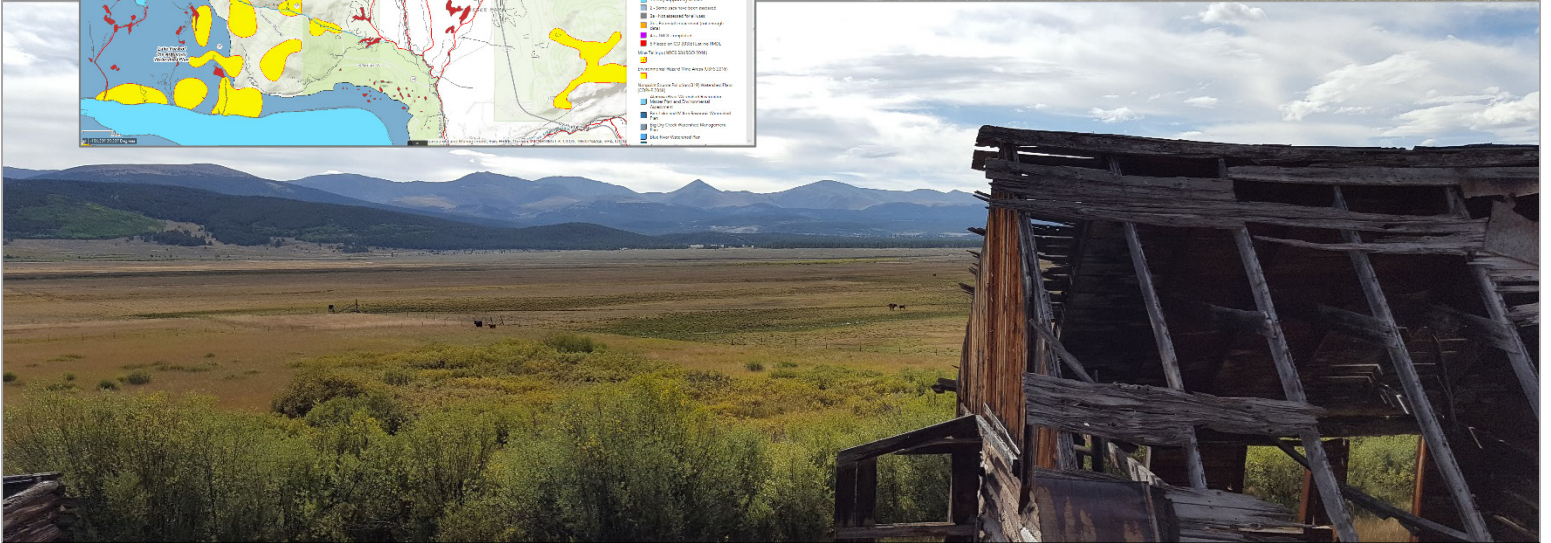
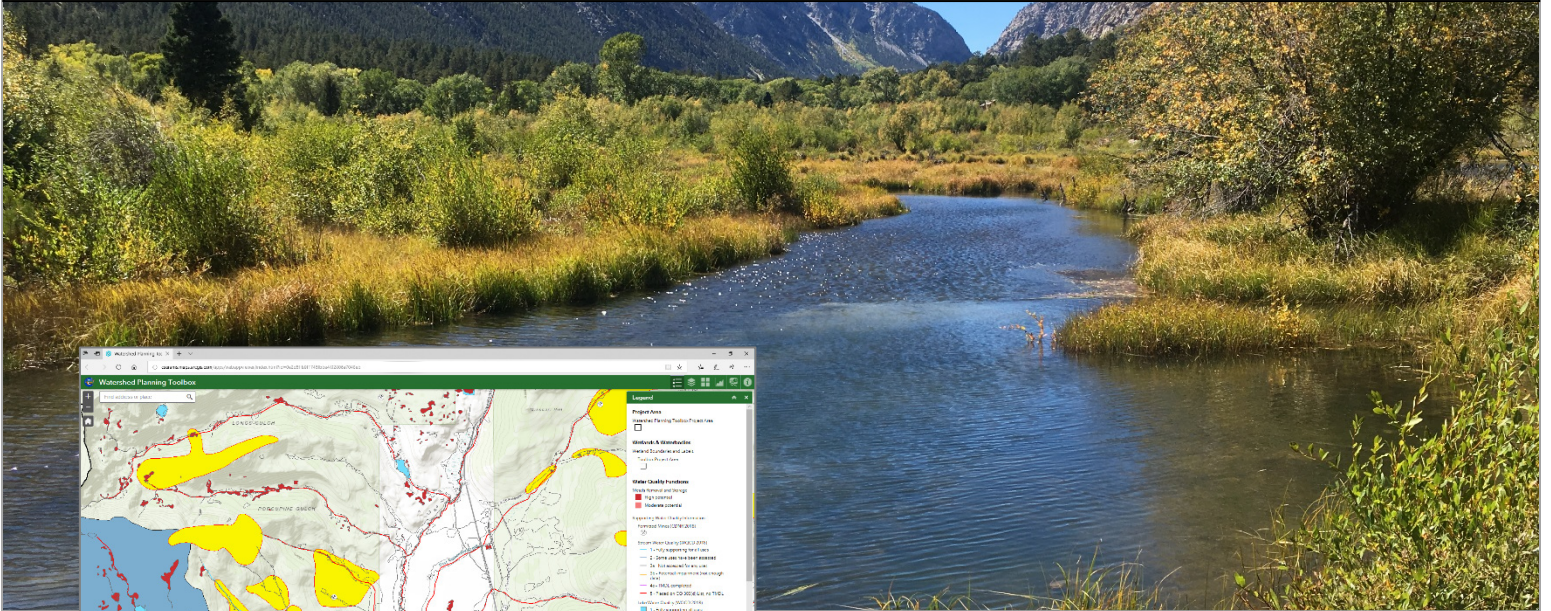


Colorado Watershed Planning Toolbox

*Bridging the Gap between Ecological Data, Applied
Restoration, and Water Resource Management*



November 2018

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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Front Cover: Wetlands of the South Platte and Arkansas Headwaters.
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Restoration, and Water Resource Management

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November 2018

EXECUTIVE SUMMARY

Wetlands are an essential component of Colorado’s landscape that greatly benefit the people of Colorado by performing a number of vital functions, including water quality improvement, flood attenuation, and wildlife habitat. Colorado’s watersheds are the headwaters of several major interstate river systems and management decisions made here have disproportionately large effects on downstream states. At the same time, Colorado is one of the fastest-growing states in the U.S., placing increasing demands on limited groundwater and surface water resources and stressing aquatic ecosystems. As resource managers, planners, and restoration practitioners attempt to mitigate for impacts to aquatic ecosystems, there is a growing need for conservation planning tools that help bridge the gap between ecological data collection and applied restoration and water resource management. The Colorado Natural Heritage Program has worked to meet this need by developing the Watershed Planning Toolbox—an online mapping interface intended to help users visualize wetland and stream distribution, landscape-scale ecological functions, hydrologic modification, stressors, and prioritization for conservation and restoration at the HUC8 subbasin scale.

Through this project, the Colorado Natural Heritage Program (CNHP):

- (1) Engaged and collaborated with interested partners and stakeholders to guide the creation of an online Watershed Planning Toolbox mapper and supporting web content to help prioritize and implement wetland restoration and conservation activities across the state.
- (2) Developed value-added GIS layers that form the basis of the online Watershed Planning Toolbox mapper. The mapper focuses on the South Platte and Arkansas Headwaters subbasins, but includes many statewide geospatial data layers relevant to wetland conservation and restoration.
- (3) Developed an online mapping website and supporting web content to present wetland information to stakeholders through an intuitive, interactive user interface.

During the development of this project, CNHP obtained feedback from various groups related to their interest and potential uses for the Toolbox. The potential uses of the data and resources were varied, including voluntary restoration by local watershed groups, wetland mitigation by the Colorado Department of Transportation, prioritization of local government funds to make sure the most optimal projects are funded, and identification of high value wetlands to target for conservation easements by land trusts. The final products have been developed with these needs in mind and will be immediately useful to many project partners. We hope that the Toolbox catalyzes and improves the efficacy of aquatic restoration activities by providing integral data to streamline restoration planning, increasing the likelihood of successful project implementation, and encouraging planners and restoration practitioners to view conservation and restoration through the lens of cumulative ecological impacts at the landscape scale.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the U.S. Environmental Protection Agency (EPA) Region 8 and Colorado Department of Transportation (CDOT)'s Wetlands Program for their financial support and encouragement of this project. Special recognition goes to EPA Project Officers Penney Trujillo, Billy Bunch, and Licia Maclear and Grant Specialists Ryan Klobberdanz, as well as Becky Pierce, CDOT Wetlands Program Coordinator.

The Watershed Planning Toolbox is a much more valuable tool and resource because of the high level of partner and stakeholder contributions and involvement in the planning and development process. The authors would like to give special thanks to members of the Arkansas Headwaters Wetland Focus Area Committee who helped identify priority restoration areas, solicit and organize input from local partners, and provided critical feedback. Buffy Lenth, Andrew Mackie, and Cindy Williams of the Central Colorado Conservancy, Mark Beardsley with EcoMetrics, Brad Johnson of Johnson Environmental Consulting, Dave Gilbert of the Bureau of Land Management, Jaime Krezelok of the U.S. Forest Service, and many others contributed valuable knowledge and energy to the Toolbox.

The new *Keys to LLWW for Inland Wetlands of the Western United States* (Appendix A) would not have been possible without our valuable partnership with GeoSpatial Services of St. Mary's University in Minnesota, particularly Andy Robertson, Kevin Stark, Eric Lundquist, and Hannah Hutchins. We are also grateful to our regional wetland partners for inspiring, reviewing, and/or contributing to the keys, specifically Linda Vance, Jennifer Chutz, Joe Fortier, Claudine Tobalske, and their colleagues at the Montana Natural Heritage Program; Diane Menuz, Ryhan Sempler, and Lindsey Smith from Utah Geologic Society; Lindsey Washkoviak and Teresa Tibbets from the Wyoming Natural Diversity Database; and Karen Menetrey of New Mexico Environmental Department's Surface Water Quality Bureau.

During the course of this project, we gained tremendous technical assistance, ideas and overall guidance from our colleagues at CNHP, especially Denise Culver, Karin Decker, Michelle Fink, Lexine Long, and Pam Smith. Additional thanks to Jeremy Sueltenfuss, former CNHP Wetland Ecologist, who helped shape the early direction of this project. Finally, we would like to thank Mary Olivas, Joe Fattor, Kelli Larson, Kris Miller, and Carmen Morales with Colorado State University for accounting support and grant administration.

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1.0 INTRODUCTION

Wetlands are an essential component of Colorado's landscape that greatly benefit the people of Colorado by performing a number of vital functions, including water quality improvement, flood attenuation, and wildlife habitat. Colorado's watersheds are the headwaters of several major interstate river systems and management decisions made here have disproportionately large effects on downstream states. There is a great need to incorporate wetlands into watershed planning to increase the efficacy of efforts aimed at wetland conservation, increase the success of wetland restoration and mitigation, and address Colorado's goal of clean and abundant water for people, farms, and wildlife.

