Pelican Lake Watershed Restoration Plan

June 2017

Prepared for:

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List of Acronyms

AgACIS – National Resource Conservation Service Agricultural Applied Climate System

BLM – U.S. Bureau of Land Management

BOR – U.S. Bureau of Reclamation

CWA – Clean Water Act (U.S. Environmental Protection Agency)

DEQ – Utah State Department of Environmental Quality

DNR – Utah State Department of Natural Resources

DWR – Utah State Division of Water Resources

EPA – U.S. Environmental Protection Agency

ESA – U.S. Endangered Species Act

GAP – USGS GAP Analysis Program

NED – National Elevation Dataset

NOAA – U.S. National Oceanic and Atmospheric Administration

NLCD – National Land Cover Dataset

NRC – National Resource Council

NRCS – U.S. National Resource Conservation Service

NWS – U.S. National Weather Service

OPIC – Ouray Park Irrigation Company

SITLA – Utah School and Institutional Trust Lands Administration

UDAF – Utah Department of Agriculture and Food

UDWQ – Utah State Division of Water Quality

UDWR – Utah Division of Wildlife Resources

UGS – Utah Geological Survey

USDA – U.S. Department of Agriculture

USFWS – U.S. Fish and Wildlife Service

USGS – U.S. Geological Survey

1.0 INTRODUCTION

Pelican Lake is a natural lake located roughly 20 miles southwest of the town of Vernal, in Uintah County, Utah. The lake is approximately 1,700 acres in size, situated just north of the confluence of the Green and Duchesne Rivers in the Leota-Randlett bottomlands (Figure 1). Pelican Lake is a historically important recreational site in the Uintah Basin, and is a nationally recognized fishery for bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*). The lake was originally used as water storage for irrigation and is still used for that purpose. Largemouth bass and bluegill weren't added to the lake until 1954 by the Randlett Lions Club and Vernal Rod and Gun Club. With the purchase of a conservation pool in 1967, it became far more accessible to anglers. In 1974 it was highlighted in Outdoor Life, and as a result, the fishery began drawing anglers from around the country, with a particular reputation for large and abundant bluegill. It has also served as an ideal family-friendly fishery, where young or inexperienced anglers could catch memorable fish. However, the quality of Pelican Lake's Blue Ribbon bluegill fishery has noticeably declined in the past decades. Bluegill catch rates have declined, and anglers have reported that large bluegill are much less common. Restoring the fishery is now a priority for the Utah Division of Wildlife Resources (UDWR) and Utah Division of Water Quality (UDWQ).

1.1 Watershed Restoration Plan and Purpose

This watershed restoration plan is an important first step in the process of restoring Pelican Lake's fishery. Its goal is to set in motion sustainable and economically feasible actions to improve the quality of the fishery and overall environmental conditions of Pelican Lake. The restoration plan documents current conditions in Pelican Lake and its watershed, identifies and discusses potential drivers of fishery impairments, and proposes a set of watershed-based measures for improving conditions. The restoration plan also recommends assessments and monitoring methods to ensure that improvements will be maintained into the future.

This restoration plan is designed to be amended and updated as needed. The restoration process is intended to be iterative, with high-priority issues and regions within the watershed receiving the bulk of initial attention and resources. As the measures presented in the plan are implemented, partners should carefully assess their impacts and make adjustments if necessary. The recommended approach is to use this plan as a framework, revising it accordingly as new results and information are obtained.

1.2 Clean Water Act Section 319 Watershed Plan Elements

A key function of this restoration plan is to aid the management agencies overseeing recovery efforts in obtaining U.S. Clean Water Act (CWA) 319 funding for watershed improvements. These funds are allocated by the U.S. Environmental Protection Agency (EPA) to state and local agencies for water quality improvements, habitat restoration, pollution management, and other actions to protect and improve the critical water resources of the U.S. For water bodies impaired primarily by non-point pollution (such as Pelican Lake), the EPA requires the development of a watershed-based restoration plan to guide CWA-funded recovery work.

The EPA requires that watershed plans developed with the intent of securing Section 319 funding include nine essential elements deemed critical for improving water quality (EPA 2008). These nine elements are presented in Table 1, along with the chapter of this watershed restoration plan that addresses each element.

Table 1. *Required elements of watershed restoration plans seeking U.S. Clean Water Act Section 319 funding.*

CWA Watershed Plan Element	Pelican Lake Watershed Restoration Plan Chapter
a. Identification of causes of impairment	4
b. Estimate of load reductions from management measures	4.6, 5
c. Non-point pollutant source management measures to achieve load reductions in (b)	5
d. Technical and financial assistance needs	5.4 – 5.5
e. Information and public education component	6
f. Schedule for implementing non-point pollutant source management measures	5.6
g. Interim milestones for progress on non-point source pollutant source management measures	7
h. Criteria for assessing success of loading reduction measures via monitoring	7
i. Monitoring program to evaluate the effectiveness of management measures, relying on criteria in (h)	7

1.3 Historical Background, Fishery Baselines, and Current Fishery Conditions

Pelican Lake is a relatively shallow lake, with a maximum depth of approximately 16 feet at full-pool. Lake levels are highest in spring, boosted by accumulating meltwater and runoff from the Uinta Mountains, but water levels in summer are often low due to irrigation drawdowns. While Pelican Lake is a natural lake, its hydrology is intensively managed, primarily for irrigation of surrounding croplands and pastures. Pelican Lake drains from its southern edge to canals and pipelines, which feed the Green River via surface and subsurface connections. Inlets to the north provide water to the Lake from the Deep Creek / Ouray Valley Canals and the Cottonwood Pipeline, which are part of a complex water storage and delivery system that supplies the lake's water. This manmade upstream system is critical to the fishery health, water quality, and overall ecological conditions in Pelican Lake.

The current primary fish species of concern, bluegill and largemouth bass, were first stocked in the Lake in 1954 (UDWR 2014). A conservation pool was purchased for Pelican Lake in 1967 to increase its water storage capacity and improve the fishery. The conservation pool doubled the lake's maximum water volume, increasing the depth and surface area of the lake. This reduced the overabundance of submerged aquatic vegetation, and kept average year-round water levels higher. These changes benefited bluegill and largemouth bass populations in the lake, and also increased angler access to most areas of the shoreline. Pelican Lake began to acquire a reputation as an excellent inland warm water fishery. Changes were made during the 1970's and 1980's to protect the older, larger bluegill and largemouth bass from a resulting increase in angler pressure. Daily catch and possession limits were reduced, but the fishery remained productive and attractive to anglers (UDWR 2014).

In the late 80's and early 90's, anglers began reporting decreased satisfaction with the Pelican Lake fishery, and UDWR monitoring began to indicate falling numbers of the large, valued bluegill the lake was known for. Further, several years of severe winter fish die-offs took place in the 1980s and 1990s, brought about by too-low water levels in the conservation pool. Utah Division of Wildlife Resources re-stocked Pelican Lake with bluegill and largemouth bass in 1995 and 1996, and the depth of the conservation pool was corrected. The additional depth eliminated the large-scale winterkill events previously observed, but populations of bluegill remained below prior levels, and anglers continued to report catching smaller bluegill than in the past. In 2008 and 2009, large numbers of non-native common carp were inadvertently introduced into Pelican Lake during water releases from upstream reservoirs. The capacity of carp to negatively impact bluegill and other native fish is well documented (e.g., Wolfe et al. 2011), and the quality of the bluegill fishery has declined further as carp populations have grown. In recent years, water quality in Pelican Lake has also been posited as a driver of problems with the bluegill fishery; pollution of the lake from sediment, fertilizer nutrients, and dissolved salts has become a major concern for UDWR and UDWQ. Recent sampling efforts by UDWR indicate that while largemouth bass populations now exceed 1970s—1980s levels, bluegill populations are diminished, overall bluegill size is depressed, and large bluegill are increasingly rare (UDWR 2014). It is likely that the decline of the bluegill fishery cannot be pinned on one factor alone – restoring the fishery is expected to require a holistic effort that aims to improve overall environmental conditions in the lake.

1.4 A Watershed-Based Restoration Approach

Addressing problems with water quality and ecosystem health can be complex and difficult if the degraded conditions result from non-point sources far from the impaired water body. Improving conditions in such systems often hinges on numerous stakeholders taking action over a large area. The EPA recommends a watershed-based approach to restoration efforts in waters impaired by non-point pollution. By considering the entire drainage of the water body in question, managers can identify which areas may be contributing most to impairments, encourage collaboration between important partners or stakeholders, and deploy resources and effort more effectively during the restoration process (EPA 2008).

The environmental conditions in Pelican Lake are dependent on water and land management practices occurring far from the lake itself. The majority of the water in Pelican Lake is supplied via an artificial system of canals and pipelines that draws from distant water sources, extending the lake's working watershed far beyond its natural drainage basin. Restoring conditions in the lake thus depends on extending the watershed-based approach favored by the EPA to the entire area from which the lake draws its water. This restoration plan describes this area, identifies specific locations within its boundaries that may be disproportionately contributing to impairment in Pelican Lake, and provides a framework for iterative, targeted improvements.

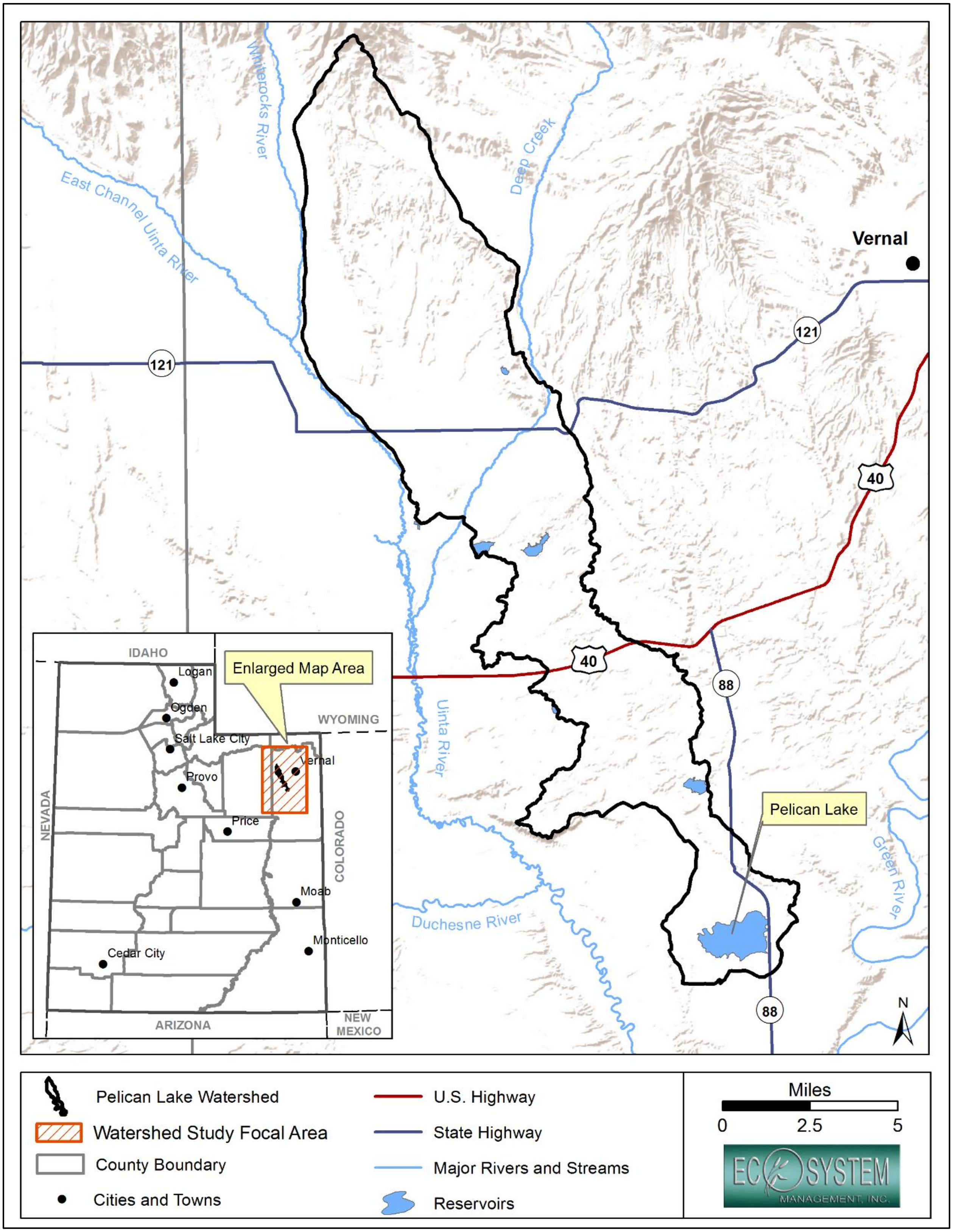

Figure 1. Overview of the Pelican Lake watershed developed for this watershed study, encompassing all areas draining to the lake via natural waterways, irrigation canals, pipelines, and other humanmade water delivery systems.

Figure 2. Aerial image of Pelican Lake near full pool in 2007.

2.0 WATERSHED DESCRIPTION AND CHARACTERISTICS

2.1 Boundaries

The natural watershed of Pelican Lake is relatively small – roughly 18,200 acres – consisting of the natural drainage basin that surrounds the lake (U.S. Bureau of Reclamation 2005). This natural watershed is composed of surface and subsurface flows, most pronounced following major precipitation or snowmelt events. However, the majority of the water in the lake is supplied by an extensive system of upstream reservoirs, canals, and pipelines outside of this natural watershed, drawing water from a much larger area. The effective boundary of the Pelican Lake watershed therefore includes, in addition to the natural watershed, all areas that drain to the canal and pipeline system feeding the lake (Figures 1-2).

The canal and pipeline system that supplies water to the lake receives water from three primary natural sources: the Uinta River, Whiterocks River, and Deep Creek. This watershed restoration plan will not address the entire extent of the sub-basins of these streams, because they are included in a recent watershed restoration plan for the Duchesne River (Uinta Basin Watershed Council 2014). The Pelican Lake watershed boundary, as discussed and presented here, includes only the portions of these sub-basins that drain to the canal and pipeline system supplying the lake. The watershed boundary was developed by the UDWR, UDWQ, and Ecosystem Management Inc., using U.S. Geological Survey (USGS) hydrological and topographic data layers.

The watershed boundary utilized in this study includes approximately 107 square miles (68,260 acres). The watershed is contained entirely within Uintah County. Roughly, the watershed is bounded to the north by foothills of the Uinta Mountains, to the east by rugged hills draining further east of the Green River, to the south by the confluence of the Green and Duchesne Rivers, and to the west by the Uinta River.

2.2 Land Ownership

Land in the Pelican Lake watershed is managed by private landowners, the U.S. Bureau of Land Management (BLM), U.S. Forest Service (USFS), the Utah State Land Trust, and the Uintah and Ouray Reservation. Land ownership status in Utah is managed jointly by the state and federal government. Federal land management and ownership, including tribal lands, is updated regularly and digitized by the BLM. The Utah School and Institutional Trust Lands Administration (SITLA) regularly revises state land ownership data to reflect changes in state and private lands. The watershed is composed primarily of private lands (44.4%), followed by tribal (31.9%), and BLM (20.7%) lands, as well as limited acreage of state and USFS lands (Table 2, Figure 3).

Table 2. *Summary of land ownership in the Pelican Lake watershed.*

Land Ownership	Area (acres)	Percent of Watershed Area
Private Lands	30,338	44.4
Uintah and Ouray Tribal Lands	21,796	31.9
U.S. Bureau of Land Management (BLM) Lands	14,114	20.7
Utah State Land Trust Lands	1,154	1.7
U.S. Forest Service (USFS) Lands	857	1.3
Total	**68,260**	**100.0**

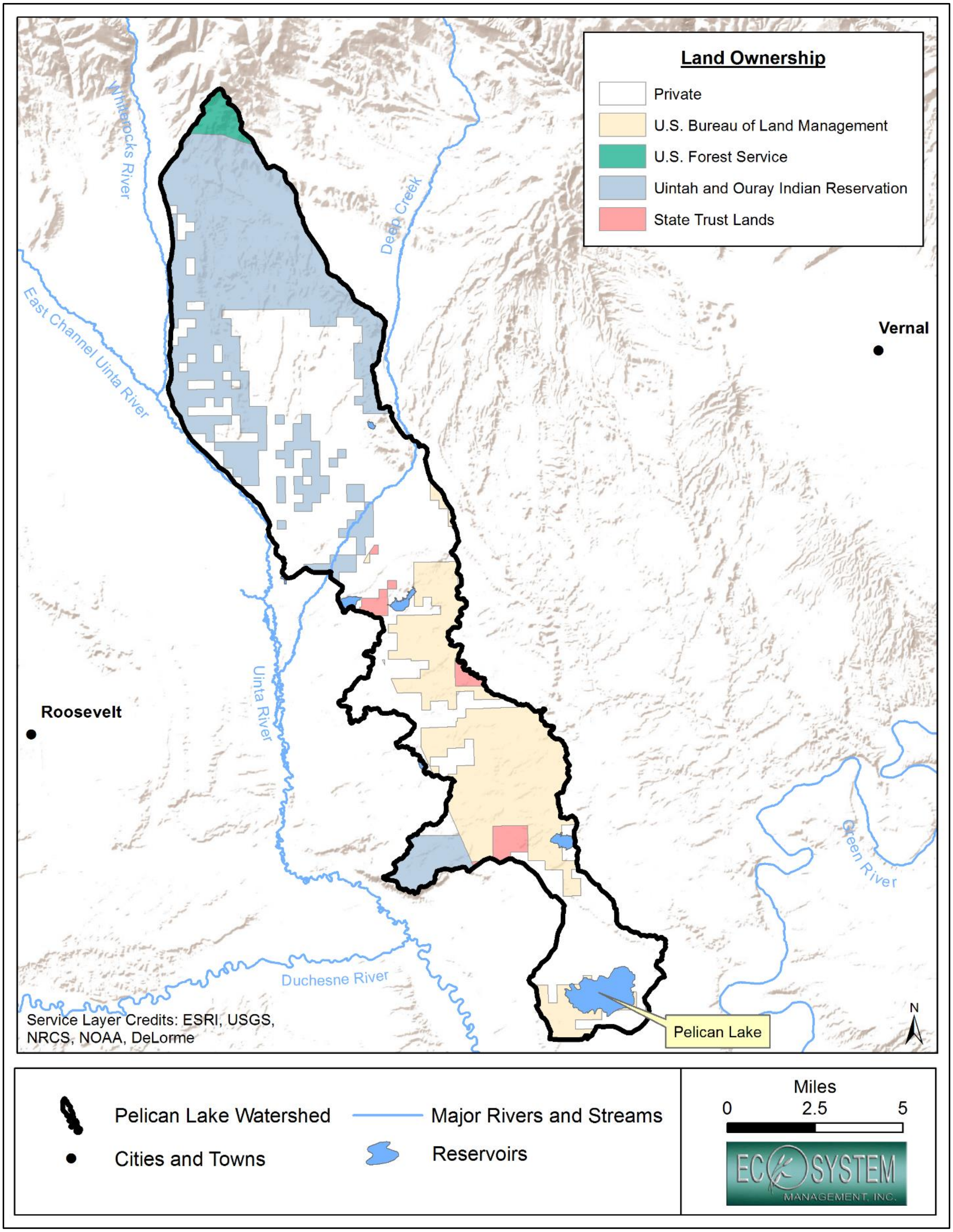

Figure 3. Land ownership within the Pelican Lake watershed.

2.3 Climate

The climate of the Pelican Lake watershed is high desert, with hot, dry summers and cold winters. The watershed experiences strong seasonal temperature variation, with extreme temperatures in summer and winter typically differing by more than 100°F (Figure 4). The watershed also frequently experiences pronounced fluctuations between daytime and nighttime extreme temperatures. The typical frost-free period is 100—120 days.

Precipitation in the watershed is dominated by winter snow (predominantly at higher altitudes) and brief, intense summer and fall storms that possibly contribute to sediment transport from the landscape. Precipitation varies along a strong north-south gradient, increasing with elevation and proximity to the Uinta Mountains. However, the bulk of the watershed is very arid, with mean annual precipitation below 8 inches (Figure 5). The watershed receives little precipitation from storm systems arriving from the Pacific Ocean due to the rain-shadow effect of the Uinta Mountains and Wasatch Range to the north and west.

Climate data were obtained from the USDA Natural Resources Conservation Service (NRCS), which maintains an extensive geospatial database of precipitation, temperature, snowpack, stream flows, surface water supply, and other climate data for the state of Utah. This database collates climate data from the NRCS and various other sources, including the National Weather Service (NWS), USGS, and National Oceanic and Atmospheric Administration (NOAA). Precipitation data shown in Figure 4 reflect NRCS estimates for the state of Utah between 1981 and 2010 (NRCS 2011). Because there are no NWS climate stations within the watershed itself; temperature data shown in Figure 4 were drawn from three stations nearest to the watershed (Fort Duchesne, Roosevelt Radio, and Ouray 4NE).

Climate change holds significant potential to change temperature and precipitation regimes in the watershed during the 21st century and beyond. Leading climate models consistently predict hotter, drier average annual conditions for the Uintah Basin and the southwestern U.S. as a whole (NOAA 2017, National Resource Council 2007). In summarizing the watershed's current climate here, it is critical to stress that conditions may shift significantly in the relatively near future.

2.4 Elevation and Topography

Elevation in the Pelican Lake watershed ranges from roughly 9,000 feet at its mountainous northern tip to roughly 4,800 feet in the Leota-Randlett bottomland areas surrounding the lake itself (Figure 6). Elevation increases rapidly just north of the watershed, peaking above 12,000 feet in the Uinta Mountains. The pronounced north-to-south elevation gradient is an important determinant of the overall environment of the watershed, exerting strong influence over precipitation regimes, hydrology, and ecological characteristics. Elevation data for the watershed were obtained from the National Elevation Dataset (NED) maintained by the USGS; Figure 6 utilizes the 30-m digital elevation model dataset developed from LiDAR remote sensing.

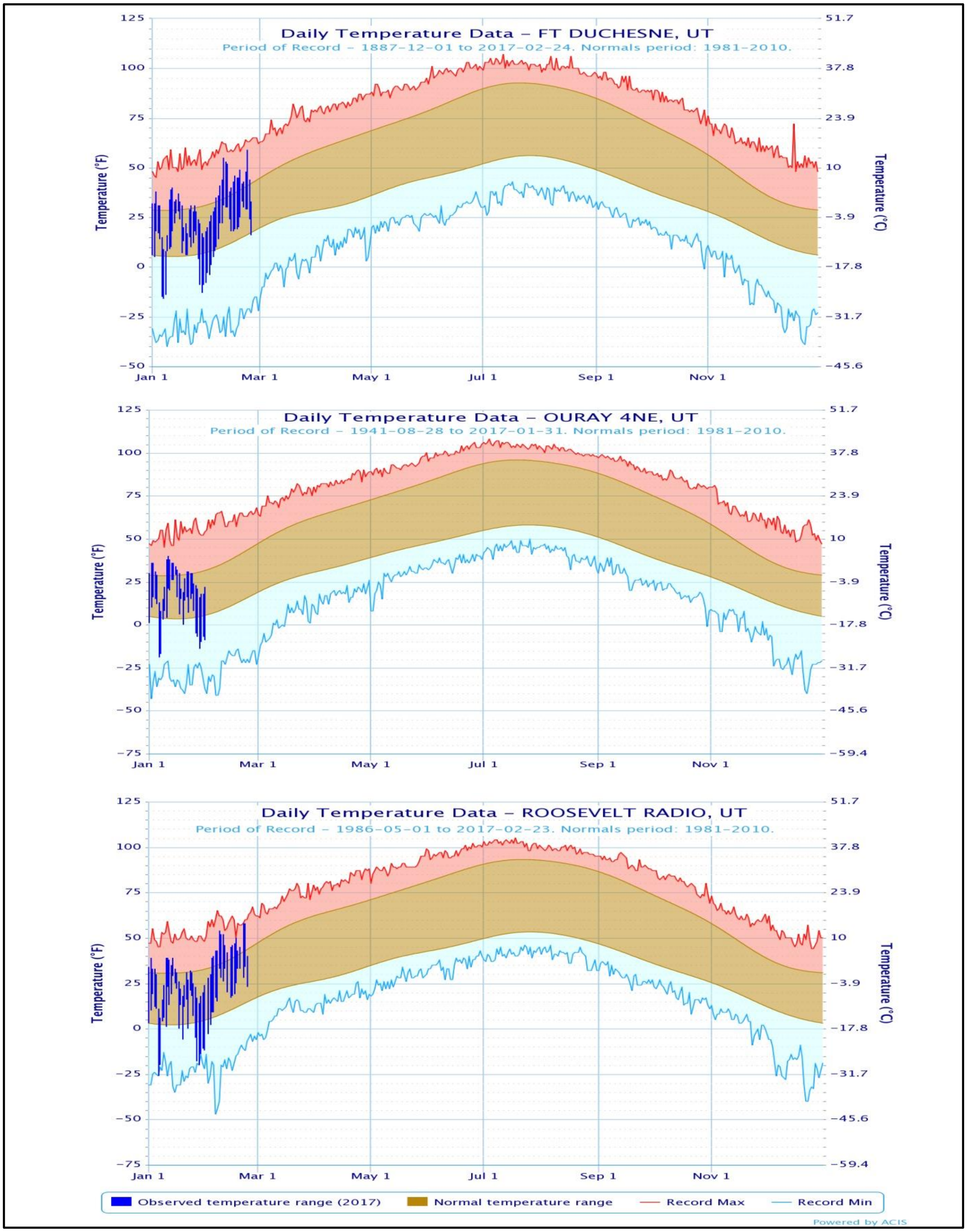

Figure 4. Annual normal and maximum temperatures from the three National Weather Service (NWS) climate stations most proximate to the Pelican Lake watershed; adapted from the Natural Resource Conservation Service Agricultural Applied Climate System (AgACIS).

