

# Arkansas River Corridor Projects

## Riparian Habitat Summary

PREPARED FOR: Tulsa County

PREPARED BY: CH2M HILL

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## Introduction

Tulsa County, as part of the Arkansas River Corridor Master Plan (Carter & Burgess, 2004; C. H. Guernsey and Company et al., 2005), is undertaking an improvement project on the Arkansas River. The primary goals of the overall project are to improve least tern habitat, improve fish habitat and fish passage, improve the function of the river system itself, enhance economic development, increase recreational opportunities, and increase connectivity between the river and surrounding communities. The conceptual project components are described in detail in the Technical Memorandum (TM) entitled Baseline Project Summary for the Arkansas River Corridor Project (CH2M HILL, 2009). Key components include:

- Design of habitat improvements along the corridor
- Design of bank stabilization in select areas
- Design of a new Sand Springs low-head dam, pedestrian bridge, and amenities
- Design of modifications to Zink Dam and lake with whitewater features
- Design of a new South Tulsa/Jenks low-head dam, pedestrian bridge, and amenities

The purpose of this TM is to summarize the existing riparian habitat along the Arkansas River from Keystone Lake to its confluence with the Verdigris River near Muskogee, Oklahoma, and to describe vegetation that is well-suited for restoration efforts. It should be noted that this study area has been extended beyond the original boundaries until alternatives have been refined and the extent of effects and need for riparian habitat is better understood. At that time, the downstream extent of the study area may move further upstream.

The study area, for the purposes of this TM, is defined as the Arkansas River corridor extending from, and including, the U.S. Army Corps of Engineers (USACE) 26,000-acre Keystone Lake (Osage, Pawnee, Creek, Tulsa, and Payne Counties) downstream to the confluence of the Arkansas River and the Verdigris River at the McClellan-Kerr Navigation Channel. The study area includes a corridor extending 2,200 feet on each side of the centerline of the river, and a 1,500-foot-wide zone around Keystone Lake. This study area was selected to account for a range of potential effects and will be subject to change as alternatives are further refined.

## Habitat Types

The study area along the Arkansas River corridor includes many different habitat types: upland forests (including cross timbers), forested wetlands, open grasslands and managed pasture, agriculture fields, and habitats associated with residential and commercial use. Table 1 lists the land cover classes represented within the study area, along with a percentage of the total study area for each class. The percentages in Table 1 were calculated and checked for accuracy using ArcGIS. Figures illustrating the location of land cover classes along the Arkansas River corridor within the study area are presented in Appendix A.

TABLE 1  
Land Cover Classes Represented within the Study Area

Land Cover Type	Area (acres)	% of Total Study Area
Open Water	36,819	34
Agriculture/Crops	17,181	16
Bottomland Forest	16,068	15
Upland Forest	13,760	13
Savanna Grass	8,203	8
Prairie	7,475	7
Residential/Industrial	7,184	7

Source: Oklahoma State University (OSU), 2001

The following sections describe various land cover types and their characteristics. These characteristics include soil types, common vegetation and wildlife, as well as any rare and protected species potentially found within the study area. Habitats are described below by vegetative succession, followed by a summary of species of concern with the potential to be found within the study area.

### Forested Riparian Habitat

Forested riparian habitat within the study area includes a variety of low-lying forest communities. Bottomland hardwood forests are an extensive component of the Arkansas River riparian corridor, occurring largely within the floodplain of the river and adjacent to small tributaries. This forest habitat is regarded as extremely important due to the wildlife diversity it supports, high soil productivity, and hydrologic regimes. A large portion of this habitat is likely to be jurisdictional under §404 of the Clean Water Act (CWA); potentially jurisdictional waters could be quantified using a Geographic Information System (GIS) analyses or field work in compliance with the 1987 Wetlands Delineation Manual produced by USACE.

The Choska-Severn Association is the predominant soil throughout the various habitats along the Arkansas River. These soils can be characterized as deep, well drained, sandy to silty loam supported by loamy and sandy alluvial material on the floodplain (Cole et al., 2006).

The dominant tree species found in bottomland forests within the study area include cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), green ash (*Fraxinus pennsylvanica*), pecan (*Carya illinoensis*), box elder (*Acer negundo*), river birch (*Betula nigra*),

black willow (*Salix nigra*), silver maple (*Acer saccharinum*), black walnut (*Juglans nigra*), sugarberry (*Celtis laevigata*), water oak (*Quercus nigra*), overcup oak (*Quercus lyrata*), and willow oak (*Quercus phellos*). Swamp privet (*Forestiera acuminata*) is commonly found as a shrub species within the understory of these bottomland forests (Oklahoma Biological Survey [OBS], 2009). Typical forested riparian habitat is shown on Figure 1.



FIGURE 1  
Typical Forested Riparian Habitat; West Bank of River, East of Bixby, OK

Upland tree species in the study area, commonly found on floodplain slopes, include white oak (*Quercus alba*), black oak (*Quercus velutina*), northern red oak (*Quercus rubra*), southern red oak (*Quercus falcata*), black gum (*Nyssa sylvatica*), and red maple (*Acer rubrum*). Typical understory species found in these upland slope areas include flowering dogwood (*Cornus florida*), redbud (*Cercis canadensis*), ironwood (*Carpinus caroliniana*), pawpaw (*Asimina triloba*), basswood (*Tilia americana*), spice bush (*Lindera benzoin*), and red mulberry (*Morus rubra*).

Common mammal species found within the forested riparian habitats in the study area include deer mouse (*Peromyscus maniculatus*), eastern mole (*Scalopus aquaticus*), gray squirrel (*Sciurus carolinensis*), fox squirrel (*Sciurus niger*), swamp rabbit (*Sylvilagus aquaticus*), beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), striped skunk (*Mephitis mephitis*), spotted skunk (*Spilogale putorius*), nine-banded armadillo (*Dasypus novemcinctus*), gray fox (*Urocyon cinereoargenteus*), red fox (*Vulpes vulpes*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), and white-tailed deer (*Odocoileus virginianus*).

Bird species commonly found in these forested habitats include pileated woodpecker (*Dryocopus pileatus*), belted kingfisher (*Ceryle alcyon*), wood duck (*Aix sponsa*), herons and egrets (*Ardea* spp. and *Egretta* spp.), barred owl (*Strix varia*), and red-shouldered hawk (*Buteo lineatus*). Riparian bottomland forests along the Arkansas River are known to be prime habitat for the bald eagle (*Haliaeetus leucocephalus*). The bald eagle is discussed in

detail below, along with other rare and protected species with the potential to be found within the study area.

Many species of reptiles and amphibians inhabit the bottomland forests along the Arkansas River, with amphibians being more prevalent in the bottomland swamp areas and other aquatic habitats. Common reptiles include the western ribbon snake (*Thamnophis proximus*), eastern hognose snake (*Heterodon platyrhinos*), fence lizard (*Sceloporus undulatus*), timber rattlesnake (*Crotalus horridus*), common snapping turtle (*Chelydra serpentina*), red-eared slider (*Chrysemys scripta elegans*), and three-toed box turtle (*Terrapene carolina triunguis*). Common amphibians include the southern leopard frog (*Rana sphenoccephala*), northern spring peeper (*Hyla crucifer*), American toad (*Bufo americanus*), bullfrog (*Rana catesbeiana*), and green frog (*Rana clamitans melanota*).

Common insects associated with forested riparian habitats include beetles (Coleoptera order), caterpillars (Lepidoptera order), ants, true flies (Diptera order), and aphids.

## Shrub Riparian Habitat

Shrub riparian habitat is found scattered throughout the study area. These are open areas dominated by shrub and hardwood saplings mixed with tallgrasses, shortgrasses, and some emergent vegetation. Typical shrub riparian habitat is shown on Figure 2.



FIGURE 2

Typical Shrub Riparian Habitat; North Bank of River, Near Proposed Dam Site

Shrub habitats provide shelter, food, and nesting protection for a variety of birds and small mammals. Bird species that can be found in these habitats include a wide assortment of song birds, hawks, owls, waterfowl, and other game birds. These birds rely on the dense vegetation for cover and the abundant food source of berries and insects common to these habitats. Eastern cottontail rabbit (*Sylvilagus floridanus*), red fox, nine-banded armadillo, and mice and voles (*Microtus sp.*) are common mammals found in shrub areas (Natural Resources Conservation Service [NRCS], 2007). These mammals prefer the dense vegetation cover for shelter and breeding, as well as the abundant food source.



Common shrubs and herbaceous species found in shrub habitat along the Arkansas River include swamp privet, buttonbush (*Cephalanthus occidentalis*), hawthorn (*Crataegus crus-galli*), deciduous holly (*Ilex decidua*), big bluestem (*Andropogon gerardii*), and soft rush (*Juncus effusus*). Young hardwoods common to this habitat may include black willow, cottonwood, oaks, sandbar willow (*Salix exigua*), and sycamore (OBS, 2009).

Insects associated with shrub riparian habitats include caterpillars, grasshoppers (*Melanoplus* spp.), flies, and bees.

## Open Water and Emergent Wetland Habitat

There are a variety of open water and emergent wetland habitats found throughout the study area (Figure 3). These include lacustrine wetlands (permanently flooded lakes and reservoirs greater than 20 acres in size) and palustrine emergent wetlands (swamps, bogs, mudflats, and ponds). Emergent wetlands are characterized by rooted, herbaceous hydrophytes, and are usually perennially flooded (Cowardin et al., 1979). Much of this habitat is likely to be jurisdictional under §404 of the CWA.



FIGURE 3  
View of Open Water and Emergent Wetland Habitat; Arkansas River West of Tulsa, OK

Keystone Lake is a 26,000-acre man-made reservoir on the Arkansas River. It is located in the northwest corner of the study area. The lake is known primarily for its game fishing, with striped bass (*Morone saxatilis*), black bass (*Micropterus* spp.), crappie (*Pomoxis* spp.), and channel catfish (*Ictalurus punctatus*) being the most common species. The lentic aquatic habitat associated with Keystone Lake contains a variety of emergent and submerged aquatic vegetation, such as algae (*Algae* spp.), coontail (*Ceratophyllum demersum*), and bladderwort (*Utricularia* spp.) (USACE, 2009).

