

Survey and Assessment of Critical Wetlands in the Roaring Fork Watershed, Colorado



September 2022

CNHP's mission is to advance the conservation of Colorado's native species and ecosystems through science, planning, and education for the benefit of current and future generations.



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Report Prepared for:
U.S. Environmental Protection Agency, Region 8
1595 Wynkoop Street
Denver, CO 80202

Recommended Citation:

Marshall, S., D. Culver, and G. Smith. 2022. Survey and Assessment of Critical Wetlands in the Roaring Fork Watershed, Colorado. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado. 125 p.

Front Cover: Wetlands along the Crystal River, Roaring Fork watershed.

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EXECUTIVE SUMMARY

At the headwaters of the Colorado River, the Roaring Fork watershed's wetlands are both biodiversity hotspots and filters for the water supplies of millions of people downstream and across the Continental Divide. The watershed is home to some of Colorado's rarest wetland types – from “old growth” fens to hanging gardens – along with wet meadows and riparian woodlands and shrublands that extend from quiet mountain valleys to the edges of cities along the Roaring Fork River.

Climate change, and a surge in development and recreation are placing increasing demands on aquatic and terrestrial ecosystems in the watershed. At the same time, more than 80% of total land area in the watershed has some form of protection. Over the last two decades alone, more than 31,056 acres of land have been protected. Beyond protection, many of the watershed's terrestrial and aquatic habitats are relatively undisturbed by human development. Nearly 70% of the 27,500 acres of wetlands and waterbodies in the watershed have minimal habitat fragmentation.

This study seeks to better understand how wetlands are doing in a watershed with impressive land protection, but increasing stress from human activities. Our foundation includes past work of the Roaring Fork Watershed Biological Inventory (Spackman 1999), the Roaring Fork Watershed Plan (Clarke et al. 2012), the Roaring Fork Watershed Biodiversity & Connectivity Study (Rondeau et al. 2002), and other watershed studies from the past two decades. Following a targeted field inventory and more comprehensive wetland mapping, we now have a better understanding of the types, condition, and unique conservation and restoration needs of wetlands across the watershed.

Key findings and outcomes from this project included:

- (1) New relationships with a network of partners and stakeholders in the watershed who helped make this study possible and will be integral to taking study results and applying them to future wetland conservation and restoration on the ground.
- (2) A species inventory and floristic quality assessment to evaluate the condition of more than 30 wetland sites visited across the watershed.
- (3) Twelve new element occurrences of rare species (1 amphibian, 3 bird, 4 plant community, and 4 plant) and 26 updated element occurrences of rare or imperiled plants, animals, and plant communities – including a population extension for the federally-threatened Ute ladies' tresses (*Spiranthes diluvialis*).
- (4) The most comprehensive, detailed wetland mapping for the watershed to date, including updated fen and beaver complex mapping, and nine different likely wetland functions.
- (5) A list of prioritized wetland conservation and restoration areas for the watershed, including five high-priority areas and four medium-priority areas.

We hope that this project catalyzes and improves the efficacy of aquatic restoration activities by providing integral data to streamline watershed planning and help our partners better understand the value, characteristics, and condition of wetlands across the watershed.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the U.S. Environmental Protection Agency (EPA) Region 8 and the Watershed Biodiversity Initiative (WBI) for their financial support and encouragement of this project. Special recognition goes to EPA Project Officers Billy Bunch and Rachel Harrington, Tanya Code, and Grant Specialists Katlyn Tovar.

The wetland survey is a much more valuable resource because of the high level of partner and stakeholder contributions and involvement in the planning, field inventory, and mapping process. The authors would like to give special thanks to Tom Cardamone with the Watershed Biodiversity Initiative, Dave Erickson with the Aspen Valley Land Trust, Jamie Werner, Mark Fuller, and the other members of the Watershed Biodiversity Science Team. We are also grateful to a host of private landowners who allowed us to visit wetlands on their ranches across the watershed. Their stewardship and care for wetlands in the watershed - from beaver ponds named after grandchildren to diligent noxious weed pulling and careful cow herding to avoid wetland areas - was truly inspiring.

During the course of this project, we gained tremendous technical assistance, ideas and overall guidance from our colleagues at CNHP, especially Amy Greenwell, Lee Grunau, Andrea Schuhmann, Renee Rondeau, Joanna Lemly, Karin Decker. Finally, we would like to thank the Office of Sponsored Programs and Warner College budget staff with Colorado State University for accounting support and grant administration.

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1.0 INTRODUCTION

At the headwaters of the Colorado River, the Roaring Fork watershed's wetlands are both biodiversity hotspots and filters for the water supplies of millions of people downstream and across the Continental Divide. The watershed is home to some of Colorado's rarest wetland types – from “old growth” fens to hanging gardens – along with wet meadows and riparian woodlands and shrublands that extend from quiet mountain valleys to the edges of cities along the Roaring Fork River.

Climate change, and a surge in development and recreation are placing increasing demands on aquatic and terrestrial ecosystems in the watershed. At the same time, more than 80% of total land area in the watershed has some form of protection, from wilderness areas in the mountains to conservation easements on valley floor ranches. Over the last two decades alone, more than 31,056 acres of land have been protected – often in the form of conservation easements on private land. Many of these recent conservation efforts have targeted wetlands, riparian areas, and other high-biodiversity habitats. Beyond protection, many of the watershed's terrestrial and aquatic habitats are relatively undisturbed by human development. Nearly 70% of the 27,500 acres of wetlands and waterbodies in the watershed have minimal habitat fragmentation.

This study seeks to better understand how wetlands are doing in a watershed with impressive land protection, but increasing stress from human activities. Our foundation includes past work of the Roaring Fork Watershed Biological Inventory (Spackman 1999), the Roaring Fork Watershed Plan (Clarke et al. 2012), the complementary Roaring Fork Watershed Biodiversity & Connectivity Study (Rondeau et al. 2002), and other watershed studies from the past two decades. Following a targeted field inventory and more comprehensive wetland mapping, we now have a much better understanding of the types, condition, and unique conservation and restoration needs of wetlands across the watershed.

CNHP employed several methods to assess wetland extent, condition, functions, and conservation and restoration needs in the watershed. First, CNHP engaged with stakeholders and partners in the watershed to identify wetland-related priorities and gather information on areas to target for the field inventory. Second, CNHP carried out a desktop review and field inventory of ecologically significant areas. Third, CNHP updated mapping and conducted geospatial analyses of wetland types, functions, and surrounding landscape condition across the watershed. Finally, CNHP compiled a series of priority conservation and restoration areas and needs based on existing watershed priorities, the Roaring Fork Watershed Biodiversity & Connectivity Study (Rondeau et al. 2022), and the field inventory.

Key findings and outcomes from this project included:

- (1) New relationships with a network of partners and stakeholders in the watershed who helped make this study possible and will be integral to taking study results and applying them to future wetland conservation and restoration on the ground.

- (2) A species inventory and floristic quality assessment to evaluate the condition of more than 30 wetland sites visited across the watershed.
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We hope that this project catalyzes and improves the efficacy of aquatic restoration activities by providing integral data to streamline watershed planning and help our partners better understand the value, characteristics, and condition of wetlands across the watershed.

2.0 THE ROARING FORK WATERSHED

The Roaring Fork watershed (HUC8: 14010004) covers 1,451 square miles (3,760 km²) within the headwaters of the Colorado River basin (Figure 1), on traditional Núu-ágha-tʼáńvę-pę (Ute) land (Native Land Digital 2021). Elevations within the watershed range from 5,700 feet near Glenwood Springs to 14,279 feet at the summit of Castle Peak. Colorado’s most well-known mountain ecosystems are represented within the watershed, from alpine tundra blanketing mountain ridges to a gradient of spruce-fir, aspen, oak, and pinyon-juniper forests heading from mountain flanks to foothills and valleys below. Riparian forests trace the path of the Roaring Fork River and its lowland tributaries, with pastures, hayfields, and cities clustered along and just above the river’s historical floodplain. Wetlands and waterbodies are scattered throughout the watershed and collectively cover around 3% of the total land area. From subalpine fens to cottonwood gallery forests, wetlands are a nexus where water, nutrients, and living things converge to support some of the highest biological diversity in the watershed.



Figure 1. Roaring Fork watershed. Map produced by Matt Annabel.

2.1 Climate

The climate of the Roaring Fork is characterized by cold winters and short summers, with clear, sunny days common throughout much of the year. Average annual precipitation in the watershed ranges from 12 inches near Carbondale to more than 50 inches in the highest elevation areas of the southern watershed (Figure 2).

Average annual temperatures vary by approximately 14 °F across the watershed, from 44 °F in the lower watershed to 30 °F around the high peaks.

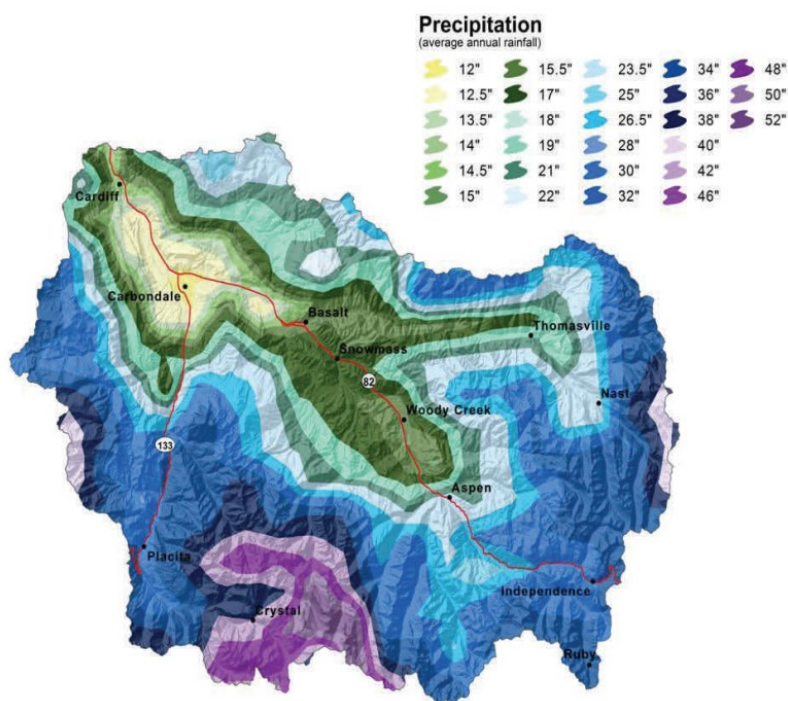


Figure 2. Average annual precipitation in the Roaring Fork watershed. Source: USDA NRCS (2008).

2.1a Climate Change Projections

Warmer temperatures, droughts and earlier snowmelt are primary climate change concerns in the Roaring Fork watershed. Over the past 70 years, mean annual temperatures in the watershed have increased by approximately 2 °F compared with historical (1950-1990) conditions, and future climate projections range from a mean increase of another 2-4 °F by 2050 (Figure 3; Climate Toolbox 2022). Mean annual precipitation in the watershed is expected to see little change from recent historical (since 1950) and current conditions under lower and higher emissions scenarios in coming decades (Climate Toolbox 2022).

Warmer temperatures will likely result in earlier spring snowmelt in the mountains, with peak runoff projected to occur 1-3 weeks earlier and reduced summer stream base flows (Childress et al. 2015). Higher air temperatures and earlier snowmelt are likely to impact aquatic ecosystems (including sensitive species like Colorado River cutthroat trout) through elevated water temperatures and reduced stream flow – particularly at lower elevations in the watershed. Wetland and riparian ecosystems are also likely to experience shorter periods with wetted soils and standing water during the growing season, especially in systems that receive most of their hydrologic inputs from surface water.

Metrics like the Palmer Drought Severity Index (PDSI), which typically ranges from -10 (dry) to 10 (wet), help track and predict the effects of increasing temperatures and evapotranspiration on soil moisture. While the Roaring Fork watershed has experienced several “very wet” (PDSI >4) periods since 1980, “extreme drought” (PDSI <-4) conditions have become more common over the past 40

years along with a general increase in drought frequency (Figure 4). Higher temperatures, reduced snowpack, earlier snowmelt, evaporation from the soil surface, and increased plant transpiration can all result in a shorter duration of groundwater saturation and surface water inundation in wetlands, and drought stress for wetland and riparian plants.

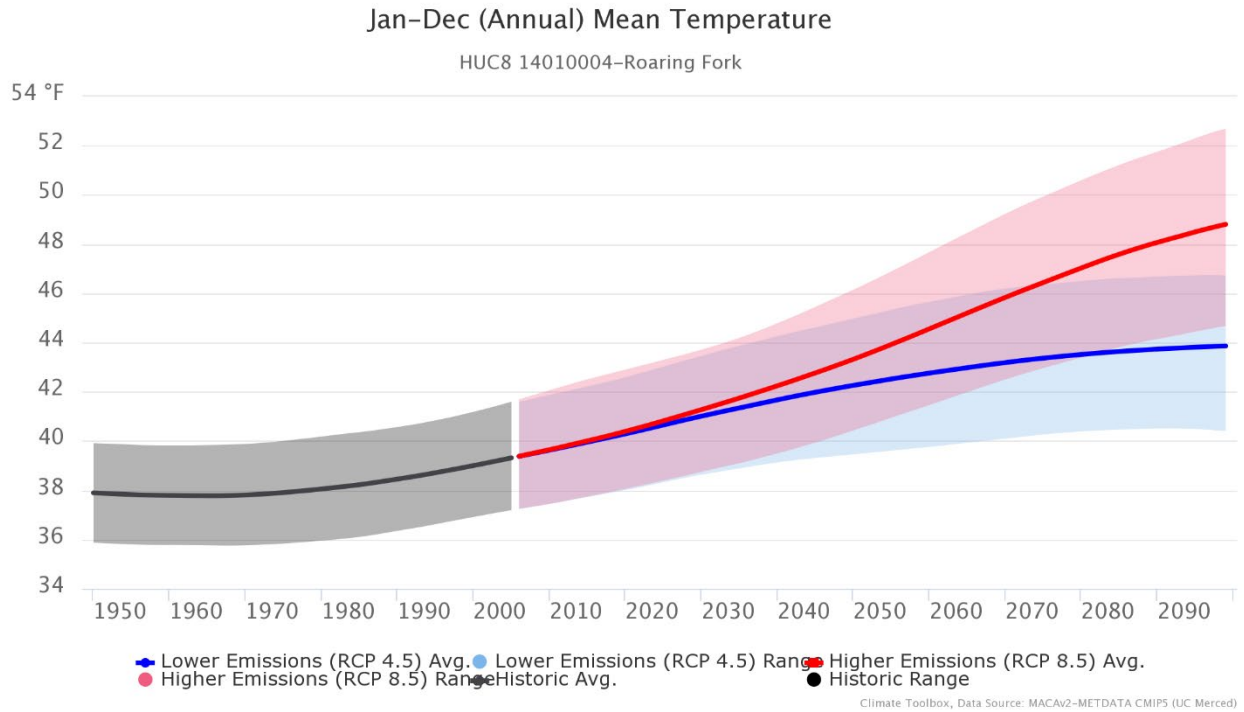


Figure 3. Historical and projected mean annual temperature from 1950-2100 for Roaring Fork watershed under lower (RCP 4.5) and higher (RCP 8.5) modeled emissions scenarios. Source: Climate Toolbox (2022).

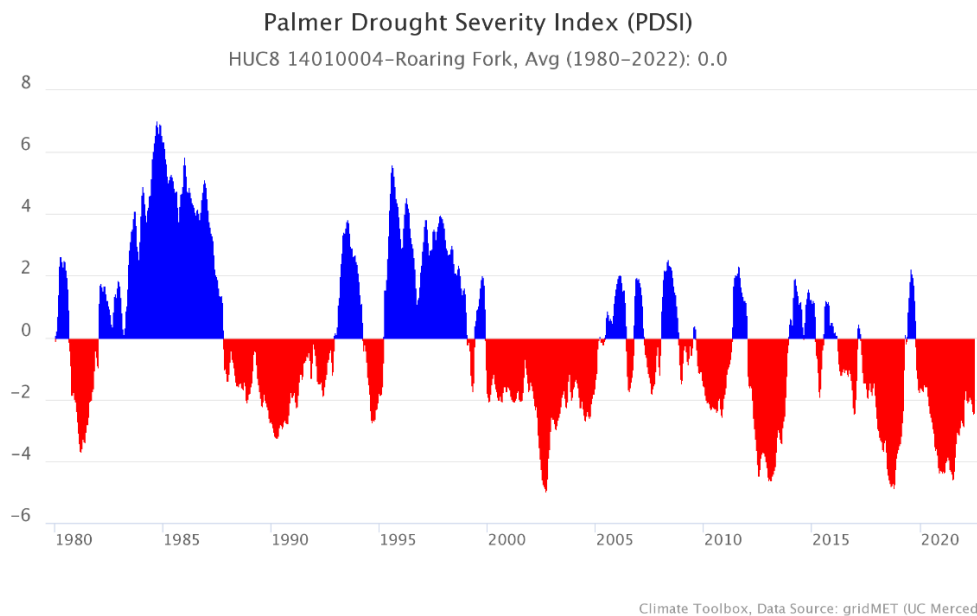


Figure 4. Palmer Drought Severity Index (PDSI) for the watershed from 1980-2022, showing an increase in the frequency of drought conditions (negative values) over time. Source: Climate Toolbox (2022).

2.2 Land Cover

Land cover within the watershed varies with elevation, slope, annual precipitation, valley bottom width, and human activities (Figure 5).

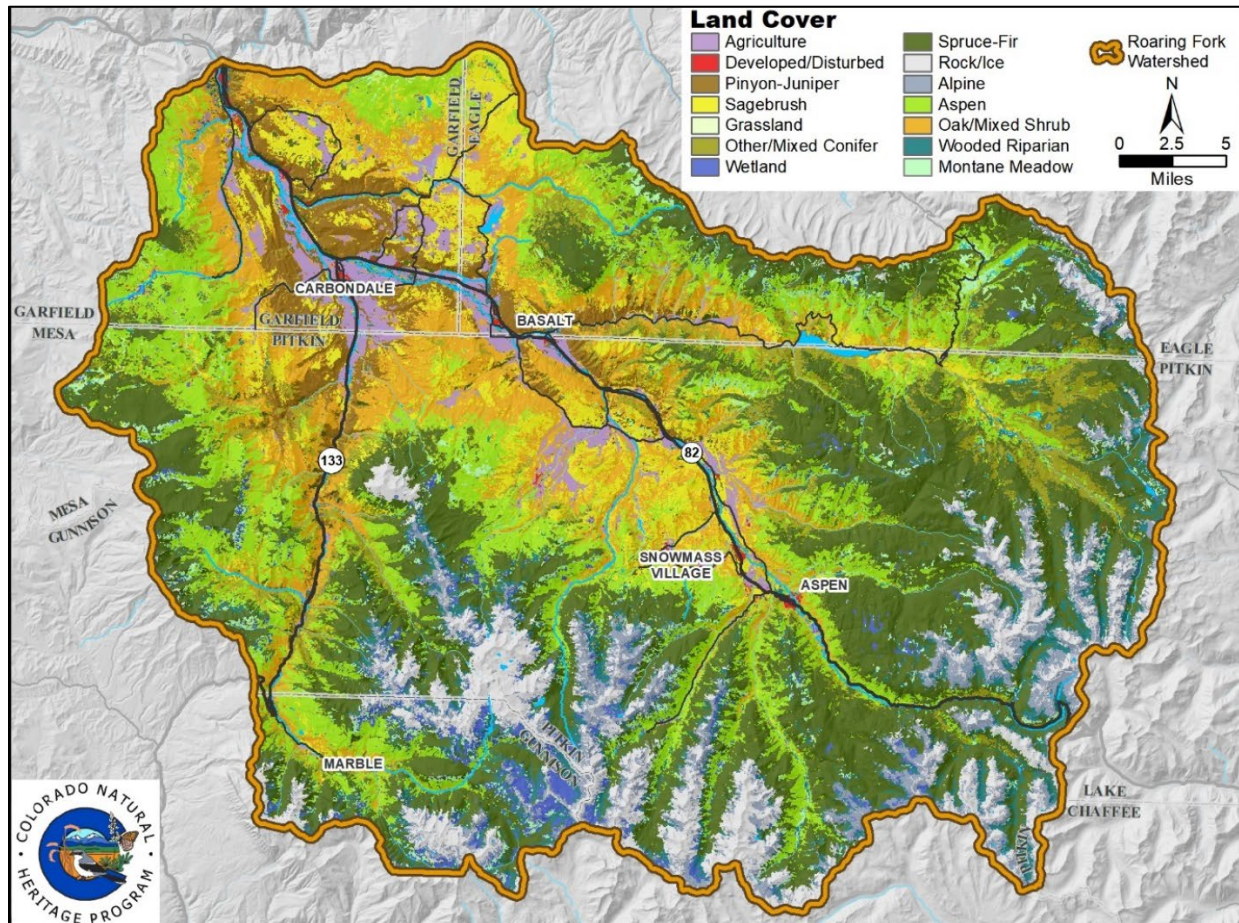


Figure 5. Land cover in the Roaring Fork watershed.

The four most prevalent land cover classes (spruce-fir and aspen forests, oak-mountain shrubland, and bare rock) cover nearly 65% of land area in the watershed and are closely tied to abundant mountainous terrain (Table 1). The highest reaches of the watershed include rock and alpine tundra. Descending into subalpine and montane drainages, spruce-fir and aspen forests cover valley slopes. In the foothills and margins of the valley floor, oak and mixed shrubland, pinyon-juniper, sagebrush, and grassland habitats form a mosaic of habitat types. On the valley floor of the watershed, agricultural and developed lands are most extensive, with wooded riparian areas and wetlands tracing the path of the Roaring Fork River and its tributaries.

Table 4. Major land cover types in the watershed, with extent in acres and percent of total watershed area.

Land Cover Type	Acres	% of Watershed
Spruce-Fir Forest	248,845	26.8%
Aspen Forest	161,675	17.4%
Oak/Mixed Shrubland	104,356	11.2%
Rock and Ice	84,973	9.2%
Alpine-Subalpine Wet	71,815	7.7%
Sagebrush	68,109	7.3%
Alpine	46,208	5.0%
Pinyon-Juniper	42,721	4.6%
Mixed Conifer	35,338	5.5%
Agriculture (Hay)	30,348	3.3%
Grassland	8,982	1.0%
Riparian/Wet	4,091	0.4%
Developed/Disturbed	2,713	0.3%
Open Water	2,481	0.3%

2.3 Hydrology and Water Management

The Roaring Fork River begins near Independence Pass in the southeast corner of the watershed, and is joined by major tributaries including Castle Creek, Maroon Creek, Snowmass Creek, Woody Creek, the Fryingpan River, the Crystal River, and Cattle Creek before it reaches the Colorado River at Glenwood Springs. The mean annual flow of the Roaring Fork River is around 1,206 cubic ft/s, with annual peak flows associated with snowmelt in June (Figure 6).

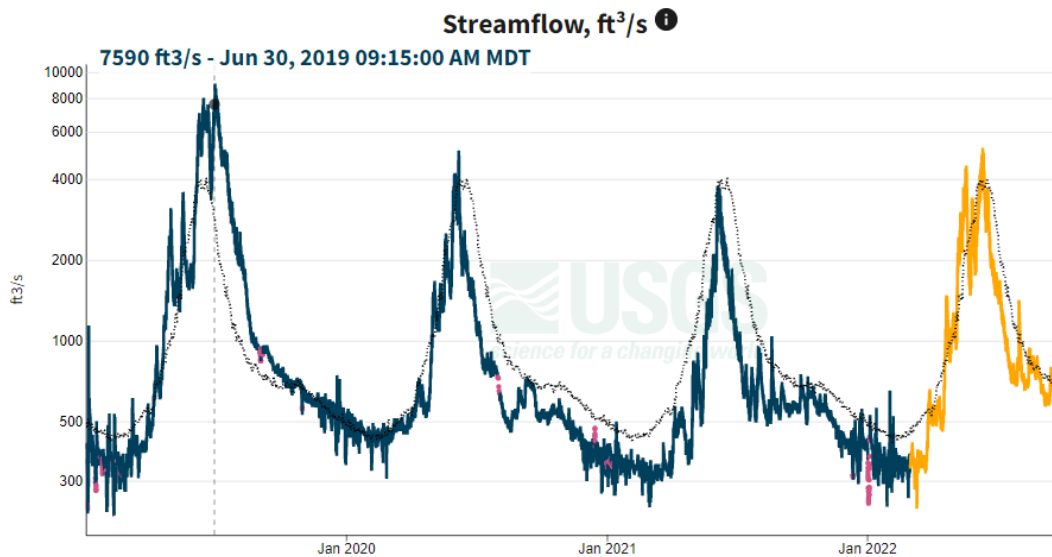


Figure 6. Roaring Fork River flows at Glenwood Springs (USGS gage No. 09085000) during the study period, showing seasonal peak flows in June and low winter base flows. Source: USGS (2022).

At the headwaters of the Colorado River basin, the Roaring Fork watershed contributes to the water supply for around 40 million people downstream. Ruedi Reservoir on the Fryingpan River is the largest waterbody in the Roaring Fork watershed and can store up to 102,000 acre-feet of water. Two transbasin diversions (Colorado’s 3rd and 5th largest) pump water from Ruedi and Grizzly Reservoirs across the Continental Divide, and into Front Range reservoirs and streams. Approximately 100,000 acre-feet of water is pumped from the headwaters of the Roaring Fork into the Arkansas River basin each year, including around 37% of the Upper Roaring Fork River and 41% of the Upper Fryingpan River surface flows (Colorado Basin Roundtable 2021). The Boustead Tunnel transports Fryingpan River water stored in Ruedi Reservoir under the Continental Divide for 5.5 miles to Turquoise Reservoir in the Arkansas River headwaters. Part of the Fryingpan—Arkansas Project, this tunnel delivers approximately 61,550 acre-feet of water each year from the Roaring Fork watershed to southeastern Colorado for municipal, agricultural, hydroelectric power generation and recreational use. The project is one of Colorado’s largest reclamation projects, second only to the Colorado-Big Thompson. Each year, approximately 40,615 acre-feet of water is also diverted from Grizzly Reservoir, in the headwaters of the Roaring Fork River, and flows under the Continental Divide through the Twin Lakes Tunnel at Independence Pass.

Surface water diversions from streams in the watershed include a mixture of municipal, residential, and agricultural uses. Irrigated pasture lands, including both flood and sprinkler irrigation, cover approximately 2% of total land area and are mostly concentrated on the valley floor. Many of these irrigated lands are closely intertwined and interspersed with natural wetlands. Changes in the flow regime of the river, surface water diversions, lowered channel elevations relative to historical floodplains, and current land use and development along the valley floor create a complex array of natural and irrigation-influenced wetland water sources (Figure 7).

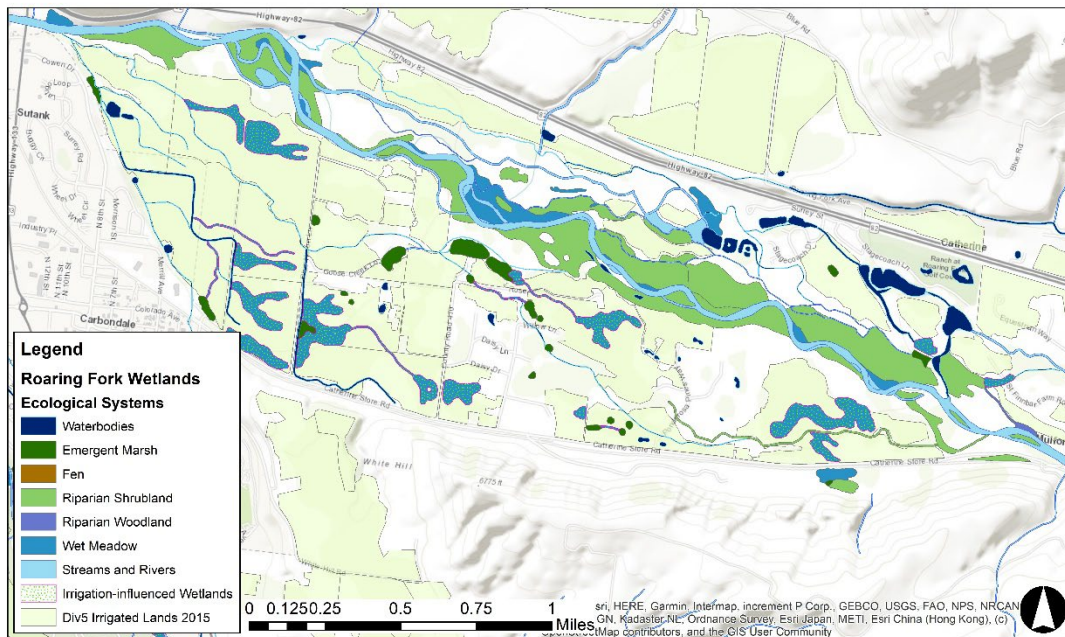


Figure 7. Example of the overlap between natural wetlands and irrigated lands along the Roaring Fork River near Carbondale, with irrigated lands overlapping current and former stream channels on the floodplain.

2.4 Land Use and Management

The watershed encompasses all or part of six counties: Pitkin, Gunnison, Eagle, and Garfield. Outside of cities and towns, much of the Roaring Fork watershed is sparsely populated. Public lands managed by the U.S. Forest Service (USFS), primarily within the White River National Forest, cover 70.4% of the watershed (Figure 8). Private lands cover 22.5% of total land area, and the U.S. Bureau of Land Management (BLM) manages 5.6% of the watershed. All other land ownership groups individually account for less than 1% of the watershed.

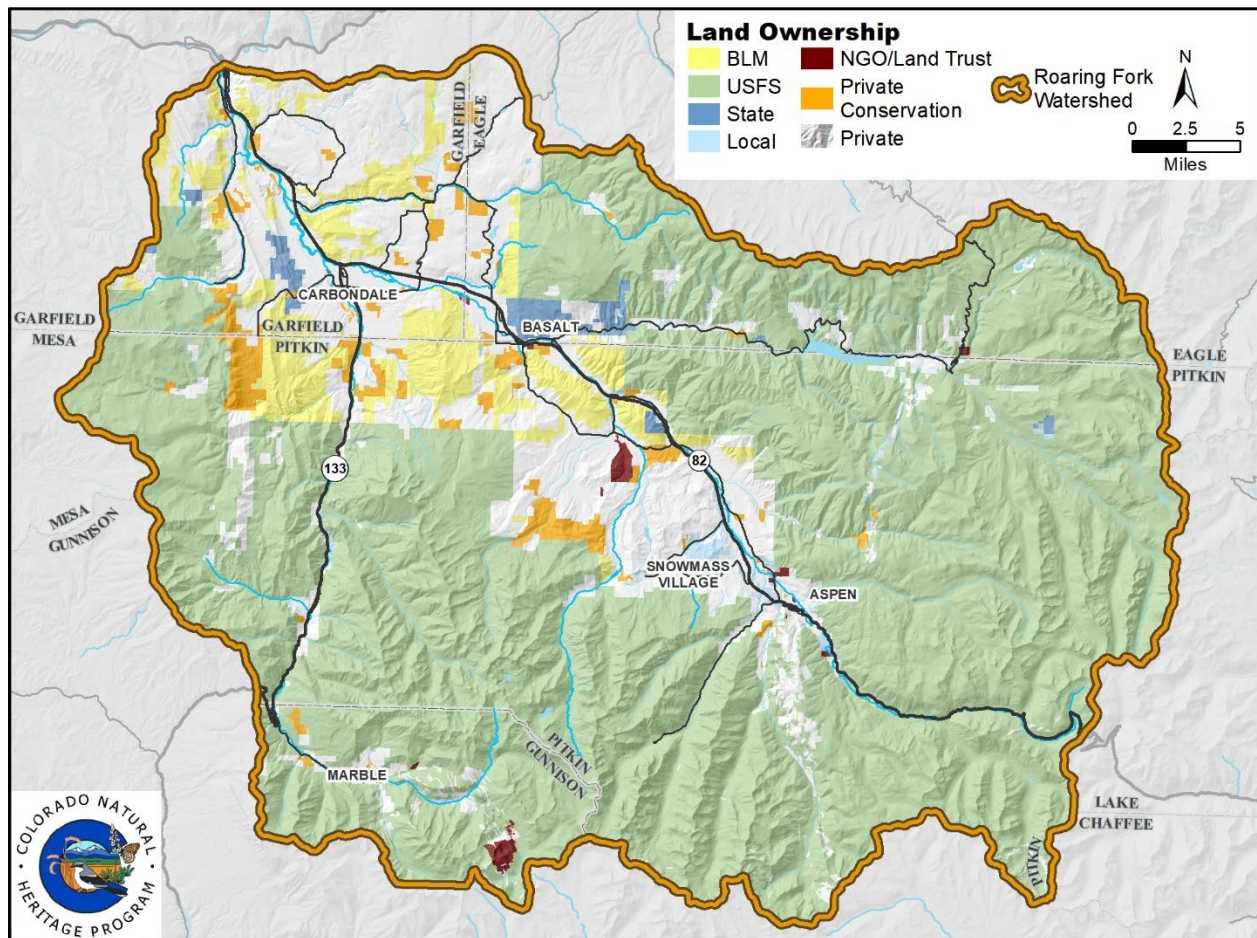


Figure 8. Land ownership and management within the Roaring Fork watershed.

Today, the economy of the Roaring Fork is dominated by outdoor recreation and tourism, as indicated by the share of revenue from accommodation, food service, and retail sales in the three largest cities in the watershed (U.S. Census Bureau 2021). Summer tourists and residents flock to locations like Maroon Lake and trails traversing all reaches of the watershed to hike, camp, fish, backpack, raft, kayak, and bike. In winter, backcountry and front country skiers, snowboarders, and snowshoers recreate around trails, peaks, and four major ski resorts. While tourism and recreation benefit the economy of the watershed, and the health and well-being of humans, land managers for recreation areas like Maroon Lake and the North Star Preserve have begun to adopt recreation

management strategies such as overnight permits and seasonal wildlife closures to preserve the ecological integrity of the watershed alongside recreational use.

2.5 Human Population and Environmental Justice

More than 32,000 people call the Roaring Fork home, and are concentrated in Glenwood Springs (10,326), Carbondale (pop. 6,491), Aspen (6,949), and Basalt (4,154) (U.S. Census Bureau 2021). The Roaring Fork valley is a desirable place to live, work, and recreate, but disparities between income levels create a complicated environmental justice landscape that varies with geographic position in the watershed. As with many Colorado mountain communities, needs for affordable housing sometimes compete with other objectives like open space preservation and even floodplain and hazard planning as seen in locations like the town of Basalt (Condon 2003).

Several areas in the watershed are considered Disproportionately Impacted Communities under Colorado’s Environmental Justice Act. Census blocks overlapping communities along the Crystal River, and in the vicinity of Glenwood Springs, El Jebel, Basalt, and Aspen and Snowmass have more than 40% of households considered “housing burdened” (CDPHE 2022) due to a disparity between income and the housing availability and affordability. Communities in, and between the towns of Carbondale and Glenwood Springs have more than 40% of households in a minority group. The census block including El Jebel (080370003013) is considered a disproportionately impacted community with 72.4% minority households and 46.8% of households considered “housing burdened” (CDPHE 2022). Glenwood Springs includes a census block (080459516002) with the highest proportion of low income households (40%), minority households (74.5%) and housing burdened households (54.4%) in the watershed (CDPHE 2022).

Transportation needs are tied to a variety of environmental justice metrics, and the residents of Glenwood Springs and Carbondale spend nearly twice the amount of time traveling one way from home to work each day (27.9 minutes), compared with Aspen residents (13.1 minutes) (U.S. Census Bureau 2021). Colorado Highway 82 traverses 85.3 miles from the valley floor to Independence Pass and is a busy commuter corridor that fragments habitats and often poses high risks for wildlife crossing the valley.

3.0 WETLANDS OF THE ROARING FORK WATERSHED

3.1 Wetland Definitions

The federal regulatory definition of jurisdictional wetlands is used by the U.S. Army Corps of Engineers (Corps) to administer the dredge and fill permit system required by Section 404 of the Clean Water Act (Mitsch and Gosselink 2007). The Corps defines wetlands as “those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstance do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.” For Corps programs, a wetland boundary is determined according to the technical criteria in the Corps Wetlands Delineation Manual (Environmental Laboratory 1987). Jurisdictional wetlands (i.e., wetlands subject to federal regulations) must meet all three of the following criteria under normal circumstances: 1) wetland plants; 2) wetland hydrology; and 3) hydric (wetland) soils.