Aquatic ecosystems are integrally linked to watershed processes, and watersheds are an important management unit in which to develop restoration and conservation goals (USEPA 2008, 2013). Currently, the State of Colorado is implementing *Colorado's Water Plan*¹, a multi-year, statewide water resource planning effort intended to help address current and future water needs. However, wetlands are rarely considered or mentioned only tangentially in statewide water plans. The document *Incorporating Wetlands into Watershed Planning* (USEPA 2013) provides guidance on connecting watershed-based wetland conservation and restoration goals with larger watershed issues. This document describes a number of tools and data sources developed by states to assist with choosing wetland restoration or conservation sites based on larger watershed goals. Many of these resources and data sources did not exist in Colorado historically, limiting the ability of watershed groups to incorporate wetlands into their watershed plans. Since many organizations are limited by time, knowledge, and access to data, the Colorado Natural Heritage Program (CNHP) was funded by a U.S. Environmental Protection Agency Region 8 Wetland Program Development Grant to develop and deliver high quality wetland data relevant to watershed planners within an easy-to-use, web-based platform. General information was developed a statewide scale, however detailed data layers on current and likely historical wetlands were developed for two pilot watersheds: the South Platte Headwaters and Arkansas Headwaters subbasins.

Through this project, the Colorado Natural Heritage Program (CNHP):

- (4) Engaged and collaborated with interested partners and stakeholders to guide the creation of an online Watershed Planning Toolbox mapper and supporting web content to help prioritize and implement wetland restoration and conservation activities across the state.
- (5) Developed value-added GIS layers that form the basis of the online Watershed Planning Toolbox mapper. The mapper focuses on the South Platte and Arkansas Headwaters subbasins, but includes many statewide geospatial data layers relevant to wetland conservation and restoration.
- (6) Developed an online mapping website and supporting web content to present wetland information to stakeholders through an intuitive, interactive user interface.

¹ For more information about Colorado's Water Plan, please visit: <https://www.colorado.gov/cowaterplan>.

Deliverables produced through this project will help catalyze and improve wetland conservation and restoration activities by providing integral data to streamline restoration planning—increasing the likelihood of successful project implementation, and encouraging planners and restoration practitioners to view wetland conservation and restoration through the lens of cumulative ecological impacts at the watershed scale. Because the primary deliverables of this projects are presented in the interactive website and mapping tool, this report focuses on process and methods rather than on fixed results. The data developed through this project can be queried in numerous different way through the online mapper.

During the development of this project, CNHP obtained feedback from various groups related to their interest and their potential uses for the Toolbox. The potential uses of the data were varied, including voluntary restoration by local watershed groups, wetland mitigation by the Colorado Department of Transportation, prioritization of local government funds to make sure the most optimal projects are funded, and identification of high value wetlands to target for conservation easements by land trusts. The final products have been developed with these needs in mind.

Because watersheds are such an important management unit to consider, we will endeavor to provide the more detailed data within the Toolbox for all of Colorado's watersheds in the years to come. The current project focused on two high priority watersheds, each of which are the headwaters of large rivers that flow east out of Colorado to multiple neighboring states. Developing the Toolbox for the South Platte and Arkansas Headwaters will serve as a test case for the development of a seamless, statewide Watershed Planning Toolbox in years to come.

2.0 TOOLBOX PROJECT AREA

Data development for the Watershed Planning Toolbox focused on two headwater subbasins, the South Platte Headwaters (HUC8: 10190001) and the Arkansas Headwaters (HUC8: 11020001), hereafter referred to as the Project Area (Figure 1). These two adjacent watersheds are located in central Colorado and encompass the highest reaches of Colorado's two major east-flowing rivers, along with many tributaries, mountain peaks, and intermountain valleys. The South Platte Headwaters covers 1,603 mi² (1.0 M acres or 4,152 km²) and is roughly round in shape. The much larger Arkansas Headwaters covers 3,063 mi² (1.9 M acres or 7,933 km²) and is elongated along a northwest to southeast axis. Both watersheds are rimmed with high mountains over 14,000 ft (4265 m), including peaks of the Continental Divide that form the northern and western edge of the Project Area.

Climate of both watersheds is characterized by long, cold winters and short summers. Even with cold temperatures, the sun often shines throughout the year and temperatures vary with elevation across the Project Area. Temperatures near Antero Reservoir, in the heart of the South Platte Headwaters reach mid-70s°F in summer, but stay below freezing in the winter with average winter lows below 0°F. Average annual precipitation is only 10.3 inches at Antero Reservoir and average annual snowfall is 47.6 inches, though much of this melts or sublimates leading to average snow depths in the winter of only 2 inches. The valley between Leadville and Salida in the Arkansas Headwaters is referred to as Colorado's Banana Belt because it is relatively warm and dry. In Salida, summer temperatures reach into the high 70s and low 80s°F, while winter temperatures are often in the 40s°F during the day and below 20°F at night. Temperatures in Leadville are ~10°F cooler on average. Average annual precipitation is only 7.32 inches in Salida and 12.5 inches in Leadville. Average annual snowfall is 34.6 inches in Salida and 116.9 inches in Leadville. Average annual snowfall in the mountains, however, is considerably more in both watersheds, up to 250 inches or more with persistent depths of 2–4 ft during winter months.²

The Middle Fork of the South Platte River begins north of Alma in the northwest corner of the South Platte Headwaters and is joined by the South Fork to become the South Platte River near the center of the watershed at Hartsel. Tarryall Creek, a major tributary that drains northeastern portions of the watershed, joins the South Platte at the southeastern edge of the watershed. The center of the South Platte Headwaters is characterized a broad, high-elevation, grassland valley known as South Park, one of four major intermountain basins in Colorado. The vast open South Park valley covers roughly 900 mi². It is bordered to the west by the Buffalo Peaks and the Mosquito Range, and to the south by Black and Thirtynine Mile mountains. These mountain ranges separate the South Platte Headwaters from the Arkansas Headwaters. To the north, South Park is bound by the southern end of the Park Range, to the east by the Kenosha Mountains, Tarryall Mountains, and Puma Hills. The elevation of the South Park valley is ~8,500–9,000 ft (2590–2745 m).

² Average climate data for Antero Reservoir (station 050263, period of record 1961–2016); Leadville (station #054884, period of record 1981–2010) and Salida (station #057371, period of record 1981–2010), accessed from Western Regional Climate Center (<http://www.wrcc.dri.edu/>).

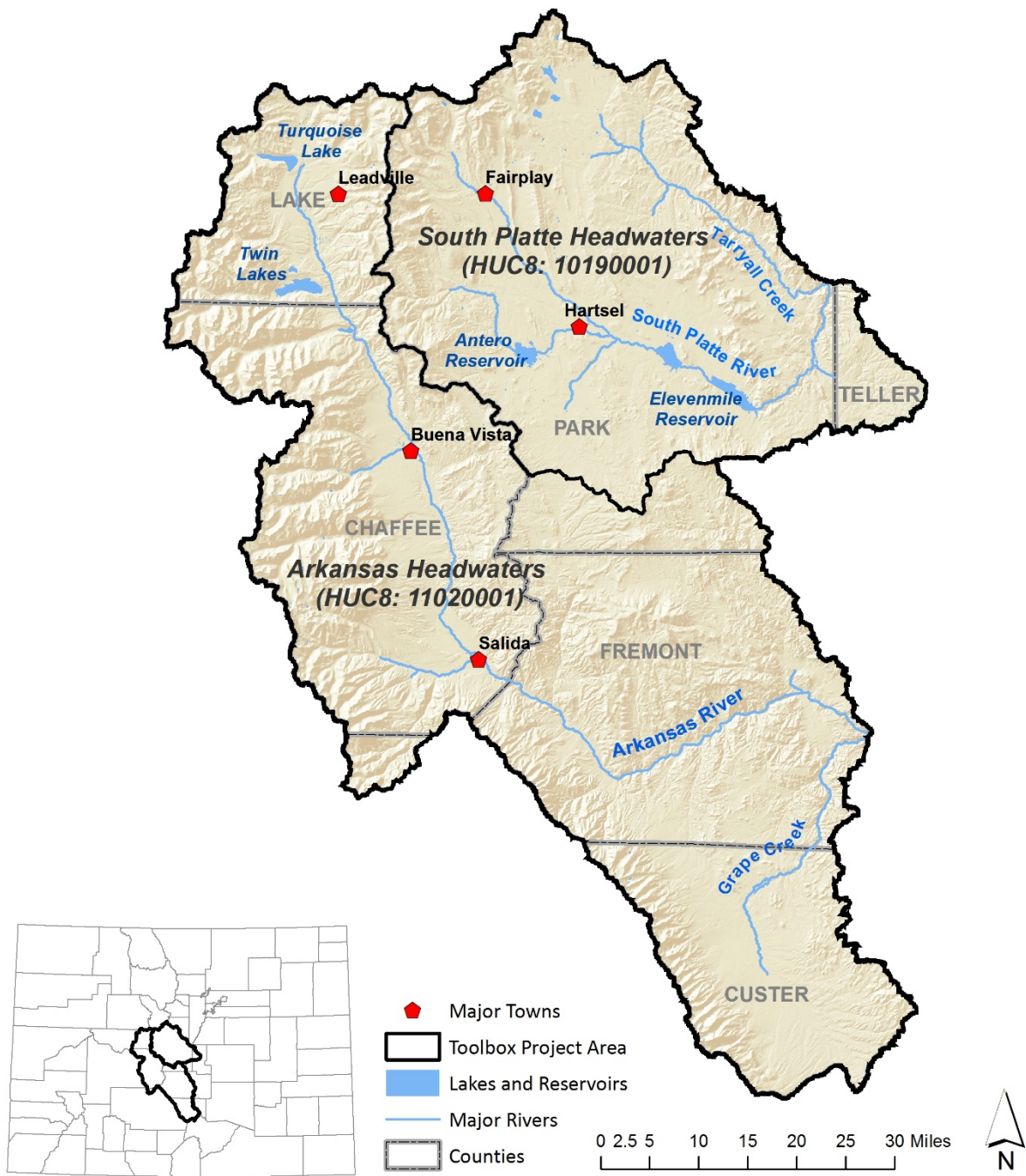


Figure 1. Toolbox Project Area, South Platte Headwaters (HUC8: 10190001) and Arkansas Headwaters (HUC8: 11020001).

In contrast to the open valley of South Park, the Arkansas River flows almost due south from its origin above Turquoise Lake near the town of Leadville through a relatively narrow, high elevation valley. Two-thirds of the way through the watershed, the river takes a turn to the east and flows through a rugged foothill zone out towards the eastern plains. The southern portion of the Arkansas Headwaters is known as the Wet Mountain Valley, which drains the eastern flank of the Sangre de Cristos and the western flank of the Wet Mountains. Grape Creek, the largest tributary in the subbasin, flows north through the Wet Mountain Valley to meet with the Arkansas River at the eastern edge of the subbasin. Elevation of the Arkansas River valley ranges from nearly 10,000 ft (3050 m) near Leadville to 7,000 ft (2135 m) near Salida; elevation within the Wet Mountain Valley is ~8,200 ft (2500 m).

Average mean annual flow in the upper reaches of the South Platte River system is relatively low (59.5 cfs along the Middle Fork near Hartsel; 187.6 cfs along Tarryall Creek near Como), and increases nearly ten-fold to 1549 cfs just beyond the watershed above Cheesman Reservoir. Average mean annual flow of the Arkansas River is similarly low in its upper reaches near Leadville (73.1 cfs), but increases to 803.5 cfs at the downstream edge of the watershed near Canyon City.³ Flows in the two subbasin are driven by spring snowmelt. Peak flows occur in June, then level off towards the end of the summer, though substantial groundwater inputs maintain base flows in both watersheds. Diversions and additions have altered the natural flows regimes by reducing peak flows and prolonging summer base flows, but the late spring pulse remains.