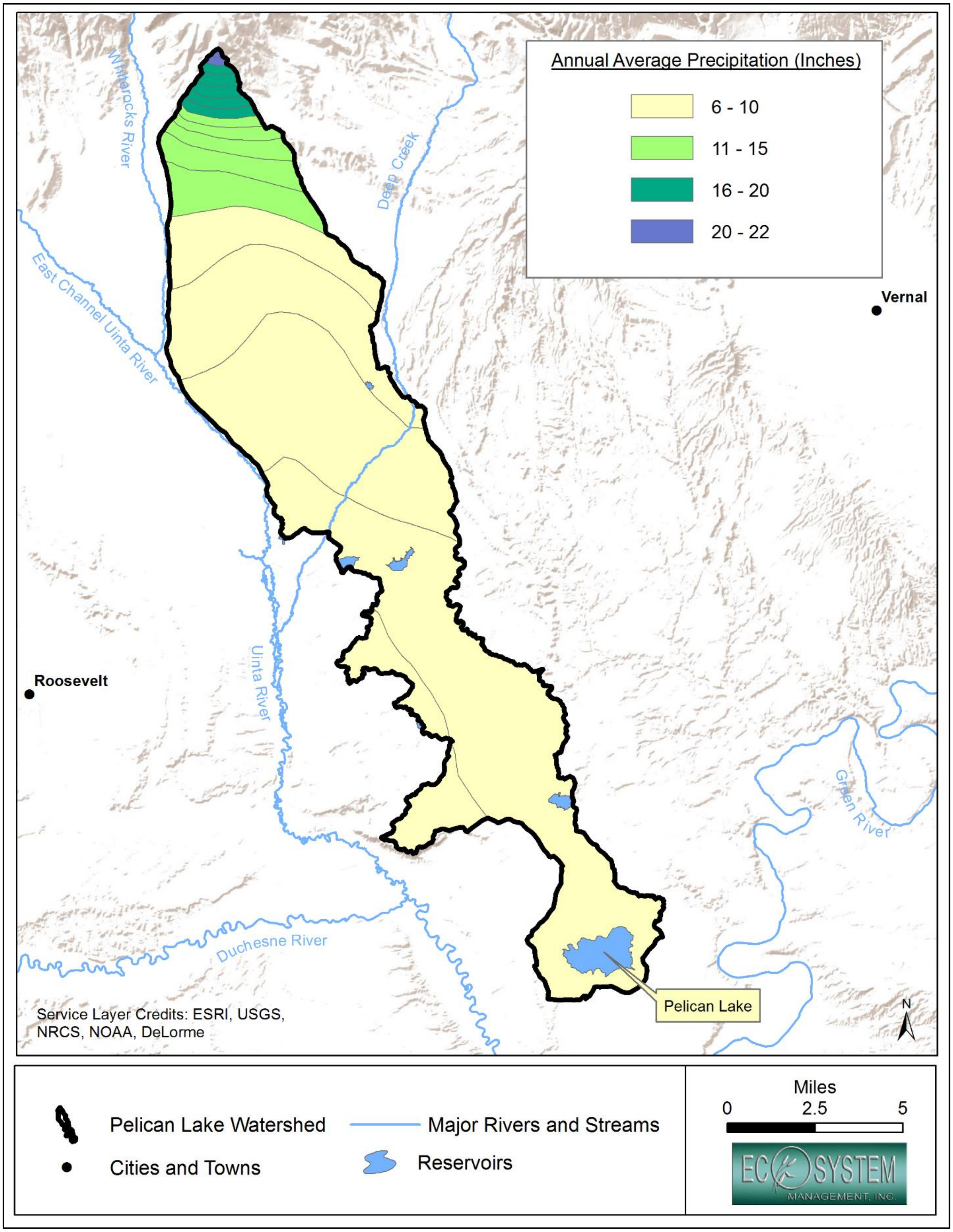

Figure 5. Annual average precipitation for the Pelican Lake watershed, 1981-2010.

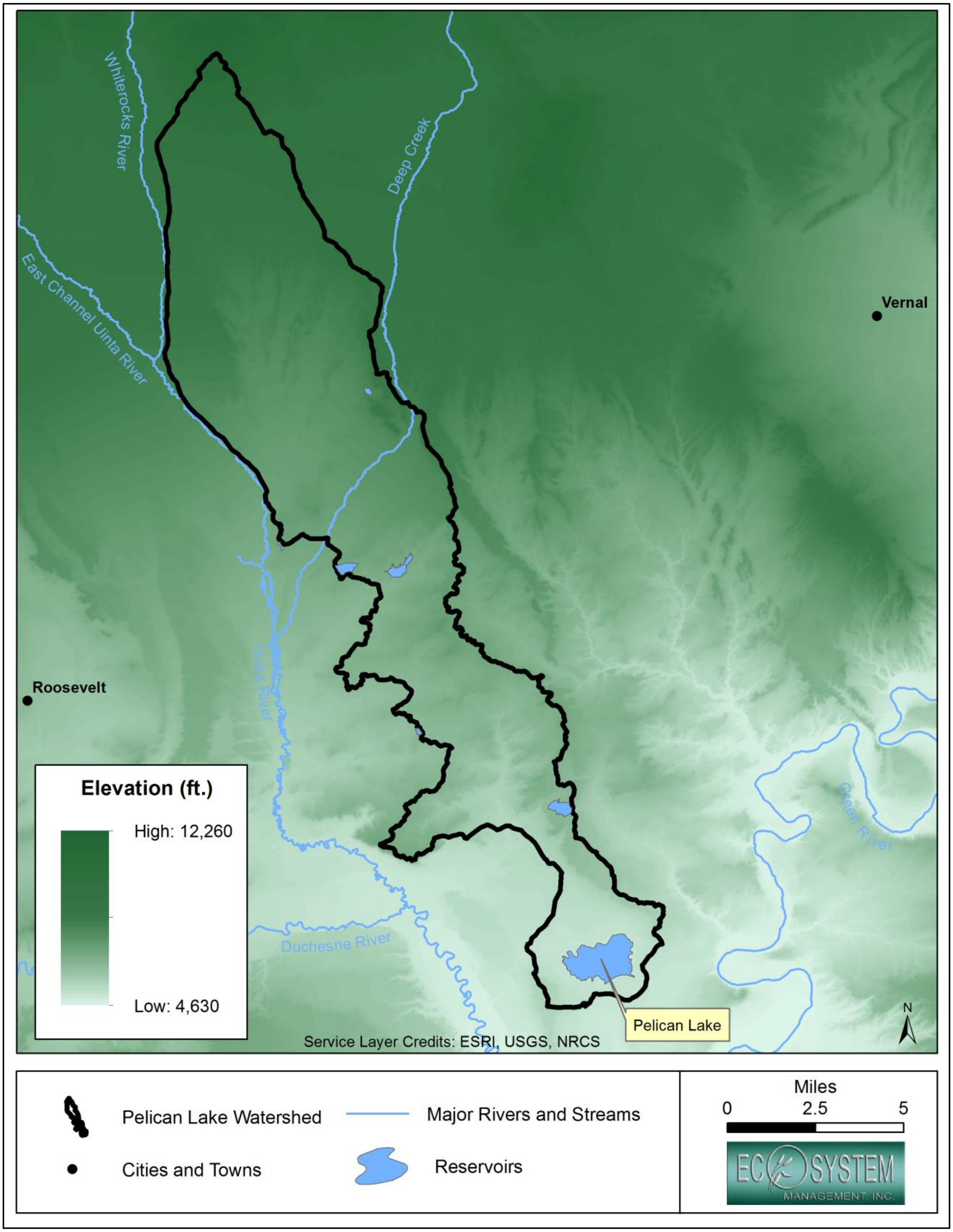

Figure 6. Elevation within the Pelican Lake watershed; drawn from the 30-m digital elevation model of the National Elevation Dataset (NED).

2.5 Hydrology

Hydrology within the Pelican Lake watershed is characterized by both natural surface and groundwater flows, as well as a complex network of manmade water infrastructure developments, which includes reservoirs, diversion dams, canals, and pipelines. Hydrological spatial data for the watershed were obtained from the NRCS via the National Hydrological Dataset, which catalogs and characterizes waterways within the U.S.

No major rivers occur within the watershed. Water is diverted into the watershed from the Uinta and Whiterocks Rivers via diversion dams; canals drawing from these rivers constitute the primary water source in the watershed. Deep Creek is the only natural stream in the watershed with perennial flows in typical years; other natural waterways are intermittent or ephemeral, and usually only support flows for short periods (Figure 7). Natural surface flows occur principally as spring snowmelt from the Uinta Mountains to the north, or as runoff following monsoonal summer storms. Groundwater flows constitute the majority of total flows in natural waterways within the watershed (U.S. Bureau of Reclamation 2005).

The network of canals, pipelines, reservoirs, and other water developments in the watershed is extensive, and substantially influences hydrological processes in the region. This interconnected system stores and transfers water drawn from the Uinta River, Whiterocks River, and Deep Creek for agricultural irrigation. Diversion dams and other structures direct water from these sources into major canals, such as the Ouray Park Canal, Ouray Valley Canal, Whiterocks Canal, and Deep Creek Canal. This water is then distributed into pipelines, smaller canals, ditches, and reservoirs (Figures 7–8). Some canals are actively used and managed to deliver irrigation water, others are no longer used for irrigation but still capture runoff and surface flows. Several small reservoirs hold water year-round; key reservoirs upstream of the lake include Cottonwood Reservoir, Bullock Draw Reservoir, and Brough Reservoir.

2.5.1 Surface Water Resources

Surface water spatial data were obtained from the National Wetlands Inventory (NWI), maintained by the U.S. Fish and Wildlife Service (USFWS), which provides detailed information on the abundance, characteristics, and distribution of wetlands and surface water resources in the U.S. The NWI classifies wetlands into distinct categories, according to their hydrologic, vegetative, and soil characteristics. These characteristics are determined primarily via aerial and Landsat imagery, as well as field site visitations.

Designated NWI surface waters in the Pelican Lake watershed are shown in Figure 9. Geospatial NWI data identifies approximately 3,850 acres of natural surface waters within the watershed, comprising approximately 5 percent of its total area. This acreage is concentrated in three primary areas: the wetland buffer around Pelican Lake itself, the complex of canals, washes, and impoundments surrounding Cottonwood and Bullock Draw Reservoirs, and the area near the confluence of the Whiterocks and Uinta Rivers. Table 3 shows the acreage and frequency of each category of NWI wetland found in the watershed.

2.5.2 Groundwater Resources

Groundwater is below-surface water stored in rock crevices, fractures, and in the soil structure. Groundwater resources may extend from just below the surface to very deep belowground, dependent on the surrounding geological structure of soil and rock formations. Groundwater is a crucial resource in the Pelican Lake watershed. It is the primary source of drinking water for people in the area (particularly rural residents dependent on individual water wells; Glover 1996), and is critical for agricultural irrigation.

Groundwater in the Pelican Lake watershed is part of the Duchesne River-Uinta aquifer, held within the Duchesne River and Uinta geological formations (Glover 1996). The combined thickness of these formations across the Uintah Basin as a whole is approximately 8,000 feet. The aquifer is a complex matrix of both deep groundwater (mineral water which has percolated deep within the aquifer over thousands of years) and shallow groundwater (recently 'recharged' water seeping into shallow sections of the aquifer from surface sources). In addition to collecting and storing surface water, the aquifer also serves as a source of surface water via discharge to springs, streams, wetlands, and, importantly in the Pelican Lake watershed, artificial water bodies such as canals and reservoirs. Discharge to surface waters is most active in alluvial deposits affiliated with perennial streams, where the water table is high and shallow groundwater can readily seep to the surface (Glover 1996).

2.6 Water Districts

Several municipal water districts occur in the Pelican Lake watershed, with additional districts and water suppliers in the area surrounding the watershed (Figure 10). Overseen by the State of Utah, these districts manage water needs and oversee wastewater requirements within their boundaries. Pelican Lake itself is located within the Ouray Park Water Improvement District.

2.7 Water-Related Land Use

The UDWRe maintains a detailed spatial database of land uses in the state that are affiliated with water, particularly with irrigation, water diversions, storage, and other water-use infrastructure (Utah Division of Water Resources 2016a). The database identifies approximately 30,600 acres within the Pelican Lake watershed as supporting water-related land use. The majority of this acreage is irrigated cropland and pasture (Table 4, Figure 11). As Figure 11 shows, water-related land use in the watershed is concentrated in two areas: the valley floodplain associated with the confluence of Deep Creek and the Whiterocks and Uinta Rivers, and the low-lying area around the lake itself. These areas are the agricultural core of the watershed, and likely have impacts on the environmental conditions in Pelican Lake and other downstream water bodies in the watershed (See Chapters 4-5).

Table 3. *Summary of NWI wetland categories in the Pelican Lake watershed.*

Wetland Type	Area (acres)	Number	Percent of Wetland Area
Freshwater Emergent Wetland	1,830	344	47.5
Lake	1,652	16	42.9
Freshwater Forested / Shrub Wetland	248	52	6.4
Freshwater Pond	117	16	3.1
Other Wetland	2	2	< 0.1
Riverine	< 1	3	< 0.1
Total	**3,850**	**553**	**100.0**

Table 4. *Water-related land uses in the Pelican Lake watershed.*

Water-Related Land Use	Area (acres)	Percent of Total Water-Related Land Use Acreage
Idle-irrigated agricultural	7,773.5	25.4
Pasture	7,035.9	23.0
Alfalfa	4,908.4	16.0
Dry land	3,130.5	10.2
Urban / Urban idle-irrigated	2,438.1	8.0
Water	2,286.1	7.5
Riparian	781.9	2.6
Corn	690.6	2.3
Grass hay	453.2	1.5
Grain	436.3	1.4
Other vegetable crops	301.3	1.0
Fallow-irrigated agricultural	120.7	< 1.0
Subirrigated pasture	76.5	< 1.0
Idle-irrigated pasture	64.4	< 1.0
Sorghum	37.7	< 1.0
Oats	37.0	< 1.0
Urban grass	13.7	< 1.0
Sewage lagoon	10.0	< 1.0
Orchard	8.8	< 1.0
Other horticultural	1.9	< 1.0
Total	**30,606**	**100.0**

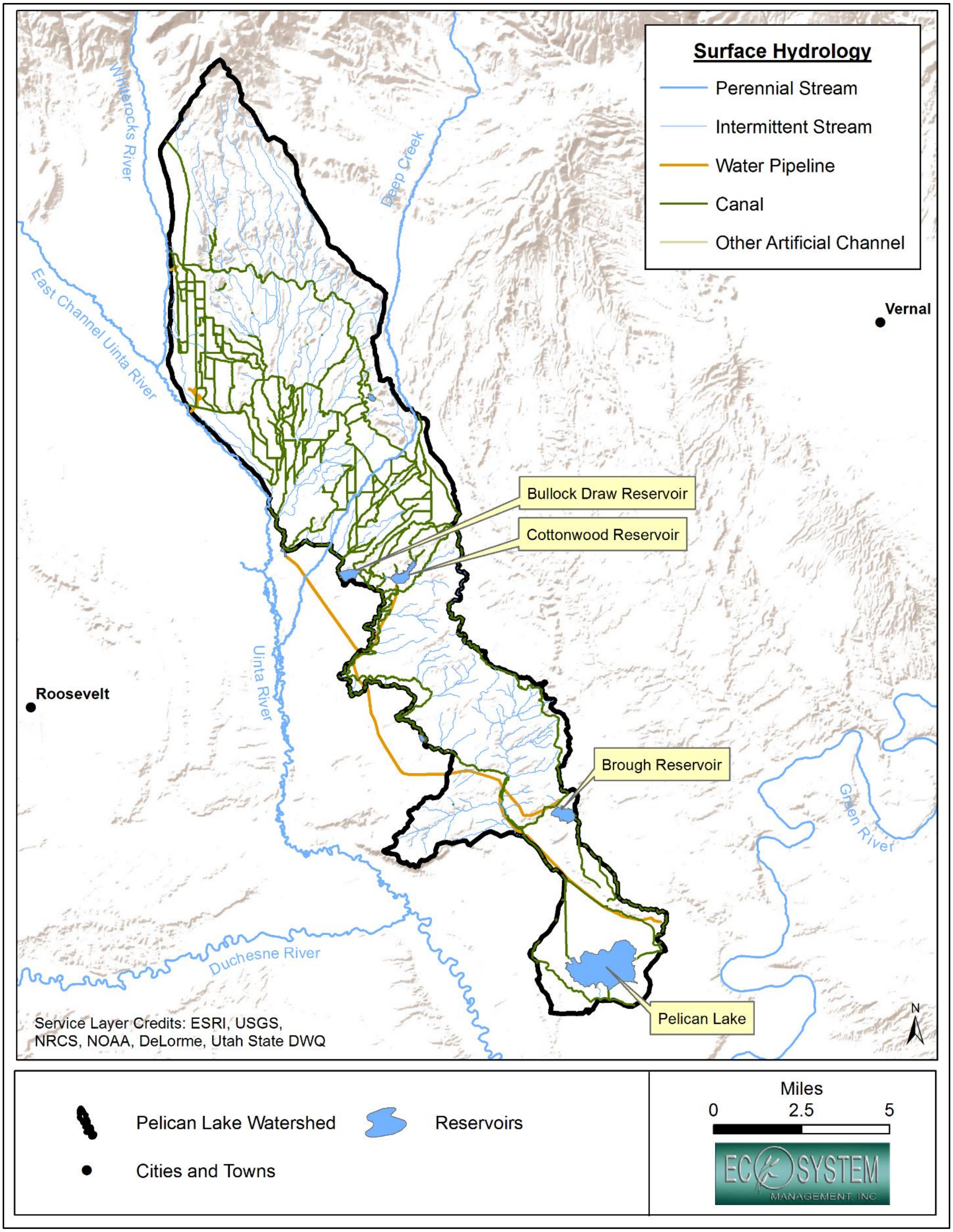

Figure 7. Natural and artificial waterways within the Pelican Lake watershed.

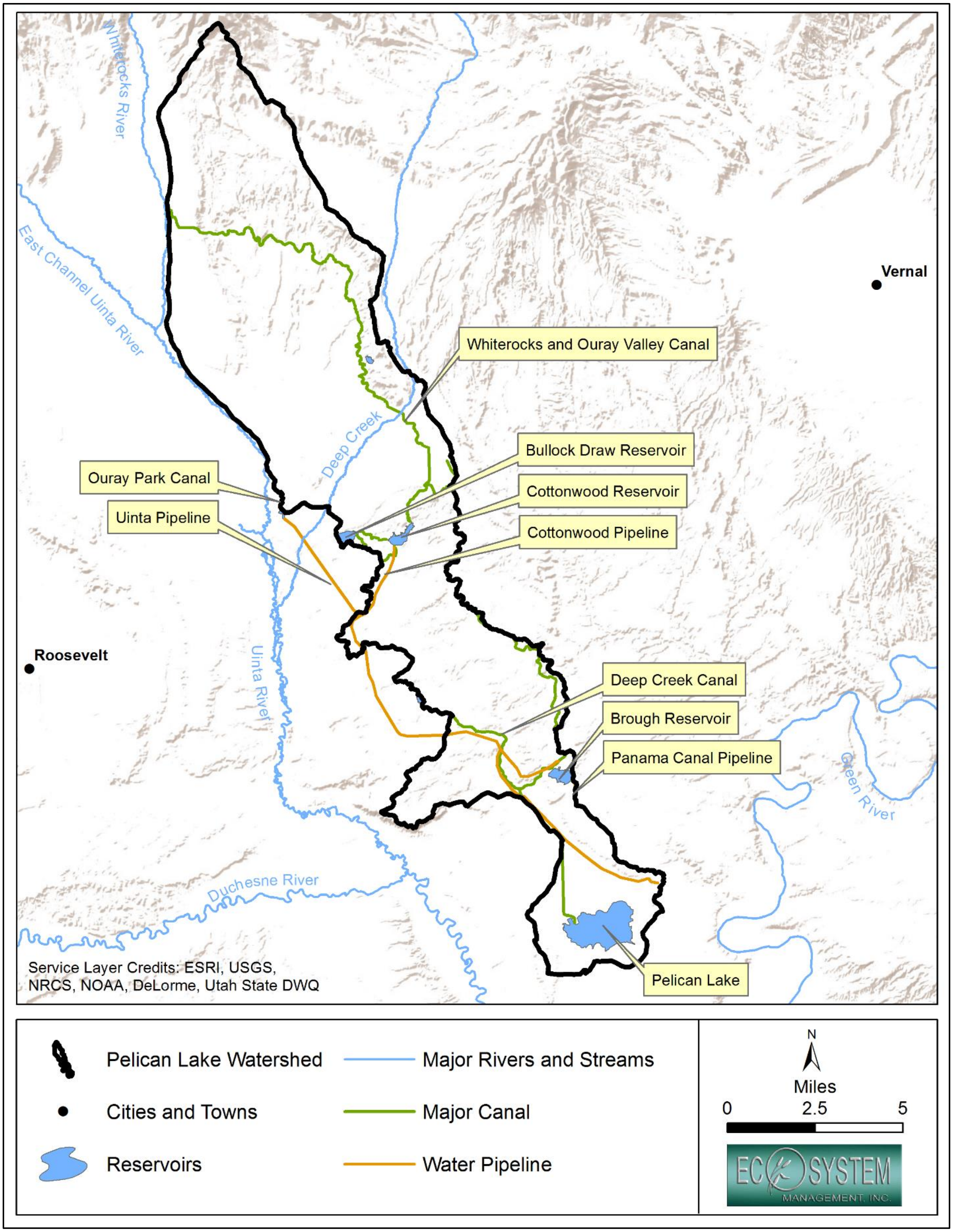

Figure 8. Major canals and water pipelines within the Pelican Lake watershed.

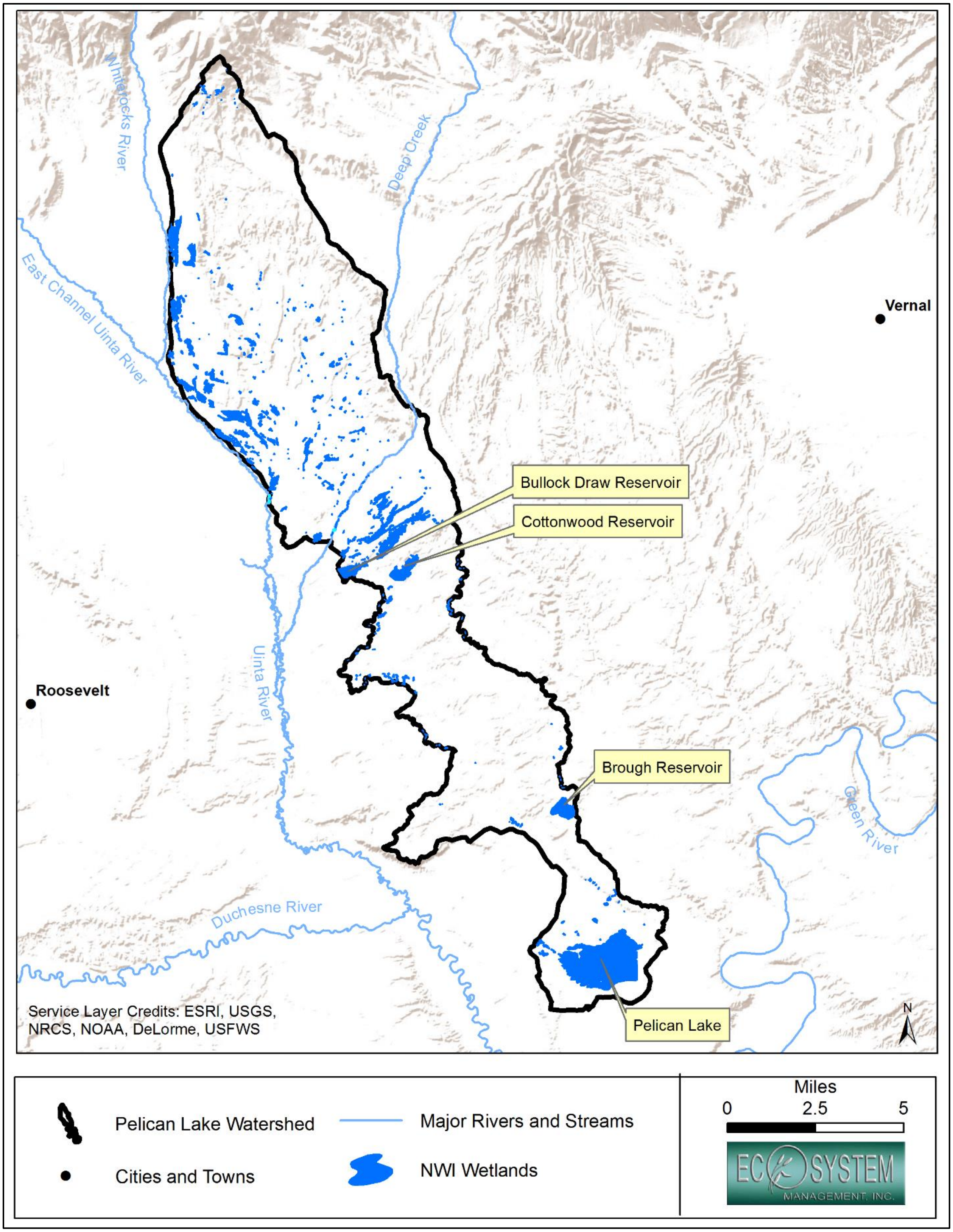

Figure 9. National Wetlands Inventory (NWI) wetland categories in the Pelican Lake watershed.

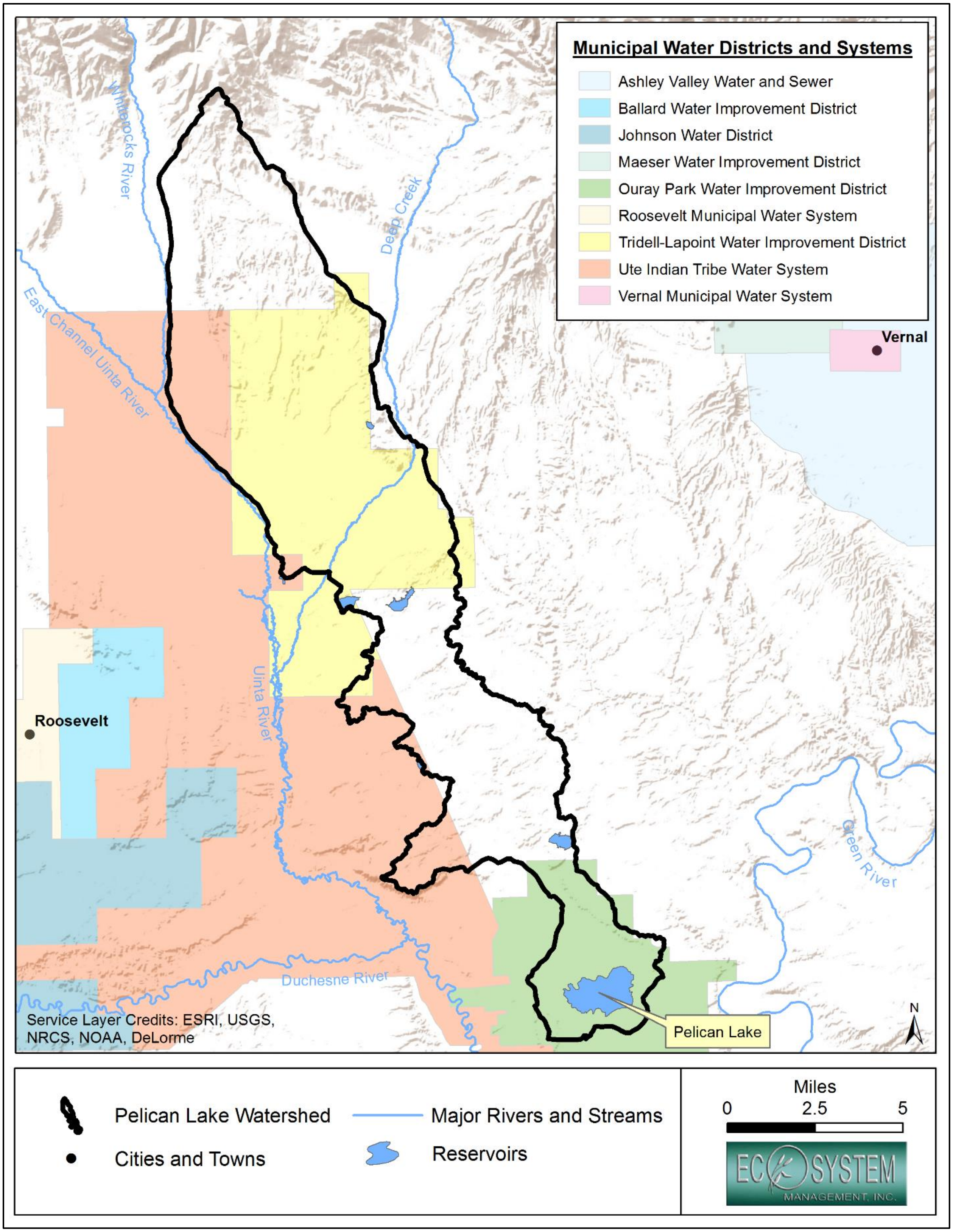

Figure 10. Municipal water systems and districts in the Pelican Lake watershed.

