\21021-001WD_02A_Wetland_and_Riparian



Horizon™
Environmental Services, Inc.

Date: 09/14/2022
Drawn: KRW
Source: Esri, 2021

0 1,000 2,000
Feet

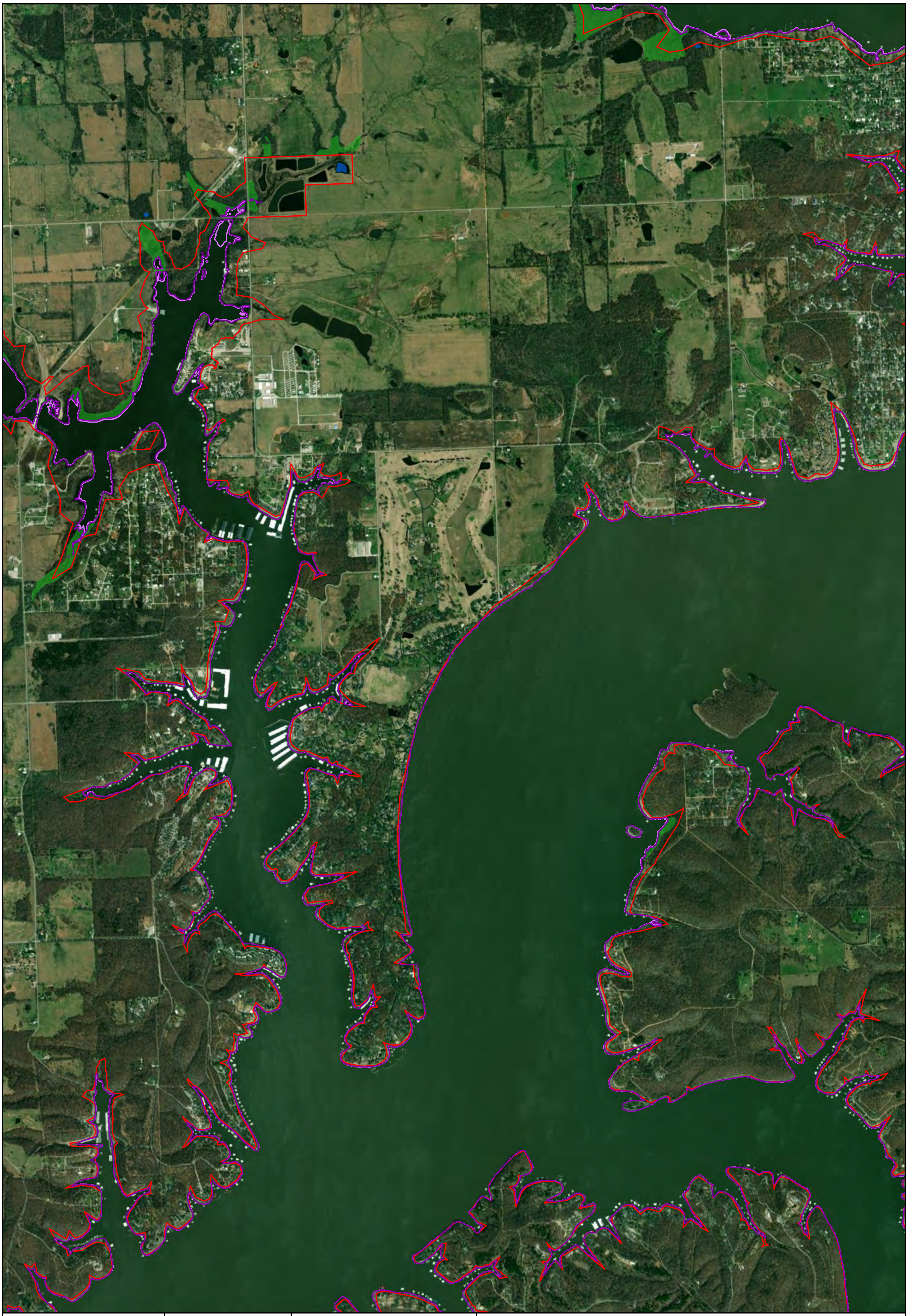
Figure 25

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

☐	Project Boundary
☐	Wetland & Riparian Anticipated Inundation Boundary
☐	Wetland & Riparian Baseline Inundation Boundary
🟩	Freshwater Forested/Shrub Wetland
🟦	Freshwater Pond

21021--GRDA_Pensacola_Project_Relicensing\Graphics\WD_2022\21021-001WD_02A_Wetland_and_Riparian



Horizon Environmental Services, Inc.

Date:	09/14/2022
Drawn:	KRW
Source:	Esri, 2021

0 1,000 2,000

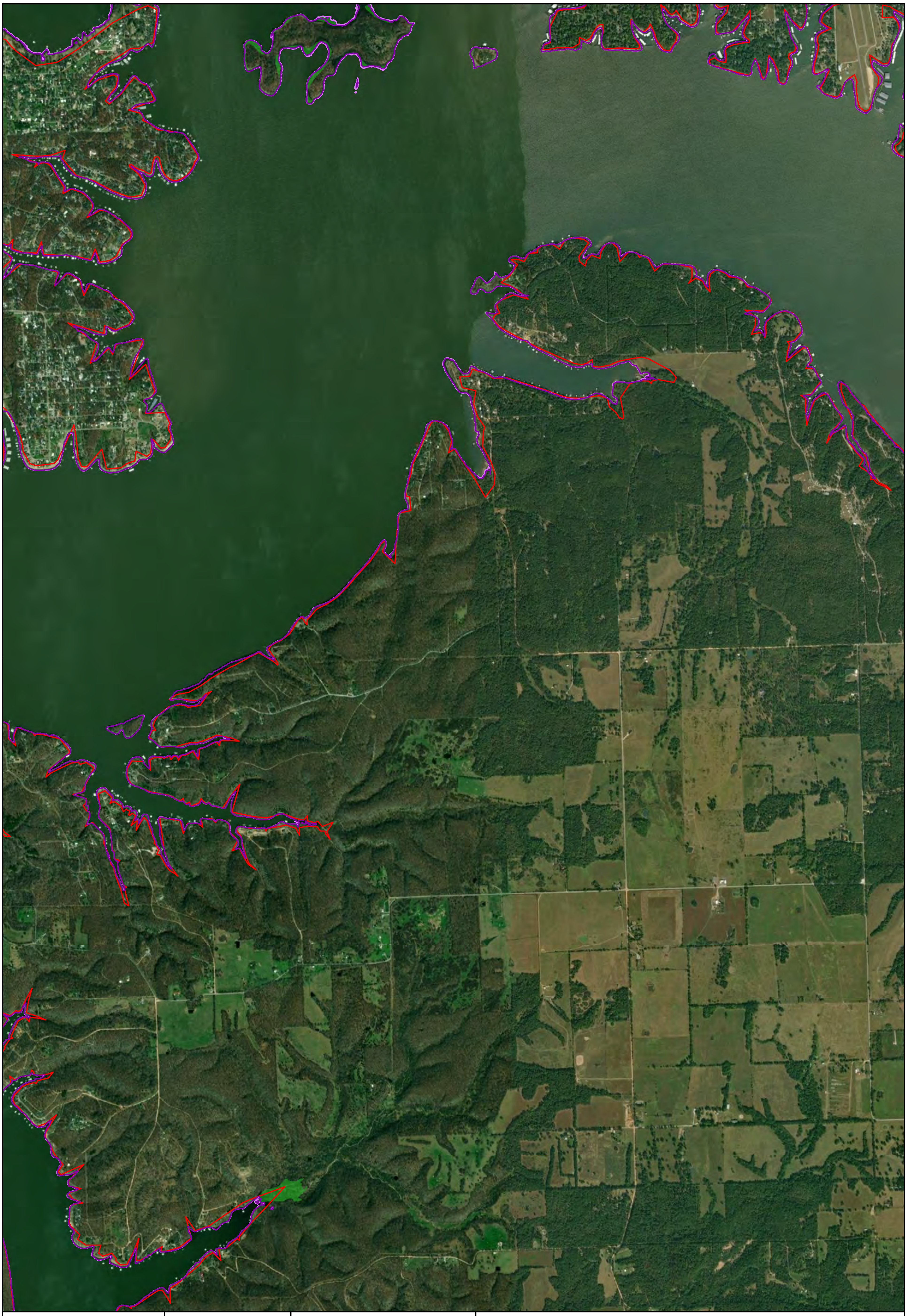
Feet

Figure 26

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

🟥	Project Boundary
🟪	Wetland & Riparian Anticipated Inundation Boundary
🟪	Wetland & Riparian Baseline Inundation Boundary
🟩	Freshwater Forested/Shrub Wetland
🟦	Freshwater Pond



Horizon™
Environmental Services, Inc.

Date:	09/14/2022
Drawn:	KRW
Source:	Esri, 2021

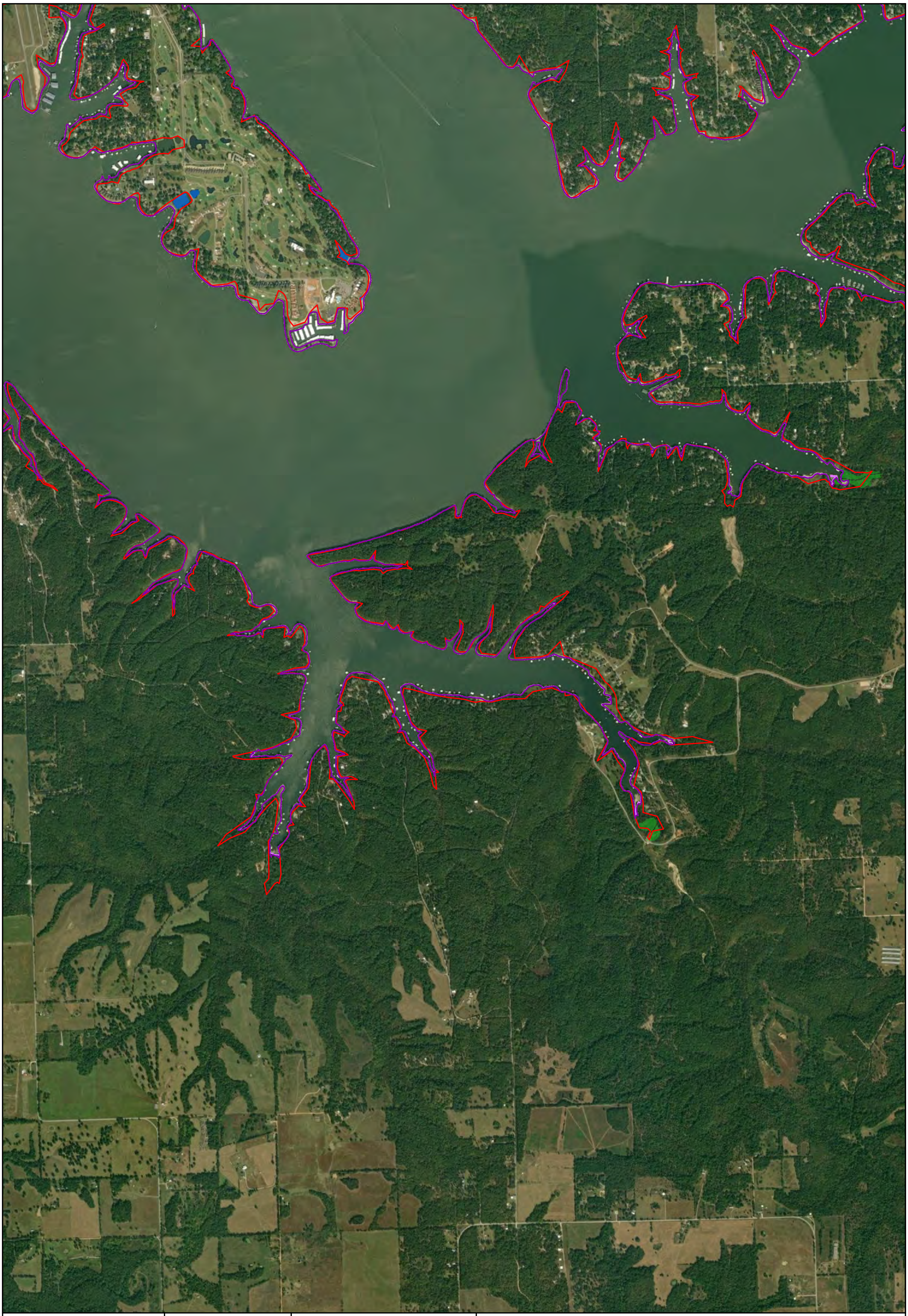
Figure 27

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

☐	Project Boundary
☐	Wetland & Riparian Anticipated Inundation Boundary
☐	Wetland & Riparian Baseline Inundation Boundary
🟩	Freshwater Forested/Shrub Wetland

21021--GRDA_Pensacola_Project_Relicensing\Graphics\WD_2022\21021-001WD_02A_Wetland_and_Riparian



Horizon™
Environmental Services, Inc.

Date:	09/14/2022
Drawn:	KRW
Source:	Esri, 2021

N

0 1,000 2,000
Feet

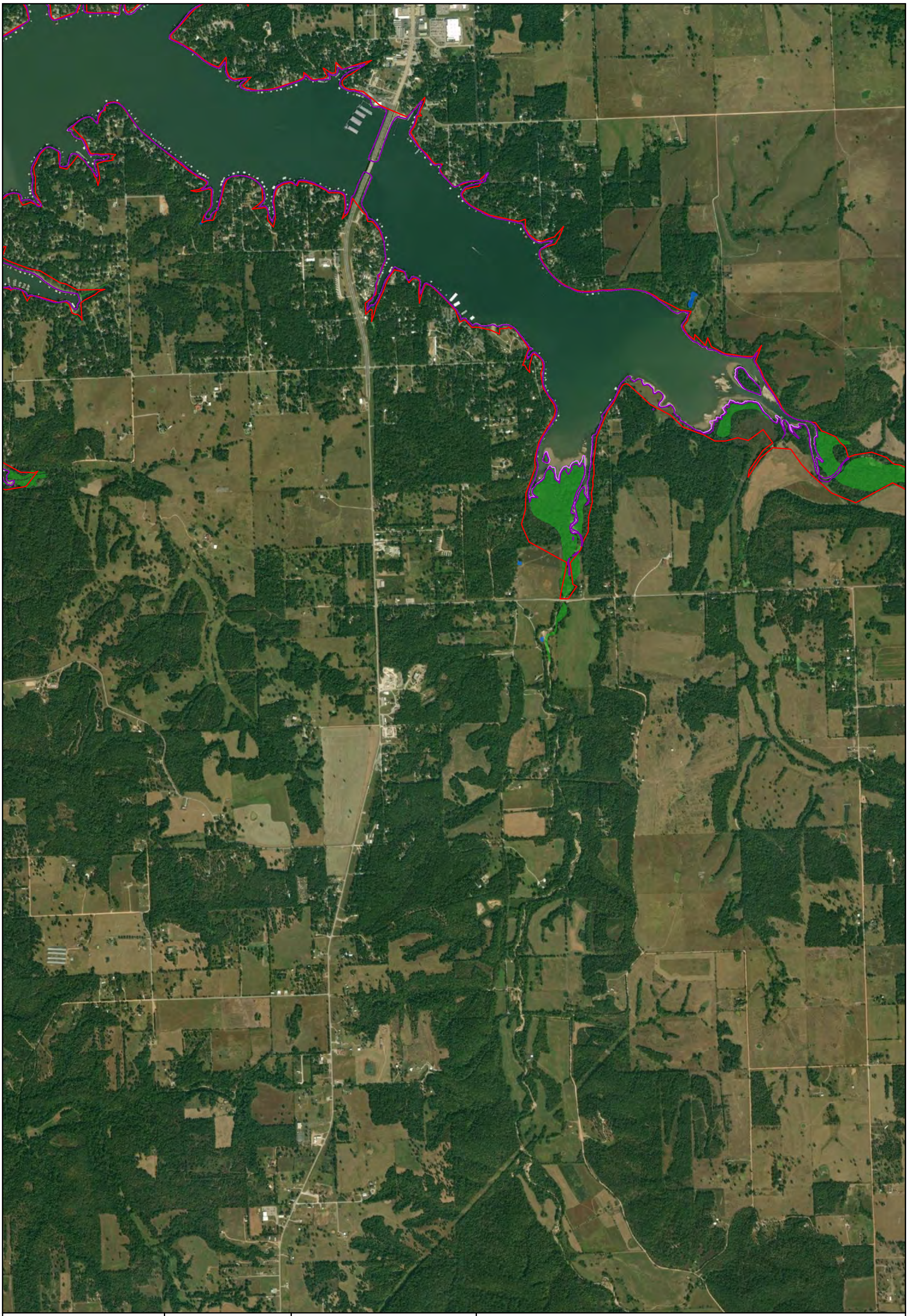
Figure 28

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

🟥	Project Boundary
🟪	Wetland & Riparian Anticipated Inundation Boundary
🟪	Wetland & Riparian Baseline Inundation Boundary
🟩	Freshwater Forested/Shrub Wetland
🟦	Freshwater Pond

21021--GRDA_Pensacola_Project_Relicensing\Graphics\WD_2022\21021-001WD_02A_Wetland_and_Riparian



Horizon™
Environmental Services, Inc.

Date:	09/14/2022
Drawn:	KRW
Source:	Esri, 2021

N

0 1,000 2,000
Feet

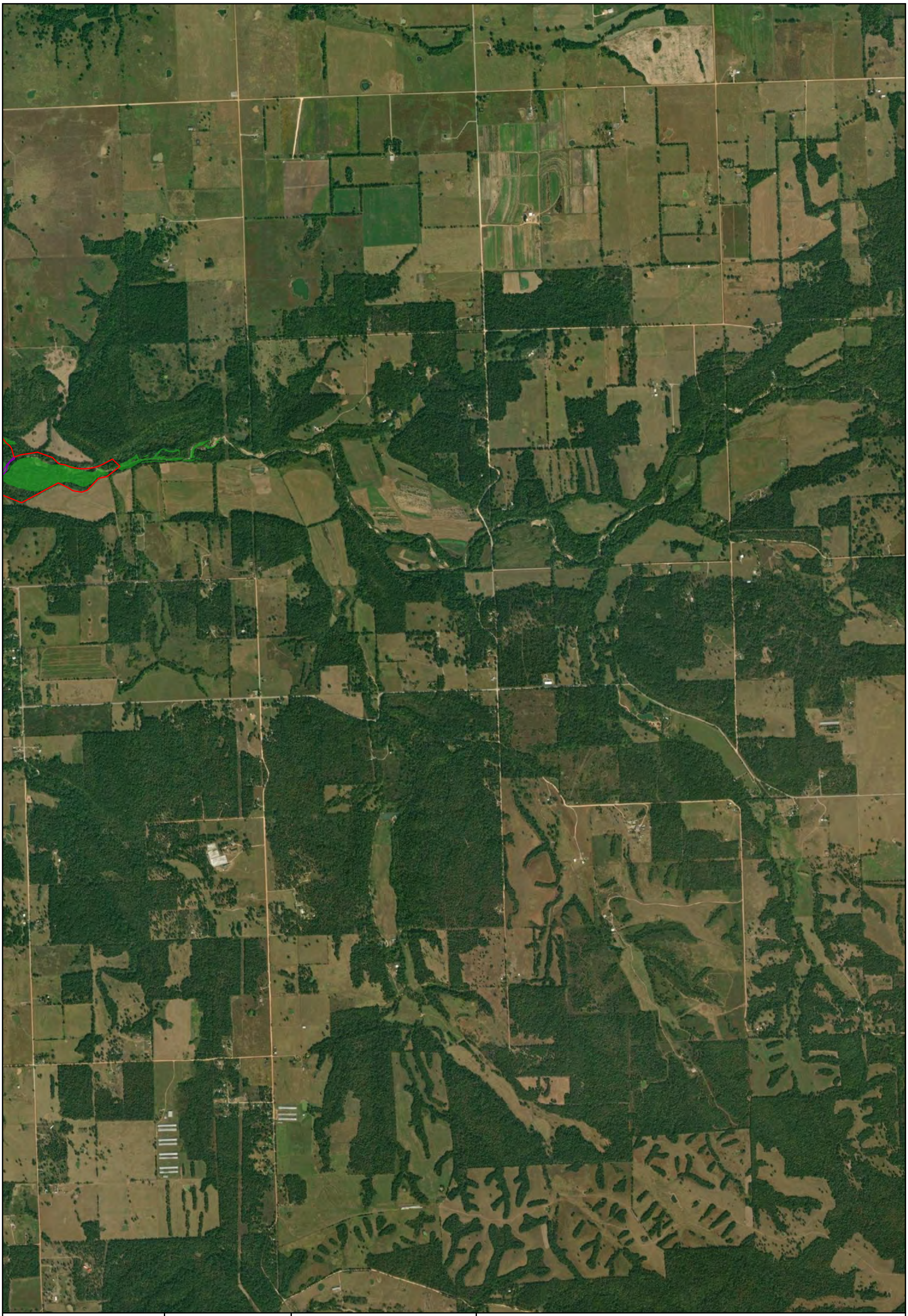
Figure 29

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

□	Project Boundary
□	Wetland & Riparian Anticipated Inundation Boundary
□	Wetland & Riparian Baseline Inundation Boundary
🟩	Freshwater Forested/Shrub Wetland
🟦	Freshwater Pond

21021--GRDA_Pensacola_Project_Relicensing\Graphics\WD_2022\21021-001WD_02A_Wetland_and_Riparian



Horizon™
Environmental Services, Inc.

Date: 09/14/2022
Drawn: KRW
Source: Esri, 2021

0 1,000 2,000
Feet

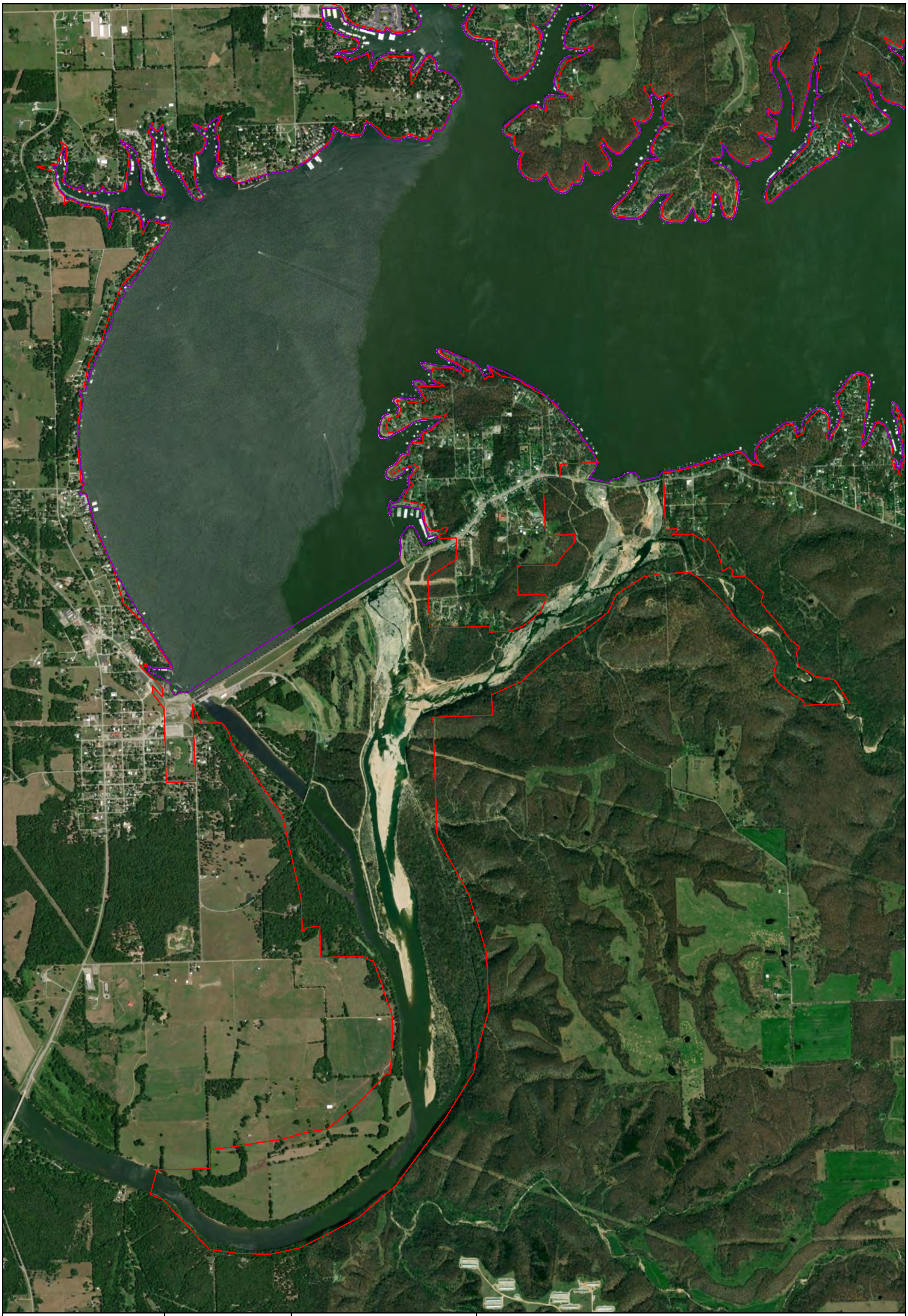
Figure 30

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

🟥	Project Boundary
🟪	Wetland & Riparian Anticipated Inundation Boundary
🟩	Freshwater Forested/Shrub Wetland

21021--GRDA_Pensacola_Project_Relicensing\Graphics\WD_2022\21021-001WD_02A_Wetland_and_Riparian



Horizon™
Environmental Services, Inc.

Date: 09/14/2022
Drawn: KRW
Source: Esri, 2021

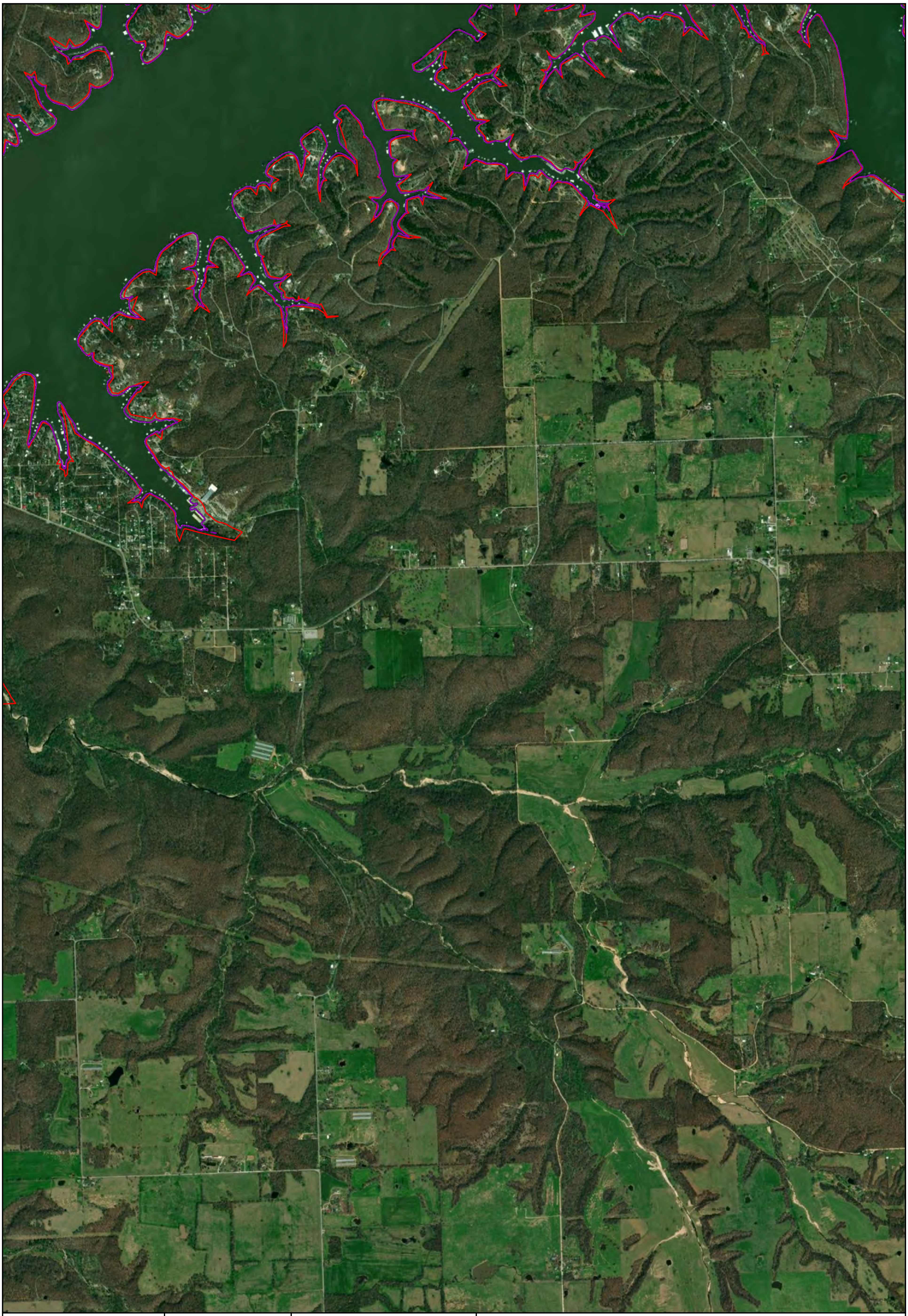
0 1,000 2,000
Feet

Figure 31

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

☐	Project Boundary
☐	Wetland & Riparian Anticipated Inundation Boundary
☐	Wetland & Riparian Baseline Inundation Boundary
🟩	Freshwater Forested/Shrub Wetland
🟦	Freshwater Pond



Date: 09/14/2022
Drawn: KRW
Source: Esri, 2021

0 1,000 2,000
Feet

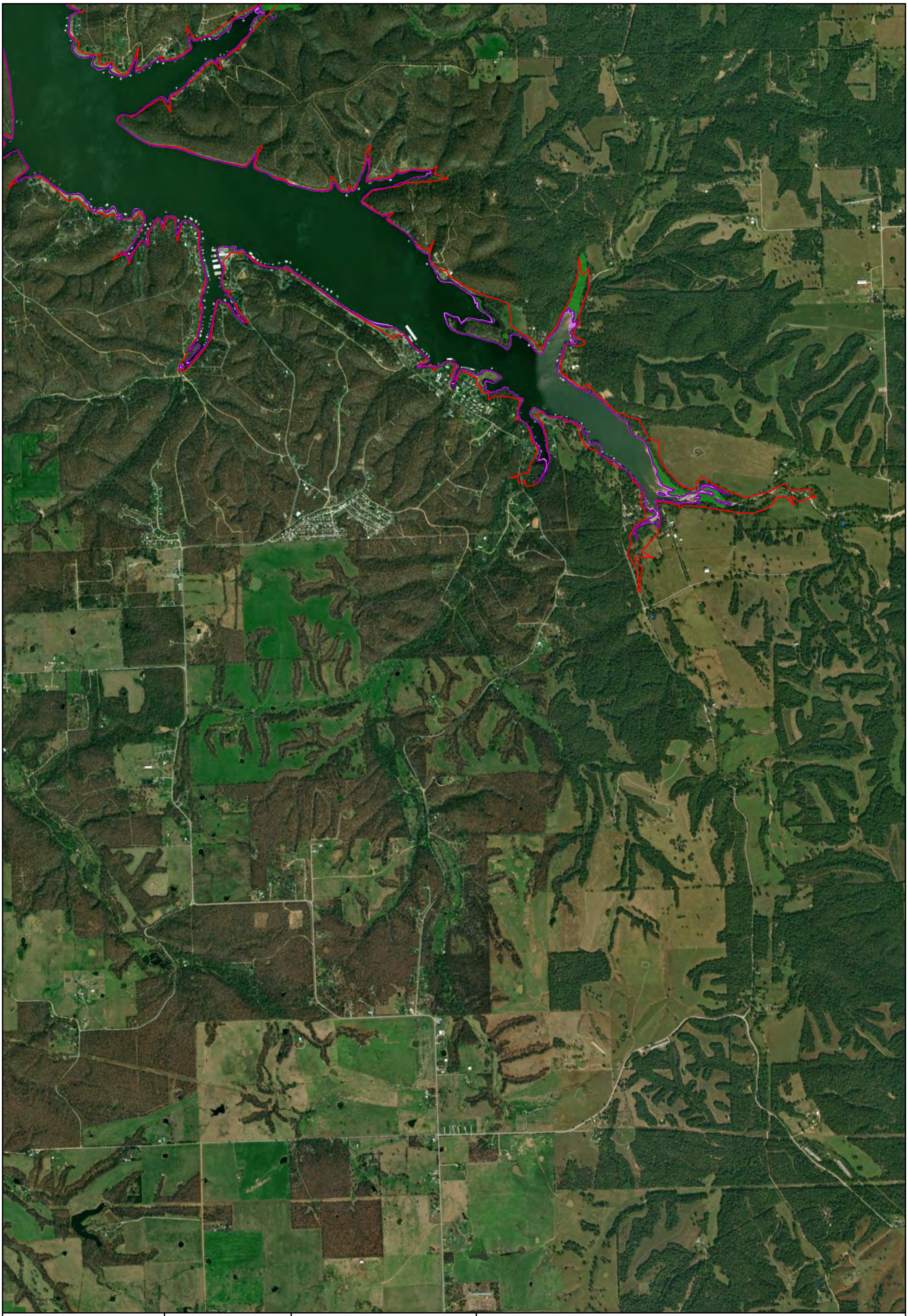
Figure 32

Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

🟥	Project Boundary
🟪	Wetland & Riparian Anticipated Inundation Boundary
🟪	Wetland & Riparian Baseline Inundation Boundary
🟩	Freshwater Forested/Shrub Wetland

21021--GRDA_Pensacola_Project_Relicensing\Graphics\WD_2022\21021-001WD_02A_Wetland_and_Riparian



Horizon™
Environmental Services, Inc.

Date:	09/14/2022
Drawn:	KRW
Source:	Esri, 2021

N

0 1,000 2,000
Feet

Figure 33

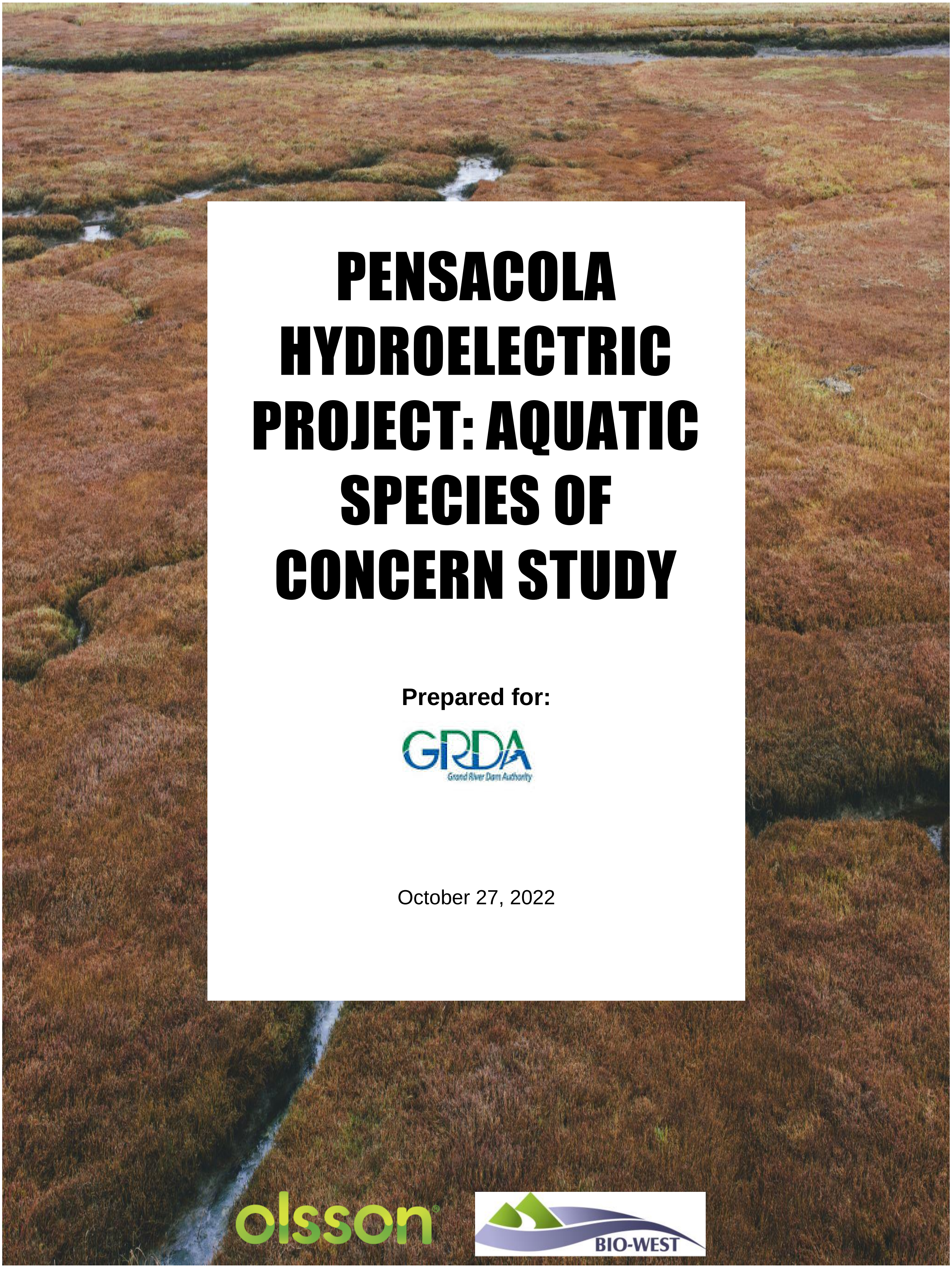
Wetland & Riparian
Inundation Changes
GRDA Pensacola Project
Craig, Delaware, Mayes &
Ottawa Counties, Oklahoma

Legend

🟥	Project Boundary
🟪	Wetland & Riparian Anticipated Inundation Boundary
🟪	Wetland & Riparian Baseline Inundation Boundary
🟩	Freshwater Forested/Shrub Wetland
🟦	Freshwater Pond

21021--GRDA_Pensacola_Project_Relicensing\Graphics\WD_2022\21021-001WD_02A_Wetland_and_Riparian

APPENDIX E-18 Aquatic Species of Concern Study Report



PENSACOLA HYDROELECTRIC PROJECT: AQUATIC SPECIES OF CONCERN STUDY

Prepared for:

GRDA
Grand River Dam Authority

October 27, 2022

olsson

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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APPENDICIES

LIST OF FIGURES

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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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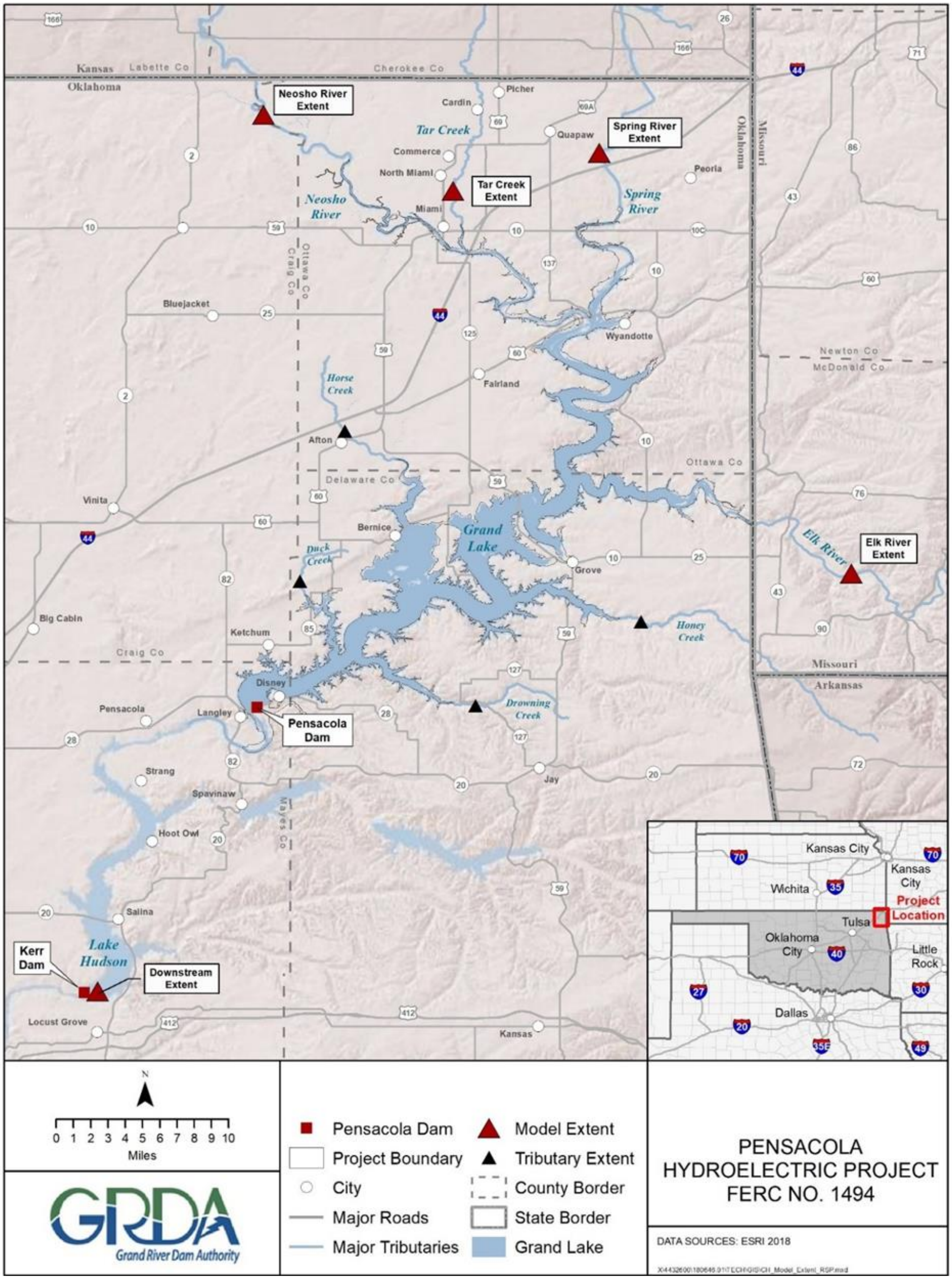
Figure 1. Study Area for the Aquatic Species of Concern



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*)

3.1.1 Habitat 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.

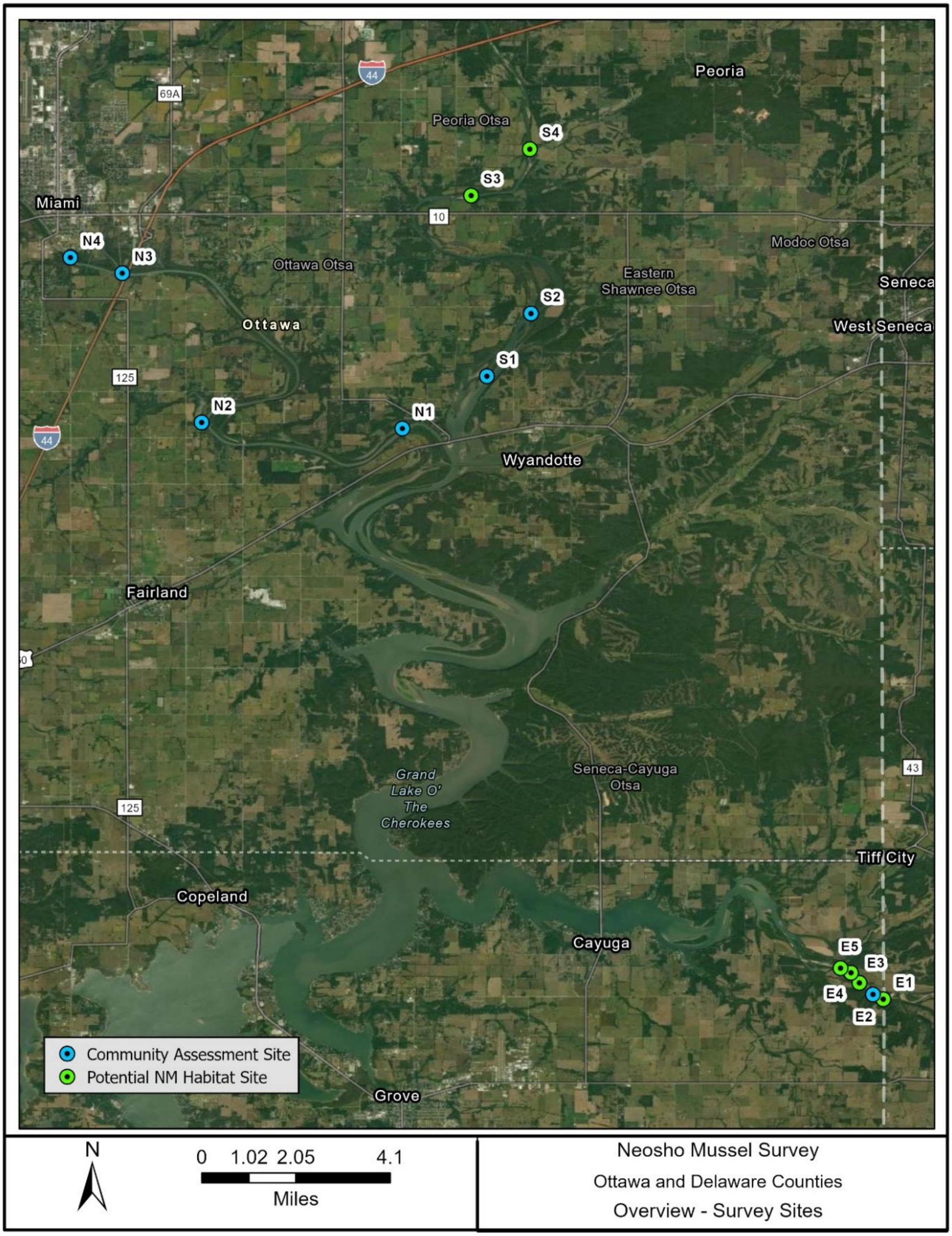

Table 3. Mussel Abundance in the Elk, Spring and Neosho Rivers

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

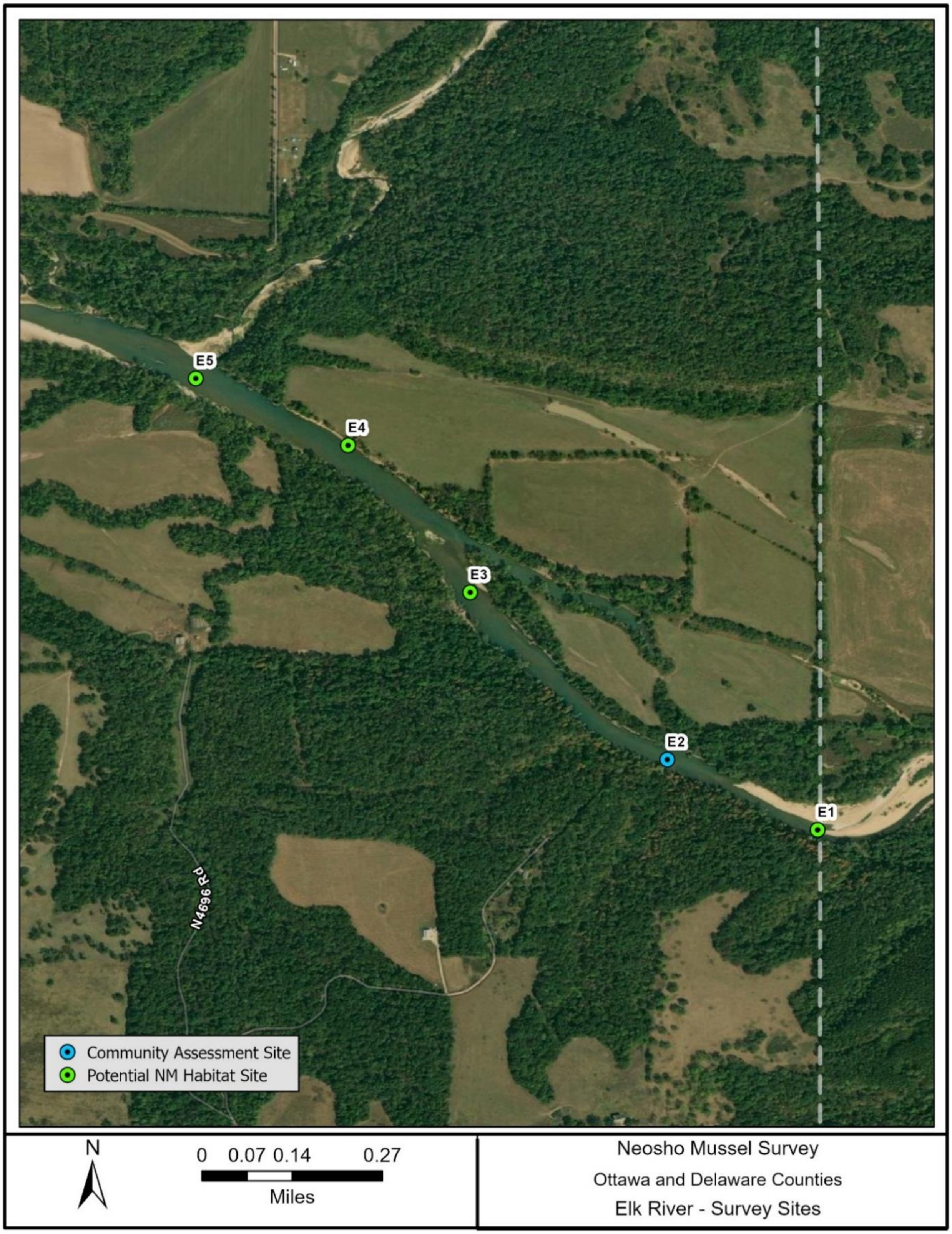

Table 4. Mussel Abundance at Elk River Sites

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

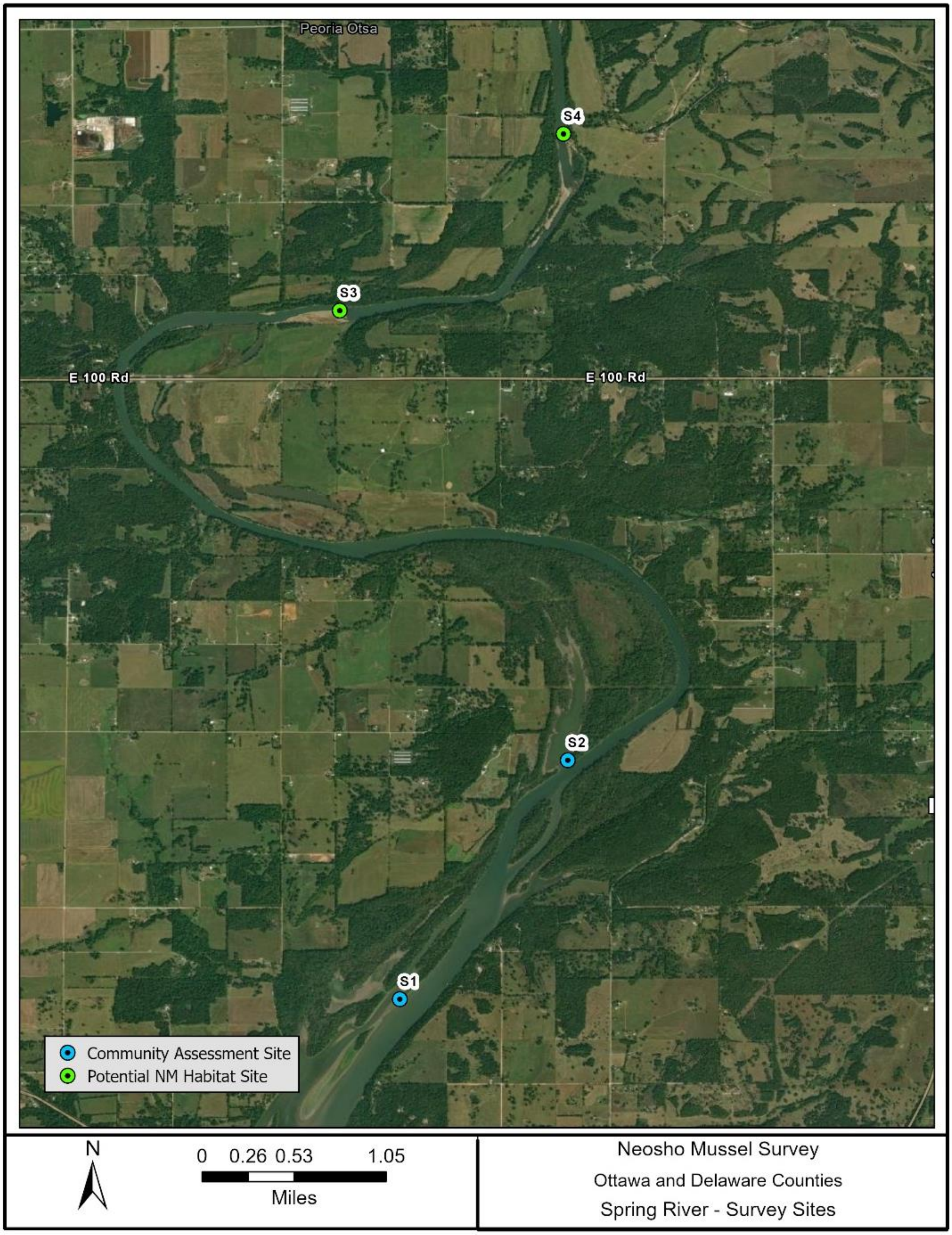
Peoria Otsa
S4
S3
E 100 Rd
E 100 Rd
S2
S1
● Community Assessment Site
● Potential NM Habitat Site
N
0 0.26 0.53 1.05
Miles
Neosho Mussel Survey
Ottawa and Delaware Counties
Spring River - Survey Sites

Table 5. Mussel Abundance at Spring River Sites

	Spring River – 1*		**Spring River – 2***		**Spring River - 3**		**Spring River - 4**		**Total**	
Species	*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

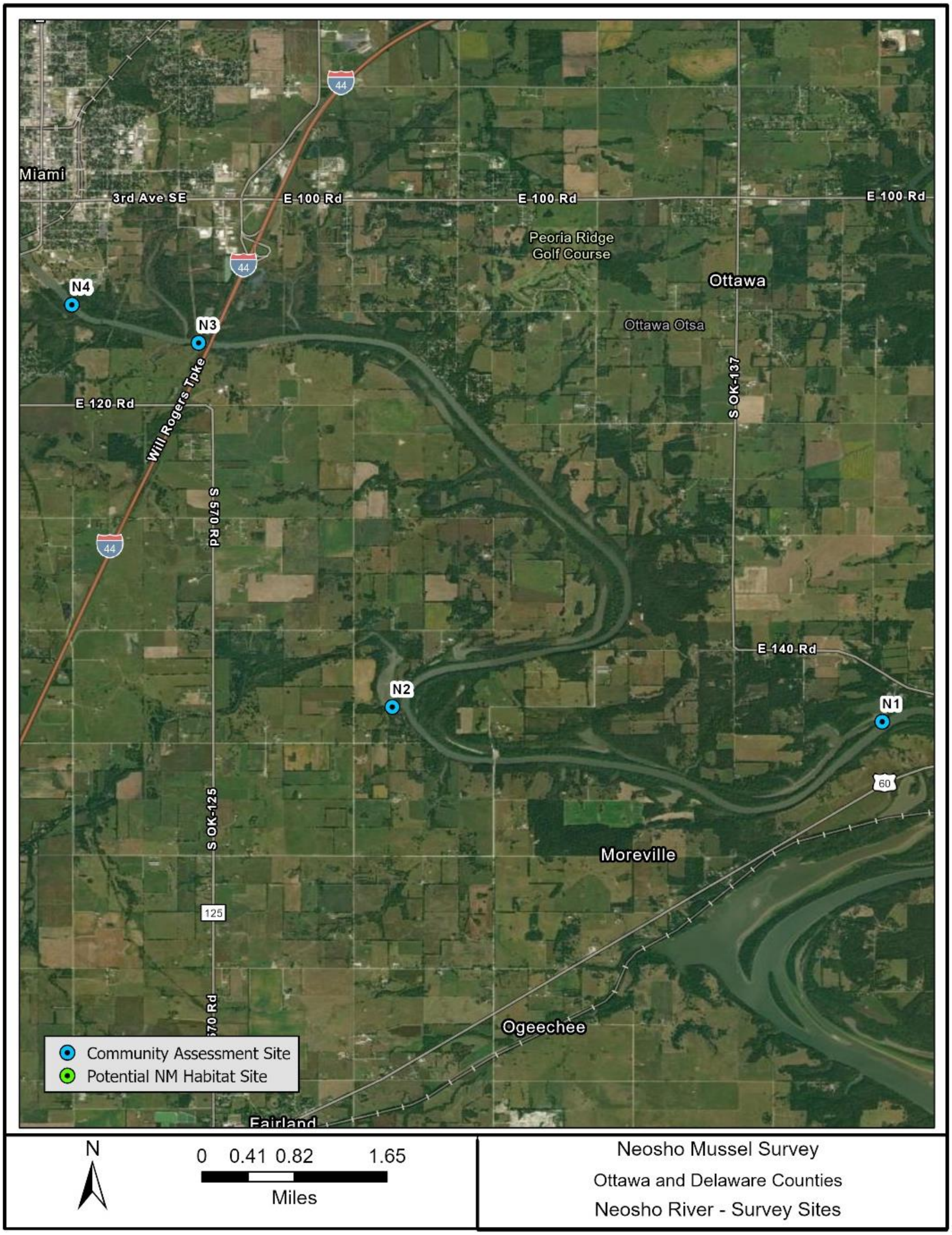

Table 6. Mussel Abundance at Neosho River Sites

	Neosho River – 1*		**Neosho River – 2***		**Neosho River – 3***		**Neosho River – 4***		**Total**	
Species	*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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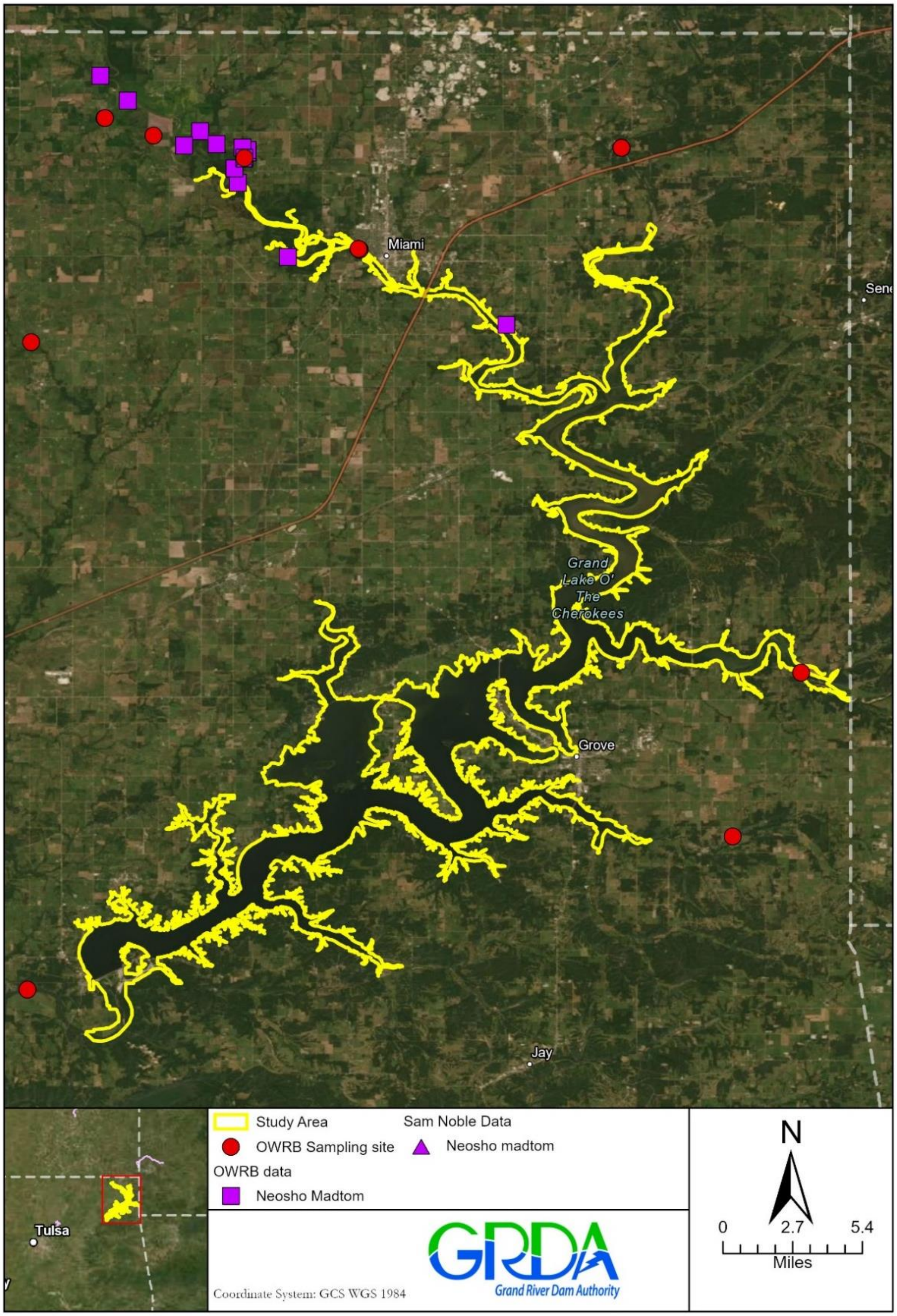
Figure 6. Known Locations of Neosho Madtom – data provided by OWRB and Sam Noble Museum.



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 Channel Catfish

(*Ictalurus punctatus*) being the most abundant species (209, 185, and 49 individuals, respectively) accounting for 77% of the individuals collected (Figure 8, Table 11). Neosho Madtoms were collected from five of nine sites surveyed, N1, N2, N3, N4, and N6 (Table 11) 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 10).

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Figure 7. Neosho Madtom Survey Sites

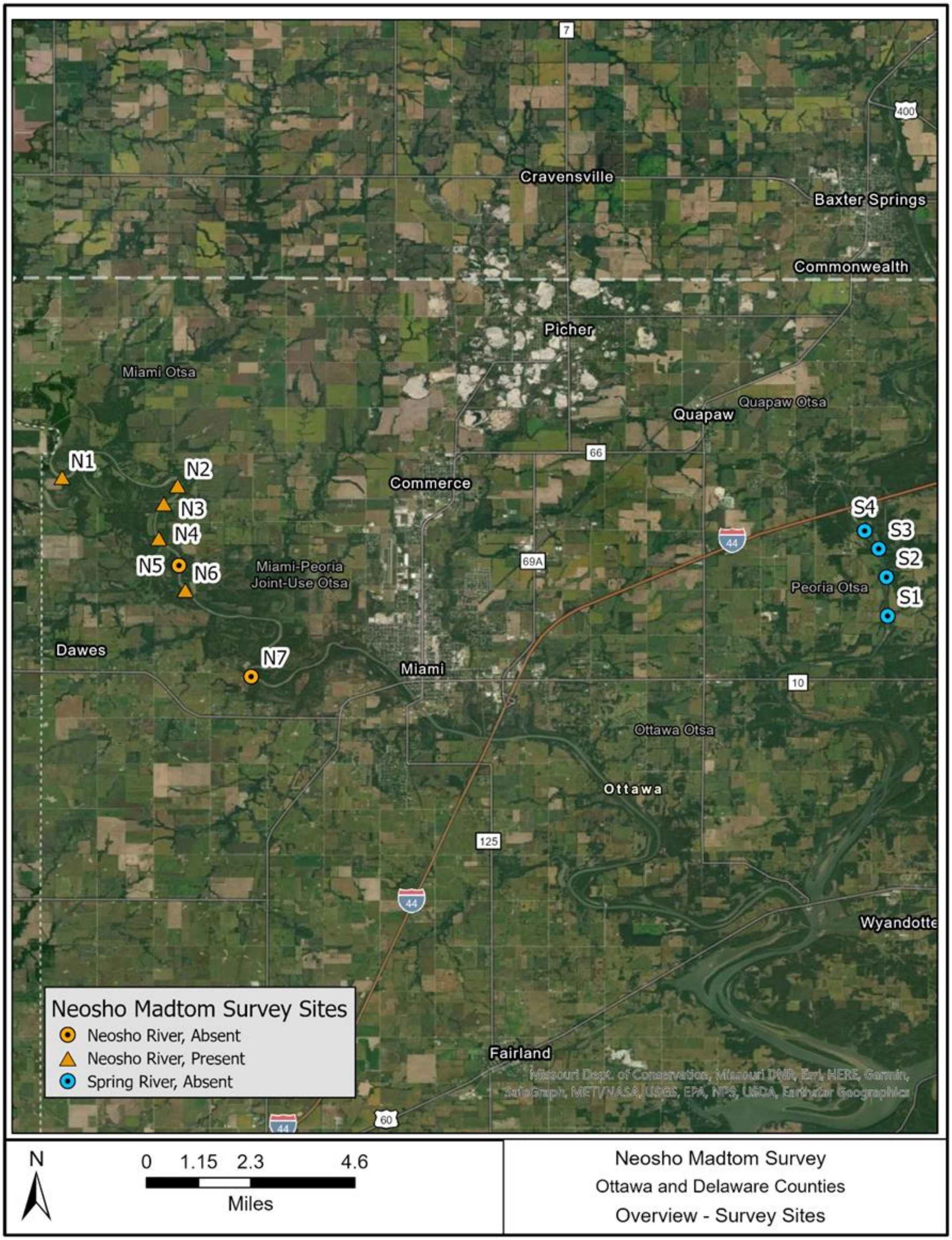


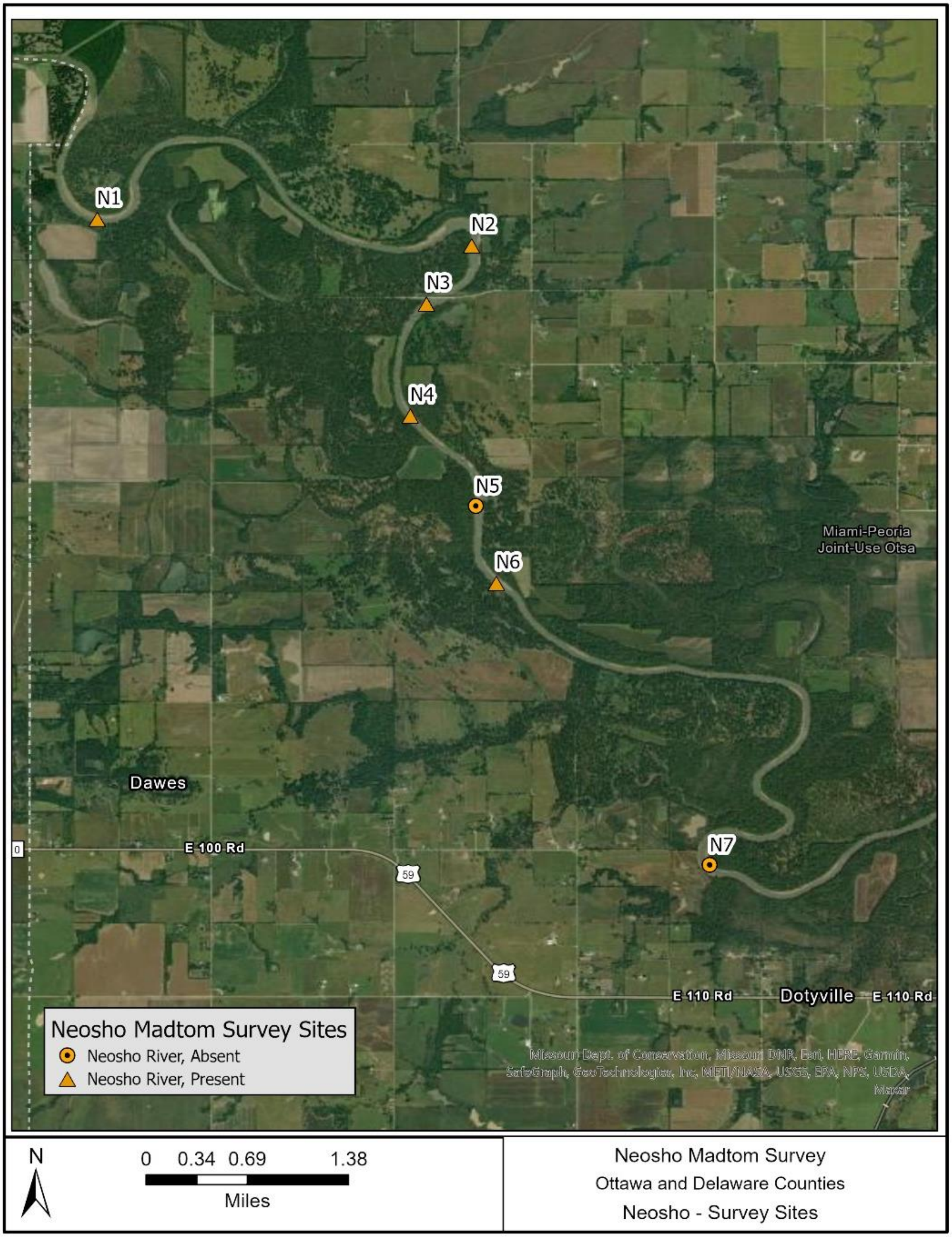
Table 9. Overall Survey Results

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



Missouri Dept. of Conservation, Missouri DNR, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA, Maxar

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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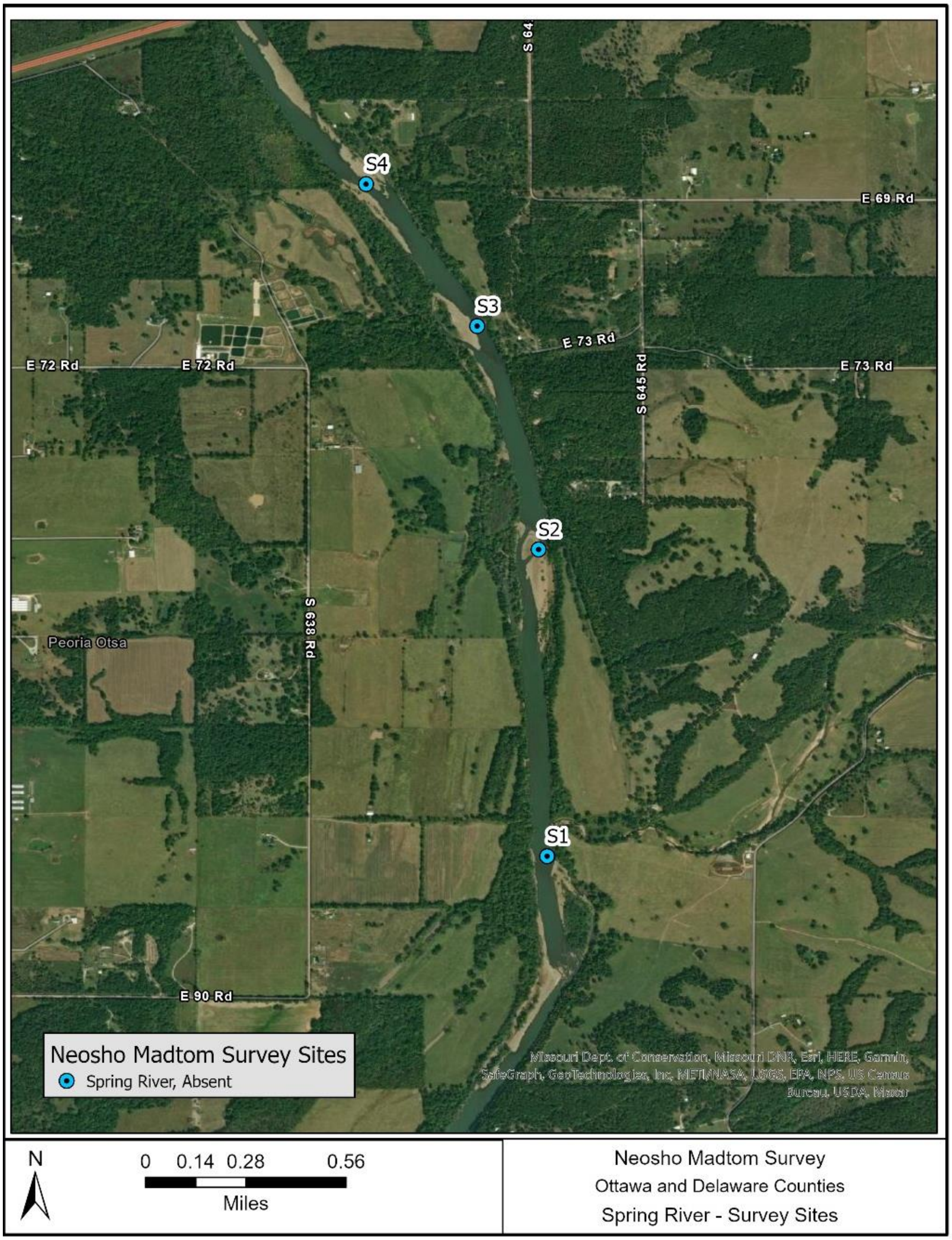
Figure 9. Spring River Survey Sites



Missouri Dept. of Conservation, Missouri DNR, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA, Maxar

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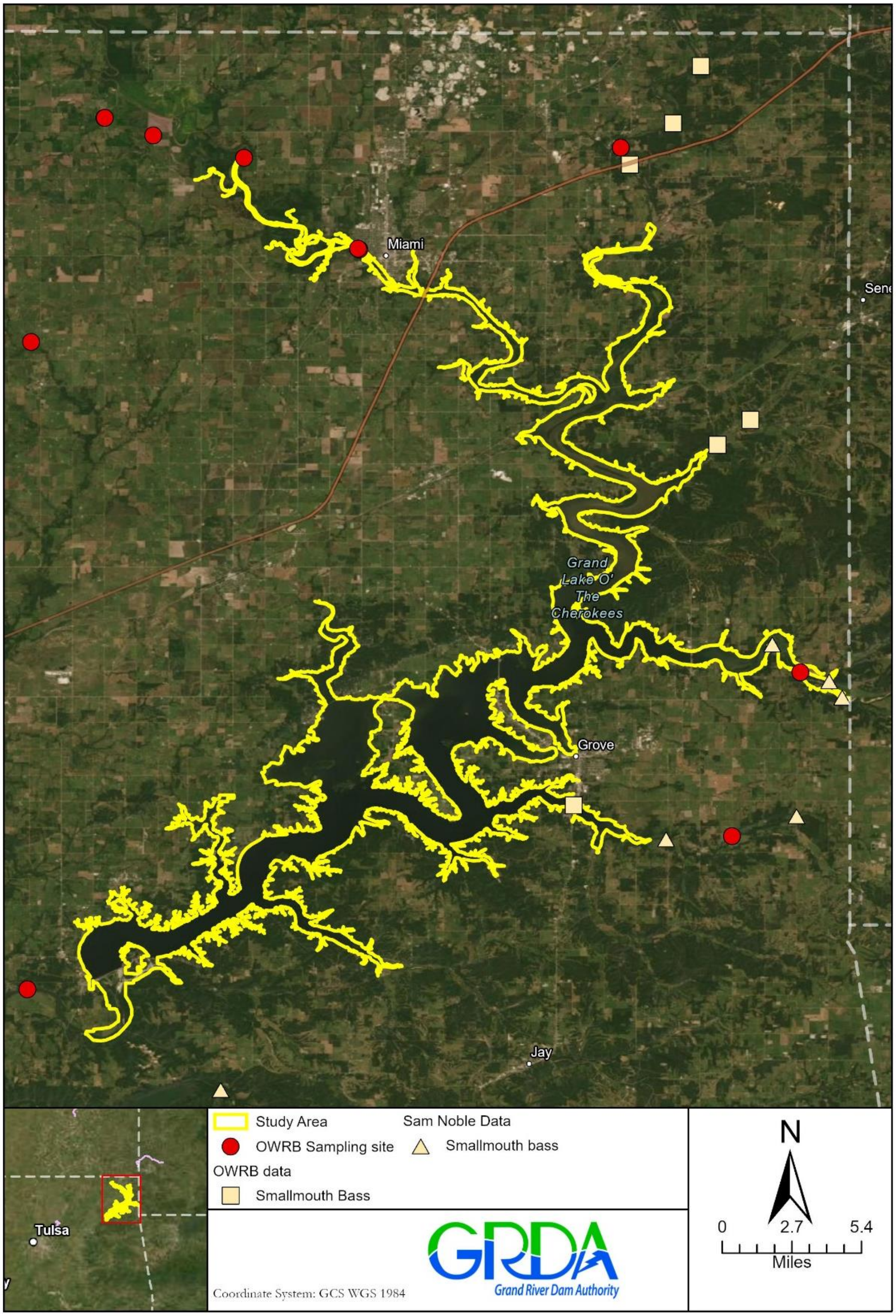
Figure 10. Known Locations of Neosho Smallmouth Bass – data provided by OWRB and Sam Noble Museum.



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.