The increase in flow along both rivers is partially due to tributary streams, but also to several major trans-basin diversions that move water from the Colorado River basin to the South Platte and Arkansas River basins, making use of reservoirs such as Elevenmile Canyon Reservoir in the South Platte Headwaters and Twin Lakes and Turquoise Lake in the Arkansas Headwaters. While some of these diversions were originally built to support irrigated agriculture in the high mountain valleys, many water rights are now owned by urban Front Range municipalities. The sale of South Platte water rights from local agriculture to urban water use in the 1980s is one of the starkest examples in Colorado of what is referred to as “buy and dry,” when former irrigated agriculture is dried up as water rights are transferred to municipal use. Only 13% of the historically irrigated lands in the South Platte Headwaters are still irrigated today (Figure 2).

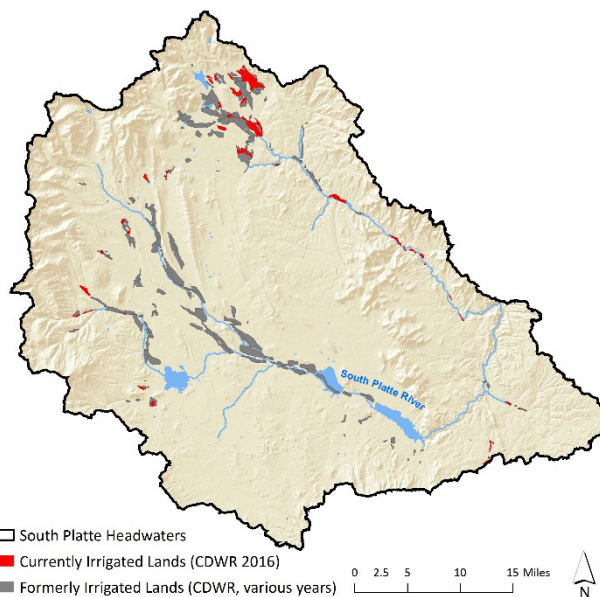


Figure 2. Current and formerly irrigated lands in the South Platte Headwaters.

³ Average mean annual flow calculated from for USGS Gage 07081200 Arkansas River near Leadville (period of record 1968–2015); USGS Gage 07094500 at Arkansas River Parkdale, CO (period of record 1946–1994); USGS Gage 06694100 at Middle Form South Platte River at Harsel (period of record 1978–1980); USGS Gage 06696980 Tarryall Creek near Como; (period of record 1978–2018); USGS Gage 06700000 South Platte River above Cheesman Lake (period of record 1924–2018). Data accessed from <http://maps.waterdata.usgs.gov/>.

The Project Area encompasses part or all of six counties: Chafee, Custer, Fremont, Lake, Park, and Teller (Figure 1). The largest town in the South Platte Headwaters is Fairplay (population 734). Much larger towns in the Arkansas Headwaters include Salida (pop. 5,856), Buena Vista (pop. 2,806), and Leadville (pop. 2,759) (U.S. Census Bureau 2017). Remaining areas of both watersheds are sparsely populated. Public lands managed by the U.S. Forest Service (USFS) within the Pike and San Isabel National Forests cover 41% of the Project Area, including the highest mountains (Figure 3). Private landowners hold another 39%, concentrated in the valley bottoms, including portions of South Park, the Arkansas River Valley, and the Wet Mountain Valley. The Bureau of Land Management (BLM) owns another significant share of the Project Area (14%), as does the State of Colorado (5%) through both the State Land Board and Colorado Parks and Wildlife.

Today, the economy of both watersheds is dominated by recreation and tourism. South Park and surrounding mountains are known for excellent fishing, backpacking, and mountain biking. The Arkansas River draws anglers, boaters, and recreationists of many types during the summer months. South Park's proximity to Denver also allows many South Park residents to commute to the Front Range for work. Remaining hay fields in both watersheds still support local cattle operations. Historically, mining played a major role in shaping the economy and the landscape of both watersheds. The mountains that separate the South Platte and Arkansas Headwaters are highly faulted and mineralized. Between 1859 and 1989, mines in the South Platte Headwaters produced hundreds of millions of dollars of precious metals (gold, silver, zinc, lead, and copper) (Scarborough 2001). In the Arkansas Headwaters, the Leadville mining district was the most productive silver mining areas in Colorado. At its peak in the 1880s, the city of Leadville had a population over 40,000 and was the second largest city in Colorado. Located northeast of Leadville, just over Fremont Pass and beyond the boundary of the Arkansas Headwaters subbasin, the Climax molybdenum mine is one of the few remaining active mines in the area. Most other mining operations have ceased today, but abandoned mining infrastructure is still visible throughout the mountains around Leadville.

The wetlands within the Project Area are of state and even global significance. The geology and hydrology found in South Park combines to create wetlands known as "extreme rich fens," so named because of their high concentrations of minerals. These fens provide habitat for a suite of rare plant species and plant communities. Porter feathergrass (*Ptilagrostis porteri*) is known only from Colorado, and only in wetlands in the vicinity of South Park. Other rare plants found here are regional endemics, species that are rarely found south of the arctic, and are believed to have been stranded as disjunct populations in South Park at the end of the last Ice Age (Spackman et al. 2001). Unfortunately, approximately 20% of the fen communities in South Park have been drained or mined for peat (Sanderson and March 1996). The upper reaches of the Arkansas Headwaters also contain numerous fen complexes, including a high concentration of kettle ponds and basins formed on old glacial moraines (Culver & Smith, *in prep*). Other wetland types located in the Project Area include playa lakes, springs, wet meadows, and riparian wetlands.

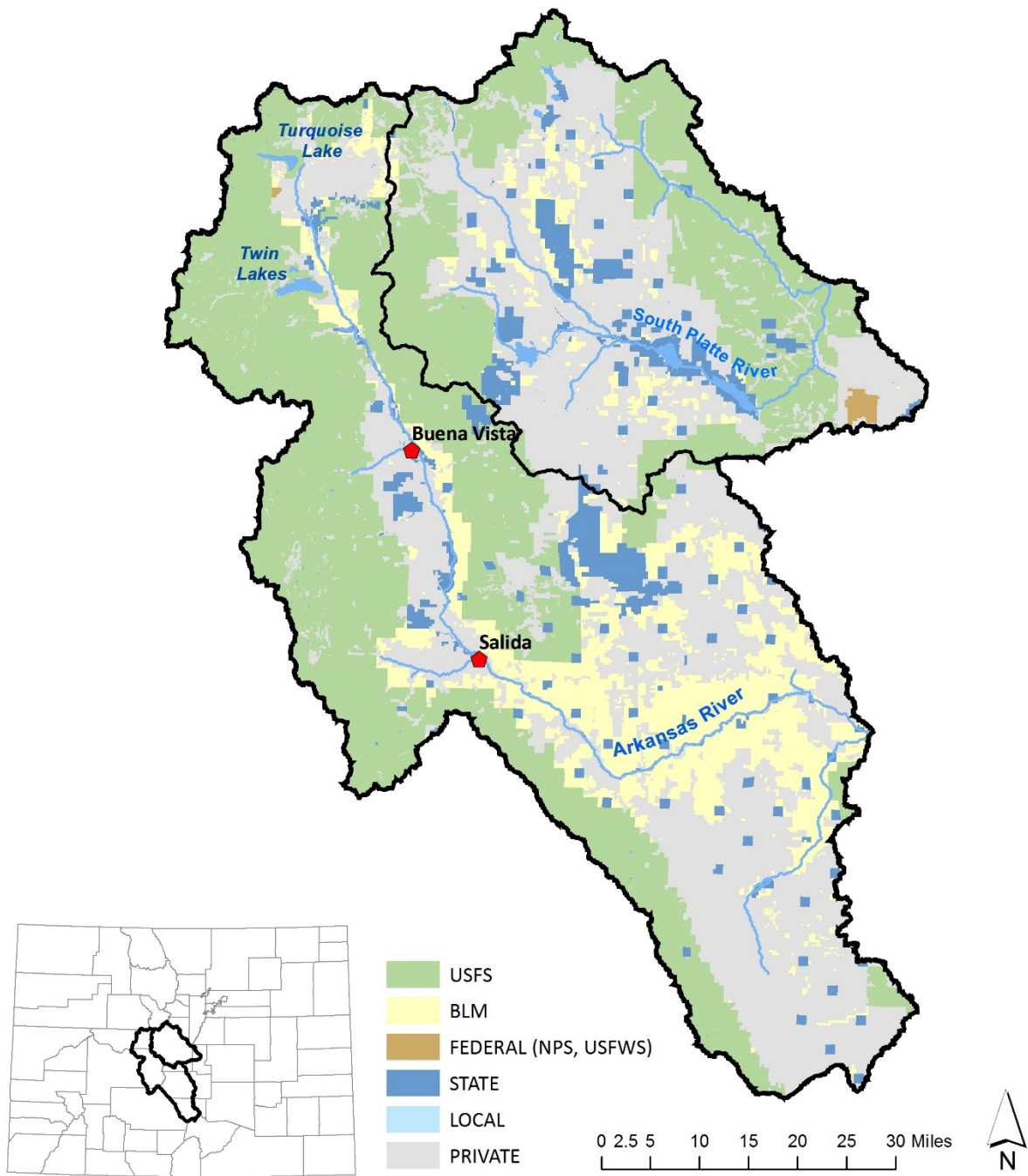


Figure 3. Land ownership within the Toolbox Project Area.

3.0 PROCESS AND METHODS

3.1 Involvement from Partners and Stakeholders

The project team engaged with wetland partners and interested stakeholders throughout the Watershed Planning Toolbox process, including travel to Buena Vista and Salida, CO to attend all meetings of the Arkansas Headwaters Wetland Focus Area Committee (AHWFAC). This group includes partners from USFS, BLM, Natural Resources Conservation Service (NRCS), the Central Colorado Conservancy, the Upper Arkansas Water Conservancy District, private consulting, as well as private landowners interested in wetland conservation, and was the primary Toolbox user group. The FAC group played a critical role in identifying and vetting priority restoration and conservation areas in the Toolbox Project Area, including hosting several meetings where participants contributed known information about priority areas and ranked them in terms of potential ecological lift and technical and economic feasibility.

Many members of the Arkansas Headwaters FAC have also been (and continue to be) involved in wetland assessment, conservation, restoration, and prioritization in the South Platte Headwaters. Mark Beardsley of EcoMetrics, LLC generously shared his existing prioritization mapping and data associated with the Park County Wetland and Stream Inventory (Beardsley 2016), which was carried out when the South Platte Headwaters FAC was still in operation, to display in the Toolbox mapper. Brad Johnson's extensive work throughout the Project Area, particularly with fens, playas, kettle ponds, and riparian wetlands, was critical in improving our understanding of the conservation and restoration needs of wetlands in the Toolbox area.

In early 2017, CNHP also created an online stakeholder survey to solicit input on wetland functions and overall Toolbox structure and content. This survey was sent to members of the AHWFAC as well as many other interested stakeholders from both the Arkansas and South Platte Headwaters subbasins, and wetland practitioners from across the state (including representatives from all state agencies involved in wetland work in Colorado). From the survey, we assembled a list of survey participants who were interested in providing continued input on Toolbox products, including web content specific to their area of expertise, and solicited their input on key intermediate products and drafts.

Final Toolbox web content, and the mapping tool was, and will continue to be, reviewed by CNHP's partners in their areas of expertise. Given Colorado's complex regulatory environment (including water law), as well as the challenges associated with everything from establishing plants in a semi-arid climate to protecting wetlands from post-fire sedimentation, the input of a wide array of people who interact with different facets of wetland conservation and restoration was invaluable in developing and refining our web pages.