Emergent wetlands occur throughout the study area in many locations and landscape features. They can be located in depressional areas within the floodplain, along the shoreline of Keystone Lake, or along the Arkansas River's edges. Common vegetation within these

wetland habitats includes sedges (*Carex* spp.), rushes (*Juncus* spp.), smartweed (*Polygonum* spp.), soft rush, and cattails (*Typha* spp.), to name a few.

This herbaceous wetland vegetation is critical in maintaining and improving water quality, along with providing food and shelter for fish and wildlife, including macroinvertebrates, which make up the foundation of the aquatic food chain. Wetlands and other aquatic habitats within the study area also provide essential habitat for a variety of amphibians, reptiles, birds, and mammals. Frogs and salamanders use these wetland areas for breeding grounds and for egg laying. Ducks and migratory birds use them for resting areas on migration routes and for nesting. Mammals commonly found around riparian wetland habitats include the opossum (*Didelphis virginiana*), swamp rabbit, and raccoon (*Procyon lotor*) (Defenders of Wildlife, 2009). Resident and migratory bird species commonly found in these areas include ducks, geese, American coot (*Fulica americana*), egrets and herons, and bald eagles.

Insects associated with open water and emergent habitats include true flies, mayflies (Ephemeroptera order), caddisflies (Trichoptera order), dragonflies and damselflies (Odonata order), and beetles. These aquatic insects not only provide a food source for birds and other invertebrates, they also break down organic material present in riverine and riparian wetland areas common throughout the study area.

## Open Grasslands and Pasture

Scattered areas of open grasslands are located within the study area (Figure 4). Overgrazing and conversion of land for agriculture have significantly modified these habitats, resulting in greater fragmentation of the natural communities.

Dominant grasses found in these areas include big bluestem, little bluestem (*Schizachyrium scoparium*), Indian grass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and grama grasses (*Bouteloua* spp.). Shortgrasses normally found in western prairies can be seen in small pockets within the study area, typically on dry and shallower soils (OSU, 1998).

Mammals commonly found in these grassland habitats include white-tailed deer and mule deer (*Odocoileus hemionus*), bobcat, red fox, jackrabbit (*Lepus californicus*), cottontail, and prairie dog (*Cynomys* spp.). Year-round bird species commonly found in these areas include ring-necked pheasant (*Phasianus* spp.), horned lark (*Eremophila alpestris*), killdeer (*Charadrius vociferous*), Eastern meadowlark (*Sturnella magna*), red-winged blackbird (*Agelaius phoeniceus*), and brown-headed cowbird (*Molothrus ater*) (George M. Sutton Avian Research Center, 2004).

Insects associated with open grassland habitats include bees, butterflies, grasshoppers, dragonflies, and aphids.



**FIGURE 4**  
North Bank of River; Pasture/Open Grasses in the Background

## Urban Areas

Urban areas, such as those shown in Figure 5, account for approximately 7,200 acres along the river within the study area. This includes residential and industrial or commercial development. These areas provide limited habitat for species acclimated to human environments. Typical species found in urban areas include American robin (*Turdus migratorius*), mourning dove (*Zenaida macroura*), turkey vulture (*Cathartes livia*), opossum, striped skunk, nine-banded armadillo, raccoon, and squirrels.



**FIGURE 5**  
Eastern View of Downtown Tulsa, OK

## Agricultural Areas

Agricultural areas, such as those shown in Figure 6, account for approximately 17,000 acres along the river within the study area. These areas include ranchlands dominated by beef cattle and horses. Major crops include hay (alfalfa and grasses), wheat, and soybeans (OSU, 2009). Common terrestrial species within these areas include eastern meadowlark, pheasant, eastern cottontail, fox, wild turkey (*Meleagris gallopavo*), bobwhite quail (*Colinus virginianus*), and white-tailed deer. Resident and migratory bird species use agricultural lands for shelter and as an important food source. Irrigation ponds provide additional habitat for waterfowl and amphibians.



FIGURE 6  
Sod Farm Along East/North Bank of River; East of Bixby, OK

Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is suitable for cropland, pastureland, range land, or forest land (7 United States Code [USC] 4201(c)(1)(A)). The study area contains 17 soil types classified as prime farmland soils, totaling approximately 24 percent of the study area (Cole et al., 2006). The official designation of these areas as prime farmland, potential exemption from the Farmland Protection Policy Act (FPPA) due to previous development, and mitigative measures to minimize impacts to prime farmland, would be evaluated through consultation with the NRCS as part of the Land Evaluation and Site Assessment (LESA) process.

## Protected Species

Table 2 lists federally protected species with the potential to occur in counties within the study area due to similar habitat requirements. Of these species, only four have been confirmed as occurring within the study area: the American burying beetle (*Nicrophorus americanus*), the bald eagle (*Haliaeetus leucocephalus*), the interior least tern (*Sterna antillarum*), and the piping plover (*Charadrius melodus*).



TABLE 2  
Federally Listed Threatened, Endangered, and Candidate Species by County, Potentially Occurring within the Study Area

County	Species	Status
Creek	American Burying Beetle	Endangered
	Interior Least Tern	Endangered
	Piping Plover	Threatened
Muskogee	American Burying Beetle	Endangered
	Gray Bat	Endangered
	Interior Least Tern	Endangered
	Whooping Crane	Endangered
	Piping Plover	Threatened
Osage	American Burying Beetle	Endangered
	Eskimo Curlew	Endangered, Possibly extinct
	Interior Least Tern	Endangered
	Whooping Crane	Endangered
	Piping Plover	Threatened
	Neosho Mucket	Candidate
Tulsa	American Burying Beetle	Endangered
	Interior Least Tern	Endangered
	Piping Plover	Threatened
Wagoner	American Burying Beetle	Endangered
	Gray Bat	Endangered
	Interior Least Tern	Endangered
	Whooping Crane	Endangered
	Piping Plover	Threatened
	Neosho Mucket	Candidate

Source: USFWS Oklahoma Ecological Services Field Office, Tulsa, OK

### American Burying Beetle (*Nicrophorus americanus*)

The American burying beetle (ABB) is the largest species of *Nicrophorus* in North America. Its shiny black body is contrasted by a distinctive orange marking on the pronotum, or shield between the head and wings. The ABB is known to occupy a diverse range of habitats. Collections in Oklahoma have come from level areas with relatively loose, well-drained soils and a well-formed litter layer. The beetle has been collected from oak-pine and oak-hickory forests, grasslands and open fields, and along forest edges. Current information suggests that this species is a habitat generalist, with a slight preference for grasslands and open understory oak/hickory forests (U. S. Fish and Wildlife Service [USFWS], 2009a).

This species was historically found in 35 states and parts of Canada. Recently, it has been found only in Arkansas, Kansas, Massachusetts, Nebraska, Oklahoma, Rhode Island, Texas, and South Dakota. In Oklahoma, confirmed sightings have occurred in more than 20 counties, including 4 that contain habitat in the study area: Muskogee, Osage, Tulsa, and Wagoner Counties (USFWS, 2005a).

This species is known for its practice of burying small animal carcasses; the larvae then feed on the carcasses upon hatching. Habitat loss and fragmentation, insecticides, and disease may be major factors for declines in this species (USFWS, 2009a).

The ABB is unlikely to be abundant along the floodplain of the Arkansas River due to its habitat preferences, but it is found within the study area. A survey was conducted over

three successive nights in August 2007 in an effort to confirm the presence or absence of the ABB within the potential area of development. The collection survey identified four ABBs within the project study area (USFWS, 2009a; Eagle Environmental Consulting, 2007).

### **Bald Eagle (*Haliaeetus leucocephalus*)**

The bald eagle's historical range was all of North America south of the Arctic Circle. After a long period of decline, migration populations and maternity colonies have increased in many counties in Oklahoma. The bald eagle was delisted under the Endangered Species List (ESA) (50 Code of Federal Regulations [CFR] 17; July 9, 2007) and is being monitored for at least 5 years to determine whether relisting is warranted. The bald eagle remains protected under the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act, which are administered by USFWS.

Bald eagle migration routes usually follow river systems or mountain ranges. They migrate through Oklahoma in early spring and return by September or October. The bulk of the eagles' diet is fish, but they also supplement their diet with a variety of living and dead vertebrate species. Large trees or cliffs near water are required for suitable nesting habitat. Bald eagles are sensitive to disturbance and pollution, and radical changes in the eagles' environment can be detrimental. While reservoir creation has caused the decline of some species, it has been beneficial to bald eagles. The river and reservoir habitat that characterizes much of the study area is highly suitable for the eagles (USFWS, 2001).

### **Interior Least Tern (*Sterna antillarum*)**

The interior population of the least tern inhabits several river systems in the West and Midwest, including the Arkansas River system. Interior least terns breed primarily in the Mississippi and Rio Grande River basins from eastern New Mexico and Colorado to Indiana and Louisiana and from Montana to Texas (USFWS, 1990). Least terns enter breeding grounds beginning in early April to early June and remain there for 3 to 5 months (Texas Parks and Wildlife Department [TPWD], 2009). Least terns nest in colonies along gravel and sand deposits within braided streams and rivers, as well as on man-made structures (such as inland beaches, wastewater treatment plants, and gravel mines). The terns prefer open, unobstructed areas rather than thick vegetation, and they eat crustaceans and small fish (TPWD, 2009). Terns experience frequent nest and chick loss due to the ephemeral nature of their nesting habitats (USFWS, 1990). Eggs typically are laid in late May, and terns re-nest until late July if young are lost; by late August the breeding season is typically over and the birds begin migrating to wintering areas (TPWD, 2009). The range of wintering areas for least terns is largely unknown, although flocks have been observed in Central and South America (USFWS, 1990).

The survival of the terns is threatened by a variety of factors. For example, the manipulation of river flow can destroy or alter sandbars, preventing the creation of new river island habitat. In addition, increased flow can wash away nests and chicks. River dredging, destruction of shoreline habitat by grazers, and recreational activities can also be detrimental to this species.