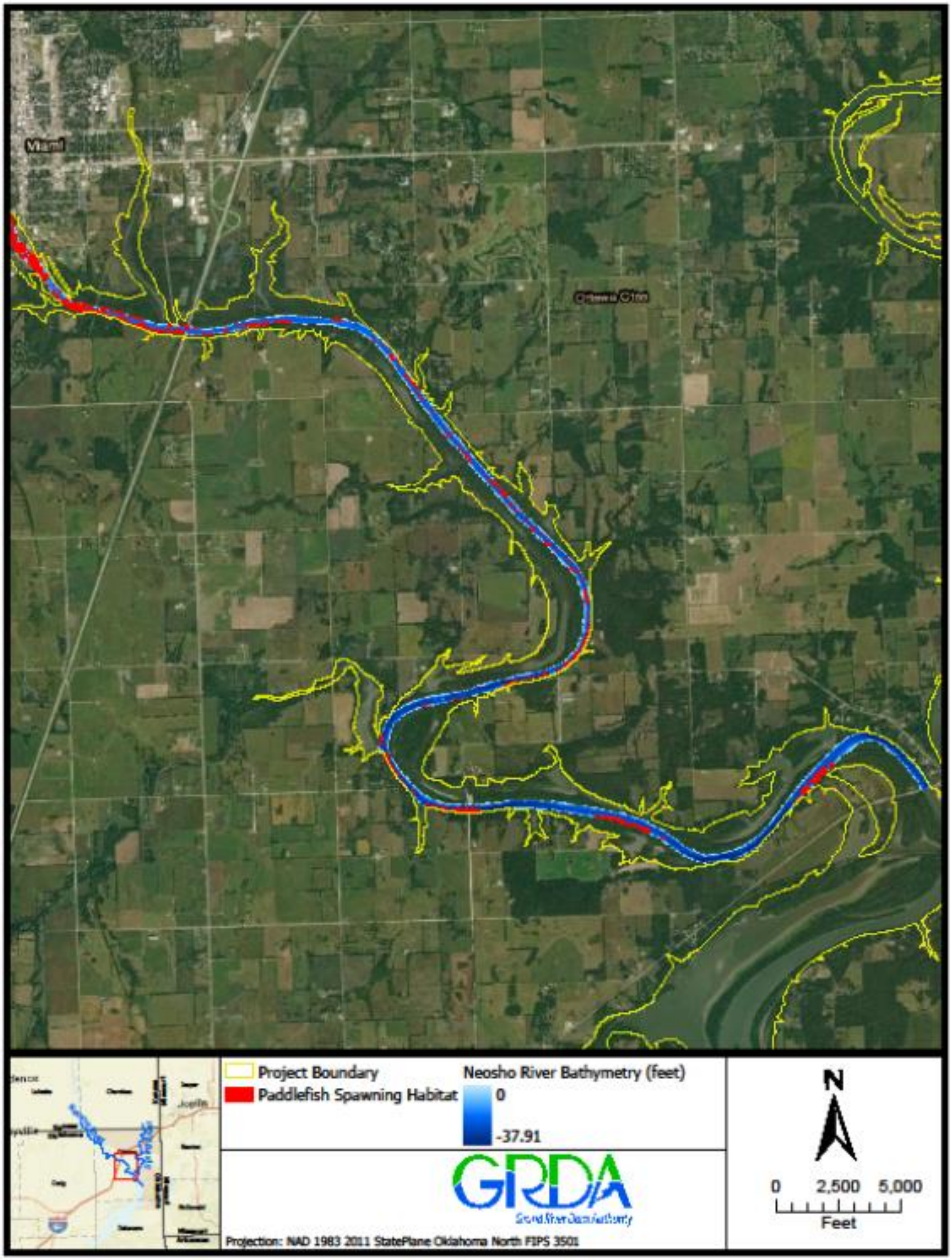

Miami
Project Boundary
Paddlefish Spawning Habitat
Neosho River Bathymetry (feet)
0
-37.91
GRDA
Grand River Dam Authority
N
0
2,500
5,000
Feet
Projection: NAD 1983 2011 StatePlane Oklahoma North FIPS 3501

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.

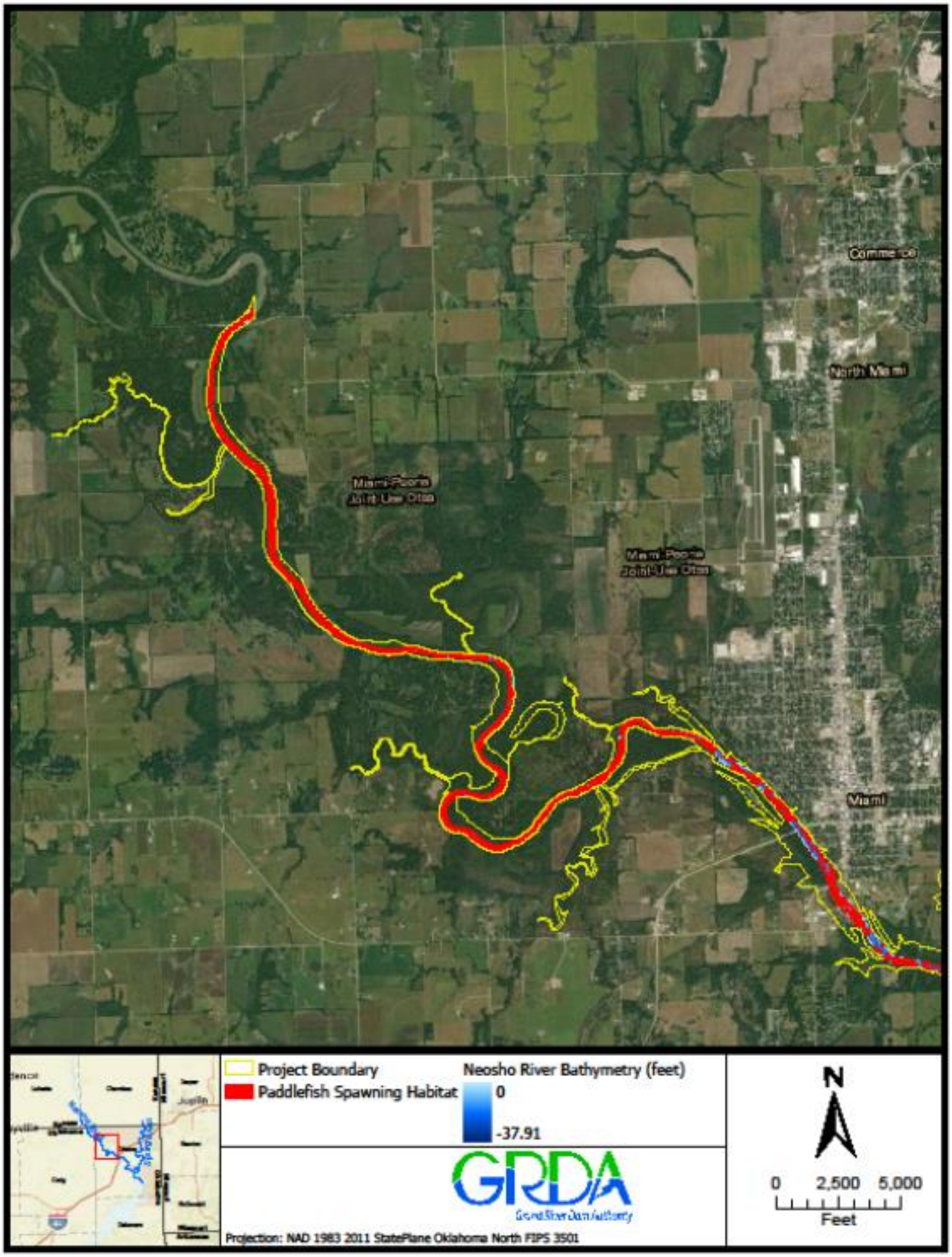
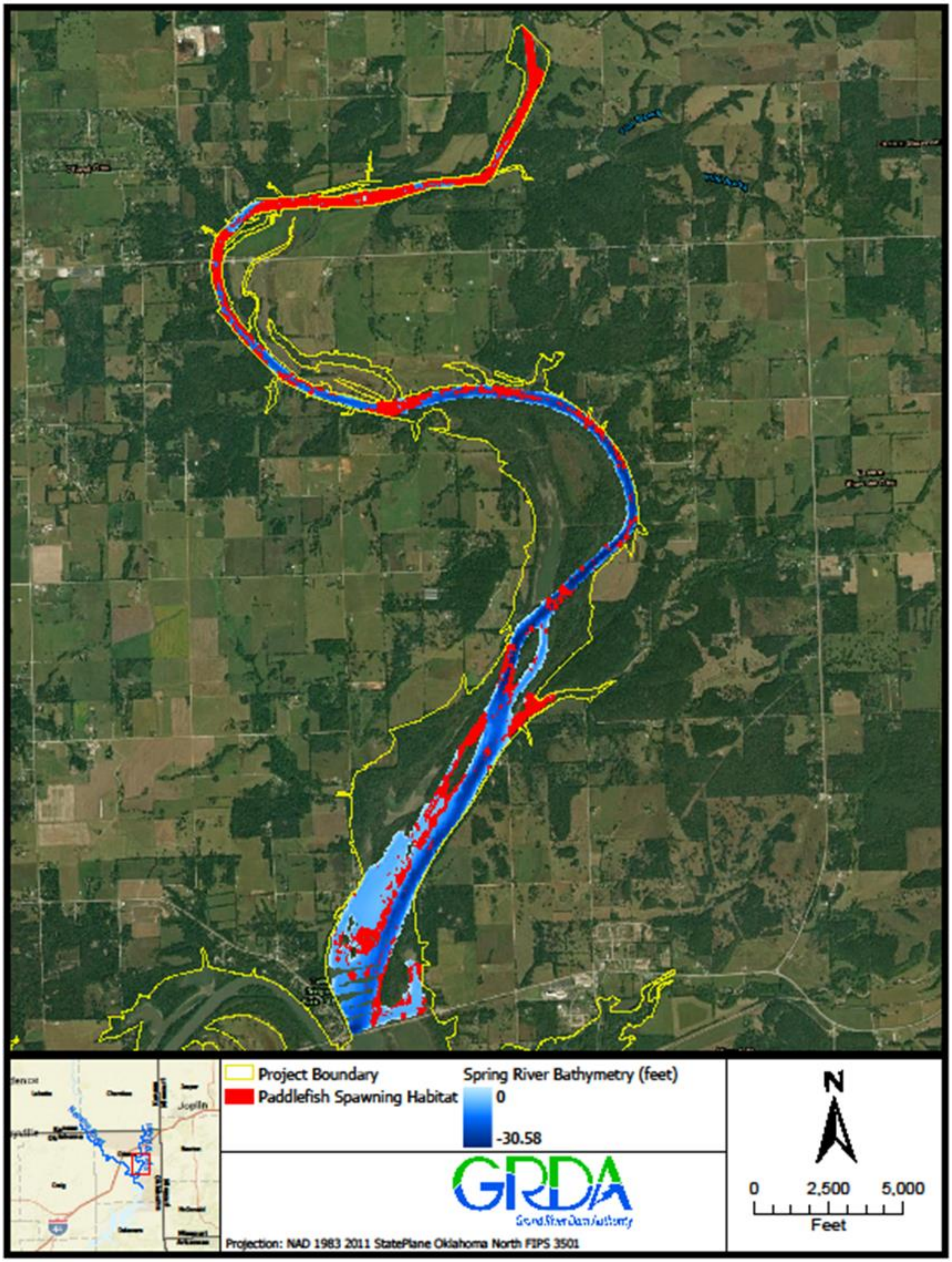

Commerce
North Miami
Miami-Peoria Joint Use Otsa
Miami-Peoria Joint-Use Otsa
Miami
Joplin
🟨 Project Boundary
🟥 Paddlefish Spawning Habitat
Neosho River Bathymetry (feet)
0
-37.91
GRDA
Grand River Dam Authority
N
0 2,500 5,000
Feet
Projection: NAD 1983 2011 StatePlane Oklahoma North FIPS 3501

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


Joplin
Project Boundary
Paddlefish Spawning Habitat
Spring River Bathymetry (feet)
0
-30.58
GRDA
Grand River Dam Authority
Projection: NAD 1983 2011 StatePlane Oklahoma North FIPS 3501
N
0
2,500
5,000
Feet

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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ECOS. 2021c. Winged Mapleleaf (*Quadrula fragosa*). Neosho Mucket (*Lampsilis rafinesqueana*). Available online at: https://ecos.fws.gov/ecp/species/4127

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APPENDIX A

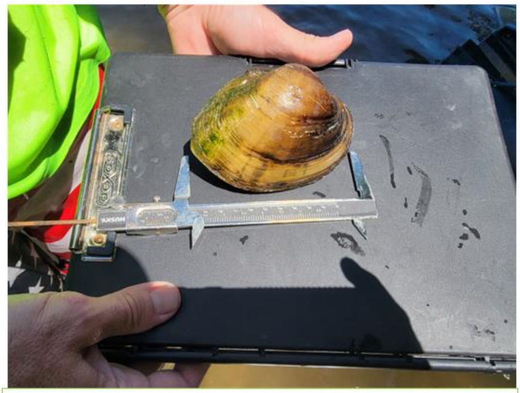
Photo log

1. Elk 1 mussel site.

2. Elk 2 mussel site.

3. Elk 3 mussel site.

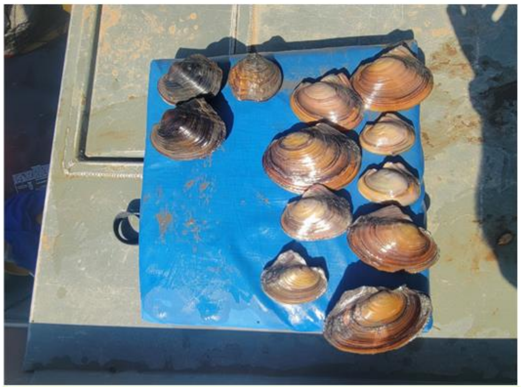
4. Elk 4 mussel site.



5. Elk 4 mussels collected.

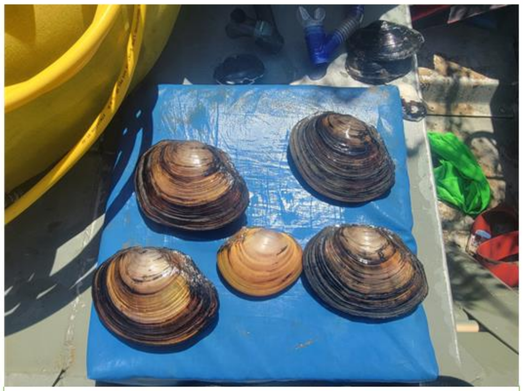
5. Elk 5 mussel site.

7. Spring 1 mussel site.



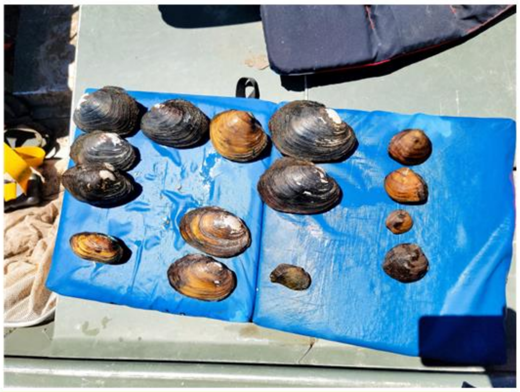
8. Spring 1 mussels collected.

9. Spring 2 mussel site.



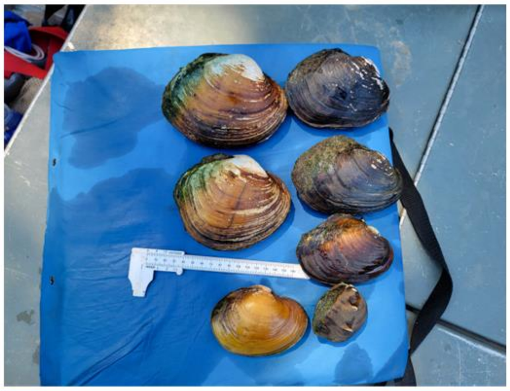
10. Spring 2 mussels collected.

11. Spring 3 mussel site.



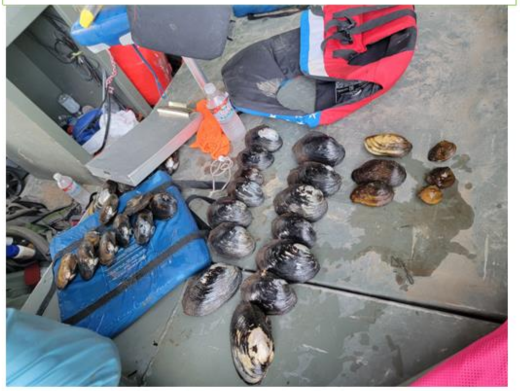
12. Spring 3 mussels collected.

13. Spring 4 mussel site.



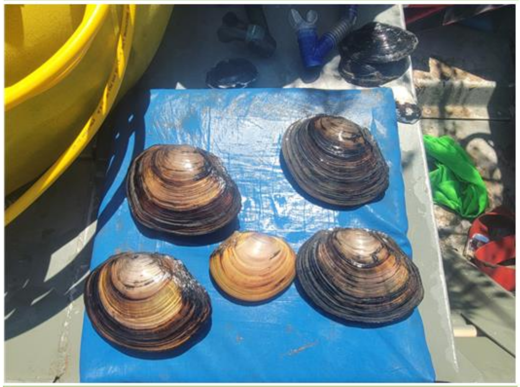
14. Spring 4 mussels collected.

15. Neosho 1 mussel site.



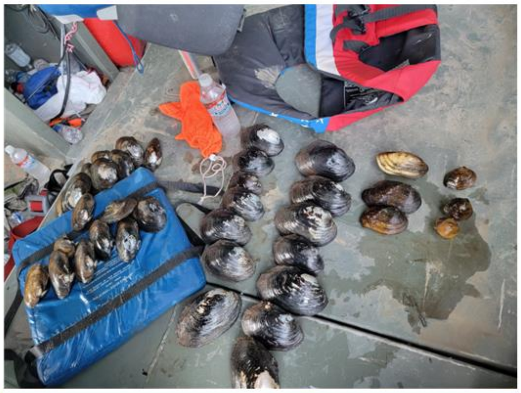
16. Neosho 1 mussels collected

17.   Neosho 2 mussel site.



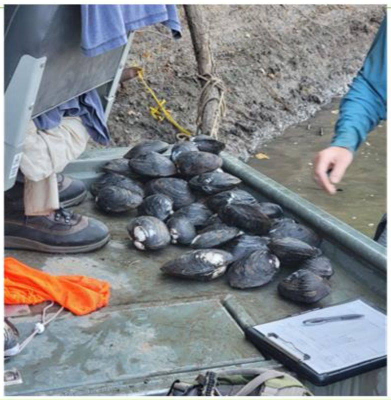
18. Neosho 2 results

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

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[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

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[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.
   .
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,

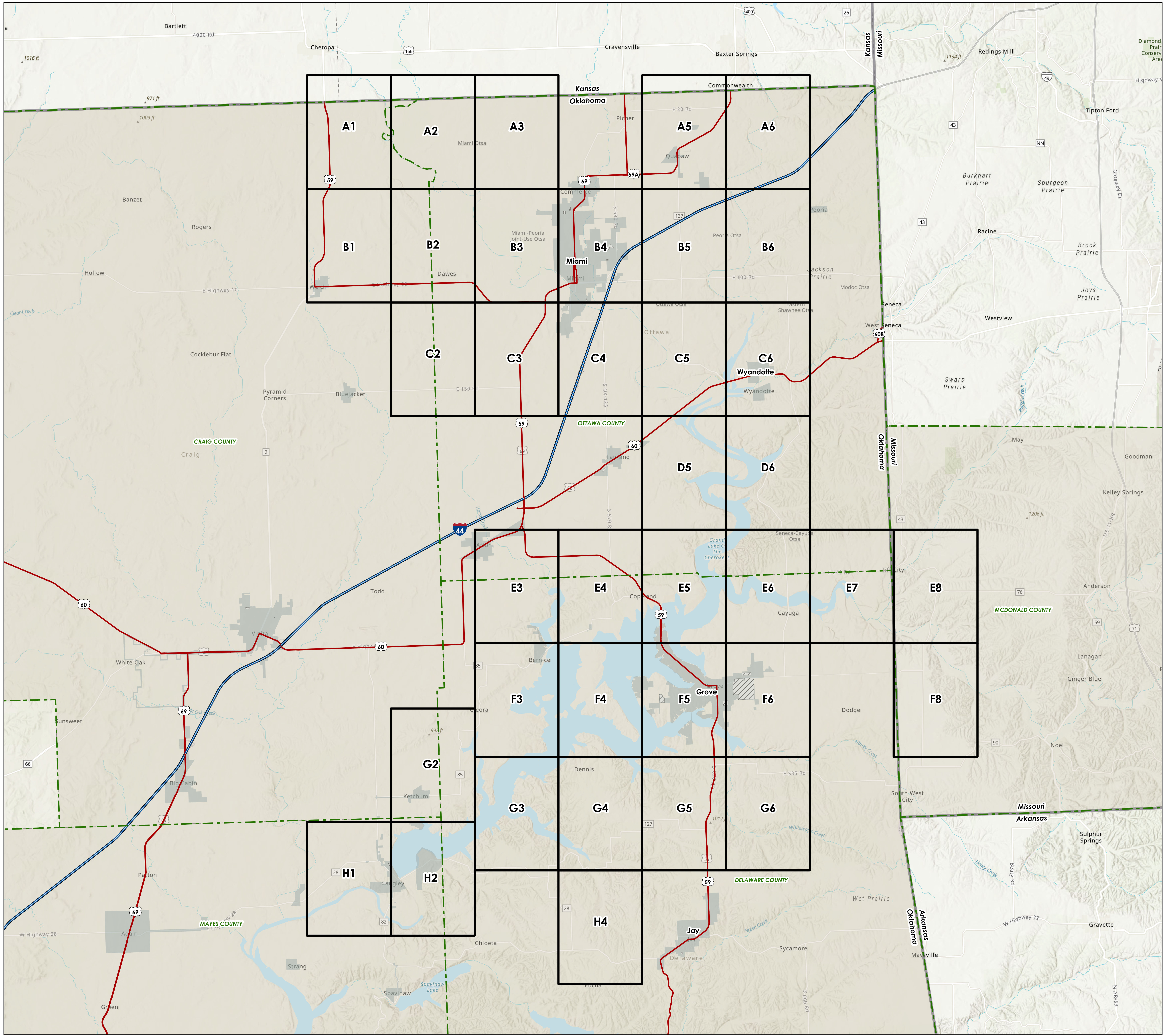
Susan Mensik

Susan Mensik, Lead Administrative Trustee Representative
Tar Creek Trustee Council

PENSACOLA HYDROELECTIC PROJECT: AQUATIC SPECIES OF CONCERN STUDY

October 27, 2022

APPENDIX E-19 Lake Spawning Habitat Changes Maps



Map Source: Missouri Dept. of Conservation, Missouri DNR, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, EPA, NPS, USDA, Esri, NASA, NGA, USGS

Lake Spawning Species Habitat Changes Overview Map

Pensacola Dam

GRAND RIVER DAM AUTHORITY

September 2022

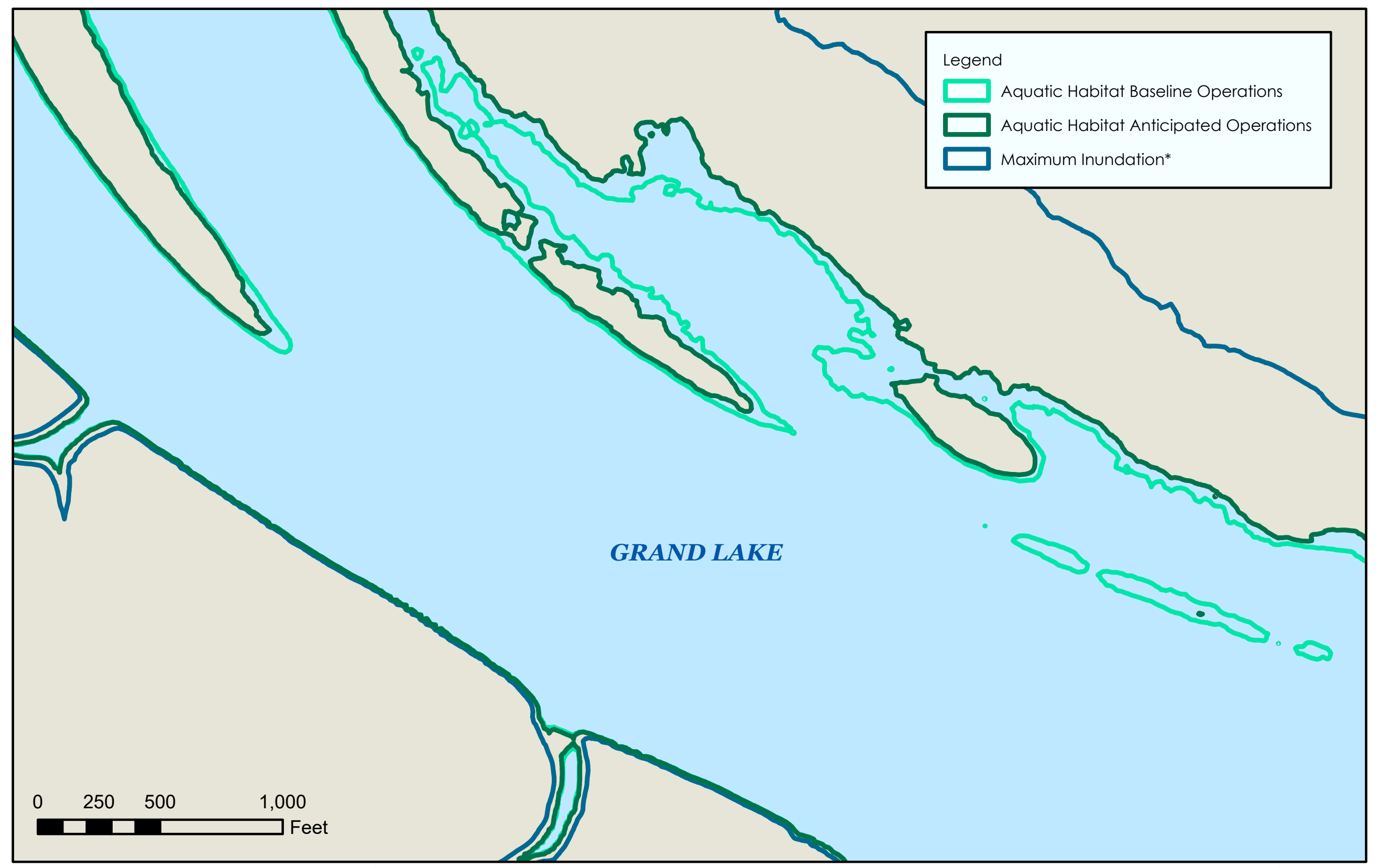
Overview Map Legend

▭ 1:24,000-scale Map Sheet
▭ State Boundary
- - - County Boundary
▨ Municipality
▨ Unincorporated

Road Class
═ Interstate
— US Highway

Lake Spawning Habitat Mapping Explanation

Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. Estimated inundation extent for normal (median) inflows and operations during the spawning season.


Legend
Aquatic Habitat Baseline Operations
Aquatic Habitat Anticipated Operations
Maximum Inundation*
GRAND LAKE
0
250
500
1,000
Feet

* Maximum inundation extents for Baseline Operations and Anticipated Operations are nearly identical. Therefore, the Maximum inundation extent shown represents both conditions. Maximum inundation extent occurs when USACE is in flood control.

Disclaimer: These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.

0 1.25 2.5 5 7.5 10
Miles

NORTH

Map Notes

Data Sources for Maps:

1. Base map images from https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019
2. Transportation network (major roads, local roads, and railroads) and county boundaries obtained from the Oklahoma Office of Geographic Information (http://okmaps.org/ogi/search.aspx).

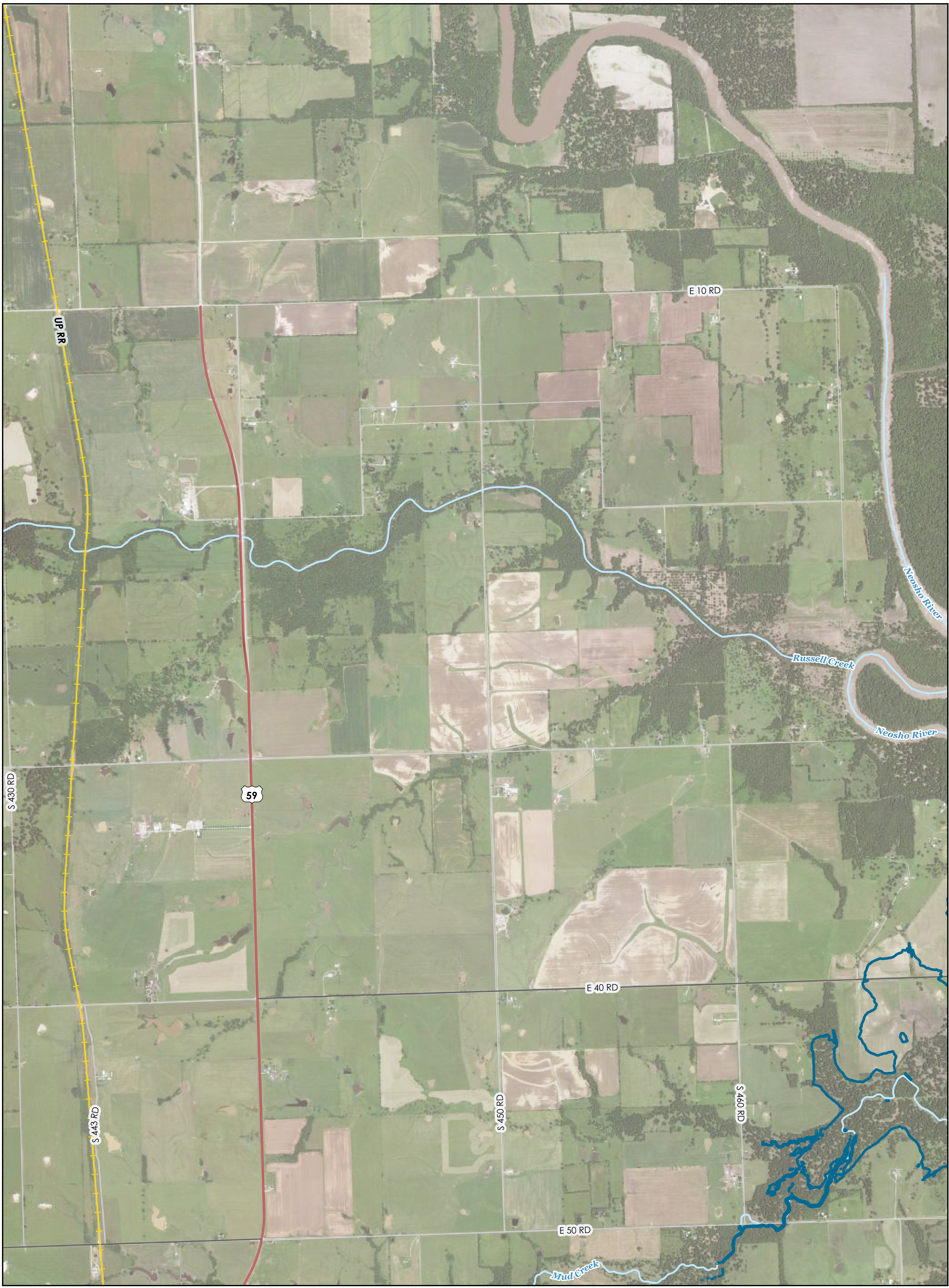


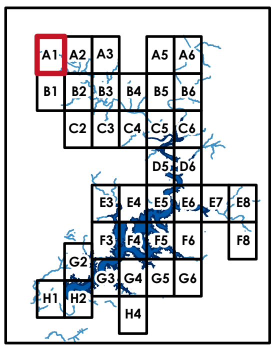
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: A1

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

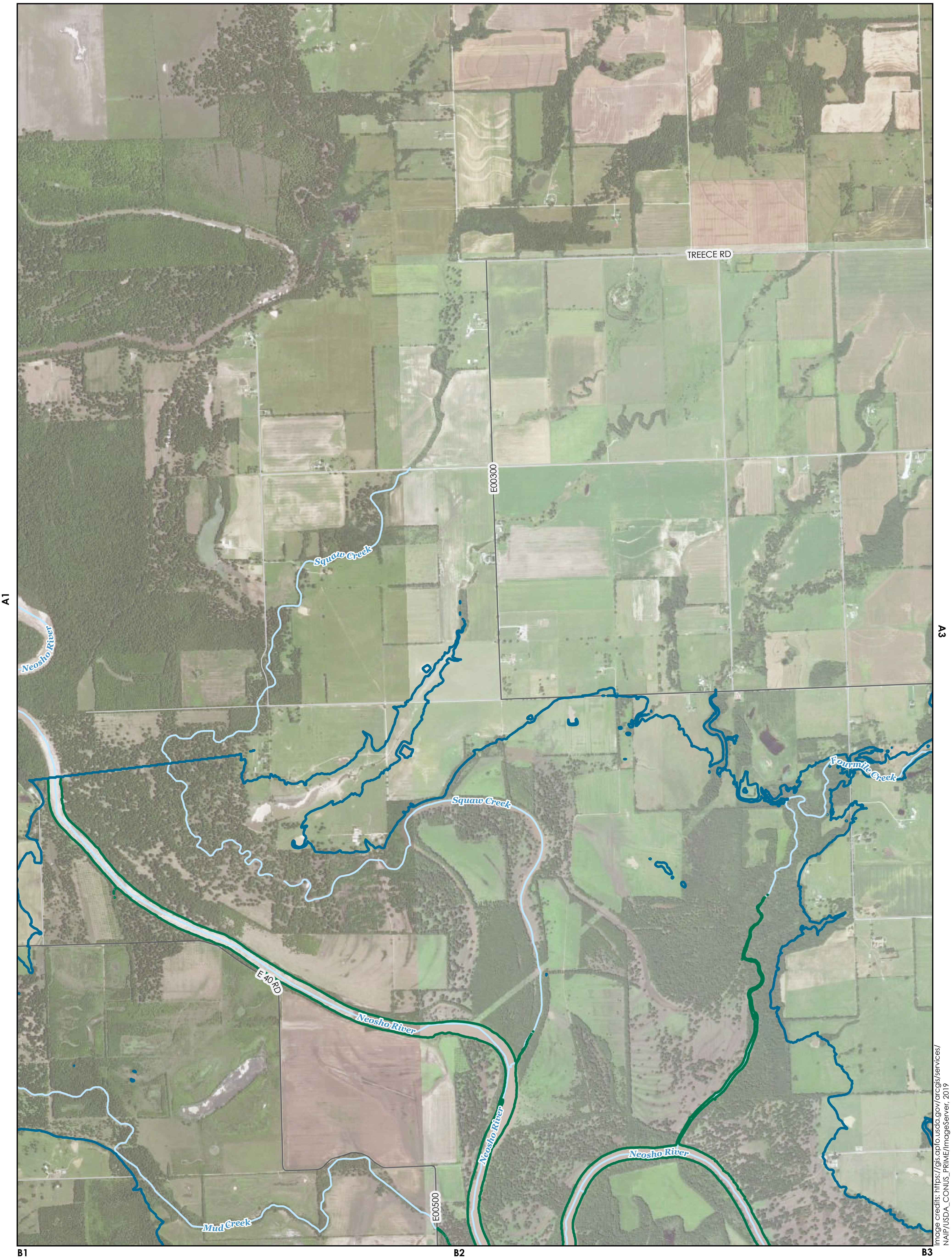


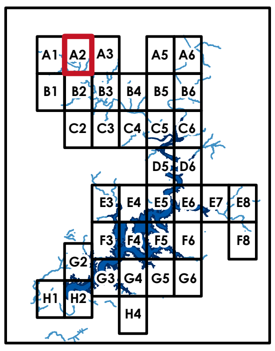
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: A2

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

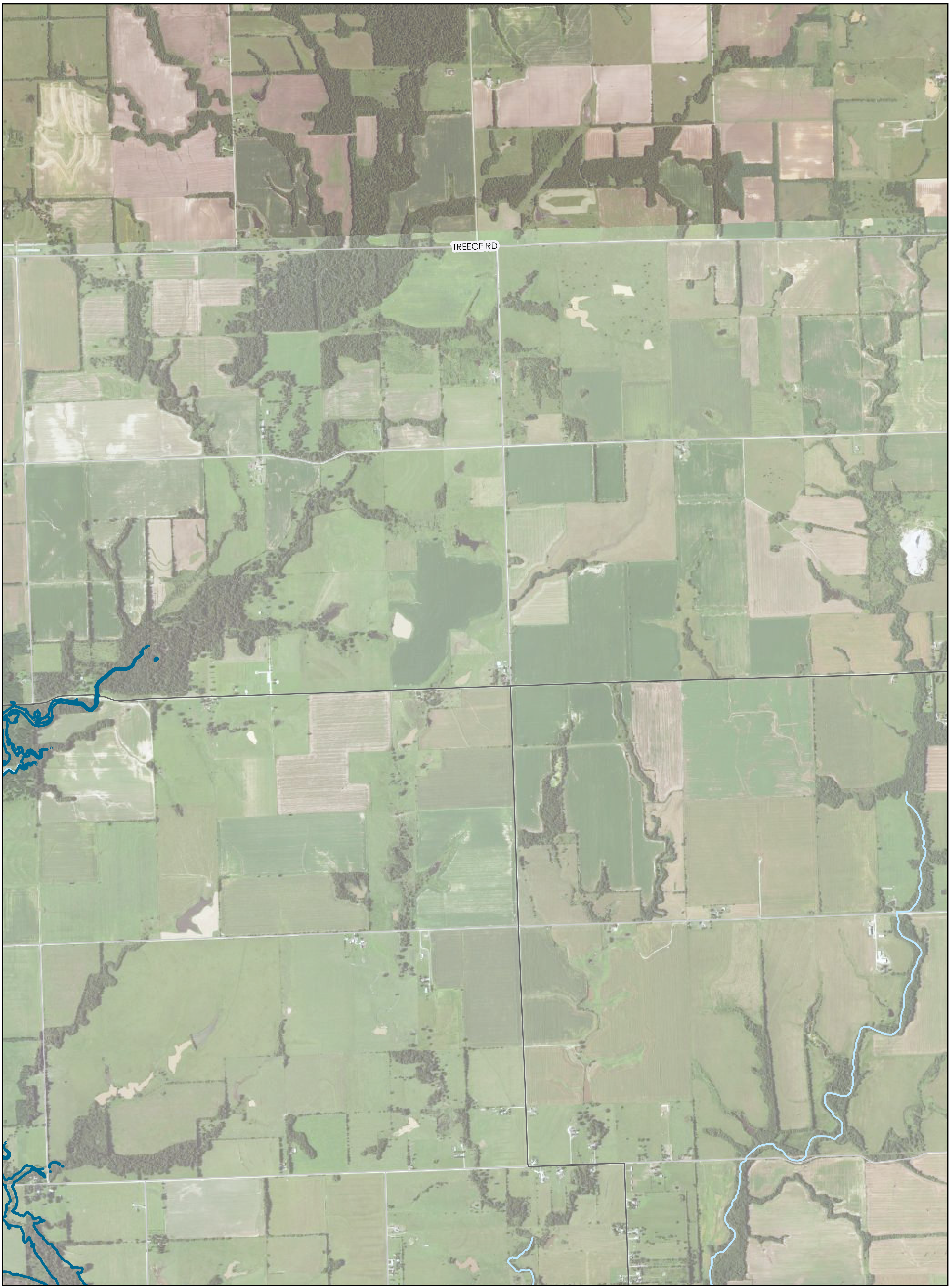


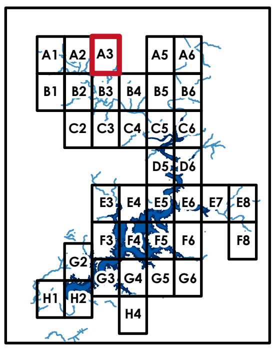
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- ═ Interstate
- — State Highway
- — US Highway
- — Major Collector
- — Local Road
- ┼ Railroad
- — Stream
- ▪▪▪ Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: A3

CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494
September 2022

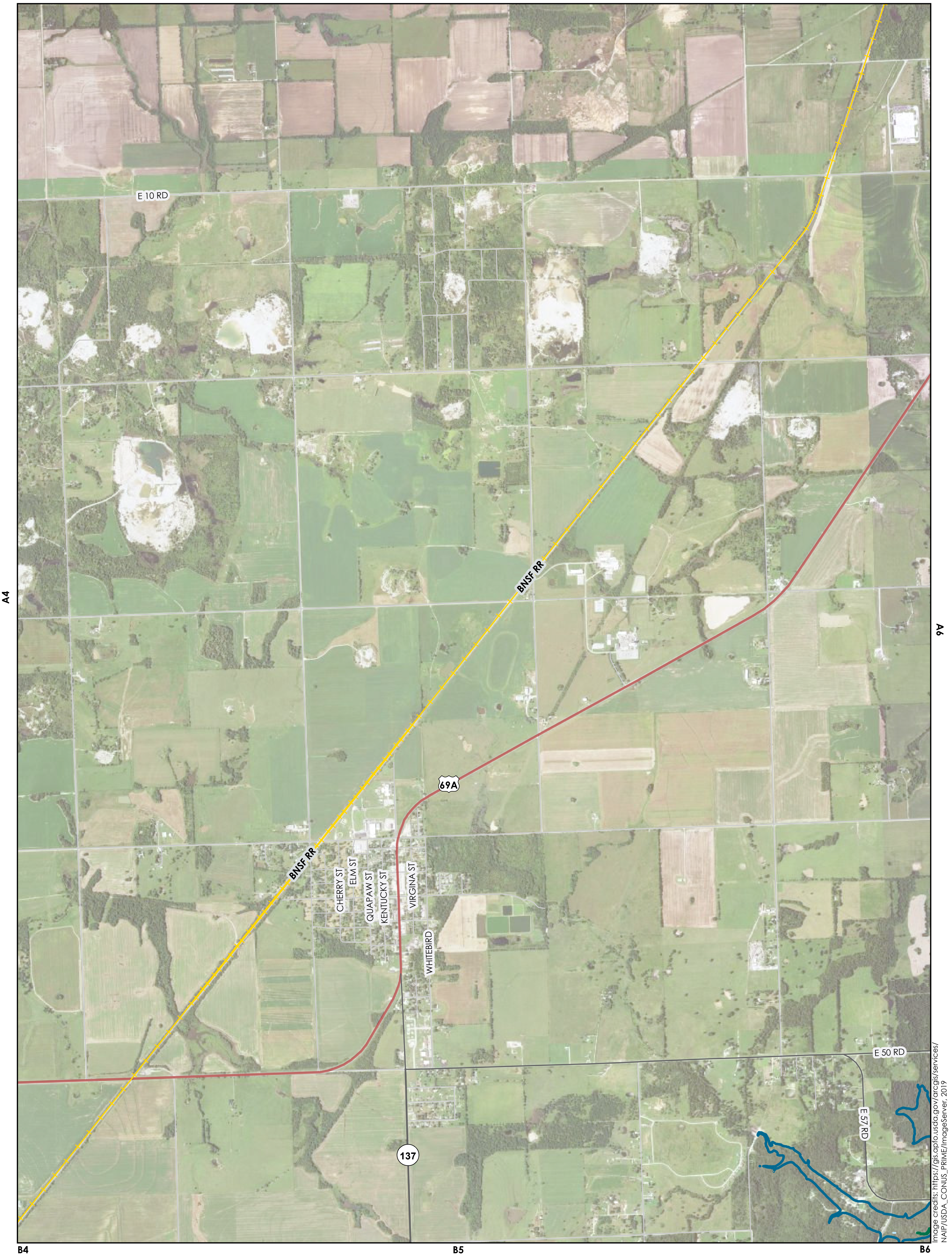
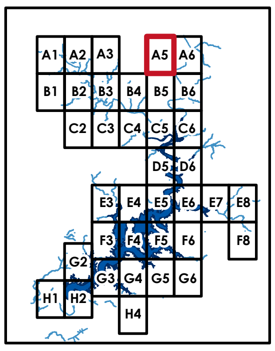


Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

1 inch = 2,000 feet



Legend

INUNDATION

▭	Aquatic Habitat Baseline Operations
▭	Aquatic Habitat Anticipated Operations
▭	Maximum Inundation

ROAD CLASS

═	Interstate
—	State Highway
—	US Highway
—	Major Collector
—	Local Road
┼	Railroad
—	Stream
▪▪▪	Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: A5

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

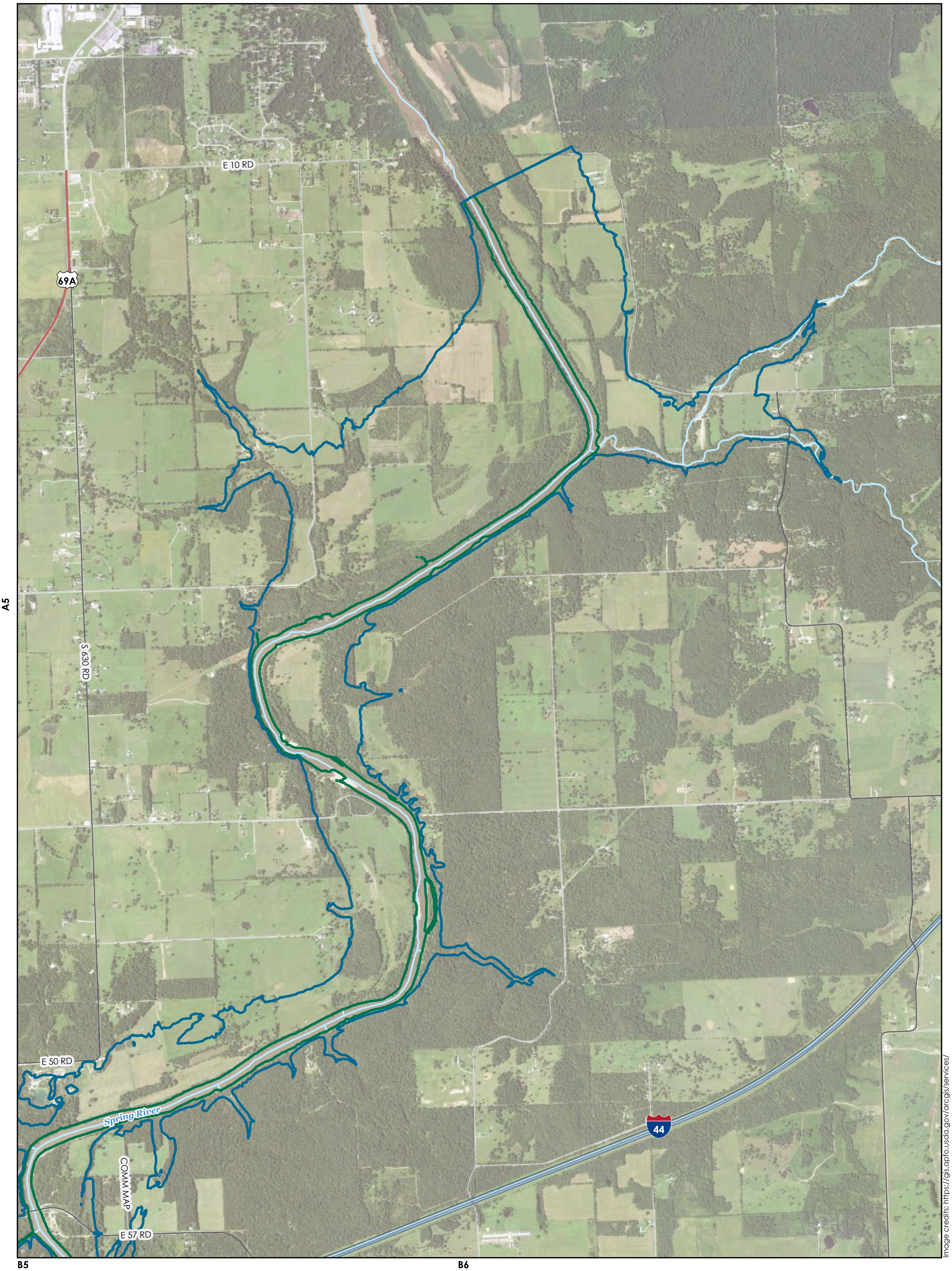


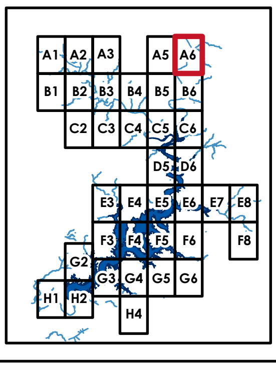
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: A6

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

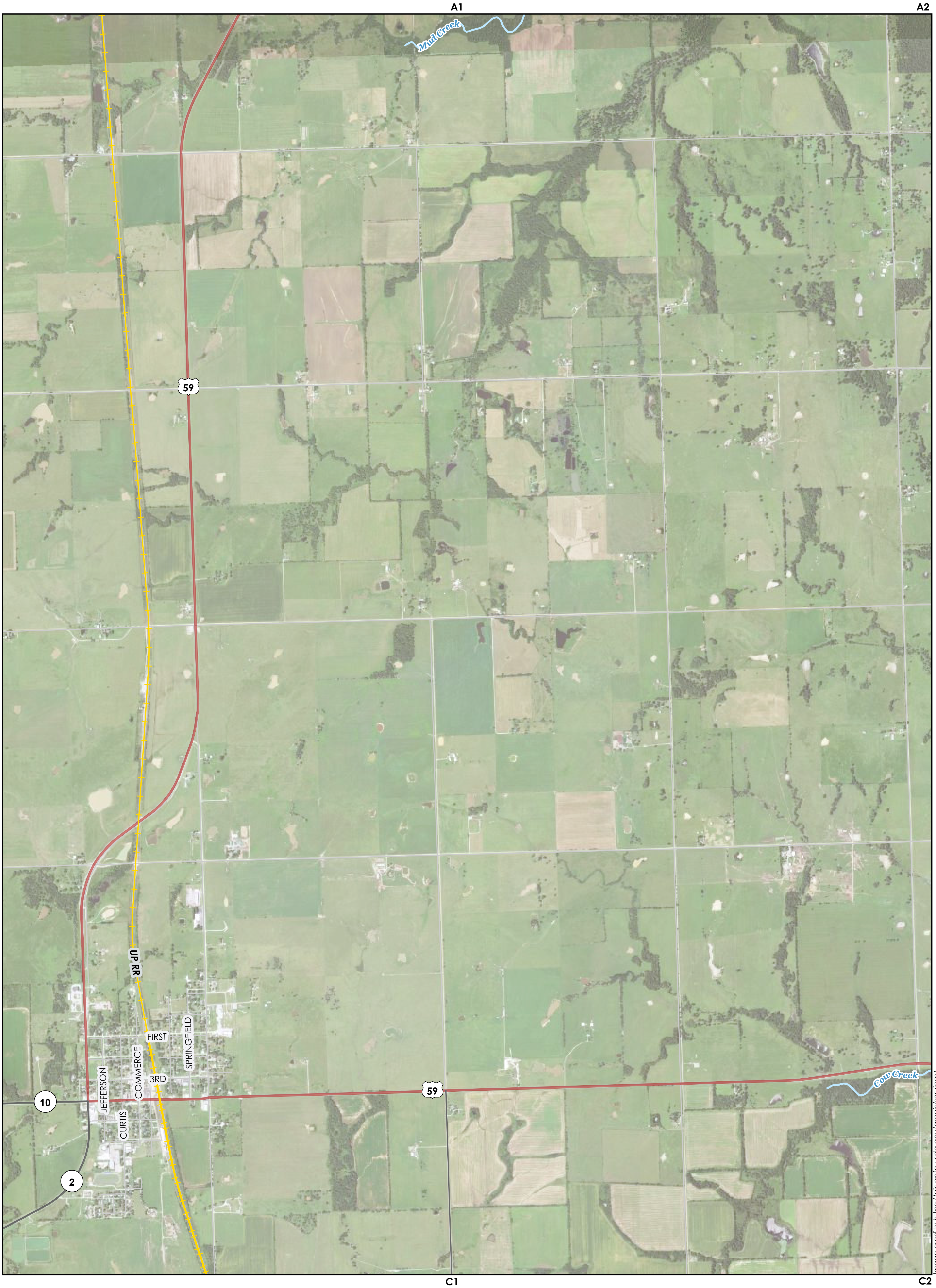
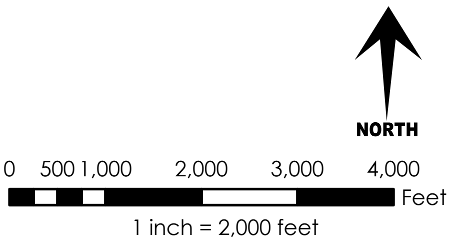
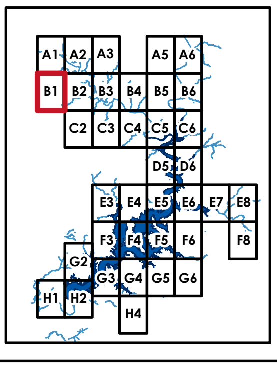


Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES



1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

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2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: B1

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

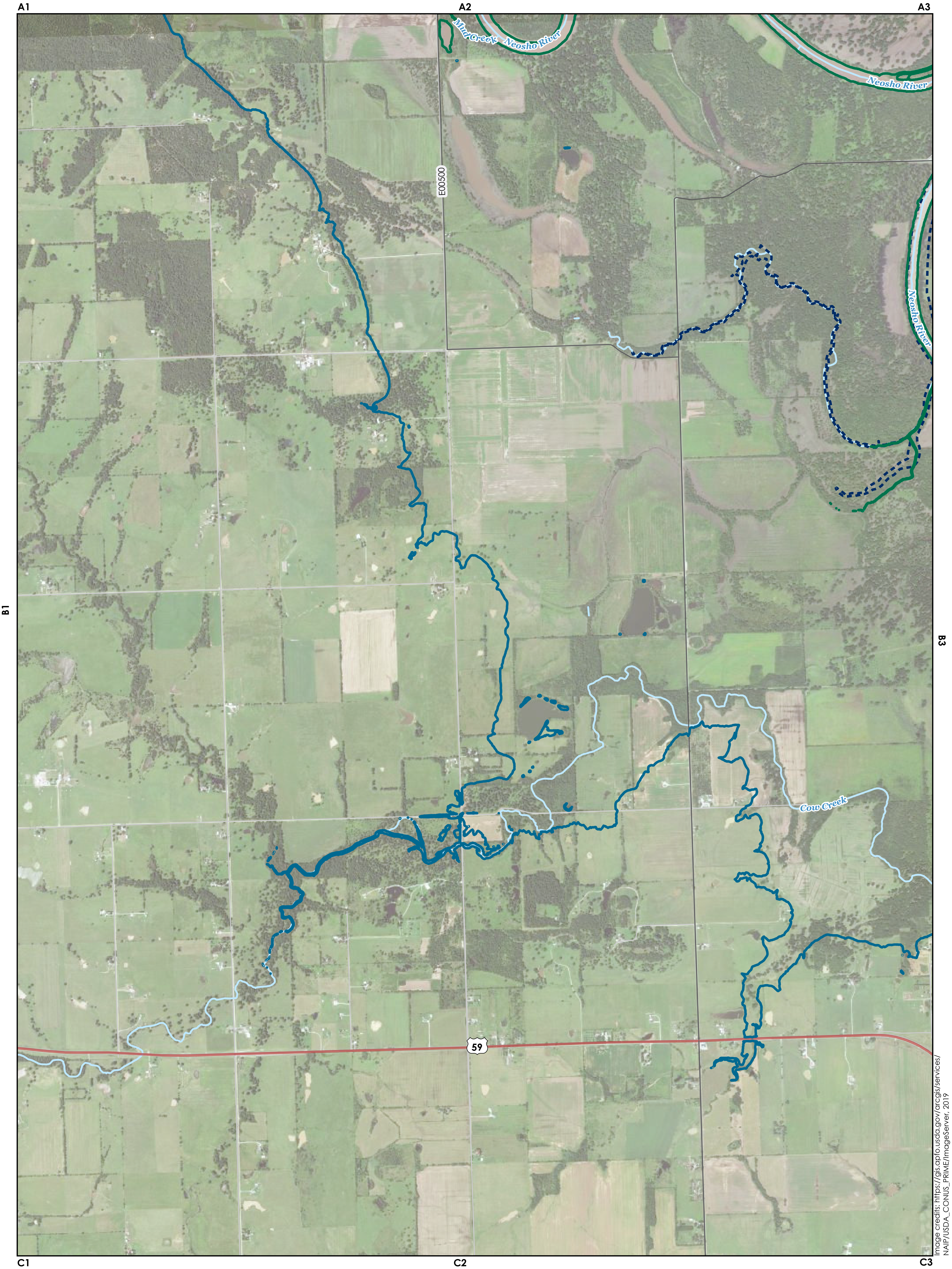


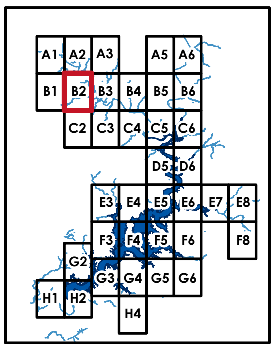
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- Aquatic Habitat Baseline Operations
- Aquatic Habitat Anticipated Operations
- Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
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3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: B2

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

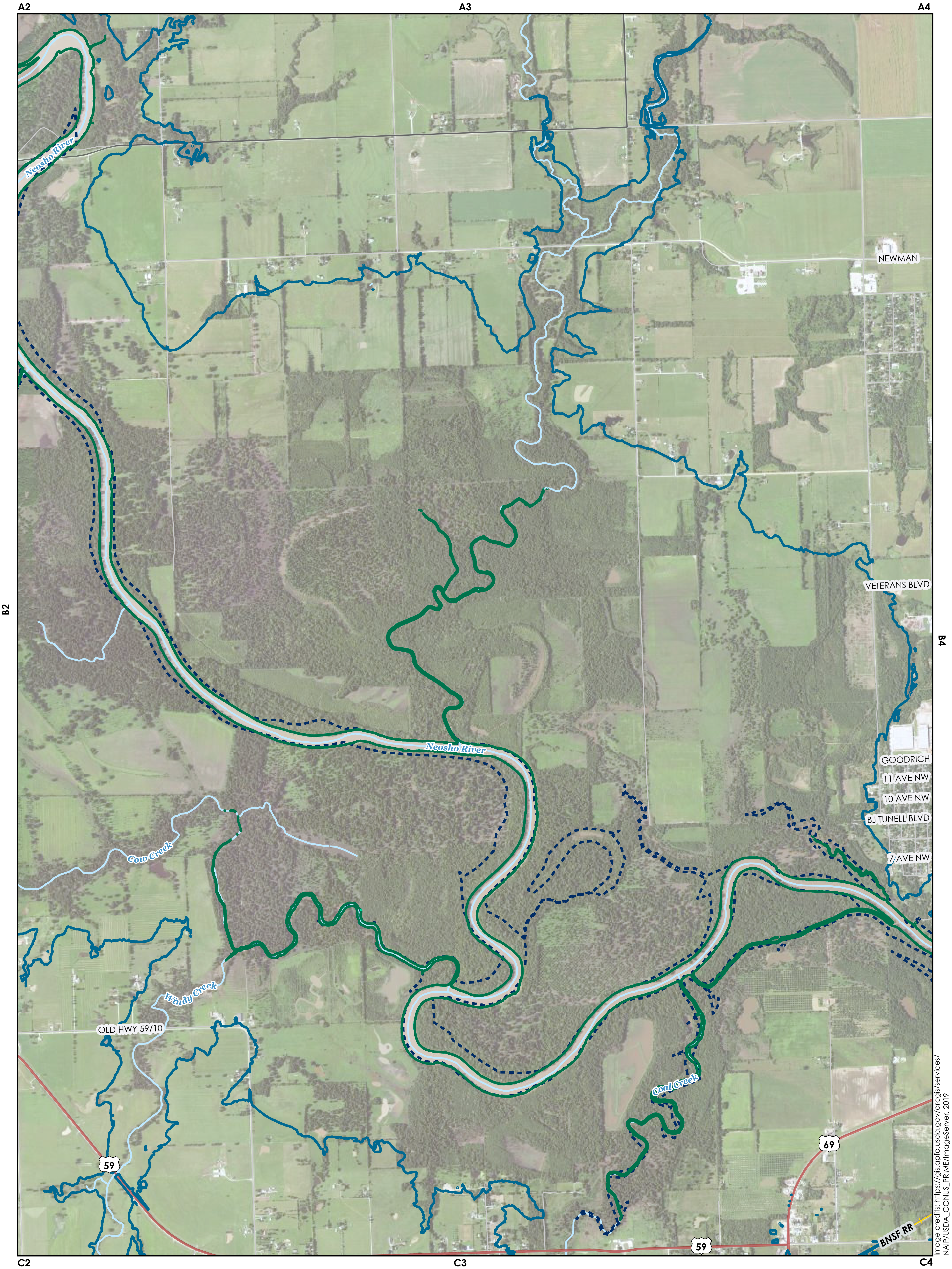


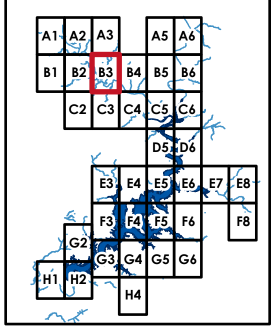
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: B3

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

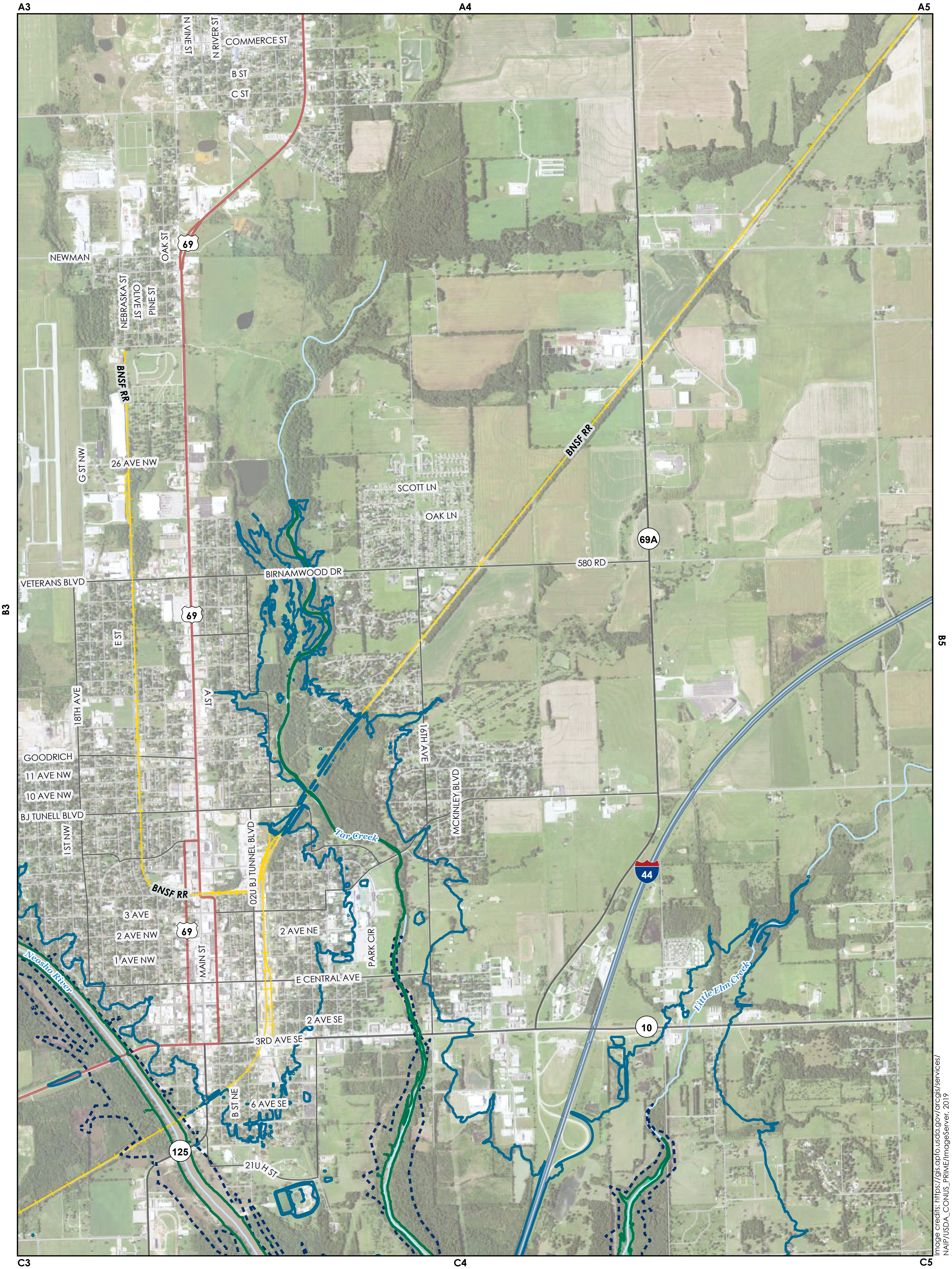
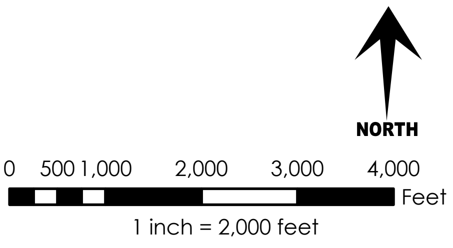
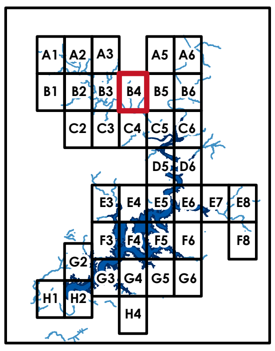


Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES





Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

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PENSACOLA DAM

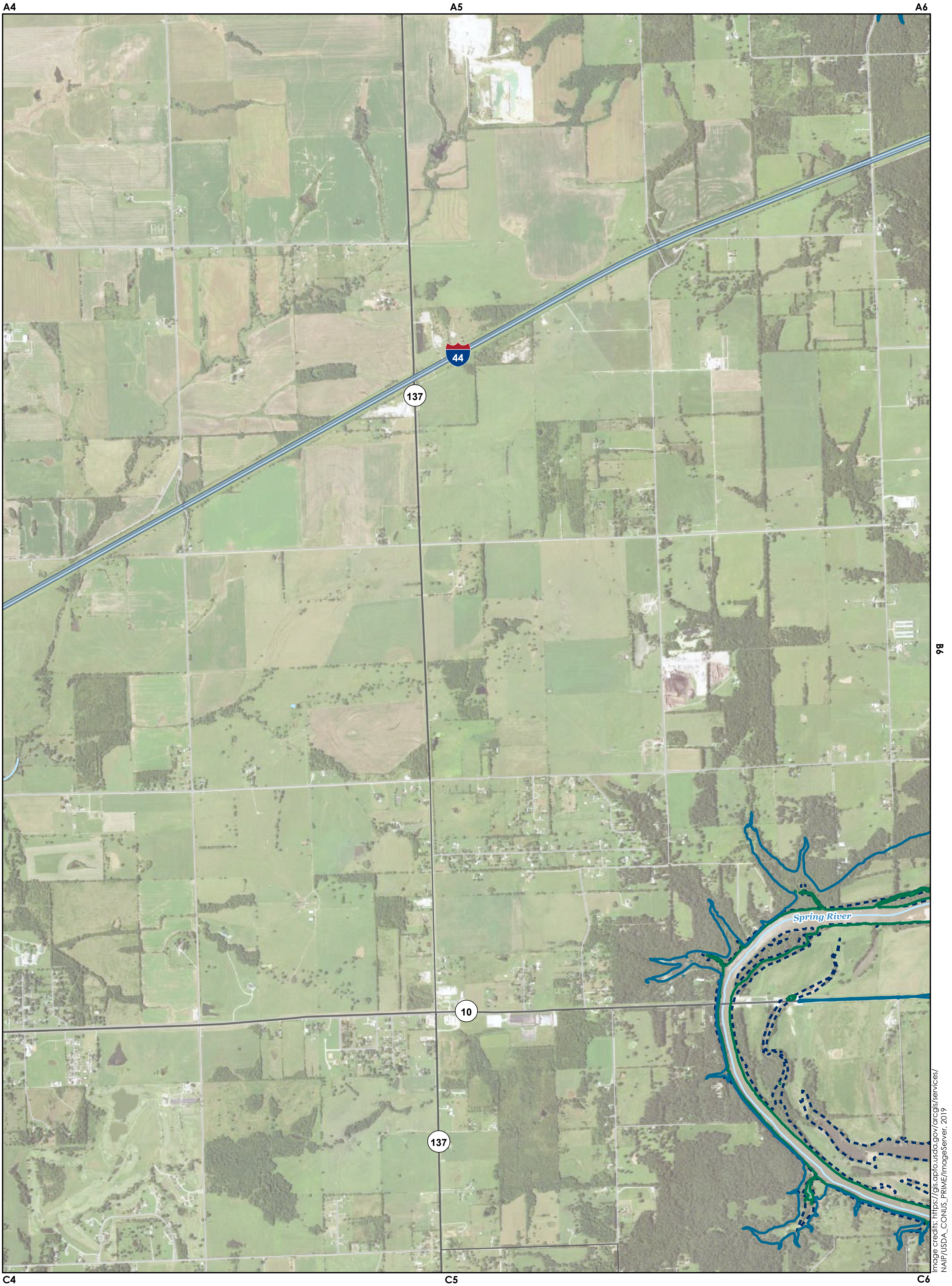
GRAND RIVER DAM AUTHORITY

MAP: B4

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022



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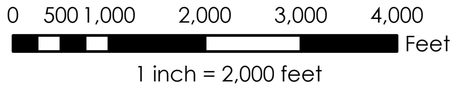
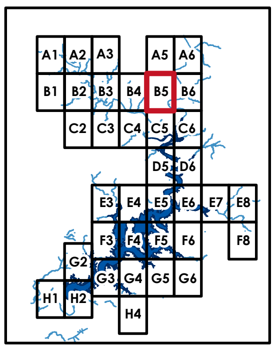
LAKE SPAWNING SPECIES HABITAT CHANGES



1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
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PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: B5

CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494
September 2022

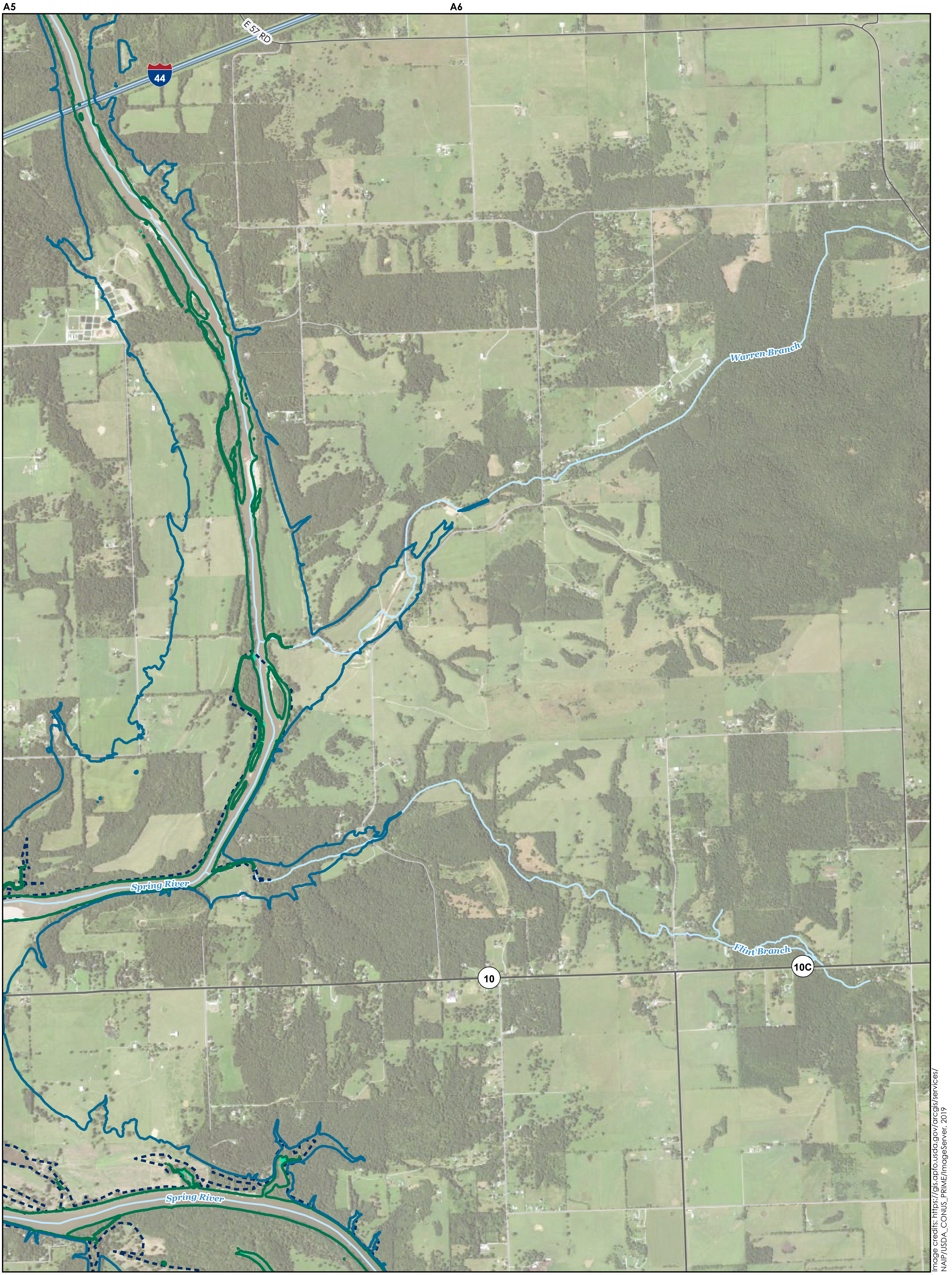


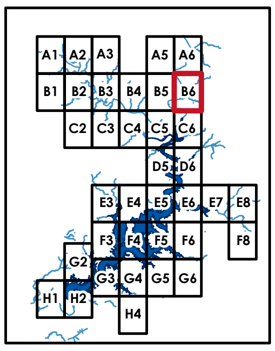
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- Aquatic Habitat Baseline Operations
- Aquatic Habitat Anticipated Operations
- Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

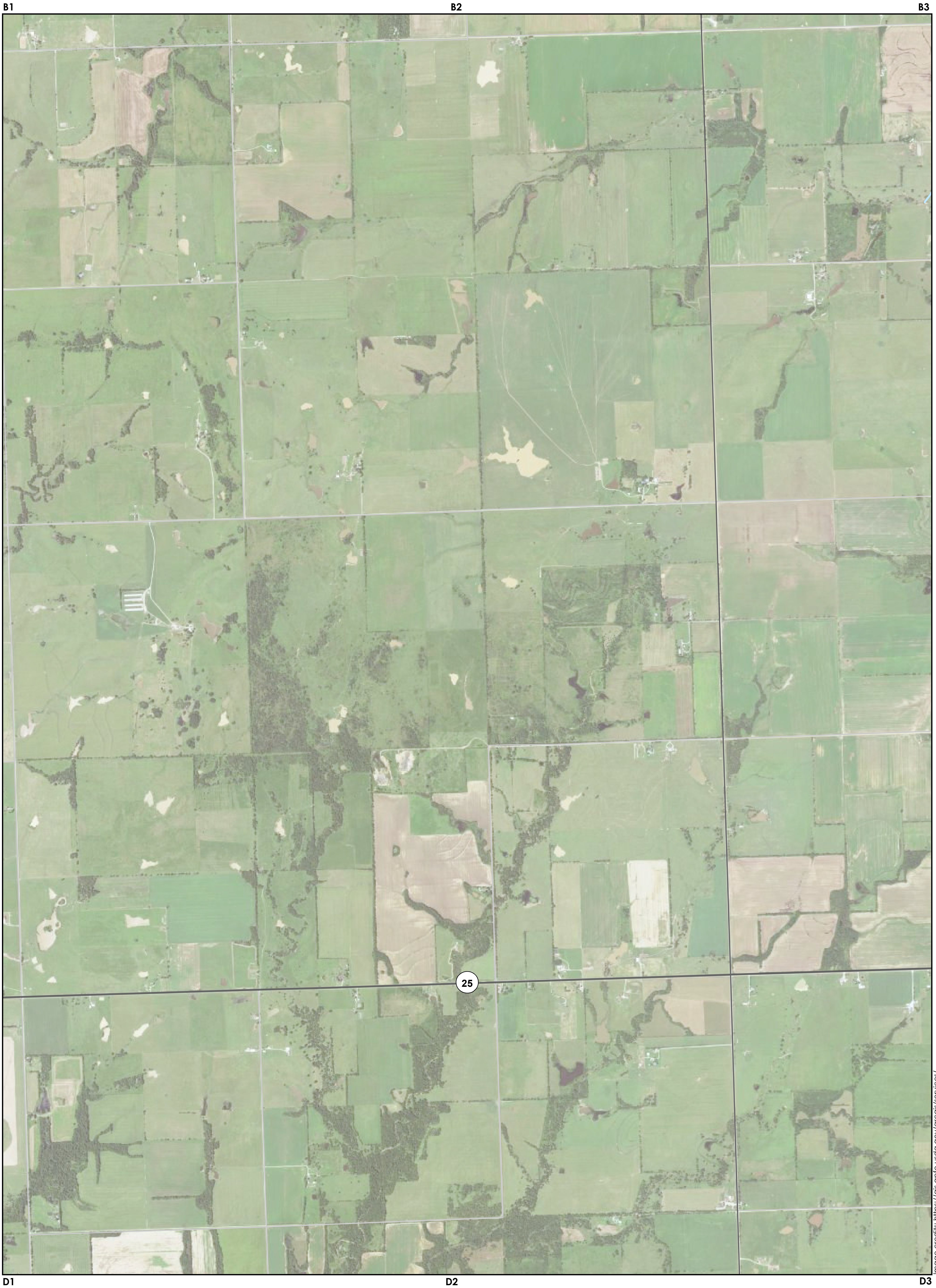
GRAND RIVER DAM AUTHORITY

MAP: B6

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022



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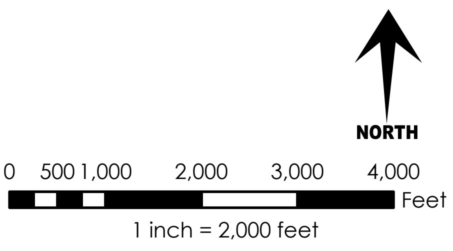
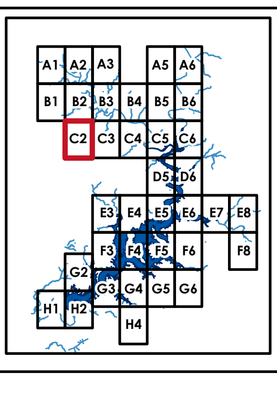
LAKE SPAWNING SPECIES HABITAT CHANGES





Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- ═ Interstate
- — State Highway
- — US Highway
- — Major Collector
- — Local Road
- ┼ Railroad
- — Stream
- ▪▪▪ Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
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PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: C2

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

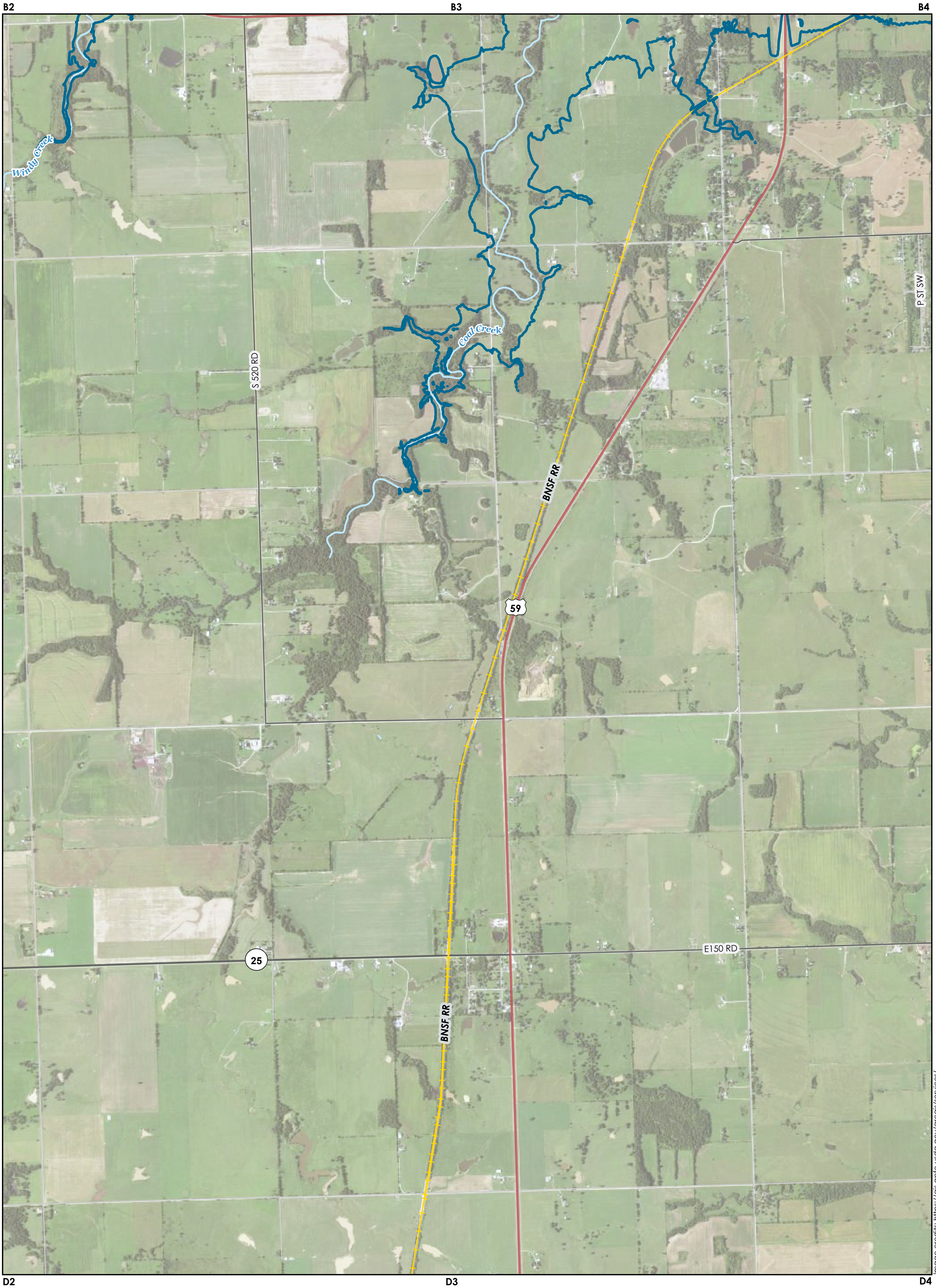


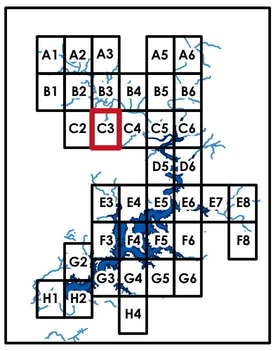
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
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PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: C3

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

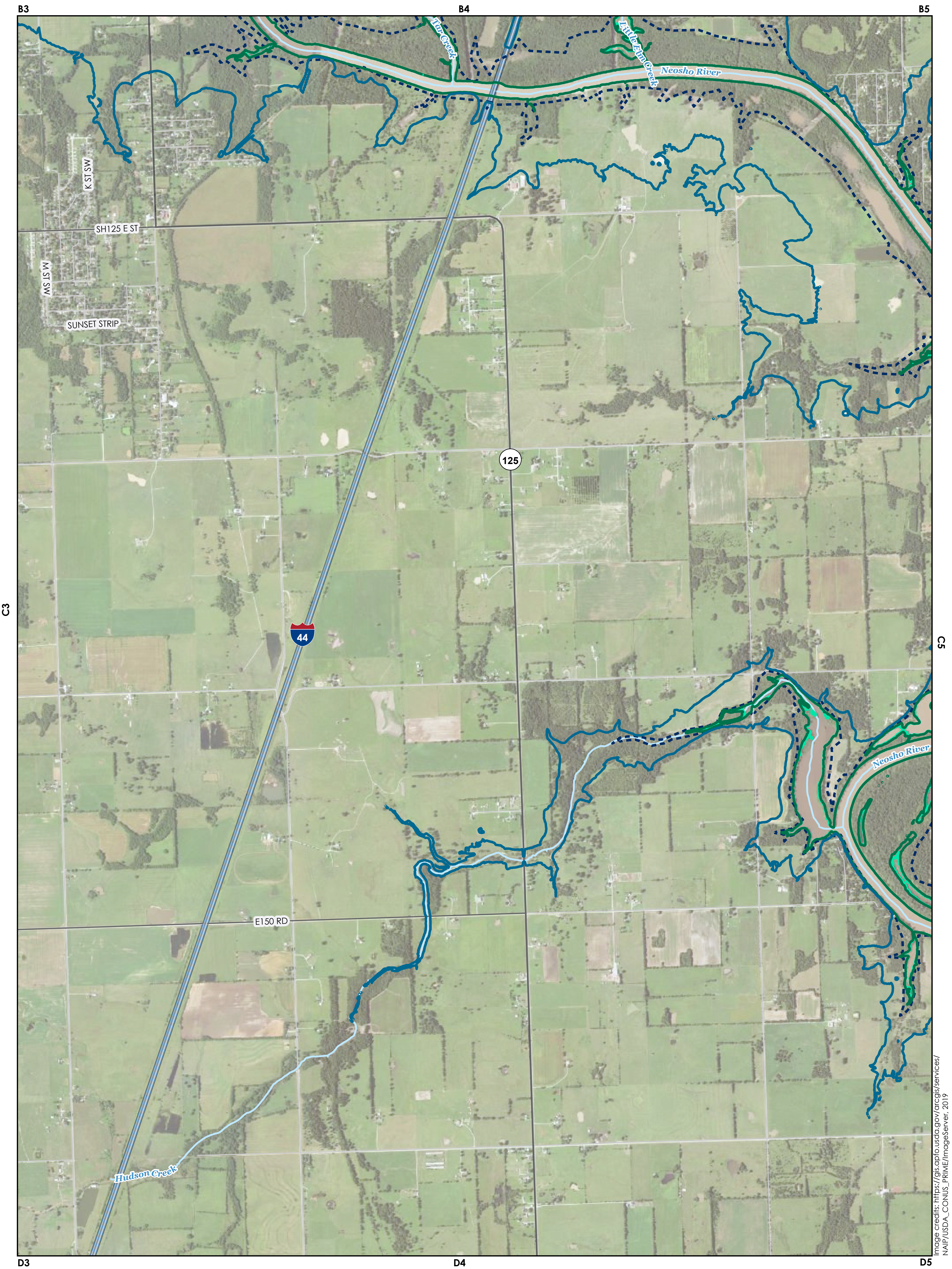


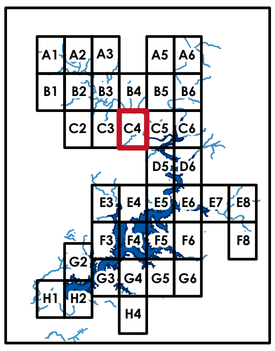
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- ▭ Aquatic Habitat Baseline Operations
- ▭ Aquatic Habitat Anticipated Operations
- ▭ Maximum Inundation

ROAD CLASS

- ═ Interstate
- — State Highway
- — US Highway
- — Major Collector
- — Local Road
- ┼ Railroad
- — Stream
- ┅ Project Boundary (2014)

MAP AND LEGEND NOTES

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PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: C4

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494
September 2022

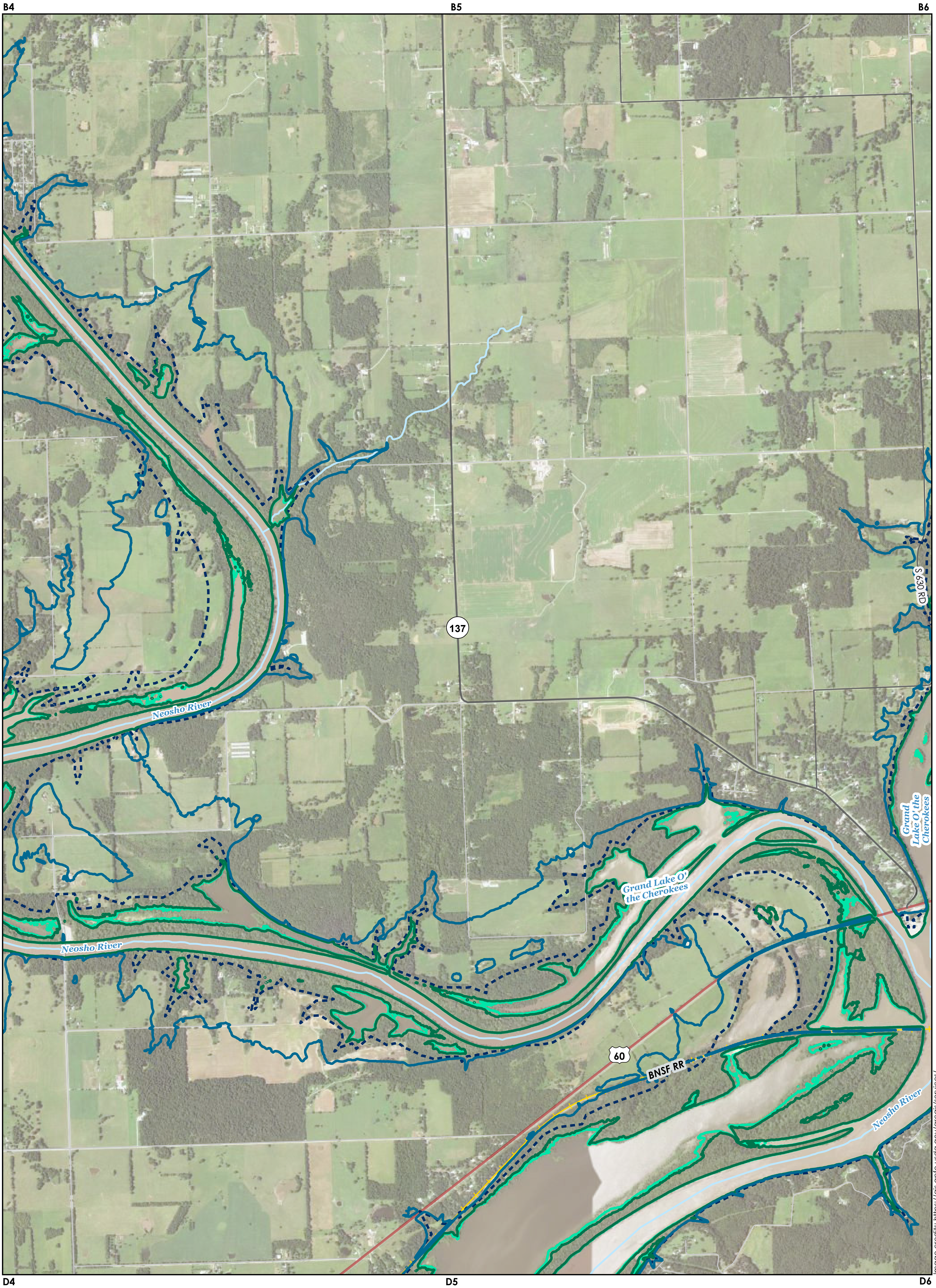


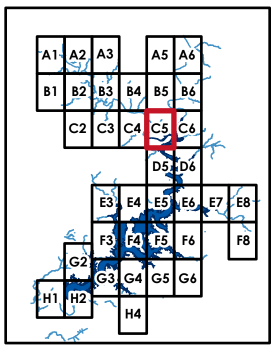
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
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PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: C5

CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494
September 2022

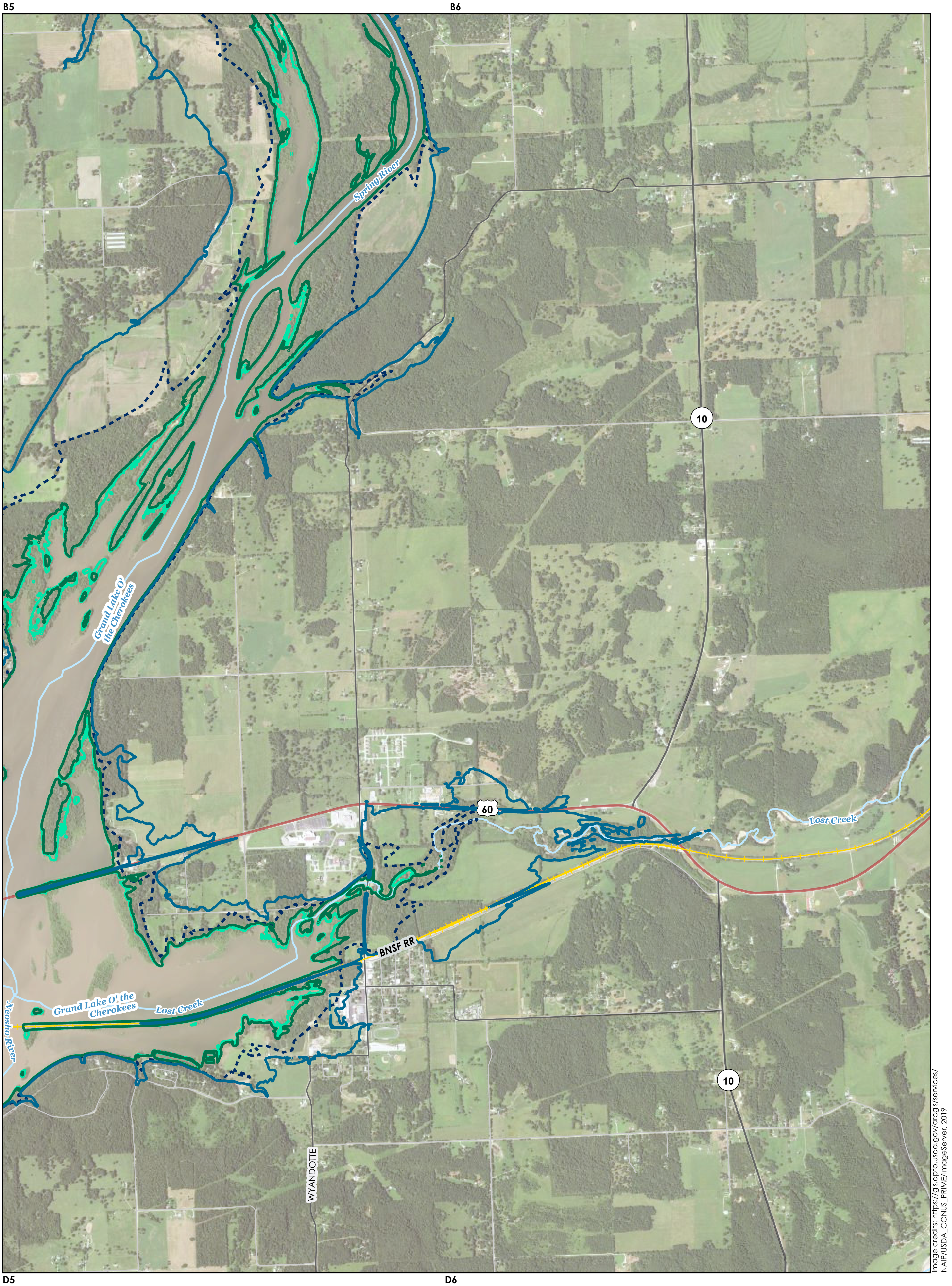
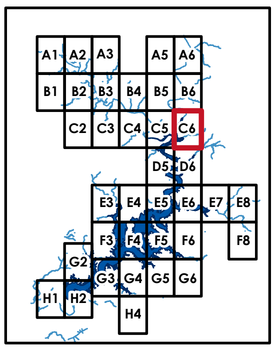


Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

1 inch = 2,000 feet



Legend

INUNDATION

🟩	Aquatic Habitat Baseline Operations
🟩	Aquatic Habitat Anticipated Operations
🟦	Maximum Inundation

ROAD CLASS

═	Interstate
—	State Highway
—	US Highway
—	Major Collector
—	Local Road
┼	Railroad
—	Stream
▪▪▪	Project Boundary (2014)

MAP AND LEGEND NOTES

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PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: C6

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

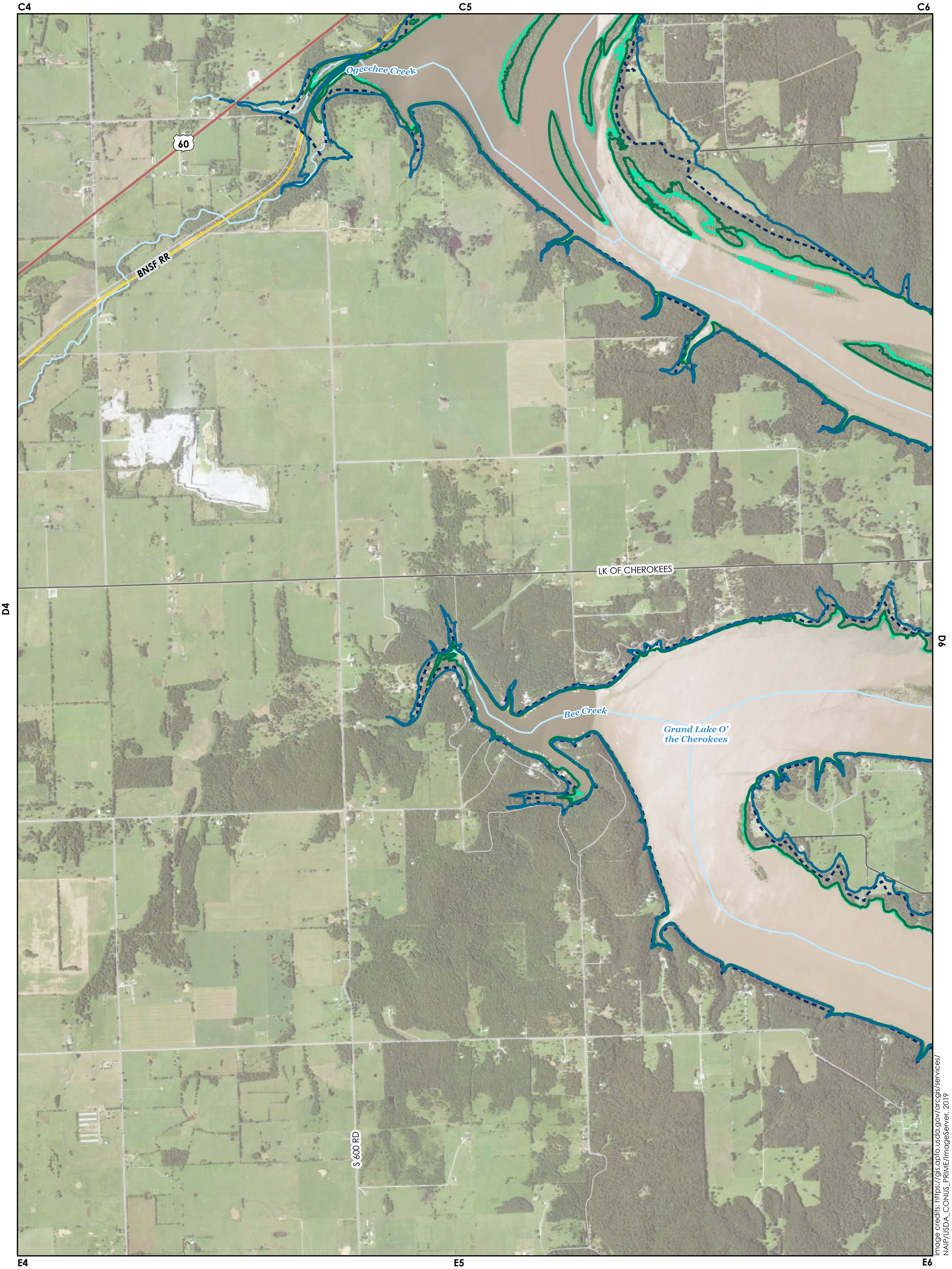


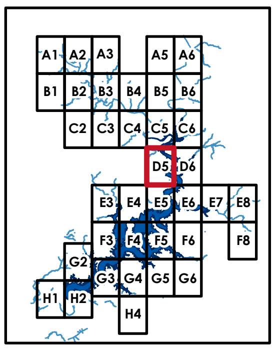
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- ═ Interstate
- — State Highway
- — US Highway
- — Major Collector
- — Local Road
- ┼ Railroad
- — Stream
- ▪▪▪ Project Boundary (2014)

MAP AND LEGEND NOTES

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PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: D5

CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494
September 2022

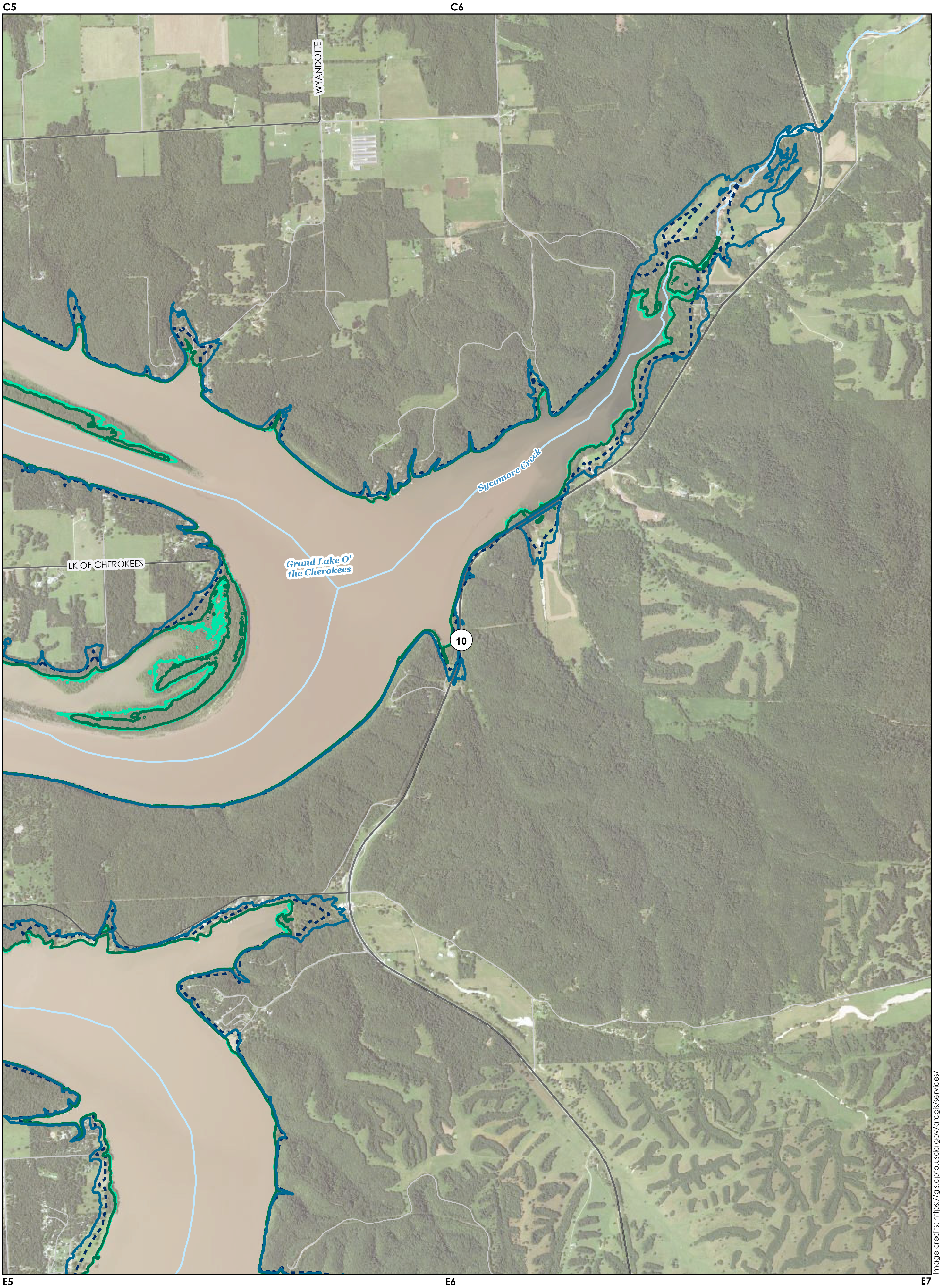
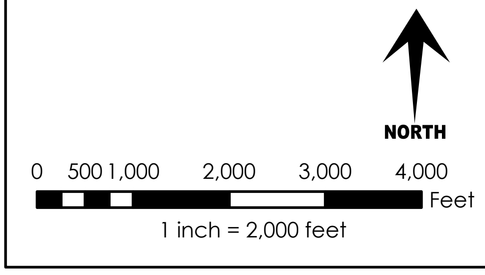
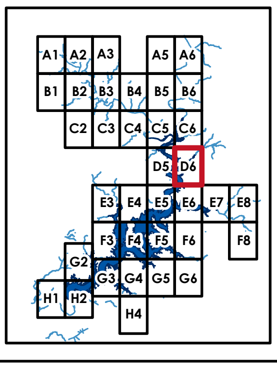


Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES



1 inch = 2,000 feet



Legend

INUNDATION

- ▭ Aquatic Habitat Baseline Operations
- ▭ Aquatic Habitat Anticipated Operations
- ▭ Maximum Inundation

ROAD CLASS

- ═ Interstate
- — State Highway
- — US Highway
- — Major Collector
- — Local Road
- ┼ Railroad
- — Stream
- ▪▪▪ Project Boundary (2014)

MAP AND LEGEND NOTES

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PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: D6

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

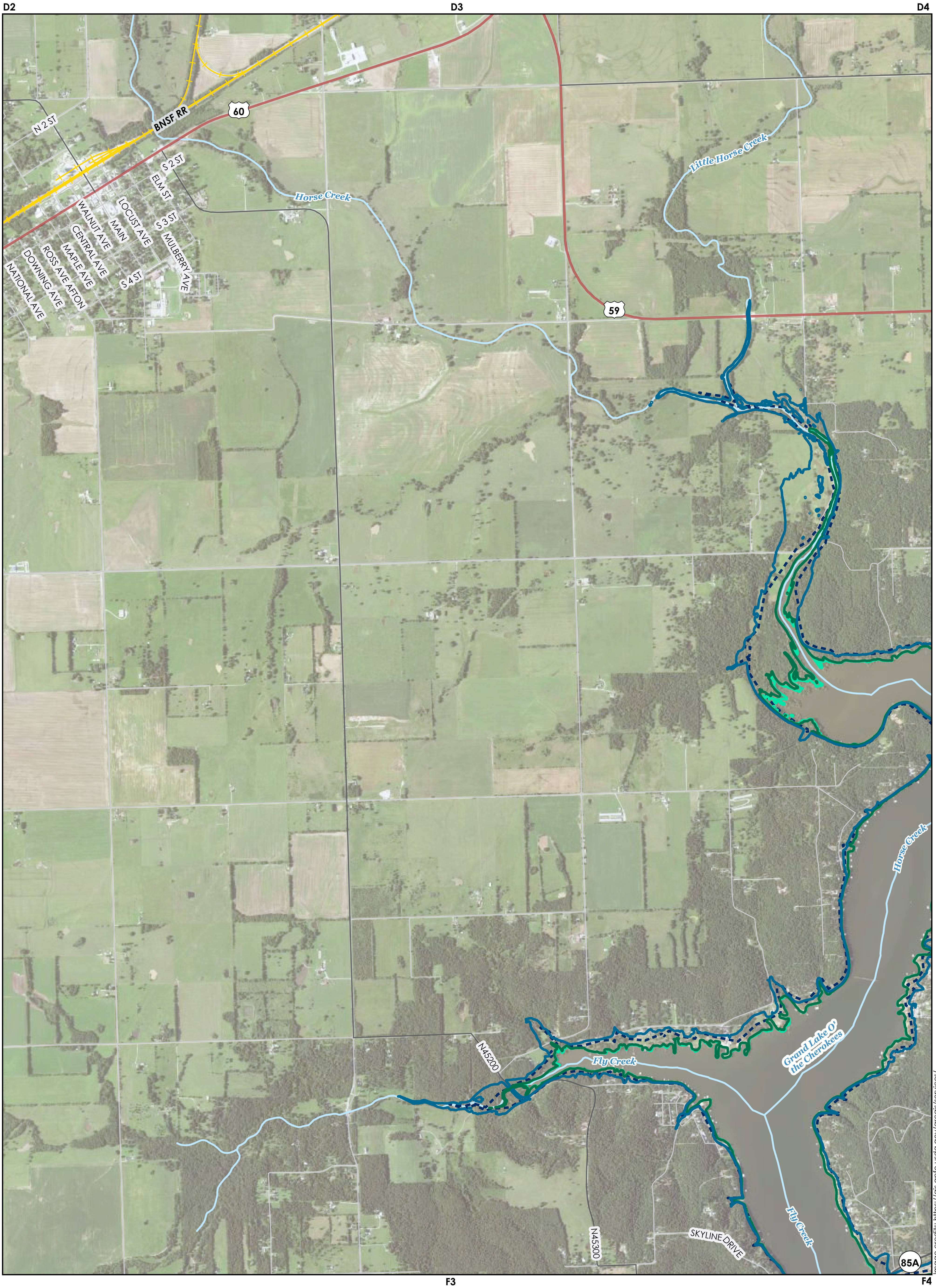


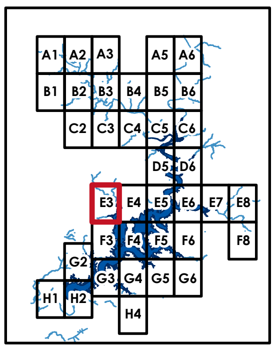
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

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2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
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PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: E3

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

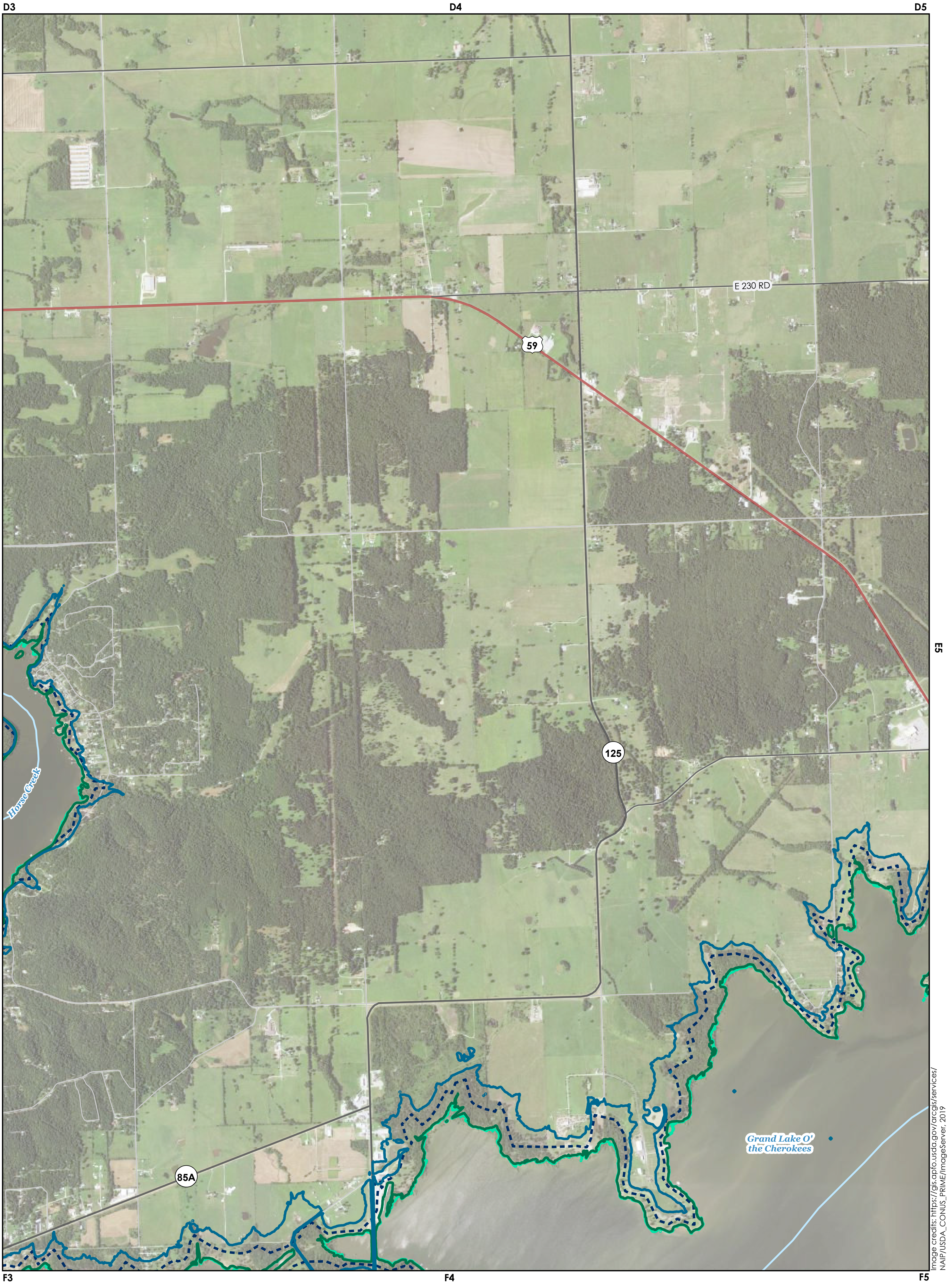


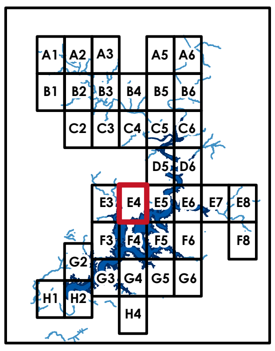
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- ▭ Aquatic Habitat Baseline Operations
- ▭ Aquatic Habitat Anticipated Operations
- ▭ Maximum Inundation

ROAD CLASS

- ═ Interstate
- — State Highway
- — US Highway
- — Major Collector
- — Local Road
- ┼ Railroad
- — Stream
- ▪▪▪ Project Boundary (2014)

MAP AND LEGEND NOTES

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PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: E4

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

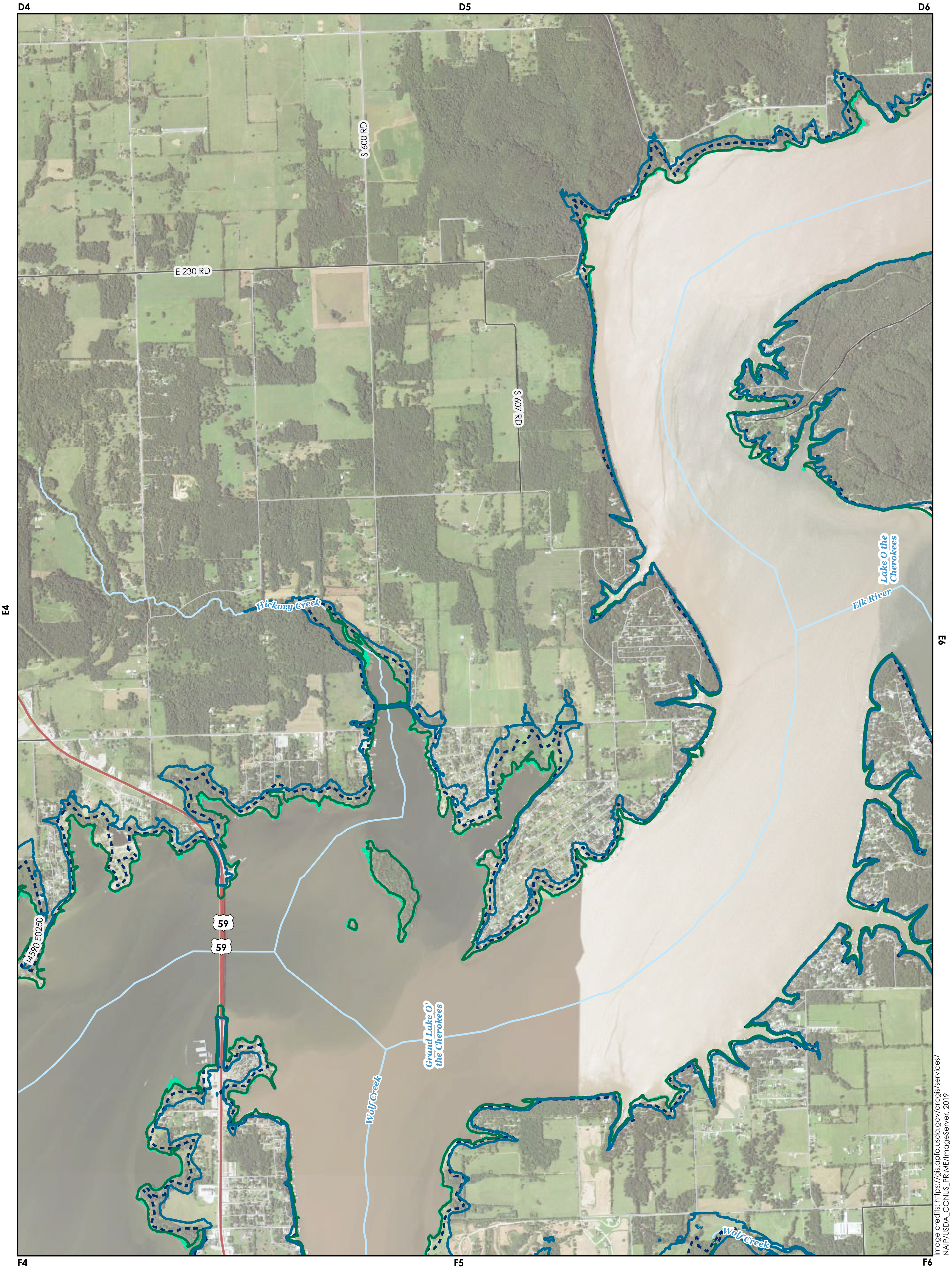


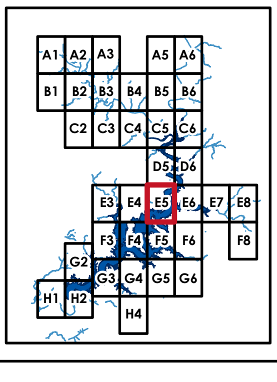
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

▭	Aquatic Habitat Baseline Operations
▭	Aquatic Habitat Anticipated Operations
▭	Maximum Inundation

ROAD CLASS

═	Interstate
─	State Highway
─	US Highway
─	Major Collector
─	Local Road
┼	Railroad
─	Stream
╍	Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
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3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: E5

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

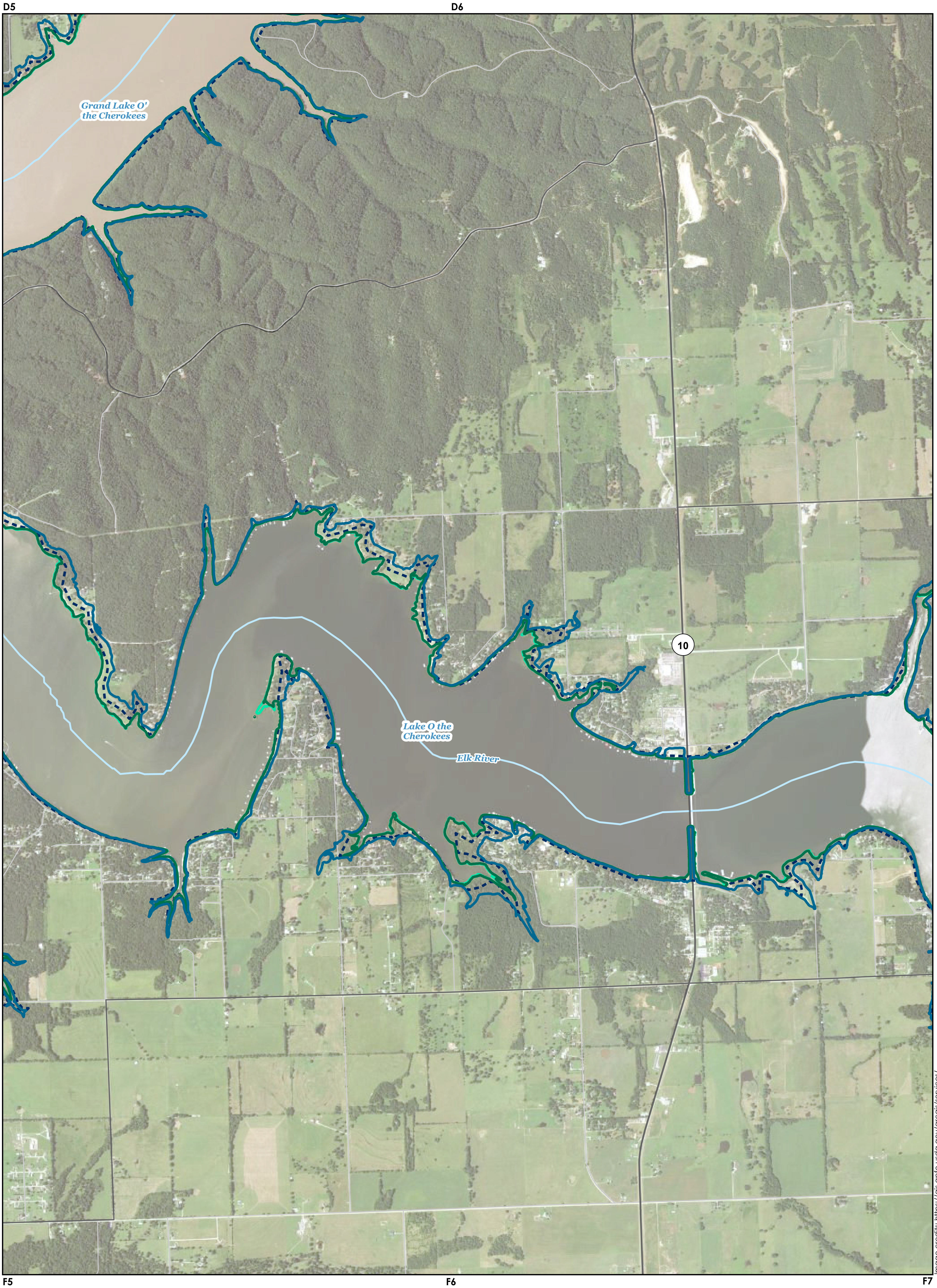


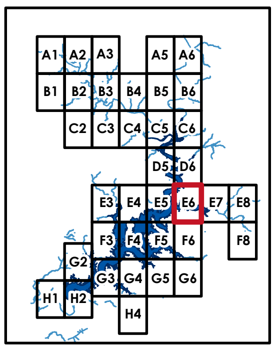
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- — Interstate
- — State Highway
- — US Highway
- — Major Collector
- — Local Road
- ┼ Railroad
- — Stream
- ▪▪▪ Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: E6

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

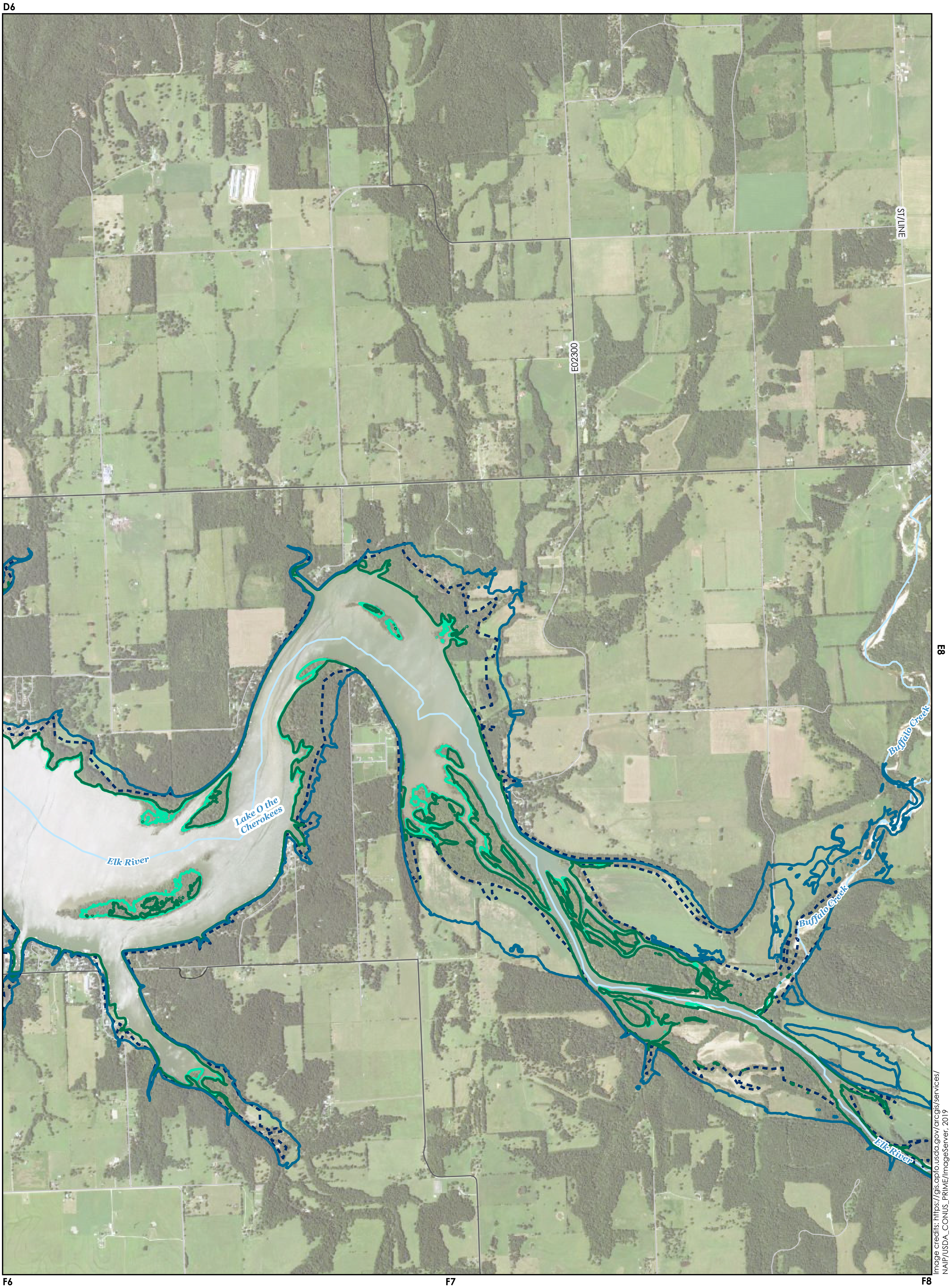


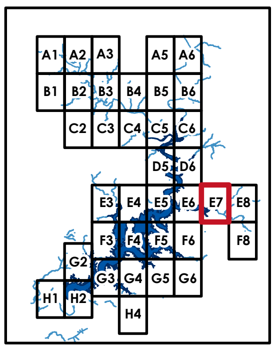
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- ═ Interstate
- — State Highway
- — US Highway
- — Major Collector
- — Local Road
- ┼ Railroad
- — Stream
- ▪▪▪ Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: E7

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

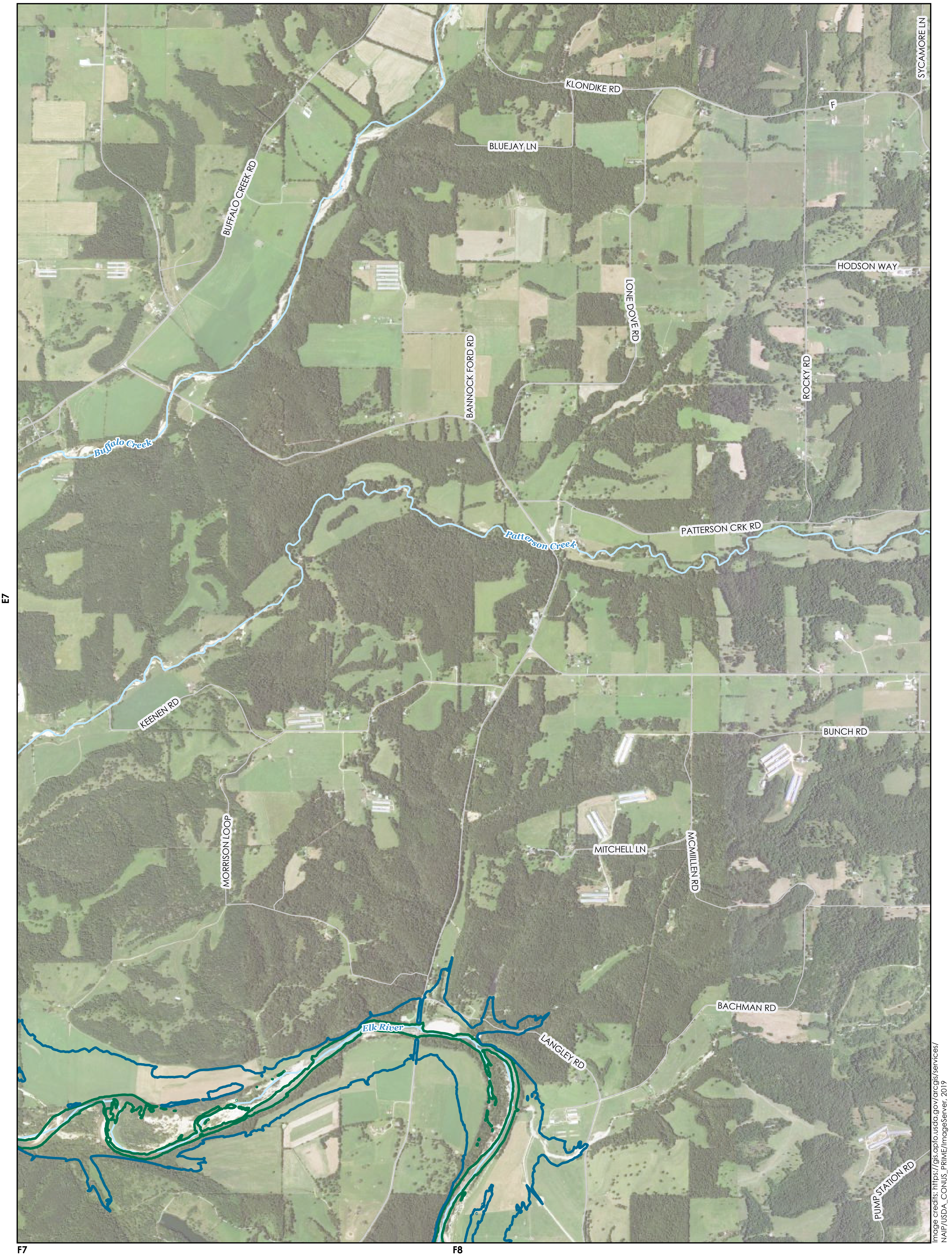
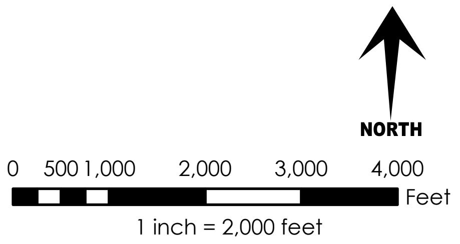
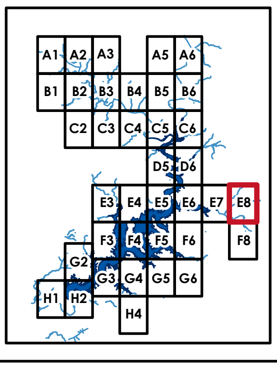


Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES





Legend

INUNDATION

🟩	Aquatic Habitat Baseline Operations
🟩	Aquatic Habitat Anticipated Operations
🟦	Maximum Inundation

ROAD CLASS

═	Interstate
—	State Highway
—	US Highway
—	Major Collector
—	Local Road
┼	Railroad
—	Stream
▪▪▪	Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

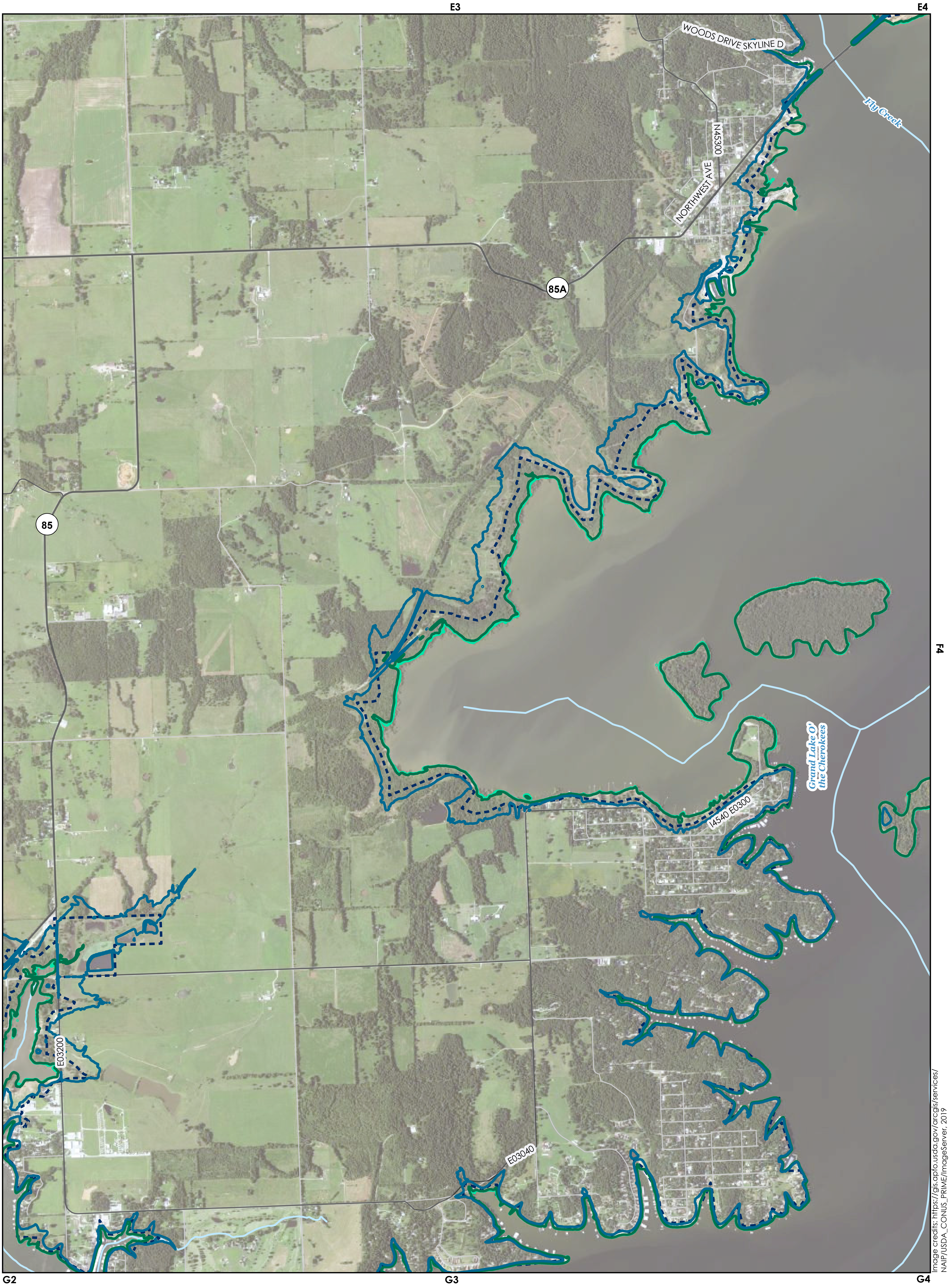
PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

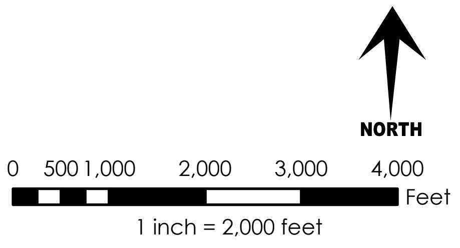
MAP: E8

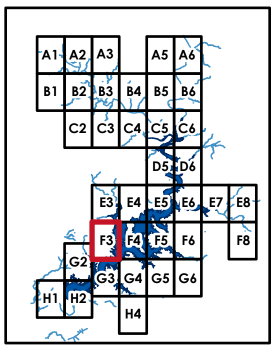
CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494
September 2022


E3
E4
WOODS DRIVE SKYLINE D
Fly Creek
N45300
NORTHWEST AVE
85A
85
F4
Grand Lake O' the Cherokees
14540 E0300
E03200
E03040
G2
G3
G4
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES





Legend

INUNDATION

🟩	Aquatic Habitat Baseline Operations
🟩	Aquatic Habitat Anticipated Operations
🟦	Maximum Inundation

ROAD CLASS

═	Interstate
―	State Highway
―	US Highway
―	Major Collector
―	Local Road
┼	Railroad
―	Stream
▪▪▪	Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM
GRAND RIVER DAM AUTHORITY

MAP: F3

CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494
September 2022

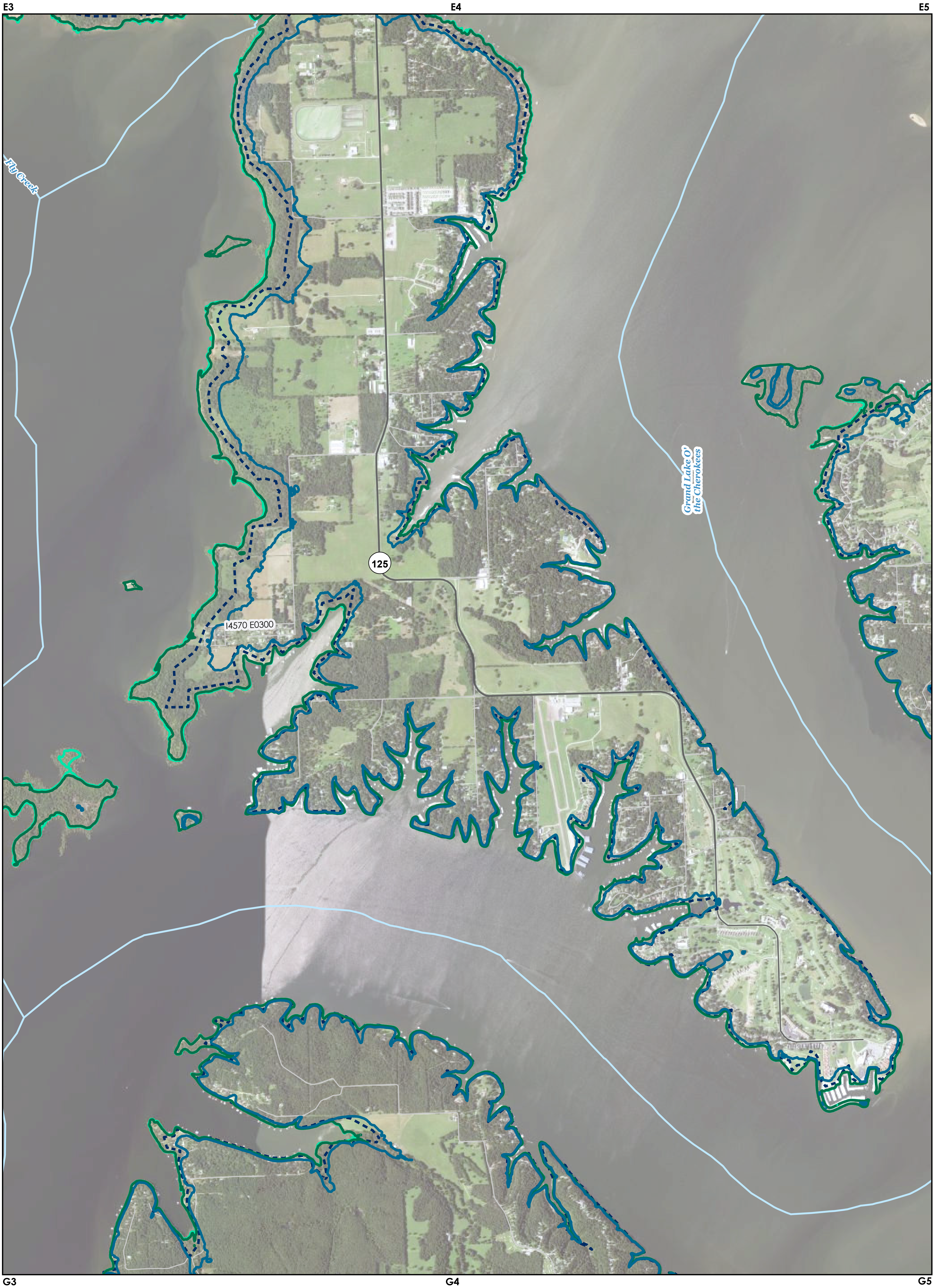


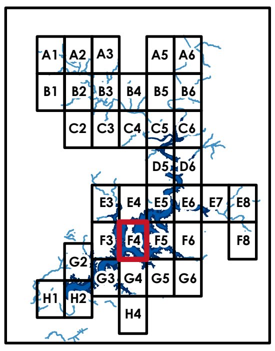
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: F4

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

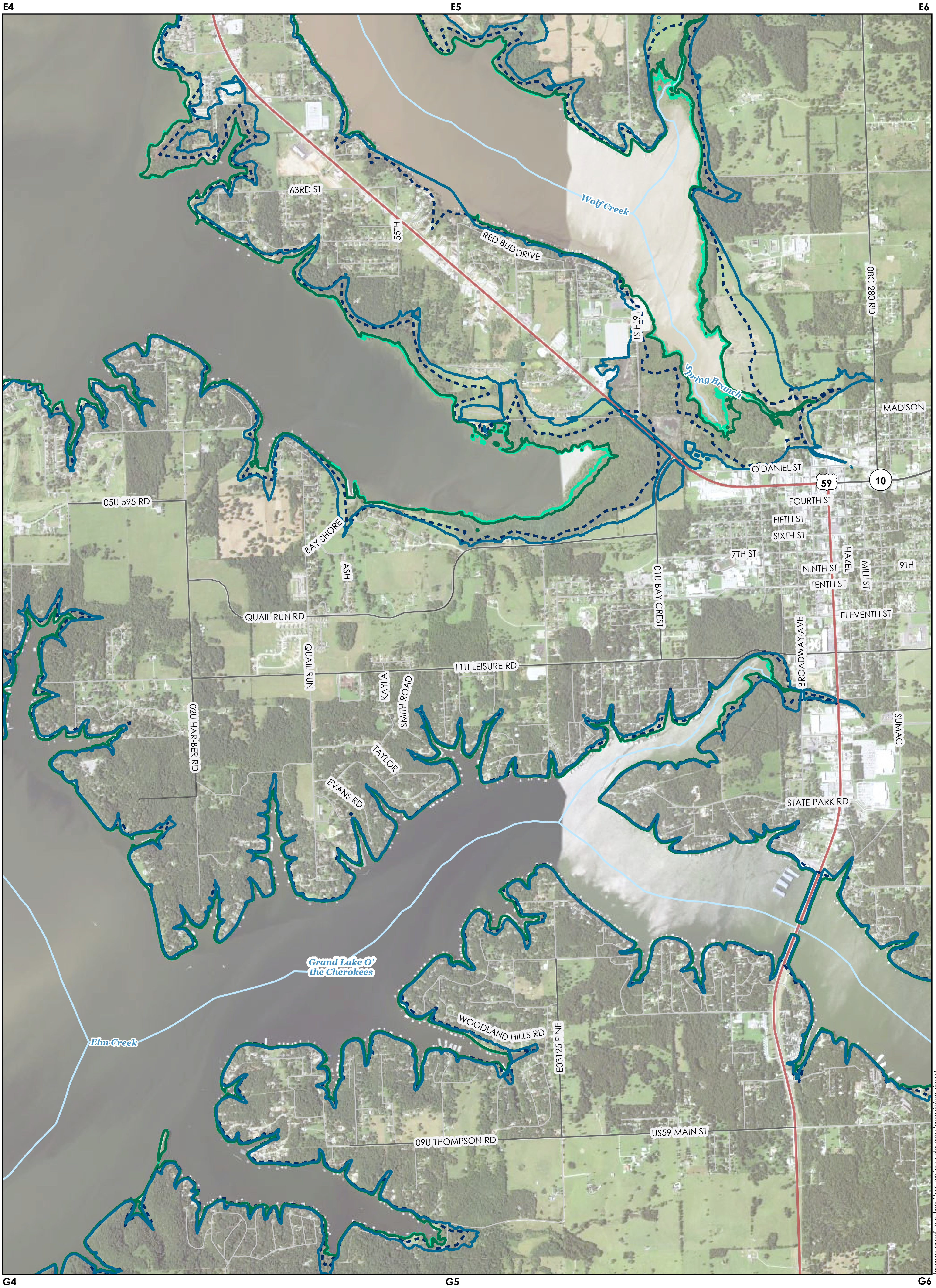


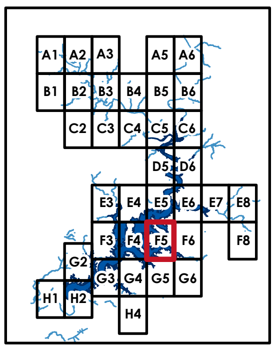
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

🟩	Aquatic Habitat Baseline Operations
🟩	Aquatic Habitat Anticipated Operations
🟦	Maximum Inundation

ROAD CLASS

═	Interstate
—	State Highway
—	US Highway
—	Major Collector
—	Local Road
┼	Railroad
—	Stream
▪▪▪	Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

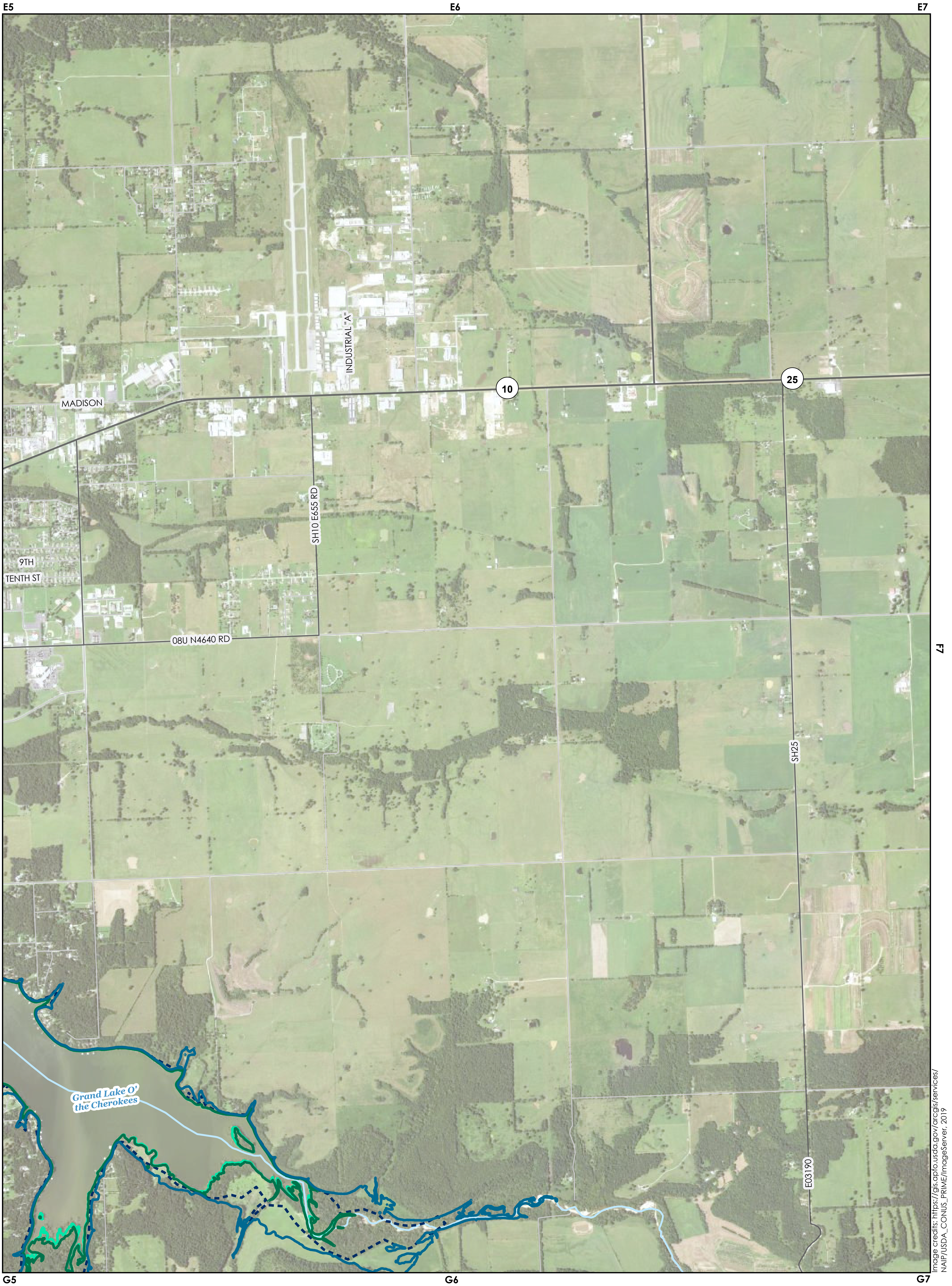
GRAND RIVER DAM AUTHORITY

MAP: F5

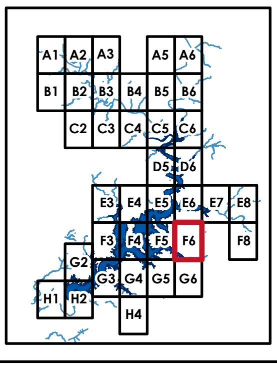
CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022


E5
E6
E7
F5
F7
G5
G6
G7
MADISON
INDUSTRIAL "A"
10
25
SH10 E655 RD
9TH
TENTH ST
08U N4640 RD
SH25
E03190
Grand Lake O' the Cherokees
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: F6

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

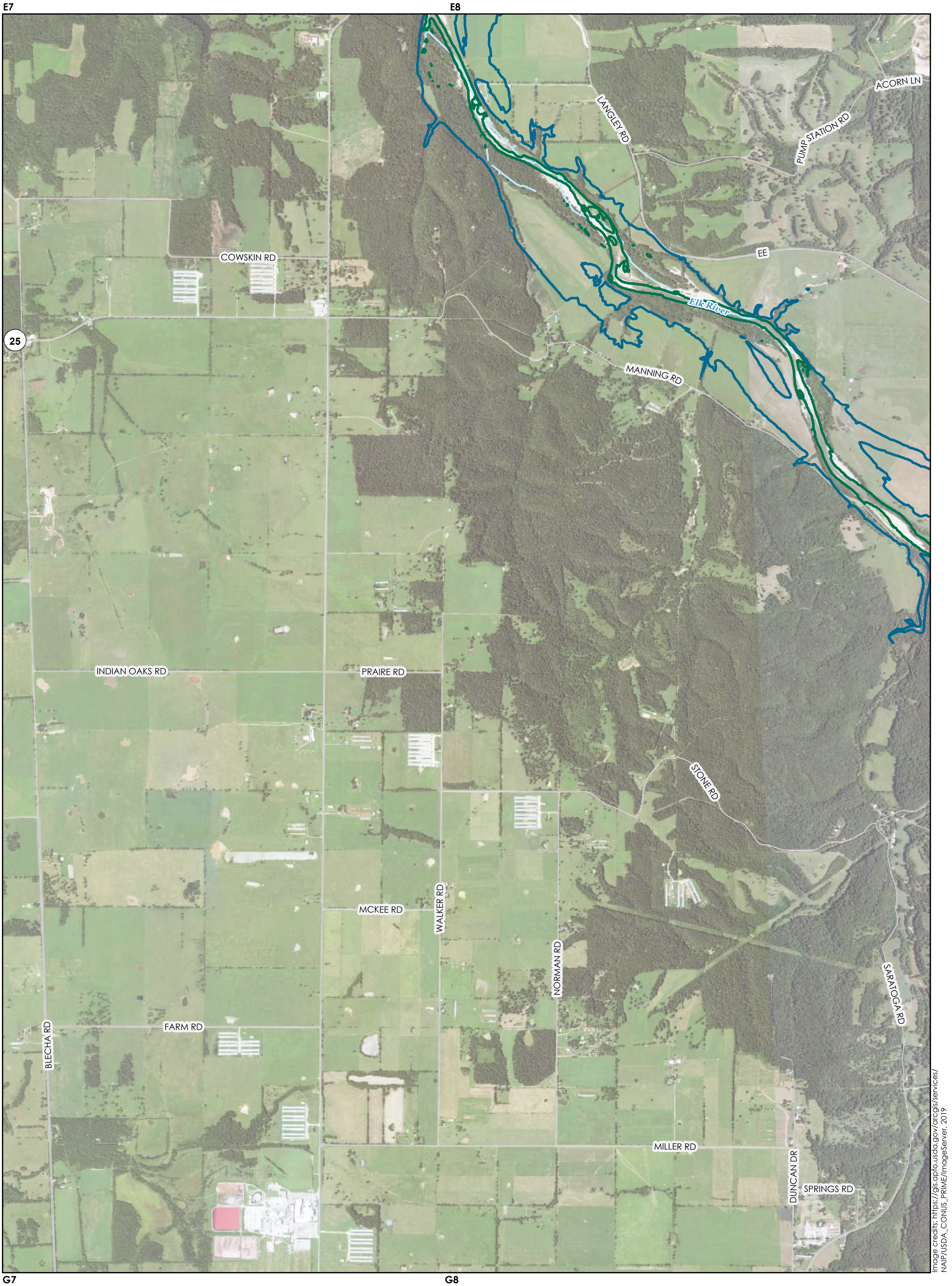


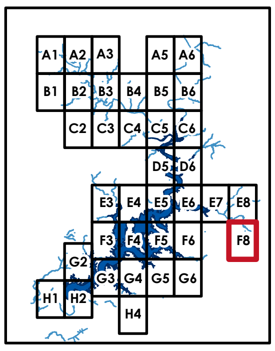
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: F8