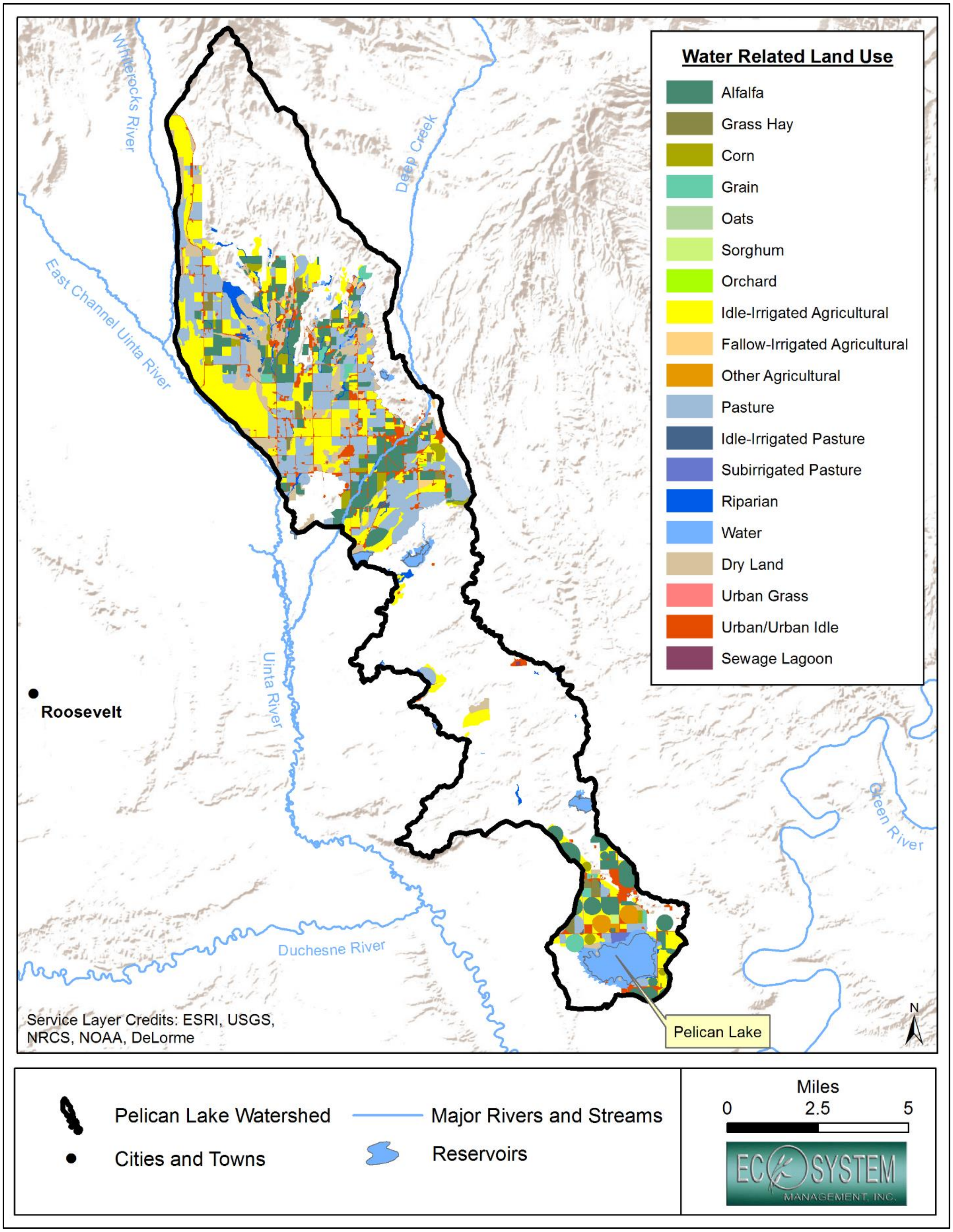

Figure 11. Water-related land use in the Pelican Lake watershed; adapted from Utah DNR data.

2.8 Geology

In partnership with the USGS, the Utah Geological Survey (UGS) has inventoried and mapped geologic data for the state of Utah. The dominant geologic layers in the Pelican Lake watershed are shown in Figure 12 and described in Table 5. The geologic underlayment of the Pelican Lake watershed, as well as the Uintah Basin more broadly, is an important driver of the hydrology, soils, vegetation, ecosystems, and water quality of the area. Many critical environmental issues for the watershed are rooted in or complicated by the area's geology, including sedimentation problems in Pelican Lake, water contamination by selenium, arsenic, and other dissolved solids, and threats associated with oil and gas development.

The dominant geologic units in the watershed, as shown in Figure 12 and Table 5, are the Duchesne River, Uinta, Bridger, Crazy Hollow, and other formations. Geologic formations are primarily sedimentary and marine deposits associated with the Mancos Shale, along with alluvium (deposits of clay, silt, sand, and gravel left by flowing streams), and colluvium (deposits accumulated at the base of steep slopes). Alluvium and colluvium deposits are concentrated in the complex of valleys and deltas in the central area of the watershed, associated with the confluences of the Uinta River, Whiterocks River, and Deep Creek.

Table 5. *Geologic formations in the Pelican Lake watershed (locations shown in Figure 12).*

Unit Symbol	Unit Name and Description	Area (acres)	Percent of Watershed Area
T3	Duchesne River, Uinta, Bridger, Crazy Hollow and other formations	27,715	40.6
Qa	Surficial alluvium and colluvium	23,030	33.7
Qls	Surficial landslide deposits	6,235	9.1
Qao	Surficial older alluvium and colluvium	6,099	8.9
Qg	Surficial glacial deposits	4,045	5.9
Water	Water	808	0.1
Qe	Surficial eolian deposits	140	< 0.1
T4	Salt Lake formation and other valley-filling alluvial, lacustrine, and volcanic units	103	< 0.1
K2	Indianola, Mancos, Frontier, Straight Cuffs, Iron Springs and other formations	82	< 0.1
Total		**68,257**	**100.0**

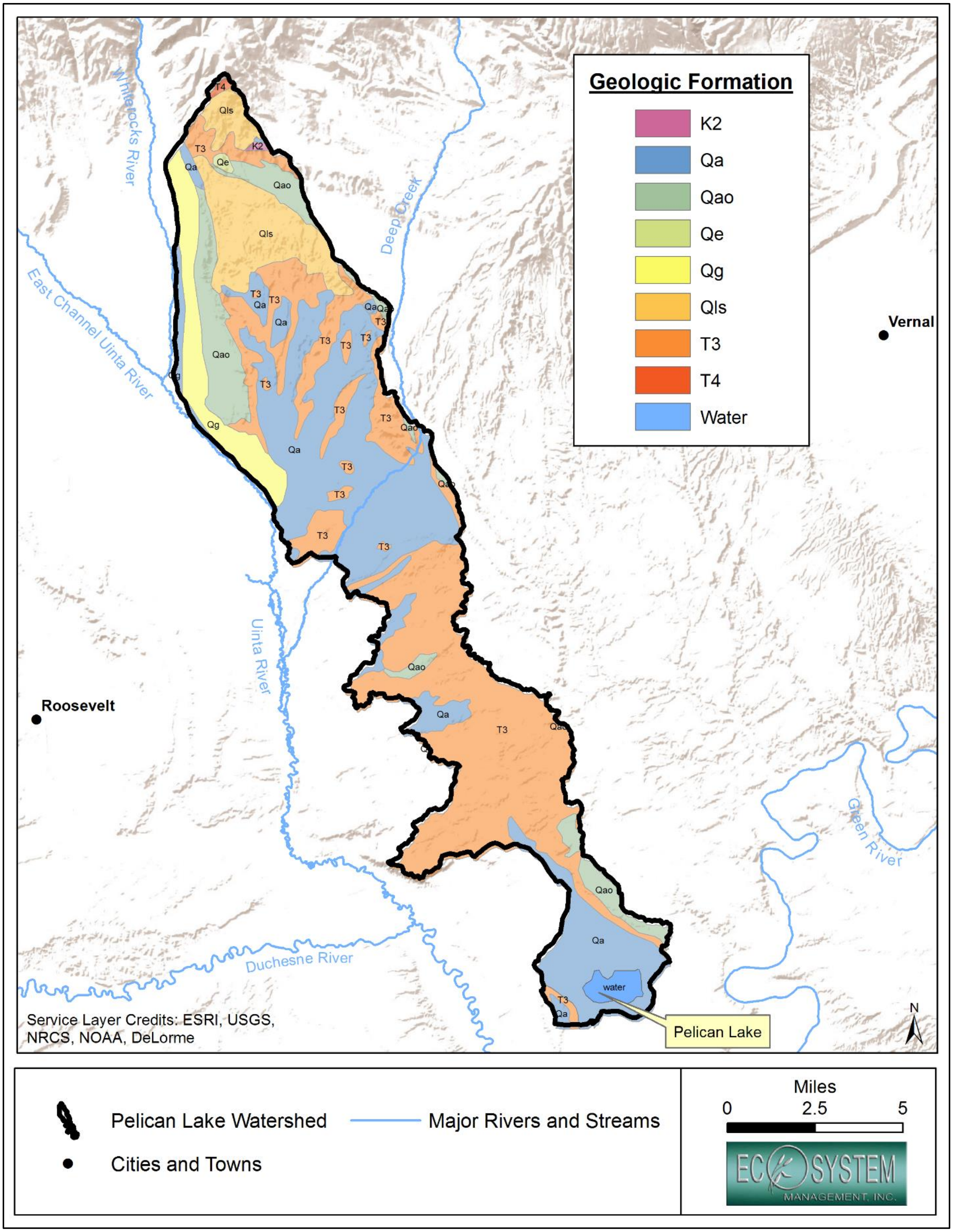

Figure 12. Geologic formations in the Pelican Lake watershed (descriptions of formations are presented in Table 5).

2.9 Energy Resources and Development

The Uintah Basin is an important energy-producing region in the state of Utah, with a long history of energy-related resource extraction. Energy development is a critical sector of the regional economy; Uintah County estimates that the energy industry typically accounts for one in five jobs in the county, though this number fluctuates substantially with the boom-bust cycles of energy development (Uintah County 2012). Energy resources in the Uintah Basin, including the Pelican Lake watershed, are primarily hydrocarbons. These include oil, natural gas, oil shale, and oil sands. The recent maturation of directional drilling and hydrological fracturing technology has led to a boom in conventional oil and natural gas development. Technological innovations are also likely to increase the development of oil shale in the Uintah Basin. The Basin's Green River formation contains the world's largest known oil shale reserves (Utah Office of Energy 2017), but oil shale development has been historically depressed by the difficulty and cost of extraction. Recent technological advancements may open the Uintah Basin to a future oil shale boom, which could significantly impact the environment of the Pelican Lake watershed. Additionally, renewable energy sources such as solar and wind are expected to be increasingly favored components of the area's future energy profile.

An estimated 165 oil and gas wells are contained within the Pelican Lake watershed; these sites are a mix of traditional vertical wells and directionally-drilled hydrological fracturing wells. Approximately 27,000 acres of the watershed are recognized by the UGS as oil and gas fields (Figure 13). Oil and gas development is extensive in the southern half of the watershed, which is located in a region of intense energy development around the confluence of the Green and Uinta Rivers in the Green River formation (Figure 14). This area supports significant current production as well as a large number of historical drilling sites. The BLM Vernal Office has designated the area immediately surrounding Pelican Lake as a "no surface occupancy" area, meaning that active drilling, storage infrastructure, or other above-ground operations cannot occur due to frequent recreation use of the area (BLM 2008).

Energy development in the Pelican Lake watershed is an important factor in the overall environmental condition of the area. Operators in Utah are required to adhere to the environmental protections stipulated by the BLM, which exist to protect water and air quality, wildlife, and landscape characteristics. Permits are issued by the Utah Department of Oil, Gas, and Mining. Despite environmental protections, oil and gas development has considerable potential to degrade water, air, and habitat quality for fish and wildlife. Encouraging best-practice environmental protocols for energy development is therefore an important priority for improving conditions in the watershed (see Chapter 5).

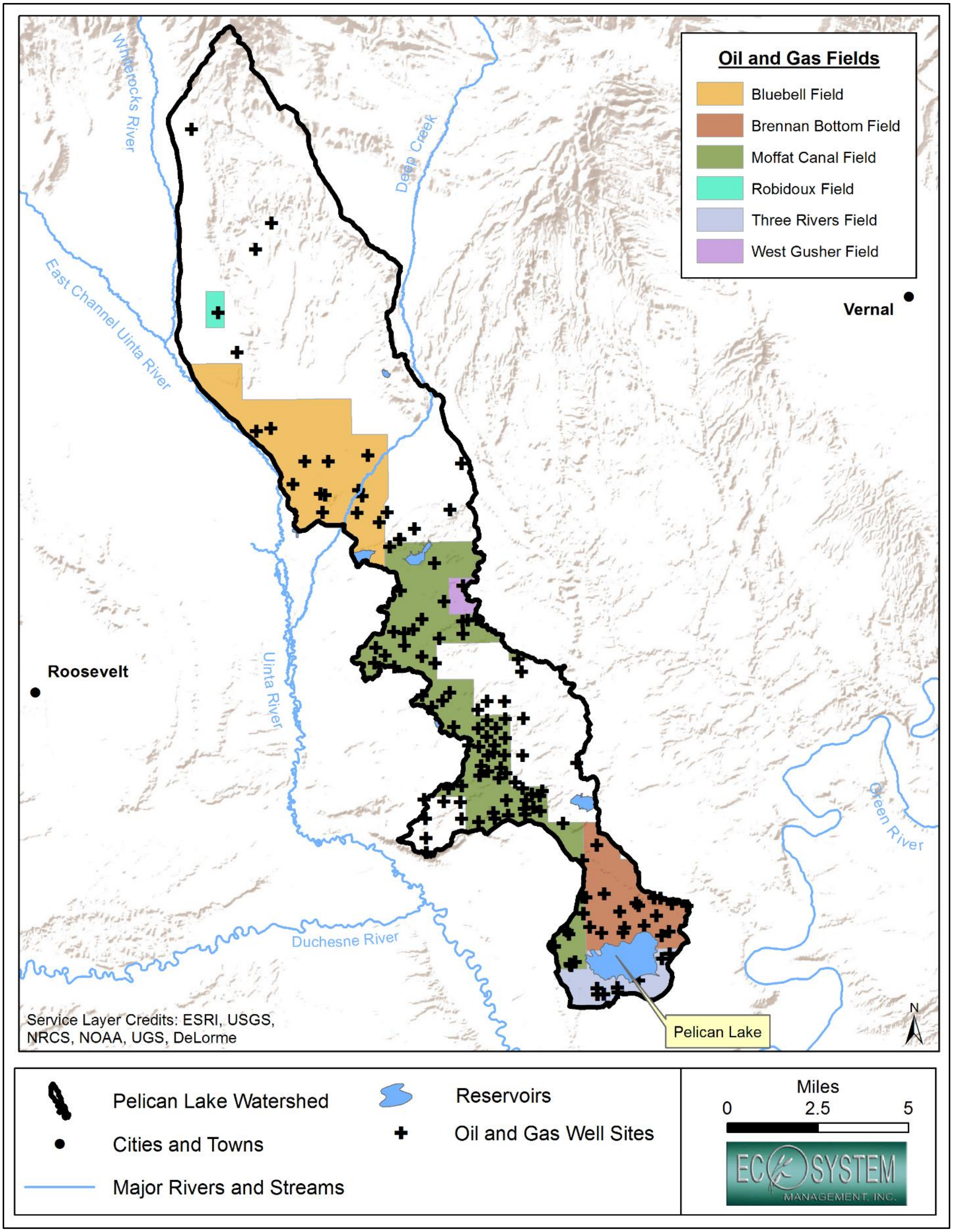

Figure 13. Oil and gas development in the Pelican Lake watershed.

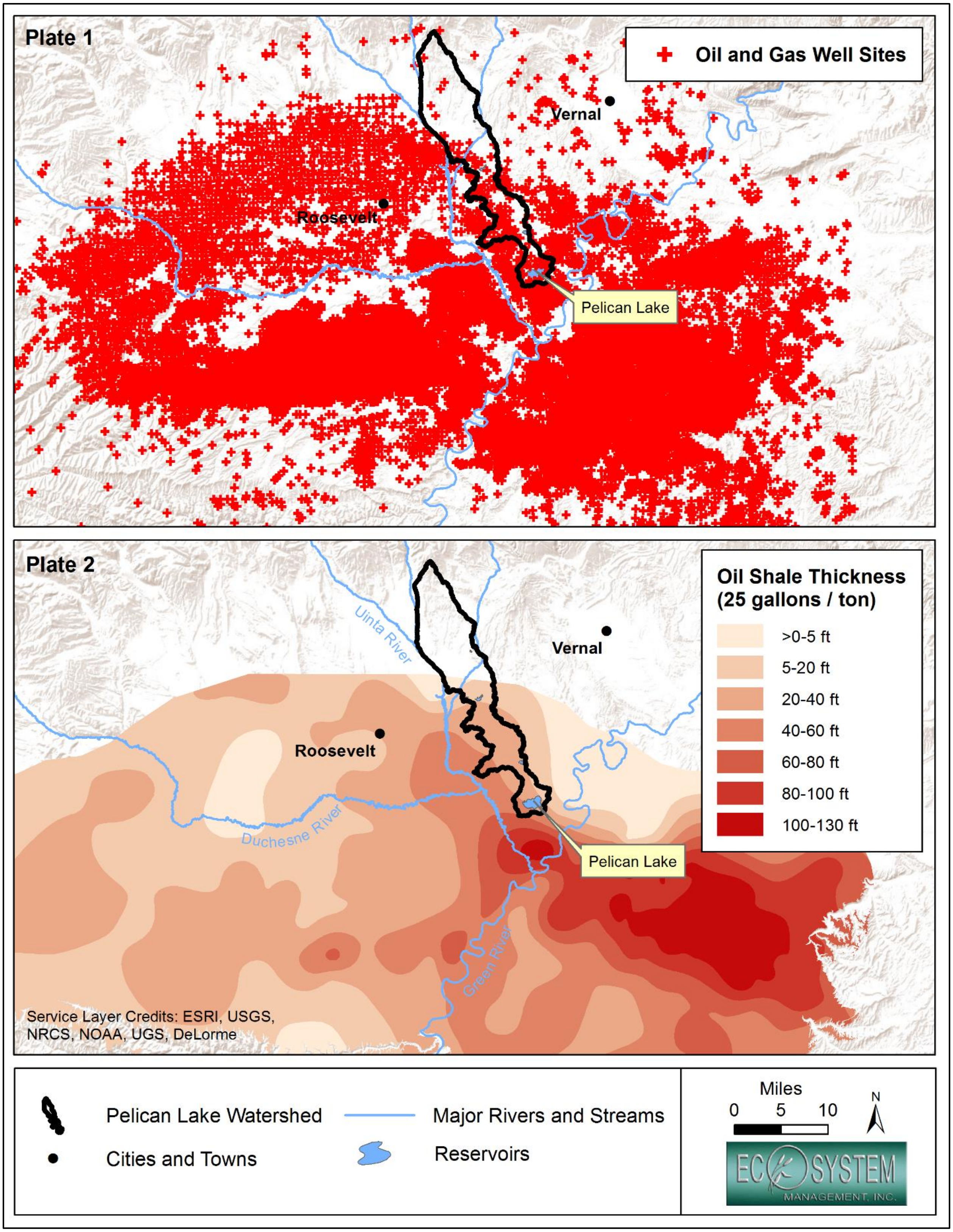

Figure 14. Oil and gas wells (Plate 1) and oil shale reserves (Plate 2) surrounding the Pelican Lake watershed.

2.10 Vegetation and Land Cover

Datasets representing land cover and vegetation classifications depict dominant ecosystems and plant community types at various spatial scales and levels of precision. Land cover classifications divide areas into generalized ecological categories, such as *Deciduous Forest* and *Cultivated Crops*. Vegetation classifications describe areas in more precise detail, organizing sites with similar vegetation into hierarchical, progressively finer categories, which are typically based on groups of commonly co-occurring species and environmental variables (such as elevation, geology, and climate). The land cover *Deciduous Forest*, for example, may be subdivided into specific classes of deciduous forest, such as "Cottonwood/Willow Riparian Forest" and "Rocky Mountain Aspen Woodland." Several national spatial datasets are available to describe land cover and vegetation conditions within the Pelican Lake watershed.

2.10.1 *Land Cover Classifications*

The National Land Cover Dataset (NLCD) was used to identify and map the most generalized land cover classifications that occur in the watershed (Homer et al. 2015). The NLCD divides land cover across the U.S. into 16 broad categories, using Landsat imagery and data provided by a consortium of federal agencies. Because NLCD classifications are very general and presented at 30-meter resolution, they can mask important distinctions between sites. However, this same broad-brush approach also provides a straightforward, easily-interpretable representation of the conditions and overall makeup of the focal area.

The Pelican Lake watershed contains 15 of the 16 NLCD land cover classifications (Table 6, Figure 15) Approximately 31,370 acres (46 percent) of the watershed is classified as Shrub/Scrub land cover; 19,246 acres (28 percent) as Pasture/Hay; and 7,634 acres (11 percent) as Evergreen Forest. The remainder of the watershed is classified as grassland/herbaceous, wetlands, open water, developed open space, and other land cover classifications with limited extents.

Table 6. National Land Cover Dataset classifications within the watershed study area.

NLCD Classification	Description	Area (acres)	Percent of Watershed Area
Shrub/Scrub	Shrubs less than 16 feet tall with canopy typically greater than 20 percent of total vegetation. This class includes shrubs and trees in early successional stages or stunted from environmental conditions.	31,370	45.9
Pasture/Hay	Grasses, legumes, or mixtures planted for livestock grazing or the production of seed or hay crops on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.	19,246	28.2
Evergreen Forest	Trees greater than 16 feet tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.	7,634	11.2
Grassland/Herbaceous	Gramanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation cover. These areas are not subject to tilling but are used for grazing.	2,776	4.0
Woody Wetlands	Forests or shrublands account for greater than 20 percent and the soil is periodically covered with water.	2,602	3.8
Open Water	Open water, usually less than 25 percent cover of vegetation or soil	1,634	2.4
Developed, Open Space	A mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of cover. These areas commonly include large-lot, single-family housing units, parks, golf courses, and vegetation planted in developments for recreation, erosion control, or aesthetics.	1,610	2.3
Barren Land (Rock/Sand/Clay)	Bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other earthen material. Vegetation accounts for less than 15 percent of total.	658	< 0.1
Developed, Low Intensity	A mixture of constructed materials and vegetation. Impervious surfaces account for 20 to 49 percent of total cover. These areas commonly include single-family housing units.	635	< 0.1
Cultivated Crops	Production of annual crops and also perennial woody crops. Crops accounts for greater than 20 percent of total vegetation. This class also includes land being tilled.	68	< 0.1
Deciduous Forest	Trees greater than 16 feet tall and greater than 20 percent of vegetation cover. More than 75 percent of the tree species shed foliage in response to a seasonal change.	40	< 0.1
Emergent Herbaceous Wetlands	Perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically covered with water.	12	< 0.1
Mixed Forest	Forested areas, individually composing less than 0.1 percent of the study area.	2	< 0.1
Developed, Medium Intensity	A mixture of constructed materials and vegetation. Impervious surfaces account for 50 to 79 percent of the total cover. These areas commonly include single-family housing units.	2	< 0.1
Developed, High Intensity	Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100 percent of total cover.	1	< 0.1
Total		**68,290**	**100.0**

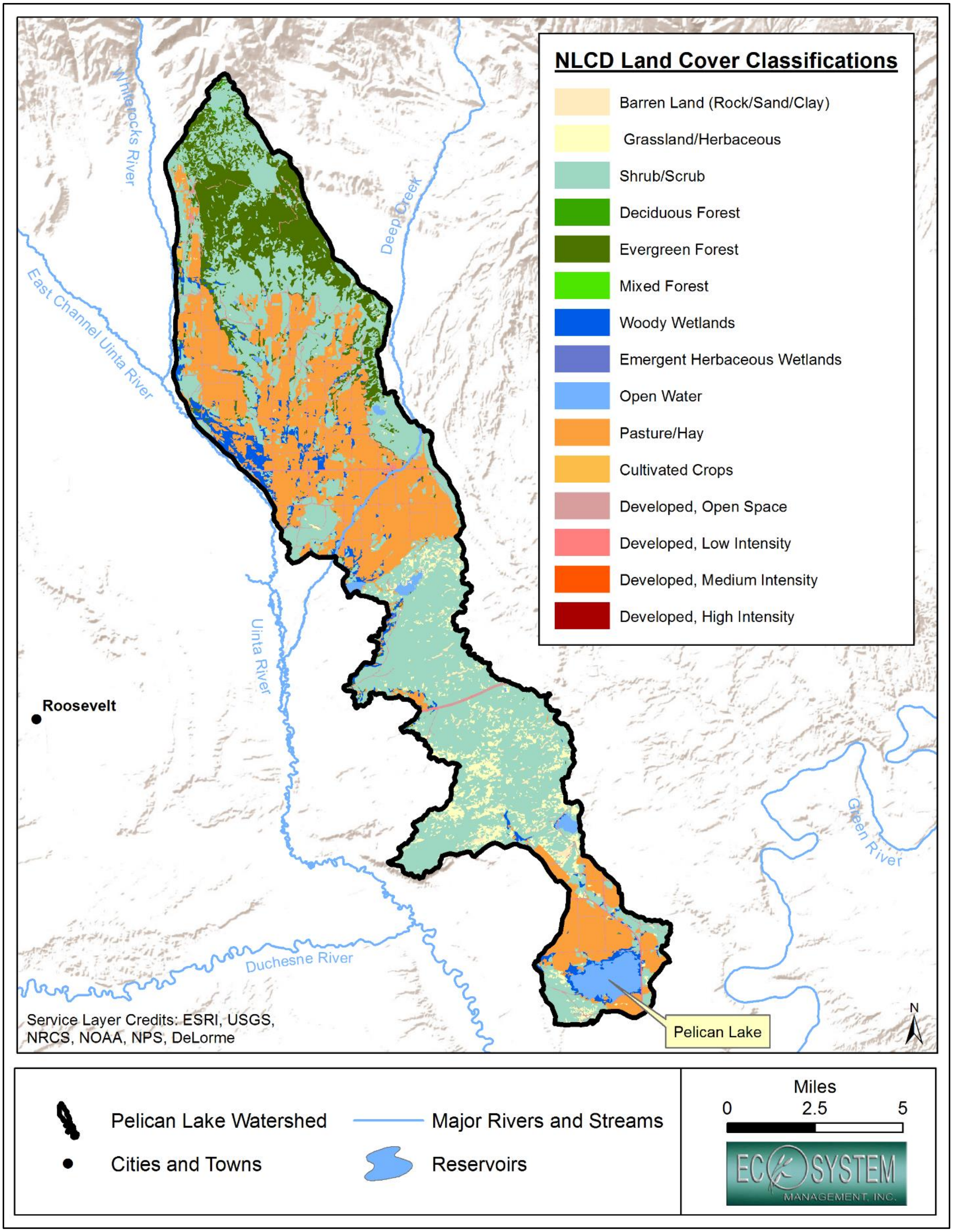

Figure 15. National Land Cover Dataset (NLCD) land cover classes in the Pelican Lake watershed.