The U.S. Fish and Wildlife Service (USFWS) defines wetlands from an ecological point of view in Cowardin et al. (1979), stating that “wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.” Wetlands must have one or more of the following three attributes: 1) at least periodically, the land supports predominantly hydrophytes (wetland plants); 2) the substrate is predominantly un-drained hydric soil; and/or 3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year.

CNHP adheres to the wetland definition used by the USFWS, recognizing the complexity of wetland types, natural disturbances, substrates, and hydroperiods in the western United States. Features like riparian wetlands and playas may not consistently meet all three Corps criteria, but perform many of the same water quality, water storage, and biodiversity functions as other wetland types (National Research Council 1995).

3.2 Wetland Plants

Wetlands support plants that can survive in saturated or inundated soils for prolonged periods of time. Wetland plants are commonly referred to as **hydrophytes**, and have adaptations such as additional pore spaces, dimorphic (two distinct forms) leaves, and complex rooting systems that allow them to thrive in wet, low-oxygen (anaerobic) soil conditions. **Phreatophytes** are another group of woody wetland and riparian plants (e.g., cottonwoods, willows, and alders) with deep roots to obtain a significant portion of their water from groundwater. Phreatophytes are typically found along rivers and streams where groundwater is near the ground surface.

Wetland plants are at the base of the food chain and provide habitat for major taxonomic groups including vertebrates, invertebrates, phytoplankton, and zooplankton. Wetland plants influence water quality in wetlands and streams through nutrient uptake and storage, and by helping trap sediment and stabilize banks and shorelines.

3.3 Wetland Soils

Wetland soils, also known as **hydric soils**, have visible characteristics that indicate the frequency and duration of saturation or inundation by water. As a wetland is flooded or saturated, water replaces air in the soil pores, leading to anaerobic conditions that cause physical and chemical changes in the soil profile. Soil microbes deplete free oxygen and begin to utilize alternative metabolic pathways involving nitrogen, iron, manganese, and sulfur, producing chemical transformations in the soil. Evidence of these transformations can be seen in hydric soil indicators, such as mottling (redoximorphic features), oxidized root channels, gleying, and a distinct, rotten egg smell from H₂S gas (USDA NRCS 2018). If soils are permanently saturated or inundated with water such that the rate of plant growth and organic matter accumulation exceeds decomposition, thick organic soils known as histosols (peats and mucks) can form. Hydric soil indicators reveal the general hydrologic signature, or **hydroperiod**, of a wetland, including how long and how frequently the soil has been saturated. Relict hydric soils that no longer support wetland vegetation can be useful in helping locate historical wetlands that have been drained, filled, or otherwise disconnected from natural surface water and groundwater inputs.

3.4 Wetland Mapping in the Roaring Fork Watershed

In the late 1970s, the U.S. Fish and Wildlife Service began an inventory of the extent and types of the nation's wetlands. The National Wetlands Inventory (NWI) uses the Cowardin et al. (1979) wetland classification system. Photo-interpretation and field reconnaissance were used to refine wetland boundaries. In Colorado, maps west of the 106th parallel were created in the early 1980s using color aerial photography. Most maps were created on paper, and weren't digitized to be used in a GIS format by CNHP until the 2010s. The most recent updates to NWI mapping in Colorado have included revised wetland hydrologic regime codes, as well as incorporation of National Hydrography Dataset (NHD) flow lines into the wetland dataset to be consistent with national guidance from the USFWS. Official NWI maps for the Roaring Fork watershed and the rest of Colorado can be accessed via CNHP's Colorado Wetland Information Center: <https://cnhp.colostate.edu/cwic/tools/mapper/>.

For NWI-mapped wetlands in the Roaring Fork watershed, the Upper Roaring Fork HUC10 watershed has the highest concentration of wetlands at 4.5% of total land area, followed by the Snowmass Creek (3.8%) and Fryingpan River (3.5%) HUC10 watersheds (Figure 15). Sections 4 and 5 further detail NWI mapping enhancement and updates, as well as more detailed wetland acreage by ecological systems, hydrogeomorphic classes, and wetland types such as beaver complexes.

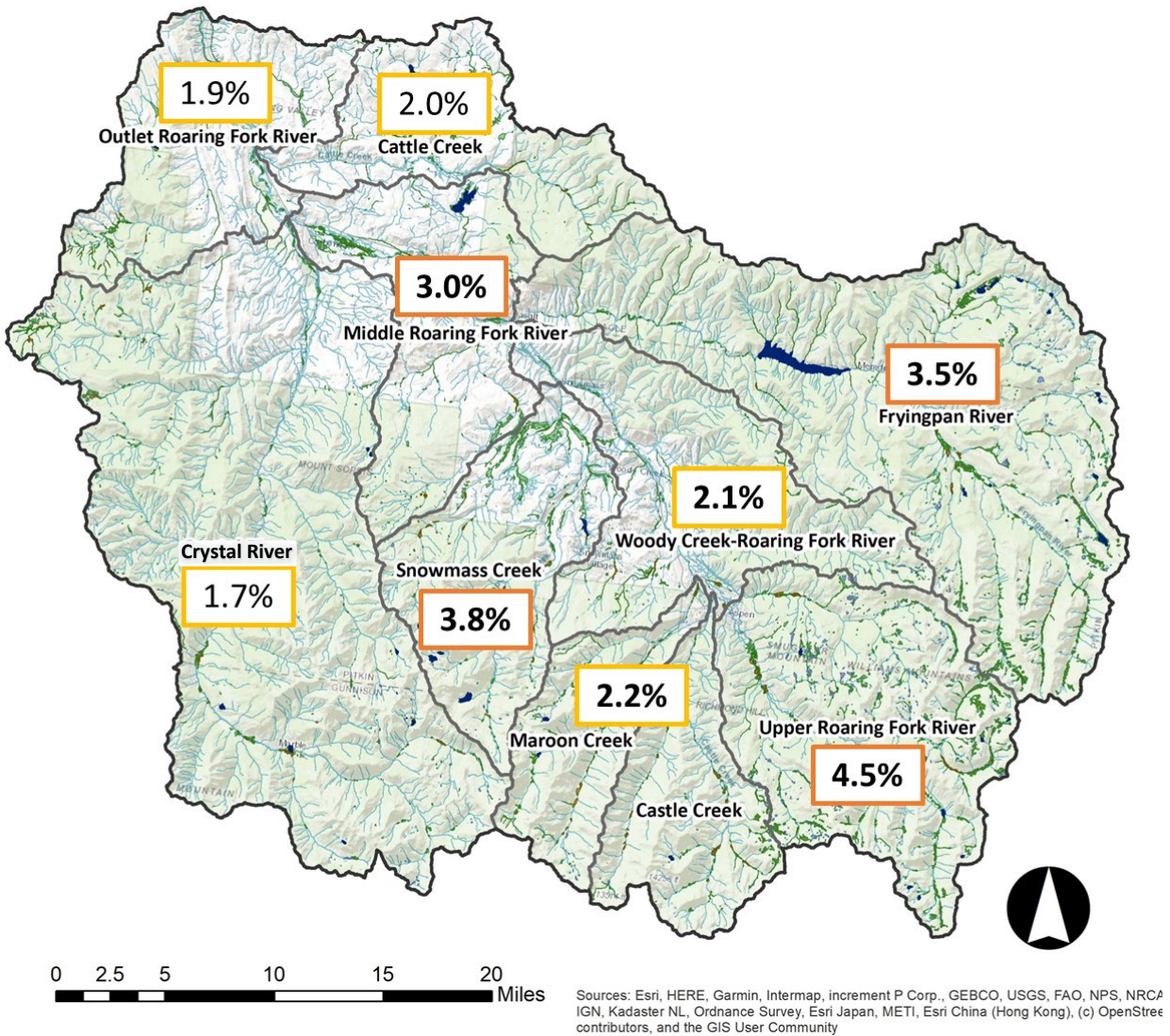


Figure 9. Percent wetland area by HUC10 watershed within the larger Roaring Fork watershed. Percent area is combined for the smaller Maroon Creek and Castle Creek HUC10 watersheds.

3.5 Wetland and Riparian Ecological Systems in the Roaring Fork Watershed

Ecological systems are used by CNHP and the NatureServe Network of heritage programs to classify recurring types of ecosystems that share common physical environments and ecological processes. The Roaring Fork watershed supports 7 of Colorado’s 15 recognized wetland and riparian ecological systems (Decker et al. 2020). Two of the most extensive systems in the watershed include riparian woodlands and shrublands, along with wet meadows. Both systems provide important wildlife habitat in the watershed (Rondeau et al. 2022). Other systems that occupy smaller areas within the watershed include fens, emergent marshes, and hanging gardens. The following sections detail each ecological system found in the watershed, including common

plant species and key ecological processes required to create and maintain each system. More information about Colorado’s ecological systems, including a key to wetland and riparian systems in Colorado and a list of all associated plant communities tracked by CNHP, can be found online at: <https://cnhp.colostate.edu/cwic/wetlandtypes/ecological-systems/>.

3.5a Riparian Woodlands and Shrublands

Riparian wetlands are supported by seasonal flooding and shallow water tables along rivers and streams, and are often corridors of high biodiversity along valley bottoms and drainages. In the Roaring Fork watershed, many riparian wetlands are intermittently flooded during spring snowmelt. Smaller peak flows may occur in the summer growing season in response to rainfall or artificial releases from upstream reservoirs. As interceptors of water, sediment, nutrients, and biological materials such as plant seeds from areas upslope and upstream, riparian ecosystems are highly productive and often help store flood waters and recharge groundwater in floodplain aquifers. Many riparian wetlands in the Roaring Fork watershed also serve as groundwater discharge areas and are fed by local or regional groundwater for some portion of the year.

Riparian wetlands and their associated aquatic habitat are important for nutrient cycling and food chain support, including fish, bird, and other wildlife habitat. The importance of riparian habitats to wildlife is well

documented (e.g. Lohman 2004). Animal use includes deer, elk, beaver, and large suite of bird species such as warblers, song sparrows, flycatchers, and woodpeckers. As with many mountain watersheds across Colorado, North American beavers (*Castor canadensis*) play a critical role in maintaining many riparian habitats throughout the Roaring Fork watershed – especially in lower-gradient, wider valley



Riparian woodland along the Roaring Fork River near Carbondale, with a cottonwood and Colorado blue spruce tree canopy and an understory of native shrubs and vines. Photo: Sarah Marshall, CNHP.

bottom areas along streams and rivers. Beaver activity is dynamic, with the distribution and density of ponds and dams changing over time and benefitting a variety of both rare and common wetland-dependent species from boreal toads (*Anaxys boreas boreas*) to waterfowl and wild ungulates. Beaver activity often enhances the sediment capture, flood attenuation, groundwater recharge, carbon sequestration, and general habitat support functions of riparian wetlands.

The Roaring Fork watershed contains three riparian ecological systems parsed by elevation range. In the lower watershed from approximately 5,700-9,000 ft in elevation, the Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland system lines the Roaring Fork River and its tributaries.

One of the best quality occurrences of this system is along the Roaring Fork River near Carbondale, which is designated as a CNHP Potential Conservation Area (PCA) with very high biodiversity significance. Common native riparian tree and shrub species associated with this system in the Roaring Fork include narrowleaf cottonwood (*Populus angustifolia*), Rio Grande cottonwood (*Populus deltoides* ssp. *wislizeni*), Colorado blue spruce (*Picea pungens*), water birch (*Betula occidentalis*), silver buffaloberry (*Shepherdia argentea*), redosier dogwood (*Cornus sericea* ssp. *sericea*), thinleaf alder (*Alnus incana* ssp. *tenuifolia*), smooth rose (*Rosa blanda*), greenleaf willow (*Salix lasiandra* var. *caudata*), coyote willow (*Salix exigua*), river hawthorn (*Crataegus rivularis*), willow hawthorn (*Crataegus saligna*), whitestem gooseberry (*Ribes inerme*), western serviceberry (*Amelanchier alnifolia*), and skunkbush sumac (*Rhus trilobata*).

From around 7,500 ft in elevation to tree line, riparian areas also include the Rocky Mountain Subalpine-Montane Riparian Woodland and Shrubland systems. Subalpine-Montane Riparian



Montane willow shrubland, also known as a willow carr, with shrub canopy openings dominated by wetland graminoids. Photo: CNHP staff.

Woodlands are distinguished by their occurrence at higher elevations and tree canopies that often include conifers like Engelmann spruce (*Picea engelmannii*) Colorado blue spruce, Rocky Mountain subalpine fir (*Abies bifolia*), and Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) along with deciduous trees like quaking aspen (*Populus tremuloides*). Shrubland systems are often treeless and can occur as narrow bands of woody vegetation along confined mountain streams or large patches of shrubs on stream terraces and low-gradient valley bottoms. Common shrubs found in these mountain systems in the Roaring Fork include a variety

of willows (e.g., *Salix monticola*, *S. drummondiana*, *S. planifolia*, *S. brachycarpa*, *S. wolfii*, and *S. boothii*), thinleaf alder, red-osier dogwood, and birch (*Betula glandulosa* and *B. occidentalis*). Both woodland and shrubland systems often support a diverse native forb and graminoid understory.

3.5b Wet Meadows

Rocky Mountain Alpine-Montane Wet Meadow systems are typically dominated by graminoids (sedges, rushes, and grasses) and have soils that are saturated near the surface in early summer, but typically dry by the end of the growing season. Soils in wet meadows are mineral and demonstrate typical hydric soil characteristics such as low chroma matrix colors and redoximorphic features. Occasionally, wet meadows have organic soil layers, but these features do

not meet the thickness criteria for a fen due to a shorter duration of saturation during the growing season. Deep standing water is rare in wet meadow systems.

In the Roaring Fork watershed, wet meadows occur in alpine, subalpine, and montane zones around mountain lakes and basins that are fed by snowmelt in spring and groundwater discharge throughout the summer. Wet meadows are also found adjacent to beaver pond complexes, and sometimes within irrigated pastures. Common wetland plants found in high elevation wet meadows include: water sedge (*Carex aquatilis*), beaked sedge (*C. utriculata*), analouge sedge (*C. simulata*), tufted hairgrass (*Deschampsia cespitosa*), and bluejoint (*Calamagrostis canadensis*). Occasionally, wet meadows have high cover of native wetland forbs along with graminoids.

Flood-irrigated wet meadows may share some similar features with natural wet meadows, including plant communities and even hydroperiods, but are not considered a naturally-occurring ecological system if they depend entirely on irrigation water inputs to sustain wetland conditions.



Wet meadow with abundant native sedge and forb cover in the headwaters of the Fryngpan River HUC10 watershed. Forbs include Oregon saxifrage (*Micranthes oregana*) in the foreground and a variety of asters. Photo: Sarah Marshall, CNHP.

3.5c Fens

Rocky Mountain Subalpine-Montane Fens are an uncommon type of peat-accumulating wetland, mostly found at or above 8,000 feet in elevation. Fens primarily receive water from a consistent



Chamisso's cottongrass (*Eriophorum chamissonis*) patch in a fen in the Crystal River headwaters. Photo: Sarah Marshall, CNHP.

source of groundwater discharge, with minimal inputs from snowmelt and direct precipitation. Peat or other organic soil within a fen must be at least 40 cm deep in the upper 80 cm of the soil profile. In the Colorado Rocky Mountains, fens accumulate peat at a very slow rate, on the order of 20 cm (8 inches) per 1,000 years (Chimner 2000), and are essentially irreplaceable. Fens tend to be small in area (<5 acres) and typically support grasses and sedges like tall and Chamisso's cottongrass (*Eriophorum angustifolia* and *E. chamissonis*), analogue sedge (*Carex simulata*), boreal bog sedge (*C. magellanica* ssp. *irrigua*), water sedge

(*C. aquatilis*), and fewflower spikerush (*Eleocharis pauciflora*). Common forbs found within fens in the Roaring Fork include marsh marigold (*Caltha leptosepala*), alpine meadowrue (*Thalictrum alpinum*), and various members of the Asteraceae and Gentianaceae families. Often, fens have scattered shrub cover including species like planeleaf willow (*Salix planifolia*) and bog birch (*Betula glandulosa*).



Small fen in the Fryingspan River headwaters, with a variety of sedges and forbs surrounded by willows and shrubby cinquefoil. Photo: Sarah Marshall, CNHP.

Fens on federal land are considered a Resource Category 1 within the U.S. Fish and Wildlife Service Mitigation Policy (USFWS 1999), signifying that every reasonable effort should be made to avoid impacting this habitat. In 2002, the U.S. Forest Service Rocky Mountain Region issued a statement to avoid impacts to fens on National Forest Lands due to their irreplaceability (USFS 2002). Fens in Colorado are further classified as poor, iron, intermediate, rich, and extreme rich. These terms refer to the levels of nutrients or minerals (calcium, magnesium, etc.) in fen soil water. Poor fens are similar to bogs (mostly precipitation-fed, peat-accumulating wetlands), where pH and conductivity are low. Plants that thrive in these conditions include bladderworts (*Utricularia* spp.) and sundews (*Drosera* spp.). Intermediate and rich fens are found throughout the granitic subalpine zone at breaks in slope, at the headwaters of streams, along spring-fed slopes, and in small water-filled depressions formed by glaciers. Intermediate and rich fens are typically dominated by sedges and willows and the pH tends to be slightly acidic (5.0-6.5). Extreme rich fens are closely associated with calcium-rich sedimentary bedrock such as the Mosquito Range in Lake and Park counties. They have a basic pH greater than 7.0 and very high calcium concentrations that are tolerated by specialized plants or calciphiles. One extreme rich fen (pH of 7.5), was documented in the Fryingpan River headwaters in Crooked Creek Park during this study.

3.5d Emergent Marshes

Western North American Emergent Marsh systems form in depressions created by water, wind, past glacial activity, and occasionally landslides and other mass movements. Marsh wetlands



Emergent marsh formed in a kettle pond in the Fryingpan headwaters. Wetland vegetation forms rings around the marsh, with willows around the outermost edge followed by sedges, spikerush, and aquatic plants along a gradient from saturated to ponded conditions heading into the center of the wetland. Photo: Sarah Marshall.

contain deeper water in spring and early summer, are frequently or continually inundated, and are characterized by emergent herbaceous vegetation. They form in depressions in the landscape (e.g., kettle ponds) or as fringes around lakes and along slow-flowing areas and side channels of streams and rivers. Marshes typically have mineral soils, and can accumulate organic material in soil and sediment, but not enough to form true organic soil. Vegetation is usually classified as emergent, including species like cattails (*Typha* spp.), bulrushes (*Schoenoplectus* spp.) and sedges (*Carex* spp.) along with woody species like cottonwoods (*Populus* spp.), and willows (*Salix* spp.). Often, marsh vegetation bands occur in rings from saturated areas around the marsh perimeter with woody species and/or wetland graminoids to deeper water areas in the marsh center with floating and submerged aquatic plants.

Natural marshes are relatively uncommon in the Roaring Fork and support a unique array of floating and submerged aquatic plants like Rocky Mountain pond-lily (*Nuphar polysepala*) and carnivorous bladderworts (*Utricularia* spp.). These wetlands provide important habitat for aquatic-dependent wildlife like wading birds, waterfowl, muskrat, beaver, western tiger salamander (*Ambystoma mavortium*, Colorado's only salamander species) and northern leopard frog (*Lithobates pipiens*).

3.5e Hanging Gardens

The Colorado Plateau Hanging Garden ecological system is one of the least extensive wetland types in the watershed and occurs in small patches associated with seeps and waterfalls along areas like the Crystal River canyon. Hanging gardens are small communities of hydrophytic plants that occupy alcoves, seeps and springs in canyon walls where they grow on permanently wet soil and wet rock surfaces. In the Roaring Fork, hanging gardens support mostly herbaceous wetland plants, including common species like monkeyflower (*Mimulus guttatus*), heartleaf bittercress (*Cardamine cordifolia*) and mosses as well as the rare hanging garden coolwort (*Sullivantia hapemanii* var. *purpusii*).

4.0 PROCESS AND METHODS

CNHP employed several methods to assess wetland extent, condition, functions, and conservation and restoration needs in the Roaring Fork watershed. First, CNHP engaged with stakeholders and partners in the watershed to identify wetland-related priorities, and gather information on areas to target for the field inventory. Second, CNHP carried out a desktop review and field inventory of ecologically significant areas. Third, CNHP updated mapping and conducted geospatial analyses of wetland types, functions, and surrounding landscape condition across the watershed. Finally, CNHP compiled a series of priority conservation and restoration areas and needs based on existing watershed priorities, the Roaring Fork Watershed Biodiversity & Connectivity Study (Rondeau et al. 2022), and the field inventory.

4.1 Partner and Stakeholder Engagement and Outreach

The project team engaged with wetland partners and interested stakeholders throughout the project, including attending and providing study updates at meetings of the complementary Roaring Fork Watershed Biodiversity and Connectivity Study science team. This group included partners from the Watershed Biodiversity Initiative, USFS, BLM, Colorado Parks and Wildlife, Pitkin County, Aspen Valley Land Trust (AVLT), Roaring Fork Conservancy, and private consulting, along with private landowners and other subject matter experts. The science team and numerous other partners played a critical role in identifying and vetting priority restoration and conservation areas in the watershed. Many members of the science team have also been (and continue to be) involved in wetland assessment, conservation, restoration, and prioritization in the watershed.

4.1a Lessons Learned through Partner and Stakeholder Engagement

Through meetings and other conversations with partners and stakeholders in the watershed, we gathered a series of themes and overarching priorities that helped shape the focus of this study.

1. **Wetlands and riparian areas are priority habitats for conservation and restoration** in the watershed. The intersection between wetlands and other watershed priorities often helps secure funding and public support for conservation and restoration.
 - a. The connection between wetlands and **habitat and migration corridors for native ungulates** is especially important for many partners in the watershed.
 - b. Many stakeholders expressed a desire to combine watershed and water management with wildlife connectivity and other habitat conservation.
 - c. **Beaver -influenced wetlands** are important to a variety of stakeholders, from along with finding suitable areas for beaver-facilitated habitat restoration.
 - d. Many stakeholders value **irrigated wet meadows and hay fields** for ungulate habitat, open space, agricultural, and aesthetic values.
2. Many stakeholders in the watershed are planning for **climate change** impacts, and working to find adaptation and mitigation strategies to protect and enhance the resilience of water supplies and habitats in the watershed, particularly with respect to earlier snowmelt and droughts. Wetlands, including beaver ponds, have been described as providing a “second

snowmelt,” by holding earlier melt water and slowly releasing it to downstream areas throughout the growing season.

3. Our partners want **better wetland and riparian mapping** to support watershed planning and targeted land conservation. Publicly available mapping tools like the Watershed Planning Toolbox are helpful, along with guidance on how to use tools and study results.
4. Our partners want to understand the overall **processes and threats influencing the condition of wetlands and riparian areas** in the watershed. This knowledge helps support effective conservation, management, and restoration amidst watershed-scale challenges like climate change and increasing recreation use.

4.1b Outreach and Education

Outreach and education activities encourage wetland conservation and stewardship, cultivate and build new relationships with partners and stakeholders, and provide learning opportunities about the unique wetland management practices, needs, and priorities of a given watershed. As a direct result of collaboration with partners and stakeholders, CNHP was involved in several wetland and riparian outreach and education events during this study, including:

- Hallam Lake BioBlitz in Aspen, June 24-28, 2019
- Outdoor wetland education event with students in the High School High Scholar program at the Colorado Rocky Mountain School, a summer STEM program for first-generation and low-income minority students from across the U.S. – July 10, 2019
- AVLT public wetland education and noxious weed pull event in the Crystal River watershed – August 9, 2019
- Coffman Ranch BioBlitz near Carbondale with AVLT – June 27- July 1, 2022
- Radio and newspaper interviews with Aspen Public Radio and Aspen Journalism



CNHP staff and interns teaching K-5 students about habitats and animals at a public education event at Hallam Lake following the BioBlitz. Photo: Sarah Marshall, CNHP.

Funding for both BioBlitzes was provided by the sponsoring organizations following initial field visits and communications with partners through this study.

In addition to leading and participating in public education and outreach events, CNHP staff shared both the Colorado Wetlands Mobile App and copies of the Common Wetland Plants of Colorado’s Southern Rocky Mountains pocket guide (Culver 2018) with numerous landowners and other members of the public interested in learning more about wetland plants and ecology.

4.2 Inventory of Ecologically Significant Areas

Since the late 1990s, when CNHP carried out the original Roaring Fork Watershed Biological Inventory from 1997-1999 (Spackman et al. 1999), the watershed has experienced an increase in developed land around population centers, intensification of recreational activity, several fires, droughts, and changes in water management – all of which have the potential to impact biodiversity and overall habitat conditions in the watershed.

CNHP identified a subset of sites from the 1999 inventory to re-visit, as well as new targeted inventory areas (TIAs) identified by federal agency scientists, land trusts, and other partners in the watershed. Examples of TIAs included numerous headwater fens, as well as specific properties with a high likelihood of supporting rare species and plant communities. Many of the sites visited during this study were on private lands. Through our partner network and landowner participation, CNHP had access to more than 30,000 acres of private lands within the watershed.

A preliminary review of biologically significant areas prior to field surveys included: 1) examining existing biological data for rare or imperiled plant and animal species and plant communities (collectively called elements); and 2) collecting existing information, including reports and interviews with local subject matter experts. Information sources included resources from Colorado State University, University of Colorado, and Rocky Mountain herbaria. Literature sources were incorporated into CNHP databases, either in the form of locational information or as biological data pertaining to a species. Other information was gathered to help locate additional occurrences of elements, including species ranges, habitats, and phenology (reproductive timing).

Following the completion of the field inventory and associated desktop analysis, CNHP databases were updated with information regarding the known locations of species and significant plant associations within the watershed. New and updated information for both element occurrences and PCAs was also entered into CNHP's Biodiversity Tracking and Conservation System (BIOTICS). A summary of the Natural Heritage methodology used to rank species, ecological communities, and Potential Conservation Areas (PCAs) is provided in Appendix A.

4.3 Wetland Condition

We used the revised Floristic Quality Assessment (FQA) indices for Colorado (Smith et al. 2020) and species lists for 31 wetland sites to evaluate wetland condition across the watershed. The Colorado FQA uses Coefficients of Conservatism, or C-values, as a measure of a plant's tolerance of human disturbance. C-values are based on available field-based condition assessments as well as a review by a panel of expert botanists. C-values can be interpreted based on categories in Table 2.

Several metrics were used to measure wetland condition: Mean Coefficient of Conservatism (Mean C), Mean C of native species (Mean Native C), Mean C of wetland species (Mean Wetland C; FAC, FACW, or OBL wetland indicator status), and the difference between Mean C and Mean Native C. Mean Native C – Mean C is a measure of the prevalence of non-native species (C = 0) at a site. We calculated Mean Wetland C values to account for upland species along wetland boundaries, and not

conducting formal wetland delineation boundaries in the field. The total number of recorded plant species was also included for each site.

Mean C and Mean Native C are effective indicators of wetland condition and degree of human disturbance, using both plot-based and “plotless” species inventories across broader wetland complexes (Rocchio 2007; Lemly and Rocchio 2009; Schweiger et al. 2016). For our calculations, we used a plotless species inventory, with breaks for pronounced changes in wetland ecological system or crossing a watershed divide or major geographic boundary. We used the revised C-Values for Colorado (Smith et al. 2020), which include nearly every plant species in the state and address cryptogenic species like cattail hybrids (*Typha* sp.) and reed canarygrass (*Phalaris arundinacea*).

Mean C values in the 7-9 range are associated with the highest condition wetlands in the watershed, given that a Mean C of 10 would be nearly impossible to attain in any natural wetland in Colorado. A list of all wetland and riparian species documented during the field inventory, including the C-value, nativity, and wetland indicator status for each species is provided in Appendix B.

Table 5. C-value interpretation.

Value	Interpretation
0	Nonnative species, prevalent in areas with disturbed soil or obligate to non-natural areas
1-3	Commonly found in natural and non-natural areas
4-6	Equally found in natural and non-natural areas
7-9	Obligate to natural areas but can sustain some habitat degradation
10	Obligate to high quality natural areas – no evidence species occurs outside high quality natural areas

4.4 Land Use Change and Conservation Analysis

In addition to the field inventory, CNHP worked with partners in the watershed to update the Colorado Ownership and Protection Map (COMaP; CNHP and Geospatial Centroid 2022) with recent geospatial data for land ownership and management. Updates included conservation easements and other land conserved in the two decades since the original CNHP Roaring Fork Watershed Biological Inventory (Spackman et al. 1999). Many of the Potential Conservation Areas (PCAs) identified in the 1999 study flagged near-term conservation and management needs to protect populations of rare species and unique plant communities (including wetlands) within the watershed. Information on land management, protection, and land use and management change was summarized by HUC10 watershed units, which are often used in watershed planning in the Roaring Fork.

Several metrics were used to track conservation and land use change over the last two decades. First, we calculated the total area of each HUC10 watershed with some form of land protection using COMaP (CNHP and Geospatial Centroid 2022). Second, we ranked different types of land protection on a scale of 1-5, with designated wilderness areas receiving a rank of 5, followed by other non-wilderness federal land (rank = 4), city, county, and state land (rank = 3), private land with conservation easements (rank = 3), and private land or clearly developed land (rank = 1; e.g., a recreation center) with no formal protection. We then weighted each protection rank by total acreage within each watershed, and normalized the values to be on a 1-100% scale. Finally, we

looked at total area of protected land within the watershed, and acreage of new protected land since the year 2000.

Wetland condition and function is often related to the extent of human disturbance within the surrounding landscape, including habitat fragmentation from roads, development, current and former mining activity, and agriculture. To evaluate overall changes in watershed land cover/use change and habitat fragmentation, we used a combination of NLCD Change Indices for 2001-2019 (USGS 2021) and the updated Landscape Disturbance Index (LDI) for Colorado (Fink 2021). The most recent version of the LDI adds different types of trails from the Colorado Trail Explorer (COTREX), along with previous anthropogenic impacts including:

- Agriculture (tilled and untilled classes)
- Urban Development (high/medium and low classes)
- Oil and Gas Development (active and inactive classes)
- Surface Mining (active and inactive classes)
- Roads (major and local classes)
- Trails (motorized/4WD, trails with off-leash dogs, and other trails classes)
- Utility lines (electrical transmission only)
- Wind turbines
- Solar installations

Each type of disturbance is weighted based on how it alters surrounding habitats, and includes a decay function for how the effects of the disturbance decrease with distance beyond the original disturbance footprint (see Appendix C for detailed information). For example, the ecological impact of a busy highway extends well beyond the physical footprint of pavement due to noise, ground disturbance during construction, altered surface runoff, and interruption of wildlife movement. The individual LDI impact layers are then additively combined to produce an overall disturbance layer. The weights are scaled to produce a final range where scores ≥ 500 are High impact, $>250 - < 500$ are Moderate impact, $>0-250$ are Low impact, and 0 is None (or minimal) impact.

4.5 Wetland Mapping

One objective for this project was to update and enhance wetland- and watershed planning-related geospatial data for wetlands in the Roaring Fork watershed as part of CNHP's online Watershed Planning Toolbox mapper. Previous detailed areas in the Toolbox included the South Platte Headwaters and the Arkansas Headwaters (Marshall et al. 2018).

4.5a NWI Wetland Mapping Updates

Updated NWI mapping forms the foundation of data development for the Watershed Planning Toolbox, CNHP's online resource for evaluating wetland functions and attributes alongside other watershed planning data layers. The Roaring Fork NWI mapping was last updated in the 1980s, and one notable issue has been the integration of National Hydrography Dataset (NHD)¹ features into

¹ The NHD is produced by U.S. Geological Survey (USGS). For more information, see: <https://www.usgs.gov/core-science-systems/ngp/national-hydrography>.

NWI mapping. Most NHD features do not match actual stream centerlines, and often include features that do not represent real wetlands and streams on the ground. Other important changes since the original NWI mapping include shifting beaver activity areas, and land use conversion and development. While a full NWI update was not within the scope of this project, CNHP made key updates and enhancements to the wetland mapping to allow for a better understanding of wetland types and likely wetland functions within the watershed. Updates included:

- Removal of disconnected artifacts (particularly “orphaned” R5UBH features) from NHD integration into the NWI dataset;
- Linking disconnected stream segments where appropriate;
- Reviewing mapped stream segments including R4SBA and R4SBC features, which often included features like avalanche paths rather than actual stream channels on the ground;
- Updates to stream and wetland boundaries in restoration and conservation priority areas, such as riparian wetlands along the Roaring Fork River near Carbondale;
- Omitting wetland features that no longer exist (e.g., former wetland that is now a building);
- Incorporating updated fen mapping from the White River National Forest, and on-the-ground fen verification from field surveys;
- Reviewing and updating beaver-influenced wetland features, including beaver complexes that have been abandoned since the original NWI mapping in the early 1980s; and
- Attributing likely wetland ecological systems to mapped wetlands using Cowardin hydrologic regimes, vegetation classes, and proximity to streams and floodplains.

4.5b Landscape Position, Landform, Water Flow Path, and Water Body (LLWW)

In addition to updating NWI data with standard NWI attributes, CNHP added Landscape Position, Landform, Water Flow Path and Waterbody (LLWW) attributes based on geomorphic and hydrodynamic characteristics (Lemly et al. 2018). This helped characterize and summarize wetland types, and develop models of likely ecological functions performed by wetlands within the watershed (see Section 4.5c).

The geomorphic setting of a wetland, its proximity to other wetlands and waterbodies, and the dominant water source and flow path all influence the functions a wetland can perform (Brinson 1993; Tiner 2014). The national standard for wetland classification in the United States is the U.S. Fish and Wildlife Service (USFWS)'s *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al. 1979, FGDC 2013), which emphasizes vegetation structure, hydroperiod, and certain natural and human modifications (e.g., beaver, excavated, impounded, and partly drained). This classification has been used by the USFWS NWI Program² since the 1970s to map wetlands across the U.S.. The NWI Program now provides a seamless digital dataset of wetlands for nearly the entire nation. The Cowardin classification is effective at characterizing diverse wetland types for mapping purposes and for natural resource management. However, this classification does not include properties essential for estimating likely wetland functions.

In the early 1990s, Mark Brinson created the hydrogeomorphic (HGM) classification system to assess wetland function (Brinson 1993). The HGM classification groups wetlands based on

² For more information on the NWI Program, see: <https://www.fws.gov/wetlands/index.html>

geomorphic position and hydrologic characteristics, such as water source and hydrodynamics. Recognizing a need to bridge NWI's Cowardin classification and Brinson's HGM classification, the NWI program developed an HGM-like coding system complimentary to the national wetlands classification system. This new classification system describes wetlands based on Landscape Position, Landform, Water Flow Path and Waterbody type and is referred to by the acronym LLWW (Tiner 1995; USFWS 2008). The LLWW codes and modifiers for wetlands can be easily correlated with the primary HGM classes, but also include a level of detail beyond HGM.

In 2018, CNHP and other wetland mapping groups working in wetlands across the Western U.S. developed a regionally specific version of the nationwide LLWW classification key originally developed by Ralph Tiner (Tiner 2003; Tiner 2011; Tiner 2014; Lemly et al. 2018). Using methods applied in the earlier version of the Watershed Planning Toolbox (Marshall et al. 2018), we used the Keys to LLWW for Inland Wetlands of the Western United States, along with ancillary datasets such as mapped fens and topographic data and on-the-ground wetland visits to inform semi-automated LLWW attribution of the NWI dataset for the Roaring Fork watershed. The LLWW key used to attribute wetland data in the Roaring Fork can be found here:

<https://cnhp.colostate.edu/cwic/tools/toolbox/>.

4.5c Beaver-influenced Wetland Analysis

Beavers are considered a Tier 1 priority wetland wildlife species by Colorado Parks and Wildlife as of 2022, and are important drivers of riparian wetland formation and maintenance across Colorado. During this study, new data became available as part of a separate project mapping beaver ponds and associated beaver-influenced wetland complexes throughout the entire Colorado River basin (CNHP and Lynker, 2022). As part of overall NWI updates, we used beaver mapping and modeling for the 2013, 2017, and 2019 imagery years along with a review of other NWI-mapped beaver complexes from the original NWI mapping for those imagery years. From this information, we mapped beaver activity change over time at the watershed scale.