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

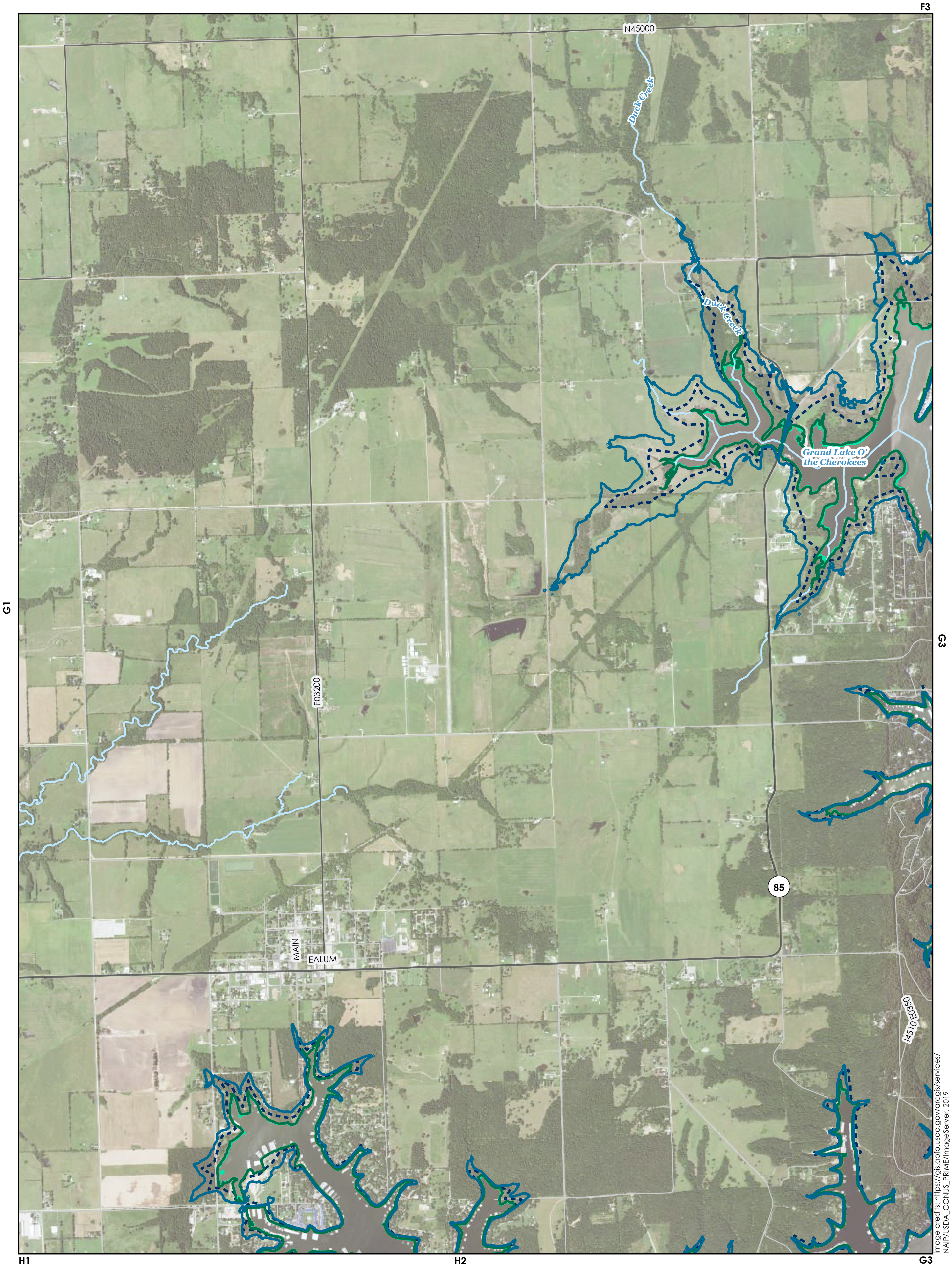
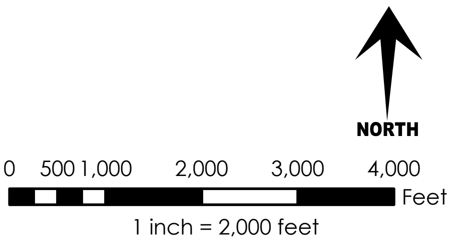
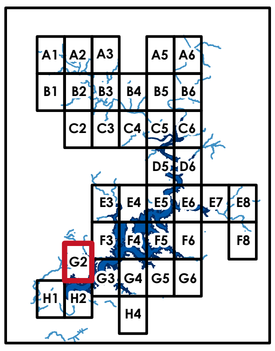


Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES



1 inch = 2,000 feet



Legend

INUNDATION

- Aquatic Habitat Baseline Operations
- Aquatic Habitat Anticipated Operations
- Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: G2

CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494
September 2022

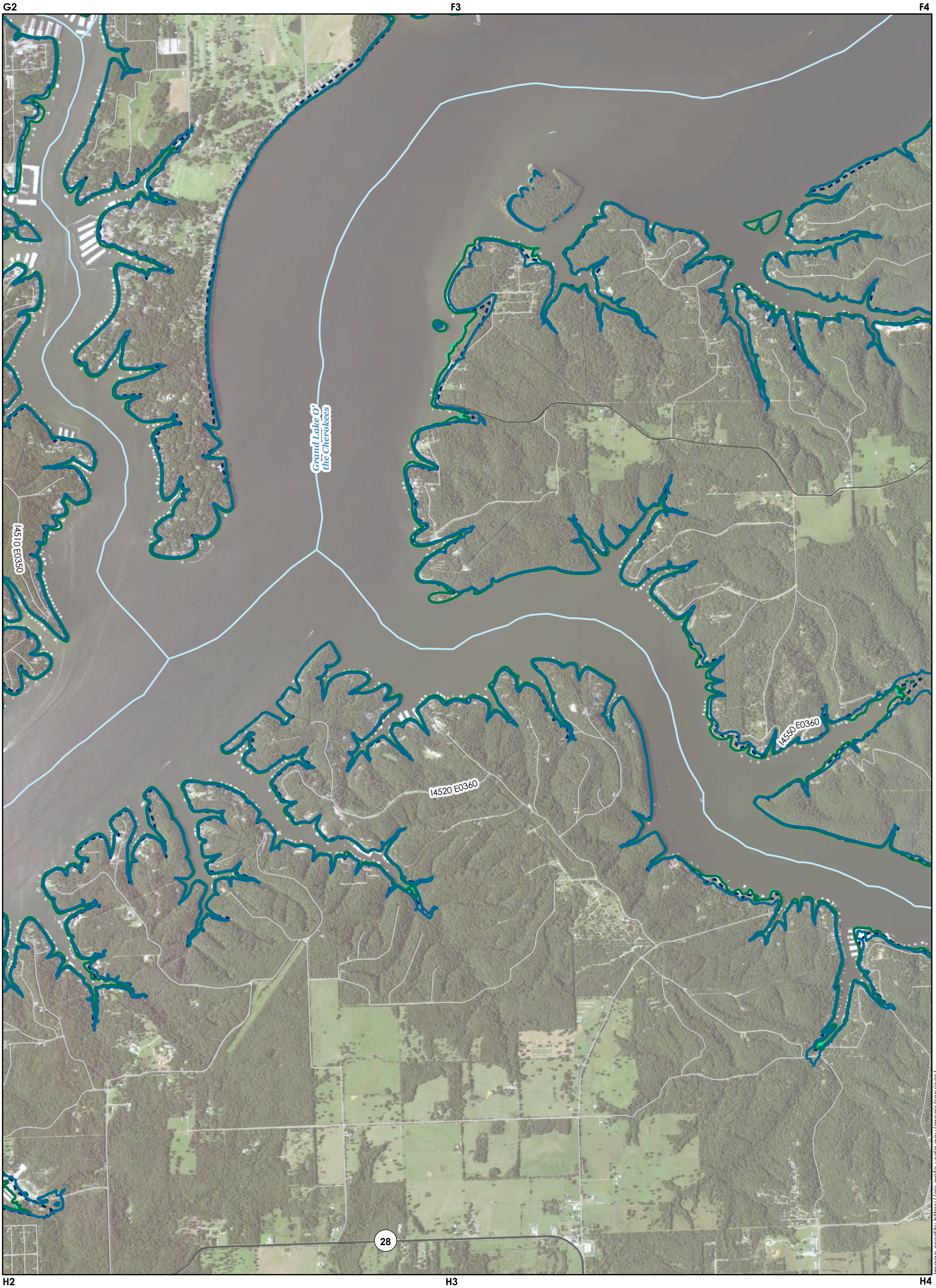
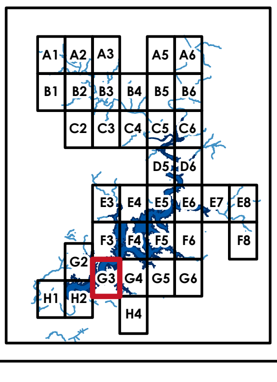


Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: G3

CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494
September 2022

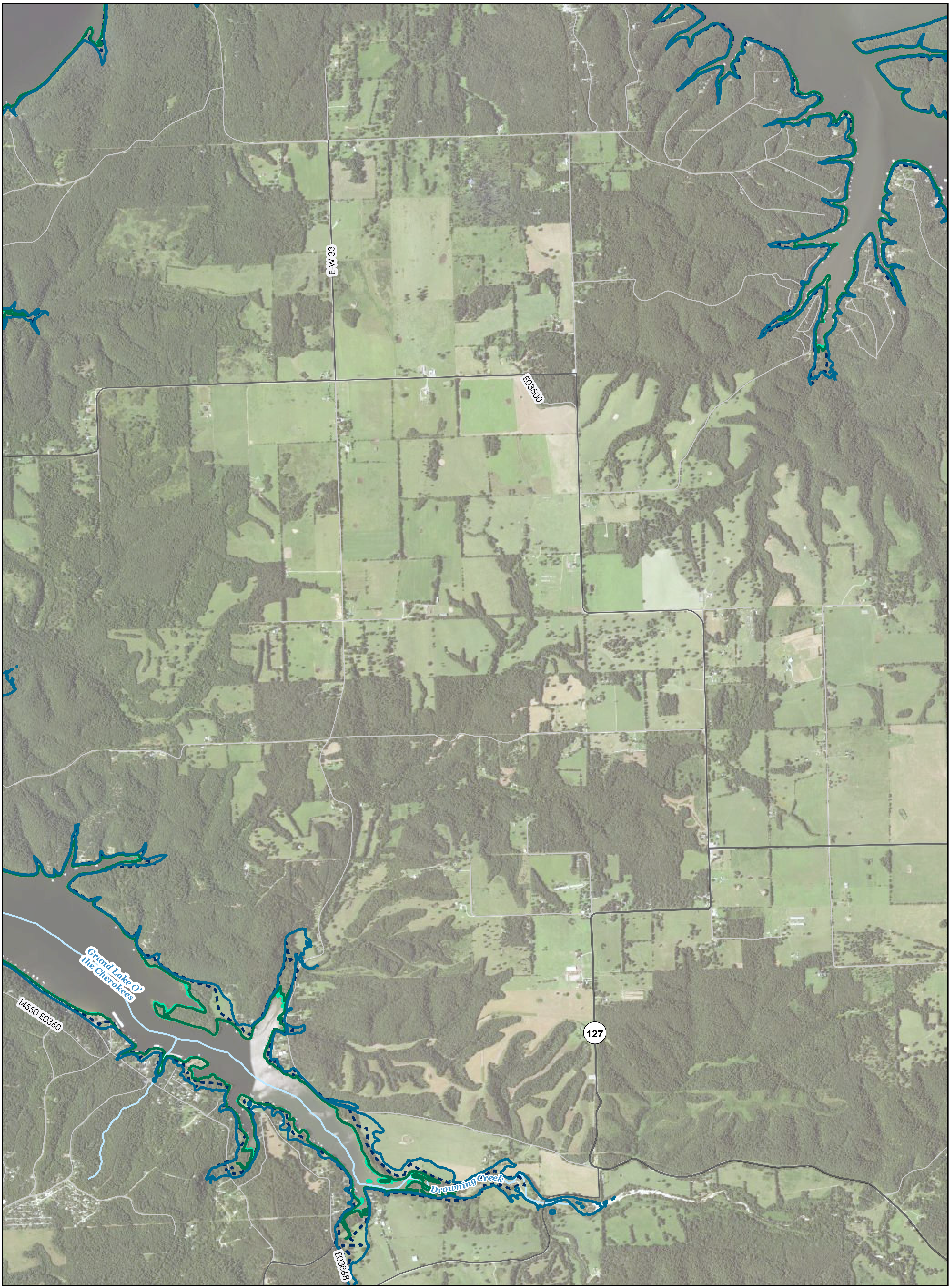


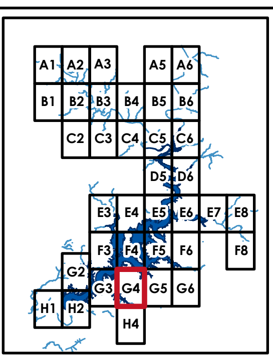
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

🟩	Aquatic Habitat Baseline Operations
🟩	Aquatic Habitat Anticipated Operations
🟦	Maximum Inundation

ROAD CLASS

—	Interstate
—	State Highway
—	US Highway
—	Major Collector
—	Local Road
┼	Railroad
—	Stream
▪▪▪	Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
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PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: G4

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

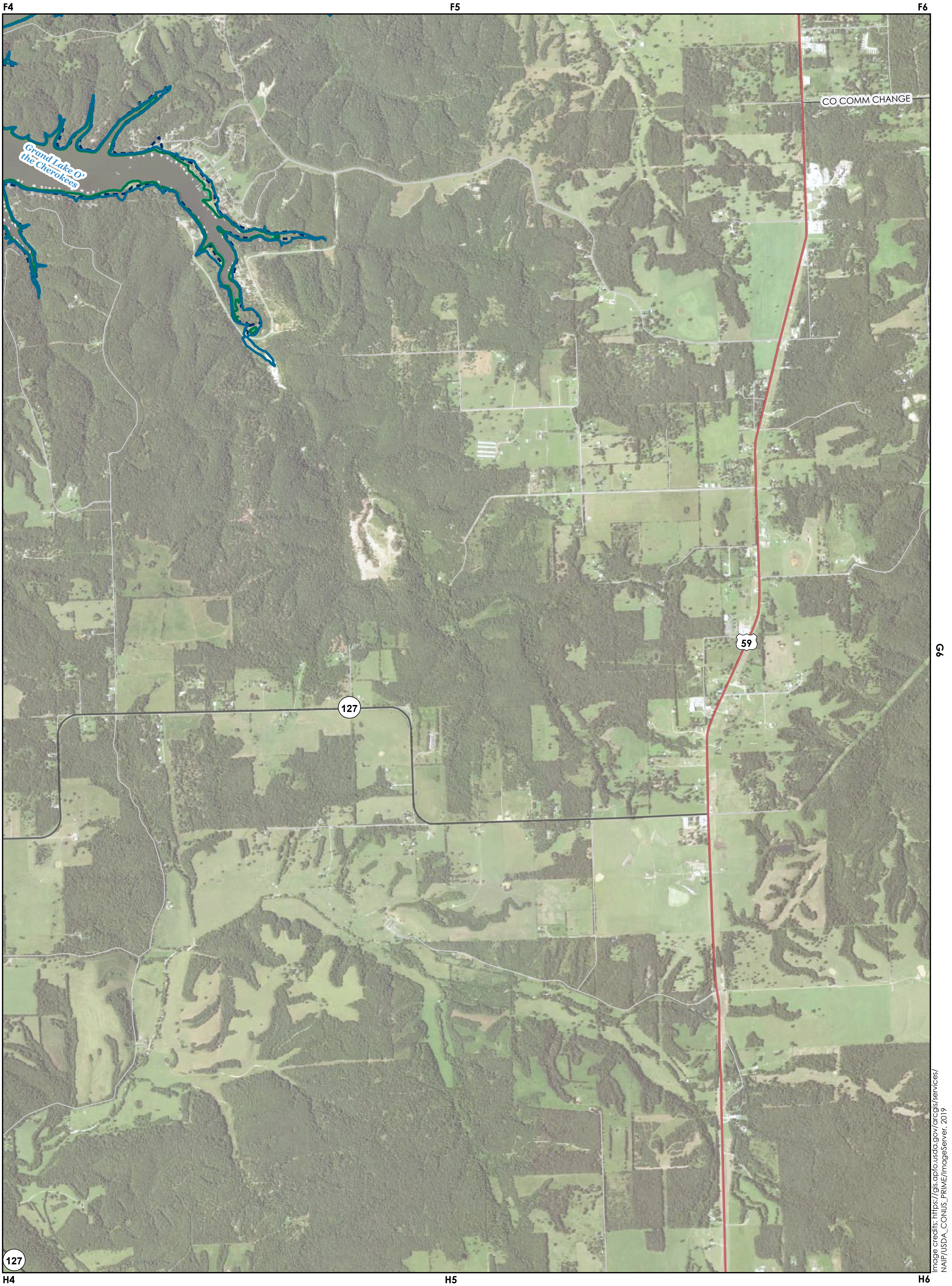


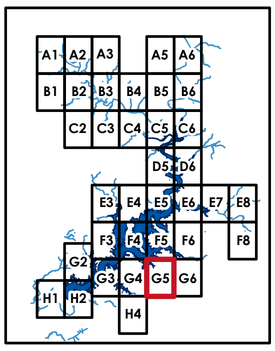
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- 🟩 Aquatic Habitat Baseline Operations
- 🟩 Aquatic Habitat Anticipated Operations
- 🟦 Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
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PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: G5

CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

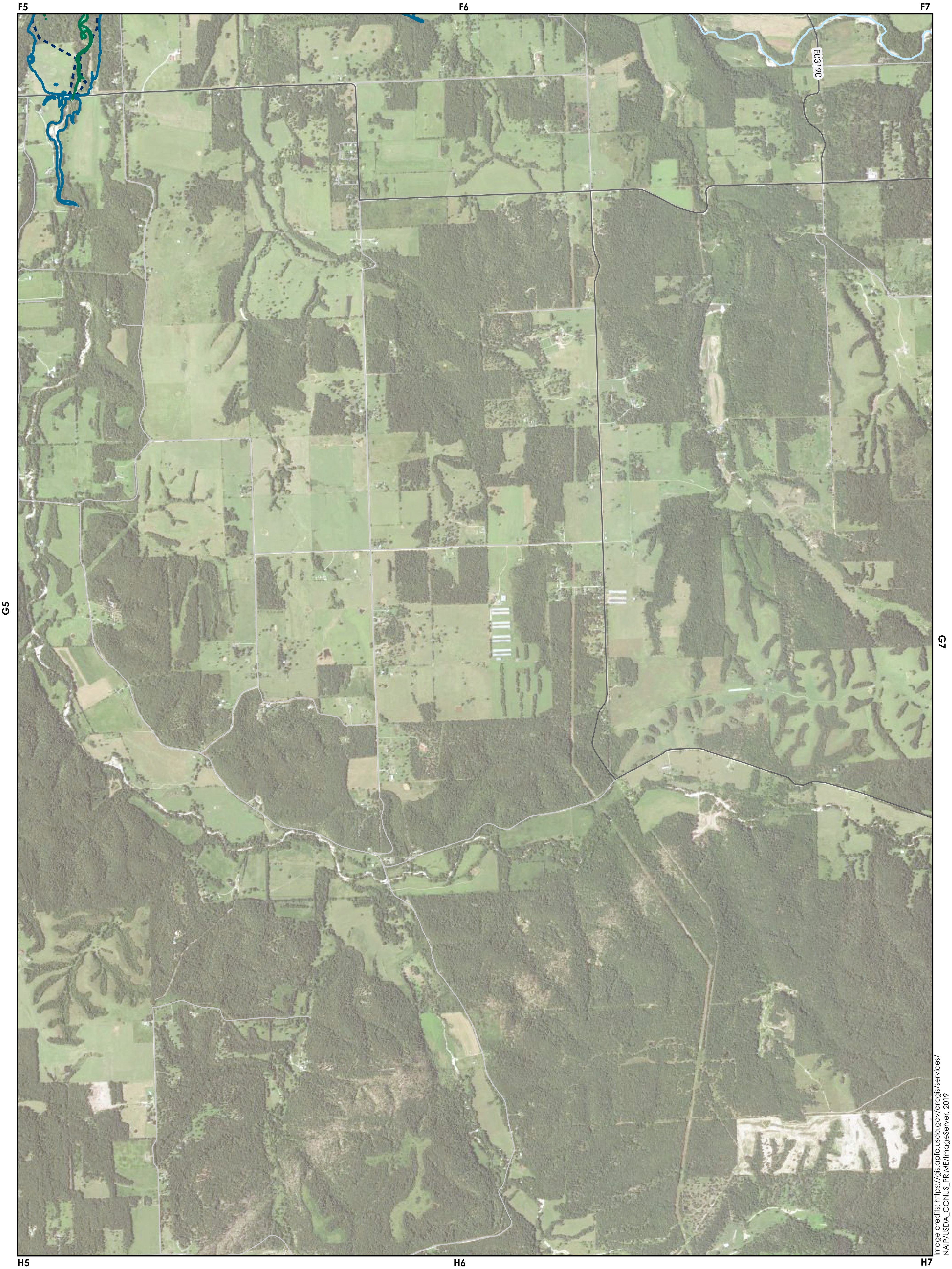
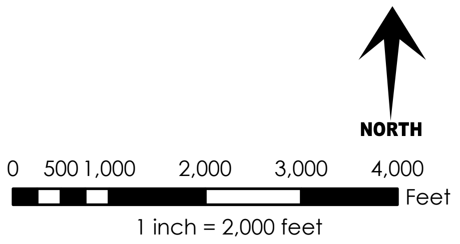
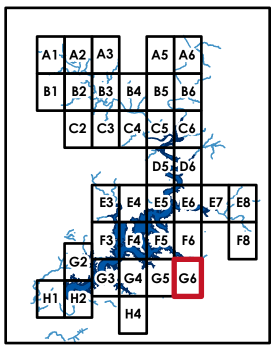


Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES



1 inch = 2,000 feet



Legend

INUNDATION

- ▭ Aquatic Habitat Baseline Operations
- ▭ Aquatic Habitat Anticipated Operations
- ▭ Maximum Inundation

ROAD CLASS

- ═ Interstate
- — State Highway
- — US Highway
- — Major Collector
- — Local Road
- ┼ Railroad
- — Stream
- ┅ Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: G6

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

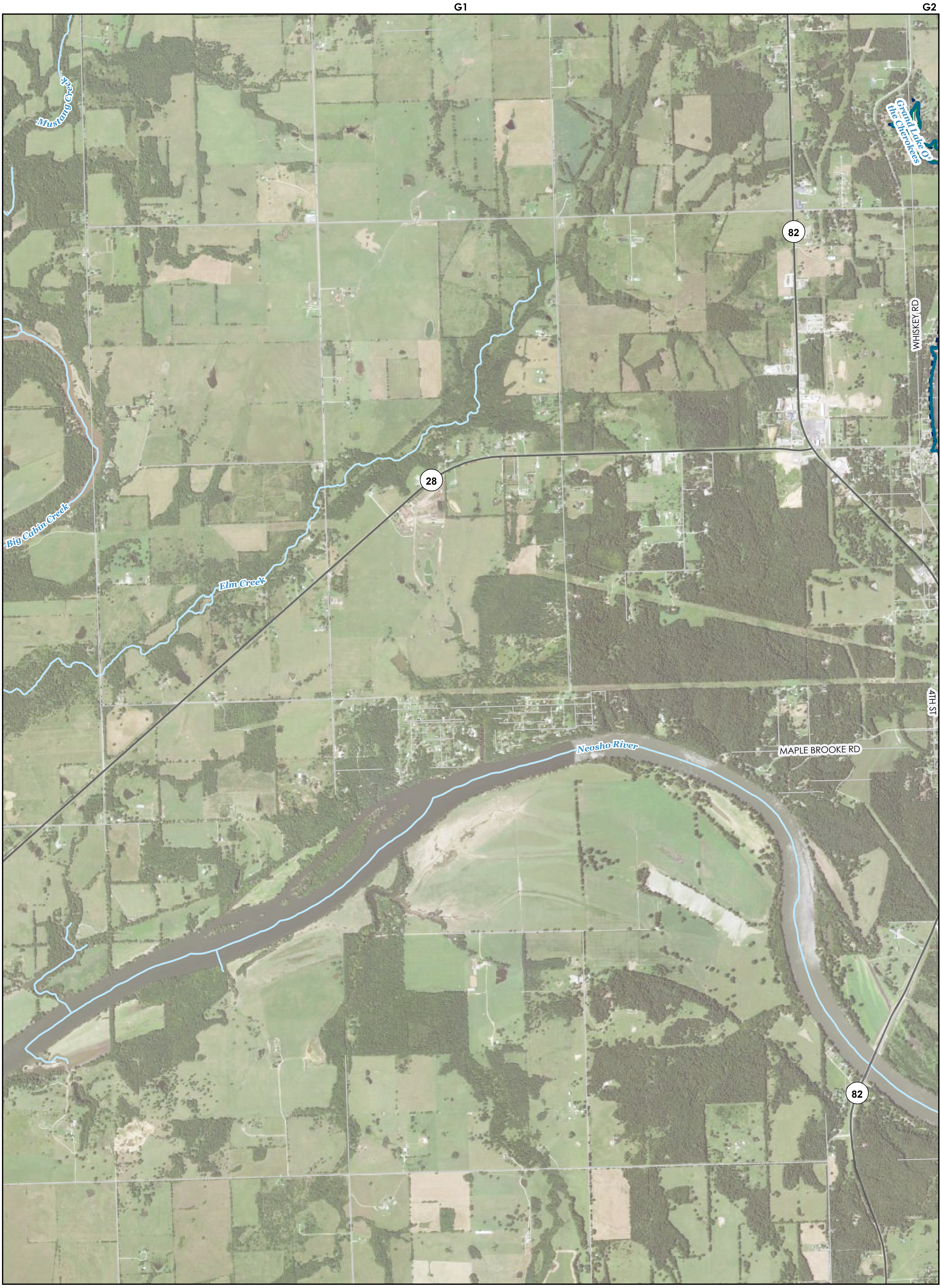
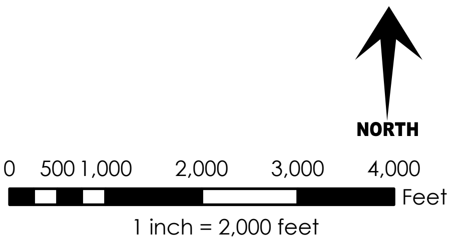
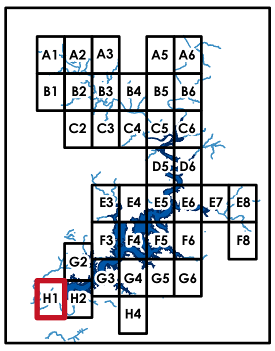


Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES



1 inch = 2,000 feet



Legend

INUNDATION

- Aquatic Habitat Baseline Operations
- Aquatic Habitat Anticipated Operations
- Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: H1

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

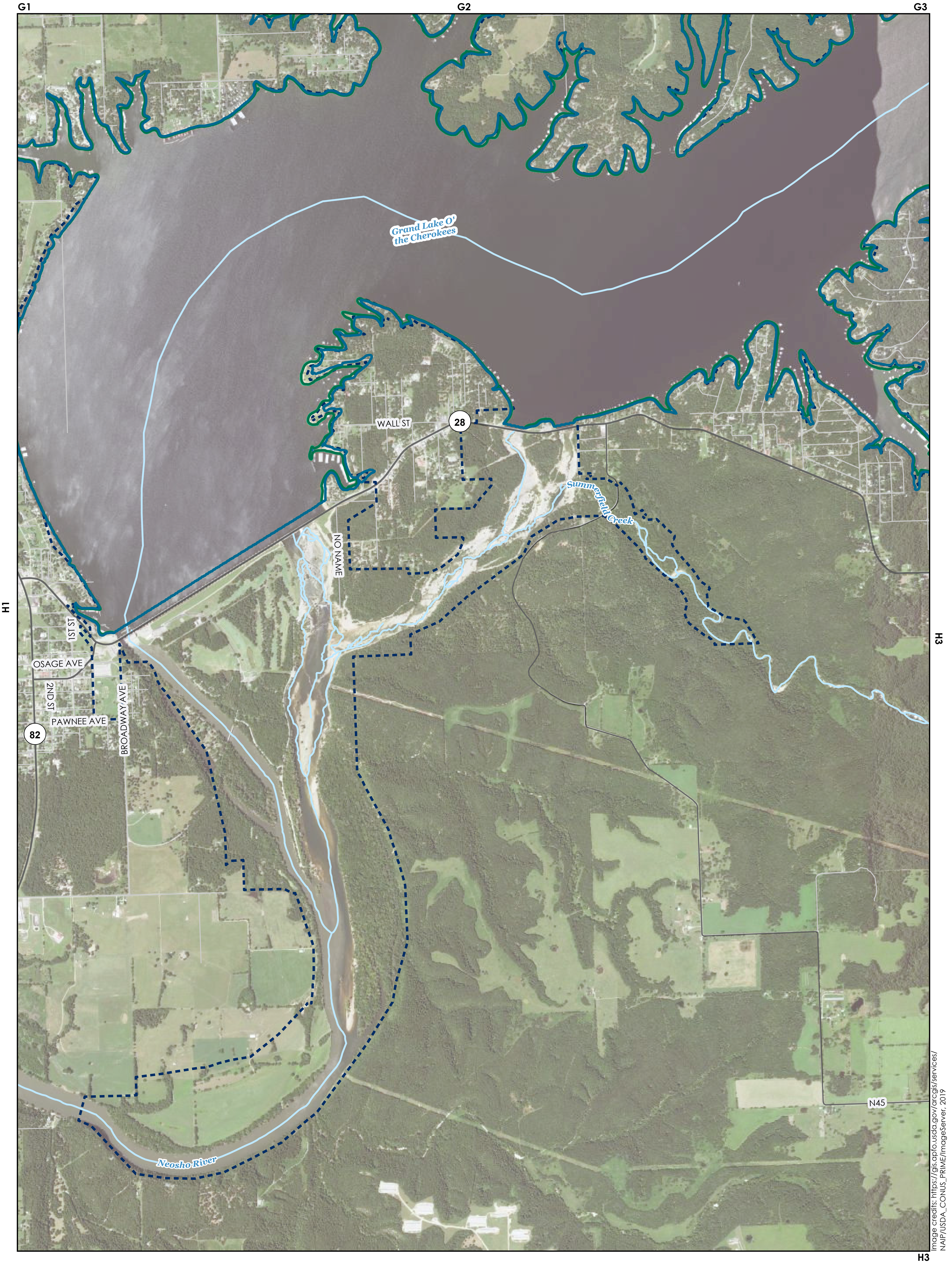


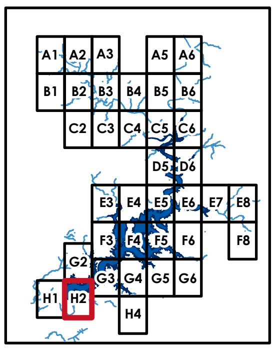
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

INUNDATION

- Aquatic Habitat Baseline Operations
- Aquatic Habitat Anticipated Operations
- Maximum Inundation

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Railroad
- Stream
- Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: H2

CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

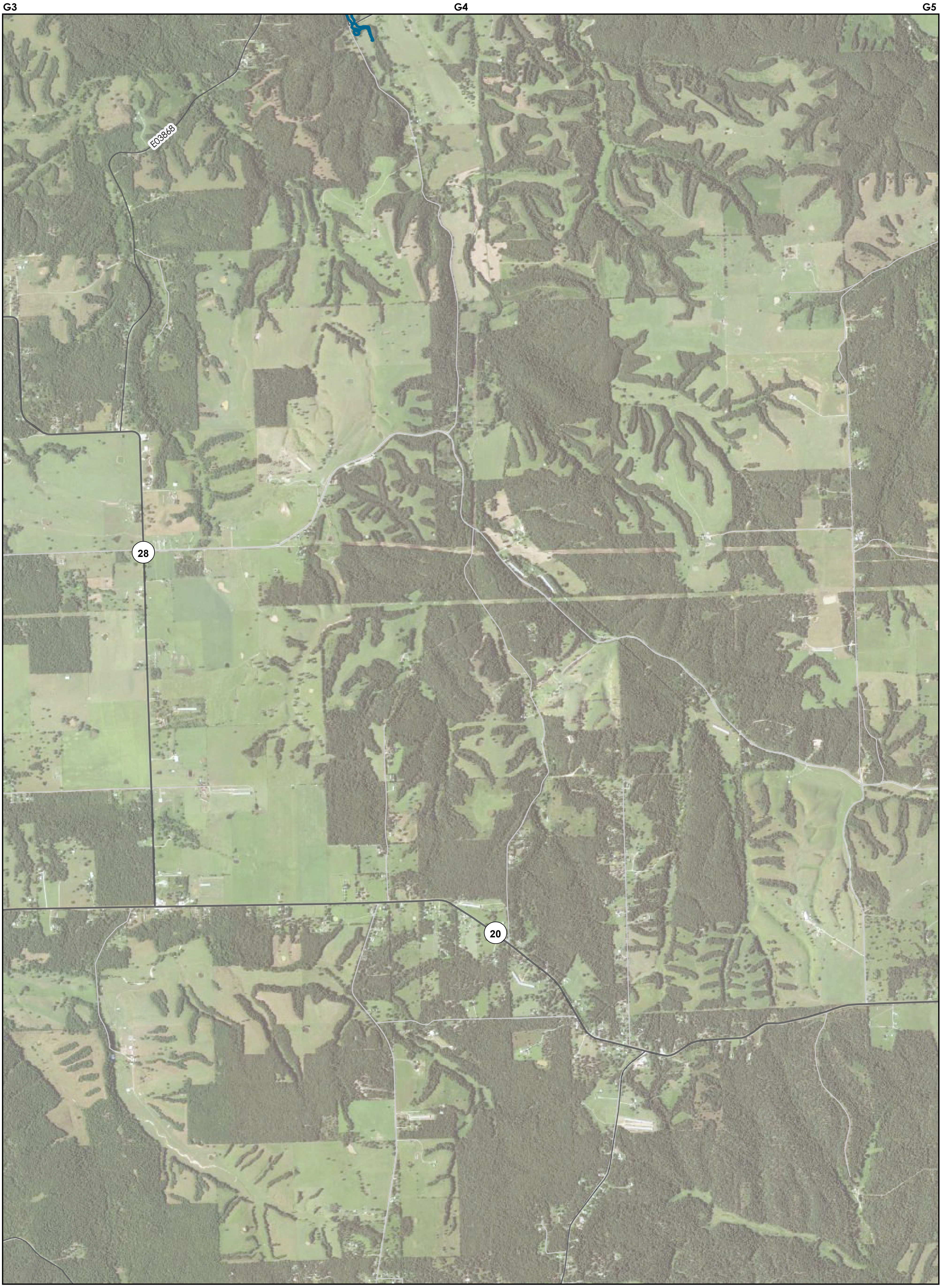
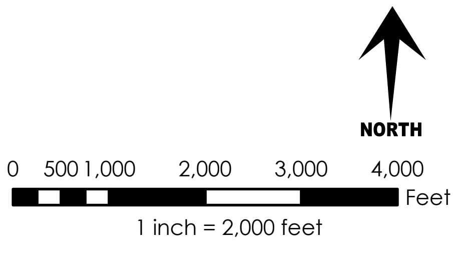
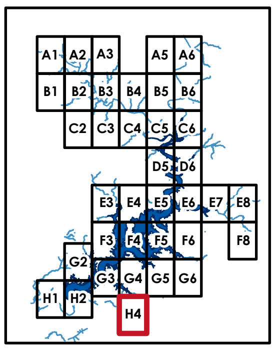


Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

LAKE SPAWNING SPECIES HABITAT CHANGES



1 inch = 2,000 feet



Legend

INUNDATION

- ▭ Aquatic Habitat Baseline Operations
- ▭ Aquatic Habitat Anticipated Operations
- ▭ Maximum Inundation

ROAD CLASS

- ═ Interstate
- ― State Highway
- ― US Highway
- ― Major Collector
- ― Local Road
- ┼ Railroad
- ― Stream
- ▪▪▪ Project Boundary (2014)

MAP AND LEGEND NOTES

1. Mapping shows the extent of inundation calculated using the H&H Study Operations Model and Upstream Hydraulic Model. **These maps represent the work of the H&H Study and are not to be used as shown for resource analysis purposes.**
2. Estimated inundation extent for normal (median) inflows and operations during the spawning season.
3. See Overview Map for an explanation of the maximum inundation extent and notes on data sources.

PENSACOLA DAM

GRAND RIVER DAM AUTHORITY

MAP: H4

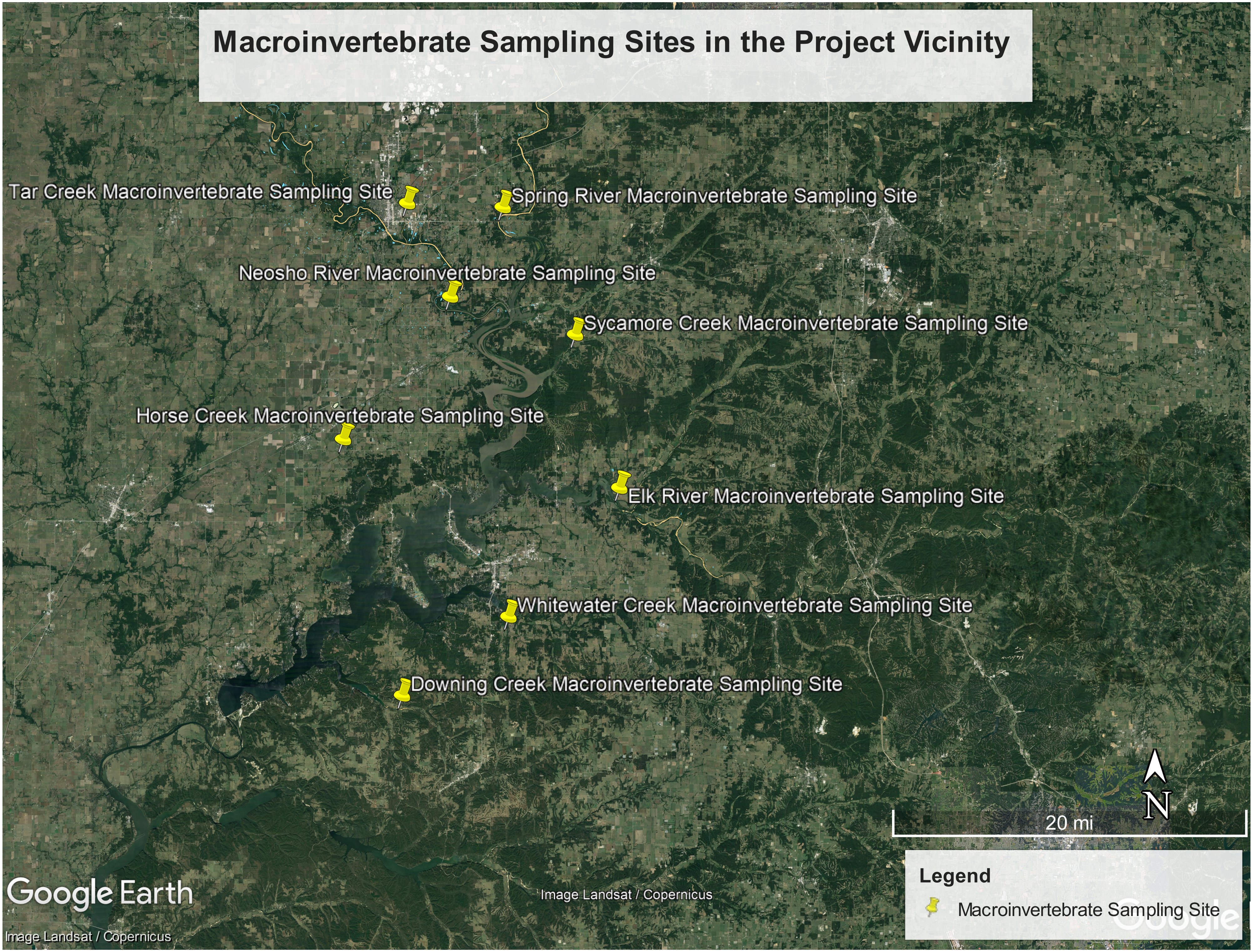
CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

APPENDIX E-20 Macroinvertebrate Sampling Site Map and Data

Macroinvertebrate Sampling Sites in the Project Vicinity


Tar Creek Macroinvertebrate Sampling Site
Spring River Macroinvertebrate Sampling Site
Neosho River Macroinvertebrate Sampling Site
Sycamore Creek Macroinvertebrate Sampling Site
Horse Creek Macroinvertebrate Sampling Site
Elk River Macroinvertebrate Sampling Site
Whitewater Creek Macroinvertebrate Sampling Site
Downing Creek Macroinvertebrate Sampling Site
N
20 mi
Legend
Macroinvertebrate Sampling Site
Google Earth
Image Landsat / Copernicus
Image Landsat / Copernicus

Macroinvertebrate Sampling Data

(Within Project Boundary)

Site	Sample number	Date	Latitude	Longitude	Daphiniidae	Cyprididae	Coenagrionidae	Ceratopogonidae	Naididae
Spring	105	9/9/2022	36.87163	-94.7655	1	4	1	1	3
Spring	106	9/9/2022	36.87163	-94.7655	1	0	0	0	11
Neosho	112	9/9/2022	36.79894	-94.8188	0	0	0	0	20
Neosho	109	9/9/2022	36.79894	-94.8188	0	0	0	0	25
Neosho	111	9/9/2022	36.79894	-94.8188	0	0	0	0	5
Spring	104	9/9/2022	36.87163	-94.7655	0	0	0	0	1
Spring	102	9/9/2022	36.87163	-94.7655	0	0	0	0	4
Spring	101	9/9/2022	36.87163	-94.7655	0	0	0	0	0
Spring	108	9/9/2022	36.87163	-94.7655	2	5	0	2	10
Spring	103	9/9/2022	36.87163	-94.7655	0	0	0	0	0
Elk	158	9/11/2022	36.64365	-94.6474	1	1	0	0	18
Elk	156	9/11/2022	36.64365	-94.6474	0	0	1	0	0
Elk	153	9/11/2022	36.64365	-94.6474	0	0	0	0	1
Elk	154	9/11/2022	36.64365	-94.6474	0	0	0	0	0
Elk	155	9/11/2022	36.64365	-94.6474	0	0	2	0	0
				Totals	5	10	4	3	98

Site	Sample number	Date	Chironomidae	Ephemeridae	Caenidae	Prostigmata	Cyclopodia	Heptageniidae	Sphaeriidae
Spring	105	9/9/2022	33	5	18	0	0	0	0
Spring	106	9/9/2022	38	2	7	1	1	2	0
Neosho	112	9/9/2022	9	3	0	0	0	0	1
Neosho	109	9/9/2022	18	8	0	0	0	0	0
Neosho	111	9/9/2022	11	0	0	0	0	0	0
Spring	104	9/9/2022	21	0	0	0	0	1	0
Spring	102	9/9/2022	30	0	0	0	0	1	0
Spring	101	9/9/2022	25	0	0	0	0	2	0
Spring	108	9/9/2022	72	1	61	0	0	2	0
Spring	103	9/9/2022	16	0	0	0	0	1	0
Elk	158	9/11/2022	76	1	67	0	0	1	0
Elk	156	9/11/2022	14	2	0	0	0	0	0
Elk	153	9/11/2022	31	0	0	0	0	0	0
Elk	154	9/11/2022	84	0	71	1	0	5	0
Elk	155	9/11/2022	53	0	26	0	0	39	0
		Totals	531	22	250	2	1	54	1

Site	Sample Number	Date	Chaoboridae	Polycentropodidae	Leptophlebiidae	Hirudinea	Hydrophilidae	Baetidae	Corixidae
Spring	105	9/9/2022	0	0	0	0	0	0	0
Spring	106	9/9/2022	0	0	0	0	0	0	0
Neosho	112	9/9/2022	18	0	0	0	0	0	0
Neosho	109	9/9/2022	23	0	0	0	0	0	0
Neosho	111	9/9/2022	1	0	0	0	0	0	0
Spring	104	9/9/2022	0	5	0	0	0	0	0
Spring	102	9/9/2022	0	7	1	0	0	0	0
Spring	101	9/9/2022	0	4	0	1	0	0	0
Spring	108	9/9/2022	0	0	0	0	11	9	2
Spring	103	9/9/2022	0	5	0	0	0	0	0
Elk	158	9/11/2022	0	0	0	0	1	9	0
Elk	156	9/11/2022	0	0	0	0	0	1	0
Elk	153	9/11/2022	0	0	1	0	0	0	0
Elk	154	9/11/2022	0	0	133	0	0	111	0
Elk	155	9/11/2022	0	0	171	0	1	60	0
		Totals	42	21	306	1	13	190	2

Site	Sample Number	Date	Hapilidae	Physidae	Culicidae	Poduridae	Gammaridae	Elmidae	Ephemerellidae	Gomphidae	Perlidae
Spring	105	9/9/2022	0	0	0	0	0	0	0	0	0
Spring	106	9/9/2022	0	0	0	0	0	0	0	0	0
Neosho	112	9/9/2022	0	0	0	0	0	0	0	0	0
Neosho	109	9/9/2022	0	0	0	0	0	0	0	0	0
Neosho	111	9/9/2022	0	0	0	0	0	0	0	0	0
Spring	104	9/9/2022	0	0	0	0	0	0	0	0	0
Spring	102	9/9/2022	0	0	0	0	0	0	0	0	0
Spring	101	9/9/2022	0	0	0	0	0	0	0	0	0
Spring	108	9/9/2022	7	10	0	0	0	0	0	0	0
Spring	103	9/9/2022	0	0	0	0	0	0	0	0	0
Elk	158	9/11/2022	1	3	1	1	0	0	0	0	0
Elk	156	9/11/2022	0	0	0	1	0	0	0	0	0
Elk	153	9/11/2022	0	0	0	0	14	0	0	0	0
Elk	154	9/11/2022	0	0	0	0	0	10	6	0	0
Elk	155	9/11/2022	0	1	0	0	0	38	28	1	1
		Totals	8	14	1	2	14	48	34	1	1

Macroinvertebrate Sampling Data

(Within Project Vicinity But Outside Project Boundary)

SiteName	Latitude	Longitude	Date	Index	SITEID	Elmidae	Psephenidae	Chironomidae	Empididae	Baetidae	Heptageniidae	Tricorythidae
Horse Creek	36.683	-94.9273	8/3/2016	Summer	OK121600	10	0	148	0	0	0	0
Horse Creek	36.683	-94.9273	2/7/2017	Winter	OK121600	6	0	128	0	0	12	0
Horse Creek	36.683	-94.9273	6/26/2017	Summer	OK121600	6	0	74	0	0	0	0
Horse Creek	36.683	-94.9273	1/25/2018	Winter	OK121600	0	0	86	0	0	2	0
Drowning Creek	36.4749	-94.8672	1/29/2002	Winter	OK121600	10	0	4	0	22	20	0
Drowning Creek	36.4749	-94.8672	7/15/2002	Summer	OK121600	2	0	6	0	46	2	0
Drowning Creek	36.4749	-94.8672	1/27/2003	Winter	OK121600	8	0	16	0	10	4	0
Sycamore Creek	36.76853	-94.692	7/31/2001	Summer	OK121600	10	74	36	0	20	24	10
Sycamore Creek	36.76853	-94.692	1/29/2002	Winter	OK121600	4	4	52	0	80	12	2
Sycamore Creek	36.76853	-94.692	7/15/2002	Summer	OK121600	8	28	22	0	50	32	8
Sycamore Creek	36.76853	-94.692	1/13/2003	Winter	OK121600	6	4	22	0	8	38	0
Sycamore Creek	36.76853	-94.692	7/10/2006	Summer	OK121600	34	8	52	0	20	30	0
Sycamore Creek	36.76853	-94.692	1/11/2007	Winter	OK121600	6	10	160	0	2	74	0
Sycamore Creek	36.76853	-94.692	8/9/2007	Summer	OK121600	8	6	162	0	0	6	4
Sycamore Creek	36.76853	-94.692	1/7/2008	Winter	OK121600	4	2	76	0	16	46	0
Sycamore Creek	36.76853	-94.692	7/11/2011	Summer	OK121600	0	6	82	0	30	22	2
Sycamore Creek	36.76853	-94.692	1/3/2012	Winter	OK121600	2	4	22	0	6	82	0
Sycamore Creek	36.76853	-94.692	7/2/2012	Summer	OK121600	8	116	16	0	2	34	4
Sycamore Creek	36.76853	-94.692	2/5/2013	Winter	OK121600	4	8	176	0	52	50	0
Sycamore Creek	36.76853	-94.692	8/3/2016	Summer	OK121600	10	4	14	2	26	74	0
Sycamore Creek	36.76853	-94.692	2/1/2017	Winter	OK121600	0	0	20	0	8	30	0
Sycamore Creek	36.76853	-94.692	6/27/2017	Summer	OK121600	16	8	72	0	64	10	4
Sycamore Creek	36.76853	-94.692	1/26/2018	Winter	OK121600	2	8	78	0	2	76	0
Tar Creek	36.87481	-94.862	7/24/2001	Summer	OK121600	0	0	42	10	0	0	0
Tar Creek	36.87481	-94.862	1/28/2002	Winter	OK121600	0	0	224	0	0	0	0
Tar Creek	36.87481	-94.862	7/15/2002	Summer	OK121600	0	0	192	38	0	0	0
Tar Creek	36.87481	-94.862	1/13/2003	Winter	OK121600	0	0	44	0	0	0	0
Tar Creek	36.87481	-94.862	7/10/2006	Summer	OK121600	0	0	10	2	0	0	0
Tar Creek	36.87481	-94.862	8/9/2007	Summer	OK121600	6	2	200	0	0	0	0
Tar Creek	36.87481	-94.862	1/7/2008	Winter	OK121600	0	0	42	2	0	0	0
Tar Creek	36.87481	-94.862	7/11/2011	Summer	OK121600	0	0	110	2	0	0	0
Tar Creek	36.87481	-94.862	1/3/2012	Winter	OK121600	0	0	28	0	2	2	0
Tar Creek	36.87481	-94.862	7/2/2012	Summer	OK121600	0	0	68	2	0	0	0
Tar Creek	36.87481	-94.862	8/3/2016	Summer	OK121600	0	0	306	0	0	0	0
Tar Creek	36.87481	-94.862	2/7/2017	Winter	OK121600	0	0	188	0	0	2	0
Tar Creek	36.87481	-94.862	6/26/2017	Summer	OK121600	2	0	336	0	0	2	0
Tar Creek	36.87481	-94.862	1/25/2018	Winter	OK121600	0	0	154	0	0	0	0
Whitewater Creek:	36.539	-94.7596389	6/21/2016	Summer	OK121600	6	4	38	2	46	2	0
Whitewater Creek:	36.539	-94.7596389	2/6/2017	Winter	OK121600	6	2	178	0	0	2	0
Whitewater Creek:	36.539	-94.7596389	7/11/2017	Summer	OK121600	8	0	74	0	56	10	8
Whitewater Creek:	36.539	-94.7596389	3/13/2018	Winter	OK121600	6	6	86	0	20	30	0

SiteName	Date	Corydalidae	Perlidae	Hydropsychidae	Odontoceridae	Dugesiidae	Asellidae	Caenidae	Ephemerellidae	Isonychiidae	Perlodidae
Horse Creek	8/3/2016	0	0	24	0	0	0	32	0	0	0
Horse Creek	2/7/2017	0	0	20	0	0	0	2	0	0	0
Horse Creek	6/26/2017	0	0	110	0	1	2	0	0	0	0
Horse Creek	1/25/2018	0	0	20	0	1	0	0	0	0	0
Drowning Creek	1/29/2002	0	0	0	0	6	178	0	0	0	0
Drowning Creek	7/15/2002	0	0	0	0	0	108	0	0	0	0
Drowning Creek	1/27/2003	0	1	0	0	4	180	0	0	0	0
Sycamore Creek	7/31/2001	12	2	2	0	0	20	18	0	4	0
Sycamore Creek	1/29/2002	2	8	4	0	0	40	0	0	22	8
Sycamore Creek	7/15/2002	8	0	10	0	5	2	4	0	58	0
Sycamore Creek	1/13/2003	4	2	6	0	0	134	0	0	102	0
Sycamore Creek	7/10/2006	2	0	6	0	2	30	16	0	6	0
Sycamore Creek	1/11/2007	2	8	2	0	3	94	0	0	18	0
Sycamore Creek	8/9/2007	12	4	18	2	0	0	0	0	4	0
Sycamore Creek	1/7/2008	0	0	20	0	1	176	0	2	52	0
Sycamore Creek	7/11/2011	12	2	16	0	0	0	2	0	16	0
Sycamore Creek	1/3/2012	0	10	14	0	0	12	0	0	56	0
Sycamore Creek	7/2/2012	8	2	36	0	0	2	0	0	12	0
Sycamore Creek	2/5/2013	0	4	20	0	0	32	4	2	34	0
Sycamore Creek	8/3/2016	14	6	34	0	1	24	10	0	20	0
Sycamore Creek	2/1/2017	2	16	34	0	0	2	0	0	76	2
Sycamore Creek	6/27/2017	0	8	0	0	0	6	8	0	0	0
Sycamore Creek	1/26/2018	0	42	8	0	2	0	0	6	10	0
Tar Creek	7/24/2001	4	0	164	0	0	0	0	0	0	0
Tar Creek	1/28/2002	0	0	22	0	0	0	0	0	0	0
Tar Creek	7/15/2002	2	0	54	0	0	0	0	0	0	0
Tar Creek	1/13/2003	2	0	198	0	0	0	0	0	0	0
Tar Creek	7/10/2006	2	0	148	0	0	0	0	0	0	0
Tar Creek	8/9/2007	8	2	36	0	0	0	14	0	0	0
Tar Creek	1/7/2008	0	0	42	0	0	0	0	0	0	0
Tar Creek	7/11/2011	0	0	54	0	0	0	0	0	0	0
Tar Creek	1/3/2012	0	2	12	0	0	0	0	0	4	0
Tar Creek	7/2/2012	2	0	112	0	0	0	0	0	0	0
Tar Creek	8/3/2016	2	0	82	0	0	2	0	0	0	0
Tar Creek	2/7/2017	2	0	8	0	0	0	0	0	0	0
Tar Creek	6/26/2017	0	0	28	0	0	0	0	0	0	0
Tar Creek	1/25/2018	0	0	12	0	0	0	0	0	0	0
Whitewater Creek:	6/21/2016	0	0	98	0	0	4	4	0	0	0
Whitewater Creek:	2/6/2017	0	0	0	0	0	2	0	0	0	0
Whitewater Creek:	7/11/2017	18	0	48	0	0	0	0	0	0	0
Whitewater Creek:	3/13/2018	0	2	14	0	1	2	10	4	2	4

SiteName	Date	Philopotamidae	Simuliidae	Tipulidae	Hyalellidae	Nemouridae	Limnephilidae	Helicopsychidae	Pleuroceridae	Hydroptilidae
Horse Creek	8/3/2016	0	0	0	13	0	0	0	0	0
Horse Creek	2/7/2017	0	0	0	1	0	0	0	0	0
Horse Creek	6/26/2017	0	4	0	0	0	0	0	0	0
Horse Creek	1/25/2018	0	14	0	9	0	0	0	0	0
Drowning Creek	1/29/2002	0	0	0	6	0	0	0	0	0
Drowning Creek	7/15/2002	0	0	0	18	0	0	0	0	0
Drowning Creek	1/27/2003	0	0	0	28	0	0	0	0	0
Sycamore Creek	7/31/2001	0	0	0	0	0	0	0	0	0
Sycamore Creek	1/29/2002	2	18	0	0	0	0	2	0	0
Sycamore Creek	7/15/2002	4	0	0	0	0	0	2	0	0
Sycamore Creek	1/13/2003	0	0	0	1	0	0	0	76	0
Sycamore Creek	7/10/2006	10	2	0	23	0	0	0	2	0
Sycamore Creek	1/11/2007	4	10	0	2	0	4	0	6	2
Sycamore Creek	8/9/2007	6	2	0	0	0	0	0	26	0
Sycamore Creek	1/7/2008	10	2	0	0	0	2	0	0	0
Sycamore Creek	7/11/2011	22	0	0	0	0	0	0	2	0
Sycamore Creek	1/3/2012	8	0	0	0	0	0	0	0	0
Sycamore Creek	7/2/2012	2	0	0	0	0	0	0	0	0
Sycamore Creek	2/5/2013	8	0	0	4	0	0	0	10	0
Sycamore Creek	8/3/2016	2	0	0	0	0	0	0	0	0
Sycamore Creek	2/1/2017	12	0	0	0	0	0	0	0	0
Sycamore Creek	6/27/2017	0	2	0	0	0	0	0	0	0
Sycamore Creek	1/26/2018	2	2	0	0	0	0	2	0	0
Tar Creek	7/24/2001	0	8	0	0	0	0	0	0	0
Tar Creek	1/28/2002	0	0	4	0	0	0	0	0	0
Tar Creek	7/15/2002	0	2	4	0	0	0	0	0	2
Tar Creek	1/13/2003	0	6	0	0	0	0	0	0	0
Tar Creek	7/10/2006	0	16	0	0	0	0	0	0	0
Tar Creek	8/9/2007	16	0	0	0	0	0	0	0	0
Tar Creek	1/7/2008	0	18	4	0	0	0	0	0	0
Tar Creek	7/11/2011	2	0	4	0	0	0	0	0	0
Tar Creek	1/3/2012	0	2	0	0	0	2	0	0	0
Tar Creek	7/2/2012	0	0	2	0	0	0	0	0	0
Tar Creek	8/3/2016	0	0	0	3	0	0	0	0	4
Tar Creek	2/7/2017	0	0	0	0	0	0	0	0	0
Tar Creek	6/26/2017	2	14	0	1	0	0	0	0	6
Tar Creek	1/25/2018	0	2	0	0	0	0	0	0	0
Whitewater Creek:	6/21/2016	0	0	0	0	0	0	0	0	0
Whitewater Creek:	2/6/2017	0	0	0	0	0	0	0	0	0
Whitewater Creek:	7/11/2017	2	6	0	0	0	0	0	0	0
Whitewater Creek:	3/13/2018	2	0	2	1	4	0	0	0	0

SiteName	Date	Naididae	Sphaeriidae	Cambaridae	Coenagrionidae	Capniidae	Physidae	Glossiphoniidae	Erpobdellidae	Ephydridae	Leptophlebiidae
Horse Creek	8/3/2016	0	0	0	0	0	0	0	0	0	0
Horse Creek	2/7/2017	8	8	0	0	0	0	2	42	0	0
Horse Creek	6/26/2017	0	4	0	0	0	0	0	8	0	0
Horse Creek	1/25/2018	32	16	0	0	0	0	0	0	0	0
Drowning Creek	1/29/2002	0	0	0	0	0	0	0	0	0	0
Drowning Creek	7/15/2002	0	0	0	2	0	0	0	0	0	0
Drowning Creek	1/27/2003	6	0	0	0	0	0	0	0	0	0
Sycamore Creek	7/31/2001	0	0	0	2	0	0	0	0	0	0
Sycamore Creek	1/29/2002	0	0	0	0	0	0	0	0	0	0
Sycamore Creek	7/15/2002	0	0	0	0	2	0	0	0	0	1
Sycamore Creek	1/13/2003	2	0	0	0	4	0	0	0	0	1
Sycamore Creek	7/10/2006	12	0	0	6	0	2	2	0	0	0
Sycamore Creek	1/11/2007	0	0	0	2	2	2	0	0	2	0
Sycamore Creek	8/9/2007	0	0	0	0	0	0	0	0	0	1
Sycamore Creek	1/7/2008	0	0	0	0	0	0	0	0	0	0
Sycamore Creek	7/11/2011	0	0	2	0	0	0	0	0	0	2
Sycamore Creek	1/3/2012	0	0	0	2	0	0	0	0	0	0
Sycamore Creek	7/2/2012	0	0	0	0	0	0	0	0	0	0
Sycamore Creek	2/5/2013	0	2	0	0	2	12	0	0	0	6
Sycamore Creek	8/3/2016	0	0	0	0	0	0	0	0	0	2
Sycamore Creek	2/1/2017	0	0	0	2	0	0	0	0	0	0
Sycamore Creek	6/27/2017	0	0	0	0	0	0	0	0	0	0
Sycamore Creek	1/26/2018	0	0	0	0	0	0	0	0	0	0
Tar Creek	7/24/2001	2	0	0	10	0	2	0	0	0	0
Tar Creek	1/28/2002	2	0	0	2	0	0	0	0	0	0
Tar Creek	7/15/2002	2	0	0	12	0	0	0	0	0	0
Tar Creek	1/13/2003	0	0	0	4	0	20	0	0	0	0
Tar Creek	7/10/2006	2	0	0	0	0	2	0	0	0	0
Tar Creek	8/9/2007	0	0	0	6	0	0	0	0	0	0
Tar Creek	1/7/2008	5	0	0	4	0	8	0	0	0	0
Tar Creek	7/11/2011	0	0	0	22	0	0	0	0	0	0
Tar Creek	1/3/2012	2	0	0	6	0	4	0	0	0	0
Tar Creek	7/2/2012	0	0	0	10	0	0	0	0	0	0
Tar Creek	8/3/2016	0	0	0	6	0	0	0	0	0	0
Tar Creek	2/7/2017	2	0	0	0	0	0	0	0	0	0
Tar Creek	6/26/2017	0	0	0	0	0	0	0	0	0	0
Tar Creek	1/25/2018	0	2	0	0	0	0	0	0	0	0
Whitewater Creek:	6/21/2016	0	0	2	0	0	0	0	0	0	1
Whitewater Creek:	2/6/2017	0	0	0	0	0	0	0	0	0	0
Whitewater Creek:	7/11/2017	0	0	0	0	0	0	0	0	0	0
Whitewater Creek:	3/13/2018	0	0	0	0	0	0	0	0	0	0

SiteName	Date	Argulidae	Hydrophilidae	Leptoceridae	Polycentropodidae	Ceratopogonidae	Calopterygidae	Macromiidae	Planorbidae
Horse Creek	8/3/2016	0	0	0	0	0	0	0	0
Horse Creek	2/7/2017	0	0	0	0	0	0	0	1
Horse Creek	6/26/2017	0	0	0	0	0	0	0	1
Horse Creek	1/25/2018	0	0	0	0	0	0	0	2
Drowning Creek	1/29/2002	0	0	0	2	0	0	0	0
Drowning Creek	7/15/2002	0	0	0	0	0	0	0	0
Drowning Creek	1/27/2003	0	0	0	0	0	0	0	0
Sycamore Creek	7/31/2001	0	0	0	0	0	0	0	0
Sycamore Creek	1/29/2002	0	0	0	0	0	0	0	0
Sycamore Creek	7/15/2002	0	0	0	2	0	0	0	0
Sycamore Creek	1/13/2003	0	0	0	0	0	0	0	0
Sycamore Creek	7/10/2006	0	0	0	0	14	0	0	2
Sycamore Creek	1/11/2007	0	0	0	0	0	0	0	2
Sycamore Creek	8/9/2007	0	0	0	0	0	0	0	0
Sycamore Creek	1/7/2008	0	0	0	0	0	6	0	0
Sycamore Creek	7/11/2011	0	0	0	0	0	0	0	0
Sycamore Creek	1/3/2012	0	0	0	0	0	0	0	0
Sycamore Creek	7/2/2012	0	0	0	0	0	0	0	0
Sycamore Creek	2/5/2013	0	0	0	0	0	2	0	0
Sycamore Creek	8/3/2016	0	0	0	2	0	0	0	0
Sycamore Creek	2/1/2017	0	0	0	4	0	0	0	0
Sycamore Creek	6/27/2017	0	0	0	0	0	0	0	0
Sycamore Creek	1/26/2018	0	0	0	0	0	0	0	0
Tar Creek	7/24/2001	0	2	0	0	0	0	0	0
Tar Creek	1/28/2002	0	4	0	0	0	0	0	0
Tar Creek	7/15/2002	0	2	0	0	0	0	0	0
Tar Creek	1/13/2003	0	16	0	0	0	0	0	0
Tar Creek	7/10/2006	0	0	0	0	0	0	0	0
Tar Creek	8/9/2007	0	0	0	0	4	0	0	0
Tar Creek	1/7/2008	1	6	0	0	0	0	0	0
Tar Creek	7/11/2011	0	0	8	6	0	0	0	0
Tar Creek	1/3/2012	0	0	0	0	0	0	0	0
Tar Creek	7/2/2012	0	12	2	2	0	0	0	0
Tar Creek	8/3/2016	0	10	0	2	0	0	0	0
Tar Creek	2/7/2017	0	0	0	0	0	0	0	0
Tar Creek	6/26/2017	0	0	0	2	0	0	2	0
Tar Creek	1/25/2018	0	4	0	0	0	0	0	0
Whitewater Creek:	6/21/2016	0	0	0	0	0	0	0	0
Whitewater Creek:	2/6/2017	0	0	0	0	0	0	0	0
Whitewater Creek:	7/11/2017	0	0	0	2	0	0	0	0
Whitewater Creek:	3/13/2018	0	0	0	0	0	0	0	0

SiteName	Date	Tetrastemmatidae	Tabanidae	Gomphidae	Glossosomatidae	Gammaridae	Psychomyiidae	Sialidae	Taeniopterygidae
Horse Creek	8/3/2016	0	0	0	0	0	0	0	0
Horse Creek	2/7/2017	0	0	0	0	0	0	0	0
Horse Creek	6/26/2017	0	0	0	0	0	0	0	0
Horse Creek	1/25/2018	0	0	0	0	0	0	0	0
Drowning Creek	1/29/2002	0	0	0	0	0	0	0	0
Drowning Creek	7/15/2002	0	0	0	0	0	0	0	0
Drowning Creek	1/27/2003	0	0	0	0	1	0	0	0
Sycamore Creek	7/31/2001	0	0	2	0	0	0	0	0
Sycamore Creek	1/29/2002	0	0	0	0	0	0	0	0
Sycamore Creek	7/15/2002	0	0	4	0	0	0	0	0
Sycamore Creek	1/13/2003	0	0	2	2	0	0	0	4
Sycamore Creek	7/10/2006	0	0	2	0	0	0	0	0
Sycamore Creek	1/11/2007	0	0	2	0	0	0	0	0
Sycamore Creek	8/9/2007	0	2	0	0	0	0	0	0
Sycamore Creek	1/7/2008	0	0	0	0	0	0	0	0
Sycamore Creek	7/11/2011	0	0	0	0	0	0	0	0
Sycamore Creek	1/3/2012	0	0	0	0	0	0	0	0
Sycamore Creek	7/2/2012	0	0	0	0	0	0	0	0
Sycamore Creek	2/5/2013	0	0	0	0	0	0	0	0
Sycamore Creek	8/3/2016	0	0	6	0	0	0	0	0
Sycamore Creek	2/1/2017	0	0	0	0	0	0	0	0
Sycamore Creek	6/27/2017	0	0	0	0	0	0	0	0
Sycamore Creek	1/26/2018	0	0	0	0	0	0	0	0
Tar Creek	7/24/2001	0	0	0	0	0	0	0	0
Tar Creek	1/28/2002	0	0	0	0	0	0	0	0
Tar Creek	7/15/2002	0	0	0	0	0	0	0	0
Tar Creek	1/13/2003	4	0	0	0	0	0	0	0
Tar Creek	7/10/2006	0	0	0	0	0	0	0	0
Tar Creek	8/9/2007	0	2	0	0	0	0	4	0
Tar Creek	1/7/2008	0	0	0	0	0	0	0	0
Tar Creek	7/11/2011	0	0	0	0	0	0	0	0
Tar Creek	1/3/2012	0	0	0	0	0	0	0	0
Tar Creek	7/2/2012	0	0	0	0	0	0	0	0
Tar Creek	8/3/2016	0	0	2	0	0	0	0	0
Tar Creek	2/7/2017	4	0	0	0	0	0	0	0
Tar Creek	6/26/2017	0	0	0	0	0	0	0	0
Tar Creek	1/25/2018	0	0	0	0	0	0	0	0
Whitewater Creek:	6/21/2016	0	0	0	0	0	0	0	0
Whitewater Creek:	2/6/2017	0	0	0	0	0	0	0	0
Whitewater Creek:	7/11/2017	0	2	0	0	0	0	0	0
Whitewater Creek:	3/13/2018	0	0	0	0	0	0	0	0

SiteName	Date	Sparganophilidae	Sperchonidae	Ephemeridae	Muscidae	Viviparidae	Scirtidae	Hygrobatidae	Corixidae	Planariidae	Talitridae
Horse Creek	8/3/2016	0	0	0	0	0	0	0	0	0	13
Horse Creek	2/7/2017	0	0	0	0	0	0	0	0	0	1
Horse Creek	6/26/2017	0	0	0	0	0	0	0	0	1	0
Horse Creek	1/25/2018	0	0	0	0	2	0	0	0	1	9
Drowning Creek	1/29/2002	0	0	0	0	0	0	0	0	6	6
Drowning Creek	7/15/2002	0	0	0	0	0	0	0	1	0	18
Drowning Creek	1/27/2003	1	0	0	0	0	0	0	0	4	28
Sycamore Creek	7/31/2001	0	0	0	0	0	0	0	0	0	0
Sycamore Creek	1/29/2002	0	0	0	0	0	0	0	0	0	0
Sycamore Creek	7/15/2002	0	0	0	0	0	0	0	0	5	0
Sycamore Creek	1/13/2003	0	2	0	0	0	0	0	0	0	1
Sycamore Creek	7/10/2006	0	0	0	0	0	0	0	0	2	23
Sycamore Creek	1/11/2007	0	0	0	0	0	0	0	0	3	2
Sycamore Creek	8/9/2007	3	0	6	0	0	0	0	0	0	0
Sycamore Creek	1/7/2008	0	0	0	1	0	4	0	0	1	0
Sycamore Creek	7/11/2011	0	0	0	0	0	0	0	0	0	0
Sycamore Creek	1/3/2012	0	0	0	0	0	0	0	0	0	0
Sycamore Creek	7/2/2012	0	0	0	0	0	0	0	0	0	0
Sycamore Creek	2/5/2013	0	0	0	0	0	0	0	0	0	4
Sycamore Creek	8/3/2016	0	2	2	0	0	0	0	0	1	0
Sycamore Creek	2/1/2017	0	0	0	0	0	0	0	0	0	0
Sycamore Creek	6/27/2017	0	0	0	0	0	0	0	0	0	0
Sycamore Creek	1/26/2018	0	0	0	0	0	0	0	0	2	0
Tar Creek	7/24/2001	0	0	0	0	0	0	0	0	0	0
Tar Creek	1/28/2002	0	0	0	0	0	0	0	0	0	0
Tar Creek	7/15/2002	0	0	0	0	0	0	0	0	0	0
Tar Creek	1/13/2003	0	0	0	0	0	0	0	0	0	0
Tar Creek	7/10/2006	0	0	0	0	0	0	0	0	0	0
Tar Creek	8/9/2007	0	0	0	0	0	0	0	0	0	0
Tar Creek	1/7/2008	0	0	0	0	0	0	0	0	0	0
Tar Creek	7/11/2011	0	0	0	0	0	0	0	0	0	0
Tar Creek	1/3/2012	0	0	0	0	0	0	0	0	0	0
Tar Creek	7/2/2012	0	0	0	0	0	0	0	0	0	0
Tar Creek	8/3/2016	0	0	0	0	0	0	0	0	0	3
Tar Creek	2/7/2017	0	0	0	0	0	0	0	0	0	0
Tar Creek	6/26/2017	0	0	0	0	0	0	0	0	0	1
Tar Creek	1/25/2018	0	0	0	0	0	0	0	0	0	0
Whitewater Creek:	6/21/2016	0	0	0	0	0	0	2	0	0	0
Whitewater Creek:	2/6/2017	0	0	0	0	0	0	0	0	0	0
Whitewater Creek:	7/11/2017	0	0	0	0	0	0	0	0	0	0
Whitewater Creek:	3/13/2018	0	0	0	0	0	0	0	0	1	1

SiteName	Date	Lumbricidae	Ancylidae	Astacidae	Glossoscolecidae	Anthomyiidae
Horse Creek	8/3/2016	0	0	0	0	0
Horse Creek	2/7/2017	0	1	0	0	0
Horse Creek	6/26/2017	0	1	0	0	0
Horse Creek	1/25/2018	0	2	0	0	0
Drowning Creek	1/29/2002	0	0	2	0	0
Drowning Creek	7/15/2002	0	0	2	0	0
Drowning Creek	1/27/2003	0	0	0	1	0
Sycamore Creek	7/31/2001	0	0	0	0	0
Sycamore Creek	1/29/2002	0	0	0	0	0
Sycamore Creek	7/15/2002	0	0	1	0	0
Sycamore Creek	1/13/2003	0	0	0	0	0
Sycamore Creek	7/10/2006	0	0	0	0	0
Sycamore Creek	1/11/2007	0	0	1	0	0
Sycamore Creek	8/9/2007	0	0	0	3	0
Sycamore Creek	1/7/2008	0	0	0	0	1
Sycamore Creek	7/11/2011	0	0	0	0	0
Sycamore Creek	1/3/2012	0	0	0	0	0
Sycamore Creek	7/2/2012	1	0	0	0	0
Sycamore Creek	2/5/2013	3	0	0	0	0
Sycamore Creek	8/3/2016	0	0	0	0	0
Sycamore Creek	2/1/2017	0	0	0	0	0
Sycamore Creek	6/27/2017	0	0	0	0	0
Sycamore Creek	1/26/2018	0	0	0	0	0
Tar Creek	7/24/2001	0	0	0	0	0
Tar Creek	1/28/2002	0	0	0	0	0
Tar Creek	7/15/2002	2	0	0	0	0
Tar Creek	1/13/2003	3	0	0	0	0
Tar Creek	7/10/2006	0	0	0	0	0
Tar Creek	8/9/2007	0	0	0	0	0
Tar Creek	1/7/2008	22	0	0	0	0
Tar Creek	7/11/2011	0	0	0	0	0
Tar Creek	1/3/2012	0	0	0	0	0
Tar Creek	7/2/2012	1	0	0	0	0
Tar Creek	8/3/2016	1	0	0	0	0
Tar Creek	2/7/2017	4	0	0	0	0
Tar Creek	6/26/2017	1	0	0	0	0
Tar Creek	1/25/2018	0	0	0	0	0
Whitewater Creek:	6/21/2016	0	0	0	0	0
Whitewater Creek:	2/6/2017	0	0	0	0	0
Whitewater Creek:	7/11/2017	1	0	0	0	0
Whitewater Creek:	3/13/2018	1	0	0	0	0

APPENDIX E-21 1990 Pensacola Entrainment Study Report

ENTRAINMENT SUSCEPTIBILITIES OF FISHES INHABITING THE LOWER PORTION OF GRAND LAKE, OKLAHOMA

By

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Bachelor of Science

South Dakota State University

Brookings, South Dakota

1985

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the requirements for
the Degree of
MASTER OF SCIENCE
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ENTRAINMENT SUSCEPTIBILITIES OF FISHES
INHABITING THE LOWER PORTION OF
GRAND LAKE, OKLAHOMA

Thesis Approved:

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Finally, I would like to thank my family. To my father, John, and my mother, Sherry, thank you for the support and understanding throughout my education. Their guidance and belief in me is highly valued as I continue to pursue a career in fisheries.

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Chapter I

INTRODUCTION

This thesis is comprised of one manuscript written for submission to the Transactions of the American Fisheries Society. Chapter I is an introduction to the rest of the thesis. The manuscript is complete as written and does not require additional support material. The manuscript is contained in Chapter II and is titled 'Entrainment susceptibilities of fishes inhabiting the lower portion of Grand Lake, Oklahoma.'

Chapter II

ENTRAINMENT SUSCEPTIBILITIES OF FISHES INHABITING THE LOWER PORTION OF GRAND LAKE, OKLAHOMA

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Abstract.-I documented the seasonal dynamics of juvenile and adult fish in the vicinity of the Pensacola Dam hydropower facility on Grand Lake, Oklahoma, to determine species-specific entrainment susceptibilities. Fishes in Grand Lake were sampled monthly from August 1988 to July 1989 using gill nets, trap nets, and electrofishing gear. Water quality profiles were recorded concurrently. I used techniques typically used to quantify foraging preferences of selective predators to estimate the entrainment susceptibilities of individual species to non-selective "predation" by hydropower intakes. Relative abundances of fishes in Grand Lake were compared to relative abundances of fishes entrained (obtained from a concurrent study estimating entrainment rates) using Strauss' electivity index to determine species-specific entrainment susceptibilities. Wilcoxon's signed-rank test was used to incorporate sampling error and test statistical significance. Fishes were not entrained at rates reflecting their relative abundance in the lake. Only 8 of the 25 species collected in Grand Lake were entrained. Entrainment of gizzard shad exceeded expectations based on their relative abundance in the reservoir and it was the only species significantly susceptible to entrainment. Susceptibility to entrainment of all other species was negative or proportional to relative abundance. High midwinter entrainment of gizzard shad resulted from their

habitation of deep water proximal to the turbine intakes and cold-induced torpor. Entrainment was size-selective being skewed to enhance the selection of small fish. Occasional entrainment of white crappie and channel catfish was probably a result of the predilection of these species for structural cover in deep water as afforded by the forebay of the intake structure. Hypolimnetic anoxia associated with summer stratification precluded entrainment of all species during summer.

Extensive research on the effects of hydropower on adult and juvenile fish has been conducted in coldwater systems. These studies addressed upstream and downstream passage associated with the completion of life cycles of anadromous salmon and shad in the Pacific Northwest and New England (e.g., Schoeneman et al. 1961; Raymond 1979; Bell and Kynard 1985). Fish passing through hydropower plants may be subject to both immediate and delayed mortality. Common forms of immediate mortality include decapitation and crushing; delayed forms include deaths resulting from internal injuries, sudden pressure changes, and predation (Cramer and Oligher 1964; Cada 1988). Of no less importance are the fishes merely displaced downstream from the dam, because they are lost from the reservoir fishery.

Entrainment in warm-water reservoirs has not been studied because of the absence of obligatory migrants in these systems. However, many warmwater reservoirs contain populations of once-anadromous, now land-locked species (e.g., striped bass, Morone saxatilis; Scruggs 1955) which range widely (Pflieger 1975) and are subject to entrainment. In addition, many reservoir fishes are pelagic and nomadic (Pflieger 1975), rendering them vulnerable to entrainment. Grand Lake O' the Cherokees (Grand Lake) is an 18,818-hectare multi-purpose hydropower impoundment completed by the Grand River Dam Authority (GRDA) in 1940 by inundation of the Grand (Neosho) River by the Pensacola Dam. Grand

Lake was authorized by Congress to provide flood control, recreation, and hydropower, and the hydroelectric generating plant was granted a 50-year operating license. The license expired in 1988 and required renewal for the GRDA to continue hydropower generation. Relicensing required the GRDA to prepare an environmental impact assessment of the hydropower project. This assessment provided an opportunity to examine the effects of entrainment by the hydropower plant on adult and juvenile fishes in a warm-water reservoir.

The only previous study on entrainment of adult and juvenile warm-water fish was on the Ohio River (Greenup Dam, Vanceburg, Kentucky). Seasonal spatial and temporal distributions of fishes remained unchanged throughout the nine month duration of the study. At least 80 percent of the fish detected hydroacoustically immediately upstream of the forebay trashracks were entrained into the turbine gallery. Of those entrained, 93 percent were gizzard shad (Dorosoma cepedianum) and freshwater drum (Aplodinotus grunniens). Sport fish were entrained at a lower rate than expected as judged by their relative abundances upstream from the dam. However, no work was done during the winter months when streamflows peaked and entrainment potentials probably were greatest (Olson et al. 1988).