2.10.2 *GAP Vegetation Classifications*

A more precise representation of vegetation within the Pelican Lake watershed is available via the USGS GAP Analysis Program (GAP, USGS 2017). The GAP system enables vegetation to be categorized at a very fine scale: the most detailed GAP vegetation level (GAP Level 3) splits the U.S. into 580 potential vegetation classes, wherein similar plant communities influenced by similar ecological processes are grouped together as a class. The data used to create GAP classes is derived from Landsat imagery, in conjunction with digital elevation model datasets (which incorporate elevation, landform, aspect, and other geospatial features). The Pelican Lake watershed contains 27 GAP Level 3 classes, though the bulk of the watershed is dominated by three of these: *Cultivated Cropland*, *Inter-Mountain Basins Big Sagebrush Shrubland,* and *Colorado Plateau Pinyon-Juniper Shrubland* (Table 7, Figure 16). Brief descriptions of each dominant vegetation class are presented below, adapted from the NatureServe descriptions of GAP Ecological Systems Classifications (NatureServe 2009).

Cultivated Cropland

Cultivated cropland comprises land in row crops or close-grown crops, as well as other cultivated cropland, for example, hay land or pastureland that is in a rotation with row or close-grown crops. This classification excludes non-cultivated cropland, such permanent hay land and horticultural cropland. Major natural resource concerns facing cropland include: (1) erosion by wind and water, (2) maintaining and enhancing soil quality, (3) water quality from nutrient and pesticides runoff and leaching, and (4) managing the quantity of water available for irrigation.

Inter-Mountain Basins Big Sagebrush Shrubland

Big sagebrush shrublands are one of the most widespread ecological systems in the western U.S., found in basins, on plains and in foothills between 1,500 and 2,300 meters (approximately 4,920–7,550 feet) in elevation. The soils are deep, well-drained, and non-saline. The most important sage species are Wyoming or basin big sagebrush (*Artemisia* spp.); other common shrubs include bitterbrush (*Purshia tridentata*), rabbitbrush (*Ericameria nauseosa*), or mountain snowberry (*Symphoricarpos oreophilus*). Shrubs are the dominant vegetation, with grasses making up less than 25 percent of the cover, distinguishing this from the Intermountain Basins Big Sagebrush Steppe system, which has higher grass cover. In recent years this system has been widely invaded by non-native annual grasses or weeds, in particular cheatgrass (*Bromus tectorum*), which changes the fire dynamics within the system.

Colorado Plateau Pinyon-Juniper Shrubland

This ecological system is characteristic of the rocky mesatops and slopes on the Colorado Plateau and western slope of Colorado, but these stunted-tree shrublands may extend further upslope along the low-elevation margins of taller pinyon-juniper woodlands. Sites are drier than Colorado Plateau Pinyon-Juniper Woodland. Substrates are shallow/rocky and shale soils at lower elevations between 1,200 and 2,000 meters (approximately 3,940–6,560 feet). Sparse examples of the system grade into Colorado Plateau Mixed Bedrock Canyon and Tableland. The vegetation is dominated by dwarfed (usually <3 m tall) pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) trees, forming extensive tall shrublands in the region along low-elevation margins of pinyon—juniper woodlands.

Table 7. USGS GAP vegetation classes within the watershed study area.

GAP Vegetation Classification	Area (acres)	Percent of Watershed Area
Cultivated Cropland	23,311	34.1
Inter-Mountain Basins Big Sagebrush Shrubland	17,832	26.1
Colorado Plateau Pinyon-Juniper Shrubland	9,884	14.5
Inter-Mountain Basins Mixed Salt Desert Scrub	3,028	4.4
Introduced Upland Vegetation - Annual Grassland	2,296	3.4
Colorado Plateau Pinyon-Juniper Woodland	2,052	3.0
Open Water (Fresh)	1,930	2.8
Inter-Mountain Basins Greasewood Flat	1,771	2.6
Rocky Mountain Lower Montane Riparian Woodland and Shrubland	1,729	2.5
Inter-Mountain Basins Montane Sagebrush Steppe	1,716	2.5
Colorado Plateau Mixed Bedrock Canyon and Tableland	1,291	1.9
Developed, High Intensity	355	0.5
Developed, Low Intensity	274	0.4
Colorado Plateau Mixed Low Sagebrush Shrubland	240	0.4
Rocky Mountain Cliff, Canyon and Massive Bedrock	112	0.2
Introduced Riparian and Wetland Vegetation	108	0.2
Inter-Mountain Basins Semi-Desert Shrub Steppe	104	0.2
Inter-Mountain Basins Shale Badland	92	0.1
Southern Rocky Mountain Montane-Subalpine Grassland	76	< 0.1
Rocky Mountain Alpine-Montane Wet Meadow	52	< 0.1
Rocky Mountain Lower Montane-Foothill Shrubland	12	< 0.1
Rocky Mountain Gambel Oak-Mixed Montane Shrubland	9	< 0.1
Inter-Mountain Basins Semi-Desert Grassland	8	< 0.1
Southern Rocky Mountain Ponderosa Pine Woodland	4	< 0.1
Rocky Mountain Subalpine-Montane Riparian Shrubland	2	< 0.1
Inter-Mountain Basins Mat Saltbush Shrubland	2	< 0.1
Rocky Mountain Aspen Forest and Woodland	1	< 0.1
Total	**68,294**	**100.0**

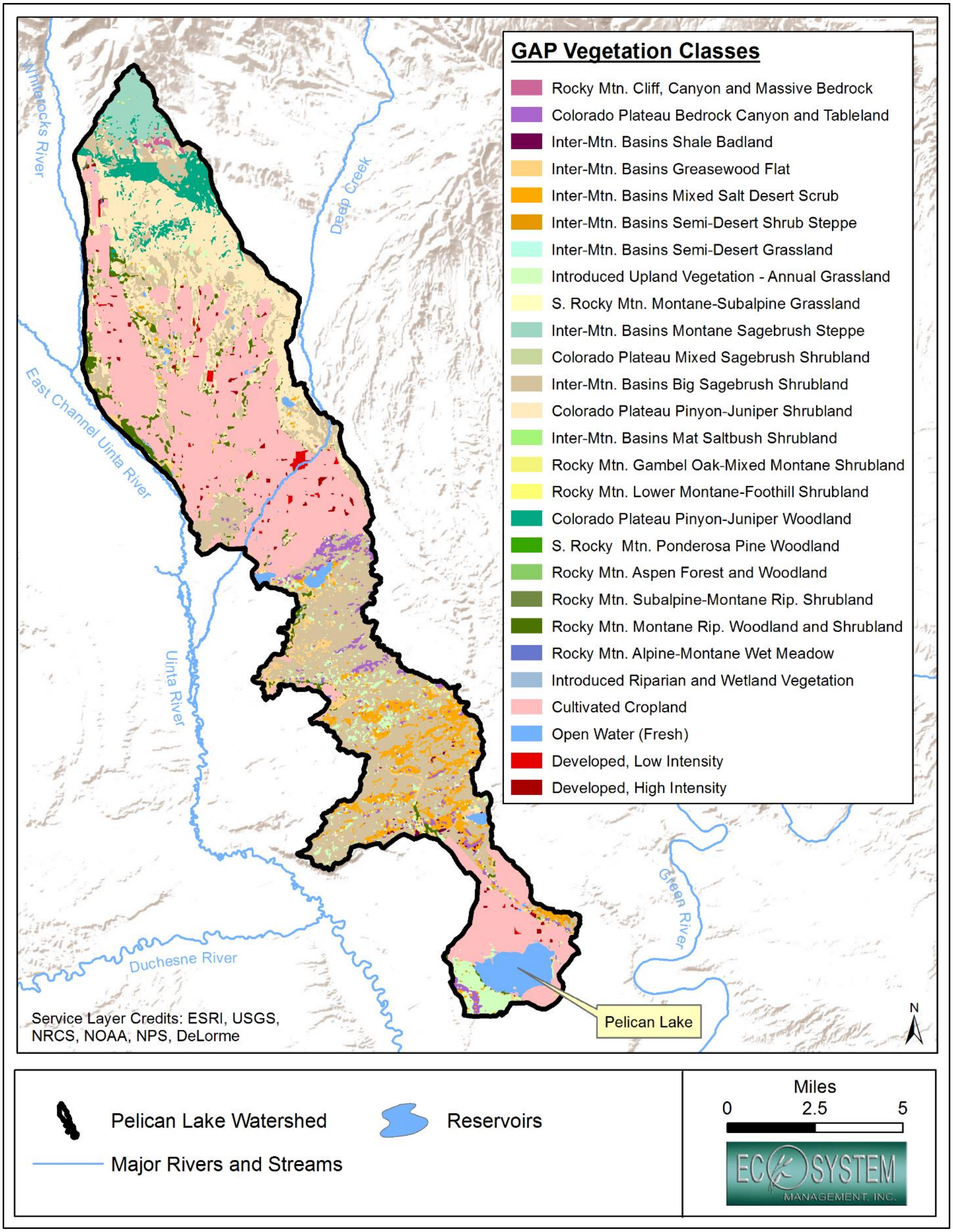

Figure 16. USGS GAP Analysis Program (GAP) land cover classes in the Pelican Lake watershed.

2.10.3 *Exotic and Invasive Vegetation*

Numerous non-native, invasive, noxious, or otherwise undesirable plant species occur within the Pelican Lake watershed. These species are considered undesirable by landowners and land managers due to their negative impacts on agriculture, ecosystem integrity, biological diversity, and forage conditions for wildlife and livestock. Undesirable plant species may be either native or non-native, though non-native species generally have greater capacity to disrupt native ecosystems and agricultural lands. Non-native plants that become invasive often lack natural controls from herbivory and disease, exhibit colonization and growth strategies that favor rapid spread (particularly in disturbed sites), and thrive under drought conditions and in degraded soils (Van Kleunen et al. 2010, Vila et al. 2011). The consequences of invasive plant encroachment for native ecosystems can be severe, and colonization of grazing and crop lands by invasive or undesirable plant species can significantly reduce yields, forage quality, stocking capacity, and land value.

The Utah Department of Agriculture and Food (UDAF) coordinates with county and local officials, landowners, and management agencies to locate weed infestations, manage serious outbreaks, and encourage control measures for noxious weeds. The UDAF focuses these efforts on species listed on its Noxious Weed List, representing species considered to be detrimental, destructive, injurious, or poisonous (UDAF Utah Weed Control Association 2017). These species are shown in Table 8, but not all species on this list currently occur in the Pelican Lake watershed. The Noxious Weed List is divided into four categories. Class 1 weeds are species considered to be major threats to the State, but currently occur as only very small populations or have not yet been documented in Utah. The UDAF prioritizes complete eradication of Class 1 weed species. Class 2 weed species are also considered a serious threat to the state, but are sufficiently widespread that statewide eradication is unlikely; local control or eradication may be possible for Class 2 weeds. Class 3 weed species are sufficiently widespread that eradication is not possible in most locations, and the UDAF prioritizes containment to minimize further spread. Class 4 weeds are species that pose a threat via potential sale or propagation in the nursery and greenhouse industry, and are prohibited for such use in the state of Utah.

Invasive weeds have been documented in the Pelican Lake watershed by various management and research agencies, including the UDAF, DNR, and BLM. Spatial data of these occurrences has been compiled by the UDAF and is shown in Figure 17. It is important to note that Figure 17 shows only the subset of invasive plant occurrences in the watershed that have been mapped, rather than a complete representation of all invasive plant colonies that may be present. This likely accounts for the concentration of locations in Figure 17 around the Whiterocks and Ouray Park Canal. Moreover, several invasive or undesirable plant species occur within the watershed that are not shown in Figure 17 and/or Table 8, including problematic and highly invasive species such as Russian thistle (*Salsola* spp.), Russian olive (*Elaegnus augustifolia*), and buffalobur (*Solanum rostratum*).

Table 8. State of Utah Noxious Weed List; adapted from UDAF Utah Weed Control Association (2017).

Scientific Name	Common Name
Class 1	
Common crupina	*Crupina vulgaris*
African rue	*Peganum harmala*
Small bugloss	*Anchusa arvensis*
Mediterranean sage	*Salvia aethiopis*
Spring millet	*Milium vernale*
Syrian beancaper	*Zygophyllum fabago*
Ventenata (North Africa grass)	*Ventenata dubia*
Plumeless thistle	*Carduus acanthoides*
Malta starthistle	*Centaurea melitensis*
Camelthorn	*Alhagi maurorum*
Garlic mustard	*Alliaria petiolata*
Purple starthistle	*Centaurea calcitrapa*
Goatsrue	*Galega officinalis*
African mustard	*Brassica tournefortii*
Giant reed	*Arundo donax*
Japanese knotweed	*Polygonum cuspidatum*
Blueweed (viper's bugloss)	*Echium vulgare*
Elongated mustard	*Brassica elongata*
Common St. Johnswort	*Hypericum perforatum*
Oxeye daisy	*Leucanthemum vulgare*
Cutleaf vipergrass	*Scorzonera laciniata*
Class 2	
Leafy spurge	*Euphorbia esula*
Medusahead	*Taeniatherum caput-medusae*
Rush skeletonweed	*Chondrilla juncea*
Spotted knapweed	*Centaurea stoebe*
Purple loosestrife	*Lythrum salicaria*
Squarrose knapweed	*Centaurea virgata*
Dyers woad	*Isatis tinctoria*
Yellow starthistle	*Centaurea solstitialis*
Yellow toadflax	*Linaria vulgaris*
Diffuse knapweed	*Centaurea diffusa*
Black henbane	*Hyoscyamus niger*
Dalmation toadflax	*Linaria dalmatica*
Class 3	
Russian knapweed	*Acroptilon repens*
Houndstounge	*Cynoglossum officianale*
Perennial pepperweed (tall whitetop)	*Lepidium latifolium*
Phragmites (common reed)	*Phragmites australis* spp.
Tamarisk (saltcedar)	*Tamarix* spp.
Hoary cress	*Cardaria* spp.
Canada thistle	*Cirsium arvense*
Poison hemlock	*Conium maculatum*
Musk thistle	*Carduus nutans*
Quackgrass	*Elymus repens*
Jointed goatgrass	*Aegilops cylindrica*
Bermudagrass	*Cynodon dactylon*
Johnson Grass	*Sorghum halepense*

Table 8, continued. State of Utah Noxious Weed List; adapted from UDAF Utah Weed Control Association (2017).

Scientific Name	Common Name
Class 3 (continued)	
Columbus Grass	Sorghum almum
Scotch thistle (cotton thistle)	*Onopordum acanthium*
Field bindweed (wild morning-glory)	*Convolvulus* spp.
Puncturevine (goathead)	*Tribulus terrestris*
Class 4	
Cogongrass (Japanese blood grass)	*Imperata cylindrica*
Myrtle spurge	*Euphorbia myrsinites*
Dames Rocket	*Hesperis matronalis*
Scotch broom	*Cytisus scoparius*
Russian olive	*Elaeagnus angustifolia*

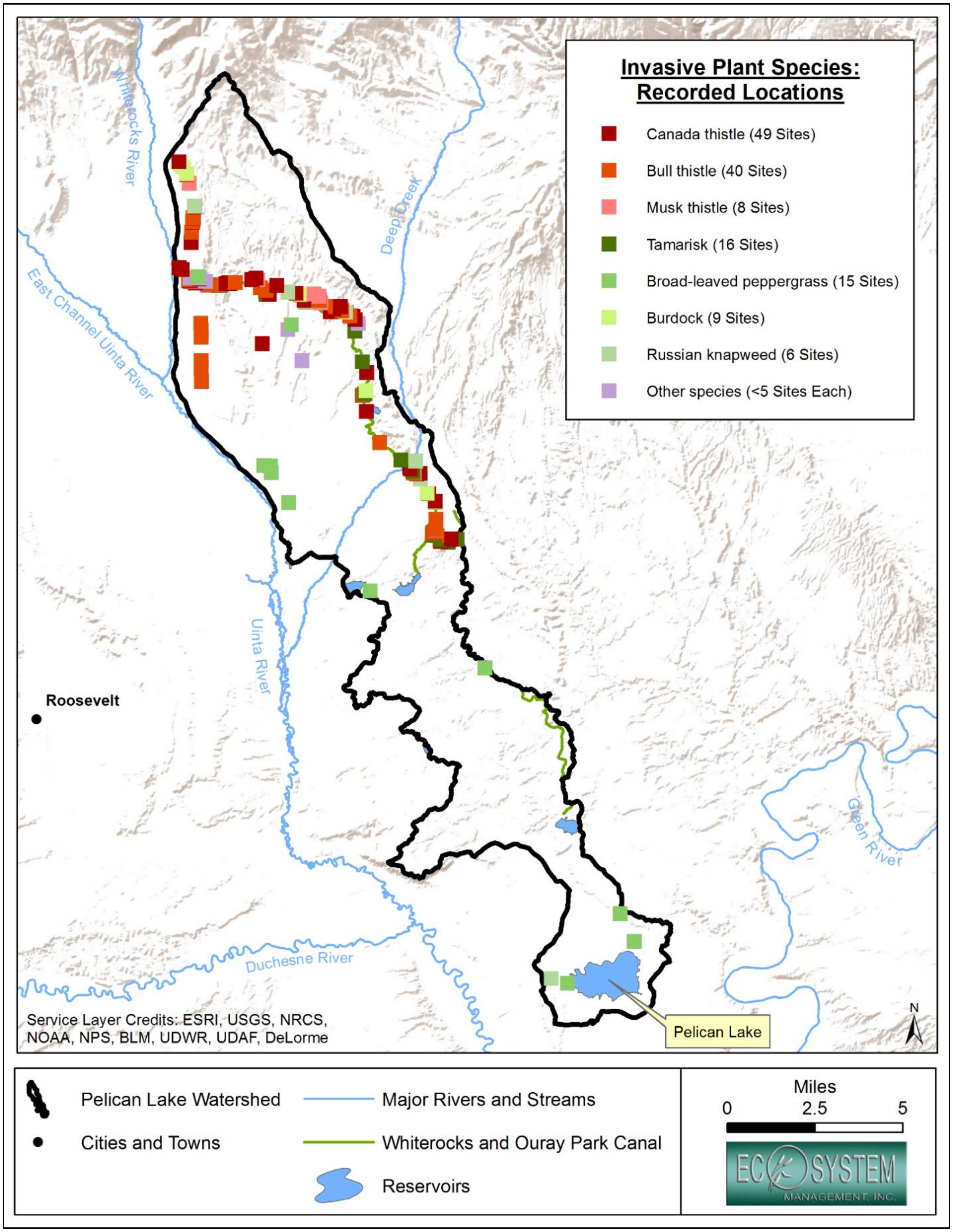

Figure 17. Recorded locations of invasive plant species in the Pelican Lake watershed.

2.11 – U.S. Endangered Species Act Protected Species

The U.S. Endangered Species Act (ESA), administered by the USFWS, is intended to protect and recover vulnerable species and their habitat. Under the ESA, species may be classified as Endangered, Threatened, or Candidate. An Endangered classification designates the species as in danger of extinction throughout all or a significant portion of its range. Species classified as Threatened are recognized as likely to become endangered within the foreseeable future. Species classified as Candidate are those in consideration for listing as endangered or threatened under the ESA.

The ESA provides a number of protections for listed species. It requires federal agencies to ensure that any actions they execute, permit, or fund are not likely to jeopardize the survival of listed species or damage critical habitat. Official consultation with the USFWS regarding ESA protections is typically required prior to any land management actions that are executed by federal agencies, take place on federal lands, or involve federal funds or permits. For example, if a project intended to reduce reservoir sedimentation received funding from the EPA, consultation with the USFWS would usually be required prior to the start of the project. It is usually the responsibility of the project manager, proponent, or executor to initiate consultation with USFWS. Consultation with the USFWS is typically not required if no federal agencies, lands, permits, or funds are involved in a proposed action. Land management projects undertaken on private land, for example, are not likely to be subject to USFWS review prior to initiation. However, the ESA does stipulate legal restrictions for listed species on private property, including prohibitions against killing, hunting, collecting, harassing, possessing, or otherwise harming listed species.

Table 9 lists species protected under the ESA that are known to occur in the Pelican Lake watershed, have the potential to occur within its boundaries, or warrant ESA protections due to potential downstream impacts from activities within the watershed. Listed species include one mammal, two birds, four fish, and two plants (USFWS 2017a, b).

The USFWS may designate critical habitat for a listed species if it deems that specific geographic areas are essential to the conservation of the species. Within critical habitat boundaries, federal agencies are required to make special efforts to protect the ecological characteristics of these areas and the features that make them essential for the conservation of the listed species. While no designated critical habitat occurs in the Pelican Lake watershed, the Ouray National Wildlife Refuge directly to the south and east of the watershed contains critical habitat for several species: the yellow-billed cuckoo (*Coccyzus americanus*), razorback sucker (*Xyrauchen texanus*), and Colorado pikeminnow (*Ptychocheilus lucius*). Efforts to improve environmental conditions in the Pelican Lake watershed are expected to have a positive impact, if any, on these critical habitat units.

Table 9. Species listed under the U.S. Endangered Species Act within the Pelican Lake watershed.

Species	ESA Status	Occurrence in Watershed	Comments
		MAMMALS	
Canada lynx	Threatened	Unlikely	Preferred habitat is disturbed and sub-climax forest communities with dense cover and high probability of snowshoe hare occupancy (such as recovering burned areas or clearcuts; USFWS 2000). This preferred habitat is not present in the watershed. Potential, non-preferred habitat for lynx in the watershed is limited its extreme northern tip, in the Uinta Mountains.
		BIRDS	
Mexican spotted owl	Threatened	Potential	Preferred nesting and breeding habitat is old growth/mature coniferous and mixed forests, associated with canyons and cliffs near water (USFWS 2012); this habitat is uncommon in the watershed. Outside of the breeding season, utilized habitat often expands to include pinon-juniper and ponderosa forest, which is present to a limited extent in the northern tip of the watershed in the Uinta Mountains.
Yellow-billed cuckoo	Threatened	Potential	Preferred habitat is broad riparian floodplain valleys associated with low-gradient perennial rivers or streams. Large stands of mature cottonwood, willow, or mesquite trees are typically required. Edge effects as well as overall stand size influence nest site selection; stands less than approximately 300 feet wide are rarely occupied (USFWS 2014, 2013). Such large stands occur at the margins of the watershed, along the Whiterocks, Uinta, and Duchesne Rivers. Designated critical habitat for this species occurs nearby, to the southeast in the Ouray National Wildlife Refuge, and west along the Duchesne River.
		FISHES	
Colorado pikeminnow	Endangered	Unlikely	Potential habitat for this large, predatory fish is limited to large rivers in the Colorado River basin. Preferred habitat is large, turbulent rivers with sand or silt bottoms, large seasonal variation in flow, and large sediment loads. The nearest such habitat to the watershed is the Green River, where critical habitat has been designated in the mainstem and in the lower Duchesne River. This species is unlikely to occur in the tributaries of the Green River that compose the Pelican Lake watershed (USFWS 1994).
Razorback sucker	Endangered	Unlikely	Habitat for this species is medium to large rivers in the Colorado River basin, with swift turbulent waters and slow backwater areas. This species is known to occur in the mainstem of the Green River and lower Duchesne River, where critical habitat has been designated. The razorback sucker is unlikely to occur in the smaller tributaries of the Green River that compose the Pelican Lake watershed (USFWS 1994).
Humpback chub	Endangered	Unlikely	Habitat for this species is major tributaries within the Colorado River basin, where it inhabits fast-flowing, turbulent sites with deep water and strong seasonal flow variation. Populations are not known to occur in the tributaries of the Green River that compose the Pelican Lake watershed; the nearest known population exists in the Green River's Desolation Canyon (USFWS 1994).

Table 9 (continued). Species listed under the U.S. Endangered Species Act within the Pelican Lake watershed.

Species	ESA Status	Occurrence in Watershed	Comments
FISHES (continued)			
Bonytail chub	Endangered	Unlikely	This species is one of the rarest fish species in the U.S., no reproducing wild populations are known. Because wild populations are very small and isolated, habitat preferences are unknown. No populations have been documented in the Pelican Lake watershed or nearby Green River, though the Green and Duchesne rivers likely supported this species historically (USFWS 1994).
PLANTS			
Ute ladies'-tresses	Threatened	Potential	This species grows in wet meadows, waterway margins, oxbows, and other mesic / riparian sites in a variety of soils. It may occur at the edges of canals or in irrigated pastures; populations may be impacted by changes in irrigation practices. Flowering period occurs between July-September.
Uinta Basin hookless cactus	Threatened	Potential	This rare cactus is endemic to the Uintah Basin, with a total estimated population of 30,000 individuals. It is found in sparsely-vegetated desert shrub and scrublands on course soils derived from alluvial deposits, or on rocky mesa slopes. All know populations occur between 4,400 – 6,200 feet (Tilley et al. 2010).

2.12 Utah State Sensitive Species

The state of Utah designates certain species as sensitive within the state. These species are deemed by UDWR as vulnerable to extirpation at the global or state level due to factors such as small population size, restricted distribution, specialized habitat requirements, habitat loss, or sensitivity to disturbance. State sensitive species are targeted for enhanced monitoring or other protections by the UDWR. The UDWR state sensitive species list for Uintah County is shown in Table 10; some of these species may occur in the broader county but not the Pelican Lake watershed itself. Species listed in Table 10 as Conservation Agreement status receive special management by UDWR to preclude future listing under the federal ESA.

Table 10. State of Utah sensitive species within the Pelican Lake watershed.