These birds are known inhabitants of the study area, specifically between Keystone Dam and Muskogee, Oklahoma. In Oklahoma, interior least tern populations and nesting success

have been monitored annually since the early 1990s by the USACE, Tulsa District. These data are summarized by the USFWS in its most recent Arkansas River Biological Opinion (USFWS, 2005b).

To provide guidelines for the management and protection of interior least terns nesting at key locations below USACE water resource projects in Oklahoma, the USACE, Tulsa District, in cooperation with the USFWS, formed a multi-agency Least Tern Committee in 2002 to develop and prepare the "Management Guidelines for Interior Least Terns." The long-term objective of the management plan includes providing suitable nesting habitat that is not adversely impacted by normal operation of water resource projects. The short-term strategies to accomplish this objective include using management practices that minimize impacts to nesting birds. Such management practices include:

- Maintain sufficient high flow releases during non-nesting periods to convey sediments and periodically scour islands to remove vegetation.
- Remove vegetation from these islands during non-nesting periods by physical or chemical means.
- Use dredged materials to replenish existing islands and to increase water depths around islands to remove land bridges during non-nesting periods.
- Limit maximum water releases during the nesting season to prevent flooding of active nests.
- Provide minimum water releases during the nesting season to prevent land-bridging of islands.

### Piping Plover (*Charadrius melodus*)

The piping plover is a small, compact shorebird with pale gray upperparts. Distinctive dark bands across the forehead and breast are present during the breeding season, which normally lasts from March through July. Piping plovers are distinguishable from similar species by their bright orange legs and short, stout bill.

The birds forage on a variety of invertebrates and various terrestrial insects. Shallow excavations in sand are made for nesting and are often lined with pebbles, shells, and/or small woody drift. Habitat degradation from reservoir construction, river channel alteration, and development are contributing factors for its decline. The piping plover is identified as a breeding seasonal resident of Oklahoma and usually arrives in April. The sandbars and bare gravel islands along the Arkansas River within the study area could provide suitable habitat during the plovers' spring and fall migration (USFWS, 2009b).

### Oklahoma State-Listed Species

The Oklahoma statute pertaining to threatened and endangered species is Section 5-412 of Title 29. Under this statute, "no person may hunt, chase, harass, capture, shoot at, wound or kill, take or attempt to take, trap, or attempt to trap, any endangered or threatened species or subspecies..." Section 5-412 of Title 29 protects only wildlife species. Plants are not currently protected under Oklahoma statute, although the Oklahoma Natural Heritage

Program (ONHP) maintains a ranked list of rare plants for Oklahoma (Oklahoma Natural Heritage Inventory [ONHI], 2009).

Table 3 lists the ONHP's rare, threatened, and endangered species with the potential to occur in counties within the study area.

TABLE 3  
State of Oklahoma Rare, Threatened, and Endangered Species by County, Potentially Occurring within the Study Area

County	Species	Status
Creek	Interior Least Tern	Endangered
	Arkansas River Shiner	Threatened
	Woodchuck	SS2
	Bachman's Sparrow	SS2
	Prairie Mole Cricket	SS2
Muskogee	American Burying Beetle	Endangered
	Bald Eagle	Endangered
	Interior Least Tern	Endangered
	Arkansas River Shiner	Threatened
	Alligator Snapping Turtle	CS SS2
	Texas Horned Lizard	CS SS2
	Woodchuck	SS2
Osage	Neosho Mucket	Endangered
	Bald Eagle	Endangered
	Interior Least Tern	Endangered
	Arkansas River Shiner	Threatened
	Prairie Mole Cricket	SS2
	Regal Fritillary	SS2
	Bachman's Sparrow	SS2
	Woodchuck	SS2
	Alligator Snapping Turtle	CS SS2
	Texas Horned Lizard	CS SS2
Tulsa	American Burying Beetle	Endangered
	interior Least Tern	Endangered
	Bald Eagle	Endangered
	Prairie Mole Cricket	SS2
	Texas Horned Lizard	CS SS2
Wagoner	Gray Myotis	Endangered
	Bald Eagle	Endangered
	Interior Least Tern	Endangered
	Arkansas River Shiner	Threatened
	Prairie Mole Cricket	SS2
	Shovelnose Sturgeon	SS2
	Oklahoma Salamander	CS SS2
	Alligator Snapping Turtle	CS SS2
	Cave Salamander	CS

Source: ONHI. SS2 - species identified by technical experts as possibly threatened or extirpated but for which additional information is needed. CS - Statewide closed season. It is unlawful at any time to possess or to kill individuals of these species, or to remove any individuals of these species from their natural habitats.



## Habitat Restoration

As part of the project, vegetative species found within the natural habitats in the Arkansas River corridor will be used to restore degraded habitats in the study area. Container-grown planting material will be available for the majority of woody species, but some herbaceous understory species may not be readily available. Species that could be used to restore riparian habitats are listed in Table 4.

TABLE 4  
Species with Potential for Riparian Habitat Restoration

Common Name	Scientific Name
<b>Forested Wetland and Riparian</b>	
<b>Trees</b>	
Cottonwood	<i>Populus Deltoides</i>
Sycamore	<i>Platanus Occidentalis</i>
Green Ash	<i>Fraxinus Pennsylvanica</i>
Pecan	<i>Carya Illinoensis</i>
Box Elder	<i>Acer Negundo</i>
River Birch	<i>Betula Nigra</i>
Black Willow	<i>Salix Nigra</i>
Silver Maple	<i>Acer Saccharinum</i>
Black Walnut	<i>Julgans Nigra</i>
Sugarberry	<i>Celtis Laevigata</i>
Water Oak	<i>Quercus Nigra</i>
Overcup Oak	<i>Quercus Lyrata</i>
Willow Oak	<i>Quercus Phellos</i>
<b>Shrubs</b>	
Swamp Privet	<i>Forestiera acuminata</i>
<b>Herbaceous</b>	
Sedges	<i>Carex spp.</i>
Rushes	<i>Juncus spp.</i>
Smartweed	<i>Polygonum spp.</i>
Big Bluestem	<i>Andropogon Gerardii</i>
Soft Rush	<i>Juncus Effusus</i>
Cattails	<i>Typha spp.</i>
<b>Forested Upland</b>	
<b>Trees</b>	
White Oak	<i>Quercus Alba</i>
Black Oak	<i>Quercus Velutina</i>
Northern Red Oak	<i>Quercus Rubra</i>
Southern Red Oak	<i>Quercus Falcata</i>
Black Gum	<i>Nyssa Sylvatica</i>
Red Maple	<i>Acer Rubrum</i>
<b>Shrubs</b>	
Flowering Dogwood	<i>Cornus Florida</i>
Redbud	<i>Cercis Canadensis</i>
Ironwood	<i>Carpinus Caroliniana</i>
Pawpaw	<i>Asimina Triloba</i>
Basswood	<i>Tilia Americana</i>
Spice Bush	<i>Lindera Benzoin</i>
Red Mulberry	<i>Morus Rubra</i>

## Bank Stabilization

Bioengineering techniques can be used to stabilize river banks in areas where shear stress from high river flows is a concern. Bioengineering integrates living woody and herbaceous materials with organic and non-organic materials to increase the strength and structure of the soil. Plants typically used for these bank treatments are established using live cuttings. Cuttings are small branches or stems removed from live, but dormant, trees or shrubs that are subsequently planted. The vegetation buttresses the contribution of the organic and non-organic materials to soil stability by forming a dense root matrix to hold the soil together. The above-ground vegetation reduces flow velocities through energy dissipation and acts as a buffer against the erosive forces of suspended sediments and also allows sediment deposition near the banks through reduction of shear stress.

Advantages of using bioengineering techniques include (Hoag and Fripp, 2002):

- **Cost-Effectiveness** – Usually less expensive to install and require little to no maintenance.
- **Environmental Compatibility** – Result in development of wildlife habitat that blends into the background and is not visually intrusive. Habitats tend to evolve with the stream over time.
- **Natural Materials** – Do not usually require steel or concrete, and locally available materials can be used. This is particularly important where it is infeasible to bring in artificial materials.
- **Labor and Skill Requirements** – Tend to rely on labor and skills rather than capital and energy.

A variety of techniques, including brush and tree revetments, brush mattresses, fascines, log crib walls, and stone sill with live joint plantings, among others, can be used. This TM provides the basis for selecting appropriate vegetation to be used in bank stabilization/bio-engineering techniques (Table 5). A more detailed review of bank stabilization/bio-engineering techniques and appropriate vegetation will be presented in a subsequent TM.

TABLE 5  
Species with Potential for Bank Stabilization

Common Name	Scientific Name
<b>Trees</b>	
Black Willow	<i>Salix Nigra</i>
Cottonwood	<i>Populus Deltoides</i>
<b>Shrubs</b>	
Sandbar Willow	<i>Salix Exigua</i>