Simply documenting the presence of fishes in areas of potentially high entrainment risk does not allow estimation of entrainment because the assumption of equal species-specific entrainment susceptibility is likely erroneous (Helvey 1985). Entrainment susceptibility is regulated by attraction to intake structures, taxis to current, and body length due to the relationship between swimming speed and body length (Jones et al. 1974). Behavioral activities of a species may enhance or diminish entrainment potential, but species-specific entrainment susceptibilities have only been inferred by investigating behaviors and life histories (Helvey 1985).

Estimates of entrainment susceptibility can be made by comparing relative abundances of fishes subject to entrainment to the relative abundances of fishes entrained. My goal was to assess the possible effects of hydropower generation on fish populations in the lower portion of Grand Lake. Accordingly, my objectives were to: determine if relative abundances of fishes in the lower portion of Grand Lake were reflected by species-specific entrainment rates; determine if seasonal distribution of fishes contributed to the entrainment susceptibilities of fishes in the lower portion of Grand Lake; and determine if temporal differences in water quality affected entrainment rates of fishes in the lower portion of Grand Lake.

STUDY SITE

Grand Lake is a monomictic reservoir in northeastern Oklahoma with a mean depth of 13 meters and a maximum depth of about 45 meters. It has a capacity of 1,672,000 acre-feet at the top of the power pool (elevation 745 feet MSL). It has a shoreline of of 998 km and is about 88 km long from the confluence of the Neosho and Spring rivers in the north to the dam in the south. It has an irregular shoreline with numerous bays and small coves and has a shoreline development index value of 43.1. The average discharge during 44 years of record (1939-1981) was 6809 cfs (Oklahoma Water Resources Board 1984). This equates to a flushing rate of about once every 100 days.

The hydropower intakes are housed in a structure about 20 meters off the face of the dam (Figure 1). Three 4.6-m diameter penstocks supply water to six-14,400-kw generators. Net generating head is about 120 ft. The top of the intake is at elevation 705 feet MSL and the bottom is at elevation 682 feet MSL. The intake structure is about 35 m long and distance between the upstream trashracks and the intakes is about 6 m.

METHODS

Field techniques

The fish assemblage inhabiting Grand Lake in the vicinity of Pensacola Dam was sampled at about monthly intervals from August 1988 to July 1989 using three gear types (gill nets, trap nets, and electrofishing). The study area encompassed the lower section of Grand Lake within about 3 km of the hydroelectric facility (Figure 2). The area was divided into 22 sampling blocks, each roughly 500-m square (Figure 2).

From August through December 1988, twelve monofilament-nylon experimental gill nets were set each month. The nets were 2.4 m deep, 91.4 m long, and included six 15.2-m panels with bar mesh sizes of 3.81, 5.08, 6.35, 7.62, 8.89, and 10.16 cm. A stratified-random sampling design was used to select net locations and depths, with emphasis placed on the four blocks in the vicinity of the hydropower intakes (blocks 1, 2, 5, and 6; Figure 2). Four nets were set at randomly selected locations in these blocks, and the remainder were set in randomly selected blocks throughout the study area. Four nets were set at the surface, four at mid-water, and four at the bottom. Nets were fished for 24 hours. All captured fish were removed, identified, weighed (g), measured (mm total length), and released. Each net set constituted one unit of effort. Effort was increased to 16 net sets per month from January through July 1989 by the addition of four nets in block 1.

Ten trap nets were set in the study area on each sampling date. Trap nets were set in coves in sampling blocks 1 (2 nets), 4 (4 nets), 8 (3 nets), and 13 (2 nets). The nets were constructed of tarred 1.3-cm nylon mesh stretched over two 1.8x0.9-m frames and four 0.76-m diameter hoops; a single 12.7-m lead extended perpendicularly from the mouth of each net. The trap nets were set perpendicular to shore with their leads extending towards shore and fished for 24 hours. All captured fish were removed, identified, weighed, measured, and released. Each net set constituted one unit of effort in the catch-rate analyses.

A commercially-produced 6.1-m aluminum electrofishing boat (Coffelt Manufacturing, Inc., Flagstaff, AZ) was used to complete 10 standardized electrofishing transects each month from August through December 1988. Pulsed direct current (300 volts, 6 to 8 amperes, 60% pulse width, 80 pulses per second) was applied in 500-m linear transects. Transects were completed at randomly selected stations stratified as follows: three along the east shoreline (blocks 4, 8, and 13), one along the west shoreline (blocks 1, 5, 9, 14, 19, 20, and 22), one along the face of the dam in block 1, one along the shoreline in block 1, and four in open-water blocks. Two of the open-water transects were in the vicinity of the hydropower intakes (blocks 1, 2, 5, and 6; Figure 1). All captured fish were identified, weighed, measured, and released. Total catches of each species in each transect will constitute catch-per-unit-effort rates (i.e., number per transect). Effort was increased to 12 electrofishing transects per month from January through July 1989 by the addition of two open water transects in block 1.

Water quality profiles of the water column about 150 m directly upstream from the hydroelectric facility were recorded in association with fish sampling. Water temperature, dissolved oxygen concentration, pH, and conductivity were measured with a Hydrolab Surveyor II at 1-m intervals from the surface to a depth of 20 m; additional measurements were taken at 5-m intervals to the bottom.

Analyses

Mean catch-per-unit-effort (CPUE) rates (by gear) of all species in aggregate and of species composing >1% of total catch were plotted over time to assess seasonal trends in abundance at the study sites. A catch index value combining the two most effective gear types for each species was calculated for each sampling date to facilitate evaluation of seasonal trends in abundance of major species; the index incorporated the relative magnitude of gear-specific catch rates by date and treated both gears equally. Monthly gear-specific CPUE rates were divided by the highest CPUE of that gear type obtained over the study duration to calculate a relative CPUE value ranging from 0 to 1. The catch index value was the mean of the two relative CPUE rates. For example: Monthly index value = [(Gear 1 monthly CPUE/Gear 1 highest observed CPUE)+(Gear 2 monthly CPUE/Gear 2 highest observed CPUE)]/2. All three gear types were used to calculate the index value for all species in aggregate. The index values were used only to facilitate evaluation of seasonal trends; they were not used in the quantitative analyses.

Analysis of variance was used to test whether significant differences existed in mean CPUE rates of all species among sampling dates. Duncan's multiple comparison procedure was used to identify months during which CPUE rates were significantly different (alpha = 0.05). Length-frequency distributions of fishes collected in Grand Lake were constructed for comparison with fishes collected in the entrainment samples.

A concurrent study conducted by the Oklahoma Cooperative Fish and Wildlife Research Unit estimated monthly entrainment of fishes at the Pensacola Dam hydropower facility (Fisher and Zale 1990). Entrained fish were collected in modified fyke nets positioned in the draft tubes. The densities of entrained fish were multiplied by monthly discharges to estimate total monthly entrainment. A total of nine species were entrained (gizzard shad, white crappie (Pomoxis annularis), channel catfish (Ictalurus punctatus), bluegill (Lepomis macrochirus), blue catfish (Ictalurus furcatus), green sunfish (Lepomis cyanellus), freshwater drum, white bass (Morone chrysops), and bigmouth buffalo (Ictiobus cyprinellus); Appendix A). Most entrained individuals were small (<200 mm), with the exception of a few catchable-sized channel catfish and one large bigmouth buffalo.

These entrainment estimates were compared to relative abundances of fishes in monthly collections from Grand Lake to estimate entrainment susceptibilities of species present. I used techniques typically used to quantify foraging preferences of selective predators to quantify susceptibilities of individual species to non-selective 'predation' by the turbine intakes. The linear electivity index (Strauss 1979) was used to determine relative susceptibilities of individual species to entrainment; the index is defined as

$$L=r-p$$

where r and p are the relative abundances of a species in entrainment samples and Grand Lake, respectively. Strauss' index was used mainly because of its simplicity, but its linear property gives the advantage of having symmetrical deviation of the index for all values where r does not equal p (Lechowicz 1982). Relative abundances of each species in pooled monthly collections (all three gear types) and in pooled monthly turbine-net samples were compared. L ranges from -1 to +1, with positive values indicating enhanced susceptibility to entrainment and negative values indicating lower susceptibility to entrainment. The expected value for a species entrained in proportion to its relative abundance (i.e., random susceptibility) is zero. Wilcoxon's signed-rank test (Hollander and Wolfe 1973; Kohler and Ney 1982) was used to determine if susceptibilities were significantly different from random. Relative abundances of each species in pooled monthly collections and in individual turbine-net samples collected in a month were compared using this nonparametric paired test (Appendix B).

RESULTS

A total of 25 species composed of 3,726 individuals was collected in the lower Grand Lake study area with all three gear types from August 1988 to July 1989. Gizzard shad dominated the total catch (34.2%), followed by white crappie (14.3%), brook silverside (Labidesthes sicculus; 13.9%) and bluegill (13.8%); 10 species individually composed >1% of the total catch and 95.4% in aggregate (Figure 3).

The white bass was the most abundant (27.3%) of the 15 species in the gill net catch, followed by white crappie (23.8%), channel catfish (18.4%), and gizzard shad (10.2%). Ten species individually composed >1% of the gill-net catch and 97.6% in aggregate. White crappie (51.7%) and bluegill (37.5%) dominated the trap-net catch. Six of the 14 species collected with trap nets individually composed >1% of the catch and 98.2% in aggregate. The electrofishing catch was dominated by gizzard shad (51.6%). Brook silversides composed 22.3% of the electrofishing catch and 7 other species individually contributed at least 1%. In aggregate, these 9 species (out of 20) composed 97.7% of the electrofishing catch (Appendix C).

Gear-specific catch rates of all species in aggregate exhibited only modest seasonal fluctuations (Table 1). Catch rates of all species in aggregate for all gear types tended to be low and stable in autumn and winter and higher, yet variable, in spring and summer (Figure 4). Significant differences existed among monthly mean catch rates of all species in aggregate (Appendix D) only for trap nets (P=0.0012); no significant difference existed among monthly mean catch rates of all species in aggregate in gill nets (P=0.1320) or by electrofishing (P=0.1177).

Of the 11 major species present in lower Grand Lake (i.e., species that composed >1% of the total catch), significant differences existed among monthly mean catch rates of only three (bluegill, channel catfish, and gizzard shad) in the gear type most effective for each. Catch rates of bluegill in trap nets and channel catfish in gill nets were significantly elevated during July 1989 and June 1989, respectively. Catch rates of gizzard shad in electrofishing samples were significantly higher in November 1988 than during the remainder of the study period. Gill net catches of white bass peaked in April 1989, but the increased catch rate was not significant. Although elevated in summer, no significant differences existed among the monthly mean catch rates of the remaining abundant and entrained species in the gear type most effective for each (white crappie in trap nets, and green sunfish in electrofishing samples).

The length-frequency distribution of gizzard shad collected in lower Grand Lake was largely unimodal and primarily composed of adult sizes; the entrained gizzard shad consisted of mainly young-of-the-year individuals (Figure 5). The length frequency distribution of white crappie in Grand Lake consisted of unimodal adult-sized (>200 mm) individuals; entrained white crappie were represented by smaller (<200 mm) individuals. Channel catfish in Grand Lake were represented by wide size ranges of individuals including multiple age-classes and catchable-sized individuals. Entrained channel catfish were represented largely by sub-adult individuals, but catchable-sized fish were also collected.

Of 9 species entrained, 8 were collected in lower Grand Lake. A single bigmouth buffalo was taken in entrainment samples, but the species was absent in Grand Lake collections. Species that composed >1% of the Grand Lake assemblage but which were not entrained, included brook silversides, largemouth bass, smallmouth buffalo, and longear sunfish. Thirteen other species also collected in Grand Lake were absent from entrainment samples.

Susceptibility to entrainment of the 9 species entrained from August 1988 to July 1989 was positive (as judged by the linear electivity index) only for gizzard shad and bigmouth buffalo over the entire period (Table 2). However, susceptibility to entrainment was significantly positive only for gizzard shad over the entire August 1988 to July 1989 period; susceptibility was significantly negative for all other species (Table 2).

Entrainment susceptibilities of individual species varied among months as relative abundances in Grand Lake and in entrainment samples changed. However, significant positive susceptibility to entrainment was limited to gizzard shad and only from February through June 1989 (Figure 6). Entrainment of gizzard shad did not differ significantly from random during other months except during November 1988 when they were significantly negatively susceptible to entrainment. Monthly entrainment susceptibilities of all other species were either random or significantly negative over the entire period (Appendix B).

Seasonal trends in susceptibility to entrainment were evident only for gizzard shad, white crappie, and channel catfish. Entrainment susceptibilities of gizzard shad were depressed in autumn and enhanced in late winter, spring, and summer (Figure 6). The inverse, albeit less dramatic, was evident for white crappie and channel catfish (Figure 6). Entrainment susceptibilities of white bass, bluegill, blue catfish, green sunfish, and freshwater drum were typically random or slightly negative and showed no distinct seasonal trends.

Limnological characteristics of the water column in the immediate vicinity of Pensacola Dam (Figures 7 and 8) were largely dictated by seasonal reservoir stratification dynamics. Strong stratification was evident from August through October 1988 (Figure 7), but dissolved oxygen concentrations in 1988 were <2 mg/L over the entire range of depths encompassed by the intakes only during August (Figure 7). Stratification was absent from November 1988 through March 1989 (Figure 8), intermediate in May 1989 (Figure 8), and returned to patterns exhibited in October 1988 (Figure 7) and August 1988 (Figure 7) in June and July 1989, respectively. Dissolved oxygen concentrations were <2 mg/L over the entire range of depths encompassed by the intakes, similar to August 1988 profiles (Figure 7), again during July 1989. Only two fish were caught in gill nets set below the thermocline during periods when the reservoir was stratified; these may have become enmeshed during net retrieval.

DISCUSSION

The relative abundances of individual fish species in the hydropower intake area of Grand Lake did not accurately reflect relative entrainment rates. Both lake and entrainment samples were dominated by gizzard shad, but entrainment of this species often exceeded its relative abundance, suggesting it was more susceptible to entrainment than other fishes present in lower reaches of Grand Lake. The gizzard shad accounted for over 99% of the total abundance in entrainment samples (Fisher and Zale 1990), but it composed about 34% of the collections in Grand Lake. The gizzard shad was also the most frequently entrained species at Greenup Dam, Kentucky (Olson et al., 1988).

Gizzard shad tend to travel in large schools (Miller and Robison 1973; Pflieger 1975) which may predispose them to additional entrainment risk. At an offshore cooling intake off the Karachi coast of Pakistan, schooling fishes were generally more vulnerable to entrainment, as they were often sluggish, weak swimmers, and were generally of small size (Moazzam and Rizvi 1980). Schooling fishes were entrained at an offshore cooling intake off the California coast more often than resident reef fishes (Helvey 1985). Whereas gizzard shad are not a physically hardy species (Miller 1960), I do not believe them to be weak swimmers. However, schooling behavior may tend to magnify the consequence of an encounter with the hydropower intakes because entrainment is the fate of many individuals simultaneously.

Entrainment susceptibilities of other entrained species in Grand Lake (white crappie, channel catfish, bluegill, blue catfish, green sunfish, bigmouth buffalo, freshwater drum, and white bass) were negative and many species present in lower Grand Lake were absent in entrainment samples. These were often species that, due to their behavior and habitat preferences were not present in the deeper waters near the intake structures. For example, the brook silverside was numerically the third most abundant fish present in Grand Lake but was absent from entrainment samples. It spends most of its life within a few centimeters of the surface and never goes deeper than a few meters (Pflieger 1975). The largemouth bass (Micropterus salmoides) was not collected in entrainment sampled despite being the seventh most abundant fish collected in Grand Lake. Largemouth bass prefer weedy littoral areas and when in deeper water are found near bottom (Pflieger 1975).

Pelagic species other than gizzard shad (i.e., white bass, hybrid striped bass, and freshwater drum) did not appear to be susceptible to entrainment. Hybrid striped bass are stocked at locations far upstream of the intakes (Jim Smith, Oklahoma Department of Wildlife Conservation, pers. com.). Stocking them far upstream allows them time to grow before encountering the intakes and renders them less apt to be entrained. White bass migrate to tributary streams to spawn (Pflieger 1975), and by the time the young encounter the intakes, they too are likely large enough to effectively resist intake velocities. Freshwater drum were not abundant in the lower portion of Grand Lake and were entrained at rates proportional to, or less than, their monthly relative abundances.

White crappie and channel catfish were the only species other than gizzard shad often entrained. Although never significantly susceptible to entrainment, these were the only other species to frequently exhibit enhanced likelihood of entrainment as indicated by Strauss' index. Because lower Grand Lake is largely devoid of cover, the entrainment of these species may have resulted from their attraction to the cover afforded by the intake structure. Inasmuch as the intake structure offered cover, it also caused local vertical velocity gradients having an unknown effect on orientation and behavior (Hocutt and Edinger 1980).

Fishes may become entrained because of behaviors that bring them into direct contact with the intake water currents at times when their vision is impaired or when intake hydraulics disorient their position in the flow (Helvey 1985). Confusion caused by these factors may prevent fishes from vacating areas where intake velocities make entrainment imminent. In addition, the Pensacola plant is a load-control facility exhibiting frequent start-ups during peak electrical demand. This method of operation may have promoted entrainment of white crappie and channel catfish that were inhabiting the forebay during periods of non-generation.

Entrainment was size-selective and consisted primarily of small, young-of-the-year individuals. Although the hydroelectric facility's trash racks precluded entrainment of exceptionally large individuals, it is likely that size-selective entrainment was a function of the positive relationship between swimming speed and body length (Jones et al. 1974). Large individuals could attain swimming speeds required to escape intake velocities whereas smaller fish were unable to escape and were entrained. High entrainment rates of young-of-the-year gizzard shad during winter were likely a product of their size-mediated swimming ability, sensitivity to low temperatures (Miller 1960; Heidinger 1983), and propensity to 'hibernate' in deep water during winter (Velasquez 1939; Jester and Jensen 1972).

Seasonal changes in relative abundance were not reflected by similar entrainment rate changes. In fact, relative abundances in the lake were most often opposite those in the entrainment samples. Gizzard shad entrainment peaked during late winter and early spring coincident with their lowest CPUE rates and relative abundances in Grand Lake. Similarly, entrainment rates of other species (white crappie and channel catfish) were highest in late summer, autumn, and early winter, corresponding temporally with their lowest CPUE rates and relative abundances. The apparent high susceptibility of gizzard shad to entrainment during winter may have been due, in part, to sampling gear limitations. Gill nets were the only gear used to sample the profundal areas inhabited by the gizzard shad in the winter. Cold water renders passive gears less effective by reducing the activity of fish, ultimately leading to underrepresentation in the abundance estimates in the lake. The enhanced electivity index values (i.e., high susceptibility) may be an artifact of inadequate sampling gear performance, which artifically lowered the relative abundance estimates of gizzard shad in the winter samples of lower Grand Lake.

Seasonal stratification of Grand Lake influenced vertical fish distributions and entrainment rates. Fish were absent from the hypolimnion, but the thermocline was typically present at depths below the upper edge of the turbine intakes. Accordingly, stratification capable of inhibiting entrainment was present only during mid-summer. The two lowest estimates of monthly turbine entrainment were recorded in August 1988 and July 1989 when dissolved oxygen concentrations were <2 mg/L over the entire range of depths encompassed by the intakes. Gizzard shad, white crappie, and channel catfish avoid waters with dissolved oxygen concentrations less than 2 mg/L (Gebhart and Summerfelt 1978). However, low rates of entrainment during these months suggested that stratification was destabilized by hydropower generation in the forebay of the intake structure and allowed habitation of the forebay structure at the depth of the intakes by fish.

To minimize the effects of entrainment at hydropower facilities, methods to divert fish away from areas of high risk and practices to increase survival of entrained fish have been used. Operation of hydropower facilities at peak efficiency minimizes the probability of encounter of excess stress during turbine passage. Operation at low efficiency subjects entrained fish to increased cavitation, excess turbulence, and shear forces. However, no single operational or design approach decreases mortality rates to <10% on a consistent basis (Cada 1988). Where operational or design alterations are not feasible, appreciable decreases in mortality are best obtained through exclusion from areas of high entrainment risk. Due to the low entrainment rates of game fish and the seasonality of gizzard shad entrainment, implementation of entrainment deterrance devices would probably not lead to a significant improvement in the fishery of Grand Lake.

In summary, entrainment of recreationally and commercially important sport and food fishes by the Pensacola Dam hydroelectric facility was limited because these species were not abundant in the vicinity of the dam and their relative susceptibilities to entrainment were low. Gizzard shad, especially young-of-the-year, were seasonally susceptible to entrainment, but dominance of the reservoir's fish assemblage by this species suggested that effects of entrainment were minimal or inconsequential. Because gizzard shad are often considered over-abundant in impoundments (Miller 1960; Jenkins 1957), it seems unlikely that selective entrainment of this species is deleterious to the ichthyofauna of Grand Lake.

My research may be applicable to many morphologically similar southern reservoirs built primarily for hydropower generation. Application to smaller reservoirs, those not stratifying, or those with faster flushing rates (i.e., more riverine in nature) may be limited. Relevance to pumped-storage facilities would only be incurred during generation periods and not to pump phases of operation.

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Table 1. Total catches (N), mean catch-per-unit-effort (CPUE) values, and standard deviations (SD) of CPUE of all fish species in aggregate, by gear type, collected in Grand Lake, August 1988 to July 1989.

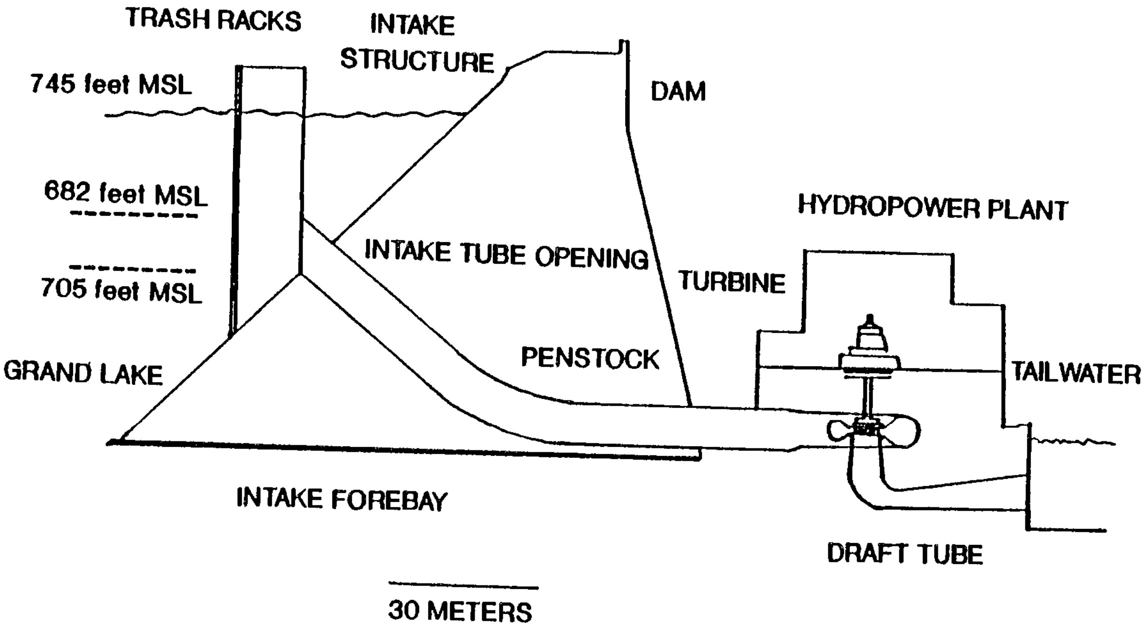
	Gill net			Trap net			Electrofishing		
Month	N	CPUE	SD	N	CPUE	SD	N	CPUE	SD
AUG 88	59	4.92	7.14	70	7.00	9.24	26	2.60	3.72
SEP 88	47	3.92	8.50	57	5.70	5.77	73	7.30	10.35
OCT 88	29	2.50	4.46	15	1.50	2.17	245	24.50	48.31
NOV 88	16	1.33	1.87	7	0.70	1.16	578	57.90	87.84
DEC 88	38	3.17	6.64	32	3.20	2.10	115	12.10	21.55
JAN 89	18	1.06	1.61	21	2.10	2.13	36	3.00	7.52
FEB 89	39	2.44	6.90	5	0.50	0.71	161	13.42	32.22
MAR 89	15	0.94	1.39	64	6.40	9.81	326	27.17	71.84
APR 89	88	5.50	6.95	124	12.40	13.47	207	17.25	20.94
MAY 89	169	7.22	9.98	52	5.20	5.29	165	13.75	19.97
JUN 89	142	8.88	16.49	100	10.00	13.22	87	7.25	9.19
JUL 89	47	2.94	7.70	146	14.60	14.49	307	25.58	33.63
	707	3.80	8.06	693	5.78	9.06	2326	17.40	40.03

Table 2. Turbine-entrainment susceptibilities of fishes in Grand Lake, August 1988 to July 1989. The relative abundances of fishes in entrainment and Grand Lake samples are denoted r and p, respectively. L is Strauss' linear electivity index. The symbols + and - represent positive and negative susceptibility, respectively. Probability values are given in parentheses (Wilcoxon's signed rank test).

Species	r	p	L	Susceptibility
Gizzard shad	0.995	0.342	+0.653	+ (0.0008)
White crappie	0.002	0.143	-0.141	- (<0.0002)
Channel catfish	0.002	0.036	-0.034	- (<0.0002)
Bluegill	<0.001	0.135	-0.135	- (<0.0002)
Blue catfish	<0.001	0.003	-0.003	- (<0.0002)
Green sunfish	<0.001	0.017	-0.017	- (<0.0002)
Bigmouth buffalo	<0.001	0.000	+<0.001	- (<0.0002)
Freshwater drum	<0.001	0.007	-0.007	- (<0.0002)
White bass	<0.001	0.074	-0.074	- (<0.0002)

FIGURE CAPTIONS

7. Water Temperature and Dissolved Oxygen Concentration Profiles Directly Upstream From the Pensacola Dam Hydroelectric Facility, August and October 1988. The bars along the right vertical axes indicate the depths of the turbine intakes.
8. Water Temperature and Dissolved Oxygen Concentration Profiles Directly Upstream From the Pensacola Dam Hydroelectric Facility, November 1988 and May 1989. The bars along the right vertical axes indicate the depths of the turbine intakes.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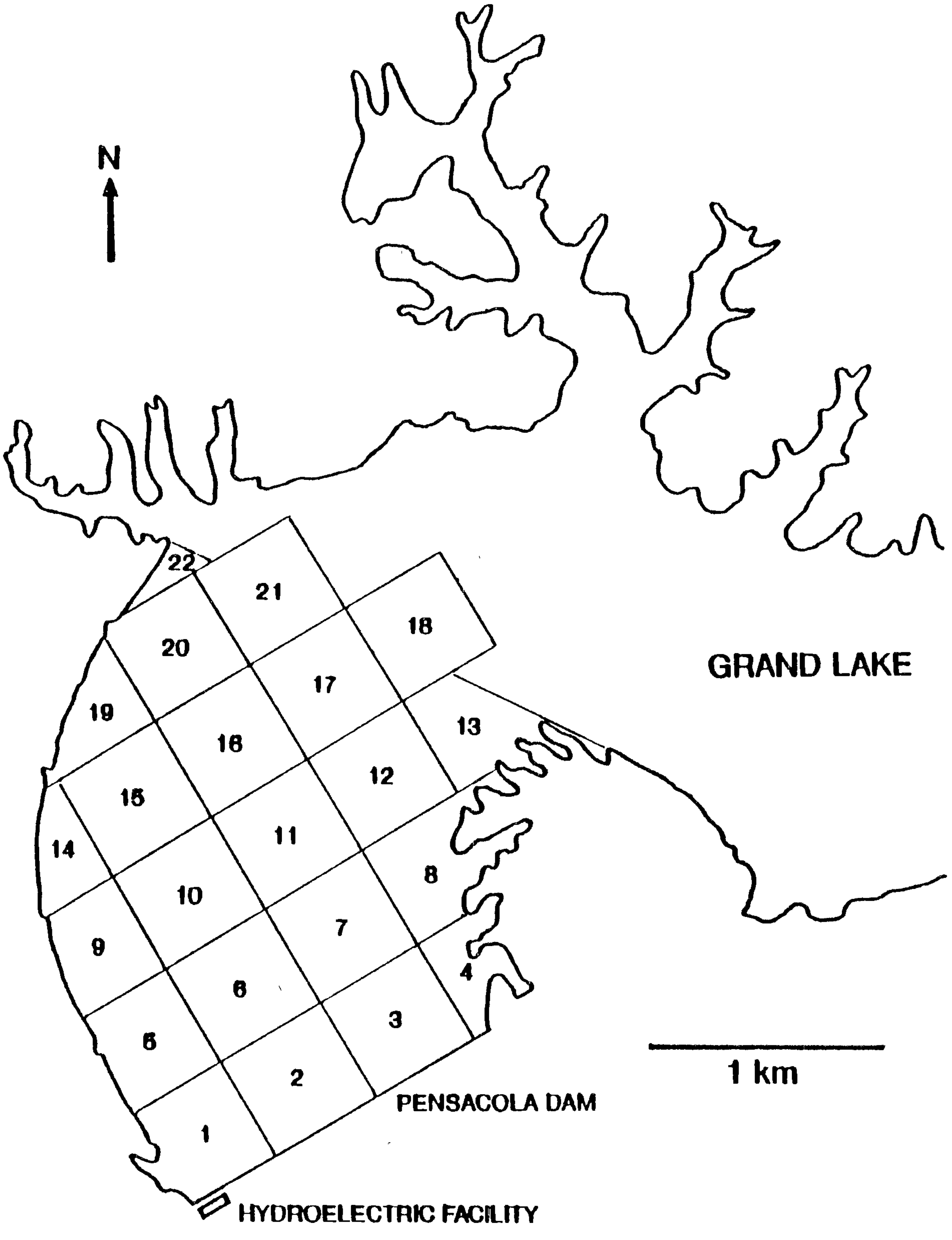
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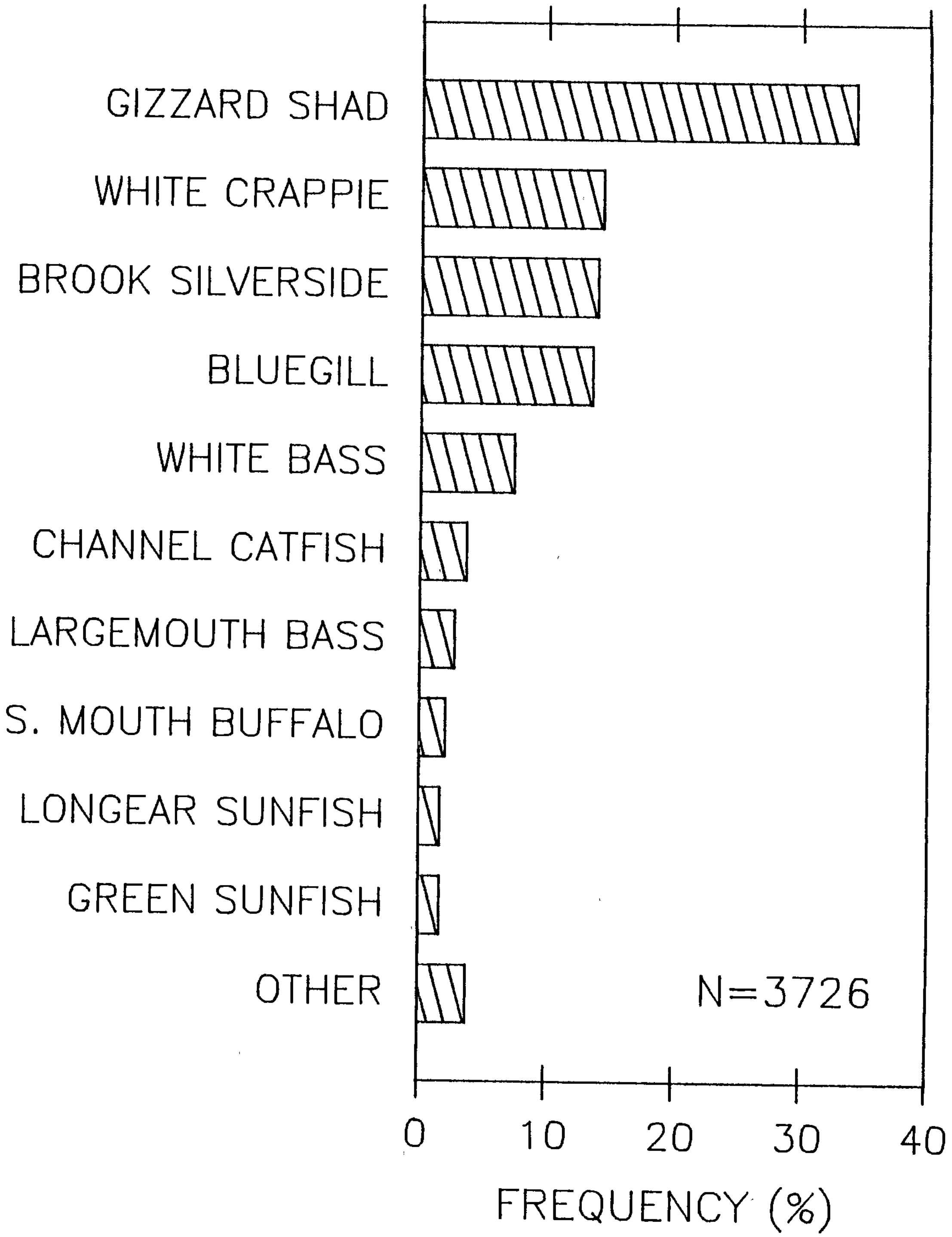
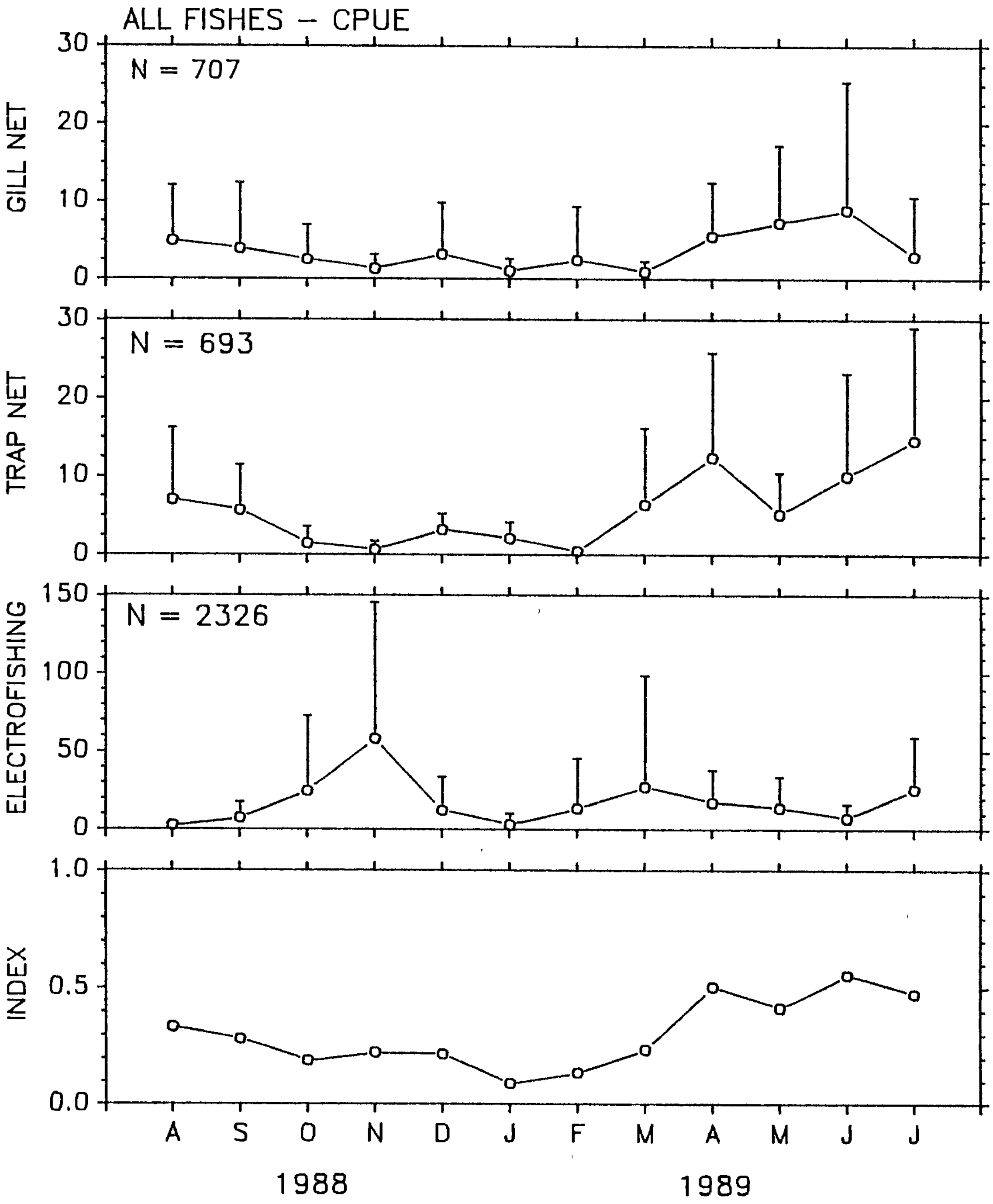
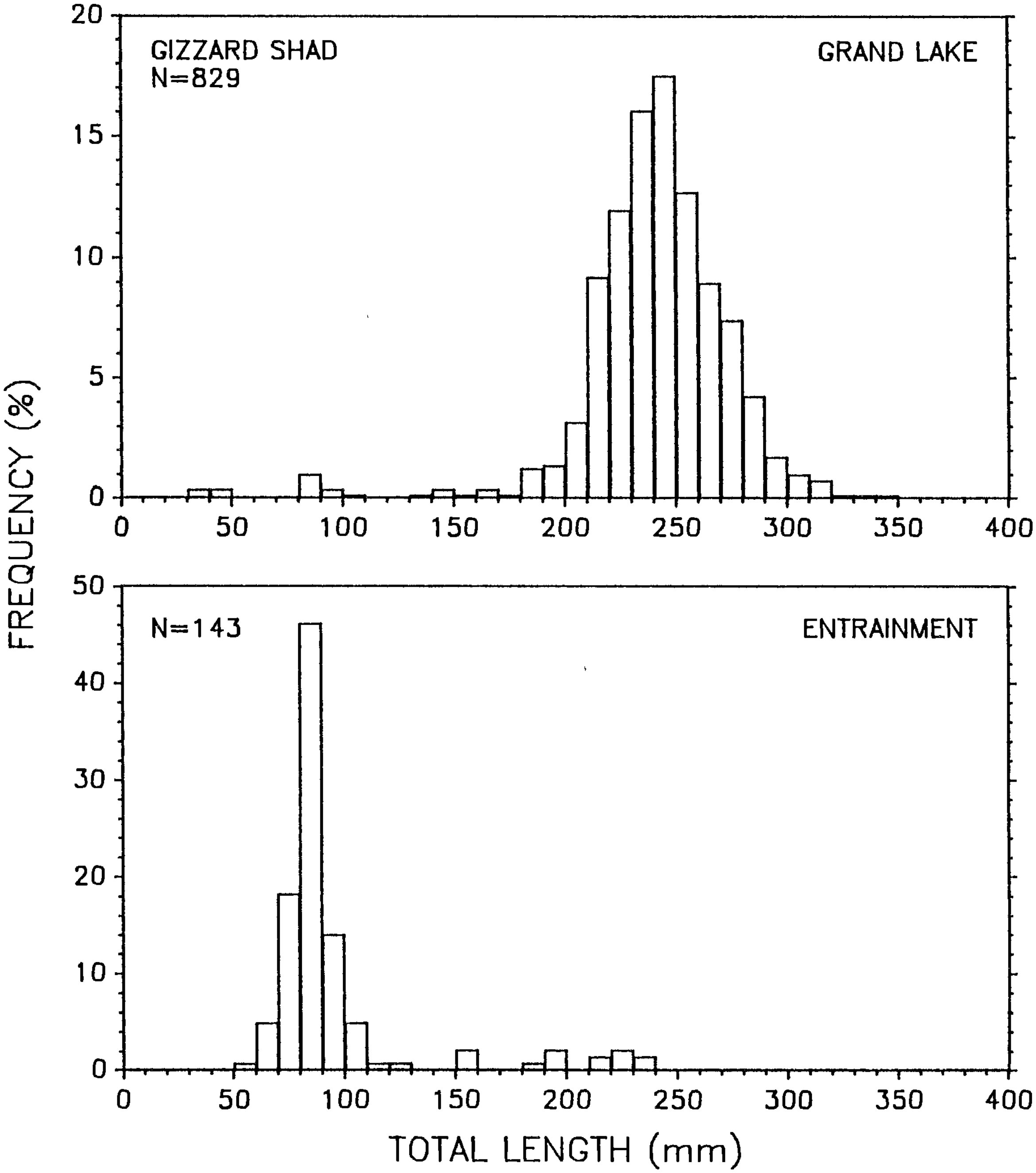
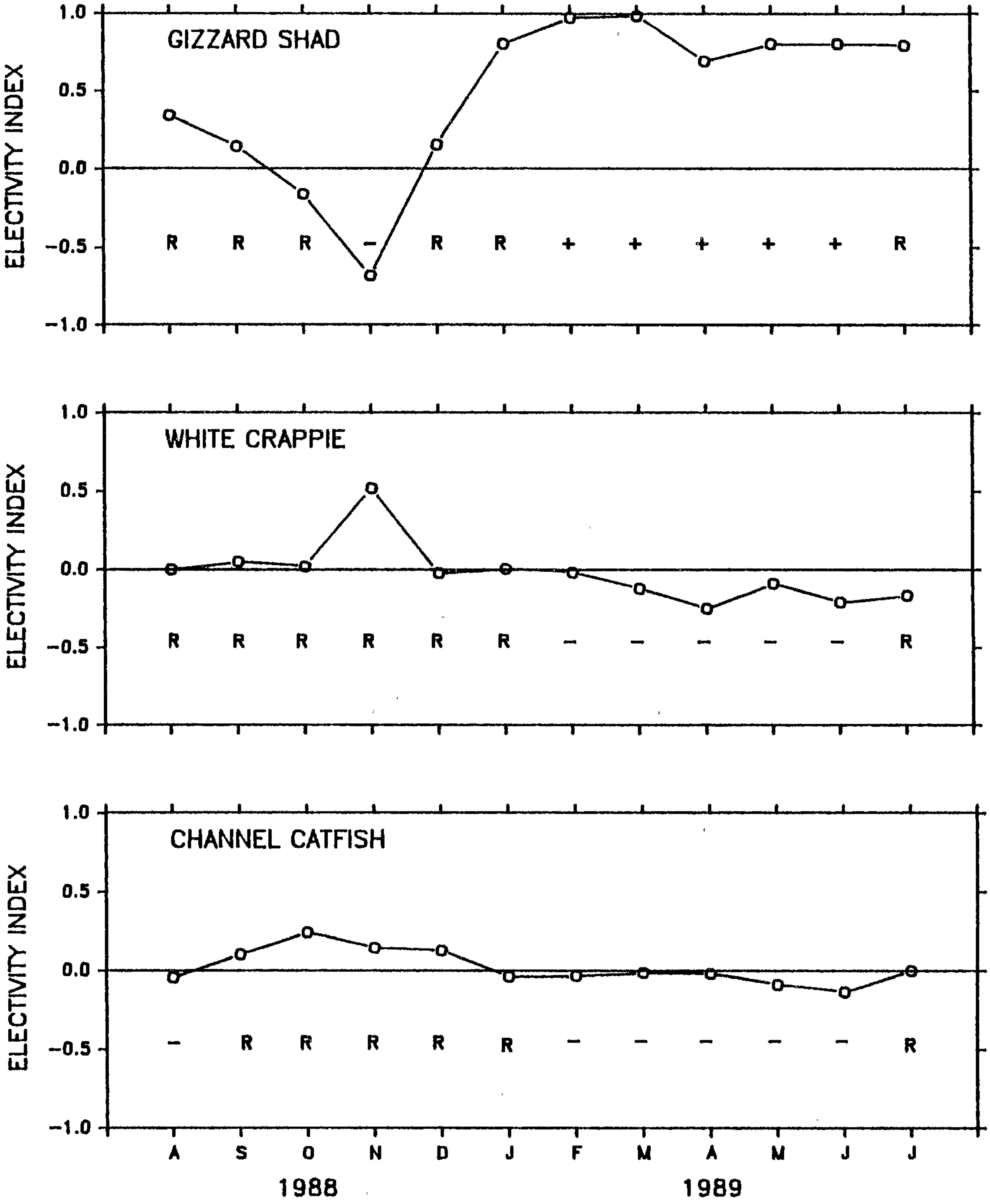
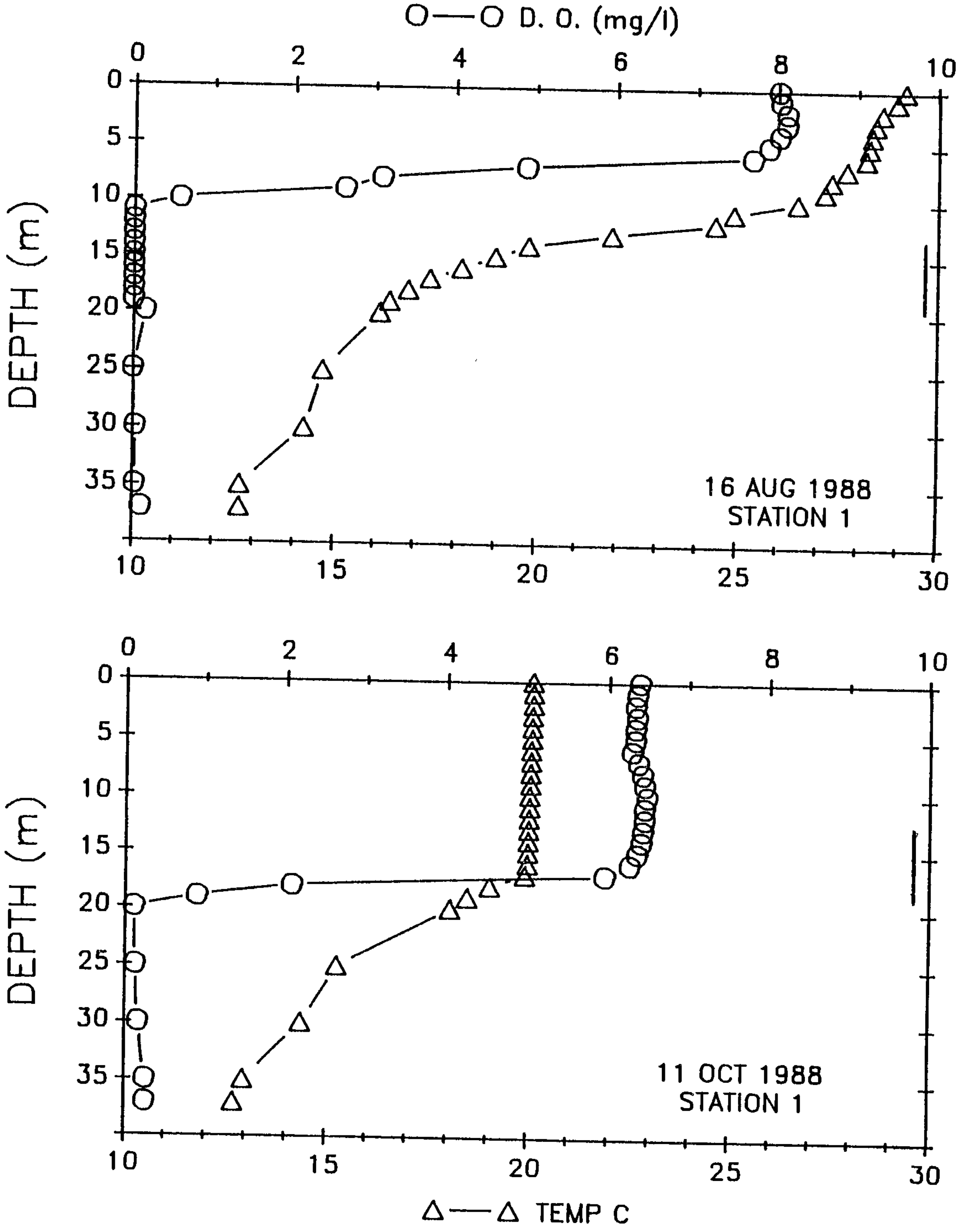
PENSACOLA DAM
HYDROELECTRIC FACILITY

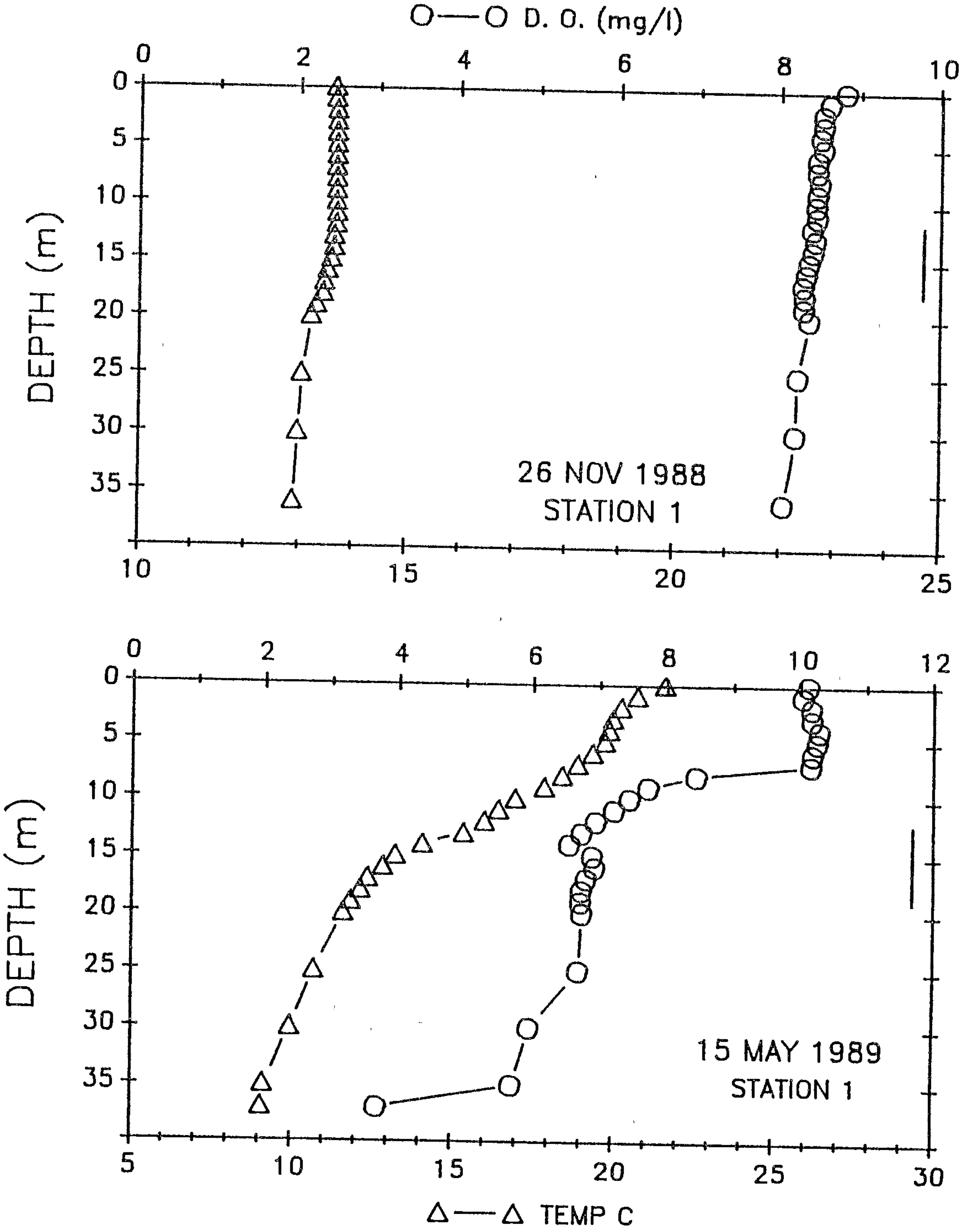

GIZZARD SHAD
WHITE CRAPPIE
BROOK SILVERSIDE
BLUEGILL
WHITE BASS
CHANNEL CATFISH
LARGEMOUTH BASS
S. MOUTH BUFFALO
LONGEAR SUNFISH
GREEN SUNFISH
OTHER
N=3726
0
10
20
30
40
FREQUENCY (%)


ALL FISHES - CPUE
GILL NET
N = 707
30
20
10
0
TRAP NET
N = 693
30
20
10
0
ELECTROFISHING
N = 2326
150
100
50
0
INDEX
1.0
0.5
0.0
A
S
O
N
D
J
F
M
A
M
J
J
1988
1989


GIZZARD SHAD
N=829
GRAND LAKE
N=143
ENTRAINMENT
FREQUENCY (%)
TOTAL LENGTH (mm)
0
5
10
15
20
30
40
50
100
150
200
250
300
350
400


GIZZARD SHAD
ELECTIVITY INDEX
1.0
0.5
0.0
-0.5
-1.0
R R R – R R + + + + + R
WHITE CRAPPIE
ELECTIVITY INDEX
R R R R R R – – – – – R
CHANNEL CATFISH
ELECTIVITY INDEX
– R R R R R – – – – – R
A S O N D J F M A M J J
1988
1989


O—O D. O. (mg/l)
0
2
4
6
8
10
DEPTH (m)
0
5
10
15
20
25
30
35
10
15
20
25
30
16 AUG 1988
STATION 1
0
2
4
6
8
10
DEPTH (m)
0
5
10
15
20
25
30
35
10
15
20
25
30
11 OCT 1988
STATION 1
△—△ TEMP C


O—O D. O. (mg/l)
0
2
4
6
8
10
DEPTH (m)
0
5
10
15
20
25
30
35
26 NOV 1988
STATION 1
10
15
20
25
0
2
4
6
8
10
12
15 MAY 1989
STATION 1
5
10
15
20
25
30
△—△ TEMP C

APPENDIX A

MONTHLY ENTRAINMENT RATES

Table A.1. Monthly entrainment rates of all fishes entrained at Pensacola Dam hydroelectric facility, August 1988 to July 1989 (Fisher and Zale 1990).

Month	Total	Gizzard shad	White crappie	Channel catfish	Bluegill	Blue catfish	Green sunfish	Bigmouth buffalo	Freshwater drum	White bass	Unidentified
Aug 88	9150	4488	4026	0	0	0	0	0	636	0	0
Sep 88	14706	6491	2047	1834	2744	722	0	0	0	816	0
Oct 88	16272	7852	1035	3984	0	913	0	0	0	0	2488
Nov 88	21563	4474	11454	3227	0	0	0	0	0	0	0
Dec 88	55144	37708	4104	9640	0	0	2408	0	0	0	0
Jan 89	21500	17307	4193	0	0	0	0	2314	1377	0	0
Feb 89	8949493	8949493	0	0	0	0	0	0	0	0	0
Mar 89	4270989	4266504	0	4449	0	0	0	0	0	0	0
Apr 89	925433	920816	4623	0	0	0	0	0	0	0	0
May 89	998264	992382	0	1850	2190	1850	0	0	0	0	0
Jun 89	44319	44319	0	0	0	0	0	0	0	0	0
Jul 89	5950	5950	0	0	0	0	0	0	0	0	0
Total		15257784	31482	2498	493	3535	2408	2314	2013	816	2488
Percent		99.5	0.21	0.16	0.03	0.02	0.01	0.01	0.01	<0.01	0.02

APPENDIX B

SUSCEPTIBILITY VALUES

Table B.1. Turbine-entrainment susceptibilities of fishes in Grand Lake, August 1988. The relative abundances of fishes in entrainment and Grand Lake samples are denoted r and p, respectively. L is Strauss' linear electivity index. The symbols +, R, and - represent positive, random, and negative susceptibility, respectively. Probability values are given in parentheses. Probability values >0.05 were judged as indicating random susceptibility (Wilcoxon's signed rank test).

Species	r	p	L	Susceptibility	
Gizzard shad	0.490	0.148	+0.342	R	(0.9680)
White crappie	0.440	0.439	+0.001	R	(0.6892)
Channel catfish	0	0.045	-0.045	-	(0.0434)
Bluegill	0	0.084	-0.084	-	(0.0434)
Blue catfish	0	0.006	-0.006	-	(0.0434)
Green sunfish	0	0.026	-0.026	-	(0.0434)
Bigmouth buffalo	0	0	--		--
Freshwater drum	0.070	0.026	+0.044	R	(0.5028)
White bass	0	0.084	-0.084	-	(0.0434)

Table B.32. Turbine-entrainment susceptibilities of fishes in Grand Lake, September 1988. The relative abundances of fishes in entrainment and Grand Lake samples are denoted r and p, respectively. L is Strauss' linear electivity index. The symbols +, R, and - represent positive, random, and negative susceptibility, respectively. Probability values are given in parentheses. Probability values >0.05 were judged as indicating random susceptibility (Wilcoxon's signed rank test).

Species	r	p	L	Susceptibility	
Gizzard shad	0.441	0.299	+0.142	R	(0.9602)
White crappie	0.139	0.090	+0.049	R	(0.0075)
Channel catfish	0.125	0.023	+0.102	R	(0.3844)
Bluegill	0.187	0.395	-0.208	R	(0.3844)
Blue catfish	0.052	0	+0.052	R	(0.3174)
Green sunfish	0	0.034	-0.034	-	(0.0052)
Bigmouth buffalo	0	0	--		--
Freshwater drum	0	0	--		--
White bass	0.055	0.028	+0.027	R	(0.0750)

Table B.3. Turbine-entrainment susceptibilities of fishes in Grand Lake, October 1988. The relative abundances of fishes in entrainment and Grand Lake samples are denoted r and p, respectively. L is Strauss' linear electivity index. The symbols +, R, and - represent positive, random, and negative susceptibility, respectively. Probability values are given in parentheses. Probability values >0.05 were judged as indicating random susceptibility (Wilcoxon's signed rank test).

Species	r	p	L	Susceptibility
Gizzard shad	0.482	0.644	-0.162	R (0.2628)
White crappie	0.064	0.045	+0.019	R (0.1616)
Channel catfis	0.245	0.003	+0.242	R (0.6744)
Bluegill	0	0.080	-0.080	- (0.0118)
Blue catfish	0.056	0.010	+0.046	R (0.1616)
Green sunfish	0	0.017	-0.017	- (0.0118)
Bigmouth buffalo	0	0	--	--
Freshwater drum	0	0.017	-0.017	- (0.0118)
White bass	0	0.017	-0.017	- (0.0118)

Table B.4. Turbine-entrainment susceptibilities of fishes in Grand Lake, November 1988. The relative abundances of fishes in entrainment and Grand Lake samples are denoted r and p, respectively. L is Strauss' linear electivity index. The symbols +, R, and - represent positive, random, and negative susceptibility, respectively. Probability values are given in parentheses. Probability values >0.05 were judged as indicating random susceptibility (Wilcoxon's signed rank test).

Species	r	p	L	Susceptibility
Gizzard shad	0.207	0.890	-0.683	- (0.0434)
White crappie	0.531	0.012	+0.519	R (0.0802)
Channel catfish	0.150	0.007	+0.143	R (0.5028)
Bluegill	0	0.030	-0.030	- (0.0434)
Blue catfish	0	0.002	-0.002	- (0.0434)
Green sunfish	0.112	0.005	+0.107	R (0.5028)
Bigmouth buffalo	0	0	--	--
Freshwater drum	0	0.002	-0.002	- (0.0434)
White bass	0	0.008	-0.008	- (0.0434)

Table B.5. Turbine-entrainment susceptibilities of fishes in Grand Lake, December 1988. The relative abundances of fishes in entrainment and Grand Lake samples are denoted r and p, respectively. L is Strauss' linear electivity index. The symbols +, R, and - represent positive, random, and negative susceptibility, respectively. Probability values are given in parentheses. Probability values >0.05 were judged as indicating random susceptibility (Wilcoxon's signed rank test).

Species	r	p	L	Susceptibility
Gizzard shad	0.684	0.530	+0.154	R (0.6600)
White crappie	0.074	0.097	-0.023	R (0.2846)
Channel catfish	0.175	0.049	+0.126	R (0.0512)
Bluegill	0	0.108	-0.108	- (0.0034)
Blue catfish	0	0	--	--
Green sunfish	0	0.016	-0.016	- (0.0034)
Bigmouth buffalo	0.042	0	+0.042	R (0.3174)
Freshwater drum	0.025	0	+0.025	R (0.3174)
White bass	0	0.070	-0.070	- (0.0034)

Table B.6. Turbine-entrainment susceptibilities of fishes in Grand Lake, January 1989. The relative abundances of fishes in entrainment and Grand Lake samples are denoted r and p, respectively. L is Strauss' linear electivity index. The symbols +, R, and - represent positive, random, and negative susceptibility, respectively. Probability values are given in parentheses. Probability values >0.05 were judged as indicating random susceptibility (Wilcoxon's signed rank test).

Species	r	p	L	Susceptibility
Gizzard shad	0.805	0	+0.805	R (1.0000)
White crappie	0.195	0.200	+0.005	R (1.0000)
Channel catfish	0	0.040	-0.040	R (0.1096)
Bluegill	0	0.120	-0.120	R (0.1096)
Blue catfish	0	0.013	-0.013	R (0.1096)
Green sunfish	0	0	--	--
Bigmouth buffalo	0	0	--	--
Freshwater drum	0	0.013	-0.013	R (0.1096)
White bass	0	0.147	-0.147	R (0.1096)

Table B.7. Turbine-entrainment susceptibilities of fishes in Grand Lake, February 1989. The relative abundances of fishes in entrainment and Grand Lake samples are denoted r and p, respectively. L is Strauss' linear electivity index. The symbols +, R, and - represent positive, random, and negative susceptibility, respectively. Probability values are given in parentheses. Probability values >0.05 were judged as indicating random susceptibility (Wilcoxon's signed rank test).

Species	r	p	L	Susceptibility
Gizzard shad	1.000	0.029	+0.971	+ (<0.0002)
White crappie	0	0.020	-0.020	- (<0.0002)
Channel catfish	0	0.034	-0.034	- (<0.0002)
Bluegill	0	0.005	-0.005	- (<0.0002)
Blue catfish	0	0.005	-0.005	- (<0.0002)
Green sunfish	0	0.005	-0.005	- (<0.0002)
Bigmouth buffalo	0	0	--	--
Freshwater drum	0	0	--	--
White bass	0	0.117	-0.117	- (<0.0002)

Table B.8. Turbine-entrainment susceptibilities of fishes in Grand Lake, March 1989. The relative abundances of fishes in entrainment and Grand Lake samples are denoted r and p, respectively. L is Strauss' linear electivity index. The symbols +, R, and - represent positive, random, and negative susceptibility, respectively. Probability values are given in parentheses. Probability values >0.05 were judged as indicating random susceptibility (Wilcoxon's signed rank test).

Species	r	p	L	Susceptibility
Gizzard shad	0.999	0.017	+0.982	+ (<0.0002)
White crappie	0	0.123	-0.123	- (<0.0002)
Channel catfish	0.001	0.015	-0.014	- (<0.0002)
Bluegill	0	0.049	-0.049	- (<0.0002)
Blue catfish	0	0	--	--
Green sunfish	0	0	--	--
Bigmouth buffalo	0	0	--	--
Freshwater drum	0	0	--	--
White bass	0	0.017	-0.017	- (<0.0002)

Table B.9. Turbine-entrainment susceptibilities of fishes in Grand Lake, April 1989. The relative abundances of fishes in entrainment and Grand Lake samples are denoted r and p, respectively. L is Strauss' linear electivity index. The symbols +, R, and - represent positive, random, and negative susceptibility, respectively. Probability values are given in parentheses. Probability values >0.05 were judged as indicating random susceptibility (Wilcoxon's signed rank test).

Species	r	p	L	Susceptibility
Gizzard shad	0.995	0.303	+0.692	+ (<0.0002)
White crappie	0.005	0.255	-0.250	- (<0.0010)
Channel catfish	0	0.021	-0.021	- (<0.0002)
Bluegill	0	0.131	-0.131	- (<0.0002)
Blue catfish	0	0	--	--
Green sunfish	0	0.021	-0.021	- (<0.0002)
Bigmouth buffalo	0	0	--	--
Freshwater drum	0	0.005	-0.005	- (<0.0002)
White bass	0	0.122	-0.122	- (<0.0002)

Table B.10. Turbine-entrainment susceptibilities of fishes in Grand Lake, May 1989. The relative abundances of fishes in entrainment and Grand Lake samples are denoted r and p, respectively. L is Strauss' linear electivity index. The symbols +, R, and - represent positive, random, and negative susceptibility, respectively. Probability values are given in parentheses. Probability values >0.05 were judged as indicating random susceptibility (Wilcoxon's signed rank test).

Species	r	p	L	Susceptibility
Gizzard shad	0.994	0.189	+0.805	+ (<0.0002)
White crappie	0	0.212	-0.212	- (<0.0002)
Channel catfish	0.002	0.093	-0.091	- (<0.0002)
Bluegill	0.002	0.111	-0.109	- (0.0010)
Blue catfish	0.002	0.010	-0.008	- (<0.0002)
Green sunfish	0	0.036	-0.036	- (<0.0002)
Bigmouth buffalo	0	0	--	--
Freshwater drum	0	0.008	-0.008	- (<0.0002)
White bass	0	0.150	-0.150	- (<0.0002)

Table B.11. Turbine-entrainment susceptibilities of fishes in Grand Lake, June 1989. The relative abundances of fishes in entrainment and Grand Lake samples are denoted r and p, respectively. L is Strauss' linear electivity index. The symbols +, R, and - represent positive, random, and negative susceptibility, respectively. Probability values are given in parentheses. Probability values >0.05 were judged as indicating random susceptibility (Wilcoxon's signed rank test).

Species	r	p	L	Susceptibility
Gizzard shad	1.000	0.195	+0.805	+ (0.0434)
White crappie	0	0.210	-0.210	- (0.0434)
Channel catfish	0	0.137	-0.137	- (0.0434)
Bluegill	0	0.222	-0.222	- (0.0434)
Blue catfish	0	0	--	--
Green sunfish	0	0.021	-0.021	- (0.0434)
Bigmouth buffalo	0	0	--	--
Freshwater drum	0	0	--	--
White bass	0	0.018	-0.018	- (0.0434)

Table B.12. Turbine-entrainment susceptibilities of fishes in Grand Lake, July 1989. The relative abundances of fishes in entrainment and Grand Lake samples are denoted r and p, respectively. L is Strauss' linear electivity index. The symbols +, R, and - represent positive, random, and negative susceptibility, respectively. Probability values are given in parentheses. Probability values >0.05 were judged as indicating random susceptibility (Wilcoxon's signed rank test).

Species	r	p	L	Susceptibility
Gizzard shad	1.000	0.206	+0.794	R (0.6528)
White crappie	0	0.166	-0.166	R (0.1802)
Channel catfish	0	0.001	-0.001	R (0.1802)
Bluegill	0	0.316	-0.316	R (0.1802)
Blue catfish	0	0	--	--
Green sunfish	0	0.020	-0.020	R (0.1802)
Bigmouth buffalo	0	0	--	--
Freshwater drum	0	0.014	-0.014	R (0.1802)
White bass	0	0.154	-0.154	R (0.1802)

APPENDIX C

TOTAL CATCHES AND RELATIVE ABUNDANCE BY GEAR

Table C.1. Total catches (N) and relative abundances (%) of fishes captured with gill nets, trap nets, and by electrofishing in Grand Lake, August 1988 to July 1989.

	Gill net		Trap net		Electrofishing		Combined	
Species	N	%	N	%	N	%	N	%
Blue catfish *Ictalurus furcatus*	11	1.6	0	0.0	0	0.0	11	0.3
Bluegill *Lepomis macrochirus*	0	0.0	260	37.5	243	10.4	514	13.8
Brook silverside *Labidesthes sicculus*	0	0.0	0	0.0	518	22.3	518	27.7
Channel catfish *Ictalurus punctatus*	130	18.4	2	0.3	4	0.2	136	3.7
Common carp *Cyprinus carpio*	11	1.6	1	0.1	11	0.5	23	0.6
Freshwater drum *Aplodinotus grunniens*	13	1.8	3	0.4	10	0.4	26	0.7
Flathead catfish *Polyodictus olivaris*	2	0.3	0	0.0	0	0.0	2	0.1
Green sunfish *Lepomis cyanellus*	0	0.0	18	2.6	44	1.9	62	1.7
Gizzard shad *Dorosoma cepedianum*	72	10.2	1	0.1	1202	51.7	1275	34.2
Hybrid striped bass *Morone saxatilis* x *M. chrysops*	34	4.8	0	0.0	0	0.0	34	0.9
Hybrid sunfish *Lepomis* sp.	0	0.0	3	0.4	1	<0.1	4	0.1
Longear sunfish *Lepomis megalotis*	0	0.0	17	2.5	46	2.0	63	1.7
Logperch *Percina caprodes*	0	0.0	0	0.0	8	0.3	8	0.2
Largemouth bass *Micropterus salmoides*	5	0.7	19	2.7	81	3.5	105	2.8
Longnose gar *Lepisosteus osseus*	0	0.0	0	0.0	2	0.1	2	0.1
Paddlefish *Polyodon spathula*	7	1.0	0	0.0	0	0.0	7	0.2
Rainbow trout *Oncorhynchus mykiss*	2	0.3	0	0.0	1	<0.1	3	0.1
River carpsucker *Carpiodes carpio*	5	0.7	0	0.0	6	0.3	11	0.3
Redear sunfish *Lepomis microlophus*	0	0.0	1	0.1	0	0.0	1	<0.1
Smallmouth buffalo *Ictiobus bubalus*	52	7.4	1	0.1	27	1.2	80	2.1
Slender madtom *Noturus exilis*	0	0.0	0	0.0	1	<0.1	1	<0.1
Spotted bass *Micropterus punctulatus*	3	0.4	2	0.3	30	1.3	35	0.9
White bass *Morone chrysops*	192	27.2	0	0.0	83	3.6	275	7.4
White crappie *Pomoxis annularis*	168	23.8	358	51.7	6	0.3	532	14.3
Warmouth *Lepomis gulosis*	0	0.0	7	1.0	2	0.1	9	0.2
TOTAL	707		693		2326		3726	

APPENDIX D

ANOVA OF MONTHLY MEAN CPUE

Table D.1. Sums of squares (SS), F, and probability values (P) of analyses of variance testing whether differences existed among monthly mean numeric catch-per-unit-effort rates, by gear, of fishes collected in Grand Lake, August 1988 to July 1989. Asterisks denote significant differences (alpha = 0.05).

Species	Gill net			Trap net			Electrofishing		
	SS	F	P	SS	F	P	SS	F	P
Blue catfish	1.34	1.15	0.3280	--	--	--	--	--	--
Bluegill	--	--	--	845.07	3.10	0.0012*	320.90	1.64	0.0956
Brook silverside	--	--	--	--	--	--	7642.59	1.30	0.2329
Channel catfish	108.61	1.85	0.0505	0.17	0.91	0.5344	0.40	0.80	0.6363
Common carp	0.59	0.73	0.7079	0.09	1.00	0.4513	1.08	0.80	0.6418
Freshwater drum	2.44	1.55	0.1186	0.27	0.73	0.7102	1.27	1.41	0.1761
Flathead catfish	0.23	1.88	0.0449*	--	--	--	--	--	--
Green sunfish	--	--	--	2.30	1.19	0.3036	10.05	0.53	0.8783
Gizzard shad	85.73	1.75	0.0665	0.09	1.00	0.4513	24836.80	3.30	0.0005*
Hybrid striped bass	11.64	1.22	0.2755	--	--	--	--	--	--
Hybrid sunfish	--	--	--	0.43	0.93	0.5173	0.09	1.14	0.3363
Longear sunfish	--	--	--	7.49	0.84	0.5964	15.37	1.25	0.2642
Logperch	--	--	--	--	--	--	2.11	0.92	0.5247
Largemouth bass	0.42	0.94	0.5014	6.49	2.50	0.0077*	37.55	1.20	0.2927
Longnose gar	--	--	--	--	--	--	0.14	0.83	0.6127
Paddlefish	0.37	1.11	0.3594	--	--	--	--	--	--
Rainbow trout	0.06	0.88	0.5617	--	--	--	0.07	0.92	0.5255
River carpsucker	0.58	0.83	0.6134	--	--	--	0.41	0.87	0.5762
Redear sunfish	--	--	--	0.09	1.00	0.4513	--	--	--
Smallmouth buffalo	24.09	1.30	0.2282	0.09	1.00	0.4513	15.99	2.55	0.0062*
Slender madtom	--	--	--	--	--	--	0.07	0.92	0.5255
Spotted bass	0.51	1.67	0.0814	0.17	0.91	0.5344	8.05	1.37	0.1961
White bass	138.14	1.58	0.1081	--	--	--	420.59	0.93	0.5169
White crappie	135.96	1.80	0.0572	795.57	1.80	0.0622	0.96	0.84	0.6025
Warmouth	--	--	--	0.05	0.94	0.5017	0.30	0.92	0.5255
TOTAL	1045.76	1.51	0.1320	2338.43	3.09	0.0012*	26340.49	1.56	0.1177

VITA

Kent Michael Sorenson

Candidate for the Degree of

Master of Science

Thesis: ENTRAINMENT SUSCEPTIBILITIES OF FISHES INHABITING THE LOWER PORTION OF GRAND LAKE, OKLAHOMA

Major Field: Wildlife and Fisheries Ecology

Biographical:

Personal Data: Born in Westbrook, Minnesota, May 21, 1963, the son of John C. and Sheryl R. Sorenson.

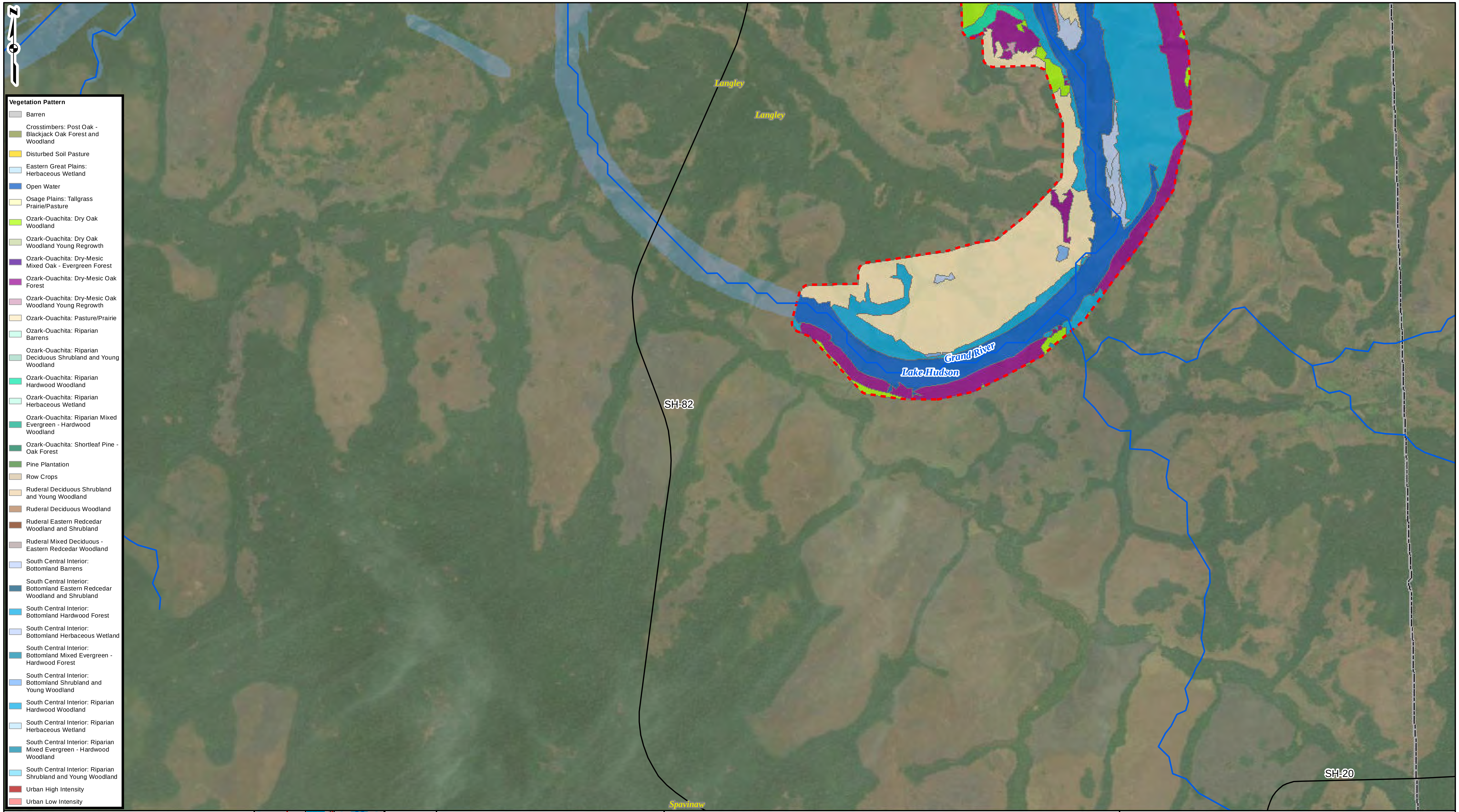
Education: Graduated from Storden-Jeffers High School, Jeffers, Minnesota, in May, 1981; received Bachelor of Science Degree in Wildlife and Fisheries Science from South Dakota State University in May, 1985; completed requirements for the Master of Science degree at Oklahoma State University in July, 1990.