4.5d Modeled Likely Wetland Functions

Wetlands provide a disproportionately large array of ecological functions given the relatively small (approximately 2%) part of the landscape that they occupy in the Roaring Fork watershed and across Colorado. Prior to modeling and mapping likely wetland functions, CNHP consulted with our wetland partners and other stakeholders to ensure that we were mapping functions that address key questions and issues facing wetland restoration practitioners, conservation planners, and the water community in the Roaring Fork watershed. Questions included where to focus restoration efforts for specific watershed functions like post-fire sediment capture, how to plan for future increases in recreation and urban development while preserving wildlife habitat and water quality, and how to evaluate the potential ecological benefits of conservation easements.

For all mapped wetlands and waterbodies in the Roaring Fork watershed, we modeled nine likely watershed-scale functions grouped into three categories (Table 3). Models were based off of methods used in the first version of the Watershed Planning Toolbox (Marshall et al. 2018), with a reduced set of functions based on the quality of wetland mapping in the Roaring Fork and updates to the list of modeled functions for Colorado since 2018. Most models consisted of geospatial data queries based on wetland types and level of habitat disturbance and fragmentation, and are detailed

in Appendices D and E. The biodiversity conservation function was structured differently than most functions modeled and split into two parts: 1) rare species and ecosystems, and 2) general biodiversity support. Each component was ranked by landscape condition using LDI scores (e.g., rare species and ecosystems with high landscape condition vs. moderate vs. poor landscape condition). Rare species and ecosystems included wetlands intersecting known occurrences of state-rare species (S1, S2, S3), along with rare wetland types like kettle ponds, spring-fed wetlands, alpine wetlands, and fens. Wetlands considered to provide high biodiversity support included more common wetland types such as beaver complexes, riparian wetlands, and headwater wetlands that often support diverse plant and animal communities.

Table 6. Wetland functions modeled for the Roaring Fork watershed.

Biodiversity & Wildlife Habitat Functions	Water Quality & Biogeochemical Functions	Water Quantity & Geomorphic Functions
Biodiversity Conservation	Nitrogen Uptake & Transformation	Surface Water Storage
Waterfowl Habitat	Phosphorus Removal & Storage	Sediment Capture & Retention
Shorebird Habitat	Metals Removal & Storage	
	Carbon Storage	

Several general notes on functional mapping include:

1. All models for functions represent wetlands that have a moderate or high potential to provide selected landscape-scale functions. Models do not capture all functions provided by wetlands, or fine/site-scale spatial or temporal (seasonal or interannual) variability in things like soil properties, water chemistry, vegetation, or hydrology. Modeled functions are intended to be a starting point for further site-specific investigations into the many ecological functions and services that wetlands provide in the Roaring Fork’s diverse landscapes.
2. Most wetland functions were ranked as high or moderate. A “high” rank indicates that a given wetland type has optimal conditions for and/or has been well-documented as providing a function in the literature or with on-site data collection. A “moderate” ranking indicates that a wetland has some potential to provide a function, but is limited by one or more characteristics (e.g., a wetland that stores surface water for several months during the growing season, but does not have year-round surface water would receive a rank of “moderate” for surface water storage). We did not use a “low” rank, as wetlands without ranking may not provide a given function, or there may be insufficient research to support evaluating the function.
3. Some wetland functions (e.g., biodiversity conservation and sediment capture & retention) were parsed by factors like sediment retention at high vs. low flow rather than ranked as high or moderate to make functions more relevant and useful to partners and stakeholders.

A summary for each of the nine modeled wetland functions is provided in Appendix D, including a brief description of the function, supporting literature reviewed in evaluating the function, and assumptions and data limitations (adapted from Marshall et al. 2018).

4.6 Wetland and Riparian Conservation and Restoration Opportunities

Over 50% of Colorado's historical wetlands have been lost or altered by drainage, flooding from water storage reservoirs, changing stream flow regimes (including dams and diversions), groundwater withdrawals, peat mining, gravel and mineral mining, historical (and recent) beaver trapping, and urban development (Dahl 1990). Finding wetlands that have been converted to uplands requires evaluation of soils, hydrology, geology, and ecological processes associated with wetland formation. In the Roaring Fork, current SSURGO soil mapping was inadequate for identifying potential historical wetland areas, with poor coverage relative to total wetland area and a single soil series mapped for wetland patches across the watershed. Instead, CNHP focused on existing restoration priority areas in the watershed and new sites with obvious wetland conversion to upland or a shift to a drier wetland hydroperiod over time – often as a result of surrounding land and water management, or reduced beaver activity.

4.6a Priority Conservation and Restoration Area Review

CNHP took several approaches to identify priority conservation and restoration areas in the Roaring Fork watershed. Key information and analyses are detailed below.

1. Updated and enhanced wetland mapping was incorporated into the Roaring Fork Watershed Biodiversity & Connectivity Study (Rondeau 2022) modeling work, which flagged areas where restoration and conservation activities could benefit habitat for elk, mule deer, and bighorn sheep as a proxy for overall habitat connectivity and condition in the watershed.
2. CNHP reviewed existing conservation and restoration priorities in the watershed, including areas detailed in the Roaring Fork Watershed Plan (Clarke et al. 2012) and the Lime Creek Watershed Restoration Action Plan (USFS 2012).
3. All existing wetland-related Potential Conservation Areas (PCAs) and Element Occurrences (EOs) of rare species and plant communities in the watershed were reviewed, along with new and updated records from the field inventory and desktop analysis.
4. The biodiversity conservation function layer, which included both rare species and general biodiversity support ranked by landscape condition, was used to identify large biodiversity hotspots in disturbed landscapes, and areas connected to existing intact habitats.
5. Updated beaver activity mapping, including trends in beaver activity over time, was evaluated to identify riparian wetland habitats where a decline in beaver activity has resulted in drier wetland conditions.
6. All final priority areas were visited by CNHP staff on the ground to verify plant community composition and overall site conditions such as the presence or absence of beaver activity and stream channel incision.

With all lines of evidence, CNHP identified 5 high priority and 4 medium priority areas where restoration and management activities in the next 5 years would likely provide the highest degree of ecological lift within wetland and riparian habitats. Each of the priority areas includes details on wetland types in the area, current and past stressors, and future protection, restoration, and management needs.

4.7 Online Mapping Tool Updates

The primary geospatial data products created by this project will be hosted in CNHP's online Watershed Planning Toolbox (<https://cnhp.colostate.edu/cwic/tools/toolbox/>), a comprehensive resource for incorporating wetland and streams into watershed planning efforts across Colorado. The Toolbox includes an interactive mapping platform that allows users to view wetlands, streams, likely aquatic ecosystem functions, ecological stressors, and high-priority sites for conservation and restoration at the watershed scale (Marshall et al. 2018). Many Toolbox geospatial data layers have statewide coverage, while some more detailed layers for wetland functions and priority conservation and restoration areas are currently limited to the Roaring Fork, Arkansas Headwaters and South Platte Headwaters HUC8 watersheds. The online mapper is also part of a comprehensive package of web pages and features that collectively provide a wealth of information to support landowners, land managers, conservation groups, and the general public in learning about, conserving and restoring Colorado wetlands and riparian areas.

As part of this study, CNHP updated wetland mapping for the Roaring Fork watershed to expand coverage of the Toolbox. All data developed for the Watershed Planning Toolbox can be explored through the Watershed Planning Toolbox mapper online in fall, 2022. The results presented here provide only an overview of the major datasets developed. Many additional aspects of the data can also be viewed online.

5.0 RESULTS

5.1 Inventory of Ecologically Significant Areas

Results of the 2019-2020 field inventory confirmed that there are many critical natural resources with biological significance in the Roaring Fork watershed, including species and communities across public and private lands. Prior to the summer 2019 field season, CNHP identified a total of 83 potential Targeted Inventory Areas (TIAs). CNHP surveyed 23 TIAs, and a total of more than 34 sites. Survey efforts were prioritized by private ownership, last observed date for rare species and communities, and access. Many of the TIAs were either difficult to access or had been visited within the past five years by other researchers.

A total of 12 new element occurrences (1 amphibian, 3 bird, 4 plant community, and 4 botany) were documented and 26 element occurrences of rare or imperiled plants, animals, and plant communities were updated (Table 4). This is not a comprehensive list of all elements of biological significance known to occur in the Roaring Fork watershed, but rather a list of species tracked by CNHP or associated with PCAs that are significant enough to be archived in CNHP’s Biodiversity Tracking and Conservation Data System (BIOTICS).

Several rare species and one plant community were newly documented in the watershed as part of this study, each restricted to a single site. *Carex microglochis* was observed in a wet meadow-fen wetland complex along the North Fork Crystal River. An *Eleocharis rostellata* (beaked spikerush) marsh community and *Epipactis gigantea* (giant helleborine) population were observed and documented along the Crystal River.

Three plant species were documented during the field inventory that are watchlisted by CNHP, and not included in Table 4. Some of these species were documented across multiple sites and include *Crataegus saligna*, *Eriophorum chamissonis*, *Limnorchis ensifolia* (*Platanthera sparsiflora* var. *ensifolia*), and *Utricularia minor*.

Table 4. List of rare and significant wetland- and riparian-associated animal and plant species and plant communities for the Roaring Fork watershed.

Scientific Name	Common Name	Global Rank	State Rank	USESA, Federal Sensitive	New Record	Updated Record	Updated and New Records
AMPHIBIANS							
<i>Anaxyrus boreas</i> pop. 1	Boreal Toad - Southern Rocky Mountain Population	G4T1T 2Q	S1	USFS		X	
<i>Lithobates pipiens</i>	Northern Leopard Frog	G5	S3	BLM, USFS			
BIRDS							
<i>Cypseloides niger</i>	Black Swift	G4	S3B	BLM, USFS			

Scientific Name	Common Name	Global Rank	State Rank	USESA, Federal Sensitive	New Record	Updated Record	Updated and New Records
<i>Haliaeetus leucocephalus</i>	Bald Eagle	G5	S1B, S3N	BLM, USFS	X		
<i>Bucephala islandica</i>	Barrow's Goldeneye	G5	S2B				
<i>Melanerpes lewis</i>	Lewis's Woodpecker	G4	S4	USFS	X		
FISH							
<i>Gila robusta</i>	Roundtail chub	G3	S2	BLM; USFS			
<i>Oncorhynchus clarkia pleuriticus</i>	Colorado River cutthroat trout	G5T3	S3	BLM; USFS			
INSECTS							
<i>Pictetiella expansa</i>	A stonefly	G3G4	S2				
<i>Rhithrogena flavianula</i>	A mayfly	G1G3	SH				
NONVASCULAR PLANTS							
<i>Sphagnum angustifolium</i>	Narrowleaf peatmoss	G5	S2	USFS			
<i>Sphagnum platyphyllum</i>	Flat-leaved sphagnum moss	G5	S1S2				
WETLAND AND RIPARIAN PLANT COMMUNITIES (communities in bold are fully tracked)							
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Alnus incana</i> Swamp Forest	Subalpine fir-Engelmann spruce/thinleaf alder Swamp Forest	G5	S5				
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Mertensia ciliata</i> Swamp Forest	Subalpine fir – Engelmann spruce/tall fringed bluebells Swamp Forest	G5	S5			X	
<i>Carex aquatilis</i> - <i>Carex utriculata</i> Wet Meadow	Water sedge-beaked sedge Wet Meadow	G4	S4			X	
<i>Carex aquatilis</i>-<i>Sphagnum</i> spp. Fen	Water sedge- <i>Sphagnum</i> Fen	G2G3	S2S3		X		
<i>Carex nebrascensis</i> Wet Meadow	Nebraska sedge Wet Meadow	G4	S4				
<i>Carex saxatilis</i> Fen	Rock sedge Fen	G3	S1				
<i>Carex simulata</i> Fen	Short-beaked sedge Fen	G4	S3		X		
<i>Eleocharis rostellata</i> Marsh	Beaked spikerush Emergent Wetland	G3	S2		X		
<i>Nuphar polysepala</i> Aquatic Vegetation	Western Slope Floating/Submergent Palustrine Wetlands	G5	S5		X		
<i>Picea pungens</i> / <i>Alnus incana</i> Riparian Woodland	Colorado blue spruce/thinleaf alder Riparian Woodland	G3	S3			X	
<i>Picea pungens</i> / <i>Cornus sericea</i> Riparian Woodland	Colorado blue spruce/redosier	G4	S2			X	

Scientific Name	Common Name	Global Rank	State Rank	USESA, Federal Sensitive	New Record	Updated Record	Updated and New Records
	dogwood Riparian Woodland						
<i>Populus angustifolia - Picea pungens / Alnus incana</i> Riparian Woodland	Narrowleaf cottonwood – Colorado blue spruce/thinleaf alder Riparian woodland	G3	S3			X	
<i>Populus angustifolia - Pseudotsuga menziesii</i> Riparian Woodland	Narrowleaf cottonwood-Douglas-fir Riparian Woodland	G3	S2			X	
<i>Populus angustifolia / Alnus incana</i> Riparian Woodland	Narrowleaf cottonwood/thinleaf alder Riparian Woodland	G3	S3			X	
<i>Populus angustifolia / Betula occidentalis</i> Riparian Woodland	Narrowleaf cottonwood/water birch Riparian Woodland	G3	S3			X	
<i>Populus angustifolia / Cornus sericea</i> Riparian Woodland	Narrowleaf cottonwood/redosier dogwood Riparian Woodland	G4	S4			X	
<i>Populus angustifolia / Prunus virginiana</i> Riparian Woodland	Narrowleaf cottonwood / chokecherry Riparian Woodland	G2Q	S2				
<i>Pseudotsuga menziesii / Cornus sericea</i> Riparian Woodland	Douglas-fir/redosier dogwood	G4	S2			X	
<i>Salix boothii / Carex utriculata</i> Wet Shrubland	Booth's willow/beaked sedge Wet Shrubland	G4	S2			X	
<i>Salix boothii / Mesic Graminoids</i> Wet Shrubland	Booth's willow/Mesic Graminoids Wet Shrubland	G3?	S3				
<i>Salix drummondiana / Calamagrostis canadensis</i> Wet Shrubland	Drummond's willow/bluejoint Wet Shrubland	G3	S3			X	
<i>Salix drummondiana / Carex utriculata</i> Wet Shrubland	Drummond's willow/beaked sedge Wet Shrubland	G4	S2			X	
<i>Salix drummondiana / Mesic Forbs</i> Wet Shrubland	Drummond's willow/ Mesic Forbs Wet Shrubland	G4	S4			X	
<i>Salix monticola / Calamagrostis canadensis</i> Wet Shrubland	Rocky Mountain willow/bluejoint Wet Shrubland	G3	S3			X	

Scientific Name	Common Name	Global Rank	State Rank	USESA, Federal Sensitive	New Record	Updated Record	Updated and New Records
<i>Salix planifolia</i> / <i>Calamagrostis canadensis</i> Wet Shrubland	Planeleaf willow/bluejoint Wet Shrubland	G4	S2			X	
<i>Salix planifolia</i> / <i>Caltha leptosepala</i> Wet Shrubland	Planeleaf willow / marsh marigold Wet Shrubland	G4	S4			X	
<i>Salix planifolia</i> / <i>Carex aquatilis</i> Wet Shrubland	Planeleaf willow / water sedge Wet Shrubland	G5	S5			X	
<i>Salix planifolia</i> / <i>Deschampsia cespitosa</i> Wet Shrubland	Planeleaf willow/tufted hairgrass Wet Shrubland	G2G3	S2			X	
PLANTS							
<i>Carex diandra</i>	Lesser paniced sedge	G5	S2	USFS			X
<i>Carex leptalea</i>	Bristle-stalk sedge	G5	S1			X	
<i>Carex microglochin</i>	Small-tipped sedge	G5	S2		X		
<i>Cypripedium calceolus</i> ssp. <i>parviflorum</i>	American yellow lady's-slipper	G5	S2			X	
<i>Epipactis gigantea</i>	Giant helleborine	G4	S1S2	USFS	X		
<i>Isoetes occidentalis</i>	Western quillwort	G4G5	S1				
<i>Listera borealis</i>	Northern twayblade	G5	S2			X	
<i>Listera convallarioides</i>	Broad-leaved twayblade	G5	S2			X	
<i>Lomatogonium rotatum</i>	Marsh felwort	G5	S2				
<i>Luzula subcapitata</i>	Colorado woodrush	G3	S3			X	
<i>Spiranthes diluvialis</i>	Ute ladies' tresses	G2G3	S2	LT		X	
<i>Sullivantia hapemanii</i> var. <i>purpusii</i>	Hanging garden sullivantia	G3T3	S3			X	
<i>Utricularia ochroleuca</i>	Northern bladderwort	G4G5	S1				

5.1a Floristic Results

As part of this study, CNHP documented 432 plant species in wetlands and riparian areas across the watershed (Appendix B). Of these species, 383 were native and 2 were cryptogenic (*Typha* sp. and *Phalaris arundinacea*). CNHP documented 267 plants that are indicative of wetland conditions (FAC, FACW, or OBL), including 30 *Carex* species alone. Five plant species, including three-hulled rush (*Juncus triglumis* var. *albescens*) had a Coefficient of Conservatism (C-value) higher than 10. These species are the most sensitive to human disturbance, and were primarily found in fens. Another 24 species, mostly wetland, had a C-value of 9.

Plant species that are given a Natural Heritage ranking of G1 or G2 are rare on both a global and statewide scale. G1 plants are critically imperiled based on several factors including rarity and vulnerability to extirpation or extinction. Typically, five or fewer occurrences or less than 1000 remaining individuals may define a G1 species. A G2 species is considered imperiled with six to 20

occurrences or between 1,000 and 3,000 remaining individuals (see Appendix A). There is one globally rare wetland plant known from the Roaring Fork watershed, Ute ladies' tresses (*Spiranthes diluvialis*), which is also an ESA-listed threatened species.

Ute ladies' tresses (*Spiranthes diluvialis*) G2S3 S2 LT SWAP Tier 1

There are scattered occurrences of *Spiranthes diluvialis* in patchy riparian woodland/shrubland and wet meadow habitats along the floodplain of the Roaring Fork River near Carbondale. As part of this study, we documented a new population extension for *Spiranthes diluvialis* on conserved private land within the Roaring Fork River at Carbondale PCA. Orchids were observed in active floodplain areas along the river, and scattered throughout irrigation-influenced wet meadow areas alongside a variety of native sedges and forbs. More information on this species can be found online in the Colorado Rare Plant Guide:



<https://cnhp.colostate.edu/rareplant/details/?plantID=17998>.

5.1b Noxious Weeds

During the field inventory, CNHP documented 12 state List B and 5 List C noxious weeds in wetlands and riparian areas in the watershed (Table 5). These weeds were primarily found at lower elevations, and in areas with current and past roads, trails, campsites, livestock grazing, and other forms of human soil and plant community disturbance. A list of all noxious weed species is provided in Table 5, along with the family, wetland indicator status (if available), noxious status, type, and duration of each plant. Almost all plants were upland species, though species like Russian olive and Canada thistle are commonly found in wetland and riparian areas across the state.

Table 5. List of state-listed noxious weeds observed at wetland and riparian sites visited throughout the Roaring Fork watershed.

Family	Latin Name	Common Name	Wetland Indicator Status	Noxious Status	Type	Duration
Asteraceae	<i>Artemisia absinthium</i>	absinthe wormwood		List B	Forb	Perennial
Asteraceae	<i>Carduus acanthoides</i>	plumeless thistle		List B	Forb	Biennial
Asteraceae	<i>Carduus nutans</i>	musk thistle	UPL	List B	Forb	Biennial, Perennial
Asteraceae	<i>Cirsium arvense</i>	Canada thistle	FAC	List B	Forb	Perennial
Asteraceae	<i>Cirsium vulgare</i>	bull thistle	FACU	List B	Forb	Biennial
Asteraceae	<i>Leucanthemum vulgare</i>	oxeye daisy	FACU	List B	Forb	Perennial
Asteraceae	<i>Tanacetum vulgare</i>	common tansy	FACU	List B	Forb	Perennial
Boraginaceae	<i>Cynoglossum officinale</i>	gypsyflower	FACU	List B	Forb	Biennial
Brassicaceae	<i>Hesperis matronalis</i>	dame's rocket	FACU	List B	Forb	Biennial, Perennial

Family	Latin Name	Common Name	Wetland Indicator Status	Noxious Status	Type	Duration
Brassicaceae	<i>Lepidium draba</i>	whitetop		List B	Forb	Perennial
Elaeagnaceae	<i>Elaeagnus angustifolia</i>	Russian olive	FAC	List B	Shrub	Perennial
Plantaginaceae	<i>Linaria vulgaris</i>	butter-and-eggs		List B	Forb	Perennial
Asteraceae	<i>Arctium minus</i>	common burdock	UPL	List C	Forb	Biennial
Clusiaceae	<i>Hypericum perforatum</i>	St. John's-wort	FACU	List C	Forb	Perennial
Convolvulaceae	<i>Convolvulus arvensis</i>	bindweed		List C	Vine	Perennial
Geraniaceae	<i>Erodium cicutarium</i>	redstem filaree		List C	Forb	Annual, Biennial
Scrophulariaceae	<i>Verbascum thapsus</i>	woolly mullein	FACU	List C	Forb	Biennial

5.1c Fauna Results

While this survey primarily focused on plants and plant communities, CNHP added or updated data on one state vulnerable species (S1 or S2) as part of this study. Three other tracked species, Bald Eagle (*Haliaeetus leucocephalus*), Lewis's Woodpecker (*Melanerpes lewis*), and Greater Sandhill Crane (*Grus Canadensis tabida*) were observed in riparian areas along the Roaring Fork and Crystal Rivers.

Boreal toad (Anaxyrus boreas boreas) (G4T1S1), BLM/USFS sensitive species, and CPW Tier 1 species

Boreal toads have recently and historically been documented in the Fryingpan River, Upper Roaring Fork River, Crystal River, Maroon Creek, Castle Creek, and Snowmass Creek HUC10 watersheds. During the project's field season in 2019, CNHP found numerous adult boreal toads and hundreds of tadpoles at a single fen site in the Fryingpan headwaters.

Boreal toads remain rare in the Roaring Fork watershed and appear to be restricted to a few small, isolated populations due to the lethal impacts of the *Batrachochytrium dendrobatidis* ("chytrid") fungus across the toad's range in Colorado. Toads are associated with a variety of wetland and waterbody habitats in the watershed including fens, beaver ponds and other emergent marsh habitats, and lakes. Several toad breeding sites are located across the Continental Divide in Lake and Eagle Counties.



Adult boreal toad. Photo: Brad Lambert, CNHP.

5.2 Wetland Condition

Of the TIAs and other sites visited during the field inventory, we used the species lists from 31 wetland and riparian sites across the watershed to evaluate Mean C, Mean Native C, and Mean Wetland C (FAC, FACW, or OBL wetland indicator status; Table 6). Sites on private land, or with rare species, were given a site alias with a generalized geographic location. Attributes evaluated alongside field data included land ownership/management, protection via conservation easements (CE), primary ecological system and HGM class, surrounding land cover, and LDI class. Sites with no mapped habitat fragmentation from human-made features have a rank of “none” and sites with the highest level of human disturbance have a rank of “high”. We also included six previously sampled points in the watershed from the CNHP Wetland and Riparian Plots database (<https://cnhp.colostate.edu/cwic/tools/plot-database/>) for comparison.

Nine sites had a rounded Mean C value greater than 7, including seven sites in the headwaters of the Fryingpan River and two sites in the headwaters of the Crystal River (Table 6). The highest Mean C values (7.38 and 7.32) were from fens in the Holy Cross Wilderness in the Fryingpan headwaters. Nearly all sites with a Mean C greater than 7 included fens and had similar Mean Native C scores. One private ranch in the Snowmass Creek watershed had a rounded Mean C value greater than 6, and three out of nine sites on private land had Native Mean C values greater than 6.

Only three sites had a Mean C value in the 1-3 range, which is indicative of the highest level of human disturbance that still supports native species. The remaining nineteen sites had a rounded Mean C value between 4 and 6, including a mix of species found in both less and most disturbed areas. Only one out of all sites evaluated had a Native Mean C value less than or equal to 3.

For sites including non-native species, we also calculated the difference between Native Mean C and Mean C to assess the prevalence of non-native species. Of the four sites with highest non-native species cover (Native Mean C – Mean C greater than 1), three were on private land and one was on public land. All had some degree of current or past livestock grazing or other soil disturbance. Non-native species included both noxious weeds and common hay and pasture species like timothy (*Phleum pratense*) and clover (*Trifolium repens*).

These findings are consistent with the range in Mean C values (3.6-7.8) reported for riparian, wet meadow, and fen wetlands in Rocky Mountain National Park (Schweiger et al. 2016), including fens having the highest Mean C values. One site, the North Star Preserve upstream of Aspen, was not surveyed as part of this study, but has recently a reported Mean C value of 4.5 and a Native Mean C value of 1.1 (Peak Ecological Services 2019).

Most sites with the highest Mean and Native C values had little to no habitat disturbance and fragmentation within visited areas, as indicated by the range in LDI scores and conditions on the ground. The LDI does not capture site-specific conditions such as invasive species, grazing intensity and timing for both wild ungulates and domestic livestock, dispersed campsite use, social trails, and stream channel incision/floodplain disconnection. Six of the wetland sites with the highest Mean C values (7-9) had some degree of dispersed camping, trails, unpaved roads, or other disturbance along their boundaries.

Several of the sites in the high disturbance LDI class are carefully managed to maintain native wetland and riparian plant communities despite surrounding urban and other intensive land use. Areas like Hallam Lake and Coffman Ranch provide important wildlife habitat alongside more developed areas, and also host frequent education and outreach events centered around native species and ecosystems.

Table 6. Attributes and Mean C calculations for wetland and riparian sites evaluated during this study, and from the CNHP Wetland and Riparian Plots Database for comparison. Sites are sorted by watershed, and highest-lowest Mean C values. Rounded mean C values reflecting the lowest level of human disturbance (>6.5) are in bold. CE = Conservation Easement. LDI = Landscape Disturbance Index.

Site Name by HUC10 Watershed	Owner/Manager	CE	Primary Ecological System	Primary HGM Class	Surrounding Land Cover	LDI Class Range	Number of Observed Species	Mean C	Mean Native C	Mean Wetland C	Mean Native C - Mean C
MAROON CREEK											
Maroon Creek near East Maroon Portal	USFS		Riparian Woodland/ Shrubland	Riverine	Forest	Low-Moderate	32	5.13	6.31	5.74	1.18
SNOWMASS CREEK											
Nickelson Creek Ranch	Private		Riparian Shrubland	Riverine	Forest	Low-Moderate	108	5.63	6.08	5.85	0.45
Snowmass Creek Ranch	Private	Y	Riparian Shrubland	Slope	Forest	Low-Moderate	127	4.94	5.56	5.18	0.62
FRYINGPAN RIVER											
South Fork Cunningham Creek Upper Fen	USFS		Fen	Depression	Forest	None	34	7.38	7.38	7.44	0.00
Holy Cross Wilderness Fen	USFS		Fen	Slope	Forest	None	41	7.32	7.32	7.38	0.00
Coffee Pot Park	USFS		Wet Meadow	Slope	Forest	None	40	7.03	7.03	7.08	0.00
South Fork Cunningham Creek Riparian Area	USFS		Riparian Shrubland	Slope	Forest	Low-Moderate	10	7.00	7.00	7.00	0.00
Sellar Lake	USFS		Fen	Slope	Forest	Low-Moderate	34	6.97	6.97	7.00	0.00
South Fork Cunningham Creek Lower Fen	USFS		Fen	Slope	Forest	Low	38	6.71	6.71	6.88	0.00
Cunningham Creek	USFS		Riparian Woodland/ Shrubland	Riverine	Forest	Low-Moderate	34	6.62	6.62	6.81	0.00
Crooked Creek Park	USFS		Riparian Shrubland	Slope	Forest	Low-Moderate	59	5.95	6.38	6.09	0.43
Lime Park	USFS		Riparian Shrubland	Slope	Forest	Low-Moderate	102	5.79	6.16	6.05	0.37

Site Name by HUC10 Watershed	Owner/ Manager	CE	Primary Ecological System	Primary HGM Class	Surrounding Land Cover	LDI Class Range	Number of Observed Species	Mean C	Mean Native C	Mean Wetland C	Mean Native C - Mean C
Sellar Park	USFS		Wet Meadow	Slope	Forest	Low-Moderate	22	5.00	5.24	4.95	0.24
UPPER MIDDLE (WOODY CREEK-) ROARING FORK RIVER											
Hallam Lake	NGO		Riparian Woodland/ Shrubland	Slope	Developed - Residential	High	134	4.55	5.55	5.30	1.00
CRYSTAL RIVER											
Geneva Lake	USFS		Fen	Slope	Alpine/Rock	None	57	6.96	6.96	7.08	0.00
North Fork Crystal	USFS		Riparian Shrubland	Slope	Forest	None	70	6.57	6.57	6.66	0.00
East Creek	USFS		Riparian Woodland/ Shrubland	Slope	Forest	None-Low	54	6.20	6.20	6.13	0.00
Baylor Park	USFS		Riparian Shrubland	Slope	Forest	Low-Moderate	71	6.08	6.17	6.75	0.09
Middle Thompson	USFS		Wet Meadow	Slope	Forest	Low-Moderate	32	6.00	6.00	6.07	0.00
Lizard Lake	USFS		Riparian Shrubland	Depression	Forest	Moderate	31	5.81	5.81	5.96	0.00
Avalanche Creek	USFS		Riparian Woodland/ Shrubland	Riverine	Forest	Low-Moderate	48	5.44	6.07	5.65	0.63
Ponds above Crystal River	Private	Y	Marsh	Depression	Forest	Low-Moderate	84	4.74	5.61	5.32	0.87
Crystal River Near Marble	Private		Riparian Shrubland	Riverine	Forest	Moderate	72	4.42	5.21	4.82	0.79
Filoha Meadows	County		Wet Meadow	Slope	Forest	High	59	4.29	5.08	4.88	0.79
LOWER (MIDDLE) ROARING FORK RIVER											
Coffman Ranch	NGO	Y	Riparian Woodland/ Shrubland	Slope	Agriculture	High	78	3.92	5.19	4.52	1.27

Site Name by HUC10 Watershed	Owner/ Manager	CE	Primary Ecological System	Primary HGM Class	Surrounding Land Cover	LDI Class Range	Number of Observed Species	Mean C	Mean Native C	Mean Wetland C	Mean Native C - Mean C
Dakota Meadows	Private		Riparian Shrubland	Riverine	Urban	High	52	2.92	4.55	3.72	1.63
Rocky Mountain School	Private		NA	Slope	Agriculture	High	6	1.67	2.33	2.00	0.66
CATTLE CREEK											
Cattle Creek	Private	Y	Riparian Shrubland	Riverine	Hayfield	High	74	3.03	4.67	3.60	1.64
OUTLET ROARING FORK RIVER											
Fourmile Park	USFS		Riparian Shrubland	Slope	Grassland	Low-Moderate	40	4.83	5.68	4.91	0.85
Private Land near Hughes Reservoir	Private	Y	Riparian Woodland/ Shrubland	Slope	Forest	Low	26	4.42	5.22	4.78	0.80
Private Land near Hughes Reservoir	Private	Y	Wet Meadow	Depression	Forest	Low	10	3.80	4.75	3.80	0.95
CNHP Wetland and Riparian Plots Database Points											
UPPER ROARING FORK RIVER											
Difficult Creek Headwaters	Public		Wet Meadow	Slope	Alpine/Rock	None	5	7.40	7.40	7.40	0.00
Difficult Creek Headwaters	Public		Wet Meadow	Slope	Alpine/Rock	None	3	6.67	6.67	6.67	0.00
Difficult Creek Headwaters	Public		Riparian Shrubland	Slope	Alpine/Rock	None	10	6.89	6.89	6.89	0.00
CRYSTAL RIVER											
South Branch Middle Thompson Creek Tributary	Public		Riparian Shrubland	Slope	Grassland	None	11	7.00	7.00	7.00	0.00
South Branch Middle Thompson Creek Tributary	Public		Wet Meadow	Slope	Forest	None	7	5.00	5.83	5.83	0.83
South Branch Middle Thompson Creek Tributary	Public		Riparian Shrubland	Slope	Forest	None	8	6.14	6.14	6.14	0.00

5.3 Land Use Change and Conservation Analysis

5.3a Land Use Change and Habitat Fragmentation

Land use change, human disturbance, and habitat fragmentation were evaluated in several different ways using the Landscape Disturbance Index (Fink 2021) and the NLCD Change Index (USGS 2021). The NLCD change indices only reflect change (vs. a gain or loss), but we assumed that urban change acres represented an increase in urban development and wetland and water change acres likely represent a loss. This was supported by mapping updates, and the field inventory. Percentages of each watershed in four LDI human disturbance classes (Table 7) help illustrate which watersheds have habitats that are most and least fragmented by human disturbance. NLCD change values are reported for areas of no change, urban change, and wetland and water land cover class change (Table 7).

Table 7. Land use change and landscape disturbance and fragmentation for each HUC10 watershed in the Roaring Fork.

HUC Name	HUC10	% of HUC10 in each LDI Class				NLCD Change Index		
		High (>500)	Mod. (>250-500)	Low (>0 - 250)	None	No Change (%)	Urban Change Acres	Wetland + Water Change Acres
Upper Roaring Fork River	1401000401	4.6%	6.5%	21.8%	67.1%	98.7	103.0	264.4
Castle Creek	1401000402	0.7%	1.4%	25.9%	71.9%	98.5	43.6	74.8
Maroon Creek	1401000403	4.6%	3.1%	10.8%	81.5%	98.9	66.5	75.4
Snowmass Creek	1401000404	4.0%	10.7%	24.9%	60.4%	99.0	39.9	175.8
Fryingpan River	1401000405	1.0%	7.7%	23.4%	68.0%	97.8	49.4	365.3
Woody Creek-Roaring Fork River	1401000406	17.3%	14.0%	30.6%	38.1%	97.9	415.0	100.7
Crystal River	1401000407	3.9%	8.1%	26.7%	61.3%	98.5	139.5	413.0
Middle Roaring Fork River	1401000408	25.3%	16.1%	27.2%	31.4%	88.3	486.2	350.5
Cattle Creek	1401000409	5.0%	20.2%	41.3%	33.5%	91.5	57.8	134.0
Outlet Roaring Fork River	1401000410	19.1%	20.9%	35.9%	24.1%	97.9	409.2	79.2
Total Change Acres							1810.1	2033.1

*Also referred to as the Upper Middle Roaring Fork River and Middle Roaring Fork River in various sources and versions of NHD layers.

**Also referred to as the Lower Roaring Fork River and Lower-Middle Roaring Fork River in various sources and versions of NHD layers.

Of the 10 HUC10 watersheds in the Roaring Fork, the Maroon Creek watershed had the highest percentage of total watershed area (82%) in the least-disturbed LDI class, followed by Castle Creek (72%). It is worth noting that these two watersheds supply water to the City of Aspen. The (Lower) Middle Roaring Fork River watershed had the highest amount of watershed area (25%) in the highest disturbance class, followed by the Woody Creek-Roaring Fork River watershed (17%).

The Lower (Middle) Roaring Fork River and Cattle Creek HUC10 watersheds had the greatest amount of land cover change from 2001-2019, with nearly 20% of land cover changing in the Lower Roaring Fork. Most HUC10 watersheds saw minimal change in land cover (1-2%). The highest number of urban change acres were along the Roaring Fork River mainstem between Aspen and Glenwood Springs. The highest amount of wetland and waterbody change acreage was in the Crystal River watershed (413 acres), followed by the Fryingpan River (365 acres) and Lower (Middle) Roaring Fork (351 acres) watersheds.

5.3b Land Conservation

Land protection within the Roaring Fork watershed includes designated wilderness, other federal, state, county, and city lands managed for conservation, non-governmental lands owned or managed by land trusts, and conservation easements on private land. Overall, 753,122 acres (80.9%) of the watershed have some form of protection as of 2022 (Table 8).

The Upper Roaring Fork River HUC10 had the highest degree of land protection (96% of HUC10 area) as of 2022, closely followed by the Maroon Creek, Fryingpan River, and Castle Creek watersheds (Table 8). The Maroon Creek HUC10 watershed, which has 31,195 acres of wilderness (83% of total HUC10 area), had the highest land protection rank (93.5%), and the Upper Roaring Fork River had the second highest land protection rank (91.7%). The Outlet Roaring Fork River HUC10 had the lowest land protection rank at 42.7% (Table 8).

The extent and location of recent land conservation is one indicator of conservation priorities in the watershed over the last two decades. Most new conservation acreage since 2000 included conservation easements, with some city and county land purchases. In total, more than 31,056 acres (3.3%; Table 8) of land in the watershed have been protected through land purchases or conservation easements in the last two decades. The Crystal River watershed had the greatest addition of conserved acres (11,152 acres) since 2000, followed by the Lower Roaring Fork River (6,476 acres).