3.2 Value-Added GIS Layers

A core objective of this project was to demonstrate the development of detailed, value-added geospatial data for wetlands in the two pilot watersheds of the Toolbox Project Area. We selected the South Platte Headwaters and the Arkansas Headwaters because CNHP previously updated the National Wetland Inventory (NWI) mapping for these areas through other projects (Grunau et al. 2012; Lemly et al. 2016). Updated NWI mapping formed the backbone of data development for the Watershed Planning Toolbox project. However, while this project was underway, the NWI program made two significant changes in the data standard and classification used for NWI mapping: 1) two previously unused hydrologic regimes were promoted for widespread use (D: Permanently Saturated and E: Seasonally Flooded/Saturated) and 2) all stream features mapped within the National Hydrography Dataset (NHD)⁴ were integrated into NWI mapping. These changes meant that all NWI mapping across the Project Area was reviewed and changes were made to bring the data up to the new standard. Many hydrologic regime codes were changed to include the new regimes. While time consuming, these changes allowed for greater differentiation between wetlands supported by streamflow and overbank flooding from those supported by groundwater saturation.

In addition to the updated and modified NWI data with standard NWI attribution, CNHP attributed all NWI mapping with the Landscape Position, Landform, Water Flow Path and Waterbody (LLWW) classification, which is based on geomorphic and hydrodynamic characteristics (see Section 3.2.1). This allowed us to develop models of likely ecological functions performed by wetlands within the Toolbox Project Area (see Section 3.2.2). In addition, we used existing soils data and available LiDAR imagery to model the potential historical distribution of wetlands in the Project Area (see Section 3.2.3). Lastly, we integrated an updated model of landscape disturbance created by CNHP (see Section 3.2.4).

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

Wetlands occur in a wide variety of landscape settings across the western United States. 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, partly drained, and farmed). This classification has been used by the USFWS NWI Program⁵ since the 1970s to map wetlands across the conterminous U.S. and many outlying areas. The NWI Program now provides a seamless digital dataset of wetlands for nearly the entire nation. The Cowardin classification has proven very effective at characterizing diverse wetlands types for mapping purposes and for

⁴ The NHD is produced by U.S. Geological Survey (USGS). For more information, see: <https://www.usgs.gov/core-science-systems/ngp/national-hydrography>.

⁵ For more information on the NWI Program, see: <https://www.fws.gov/wetlands/index.html>

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 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. To assist with the application of the LLWW classification, NWI's Ralph Tiner developed a series of dichotomous keys for LLWW codes (Tiner 2003; Tiner 2011; Tiner 2014) and these keys have been used for landscape-scale assessments of potential wetland functions in several states (e.g., Tiner & Berquist 2003; Tiner et al. 2013; Stark et al. 2016).

The LLWW classification was originally developed in the eastern United States and has primarily been applied to wetlands east of the Great Plains. Wetlands in the western United States differ from eastern wetlands in many respects, due to differences in climate, geography, and common landscape stressors. CNHP has applied the standard LLWW classification in previous projects (Carlson & Lemly 2011; Smith & Kuhn 2015), and the LLWW classification has been used in other western states (e.g., Newlon & Burns 2010; Stark et al. 2016). However, we recognized a need to develop a regional version of the classification to better represent the western landscape, including wetland types unique to arid and semi-arid climates, and to simplify the application of the classification.

Early in this project, CNHP developed a preliminary version of the LLWW classification specific to the Rocky Mountains (Sueltenfuss & Lemly 2015) and this preliminary approach was applied to the NWI mapping within the Arkansas Headwaters. Comparing this version of the classification to the approach used in other western states, however, we realized that many practitioners were interpreting and applying LLWW codes differently throughout the West. Instead of creating a version of classification that would only apply in Colorado, we engaged in a productive collaboration with wetland mapping groups from St. Mary's University in Minnesota,⁶ New Mexico, Montana, Utah, and Wyoming to develop a standard LLWW classification for the western U.S., along with a common LLWW-based functional assessment methodology to ensure consistency in mapping likely wetland functions across the west. This collaborative effort was not anticipated at the beginning of this project, but produced a stronger and more regionally applicable classification. Through the collaborative effort, we developed a set of keys to apply the LLWW classification to inland wetlands within the western U.S., which can be found in Appendix A. This revised classification was applied across the entire Toolbox Project Area.

⁶ The GeoSpatial Services group at St Mary's University is highly involved in wetland mapping across the west, specifically in New Mexico, Wyoming, and Alaska.

3.2.2 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 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 on our state. Questions included where to focus restoration efforts for specific watershed functions like post-fire sediment and flood attenuation, 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 wetlands and waterbodies within the Toolbox Project Area, we modeled fourteen likely watershed-scale functions grouped into three main categories (Table 1). Models were informed by literature review of both peer-reviewed articles and gray literature, as well as fundamental processes in wetlands and waterbodies (e.g., surface water storage in ponds and lakes). We then crosswalked mappable attributes from our literature review to attributes within the NWI Cowardin and LLWW classifications, as well as several landscape or land use attributes derived from ancillary data sources. Most models consisted of strings of geospatial data queries. However, we also used existing CNHP habitat models for several wetland-dependent species like the boreal toad and northern leopard frog (Fink and Siemers 2015), which are shown separately in the Toolbox Mapper.

Table 1. Wetland functions modeled within the Watershed Planning Toolbox.

<i>Biodiversity & Wildlife Habitat Functions</i>	<i>Water Quality & Biogeochemical Functions</i>	<i>Water Quantity & Geomorphic Functions</i>
Conservation of Biodiversity	Nitrogen Uptake & Transformation	Surface Water Storage
Aquatic Invertebrate Habitat	Phosphorus Removal & Storage	Flood Attenuation
Shorebird Habitat	Metals Removal & Storage	Sediment Capture & Retention
Waterfowl Habitat	Carbon Storage	Stream Flow Maintenance
	Temperature Regulation	Groundwater Recharge
		Bank and Shoreline Stabilization

Several general notes on functional mapping include:

1. All models for functions represent wetlands that are *likely* to provide a selected set of landscape-scale functions. We acknowledge that these models do not capture all of the functions that wetlands provide, or fine/site-scale spatial or temporal (seasonal or interannual) variability in things like soil properties, water chemistry, vegetation, or hydrology. We hope that modeled functions will be a starting point for further site-specific investigations into the many ecological functions and services that wetlands provide in Colorado’s diverse landscapes, and plan to update the models over time as new data and information are available.
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 in order to make functions more relevant and useful to partners and stakeholders.

A summary for each of the fourteen modeled wetland functions is provided in Appendix B, including a description, literature review and rationale for model development, and statement of model assumptions and limitations. GIS queries for functions are provided in Appendix C.

3.2.3 Mapped Potential Historical Wetland Areas

In order to better understand the distribution and genesis of existing wetlands, and identify large potential wetland restoration areas, CNHP mapped potential historical wetland areas in the Toolbox Project Area. The term “historical” is used to describe wetlands that likely existed before the 1840s, prior to beaver trapping, irrigation, stream flow modification, groundwater pumping, dredge mining, and other activities that have modified local and regional hydrology across Colorado. Each potential historical wetland polygon was assigned with a confidence rating of 1, 3, or 5 (low, moderate, or high), based on available data and existing vegetation, topographic, and hydrologic features. Wetland polygons were also attributed with likely hydrogeomorphic wetland type, along with associated SSURGO attributes if the wetlands coincided with hydric soil map units.

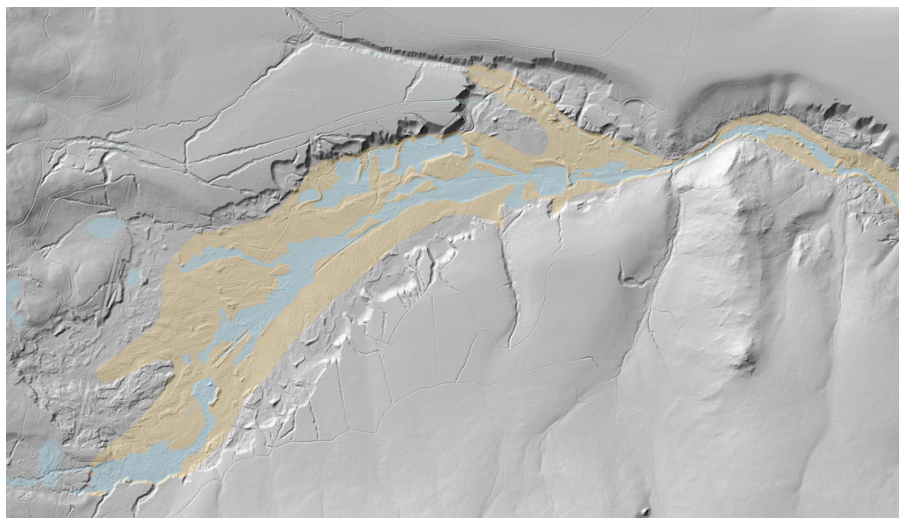


Figure 4. Cache Creek, a tributary to the Arkansas River, with LiDAR-derived digital elevation model as a base layer, showing existing floodplain and slope wetlands (blue), potential historical wetlands (tan), and extensive modification from historical mining activities, roads, and erosion/incision. Portions of the disturbed area have been reoccupied by beaver since historic mining activities ceased, raising water table elevations and increasing wetland area. CNHP visited this area to document wetland extent and characteristics in the summer of 2018.

Many likely historical wetlands within the Toolbox Project Area are associated with stream channels and floodplains of the major rivers (Arkansas and South Platte), and their tributaries (Figure 4), as well as slope wetlands fed by groundwater discharge (including fens and mires) and occasional playas, kettle ponds, and other depressional wetlands.

Active channels, old meander scars, oxbows, floodplain terraces, and other alluvial features are clearly visible in LiDAR-derived and 10 m digital elevation models (DEMs), and indicate that unconfined portions of historical floodplains were comprised of a more extensive riparian complex including features along a gradient from open water and wetlands to drier upland areas.

Descriptions of least-altered and likely historical wetland types can be found in CNHP’s County Survey reports for Park (Spackman et al. 2001), Fremont (Neid 2006), Chaffee (Culver et al. 2009), Teller (Culver et al. 2011), Jefferson (Sovell et al. 2012), and Lake (Culver & Smith, *in prep*) Counties, along with descriptions for the Ecological Systems in Table 2.

Table 2. Ecological Systems associated with existing and potential historical wetland areas within the Toolbox Project Area.