Professional Experience: Professional Aide, South Dakota Department of Game, Fish, and Parks, Pierre, South Dakota, April 1986, to August, 1987; Graduate Research Assistant, Oklahoma Cooperative Fish and Wildlife Research Unit, Oklahoma State University, August, 1987, to June, 1990.

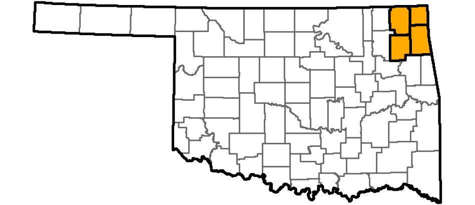
Organizational Memberships: American Fisheries Society, Oklahoma Academy of Science, Oklahoma Chapter of the American Fisheries Society.

Document Content(s)

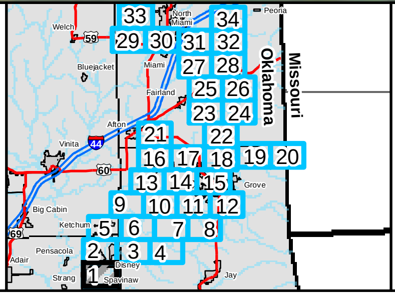
APPENDIX E-22 Vegetative Communities in the Pensacola Project Vicinity


N
Vegetation Pattern
Barren
Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
Disturbed Soil Pasture
Eastern Great Plains: Herbaceous Wetland
Open Water
Osage Plains: Tallgrass Prairie/Pasture
Ozark-Ouachita: Dry Oak Woodland
Ozark-Ouachita: Dry Oak Woodland Young Regrowth
Ozark-Ouachita: Dry-Mesic Mixed Oak - Evergreen Forest
Ozark-Ouachita: Dry-Mesic Oak Forest
Ozark-Ouachita: Dry-Mesic Oak Woodland Young Regrowth
Ozark-Ouachita: Pasture/Prairie
Ozark-Ouachita: Riparian Barrens
Ozark-Ouachita: Riparian Deciduous Shrubland and Young Woodland
Ozark-Ouachita: Riparian Hardwood Woodland
Ozark-Ouachita: Riparian Herbaceous Wetland
Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
Ozark-Ouachita: Shortleaf Pine - Oak Forest
Pine Plantation
Row Crops
Ruderal Deciduous Shrubland and Young Woodland
Ruderal Deciduous Woodland
Ruderal Eastern Redcedar Woodland and Shrubland
Ruderal Mixed Deciduous - Eastern Redcedar Woodland
South Central Interior: Bottomland Barrens
South Central Interior: Bottomland Eastern Redcedar Woodland and Shrubland
South Central Interior: Bottomland Hardwood Forest
South Central Interior: Bottomland Herbaceous Wetland
South Central Interior: Bottomland Mixed Evergreen - Hardwood Forest
South Central Interior: Bottomland Shrubland and Young Woodland
South Central Interior: Riparian Hardwood Woodland
South Central Interior: Riparian Herbaceous Wetland
South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity
Langley
Langley
SH-82
Grand River
Lake Hudson
SH-20
Spavinaw

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA



REFERENCE:
Transporation, OkDOT, 2012, 2017; Hydrology, Oklahoma Conservation Commission, 2020; Municipal Boundaries, Oklahoma Tax Commission, 2/2021.
ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

—	Major Roadway	▭	Waterbody
—	Waterway	⬚	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 1 OF 34

gai consultants

PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

Mead&Hunt

DRAWN BY: EMW
DATE: 3/9/2022
CHECKED: TDB
APPROVED: DMJ

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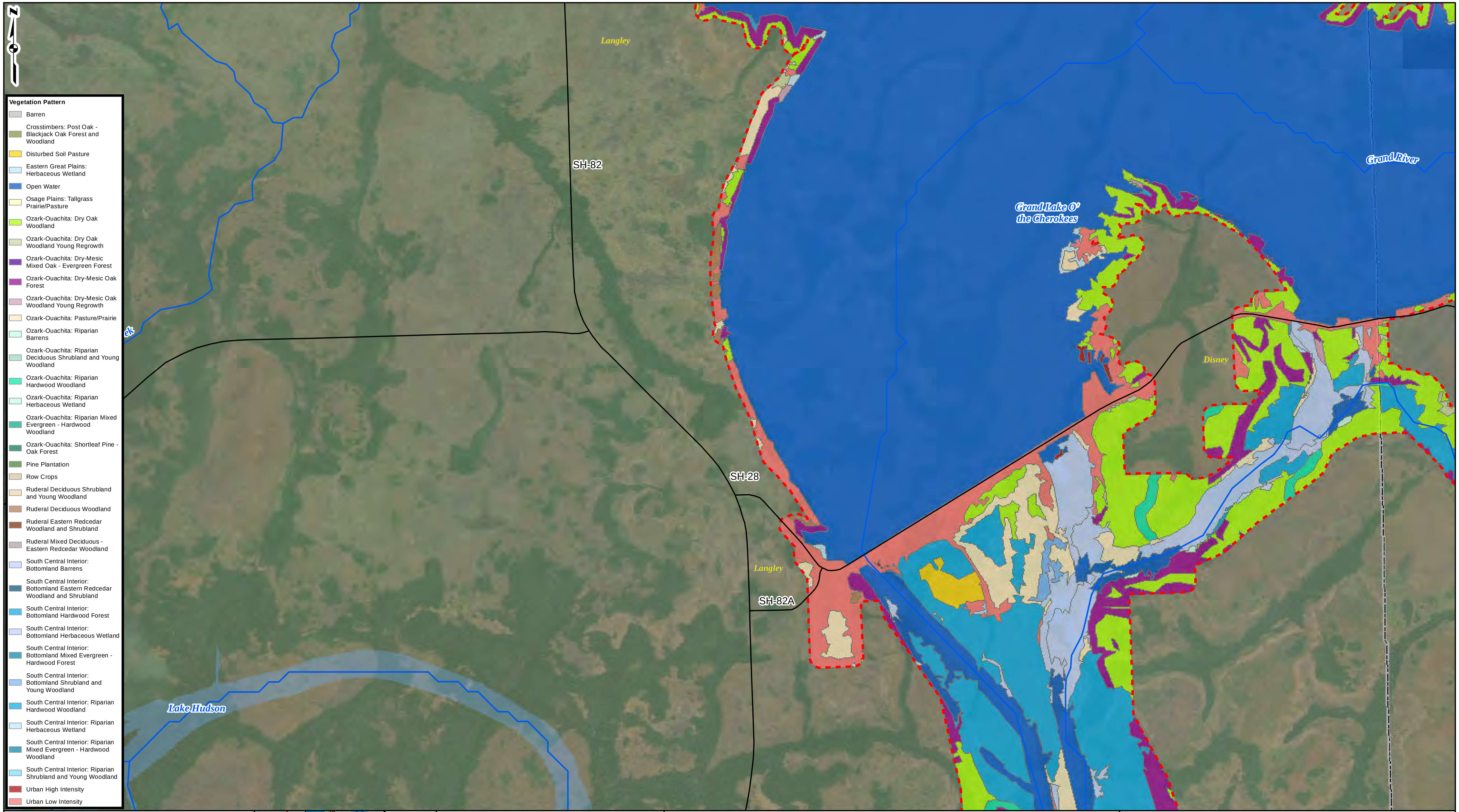

Vegetation Pattern

- ▨ Barren
- ▨ Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
- ▨ Disturbed Soil Pasture
- ▨ Eastern Great Plains: Herbaceous Wetland
- ▨ Open Water
- ▨ Osage Plains: Tallgrass Prairie/Pasture
- ▨ Ozark-Ouachita: Dry Oak Woodland
- ▨ Ozark-Ouachita: Dry Oak Woodland Young Regrowth
- ▨ Ozark-Ouachita: Dry-Mesic Mixed Oak - Evergreen Forest
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- ▨ Ozark-Ouachita: Riparian Herbaceous Wetland
- ▨ Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
- ▨ Ozark-Ouachita: Shortleaf Pine - Oak Forest
- ▨ Pine Plantation
- ▨ Row Crops
- ▨ Ruderal Deciduous Shrubland and Young Woodland
- ▨ Ruderal Deciduous Woodland
- ▨ Ruderal Eastern Redcedar Woodland and Shrubland
- ▨ Ruderal Mixed Deciduous - Eastern Redcedar Woodland
- ▨ South Central Interior: Bottomland Barrens
- ▨ South Central Interior: Bottomland Eastern Redcedar Woodland and Shrubland
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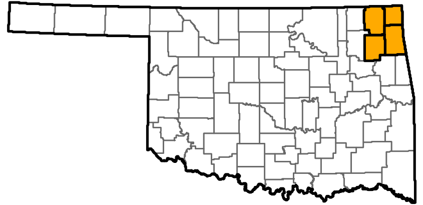
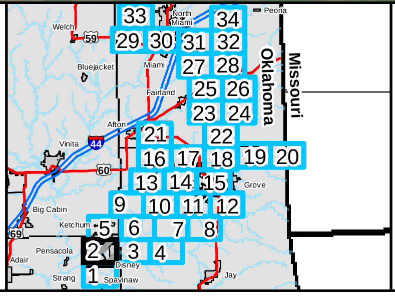
- ▨ South Central Interior: Riparian Herbaceous Wetland
- ▨ South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
- ▨ South Central Interior: Riparian Shrubland and Young Woodland
- ▨ Urban High Intensity
- ▨ Urban Low Intensity

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA



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Legend

― Major Roadway	▭ Waterbody
― Waterway	⬚ 200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT

SHEET 2 OF 34

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PENSACOLA HYDROELECTRIC
PROJECT
FERC No. P-1494

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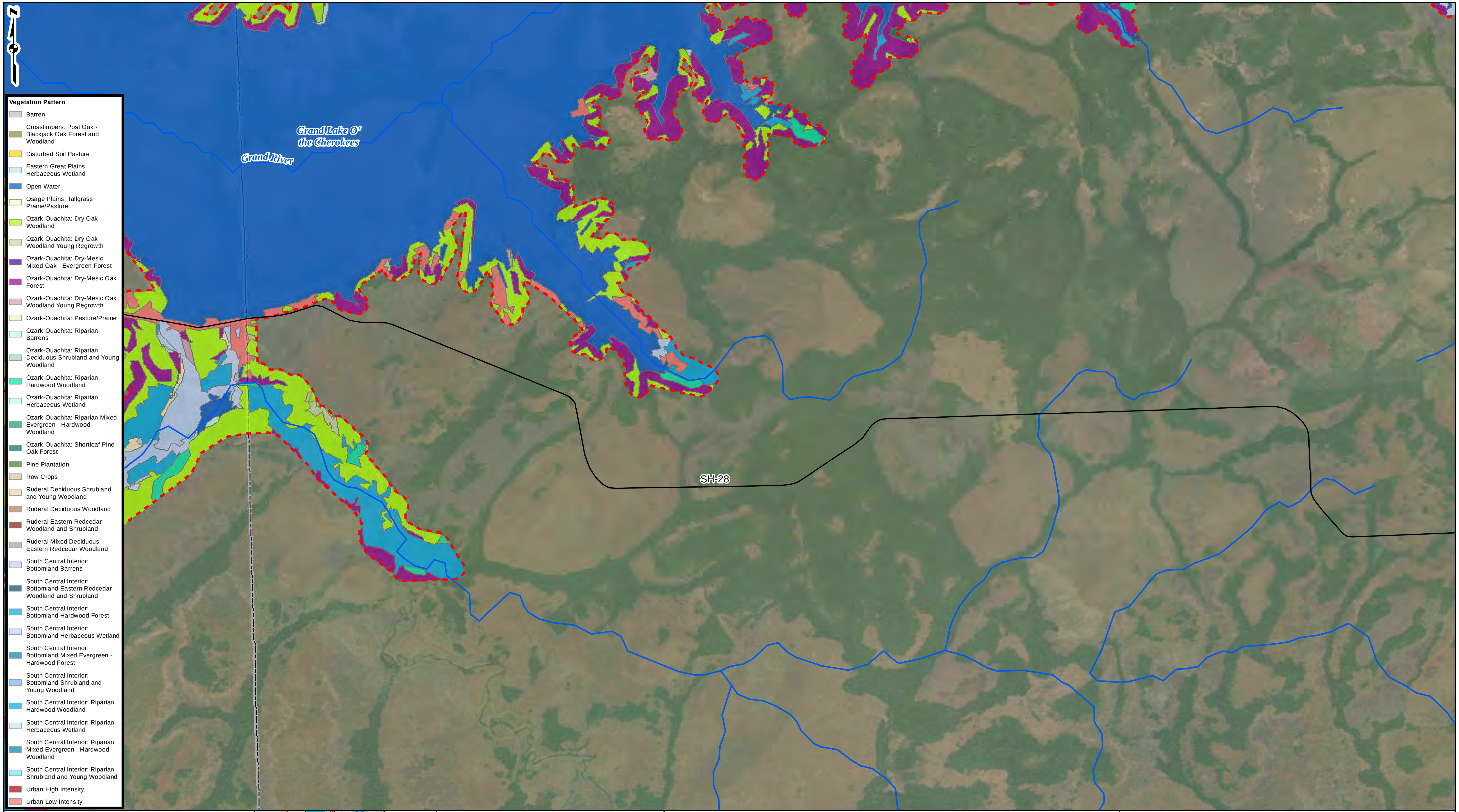
N
Grand Lake O' the Cherokees
Grand River
SH-28
Vegetation Pattern
Barren
Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
Disturbed Soil Pasture
Eastern Great Plains: Herbaceous Wetland
Open Water
Osage Plains: Tallgrass Prairie/Pasture
Ozark-Ouachita: Dry Oak Woodland
Ozark-Ouachita: Dry Oak Woodland Young Regrowth
Ozark-Ouachita: Dry-Mesic Mixed Oak - Evergreen Forest
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Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
Ozark-Ouachita: Shortleaf Pine - Oak Forest
Pine Plantation
Row Crops
Ruderal Deciduous Shrubland and Young Woodland
Ruderal Deciduous Woodland
Ruderal Eastern Redcedar Woodland and Shrubland
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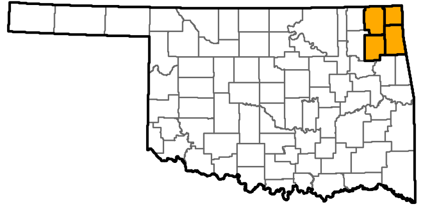
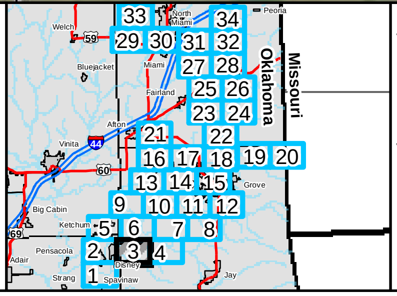
South Central Interior: Bottomland Shrubland and Young Woodland
South Central Interior: Riparian Hardwood Woodland
South Central Interior: Riparian Herbaceous Wetland
South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA



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Vegetation and Landcover, MoRAP, 3/2015

Legend

Major Roadway
Waterway
Waterbody
200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600 Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 3 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

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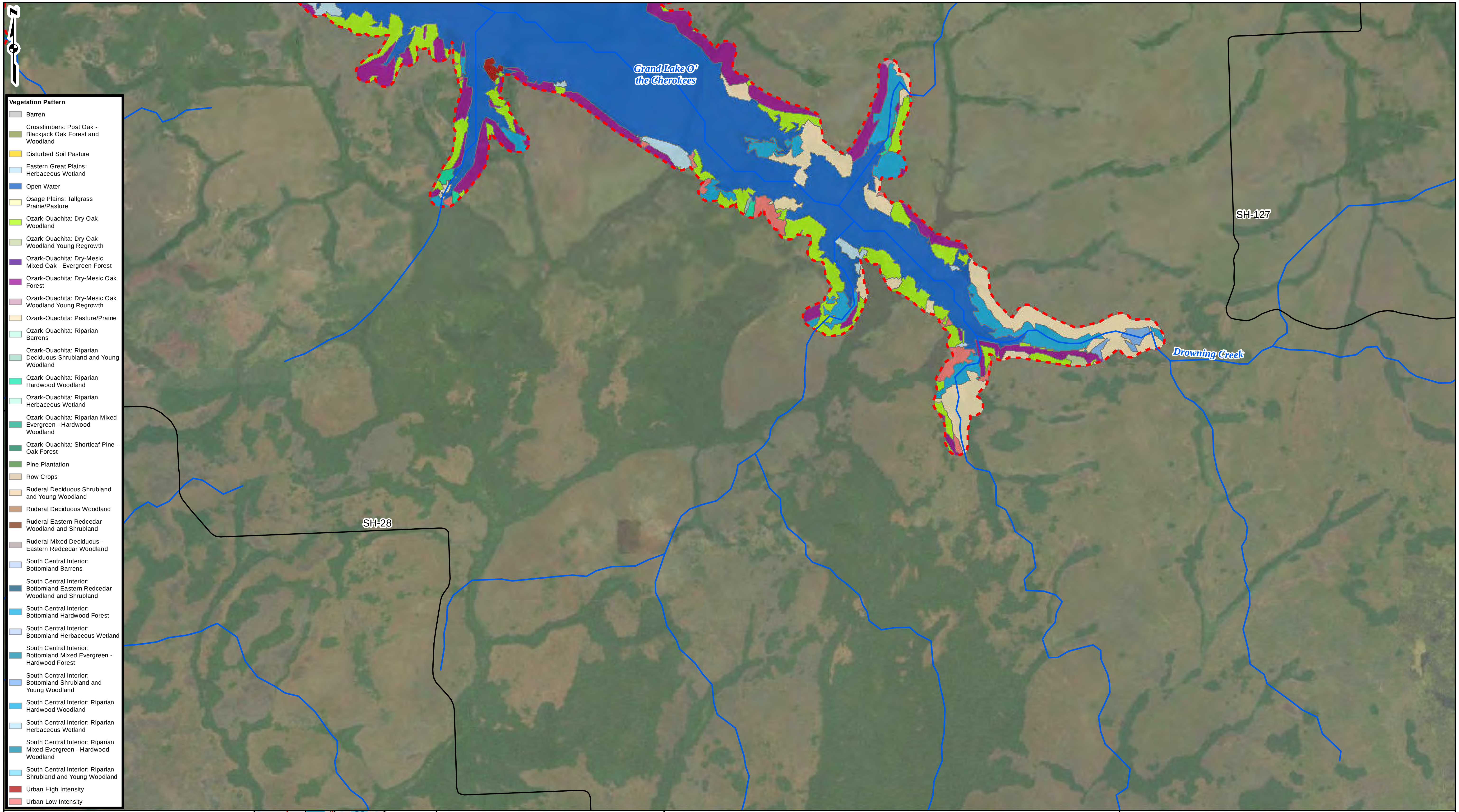

Vegetation Pattern

- ⬜ Barren
- 🟩 Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
- 🟨 Disturbed Soil Pasture
- ⬜ Eastern Great Plains: Herbaceous Wetland
- 🟦 Open Water
- 🟨 Osage Plains: Tallgrass Prairie/Pasture
- 🟩 Ozark-Ouachita: Dry Oak Woodland
- 🟩 Ozark-Ouachita: Dry Oak Woodland Young Regrowth
- 🟪 Ozark-Ouachita: Dry-Mesic Mixed Oak - Evergreen Forest
- 🟪 Ozark-Ouachita: Dry-Mesic Oak Forest
- 🟪 Ozark-Ouachita: Dry-Mesic Oak Woodland Young Regrowth
- 🟨 Ozark-Ouachita: Pasture/Prairie
- 🟩 Ozark-Ouachita: Riparian Barrens
- 🟩 Ozark-Ouachita: Riparian Deciduous Shrubland and Young Woodland
- 🟩 Ozark-Ouachita: Riparian Hardwood Woodland
- 🟩 Ozark-Ouachita: Riparian Herbaceous Wetland
- 🟩 Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
- 🟩 Ozark-Ouachita: Shortleaf Pine - Oak Forest
- 🟩 Pine Plantation
- 🟫 Row Crops
- 🟨 Ruderal Deciduous Shrubland and Young Woodland
- 🟫 Ruderal Deciduous Woodland
- 🟫 Ruderal Eastern Redcedar Woodland and Shrubland
- ⬜ Ruderal Mixed Deciduous - Eastern Redcedar Woodland
- 🟦 South Central Interior: Bottomland Barrens
- 🟦 South Central Interior: Bottomland Eastern Redcedar Woodland and Shrubland
- 🟦 South Central Interior: Bottomland Hardwood Forest
- 🟦 South Central Interior: Bottomland Herbaceous Wetland
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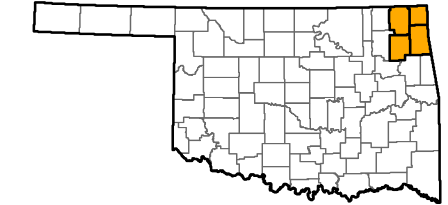
- 🟦 South Central Interior: Bottomland Shrubland and Young Woodland
- 🟦 South Central Interior: Riparian Hardwood Woodland
- 🟦 South Central Interior: Riparian Herbaceous Wetland
- 🟦 South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
- 🟦 South Central Interior: Riparian Shrubland and Young Woodland
- 🟥 Urban High Intensity
- 🟥 Urban Low Intensity

PROJECT LOCATION



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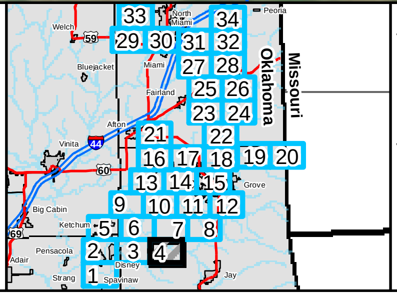

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Vegetation and Landcover, MoRAP, 3/2015

Legend

— Major Roadway	🟦 Waterbody
— Waterway	⬚ 200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 4 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

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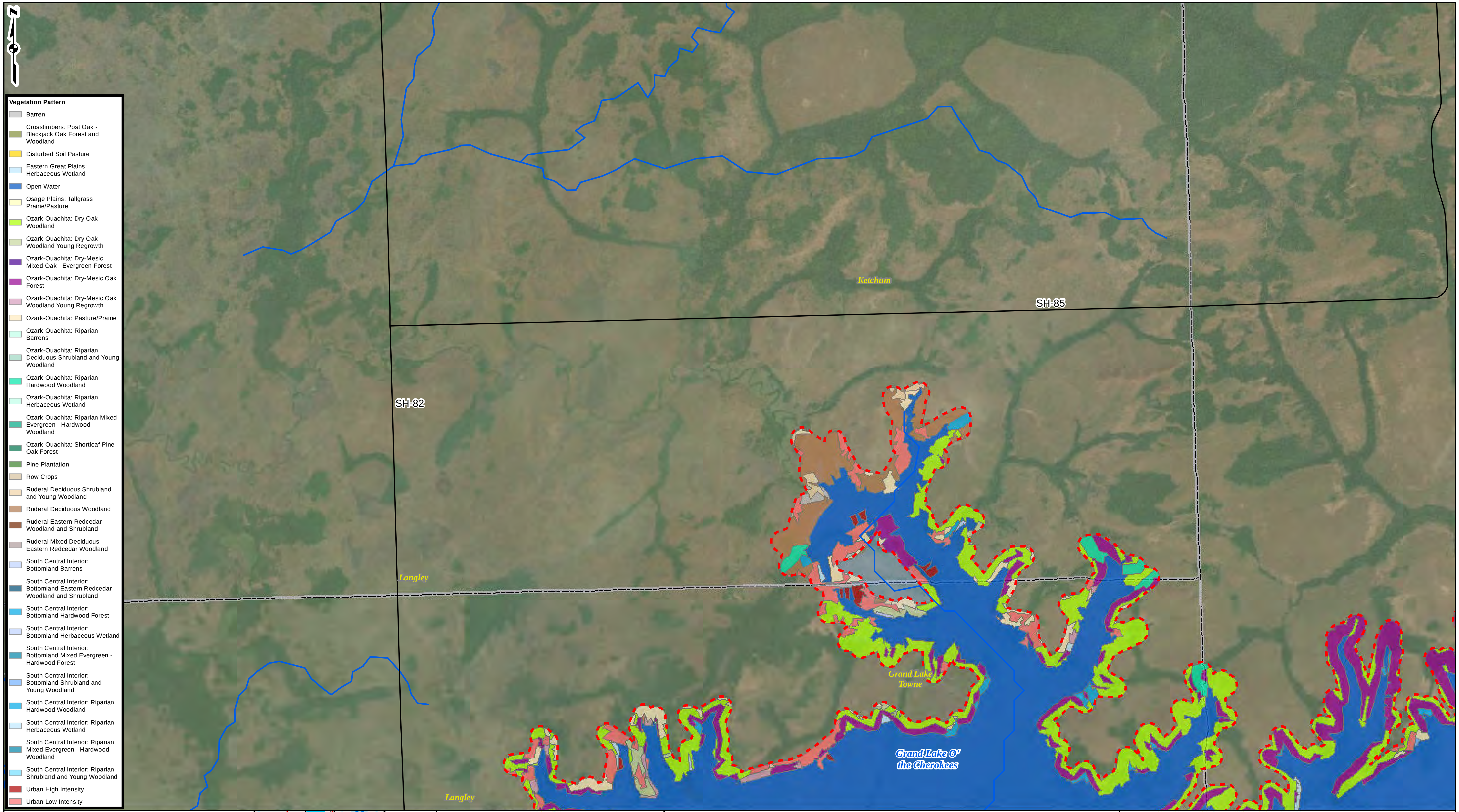
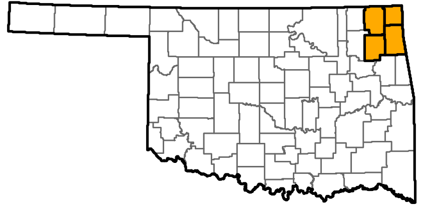


Vegetation Pattern

▭	Barren
🟩	Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
🟨	Disturbed Soil Pasture
▭	Eastern Great Plains: Herbaceous Wetland
🟦	Open Water
▭	Osage Plains: Tallgrass Prairie/Pasture
🟩	Ozark-Ouachita: Dry Oak Woodland
▭	Ozark-Ouachita: Dry Oak Woodland Young Regrowth
🟪	Ozark-Ouachita: Dry-Mesic Mixed Oak - Evergreen Forest
🟪	Ozark-Ouachita: Dry-Mesic Oak Forest
▭	Ozark-Ouachita: Dry-Mesic Oak Woodland Young Regrowth
▭	Ozark-Ouachita: Pasture/Prairie
▭	Ozark-Ouachita: Riparian Barrens
▭	Ozark-Ouachita: Riparian Deciduous Shrubland and Young Woodland
🟩	Ozark-Ouachita: Riparian Hardwood Woodland
▭	Ozark-Ouachita: Riparian Herbaceous Wetland
🟩	Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
🟩	Ozark-Ouachita: Shortleaf Pine - Oak Forest
🟩	Pine Plantation
▭	Row Crops
▭	Ruderal Deciduous Shrubland and Young Woodland
🟫	Ruderal Deciduous Woodland
🟫	Ruderal Eastern Redcedar Woodland and Shrubland
▭	Ruderal Mixed Deciduous - Eastern Redcedar Woodland
▭	South Central Interior: Bottomland Barrens
🟦	South Central Interior: Bottomland Eastern Redcedar Woodland and Shrubland
🟦	South Central Interior: Bottomland Hardwood Forest
▭	South Central Interior: Bottomland Herbaceous Wetland
🟦	South Central Interior: Bottomland Mixed Evergreen - Hardwood Forest
🟦	South Central Interior: Bottomland Shrubland and Young Woodland
🟦	South Central Interior: Riparian Hardwood Woodland
▭	South Central Interior: Riparian Herbaceous Wetland
🟦	South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
🟦	South Central Interior: Riparian Shrubland and Young Woodland
🟥	Urban High Intensity
🟥	Urban Low Intensity

PROJECT LOCATION



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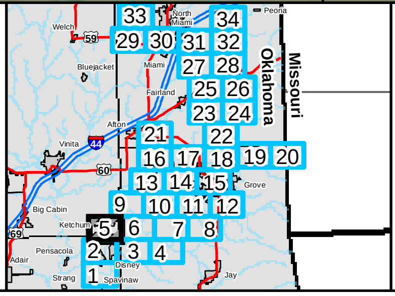

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Vegetation and Landcover, MoRAP, 3/2015

Legend

―	Major Roadway	▭	Waterbody
―	Waterway	⬚	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 5 OF 34

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PENSACOLA HYDROELECTRIC
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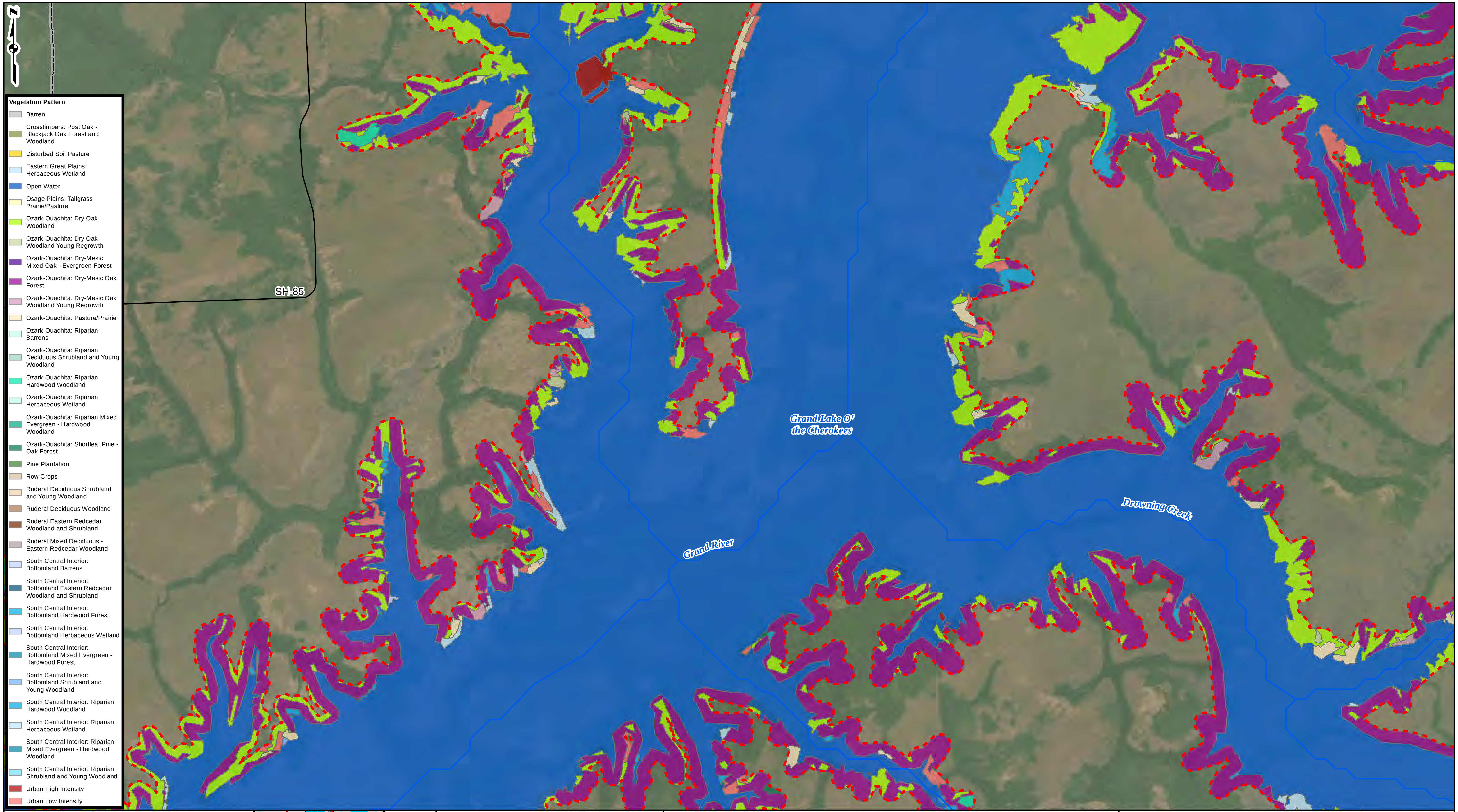
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Vegetation Pattern
Barren
Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
Disturbed Soil Pasture
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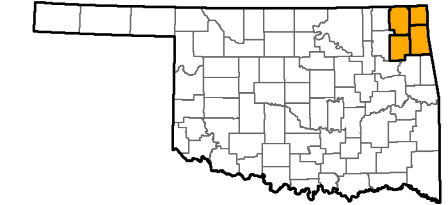
South Central Interior: Riparian Herbaceous Wetland
South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity
SH-85
Grand Lake O' the Cherokees
Grand River
Drowning Creek

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
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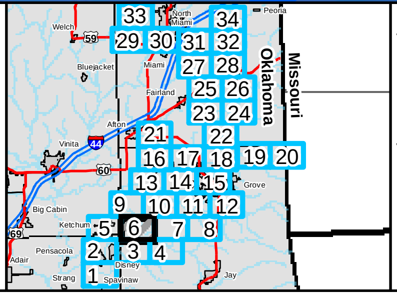

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Vegetation and Landcover, MoRAP, 3/2015

Legend

—	Major Roadway	🟦	Waterbody
—	Waterway	⬚	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 6 OF 34

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PENSACOLA HYDROELECTRIC
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FERC No. P-1494

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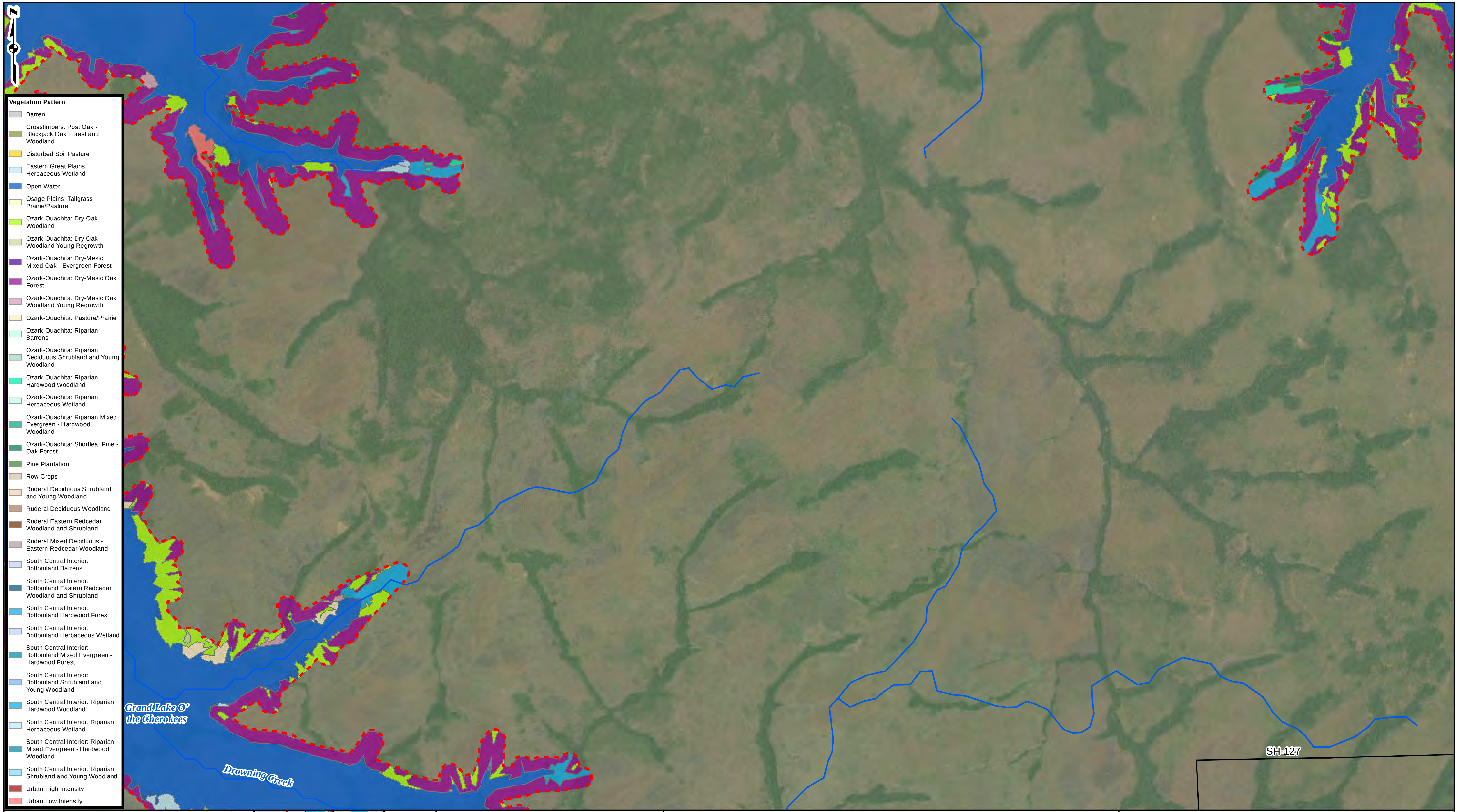
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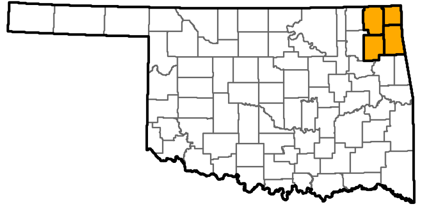
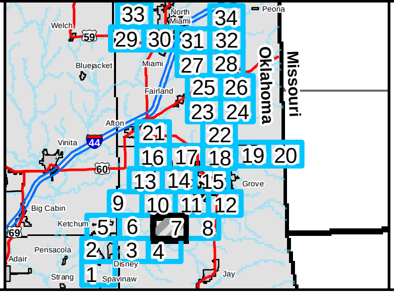
South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity
Grand Lake O' the Cherokees
Drowning Creek
SH-127

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA



REFERENCE:
Transporation, OkDOT, 2012, 2017; Hydrology, Oklahoma Conservation Commission, 2020; Municipal Boundaries, Oklahoma Tax Commission, 2/2021.
ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

― Major Roadway	▭ Waterbody
― Waterway	⬚ 200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT SHEET 7 OF 34

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PENSACOLA HYDROELECTRIC
PROJECT
FERC No. P-1494

Mead&Hunt

DRAWN BY: EMW
CHECKED: TDB

DATE: 3/9/2022
APPROVED: DMJ

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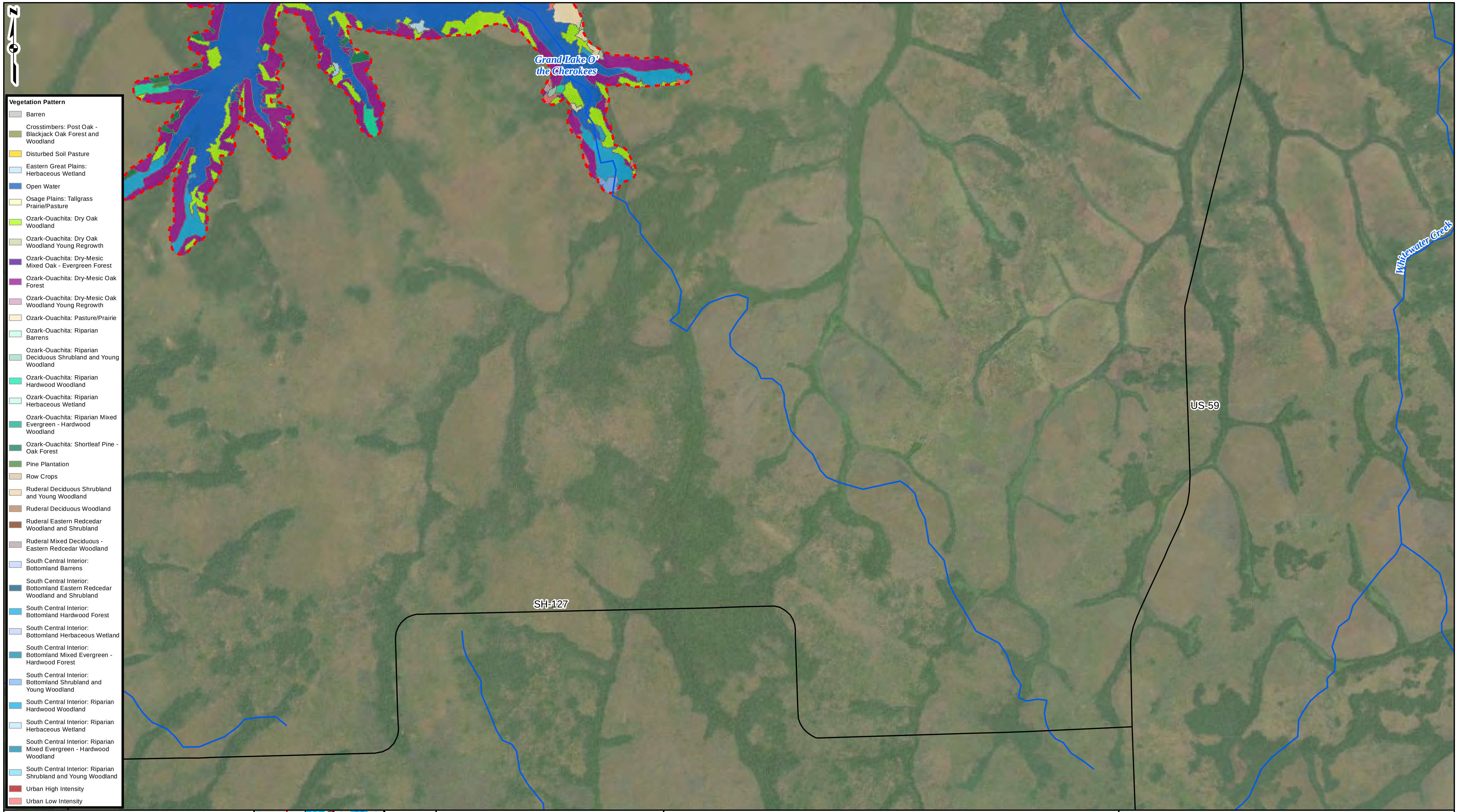

Vegetation Pattern

- Barren
- Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
- Disturbed Soil Pasture
- Eastern Great Plains: Herbaceous Wetland
- Open Water
- Osage Plains: Tallgrass Prairie/Pasture
- Ozark-Ouachita: Dry Oak Woodland
- Ozark-Ouachita: Dry Oak Woodland Young Regrowth
- Ozark-Ouachita: Dry-Mesic Mixed Oak - Evergreen Forest
- Ozark-Ouachita: Dry-Mesic Oak Forest
- Ozark-Ouachita: Dry-Mesic Oak Woodland Young Regrowth
- Ozark-Ouachita: Pasture/Prairie
- Ozark-Ouachita: Riparian Barrens
- Ozark-Ouachita: Riparian Deciduous Shrubland and Young Woodland
- Ozark-Ouachita: Riparian Hardwood Woodland
- Ozark-Ouachita: Riparian Herbaceous Wetland
- Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
- Ozark-Ouachita: Shortleaf Pine - Oak Forest
- Pine Plantation
- Row Crops
- Ruderal Deciduous Shrubland and Young Woodland
- Ruderal Deciduous Woodland
- Ruderal Eastern Redcedar Woodland and Shrubland
- Ruderal Mixed Deciduous - Eastern Redcedar Woodland
- South Central Interior: Bottomland Barrens
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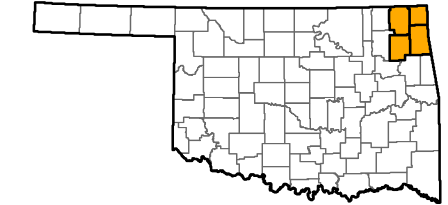
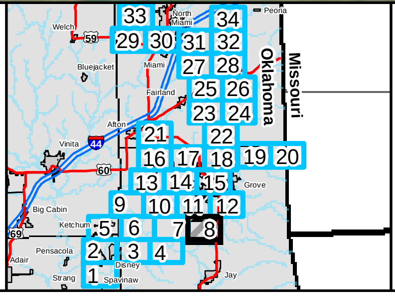
- South Central Interior: Riparian Hardwood Woodland
- South Central Interior: Riparian Herbaceous Wetland
- South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
- South Central Interior: Riparian Shrubland and Young Woodland
- Urban High Intensity
- Urban Low Intensity

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA



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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

Major Roadway	Waterbody
Waterway	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600 Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 8 OF 34

PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

gai consultants
Mead&Hunt

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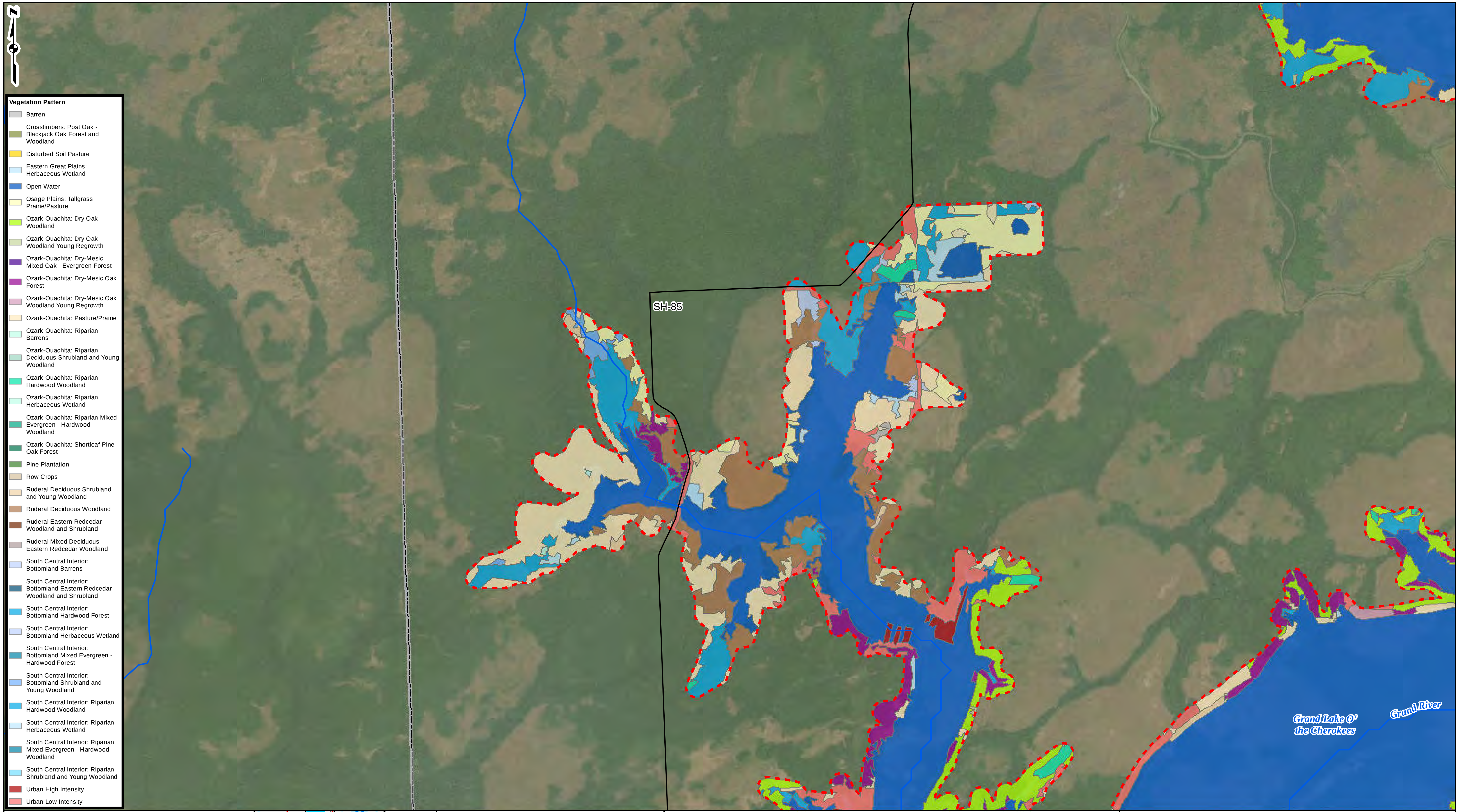

Vegetation Pattern

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- Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
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- Ozark-Ouachita: Shortleaf Pine - Oak Forest
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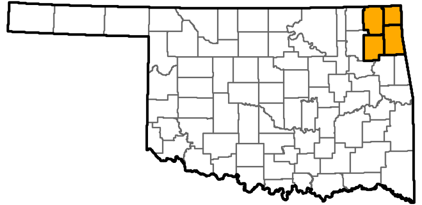
- South Central Interior: Riparian Shrubland and Young Woodland
- Urban High Intensity
- Urban Low Intensity

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
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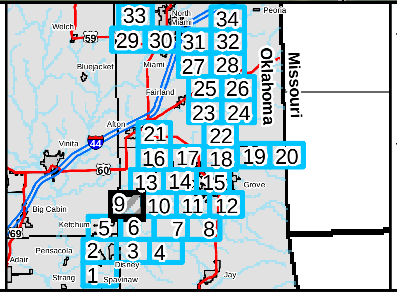

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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

- Major Roadway
- Waterway
- Waterbody
- 200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600 Feet

VEGETATION PATTERNS IN THE VICINITY OF THE
PENSACOLA HYDROELECTRIC PROJECT
SHEET 9 OF 34

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PENSACOLA HYDROELECTRIC
PROJECT
FERC No. P-1494

Mead&Hunt

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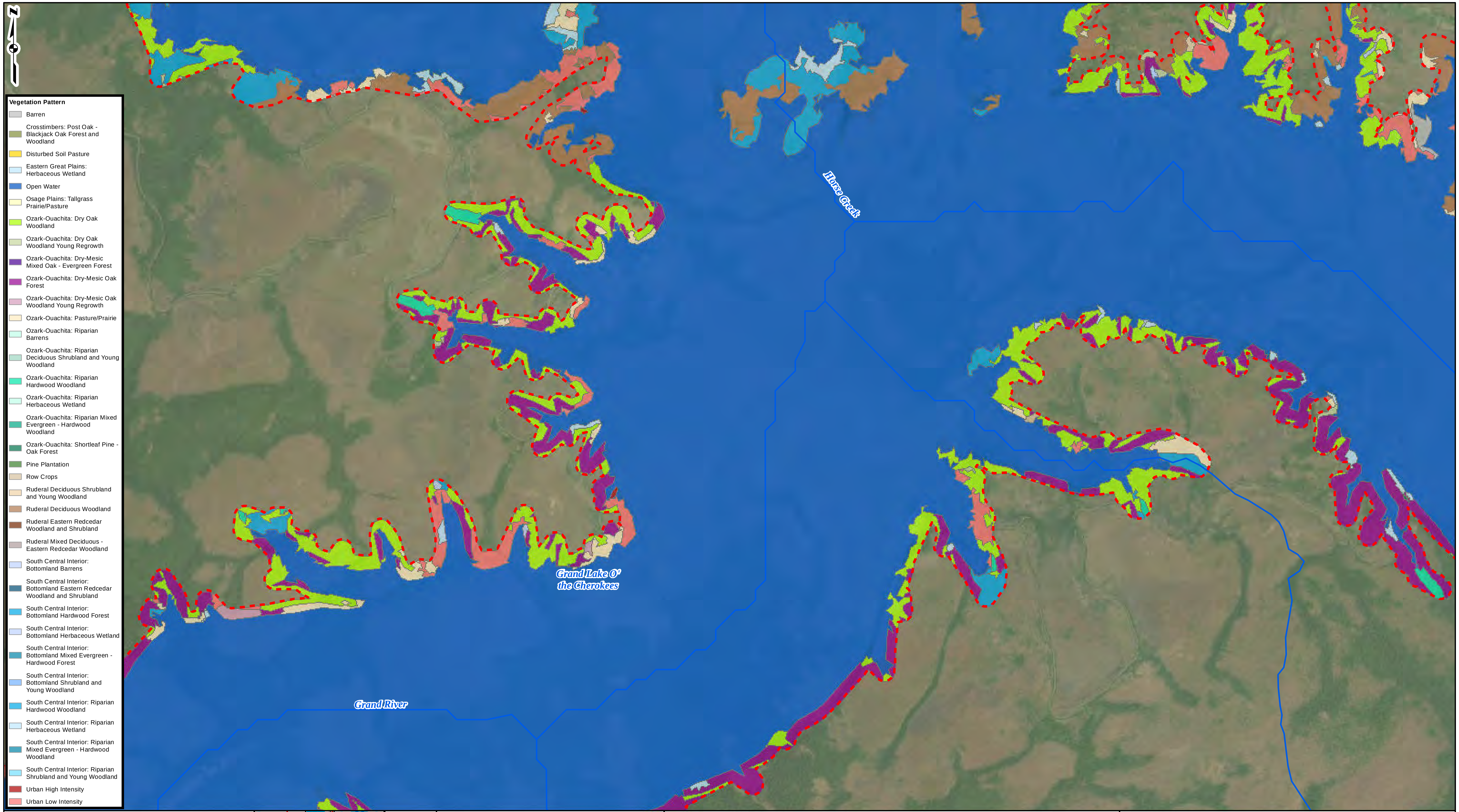
N
Horse Creek
Grand Lake O' the Cherokees
Grand River
Vegetation Pattern
Barren
Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
Disturbed Soil Pasture
Eastern Great Plains: Herbaceous Wetland
Open Water
Osage Plains: Tallgrass Prairie/Pasture
Ozark-Ouachita: Dry Oak Woodland
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Ozark-Ouachita: Shortleaf Pine - Oak Forest
Pine Plantation
Row Crops
Ruderal Deciduous Shrubland and Young Woodland
Ruderal Deciduous Woodland
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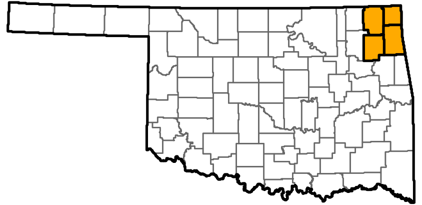
South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
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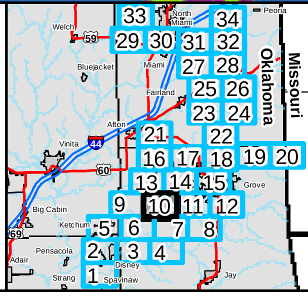

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Vegetation and Landcover, MoRAP, 3/2015

Legend

— Major Roadway
— Waterway
▭ Waterbody
⬚ 200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 10 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

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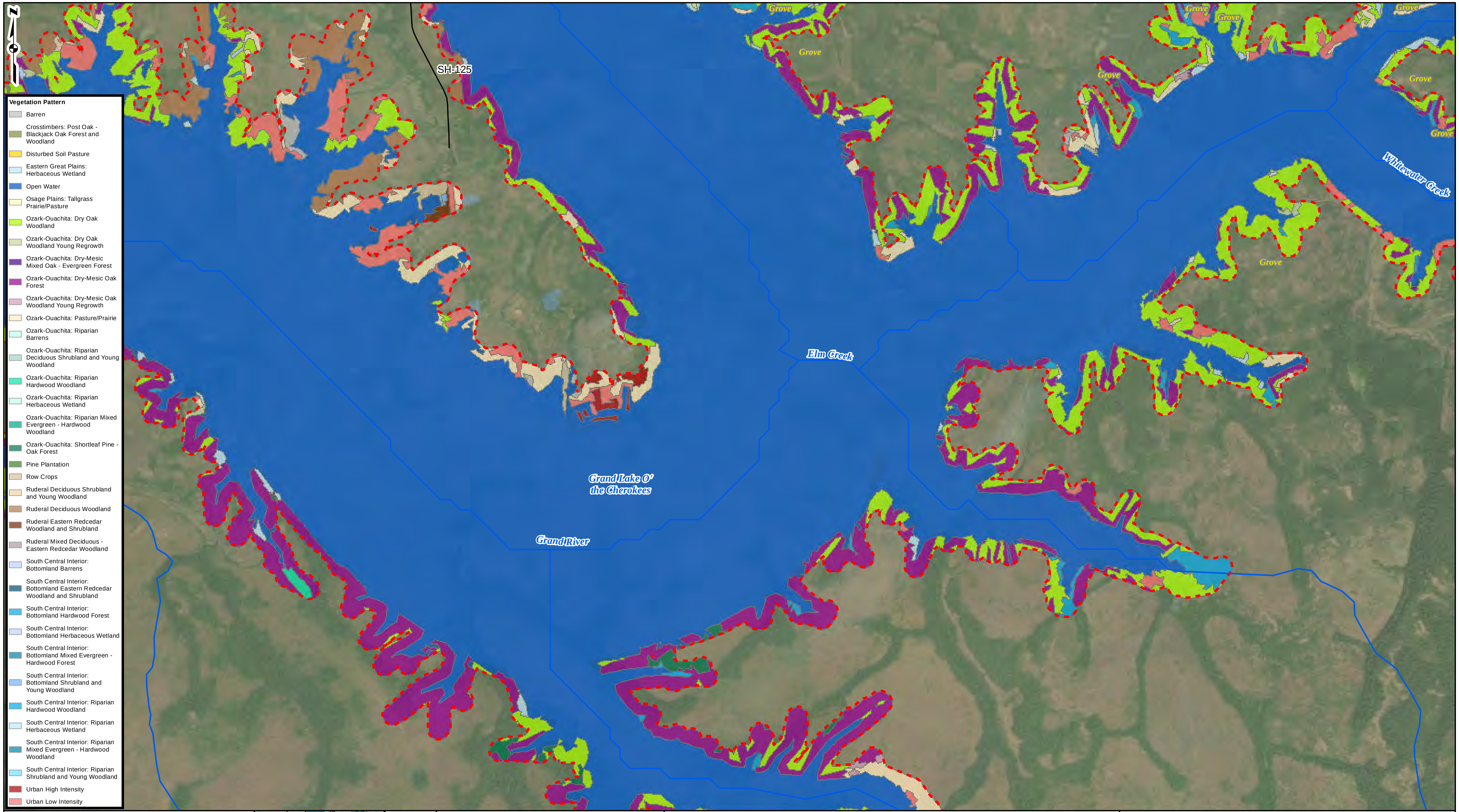
N
Vegetation Pattern
Barren
Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
Disturbed Soil Pasture
Eastern Great Plains: Herbaceous Wetland
Open Water
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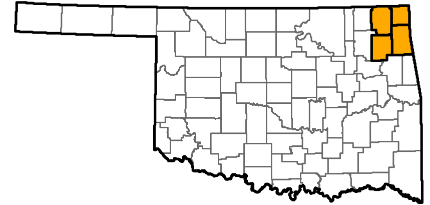
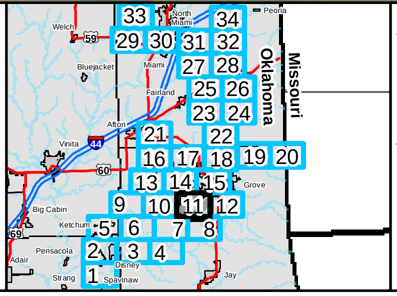
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity
SH-125
Grove
Grove
Grove
Grove
Grove
Grove
Grove
Grove
Grove
Whitewater Creek
Elm Creek
Grand Lake O' the Cherokees
Grand River

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA



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Vegetation and Landcover, MoRAP, 3/2015

Legend

— Major Roadway
— Waterway
▭ Waterbody
⬚ 200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 11 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

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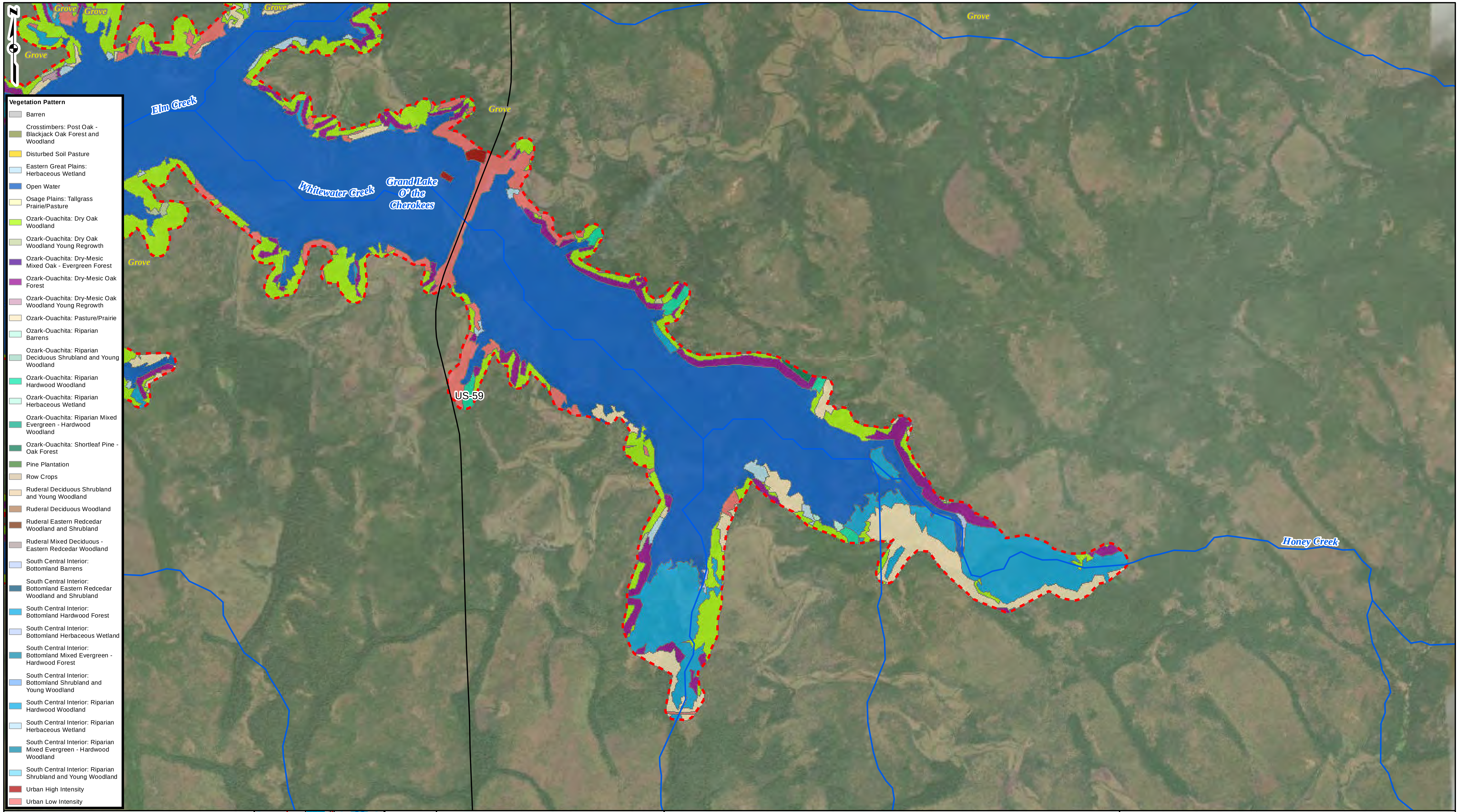

Vegetation Pattern

- Barren
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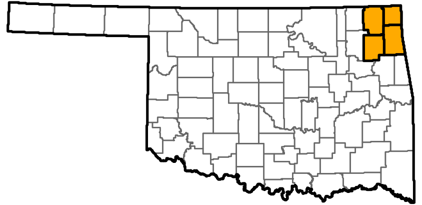
- Urban High Intensity
- Urban Low Intensity

PROJECT LOCATION



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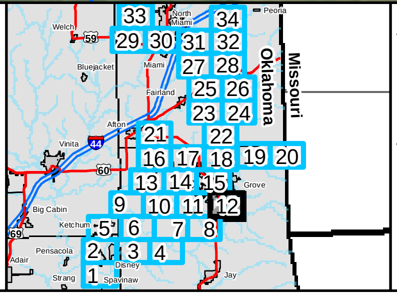

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Legend

Major Roadway	Waterbody
Waterway	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 12 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
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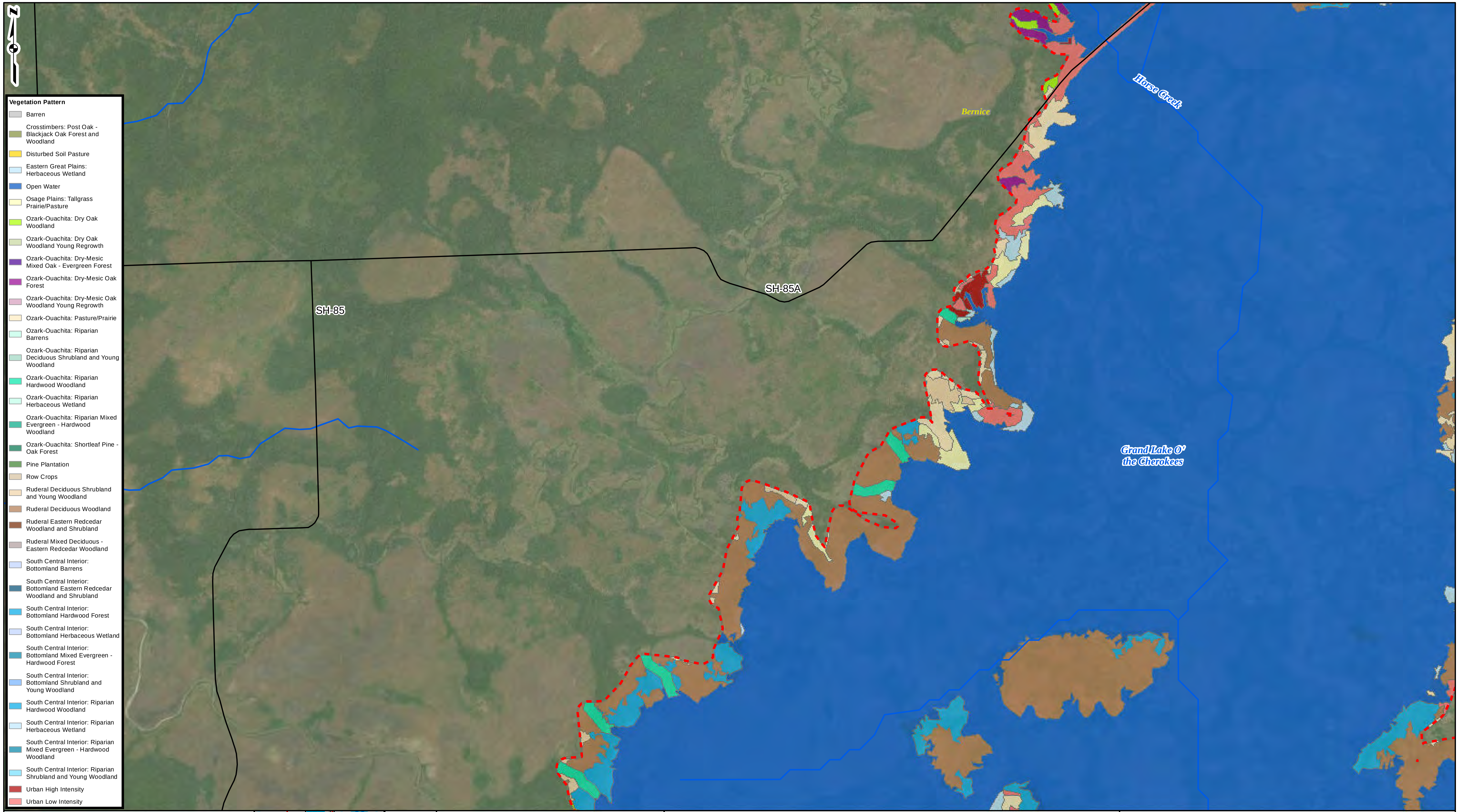
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Vegetation Pattern
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Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
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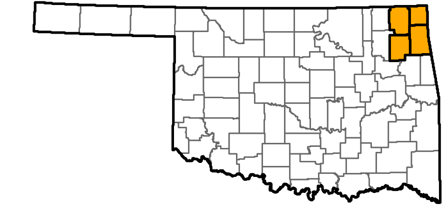
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity
SH-85
SH-85A
Bernice
Horse Creek
Grand Lake O' the Cherokees

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
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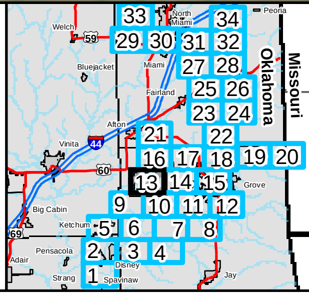

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Legend

— Major Roadway
— Waterway
▭ Waterbody
⬚ 200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 13 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

Mead&Hunt

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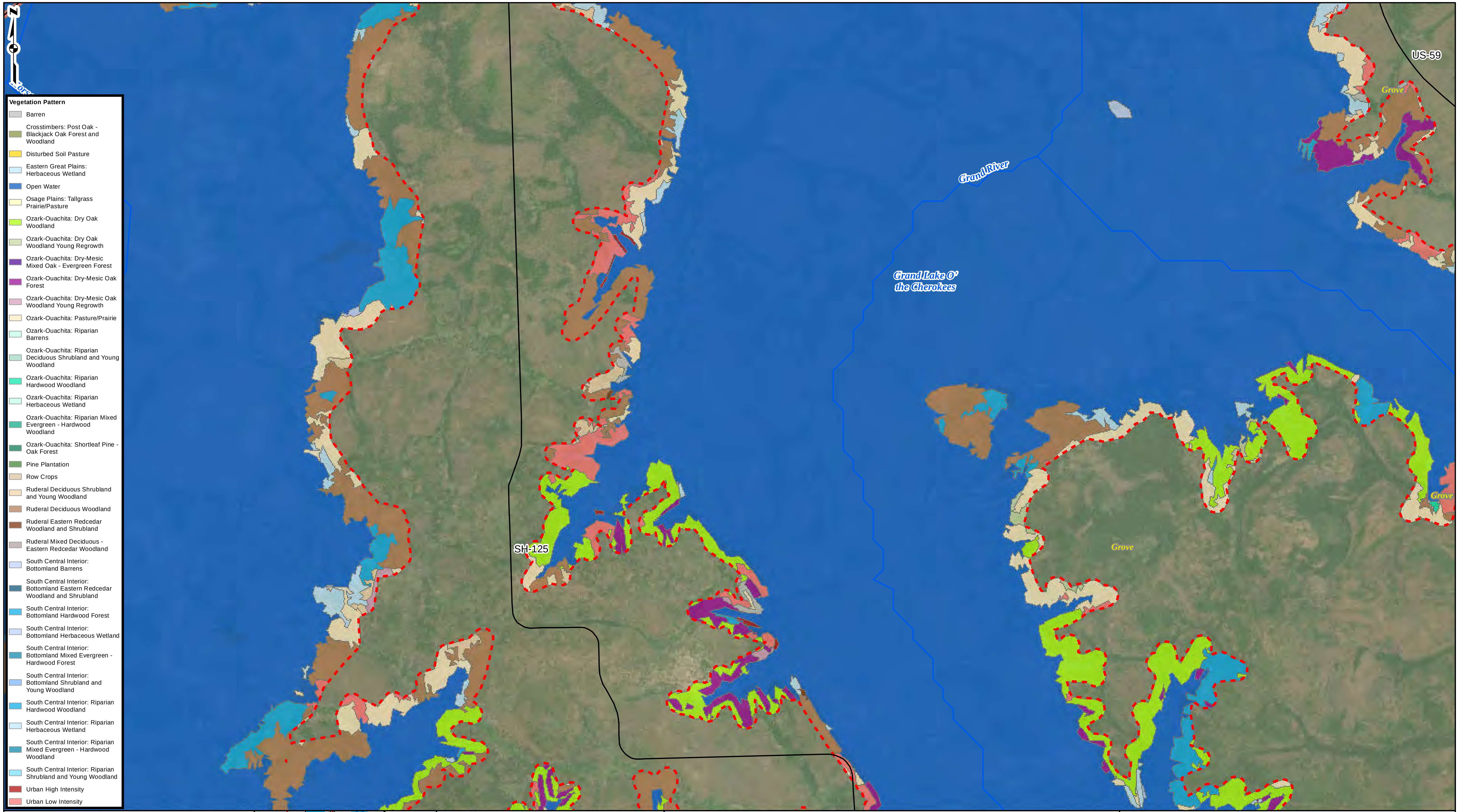
N
Vegetation Pattern
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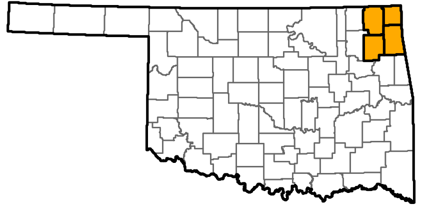
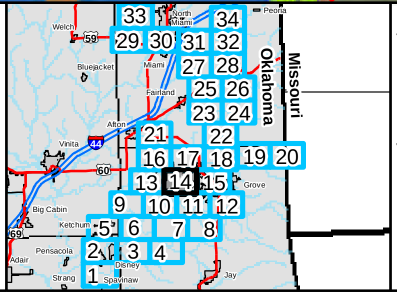
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity
US-59
Grove
Grand River
Grand Lake O' the Cherokees
SH-125
Grove
Grove

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA



REFERENCE:
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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

—	Major Roadway	🟦	Waterbody
—	Waterway	▭	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 14 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

Mead&Hunt

DRAWN BY: EMW
DATE: 3/9/2022
CHECKED: TDB
APPROVED: DMJ

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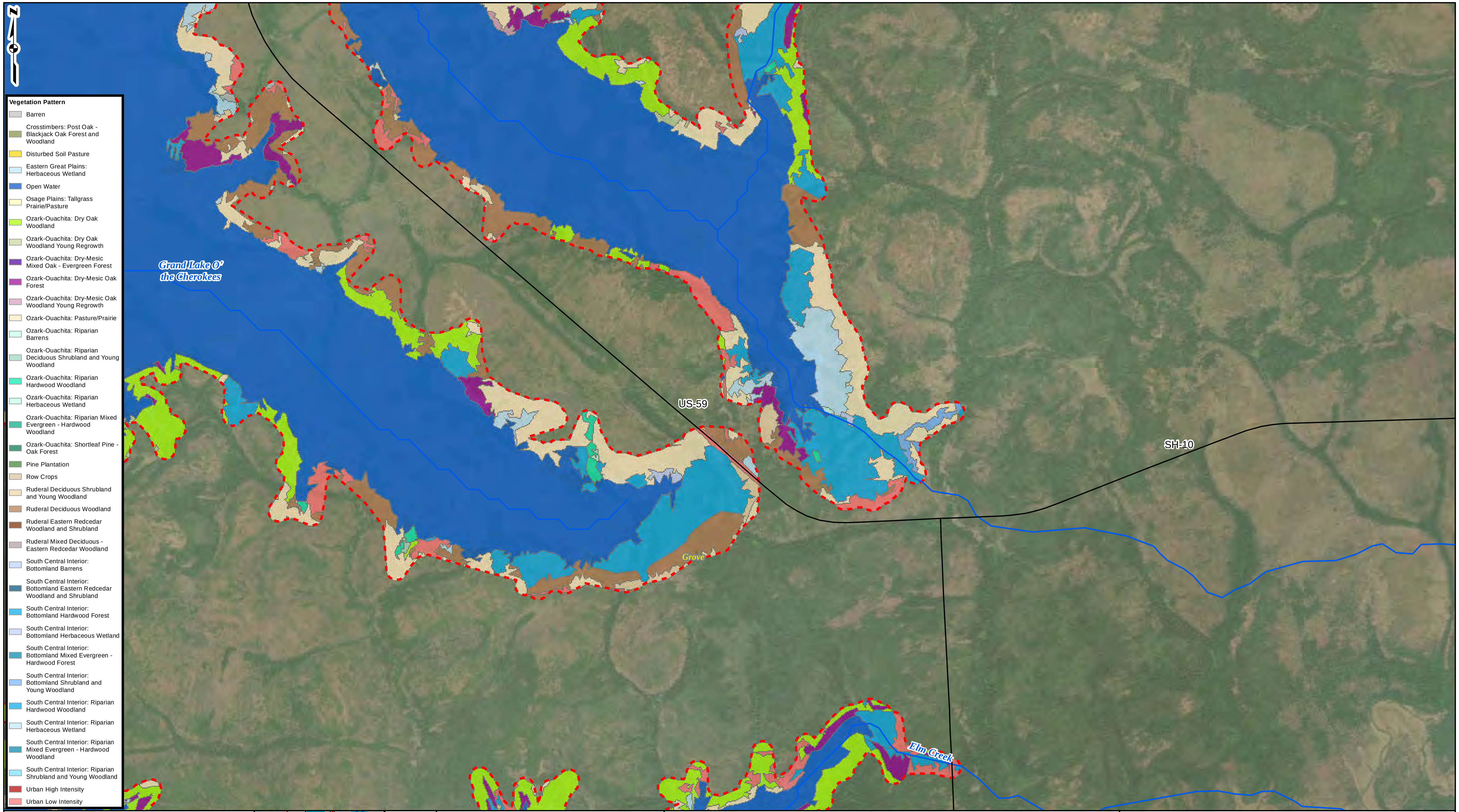
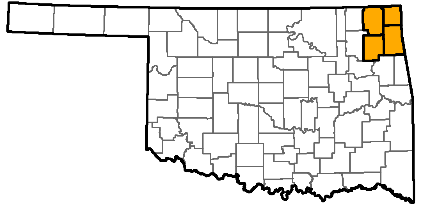