Species	State of Utah Status	Federal ESA Status
MAMMALS		
Big free-tailed bat	Sensitive	
Black-footed ferret	Sensitive	Endangered
Grizzly bear	Sensitive	Threatened
Canada lynx	Sensitive	Threatened
Fringed myotis	Sensitive	
Kit fox	Sensitive	
Spotted bat	Sensitive	
Townsend's big-eared bat	Sensitive	
White-tailed prairie dog	Sensitive	
BIRDS		
American Three-toed Woodpecker	Sensitive	
American Pelican	Sensitive	
Bald Eagle	Sensitive	
Bobolink	Sensitive	
Burrowing Owl	Sensitive	
Ferruginous Hawk	Sensitive	
Greater Sage-Grouse	Sensitive	
Lewis' Woodpecker	Sensitive	
Long-billed Curlew	Sensitive	
Mountain Plover	Sensitive	
Northern Goshawk	Conservation Agreement	
Short-eared Owl	Sensitive	
Western Yellow-billed Cuckoo	Sensitive	Threatened
REPTILES		
Corn snake	Sensitive	
Smooth green snake	Sensitive	
FISHES		
Bluehead sucker	Conservation Agreement	
Bonytail chub	Sensitive	Endangered
Colorado pikeminnow	Sensitive	Endangered
Colorado River cutthroat trout	Conservation Agreement	
Flannelmouth sucker	Conservation Agreement	
Humpback chub	Sensitive	Endangered
Roundtail chub	Conservation Agreement	

3.0 PELICAN LAKE WATERSHED WATER QUALITY CONDITIONS

3.1 Utah DWQ Beneficial Uses

The Clean Water Act (CWA) and its associated regulations stipulate that waterways in the U.S. be protected to provide critical services to humans and ecological communities. However, the protections granted to surface waters under the CWA vary with how the water body is used. The CWA requires each state to establish *beneficial use classes* that categorize water bodies according to their usage (e.g., human drinking water, recreation, agriculture, wildlife habitat, or other uses). The number of use classes varies by state, but at a minimum, the CWA mandates that the classes ensure protection of aquatic life and human recreation uses for all surface waters ((40 CFR §131.10(a)). This beneficial use class system is intended to protect against controllable sources of pollution and degradation, as each use class is assigned an acceptable range of various pollutants. A water body may fail to qualify for the protections of a use class if it exceeds these specified pollutant levels. Under this classification system, acceptable pollution concentrations for a water body can be dictated by the beneficial uses assigned to the water body.

The Utah DWQ assigns the beneficial use classes for surface waters within the state (Table 11; Utah Department of Administrative Services 2017: UAC R317-2-6). Beneficial use classes frequently protect numerous activities in addition to the primary protection objective; protections for drinking water quality, for example, may also shield cold water fisheries from habitat degradation.

Table 11. Utah DWQ Beneficial Uses for Surface Waters (adapted from Utah Department of Administrative Services 2017: UAC R317-2-6).

Beneficial Use Class	Use Description
1C	Protected for domestic purposes with prior treatment by treatment processes as required by the Utah Division of Drinking Water
2A	Protected for frequent primary contact recreation where there is a high likelihood of ingestion of water or a high degree of bodily contact with the water (e.g., swimming, rafting, water skiing)
2B	Protected for infrequent primary contact recreation, or secondary contact recreation with low likelihood of ingestion or limited bodily contact with the water (e.g., wading, fishing, hunting)
3A	Protected for cold water game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain
3B	Protected for warm water game fish and other warm water aquatic life, including the necessary aquatic organisms in their food chain
3C	Protected for nongame fish and other aquatic life, including the necessary aquatic organisms in their food chain
3D	Protected for waterfowl, shore birds and other water-oriented wildlife not included in Classes 3A-C, including the necessary aquatic organisms in their food chain
3E	Severely habitat-limited waters; narrative standards will be applied to protect these waters for aquatic wildlife
4	Protected for agricultural uses including irrigation of crops and stock watering
5	Classes specific to the Great Salt Lake

3.2 Utah Water Quality Standards

Water quality standards are the benchmarks used to determine if a water body can effectively support a particular UDWQ beneficial use class (see Section 3.1 above). Utah water quality standards have both numeric and narrative components. Numeric criteria specify the concentrations of specific pollutants in a water body that cannot be exceeded for it to support a beneficial use. Narrative standards are less specific and apply to all surface waters in Utah. Narrative standards require that waters are free of floating debris, oil, garbage, and other substances, do not contaminate desirable fish and wildlife, do not promote undesirable species, and do not endanger human health (Utah Department of Administrative Services 2017: UAC R317-2-7).

3.3 Subwatershed Assessment Units (AUs)

Surface waters in Utah are subdivided into segments called Assessment Units (AUs) or subwatersheds. These AUs are established based on factors such as stream morphology, topography, flow, substrate, surrounding lands, contributing tributaries, and potential pollution sources. Each AU is defined in such a way that the characteristics of the water body within the AU are identifiably different from adjoining AUs. Beneficial use classes often play a key role in establishing the boundaries of AUs, as a change in use class within a water body always marks the beginning of a distinct AU. Other factors may also cause separation of AUs, including a stream passing through an urban area, or the confluence of a river with a major tributary. Reservoirs and lakes are typically considered to be individual AUs; in the Pelican Lake watershed, both the lake itself and Brough Reservoir are classified as distinct AUs. Overall, the watershed contains all or part of eight AUs, listed in Table 12 and shown in Figures 18–19.

Table 12. Utah DWQ Subwatershed Assessment Units contained (all or in part) within the Pelican Lake watershed.

Subwatershed Assessment Unit (AU)	Assessment Unit ID	Description
Pelican Lake	UT-L-14060010-001	Pelican Lake
Brough Reservoir	UT-L-14060010-002	Brough Reservoir
Duchesne River - 1	UT14060003-001	Duchesne River and tributaries from Green River confluence to Uinta River confluence
Uinta River - 2	UT14060003-004	Uinta River and tributaries from Dry Gulch confluence upstream to U.S. Highway 40
Uinta River – 3	UT14060003-010	Uinta River and tributaries from U.S. Highway 40 to USFS boundary, excluding all of Whiterocks River and Farm, Pole, and Deep Creeks
Green River – 2 Tributaries	UT14060001-001	Green River tributaries from Duchesne River confluence to Utah-Wyoming border, except Ashley, Brush, and Jones Hole Creeks
Whiterocks River Lower	UT14060003-011	Whiterocks River and tributaries from confluence with Uintah River to Tridell Water Treatment Plant
Deep Creek	UT14060003-012	Deep Creek and tributaries from Uintah River confluence to headwaters

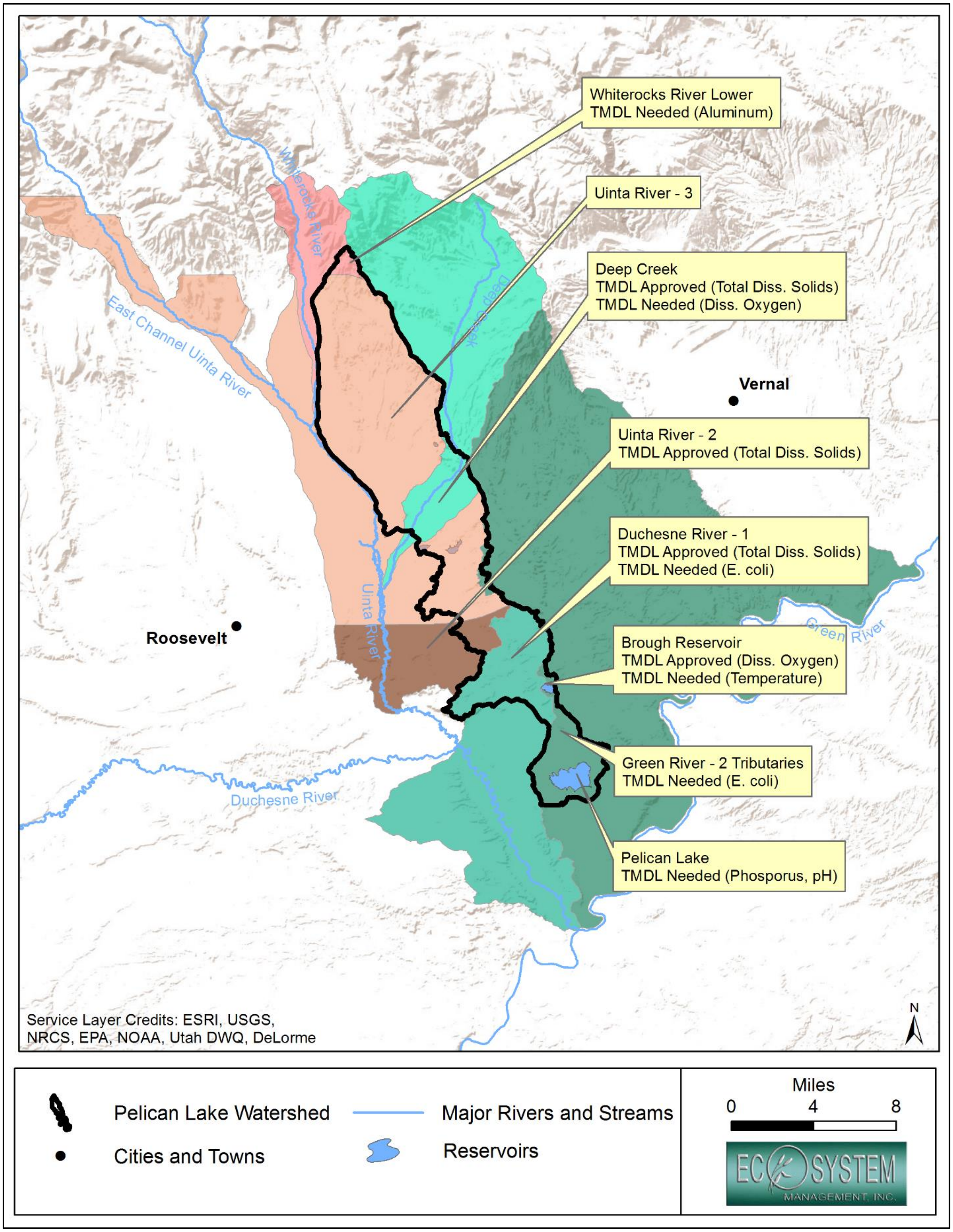

Figure 18. Subwatershed AU's in the Pelican Lake watershed. Note that most AUs are not completely contained within the Pelican Lake watershed due to the canal and pipeline system that supplies water to Pelican Lake. UDWQ 303(d) impairments are shown.

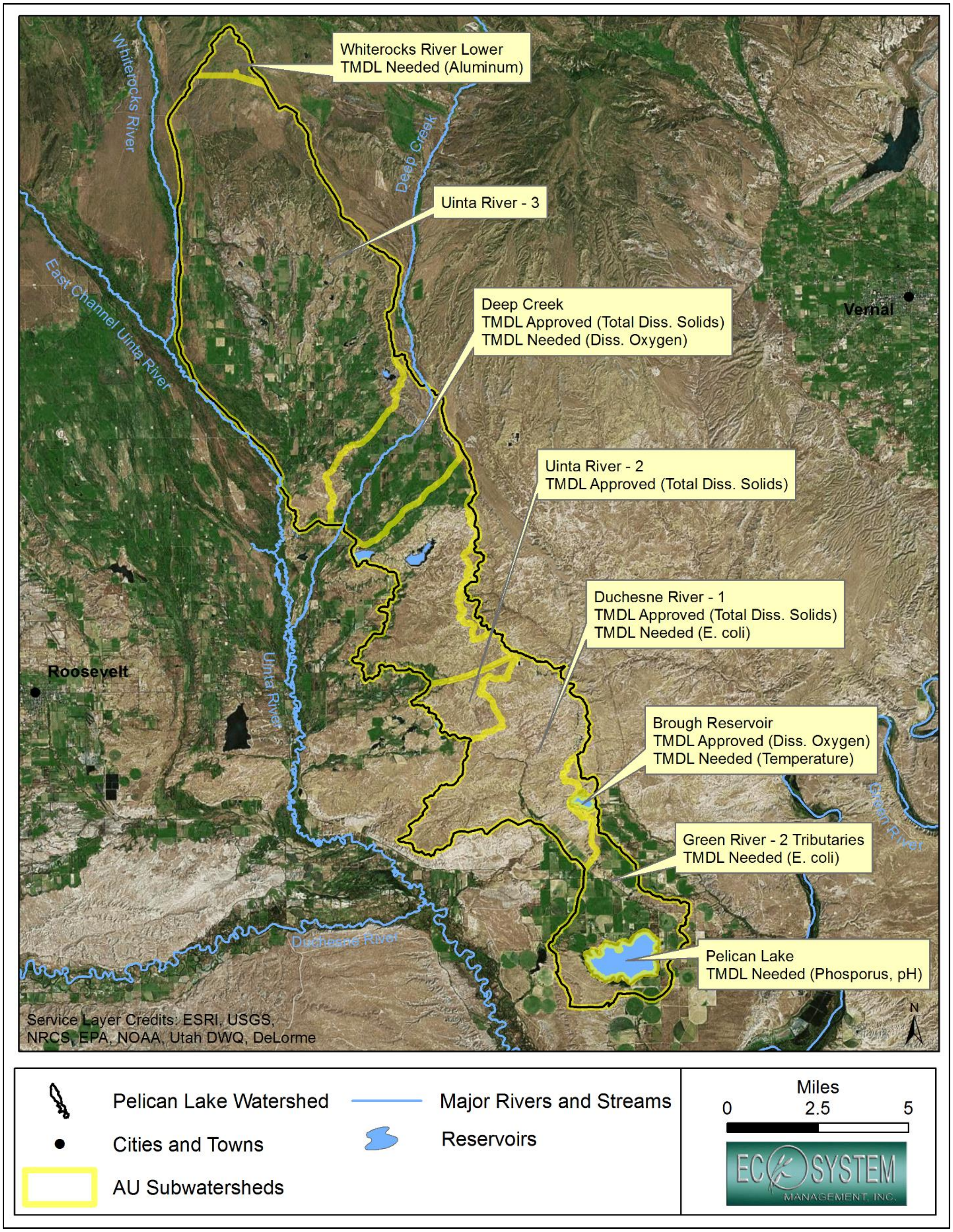

Figure 19. Aerial imagery of subwatershed AU's in the Pelican Lake watershed; UDWQ 303(d) impairments are shown.

3.4 Assessment of Impaired Subwatersheds

As required by the CWA, the UDWQ assesses the condition of all subwatershed AUs in Utah every two years. The findings are compiled into an *Integrated Report* that is submitted to the federal government. This report serves two important functions. First, it lays out the overall conditions of AUs in the state, identifying sources of water quality problems and estimating the relative importance of factors contributing to water quality degradation. Second, the *Integrated Report* identifies any AUs that are failing to meet the water quality standards of their beneficial use class. These waters are officially classified as impaired and listed on the 303(d) list of the *Integrated Report*. The CWA requires that the UDWQ develop a restoration plan to restore each AU on the 303(d) list. This is accomplished by establishing a maximum acceptable concentration of each pollutant causing impairment. This threshold is termed the *Total Maximum Daily Load* (TMDL) for the pollutant in the AU and forms the central benchmark of restoration goals. Each TMDL proposed by the UDWQ must be approved by the EPA.

AUs in the Pelican Lake watershed that have been identified as failing the water quality standards for one or more beneficial use classes are presented in Table 13; AU locations are shown in Figures 18–19. TMDLs have been approved by the EPA for only a subset of these AUs. Specific impairments to Pelican Lake watershed AUs are discussed in depth in Chapter 4.

Table 13. Water bodies within the Pelican Lake watershed identified as impaired by the Utah DWQ (adapted from DEQ 2016).

Assessment Unit (AU)	Major Water Body	Beneficial Use Class (see Table 11)	Impaired Parameter	TMDL Status
Pelican Lake	Pelican Lake	3B	Total phosphorous; pH	Needed
Brough Reservoir	Brough Reservoir	3A	Temperature	Needed
Brough Reservoir	Brough Reservoir	3A	Dissolved oxygen	Approved
Deep Creek	Deep Creek – Uinta	3A	Dissolved oxygen	Needed
Deep Creek	Deep Creek – Uinta	2B, 4	Total dissolved solids	Approved
Duchesne River - 1	Duchesne River	2B, 3B	*E. coli*	Needed
Duchesne River - 1	Duchesne River	4	Total dissolved solids	Approved
Green River – 2 Tributaries	Green River	1C, 2A, 3A	*E. coli*	Needed
Uinta River - 2	Uinta River	2B, 3B, 4	Total dissolved solids	Approved
Whiterocks River Lower	Whiterocks River	3A	Dissolved Aluminum	Needed

4.0 TMDLs AND IMPAIRED AU SUBWATERSHEDS

The EPA has approved TMDLs in some AUs in the Pelican Lake watershed. Each of these TMDLs identifies the maximum load for a particular pollutant that would allow the AU to meet its beneficial use class. This value is compared with current concentrations to assess the amount of reduction needed. Additionally, approved TMDLs identify likely pollutant sources, describe desired restoration outcomes (such as reducing algae growth or fish kills), and lay out an implementation strategy for attaining these targets. Summaries of the approved TMDLs in the watershed are presented in Sections 4.1–4.2. It should be noted that since the approval of these TMDLs, practices have been implemented to address water quality impairments, primarily as part of the Colorado River Basin Salinity Control Program. A summary of the implementation work is provided in Chapter 5.

Several AUs in the Pelican Lake watershed are recognized by the UDWQ as 303(d) impaired, but do not have approved TMDLs for the pollutant causing impairment. The UDWQ categorizes TMDL development for impaired water bodies as either low or high priority. Impaired waters with the potential to impact human health or drinking water, such as those polluted with *Escherichia coli* (*E. coli*) bacteria, are classified as high priority for TMDL development. High priority is also often given if a specific pollutant impacts many beneficial uses of an AU, and correcting the problem would bring significant benefits to both human health and environmental conditions. Practical feasibility is also an important factor; TMDLs are more likely to be prioritized if the impairment could be corrected with realistic allocations of resources and effort (DWQ 2016b). Guidelines for prioritizing TMDL development in Utah are summarized in Table 14.

Table 14. DWQ guidelines for prioritizing TMDL development (adapted from UDWQ 2016b).

Water Body Characteristics	Pollutants	Impaired Uses	Pollutant Sources
HIGH PRIORITY FACTORS			
Drinking water source National Park/State Park High recreation use Blue Ribbon Fishery Important bird area Permit administration Ongoing study	1. Toxics 2. Metals 3. Bacteria 4. Dissolved Oxygen 5. Nutrients linked to algae blooms	6. Drinking water 7. Recreation 8. Aquatic life	Combination of point and non-point sources
LOW PRIORITY FACTORS			
Habitat degraded Hydrological modifications Best assessed through local restoration efforts	9. Temperature 10. pH 11. Sediment	Various	Non-point and/or natural sources only

4.1 Total Dissolved Solids TMDLs

Elevated concentration of total dissolved solids (TDS) impairs three AU subwatersheds in the Pelican Lake watershed, which are each discussed in detail in this section. Dissolved solids are cations and anions of elements such as sodium, selenium, lead, arsenic, sulfur, and magnesium suspended in water. TDS concentration in water is also referred to as salinity.

Total dissolved solids typically enter water bodies via erosion from deposits in soils and geologic formations. Marine formations often contain large amounts of TDS elements, and if surface or groundwater contacts these deposits under the correct conditions, TDS elements can be mobilized into water and begin to accumulate to undesirable concentrations in water bodies. The Mancos Shale, which underlies much of the Uintah Basin, is highly saline and likely a key source of TDS elements in the Pelican Lake watershed (Weltz et al. 2014, Duffy et al. 1985). Other nearby formations, including the Uinta and Duchesne formations, also contain large deposits of TDS elements.

While TDS elements are generally not harmful in trace amounts (some are even important biological building-blocks), high concentrations can render water unsafe for human consumption, harm fish and wildlife, and make water unsuitable for crops and livestock. Aquatic organisms are particularly sensitive to salinity changes, because the salinity of the surrounding water influences cell osmotic activity. While native species in the Pelican Lake watershed are likely to be adapted to the naturally high background TDS concentrations, this tolerance may not protect against significant additional increases in salinity.

Evaporation, transpiration, and even accumulation in biological tissues can accelerate the concentration of TDS in water bodies. Irrigation and water management practices also play a key role, for a variety of interconnected reasons. When TDS-laden water is used for irrigation, some of this water percolates down through the soil into groundwater. As it passes through underlying soil and rock layers, it gathers still more TDS. When this water returns to the surface as base flow, the cycle is repeated, but begins with greater initial TDS loads. Irrigation water containing TDS can also evaporate at the soil surface, leaving salt deposits behind on the ground from the TDS-laden water. This surface crust of salts reduces the absorptive capacity of the soil, which increases surface runoff velocity and accelerates erosion, exacerbating the mobilization of surface crust salts into waterways. If a canal system is used for irrigation, surface runoff and erosion further mobilize salts into the system, and seepage from the canal into groundwater can contribute large TDS loads to shallow aquifers, to be used again in a repetition of the cycle discussed above.

Irrigation of crops and pasture land is a defining feature of water use in the Pelican Lake watershed. Thus, while salinity impairments in the watershed ultimately stem from the area’s underlying geology, irrigation practices may exacerbate problems with TDS accumulation (Weltz et al. 2014, Suarez 2010). It should be noted that in recent years, landowners throughout the subwatersheds described below have replaced flood irrigation with sprinkler-based irrigation. This is a beneficial practice for controlling salinity, as sprinklers use water more efficiently, leaving smaller volumes to percolate back to shallow aquifers or evaporate at the surface. Further adoption of sprinklers to replace canal irrigation would go a long way towards watershed restoration efforts. However, sprinkler-based irrigation is unlikely to completely eliminate salinity accumulation in areas with highly saline geology (Suarez 2010, Wang et al. 2002). Salinity is expected to remain an important water quality issue in the watershed for the foreseeable future.

4.1.1 *Deep Creek Subwatershed*

The Deep Creek subwatershed runs through the middle of the Pelican Lake watershed, extending from the east entrance of Deep Creek to its intersection with the Ouray Park Canal. In 2006, Deep Creek was included, along with the Uinta River and Dry Gulch Creek, in a TMDL addressing elevated TDS concentrations in these waterways (UDWQ 2006). Elevated concentrations of TDS in the AU impairs beneficial uses for recreation and agriculture. A summary of TDS loads and restoration goals is presented in Table 15.

Only one water quality monitoring station associated with Deep Creek is both located within the Pelican Lake watershed and sampled with sufficient frequency to satisfy TMDL approval requirements. TDS data from this station are shown in Table 16, which summarizes data from the UDWQ Ambient Water Quality Monitoring Program portal (UDWQ 2017). Data are only available intermittently from 1996-2011, but suggest that TDS concentrations in Deep Creek are only occasionally high enough to warrant failure of water quality standards. However, data from other stations in the Deep Creek AU, collected over a broader range of years, show that a TDS problem exists in the subwatershed. TDS concentrations are also reliably higher at further-downstream stations in the AU, consistent with the pattern of TDS accumulation in water bodies (UDWQ 2006). Also consistent with typical TDS accumulation patterns (Weltz et al. 2014), higher concentrations are observed, on average, at stations downstream of irrigated areas.

Meeting water quality standards for TDS in the Deep Creek AU will likely depend on concerted efforts by stakeholders and restoration partners to manage saline water. In particular, the TMDL recommends several specific agricultural practices that should help to reduce TDS loading (UDWQ 2006); many of these have been implemented since the TMDL's publication. Recommendations include:

1. Replace open canals with pipelines or lined canals, to reduce canal seepage and re-entry of TDS-laden runoff;
2. Limiting irrigation water to the amount that crops can uptake, thus reducing percolation to groundwater and evaporation from saturated fields;
3. Maintain buffer vegetation strips along streams and canals to reduce runoff from fields;
4. Construct check-dams at canal margins to reduce return flows of irrigation water;
5. Promote grazing management in uplands and riparian areas to maintain sufficient plant cover to limit erosion and protect soil;
6. Improve conditions in riparian areas via vegetation planting, streambank stabilization, and temporary grazing exclusions.

Table 15. Summary of TMDL results from Deep Creek AU; adapted from UDWQ (2006).

Deep Creek Subwatershed	Assessment Unit: UT14060003-012
Beneficial Use Class	2B–infrequent primary contact, secondary contact recreation (wading, fishing, hunting); 4–agricultural uses
Impairment	Elevated toxin and salt levels; poor water quality for recreation, agriculture and irrigation uses
Impairment Mechanism	Mobilization of soil elements via groundwater and surface water runoff
Pollutant	Total dissolved solids (TDS)
Pollutant Source	Non-point: naturally-occurring soil elements mobilized by water contact and concentrated by evaporation
Current Pollutant Load	92,500 tons/year at Uinta River mouth (TMDL analysis considers Deep Creek and Uinta River together)
Acceptable Pollutant Load (use class 2B, 4)	77,000 tons/year at Uinta River mouth (TMDL analysis considers Deep Creek and Uinta River together)
Improvement Targets	1.) Maximum 1,200 mg/L TDS in Deep Creek samples 2.) Monitor to ensure TDS concentrations do not increase with desired decreases in overall TDS loads
Implementation Strategy	Continue successful efforts to reduce irrigation runoff. Priorities include converting water conductance from canals to pipelines, and adjusting irrigation practices to reduce runoff and salt accumulation.

Table 16. Summary of total dissolved solids data from Deep Creek's water monitoring station inside the Pelican Lake watershed. Data is adapted from the UDWQ TMDL (UDWQ 2006) and UDWQ's Ambient Water Quality Monitoring Program portal (UDWQ 2017).

Monitoring Station ID	Sample Year Range	Number of Samples	Mean Dissolved Solids in Sample (mg/L)	Std. Dev. Dissolved Solids in Sample (mg/L)	% Samples Exceeding Water Quality Criteria
Station 4934980	1996 - 2011	30	722.46	N/A	13

4.1.2 *Duchesne River – 1 Subwatershed*

This AU subwatershed bisects the southern section of the Pelican Lake watershed, and is comprised of tributaries of the Duchesne River. Land cover is primarily arid hills with a small irrigated section near the confluence of the Duchesne and Uinta rivers. The TDS TMDL for this AU was finalized in 2007, concluding that TDS caused the AU to fall short of agricultural water quality standards.

Total dissolved solids in the Duchesne River – 1 subwatershed originate primarily from the underlying Mancos Shale, and are spread and concentrated by groundwater movement, surface flows, irrigation practices, and evaporation. The TMDL identifies the prevalence of flood irrigation using canals as a key driver of TDS problems in this AU. The TMDL proposes replacing flood irrigation with sprinkler systems as a potential strategy for reducing TDS concentrations, as this method more precisely matches water usage to the requirements of crops, and reduces evaporation by delivering water in smaller increments (UDWQ 2007). Since completion of the TMDL, the majority of landowners have converted to sprinkler irrigation. A summary of TDS loads and restoration goals is presented in Table 17.

No water quality monitoring stations for this AU are located inside the Pelican Lake watershed. However, the TMDL uses data from other monitoring stations in the AU to show when impairment conditions in this AU typically occur. Impairment at these monitoring stations is most common during low flows, when the ratio of TDS to water is highest, and during high-flow pulses following storm events. The TDS reduction presented in the TMDL focuses on minimizing TDS loading during both these low-flow periods and flood events. Specific recommendations include:

1. Continue efforts to encourage landowner adoption of sprinkler-based irrigation systems, phasing out canal-based flood irrigation;
2. Replace open canals with pipelines, or line canals with impermeable materials to reduce seepage and re-entry of TDS-laden irrigation runoff into groundwater and surface waters;
3. Reduce irrigation volumes to the amount usable by crops, to reduce percolation to groundwater and evaporation from saturated fields;
4. Maintain buffer vegetation strips along waterways, including canals, to reduce runoff from fields;
5. Construct check-dams at canal margins to reduce return flows of irrigation water;
6. Improve conditions in riparian areas by planting vegetation, encouraging tree recruitment, stabilizing banks, and properly managing riparian grazing to reduce erosion.