## References

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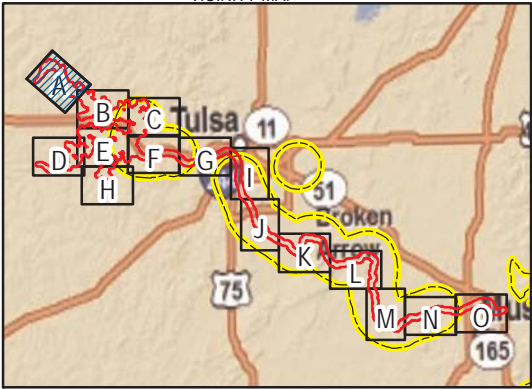
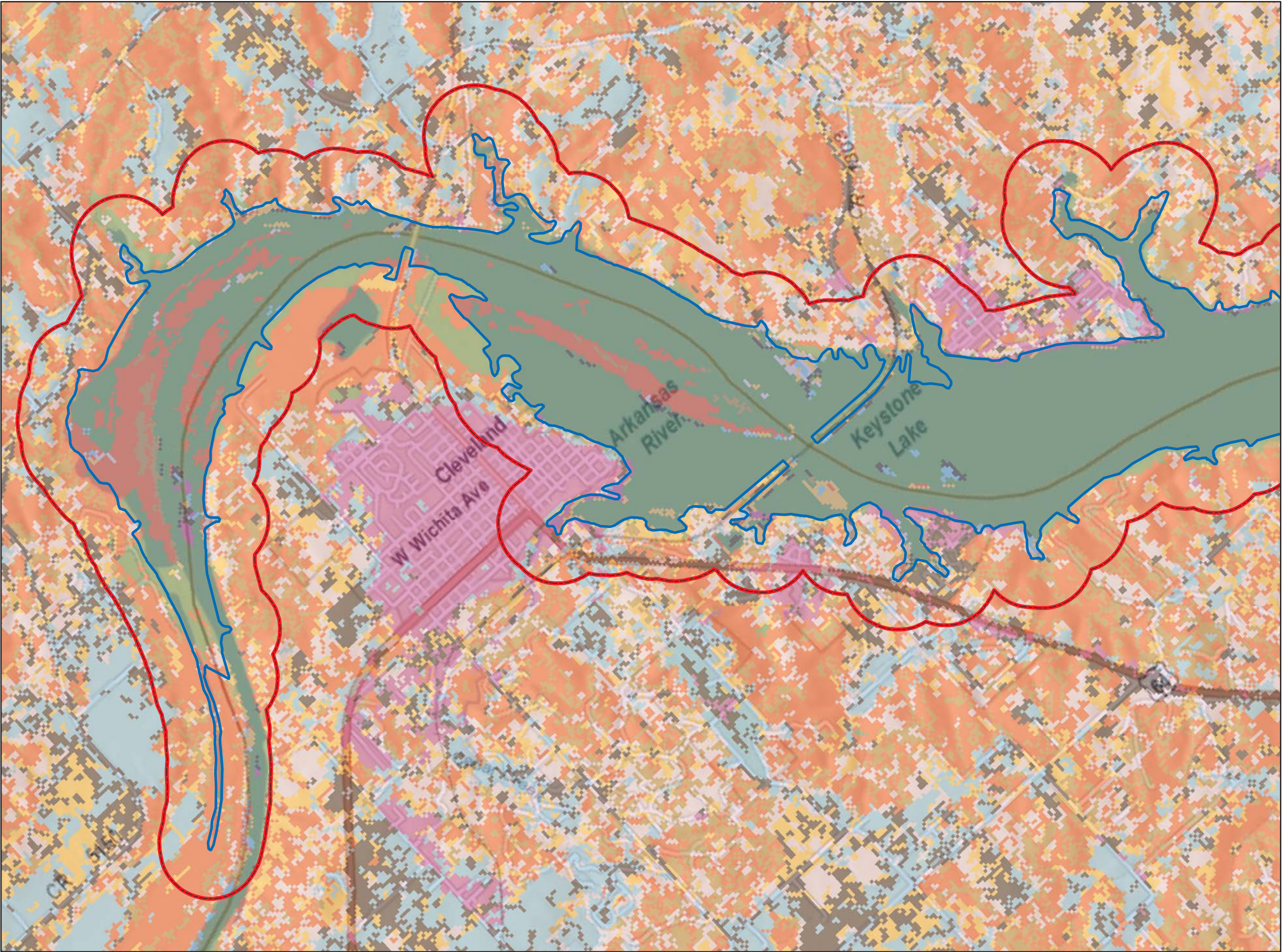
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## Appendix A

### Land Classification Figures





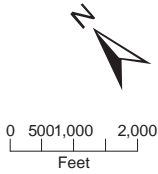
**LEGEND**

- Bald Eagle Imperiled Areas
- Existing Dam
- Proposed Dam
- Arkansas River
- Keystone Lake
- Arkansas River Buffer

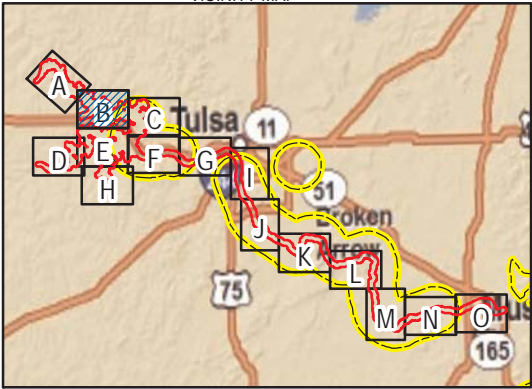
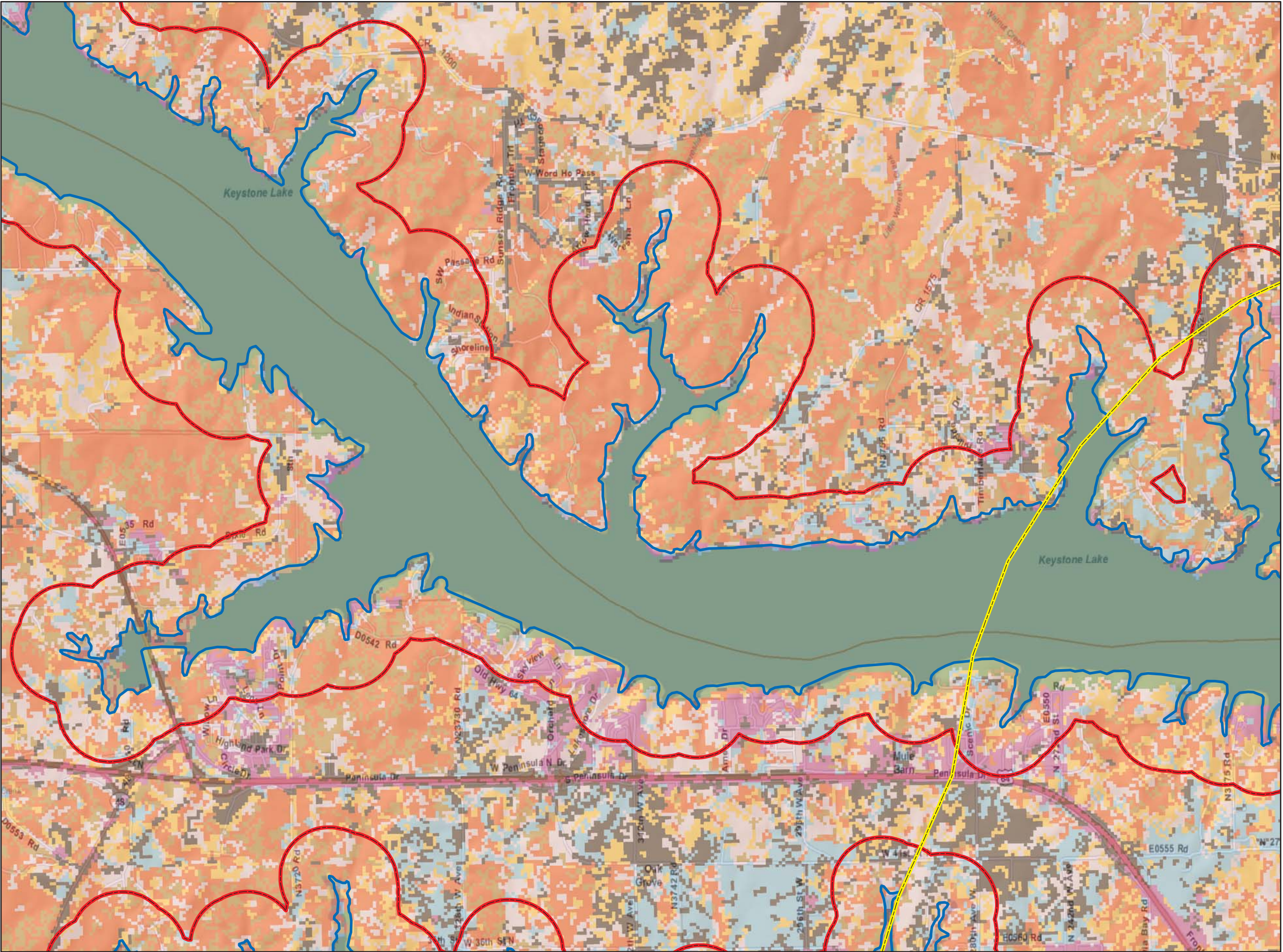
**Vegetation Type**

- Agriculture/Crops
- Sandy Areas/Barren
- Bottomland Forests/Crosstimbers
- Woodland
- Prairie
- Gypsum Grasslands
- Water
- Deciduous Coniferous Forests
- Savanna Grass
- Shrubland
- Residential/Industrial

**Note:**  
The following imperiled species cover the entire study area.  
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**LEGEND**

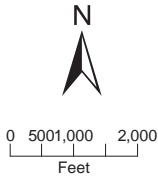
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- Existing Dam
- Proposed Dam
- Arkansas River
- Keystone Lake
- Arkansas River Buffer

**Vegetation Type**

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**Vegetation/Habitat**  
Arkansas River Corridor  
Tulsa, OK