Many areas protected over the last two decades have included riparian areas, wetlands, and other areas of biodiversity significance. Other protection has centered around habitat corridors, recreation areas, and agricultural lands. The Aspen Valley Land Trust (AVLT) and Pitkin County Open Space & Trails have conserved many of the total acres since 2000, often in collaboration with private landowners. AVLT alone has conserved more than 1,500 wetland acres in their service area (AVLT 2022).

Table 8. Conservation Metrics by HUC10 watershed within the Roaring Fork.

Watershed	HUC10	% of Watershed Area Protected	Normalized Land Protection Rank (%)	Acres Protected Since 2000
Upper Roaring Fork River	1401000401	96.0	91.7	555
Castle Creek	1401000402	90.9	84.4	169
Maroon Creek	1401000403	95.2	93.5	61
Snowmass Creek	1401000404	70.4	70.4	4,059
Fryingpan River	1401000405	94.8	82.7	779
Woody Creek-Roaring Fork River*	1401000406	74.0	64.5	3,579
Crystal River	1401000407	88.9	78.3	11,152
Middle Roaring Fork River**	1401000408	60.5	52.9	6,476
Cattle Creek	1401000409	48.7	47.8	2,032
Outlet Roaring Fork	1401000410	41.7	42.7	2,195
Total Acres of Land Protected Since 2000				31,056

*Also referred to as the Upper Middle Roaring Fork River and Middle Roaring Fork River in various sources and versions of NHD layers.

**Also referred to as the Lower Roaring Fork River and Lower-Middle Roaring Fork River in various sources and versions of NHD layers.

5.3c Landscape Disturbance and Habitat Fragmentation

The majority of the Roaring Fork watershed has protected land with minimal habitat fragmentation (Figure 10). Wetlands and waterbodies generally follow this pattern, with the exception of habitats along river corridors paralleled by highways, roads, and other human disturbance. Most wetlands and waterbodies (18,519 acres) in the watershed were in the “low” (0-250) LDI disturbance class. These areas were concentrated in headwater areas with minimal road and trail fragmentation. A smaller number of wetland and waterbody acres (5,731 acres) were in the “moderate” (250-500) disturbance class, followed by 3,247 acres in the “high” (>500) LDI class. Most wetland and waterbody acres in the “high” LDI class were in valley bottoms adjacent to urban and residential areas. A limited number of wetland and waterbody features, mostly long, linear stream features spanning large reaches of the watershed, were unable to be ranked with an LDI score.

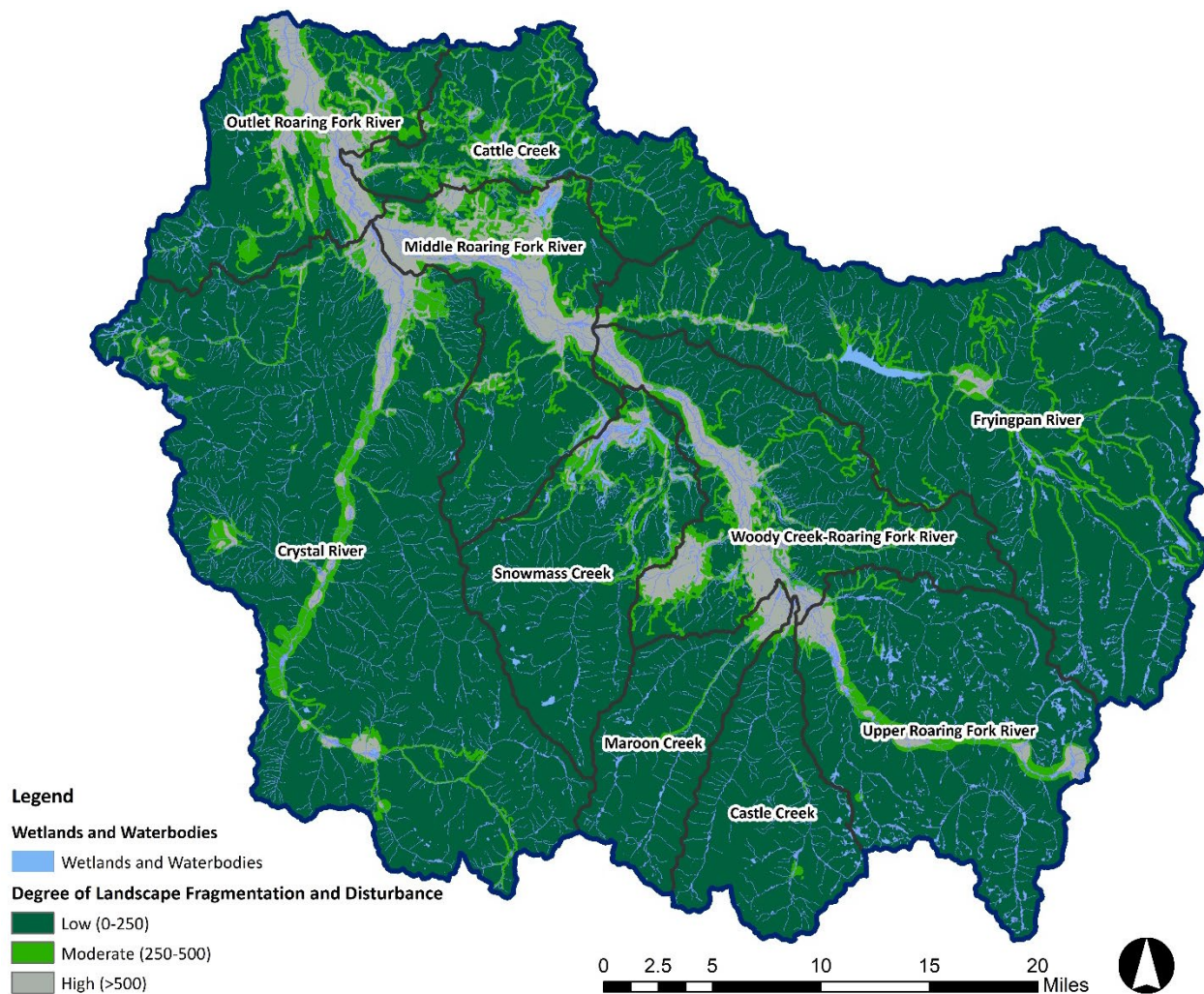


Figure 10. Landscape disturbance and habitat fragmentation within the Roaring Fork watershed.

5.4 Wetland Mapping

5.4a Wetland Ecological Systems

There were 27,529 acres of wetlands and waterbodies mapped within the Roaring Fork watershed, and 75 acres of non-wetland riparian area (Figure 11, Table 9). 14,884 wetland acres were assigned to an ecological system, using vegetation classes, proximity to rivers and streams, and hydrologic regimes. The most common wetland ecological system mapped in the Roaring Fork was wet meadow, with a total of 6,220 acres (Table 9). Parsing irrigation influence from natural wetland hydrology can be challenging in wet meadows, and acreage is reported with and without overlap with mapped irrigated lands from the Colorado Division of Water Resources. The second most common ecological system was riparian shrublands and woodlands (5,992 acres), followed by fens (1,752 acres) and emergent marshes (901 acres). The concentration of fens is highest in the headwaters of the Upper Roaring Fork River and Frypan River HUC10 watersheds.

Hanging gardens are not well-captured in the NWI mapping, as they are often found on near-vertical surfaces, and sometimes surrounded by forest. Riparian shrublands and woodlands were likely under-mapped in the watershed, as there is a gradient between obvious wetlands and coniferous and deciduous upland forest along many headwater streams. While CNHP updated some stream and river boundaries in the wetland mapping, a comprehensive NWI mapping update was not within the scope of this project and NHD flow line mis-matches with natural channel boundaries pose challenges for accurate riparian wetland mapping.

Table 9. Mapped wetland and riparian acres within the Roaring Fork watershed by likely Ecological System.

Wetland and Riparian Ecological Systems	Total Acres
Wet Meadows	6,220
Without irrigated lands overlap	3,952
Overlapping irrigated lands (primarily flood irrigation)	2,268
Riparian Shrublands and Woodlands	5,992
Riparian Shrublands	5,820
Riparian Woodlands	172
Fens	1,752
Emergent Marshes	920
Grand Total	14,884

5.4b NWI Enhancement with LLWW

The regionalized LLWW classification provided an intuitive system for grouping different types of wetlands and waterbodies in the watershed. The codes can be parsed by landscape position, landform, waterbody type, and water flow path, as well as numerous modifiers. For ease of interpretation, we grouped one or more combinations of LLWW types into logical HGM-like wetland and waterbody types (Figure 11; Tables 10 and 11).

Of the 14,316 mapped non-waterbody wetland acres, more than 60% (8,856 acres) were classified as slope wetlands (TESL) based on evidence of snowmelt, groundwater, or irrigation inputs. These acres include snowmelt-fed and groundwater-fed headwater wetlands, fens, and many large irrigation-influenced hay fields maintained by flood irrigation. Another one-third of wetland acres were classified as either 1) floodplain and streamside wetlands (LOFP: 4,358 acres), or 2) sandbars (LOFR: 194 acres). Both types are driven by overbank flow from rivers and streams. Remaining wetland acres were classified as depressions (838 acres) and lakeshore wetlands (70 acres).



Figure 11. Wetland hydrogeomorphic types within the Roaring Fork watershed.

The second most common flow path was outflow (5,841 wetland acres). These acres included headwater and snowmelt-fed wetlands that feed into stream systems. No wetlands were classified as inflow wetlands, which are sinks of water. The 71 acres of lakeshore wetlands were classified with the bidirectional flow path, dominated by the rise and fall of lake levels. Many lakes in the watershed have steep shorelines, or otherwise lack abundant fringe wetland cover around their margins. Lastly 1,493 acres were classified as vertical flow wetlands, which lack a mapped perennial or seasonal surface water connection with other wetlands or waterbodies, though ephemeral connections may exist.

More than 70% of the waterbody acres mapped in the watershed were streams, ditches, or canals (9,542 acres; Table 11). This number is likely inflated by the large number of seasonal intermittent streams in the dataset and how NHD flow lines were incorporated into the NWI dataset. Current NWI data standards mandate that all NWI data are polygonal rather than linear features. To accommodate this standard, NHD intermediate flow lines have a polygon width of three meters by default, though many of these features are likely narrower or have more vegetated riparian wetland area than surface water area in a defined channel.

Table 10. Wetland acres in the watershed by LLWW Landscape Position, Landform, and Water Flow Path.

Landscape Position and Landform Groups	Water Flow Path (acres)					Grand Total
	IN (Inflow)	OU (Outflow)	TH (Through-flow)	BI (Bi-directional)	VR (Vertical Flow)	
Lakeshore wetlands				71		70
LEFP (Lentic Floodplain)				67		67
LEFR (Lentic Fringe)				4		4
Floodplain wetlands		5	4,353			4,358
LOFP (Lotic floodplain)		5	4,353			4,358
Sandbars and other in-channel wetlands			194			194
LOFR (Lotic Fringe)			194			194
Slope wetlands		5,821	2,087		948	8,856
TESL (Terrene Slope)		5,821	2,087		948	8,856
Depressional wetlands		15	277		545	838
LOBA (Lotic Basin)			250		1	251
TEBA (Terrene Basin)					479	521
TEFR (Terrene Fringe)		15	27		6	6
LEBA (Lentic Basin)					59	59
Grand Total (acres)		5,841	6,911	70	1,493	14,316

Table 11. Waterbody acres in the watershed by LLWW Landscape Position, Waterbody, and Water Flow Path.

Landscape Position and Waterbody Type Groups	Water Flow Path (acres)						Grand Total
	Inflow (IN)	Outflow (OU)	Through-flow (TH)	Throughflow-Bidirectional Flow (TB)	Bi-directional Flow (BI)	Vertical Flow (VR)	
Lakes		270	86	1,802	50	1	2,209
LOLK (Lotic Lakes)			86	1,779			1,865
LELK (Lentic Lakes)					25		25
TELK (Terrene Lakes)		270		23	25	1	319
Ponds	10	245	669			540	1,464
LOPD (Lotic Ponds)		4	623			10	637
TEPD (Terrene Ponds)	10	241	46			530	827
Rivers and streams			9,542				9,634
LOST1 (Perennial streams)			3,792				3,897
LOST2 (Seasonal intermittent streams)			4,910				4,898
LOST3 (Temporary intermittent streams)			64				64
TEST5 (Ditches and canals)			775				775
Grand Total (acres)	10	515	10,297	1,802	50	541	13,215

Waterbody acreage for lakes and ponds is likely more accurate, as it is determined using aerial imagery. There were 2,209 acres of lakes, of which 1,865 acres are located within stream corridors (LOLK). Only 319 acres are situated at the headwaters of streams (TELK). Most lotic lake acres are within artificially impounded reservoirs. Total pond area in the watershed was 1,464 acres.

One caveat with any wetland attribution based on flow paths is that the NHD flowlines in Colorado are not often a perfect match with stream channel locations on the ground, and miss many small channels – particularly in forested catchments like the headwaters of the Roaring Fork. The figures presented in Table 10 and Table 11 likely underestimate the total surface water network, and degree of surface water and groundwater connectivity between wetlands and waterbodies.

5.4c Beaver-influenced Wetlands

Beavers-influenced wetlands cover more than 1,643 acres, or 11% of total Palustrine wetland acres within the Roaring Fork watershed, and often intersect and support biodiversity hotspots for a variety of native wetland plant communities and wildlife species. More than half of the wetlands visited during the field inventory had evidence of past or current beaver activity. Compared to neighboring HUC8 watersheds like the South Platte Headwaters and East Fork Taylor, beaver activity is relatively low in the Roaring Fork watershed. Figure 12 shows buffered areas with observed beaver activity in 2013, 2017, and 2019 NAIP imagery along with areas that were mapped as having beaver activity in the 1980s when the original NWI mapping was produced.

Between the original NWI mapping in the 1980s and the 2013-2019 period, more than 552 acres of wetlands lost visible beaver activity. Notable areas of beaver activity decline since the original NWI mapping include the Fryingpan River headwaters above Ruedi Reservoir, scattered areas within the Upper Roaring Fork HUC10 watershed, the headwaters of Fourmile Creek, and headwater areas west of the Crystal River mainstem including Thompson Creek and Coal Creek. Cattle Creek had the most notable increase in beaver activity since the original NWI mapping, with beaver activity spreading downstream from the headwaters.

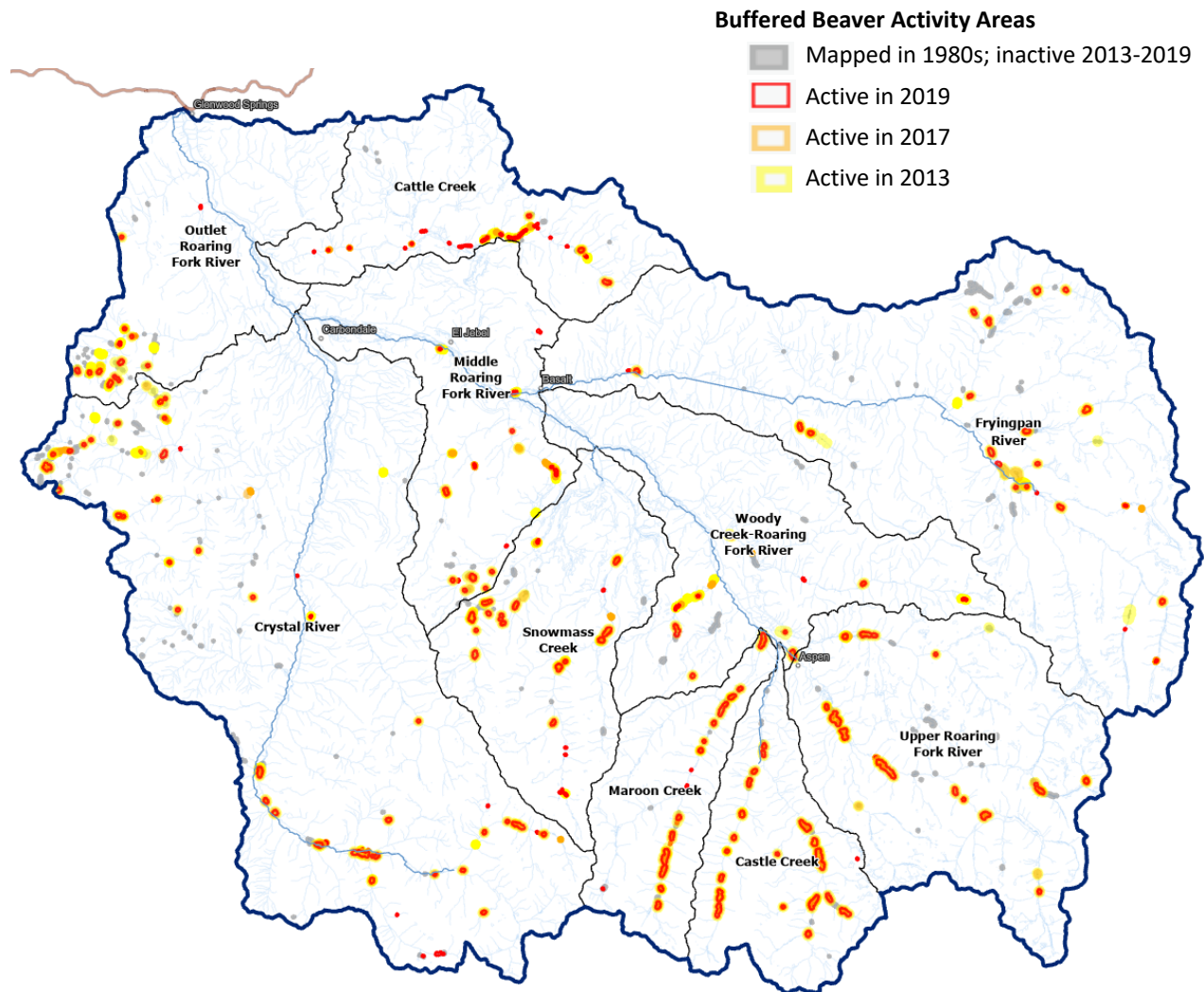


Figure 12. Mapped beaver activity in the watershed in the 1980s, and in 2013, 2017, and 2019. Buffers were added to beaver complexes to make them more visible at the scale of the entire watershed.

5.5 Modeled Likely Wetland Functions

We modeled nine different functions, grouped into three different categories, provided by wetlands and waterbodies within the Roaring Fork watershed. Given the quality of mapping for stream and river corridors in the watershed, functions were only evaluated for wetlands and non-stream waterbodies.

5.5a Biodiversity and Wildlife Habitat Functions

Among the biodiversity and wildlife habitat functions, around 87% (15,629 acres) of the wetland and waterbody acres in the watershed were rated as providing some degree of biodiversity conservation (Table 12, Figure 13). The majority of wetlands providing habitat for rare species or general biodiversity support (13,118 acres) are in high or moderate landscape condition and are good candidates for conservation or protection. Only 2,511 of acres providing biodiversity conservation are in poor landscape condition. Some of these areas may warrant restoration

activities to improve wetland condition. The Upper Roaring Fork River and Fryingpan River HUC10 watersheds together account for 72% of acres with rare species and ecosystems and high landscape condition. Both watersheds have a high concentration of fens, alpine wetlands, and rare plants and animals.

Waterfowl and shorebird habitat is also provided by many wetland and waterbody acres in the watershed. Colorado’s wetlands provide important stopover habitat for many waterfowl during spring and fall migration, along with habitat for overwintering and breeding ducks and geese. Key habitat elements include submerged and emergent aquatic vegetation (interspersed with open water), along with other food sources like invertebrates, seeds and grains. Our model suggests that 35% of wetland and water body acres likely provide waterfowl habitat. Shorebirds like sandpipers, plovers, and curlews utilize a narrower range of Colorado wetland habitats than waterfowl or invertebrates, primarily lake shores, river sand bars, and playas. Our models predict that roughly 16% of wetland and waterbody acres in the Roaring Fork provide habitat for shorebirds.

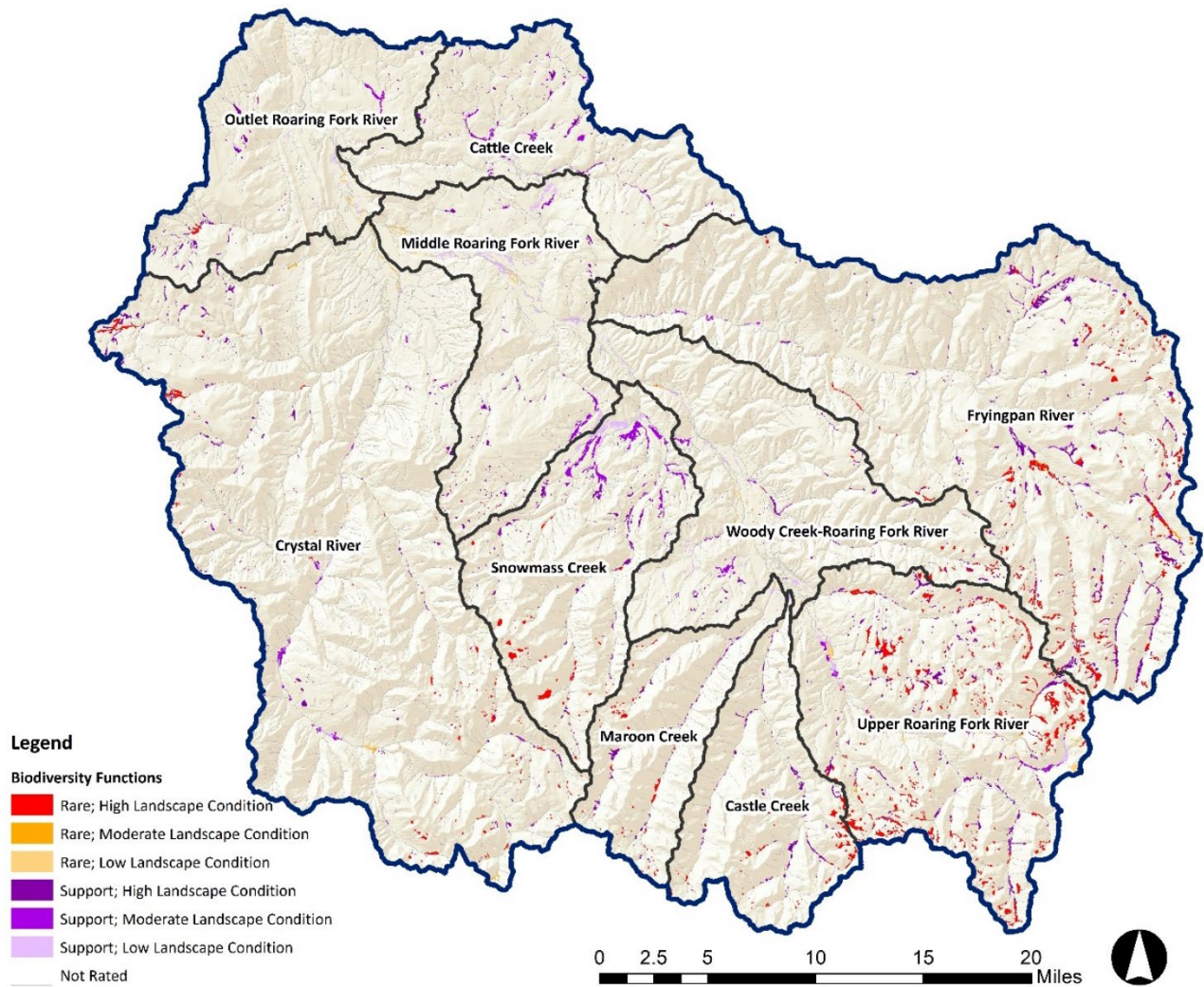


Figure 13. Map of biodiversity conservation functions in the watershed, ranked by landscape condition. Includes support for rare species and ecosystems as well as general biodiversity support.

Table 12. Biodiversity and wildlife habitat functions performed by wetlands and waterbodies within the Roaring Fork watershed. For each function, numbers show the acres of wetlands and waterbodies potentially performing the function at either a high or moderate level, unless specified. Total acres for each function are in bold, along with the percent of total wetland and non-stream waterbody acreage in the watershed.

Biodiversity & Wildlife Habitat Functions	Wetland and Waterbody Acres
Biodiversity Conservation	15,629 86.9%
Rare Species and Ecosystems	
High Landscape Condition	5,404
Moderate Landscape Condition	180
Poor Landscape Condition	776
High Biodiversity Support	
High Landscape Condition	5,116
Moderate Landscape Condition	2,418
Poor Landscape Condition	1,735
Shorebird Habitat	2,799 15.6%
High	1,308
Moderate	1,491
Waterfowl Habitat	6,372 35.4%
High	6,061
Moderate	311

5.5b Water Quality and Biogeochemical Functions

Wetlands and waterbodies contribute to clean water through a number of different functions. Nearly 35% of wetland and non-stream waterbody acres likely reduce nitrogen through uptake and transformation (Table 13). Humans have greatly increased the amount of available nitrogen in the environment, from atmospheric deposition to fertilizer application, animal waste, and septic systems. As one of several limiting nutrients in most ecosystems, excess nitrogen can lead to eutrophication of waterbodies (and associated algal blooms), altered plant community composition, and drinking water contamination (especially with nitrate-nitrogen). Many wetlands are local and regional hotspots for denitrification (nitrate removal) and processing other forms of nitrogen. Terrene and riparian wetlands that excel at removing nitrate have sufficient soil carbon (for denitrifying bacteria), are intercepting flow (and have higher soil water residence time for that flow), and have reducing conditions in the soil when water passes through the system. Large slope wetland complexes and a variety of riparian wetlands are likely hotspots for nitrogen removal in the watershed.

Around 21% of wetland and waterbody acres may remove or store metals. Metals are naturally present in soils and rock formations, but often a concern for water quality in Colorado streams, rivers, lakes, and wetlands due to historic and current mining and industrial activities, as well as runoff from urban land use. Many of our state’s streams and rivers are on the 303(d) list of impaired waterways for metals like lead, arsenic, zinc, iron, uranium, and cadmium. These metals are detrimental to fish and other aquatic life, as well as recreational and water supply uses. The ability of wetlands to remove and store metals is highly dependent on factors like pH, temperature, and substrate (e.g., soil vs. sediment and organic vs. mineral soil). Wetland soils with a high organic matter content, including peat-forming fens and mires, and certain types of clay particles, generally have the highest capacity for adsorbing metals (referred to as cation exchange capacity). The model provides a landscape-scale assessment of potential hotspots for metal removal and storage, based on key fundamental processes (e.g., retention of water) and mappable landscape attributes associated with elevated capacity to capture and transform various metal species commonly present in areas impacted by mining and urban development. However, soil organic matter, degree of metal loading, pH, metal transport pathways (including hydrologic flow paths) and temperature all influence how metals are transported through/stored in wetlands.

Table 13. Water quality and biogeochemical functions performed by wetlands and waterbodies within the Roaring Fork watershed. For each function, numbers show the acres of wetlands and waterbodies potentially performing the function at either a high or moderate level. Total acres for each function are in bold, along with the percent of total wetland and non-stream waterbody acres.

Water Quality & Biogeochemical Functions	Wetland and Waterbody Acres
Nitrogen Uptake and Transformation	6,215
	34.6%
High	1,846
Moderate	4,369
Phosphorus Removal and Storage	2,895
	16.1%
High	2,211
Moderate	684
Metals Removal and Storage	3,746
	20.8%
High	3,668
Moderate	78
Carbon Sequestration and Storage	12,199
	67.8%
High	3,327
Moderate	8,872

A smaller subset of wetlands and waterbodies (16% of total acres) provide at least a moderate ability to remove or store phosphorus, primarily associated with particulate phosphorus bound to soil and sediment. Common phosphorus (P) sources include fertilizer, animal waste, septic systems, and bank erosion (P bound to soil and sediment particles). The ability of wetlands to remove and store phosphorus depends on a complex array of biogeochemical, hydrologic, and biological processes. Phosphorus is often bound to soil and sediment particles, so this function is correlated with sediment retention and capture. In general, wetlands are better at capturing particulate P than removing and storing dissolved forms of P.

Approximately 68% of wetland and waterbody acres across the watershed likely have at least a moderate potential to sequester and store carbon in their soil, sediment, and living and dead plant material (Table 13; Figure 14). In general, least-altered wetlands have the greatest potential to store carbon. Fens and beaver complexes, along with riparian shrublands and woodlands, are types of Colorado wetlands that provide abundant carbon storage relative to forests and other adjacent terrestrial ecosystems. Wetlands with altered groundwater levels, such as drained fens, often become carbon sources rather than sinks when stored carbon is oxidized.



Figure 14. Likely hotspots for wetland carbon sequestration and storage in the Roaring Fork watershed.

5.5c Water Storage and Sediment Capture Functions

Wetlands and waterbodies can play a significant role in protecting and enhancing water supplies. The most obvious function provided by wetlands and waterbodies is to store surface water for future use. Colorado's wetlands provide both seasonal and semi-permanent surface water storage. Surface water provides habitat for waterfowl, shorebirds, amphibians, fish, aquatic invertebrates, and other wildlife species, and supports wetland plant communities and adjacent terrestrial ecosystems. Natural wetlands and waterbodies also store water recharge groundwater aquifers and supply surface water for drinking water, irrigation, and other human water use. Across the watershed, 4,099 acres of wetlands and waterbodies (23% of total wetland and waterbody acres; excluding streams) provide seasonal or long-term surface water storage (Table 14). Of these storage features, 1,649 acres are natural wetlands and waterbodies. The remaining water storage features are artificially impounded or excavated to enhance water storage, including reservoirs for drinking water and transmountain diversion water storage. Lake areas (often margins) with temporary or seasonal inundation, and wetland basins and ponds with temporary, seasonal, or semi-permanent inundation were ranked as providing a moderate degree of surface water storage.



Figure 15. Permanent/long-term and seasonal surface water storage provided by wetlands and waterbodies in the Roaring Fork watershed.

A related function to water storage is sediment capture and retention. Soil erosion and sediment transport in streams are natural processes that are often altered or accelerated by land and water management (e.g., excess bank and channel erosion due to reduced sediment loads in streams and rivers downstream of dams or excess soil erosion from tilled soil). Excess sediment in streams can be detrimental to aquatic organisms that depend on gravel and cobble beds that are free of fine sediment (including spawning trout and many aquatic invertebrates), and costly for water providers to remove from in-stream reservoirs used to store drinking and irrigation water. Vegetated wetlands can stabilize soil and sediment to limit erosion, or intercept and physically filter sediment particles entrained in surface runoff or stream flow. However, some wetlands may become *sources* of sediment during high flow/intense storm events due to bypass flow and because berms may become eroded. To model sediment retention, we differentiated wetlands that capture and retain sediment during frequent, low intensity flow events vs. those that capture sediment in high intensity events or both. Together, over 6,791 acres of wetlands and waterbodies provide some degree of sediment retention in the Roaring Fork watershed.

Table 14. Surface water storage and sediment capture and retention functions performed by wetlands and waterbodies in the Roaring Fork watershed. Total acres for each function are in bold, along with the percent of all wetland and non-stream waterbodies acres in the watershed.

Water Quantity & Geomorphic Functions	All Wetland and Waterbody Acres	Natural Waterbodies and Wetlands
Surface Water Storage	4,099	1,649
	22.8%	9.2%
Long-term storage	3,163	1,320
Seasonal Storage	936	329
Sediment Capture and Retention	6,791	
	37.8%	
Frequent, low intensity flooding (approximate 1-2 year recurrence interval flood)	2,292	
High intensity flooding (>2 year recurrence interval flood)	3,127	
Both frequent and high intensity flooding	1,372	

5.6 Wetland and Riparian Conservation and Restoration Opportunities

5.6a Potential Conservation Areas

The watershed contains a total of 59 existing Potential Conservation Areas (PCAs), 32 of which have one or more wetland-, riparian-, or aquatic-associated elements (Table 15). These sites include the immediate habitat needed for the viability of critical biological elements including both rare species and unique or rare plant communities. Of the PCAs presented in this report (Figure 16), there are:

- 5 very high biodiversity significance (B2) sites,
- 19 high biodiversity significance (B3) sites, and
- 8 moderate biodiversity significance (B4).

The Crystal River (6 species) and Roaring Fork River at Carbondale (5 species) PCAs have the highest number of driving rare species, followed by the Upper Roaring Fork River (4 species). In general, most wetland and riparian plant community elements within PCAs are related to general biodiversity significance or representation of a community type. One challenge in updating PCAs within the Roaring Fork is old data for aquatic species like Colorado River cutthroat trout and boreal toad.

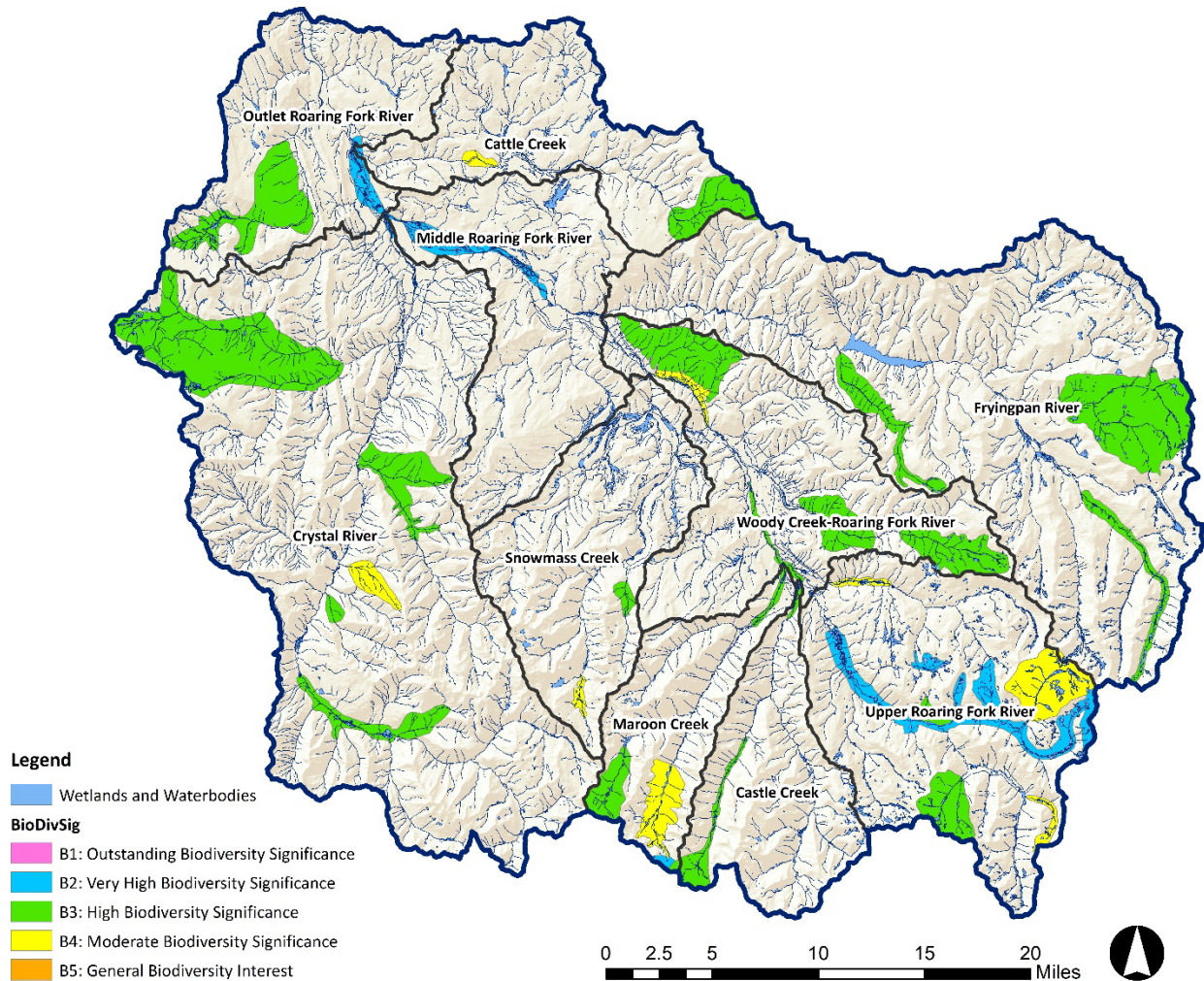


Figure 16. Potential Conservation Areas including wetland or aquatic elements in the Roaring Fork watershed, ranked by biodiversity significance.