Ecological System	Associated Landform(s)	Plant Community Characteristics	Key Formative Processes and Attributes
Rocky Mountain Alpine-Montane Wet Meadow	Slopes (including 0-10% sloping areas and toe-of-slope seeps); alpine basins; less frequently flooded areas of floodplains	Sedges (<i>Carex</i> spp.), along with other graminoids (e.g., <i>Calamagrostis</i> spp. and <i>Deschampsia cespitosa</i>) and forbs, often occurring in mosaics with willow (<i>Salix</i> spp.)- and shrubby cinquefoil (<i>Potentilla fruticosa</i>)-dominated shrub communities	Seasonally saturated and/or flooded mineral soil, typically with wettest conditions in spring and drier conditions in late summer; often groundwater-dominated, with some low-velocity surface flow
Rocky Mountain Subalpine-Montane Fen	Slopes; basins; floating mats covering or extending into ponds and lakes	Sedges (<i>Carex</i> spp.), along with other graminoids, forbs, and occasional trees and shrubs including willow species (<i>Salix</i> spp.); may include rare plant species and communities	Peat-accumulating landforms, with at least 40 cm of peat in the upper 80 cm of the soil profile; permanent or near-permanent saturation maintained primarily by groundwater discharge
Rocky Mountain Subalpine-Montane Riparian Woodland and Shrubland	Floodplains and terraces; stream valleys; pond and lake margins	Vegetation ranges from willow (<i>Salix</i> spp.)-dominated communities at higher elevations to a variety of woody trees and shrubs including fir (<i>Abies</i> spp. and <i>Pseudotsuga menziesii</i>), spruce (<i>Picea</i> spp.), pine (<i>Pinus</i> spp.), aspen and cottonwood (<i>Populus</i> spp.), alder (<i>Alnus incana</i> ssp. <i>tenuifolia</i>), birch (<i>Betula</i> spp.), and red-osier dogwood (<i>Cornus sericea</i>) with an understory of graminoids and forbs	Dynamic systems, with seasonal flooding (generally associated with spring snowmelt), seasonally high groundwater, and beaver activity all playing critical roles in maintaining this system
Inter-Mountain Basin Playa	Basins in broad, sediment-filled valleys	Characteristic species in the Project Area include primarily herbaceous species like inland saltgrass (<i>Distichlis spicata</i>), purshe seepweed (<i>Suaeda calceoliformis</i>), sea milkwort (<i>Glaux maritima</i>), Nuttall’s alkaligrass (<i>Puccinellia nuttalliana</i>), seaside arrowgrass (<i>Triglochin maritima</i>), and other salt-tolerant species	Temporary intermittent flooding by precipitation and surface runoff; sparsely vegetated (<10%), and often having saline soil and salt-tolerant plants; typically underlain by low-permeability soil horizons; may have a seasonally high water table

The reduced and fragmented extent of current floodplains is the product of altered stream flow regimes, including reduced spring peak flow magnitudes due to dams and other water control structures upstream, channelization and channel incision, historical beaver trapping and current beaver exclusion, historical dredge mining (Figure 5), some irrigation diversions and return flows, and low summer base flows in select locations. Beaver activity is currently limited to areas upslope of the valley floors in both of the Project Area subbasins, partly due to beaver trapping and grazing of willows and other woody vegetation by cattle and native ungulates, and was likely more prevalent in maintaining wetlands and riparian areas across the entire Project Area prior to development of the two watersheds.



Figure 5. 1938 aerial photo of dredge mining near Fairplay, Colorado, in the South Platte Headwaters subbasin. Mining, as well as road construction, flood irrigation and other human activities were already occurring in the Project Area prior to the earliest aerial photos on record.

Geospatial data used to map likely historical wetlands included:

- Updated NWI mapping with Landscape, Landform, Water Flow Path, Waterbody (LLWW) attribution (CNHP 2018)
- National Hydrography Database (NHD), including seeps, springs, and streams (USGS 2017)
- Colorado Division of Water Resources Irrigated Lands data (CDWR 2018)
- National Flood Hazard Layer (FEMA 2017)
- National Agricultural Imagery Program (NAIP) 2015 aerial imagery (USDA)

- Environmental Systems Research Institute (ESRI) world imagery (2018)
- SSURGO Soil Map Units for all or part of Chaffee, Custer, Fremont, Jefferson Lake, Park, and Teller Counties (NRCS 2018)
- LiDAR-derived DEM web service (CGS 2018)
- CNHP Level 4 Potential Conservation Areas (2018)
- CNHP fen mapping (2018)

Mapping was conducted using a combination of automated geospatial analyses, such as intersections between wetland features and soil map units with a high percentage of hydric soils (including floodplain areas), manual interpretation of landscape-scale landforms and other features such as floodplains, and some field verification of select large, high probability historical wetland areas (e.g., digging soil pits to confirm sufficient peat depth for likely historical fens). While 1930s aerial imagery was available for the Toolbox Project Area, much of the hydrologic and land use modifications that greatly altered wetland extent and condition had already occurred (e.g., floodplain dredge mining in Figure 5). Following initial assignment of default historical wetland ranks, all remaining wetland polygons without ranks were reviewed individually, or in batches of similar wetland codes, and assigned ranks. Once ranks had been assigned to the all wetland polygons in the Project Area, we reviewed wetland distribution at the landscape scale and made corrections to ensure that the following criteria were met:

1. Wetlands and riparian areas within the Arkansas, South Platte, and other major stream and river floodplains were ranked as having a high likelihood of providing historical wetland habitat (note: we assumed that these areas were a mosaic of dynamic wetland and upland riparian areas in their “historical” state, prior to construction of reservoirs upstream, augmentation from transbasin diversions, irrigation and other withdrawals, and beaver exclusion);
2. Wetlands on high probability upland soils and/or landforms were ranked with a “1” for historical wetland likelihood; and
3. Wetlands in areas with some uncertainty about whether they were historical wetlands (vs. dry-end riparian vegetation), or in soil map units where wetlands would have comprised a relatively small percentage of the unit, were attributed with “3”, or other appropriate rank given landscape position and hydrology upstream of irrigated areas.

Mapping likely historical wetlands in Colorado is a challenging exercise involving the collection and synthesis of all available evidence for the hydrogeomorphic context, driving ecological processes, and general plant community characteristics found in wetland ecosystems prior to large-scale changes in land and water management. Many of the available geospatial data, from soil mapping to National Wetland Inventory mapping, are based on remote sensing, aerial imagery and coarse-scale topographic data. Often, geospatial data such as the NHD and NWI only capture well-known, or prominent features and miss finer-scale features like small groundwater seeps and springs or other wetlands. In order to prepare for the current mapping effort, CNHP staff reviewed and updated NWI codes, and updated boundaries for key features such as fens.

3.2.4. Updated Landscape Disturbance Index (LDI)

Wetland condition and function is often related to the extent of human disturbance within the surrounding landscape, including road, development, current and former mining activity, and agriculture. To provide landscape-level context of human disturbance, we used a newly updated model developed by CNHP (Fink 2016), which included a revised ranking for tilled (same) vs. untilled (lower) agriculture. The Landscape Disturbance Index (LDI) model includes eight individually modeled anthropogenic impacts combined into a single layer. Impacts represented are:

- Agriculture
- Urban Development
- Oil and Gas Development
- Surface Mining
- Roads
- Utility lines (electrical transmission only)
- 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. Details on the model are included in Appendix D.

3.3 Online Mapping Tool and Supporting Web Content

The primary product created by this project is an online mapping tool that showcases the value-added GIS layers created by CNHP alongside a collection of ancillary data sources created by either CNHP or our partners. The online mapper is part of a comprehensive package of new website 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.

3.3.1 Key Toolbox Elements

There are four key elements to the Watershed Toolbox, all of which live on CNHP's newly redesigned Colorado Wetlands Information Website (CWIC: www.cnhp.colostate.edu/cwic).

- **Updated and expanded wetland mapping and attributes** for the South Platte and Arkansas Headwaters subbasins, including potential historical wetlands.
- **Online mapping tool** to support user groups ranging from federal agency partners to private landowners and consultants.
- **Supporting web content** for the online mapping tool, with a comprehensive list of statewide and regional resources related to wetland conservation, restoration, regulations, best management practices, and funding and technical support.
- **Clear linkages** between CNHP wetland data, and resources to support a more holistic, science-based approach to wetland conservation and restoration in Colorado.

3.3.2 The Online Mapping Tool

The Colorado Watershed Planning Toolbox mapping tool is located within our Data & Tools content in CWIC, and is the landing page that provides an overview of the Toolbox and directs CWIC website users to the online mapping platform and supporting web content. There is also a link to the Toolbox via the main CNHP webpage, under the Our Work→Wetlands section. A Quick Guide for using the mapping tool is provided in Appendix E.

Map layers include:

- Wetland mapping, including classification by NWI and LLWW (see Section 3.2.1; Figure 6, along with Appendix A for a Key to LLWW)
- Models for fourteen different wetland functions (Figure 7; Figure 8) based on a literature review and expert input (see Section 3.2.2, along with Appendix B for a description and literature review for each function, and Appendix C for data layers, GIS attributes, and queries used to assign functions to each wetland polygon in the dataset)
- Potential historical wetlands (see Section 3.2.3)
- CNHP's statewide Landscape Disturbance Index (see Section 3.2.4; Appendix D)
- Prioritized wetland restoration and conservation areas (includes Toolbox Project Area along with playas on the eastern plains (see Section 3.1))
- A variety of ancillary data sources, grouped by the three main function categories, that provide landscape-scale context to the wetland mapping and help users understand wetland stressors and opportunities in a spatially explicit interface (see Appendix F for a table of supporting data layers).

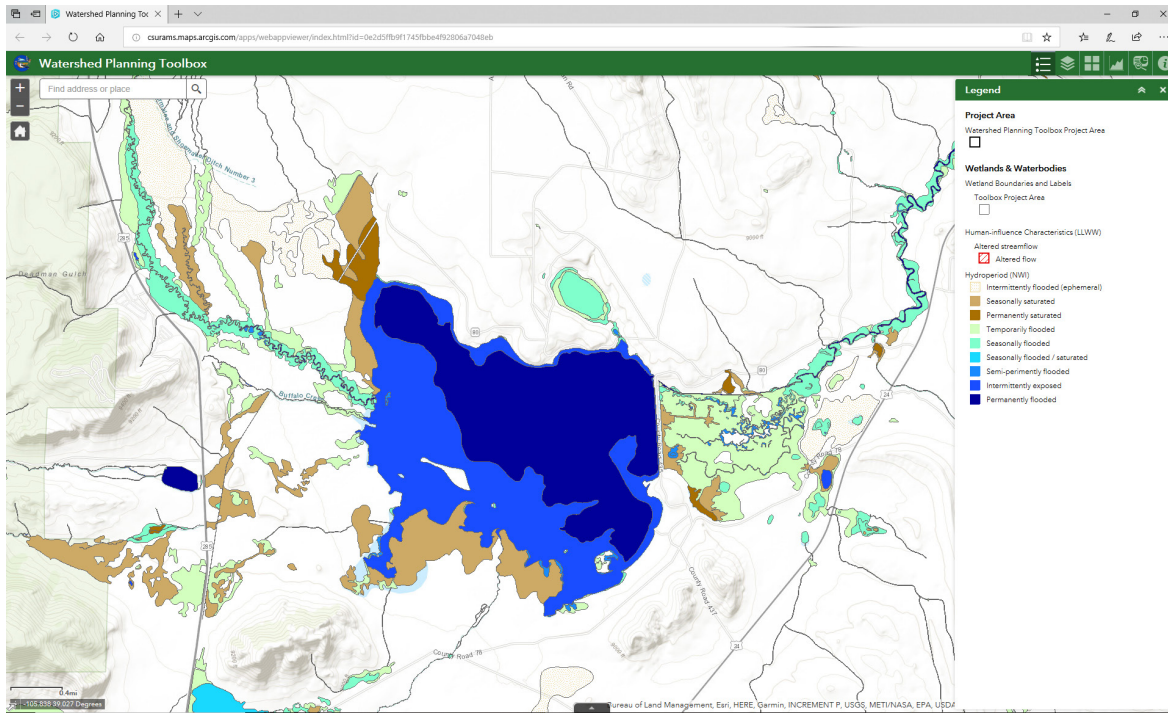


Figure 6. Screen shot from the Watershed Planning Toolbox mapper, showing wetland hydrologic regimes in the wetland complex surrounding Antero Reservoir in the South Platte Headwaters.