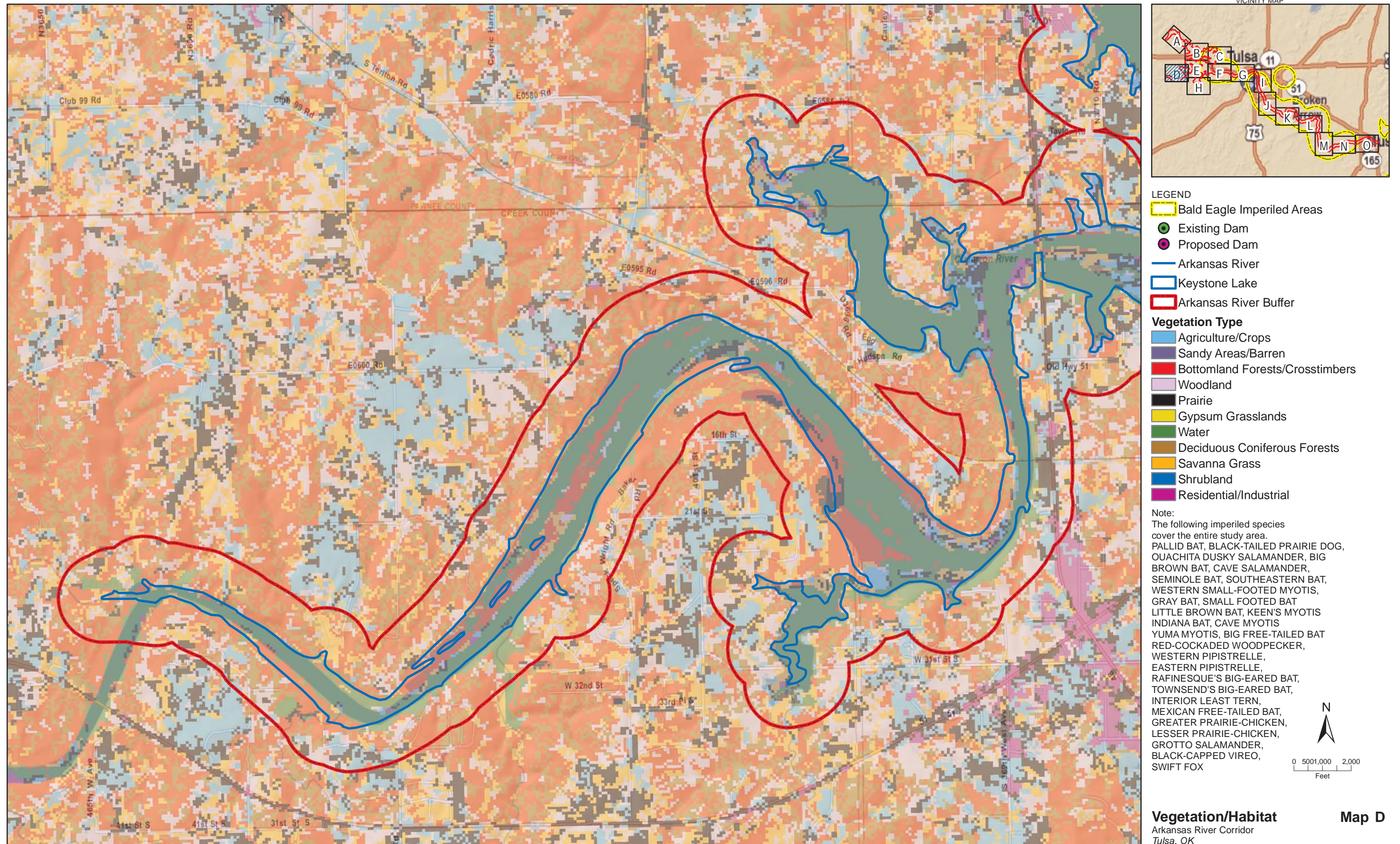


Map B

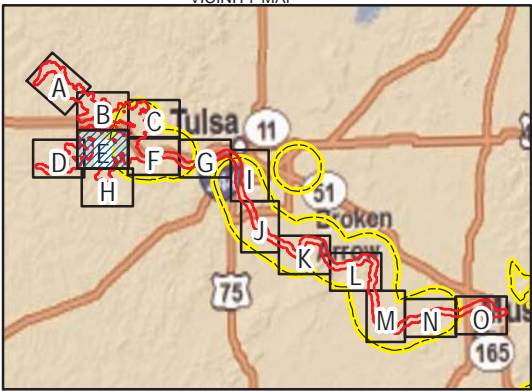
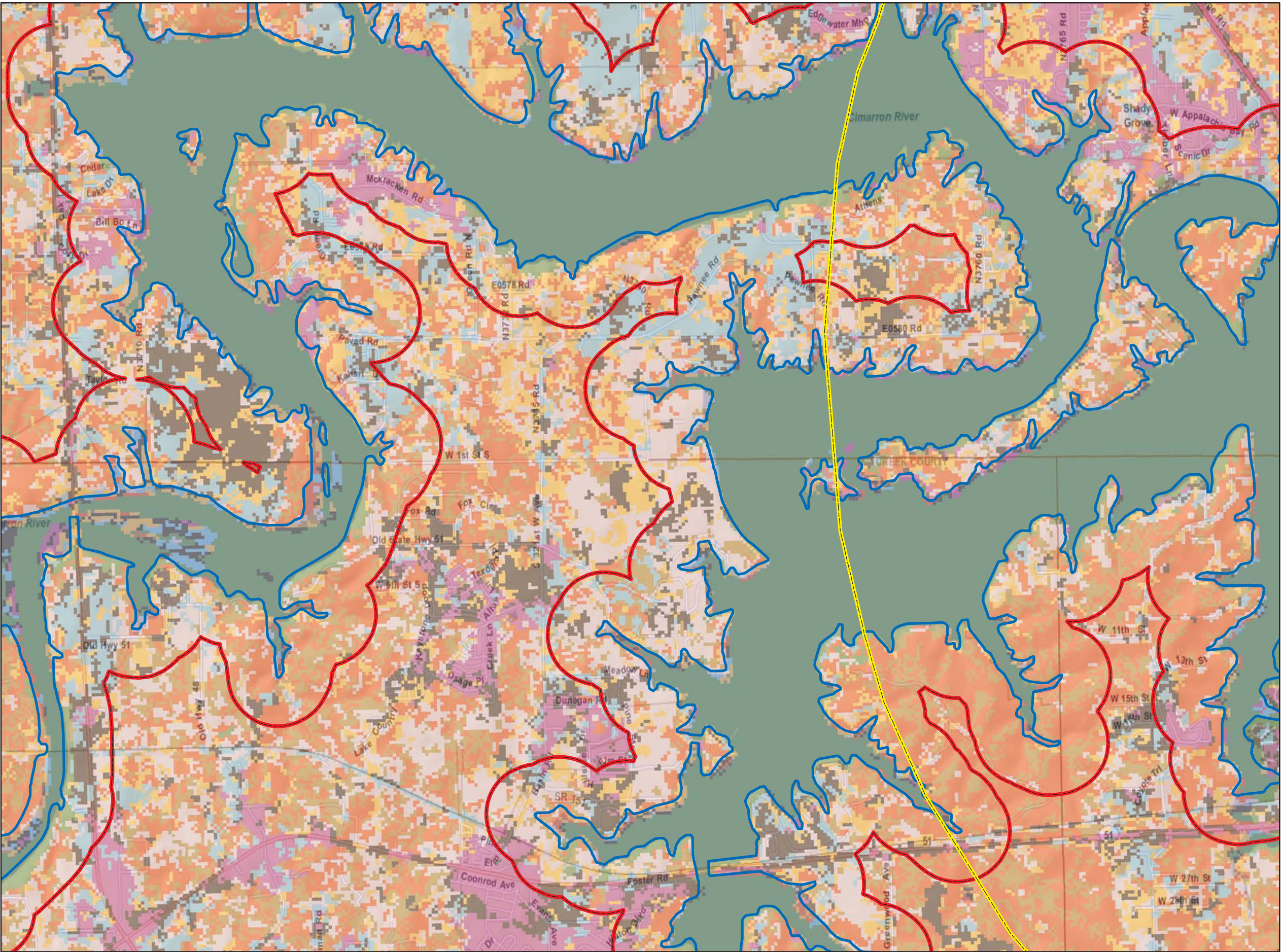












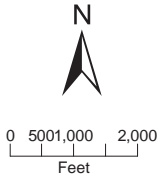
**LEGEND**

- Bald Eagle Imperiled Areas
- Existing Dam
- Proposed Dam
- Arkansas River
- Keystone Lake
- Arkansas River Buffer

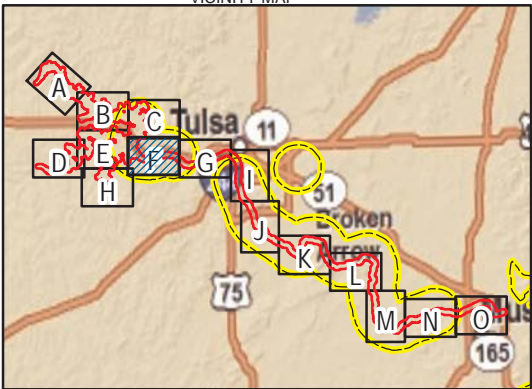
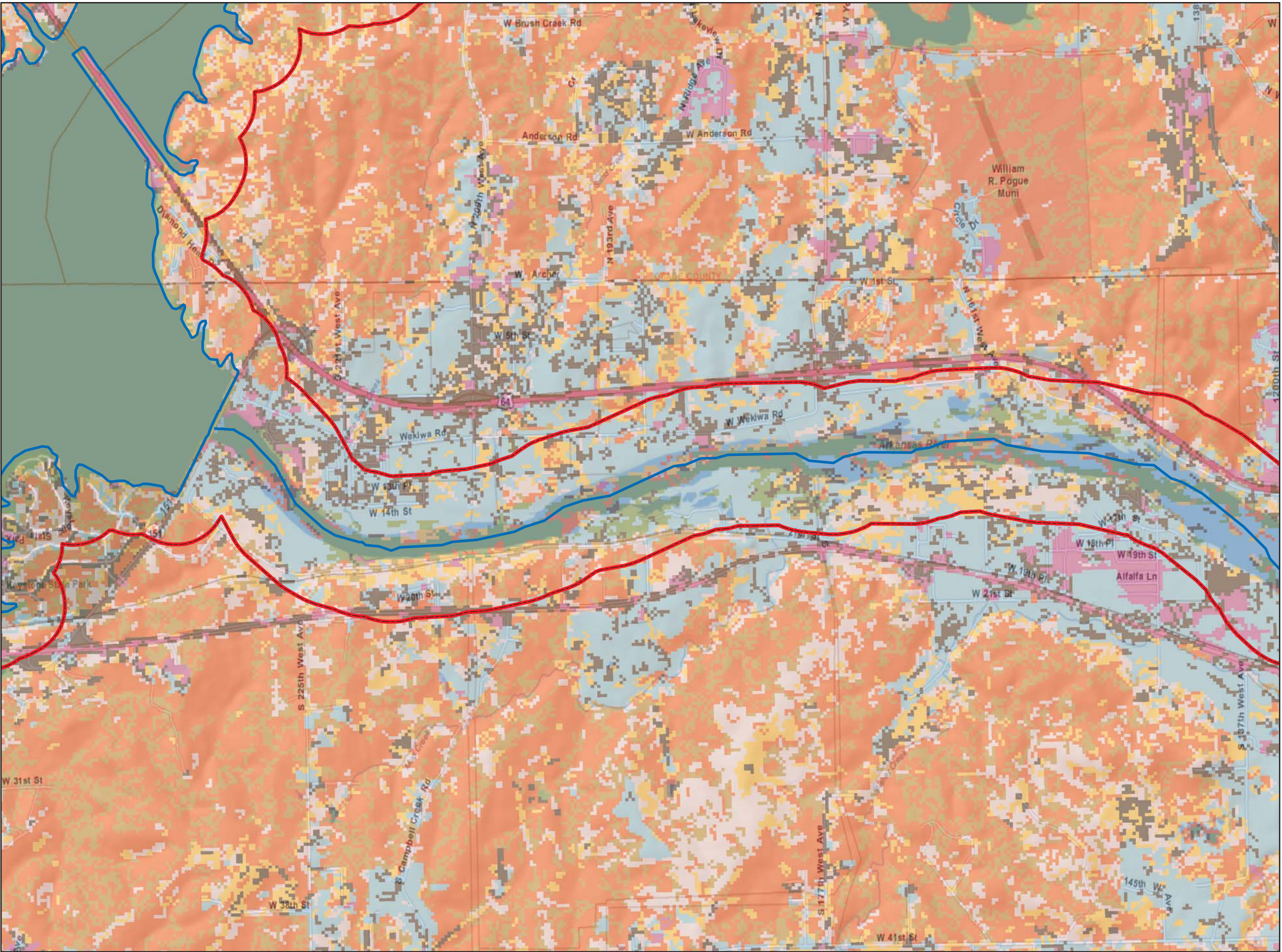
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- Sandy Areas/Barren
- Bottomland Forests/Crosstimbers
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- Gypsum Grasslands
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**LEGEND**