Many of the conservation needs in PCAs identified in the late 1990s are ongoing, particularly in areas with continued development pressure, and protection and management ranks were not changed (Figure 15). One new PCA (Lime Park, B3) was nominated as a result of this study. Minor changes were made to several PCA descriptions and boundaries to reflect the current tracking status of rare species and communities and ensure that new occurrences since the first Roaring Fork PCAs were designated in the 1990s are included in PCAs. All PCA changes will be reflected in future updates of the Colorado Conservation Data Explorer (CODEX), Wetland Inventory Mapper, and Watershed Planning Toolbox along with the underlying CNHP and BIOTICS databases.

Table 15. Potential Conservation Areas (PCAs) with wetland- or riparian-dependent elements in the Roaring Fork watershed by biodiversity rank. Protection and management ranks, LDI scores, number of wetland/riparian/aquatic-dependent rare species and communities are listed for each PCA. Areas with high and moderate landscape disturbance scores are shaded with dark and light orange, respectively.

Site Name	Wetland/ Riparian/ Aquatic Species	Wetland/ Riparian Communities	Protection Rank*	Management Rank*	Mean LDI (Min-Max)
B2 – Very High Biodiversity Significance					
No Name Creek at Smuggler Mountain		1	P4	M3	0 (0 - 0)
Roaring Fork River at Carbondale	5	2	P3	M2	929 (280 - 1,767)
Triangle Pass	1		P4	M4	11 (0 - 780)
Twining Peak	1	1	P4	M3	117 (0 - 780)
Upper Roaring Fork River	4	1	P3	M2	346 (0 - 996)
B3 – High Biodiversity Significance					
Avalanche Creek	2	1	P3	M3	37 (0 – 766)
Big Kline Creek		1	P4	M4	43 (0 – 477)
Cattle Creek	1*		P4	M3	73 (0 – 300)
Cerise Gulch		1	P3	M3	61 (0 – 752)
Conundrum Creek	1		P4	M3	14 (0 – 100)
Crystal River	6	3	P2	M2	255 (0 – 891)
East Snowmass Creek		1	P4	M3	13 (0 – 100)
Fourmile Creek at Sunlight		2	P2	M2	97 (0 – 627)
Fryingpan River	1	1	P4	M4	38 (0 – 300)
Maroon Creek/Castle Creek		3	P2	M1	711 (51 – 1,046)
Middle Thompson Creek	2	1	P3	M3	84 (0 – 650)
New York Creek		1	P4	M3	4 (0 – 100)
North Fork Fryingpan River	3	1	P2	M2	35 (0 – 341)
Roaring Fork River at Brush Creek		1	P2	M1	814 (408 – 1,452)
Rocky Fork Creek	1*		P4	M4	47 (0 – 300)
The Grottos	2		P4	M1	289 (0 – 985)
West Maroon Creek	1	1	P3	M3	7 (0 – 100)
Woody Creek at Horseshoe Draw		1	P2	M2	30 (0 – 397)
Woody Creek Headwaters		5	P4	M4	13 (0 – 200)
B4 – Moderate Biodiversity Significance					
Cattle Creek at Coulter Creek		1	P2	M1	186 (0 – 470)
East Creek	1	1	P4	M3	13 (0 – 204)
East Maroon Creek	1	1	P3	M3	7 (0 – 100)
Grizzly Creek		1	P4	M3	20 (0 – 250)
Hunter Creek	1	1	P2	M3	156 (0 – 694)
Lost Man Creek	1		P4	M3	5 (0 – 105)
Roaring Fork at Old Snowmass	1	2	P2	M3	156 (0 – 694)
Snowmass Creek at Snowmass Peak	1		P4	M3	10 (0 – 100)

*M1/P1 = essential within 1 year, P2/M2 = threat/need within 5 years, P3/M3 = threat/need within >5 years, and P4/M4 = no threat/need at this time. **Only tracked element is Colorado River cutthroat trout, based on 1990s-era data.

5.6b High Priority Wetland Conservation and Restoration Areas

Most of the highest priority wetland conservation and restoration areas identified in this study overlap or are near existing CNHP PCAs. A compilation of wetland and aquatic restoration priorities from this study, and from the Roaring Fork Watershed Plan (2012) is provided in Table 16. Often, these areas also overlap other local restoration and conservation priorities in the watershed.

Several areas emerge as high priorities for conservation and habitat restoration in the next 5-10 years in order to maintain large patches of biologically significant wetland and riparian habitats in the watershed. Candidate priority areas are described below, including justification for restoration and conservation, along with a brief summary of protection, restoration, and management needs.

The Upper Roaring Fork River (B2 PCA) is a long-term wetland conservation and restoration priority area for a variety of partners and stakeholders. The PCA encompasses one of the largest riparian wetland complexes in the watershed, along with associated rare plant and animal species. Public wetland areas like the North Star Preserve are popular birding, hiking, and river floating areas. Threats to wetland ecosystems in the PCA include a 40% reduction in flows in the river from a transbasin diversion upstream, along with past agricultural activity, aggressive weeds like reed canarygrass, recreational pressure, and nearby roads and residential development. Combined, altered hydrology has led to a likely reduction of approximately 30% of wetland area at North Star Preserve alone (Pitkin County 2020). Current restoration and management activities are focused primarily on restoring wetland hydrology in the vicinity of North Star Preserve and areas immediately upstream by plugging drainage features and encouraging beaver activity. Detailed information on management and restoration needs and activities can be found in the most recent North Star Management Plan and a variety of supporting studies (Pitkin County 2020).

The Roaring Fork River at Carbondale (B2 PCA) includes one of the largest, most intact riparian woodland-shrubland areas in the lower Roaring Fork watershed. This area supports numerous global- and state-rare species and plant communities and overlaps several restoration priorities from the Roaring Fork Watershed Plan (Clarke et al. 2012) and the more recent Roaring Fork Watershed Biodiversity and Connectivity Study (Rondeau et al. 2022). While the area is well-recognized for its conservation value, it continues to face some of the greatest land development threats of any B2 PCA in the watershed. Several recent conservation easements and NGO land purchases have helped conserve some of the most intact wetland and riparian habitats within the PCA (Figure 17), but a lack of riparian setbacks or other policy protections allow for soil and plant community disturbance associated with residential and urban development to continue to encroach upon sensitive habitats along river.

- **Protection needs:** conservation easements, and riparian development setbacks to limit soil and plant community disturbance, along with new impervious surfaces within the Roaring Fork River riparian area.
- **Restoration needs:** reconnect natural surface water and groundwater hydrology where possible, including encourage continued beaver activity in areas like Rock Bottom Ranch and Coffman Ranch. Carefully consider the role of long-term flood irrigation in supporting wetland hydrology where the Roaring Fork River and its lowland tributaries have become

increasingly disconnected from riparian wetlands due to reduced peak flows and channel erosion.

- Management needs:** monitor known populations and continue to survey for new occurrences of the ESA-listed Ute ladies-tresses orchid (*Spiranthes diluvialis*) along with a variety of other rare species and plant communities within the boundaries of the PCA. Consider managing woody cover and thatch, as well as encouraging native plants that support pollinators in areas with rare orchids. Follow integrated weed management best practices and carefully target noxious weed management to ensure that native wetland and riparian species are preserved.

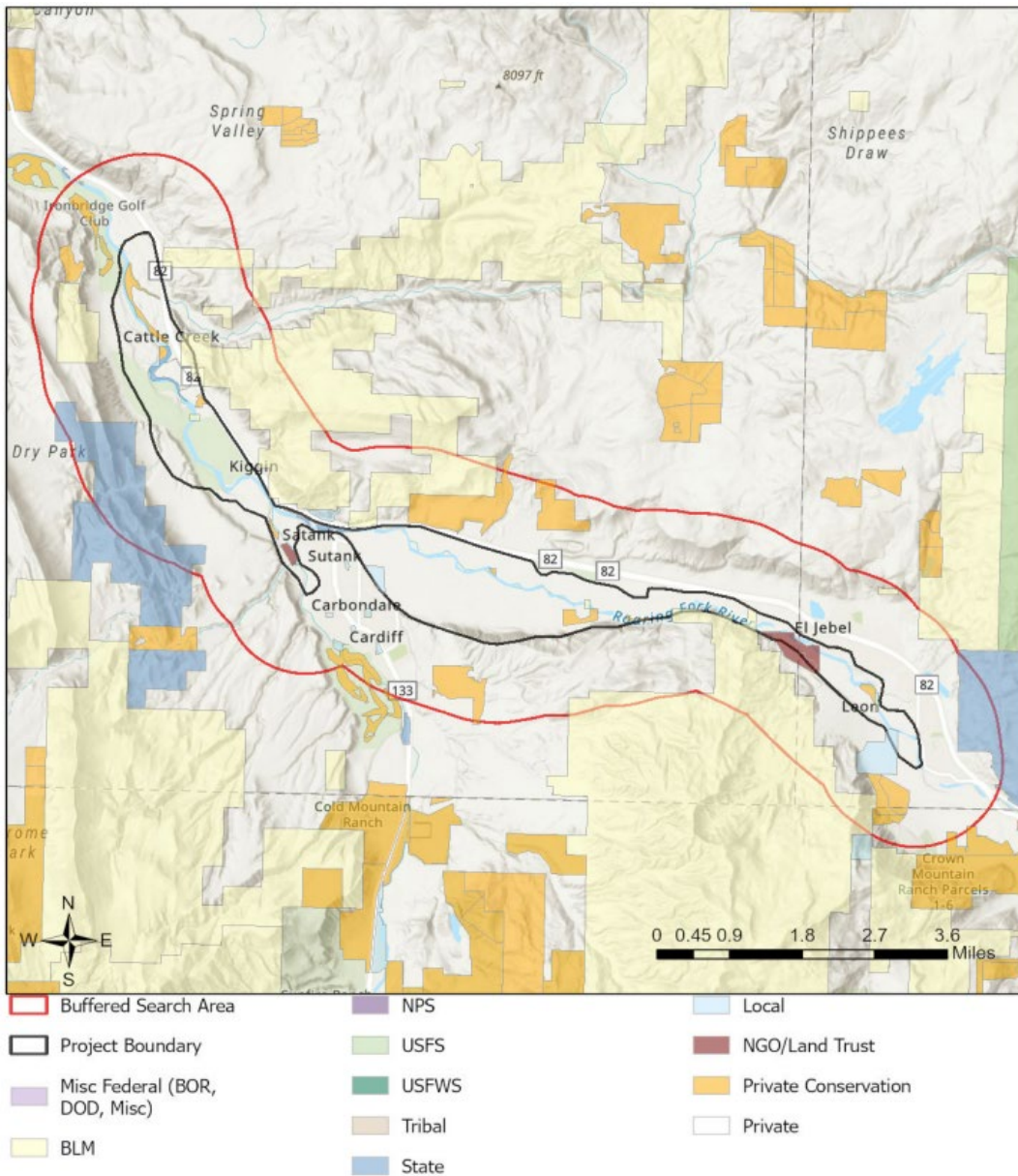


Figure 17. The Roaring Fork River at Carbondale PCA (“Project Boundary”) has the most developed land of any wetland-related PCA in the watershed. Map from the Colorado Conservation Data Explorer (CODEX), 2022.

Lime Park was nominated as a new B3 PCA as a result of the field inventory for this study, along with independent surveys from other CNHP staff. Several occurrences of rare wetland and upland plants and animals, and plant communities, have been documented within the watershed, and the HUC 12 Lime Creek watershed is a U.S. Forest Service (USFS) priority watershed for management and restoration, designated in 2011. Located in the headwaters of the Fryingpan River, the park includes extensive willow carrs, fens and other unique montane, subalpine, and alpine wetland and upland plant communities. In the park's interior, a diverse array of native forbs and grasses cover rolling hills. Much of the park sits atop limestone bedrock that is often close to the surface. The park's unique geology and groundwater seeps and springs are associated with scattered fens on topographic benches and terraces along Lime Creek below Woods Creek Reservoir, in Crooked Creek Park, and in the headwaters of Lime Creek above Fairview Lake. Other prevalent wetland types include wet meadows, primarily associated with past and recent beaver activity.

- **Management Needs:** Management issues include dispersed camping and other recreational impacts, rural residential land use, and scattered noxious weeds along roads and other disturbed areas. The roads throughout the park rapidly develop an unconsolidated surface when wet, and the Lime Creek/Lime Park area is described as a “known USFS dispersed recreation impacted area” with “significant sediment issues resulting from roads” in the Roaring Fork Watershed Plan (Clarke et al. 2012). Grazing management should be evaluated for both cows and wild ungulates around fens and other sensitive wetlands.
- **Restoration Needs:** Opportunities for wetland restoration and floodplain reconnection exist throughout the park, particularly along Lime Creek below Woods Creek Reservoir and in Crooked Creek Park where mapped beaver-influenced wetlands have declined by nearly 90% (from 133 to 17 acres) since wetlands were first mapped in the 1980s National Wetland Inventory. Beaver likely helped create and maintain many of the park's unique riparian wetland communities over time, and current beaver activity is minimal. Most ponds observed in 2019 and 2021 were inactive. Consider monitoring beaver activity, and using beaver dam analogs (BDAs) and other techniques to encourage beavers to re-occupy and re-wet drying wet meadows and shrublands along Lime Creek and Crooked Creek. Wild ungulate and livestock activity in fens within Crooked Creek park is disturbing organic soils and native fen vegetation. Consider a combination of meadow and shrubland re-wetting with BDAs or other process-based structures to reduce channel incision and disconnection from surrounding wetland areas, and explore options to discourage ungulates from congregating in fen areas. Additional restoration opportunities include replacing the undersized culvert where Woods Lake Road crosses Lime Creek downstream of Woody Lake.

The Middle Thompson Creek Headwaters (B3 PCA) area has experienced new oil and gas (re)development within the last 5 years, along with dispersed recreation and grazing activities that have impacted wetland hydrology and plant community condition in the upper reaches of a large complex of wet meadows, fens, and riparian wetlands. When CNHP visited the area in 2019, an oil and gas well, and associated pad with cleared vegetation was situated at the boundary of a willow carr and wet meadow, and cows were observed grazing throughout wet

areas. A previously mapped fen at the head of the drainage was visibly dry, along with a number of recently drained large beaver ponds. At least one beaver dam appeared to be human-breached. At the headwaters of the wetland complex, multiple dispersed campsites with fire rings and bare, compacted soil were observed off existing dirt roads.



Oil and gas well at the edge of a wetland complex in the Middle Thompson Creek headwaters (2019).

- **Protection needs:** wetland and riparian setbacks and buffers to limit hydrologic, soil and plant community disturbance from oil and gas development and dispersed recreation.
- **Restoration needs:** reconnect natural surface water and groundwater hydrology where possible, and encourage beaver activity in areas with obvious recent and past activity along Middle Thompson Creek. Monitor beaver activity and consider beaver dam analogs or wet meadow restoration techniques in areas with incised channels if beavers don't return in the next 5 years. Revegetate bare and compacted areas upstream and upslope of wetland and riparian areas, including dispersed camping areas and the well pad when it is decommissioned in the future.
- **Management needs:** survey for boreal toads in areas that have historically supported this species, given human disturbance in the area. Monitor fens and other sensitive wetland areas to ensure that natural hydrologic inputs, wetland soils, and intact native plant community composition are maintained under future grazing management and human activities in the area.

Cattle Creek, from the middle portion of the watershed downstream to the confluence with the Roaring Fork River. The Cattle Creek riparian area has a patchwork of federal, state, and private land and is connected to a number of high-quality native shrubland and grassland habitats likely used by a variety of native wildlife species. Two PCAs are located along the creek, at the Coulter Creek confluence and in the headwaters. While much of the original woody riparian vegetation has been cleared along the creek, there are abundant opportunities to allow lingering native shrubs and other wetland plants to thrive. Beaver activity is scattered along the creek, and could be a cost-effective way to restore wetland and riparian habitats over time.

- **Protection needs:** voluntary conservation easements may be beneficial in helping connect riparian habitats across public and private land boundaries along Cattle Creek.
- **Restoration needs:** beavers are present along much of Cattle Creek, and have increased activity levels over the last several decades. Restoration activities could include voluntary land conservation to make room for beavers and the associated habitats they create, as well as allowing willows, cottonwoods, and other native shrubs to colonize riparian areas that have been cleared in the past. Beaver coexistence structures such as limited tree fencing and culvert protection may be necessary given the numerous road crossings and limited mature native woody vegetation along many areas of the creek at present.
- **Management needs:** given the extensive private land along the lower and middle sections of Cattle Creek, management will likely entail collaboration with private landowners and a compromise between livestock grazing, hay production, and giving native riparian vegetation sufficient time to rest and thrive alongside agricultural land use. Livestock grazing could be carefully timed to help reduce the cover of aggressive weeds like reed canarygrass.

5.6c Medium Priority Wetland Conservation and Restoration Areas

Some wetland restoration areas in the watershed are either undergoing current restoration management activities, or warrant further monitoring and research to better understand restoration needs. Four medium priority restoration areas are briefly described below.

Sellar Park, in the headwaters of the Fryingpan River, would benefit from increased beaver activity to help reconnect a large wet meadow with an incised stream channel and an inactive beaver complex near the outlet of the park. During the field inventory, one large beaver dam was breached, reducing the extent of emergent marsh wetland habitat upstream.

Filoha Meadows, owned by Pitkin County Open Space, supports unique and rare plant communities and provides important winter elk habitat. The area continues to be managed for noxious weeds, and evaluated for potential restoration activities to maintain fen, wet meadow, emergent marsh, and riparian shrubland and woodland habitats.

Baylor and Mancon Parks, located in the Middle Thompson Creek B3 PCA in the headwaters of the Crystal River, have some threats from dispersed recreation and dirt roads that alter the flow of water and sediment in both parks. Beaver activity helps maintain wetland habitats, and should be monitored to ensure that beavers can continue to maintain and reconnect riparian wetland habitats to stream channels in the park.

Fourmile Creek at Sunlight (B3 PCA) experiences fluctuating grazing intensity over time, and floodplain disconnection in the headwaters. During the field inventory, CNHP staff and partners observed extensive dry reaches of the creek and channel incision resulting in drying riparian wetlands. Beaver activity has declined in the area over time, and many headwater reaches could benefit from encouraging beavers to re-occupy these habitats. Beaver dam analogs may be considered to help entice beavers back into the area.

Table 16. Summary of wetland, riparian, and aquatic restoration and conservation priority areas in the Roaring Fork watershed, including existing plans and areas identified during the CNHP field inventory. Each area includes needs and opportunities, dominant wetland types, and whether areas are in a Potential Conservation Area (PCA), have existing or planned instream flow protections, historically had more beaver activity, are in an existing watershed plan, or were visited by CNHP in 2019-2020.

HUC 10	HUC12(s)	Area	Needs/ Opportunities	Wetland Type(s)	PCA	ISF or Target ISF	Needs more beavers	Plans	Visited by CNHP?
Upper Roaring Fork River	Hunter Creek	Hunter Creek	Beaver activity has declined over time, and is important in maintaining riparian wetland habitats	Riverine, riparian	Y	Y	Y		
Upper Roaring Fork River	Roaring Fork River in Aspen	North Star Preserve	Flagged as "major wetland area requiring restoration" in RFW Plan	Riverine, riparian, fen, wet meadow	Y	Y	Y	RFW Plan (2012)***	(x)
Castle Creek	Lower Castle Creek, Upper Castle Creek	Castle Creek	Sediment issues caused by roads	Riverine, riparian	N	Y		RFW Plan (2012)	
Maroon Creek	East Maroon Creek	East Maroon Creek	Maintain floodplain connectivity	Riverine, riparian	Y	Y	Y		
Maroon Creek	Lower Maroon Creek	Lower Maroon Creek	Opportunities for more beavers, especially above confluence with Roaring Fork, north of Hwy 82	Riverine, riparian	(Y)	Y	Y		
Fryingpan River	Fryingpan River Around Norrie	Sellar Park	Channel incision; rewetting meadow	Wet meadow, riparian	N	N	Y		x
Fryingpan River	Fryingpan River around Norrie	Chapman Campground area	Maintain floodplain connectivity	Riverine, riparian	N	(Y)	Y		x

HUC 10	HUC12(s)	Area	Needs/ Opportunities	Wetland Type(s)	PCA	ISF or Target ISF	Needs more beavers	Plans	Visited by CNHP?
Fryingpan River	Lime Creek	Lime Creek/Lime Park	Sediment issues caused by roads; protect fens; floodplain reconnection; grazing management; noxious weeds; dispersed camping	Riverine, riparian, wet meadow, fen	N	(Y)	Y	RFW Plan (2012); USFS Priority Watershed	x
Fryingpan River	Mouth of Fryingpan River, Fryingpan River below Ruedi	Lower Fryingpan	Sediment issues	Riverine, riparian	N	Y		RFW Plan (2012)	x
Fryingpan River	Multiple	Fryingpan River	Fish passage improvement	Riverine, riparian	N	Y		RFW Plan (2012)	
Woody Creek-Roaring Fork River*	Brush Creek	Brush Creek	Sediment issues	Riverine, riparian	N	N		RFW Plan (2012)	
Woody Creek-Roaring Fork River	Woody Creek	Lower Woody Creek area	Floodplain reconnection	Riverine, riparian	(Y)	Y	Y	RFW Plan (2012)	
Crystal River	Coal Creek	Coal Creek	Sediment issues (mostly caused by roads); grazing issues; recent mine reclamation	Riverine, riparian	N	N		RFW Plan (2012)	
	Coal Creek/Crystal	Coal Creek confluence with the Crystal River	Flagged as "major wetland area requiring restoration" in RFW Plan	Riverine, riparian	N	N		RFW Plan (2012)	

HUC 10	HUC12(s)	Area	Needs/ Opportunities	Wetland Type(s)	PCA	ISF or Target ISF	Needs more beavers	Plans	Visited by CNHP?
	River Around Redstone								
	Multiple	Crystal River	Fish passage improvement; sediment issues; grazing issues	Riverine, riparian	(Y)	Y		RFW Plan (2012)	
	North Fork Crystal River	NF Crystal	Sediment issues caused by roads; also consider recreation pressure along Four Pass Loop	Riverine, riparian	N	Y	Y	RFW Plan (2012)	x
Crystal River	North Thompson Creek	Baylor/Mancon Park	Opportunities for channel reconnection; grazing management; recreation/road management	Riverine, riparian, wet meadow	Y	N	Y		x
Crystal River	Thompson Creek	Thompson Creek confluence with the Crystal River	Flagged as "major wetland area requiring restoration" in RFW Plan	Riverine, riparian	N	Y		RFW Plan (2012)	
Crystal River	Thompson Creek	Middle Thompson	Sediment issues caused by roads; grazing issues	Riverine, riparian, wet meadow, fen	Y	Y	Y	RFW Plan (2012)	x
Middle Roaring Fork River	Roaring Fork River above Carbondale	Roaring Fork River between Carbondale and Basalt	Flagged as "major wetland area requiring restoration" in RFW Plan	Riverine, riparian, wet meadow	(Y)	Y		RFW Plan (2012)	x
Middle Roaring Fork River	Roaring Fork River above Carbondale	Roaring Fork River near Emma	Flagged as "major wetland area requiring restoration" in RFW Plan	Riverine, riparian	N	Y		RFW Plan (2012)	x

HUC 10	HUC12(s)	Area	Needs/ Opportunities	Wetland Type(s)	PCA	ISF or Target ISF	Needs more beavers	Plans	Visited by CNHP?
Middle Roaring Fork River	Upper East Sopris Creek, Lower East Sopris Creek, West Sopris Creek	East and West Sopris Creek watersheds	Fish passage improvement	Riverine, riparian	(Y)	Y		RFW Plan (2012)	x
Middle Roaring Fork River**	Roaring Fork River above Carbondale	USFS Tree Farm	High-quality habitat; development pressure in area	Riverine, riparian	Y	Y	?	RFW Plan (2012)	x
Cattle Creek	Lower Cattle Creek/Roaring Fork above Glenwood	Cattle Creek confluence with Roaring Fork/Roaring Fork near Cattle Creek	Flagged as "major wetland area requiring restoration" in RFW Plan	Riverine, riparian	Y	N/ (Y)	Y	RFW Plan (2012)	x
	Multiple	Cattle Creek	Fish passage improvement; grazing issues	Riverine, riparian	(Y)	(Y)	Y	RFW Plan (2012)	x
Outlet Roaring Fork River	Upper Fourmile Creek	Fourmile Creek headwaters	Opportunities for channel-floodplain reconnection; grazing management	Riverine, riparian	Y	N/ (Y)	Y		x
<p>*Also referred to as the Upper Middle Roaring Fork River and Middle Roaring Fork River in various sources and versions of NHD layers. **Also referred to as the Lower Roaring Fork River and Lower-Middle Roaring Fork River in various sources and versions of NHD layers. ***RFW (2012) = Roaring Fork Watershed Plan (Clarke et al. 2012)</p>									

5.6d Watershed-wide Wetland and Riparian Best Management Practices

While some restoration and conservation needs are site-, or watershed-specific, there were several widespread conservation and management needs observed during the field inventory. General recommendations for Best Management Practices (BMPs) are provided below, with more detailed information on wetland and riparian BMPs is provided in the Colorado Wetland Information Center (CWIC): <https://cnhp.colostate.edu/cwic/work/bmps/>. Additional technical and financial support for recommended activities is available through numerous federal, state, and local programs. Links to many of these programs can be found at the Funding and Technical Support web page in CWIC: <https://cnhp.colostate.edu/cwic/work/funding-technical-support/>.

Grazing

During the field inventory, CNHP staff observed a variety of livestock grazing management systems along with the impacts of native ungulate grazing. Observed grazing management strategies that can sustainably occur in and around wetlands and riparian areas include:

- Short-duration, carefully timed grazing when soils are dry, and
- Off-channel (and wetland) water tanks and salt blocks to help divert livestock away from wetlands and riparian areas.



Soil compaction and other disturbance in wet soil around the margins of a beaver pond in Baylor Park.

Grazing activities that are generally incompatible with maintaining intact wetland soils, hydrology, and sensitive plant and animal species and communities include:

- Unsupervised, season-long grazing, and
- Grazing in fens and other wetland types that are most sensitive to disturbance.

Recreation

The Roaring Fork watershed, like many mountain areas in Colorado, has seen an increase in the extent and intensity of recreational use over the past several decades. General recommendations for recreation BMPs based on field observations include:

- Monitor recreation impacts around sensitive wetlands and riparian areas, particularly in high-use areas. Sensitive wetlands of particular importance for avoiding human impacts in both wetlands and surrounding buffer areas include fens and known boreal toad sites.
- Carefully manage trails in and around wetlands and riparian areas, avoiding cutting across wetlands when possible. For trails that cross wet areas, redirecting trails into adjacent upland areas or creating raised boardwalks can reduce impacts to surface water and groundwater flow, and help minimize vegetation trampling and soil compaction.
- Ensure that horses, mules, and other pack animals are consuming weed-free hay and otherwise not transporting noxious weeds into natural areas.

Recreational activities that are generally incompatible with wetlands include:

- Dispersed campsites and associated soil compaction, vegetation alteration, and human waste in or immediately adjacent to wetlands.
- Motorized vehicles and bikes in wet areas.
- Any form of human recreation at or immediately adjacent to boreal toad sites, given the risk of spreading chytrid fungus (lethal to toads) between sites.

Roads

Roads are one of the greatest sources of habitat fragmentation in the Roaring Fork watershed, and invasive and noxious weeds often follow these disturbance pathways across the landscape. Roads can also serve as conduits for water and sediment, and can either divert natural surface water and groundwater inputs away from wetlands, or discharge an excess amount of water and sediment into wetlands and streams downslope. Several BMPs can ease the impacts of roads on wetland and aquatic ecosystems.

- Ensure that culverts are sized to match a range of peak flows at stream crossings, or replace culverts with low-water crossings or bridges when possible.
- In areas with beaver activity, consider coexistence structures such as pond levelers upstream to allow for the myriad benefits of beavers while protecting human infrastructure.
- When possible, decommission derelict roads that interrupt natural water flow paths into and out of wetlands.

- Where roads fragment wetland habitats and can't be relocated, consider drainage improvements to restore natural surface water and groundwater flows into and out of wetlands and riparian areas.

Oil and Gas Operations

Oil and gas operations are primarily concentrated in the headwaters of Coal Creek, North and Middle Thompson Creeks, and Fourmile Creek in the Crystal River and Outlet Roaring Fork River HUC10 watersheds (Figure 18). Colorado's latest oil and gas permitting process (300 Series) contains guidance and requirements for avoiding adverse impacts to wildlife and water resources including wetlands (COGCC 2022a). The newest rules for oil and gas operators were not yet in place at the time of the field inventory for this study. Current rules require operators to "identify Best Management Practices to avoid, minimize, or mitigate potential adverse impacts to the identified riparian corridors, wetlands, or surface Waters of the State."

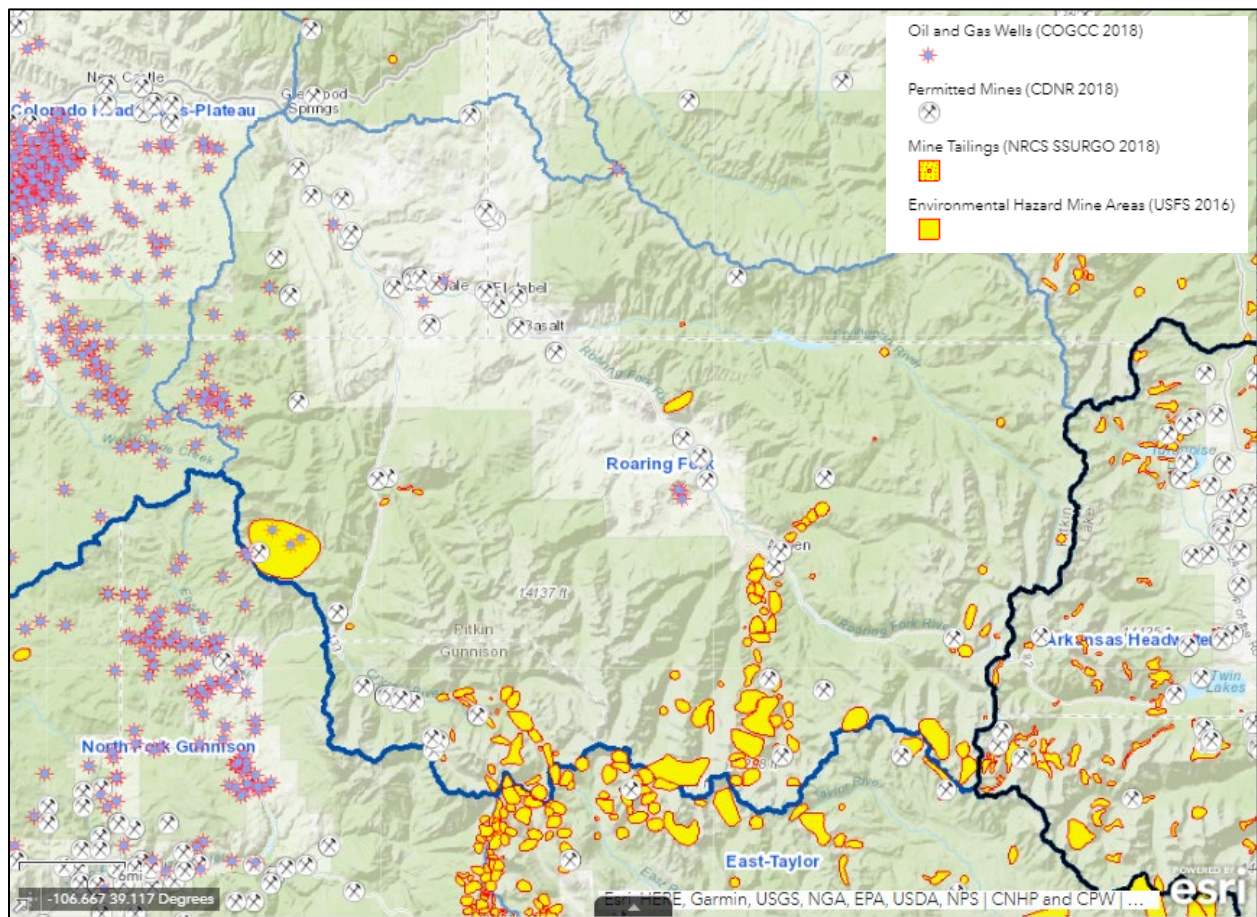


Figure 18. Permitted oil and gas wells and mines, and USFS Environmental Hazard Mine Areas in the Roaring Fork watershed from the Watershed Planning Toolbox online mapper.

These requirements include identification of potential pollutant pathways between oil and gas operations and downstream riparian corridors, wetlands, and other Waters of the State. Ecological evaluations include identification of priority habitats within 1 mile of proposed well pads and other infrastructure, along with calculation of anticipated disturbed acres in high priority habitats. Other

considerations include alternative location analyses for any sites “within the boundaries of, or...immediately upgradient from, a mapped, visible, or field-verified wetland or riparian corridor.” For new and existing operations, operators are prohibited from situating “new staging, refueling, or Chemical storage areas within 500 feet of the Ordinary High Water Mark (‘OHWM’) of any river, perennial or intermittent stream, lake, pond, or wetland (COGCC 2022b).”

6.0 OUTCOMES AND FUTURE DIRECTIONS

Through this project, CNHP worked with a variety of partners to ensure that results and deliverables are useful and intuitive, and support wetland and riparian conservation and restoration planning and implementation in the Roaring Fork watershed.

The following projects and efforts have used, or will be using, products and findings of this study.

The Roaring Fork Watershed Biodiversity & Connectivity Study (Rondeau et al. 2022) incorporated enhanced NWI wetland mapping, including fen mapping for the White River National Forest, into modeling for watershed conservation and restoration priorities and areas of biodiversity importance.

The Aspen Valley Land Trust, a leader in land conservation within and downstream of the Roaring Fork Valley, used information from CNHP's wetland TIA visit as part of their grant application package to secure funding to purchase the Coffman Ranch. The ranch is located within a CNHP Potential Conservation Area of "Very High Biodiversity Significance" along the Roaring Fork mainstem near Carbondale, and supports a variety of rare species and plant communities. As a result of CNHP's initial wetland visit, AVLT asked CNHP to return for a full BioBlitz at Coffman, to further document baseline ecological conditions and species present at the ranch in the summer of 2022. AVLT has also used updated wetland mapping from this project, and their latest strategic conservation plan includes a goal to "preserve and restore wetlands and riparian areas to protect habitat and water quality and quantity" over the next decade (AVLT 2022).

The **Watershed Planning Toolbox**, **Colorado Conservation Data Explorer (CODEX)**, **Colorado Ownership, Management, and Protection Map (COMaP)**, and a variety of other public-facing tools and databases hosted by CNHP will benefit from updated biological information and geospatial data layers generated through this project, supporting conservation and watershed planning efforts in the Roaring Fork watershed and statewide. and statewide conservation planning efforts in the Roaring Fork watershed and statewide.

We look forward to continuing CNHP's work in the watershed through the EPA-funded **Wetland Restoration for Resilient Colorado Headwaters** project in coming years, which will build off information and partnerships from this study, and further refine restoration priority areas for multiple water quality, water quantity, and habitat benefits.

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APPENDIX A: NATURAL HERITAGE METHODOLOGY

CNHP regularly gathers and reviews information on plants, animals and plant communities to determine the status of each **element** (species or community) of natural diversity in Colorado. Each element is assigned a rank that indicates its relative degree of imperilment on a scale from 1 (extremely rare/imperiled) to 5 (abundant/secure). The primary, and most heavily weighted criterion for ranking elements is the number of **occurrences**, or known distinct localities or populations. The size of each element’s geographic range, number of individuals, trends in population and distribution, identifiable threats, and the number of protected occurrences are also considered.

Element **imperilment ranks** are assigned to capture an element's degree of imperilment within Colorado (State-rank or S-rank) and over its entire range (Global-rank or G-rank). Together, these two ranks indicate the degree of imperilment of an element. CNHP collects maps and electronically processes occurrence information for critically imperiled (S1), imperiled (S2), and vulnerable (S3) elements in Colorado. Several factors, such as rarity, evolutionary distinctiveness, and endemism (specificity of habitat requirements), contribute to the conservation priority of each species. Certain species are **watchlisted**, meaning that occurrence data are collected and periodically analyzed to determine whether more active tracking is warranted. A complete description of each of the Natural Heritage ranks is provided in Table 1.