The TMDL addresses the possibility that more efficient irrigation practices, implemented as part of salinity reduction efforts, could increase TDS concentrations despite reducing overall TDS loads. This could occur as a result of more efficient irrigation uptake and less overall irrigation water flows available for dilution, and would most likely be a relatively short-term problem (UDWQ 2007). Over time, as irrigation practices change and less TDS-laden irrigation water percolates to shallow aquifers, TDS concentrations in groundwater should decrease. The concentration of TDS in base flows feeding waterways would be expected to decrease in turn. The TMDL advocates careful monitoring and data collection to confirm this expected long-term decline in TDS concentration.

Table 17. Summary of TMDL results from Duchesne River – 1 AU; adapted from UDWQ (2007).

Duchesne River – 1 Subwatershed	Assessment Unit: UT14060003-001
Beneficial Class	4 – agricultural uses
Impairment	Elevated toxin and salt levels; poor water quality for agriculture and irrigation uses
Impairment Mechanism	Mobilization of soil elements via groundwater and surface water runoff
Pollutant	Total dissolved solids (TDS)
Pollutant Source	Non-point: naturally-occurring soil elements mobilized by water contact and concentrated by evaporation
Current Pollutant Load	84,720 tons/year at the 0-30% flow percentile range
Acceptable Pollutant Load (use class 2B, 4)	74,420 tons/year at the 0-30% flow percentile range
Improvement Targets	1.) 1,200 mg/L TDS in water samples 2.) Total TDS load of 74,420 tons/year at the 0-30% flow percentile range 3.) Reduction of TDS of 10,300 tons/year at the 0-30% flow percentile range
Implementation Strategy	Continue successful efforts to reduce irrigation runoff. Key measures include replacing canal-based flood irrigation with sprinkler systems, replacing open canals with pipelines or lined canals, and maintaining vegetated edges of waterways to reduce erosion.

4.1.3 *Uinta River – 2 Subwatershed*

This AU subwatershed crosses the southeast portion of the Pelican Lake watershed, and is made up of tributaries flowing west to the Uinta River. In 2006, the Uinta River AUs were included, along with Deep Creek and Dry Gulch Creek, in a TMDL addressing elevated TDS concentrations in these waterways (UDWQ 2006). Elevated concentrations of TDS in the AU impairs beneficial uses for agricultural uses. A summary of TDS loads and restoration goals is shown in Table 18.

Like the other AUs discussed in this section, elevated concentrations of TDS in the Uinta River – 2 subwatershed are likely a consequence of both underlying geology and anthropogenic factors. The Mancos Shale and other saline formations hold large deposits of TDS elements, which are spread and concentrated by groundwater movement, surface flows, and evaporation. Irrigation practices are also likely to play an important role in TDS loading in this subwatershed. The TMDL estimates that in this AU, each acre-foot of irrigation water that bypasses plant roots into shallow aquifers contributes an additional 3.19 tons of TDS to area waters (UDWQ 2006). Sprinkler irrigation can significantly reduce such deep percolation, and is becoming more prevalent in this AU.

No water quality monitoring stations for this AU are located inside the Pelican Lake watershed. However, data from monitoring stations further downstream on the Uinta River are helpful in inferring TDS conditions in this section of the Pelican Lake watershed. All stations in the Uinta River – 2 AU with TDS water quality violations are located lower in the Uinta River watershed, where irrigated crops and pastures are a dominant land use and sediment loads are larger (UDWQ 2006). It is thus reasonable to expect TDS concentrations to be highest in this AU near the Uinta River, and lower in more upland areas.

The TMDL recommends adjustment to agricultural watering practices to lower TDS contamination in this AU. As with other AUs in the watershed, landowners have increasingly adopted these practices in recent years. Specific recommendations are similar to those in the other Pelican Lake watershed AUs with TDS problems, including:

1. Continue efforts to phase out canal-based flood irrigation, in favor sprinkler irrigation systems;
2. Limit irrigation water to the amount that crops can uptake, thus reducing percolation of TDS-laden water to aquifers and evaporation from saturated fields;
3. Replace open canals with pipelines or lined canals, to reduce canal seepage and re-entry of TDS-laden runoff;
4. Maintain buffer vegetation strips along streams and canals to reduce runoff from fields;
5. Construct check-dams at canal margins to reduce return flows of irrigation water;
6. Promote grazing management in uplands and riparian areas to maintain sufficient plant cover to limit erosion and protect soil;
7. Improve conditions in riparian areas via vegetation planting, streambank stabilization, and temporary grazing exclusions.

It is possible that more efficient irrigation practices, implemented as part of TDS control efforts, could increase TDS concentrations despite reducing overall TDS loads. More efficient irrigation uptake and lower overall irrigation water flows could produce this effect, but the TMDL states that this would likely be a short-term problem (UDWQ 2006). If the recommended changes are implemented, long-term impacts to water quality should be positive. Over time, less TDS-laden irrigation water will percolate to shallow aquifers, ultimately resulting in lower TDS in base flows feeding waterways. The TMDL advocates careful monitoring and data collection to confirm this expected long-term decline in TDS concentration.

Table 18. Summary of TMDL results from Uinta River – 2 AU; adapted from UDWQ (2006).

Uinta River – 2 Subwatershed	Assessment Unit: UT14060003-004
Beneficial Use Class	4 – agricultural uses
Impairment	Elevated toxin and salt levels; poor water quality for agriculture and irrigation uses
Impairment Mechanism	Mobilization of soil elements via groundwater and surface water runoff
Pollutant	Total dissolved solids (TDS)
Pollutant Source	Non-point: naturally-occurring soil elements mobilized by water contact and concentrated by evaporation
Current Pollutant Load	92,500 tons/year at Uinta River mouth
Acceptable Pollutant Load (use class 2B, 4)	77,000 tons/year at Uinta River mouth
Improvement Targets	1.) Maximum 1,200 mg/L TDS in Uinta River samples 2.) Monitor to ensure TDS concentrations do not increase with desired decreases in overall TDS loads
Implementation Strategy	Continue successful efforts to reduce irrigation runoff. Priorities include transitioning from flood irrigation to sprinklers, converting water conductance from canals to pipelines, and adjusting irrigated-lands management to reduce runoff and salt accumulation.

4.2 Brough Reservoir – Dissolved Oxygen TMDL

Brough Reservoir was built in 1975, as an off-stream earthen dam catchment. It was constructed primarily to store and deliver irrigation water, diverted from the Ouray Valley canal and ultimately the Whiterocks and Uinta Rivers. The approved TMDL for Brough Reservoir addresses dissolved oxygen depletion, which impairs the reservoir's beneficial use as a cold water fishery and food web (Table 19). Dissolved oxygen in Brough Reservoir is limited by excess phosphorus entering the system. In a phosphorus-polluted system, aquatic algae bloom in large numbers near the surface and then fall in the water column, their photosynthetic activity reducing the available oxygen in these lower layers resulting in anoxic conditions (UDWQ 2008).

Three water quality monitoring stations associated with Brough Reservoir have been sampled with sufficient frequency to satisfy TMDL approval requirements. Dissolved oxygen data from these stations is shown in Table 20, which summarizes data from the UDWQ Ambient Water Quality Monitoring Program portal (UDWQ 2017). When interpreting these results, it is important to note that the target for meeting Brough Reservoir's water quality criteria is 4 mg/L dissolved oxygen in at least 50% of the water column. While the mean dissolved oxygen values in Table 20 are above the 4 mg/L target, the high standard deviation between samples suggests that dissolved oxygen within Brough Reservoir varies widely across time and water depth. Further, dissolved oxygen levels are consistently lower in samples from the reservoir itself, compared to canal samples taken immediately upstream.

Brough Reservoir's TMDL notes that the rate of oxygen depletion in the reservoir is nearly three times the rate required to meet the cold water fishery water quality standard (UDWQ 2008). The TMDL estimates that a 97% reduction in phosphorus inputs would be necessary for dissolved oxygen levels to satisfy this standard. Further, the TMDL suggests that the relationship between phosphorus load reduction and increasing dissolved oxygen is relatively weak, indicating that disproportionately large reductions in phosphorus inputs would be required to bring dissolved oxygen levels within an acceptable range. The needed reduction in phosphorus is sufficiently large that the TMDL considers it to be unfeasible, and recommends that the use class designation for Brough Reservoir be re-evaluated.

Table 19. Summary of TMDL results from Brough Reservoir AU; adapted from UDWQ (2008).

Brough Reservoir	**Assessment Unit: UT-L-14060010-002**
Beneficial Use Class	3A: cold water sport fishery and food web
Impairment	Reduced dissolved oxygen
Impairment Mechanism	Oxygen limitation due to elevated phosphorus loading
Pollutant	Phosphorus
Pollutant Source	Non-point: internal loading, canal erosion, animal waste, recreational waste
Current Pollutant Load	298 kg/year phosphorus
Acceptable Pollutant Load (use class 3A)	9 kg/year phosphorus
Improvement Targets	1.) Mean Trophic State Index 40-50 2.) No fish-kills 3.) Decrease dominance of blue-green algae 4.) Total phosphorus concentrations of < 0.025 mg/L (in-lake) and 0.05 mg/L (tributary inflow) 5.) Dissolved oxygen concentrations of $\geq$ 4.0 mg/L in at least 50% of the water column
Implementation Strategy	Target phosphorus load reduction is not feasible. Use attainability analysis to better characterize whether or not use class requirements are satisfied; adoption of a tiered aquatic life use class is recommended.

Table 20. Summary of dissolved oxygen data from Brough Reservoir water monitoring stations; adapted from UDWQ (2017).

Monitoring Station ID	**Sample Year Range**	**Number of Samples**	**Mean Dissolved Oxygen in Sample (mg/L)**	**Std. Dev. Dissolved Oxygen in Sample (mg/L)**	**% Samples Exceeding Water Quality Criteria**
Station 5932430 (Above dam)	1998 - 2016	260	4.87	2.56	38
Station 5932440 (Mid-reservoir)	1998 - 2016	153	5.50	2.81	25
Station 5932450 (Above reservoir)	1998 - 2016	33	8.93	1.71	0

4.3 Impaired AU Subwatersheds – TMDLs Needed

The Pelican Lake watershed contains AUs that do not have approved TMDLs for the pollutant causing impairment. Development of TMDLs is considered a high priority for some AUs, and low priority for others; rationale for this designation is discussed in Section 4.0 and Table 14. Important water quality impairments in the watershed that currently lack TMDLs are discussed below.

4.3.1 *Phosphorus*

Assessment Units impaired: Pelican Lake (UT-L-14060010-001)

Phosphorus is a natural nutrient, supporting growth of algae and aquatic plants that provide the basic primary productivity of aquatic ecosystems. In excess, however, phosphorus can result in nutrient pollution and cause significant water quality problems. At high concentrations in water, phosphorus can support abnormally large populations of aquatic algae and bacteria. These blooms reduce the concentration of dissolved oxygen in water, increase water turbidity, and exclude competing native vegetation. The resulting conditions reduce drinking water quality, harm fish and aquatic wildlife, threaten recreational water use, and lay the groundwork for a variety of other water quality problems. Elevated phosphorus levels in water can be caused by crop fertilizers, including animal manure and chemical fertilizers, which contain large quantities of the element (USGS 1999) or high levels can also be a product of underlying geology if there are exposed layers high in phosphorous.

Pelican Lake was designated as impaired for beneficial use class 3B (warm water sport fishery) by phosphorus pollution in 2012. For several decades, phosphorus concentrations in Pelican Lake have exceeded the 0.025 mg/L benchmark used by UDWQ to indicate a polluted lake or reservoir. While water samples from the lake do not universally contain elevated phosphorus, the overall pattern across samples and monitoring stations shows problematic concentrations of total phosphorus (Table 21). Of particular note is data from the Ouray Park Canal monitoring station directly north of the canal inlet into the lake, which shows consistently high levels of phosphorus in canal water just prior to its entry into the lake (Table 21).

Elevated phosphorus concentrations in Pelican Lake have likely contributed to the decline of the bluegill fishery. Phosphorus-induced algae blooms reduce water quality for bluegill, which have relatively high requirements of dissolved oxygen (Moss and Scott 2011). As visual predators requiring clear water to locate and capture prey, bluegill foraging efficiency declines in turbid, algae-dense water (Gardner 1981). Elevated phosphorus also provides a competitive advantage to (and favors population growth of) invasive common carp, which are tolerant of eutrophic and anoxic conditions. The foraging method used by carp stirs up sediment (increasing turbidity) and damages aquatic vegetation, which degrades habitat for bluegill fry and the invertebrate prey of adult bluegill (Wolfe et al. 2011, Bajer and Sorensen 2015, Pelican Lake Advisory Committee 2016). Reducing total phosphorus loading into Pelican Lake is a key step toward restoring the bluegill fishery in the lake.

Pelican Lake is the only AU in the watershed recognized as impaired by phosphorus pollution. However, elevated phosphorus levels may play a role in many of the other designated AU impairments in the watershed. Impairment in water bodies due to depleted dissolved oxygen, elevated pH, and high temperature are often related in some fashion to excessive phosphorus loads (Carpenter 1998, USGS 1999). Consequently, limiting phosphorus inputs and concentration has potential to address other water quality problems throughout the watershed.

High phosphorous concentrations in Pelican Lake are likely the result of a combination of factors that include internal cycling in the lake itself, natural background sources, and agricultural sources. Soil sampling was recently conducted by the Uintah County conservation district at six locations in the canal that periodically flows into the lake. Soil phosphorous values ranged from 2.0 to 3.4 mg/kg. Uintah County conservation district also conducted a survey of landowners near the lake with regard to phosphorus fertilizer use. Of the 11 areas surveyed, phosphorous concentrations ranged from 8.2 parts per million (ppm) to 23 ppm with a mean of 14.5 ppm. Given the low phosphorous concentrations in both the canal and on adjacent agricultural lands, additional soil and water quality sampling at strategic locations in the lake itself and throughout the watershed is needed to further differentiate between sources. Other common anthropogenic sources of phosphorus such as stormwater runoff from urban areas, human wastewater, and power generation have limited or nonexistent footprints in this watershed.

Table 21. Summary of total phosphorus concentrations from monitoring stations in and adjacent to Pelican Lake; adapted from UDWQ, USGS, and EPA water quality data. The beneficial use class 3B pollution indicator for total phosphorus is 0.025 mg/L (Utah Department of Administrative Services 2017: UAC R317-2-7).

Monitoring Station ID	Sample Year Range	Number of Samples	Mean Total Phosphorus in Sample (mg/L)	Minimum Total Phosphorus in Sample (mg/L)	Maximum Total Phosphorus in Sample (mg/L)
Station 4937120 (Ouray Park Canal above Lake)	1992–2012	59	0.084	0.01	0.517
Station 4937130 (Pelican Lake 01 W Midlake)	1990–2016	63	0.028	0.01	0.05
Station 4937140 (Pelican Lake 02 E Midlake)	1990–2016	60	0.028	0.01	0.05
Station 4937150 (Pelican Lake 04 NR West Inlet)	1995–1996	26	0.024	0.01	0.084
Station 4937160 (Pelican Lake 03 SE Bay)	1995–1996	23	0.050	0.01	0.8
Station 4937180 (Pelican Lake 05 100 m from boat ramp)	2010	2	0.047	0.044	0.05

4.3.2 *pH*

Assessment Units impaired: Pelican Lake (UT-L-14060010-001)

In water bodies, elevated pH is typically caused by excessive algae and plant growth, often the result of nutrient pollution. Photosynthesis by plants and algae uses up dissolved carbon dioxide, an important acidifying agent in water. As photosynthetic activity increases, dissolved carbon dioxide declines and the water becomes more alkaline. A feedback loop between pH and nutrient pollution can develop, because rising pH can make phosphorus and nitrogen more available for plant growth, further reducing dissolved oxygen and raising pH still higher. Water pH levels also influence the toxicity of other substances. At elevated pH levels, alkaline substances such as ammonia can be disproportionately harmful to water quality, while toxicity of acidic contaminants may be decreased (Thurston et al. 1981).

Pelican Lake is the only AU in the watershed recognized as impaired by pH. Pelican Lake was designated as impaired for beneficial use class 3B (warm water sport fishery) by pH in 2004. Elevated phosphorus levels (Section 4.3.1) are the probable cause of pH problems (USGS 1999), and a feedback loop between nutrient pollution and pH (as described above) may be occurring in Pelican Lake.

Because pH is a logarithmic measure (meaning that a water sample with a pH of 7.0 has ten times the concentration of hydrogen atoms than a sample with a pH of 8.0), it is not mathematically correct to report simple averages of pH values from multiple water samples. Table 22 shows a median and range of pH values from Pelican Lake monitoring station samples.

Table 22. Summary of pH data from monitoring stations in and adjacent to Pelican Lake; adapted from UDWQ and EPA water quality data.

Monitoring Station ID	Sample Year Range	Number of Samples	Median pH in Sample	Range of pH in Samples
Station 4937120 (Ouray Park Canal above Lake)	1992–2012	68	8.4	7.3–9.2
Station 4937130 (Pelican Lake 01 W Midlake)	1990–2016	77	9.0	7.8–10.1
Station 4937140 (Pelican Lake 02 E Midlake)	1990–2016	75	8.8	7.7–10.1
Station 4937150 (Pelican Lake 04 NR West Inlet)	1995–1996	27	8.7	7.0–10.1
Station 4937160 (Pelican Lake 03 SE Bay)	1995–1996	25	8.8	8.1–10.1
Station 4937180 (Pelican Lake 05 100 m from boat ramp)	2006–2012	4	8.7	8.7–9.5

4.3.3 *Dissolved Oxygen*

Assessment Units impaired: Deep Creek (UT14060003-012)

Like Brough Reservoir, Deep Creek is recognized on the UDWQ 303(d) list as impaired by depleted dissolved oxygen. The impaired Deep Creek beneficial use class is 3A (cold water sport fishery). Much of the Deep Creek drainage, particularly in the lower half of the subwatershed inside the Pelican Lake watershed boundary, is dominated by irrigated agricultural land use (Figures 15–16). It is possible that phosphorus inputs into Deep Creek from this area are derived from fertilizer runoff, animal waste, and erosion; other anthropogenic sources such as stormwater runoff from urban areas are unlikely to make major contributions. Table 23 shows dissolved oxygen data from the Deep Creek water quality monitoring station near Lapoint. It is important to note, when assessing these data, that this station is upstream of the agricultural corridor between Lapoint and the confluence with the Uinta River.

Table 23. Summary of total dissolved oxygen data from the Deep Creek water monitoring station inside the Pelican Lake watershed, adapted from UDWQ (2017).

Monitoring Station ID	Sample Year Range	Number of Samples	Mean Dissolved Oxygen in Sample (mg/L)	Std. Dev. Dissolved Oxygen in Sample (mg/L)	% Samples Exceeding Water Quality Criteria
Station 4934980	1995–2006	35	8.8	2.3	11

4.3.4 *E. coli*

Assessment Units impaired:
Green River – 2 Tributaries (UT14060001-001);
Duchesne River – 1 (UT14060003-001)

The bacterium *Escherichia coli* (*E. coli*) is a commonly occurring bacterium in the digestive systems and feces of animals. Most strains of *E. coli* are harmless themselves (though some can cause diarrhea, infections, or other illnesses), but testing for *E. coli* in water bodies is widely used as an indicator of fecal contamination and the presence of potentially dangerous microorganisms. *E. coli* and other fecal bacteria are introduced into water bodies via human and animal waste, from sources such as manure fertilization, improper animal waste disposal, malfunctioning septic systems, stormwater runoff, and large concentrations of waterfowl or other wildlife. Because fecal bacteria are usually deposited on the surface, concentrations typically decrease with depth in the soil. Surface water runoff is thus key to transporting fecal bacteria into waterways. Fecal contamination of streams, lakes, and reservoirs can compromise their use for drinking water, recreation, and various other beneficial uses.

Not all water bodies in Utah are tested for *E. coli*. The UDWQ annually monitors lakes and reservoirs that experience heavy recreation use; rivers and streams are monitored semi-annually on a rotating, watershed-based schedule. Pelican Lake itself is the only high-priority water body for *E. coli* sampling in the Pelican Lake watershed. The main body of the Green River is also prioritized for regular *E. coli* sampling, but its tributaries inside the Pelican Lake watershed are sampled only semi-annually.

E. coli contamination is recognized as impairing two AUs within the Pelican Lake watershed: the Green River – 2 Tributaries (use classes 1C, 2A, 3A) and Duchesne River – 1 (use classes 2B, 3B) subwatersheds. Both of these AUs (particularly Green River – 2 Tributaries) are high priorities for TMDL development, due to frequent human recreation use, fisheries, and, in the case of the Green River, drinking water. No water quality monitoring stations for either AU are present within the Pelican Lake watershed.

4.3.5 *Temperature*

Assessment Units impaired: Brough Reservoir (UT-L-14060010-002)

Water temperatures in excess of 20°C (68°F) exceed the UDWQ standard for cold water fisheries (use class 3A). Elevated temperatures stress cold water fish species such as trout. Over time, high temperatures can lead to the extirpation of cold water fish species.

Brough Reservoir is the only AU in the watershed recognized as impaired by elevated temperatures. The impaired beneficial use class is cold water fishery (3A), though it is important to note that the UDWR manages Brough Reservoir as a warm water fishery. While cold water species such as rainbow trout occur in the Reservoir, warm water fish species are also prevalent (DEQ 2006), the result of downstream invasion from Cottonwood Reservoir.

Table 23 shows water temperatures from the three water quality monitoring stations associated with Brough Reservoir. Temperature data is collected in both summer and winter, which depresses the overall temperature mean. Because summer temperatures are the concerning factor for cold water fisheries, the number of samples exceeding the 20 °C standard is reported in Table 24.

Table 24. Summary of temperature data from Brough Reservoir water monitoring stations; adapted from UDWQ (2017).

Monitoring Station ID	Sample Year Range	Number of Samples	Number of Samples Exceeding 20 °C	% Samples Exceeding Water Quality Criteria
Station 5932430 (Above dam)	1978–2011	311	73	23.4
Station 5932440 (Mid-reservoir)	1979–2011	187	55	29.4
Station 5932450 (Above reservoir)	1995–2011	37	12	32.4

4.3.6 *Aluminum*

Assessment Units impaired: Whiterocks River Lower (UT14060003-011)

Aluminum is a naturally occurring metal element found commonly as aluminum silicate in rocks and soil deposits. It occurs in relatively large concentrations in the geological formations underlying the northern Uintah Basin and Uinta Mountains. Water erosion and dissolution of soil and bedrock aluminum can result in elevated concentrations in water bodies; various streams in the Uintah Basin exhibit this characteristic (L. Parham, personal communication, 2017a). In the Pelican Lake watershed, only the Whiterocks River Lower subwatershed AU is recognized as impaired by elevated aluminum.

The upper threshold for dissolved aluminum in Utah cold water fisheries is 87 µg/L; higher concentrations warrant an impairment designation for use class 3A. One water quality monitoring station on the Whiterocks River occurs inside the Pelican Lake watershed. Dissolved aluminum data from this station are shown in Table 25. While the mean dissolved aluminum value at this station is below the UDWQ impairment threshold, it is important to recognize that concentrations at the site are highly variable between samples. For example, aluminum concentration in samples from 2011 ranged between 5 to 175 µg/L. This variability appears to be strongly seasonal, with higher concentrations occurring during relatively high flows.

Table 25. Summary of dissolved aluminum data from the Whiterocks River monitoring station inside the Pelican Lake watershed; adapted from UDWQ (2017).

Monitoring Station ID	Sample Year Range	Number of Samples	Mean Dissolved Aluminum in Sample (µg/L)	Std. Dev. Dissolved Aluminum in Samples (µg/L)	% Samples Exceeding Water Quality Criteria
Station 4937180	1995–2010	31	46.5	47.8	16

4.4 Other Pollutants

4.4.1 *Selenium*

Selenium is not recognized as impairing any AUs in the Pelican Lake watershed, but is a pollutant of particular concern in the Lake itself for the UDWQ and UDWR (T. Hedrick, personal communication, 2017a). Similar water bodies in the Uintah Basin have experienced selenium problems, and the physical setting and land use practices surrounding Pelican Lake make it vulnerable to selenium contamination.

Selenium is a naturally occurring, semi-metallic element with chemical properties similar to sulfur and tellurium. Trace amounts of selenium are critical to the creation of some amino acids in animals, but the element is an issue of ecological and public health concern because it is toxic to animals, plants, and people in higher concentrations.

Selenium is typically introduced into ecological systems via water erosion of soil deposits that naturally contain the element. Watersheds with large soil concentrations of selenium are thus at increased risk for selenium contamination (Seiler 1997). Selenium is often present at elevated concentrations in Tertiary and Cretaceous marine formations and their derived soils (Seiler et al. 1999). As water infiltrates through these geologic formations and soils, selenium contained in deposits can be dissolved and transported via shallow ground-water movement or irrigation drainage, and ultimately be discharged into surface waters. As with other dissolved solids, evaporation, transpiration, and re-use of selenium-laden irrigation water concentrates selenium in surface waters and groundwater (see Section 4.1). This problem is most pronounced in hot, arid climates, particularly those with terminal drainage basins, artificial reservoirs, and intensive crop irrigation (Seiler 1997, Seiler et al. 1999, Suarez 2010).

Prolonged exposure to elevated selenium has been shown to produce mortality, congenital deformities, and reproductive failure in birds, fish, and other aquatic organisms (Spallholz and Hoffman 2002, Lemly 2002, Seiler et al. 1999). Further, selenium toxicity has been identified as a primary driver of large-scale fisheries collapses in several lakes and reservoirs in the U.S. (Hamilton 2004). Selenium bioaccumulates in animal tissues and moves readily throughout ecological food webs, meaning that relatively small amounts of the element in water and soil can lead to much higher concentrations within organisms via dietary exposure. Adverse impacts from selenium exposure, due to this bio-accumulative effect, have been demonstrated in multiple taxa when the concentration of total recoverable selenium is as low as 2–4 µg/L in water, and 4 µg/g dry weight in sediment (Presser et al. 1994, Hamilton 2004). In one outdoor-stream experiment, bluegill residing in streams supplemented with 2.5 µg/L of selenium for less than one year produced larvae with significantly elevated frequencies of hemorrhaging, lordosis, and edema (Hermanutz et al. 1992).

Some species appear to be particularly sensitive to selenium toxicity, though the underlying causes of discrepancies between species is not well understood (U.S. Department of the Interior 1998a, Lemly 1993). Importantly for the purposes of restoration efforts in Pelican Lake, bluegill are categorized among those species with apparently low thresholds for selenium toxicity (Lemly 1993).

It is important to note that selenium toxicity in fish typically results in reproductive disruption at the population level, meaning that fisheries can be dramatically impacted without large die-offs of adult fish. This is because the primary impact of selenium toxicity in fish is on developing larvae and fry, as selenium accumulated in the egg from the female’s diet is metabolized. Because adult fish appear otherwise normal, fisheries monitoring programs that focus primarily on adult fish or egg production can overlook significant declines in survival and viability of larvae, fry, and fingerlings. Reproductive impairment in many fish species is likely occurring when the concentration of selenium in whole-body fish tissue reaches 4 to 6 (µg/g) dry weight, despite the fact that adult fish with these tissue concentrations may show no other ill-effects (U.S. Department of the Interior 1998a, Lemly 2002).