- Bald Eagle Imperiled Areas
- Existing Dam
- Proposed Dam
- Arkansas River
- Keystone Lake
- Arkansas River Buffer

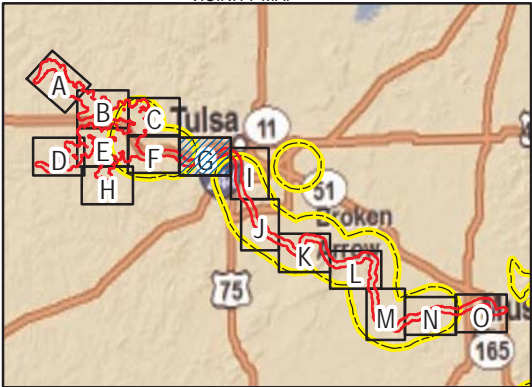
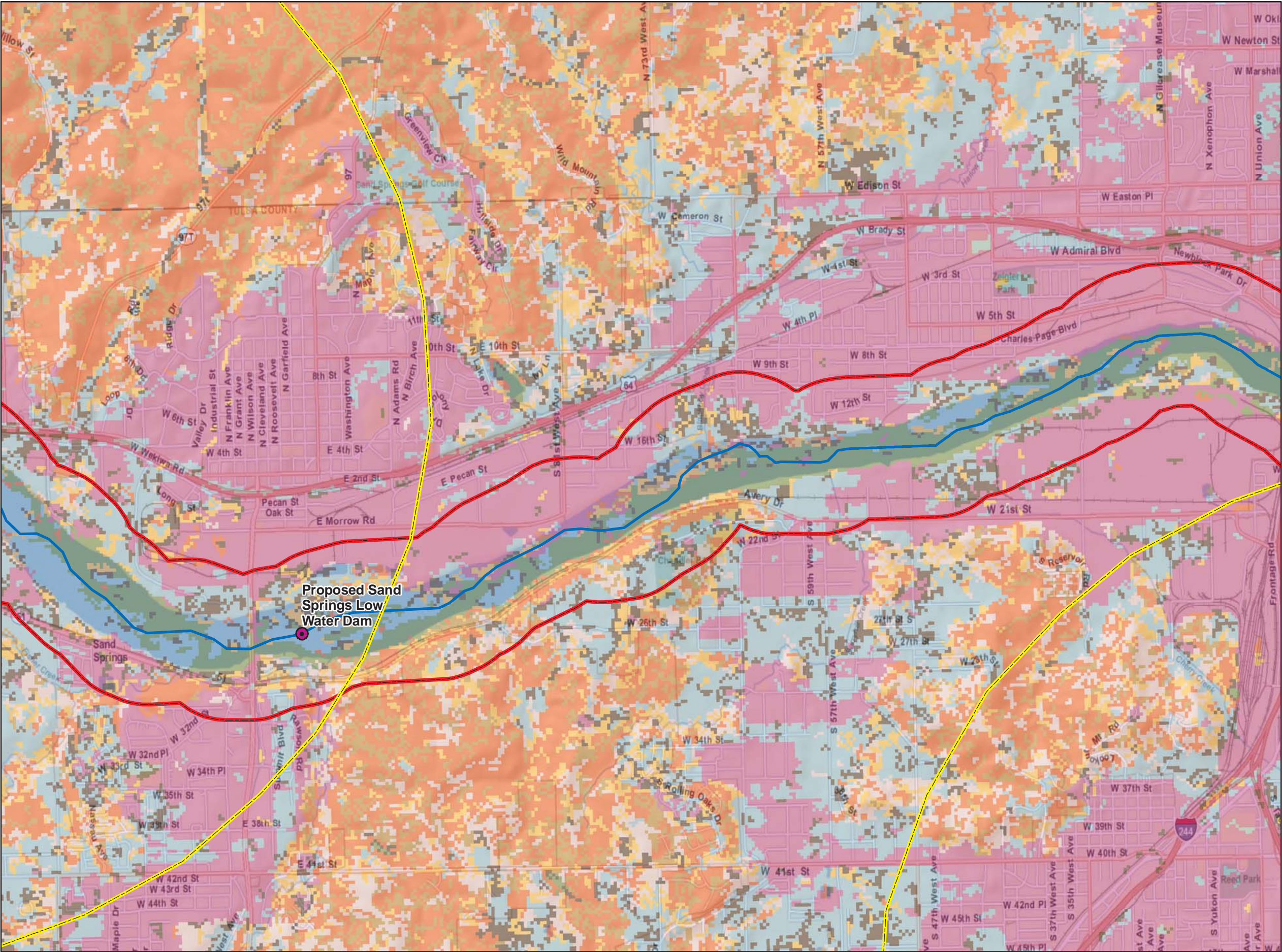
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0 5001,000 2,000  
Feet





**LEGEND**

- Bald Eagle Imperiled Areas
- Existing Dam
- Proposed Dam
- Arkansas River
- Keystone Lake
- Arkansas River Buffer

**Vegetation Type**

- Agriculture/Crops
- Sandy Areas/Barren
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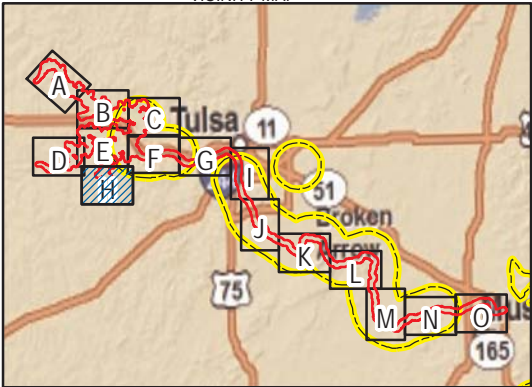
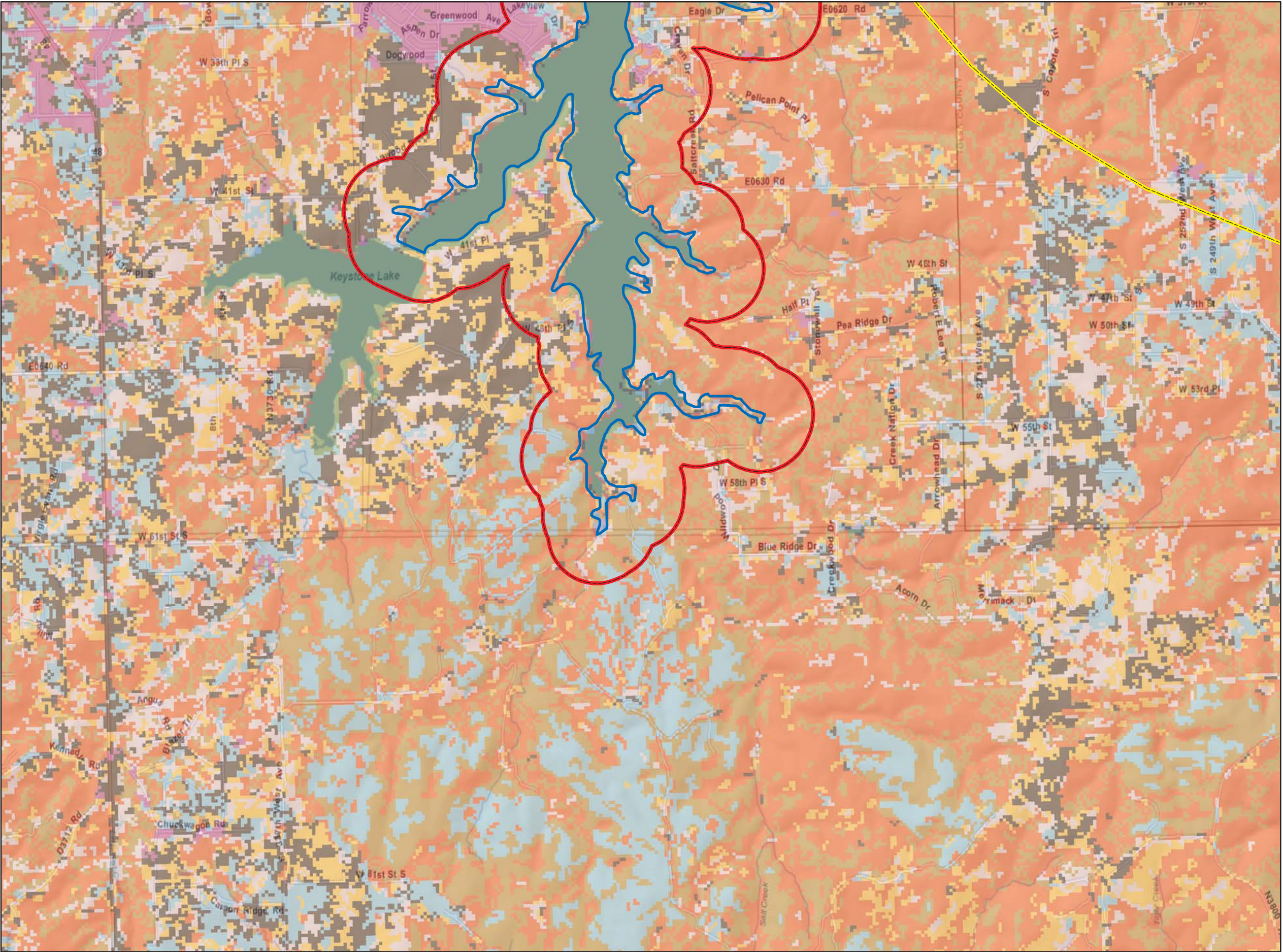
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**Vegetation/Habitat**  
Arkansas River Corridor  
Tulsa, OK