This single rank system works well for all non-migratory species. Animals that migrate may spend only a portion of their life cycles within the state. In these cases, it is necessary to distinguish between breeding, non-breeding, and resident species. As noted in Table 1, ranks followed by a "B," for example S1B, indicate that the rank applies only to the status of breeding occurrences. Similarly, ranks followed by an "N," for example S4N, refer to non-breeding status, typically during migration and winter. Elements without this notation are believed to be year-round residents within the state.

Table 1. Definition of Natural Heritage Imperilment Ranks.

G/S1	Critically imperiled -at very high risk of extinction due to extreme rarity (often 5 or fewer occurrences) in the world/statewide, very steep declines, or other factors.
G/S2	Imperiled - at high risk of extinction or elimination globally/statewide because of rarity (6 to 20 occurrences, or 1,000 to 3,000 individuals) due to very restricted range, very few populations, steep declines, or other factors.
G/S3	Vulnerable -at moderate risk of extinction or elimination through its range or found locally in a restricted range (21 to 100 occurrences, or 3,000 to 10,000 individuals).
G/S4	Apparently secure globally/statewide, though it may be quite rare in parts of its range, especially at the periphery. Usually more than 100 occurrences and 10,000 individuals.
G/S5	Secure -common; widespread and abundant globally/statewide, though it may be quite rare in parts of its range, especially at the periphery.
G/SX	Presumed extinct (species)/ Eliminated (ecological communities) globally, or extirpated within the state.
G#?	Indicates uncertainty about an assigned global rank.
G/SU	Unable to assign rank due to lack of available information.

GQ	Indicates uncertainty about taxonomic status.
G/SH	Possibly Extinct (species)/ Eliminated (ecological communities) known from only historically occurrences but still hope of rediscovery.
G#T#	Trinomial rank (T) is used for subspecies or varieties. These taxa are ranked on the same criteria as G1-G5.
S#B	Refers to the breeding season imperilment of elements that are not residents.
S#N	Refers to the non-breeding season imperilment of elements that are not permanent residents. Where no consistent location can be discerned for migrants or non-breeding populations, a rank of SZN is used.
SZ	Migrant whose occurrences are too irregular, transitory and/or dispersed to be reliably identified, mapped and protected.
SA	Accidental in the state.
SR	Reported to occur in the state but unverified.
S?	Unranked. Some evidence that species may be imperiled, but awaiting formal rarity ranking. Note: Where two numbers appear in a state or global rank (for example, S2S3), the actual rank of the element is uncertain, but falls within the stated range.

Legal Designations for Rare Species

Natural Heritage imperilment ranks are not legal designations. Although most species protected under state or federal endangered species laws are extremely rare, not all rare species receive legal protection. Legal status is designated by both the U.S. Fish and Wildlife Service under the Endangered Species Act or by Colorado Parks and Wildlife under Colorado Statutes 33-2-105 Article 2. In addition, the U.S. Forest Service recognizes some species as “Sensitive,” as does the Bureau of Land Management. Table 2 defines the special status assigned by these agencies and provides a key to abbreviations used by CNHP.

Table 2. Federal and State Agency Special Designations for Rare Species.

Federal Status:	
1. U.S. Fish and Wildlife Service (58 Federal Register 51147, 1993) and (61 Federal Register 7598, 1996):	
LE	Listed Endangered: defined as a species, subspecies, or variety in danger of extinction throughout all or a significant portion of its range.
LT	Listed Threatened: defined as a species, subspecies, or variety likely to become endangered in the foreseeable future throughout all or a significant portion of its range.
P	Proposed: taxa formally proposed for listing as Endangered or Threatened (a proposal has been published in the Federal Register, but not a final rule).
C	Candidate: taxa for which substantial biological information exists to support proposals for listing as endangered or threatened, but no proposal has been published in the Federal Register.
PDL	Proposed for delisting.
XN	Nonessential experimental population.
2. U.S. Forest Service (Forest Service Manual 2670.5) (noted by the Forest Service as “S”):	
FS	Sensitive: those plant and animal species identified by the Regional Forester for which population viability is a concern as evidenced by: Significant current or predicted downward trends in population numbers or density.

Significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution.

3. Bureau of Land Management (BLM Manual 6840.06D) (noted by BLM as “S”):

BLM Sensitive: those species found on public lands designated by a State Director that could easily become endangered or extinct in a state. The protection provided for sensitive species is the same as that provided for C (candidate) species.

4. State Status:

The Colorado Division of Wildlife has developed categories of imperilment for non-game species (refer to the Colorado Division of Wildlife's Chapter 10 – Nongame Wildlife of the Wildlife Commission's regulations). The categories being used and the associated CNHP codes are provided below.

E Endangered: those species or subspecies of native wildlife whose prospects for survival or recruitment within this state are in jeopardy, as determined by the Commission.

T Threatened: those species or subspecies of native wildlife which, as determined by the Commission, are not in immediate jeopardy of extinction but are vulnerable because they exist in such small numbers, are so extremely restricted in their range, or are experiencing such low recruitment or survival that they may become extinct.

SC Special Concern: those species or subspecies of native wildlife that have been removed from the state threatened or endangered list within the last five years; are proposed for federal listing (or are a federal listing “candidate species”) and are not already state listed; have experienced, based on the best available data, a downward trend in numbers or distribution lasting at least five years that may lead to an endangered or threatened status; or are otherwise determined to be vulnerable in Colorado.

Element Occurrences and their Ranking

Actual locations of elements, whether they are single organisms, populations, or plant communities, are referred to as **element occurrences**. The element occurrence is considered the most fundamental unit of conservation interest in the Natural Heritage Methodology. To prioritize element occurrences for a given species, an element occurrence rank (EO-Rank) is assigned according to the ecological quality of the occurrences when sufficient information is available. This ranking system is designed to indicate which occurrences are the most ecologically viable, and focus conservation efforts where they will be most successful. EO-Ranks are based on three factors:

Size – a measure of the area or abundance of the element’s occurrence. Considers factors like area of occupancy, population abundance, population density, population fluctuation, and minimum dynamic area (the area needed to ensure survival or re-establishment of an element after natural disturbance). This factor is evaluated relative to other known and/or presumed viable examples.

Condition/Quality – an integrated measure of the composition, structure, and biotic interactions that characterize the occurrence. This includes measures such as reproduction, age structure, community composition (e.g., presence of exotic versus native species), structure (e.g., canopy, understory, and ground cover in a forest community), and biotic interactions (levels of competition, predation, disease, etc.).

Landscape Context – an integrated measure of two factors: the dominant environmental regimes and processes that establish and maintain the element and its habitat connectivity. Dominant environmental regimes and processes include herbivory, hydrology and water chemistry (surface

and groundwater), geomorphic processes, climate, fire regimes, and natural disturbances. Connectivity includes factors such as access to habitats and resources needed for life cycle completion, fragmentation of ecological communities and systems and the ability of the species to respond to environmental change through dispersal, migration, or re-colonization.

Each of these factors is rated on a scale of A through D, with A representing an excellent rank and D representing a poor rank. These ranks are then averaged to determine an appropriate EO-Rank for the occurrence. If not enough information is available to rank an element occurrence, an EO-Rank of E is assigned. EO-Ranks and their definitions are summarized in Table 3.

Table 3. Element Occurrence Ranks and their Definitions.

A	Excellent viability
B	Good viability
C	Fair viability
D	Poor viability
H	Historic: known from historical record, but not verified for an extended period of time
X	Extirpated (extinct within the state)
E	Extant: the occurrence does exist but not enough information is available to rank
F	Failed to find: the occurrence could not be relocated

Potential Conservation Areas

Locations in the county with natural heritage significance (places where elements have been documented) are presented in this report as **Potential Conservation Areas** (PCAs). The goal of delineating PCAs is to identify a land area that can provide the habitat and ecological needs that a particular element or suite of elements depends on for their continued existence. Best available knowledge of each species' life history is used in conjunction with information about topographic, geomorphic, and hydrologic features, vegetative cover, and current and potential land uses to delineate PCA boundaries.

PCA boundaries delineated in this report are meant to be used for conservation planning purposes and do not confer any regulatory protection of sites, nor do they automatically recommend exclusion of all activity. Boundaries represent a best professional estimate of the primary area supporting the long-term survival of targeted species or plant communities and are presented for planning purposes. They delineate ecologically sensitive areas where land use practices should be carefully planned and managed to ensure that planned activities are compatible with protection of natural heritage resources and sensitive species. A detailed analysis of the human context, site history, and potential stressors has not been conducted and some PCAs may warrant further research related to specific restoration and management needs.

Nearly all PCAs include populations or occurrences of rare and unique species and communities, along with the ecological processes that are necessary to support the continued existence of element occurrence(s) within each PCA. PCAs are designed to include protection buffers for element occurrences that will sustain key habitat and ecological processes upon which a particular

element occurrence, or suite of element occurrences, depends for its continued existence. The best available knowledge about each species' life history is used in conjunction with information about topographic, geomorphic, and hydrologic features; vegetative cover; and current and potential land uses. In developing the boundaries of a PCA, CNHP scientists consider several factors that include, but are not limited to:

- Ecological processes necessary to maintain or improve existing conditions;
- Species movement and migration corridors;
- Maintenance of surface water quality within the PCA and the surrounding watershed;
- Maintenance of groundwater recharge and subsurface flow that sustains groundwater-dependent wetlands and riparian areas;
- Land intended to buffer the PCA against future changes in the use of surrounding lands;
- Exclusion or control of invasive exotic species; and
- Land necessary for management or monitoring activities.

Ranking of Potential Conservation Areas

CNHP uses the Heritage Ranking Methodology to prioritize conservation actions by identifying those areas that have the greatest chance of conservation success for the most imperiled elements. Sites are prioritized according to their biodiversity significance rank, or “B-rank,” which ranges from B1 (outstanding significance) to B5 (general or statewide significance). Biodiversity ranks are based on the conservation (imperilment or rarity) ranks for each element and the element occurrence ranks (viability rank) for that geographic location. The highest quality occurrences (those with the greatest likelihood of long-term survival) of the most imperiled elements are the highest priority (receive the highest B-rank). The B1-B3 sites are the highest priorities for conservation actions. Based on current knowledge, the sites in this report represent areas that CNHP recommends for protection to preserve the natural heritage of the Roaring Fork watershed. A summary of B-ranks is provided in Table 4.

Table 4. Natural Heritage Program biological diversity ranks and their definitions.

B1	<p>Outstanding Significance (indispensable):</p> <ul style="list-style-type: none"> • Only known occurrence of an element • A-ranked occurrence of a G1 element (or at least C-ranked if best available occurrence) • Concentration of A- or B-ranked occurrences of G1 or G2 elements (four or more)
B2	<p>Very High Significance:</p> <ul style="list-style-type: none"> • B- or C-ranked occurrence of a G1 element • B-ranked occurrence of a G2 element • One of the most outstanding (for example, among the five best) occurrences range wide (at least A- or B-ranked) for a G3 element • Concentration of A- or B-ranked G3 elements (four or more) • Concentration of C-ranked G2 elements (four or more)
B3	<p>High Significance:</p> <ul style="list-style-type: none"> • C-ranked occurrence of a G2 element • B-ranked occurrence of a G3 element

	<ul style="list-style-type: none"> • D-ranked occurrence of a G1 element (if best available occurrence) • Up to five of the best occurrences of a G4 or G5 community (at least A- or B-ranked) in an ecoregion (requires consultation with other experts)
B4	<p>Moderate Significance:</p> <ul style="list-style-type: none"> • Other A- or B-ranked occurrences of a G4 or G5 community • C-ranked occurrence of a G3 element • B-ranked occurrence of a G4 or G5 S1 species (or at least C-ranked if it is the only state, provincial, national, or ecoregional occurrence) • Concentration of A- or B-ranked occurrences of G4 or G5 N1-N2, S1-S2 elements (four or more) • D-ranked occurrence of a G2 element • At least C-ranked occurrence of a disjunct G4 or G5 element
B5	<p>General or State-wide Biological Diversity Significance: good or marginal occurrence of common community types and globally secure S1 or S2 species</p>

Protection Urgency Ranks

Protection urgency ranks (P-ranks) refer to the timeframe in which protection activities are recommended. In most cases, this rank refers to the need for a major change of protective status (for example agency special area designations or ownership). The urgency for protection rating reflects the need to take legal, political, or other administrative measures to protect the area. Table 5 summarizes the P-ranks and their definitions.

Table 5. Natural Heritage Program Protection Urgency Ranks and their Definitions

P1	Protection actions needed immediately. Current stressors may reduce the viability of the elements in the PCA within 1 year.
P2	Protection actions may be needed within 5 years. Current stressors may reduce the viability of the elements in the PCA within this approximate timeframe.
P3	Protection actions may be needed, but not within the next 5 years. Current stressors may reduce the viability of the elements in the PCA if protection action is not taken.
P4	No protection actions are needed in the foreseeable future.
P5	Land protection is complete and no protection actions are needed.

A protection action involves increasing the current level of protection for one or more tracts within a PCA. It may also include activities such as public education or outreach, or collaborative planning efforts with public or private entities to minimize adverse impacts to element occurrences at a site. It does not include management actions. Situations that may require a protection action may include the following:

- Forces that threaten the existence of one or more element occurrences in a PCA. For example, development that would destroy, degrade, or seriously compromise the long-term viability of an element occurrence; or timber, range, recreational, or hydrologic management that is incompatible with an element occurrence's existence.
- The inability to undertake a management action in the absence of a protection action; for example, obtaining a management agreement.
- A prospective change in ownership or management that will make future protection actions more difficult.

Management Urgency Ranks

Management urgency ranks (M-ranks) indicate the timeframe in which management changes are needed within a PCA. This rank refers to the need for management in contrast to protection (e.g., increased fire frequency, decreased grazing, weed control, etc.). The urgency for management ranking focuses on land use management or land stewardship action required to maintain element occurrences within a PCA.

A management action may include biological management (prescribed burning, removal of exotics, mowing, etc.), ecological restoration activities, or people and site management (building barriers, re-routing trails, patrolling for collectors, hunters, or trespassers, etc.). Management action does not include legal, political, or administrative measures taken to protect a PCA. Table 6 summarizes M-ranks and their definitions.

Table 6. Natural Heritage Program Management Urgency Ranks and their Definitions

M1	Management actions needed immediately. Current stressors may reduce the viability of the elements in the PCA within 1 year.
M2	Management actions may be needed within 5 years. Current stressors may reduce the viability of the elements in the PCA within this approximate timeframe.
M3	Management actions may be needed, but not within the next 5 years. Current stressors may reduce the viability of the elements in the PCA if management action is not taken.
M4	No management actions are needed in the foreseeable future.
M5	No management actions are needed.

APPENDIX B. ROARING FORK WATERSHED PLANT LIST

Family	Latin Name	Common Name	C-Value	Wetland Indicator Status	Nativity	Noxious	Growth Habit
Adoxaceae	<i>Sambucus racemosa</i>	red elderberry	6	FACU	Native	0	Tree
Alismataceae	<i>Alisma triviale</i>	northern water-plantain	3	OBL	Native	0	Forb
Anacardiaceae	<i>Rhus trilobata</i>	skunkbush sumac	5	UPL	Native	0	Shrub
Apiaceae	<i>Angelica ampla</i>	giant angelica	4	FACW	Native	0	Forb
	<i>Angelica grayi</i>	Gray's angelica	10	0	Native	0	Forb
	<i>Angelica pinnata</i>	small-leaf angelica	5	FACW	Native	0	Forb
	<i>Cicuta maculata</i>	water hemlock	3	OBL	Native	0	Forb
	<i>Conioselinum scopulorum</i>	Rocky Mountain hemlockparsley	7	FACW	Native	0	Forb
	<i>Cymopterus lemmonii</i>	ligusticoid springparsley	6	0	Native	0	Forb
	<i>Heracleum maximum</i>	common cowparsnip	6	FAC	Native	0	Forb
	<i>Ligusticum porteri</i>	osha	7	FACU	Native	0	Forb
	<i>Ligusticum tenuifolium</i>	slender ligusticum	8	FACW	Native	0	Forb
	<i>Osmorhiza depauperata</i>	blunt sweet-cicely	7	0	Native	0	Forb
	<i>Oxypolis fendleri</i>	Fendler's cowbane	7	FACW	Native	0	Forb
	<i>Sium suave</i>	waterparsnip	6	OBL	Native	0	Forb
	<i>Pastinaca sativa</i>	wild parsnip	0	0	Non-native	0	Forb
Apocynaceae	<i>Apocynum cannabinum</i>	Indian hemp	2	FAC	Native	0	Forb
	<i>Asclepias speciosa</i>	showy milkweed	3	FAC	Native	0	Forb
Araceae	<i>Lemna minor</i>	common duckweed	2	OBL	Native	0	Forb
Asteraceae	<i>Achillea millefolium</i>	common yarrow	4	FACU	Native	0	Forb
	<i>Agoseris aurantiaca</i>	orange agoseris	6	FACU	Native	0	Forb
	<i>Agoseris aurantiaca var. purpurea</i>	orange agoseris	6	FACU	Native	0	Forb
	<i>Anaphalis margaritacea</i>	pearly everlasting	4	FACU	Native	0	Forb
	<i>Antennaria anaphaloides</i>	pearly pussy-toes	5	FAC	Native	0	Forb
	<i>Antennaria media</i>	Rocky Mountain pussy-toes	5	FAC	Native	0	Forb
	<i>Antennaria pulcherrima</i>	showy pussy-toes	5	FAC	Native	0	Forb
	<i>Antennaria rosea</i>	rosy pussy-toes	5	0	Native	0	Forb
	<i>Arnica chamissonis</i>	Chamisso arnica	8	FACW	Native	0	Forb
	<i>Arnica cordifolia</i>	heartleaf arnica	7	0	Native	0	Forb
	<i>Arnica mollis</i>	hairy arnica	7	FAC	Native	0	Forb
	<i>Artemisia dracunculus</i>	tarragon	3	FACU	Native	0	Forb
	<i>Artemisia frigida</i>	fringed sage	4	0	Native	0	Shrub
	<i>Artemisia tridentata var. vaseyana</i>	mountain big sagebrush	5	0	Native	0	Shrub
	<i>Balsamorhiza sagittata</i>	balsamroot	5	0	Native	0	Forb
	<i>Chrysothamnus viscidiflorus</i>	viscid rabbitbrush	5	0	Native	0	Shrub
	<i>Cirsium clavatum</i>	Fish Lake thistle	6	0	Native	0	Forb
	<i>Cirsium clavatum var. americanum</i>	Rocky Mountain fringed thistle	6	0	Native	0	Forb
	<i>Cirsium eatonii</i>	Eaton's thistle	6	0	Native	0	Forb
	<i>Cirsium scariosum</i>	elk thistle	6	FAC	Native	0	Forb
	<i>Crepis intermedia</i>	limestone hawk's-beard	6	0	Native	0	Forb
	<i>Crepis runcinata ssp. runcinata</i>	fiddleleaf hawk's-beard	6	FACU	Native	0	Forb
	<i>Dyssodia papposa</i>	fetid marigold	2	0	Native	0	Forb
	<i>Ericameria nauseosa</i>	rabbitbrush	3	0	Native	0	Shrub
	<i>Erigeron coulteri</i>	Coulter's daisy	8	FACW	Native	0	Forb
	<i>Erigeron divergens</i>	spreading daisy	4	0	Native	0	Forb
	<i>Erigeron elatior</i>	tall fleabane	7	FAC	Native	0	Forb
	<i>Erigeron flagellaris</i>	trailing daisy	3	FACU	Native	0	Forb
	<i>Erigeron formosissimus</i>	beautiful fleabane	6	UPL	Native	0	Forb
	<i>Erigeron glacialis</i>	glacial daisy	7	FACW	Native	0	Forb
	<i>Erigeron lonchophyllus</i>	shortray fleabane	5	FACW	Native	0	Forb
	<i>Erigeron speciosus</i>	aspen daisy	5	0	Native	0	Forb

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Asteraceae	<i>Erigeron subtrineris</i>	threenerve daisy	5	0	Native	0	Forb
	<i>Eucephalus engelmannii</i>	Engelmann's aster	7	0	Native	0	Forb
	<i>Gnaphalium uliginosum</i>	marsh cudweed	5	FAC	Native	0	Forb
	<i>Helianthella quinquevervis</i>	five-nerve little sunflower	7	FACU	Native	0	Forb
	<i>Helianthus nuttallii</i>	Nuttall's sunflower	3	FACW	Native	0	Forb
	<i>Heliomeris multiflora</i>	goldeneye	4	0	Native	0	Forb
	<i>Heterotheca villosa</i>	hairy false goldenaster	3	0	Native	0	Forb
	<i>Hymenoxys hoopesii</i>	orange sneezeweed	5	FAC	Native	0	Forb
	<i>Madia glomerata</i>	mountain tarweed	3	FACU	Native	0	Forb
	<i>Packera crocata</i>	saffron ragwort	6	FAC	Native	0	Forb
	<i>Packera pseud aurea var. flavula</i>	falsegold groundsel	7	FACW	Native	0	Forb
	<i>Rudbeckia laciniata var. ampla</i>	cutleaf coneflower	6	FAC	Native	0	Forb
	<i>Rudbeckia montana</i>	montane coneflower	7	FACW	Native	0	Forb
	<i>Senecio bigelovii var. hallii</i>	Hall's ragwort	7	0	Native	0	Forb
	<i>Senecio integerrimus</i>	lamb's-tongue ragwort	5	FACU	Native	0	Forb
	<i>Senecio serra var. admirabilis</i>	saw-toothed ragwort	7	FACU	Native	0	Forb
	<i>Senecio triangularis</i>	arrowleaf ragwort	7	FACW	Native	0	Forb
	<i>Solidago canadensis</i>	Canada goldenrod	5	FACU	Native	0	Forb
	<i>Solidago multiradiata var. scopulorum</i>	Rocky Mountain goldenrod	5	FACU	Native	0	Forb
	<i>Solidago simplex var. simplex</i>	Mt. Albert goldenrod	6	FACU	Native	0	Forb
	<i>Symphotrichum ascendens</i>	western aster	5	FACU	Native	0	Forb
	<i>Symphotrichum foliaceum</i>	leafy aster	5	FACU	Native	0	Forb
	<i>Symphotrichum laeve var. geyeri</i>	smooth blue aster	6	FACU	Native	0	Forb
	<i>Symphotrichum spathulatum</i>	western mountain aster	6	FAC	Native	0	Forb
	<i>Wyethia amplexicaulis</i>	mule's ears	3	FACU	Native	0	Forb
	<i>Xanthium strumarium</i>	common cocklebur	1	FAC	Native	0	Forb
	<i>Arctium minus</i>	common burdock	0	UPL	Non-native	List C	Forb
	<i>Artemisia absinthium</i>	absinthe wormwood	0	0	Non-native	List B	Forb
	<i>Carduus acanthoides</i>	plumeless thistle	0	0	Non-native	List B	Forb
	<i>Carduus nutans</i>	musk thistle	0	UPL	Non-native	List B	Forb
	<i>Cirsium arvense</i>	Canada thistle	0	FAC	Non-native	List B	Forb
	<i>Cirsium vulgare</i>	bull thistle	0	FACU	Non-native	List B	Forb
<i>Leucanthemum vulgare</i>	oxeye daisy	0	FACU	Non-native	List B	Forb	
<i>Tanacetum vulgare</i>	common tansy	0	FACU	Non-native	List B	Forb	
<i>Taraxacum officinale</i>	common dandelion	0	FACU	Non-native	0	Forb	
<i>Tragopogon dubius</i>	western salsify	0	0	Non-native	0	Forb	
Balsaminaceae	<i>Impatiens capensis</i>	jewelweed	4	FACW	Native	0	Forb
Berberidaceae	<i>Berberis repens</i>	Oregon-grape	5	0	Native	0	Shrub
Betulaceae	<i>Alnus incana ssp. tenuifolia</i>	thinleaf alder	6	FACW	Native	0	Shrub
	<i>Betula glandulosa</i>	dwarf birch	9	OBL	Native	0	Shrub
	<i>Betula occidentalis</i>	water birch	8	FACW	Native	0	Shrub
Boraginaceae	<i>Hackelia floribunda</i>	manyflower stickseed	3	FACU	Native	0	Forb
	<i>Mertensia ciliata</i>	streamside bluebells	7	FACW	Native	0	Forb
	<i>Mertensia franciscana</i>	Franciscan bluebells	8	FACW	Native	0	Forb
	<i>Plagiobothrys scouleri var. hispidulus</i>	sleeping popcorn flower	3	FACW	Native	0	Forb
	<i>Cynoglossum officinale</i>	gypsyflower	0	FACU	Non-native	List B	Forb
Brassicaceae	<i>Cardamine cordifolia</i>	heartleaf bittercress	8	FACW	Native	0	Forb
	<i>Cardamine pensylvanica</i>	Pennsylvania bittercress	9	FACW	Native	0	Forb
	<i>Noccaea fendleri ssp. glauca</i>	alpine pennycress	5	0	Native	0	Forb
	<i>Rorippa alpina</i>	alpine yellow-cress	4	0	Native	0	Forb
	<i>Rorippa palustris</i>	bog yellow-cress	4	OBL	Native	0	Forb

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Brassicaceae	<i>Descurainia sophia</i>	flixweed	0	0	Non-native	0	Forb
	<i>Hesperis matronalis</i>	dame's rocket	0	FACU	Non-native	List B	Forb
	<i>Lepidium draba</i>	whitetop	0	0	Non-native	List B	Forb
	<i>Lepidium perfoliatum</i>	clasping pepperweed	0	FACU	Non-native	0	Forb
	<i>Nasturtium officinale</i>	watercress	0	OBL	Non-native	0	Forb
	<i>Thlaspi arvense</i>	field pennycress	0	UPL	Non-native	0	Forb
Campanulaceae	<i>Campanula parryi</i> var. <i>parryi</i>	Rocky mountain bellflower	7	FAC	Native	0	Forb
	<i>Campanula rotundifolia</i>	bluebells of Scotland; harebell	5	FACU	Native	0	Forb
Cannabaceae	<i>Humulus neomexicanus</i>	New Mexican hop	5	FACU	Native	0	Vine
Caprifoliaceae	<i>Lonicera involucrata</i>	black twinberry	7	FAC	Native	0	Shrub
	<i>Symphoricarpos occidentalis</i>	wolfberry	3	FAC	Native	0	Shrub
	<i>Symphoricarpos rotundifolius</i>	mountain snowberry	5	0	Native	0	Shrub
	<i>Lonicera tatarica</i>	Tatarian honeysuckle	0	FACU	Non-native	0	Shrub
Caryophyllaceae	<i>Cerastium arvense</i> ssp. <i>strictum</i>	prairie mouse-ear	5	FACU	Native	0	Forb
	<i>Stellaria longifolia</i>	long-leaved starwort	7	FACW	Native	0	Forb
	<i>Stellaria longipes</i>	long-stalked starwort	8	FACW	Native	0	Forb
	<i>Stellaria umbellata</i>	umbellate starwort	8	FACW	Native	0	Forb
	<i>Silene latifolia</i>	white campion	0	0	Non-native	0	Forb
Celastraceae	<i>Paxistima myrsinites</i>	mountain lover	7	FACU	Native	0	Shrub
Ceratophyllaceae	<i>Ceratophyllum demersum</i>	coon's tail	1	OBL	Native	0	Forb
Chenopodiaceae	<i>Chenopodium glaucum</i>	oakleaf goosefoot	0	FAC	Non-native	0	Forb
Clusiaceae	<i>Hypericum scouleri</i> ssp. <i>nortoniae</i>	Norton's St. John's-wort	7	FACW	Native	0	Forb
	<i>Hypericum perforatum</i>	St. John's-wort	0	FACU	Non-native	List C	Forb
Convolvulaceae	<i>Convolvulus arvensis</i>	bindweed	0	0	Non-native	List C	Vine
Cornaceae	<i>Cornus sericea</i> ssp. <i>sericea</i>	redosier dogwood	7	FACW	Native	0	Shrub
Crassulaceae	<i>Rhodiola integrifolia</i>	king's crown	8	FACU	Native	0	Forb
	<i>Rhodiola rhodantha</i>	rose crown	8	FACW	Native	0	Forb
	<i>Sedum acre</i>	goldmoss stonecrop	0	0	Non-native	0	Forb
Cupressaceae	<i>Juniperus communis</i> var. <i>depressa</i>	common juniper	6	UPL	Native	0	Shrub
	<i>Juniperus scopulorum</i>	Rocky Mountain juniper	5	0	Native	0	Shrub
Cyperaceae	<i>Carex aquatilis</i>	water sedge	6	OBL	Native	0	Graminoid
	<i>Carex atherodes</i>	awned sedge	6	OBL	Native	0	Graminoid
	<i>Carex athrostachya</i>	long-bract sedge	7	FACW	Native	0	Graminoid
	<i>Carex aurea</i>	golden sedge	7	FACW	Native	0	Graminoid
	<i>Carex canescens</i> ssp. <i>canescens</i>	gray sedge	8	OBL	Native	0	Graminoid
	<i>Carex capillaris</i>	hair sedge	9	FACW	Native	0	Graminoid
	<i>Carex deweyana</i>	Dewey's sedge	8	FAC	Native	0	Graminoid
	<i>Carex diandra</i>	lesser panicled sedge	9	OBL	Native	0	Graminoid
	<i>Carex disperma</i>	soft-leaved sedge	9	FACW	Native	0	Graminoid
	<i>Carex douglasii</i>	Douglas' sedge	5	FAC	Native	0	Graminoid
	<i>Carex ebenea</i>	ebony sedge	4	0	Native	0	Graminoid
	<i>Carex geyeri</i>	Geyer's sedge	6	0	Native	0	Graminoid
	<i>Carex illota</i>	sheep sedge	9	FACW	Native	0	Graminoid
	<i>Carex interior</i>	inland sedge	7	OBL	Native	0	Graminoid
	<i>Carex jonesii</i>	Jones' sedge	9	OBL	Native	0	Graminoid
	<i>Carex magellanica</i> ssp. <i>irrigua</i>	little sedge	9	OBL	Native	0	Graminoid
	<i>Carex microglochin</i>	small-tipped sedge	9	FACW	Native	0	Graminoid
	<i>Carex microptera</i>	small-winged sedge	5	FACU	Native	0	Graminoid
	<i>Carex nebrascensis</i>	Nebraska sedge	5	OBL	Native	0	Graminoid
	<i>Carex nigricans</i>	black alpine sedge	8	FACW	Native	0	Graminoid
	<i>Carex nova</i>	black sedge	10	FAC	Native	0	Graminoid
	<i>Carex pachystachya</i>	thick-headed sedge	7	FAC	Native	0	Graminoid
	<i>Carex pellita</i>	woolly sedge	6	OBL	Native	0	Graminoid

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Cyperaceae	<i>Carex praeceptorum</i>	early sedge	9	OBL	Native	0	Graminoid	
	<i>Carex praegracilis</i>	clustered field sedge	5	FACW	Native	0	Graminoid	
	<i>Carex scopulorum</i>	cliff sedge	7	OBL	Native	0	Graminoid	
	<i>Carex simulata</i>	analogue sedge	6	OBL	Native	0	Graminoid	
	<i>Carex stevenii</i>	Norway sedge	8	FAC	Native	0	Graminoid	
	<i>Carex utriculata</i>	beaked sedge	5	OBL	Native	0	Graminoid	
	<i>Carex vesicaria</i>	blister sedge	8	OBL	Native	0	Graminoid	
	<i>Eleocharis acicularis</i>	needle spikerush	5	OBL	Native	0	Graminoid	
	<i>Eleocharis palustris</i>	common spikerush	3	OBL	Native	0	Graminoid	
	<i>Eleocharis pauciflora</i>	fewflower spikerush	8	OBL	Native	0	Graminoid	
	<i>Eleocharis rostellata</i>	beaked spikerush	6	OBL	Native	0	Graminoid	
	<i>Eriophorum angustifolium</i>	tall cotton-grass	9	OBL	Native	0	Graminoid	
	<i>Eriophorum chamissonis</i>	Chamisso's cotton-grass	9	OBL	Native	0	Graminoid	
	<i>Schoenoplectus acutus</i>	hardstem bulrush	3	OBL	Native	0	Graminoid	
	<i>Schoenoplectus americanus</i>	Olney's three-square bulrush	4	OBL	Native	0	Graminoid	
	<i>Schoenoplectus tabernaemontani</i>	softstem bulrush	3	OBL	Native	0	Graminoid	
	<i>Scirpus microcarpus</i>	panicked bulrush	5	OBL	Native	0	Graminoid	
	Dennstaedtiaceae	<i>Pteridium aquilinum var. pubescens</i>	hairy bracken fern	5	FACU	Native	0	Forb
	Elaeagnaceae	<i>Shepherdia argentea</i>	silver buffaloberry	7	FACU	Native	0	Shrub
		<i>Shepherdia canadensis</i>	Canadian buffaloberry	7	UPL	Native	0	Shrub
<i>Elaeagnus angustifolia</i>		Russian olive	0	FAC	Non-native	List B	Shrub	
Equisetaceae	<i>Equisetum arvense</i>	field horsetail	4	FAC	Native	0	Forb	
	<i>Equisetum hyemale ssp. affine</i>	scouring-rush horsetail	4	FACW	Native	0	Forb	
	<i>Equisetum laevigatum</i>	smooth horsetail	4	FACW	Native	0	Forb	
	<i>Equisetum variegatum ssp. variegatum</i>	variegated scouring rush	5	FACW	Native	0	Forb	
Ericaceae	<i>Gaultheria humifusa</i>	alpine spicy-wintergreen	8	FACW	Native	0	Shrub	
	<i>Kalmia microphylla</i>	alpine laurel	9	OBL	Native	0	Shrub	
	<i>Pyrola asarifolia</i>	pink wintergreen	8	FACU	Native	0	Shrub	
	<i>Vaccinium cespitosum</i>	dwarf bilberry	7	FAC	Native	0	Shrub	
	<i>Vaccinium scoparium</i>	dwarf red whortleberry	7	FACU	Native	0	Shrub	
Fabaceae	<i>Astragalus alpinus</i>	alpine milkvetch	6	FACU	Native	0	Forb	
	<i>Glycyrrhiza lepidota</i>	wild licorice	3	FAC	Native	0	Forb	
	<i>Lathyrus lanszwertii var. laetivirens</i>	Lanszwert's pea	6	0	Native	0	Vine	
	<i>Lupinus argenteus</i>	silvery lupine	5	0	Native	0	Forb	
	<i>Lupinus polyphyllus var. prunophilus</i>	hairy bigleaf lupine	6	FACU	Native	0	Forb	
	<i>Vicia americana ssp. americana</i>	American vetch	5	FAC	Native	0	Vine	
	<i>Medicago lupulina</i>	black medick	0	FACU	Non-native	0	Forb	
	<i>Melilotus albus</i>	white sweet clover	0	FACU	Non-native	0	Forb	
	<i>Melilotus officinalis</i>	yellow sweet clover	0	FACU	Non-native	0	Forb	
	<i>Trifolium pratense</i>	red clover	0	FACU	Non-native	0	Forb	
	<i>Trifolium repens</i>	white clover	0	FAC	Non-native	0	Forb	
	Fagaceae	<i>Quercus gambelii</i>	gambel oak	5	0	Native	0	Shrub
	Gentianaceae	<i>Frasera speciosa</i>	elkweed	6	0	Native	0	Forb
<i>Gentiana affinis</i>		Rocky Mountain gentian	8	FACU	Native	0	Forb	
<i>Gentianella heterosepala</i>		autumn dwarf gentian	8	FACW	Native	0	Forb	
<i>Gentianopsis detonsa var. elegans</i>		Rocky Mountain fringed gentian	8	FACW	Native	0	Forb	
<i>Swertia perennis</i>		felwort	8	FACW	Native	0	Forb	
Grossulariaceae	<i>Geranium richardsonii</i>	Richardson's geranium	6	FAC	Native	0	Forb	
	<i>Geranium viscosissimum var. incisum</i>	sticky purple geranium	5	FACU	Native	0	Forb	
	<i>Erodium cicutarium</i>	redstem filaree	0	0	Non-native	List C	Forb	
	<i>Ribes aureum</i>	golden currant	6	FAC	Native	0	Shrub	