Due to the bioaccumulative properties of selenium, dissolved concentrations in water may be dramatically lower than concentrations in biological tissues and the ecosystem as a whole. Low selenium concentration in water can thus reflect either low overall available selenium, or a high degree of biotic uptake. This partitioning changes seasonally in response to biological productivity, and can be quite pronounced in eutrophic systems such as Pelican Lake. Total selenium concentrations in eutrophic water bodies can be many times higher than dissolved concentrations in the water column, making water samples alone unable to detect significant selenium contamination (U.S. Department of the Interior 1998a).

A small number of samples from Pelican Lake water quality monitoring stations show selenium concentrations in water from the Lake and the Ouray Park Canal immediately upstream. These samples, taken from five monitoring stations between 1995 and 2016, generally do not show elevated levels of selenium (Table 26). However, the number of samples is small, and, as discussed above, low concentrations in water samples from eutrophic systems cannot rule out selenium contamination problems. It is possible that water quality samples may not reflect overall selenium concentrations in the lake due to the bioaccumulative properties of selenium (U.S. Department of the Interior 1998a).

Numerous factors suggest that selenium contamination may be a concern in Pelican Lake. The lake is situated in an arid environment overlying the Mancos Shale, is largely fed by irrigation waters, and has experienced declines in fish species known to be sensitive to selenium toxicity. Additionally, several similar, nearby water bodies have experienced selenium problems. For example, at Stewart Lake, a canal-fed off-stream reservoir along the Green River approximately 20 miles northeast of Pelican Lake, high selenium levels prompted a major remediation campaign in the 1990s. Prior to remediation, selenium concentrations in the bottom sediment at Stewart Lake were recorded at over 250 µg/g, more than 60 times the level known to cause reproductive impairment in fish (Stephens et al. 1992, Rowland et al. 2002). At both Stewart Lake and Ouray National Wildlife Refuge, a wetland complex associated with the Green River just southeast of Pelican Lake, selenium concentrations in body tissues of common carp and other fish species have been routinely recorded above the 4–6 µg/g levels known to cause reproductive damage in many species. Selenium contamination is clearly a concern in the Uintah Basin, and should be carefully examined at Pelican Lake. Specific recommendations for further investigation are discussed in Chapter 5.

Table 26. Summary of selenium concentrations from monitoring stations in and adjacent to Pelican Lake; adapted from UDWQ, USGS, and EPA water quality data.

Monitoring Station ID	Sample Year Range	Number of Samples	Mean Dissolved Selenium in Sample (µg/L)	Range Dissolved Selenium in Sample (µg/L)
Station 4937120 (Ouray Park Canal above Lake)	1995–2016	25	1.2	0.1–4.0
Station 4937130 (Pelican Lake 01 W Midlake)	1978–2016	41	1.1	0.1–5.0
Station 4937140 (Pelican Lake 02 E Midlake)	1995–2015	19	1.0	0.1–1.1
Station 4937150 (Pelican Lake 04 NR West Inlet)	1995–1996	9	1.1	0.1–0.8
Station 4937160 (Pelican Lake 03 SE Bay)	1995–1996	2	1.0	1.0–1.0

4.4.2 *Arsenic*

Like selenium, the UDWQ and UDWR consider arsenic a potential pollutant of concern in Pelican Lake, though it has not been recognized as impairing any Pelican Lake watershed AU subwatersheds (T. Hedrick, personal communication, 2017a).

Arsenic is a naturally occurring element with chemical properties between a metal and non-metal, found in low concentrations in soils, water, and living organisms. The background concentration of arsenic is normally < 10 µg/L in water and 1–10 mg/kg in soil (U.S. Department of the Interior 1998b). Elevated arsenic concentrations are typically the result of proximity to geothermally active areas or human actions. Agricultural and industrial processes are the primary anthropogenic sources of arsenic. Particularly problematic sources of arsenic include agricultural wastes from herbicides, fungicides, algicides, and wood preservatives, as well as mine tailings, smelter waste, and other industrial byproducts.

There is ambiguity about what constitutes a problematic concentration of arsenic, and toxic effects have been shown over a wide but inconsistent range of concentrations in aquatic systems. There are a variety of reasons for this. First, there appear to be considerable differences between taxa in both sensitivity to arsenic toxicity and ability to accumulate the element in tissues. Certain taxa have shown particular capacity to accumulate arsenic. One study found the arsenic concentrations in tissues of stoneflies and snails to be approximately 100 times waterborne concentrations, even while other aquatic species showed no indication of accumulation (Spehar et al. 1980). Second, the toxicity and biological availability of arsenic varies with the chemical form of the element, the exposure pathway, and environmental conditions. In aquatic systems, factors such as pH, water temperature, suspended sediments, and the concentration of dissolved solids and phosphorus influence the toxicity of arsenic. Finally, arsenic is generally persistent in aquatic ecosystems, though evidence indicates that arsenic concentration does not magnify across trophic levels in freshwater aquatic systems as easily as some other pollutants (Eisler 1998). This means that relatively large concentrations can linger within the system's overall biomass, even while water concentrations remain low and toxicity is not observed in fish and other consumer guilds (U.S. Department of the Interior 1998b). Overall, major arsenic poisoning incidents of fish and wildlife are relatively rare.

It is important to note that many of the environmental factors known to influence arsenic toxicity, mentioned above, are common water quality impairments in the Pelican Lake watershed. Little data is currently available to assess this possibility. Arsenic concentration data are available from five water quality monitoring stations in and surrounding the lake, but the overall sample size is small and only intermittently collected (Table 27). Concentration of dissolved arsenic concentrations in water from these samples is universally low. However, as with selenium, logic and environmental indicators suggest that arsenic contamination in Pelican Lake should be more thoroughly investigated (see Chapter 5).

Table 27. Summary of dissolved arsenic concentrations from monitoring stations in and adjacent to Pelican Lake; adapted from UDWQ, USGS, and EPA water quality data.

Monitoring Station ID	Sample Year Range	Number of Samples	Mean Dissolved Arsenic in Sample (µg/L)	Range Dissolved Arsenic in Sample (µg/L)
Station 4937120 (Ouray Park Canal above Lake)	1978–2016	26	1.3	1.2–3.0
Station 4937130 (Pelican Lake 01 W Midlake)	1978–2016	42	2.4	0.5–5.2
Station 4937140 (Pelican Lake 02 E Midlake)	1995–2015	19	2.9	1.3–6.3
Station 4937150 (Pelican Lake 04 NR West Inlet)	1995–1996	9	2.5	2.4–2.5
Station 4937160 (Pelican Lake 03 SE Bay)	1995–1996	2	2.5	2.5–2.4

4.5 Summary of Water Quality Impairments

The overall impairment status of the Pelican Lake watershed and Pelican Lake itself is the result of a relatively small number of water quality problems. The watershed's common impairments – elevated salinity, nutrient pollution, oxygen limitation, and alkalinity – are driven by a variety of factors that likely include agricultural activities and natural background sources. The geology underlying the watershed is high in various solid elements that can cause water contamination in elevated concentrations. Background loading of some waterborne pollutants could thus be problematic, regardless of human activities. However, irrigation practices have the potential to both magnify the concentration of these pollutants and exacerbate their effects. Surface and groundwater in the watershed is already high in elements such as selenium, aluminum, and sodium. When this water is used for irrigation, a portion will not be utilized by crops, and either seeps back into the groundwater or evaporates on the surface. Water returning to shallow aquifers passes through soil and bedrock, picking up additional solid loads before the next irrigation use cycle. Evaporating water leaves behind solid deposits on the soil surface, which can be flushed into surface waters by runoff. In the Pelican Lake watershed, these surface waterways are often unlined irrigation canals, which seep large quantities of water back into shallow aquifers, repeating the salinity accumulation cycle. Irrigation use near the lake is primarily sprinkler based; however, the northern portion of the watershed appears to employ both sprinkler and flood techniques.

Other human activities may also contribute to the water quality problems found in the Pelican Lake watershed. Activities that contribute to soil erosion and water use are particularly important. Soil erosion can increase salinity concentration in water via sediment loading, amplify surface runoff, and remove vegetation that helps to mitigate pollutants. Oil and gas development causes significant soil disturbance, particularly where it occurs in concentrated areas such as the southern half of the watershed. Oil and gas extraction, particularly hydrological fracturing, also requires large volumes of water, which is either diverted from surface waters or pumped from groundwater. Many of the same issues involved in the agricultural salinity accumulation cycle also apply to oil and gas water use in the watershed. However, current energy-related water use is a small fraction of agricultural water use (Utah Division of Water Resources 2016). If the projected future increase in oil shale development takes place, this could drive a significant increase in soil erosion and water use from the energy sector. Livestock grazing also contributes to soil erosion and compaction, often concentrating these impacts around waterways, and can be a source of fecal contamination in waterways.

Point sources of pollution do not appear to be important contributors to water quality impairment in the watershed. Likewise, municipal non-point sources appear insignificant. Other than energy development, industrial development in the watershed is quite limited. No major cities or towns occur in the watershed.

In assessing the causes and sources of pollution in the Pelican Lake watershed, it should be stressed that the hydrology is modified to such an extent that characterizing a natural condition is not realistic. Even the boundary of the watershed used here is a product of this modification, with canals and other infrastructure extending the practical watershed of Pelican Lake far beyond the area it would otherwise drain. This complicates the process of establishing a baseline for environmental conditions in the watershed. However, because the watershed's arterial system is largely artificial and heavily managed, changes in this management may have considerable capacity to improve conditions.

4.6 Pollutant Load Reduction

An important component of the TMDL process is an analysis of pollutant loads contributed by both point and non-point sources. Once current pollutant loads are estimated, target reductions can be developed that will bring the AU into compliance with water quality standards. Pollutant loads are typically estimated using a combination of watershed modeling and statistical analysis of water quality data. Watershed modeling has become increasingly sophisticated and widely used; however, this approach can be unreliable in watersheds with major hydrological modifications such as Pelican Lake. For this watershed plan, a pollutant load reduction was estimated using available data for total phosphorous. In addition, load reduction estimates for TDS presented in previously approved TMDLs in the Pelican Lake watershed are summarized as well. Many of the management strategies identified to address TDS impairments will also assist in reducing both phosphorous and suspended sediment, therefore it is important to consider those load reductions as well even through Pelican Lake is not currently impaired for TDS.

4.6.1 *Pelican Lake* (UT-L-14060010-001)

Pelican Lake was listed as impaired for total phosphorous in 2012. There is no state water quality criteria for total phosphorous; however, there is a phosphorous pollution indicator concentration for rivers of 0.05 mg/L and for lakes of 0.025 mg/L. Parameters that are assessed as pollution indicators typically warrant further investigation into both the beneficial use classification and impairment status. Table 21 presents a summary of phosphorous concentrations for both Pelican Lake and the canal feeding the lake. With the exception of one monitoring station in the lake, all sites exceed the pollution indicator concentration for total phosphorous.

For the purposes of this watershed plan, load reductions for phosphorous are focused primarily on the primary source of water to the lake – an irrigation canal that feeds into the northwest corner (Figure 20). The earthen canal flows at least four months out of the year and is used primarily for capturing water for irrigation. Water quality data from the monitoring station on the canal located at the road crossing of 7000 S (see red dot in Figure 20) indicates that phosphorous concentrations are high with an average of 0.084 mg/L since 1992. A visual assessment of the canal during certain flows indicates that the sediment load (and consequently, the phosphorous load) can be high (Figure 21a and Figure 21b). Total suspended sediment and phosphorous are significantly correlated in the canal ($R^2 = 0.6$, $p \leq 0.05$), therefore it is likely that any reductions achieved in the sediment load will result in reductions to the phosphorous load.

Based on 57 pairs of matched flow and phosphorous data, the current daily average phosphorous load to the lake is 90 kg/day. When phosphorous concentrations are replaced with the 0.05 mg/L pollution indicator concentration, the daily average load to the lake is 58 kg/day resulting in a **36% reduction needed in phosphorous loading** to the lake from the canal. This reduction is an estimate based on available data and does not take into account internal phosphorous loading of the lake. Additional water quality modeling is needed to link phosphorous reductions in the canal to reductions in the lake as well as to determine that the assigned pollution indicators are appropriate for these specific waterbodies.

Figure 20. Location of the canal feeding Pelican Lake denoted by the yellow star. The red dot indicates the location where photos were taken (Figure 21a and Figure 21b).

Figure 21a. The canal feeding the lake. Photo was taken on 05/15/17 approximately 0.6 miles north of the lake (facing south).

Figure 21b. The canal feeding the lake. Photo was taken on 05/15/17 approximately 0.6 miles north of the lake (facing north).

Elevated levels of pH are typically a direct indicator that nutrient enrichment is occurring in a waterbody; therefore, any nutrient reductions (i.e., phosphorous) achieved will likely also have an effect on pH. As a result, load reductions were not estimated for this parameter. It appears that since the original listing for pH in 2004, pH has been declining. Over the past 10 years, there have been only two exceedances of the water quality criteria with a median value of 8.5 (Figure 22).

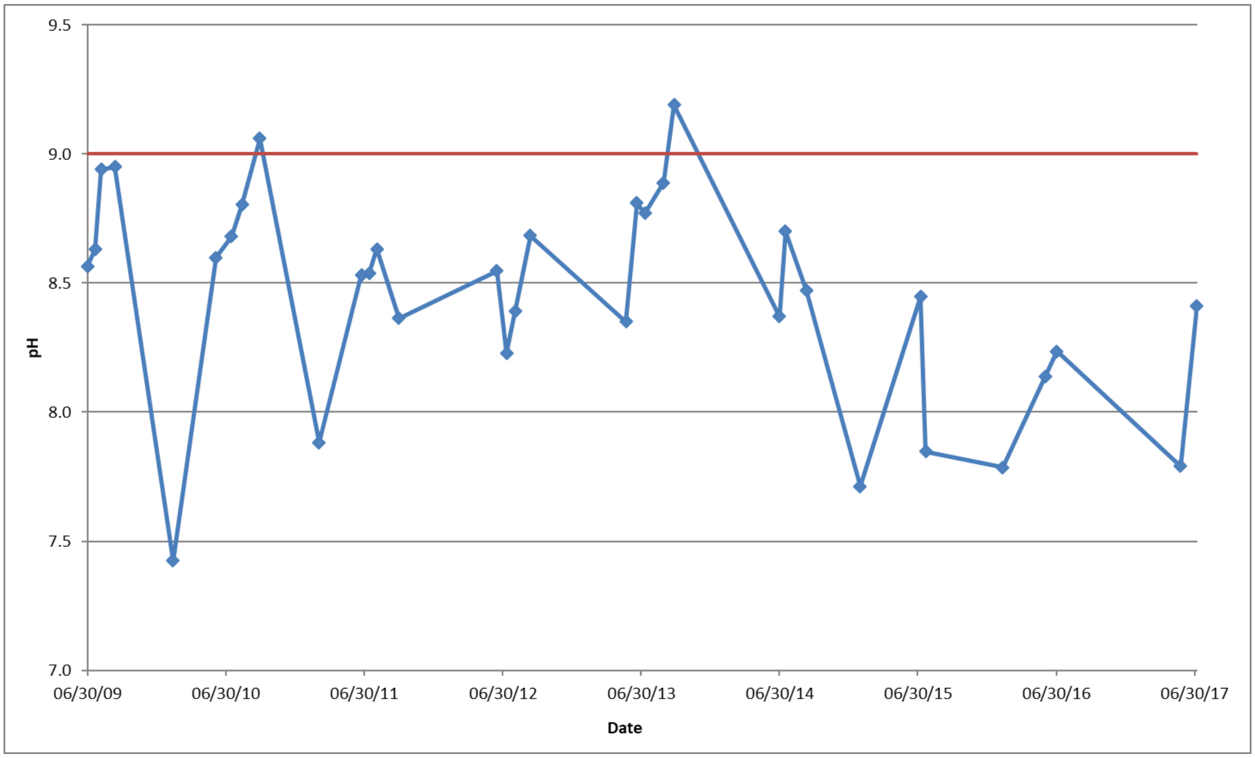

Figure 22. pH in Pelican Lake since 2009. The red line represents the state water quality criteria for pH.

4.6.2 *Other AUs*

Because of its modified hydrology, the Pelican Lake watershed contains portions of several subwatershed AUs, rather than natural drainages (see Figure 18). For those subwatersheds with approved TMDLs (i.e., Deep Creek, Uinta River-2, Duchesne River-1), pollutant load reductions were calculated as a part of the TMDL process. For Deep Creek, Uinta River-2, and Duchesne River-1, flow-specific reductions were estimated for total dissolved solids (Table 28). TDS impairments in the Deep Creek and Uinta River-2 AUs occur at low and medium flows, with the most severe impairments in the low flow percentile. This suggests that TDS concentrations peak at low flows (when high-salinity groundwater composes most of the streamflow), but also rise to impairing levels during typical conditions when irrigation is ongoing (UDWQ 2006). Impairments in the Duchesne River-11 AU occur at low flows (0–30%), indicating high, consistent loading of TDS which reach particularly high concentrations when less water is available to dilute the salinity. These conditions typically occur in spring and fall when stream flows are reduced (UDWQ 2007).

Table 28. Required percentage of TDS load reduction at changing flow rates from TMDL AUs in the Pelican Lake watershed; adapted from UDWQ (2006, 2007).

Flow Percentile	Percent Load Reduction Required	
	Deep Creek (UT14060003-012) and Uinta River – 2 (UT14060003-004); Dissolved Solids	Duchesne River – 1 (UT14060003-001); Dissolved Solids
Low (0-30)	32	12

Medium (30-70)	23	0
High (70-100)	0	0

Several other TMDLs have been developed for Uintah Basin AUs impaired by TDS. These also conclude that TDS impairments are most significant at low flows. This consistent pattern throughout the Basin is unsurprising, considering similar underlying geology, land use, and widespread hydrological modification. The pattern likely holds throughout the Pelican Lake watershed as well: total dissolved solids are expected to reach highest concentrations during low flows. While this has not been established by TMDLs for specific TDS components such as selenium, arsenic, and aluminum, the same principles that drive TDS loading patterns will also likely govern loading of individual TDS component pollutants.

5.0 WATERSHED IMPLEMENTATION STRATEGY

Managing non-point source pollutant loads and sedimentation from surrounding lands is key to improving conditions in the Pelican Lake watershed, as well as restoring the fishery and water quality values of Pelican Lake. Critical among the implementation strategies recommended here, therefore, are measures intended to reduce surface runoff,upstream erosion, and sediment loading and accumulation in Pelican Lake. Limiting phosphorus runoff during irrigation and precipitation events should be prioritized, along with minimizing TDS loading in low flow conditions when salinity problems are most pronounced. Other important measures include management to remove and exclude exotic fish and plant species, restore riparian areas, and guide energy development to protect the watershed. The management strategies presented below focus primarily on the lake and the canal that feeds the lake. These locations should be prioritized over implementation in the upper portion of the watershed until additional data is collected to determine the primary sources of sediment and phosphorous.

5.1 Objectives

The primary restoration goals for the Pelican Lake watershed are:

- Restore past bluegill and largemouth bass fishery conditions in Pelican Lake.
- Improve water quality throughout the watershed by reducing TDS loads.
- Reduce phosphorus loading into the watershed, with anticipated improvements in water quality impairments related to nutrient pollution.
- Reduce sedimentation into Pelican Lake, lowering inputs of phosphorus, TDS, and TSS.
- Work with the landowners, agricultural producers, agency partners, and the public to develop management practices that improve water quality and protect aquatic habitats while maintaining water rights and agricultural operations.

5.2 Colorado River Salinity Control Program

The Colorado River Salinity Control Program (CRSCP) was developed in order to address increasing salinity concentration in the Lower Colorado River. Since the program’s inception, the annual salt load to the river has been reduced by 1.3 million tons and concentration reduced by more than 100mg/L.
The Bureau of Reclamation (BOR) is responsible for implementing the program however; it works with other state and federal agencies to implement on the ground salinity controls measures. One such program is the Environmental Quality Incentives Program (EQIP) managed through the NRCS.

The Uinta Basin has been very active in addressing salinity. According to BOR’s Quality of Water Progress Report No. 25 published in 2017, implementation began in this unit in 1980. The original salt control goal was reached several years ago but approximately 60,000 acres might still be improved. Sixteen new contracts were developed in 2015 on 560 acres for approximately $1.4 M. Once implemented, these projects will control 873 tons of salt annually. Irrigation improvements are typically either sprinklers, buried pipelines or some combination of the two. Many systems in the region have reached or are nearing the end of their useful life; however, NRCS will begin providing incentives for replacement or up-grading.

Data on irrigation improvements specific to the Pelican Lake watershed is not currently available but will be added as it becomes available in the future. According to local sources, much of the irrigation in the area, particularly directly north of the lake, was converted to sprinkler several years ago.

5.3 Current and Planned Restoration Efforts

5.3.1 *Common Carp Removal*

Drawing from conclusions of an advisory committee and substantial input from the public, the UDWR plans to remove common carp from Pelican Lake in fall 2018. Carp are recognized to damage conditions in the lake, and are believed to be a major factor in the decline of the bluegill fishery. Utah Division of Wildlife Resources biologists believe that carp removal will allow for macrophyte reestablishment, reduce turbidity, and eliminate a non-native predator and competitor.

Carp have occurred in Pelican Lake at low numbers for decades, but populations have recently expanded substantially. Inadvertent releases of large numbers of carp from Cottonwood Reservoir in 2008 and 2009 are the likely culprit of this spike, and water quality issues in Pelican Lake have likely favored the persistence of an ecologically impactful carp population (Pelican Lake Advisory Committee 2016). The major potential sources of future carp colonization in Pelican Lake have been addressed by UDWR in recent years. Carp populations are not able to move from Brough Reservoir to Pelican Lake via surface waters, and carp management strategies have been implemented at Cottonwood and Bullock Draw to prevent the establishment of large carp populations in those potential source sites. Carp have been eradicated from private ponds upstream of Pelican Lake, via UDWR efforts including pond-draining and rotenone treatments. As a consequence, UDWR is confident that the carp removal at Pelican Lake will be an effective long-term strategy (T. Hedrick, personal communication, 2017c).

Various methods were considered to remove or reduce the impact of carp in Pelican Lake, and create a long-term plan for preventing future carp colonization. To address the carp population in the Lake over the short term, the UDWR plans to treat the entire lake with rotenone, the isofalvone piscicide, in October 2018. This treatment would kill all fish in the lake; following treatment, desirable fish species would be re-stocked, with the goal of restoring the species assemblage that was present in Pelican Lake in the 1970s and 1980s (Pelican Lake Advisory Committee 2016), when limits of one-pound bluegill were reportedly common. The long-term success of this approach hinges entirely on preventing future colonization of carp into Pelican Lake; the removal will have no impact if carp simply recolonize the Lake from upstream populations.

To prevent future colonization of common carp, the UDWR plans to install a fish screen above Pelican Lake. RB&G Engineering has recommended that UDWR install a Coanda screen, which are preferred because of their effectiveness for controlling carp movement and low maintenance requirements (RB&G Engineering 2016). The engineering and design work for this screen has been completed; construction is planned for fall 2018 pending the receipt of funding. Improvements to water quality are also key to UDWR’s approach to long-term carp control in Pelican Lake (Pelican Lake Advisory Committee 2016).

5.3.2 *Pelican Lake Sedimentation Mitigation*

Sedimentation into Pelican Lake from the Ouray Park Canal is a concern for UDWR and UDWQ. The current sediment and phosphorous loads received from the canal decrease water quality in the lake, reduce fishery value, interfere with irrigation water storage, and impede access of anglers and other recreational users. Reducing overall sedimentation into Pelican Lake over the long term is best addressed by a watershed-wide mitigation approach, implementing the measures recommended in this restoration plan. However, direct sedimentation control in the area immediately upstream of Pelican Lake could produce relatively rapid and cost-effective improvements to water quality. The UDWR and UDWQ, in conjunction with the Ouray Park Irrigation Company (OPIC) are currently designing sediment control measures around the Pelican Lake inlet, as well as immediately upstream in the Ouray Park Canal.

The planned effort to control sedimentation around the Pelican Lake inlet has two key components. First, the channel of the Ouray Park Canal will be stabilized and widened near the lake inlet. The channel stabilization will be accomplished by installing rip-rap armoring at the canal's margins near the lake. This is expected to reduce bank erosion and accompanying sediment inputs. Widening the canal near the outlet is intended to slow incoming water before it reaches Pelican Lake, encouraging sediment to fall from suspension and accumulate at the canal bottom. The canal bottom in this area could also be lined with a solid base material, allowing it to be dredged without significant disturbances to the wetland area surrounding the lake inlet.

The second proposed component for mitigating sedimentation around the Pelican Lake inlet is the installation of a sediment catchment dyke and basin in the lake, just below the inlet of the Ouray Park Canal. This structure will catch sediment flowing from the mouth of the canal, restricting its movement into other areas of the lake. Currently, sediment inputs from the canal are easily transported away from the inlet via wave action. The catchment dyke would also improve the efficiency and effectiveness of dredging, because the sediment would be concentrated in one area designed to allow easy access for dredging equipment.

In future phases, the partners in the Pelican Lake restoration effort will be requesting funds to install rip-rap armor along the peninsula extending into the lake adjacent to the Ouray Park Canal inlet. This will help protect the area from wind erosion and wave action. The partners also hope to work with the Four Star Ranch to construct a sediment catchment basin alongside the Ouray Park Canal on that property. This basin would collect sediment from all upstream sources. Regular excavation and maintenance would be prioritized due to the proximity of the catchment to the active ranchland. Finally, the partners also hope to install rip-rap armor around drop structures in the 1.5 miles of the Ouray Park Canal immediately above Pelican Lake. These drop structures have fallen into disrepair; some are currently the cause of a great deal of erosion in the canal. Further work to control erosion along the canal immediately below Bullock and Cottonwood Reservoirs would be beneficial to sedimentation control efforts, but will not be planned or carried out until the major downstream sedimentation sources have been addressed (T. Hedrick, personal communication, 2017c).

5.4 Recommended Restoration Measures

5.4.1 *Pelican Lake*

Pelican Lake is the focal point of this restoration plan and the drainage point for waterways throughout the watershed. Environmental conditions in Pelican Lake are a snapshot of conditions in the watershed as a whole, as the Lake receives water from all other AUs in the watershed. The major water quality issues in Pelican Lake are shown in Table 29, along with recommended implementation strategies and estimated removal efficiencies for sediment and phosphorous. Removal efficiencies were extracted from the Spreadsheet Tool for Estimating Pollutant Load (STEPL) BMP list.

Addressing the decline of the bluegill fishery is a special priority for UDWR, as Pelican Lake was once a nationally recognized Blue Ribbon bluegill fishery. The immediate factors suspected by UDWR as driving the bluegill fishery decline (such as turbidity, common carp invasion, and water temperature) are heavily influenced by water quality. Improving water quality conditions should thus be central to efforts to restore the Lake's bluegill fishery over the long term (Pelican Lake Advisory Committee 2016).