**Map G**

**CH2MHILL**





LEGEND

- Bald Eagle Imperiled Areas
- Existing Dam
- Proposed Dam
- Arkansas River
- Keystone Lake
- Arkansas River Buffer

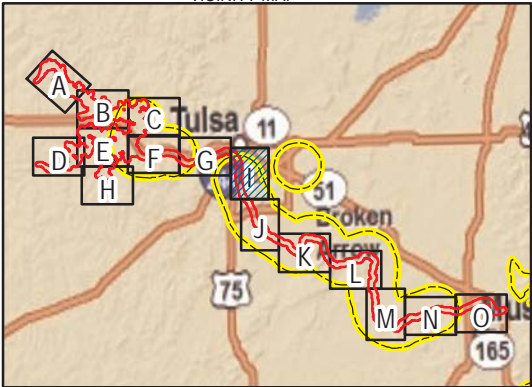
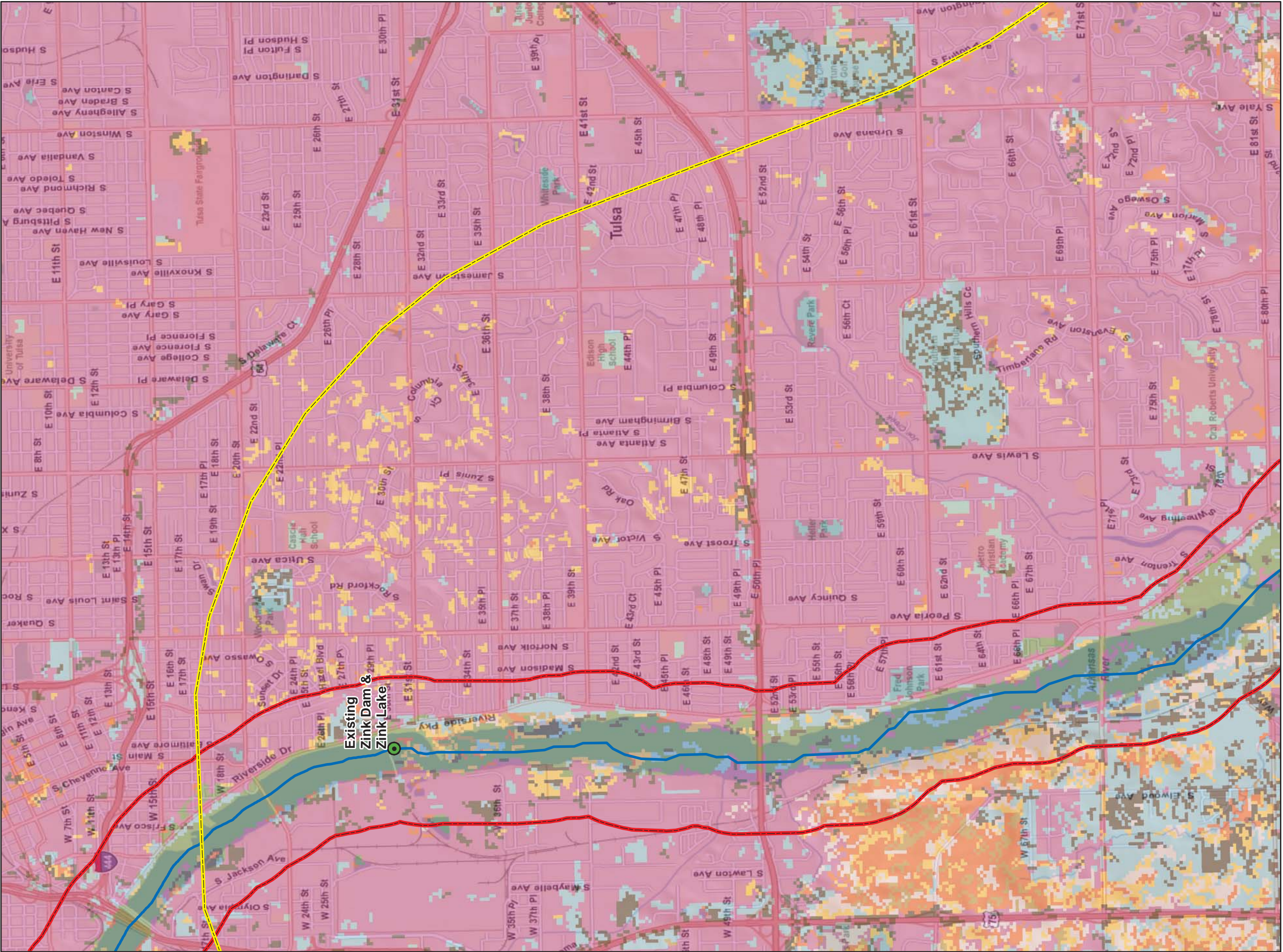
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**LEGEND**

- Bald Eagle Imperiled Areas
- Existing Dam
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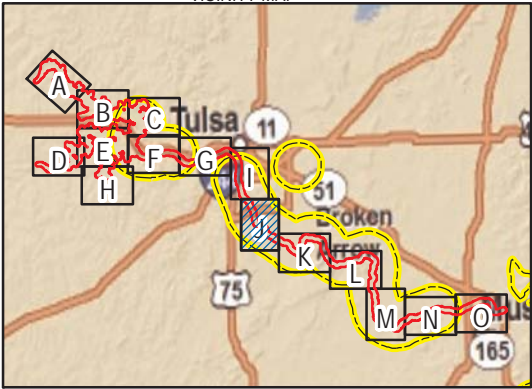
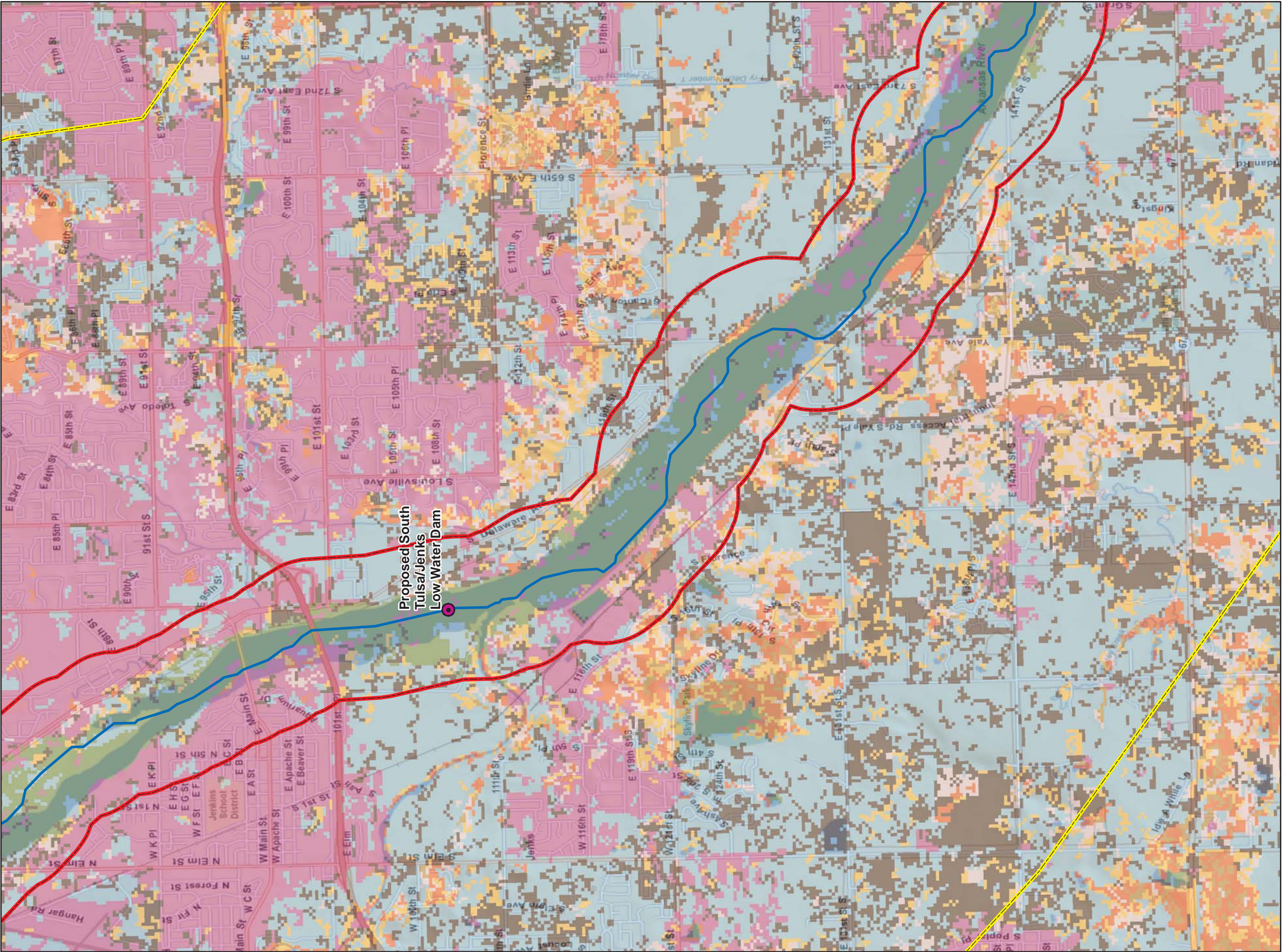
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0 5001,000 2,000 Feet