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Grossulariaceae	<i>Ribes inerme</i>	whitestem gooseberry	5	FAC	Native	0	Shrub
	<i>Ribes montigenum</i>	alpine prickly currant	6	0	Native	0	Shrub
	<i>Ribes wolfii</i>	Wolf's currant	7	FAC	Native	0	Shrub
Haloragaceae	<i>Myriophyllum sibiricum</i>	shortspike water milfoil	3	OBL	Native	0	Forb
	<i>Myriophyllum verticillatum</i>	whorled water milfoil	8	OBL	Native	0	Forb
Hydrophyllaceae	<i>Hydrophyllum fendleri</i> var. <i>fendleri</i>	Fendler's waterleaf	7	FAC	Native	0	Forb
	<i>Sisyrinchium idahoense</i> var. <i>occidentale</i>	Idaho blue-eyed grass	7	FACW	Native	0	Forb
Iridaceae	<i>Sisyrinchium montanum</i> var. <i>montanum</i>	Rocky Mountain blue-eyed grass	6	FAC	Native	0	Forb
	<i>Juncus arcticus</i> var. <i>balticus</i>	arctic rush	4	FACW	Native	0	Graminoid
Juncaceae	<i>Juncus bufonius</i>	toad rush	3	FACW	Native	0	Graminoid
	<i>Juncus confusus</i>	Colorado rush	5	FAC	Native	0	Graminoid
	<i>Juncus drummondii</i>	Drummond's rush	6	FACW	Native	0	Graminoid
	<i>Juncus ensifolius</i>	swordleaf rush	6	FACW	Native	0	Graminoid
	<i>Juncus hallii</i>	Hall's rush	8	FAC	Native	0	Graminoid
	<i>Juncus longistylis</i>	longstyle rush	6	FACW	Native	0	Graminoid
	<i>Juncus mertensianus</i>	Mertens' rush	7	OBL	Native	0	Graminoid
	<i>Juncus parryi</i>	Parry's rush	7	FAC	Native	0	Graminoid
	<i>Juncus torreyi</i>	Torrey's rush	5	FACW	Native	0	Graminoid
	<i>Juncus triglumis</i> var. <i>albescens</i>	three-hulled rush	10	OBL	Native	0	Graminoid
	<i>Luzula comosa</i>	Pacific woodrush	7	FAC	Native	0	Graminoid
	<i>Luzula parviflora</i>	small-flowered woodrush	7	FAC	Native	0	Graminoid
	<i>Juncus compressus</i>	roundfruit rush	0	OBL	Non-native	0	Graminoid
	Juncaginaceae	<i>Triglochin palustris</i>	marsh arrowgrass	7	OBL	Native	0
Lamiaceae	<i>Mentha arvensis</i>	wild mint	4	FACW	Native	0	Forb
	<i>Monarda fistulosa</i> var. <i>menthifolia</i>	wild bergamot	6	FACU	Native	0	Shrub
	<i>Prunella vulgaris</i>	heal-all	4	FACU	Native	0	Forb
	<i>Scutellaria galericulata</i>	marsh skullcap	7	OBL	Native	0	Forb
Lentibulariaceae	<i>Utricularia minor</i>	lesser bladderwort	9	OBL	Native	0	Forb
	<i>Utricularia vulgaris</i>	greater bladderwort	7	OBL	Native	0	Forb
Liliaceae	<i>Prosartes trachycarpa</i>	rough-fruited fairy bells	8	FACU	Native	0	Forb
	<i>Streptopus amplexifolius</i>	clasp leaf twisted stalk	7	FAC	Native	0	Forb
Linaceae	<i>Linum lewisii</i>	Lewis flax	4	0	Native	0	Forb
Malvaceae	<i>Sidalcea candida</i>	white checker-bloom	5	FACW	Native	0	Forb
	<i>Sidalcea neomexicana</i>	Rocky Mountain checker-bloom	5	FACW	Native	0	Forb
Melanthiaceae	<i>Veratrum californicum</i>	California false hellebore	4	FAC	Native	0	Forb
	<i>Zigadenus elegans</i>	mountain death camas	6	FACU	Native	0	Forb
Nymphaeaceae	<i>Nuphar polysepala</i>	Rocky Mountain pond-lily	7	OBL	Native	0	Forb
Onagraceae	<i>Chamerion angustifolium</i>	fireweed	4	FACU	Native	0	Forb
	<i>Epilobium brachycarpum</i>	panicled willow-herb	2	FAC	Native	0	Forb
	<i>Epilobium ciliatum</i>	American willow-herb	4	FACW	Native	0	Forb
	<i>Epilobium hornemannii</i>	Hornemann's willow-herb	6	FACW	Native	0	Forb
Orchidaceae	<i>Corallorhiza striata</i>	striped coralroot	7	FACU	Native	0	Forb
	<i>Cypripedium fasciculatum</i>	purple lady's slipper	9	FACU	Native	0	Forb
	<i>Epipactis gigantea</i>	giant helleborine	9	OBL	Native	0	Forb
	<i>Goodyera oblongifolia</i>	western rattlesnake plantain	9	FACU	Native	0	Forb
	<i>Listera cordata</i> var. <i>nephrophylla</i>	heartleaf twayblade	9	FAC	Native	0	Forb
	<i>Platanthera aquilonis</i>	northern green orchid	7	FACW	Native	0	Forb
	<i>Platanthera dilatata</i>	scentbottle	8	FACW	Native	0	Forb
	<i>Platanthera huronensis</i>	Huron green orchid	7	OBL	Native	0	Forb
	<i>Platanthera purpurascens</i>	purple-petal bog orchid	8	OBL	Native	0	Forb
	<i>Platanthera tescamnis</i>	stream bog orchid	9	OBL	Native	0	Forb

Family	Latin Name	Common Name	C-Value	Wetland Indicator Status	Nativity	Noxious	Growth Habit
Orchidaceae	<i>Spiranthes diluvialis</i>	Ute lady's tresses	7	FACW	Native	0	Forb
	<i>Spiranthes romanzoffiana</i>	hooded lady's tresses	7	FACW	Native	0	Forb
Orobanchaceae	<i>Castilleja rhexiifolia</i>	splitleaf Indian paintbrush	8	FAC	Native	0	Forb
	<i>Castilleja sulphurea</i>	sulphur indian paintbrush	7	FACW	Native	0	Forb
	<i>Pedicularis bracteosa</i> var. <i>paysoniana</i>	Payson's lousewort	7	0	Native	0	Forb
	<i>Pedicularis crenulata</i>	meadow lousewort	7	FACW	Native	0	Forb
	<i>Pedicularis groenlandica</i>	elephant's head	8	OBL	Native	0	Forb
	<i>Pedicularis procera</i>	giant lousewort	8	FACU	Native	0	Forb
Parnassiaceae	<i>Parnassia fimbriata</i>	Rocky Mountain grass-of-Parnassus	8	OBL	Native	0	Forb
Phrymaceae	<i>Mimulus guttatus</i>	yellow monkey-flower	8	OBL	Native	0	Forb
Pinaceae	<i>Abies bifolia</i>	Rocky Mountain subalpine fir	5	FACU	Native	0	Tree
	<i>Picea engelmannii</i> var. <i>engelmannii</i>	Engelmann spruce	5	FAC	Native	0	Tree
	<i>Picea pungens</i>	Colorado blue spruce	6	FAC	Native	0	Tree
	<i>Pinus contorta</i> var. <i>latifolia</i>	lodgepole pine	5	FAC	Native	0	Tree
	<i>Pinus flexilis</i>	limber pine	7	0	Native	0	Tree
	<i>Pseudotsuga menziesii</i> var. <i>glauca</i>	Douglas-fir	5	FACU	Native	0	Tree
	Plantaginaceae	<i>Callitriche palustris</i>	vernal water-starwort	5	OBL	Native	0
<i>Hippuris vulgaris</i>		common mare's tail	6	OBL	Native	0	Forb
<i>Penstemon strictus</i>		Rocky Mountain penstemon	5	0	Native	0	Forb
<i>Veronica americana</i>		American speedwell	6	OBL	Native	0	Forb
<i>Veronica anagallis-aquatica</i>		water speedwell	1	OBL	Native	0	Forb
<i>Veronica serpyllifolia</i> var. <i>humifusa</i>		thyme-leaf speedwell	6	FAC	Native	0	Forb
<i>Veronica wormskjoldii</i>		American alpine speedwell	7	FACW	Native	0	Forb
<i>Linaria vulgaris</i>		butter-and-eggs	0	0	Non-native	List B	Forb
<i>Plantago lanceolata</i>		narrowleaf plantain	0	FACU	Non-native	0	Forb
<i>Plantago major</i>		common plantain	0	FAC	Non-native	0	Forb
Poaceae		<i>Phalaris arundinacea</i>	reed canary grass	1	FACW	Cryptogenic	0
	<i>Achnatherum hymenoides</i>	Indian ricegrass	5	UPL	Native	0	Graminoid
	<i>Achnatherum lettermanii</i>	Letterman's needlegrass	6	0	Native	0	Graminoid
	<i>Agrostis scabra</i>	tickle grass	4	FAC	Native	0	Graminoid
	<i>Alopecurus aequalis</i>	short-awn foxtail	4	OBL	Native	0	Graminoid
	<i>Anthoxanthum hirtum</i>	northern sweetgrass	9	FACW	Native	0	Graminoid
	<i>Beckmannia syzigachne</i>	American sloughgrass	4	OBL	Native	0	Graminoid
	<i>Bromus ciliatus</i>	fringed brome	5	FAC	Native	0	Graminoid
	<i>Bromus porteri</i>	nodding brome	5	0	Native	0	Graminoid
	<i>Calamagrostis canadensis</i>	bluejoint	6	FACW	Native	0	Graminoid
	<i>Calamagrostis purpurascens</i>	purple reedgrass	7	0	Native	0	Graminoid
	<i>Calamagrostis stricta</i>	slimstem reedgrass	7	FACW	Native	0	Graminoid
	<i>Catabrosa aquatica</i>	brookgrass	7	OBL	Native	0	Graminoid
	<i>Deschampsia cespitosa</i>	tufted hairgrass	4	FACW	Native	0	Graminoid
	<i>Elymus elymoides</i>	squirreltail; bottlebrush	4	FACU	Native	0	Graminoid
	<i>Elymus trachycaulus</i>	slender wheatgrass	4	FAC	Native	0	Graminoid
	<i>Festuca arizonica</i>	Arizona fescue	6	0	Native	0	Graminoid
	<i>Festuca idahoensis</i>	Idaho fescue	7	FACU	Native	0	Graminoid
	<i>Glyceria borealis</i>	small floating mannagrass	8	OBL	Native	0	Graminoid
	<i>Glyceria elata</i>	tall mannagrass	6	FACW	Native	0	Graminoid
	<i>Glyceria grandis</i>	tall mannagrass	6	OBL	Native	0	Graminoid
<i>Glyceria striata</i>	fowl mannagrass	5	OBL	Native	0	Graminoid	
<i>Hesperostipa comata</i>	needle and thread	6	0	Native	0	Graminoid	
<i>Hordeum brachyantherum</i>	meadow barley	4	FACW	Native	0	Graminoid	
<i>Hordeum jubatum</i>	foxtail barley	2	FAC	Native	0	Graminoid	

Family	Latin Name	Common Name	C-Value	Wetland Indicator Status	Nativity	Noxious	Growth Habit
Poaceae	<i>Koeleria macrantha</i>	prairie junegrass	6	0	Native	0	Graminoid
	<i>Melica porteri</i>	Porter's melic	9	0	Native	0	Graminoid
	<i>Muhlenbergia asperifolia</i>	scratchgrass	4	FACW	Native	0	Graminoid
	<i>Muhlenbergia filiformis</i>	pull-up muhly	8	FACW	Native	0	Graminoid
	<i>Nassella viridula</i>	green needlegrass	4	0	Native	0	Graminoid
	<i>Pascopyrum smithii</i>	western wheatgrass	5	FACU	Native	0	Graminoid
	<i>Phleum alpinum</i>	alpine timothy	6	FAC	Native	0	Graminoid
	<i>Poa alpina</i>	alpine bluegrass	7	FAC	Native	0	Graminoid
	<i>Poa leptocoma</i>	marsh bluegrass	8	FACW	Native	0	Graminoid
	<i>Poa palustris</i>	fowl bluegrass	6	FAC	Native	0	Graminoid
	<i>Poa reflexa</i>	nodding bluegrass	8	OBL	Native	0	Graminoid
	<i>Sporobolus cryptandrus</i>	sand dropseed	2	FACU	Native	0	Graminoid
	<i>Trisetum spicatum</i>	spike trisetum	7	UPL	Native	0	Graminoid
	<i>Trisetum wolfii</i>	Wolf's trisetum	7	FACU	Native	0	Graminoid
	<i>Agrostis gigantea</i>	redtop bent	0	FAC	Non-native	0	Graminoid
	<i>Agrostis stolonifera</i>	creeping bentgrass	0	FAC	Non-native	0	Graminoid
	<i>Alopecurus geniculatus</i>	marsh foxtail	0	OBL	Non-native	0	Graminoid
	<i>Alopecurus pratensis</i>	meadow foxtail	0	FAC	Non-native	0	Graminoid
	<i>Bromus inermis</i>	smooth brome	0	UPL	Non-native	0	Graminoid
	<i>Dactylis glomerata</i>	orchard grass	0	FACU	Non-native	0	Graminoid
	<i>Phleum pratense</i>	timothy	0	FAC	Non-native	0	Graminoid
	<i>Poa pratensis</i>	Kentucky bluegrass	0	FAC	Non-native	0	Graminoid
	<i>Schedonorus pratensis</i>	meadow fescue	0	FACU	Non-native	0	Graminoid
Polemoniaceae	<i>Collomia linearis</i>	tiny trumpet	4	FACU	Native	0	Forb
	<i>Ipomopsis aggregata</i>	skyrocket; scarlet gilia	5	0	Native	0	Forb
Polygonaceae	<i>Bistorta bistortoides</i>	American bistort	7	FACW	Native	0	Forb
	<i>Bistorta vivipara</i>	alpine bistort	8	FAC	Native	0	Forb
	<i>Eriogonum umbellatum</i>	sulphur flower	6	0	Native	0	Forb
	<i>Persicaria amphibia</i>	water smartweed	4	OBL	Native	0	Forb
	<i>Polygonum douglasii</i>	Douglas' knotweed	3	FACU	Native	0	Forb
	<i>Rumex densiflorus</i>	dense-flowered dock	5	FACW	Native	0	Forb
	<i>Rumex occidentalis</i>	western dock	5	FACW	Native	0	Forb
	<i>Rumex triangulivalvis</i>	willow dock	4	FAC	Native	0	Forb
	<i>Rumex acetosella</i>	sheep sorrel	0	FACU	Non-native	0	Forb
	<i>Rumex crispus</i>	curly dock	0	FAC	Non-native	0	Forb
	<i>Rumex stenophyllus</i>	narrowleaf dock	0	FACW	Non-native	0	Forb
	Potamogetonaceae	<i>Potamogeton foliosus</i>	leafy pondweed	4	OBL	Native	0
<i>Potamogeton gramineus</i>		variable-leaf pondweed	4	OBL	Native	0	Forb
<i>Potamogeton pusillus</i>		small pondweed	5	OBL	Native	0	Forb
<i>Stuckenia pectinata</i>		narrowleaf pondweed	3	OBL	Native	0	Forb
Primulaceae	<i>Androsace septentrionalis</i>	pygmyflower rockjasmine	6	FACU	Native	0	Forb
	<i>Dodecatheon pulchellum</i>	darkthroat shooting star	8	FACW	Native	0	Forb
Ranunculaceae	<i>Aconitum columbianum</i>	Columbian monkshood	8	FACW	Native	0	Forb
	<i>Actaea rubra</i>	red baneberry	9	FACU	Native	0	Forb
	<i>Aquilegia coerulea</i>	Colorado blue columbine	8	FAC	Native	0	Forb
	<i>Aquilegia elegantula</i>	western red columbine	10	0	Native	0	Forb
	<i>Caltha leptosepala</i>	marsh marigold	7	OBL	Native	0	Forb
	<i>Clematis ligusticifolia</i>	western white virgin's-bower	4	FAC	Native	0	Vine
	<i>Delphinium barbeyi</i>	sub-alpine larkspur	7	FAC	Native	0	Forb
	<i>Delphinium ramosum</i>	mountain larkspur	5	0	Native	0	Forb
	<i>Ranunculus acriformis</i>	sharp buttercup	6	FACW	Native	0	Forb
	<i>Ranunculus alismifolius</i> var. <i>montanus</i>	waterplantain buttercup	6	FACW	Native	0	Forb

Family	Latin Name	Common Name	C-Value	Wetland Indicator Status	Nativity	Noxious	Growth Habit
Ranunculaceae	<i>Ranunculus aquatilis</i> var. <i>diffusus</i>	water crowfoot	3	OBL	Native	0	Forb
	<i>Ranunculus gmelinii</i>	Gmelin's buttercup	6	FACW	Native	0	Forb
	<i>Ranunculus inamoenus</i> var. <i>inamoenus</i>	graceful buttercup	7	FACW	Native	0	Forb
	<i>Ranunculus macounii</i>	Macoun's buttercup	7	OBL	Native	0	Forb
	<i>Thalictrum alpinum</i>	alpine meadowrue	8	FACW	Native	0	Forb
	<i>Thalictrum fendleri</i>	Fendler's meadowrue	6	FAC	Native	0	Forb
	<i>Trollius albiflorus</i>	white globeflower	8	OBL	Native	0	Forb
Rosaceae	<i>Amelanchier alnifolia</i> var. <i>alnifolia</i>	western serviceberry	6	FACU	Native	0	Shrub
	<i>Crataegus rivularis</i>	river hawthorn	6	FACW	Native	0	Shrub
	<i>Crataegus saligna</i>	willow hawthorn	6	FACW	Native	0	Shrub
	<i>Fragaria vesca</i>	woodland strawberry	5	FACU	Native	0	Forb
	<i>Fragaria virginiana</i>	mountain strawberry	5	FACU	Native	0	Forb
	<i>Geum aleppicum</i>	yellow avens	6	FACW	Native	0	Forb
	<i>Geum macrophyllum</i> var. <i>perincisum</i>	large-leaved avens	6	FAC	Native	0	Forb
	<i>Geum rivale</i>	purple avens	5	FACW	Native	0	Forb
	<i>Geum triflorum</i>	old man's whiskers; prairie smoke	7	FACU	Native	0	Forb
	<i>Physocarpus monogynus</i>	mountain ninebark	7	UPL	Native	0	Shrub
	<i>Potentilla fruticosa</i>	shrubby cinquefoil	4	FAC	Native	0	Shrub
	<i>Potentilla gracilis</i>	slender cinquefoil	5	FAC	Native	0	Forb
	<i>Potentilla gracilis</i> var. <i>elmeri</i>	slender cinquefoil	5	FAC	Native	0	Shrub
	<i>Potentilla hippiana</i>	wooly cinquefoil	5	FACU	Native	0	Forb
	<i>Prunus virginiana</i> var. <i>melanocarpa</i>	chokecherry	4	FACU	Native	0	Shrub
	<i>Rosa woodsii</i>	smooth rose	5	FACU	Native	0	Shrub
	<i>Rubus idaeus</i> var. <i>strigosus</i>	red raspberry	5	FACU	Native	0	Shrub
	<i>Rubus parviflorus</i> var. <i>parviflorus</i>	thimbleberry	7	FACU	Native	0	Shrub
	<i>Sibbaldia procumbens</i>	creeping sibbaldia	6	FACU	Native	0	Forb
	<i>Sorbus scopulina</i> var. <i>scopulina</i>	mountain ash	7	FACU	Native	0	Shrub
Rubiaceae	<i>Galium boreale</i>	northern bedstraw	6	FACU	Native	0	Forb
	<i>Galium multiflorum</i> var. <i>coloradoense</i>	Colorado bedstraw	7	0	Native	0	Forb
	<i>Galium trifidum</i> ssp. <i>subbiflorum</i>	threepetal bedstraw	7	FACW	Native	0	Forb
	<i>Galium triflorum</i>	fragrant bedstraw	7	FACU	Native	0	Forb
	<i>Galium odoratum</i>	sweet woodruff	0	0	Non-native	0	Forb
Ruscaceae	<i>Maianthemum racemosum</i> ssp. <i>amplexicaule</i>	large false Solomon's seal	7	FAC	Native	0	Forb
	<i>Maianthemum stellatum</i>	false Solomon's seal	7	FAC	Native	0	Forb
Salicaceae	<i>Populus angustifolia</i>	narrowleaf cottonwood	5	FACW	Native	0	Tree
	<i>Populus balsamifera</i>	balsam poplar	6	FAC	Native	0	Tree
	<i>Populus deltoides</i> ssp. <i>wislizeni</i>	Rio Grande cottonwood	4	FAC	Native	0	Tree
	<i>Populus tremuloides</i>	quaking aspen	5	FACU	Native	0	Tree
	<i>Salix bebbiana</i>	Bebb willow	6	FACW	Native	0	Shrub
	<i>Salix boothii</i>	shortfruit willow	7	FACW	Native	0	Shrub
	<i>Salix brachycarpa</i> var. <i>brachycarpa</i>	shortfruit willow	8	FACW	Native	0	Shrub
	<i>Salix drummondiana</i>	Drummond's willow	6	FACW	Native	0	Shrub
	<i>Salix eriocephala</i>	strapleaf willow	6	0	Native	0	Shrub
	<i>Salix eriocephala</i> var. <i>ligulifolia</i>	strapleaf willow	7	FAC	Native	0	Shrub
	<i>Salix exigua</i>	coyote willow	3	FACW	Native	0	Shrub
	<i>Salix geyeriana</i>	Geyer willow	6	FACW	Native	0	Shrub
	<i>Salix lasiandra</i>	greenleaf willow	6	FACW	Native	0	Tree
	<i>Salix lasiandra</i> var. <i>caudata</i>	greenleaf willow	7	FACW	Native	0	Shrub
	<i>Salix lasiandra</i> var. <i>lasiandra</i>	Pacific willow	6	FACW	Native	0	Shrub
<i>Salix monticola</i>	mountain willow	6	OBL	Native	0	Shrub	

APPENDIX C: LANDSCAPE DISTURBANCE INDEX LAYER FOR COLORADO ABRIDGED METADATA

Metadata:

- [Identification Information](#)
- [Data Quality Information](#)
- [Spatial Data Organization Information](#)
- [Spatial Reference Information](#)
- [Entity and Attribute Information](#)
- [Distribution Information](#)
- [Metadata Reference Information](#)

Identification Information:

Citation:

Citation Information:

Originator: Colorado Natural Heritage Program

Publication Date: 20210421

Title: Landscape Disturbance Index Layer for Colorado

Edition: 04_2021

Geospatial Data Presentation Form: Raster Digital Data Set

Publication Information:

Publication Place: Fort Collins, CO

Publisher: Colorado Natural Heritage Program

Description:

Abstract:

This metadata looks best with the FGDC viewer, or as the exported html in Firefox.

This is the eighth edition of the landscape integrity/disturbance layer for the state of Colorado. This layer supersedes LDI_7_2020.tif and previous versions. This update focused on oil and gas development, with only minor updates to surface mining, wind turbines, and solar installations. All other inputs have not changed from the 2020 version.

This represents 8 individually modeled anthropogenic impacts that were then combined into a single layer. Impacts represented are:

- * Agriculture
- * Urban Development
- * Oil and Gas Development
- * Surface Mining
- * Roads and Trails
- * Wind turbines
- * Solar installations

Each individual layer has its own relevant weight and decay function type (see Supplemental Information). The individual impact layers are then additively combined to produce an overall disturbance layer. The weights are scaled to produce a final range where scores => 500 are High impact. Suggested classification of values:

Value range	Level of Impact
0	None (or Minimal)

> 0 - 250	Low
> 250 - < 500	Moderate
>= 500	High

Purpose:

Originally for use in determining the Landscape Integrity score components of plants and ecological communities as reported in: Rondeau, R., K. Decker, J. Handwerk, J. Siemers, L. Grunau, and C. Pague. 2011. The state of Colorado's biodiversity 2011. Prepared for The Nature Conservancy. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado. <http://www.cnhp.colostate.edu/download/scorecard.asp>

Due to its popularity for general condition assessments, however, this layer continues to be updated as time and funding allow.

Supplemental Information:

The model is based on distance decay functions for each input threat. The method of using distance decay was originally based on work by Tuffly and Comer (2005a and b), however the equations and parameters used are our own. We used modifications of a sigmoid curve for the decay functions. By adjusting the shift and spread of the curve, it can be tailored to specific threats. The curve created is asymptotic at both ends, and so requires post-function adjustments to make the area beyond the maximum distance = 0 and the area representing the physical footprint of the impact = the full weight.

These layers are not mutually exclusive in the threats they represent, and are in fact chosen to complement one another so as to make up for incomplete and inaccurate source data.

Impact type	weight	distance decay function	type	source
Development - High/Medium 2014	500	gradual		LANDFIRE 1.3 & NLCD
Development - Low 2014	300	gradual		LANDFIRE 1.3 & NLCD
Agriculture - Tilled & SWReGAP 2004	300	moderate-abrupt		Cropscape 2015
Agriculture - Untilled & SWReGAP 2004	100	moderate-abrupt		Cropscape 2015
Roads - Primary/Secondary	500	moderate		TIGER/Line 2019
Roads - Local	300	abrupt		TIGER/Line 2019
Roads - 4WD + Motorized Trails 2019	250	abrupt		TIGER/Line 2019 & COTREX
Trails - unleashed dogs	200	abrupt		COTREX Trails 2019
Trails - foot/horse/leashed dogs	100	very-abrupt		COTREX Trails 2019
Oil & Gas wells - Active	400	moderate		COGCC 2021
Oil & Gas wells - Inactive	200	moderate/abrupt		COGCC 2021
wind turbines	200	abrupt		USGS 2020
solar farms	200	abrupt		USGS 2016
Surface Mines - Active	500	moderate		CO-DRMS 2021
Surface Mines - Inactive	300	moderate		CO-DRMS 2021

* Note that most sources were heavily edited by CNHP to improve accuracy.

Because the focus of effort for this update was oil and gas wells, only minor updates were made to surface mining, wind turbines, and solar installations. All other inputs have not changed from the 2020 version.

where:

Decay Function	Cut off Distance	Equation
Very-Abrupt $(1 / (1 + \text{Exp}(((\text{Distance} / 100) - 0.5) * 10))) * \text{weight}$	100 m	$(1 / (1 + \text{Exp}(((\text{Distance} / 100) - 0.5) * 10))) * \text{weight}$
Abrupt $(1 / (1 + \text{Exp}(((\text{Distance} / 100) - 1) * 5))) * \text{weight}$	250 m	$(1 / (1 + \text{Exp}(((\text{Distance} / 100) - 1) * 5))) * \text{weight}$
Moderate-Abrupt $(1 / (1 + \text{Exp}(((\text{Distance} / 100) - 2.5) * 2))) * \text{weight}$	600 m	$(1 / (1 + \text{Exp}(((\text{Distance} / 100) - 2.5) * 2))) * \text{weight}$
Moderate $(1 / (1 + \text{Exp}((\text{Distance} / 100) - 5))) * \text{weight}$	1250 m	$(1 / (1 + \text{Exp}((\text{Distance} / 100) - 5))) * \text{weight}$
Gradual $(1 / (1 + \text{Exp}(((\text{Distance} / 100) - 10) * 0.5))) * \text{weight}$	2000 m	$(1 / (1 + \text{Exp}(((\text{Distance} / 100) - 10) * 0.5))) * \text{weight}$

Tuffly, M., and P. Comer. 2005a. Calculating Landscape Integrity: A Working Model. Draft of 4/19/2005. NatureServe, Boulder, CO. Available online at: <http://conserveonline.org/workspaces/human.activity.index/li_data_4_19_2005.doc>
Tuffly, M., and P. Comer. 2005b. Example of landscape integrity from Puerto Rico. NatureServe, Boulder, CO. Available online at: <http://conserveonline.org/workspaces/human.activity.index/PR%20example_Landscape%20Integrity.doc>

See the Process Steps and Data Source sections for further detail.

Time Period of Content:

Time Period Information:

Single Date/Time:

Calendar Date: 20210421

Currentness Reference: Publication date

Status:

Progress: In work

Maintenance and Update Frequency: Irregular

Access Constraints: Please do not distribute without consent from CNHP.

Use Constraints:

This is a model based on currently available data and was created at a statewide scale. A model is only as good as its input data and the assumptions of the equations and parameters used. The input data is known to contain errors, inaccuracies, and omissions. This layer should be used for initial planning at the statewide scale only. All planning decisions should be verified in the field and/or with subject matter experts. It is inappropriate to use this data for local analyses. The parameters chosen for the distance decay functions were originally intended to reflect impacts to matrix forming ecological systems and may not be appropriate for other conservation elements. Specific species or communities may have completely different requirements and sensitivities. The data contained herein are provided on an as-is, as-available basis without warranties of any kind, expressed or implied, including (but not limited to) warranties of merchantability, fitness for a particular purpose, and non-infringement. CNHP, Colorado State University and the State of Colorado further expressly disclaim any warranty that the data are error-free or current as of the date supplied.

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Data Set Credit: Model created by the Colorado Natural Heritage Program.

Native Data Set Environment:

Environment as of Metadata Creation: Microsoft Windows 10 Version 6.2 (Build 9200) ; Esri ArcGIS 10.6.1 (Build 9328) Service Pack N/A (Build N/A)

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Standard Order Process:

Digital Form:

Digital Transfer Information:

Format Name: Raster Digital Data Set

APPENDIX D: SUPPORTING INFORMATION FOR MODELED AND MAPPED WETLAND FUNCTIONS

Each wetland function described below includes an overview (repeated on the Colorado Wetland Information Center “Why are Wetlands Important” webpage), along with a brief literature review and other key model information, justification, assumptions, and limitations associated with a landscape (Level 1)-scale wetland assessment. GIS data processing steps and queries can be found in Appendix E.

Biodiversity and Wildlife Habitat Functions

Conservation of Biodiversity

Biodiversity, or the presence of the full suite of organisms capable of inhabiting a given environment, is a critical part of maintaining Colorado’s wetland and terrestrial ecosystems into the future. In the web of living organisms, each species is tied to many other species, and removing one species—from a tiny aquatic invertebrate to a large carnivore—may have rippling direct and indirect effects on the rest of the ecosystem. Often, these effects include an ecosystem’s ability to sustain the clean water and natural resources that we depend on to meet our basic needs. As Aldo Leopold once said, *“If the land mechanism as a whole is good then every part is good, whether we understand it or not... To keep every cog and wheel is the first precaution of intelligent tinkering.”* Beyond the web of life, biodiversity provides aesthetic values, and many of our essential Colorado landscapes are tied to specific communities of plants, animals, and other organisms.

Supporting Information for Model Development

Wetlands that provide a high degree of biodiversity support include those known to host endemic and rare species, such as fens, as well as riparian wetlands and other ecosystems known to host high overall biodiversity (e.g., Gregory et al. 1991). Riparian wetlands like beaver complexes are known to support overall enhanced biodiversity (e.g., Law et al. 2016), as well as higher diversity for specific groups of organisms like fish (e.g., Smith and Mather 2013). Many areas (including beaver complexes) that support high biodiversity also provide refugia for Colorado’s native aquatic and terrestrial species, which allow species to persist and relocate/disperse as needed during droughts or other extreme climate or disturbance events (e.g., Gregory et al. 1991).

For this function, we relied heavily on CNHP biodiversity data, including (buffered) element occurrence records for rare species and plant communities as well as mapping for specific wetland types like fens. The biodiversity function was split into two parts: 1) rare species and ecosystems and 2) general biodiversity support. Each component was ranked by landscape condition, using LDI scores (e.g., rare species and ecosystems with high landscape condition vs. moderate or poor landscape condition). Rare species and ecosystems included wetlands intersecting buffered element occurrence records for state-rare species (S1, S2, S3), along with rare wetland types like kettle ponds, playas, spring-fed wetlands, alpine wetlands, floating mats, and fens. Wetlands considered to provide high biodiversity support included more common wetland types such as

beaver complexes, riparian wetlands, mires, and headwater wetlands that often support diverse plant and animal communities.

Assumptions and Data Limitations

Some site-specific biodiversity information is not public domain data, including occurrences of rare species and ecosystems on private lands. This information must often be generalized from a point location to lower-resolution polygons such as PCAs. The model provides a landscape-scale assessment of potential hotspots for biodiversity, based on available biodiversity data and mappable landscape attributes associated with elevated capacity to support rare biota and ecosystems.

Shorebird Habitat

Shorebirds like sandpipers, plovers, and curlews utilize a variety of Colorado wetland habitats from lake shores to river sand bars and playas. Most Colorado shorebirds are migratory species, and rely on Colorado wetlands and adjacent grassland habitats to rest, forage, and sometimes nest between seasonal flights across state and international boundaries. While shorebirds can often coexist with agricultural and ranching activities, they are sensitive to wetland and grassland conversion and loss (including woody species encroachment), impacts to insect prey from insecticides, human disturbance, and factors that increase their exposure to native and non-native predators. In addition to being an important part of Colorado's wetland ecosystems, these avian travelers often benefit Colorado's rural communities when birders flock to local wildlife areas to observe shorebirds during migration.

Supporting Information for Model Development

Wetlands ranked as having a high potential to provide shorebird habitat included saline lakes and playas (e.g., Oring et al. 2000), as well as freshwater marshes, ponds, and lake fringes in all landscape positions, with a variety of vegetation cover types depending on species (e.g., Oring et al. 2000). Other shorebird habitat features include sand and gravel bars, along with mud flats in riverine areas (e.g., Oring et al. 2000), and other wetland areas with less than 25% vegetation cover (Helmert 1992). The NWI classes with vegetation thresholds below 30% include Rock Bottom, Unconsolidated Bottom, Unconsolidated Shore, and Rocky Shore. Species like the Least Tern prefer areas with very low vegetation and abundant bare ground next to water (Helmert 1992; CPW 2016), and many shorebird species use flooded agricultural fields used for foraging (e.g., Oring et al. 2000; Plaunoy 2000).

Ephemeral playas and other dry-end basins (e.g., Oring et al. 2000) were ranked as having a moderate potential to provide shorebird habitat. All wetlands included in shorebird habitat queries had to have at least moderate landscape integrity (LDI score < 500).

Assumptions and Data Limitations

Shorebird habitat varies greatly by species (e.g., species that inhabit upland grasslands adjacent to water vs. species that require large, mostly bare islands for nesting), life stage (e.g., nesting vs. migrating), and time of year. Many factors, such as detailed information on substrate and vegetation height, that influence the suitability of shorebird habitat cannot be mapped or detected at the scale of NWI mapping.

Waterfowl Habitat

Colorado's wetlands provide important stopover habitat during spring and fall migration, along with habitat for overwintering and breeding ducks and geese. Seasonal and permanently inundated wetlands provide waterfowl habitat across Colorado's diverse landscapes, from agricultural areas in intermountain valleys like North Park and the San Luis Valley to riverine wetlands along the South Platte as it flows through the eastern plains and montane beaver complexes. Key habitat elements include submerged and emergent aquatic vegetation (interspersed with open water), along with other food sources like invertebrates, seeds and grains. Waterfowl provide prey for raptors and other wildlife, as well as hunting and other recreational (birding) resources for humans.

Supporting Information for Model Development

Waterfowl occupy a wide array of seasonally and permanently flooded wetland habitats, from freshwater marshes to cattle ponds, reservoirs, playa lakes, riparian wetlands, rivers, irrigation canals, and flooded agricultural land (e.g., Davis et al. 2014). Johnson et al. (1996) note that the key to providing habitat for a diverse array of waterfowl species along the South Platte (and presumably other larger Colorado rivers) is to have a variety of habitat types. Dabbling ducks were observed using large pools, side channels, riffles, the main river channel between pools and riffles, and sand bars, whereas diving ducks were observed in large and small pools, along with the main river channel (Johnson et al. 1996). McKinstry et al. (2001) found that waterfowl density in beaver complexes was higher (7.5 ducks/km) than similar stream systems without beaver (0.1 ducks/km), due to increased habitat complexity and riparian width. Neff (1957) also documented higher waterfowl nesting activity in beaver-occupied stream segments in the Colorado Rockies. The Colorado Parks & Wildlife Dabbling Ducks habitat scorecard (CPW 2016) was also used to inform mapping for this function.

Waterfowl use of wetlands varies throughout the year. During spring and winter migration, dabbling ducks rely on features like beaver ponds, emergent marshes, warm water sloughs, managed waterfowl areas, wet meadows, and herbaceous riparian wetlands (CPW 2016). In the winter, dabbling ducks utilize deeper water areas like river channels, warm water sloughs, reservoirs, lakes and ponds associated with gravel mining, and open sand bars (CPW 2016). While waterfowl will use wetlands in disturbed landscapes, certain factors like high levels of grazing by cattle and other ungulates, and some burning, may reduce nesting density (e.g., Gilbert et al. 1996). Wetlands queried for high waterfowl habitat functions included palustrine emergent wetlands with seasonally flooded or wetter hydrologic regimes that are greater than 2 acres in size and ponds, lakes, and streams. Wetlands with palustrine emergent vegetation that are less than or equal to 2 acres and greater than 0.25 acres in size, with seasonally flooded or wetter hydrologic regimes, were ranked as providing moderate waterfowl habitat.