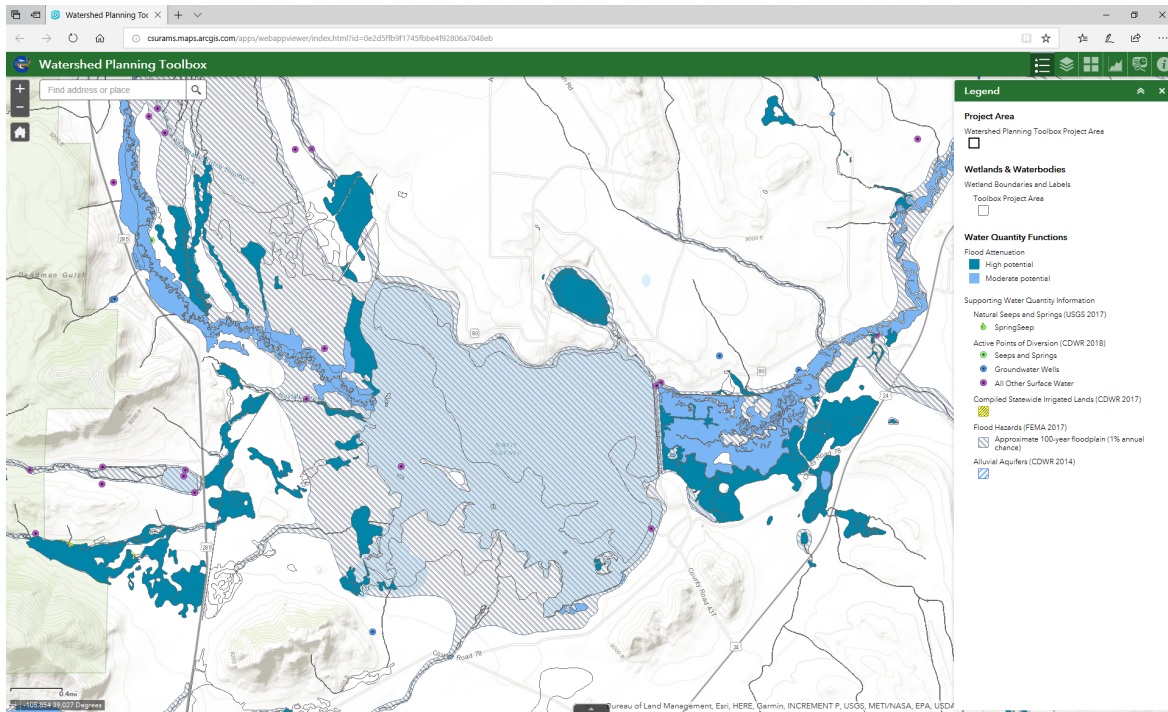


Figure 7. Screen shot from the Watershed Planning Toolbox mapper, showing the flood attenuation function and supporting water quantity geospatial data layers for the wetland complex surrounding Antero Reservoir in the South Platte Headwaters.

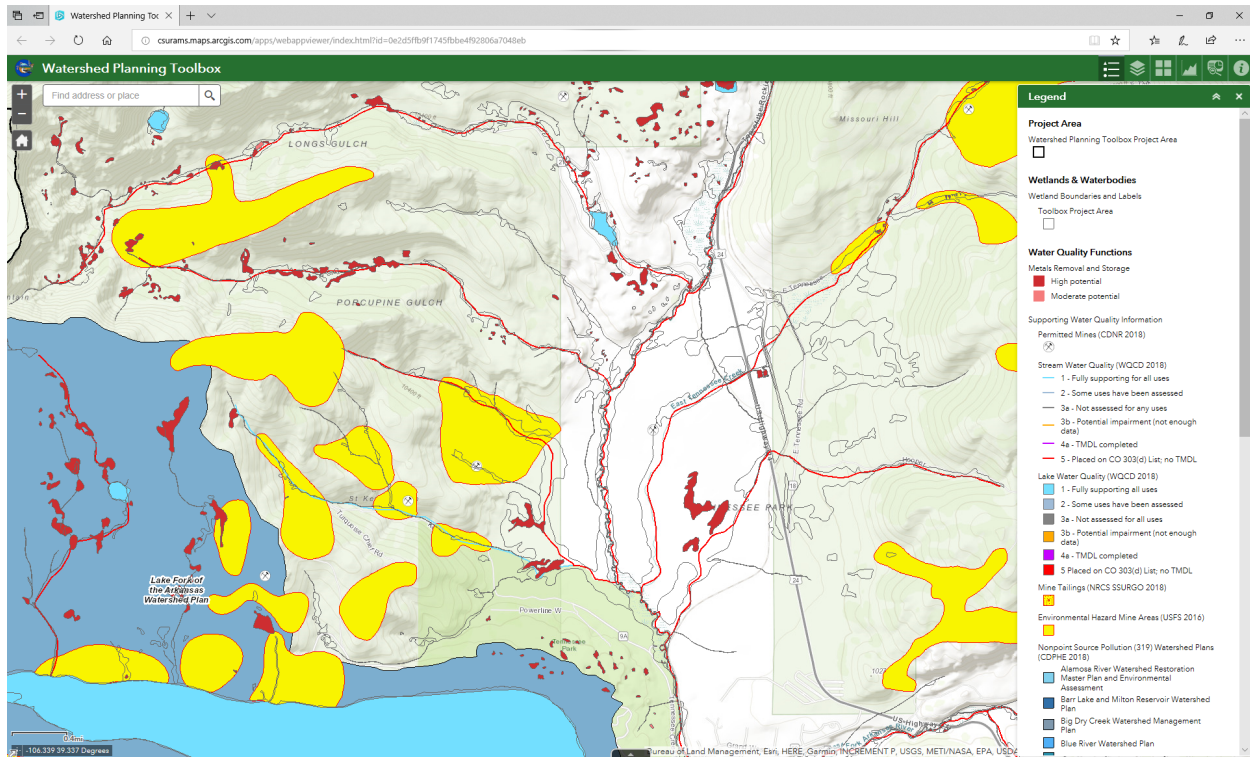


Figure 8. Screen shot from the Watershed Planning Toolbox mapper, showing the metal removal and storage function alongside a variety of supporting water quality geospatial data layers including abandoned mines, 303(d)-listed streams, permitted mines, and existing watershed plans related to nonpoint source pollution.

3.3.3 Supporting Web Content

CNHP created new web content to support the Toolbox, including six new pages and two revised and reorganized pages within the Colorado Wetland Information Center (CWIC) website, Colorado's most comprehensive wetland resource. The originally planned Toolbox rollout was delayed slightly to coincide with a complete overhaul and update of the CWIC website, as well as our main CNHP website, to ensure a seamless, current, more user-friendly, and easy-to-update web platform. We've provided a brief description of each page and sample screen captures for some of the key elements on each page below. The full website can be found at: <https://cnhp.colostate.edu/cwic/>, and a summary of the key pages associated with the Watershed Planning Toolbox (including screen shots) can be found in Appendix G.

4.0 RESULTS

All data developed for the Watershed Planning Toolbox can be explored through the Watershed Planning Toolbox mapper online. The results presented here provide only an overview of the major datasets developed. Many additional aspects of the data can also be viewed online.

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

The regionalized LLWW classification (see Section 2.3.1 and Appendix A) provided an intuitive hydrogeomorphic system for grouping wetlands and waterbodies. The codes can be parsed by Landscape Position, Landform, Waterbody Type, and Water Flow Path, as well as by numerous modifiers (shown online). For ease of interpretation, we grouped one or more combinations of Landscape Position and Landform or Landscape Position and Waterbody Type into logical HGM-like wetland and waterbody types.

There were 104,725 acres of wetlands and 37,195 acres of waterbodies mapped within the Toolbox Project Area (Figure 9, Tables 3 and 4). Roughly two-thirds of all mapped wetland acres (65,775 acres) were classified as slope wetlands (TESL) based on evidence of snowmelt, groundwater, or irrigation inputs. These acres include snowmelt-fed headwater wetlands in both watersheds, large fen complexes within South Park and the upper reaches of the Arkansas Headwaters, 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: 35,030 acres) or 2) sandbars (LOFR: 299 acres). Both of these types are driven by overbank flow from the major rivers and smaller tributaries. A smaller share of wetland acres were classified as either depressions (2,947 acres) or lakeshore wetlands (675 acres).

The primary flow path of mapped wetlands within the Project Area was throughflow (Table 3), indicating surface water flows through the wetlands at least seasonally. This flow path was applied to over two-thirds of the mapped wetland acres (69,268 acres), including all floodplain and sandbar wetlands, as well as slope wetlands within stream valleys and many irrigation-fed wetlands. Throughflow wetlands are conduits for water, sediment, and organic material and can absorb and transform constituents within the water. In addition, just over 30,000 wetlands acres were classified as outflow wetlands, the second most common flow path. These acres included all headwater and snowmelt-fed wetlands that feed into stream systems and toe-of-slope fens that discharge to streams. Only 227 acres of wetlands were classified as inflow wetlands, which are sinks of water from higher elevation. All inflow wetlands were playa basins within closed basins in South Park. The 675 acres of lakeshore wetlands were classified with the bidirectional flow path, which is reserved for wetlands dominated by the rise and fall of large lake levels. Altogether, throughflow, outflow, inflow, and bidirectional wetlands comprise the connected surface water network from source to sink. As headwater subbasins, the Project Area is dominated by outflow and throughflow wetlands. Lastly 4,326 acres were classified as vertical flow wetlands, meaning they lacked perennial or seasonal surface water connections with other wetlands or waterbodies, though ephemeral connections may exist.

Over half of the waterbody acres mapped in the Project Area were streams or canals (20,217 acres; Table 4). This number is likely inflated by the large number of temporary intermittent streams in the dataset. Many of these streams were burned into the NWI dataset based on NHD intermittent stream lines when NWI began including all NHD features. Current NWI data standards mandate that all NWI data are polygonal rather than linear features. To accommodate this standard, NHD intermediate stream lines were given a polygon width of three meters by default, though many of these features are likely narrower. While the 10,967 acres of temporary intermittent streams is likely inflated, the acreage for other waterbody types is likely accurate, as they were mapped from air photo interpretation. There were 14,406 acres of lakes, of which 13,322 acres are located within stream corridors (LOLK) while only 1,007 acres are situated at the headwaters of streams (TELK). The vast majority of these lotic lake acres are within artificially impounded reservoirs.