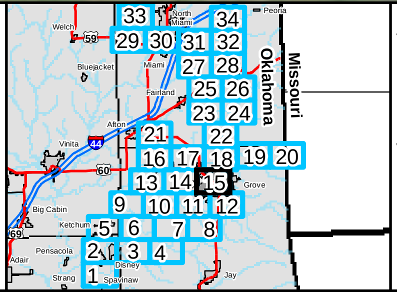
Vegetation Pattern

■	Barren
■	Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
■	Disturbed Soil Pasture
■	Eastern Great Plains: Herbaceous Wetland
■	Open Water
■	Osage Plains: Tallgrass Prairie/Pasture
■	Ozark-Ouachita: Dry Oak Woodland
■	Ozark-Ouachita: Dry Oak Woodland Young Regrowth
■	Ozark-Ouachita: Dry-Mesic Mixed Oak - Evergreen Forest
■	Ozark-Ouachita: Dry-Mesic Oak Forest
■	Ozark-Ouachita: Dry-Mesic Oak Woodland Young Regrowth
■	Ozark-Ouachita: Pasture/Prairie
■	Ozark-Ouachita: Riparian Barrens
■	Ozark-Ouachita: Riparian Deciduous Shrubland and Young Woodland
■	Ozark-Ouachita: Riparian Hardwood Woodland
■	Ozark-Ouachita: Riparian Herbaceous Wetland
■	Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
■	Ozark-Ouachita: Shortleaf Pine - Oak Forest
■	Pine Plantation
■	Row Crops
■	Ruderal Deciduous Shrubland and Young Woodland
■	Ruderal Deciduous Woodland
■	Ruderal Eastern Redcedar Woodland and Shrubland
■	Ruderal Mixed Deciduous - Eastern Redcedar Woodland
■	South Central Interior: Bottomland Barrens
■	South Central Interior: Bottomland Eastern Redcedar Woodland and Shrubland
■	South Central Interior: Bottomland Hardwood Forest
■	South Central Interior: Bottomland Herbaceous Wetland
■	South Central Interior: Bottomland Mixed Evergreen - Hardwood Forest
■	South Central Interior: Bottomland Shrubland and Young Woodland
■	South Central Interior: Riparian Hardwood Woodland
■	South Central Interior: Riparian Herbaceous Wetland
■	South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
■	South Central Interior: Riparian Shrubland and Young Woodland
■	Urban High Intensity
■	Urban Low Intensity

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA



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Vegetation and Landcover, MoRAP, 3/2015

Legend

—	Major Roadway	■	Waterbody
—	Waterway	▭	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 15 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
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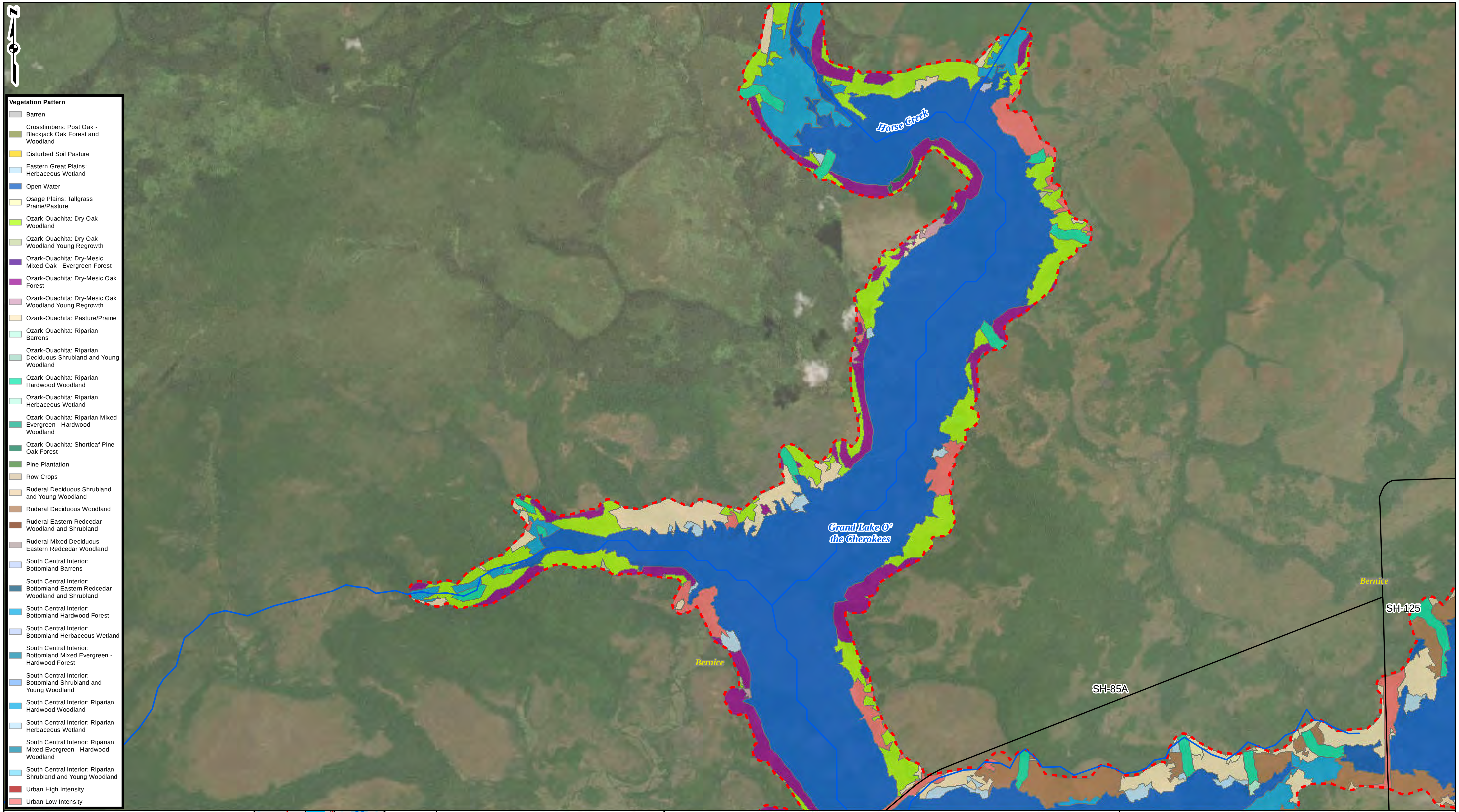

Vegetation Pattern
- Barren
- Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
- Disturbed Soil Pasture
- Eastern Great Plains: Herbaceous Wetland
- Open Water
- Osage Plains: Tallgrass Prairie/Pasture
- Ozark-Ouachita: Dry Oak Woodland
- Ozark-Ouachita: Dry Oak Woodland Young Regrowth
- Ozark-Ouachita: Dry-Mesic Mixed Oak - Evergreen Forest
- Ozark-Ouachita: Dry-Mesic Oak Forest
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- Ozark-Ouachita: Riparian Hardwood Woodland
- Ozark-Ouachita: Riparian Herbaceous Wetland
- Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
- Ozark-Ouachita: Shortleaf Pine - Oak Forest
- Pine Plantation
- Row Crops
- Ruderal Deciduous Shrubland and Young Woodland
- Ruderal Deciduous Woodland
- Ruderal Eastern Redcedar Woodland and Shrubland
- Ruderal Mixed Deciduous - Eastern Redcedar Woodland
- South Central Interior: Bottomland Barrens
- South Central Interior: Bottomland Eastern Redcedar Woodland and Shrubland
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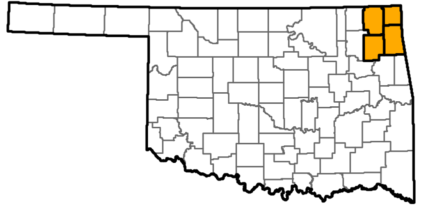
- South Central Interior: Bottomland Mixed Evergreen - Hardwood Forest
- South Central Interior: Bottomland Shrubland and Young Woodland
- South Central Interior: Riparian Hardwood Woodland
- South Central Interior: Riparian Herbaceous Wetland
- South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
- South Central Interior: Riparian Shrubland and Young Woodland
- Urban High Intensity
- Urban Low Intensity

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
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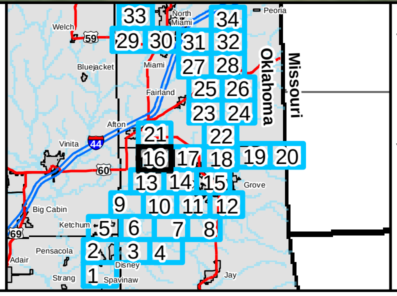

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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend
- Major Roadway
- Waterway
- Waterbody
- 200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 16 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
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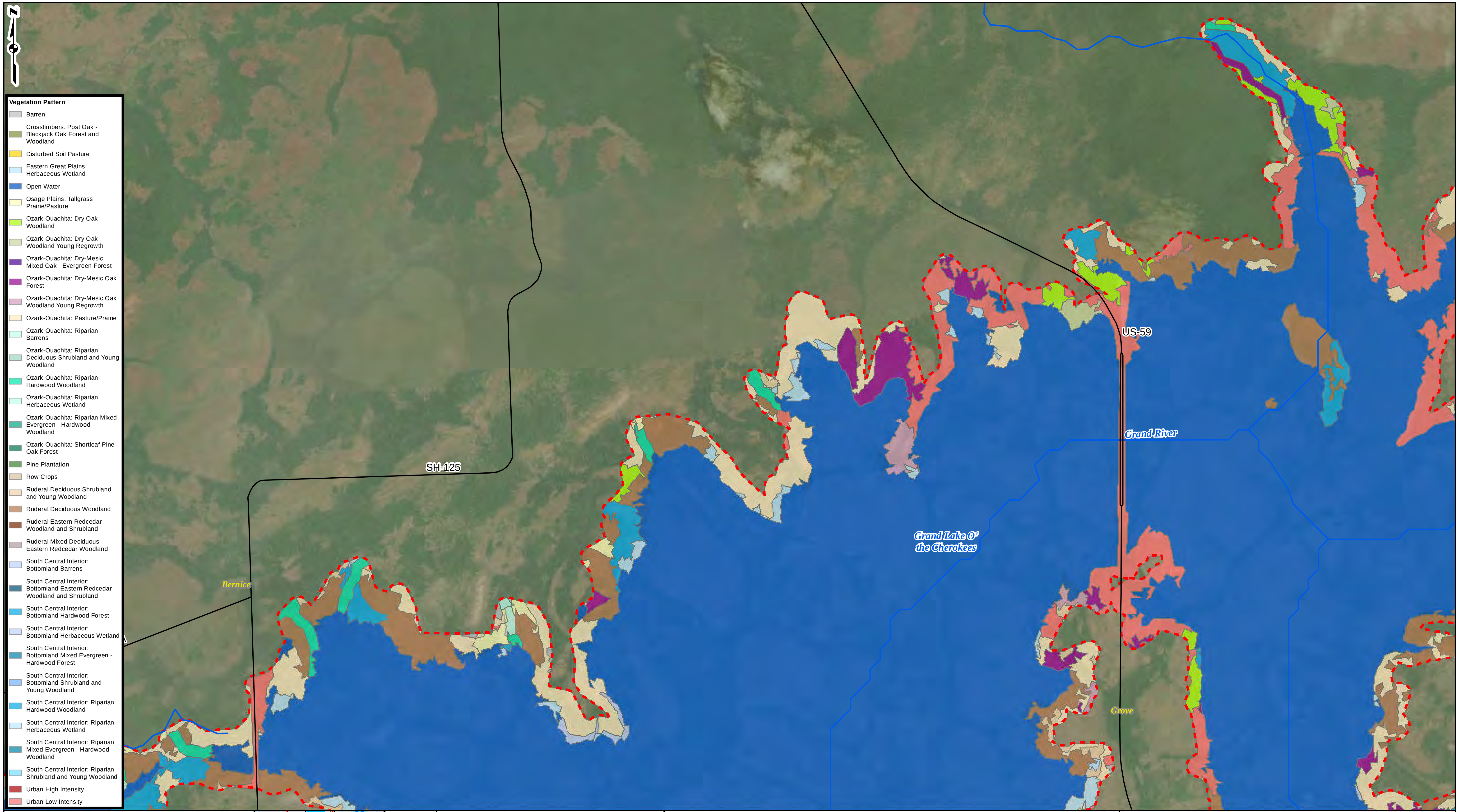
N
Vegetation Pattern
Barren
Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
Disturbed Soil Pasture
Eastern Great Plains: Herbaceous Wetland
Open Water
Osage Plains: Tallgrass Prairie/Pasture
Ozark-Ouachita: Dry Oak Woodland
Ozark-Ouachita: Dry Oak Woodland Young Regrowth
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Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
Ozark-Ouachita: Shortleaf Pine - Oak Forest
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Row Crops
Ruderal Deciduous Shrubland and Young Woodland
Ruderal Deciduous Woodland
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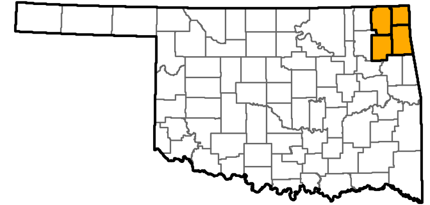
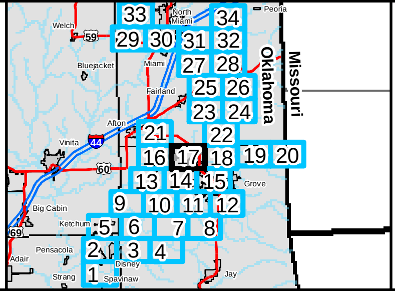
South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity
US-59
SH-125
Grand River
Grand Lake O' the Cherokees
Bernice
Grove

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA



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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

Major Roadway	Waterbody
Waterway	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 17 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

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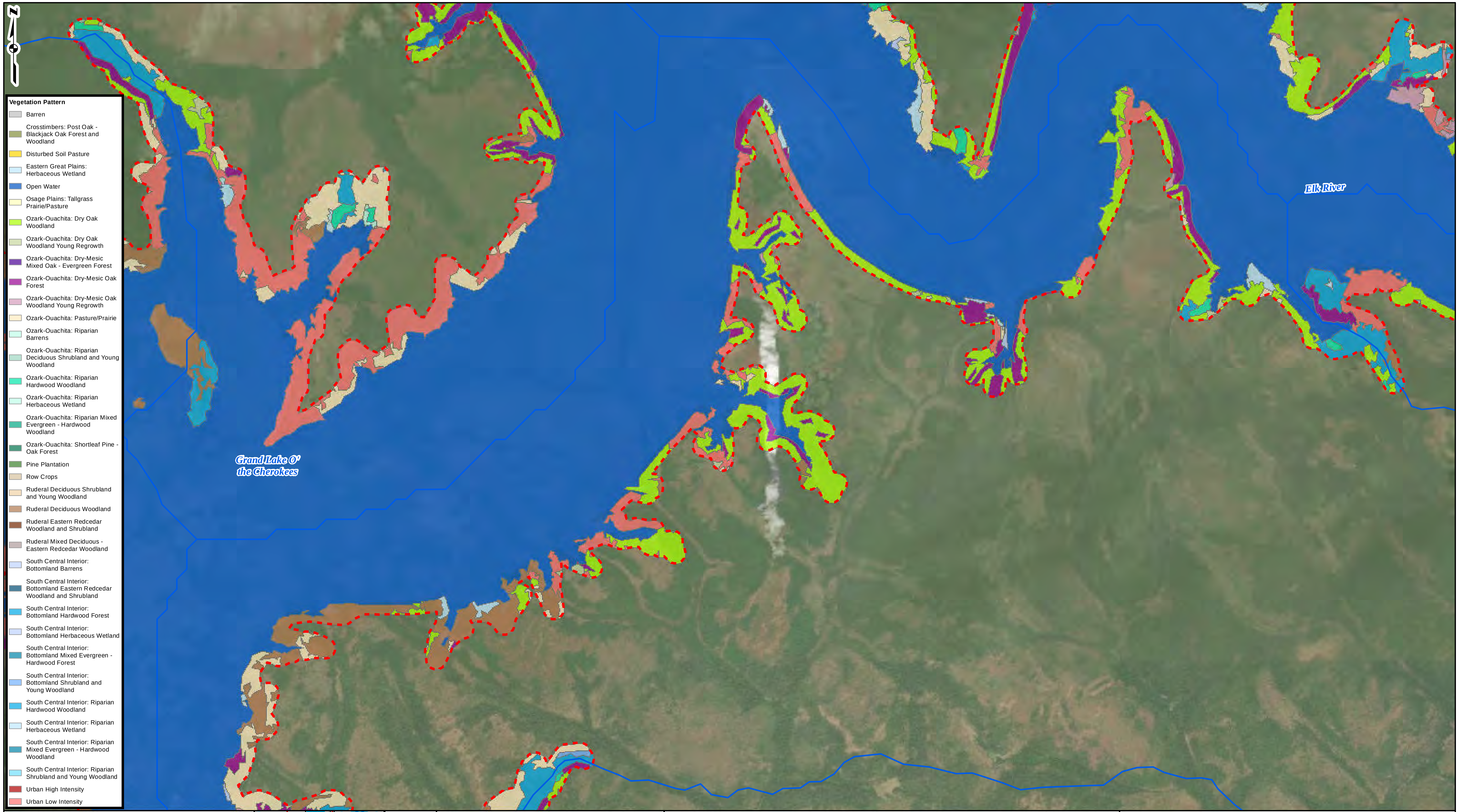
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Vegetation Pattern
Barren
Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
Disturbed Soil Pasture
Eastern Great Plains: Herbaceous Wetland
Open Water
Osage Plains: Tallgrass Prairie/Pasture
Ozark-Ouachita: Dry Oak Woodland
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Row Crops
Ruderal Deciduous Shrubland and Young Woodland
Ruderal Deciduous Woodland
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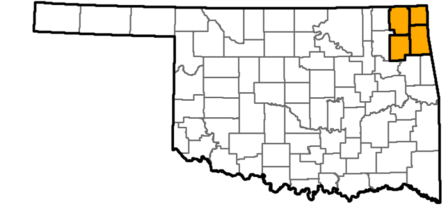
South Central Interior: Riparian Herbaceous Wetland
South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity
Grand Lake O' the Cherokees
Elk River

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
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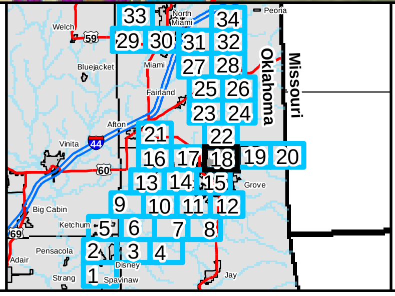

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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

— Major Roadway
— Waterway
▭ Waterbody
▭ 200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 18 OF 34

PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

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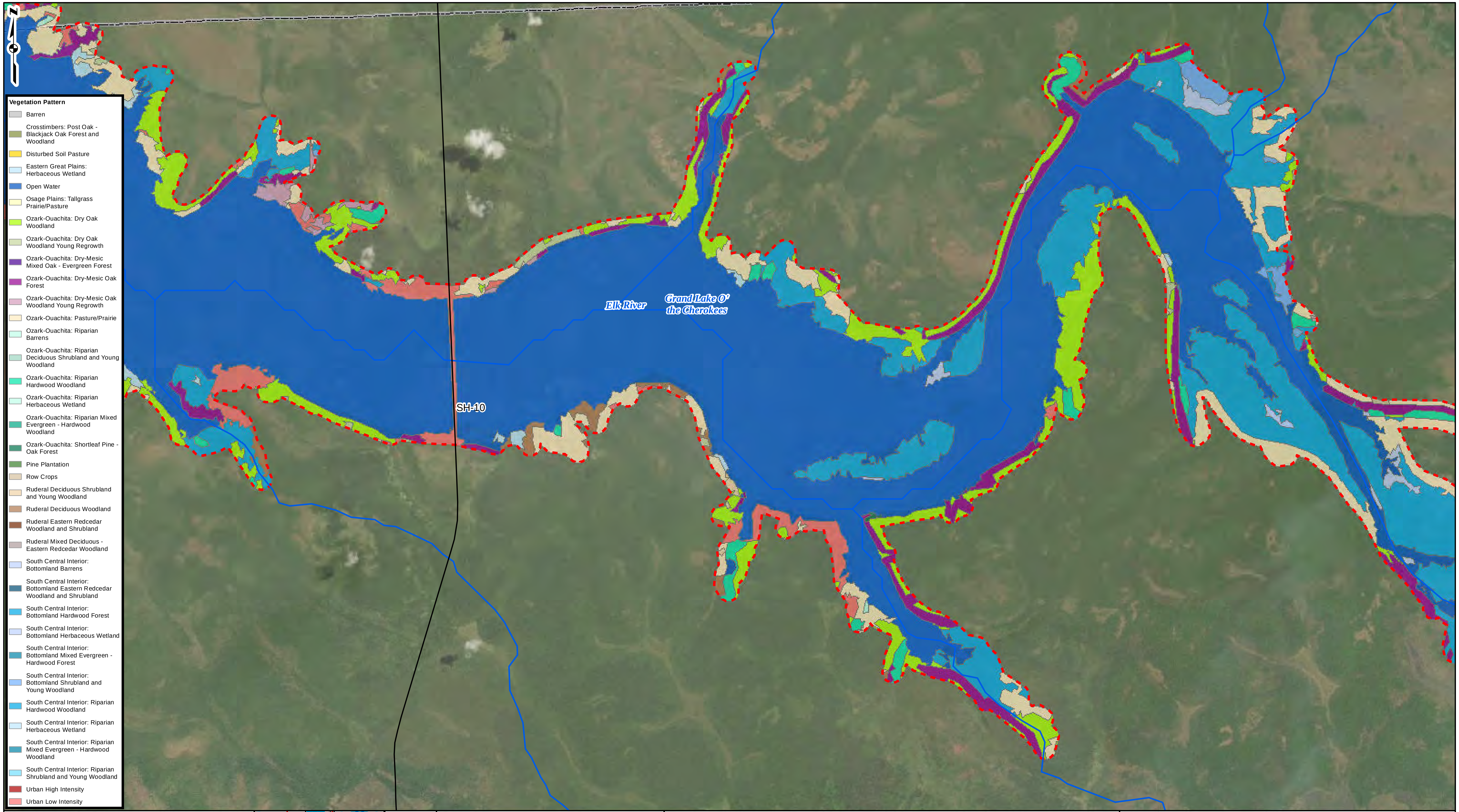
N
Elk River
Grand Lake O' the Cherokees
SH-10
Vegetation Pattern
Barren
Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
Disturbed Soil Pasture
Eastern Great Plains: Herbaceous Wetland
Open Water
Osage Plains: Tallgrass Prairie/Pasture
Ozark-Ouachita: Dry Oak Woodland
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Row Crops
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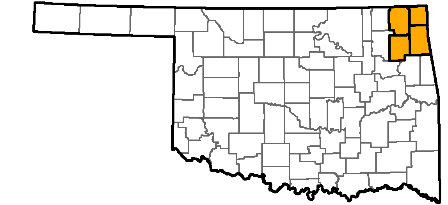
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity

PROJECT LOCATION



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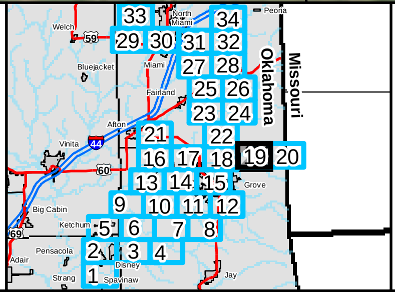

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Vegetation and Landcover, MoRAP, 3/2015

Legend

Major Roadway	Waterbody
Waterway	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600 Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 19 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
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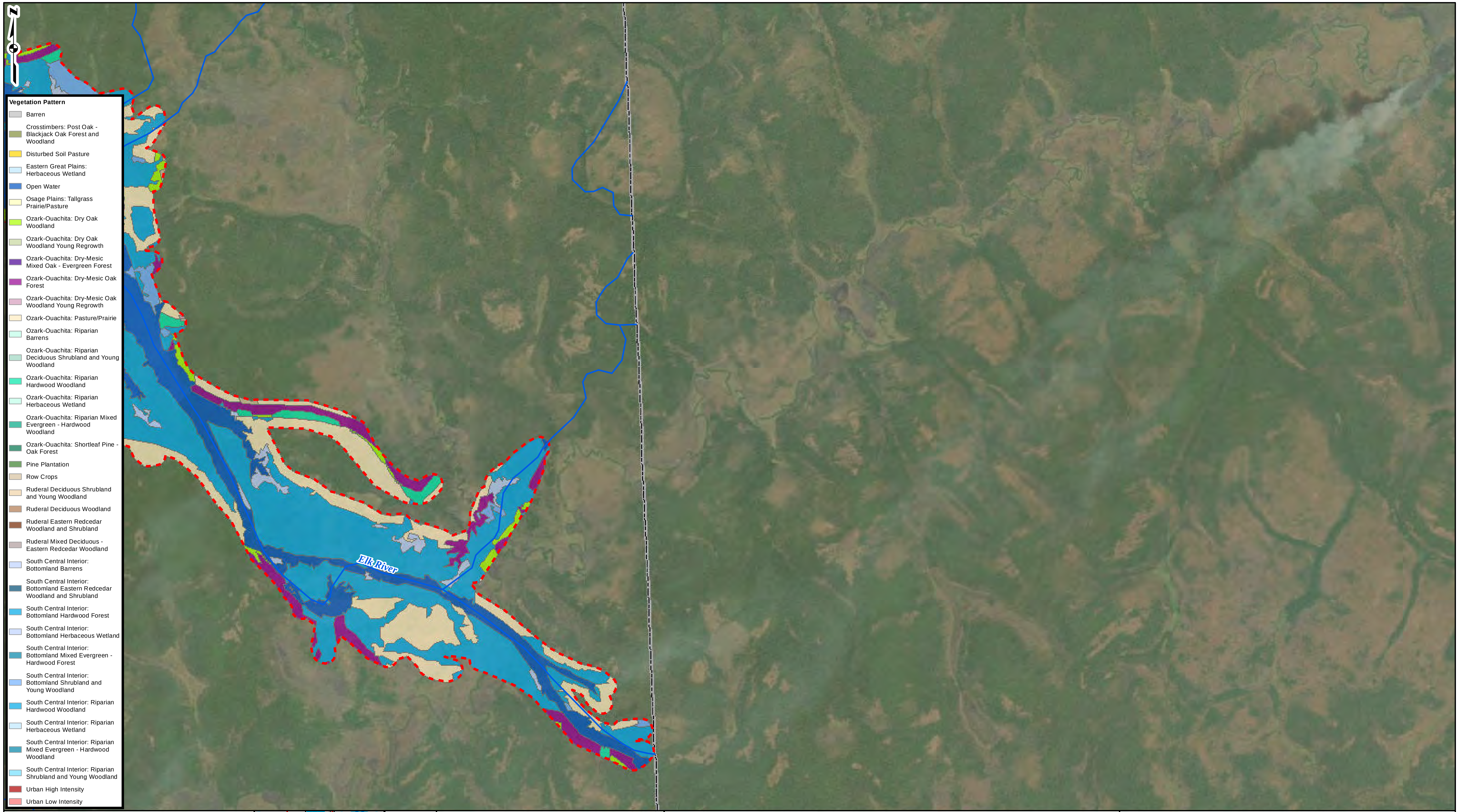
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Vegetation Pattern
Barren
Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
Disturbed Soil Pasture
Eastern Great Plains: Herbaceous Wetland
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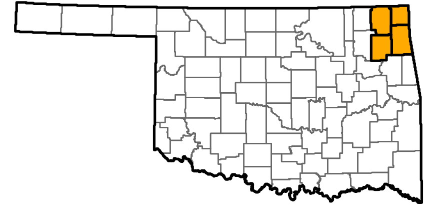
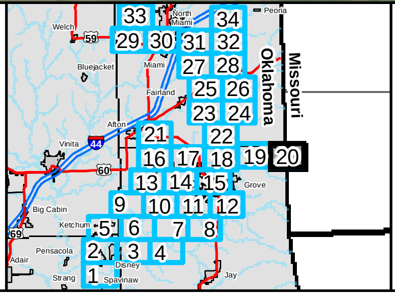
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity
Elk River

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA



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Vegetation and Landcover, MoRAP, 3/2015

Legend

Major Roadway	Waterbody
Waterway	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600 Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 20 OF 34

PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

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Mead&Hunt

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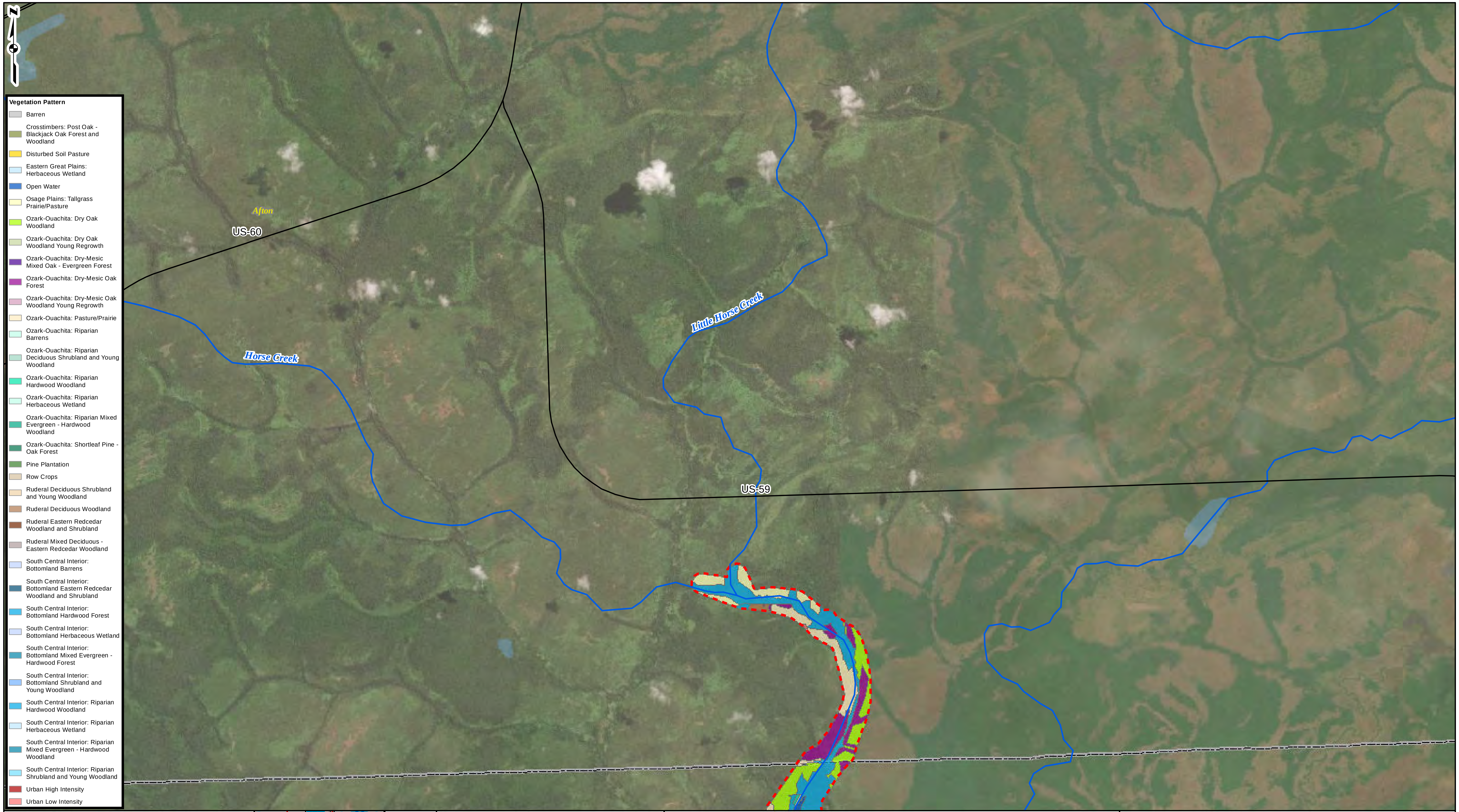

Vegetation Pattern

⬜	Barren
🟩	Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
🟨	Disturbed Soil Pasture
🟦	Eastern Great Plains: Herbaceous Wetland
🟦	Open Water
🟨	Osage Plains: Tallgrass Prairie/Pasture
🟩	Ozark-Ouachita: Dry Oak Woodland
🟩	Ozark-Ouachita: Dry Oak Woodland Young Regrowth
🟪	Ozark-Ouachita: Dry-Mesic Mixed Oak - Evergreen Forest
🟪	Ozark-Ouachita: Dry-Mesic Oak Forest
🟪	Ozark-Ouachita: Dry-Mesic Oak Woodland Young Regrowth
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🟩	Ozark-Ouachita: Riparian Deciduous Shrubland and Young Woodland
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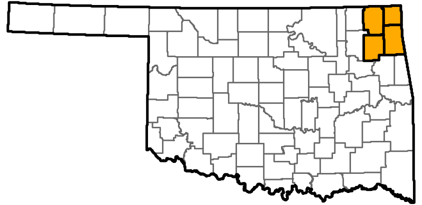
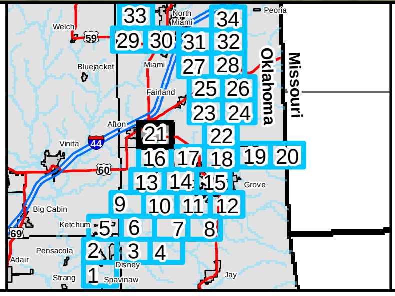
🟩	Ozark-Ouachita: Riparian Herbaceous Wetland
🟩	Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
🟩	Ozark-Ouachita: Shortleaf Pine - Oak Forest
🟩	Pine Plantation
🟫	Row Crops
🟧	Ruderal Deciduous Shrubland and Young Woodland
🟫	Ruderal Deciduous Woodland
🟫	Ruderal Eastern Redcedar Woodland and Shrubland
⬜	Ruderal Mixed Deciduous - Eastern Redcedar Woodland
🟦	South Central Interior: Bottomland Barrens
🟦	South Central Interior: Bottomland Eastern Redcedar Woodland and Shrubland
🟦	South Central Interior: Bottomland Hardwood Forest
🟦	South Central Interior: Bottomland Herbaceous Wetland
🟦	South Central Interior: Bottomland Mixed Evergreen - Hardwood Forest
🟦	South Central Interior: Bottomland Shrubland and Young Woodland
🟦	South Central Interior: Riparian Hardwood Woodland
🟦	South Central Interior: Riparian Herbaceous Wetland
🟦	South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
🟦	South Central Interior: Riparian Shrubland and Young Woodland
🟥	Urban High Intensity
🟥	Urban Low Intensity

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA



REFERENCE:
Transporation, OkDOT, 2012, 2017; Hydrology, Oklahoma Conservation Commission, 2020; Municipal Boundaries, Oklahoma Tax Commission, 2/2021.
ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

—	Major Roadway	🟦	Waterbody
—	Waterway	⬚	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 21 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

Mead&Hunt

DRAWN BY: EMW
DATE: 3/9/2022
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APPROVED: DMJ

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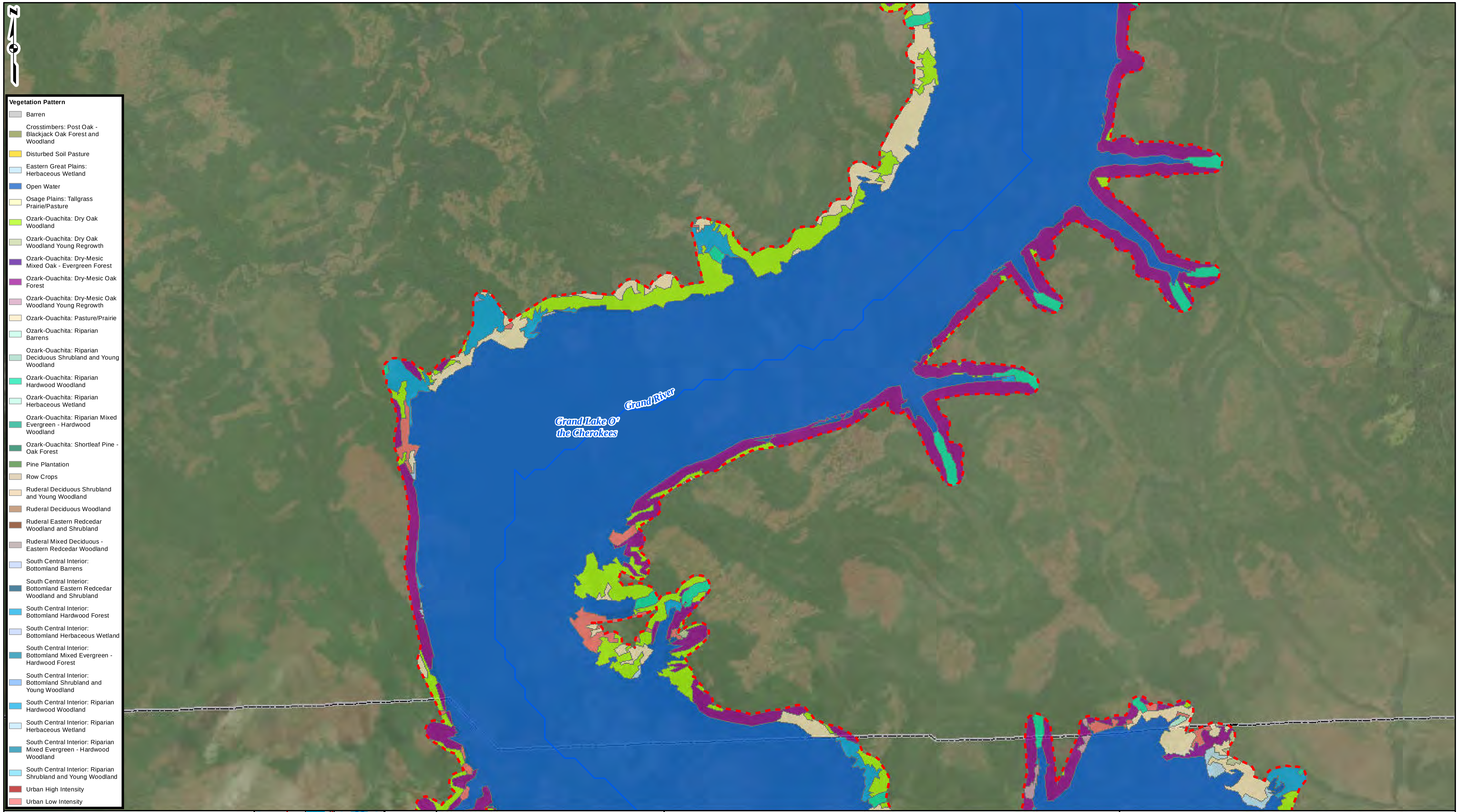

Vegetation Pattern

- Barren
- Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
- Disturbed Soil Pasture
- Eastern Great Plains: Herbaceous Wetland
- Open Water
- Osage Plains: Tallgrass Prairie/Pasture
- Ozark-Ouachita: Dry Oak Woodland
- Ozark-Ouachita: Dry Oak Woodland Young Regrowth
- Ozark-Ouachita: Dry-Mesic Mixed Oak - Evergreen Forest
- Ozark-Ouachita: Dry-Mesic Oak Forest
- Ozark-Ouachita: Dry-Mesic Oak Woodland Young Regrowth
- Ozark-Ouachita: Pasture/Prairie
- Ozark-Ouachita: Riparian Barrens
- Ozark-Ouachita: Riparian Deciduous Shrubland and Young Woodland
- Ozark-Ouachita: Riparian Hardwood Woodland
- Ozark-Ouachita: Riparian Herbaceous Wetland
- Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
- Ozark-Ouachita: Shortleaf Pine - Oak Forest
- Pine Plantation
- Row Crops
- Ruderal Deciduous Shrubland and Young Woodland
- Ruderal Deciduous Woodland
- Ruderal Eastern Redcedar Woodland and Shrubland
- Ruderal Mixed Deciduous - Eastern Redcedar Woodland
- South Central Interior: Bottomland Barrens
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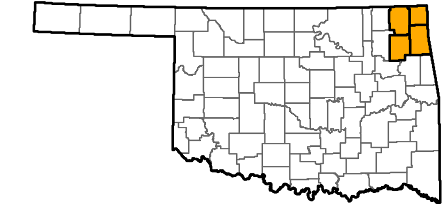
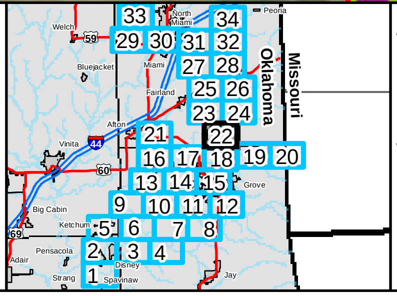
- South Central Interior: Riparian Herbaceous Wetland
- South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
- South Central Interior: Riparian Shrubland and Young Woodland
- Urban High Intensity
- Urban Low Intensity

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA



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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

- Major Roadway
- Waterway
- Waterbody
- 200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 22 OF 34

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PENSACOLA HYDROELECTRIC
PROJECT
FERC No. P-1494

Mead&Hunt

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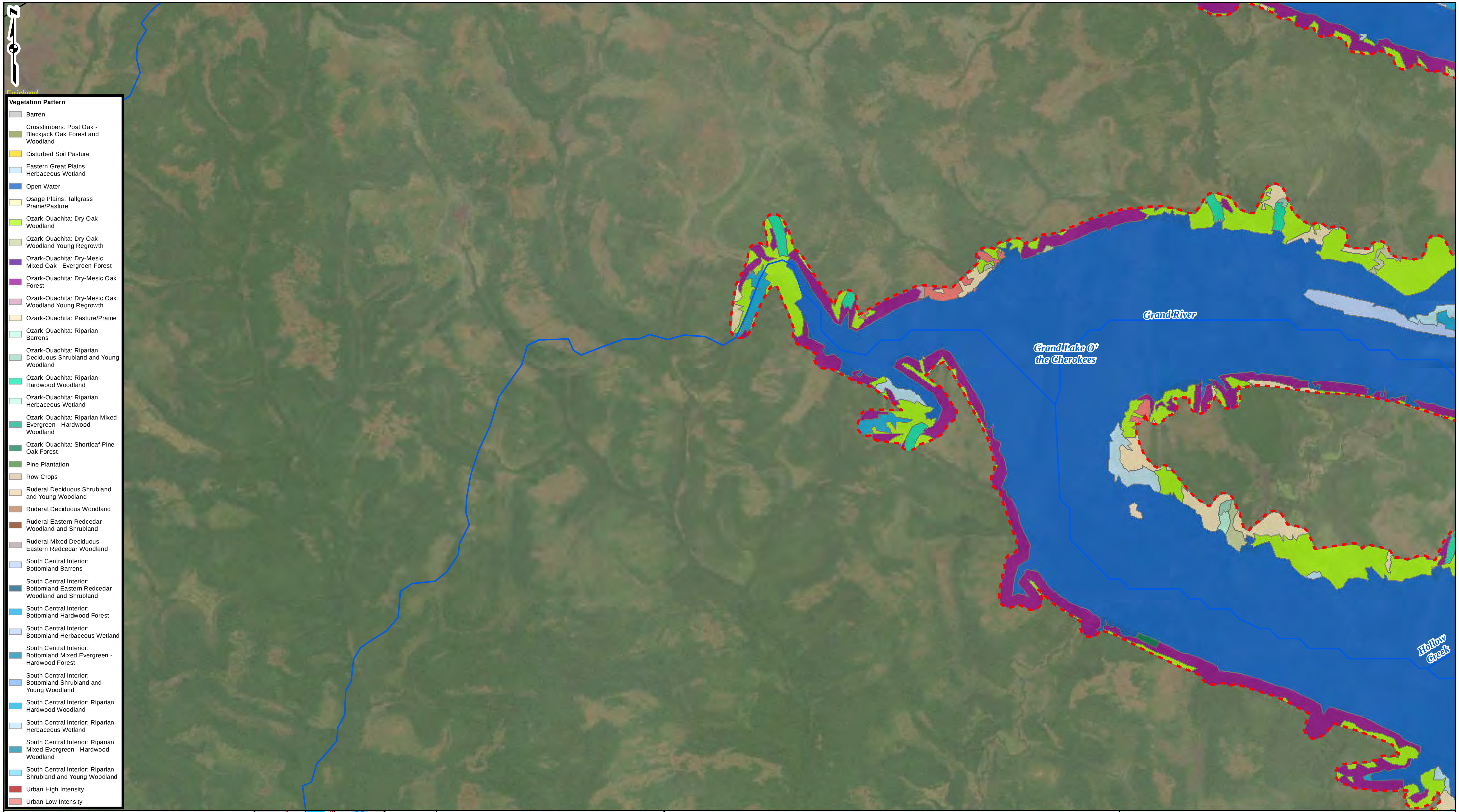
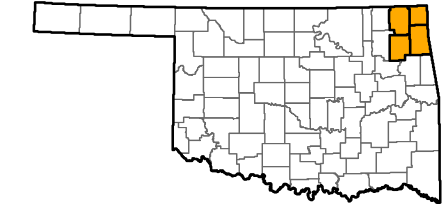


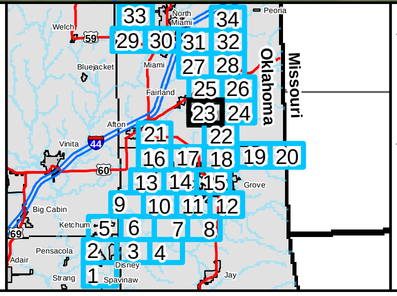
Vegetation Pattern

- ⬜ Barren
- 🟩 Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
- 🟨 Disturbed Soil Pasture
- ⬜ Eastern Great Plains: Herbaceous Wetland
- 🟦 Open Water
- ⬜ Osage Plains: Tallgrass Prairie/Pasture
- 🟩 Ozark-Ouachita: Dry Oak Woodland
- ⬜ Ozark-Ouachita: Dry Oak Woodland Young Regrowth
- 🟪 Ozark-Ouachita: Dry-Mesic Mixed Oak - Evergreen Forest
- 🟪 Ozark-Ouachita: Dry-Mesic Oak Forest
- ⬜ Ozark-Ouachita: Dry-Mesic Oak Woodland Young Regrowth
- ⬜ Ozark-Ouachita: Pasture/Prairie
- ⬜ Ozark-Ouachita: Riparian Barrens
- ⬜ Ozark-Ouachita: Riparian Deciduous Shrubland and Young Woodland
- 🟩 Ozark-Ouachita: Riparian Hardwood Woodland
- ⬜ Ozark-Ouachita: Riparian Herbaceous Wetland
- 🟩 Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
- 🟩 Ozark-Ouachita: Shortleaf Pine - Oak Forest
- 🟩 Pine Plantation
- ⬜ Row Crops
- ⬜ Ruderal Deciduous Shrubland and Young Woodland
- 🟫 Ruderal Deciduous Woodland
- 🟫 Ruderal Eastern Redcedar Woodland and Shrubland
- ⬜ Ruderal Mixed Deciduous - Eastern Redcedar Woodland
- ⬜ South Central Interior: Bottomland Barrens
- 🟦 South Central Interior: Bottomland Eastern Redcedar Woodland and Shrubland
- 🟦 South Central Interior: Bottomland Hardwood Forest
- ⬜ South Central Interior: Bottomland Herbaceous Wetland
- 🟦 South Central Interior: Bottomland Mixed Evergreen - Hardwood Forest
- 🟦 South Central Interior: Bottomland Shrubland and Young Woodland
- 🟦 South Central Interior: Riparian Hardwood Woodland
- ⬜ South Central Interior: Riparian Herbaceous Wetland
- 🟦 South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
- 🟦 South Central Interior: Riparian Shrubland and Young Woodland
- 🟥 Urban High Intensity
- 🟥 Urban Low Intensity

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA



REFERENCE:
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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

- ― Major Roadway
- ― Waterway
- ⬜ Waterbody
- ▭ 200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 23 OF 34

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PENSACOLA HYDROELECTRIC
PROJECT
FERC No. P-1494

Mead&Hunt

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CHECKED: TDB
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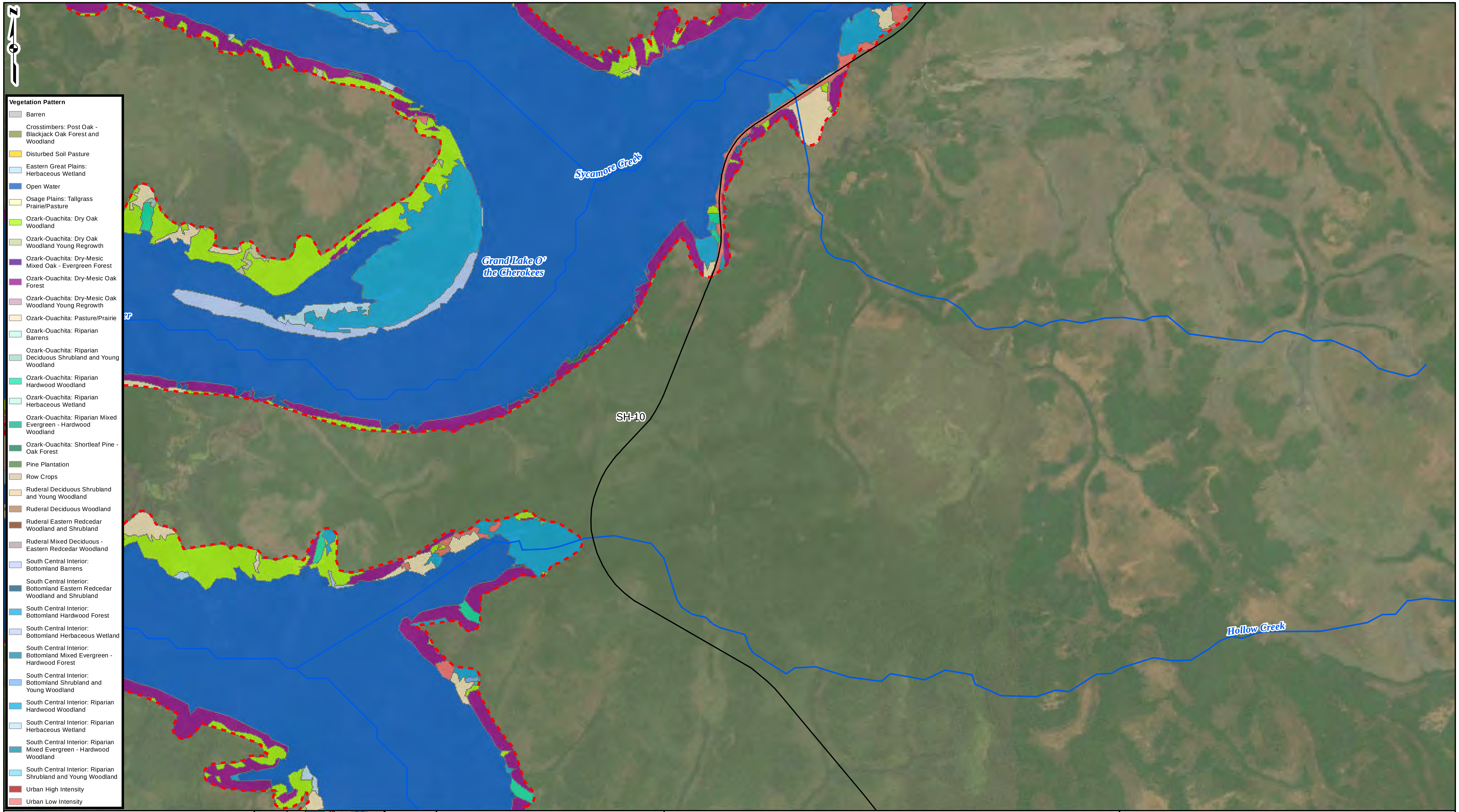
Vegetation Pattern
Barren
Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
Disturbed Soil Pasture
Eastern Great Plains: Herbaceous Wetland
Open Water
Osage Plains: Tallgrass Prairie/Pasture
Ozark-Ouachita: Dry Oak Woodland
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Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
Ozark-Ouachita: Shortleaf Pine - Oak Forest
Pine Plantation
Row Crops
Ruderal Deciduous Shrubland and Young Woodland
Ruderal Deciduous Woodland
Ruderal Eastern Redcedar Woodland and Shrubland
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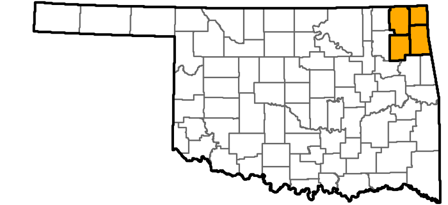
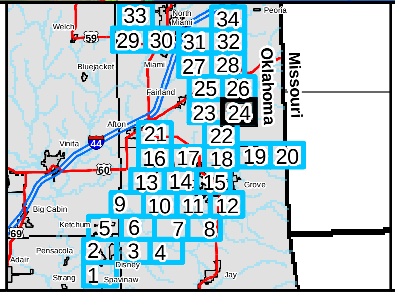
South Central Interior: Riparian Herbaceous Wetland
South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity
N
Sycamore Creek
Grand Lake O' the Cherokees
SH-10
Hollow Creek

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA



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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

—	Major Roadway	▭	Waterbody
—	Waterway	⬚	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 24 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

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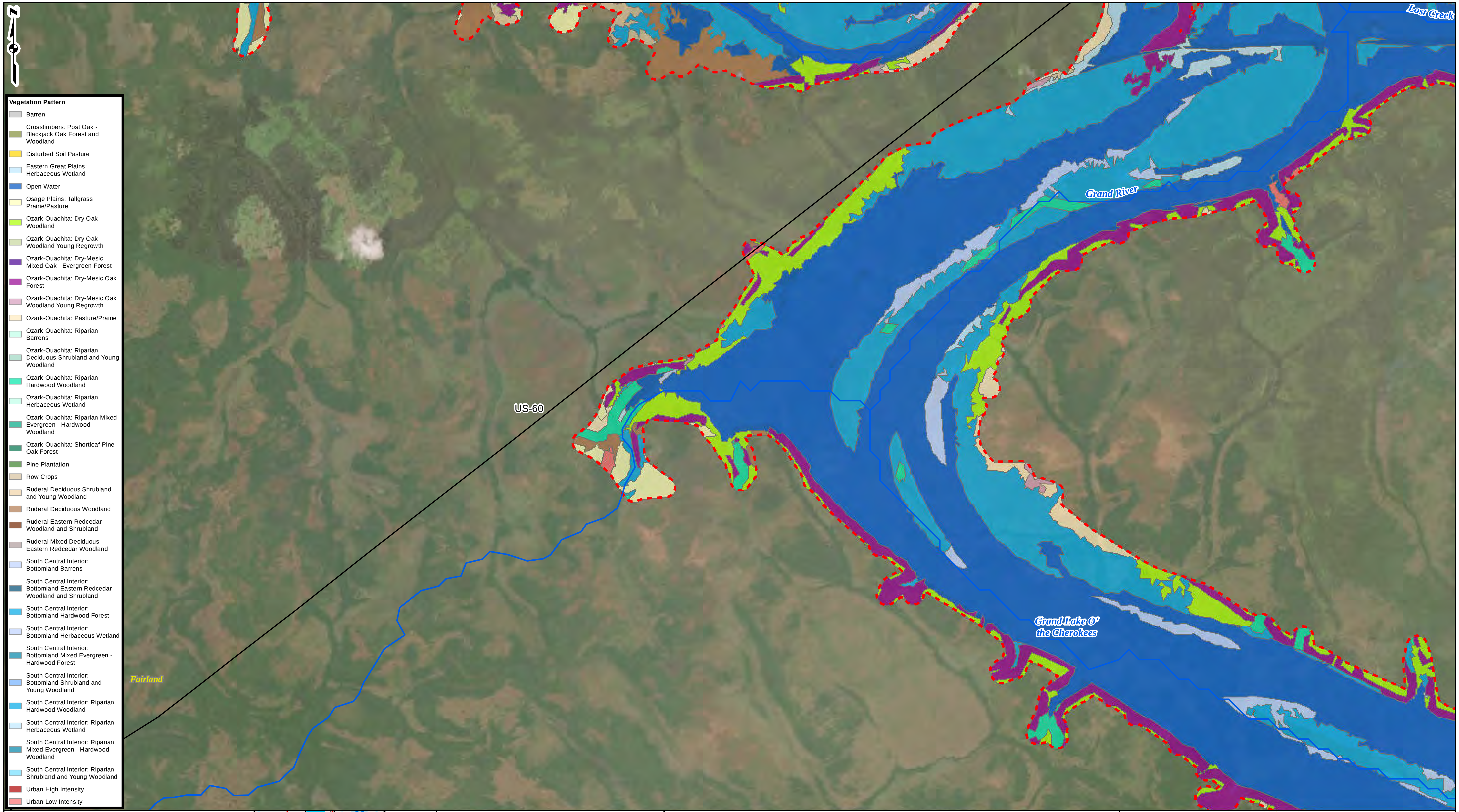
N
Vegetation Pattern
Barren
Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
Disturbed Soil Pasture
Eastern Great Plains: Herbaceous Wetland
Open Water
Osage Plains: Tallgrass Prairie/Pasture
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Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
Ozark-Ouachita: Shortleaf Pine - Oak Forest
Pine Plantation
Row Crops
Ruderal Deciduous Shrubland and Young Woodland
Ruderal Deciduous Woodland
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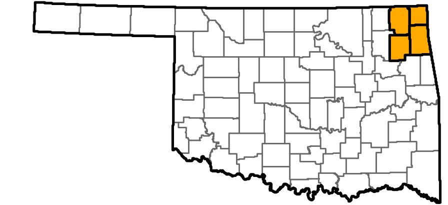
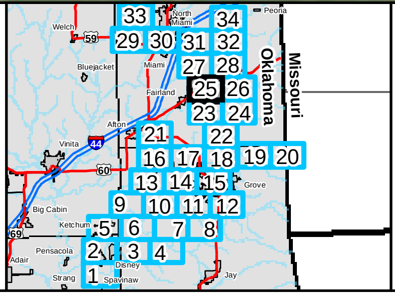
South Central Interior: Riparian Herbaceous Wetland
South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity
Lost Creek
Grand River
US-60
Grand Lake O' the Cherokees
Fairland

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA



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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

— Major Roadway
— Waterway
▭ Waterbody
▭ 200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 25 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

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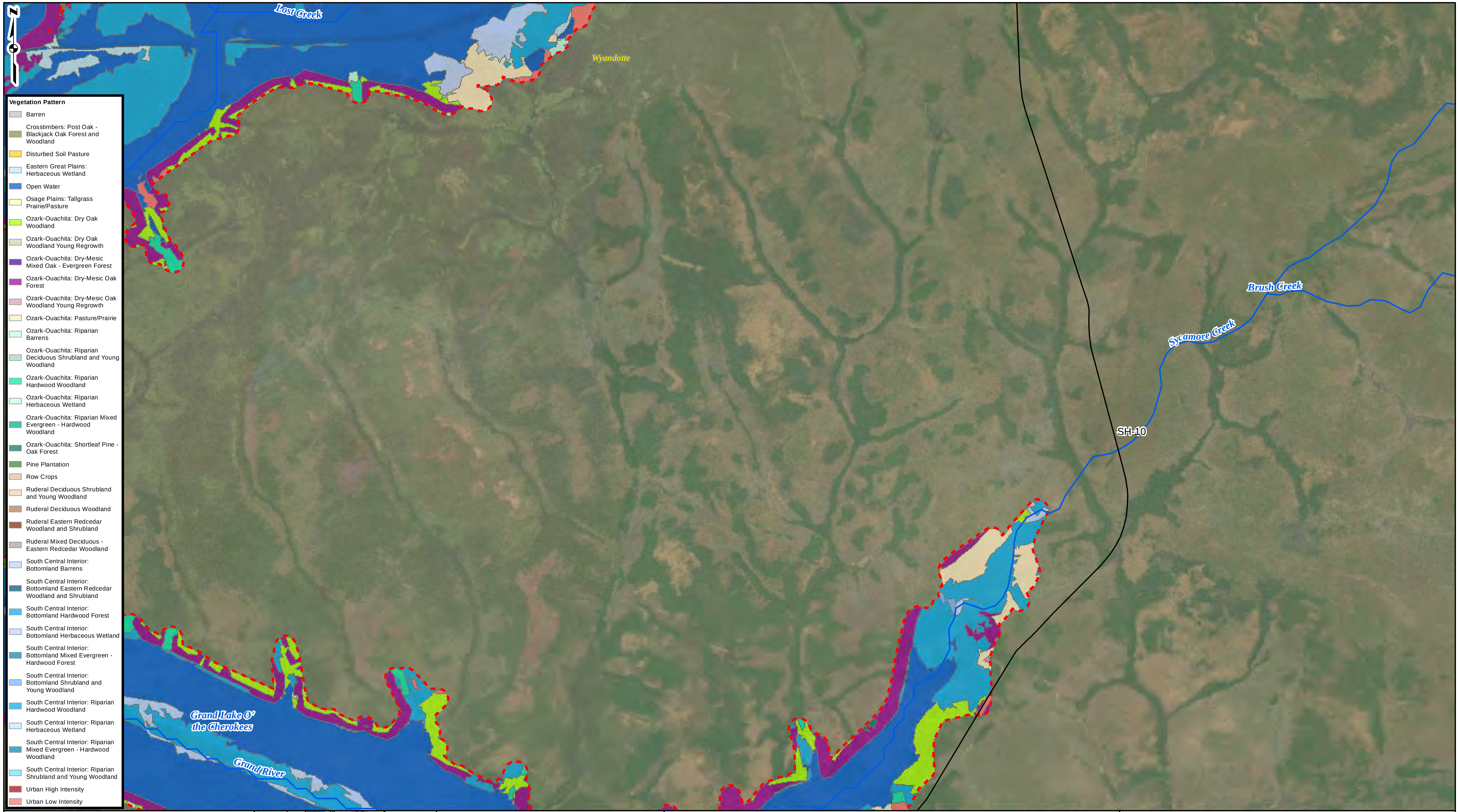

Vegetation Pattern

- Barren
- Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
- Disturbed Soil Pasture
- Eastern Great Plains: Herbaceous Wetland
- Open Water
- Osage Plains: Tallgrass Prairie/Pasture
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- Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
- Ozark-Ouachita: Shortleaf Pine - Oak Forest
- Pine Plantation
- Row Crops
- Ruderal Deciduous Shrubland and Young Woodland
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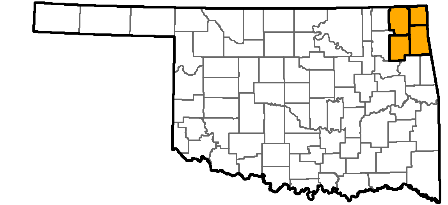
- South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
- South Central Interior: Riparian Shrubland and Young Woodland
- Urban High Intensity
- Urban Low Intensity

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
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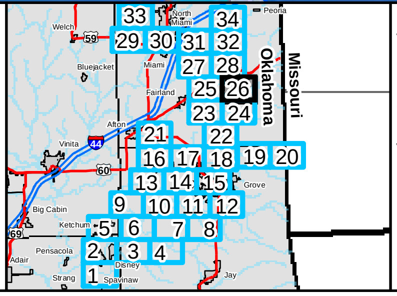

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Vegetation and Landcover, MoRAP, 3/2015

Legend

Major Roadway	Waterbody
Waterway	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 26 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

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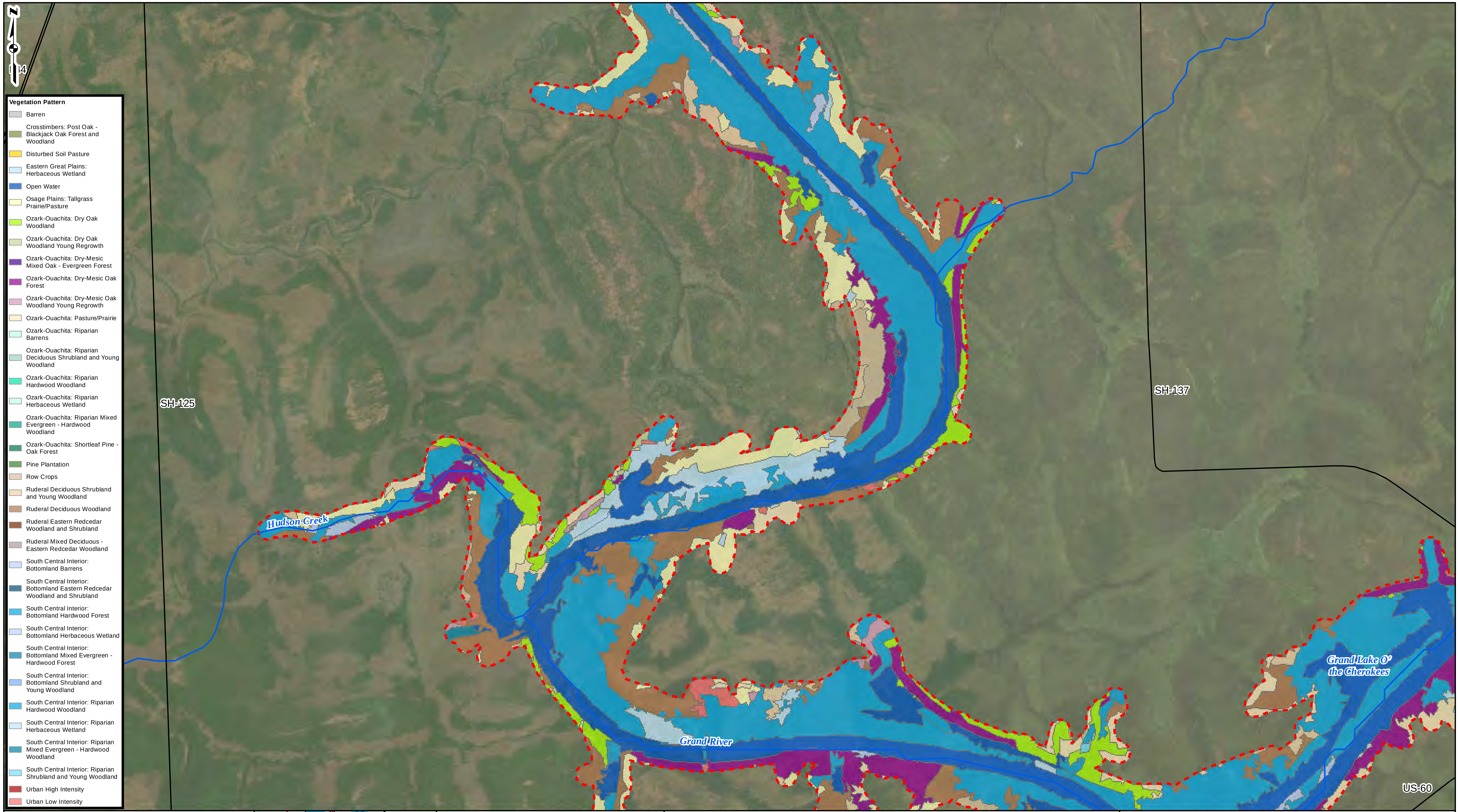
N
I-44
Vegetation Pattern
Barren
Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
Disturbed Soil Pasture
Eastern Great Plains: Herbaceous Wetland
Open Water
Osage Plains: Tallgrass Prairie/Pasture
Ozark-Ouachita: Dry Oak Woodland
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Pine Plantation
Row Crops
Ruderal Deciduous Shrubland and Young Woodland
Ruderal Deciduous Woodland
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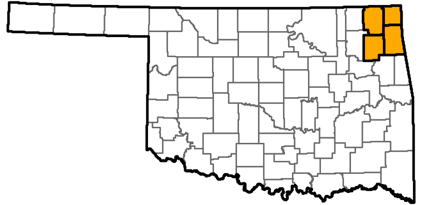
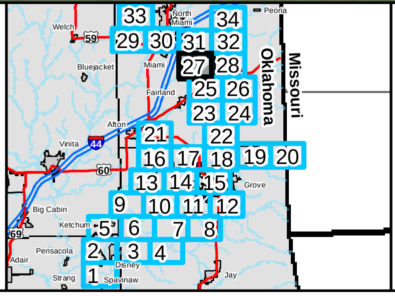
South Central Interior: Riparian Herbaceous Wetland
South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity
SH-125
SH-137
Hudson Creek
Grand River
Grand Lake O' the Cherokees
US-60

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
OTTAWA COUNTIES, OKLAHOMA



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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

Major Roadway

Waterway

Waterbody

200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 27 OF 34

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PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

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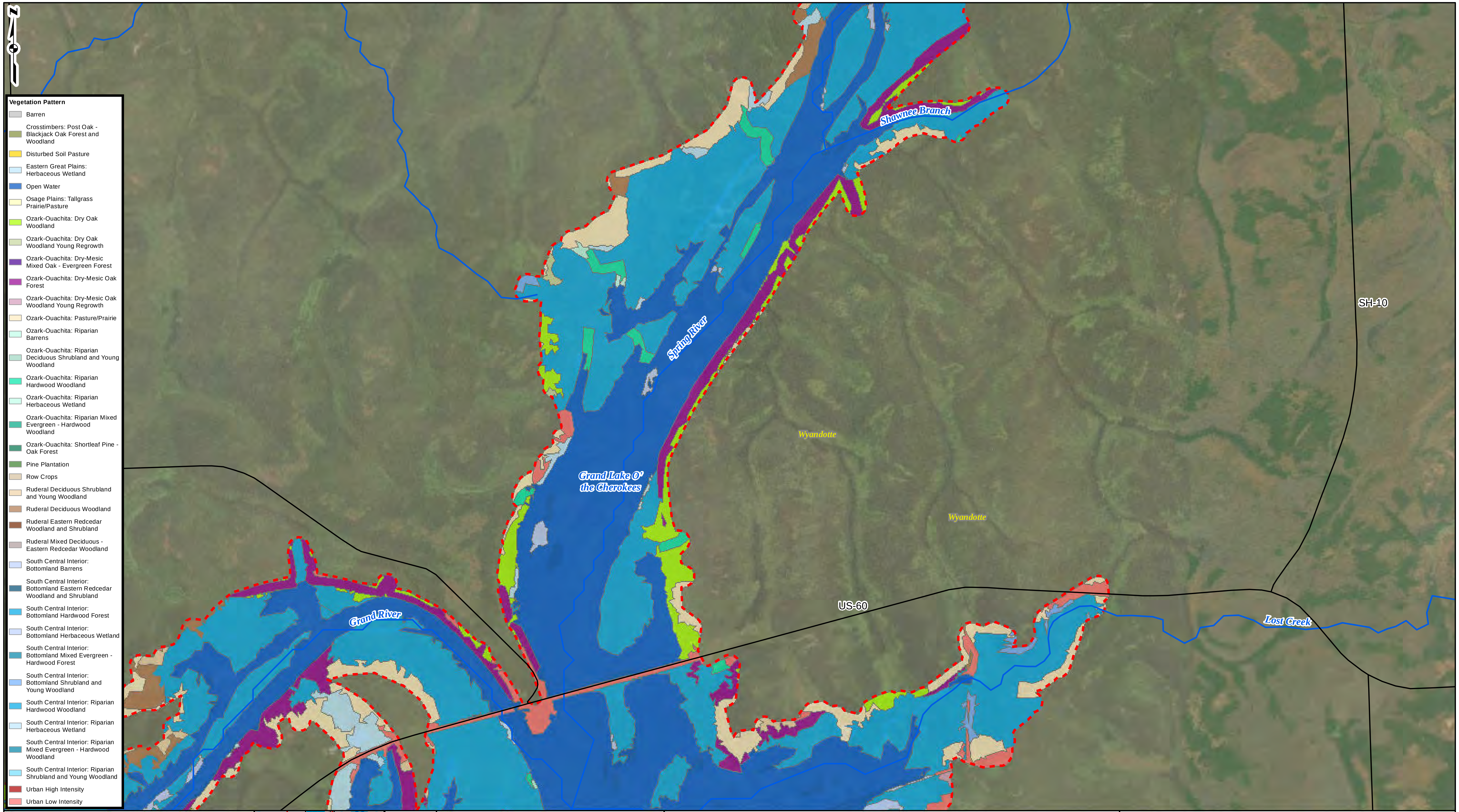

Vegetation Pattern

- Barren
- Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
- Disturbed Soil Pasture
- Eastern Great Plains: Herbaceous Wetland
- Open Water
- Osage Plains: Tallgrass Prairie/Pasture
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- Ozark-Ouachita: Dry-Mesic Oak Woodland Young Regrowth
- Ozark-Ouachita: Pasture/Prairie
- Ozark-Ouachita: Riparian Barrens
- Ozark-Ouachita: Riparian Deciduous Shrubland and Young Woodland
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- Ozark-Ouachita: Riparian Herbaceous Wetland
- Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland
- Ozark-Ouachita: Shortleaf Pine - Oak Forest
- Pine Plantation
- Row Crops
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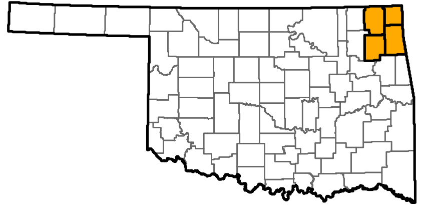
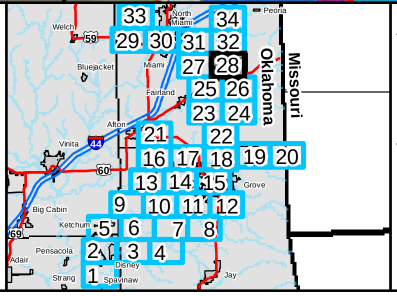
- South Central Interior: Riparian Shrubland and Young Woodland
- Urban High Intensity
- Urban Low Intensity

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND OTTAWA COUNTIES, OKLAHOMA



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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

- Major Roadway
- Waterway
- Waterbody
- 200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600 Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 28 OF 34

PENSACOLA HYDROELECTRIC PROJECT
FERC No. P-1494

gai consultants
Mead&Hunt

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DATE: 3/9/2022
CHECKED: TDB
APPROVED: DMJ

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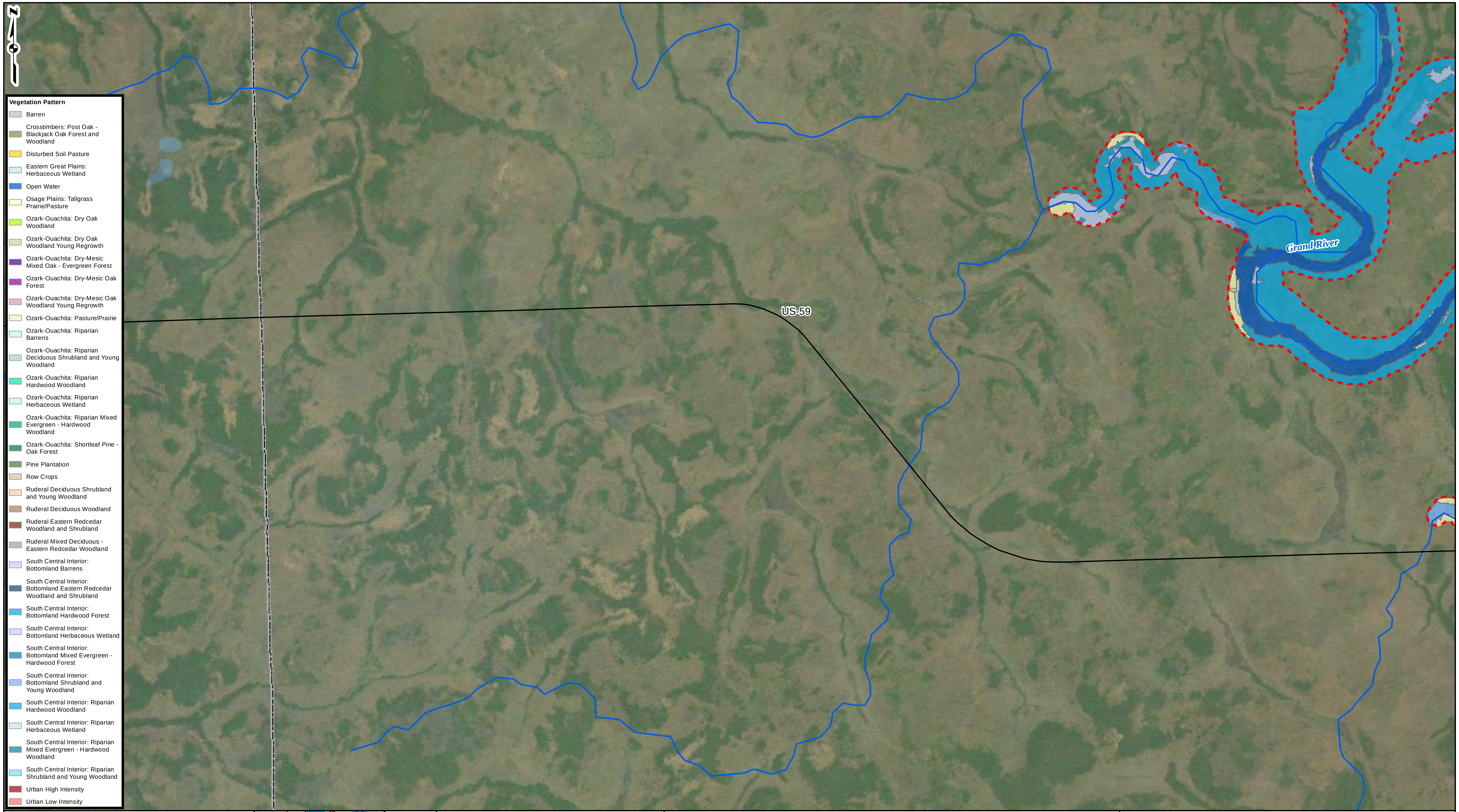
N
Vegetation Pattern
Barren
Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
Disturbed Soil Pasture
Eastern Great Plains: Herbaceous Wetland
Open Water
Osage Plains: Tallgrass Prairie/Pasture
Ozark-Ouachita: Dry Oak Woodland
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Row Crops
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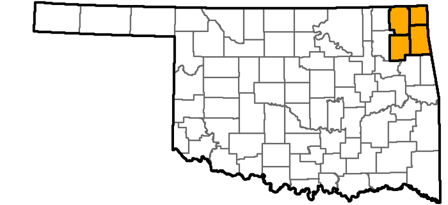
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity
US-59
Grand River

PROJECT LOCATION



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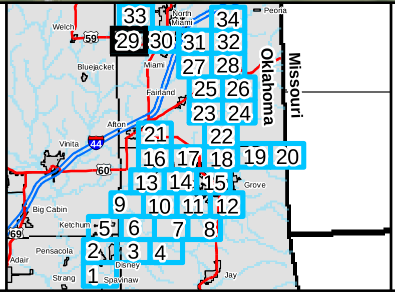