Assumptions and Data Limitations

The model provides a coarse, landscape-scale assessment of potential waterfowl habitat, based on mappable landscape attributes associated with waterfowl habitat throughout different times of year. Factors such as wildlife stressors (including excess predation, poor water quality, or reduced food resources) are difficult to map at this scale, and are not explicitly included.

Assumptions and Data Limitations

Site-specific biodiversity information is not public domain data, including occurrences of rare species and ecosystems on private lands. The inductive models provide a landscape-scale assessment of potential habitat for two priority amphibians in Colorado, based on available biodiversity data and mappable landscape attributes. The models do not indicate occupancy, or account for boreal toad mortality due to the chytrid fungus.

Water Quality and Biogeochemical Functions

Nitrogen Uptake and Transformation

Humans have greatly increased the amount of available nitrogen in the environment, from atmospheric deposition to fertilizer application, animal waste, and septic systems. As one of several limiting nutrients in most ecosystems, excess nitrogen can lead to eutrophication of waterbodies (and associated algal blooms), altered plant community composition, and drinking water contamination (especially with nitrate-nitrogen). Many wetlands are local and regional hotspots for denitrification (nitrate removal) and processing other forms of nitrogen. Terrene and riparian wetlands that excel at removing nitrate have sufficient soil carbon (for denitrifying bacteria), are intercepting flow (and have higher soil water residence time for that flow), and have reducing conditions in the soil when water passes through the system.

Supporting Information for Model Development

The length of contact between wetlands and uplands is important for denitrification in riparian zones, particularly where wetlands are downslope of agricultural nitrate sources (McClain et al. 2003). Toe-of-slope wetlands along riparian areas (that have the potential to intercept groundwater-dominated irrigation return flows) were mapped as having a high likelihood of providing nitrogen uptake and transformation functions, as well as vegetated wetland basins and ponds with longer retention times for water, which are likely to have the highest capacity for N retention and denitrification (e.g., Saunders and Kalff 2001; Clary et al. 2017), including wetlands in agricultural landscapes (Hansen et al. 2018).

In lotic environments, transient storage zones, such as pools, side channels, and back channels with longer retention times for water often serve as biogeochemical hot spots for nitrate transformation and other nutrient cycling (Wollheim et al. 2014). Fluvial wetlands with a high degree of flow connectivity with stream channels are more likely to capture and cycle nutrients on a frequent basis. Beaver complexes with multi-thread channels may serve as a sink for ammonium-N, nitrate-N, dissolved organic N (DON), and total dissolved N (TDN) during high flows (e.g., spring snowmelt), a source for all of these forms of N during low flows, and a net sink for nitrate-N, DON, and TDN (e.g., Hammerson 1994; Law et al. 2016; Wegener et al. 2017).

Other low-elevation areas in riparian zones in semi-arid climates have been documented as hotspots for nutrient cycling (Harms and Grimm 2008). Floodplain wetlands are included as high-functioning for nitrogen uptake and transformation, as they are likely to assist in nutrient capture during flood events (e.g., Wollheim et al. 2014). Excavated ponds are excluded, given that they are often highly disturbed systems and devoid of vegetation.

Vegetated wetland channels have a moderate capacity for capturing and processing various forms of nitrogen (Clary et al. 2017).

Assumptions and Data Limitations

Mapping potential water quality functions at the landscape scale, particularly functions that rely on complex biogeochemical processes, is challenging. The model provides a landscape-scale assessment of potential hotspots for nutrient cycling, based on key fundamental processes (e.g., retention of water) and mappable landscape attributes associated with elevated capacity to capture and transform various forms of nitrogen. Plant community characteristics, presence of denitrifying bacteria and a sufficient carbon source, presence or absence of bypass flowpaths, and a myriad of other site-scale factors influence nitrogen cycling.

Phosphorus Removal and Storage

Phosphorus is a key limiting nutrient in many aquatic and terrestrial systems, and in excess, can cause eutrophication and associated algal blooms in surface water. Common phosphorus (P) sources include fertilizer, animal waste, septic systems, and bank erosion (P bound to soil and sediment particles). The ability of wetlands to remove and store P depends on a complex array of biogeochemical, hydrologic, and biological processes. Phosphorus is often bound to soil and sediment particles, so this function is correlated with sediment retention and capture. In general, wetlands are better at capturing particulate P than removing and storing dissolved forms of P.

Supporting Information for Model Development

In a review of 60 wetland publications, Fisher and Acreman (2004) concluded that particulate P is more likely to be retained in wetlands, and that drier-end wetlands with non-reducing substrates most effectively remove P. Vegetated systems with high water retention time (NWI seasonally flooded hydrologic regime or wetter in the model) have the highest capacity for P retention and removal, given that longer retention time allows for more plant uptake and capture of suspended soil and sediment particles (e.g., Woltemade 2000; Fisher and Acreman 2004; Clary et al. 2017). Non-lotic wetlands with limited surface water connections to streams, and emergent or floating macrophytes may provide high P assimilation and storage (Reddy et al. 1999).

Aldous et al. (2005) found that the histosols they examined ($>20 \text{ mg/cm}^3$ organic C) had 30-50% of P as humic-P, and that peat oxidation may be partly responsible for eutrophication problems in Klamath Marsh in Southwestern Oregon. Reflooding marsh areas released a substantial amount of soluble reactive phosphorus, and the authors also note that semi-permanent flooding of lentic areas could result in the release of Fe-bound P under anoxic conditions (Aldous et al. 2005).

Vegetated wetland basins and wetland channels, and other types of ponds have a moderate capacity for P retention (e.g., Clary et al. 2017). Other wetlands with a moderate to high sediment capture and retention function are likely to capture P bound to soil and sediment particles, and limit bank erosion. Riparian floodplain sediments may have high P retention from flooding, and general sediment accumulation (Reddy et al. 1999). Forested riparian buffer strips may also provide P removal and storage (Woltemade 2000).

Assumptions and Data Limitations

Mapping potential water quality functions at the landscape scale, particularly functions that rely on complex biogeochemical processes, is challenging. The model provides a landscape-scale assessment of potential hotspots for nutrient cycling, based on key fundamental processes (e.g., retention of water) and mappable landscape attributes associated with elevated capacity to retain and store P. We acknowledge that this model does not capture site-scale spatial or temporal variations in nutrient cycling. Factors that were not captured during this landscape-scale assessment include a detailed evaluation of how different forms of P (including soluble P) move through, are stored, and are released in the landscape; bypass flow (e.g., direct groundwater transport of soluble phosphorus that bypasses wetlands prior to discharge into a stream); seasonal P dynamics, P release from decomposing plant matter; and degree and extent of livestock use of wetlands and surrounding upland contributing areas. For example, P release is enhanced during the summer growing season due to high temperatures and plant matter decomposition rates (e.g., Beutel et al. 2014).

Metal Removal and Storage

Metals are naturally present in soils and rock formations, but often a concern for water quality in Colorado streams, rivers, lakes, and wetlands due to historic and current mining and industrial activities, as well as runoff from urban land use. Many of our state's streams and rivers are on the 303(d) list of impaired waterways for metals like lead, arsenic, zinc, iron, uranium, and cadmium. These metals are detrimental to fish and other aquatic life, as well as recreational and water supply uses. The ability of wetlands to remove and store metals is highly dependent on factors like pH, temperature, and substrate (e.g., soil vs. sediment and organic vs. mineral soil). Wetland soils with a high organic matter content, including peat-forming fens and mires, and certain types of clay particles, generally have the highest capacity for adsorbing metals (referred to as cation exchange capacity). Overall, wetlands are most effective in removing total metals (solids) than removing dissolved metals, and may often be sources of dissolved metals depending on their hydroperiod, hydrologic regime, water inflows and outflows (including dissolved metals and metals adsorbed to suspended sediment and soil particles), pH, temperature, and history of metal loading.

Supporting Information for Model Development

A USGS study found that 67 of 145 sampled Colorado mountain wetlands contained uranium in their sediments, and that the humic and fulvic acids found in well-decomposed peat have a high sorption capacity for uranium and other metals considered harmful to human health in low concentrations (Owen and Otton 1995). The authors suggest that mining and oxidation of peat (resulting from drainage or other hydrologic alteration of organic soils), as well as acidification from acid mine drainage, has the potential to release stored uranium and other metals to surface and groundwater (Owen and Otton 1995). A study of wetland functions in Colorado reference wetlands is consistent with these findings for organic soil wetlands (Kolm et al. 1998), with a decrease in the concentration of Zn with distance along hydrologic flow paths in one wetland in a historic mining area. Mires were mapped as having a moderate potential to store metals (if they were not captured in other model queries), since they have less peat accumulation than fens.

In the International Stormwater BMP Database, which included data collection for many Colorado stormwater wetlands, vegetated wetland basin/retention pond combinations had statistically

significant reductions in total Zn, Ni, Pb, Fe, Cu, Cr, and Cd, along with dissolved Zn and Cu (Clary et al. 2017). Generally, *retention* ponds and basins tend to have longer retention times for water than *detention* ponds and basins. In the functional assessment of Colorado reference wetlands, soils consistently had the highest cation loading, compared to water and vegetation storage pools, with the exception of potassium (Kolm et al. 1998). In the International Stormwater BMP Database (Clary et al. 2017), wetland basins had statistically significant reductions in total zinc, lead, and copper, along with dissolved zinc and copper. Wetland channels had statistically significant reductions in total Zn, P, Cu, Cr, and Cd (Clary et al. 2017).

Assumptions and Data Limitations

Mapping potential water quality functions at the landscape scale, particularly functions that rely on complex biogeochemical processes, is challenging. The model provides a landscape-scale assessment of potential hotspots for metal removal and storage, based on key fundamental processes (e.g., retention of water) and mappable landscape attributes associated with elevated capacity to capture and transform various metal species commonly present in areas impacted by mining and urban development. Soil organic matter, degree of metal loading, pH, metal transport pathways (including hydrologic flow paths) and temperature all influence how metals are transported through/stored in wetlands.

Carbon Sequestration and Storage

Carbon storage in wetlands is a complex phenomenon that is geographically and temporally (seasonally and over longer periods of time) variable. Wetlands often store a disproportionately large volume of carbon for their relatively small area on the landscape, but can also be sources of methane and other greenhouse gases (e.g., Bridgham et al. 2006). The ability of wetlands to sequester carbon in the form of soil organic matter, sediment, and biomass (roots, woody plants, etc.) depends on growing season length (influenced by elevation and climate), the balance between production and decomposition of organic matter, degree of soil and vegetation disturbance, the duration (and depth) of soil or sediment saturation and inundation, soil temperature, and other environmental factors. In general, least-altered wetlands have the greatest potential to store carbon. Fens and beaver complexes are two types of Colorado wetlands that provide abundant carbon storage relative to forests and other adjacent terrestrial ecosystems. Wetlands with altered groundwater levels, such as drained fens, often become carbon sources rather than sinks when stored carbon is oxidized.

Supporting Information for Model Development

Bridgham et al. (2006) estimate that around 98% of carbon stored in North American wetlands is in the soil, and that peatlands like bogs and fens account for approximately 83% of this stored carbon (mostly in Canadian peatlands). Undisturbed histosols and other deep organic soils have some of the highest soil organic carbon densities (e.g., Nahlik and Fennessey 2016). Overall, least-disturbed wetland sites (few to no physical, chemical, or biological stressors related to land use/management) are more likely to have higher mean organic carbon density in the soil profile (approximately twice the storage of most disturbed sites; Nahlik and Fennessey 2016). In Colorado peatlands, Chimner and Cooper (2003) found that CO₂ emissions in a subalpine fen in Rocky Mountain National Park were highly sensitive to water table manipulation, with emissions nearly

doubling with each decrease in water table elevation above the ground surface from +6-10cm to +1-5cm to 0-5cm below ground. The highest CO₂ emissions were observed as soil temperatures increased in early summer, with lower emissions observed along with cooler temperatures in the fall, and with an abrupt water table decline and ground surface exposure (Chimner and Cooper 2003).

Beaver complexes, including multi-thread channels, are well-documented in providing organic matter retention (e.g., Naiman et al. 1986; Hammerson 1994; Law et al. 2016), and may serve as a sink for dissolved organic carbon (DOC) during high flows (e.g., spring snowmelt) and a source for DOC during low flows (Wegener et al. 2017). Wohl (2012) estimated that beaver complexes (including beaver meadows) can comprise around 8% of total landscape carbon storage at low levels of activity (“relict” complexes) and around 23% at high levels of activity in Colorado montane headwater catchments, with an average of around 3.3% of total organic carbon stored in sediment within relict beaver complexes and 12% in active complexes.

Least-disturbed, vegetated, mineral soil wetlands (e.g., Nahlik and Fennessey 2016) not included in the queries for a “high” degree of carbon storage were ranked as providing a moderate degree of carbon storage.

Assumptions and Data Limitations

Mapping potential water quality functions at the landscape scale, particularly functions that rely on complex biogeochemical processes, is challenging. The model provides a landscape-scale assessment of potential hotspots for carbon sequestration and storage, based on key fundamental processes (e.g., accumulation of organic matter) and mappable landscape attributes associated with elevated capacity to capture and transform various forms of carbon. Plant community characteristics, degree of soil and hydrologic disturbance, and a myriad of other site-scale factors influence carbon sequestration and storage.

Water Quantity and Geomorphic Functions

Surface Water Storage

Colorado’s wetlands provide both seasonal and semi-permanent surface water storage, along with associated subsurface groundwater storage. Surface water storage is associated with habitat for waterfowl, shorebirds, amphibians, fish, aquatic invertebrates, and other wildlife species, along with supporting wetland plant communities and adjacent terrestrial ecosystems. Natural wetlands and waterbodies also store water used to recharge groundwater aquifers and supply surface water for drinking water, irrigation, and other human water use.

Supporting Information for Model Development

This function focuses on wetlands and waterbodies that collect and store large volumes of surface water per areal extent on the landscape. Many of Colorado’s surface water storage features are artificially impounded or excavated to enhance water storage, including reservoirs for drinking water and transmountain diversion water storage. The high and moderate ranks do not distinguish between natural and impounded or excavated water storage features, which are indicated in the NWI mapping attributes with an “h” or “x” modifier, respectively, or the “ip” or “ex” LLWW

modifiers. Lakes, reservoirs, and ponds with semi-permanent to permanent water storage were ranked as providing a high degree of surface water storage.

Lake areas (often margins) with temporary or seasonal inundation, and wetland basins and ponds with temporary, seasonal, or semi-permanent inundation were ranked as providing a moderate degree of surface water storage.

Assumptions and Data Limitations

The mapping used to evaluate surface water storage lacks information on water depth, or specific information about the timing and duration of ponding or flooding.

Sediment Capture and Retention

Soil erosion and sediment transport are natural landscape-scale processes that are often altered or accelerated by land and water management (e.g., excess bank and channel erosion due to reduced sediment loads in streams and rivers downstream of dams or excess soil erosion from tilled soil). Excess sediment in streams can be detrimental to aquatic organisms that depend on gravel and cobble beds that are free of fine sediment (including spawning trout and many aquatic invertebrates), and costly for water providers to remove from in-stream reservoirs used to store drinking and irrigation water. Vegetated wetlands can stabilize soil and sediment to limit erosion, or intercept and physically filter sediment particles entrained in surface runoff or stream flow. The ability of wetlands to capture and retain sediment has both positive and negative consequences for wetland ecosystems. Most riverine wetland plant communities, including willow thickets in beaver complexes, have evolved to survive and thrive in dynamic environments, including periodic sediment scouring and deposition associated with floods. Playas and other natural wetland basins may have some natural sediment deposition, but can be filled by excess sediment in surface runoff from surrounding areas with tilling and other soil disturbance. Montane and subalpine fens and mires are relatively stable environments, and may be lost if large volumes of sediment are deposited by soil erosion or landslides (e.g., from a catastrophic wildfire).

Supporting Information for Model Development

Beaver dams, particularly in geomorphically unconfined (and to some extent partially confined) stream systems, have been shown to store large volumes of sediment and increase channel complexity in Colorado and elsewhere in the Western U.S. (e.g., Naiman et al. 1986; Butler and Malanson 1995; Wohl 2011; Wohl 2013). Wetland basins with high hydraulic retention time, wetland channels, and detention basins all have high sediment retention capacity (e.g., Clary et al. 2017). Lotic wetlands that are impounded are likely to intercept sediment during low to moderate flows, but may become *sources* of sediment during high flow/intense storm events due to bypass flow AND because berms may become eroded. Other vegetated riparian wetlands are likely to capture sediment during low/normal flow events. Systems that are heavily influenced by irrigation are excluded from the highest rank for sediment capture/retention. In-channel islands and bars are included here, as they are, by definition, locations of sediment deposition (e.g., Cooper et al. 1998).

Other wetlands included as having a high potential to capture and retain sediment during more frequent precipitation and flow events include vegetated wetlands that receive overland flow, and have the potential to capture or retain sediment prior to flow leaving the wetland and traveling into stream channels or ditches, including vegetated swales and vegetated gently sloping wetlands.

Other impounded waterbodies and basins, including many of Colorado's reservoirs, also trap sediment moving downstream.

Wetlands that may or may not frequently accumulate sediment, but are capable of storing sediment during monsoons, floods, and other >2 yr recurrence interval events include floodplain wetlands and upland riparian areas that are not within the main channel (or the approximate floodway). Impounded lotic wetlands are excluded here, which tend to capture sediment during lower flow events, as they may fail during high flow events and become sediment sources.

Assumptions and Data Limitations

The mapping used to evaluate sediment capture and retention lacks detailed information on soil erodibility, surface runoff and hydraulic characteristics (e.g., eroded channels vs. diffuse flow), or specific information about stormwater systems, irrigation systems and water application rates.

In addition to data and mapping limitations, the model assumes healthy, relatively dense vegetation that provides physical straining of sediment. In areas with extensive bare ground, or where vegetation has been heavily grazed, stressed by heat or drought, or is dominated by shallow-rooted annual plant species, the capacity of a wetland to capture and retain sediment will likely be reduced.

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APPENDIX E: GEOSPATIAL DATA PROCESSING AND QUERIES FOR LIKELY WETLAND FUNCTIONS

Data Preparation

- Attribute NWI wetland dataset with Landscape, Landform, Water Flow Path, Waterbody (LLWW) and associated modifiers
- Calculate Geometry in Acres
- Zonal Statistics as a Table (mean only) for Elevation, Slope, LDI
- Join all three tables and bring in the values
- Feature to Point to get centroids for small polygons that are missed with Zonal Statistics, enforce that point is inside, delete fields to make table simpler
- Extract Values to Points for Elevation, Slope, LDI
- Join those tables to bring over the point values

Notes

- Appendix D provides supporting information used to generate geospatial data queries.
- Please see Classification of Wetlands and Deepwater Habitats of the United States for definitions of vegetation types, water regimes and other National Wetland Inventory codes used in the GIS queries (FGDC 2013).
- Interpreting Landscape Disturbance Index (LDI) scores:
 - $LDI \leq 250$ = low landscape disturbance
 - $250 > LDI \leq 500$ = moderate landscape disturbance
 - $LDI \geq 500$ = high landscape disturbance

Habitat Functions

Conservation of Biodiversity

Rare species and ecosystems, high integrity landscape (Biodiv Fn = 1)

Rare EORs (buffered) with $LDI \leq 250$ (excludes streams and impounded lakes)

- *Select by Location, Select features from:* Target [Wetland Layer], Source [EORs (Not S4, S5) selected]. Spatial selection method: Intersect the source layer feature. Apply a search distance of 10 m.
- *Select by Attribute, Select from current selection:* AveLDI ≤ 250
- *Select by Attribute, Remove from current selection:* LLWW_Waterbody LIKE 'ST%' OR (LLWW_Waterbody LIKE 'LK%' AND im = 'im')
 - *Assign Biodiv_Fn = 1 to selected features*

Rare wetland types with $LDI \leq 250$ (excludes streams and impounded lakes)

- *Select by Attribute, Create a new selection: AveLDI <= 250 AND (al = 'al' OR fm = 'fm' OR fn = 'fn' OR kt = 'kt' OR pl = 'pl' AND sf = 'sf') AND Biodiv_Fn IS NULL*
 - *Assign Biodiv_Fn = 1 to selected features*

Rare species and ecosystems, moderate integrity landscape (Biodiv Fn = 2)

Rare EORs (buffered) with LDI <= 500 (excludes streams and impounded lakes)

- *Select by Location, Select features from: Target [Wetland Layer], Source [EORs (Not S4, S5) selected]. Spatial selection method: Intersect the source layer feature. Apply a search distance of 10 m.*
- *Select by Attribute, Select from current selection: AveLDI <= 500 AND Biodiv_Fn IS NULL*
- *Select by Attribute, Remove from current selection: LLWW_Waterbody LIKE 'ST%' OR (LLWW_Waterbody LIKE 'LK%' AND im = 'im')*
 - *Assign Biodiv_Fn = 2 to selected features*

Rare wetland types with LDI <= 500 (not streams or impounded lakes)

- *Select by Attribute, Create a new selection: AveLDI <= 500 AND (al = 'al' OR fm = 'fm' OR fn = 'fn' OR kt = 'kt' OR pl = 'pl' AND sf = 'sf') AND Biodiv_Fn IS NULL*
 - *Assign Biodiv_Fn = 2 to selected features*

Rare species and ecosystems, low integrity landscape (Biodiv Fn = 3)

Rare EORs (buffered) with LDI > 500 (excludes streams and impounded lakes)

- *Select by Location, Select features from: Target [Wetland Layer], Source [EORs (Not S4, S5) selected]. Spatial selection method: Intersect the source layer feature.*
- *Select by Attribute, Select from current selection: Biodiv_Fn IS NULL*
- *Select by Attribute, Remove from current selection: LLWW_Waterbody LIKE 'ST%' OR (LLWW_Waterbody LIKE 'LK%' AND im = 'im') Assign Biodiv_Fn = 1 to selected features*
 - *Assign Biodiv_Fn = 3 to selected features*

Rare wetland types with LDI >500 (excludes streams and impounded lakes)

- *Select by Attribute, Create a new selection: (al = 'al' OR fm = 'fm' OR fn = 'fn' OR kt = 'kt' OR pl = 'pl' AND sf = 'sf') AND Biodiv_Fn IS NULL*
 - *Assign Biodiv_Fn = 3 to selected features*

High biodiversity support, high integrity landscape (Biodiv Fn = 4)

Common EORs with LDI <= 250 (excludes streams and impounded lakes)

- *Select by Location, Select features from: Target [Wetland Layer], Source [EORs]. Spatial selection method: Intersect the source layer feature. Apply a search distance of 10 m.*

- *Select by Attribute, Select from current selection: AveLDI <= 250 AND Biodiv_Fn IS NULL*
- *Select by Attribute, Remove from current selection: LLWW_Waterbody LIKE 'ST%' OR (LLWW_Waterbody LIKE 'LK%' AND im = 'im')*
 - *Assign Biodiv_Fn = 4 to selected features*

Wetland types with high general biodiversity and LDI <= 250 (excludes streams and impounded lakes)

- *Select by Attribute, Create a new selection: ((bv = 'bv' OR fp = 'fp' OR mr = 'mr' OR hw = 'hw') AND rf IS NULL) AND AveLDI <=250 AND Biodiv_Fn IS NULL*
- *Select by Attribute, Remove from current selection: LLWW_Waterbody LIKE 'ST%' OR (LLWW_Waterbody LIKE 'LK%' AND im = 'im')*
 - *Assign Biodiv_Fn = 4 to selected features*

High biodiversity support, moderate integrity landscape (Biodiv Fn = 5)

Common EORs with LDI <= 500 (excludes streams and impounded lakes)

- *Select by Location, Select features from: Target [Wetland Layer], Source [EORs]. Spatial selection method: Intersect the source layer feature. Apply a search distance of 10 m.*
- *Select by Attribute, Select from current selection: AveLDI <= 500 AND Biodiv_Fn IS NULL*
- *Select by Attribute, Remove from current selection: LLWW_Waterbody LIKE 'ST%' OR (LLWW_Waterbody LIKE 'LK%' AND im = 'im')*
 - *Assign Biodiv_Fn = 5 to selected features*

Wetland types with high general biodiversity and LDI <= 500 (excludes streams and impounded lakes)

- *Select by Attribute, Create a new selection: ((bv = 'bv' OR fp = 'fp' OR mr = 'mr' OR hw = 'hw') AND rf IS NULL) AND AveLDI <=500 AND Biodiv_Fn IS NULL*
- *Select by Attribute, Remove from current selection: LLWW_Waterbody LIKE 'ST%' OR (LLWW_Waterbody LIKE 'LK%' AND im = 'im')*
 - *Assign Biodiv_Fn = 5 to selected features*

High biodiversity support, low integrity landscape (Biodiv Fn = 6)

Common EORs with LDI >500 (excludes streams and impounded lakes)

- *Select by Location, Select features from: Target [Wetland Layer], Source [EORs]. Spatial selection method: Intersect the source layer feature. Apply a search distance of 10 m.*
- *Select by Attribute, Select from current selection: Biodiv_Fn IS NULL*
- *Select by Attribute, Remove from current selection: LLWW_Waterbody LIKE 'ST%' OR (LLWW_Waterbody LIKE 'LK%' AND im = 'im')*
 - *Assign Biodiv_Fn = 6 to selected features*

Wetland types with high general biodiversity and LDI >500 (excludes streams and impounded lakes)

- *Select by Attribute, Create a new selection:* ((bv = 'bv' OR fp = 'fp' OR mr = 'mr' OR hw = 'hw') AND rf IS NULL) AND Biodiv_Fn IS NULL
- *Select by Attribute, Remove from current selection:* LLWW_Waterbody LIKE 'ST%' OR (LLWW_Waterbody LIKE 'LK%' AND im = 'im')
 - *Assign Biodiv_Fn = 6 to selected features*

Shorebird Habitat

High potential to provide shorebird habitat (Shrbird_Fn = 1)

- *Select by Attribute, Create a new selection:* (pl = 'pl' OR ((LLWW_Landform = 'BA' OR LLWW_Waterbody IN ('PD', 'LK')) AND sa = 'sa')) AND Hydro IN ('C', 'F') AND AveLDI <= 500
 - *Assign Shrbird_Fn = 1 to selected features*
- *Select by Attribute, Create a new selection:* (LLWW_Landform = 'BA' OR LLWW_Waterbody = 'PD') AND Class IN ('AB', 'EM1') AND AveLDI <= 500
 - *Assign Shrbird_Fn = 1 to selected features*
- *Select by Attribute, Create a new selection:* ((LLWW_Landscape = 'LE' AND LLWW_Landform IN ('FP', 'FR')) OR (Class IN ('US', 'UB') AND (LLWW_Landform = 'FR' OR il = 'il'))) OR (LLWW_Landscape = 'LO' AND Class = 'US')) AND AveLDI <= 500
 - *Assign Shrbird_Fn = 1 to selected features*
- *Select by Attribute, Create a new selection:* LLWW_Waterbody = 'LK'
- *Select by Location, Select features from:* Target [Wetland Layer, select from selected features], Source [Wetland Layer with LLWW_Waterbody = 'LK' selected]. Spatial selection method: Intersect the source layer feature. Apply a search distance of 50 m.
- *Select by Attribute, Remove from current selection:* Class IN ('SS1', 'FO', 'FO1', 'FO4')
 - *Assign Shrbird_Fn = 1 to selected features*

Moderate potential to provide shorebird habitat (Shrbird_Fn = 2)

- *Select by Attribute, Create a new selection:* (((pl = 'pl' OR LLWW_Landform = 'BA') AND Hydro IN ('A', 'J')) OR (Class = 'EM1' AND LLWW_Landform = 'SL' AND ir = 'ir')) AND AveLDI <= 500 AND Shrbird_Fn IS NULL
 - *Assign Shrbird_Fn = 2 to selected features*

Waterfowl Habitat

High potential to provide waterfowl habitat (Wfowl_Fn = 1)

- *Select by Attribute, Create a new selection:* ((Class = 'EM1' AND Hydro IN ('C', 'E', 'F', 'G', 'H') AND Acres >= 2) OR LLWW_Waterbody IN ('PD', 'LK')) AND AveLDI <= 500
 - *Assign Wfowl_Fn = 1 to selected features*

Moderate potential to provide waterfowl habitat (Wfowl_Fn = 2)

- *Select by Attribute, Create a new selection:* Class = 'EM1' AND Hydro IN ('C', 'E', 'F', 'G', 'H') AND Acres >= 0.25 AND Acres < 2) AND AveLDI <= 500
 - *Assign Wfowl_Fn = 2 to selected features*

Water Quality and Biogeochemical Functions

Nitrogen Uptake and Transformation

High potential to provide N functions (WQN_Fn = 1)

- *Select by Attribute, Create a new selection:* LLWW_Landscape = 'TE' AND LLWW_Landform = 'SL' AND fp = 'fp'
 - *Assign WQN_Fn = 1 to selected features*
- *Select by Attribute, Create a new selection:* LLWW_Landscape = 'TE' AND (LLWW_Landform = 'BA' OR LLWW_Waterbody = 'PD') AND Class IN ('AB', 'EM1') AND WQN_Fn IS NULL
 - *Assign WQN_Fn = 1 to selected features*
- *Select by Attribute, Create a new selection:* (bv = 'bv' OR (fp = 'fp' AND (LLWW_Landform = 'BA' OR LLWW_Waterbody = 'PD'))) AND WQN_Fn IS NULL
 - *Assign WQN_Fn = 1 to selected features*

Moderate potential to provide N functions (WQN_Fn = 2)

- *Select by Attribute, Create a new selection:* LLWW_Landscape = 'LO' AND LLWW_Landform IN ('FP', 'FR') AND LLWW_Flowpath IN ('IN', 'TH') AND Class IN ('EM1', 'SS1', 'FO', 'FO1', 'FO4', 'US') AND WQN_Fn IS NULL
 - *Assign WQN_Fn = 2 to selected features*

Phosphorus Removal and Storage

High potential to provide P functions (WQP_Fn = 1)

- *Select by Attribute, Create a new selection:* LLWW_Landscape = 'TE' AND (LLWW_Landform = 'BA' OR LLWW_Waterbody = 'PD') AND LLWW_Flowpath IN ('VR', 'IN') AND Class IN ('AB', 'EM1')
 - *Assign WQP_Fn = 1 to selected features*
- *Select by Attribute, Create a new selection:* fn = 'fn' AND dr IS NULL AND WQP_Fn IS NULL
 - *Assign WQP_Fn = 1 to selected features*

Moderate potential to provide P functions (WQP_Fn = 2):

- *Select by Attribute, Create a new selection:* LLWW_Landscape = 'LO' AND (LLWW_Landform = 'BA' OR LLWW_Waterbody = 'PD') AND LLWW_Flowpath IN ('TH', 'IN') AND Class IN ('AB', 'EM1') AND WQP_Fn IS NULL
 - *Assign WQP_Fn = 2 to selected features*
- *Select by Attribute, Create a new selection:* Sed_FnHiQ = 1 OR Sed_FnAvgQ = 1
 - *Assign WQP_Fn = 2 to selected features*

Metal Removal and Storage

High potential to provide metal removal and storage functions (Metal_Fn = 1)

- *Select by Attribute, Create a new selection: fn = 'fn' AND dr IS NULL*
 - *Assign Metal_Fn = 1 to selected features*
- *Select by Attribute, Create a new selection: (LLWW_Landform = 'BA' OR LLWW_Waterbody = 'PD') AND Hydro IN ('C', 'E', 'F', 'G', 'H') AND Class <> 'US' AND Metal_Fn IS NULL*
 - *Assign Metal_Fn = 1 to selected features*

Moderate potential to provide metal removal and storage functions (Metal_Fn = 2)

- *Select by Attribute, Create a new selection: mr = 'mr' AND Metal_Fn IS NULL*
 - *Assign Metal_Fn = 2 to selected features*
- *Select by Attribute, Create a new selection: LLWW_Landform = 'BA' AND Hydro = 'A' AND Metal_Fn IS NULL*
 - *Assign Metal_Fn = 2 to selected features*
- *Select by Attribute, Create a new selection: LLWW_Landscape = 'LO' AND LLWW_Landform = 'BA' AND LLWW_Flowpath IN ('IN', 'TH') AND Class IN ('EM1', 'SS1', 'FO', 'FO1', 'FO4', 'US') AND Metal_Fn IS NULL*
 - *Assign Metal_Fn = 2 to selected features*

Carbon Sequestration and Storage

High potential to provide C functions (CStore_Fn = 1)

- *Select by Attribute, Create a new selection: fn = 'fn' AND AveLDI <= 250*
 - *Assign CStore_Fn = 1 to selected features*
- *Select by Attribute, Create a new selection: bv = 'bv' AND CStore_Fn IS NULL*
 - *Assign CStore_Fn = 1 to selected features*

Moderate potential to provide C functions (CStore_Fn = 2)

- *System = 'P' AND AveLDI <= 250 AND CStore_Fn IS NULL*
 - *Assign CStore_Fn = 2 to selected features*

Water Quantity and Geomorphic Functions

Surface Water Storage

High (permanent or semi-permanent) storage (H2OStor_Fn = 1)

- *Select by Attribute, Create a new selection: (LLWW_Waterbody = 'LK' AND Hydro IN ('F', 'G', 'H')) OR (LLWW_Waterbody = 'PD' AND Hydro IN ('G', 'H'))*
 - *Assign H2OStor_Fn = 1 to selected features*

Moderate (seasonal) surface water storage ($H2OStor_Fn = 2$): Wetlands that may or may not frequently store and delay water.

- (System LIKE 'L%' AND Hydro IN ('A', 'C', 'E')) OR ((LLWW_Landform = 'BA' OR LLWW_Waterbody = 'PD') AND Hydro IN ('C', 'E', 'F'))
 - Assign $H2OStor_Fn = 2$ to selected features

Sediment Capture and Retention

Frequent Sediment Accumulation ($Sed_FnAvgQ = 1$): Wetlands that are most likely to intercept and accumulate sediment on a frequent basis (e.g., <1-2 yr recurrence interval events, such as surface runoff from bare ground during precipitation).

- Select by Attribute, Create a new selection: $bv = 'bv'$
 - Assign $Sed_FnAvgQ = 1$ to selected features
- Select by Attribute, Create a new selection: $fp = 'fp'$ AND (LLWW_Landform IN ('BA', 'FR') OR LLWW_Waterbody = 'PD') AND Class IN ('EM1', 'SS1', 'FO', 'FO1', 'FO4', 'US') AND Sed_FnAvgQ IS NULL
 - Assign $Sed_FnAvgQ = 1$ to selected features
- Select by Attribute, Create a new selection: LLWW_Landscape = 'TE' AND LLWW_Flowpath IN ('OU', 'TH') AND Class IN ('EM1', 'SS1') AND (LLWW_Landform = 'BA' OR AveSlope <= 2) AND Sed_FnAvgQ IS NULL
 - Assign $Sed_FnAvgQ = 1$ to selected features
- Select by Attribute, Create a new selection: (LLWW_Waterbody IN ('LK', 'PD') OR $im = 'im'$) AND Sed_FnAvgQ IS NULL
 - Assign $Sed_FnAvgQ = 1$ to selected features

Storm and Large Geomorphic Disturbance Event Accumulation ($Sed_FnHiQ = 1$): Wetlands that may or may not frequently accumulate sediment, but are capable of storing sediment during monsoons, floods, and other >2 yr recurrence interval events.

- Select by Attribute, Create a new selection: $fp = 'fp'$ AND (LLWW_Landform = 'BA' OR (LLWW_Waterbody = 'PD' AND im IS NULL))
 - Assign $Sed_FnHiQ = 1$ to selected features
- Select by Attribute, Create a new selection: $fp = 'fp'$ AND LLWW_Landform = 'FP' AND Class IN ('SS1', 'FO', 'FO1', 'FO4') AND Sed_FnHiQ IS NULL
 - Assign $Sed_FnHiQ = 1$ to selected features

For combined field (Sed_Fn): $Sed_FnAvgQ = 1 \rightarrow 1$, $Sed_FnHiQ = 1 \rightarrow 2$, Both field = 1 $\rightarrow 3$