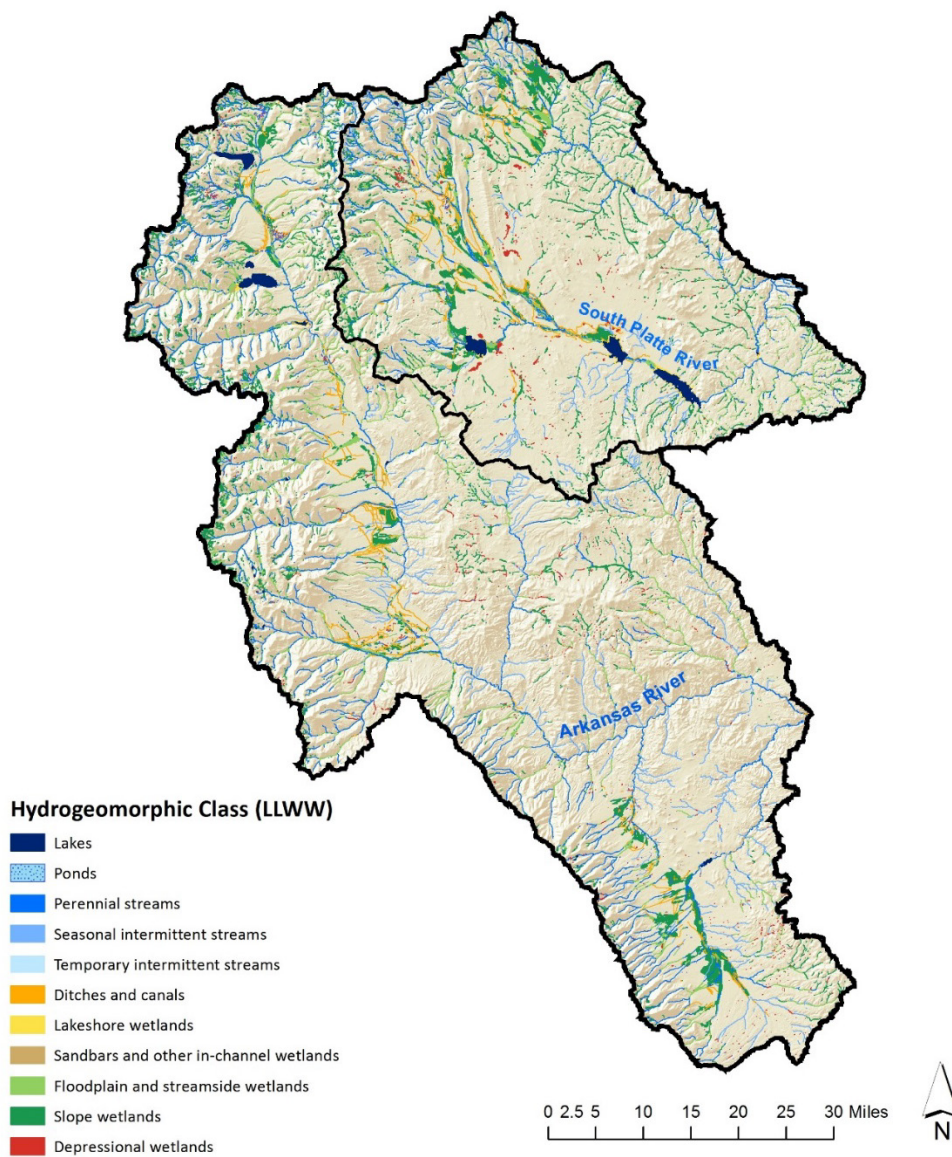


Figure 9. Map of wetlands and waterbodies within the Toolbox Project Area by grouped LLWW type.

Table 3. Wetland acres within the Toolbox Project Area by LLWW Landscape Position, Landform, and Water Flow Path.

<i>Landscape Position and Landform Groups</i>	<i>Water Flow Path (acres)</i>					<i>Grand Total</i>
	<i>IN (Inflow)</i>	<i>OU (Outflow)</i>	<i>TH (Throughflow)</i>	<i>BI (Bidirectional)</i>	<i>VR (Vertical Flow)</i>	
Lakeshore wetlands					675	675
LEFP (Lentic Floodplain)					543	543
LEFR (Lentic Fringe)					132	132
Floodplain and streamside wetlands			35,031			35,031
LOFP (Lotic floodplain)			35,031			35,031
Sandbars and other in-channel wetlands			299			299
LOFR (Lotic Fringe)			299			299
Slope wetlands		30,131	32,965		2,678	65,774
TESL (Terrene Slope)		30,131	32,965		2,678	65,774
Depressional wetlands	227	98	974		1,648	2,947
LOBA (Lotic Basin)			507		13	519
TEBA (Terrene Basin)	227	76	467		1,632	2,402
TEFR (Terrene Fringe)		23			3	25
Grand Total	227	30,229	69,268	675.1	4,326	104,726

Table 4. Waterbody acres within the Toolbox Project Area by LLWW Landscape Position, Waterbody Type, and Water Flow Path.

<i>Landscape Position and Waterbody Type Groups</i>	<i>Water Flow Path (acres)</i>						<i>Grand Total</i>
	<i>IN (Inflow)</i>	<i>OU (Outflow)</i>	<i>TH (Throughflow)</i>	<i>TB (Throughflow-Bidirectional)</i>	<i>BI (Bidirectional)</i>	<i>VR (Vertical Flow)</i>	
Lakes	34	577	76	13,323		397	14,406
LOLK (Lotic Lake)			76	13,323			13,399
TELK (Terrene Lakes)	34	577				397	1,007
Ponds	32	230	1,464		1	845	2,572
LEPD (Lentic Ponds)					1		1
LOPD (Lotic Ponds)			1,246			12	1,258
TEPD (Terrene Ponds)	32	230	217			834	1,313
Rivers and streams			20,217				20,217
LOST1 (Perennial streams)			5,485				5,485
LOST2 (Seasonal intermittent streams)			2,637				2,637
LOST3 (Temporary intermittent streams)			10,967				10,967
TEST5 (Ditches and canals)			1,128				1,128
Grand Total	66	807	21,757	13,323	1	1,242	37,195

4.2 Modeled Likely Wetland Functions

We modeled fourteen different functions, grouped into three different categories, likely performed by the wetlands and waterbodies within the Toolbox Project Area. Among the biodiversity and wildlife habitat functions, over half of the wetland and waterbody acres were rated as providing biodiversity conservation and aquatic invertebrate habitat (Table 5, Figure 10). The biodiversity conservation function was structured differently than most functions modeled. This 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 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, 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. Altogether, over 78,000 acres within the Project Area, or 55.0% of all wetland and waterbody acres, provide biodiversity conservation. The vast majority of those acres are in high or moderate landscape condition and are good candidates for conservation or protection. Only 6,378 of those acres are in poor landscape condition. A greater share of the wetlands within the South Platte Headwaters have high conservation value compared to the Arkansas Headwaters. This is driven primarily by the large fen and mire complexes located within South Park and the wider riparian floodplains at high elevation that support large beaver complexes.

In addition to general biodiversity support, over half the wetland and waterbody acres likely provide aquatic invertebrate habitat. Aquatic invertebrates, including insect larvae, inhabit a variety of wetland habitats from bare areas with flowing water in the mountains to vegetated areas with standing water in the plains. Larval and adult invertebrates provide a critical food source for fish (including trout and other recreationally important species), amphibians, reptiles, migratory shorebirds, wading birds, ducks and other waterfowl, mammals, and other wetland-dependent species, and often help break down leaves, woody material, algae, and other material in streams and other aquatic environments. The types of invertebrates present in a wetland or waterbody are often used as an indicator of water quality (temperature, dissolved oxygen, etc.). The acres modeled here provide an estimate of likely aquatic invertebrate habitat, but field sampling of macroinvertebrates would supplement the model.

Waterfowl and shorebird habitat is also provided by many wetland and waterbody acres across the Project Area. 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 suggest that 34% of wetland and water body acres 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 20% of wetland and waterbody acres provide habitat for shorebirds.

Table 5. Biodiversity and wildlife habitat functions performed by wetlands and waterbodies within the Toolbox Project Area by 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 all wetland and waterbodies acres each watershed and in the full Project Area.

<i>Biodiversity & Wildlife Habitat Functions</i>	<i>Wetland and Waterbody Acres</i>		<i>Total Acres</i>
	<i>South Platte Headwaters</i>	<i>Arkansas Headwaters</i>	
Biodiversity Conservation	41,769	36,323	78,092
	61.8%	48.9%	55.0%
Rare Species and Ecosystems			
High Landscape Condition	17,722	13,654	31,376
Moderate Landscape Condition	4,045	3,782	7,827
Poor Landscape Condition	1,246	2,349	3,594
High Biodiversity Support			
High Landscape Condition	13,694	9,544	23,238
Moderate Landscape Condition	4,220	5,052	9,272
Poor Landscape Condition	839	1,945	2,784
Aquatic Invertebrate Habitat	33,257	43,709	76,965
	49.2%	58.8%	54.2%
High	14,929	26,107	41,036
Moderate	18,328	17,602	35,929
Shorebird Habitat	7,708	19,533	27,240
	11.4%	26.3%	19.2%
High	4,131	1,811	5,941
Moderate	3,577	17,722	21,299
Waterfowl Habitat	23,457	25,104	48,561
	34.7%	33.8%	34.2%
High	22,189	24,168	46,357
Moderate	1,268	936	2,204

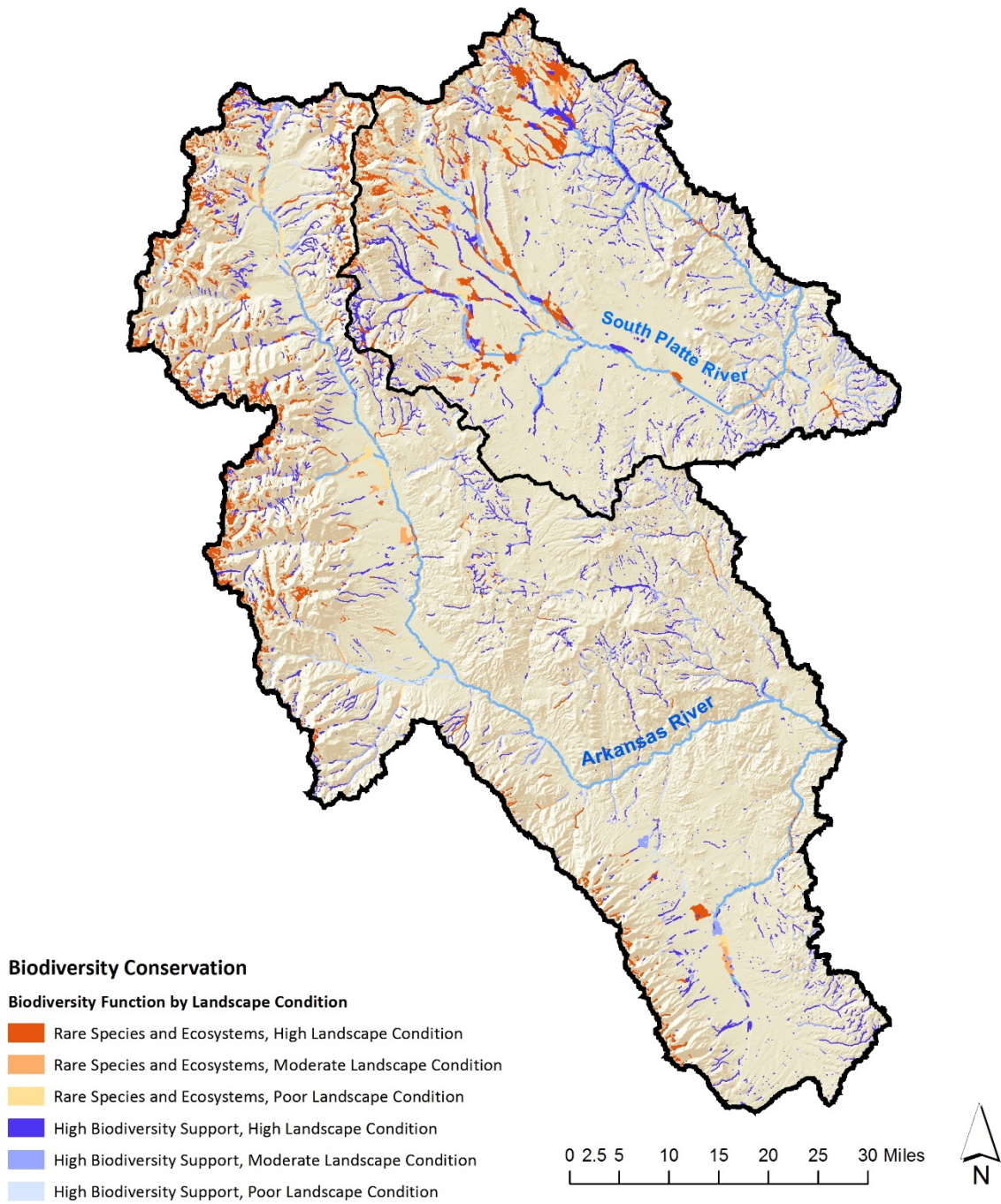


Figure 10. Map of biodiversity conservation function within the Toolbox Project Area.