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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

—	Major Roadway	🟦	Waterbody
—	Waterway	▭	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 29 OF 34

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PENSACOLA HYDROELECTRIC
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FERC No. P-1494

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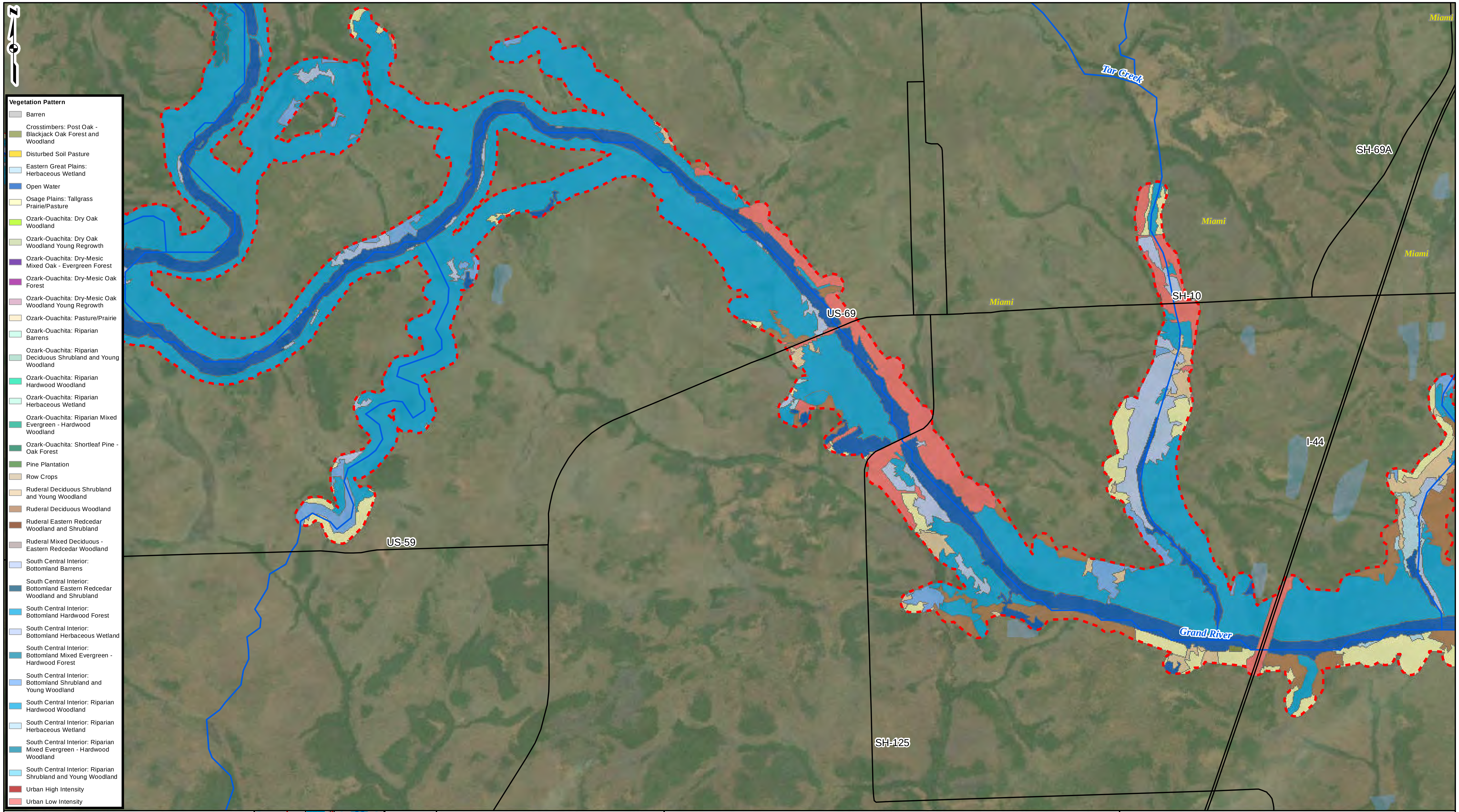

Vegetation Pattern

- ▨ Barren
- ▨ Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
- ▨ Disturbed Soil Pasture
- ▨ Eastern Great Plains: Herbaceous Wetland
- ▨ Open Water
- ▨ Osage Plains: Tallgrass Prairie/Pasture
- ▨ Ozark-Ouachita: Dry Oak Woodland
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- ▨ Ozark-Ouachita: Shortleaf Pine - Oak Forest
- ▨ Pine Plantation
- ▨ Row Crops
- ▨ Ruderal Deciduous Shrubland and Young Woodland
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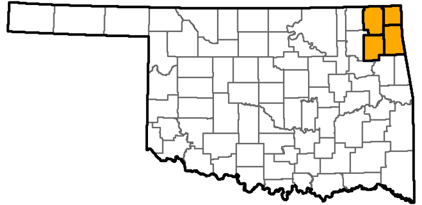
- ▨ Urban High Intensity
- ▨ Urban Low Intensity

PROJECT LOCATION



CRAIG, DELAWARE, MAYES, AND
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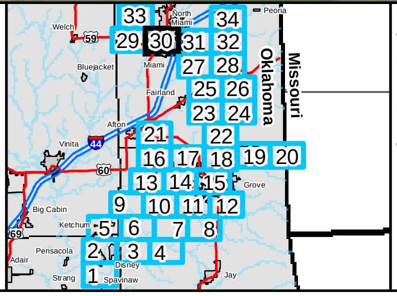

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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

—	Major Roadway	▨	Waterbody
—	Waterway	⬚	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 30 OF 34

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PENSACOLA HYDROELECTRIC
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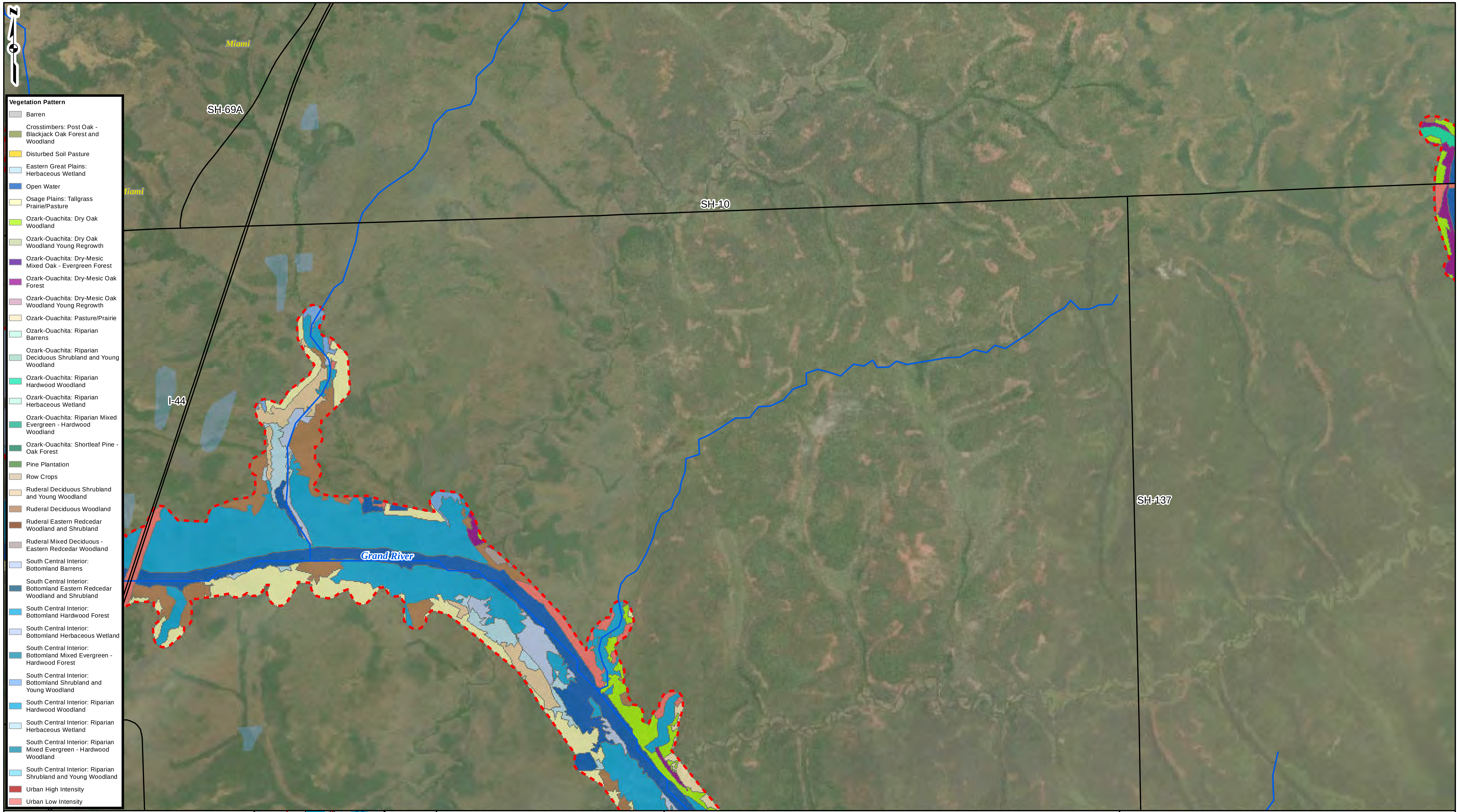
Vegetation Pattern
Barren
Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland
Disturbed Soil Pasture
Eastern Great Plains: Herbaceous Wetland
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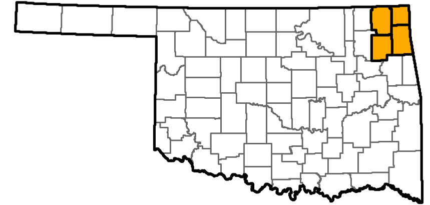
South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity
N
Miami
Miami
SH-69A
SH-10
I-44
SH-137
Grand River

PROJECT LOCATION



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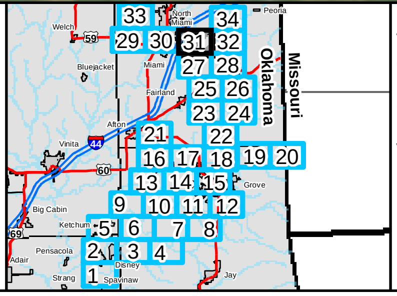

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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

Major Roadway
Waterbody
Waterway
200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 31 OF 34

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PENSACOLA HYDROELECTRIC
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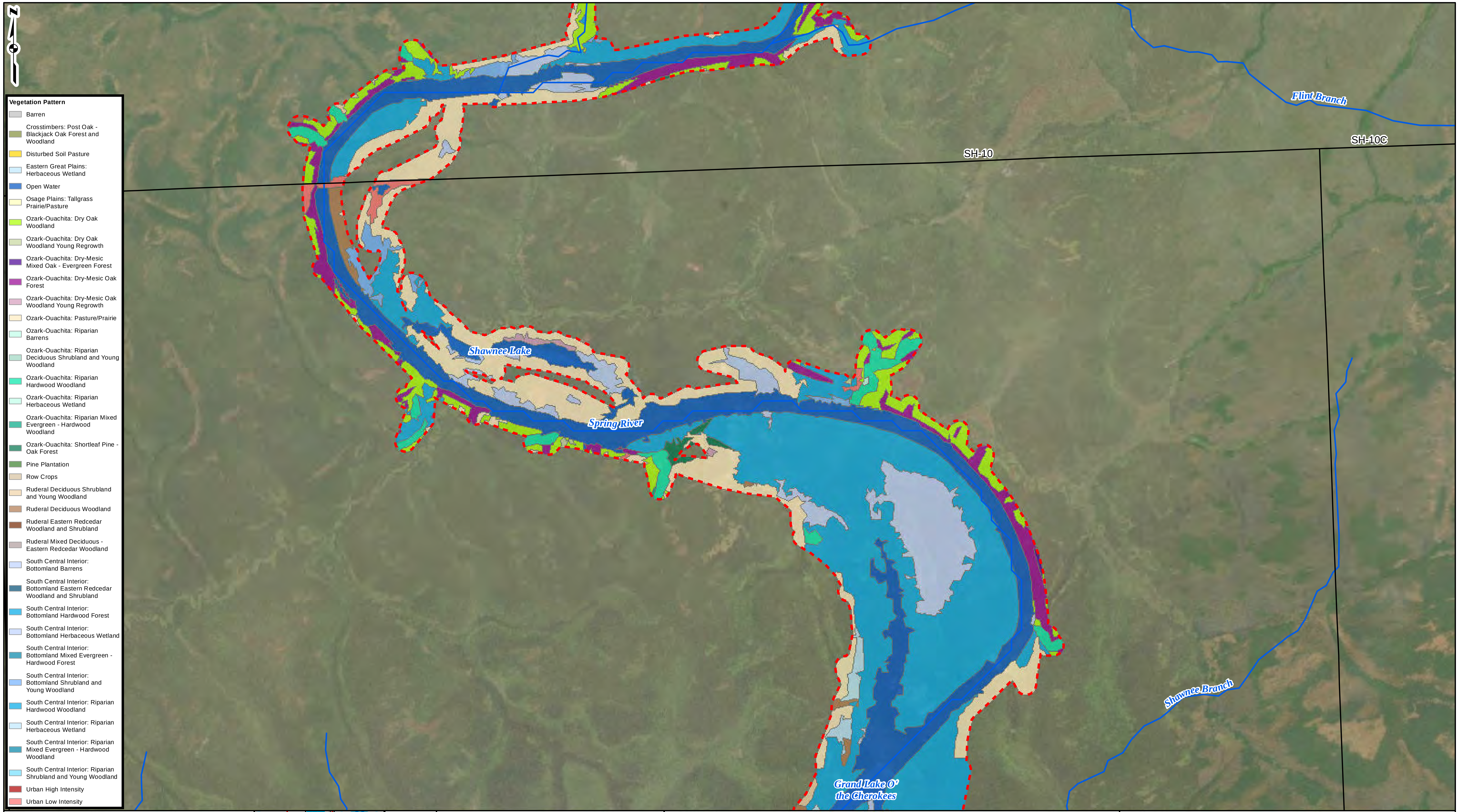
N
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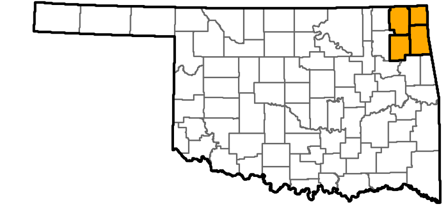
South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland
South Central Interior: Riparian Shrubland and Young Woodland
Urban High Intensity
Urban Low Intensity
Flint Branch
SH-10
SH-10C
Shawnee Lake
Spring River
Shawnee Branch
Grand Lake O' the Cherokees

PROJECT LOCATION



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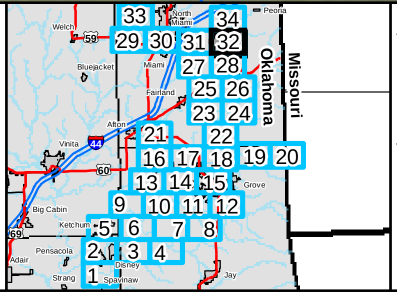

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ESRI World Imagery, 2021, Accessed 1/2022.
Vegetation and Landcover, MoRAP, 3/2015

Legend

— Major Roadway
— Waterway
▭ Waterbody
▭ 200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600 Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 32 OF 34

PENSACOLA HYDROELECTRIC PROJECT
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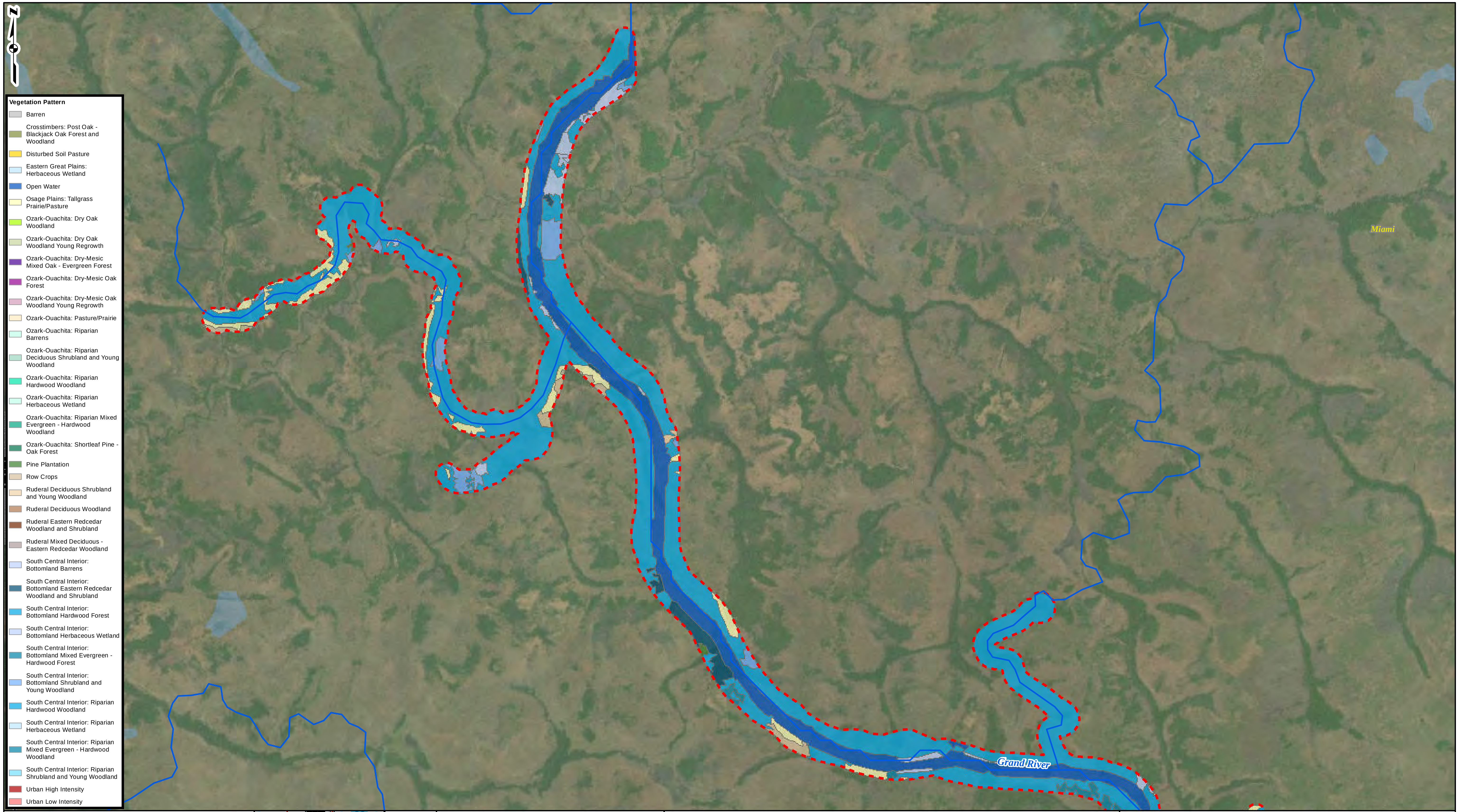

Vegetation Pattern

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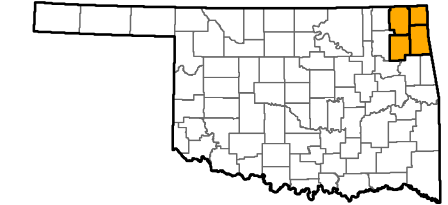

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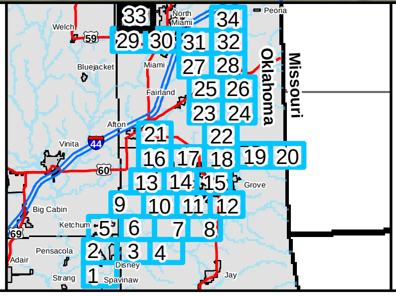

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Legend

Major Roadway	Waterbody
Waterway	200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 33 OF 34

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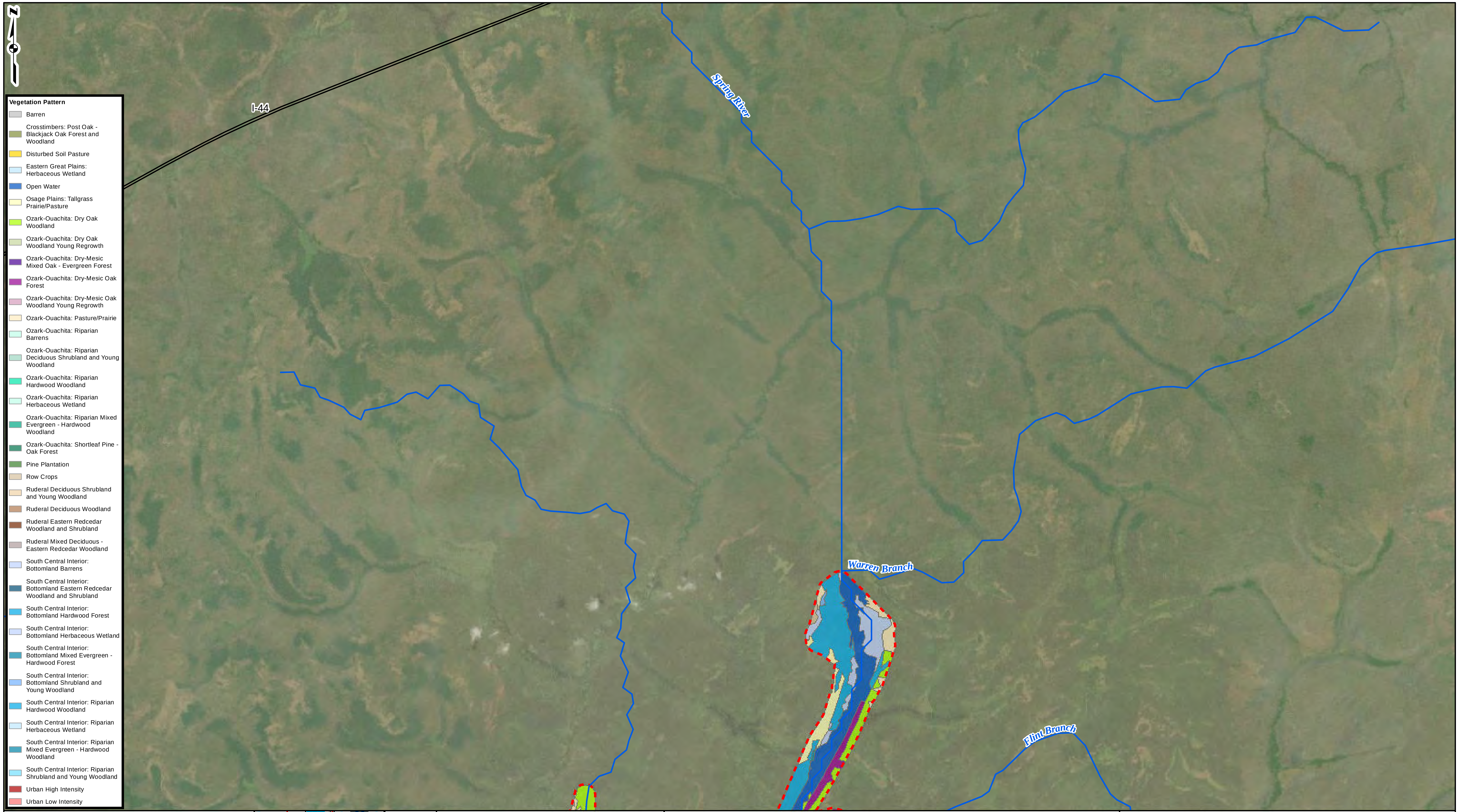

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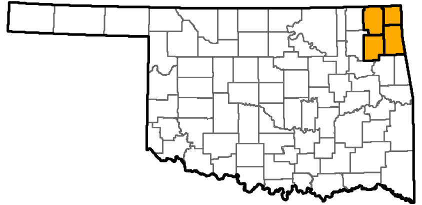
- Urban High Intensity
- Urban Low Intensity

PROJECT LOCATION



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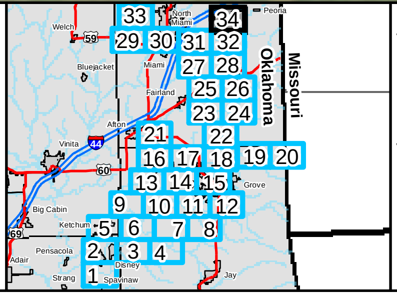

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Legend

- Major Roadway
- Waterway
- Waterbody
- 200 ft Buffer Project Boundary (1/27/2014)

0 900 1,800 3,600
Feet

VEGETATION PATTERNS IN THE VICINITY OF THE PENSACOLA HYDROELECTRIC PROJECT
SHEET 34 OF 34

PENSACOLA HYDROELECTRIC
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APPENDIX E-23 Grand Lake O’ the Cherokees E-Bird Checklist (Cherokee State Park)

eBird Field Checklist

Grand Lake O' the Cherokees--Recreation Area Number 1

Mayes, Oklahoma, US

ebird.org/hotspot/L2170720

128 species (+5 other taxa) - Year-round, All years

Date:______
Start time:______
Duration:______
Distance:______
Party size:______
Notes:

This checklist is generated with data from eBird (ebird.org), a global database of bird sightings from birders like you. If you enjoy this checklist, please consider contributing your sightings to eBird. It is 100% free to take part, and your observations will help support birders, researchers, and conservationists worldwide.

Go to ebird.org to learn more!

Waterfowl

___Canada Goose
___Muscovy Duck (Domestic type)
___Wood Duck
___Blue-winged Teal
___Northern Shoveler
___Gadwall
___Mallard
___Green-winged Teal

Grouse, Quail, and Allies

___Northern Bobwhite

Grebes

___Pied-billed Grebe
___Horned Grebe
___Eared Grebe

Pigeons and Doves

___Rock Pigeon
___Eurasian Collared-Dove
___Mourning Dove

Cuckoos

___Yellow-billed Cuckoo

Hummingbirds

___Ruby-throated Hummingbird

Rails, Gallinules, and Allies

___American Coot

Shorebirds

___Killdeer
___Spotted Sandpiper
___Willet

Gulls, Terns, and Skimmers

___Bonaparte's Gull
___Franklin's Gull
___Ring-billed Gull
___Herring Gull
___gull sp.
___Caspian Tern
___Forster's Tern

Loons

___Common Loon

Cormorants and Anhingas

___Double-crested Cormorant

Pelicans

___American White Pelican

Herons, Ibis, and Allies

___Great Blue Heron
___Great Egret
___Snowy Egret
___Cattle Egret
___Green Heron
___Black-crowned Night-Heron

Vultures, Hawks, and Allies

___Black Vulture
___Turkey Vulture
___Osprey
___Mississippi Kite
___Cooper's Hawk
___Bald Eagle
___Red-shouldered Hawk
___Red-tailed Hawk

Owls

___Barred Owl

Kingfishers

___Belted Kingfisher

Woodpeckers

___Yellow-bellied Sapsucker
___Red-headed Woodpecker
___Red-bellied Woodpecker
___Downy Woodpecker
___Hairy Woodpecker
___Downy/Hairy Woodpecker
___Pileated Woodpecker
___Northern Flicker

Falcons and Caracaras

___American Kestrel

Tyrant Flycatchers: Pewees, Kingbirds, and Allies

___Eastern Wood-Pewee
___Acadian Flycatcher
___Eastern Phoebe
___Great Crested Flycatcher
___Eastern Kingbird
___Scissor-tailed Flycatcher

Vireos

___White-eyed Vireo
___Bell's Vireo
___Yellow-throated Vireo
___Warbling Vireo
___Red-eyed Vireo

Shrikes

___Loggerhead Shrike

Jays, Magpies, Crows, and Ravens

___Blue Jay
___American Crow
___Fish Crow
___crow sp.

Tits, Chickadees, and Titmice

___Carolina Chickadee
___Tufted Titmouse

Martins and Swallows

___Northern Rough-winged Swallow
___Purple Martin
___Tree Swallow
___Barn Swallow
___Cliff Swallow
___swallow sp.

Kinglets

___Ruby-crowned Kinglet
___Golden-crowned Kinglet

Nuthatches

___Red-breasted Nuthatch
___White-breasted Nuthatch

Gnatcatchers

___Blue-gray Gnatcatcher

Wrens

___House Wren
___Carolina Wren
___Bewick's Wren

Starlings and Mynas

___European Starling

Catbirds, Mockingbirds, and Thrashers

___Gray Catbird
___Brown Thrasher
___Northern Mockingbird

Thrushes

___Eastern Bluebird
___Swainson's Thrush
___Wood Thrush
___American Robin

Waxwings

___Cedar Waxwing

Old World Sparrows

___House Sparrow

Finches, Euphonias, and Allies

___House Finch
___American Goldfinch

New World Sparrows

___Chipping Sparrow
___Lark Sparrow
___Dark-eyed Junco
___White-throated Sparrow
___Savannah Sparrow

Blackbirds

___Eastern Meadowlark
___Orchard Oriole
___Baltimore Oriole
___Red-winged Blackbird
___Brown-headed Cowbird
___Common Grackle
___Great-tailed Grackle

This field checklist was generated using eBird (ebird.org)

Wood-Warblers

___Louisiana Waterthrush
___Black-and-white Warbler
___Prothonotary Warbler
___Tennessee Warbler
___Orange-crowned Warbler
___Nashville Warbler
___Kentucky Warbler
___Common Yellowthroat
___American Redstart
___Northern Parula
___Yellow Warbler
___Yellow-rumped Warbler
___Yellow-throated Warbler
___Black-throated Green Warbler
___Wilson's Warbler

Cardinals, Grosbeaks, and Allies

___Summer Tanager
___Northern Cardinal
___Blue Grosbeak
___Indigo Bunting
___Painted Bunting
___Dickcissel

This field checklist was generated using eBird (ebird.org)

APPENDIX E-24 2018 IPaC Official Species List

FEDERAL ENERGY REGULATORY COMMISSION
MEMORANDUM

DATE: January 11, 2018

FROM: Rachel McNamara, Pensacola Project Relicensing Coordinator
South Branch, Division of Hydropower Licensing
Office of Energy Projects

TO: Public Files for the Pensacola Hydroelectric Project
(FERC Project No. 1494-438)

SUBJECT: List of Threatened, Endangered, Candidate, and Proposed Species
Generated by ECOS-IPaC Website on January 10, 2018.

On January 10, 2018, Commission staff accessed the U.S. Fish and Wildlife Service's ECOS-IPaC website (https://ecos.fws.gov/ipac/).

The endangered gray bat, Indiana bat, Ozark big-eared bat, Neosho mucket, winged mapleleaf, and American burying beetle may occur within the Pensacola Hydroelectric Project boundary or be affected by the project.

The threatened northern long-eared bat, piping plover, Neosho madtom, Ozark cavefish, and rabbitsfoot mussel may occur within the Pensacola Hydroelectric Project boundary or be affected by the project.

The endangered least tern may also occur within the project boundary; however, the IPaC report states that the species needs to be considered only for projects involving towers (i.e., radio, television, cellular, microwave, meteorological), wind turbines, and wind farms. The Pensacola Hydroelectric Project does not include such features.

No proposed or candidate species may occur within the project boundary or be affected by the project. No designated critical habitat is located within the project boundary.

A copy of the list is attached.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Oklahoma Ecological Services Field Office
9014 East 21st Street
Tulsa, OK 74129-1428
Phone: (918) 581-7458 Fax: (918) 581-7467
http://www.fws.gov/southwest/es/Oklahoma/

In Reply Refer To:
Consultation Code: 02EKOK00-2018-SLI-0635
Event Code: 02EKOK00-2018-E-01483
Project Name: Pennsicola

January 10, 2018

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and/or may be affected by your proposed project. The species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 *et seq.*).

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. Please feel free to contact us if you need more current information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat. Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the Act, the accuracy of this species list should be verified after 90 days. This verification can be completed formally or informally as desired. The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

The purpose of the Act is to provide a means whereby threatened and endangered species and the ecosystems upon which they depend may be conserved. Under sections 7(a)(1) and 7(a)(2) of the Act and its implementing regulations (50 CFR 402 *et seq.*), Federal agencies are required to utilize their authorities to carry out programs for the conservation of threatened and endangered species and to determine whether projects may affect threatened and endangered species and/or designated critical habitat.

A Biological Assessment is required for construction projects (or other undertakings having similar physical impacts) that are major Federal actions significantly affecting the quality of the human environment as defined in the National Environmental Policy Act (42 U.S.C. 4332(2)(c)). For projects other than major construction activities, the Service suggests that a biological evaluation similar to a Biological Assessment be prepared to determine whether the project may affect listed or proposed species and/or designated or proposed critical habitat. Recommended contents of a Biological Assessment are described at 50 CFR 402.12.

If a Federal agency determines, based on the Biological Assessment or biological evaluation, that listed species and/or designated critical habitat may be affected by the proposed project, the agency is required to consult with the Service pursuant to 50 CFR 402. In addition, the Service recommends that candidate species, proposed species and proposed critical habitat be addressed within the consultation. More information on the regulations and procedures for section 7 consultation, including the role of permit or license applicants, can be found in the "Endangered Species Consultation Handbook" at:

http://www.fws.gov/endangered/esa-library/pdf/TOC-GLOS.PDF

Non-federal entities conducting activities that may result in take of listed species should consider seeking coverage under section 10 of the ESA, either through development of a Habitat Conservation Plan (HCP) or, by becoming a signatory to the General Conservation Plan (GCP) currently under development for the American burying beetle. Each of these mechanisms provides the means for obtaining a permit and coverage for incidental take of listed species during otherwise lawful activities.

Please be aware that bald and golden eagles are protected under the Bald and Golden Eagle Protection Act (16 U.S.C. 668 *et seq.*), and projects affecting these species may require development of an eagle conservation plan (http://www.fws.gov/windenergy/eagle_guidance.html). Additionally, wind energy projects should follow the wind energy guidelines (http://www.fws.gov/windenergy/) for minimizing impacts to migratory birds and bats.

Guidance for minimizing impacts to migratory birds for projects including communications towers (e.g., cellular, digital television, radio, and emergency broadcast) can be found at: http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/towers.htm; http://www.towerkill.com; and http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/comtow.html.

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. Please include the Consultation Tracking Number in the header of this letter with any request for consultation or correspondence about your project that you submit through our Project Review step-wise process http://www.fws.gov/southwest/es/oklahoma/OKESFO%20Permit%20Home.htm.

Attachment(s):

- Official Species List
- USFWS National Wildlife Refuges and Fish Hatcheries
- Migratory Birds
- Wetlands

Official Species List

This list is provided pursuant to Section 7 of the Endangered Species Act, and fulfills the requirement for Federal agencies to "request of the Secretary of the Interior information whether any species which is listed or proposed to be listed may be present in the area of a proposed action".

This species list is provided by:

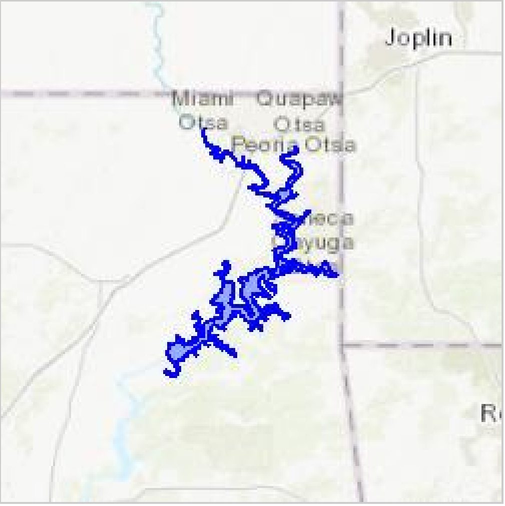
Oklahoma Ecological Services Field Office
9014 East 21st Street
Tulsa, OK 74129-1428
(918) 581-7458

Project Summary

Consultation Code:	02EKOK00-2018-SLI-0635
Event Code:	02EKOK00-2018-E-01483
Project Name:	Pennsicola
Project Type:	POWER GENERATION
Project Description:	Hydro relicense

Project Location:

Approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/place/36.67849039200004N94.77664843515234W



Counties: Craig, OK | Delaware, OK | Mayes, OK | Ottawa, OK

Endangered Species Act Species

There is a total of 13 threatened, endangered, or candidate species on this species list. Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Note that 1 of these species should be considered only under certain conditions. See the "Critical habitats" section below for those critical habitats that lie wholly or partially within your project area under this office's jurisdiction. Please contact the designated FWS office if you have questions.

Mammals

NAME	STATUS
Gray Bat *Myotis grisescens* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/6329	Endangered
Indiana Bat *Myotis sodalis* There is **final** critical habitat for this species. Your location is outside the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/5949	Endangered
Northern Long-eared Bat *Myotis septentrionalis* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/9045	Threatened
Ozark Big-eared Bat *Corynorhinus (=Plecotus) townsendii ingens* There is **proposed** critical habitat for this species. The location of the critical habitat is not available. Species profile: https://ecos.fws.gov/ecp/species/7245	Endangered

Birds

NAME	STATUS
Least Tern *Sterna antillarum* Population: interior pop. No critical habitat has been designated for this species. This species only needs to be considered under the following conditions: ▪ Towers (i.e. radio, television, cellular, microwave, meterological) ▪ Wind Turbines and Wind Farms Species profile: https://ecos.fws.gov/ecp/species/8505	Endangered
Piping Plover *Charadrius melodus* Population: [Atlantic Coast and Northern Great Plains populations] - Wherever found, except those areas where listed as endangered. There is **final** critical habitat for this species. Your location is outside the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/6039	Threatened
Red Knot *Calidris canutus rufa* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/1864	Threatened

Fishes

NAME	STATUS
Neosho Madtom *Noturus placidus* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/2577	Threatened
Ozark Cavefish *Amblyopsis rosae* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/6490	Threatened

Clams

NAME	STATUS
Neosho Mucket *Lampsilis rafinesqueana* There is **final** critical habitat for this species. Your location is outside the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/3788	Endangered
Rabbitsfoot *Quadrula cylindrica cylindrica* There is **final** critical habitat for this species. Your location is outside the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/5165	Threatened
Winged Mapleleaf *Quadrula fragosa* Population: Wherever found, except where listed as an experimental population No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/4127	Endangered

Insects

NAME	STATUS
American Burying Beetle *Nicrophorus americanus* Population: Wherever found, except where listed as an experimental population No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/66	Endangered

Critical habitats

THERE ARE NO CRITICAL HABITATS WITHIN YOUR PROJECT AREA UNDER THIS OFFICE'S JURISDICTION.

USFWS National Wildlife Refuge Lands And Fish Hatcheries

Any activity proposed on lands managed by the National Wildlife Refuge system must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

REFUGE INFORMATION WAS NOT AVAILABLE WHEN THIS SPECIES LIST WAS GENERATED. PLEASE CONTACT THE FIELD OFFICE FOR FURTHER INFORMATION.

Migratory Birds

Certain birds are protected under the Migratory Bird Treaty Act[1] and the Bald and Golden Eagle Protection Act[2].

Any person or organization who plans or conducts activities that may result in impacts to migratory birds, eagles, and their habitats should follow appropriate regulations and consider implementing appropriate conservation measures, as described below.

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1. The Migratory Birds Treaty Act of 1918.
2. The Bald and Golden Eagle Protection Act of 1940.
3. 50 C.F.R. Sec. 10.12 and 16 U.S.C. Sec. 668(a)

The birds listed below are birds of particular concern either because they occur on the USFWS Birds of Conservation Concern (BCC) list or warrant special attention in your project location. To learn more about the levels of concern for birds on your list and how this list is generated, see the FAQ below. This is not a list of every bird you may find in this location, nor a guarantee that every bird on this list will be found in your project area. To see maps of where birders and the general public have sighted birds in and around your project area, visit E-bird tools such as the E-bird data mapping tool (search for the name of a bird on your list to see specific locations where that bird has been reported to occur within your project area over a certain timeframe) and the E-bird Explore Data Tool (perform a query to see a list of all birds sighted in your county or region and within a certain timeframe). For projects that occur off the Atlantic Coast, additional maps and models detailing the relative occurrence and abundance of bird species on your list are available. Links to additional information about Atlantic Coast birds, and other important information about your migratory bird list can be found below.

For guidance on when to schedule activities or implement avoidance and minimization measures to reduce impacts to migratory birds on your list, click on the PROBABILITY OF PRESENCE SUMMARY at the top of your list to see when these birds are most likely to be present and breeding in your project area.

NAME	BREEDING SEASON
Bald Eagle *Haliaeetus leucocephalus* This is not a Bird of Conservation Concern (BCC) in this area, but warrants attention because of the Eagle Act or for potential susceptibilities in offshore areas from certain types of development or activities. https://ecos.fws.gov/ecp/species/1626	Breeds Sep 1 to Aug 31

NAME	BREEDING SEASON
Black-billed Cuckoo *Coccyzus erythropthalmus* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/9399	Breeds May 15 to Oct 10
Bobolink *Dolichonyx oryzivorus* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds May 20 to Jul 31
Cerulean Warbler *Dendroica cerulea* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/2974	Breeds Apr 21 to Jul 20
Eastern Whip-poor-will *Antrostomus vociferus* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds May 1 to Aug 20
Henslow's Sparrow *Ammodramus henslowii* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/3941	Breeds May 1 to Aug 31
Kentucky Warbler *Oporornis formosus* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds Apr 20 to Aug 20
Lesser Yellowlegs *Tringa flavipes* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/9679	Breeds elsewhere
Prairie Warbler *Dendroica discolor* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds May 1 to Jul 31
Prothonotary Warbler *Protonotaria citrea* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds Apr 1 to Jul 31
Red-headed Woodpecker *Melanerpes erythrocephalus* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds May 10 to Sep 10
Rusty Blackbird *Euphagus carolinus* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds elsewhere

NAME	BREEDING SEASON
Semipalmated Sandpiper *Calidris pusilla* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds elsewhere
Wood Thrush *Hylocichla mustelina* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds May 10 to Aug 31

Probability Of Presence Summary

The graphs below provide our best understanding of when birds of concern are most likely to be present in your project area. This information can be used to tailor and schedule your project activities to avoid or minimize impacts to birds.

Probability of Presence (🟩)

Each green bar represents the bird's relative probability of presence in your project's counties during a particular week of the year. (A year is represented as 12 4-week months.) A taller bar indicates a higher probability of species presence. The survey effort (see below) can be used to establish a level of confidence in the presence score. One can have higher confidence in the presence score if the corresponding survey effort is also high.

How is the probability of presence score calculated? The calculation is done in three steps:

1. The probability of presence for each week is calculated as the number of survey events in the week where the species was detected divided by the total number of survey events for that week. For example, if in week 12 there were 20 survey events and the Spotted Towhee was found in 5 of them, the probability of presence of the Spotted Towhee in week 12 is 0.25.
2. To properly present the pattern of presence across the year, the relative probability of presence is calculated. This is the probability of presence divided by the maximum probability of presence across all weeks. For example, imagine the probability of presence in week 20 for the Spotted Towhee is 0.05, and that the probability of presence at week 12 (0.25) is the maximum of any week of the year. The relative probability of presence on week 12 is 0.25/0.25 = 1; at week 20 it is 0.05/0.25 = 0.2.
3. The relative probability of presence calculated in the previous step undergoes a statistical conversion so that all possible values fall between 0 and 10, inclusive. This is the probability of presence score.

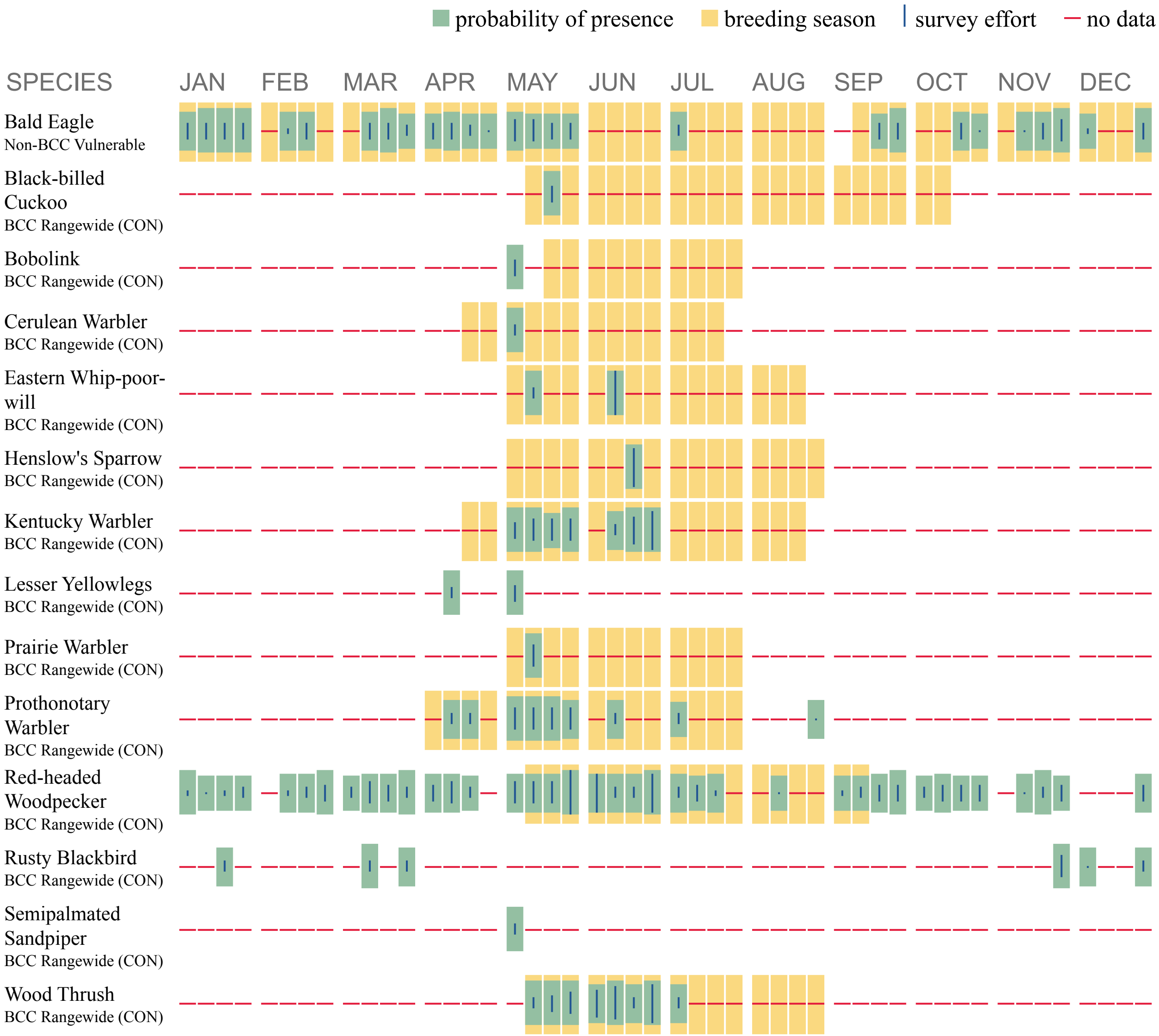
Breeding Season (🟨)
Yellow bars denote a very liberal estimate of the time-frame inside which the bird breeds across its entire range. If there are no yellow bars shown for a bird, it does not breed in your project area.

Survey Effort (|)

Vertical black lines superimposed on probability of presence bars indicate the number of surveys performed for that species in the counties of your project area. The number of surveys is expressed as a range, for example, 33 to 64 surveys.

No Data (–)
A week is marked as having no data if there were no survey events for that week.

Survey Timeframe
Surveys from only the last 10 years are used in order to ensure delivery of currently relevant information.



Additional information can be found using the following links:

- Birds of Conservation Concern http://www.fws.gov/birds/management/managed-species/birds-of-conservation-concern.php
- Measures for avoiding and minimizing impacts to birds http://www.fws.gov/birds/management/project-assessment-tools-and-guidance/conservation-measures.php
- Nationwide conservation measures for birds http://www.fws.gov/migratorybirds/pdf/management/nationwidestandardconservationmeasures.pdf

Migratory Birds FAQ

Tell me more about conservation measures I can implement to avoid or minimize impacts to migratory birds.

Nationwide Conservation Measures describes measures that can help avoid and minimize impacts to all birds at any location year round. Implementation of these measures is particularly important when birds are most likely to occur in the project area. When birds may be breeding in the area, identifying the locations of any active nests and avoiding their destruction is a very helpful impact minimization measure. To see when birds are most likely to occur and be breeding in your project area, view the Probability of Presence Summary. Additional measures and/or permits may be advisable depending on the type of activity you are conducting and the type of infrastructure or bird species present on your project site.

What does IPaC use to generate the migratory birds potentially occurring in my specified location?

The Migratory Bird Resource List is comprised of USFWS Birds of Conservation Concern (BCC) and other species that may warrant special attention in your project location.

The migratory bird list generated for your project is derived from data provided by the Avian Knowledge Network (AKN). The AKN data is based on a growing collection of survey, banding, and citizen science datasets and is queried and filtered to return a list of those birds reported as occurring in the counties which your project intersects, and that have been identified as warranting special attention because they are a BCC species in that area, an eagle (Eagle Act requirements may apply), or a species that has a particular vulnerability to offshore activities or development.

Again, the Migratory Bird Resource list includes only a subset of birds that may occur in your project area. It is not representative of all birds that may occur in your project area. To get a list of all birds potentially present in your project area, please visit the E-bird Explore Data Tool.

What does IPaC use to generate the probability of presence graphs for the migratory birds potentially occurring in my specified location?

The probability of presence graphs associated with your migratory bird list are based on data provided by the Avian Knowledge Network (AKN). This data is derived from a growing collection of survey, banding, and citizen science datasets .

Probability of presence data is continuously being updated as new and better information becomes available. To learn more about how the probability of presence graphs are produced and how to interpret them, go the Probability of Presence Summary and then click on the "Tell me about these graphs" link.

How do I know if a bird is breeding, wintering, migrating or present year-round in my project area?

To see what part of a particular bird's range your project area falls within (i.e. breeding, wintering, migrating or year-round), you may refer to the following resources: The The Cornell Lab of Ornithology All About Birds Bird Guide, or (if you are unsuccessful in locating the bird of interest there), the Cornell Lab of Ornithology Neotropical Birds guide. If a bird entry on your migratory bird species list indicates a breeding season, it is probable that the bird breeds in your project's counties at some point within the timeframe specified. If "Breeds elsewhere" is indicated, then the bird likely does not breed in your project area.

What are the levels of concern for migratory birds?

Migratory birds delivered through IPaC fall into the following distinct categories of concern:

1. "BCC Rangewide" birds are Birds of Conservation Concern (BCC) that are of concern throughout their range anywhere within the USA (including Hawaii, the Pacific Islands, Puerto Rico, and the Virgin Islands);
2. "BCC - BCR" birds are BCCs that are of concern only in particular Bird Conservation Regions (BCRs) in the continental USA; and
3. "Non-BCC - Vulnerable" birds are not BCC species in your project area, but appear on your list either because of the Eagle Act requirements (for eagles) or (for non-eagles) potential susceptibilities in offshore areas from certain types of development or activities (e.g. offshore energy development or longline fishing).

Although it is important to try to avoid and minimize impacts to all birds, efforts should be made, in particular, to avoid and minimize impacts to the birds on this list, especially eagles and BCC species of rangewide concern. For more information on conservation measures you can implement to help avoid and minimize migratory bird impacts and requirements for eagles, please see the FAQs for these topics.

Details about birds that are potentially affected by offshore projects

For additional details about the relative occurrence and abundance of both individual bird species and groups of bird species within your project area off the Atlantic Coast, please visit the Northeast Ocean Data Portal. The Portal also offers data and information about other taxa besides birds that may be helpful to you in your project review. Alternately, you may download the bird model results files underlying the portal maps through the NOAA NCCOS Integrative Statistical

Modeling and Predictive Mapping of Marine Bird Distributions and Abundance on the Atlantic Outer Continental Shelf project webpage.

Bird tracking data can also provide additional details about occurrence and habitat use throughout the year, including migration. Models relying on survey data may not include this information. For additional information on marine bird tracking data, see the Diving Bird Study and the nanotag studies or contact Caleb Spiegel or Pam Loring.

What if I have eagles on my list?

If your project has the potential to disturb or kill eagles, you may need to obtain a permit to avoid violating the BGEPA should such impacts occur.

Wetlands

Impacts to NWI wetlands and other aquatic habitats may be subject to regulation under Section 404 of the Clean Water Act, or other State/Federal statutes.

For more information please contact the Regulatory Program of the local U.S. Army Corps of Engineers District.

FRESHWATER EMERGENT WETLAND

- PEM1Ah
- PEM1Ch
- PEM1C
- PEM1A
- PEM1/SS1Ch
- PEM1Fh

FRESHWATER FORESTED/SHRUB WETLAND

- PFO1A
- PFO6F
- PFO1Ah
- PFO1/SS1Ah
- PFO1Ch
- PFO1C
- PFO1Fh
- PSS1Ch
- PSS1Fh
- PFO1/SS1Ch
- PSS1C
- PFO1/UBFh
- PSS1Ah
- PSS1A
- PFO5/UBHh
- PSS1/EM1Ad
- PSS1/EM1Ch
- PSS1F
- PSS1Cx
- PFO1/USCh
- PFO1F

FRESHWATER POND

- PUBHh
- PUBH
- PUBHx
- PUBFx
- PUBFh
- PUSC

LAKE

- L2USCh
- L1UBHh
- L2UBFh
- L1UBH

RIVERINE

- R2UBH
- R2USC

APPENDIX E-25 2022 Updated IPaC Official Species List

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Oklahoma Ecological Services Field Office
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In Reply Refer To:
Project Code: 2023-0004702
Project Name: Pensacola Hydroelectric Project Relicensing

October 14, 2022

Subject: List of threatened and endangered species that may occur in your proposed project location or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and/or may be affected by your proposed project. The species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 *et seq.*).

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. Please feel free to contact us if you need more current information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat. Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the Act, the accuracy of this species list should be verified after 90 days. This verification can be completed formally or informally as desired. The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

The purpose of the Act is to provide a means whereby threatened and endangered species and the ecosystems upon which they depend may be conserved. Under sections 7(a)(1) and 7(a)(2) of the Act and its implementing regulations (50 CFR 402 *et seq.*), Federal agencies are required to utilize their authorities to carry out programs for the conservation of threatened and endangered species and to determine whether projects may affect threatened and endangered species and/or designated critical habitat.

A Biological Assessment is required for construction projects (or other undertakings having similar physical impacts) that are major Federal actions significantly affecting the quality of the human environment as defined in the National Environmental Policy Act (42 U.S.C. 4332(2)(c)). For projects other than major construction activities, the Service suggests that a biological evaluation similar to a Biological Assessment be prepared to determine whether the project may affect listed or proposed species and/or designated or proposed critical habitat. Recommended contents of a Biological Assessment are described at 50 CFR 402.12.

If a Federal agency determines, based on the Biological Assessment or biological evaluation, that listed species and/or designated critical habitat may be affected by the proposed project, the agency is required to consult with the Service pursuant to 50 CFR 402. In addition, the Service recommends that candidate species, proposed species and proposed critical habitat be addressed within the consultation. More information on the regulations and procedures for section 7 consultation, including the role of permit or license applicants, can be found in the "Endangered Species Consultation Handbook" at:

http://www.fws.gov/endangered/esa-library/pdf/TOC-GLOS.PDF

Migratory Birds: In addition to responsibilities to protect threatened and endangered species under the Endangered Species Act (ESA), there are additional responsibilities under the Migratory Bird Treaty Act (MBTA) and the Bald and Golden Eagle Protection Act (BGEPA) to protect native birds from project-related impacts. Any activity, intentional or unintentional, resulting in take of migratory birds, including eagles, is prohibited unless otherwise permitted by the U.S. Fish and Wildlife Service (50 C.F.R. Sec. 10.12 and 16 U.S.C. Sec. 668(a)). For more information regarding these Acts see https://www.fws.gov/birds/policies-and-regulations.php.

The MBTA has no provision for allowing take of migratory birds that may be unintentionally killed or injured by otherwise lawful activities. It is the responsibility of the project proponent to comply with these Acts by identifying potential impacts to migratory birds and eagles within applicable NEPA documents (when there is a federal nexus) or a Bird/Eagle Conservation Plan (when there is no federal nexus). Proponents should implement conservation measures to avoid or minimize the production of project-related stressors or minimize the exposure of birds and their resources to the project-related stressors. For more information on avian stressors and recommended conservation measures see https://www.fws.gov/birds/bird-enthusiasts/threats-to-birds.php.

In addition to MBTA and BGEPA, Executive Order 13186: *Responsibilities of Federal Agencies to Protect Migratory Birds*, obligates all Federal agencies that engage in or authorize activities that might affect migratory birds, to minimize those effects and encourage conservation measures that will improve bird populations. Executive Order 13186 provides for the protection of both migratory birds and migratory bird habitat. For information regarding the implementation of Executive Order 13186, please visit https://www.fws.gov/birds/policies-and-regulations/executive-orders/e0-13186.php.

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. Please include the Consultation Code in the header of this letter with any request for consultation or correspondence about your project that you submit to our office.

Attachment(s):

- Official Species List
- USFWS National Wildlife Refuges and Fish Hatcheries
- Migratory Birds
- Wetlands

Official Species List

This list is provided pursuant to Section 7 of the Endangered Species Act, and fulfills the requirement for Federal agencies to "request of the Secretary of the Interior information whether any species which is listed or proposed to be listed may be present in the area of a proposed action".

This species list is provided by:

Oklahoma Ecological Services Field Office
9014 East 21st Street
Tulsa, OK 74129-1428
(918) 581-7458

Project Summary

Project Code: 2023-0004702

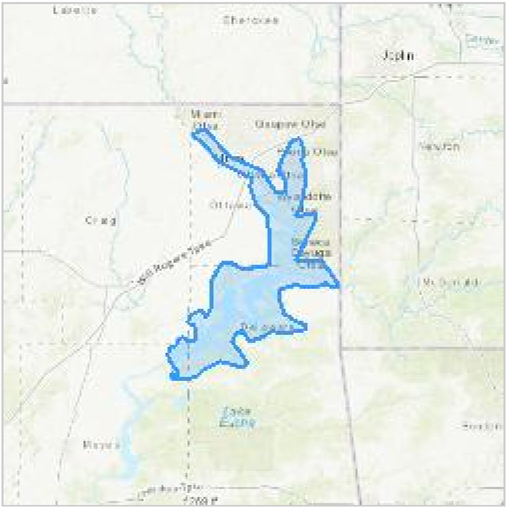
Project Name: Pensacola Hydroelectric Project Relicensing

Project Type: Dam - Operations

Project Description: Hydro relicensing. Draft License Application will be filed by January 1, 2023.

Project Location:

Approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/@36.69235865,-94.76001548651183,14z



Counties: Oklahoma

Endangered Species Act Species

There is a total of 13 threatened, endangered, or candidate species on this species list.

Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species.

IPaC does not display listed species or critical habitats under the sole jurisdiction of NOAA Fisheries[1], as USFWS does not have the authority to speak on behalf of NOAA and the Department of Commerce.

See the "Critical habitats" section below for those critical habitats that lie wholly or partially within your project area under this office's jurisdiction. Please contact the designated FWS office if you have questions.

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1. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

Mammals

NAME	STATUS
Gray Bat *Myotis grisescens* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/6329	Endangered
Indiana Bat *Myotis sodalis* There is **final** critical habitat for this species. Your location does not overlap the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/5949	Endangered
Northern Long-eared Bat *Myotis septentrionalis* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/9045	Threatened
Ozark Big-eared Bat *Corynorhinus (=Plecotus) townsendii ingens* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/7245	Endangered
Tricolored Bat *Perimyotis subflavus* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/10515	Proposed Endangered

Birds

NAME	STATUS
Piping Plover *Charadrius melodus* Population: [Atlantic Coast and Northern Great Plains populations] - Wherever found, except those areas where listed as endangered. There is **final** critical habitat for this species. Your location does not overlap the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/6039	Threatened
Red Knot *Calidris canutus rufa* There is **proposed** critical habitat for this species. Species profile: https://ecos.fws.gov/ecp/species/1864	Threatened

Reptiles

NAME	STATUS
Alligator Snapping Turtle *Macrochelys temminckii* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/4658	Proposed Threatened

Fishes

NAME	STATUS
Neosho Madtom *Noturus placidus* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/2577	Threatened
Ozark Cavefish *Amblyopsis rosae* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/6490	Threatened

Clams

NAME	STATUS
Neosho Mucket *Lampsilis rafinesqueana* There is **final** critical habitat for this species. Your location overlaps the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/3788	Endangered

Insects

NAME	STATUS
American Burying Beetle *Nicrophorus americanus* Population: Wherever found, except where listed as an experimental population No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/66	Threatened
Monarch Butterfly *Danaus plexippus* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/9743	Candidate

Critical habitats

There is 1 critical habitat wholly or partially within your project area under this office's jurisdiction.

NAME	STATUS
Neosho Mucket *Lampsilis rafinesqueana* https://ecos.fws.gov/ecp/species/3788#crithab	Final

USFWS National Wildlife Refuge Lands And Fish Hatcheries

Any activity proposed on lands managed by the National Wildlife Refuge system must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

The following FWS National Wildlife Refuge Lands and Fish Hatcheries lie fully or partially within your project area:

FACILITY NAME	ACRES
OZARK PLATEAU NATIONAL WILDLIFE REFUGE https://www.fws.gov/refuges/profiles/index.cfm?id=21645	81.098

Migratory Birds

Certain birds are protected under the Migratory Bird Treaty Act[1] and the Bald and Golden Eagle Protection Act[2].

Any person or organization who plans or conducts activities that may result in impacts to migratory birds, eagles, and their habitats should follow appropriate regulations and consider implementing appropriate conservation measures, as described below.

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1. The Migratory Birds Treaty Act of 1918.
2. The Bald and Golden Eagle Protection Act of 1940.
3. 50 C.F.R. Sec. 10.12 and 16 U.S.C. Sec. 668(a)

The birds listed below are birds of particular concern either because they occur on the USFWS Birds of Conservation Concern (BCC) list or warrant special attention in your project location. To learn more about the levels of concern for birds on your list and how this list is generated, see the FAQ below. This is not a list of every bird you may find in this location, nor a guarantee that every bird on this list will be found in your project area. To see exact locations of where birders and the general public have sighted birds in and around your project area, visit the E-bird data mapping tool (Tip: enter your location, desired date range and a species on your list). For projects that occur off the Atlantic Coast, additional maps and models detailing the relative occurrence and abundance of bird species on your list are available. Links to additional information about Atlantic Coast birds, and other important information about your migratory bird list, including how to properly interpret and use your migratory bird report, can be found below.

For guidance on when to schedule activities or implement avoidance and minimization measures to reduce impacts to migratory birds on your list, click on the PROBABILITY OF PRESENCE SUMMARY at the top of your list to see when these birds are most likely to be present and breeding in your project area.

NAME	BREEDING SEASON
Bald Eagle *Haliaeetus leucocephalus* This is not a Bird of Conservation Concern (BCC) in this area, but warrants attention because of the Eagle Act or for potential susceptibilities in offshore areas from certain types of development or activities.	Breeds Sep 1 to Aug 31
Chimney Swift *Chaetura pelagica* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds Mar 15 to Aug 25
Eastern Whip-poor-will *Antrostomus vociferus* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds May 1 to Aug 20

NAME	BREEDING SEASON
Field Sparrow *Spizella pusilla* This is a Bird of Conservation Concern (BCC) only in particular Bird Conservation Regions (BCRs) in the continental USA	Breeds Mar 1 to Aug 15
Kentucky Warbler *Oporornis formosus* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds Apr 20 to Aug 20
Lesser Yellowlegs *Tringa flavipes* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/9679	Breeds elsewhere
Prothonotary Warbler *Protonotaria citrea* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds Apr 1 to Jul 31
Red-headed Woodpecker *Melanerpes erythrocephalus* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds May 10 to Sep 10
Rusty Blackbird *Euphagus carolinus* This is a Bird of Conservation Concern (BCC) only in particular Bird Conservation Regions (BCRs) in the continental USA	Breeds elsewhere
Wood Thrush *Hylocichla mustelina* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds May 10 to Aug 31

Probability Of Presence Summary

The graphs below provide our best understanding of when birds of concern are most likely to be present in your project area. This information can be used to tailor and schedule your project activities to avoid or minimize impacts to birds. Please make sure you read and understand the FAQ "Proper Interpretation and Use of Your Migratory Bird Report" before using or attempting to interpret this report.

Probability of Presence (🟩)

Each green bar represents the bird's relative probability of presence in the 10km grid cell(s) your project overlaps during a particular week of the year. (A year is represented as 12 4-week months.) A taller bar indicates a higher probability of species presence. The survey effort (see below) can be used to establish a level of confidence in the presence score. One can have higher confidence in the presence score if the corresponding survey effort is also high.

How is the probability of presence score calculated? The calculation is done in three steps:

1. The probability of presence for each week is calculated as the number of survey events in the week where the species was detected divided by the total number of survey events for that week. For example, if in week 12 there were 20 survey events and the Spotted Towhee

was found in 5 of them, the probability of presence of the Spotted Towhee in week 12 is 0.25.

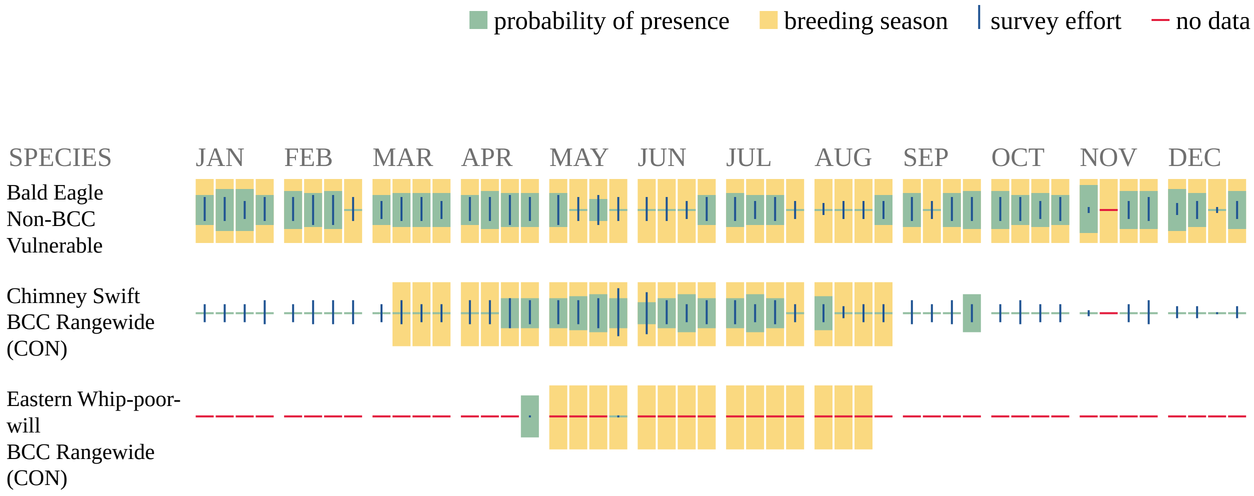
2. To properly present the pattern of presence across the year, the relative probability of presence is calculated. This is the probability of presence divided by the maximum probability of presence across all weeks. For example, imagine the probability of presence in week 20 for the Spotted Towhee is 0.05, and that the probability of presence at week 12 (0.25) is the maximum of any week of the year. The relative probability of presence on week 12 is 0.25/0.25 = 1; at week 20 it is 0.05/0.25 = 0.2.
3. The relative probability of presence calculated in the previous step undergoes a statistical conversion so that all possible values fall between 0 and 10, inclusive. This is the probability of presence score.

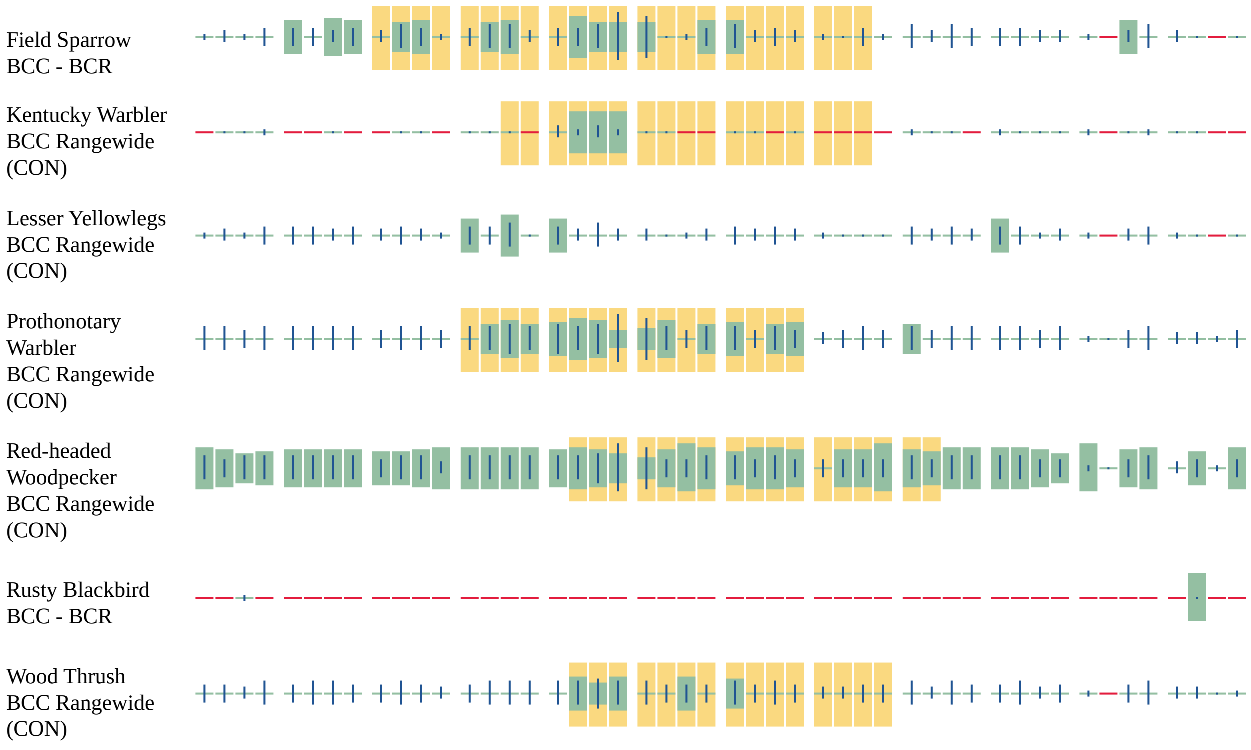
Breeding Season (🟨)
Yellow bars denote a very liberal estimate of the time-frame inside which the bird breeds across its entire range. If there are no yellow bars shown for a bird, it does not breed in your project area.

Survey Effort (|)
Vertical black lines superimposed on probability of presence bars indicate the number of surveys performed for that species in the 10km grid cell(s) your project area overlaps. The number of surveys is expressed as a range, for example, 33 to 64 surveys.

No Data (–)
A week is marked as having no data if there were no survey events for that week.

Survey Timeframe
Surveys from only the last 10 years are used in order to ensure delivery of currently relevant information. The exception to this is areas off the Atlantic coast, where bird returns are based on all years of available data, since data in these areas is currently much more sparse.





Additional information can be found using the following links:

- Birds of Conservation Concern https://www.fws.gov/program/migratory-birds/species
- Measures for avoiding and minimizing impacts to birds https://www.fws.gov/library/collections/avoiding-and-minimizing-incidental-take-migratory-birds
- Nationwide conservation measures for birds https://www.fws.gov/sites/default/files/documents/nationwide-standard-conservation-measures.pdf

Migratory Birds FAQ

Tell me more about conservation measures I can implement to avoid or minimize impacts to migratory birds.

Nationwide Conservation Measures describes measures that can help avoid and minimize impacts to all birds at any location year round. Implementation of these measures is particularly important when birds are most likely to occur in the project area. When birds may be breeding in the area, identifying the locations of any active nests and avoiding their destruction is a very helpful impact minimization measure. To see when birds are most likely to occur and be breeding in your project area, view the Probability of Presence Summary. Additional measures or permits may be advisable depending on the type of activity you are conducting and the type of infrastructure or bird species present on your project site.

What does IPaC use to generate the list of migratory birds that potentially occur in my specified location?

The Migratory Bird Resource List is comprised of USFWS Birds of Conservation Concern (BCC) and other species that may warrant special attention in your project location.

The migratory bird list generated for your project is derived from data provided by the Avian Knowledge Network (AKN). The AKN data is based on a growing collection of survey, banding, and citizen science datasets and is queried and filtered to return a list of those birds reported as occurring in the 10km grid cell(s) which your project intersects, and that have been identified as warranting special attention because they are a BCC species in that area, an eagle (Eagle Act requirements may apply), or a species that has a particular vulnerability to offshore activities or development.

Again, the Migratory Bird Resource list includes only a subset of birds that may occur in your project area. It is not representative of all birds that may occur in your project area. To get a list of all birds potentially present in your project area, please visit the Rapid Avian Information Locator (RAIL) Tool.

What does IPaC use to generate the probability of presence graphs for the migratory birds potentially occurring in my specified location?
The probability of presence graphs associated with your migratory bird list are based on data provided by the Avian Knowledge Network (AKN). This data is derived from a growing collection of survey, banding, and citizen science datasets.

Probability of presence data is continuously being updated as new and better information becomes available. To learn more about how the probability of presence graphs are produced and how to interpret them, go the Probability of Presence Summary and then click on the "Tell me about these graphs" link.

How do I know if a bird is breeding, wintering or migrating in my area?
To see what part of a particular bird's range your project area falls within (i.e. breeding, wintering, migrating or year-round), you may query your location using the RAIL Tool and look at the range maps provided for birds in your area at the bottom of the profiles provided for each bird in your results. If a bird on your migratory bird species list has a breeding season associated with it, if that bird does occur in your project area, there may be nests present at some point within the timeframe specified. If "Breeds elsewhere" is indicated, then the bird likely does not breed in your project area.

What are the levels of concern for migratory birds?
Migratory birds delivered through IPaC fall into the following distinct categories of concern:

1. "BCC Rangewide" birds are Birds of Conservation Concern (BCC) that are of concern throughout their range anywhere within the USA (including Hawaii, the Pacific Islands, Puerto Rico, and the Virgin Islands);
2. "BCC - BCR" birds are BCCs that are of concern only in particular Bird Conservation Regions (BCRs) in the continental USA; and
3. "Non-BCC - Vulnerable" birds are not BCC species in your project area, but appear on your list either because of the Eagle Act requirements (for eagles) or (for non-eagles) potential susceptibilities in offshore areas from certain types of development or activities (e.g. offshore energy development or longline fishing).

Although it is important to try to avoid and minimize impacts to all birds, efforts should be made, in particular, to avoid and minimize impacts to the birds on this list, especially eagles and BCC species of rangewide concern. For more information on conservation measures you can implement to help avoid and minimize migratory bird impacts and requirements for eagles, please see the FAQs for these topics.

Details about birds that are potentially affected by offshore projects
For additional details about the relative occurrence and abundance of both individual bird species and groups of bird species within your project area off the Atlantic Coast, please visit the Northeast Ocean Data Portal. The Portal also offers data and information about other taxa besides birds that may be helpful to you in your project review. Alternately, you may download the bird model results files underlying the portal maps through the NOAA NCCOS Integrative Statistical Modeling and Predictive Mapping of Marine Bird Distributions and Abundance on the Atlantic Outer Continental Shelf project webpage.

Bird tracking data can also provide additional details about occurrence and habitat use throughout the year, including migration. Models relying on survey data may not include this information. For additional information on marine bird tracking data, see the Diving Bird Study and the nanotag studies or contact Caleb Spiegel or Pam Loring.

What if I have eagles on my list?
If your project has the potential to disturb or kill eagles, you may need to obtain a permit to avoid violating the Eagle Act should such impacts occur.

Proper Interpretation and Use of Your Migratory Bird Report
The migratory bird list generated is not a list of all birds in your project area, only a subset of birds of priority concern. To learn more about how your list is generated, and see options for identifying what other birds may be in your project area, please see the FAQ "What does IPaC use to generate the migratory birds potentially occurring in my specified location". Please be aware this report provides the "probability of presence" of birds within the 10 km grid cell(s) that overlap your project; not your exact project footprint. On the graphs provided, please also look carefully at the survey effort (indicated by the black vertical bar) and for the existence of the "no data" indicator (a red horizontal bar). A high survey effort is the key component. If the survey effort is high, then the probability of presence score can be viewed as more dependable. In contrast, a low survey effort bar or no data bar means a lack of data and, therefore, a lack of certainty about presence of the species. This list is not perfect; it is simply a starting point for identifying what birds of concern have the potential to be in your project area, when they might be there, and if they might be breeding (which means nests might be present). The list helps you know what to look for to confirm presence, and helps guide you in knowing when to implement conservation measures to avoid or minimize potential impacts from your project activities, should presence be confirmed. To learn more about conservation measures, visit the FAQ "Tell me about conservation measures I can implement to avoid or minimize impacts to migratory birds" at the bottom of your migratory bird trust resources page.

Wetlands

Impacts to NWI wetlands and other aquatic habitats may be subject to regulation under Section 404 of the Clean Water Act, or other State/Federal statutes.

For more information please contact the Regulatory Program of the local U.S. Army Corps of Engineers District.

Please note that the NWI data being shown may be out of date. We are currently working to update our NWI data set. We recommend you verify these results with a site visit to determine the actual extent of wetlands on site.

WETLAND INFORMATION WAS NOT AVAILABLE WHEN THIS SPECIES LIST WAS GENERATED. PLEASE VISIT HTTPS://WWW.FWS.GOV/WETLANDS/DATA/MAPPER.HTML OR CONTACT THE FIELD OFFICE FOR FURTHER INFORMATION.

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