**LEGEND**

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- Existing Dam
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- Keystone Lake
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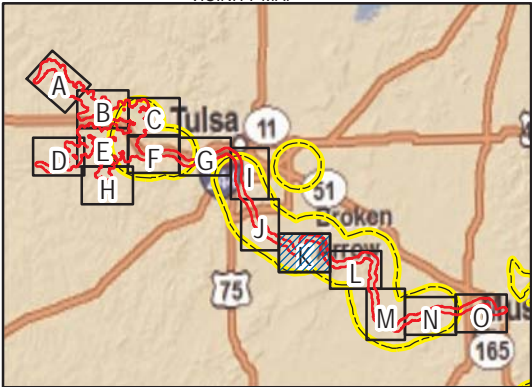
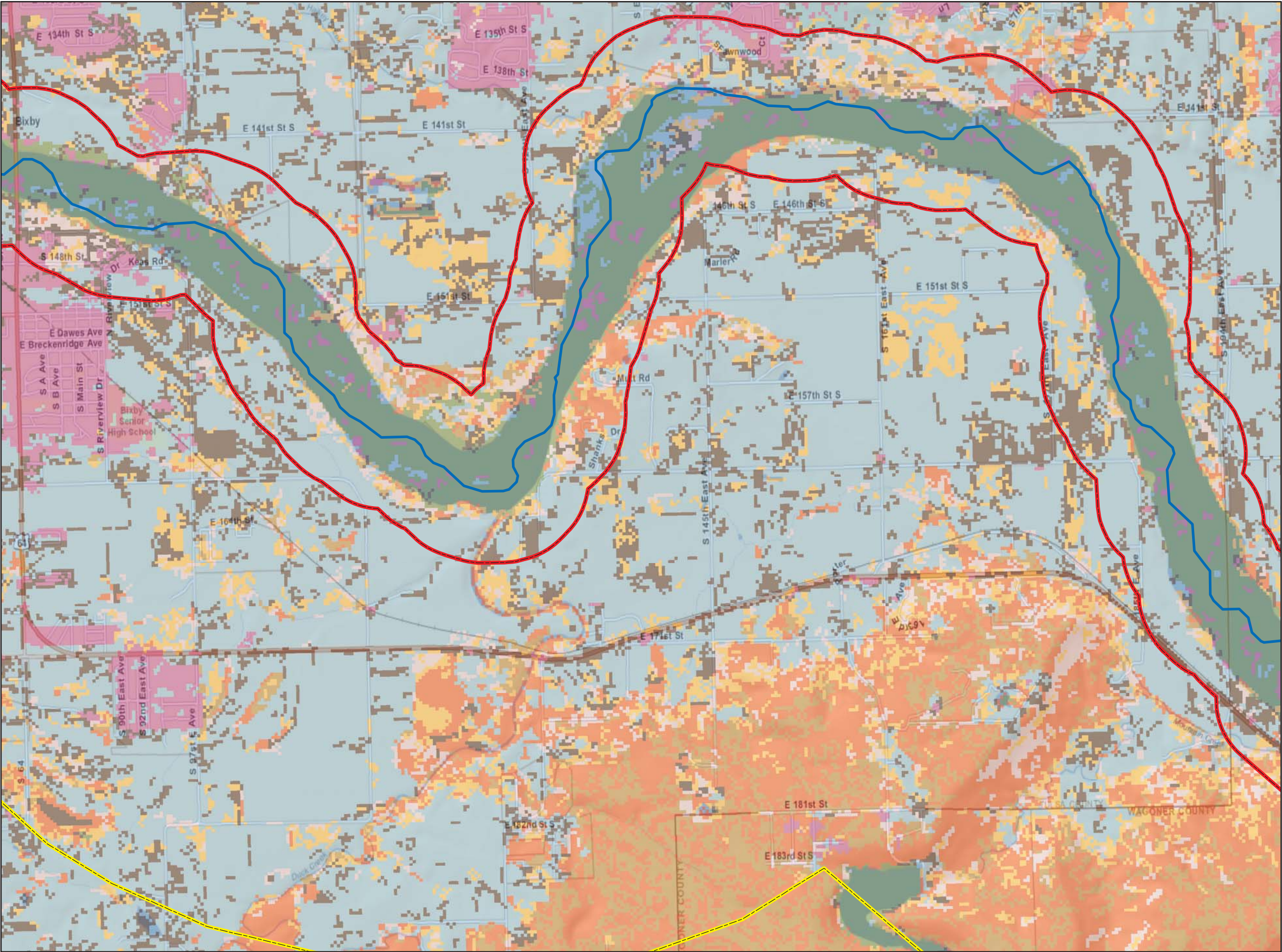
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**LEGEND**

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- Existing Dam
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**Vegetation/Habitat**  
Arkansas River Corridor  
Tulsa, OK

**Map K**

**CH2MHILL**





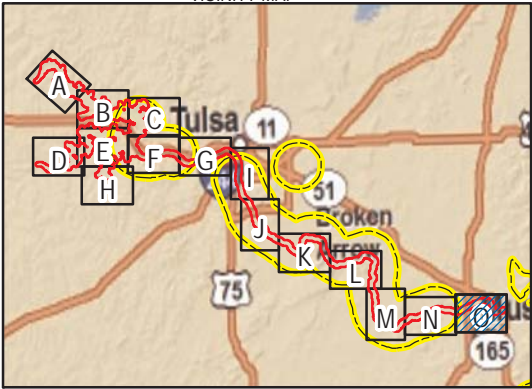
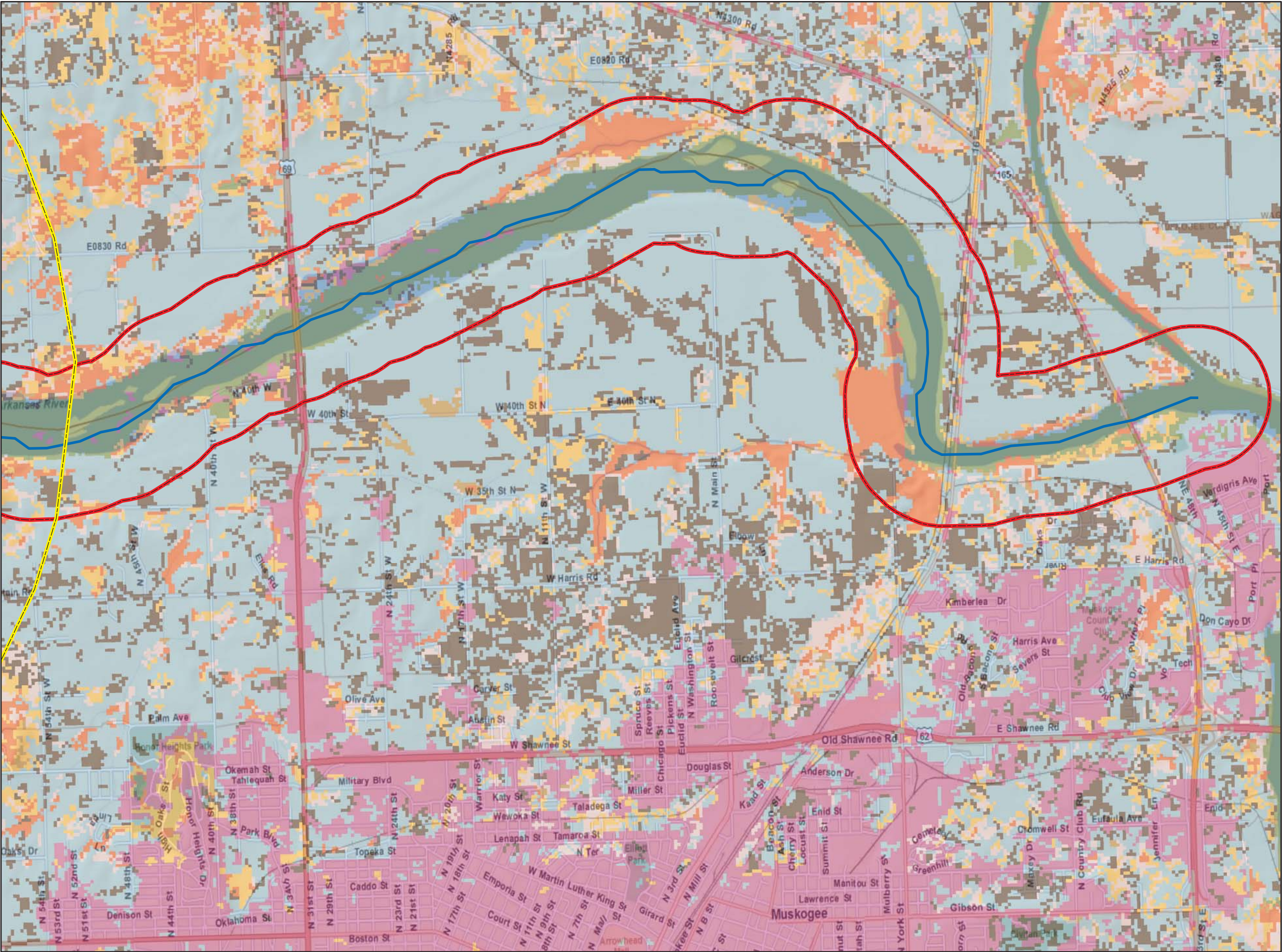












**LEGEND**

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