Efforts to reduce phosphorus loading into Pelican Lake could have significant benefits for water quality and ecosystem health. Elevated phosphorus drives eutrophication, raises water pH, alters water temperature dynamics, reduces fitness of many aquatic species, and favors carp and other undesirable species which themselves produce a host of problems. Because phosphorous inputs are likely a result of both agriculture and natural background sources, an important first step is to conduct soil and water quality sampling to determine how these sources vary. Additionally, agricultural fields that have yet to be converted to sprinkler irrigation could be examined to determine if conversion is a possible option. Identifying specific fields within the watershed with the greatest potential to contribute phosphorus is a potentially valuable approach.

Phosphorus loading into Pelican Lake is likely to be significantly correlated with sediment inputs and TSS in waterways (Sharply and Beegle 2001, Gitau et al. 2005). Efforts to manage sedimentation may thus be critical to reducing phosphorus and its associated suite of problems, and reducing sedimentation in Pelican Lake would also benefit water clarity and habitat. Various methods to control sedimentation immediately around Pelican Lake are being considered by UDWR, and are at various stages of implementation. In the lake itself, sedimentation could be better managed by installing a sediment catchment dyke near the inlet from the Ouray Park Canal or a sediment catchment basin on Four Star Ranch, both of which would capture sediments prior to their further spread into the lake. This area could be dredged occasionally to remove accumulated sediments. Widening the inlet area of the Ouray Park Canal would have similar sediment-catching effects, by slowing water flow immediately before it enters the lake. This inlet area could also be dredged when needed and engineered to act as a biofilter, especially if the sediment catchment dyke proves too expensive. Installing rip-rap erosion control banks near the Ouray Park Canal inlet, as well as at erosion-prone locations along the Pelican Lake shoreline, would reduce also reduce erosion and sediment inputs. Installing meanders in the canal between the pipeline outflow and the lake would slow the flow and encourage deposition before the lake; inside bends on meanders would have to be dredged occasionally to maintain the original flow capability.

Selenium concentration in the Pelican Lake ecosystem overall should be studied. Selenium has a documented capacity to disrupt bluegill fisheries, and numerous lines of evidence suggest that overall selenium levels may be elevated in Pelican Lake. Because of its bioaccumulative properties, selenium may be problematically elevated in aquatic systems despite low concentrations in water samples. Considering the underlying geology, selenium pollution in nearby waterways, and bluegill declines; this may be the case in Pelican Lake. Replacing open-ditch irrigation canals with pipelines has been repeatedly demonstrated as a method to reduce selenium concentrations in water bodies (Butler 2001). Pipelines do not receive or contribute to groundwater flows, reducing the overall contact between water and seleniferous soil and thus the mobilization of selenium into water bodies, and do not directly receive surface runoff. Additionally, a pipeline draining a selenium-laden reservoir should carry lower concentrations than an upstream canal feeding the reservoir, because a large proportion of the selenium entering the reservoir will accumulate in bottom sediments and biota prior to entering the outflow pipeline (Rowland et al. 2002). The Cottonwood Pipeline, which feeds Pelican Lake from Cottonwood Reservoir, likely reduces selenium loads into Pelican Lake in this fashion.

Table 29. Major water quality issues in Pelican Lake, and recommended management measures.

Water Quality Issue	Management Strategies	Removal Efficiency
Phosphorous/Sediment input to Pelican Lake	1. Construct sediment catchment basins along the canal to allow places for sediment to settle out before it gets to the lake 2. Streambank stabilization along the irrigation canal north of the lake to reduce sediment input to Pelican Lake o Work with Ouray Park Canal managers to identify problematic sites o Stabilize canal margins at key erosion points 3. Identify areas with high likelihood of phosphorus/sediment loading via surface runoff. Characteristics likely to produce loading include: o Sloped fields o Flood-irrigated fields o Fields adjacent to major waterways o Fields with impermeable soils, compacted soils, salt crusts increasing surface runoff, or saturated soils preventing percolation o Fields with degraded or absent vegetation buffers between crops and waterways 4. Decrease surface runoff to reduce sediment and phosphorous inputs into irrigation canals o Develop buffering vegetation strips between crop fields and waterways, especially immediately upstream of Pelican Lake 5. Replace irrigation canals with pipelines where possible, emphasizing canals immediately upstream of Pelican Lake 6. Burn the bulrush around Pelican Lake to assist in reducing the internal phosphorus load.	1. 50% - 80% 2. 75% 3. NA 4. 40% - 60% 5. 90% 6. NA
Inputs of TDS from upstream waterways	7. Reduce TDS inputs by decreasing salinity of ground and surface waters in the watershed o Replace irrigation canals with pipelines wherever possible o Replace any remaining canal-based flood irrigation with sprinklers o Encourage removal of salinity-augmenting tamarisk, particularly large stands at waterway margins 8. Conduct further study of the potential for selenium and arsenic contamination in Pelican Lake, with a focus on selenium due to its known impacts on bluegill fisheries. Efforts should examine system-wide concentrations rather than only dissolved concentrations in water to account for potential bioaccumulation. Unfiltered water samples should be analyzed for both dissolved and particulate selenium and arsenic, and examined alongside samples from sediment and animal tissues.	NA
Common carp invasion	9. Remove current common carp population o Rotenone treatment (planned for fall 2018) o Long-term success of rotenone treatment depends on preventing future colonization 10. Prevent future common carp colonization o Install fish barriers (Coanda screens) near inlets to Brough Reservoir and Pelican Lake, to prevent re-entry of carp from upstream populations	NA

	○ Identify potential upstream sources of carp invasion (including Cottonwood and Bullock Draw Reservoirs and the Uinta River), work with private pond and reservoir managers to remove common carp from these sites as necessary 11. Improve water quality in Pelican Lake to reduce conditions favoring common carp over desirable native species ○ Reduce long term phosphorus inputs to lessen eutrophic and alkaline conditions favoring carp (see strategies for reducing phosphorus, below in table) ○ Reduce TDS inputs to decrease salinity, which carp tolerate better than many desirable fish species (see strategies below in table) ○ Reduce sedimentation inputs (see strategies below in table) 12. Conduct public outreach to increase awareness of detrimental impacts of carp in Pelican Lake 13. Monitor fish community regularly to quickly detect future carp invasion	

5.4.2 *Other AUs*

Various management measures are recommended for other AUs in the watershed; however, this portion of the Pelican Lake watershed should not be the initial focus until further sampling is conducted to determine primary sources of phosphorous and sediment. Table 30 provides a summary of the impairments and recommended management strategies.

Table 30. Major impairments of environmental conditions in the upper portion of the Pelican Lake watershed, and recommended management measures.

Environmental Impairment	Source	Management Strategies
Low dissolved oxygen and elevated water temperature	Elevated total phosphorus	1. Identify specific areas with high likelihood of phosphorus loading via surface runoff, focusing mitigation measures on these sites. Field characteristics likely to produce heavy phosphorus loading include: o Sloped fields o Flood-irrigated fields o Fields adjacent to major waterways o Fields with impermeable soils, compacted soils, salt crusts increasing surface runoff, or saturated soils preventing percolation o Fields with degraded or absent vegetation buffers between crops and waterways o Frequent severe thunderstorms producing surface runoff 2. Reduce surface runoff of phosphorous o Vegetative barriers between fields and waterways o Replace irrigation canals with pipelines wherever possible o Maintain riparian areas and waterway margins to increase phosphorus uptake o Reduce surface salt deposits on crop fields to improve soil permeability and limit surface runoff
Elevated Salinity	Large inputs of dissolved solids (TDS)	3. Reduce TDS inputs by decreasing salinity of ground and surface waters o Replace irrigation canals with pipelines wherever possible o Replace canal-based flood irrigation with sprinklers o Improve water storage and delivery infrastructure to encourage landowner adoption of irrigation sprinklers o Encourage removal of salinity-augmenting tamarisk, particularly large stands at waterway margins 4. Encourage grazing practices to control erosion, particularly at waterway margins and in riparian areas
***E. coli* fecal contamination**	Manure fertilizer	5. Identify specific areas with high likelihood of manure inputs via surface runoff, focusing mitigation measures on these sites. Site characteristics most likely to contribute to fecal bacteria loading include: o Manure-fertilized crop fields, particularly if flood irrigation is used o Feedlots or other concentrations of cattle, sheep, horses, or poultry o Pastures or crop fields adjacent to major waterways o Crop fields or pastures with impermeable soils, compacted soils, salt crusts increasing surface runoff, or saturated soils preventing percolation o Fields or pastures with degraded or absent vegetation buffers at waterway margins 6. Reduce fecal bacteria inputs into waterways by limiting surface runoff from sites identified (as above) o Protect and develop vegetative barriers between fields and waterways

		○ Encourage planting of cover crops to reduce surface runoff ○ Replace irrigation canals with pipelines wherever possible ○ Reduce surface salt deposits on crop fields to improve soil permeability and limit surface runoff 7. Work with landowners to manage animal fecal waste, particularly around waterways

5.4.3 *Estimated Load Reductions*

To quantify the effectiveness of BMP implementation on total phosphorus and total suspended sediment for the Ouray Park Canal, several pieces of information were used (Table 31). Average annual loads were calculated for both TP and TSS from 1992 – 2016 using data from the monitoring station located along the canal and upstream of the lake (4997120). BMP removal efficiency rates were extracted from the Spreadsheet Tool for Estimating Pollutant Load (STEPL) BMP list for streambank stabilization and sediment basins. The STEPL model was originally explored as a tool to estimate reductions however, due to the absence of key pieces of data for this region, the tool was not a viable option. The average annual load was multiplied by the removal efficiencies to generate pollutant removal per year. The total reduction in phosphorus is estimated at 15,896 lbs/yr. Sediment reduction was estimated at approximately 298 tons/yr.

Table 31. Pollutant load reduction estimate for phosphorous and sediment.

Pollutant	Annual load	Estimated Load Removal	Estimated % Removal	Remaining Annual Load
TP (lb/yr)	24,403	15,896	65	8,507
TSS (tons/yr)	344	298	87	46

5.5 Funding Needs

Estimated funding needs for restoration efforts in the Pelican Lake watershed are shown in Table 32. These figures are estimates; adjustments are anticipated as the details of the restoration effort are finalized.

Table 32. Estimates of funding needs for Pelican Lake watershed restoration efforts.

Restoration Element	Total Costs	CWA 319 Funds	Match Funds	Match Funds Source
Seed stabilization below Cottonwood Reservoir	$14,500	$0	$14,500	Habitat Council
Watershed restoration plan	$25,300	$25,300	$0	
Ouray Park Canal management plan	$16,000	$0	$16,000	OPIC
Design of inlet fish screen above Pelican Lake	$46,187	$0	$46,187	Blue Ribbon Fisheries Fund / Habitat Council
Design of outlet fish screen below Pelican Lake	$30,940	$0	$30,940	Blue Ribbon Fisheries Fund

Rotenone treatment (common carp removal)	$211,000	$0	$211,000	UDWR
Engineering and design of sedimentation reduction projects around Pelican Lake	$162,100	$35,000	$87,100	Blue Ribbon Fisheries Fund / Habitat Council
Construction of inlet fish screen above Pelican Lake	$247,625	$0	$247,625	Blue Ribbon Fisheries Fund / Habitat Council
Construction of outlet fish screen below Pelican Lake	$100,000	$0	$100,000	Blue Ribbon Fisheries Fund / Habitat Council
Execution of sedimentation reduction projects around Pelican Lake	$2,098,000	$300,000	$1,798,800	NRCS RCPP / Blue Ribbon Fisheries Fund / Habitat Council / UDWR

5.6 Technical Assistance Needs

The Pelican Lake restoration efforts focused within the lake itself will be led by UDWR, as the agency primarily responsible for the management of the aquatic habitat and fishery of the lake itself, as well as other water bodies in the watershed. All restoration efforts targeting the Ouray Park Canal will be led by the OPIC. Other key partners include the UDEQ and UDWQ, UDAF, NRCS, BOR, and BLM. A summary of the key partners and their expected role is presented in Table 33.

Table 33. Anticipated key partners in Pelican Lake watershed restoration efforts, and their major duties or roles in the process.

Partner	Key Role / Actions
UDWR	1. Act as project leader, providing guidance and assistance during all phases of restoration within Pelican Lake 2. Assemble and organize project components and partners 3. Execute or supervise field tasks such as watershed restoration plan, common carp removal, desirable fish stocking, sediment control measures, fish screen installations, upstream improvement projects, and ongoing habitat and water quality monitoring 4. Locate potential sources of funding for watershed improvements, including submittal of application for CWA 319 funding 5. Provide funding support
OPIC	6. Act as project leader, providing guidance and assistance during all phases of restoration within the Ouray Park Canal 7. Continue operations and critical maintenance of the Ouray Park Canal, Cottonwood Pipeline, and Cottonwood, Bullock Draw, and Brough Reservoirs, which are key to the long term success of restoration efforts in the watershed 8. Provide technical assistance with the design and execution of restoration tasks involving the above water bodies, such as efforts to improve irrigation efficiency and reduce sediment inputs to Pelican Lake 9. Assist with involvement of local landowners and water-rights holders in the restoration process
UDAF	10. Utilize existing relationships with landowners to encourage participation and provide guidance on dominant agricultural practices in the region.

UDEQ / UDWQ	11. Provide guidance during the planning stages of restoration efforts (including direction and feedback during the development of the watershed restoration plan) 12. Provide water quality monitoring assistance to help track restoration progress 13. Lead public outreach and education component of watershed restoration
NRCS	14. Utilize existing relationships with landowners and agricultural producers to encourage participation of these stakeholders in the restoration process 15. Provide funding support
BOR	16. Provide advisory and environmental support 17. Function as the lead NEPA agency for watershed restoration efforts
BLM	18. Integrate watershed restoration efforts with existing management plan for BLM lands within the watershed, including the campground and other BLM lands adjacent to Pelican Lake 19. Provide guidance and/or field support during restoration efforts impacting BLM lands
EPA	20. Provide technical guidance in executing restoration efforts if needed 21. Provide funding support

5.7 Schedule for Implementation

Completed or scheduled components of Pelican Lake watershed restoration efforts are outlined in Table 34. This schedule should be considered a general framework for implementation, and is expected to be revised according to logistical constraints, funding, and the completion of prerequisite tasks.

Table 34. Schedule of implementation for restoration efforts in the Pelican Lake watershed. Timelines are presented using the fiscal year schedule for the State of Utah, which runs from July 1 – June 30.

Restoration Component	Goals / Objectives	Schedule for Implementation
Pelican Lake watershed restoration plan	1. Document current watershed conditions and provide overview of key watershed characteristics 2. Identify likely drivers of Pelican Lake fishery impairments 3. Propose improvement measures, establish a schedule for their implementation, and lay out objectives for monitoring progress	FY 2017
Ouray Park Canal management plan	4. Identify important stormwater drainage locations 5. Identify slope stability areas and erosion hotspots 6. Identify needed canal repairs	FY 2017
Seed stabilization of Ouray Park Canal flood zone	7. Perform seeding to stabilize frequent flood-overflow area of the Ouray Park Canal below Cottonwood Reservoir (private land)	FY 2017
Conceptual design and permitting for proposed Pelican Lake modifications and improvements	8. Develop conceptual designs and obtain permits for planned Pelican Lake improvements, including: o Sediment dredging and control structures o Boater and angler access points o Dredging of lakeside area / Ouray Park Canal inlet o Ouray Park Canal bank stabilization o Rip-rap armoring of shoreline and canal margins o Fish screen above Pelican Lake inlet to prevent future common carp invasion	FY 2017-18
Design and engineering of fish screen at Pelican Lake outlet	9. Design and engineer fish screen at the Pelican Lake outlet to prevent escape of bluegill and bass into the Green River	FY 2018

	and Ouray National Wildlife Refuge	
Common carp removal in Pelican Lake	10. Implement rotenone treatment in Pelican Lake to eliminate existing common carp population 11. Re-stock Pelican Lake with native and desirable fish species	FY 2019
Install fish screen at Pelican Lake outlet	12. Finalize design and install fish screen at the Pelican Lake outlet to prevent escape of bluegill and bass into the Green River and Ouray National Wildlife Refuge; timing and execution is expected to be contingent on Habitat Council and/or Blue Ribbon funding	FY 2019-20
Design and engineering of proposed Pelican Lake modifications and improvements	13. Final design, engineering, and execution of planned Pelican Lake improvements, including: o Dredging of lakeside area, sediment basin, and Ouray Park Canal inlet o Ouray Park Canal bank stabilization (rip-rap armoring) and widening of channel near inlet to Pelican Lake o Sediment control dyke near canal inlet o Sediment catchment structure on the Four Star Ranch property o Rip-rip armoring of key Pelican Lake shoreline sites (peninsula and breakwater areas) o Boater and angler access points o Install Coanda fish screen above Pelican Lake inlet to prevent future common carp invasion o Install fish screen at Pelican Lake outlet to prevent escape of bluegill and bass into the Green River and Ouray National Wildlife Refuge	FY 2019-20
Implementation of sedimentation reduction and control measures	14. Implement further sedimentation control measures in targeted sites within the Pelican Lake watershed; the scope and timing of these efforts is expected to be contingent upon CWA 319 funds and other funding sources	FY 2019-20
Install upstream fish screens at other sites within the watershed	15. Install additional upstream fish screens to prevent the spread of common carp within the watershed; timing and execution is expected to be contingent on Habitat Council and/or Blue Ribbon funding	FY 2020

6.0 EDUCATION AND OUTREACH EFFORTS

Outreach to area stakeholders, landowners, and the public at large is often critical to the success of watershed restoration efforts over the long term (EPA 2008). Outreach campaigns can increase awareness of the issues and problems faced by watersheds, involve upstream landowners and managers whose actions most directly impact watershed conditions, and lay the groundwork for protecting resources into the future.

Outreach and education campaigns conducted as part of watershed restoration plans receiving CWA Section 319 funding often have two main components. First, outreach is conducted to individual landowners or stakeholders within the watershed, often in the form of one-on-one meetings or conversations. The purpose of this outreach is to gauge understanding of water quality issues, identify specific practices at the scale of individual properties that may be contributing to problems in the watershed, and work with landowners to implement watershed restoration measures. Landowners are most likely to help with restoration measures if these measures also improve their crop and grazing lands, simplify irrigation, or solve other problems. Watershed restoration efforts can often accomplish this goal (EPA 2008), and many of the measures recommended for improving conditions in the Pelican Lake watershed could also benefit area landowners. For example, allocating restoration efforts and funding to improve riparian corridors at crop field margins, upgrading irrigation infrastructure, or increasing crop watering efficiency via sprinklers would benefit agricultural producers as well as watershed health.

Outreach conducted as part of Pelican Lake watershed restoration efforts should be prioritized to target agricultural producers, and in particular, those with the most influence over water quality conditions. These producers can be identified during the planning phase of watershed restoration efforts, using the same selection criteria as may be used to identify individual crop fields or sites most likely to be important sources of non-point pollution (see Section 5.2). Landowner participation can be encouraged by emphasizing that restoration efforts may benefit both landowners and the watershed, and that substantial funding may be available to facilitate improvements to private property and irrigation infrastructure (EPA 2008).

The second common component of education and outreach efforts in CWA 319 watershed restoration plans is a campaign to inform the public of water quality issues, and increase appreciation of the focal water body. In the past several years, UDWR has conducted public outreach efforts via information on its website, news releases announcing its intent to restore the fishery, and surveys of anglers and other lake users. As the restoration process moves forward into its implementation phase, public involvement and input will continue to be important. Informational sessions or public meetings regarding watershed improvement efforts may help to increase public participation. These meetings can also be helpful to encourage cooperation between key stakeholders who may be unaware that watershed restoration efforts can benefit all parties. For example, these meetings could be used to foster collaboration between anglers and upstream agricultural producers, by illustrating that both could benefit from restoration efforts in the watershed.

7.0 MONITORING

Monitoring water quality and fishery conditions is a critical component of the Pelican Lake restoration effort. Monitoring will allow key agencies and partners to quantify the progress of major restoration goals, such as reducing sedimentation in Pelican Lake, managing phosphorus inputs further upstream within the watershed, and controlling erosion in the Ouray Park Canal. Monitoring will also provide data to help answer important unresolved questions about environmental conditions in the watershed, such as the possibility of a selenium contamination problem in Pelican Lake. And ultimately, monitoring will play an important role in determining if the primary goal of the restoration effort – the revival of Pelican Lake's once-esteemed fishery – has been achieved.

Monitoring during the watershed restoration effort is expected to be led by UDWR and UDWQ. These agencies currently collect data on various water bodies in the Pelican Lake watershed; monitoring conducted as part of this restoration effort will be essentially an extension of their existing protocols. A Sampling and Analysis Plan (SAP) that details monitoring efforts is presented below in Appendix A. In short, the UDWR conducts annual fish and zooplankton sampling in the reservoirs within the watershed, and will continue this sampling scheme into the future. Once the restoration efforts are underway, UDWR will devote particular attention to collecting and interpreting data from the bluegill fishery (T. Hedrick, personal communication, 2017d). Communication with anglers and other resource uses is also an important part of UDWR efforts to monitor conditions in Pelican Lake, and will remain so during restoration efforts. Angler surveys, creel censuses, and other feedback can provide crucial information about fish size, condition, abundance, and public satisfaction with the fishery. The UDWQ intensively samples water quality from each of Utah's six major drainage basins on a yearly rotating basis; the next year of intensive sampling for the Uintah Basin is scheduled for 2023. This approach typically collects water quality samples every 2-4 weeks. However, the UDWQ also conducts additional sampling to accompany non-point pollution reduction projects. This typically takes the form of a year of monthly pre-project sampling to establish a firm baseline of conditions, followed by 5 years of post-project monitoring to gauge progress (L. Parham, personal communication, 2017b). This approach should provide sufficient water quality data to evaluate the efficacy of restoration efforts in Pelican Lake. Water quality monitoring should be primarily focused on the stations just upstream of Pelican Lake in the Ouray Park Canal, just below the canal inlet into the Lake, as well as at least one mid-lake station. Other existing monitoring stations within the watershed should be sampled as well, and establishing new sampling locations may be beneficial. For example, new water sampling sites could provide more detailed information on phosphorus inputs from upstream areas. Sampling immediately upstream and downstream of these areas could illuminate the degree to which the phosphorus loading originates from agricultural sources versus natural sources and help to pinpoint additional mitigation sites.

In combination, monitoring of water quality, pollutant concentrations, fisheries, and other ecological communities should reveal trends toward improvement in Pelican Lake, and thus signal that restoration efforts are working. Importantly, this broad monitoring approach could also show that conditions are not improving despite restoration efforts, providing an early alert that different measures may need to be implemented. It should be noted that the SAP, similar to the watershed plan, is adaptive and will be updated on an annual basis to reflect current monitoring efforts.

7.1 Interim Milestones

The UDWR and UDWQ will assess monitoring data at regular intervals to assess changes in response to restoration efforts. This assessment will include water pollutants, pH, temperature, and turbidity, as well as fishery data documenting body condition, abundance, and species assemblages. A complete list of specific milestones to mark improvements has not yet been specified by UDWR or UDWQ. However, several critical steps toward recovery will need to be fulfilled during the restoration process.

The UDWQ anticipates gradual reductions in the concentration of key water pollutants such as phosphorus, TDS, and TSS, with the ultimate goal of meeting state water quality criteria. Efforts to reduce sedimentation inputs to Pelican Lake (such as canal lining and widening, installing sediment catchment structures, and reducing erosional runoff upstream in the watershed) are expected to produce measurable decreases in the concentration of phosphorus, TDS, and TSS in the lake. Lowering the concentrations of these pollutants may, in turn, alleviate pH and temperature impairments. Specific interim concentration goals for pollutants may be identified later in the restoration process, but currently the ultimate achievement of state water quality criteria is the goal of UDWQ.

Interim milestones for the recovery of the Pelican Lake fishery have been developed by UDWR, with the ultimate goal of restoring the bluegill fishery to its Blue Ribbon status. However, as with water quality, these may be amended during the watershed restoration process. A major milestone for restoring the fishery is the elimination of common carp from Pelican Lake, accompanied by measures to prevent future colonization by this damaging invasive species. This will be accomplished via a rotenone treatment of Pelican Lake, installation of fish screens above the lake to prevent carp entry, and continued management to reduce upstream carp populations. Once carp have been eliminated from Pelican Lake, the subsequent interim milestone will be re-stocking of largemouth bass and bluegill, and the establishment of healthy, reproducing populations of both species. Field sampling and communication with anglers should provide information regarding progress towards this goal, and water quality improvements in the lake should increase the odds of its achievement. Once the population has been established, UDWR will manage Pelican Lake with the intent of reproducing the renowned bluegill fishery of the 1970s-1980's.

7.2 Criteria for Success

The success of this watershed restoration effort is expected to hinge principally on the resurgence of the bluegill fishery in Pelican Lake, with coinciding improvements to water quality which will benefit the lake in myriad ways. The status of the bluegill fishery will be assessed by UDWR via sampling surveys and communication with anglers. If restoration efforts are successful, bluegill populations in Pelican Lake should grow, overall fish size should increase, and very large, memorable bluegill (defined as a bluegill 10 inches or longer in total length) should become more abundant and more frequently caught.

Fishery targets for bluegill in Pelican Lake include 50% of individual fish in the population measuring greater than 6 inches in length, 30% of the population greater than 8 inches, and numerous fish greater than 10 inches. The remaining fish would be stock length (< 3 inches). In order to reach ideal growth rates in bluegill, the large majority (>90%) of largemouth bass should be 15 inches or less, which promotes predation on small bluegill, thereby reducing competition in that population. The UDWR uses relative weight (W*r*) to refer to fish condition; *Wr* can also be used as a metric of prey availability in a system. Fish samples collected from Pelican Lake in 2013 and 2015 showed satisfactory *Wr* for bluegill 8 inches or less in length, but poor body condition for fish larger than 8 inches. In 2015 sampling, no fish larger than 8 inches were collected. If the fishery restoration efforts are successful, UDWR anticipates Pelican Lake will support a robust population of bluegill over 8 inches long, with average relative weights above 90. The UDWR anticipates meeting these targets 6-7 years after implementation of the rotenone treatment, sediment reduction projects, and other efforts linked to the restoration effort of the watershed.

Evaluating the success of this restoration effort based only on the bluegill fishery is not the recommended approach, however. Significant improvements in water quality, water use efficiency, riparian habitat health, hydrological dynamics, recreational opportunities, and overall ecological conditions in the watershed are likely to result from this restoration effort. Thus, while the bluegill fishery may be the organizing force behind this project, the potential benefits extend well beyond the fishery. For example, reducing phosphorus concentrations in Pelican Lake to state water quality criteria levels will require a host of perquisite improvements, such as lowering upstream runoff from fertilized fields and controlling irrigation ditch erosion. Measures intended to accomplish this would restore and protect riparian habitat, improve irrigation efficiency, and reduce TDS accumulation in waterways, among other benefits. This example illustrates the fact the efforts to improve Pelican Lake's bluegill fishery may be greatly beneficial to the watershed's overall ecology, irrespective of the outcome for bluegill.

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Appendix A