Wetlands and waterbodies contribute to clean water through a number of different functions. Nearly 40% of wetland and waterbody acres likely reduce nitrogen through uptake and transformation (Table 6). 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. The large sloping wetland complexes in South Park are likely hotspots for nitrogen removal in the Project Area, as are the wider vegetated riparian corridors (Figure 11).

Modeled phosphorus removal is even higher than nitrogen removal. Nearly 60% of wetland and waterbody 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 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.

A smaller subset of wetlands within the Project Area (less than 15% of 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.

Many wetland acres across the Project Area provide at least moderate carbon storage and temperature regulation. 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. For temperature regulation, wetlands help maintain low surface water temperatures during the growing season in several key ways. First, many headwater wetlands are subsurface flow-through systems (including wetlands that intercept seeps and springs) that augment summer and fall base flows with cool groundwater. Second, wetlands collect and store surface water (including snowmelt), often in the subsurface, which can then be slowly released to streams and other waterbodies throughout the growing season. Finally, trees, shrubs, and other dense wetland vegetation can physically shade surface water—especially on smaller streams. Riparian forested wetlands and shrublands (including willow carrs and lowland willow thickets) often provide dense shade over surface water.

Table 6. Water quality and biogeochemical functions performed by wetlands and waterbodies within the Toolbox Project Area by 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 all wetland and waterbodies acres each watershed and in the full Project Area.

<i>Water Quality & Biogeochemical Functions</i>	<i>Wetland and Waterbody Acres</i>		<i>Total Acres</i>
	<i>South Platte Headwaters</i>	<i>Arkansas Headwaters</i>	
Nitrogen Uptake and Transformation	31,056	24,162	55,217
	45.9%	32.5%	38.9%
High	16,270	11,763	28,032
Moderate	14,786	12,399	27,185
Phosphorus Removal and Storage	35,293	41,274	76,567
	52.2%	55.5%	54.0%
High	907	2,471	3,378
Moderate	34,386	38,803	73,189
Metals Removal and Storage	15,224	5,136	20,360
	22.5%	6.9%	14.3%
High	3,061	4,563	7,624
Moderate	12,163	573	12,736
Carbon Storage	34,652	34,176	68,828
	51.3%	46.0%	48.5%
High	5,724	8,875	14,599
Moderate	28,928	25,301	54,229
Temperature Regulation	34,827	50,147	84,974
	51.5%	67.5%	59.9%
High	33,303	46,303	79,606
Moderate	1,524	3,844	5,368

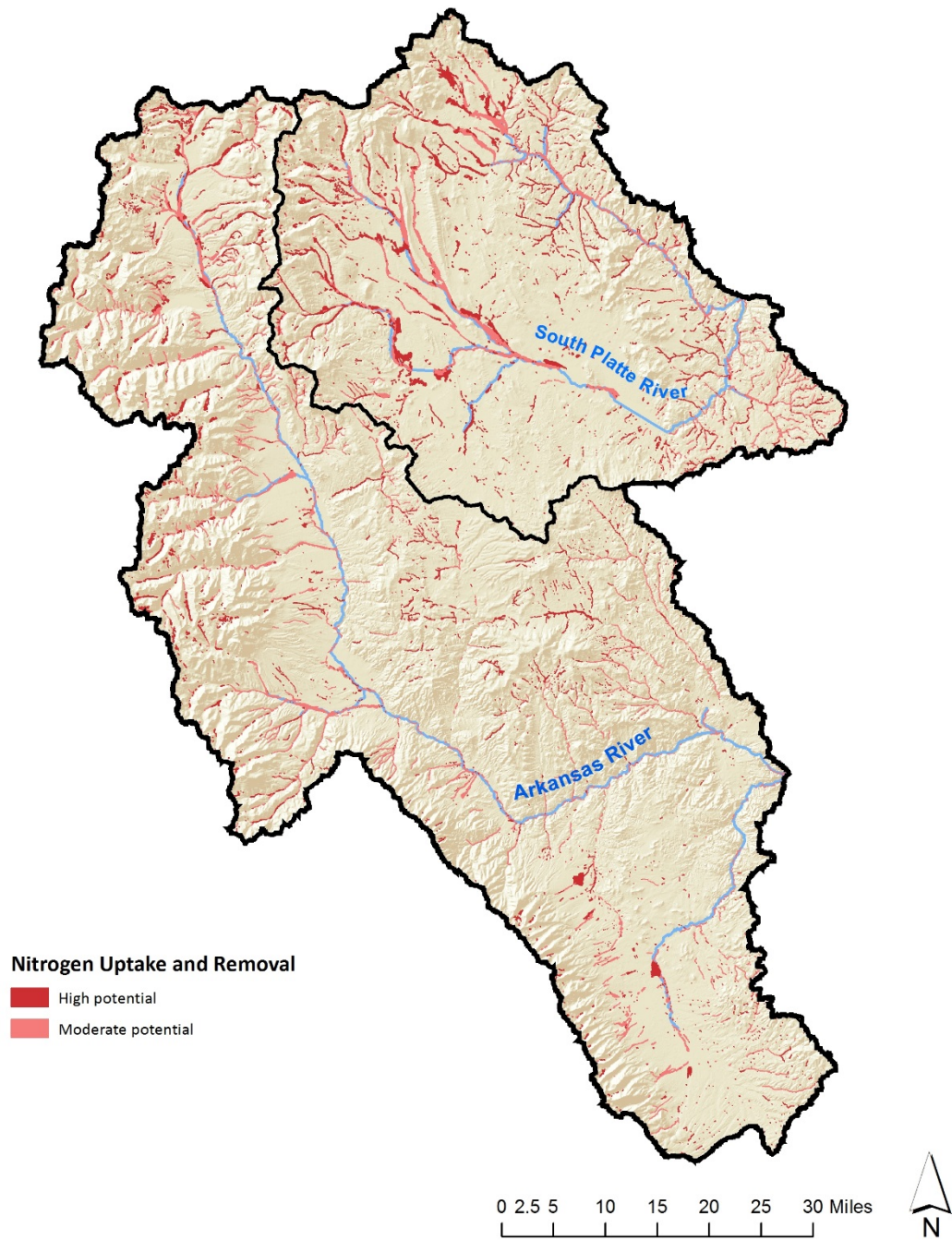


Figure 11. Map of nitrogen uptake and transformation function within the Toolbox Project Area.

Maintaining abundant water supplies for this generation and those to come is a paramount goal for the citizens of Colorado. 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, 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. Across the Toolbox Project Area, 18,208 acres of wetlands and waterbodies (12.8%) are able to store surface water (Table 8). The bulk of these 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.

A second chief concern regarding water quantity is flooding. Many types of wetlands store and delay water during rain storms or spring snowmelt; lowering and delaying peak flows and extending the overall duration of elevated stream flow. These wetlands can help save human lives and property downstream, buffer aquatic ecosystems from extreme peak flows, and store water during drier periods following floods. Wetlands with the greatest potential to attenuate flood flows include floodplain wetlands, and basins and ponds with available water storage capacity during peak runoff or flooding. Over 60,000 acres (42.6%) of wetlands and waterbodies likely attenuate flooding within the Project Area, and these acres are even split between the two watersheds. Flood waters often carry excess sediment, particularly following large forest fires.

A related function to flood attenuation is 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. 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 73,000 acres of wetlands and waterbodies (51.5%) provide some degree of sediment retention.

Wetlands augment both surface and ground water supplies through two additional functions, stream flow maintenance and groundwater recharge. Headwater wetlands collect and store water from precipitation, snowmelt, surface runoff, and groundwater seeps and springs that is then

discharged to streams and rivers during the growing season, or throughout the year. Often, wetlands help maintain stream base flows and cool water temperatures into the late summer and fall. These base flows sustain fish and other aquatic organisms, along with human water uses from fishing and whitewater boating to drinking water and irrigation. Groundwater recharge, or downward flow of water through the soil to replenish groundwater aquifers, is a commonly cited wetland function that varies spatially and temporally due to factors like subsurface geology, soil type, surface water depth, depth to impermeable soil or rock layers, regional and local groundwater flow gradients, and wetland water source(s) and outflow(s), and evapotranspiration rates (surface water evaporation + transpiration by plants). Many of Colorado's wetlands are groundwater discharge systems, as opposed to recharge-dominated systems, during all or part of the year. Select Colorado wetlands recharge local alluvial aquifers during all or part of the year (e.g., floodplain wetlands, many beaver complexes, and some irrigated wetlands), or other local and regional aquifers during spring snowmelt (e.g., kettle ponds) or summer monsoons (e.g., playas). Modeled results suggest that roughly 40,000 wetland acres maintain stream flows in the Project Area. Loss of these acres would require costly investments in surface water storage downstream. Another 49,467 acres of wetlands recharge the alluvial aquifer, at least to some degree and at certain periods of the year, and 2,667 acres of wetlands are in isolated locations where they recharge local non-alluvial aquifers.

Lastly, over 30,000 acres of wetlands help to stabilize shore and banks across the Project Area. Vegetated wetlands help to minimize waterbody shoreline and stream bank erosion from wave action and flowing water by providing structural stability for soil and sediment, and hydraulic (surface) roughness. The ability of wetlands to stabilize banks and shorelines depends on many environmental factors, including vegetation density, rooting depth, strength and structural complexity of vegetation (e.g., multi-layered vegetation canopies with a mixture of woody and emergent herbaceous plants), soil and/or sediment composition and structure, amount and distribution of bare soil and sediment, degree of soil and plant disturbance (e.g., from livestock or wild ungulate grazing), and the degree of alteration of the natural flow regime (streams), surface water levels (lakes and ponds), or wave action.

Table 7. Water quantity and geomorphic functions performed by wetlands and waterbodies within the Toolbox Project Area by 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 all wetland and waterbodies acres each watershed and in the full Project Area.

<i>Water Quantity & Geomorphic Functions</i>	<i>Wetland and Waterbody Acres</i>		<i>Total Acres</i>
	<i>South Platte Headwaters</i>	<i>Arkansas Headwaters</i>	
Surface Water Storage	10,078	8,130	18,208
	14.9%	10.9%	12.8%
Long-term storage	9,414	7,260	16,673
Seasonal Storage	664	870	1,535
Flood Attenuation	30,053	30,361	60,415
	44.5%	40.8%	42.6%
High	15,495	20,808	36,303
Moderate	14,558	9,553	24,112
Sediment Capture and Retention	34,386	38,803	73,189
	50.9%	52.2%	51.6%
Frequent, low intensity flooding	28,011	24,512	52,523
High intensity flooding	2,404	8,504	10,908
Both frequent and high intensity flooding	3,971	5,787	9,759
Stream Flow Maintenance	21,242	20,236	41,478
	31.4%	27.2%	29.2%
High	6,841	8,481	15,322
Moderate	14,401	11,755	26,156
Groundwater Recharge	19,848	32,287	52,135
	29.4%	43.4%	36.7%
Recharge of alluvial and floodplain aquifers	18,569	30,898	49,468
Recharge of non-alluvial aquifers	1,278	1,389	2,667
Bank and Shoreline Stabilization	15,738	14,878	30,616
	23.3%	20.0%	21.6%
High	4,798	11,542	16,340
Moderate	10,941	3,335	14,276

4.3 Mapped Potential Historical Wetlands

Potential historical wetlands (Figure 12) are synonymous with likely wetland loss and conversion to uplands, and may be used to identify potential restoration areas. CNHP identified over 32,600 acres of potential historical wetlands and riparian areas in the Project Area mapped with moderate or high confidence. These areas represent slope complexes and floodplains likely occupied by a dynamic mosaic of wetland and upland riparian habitats under historical stream flow, biological (including more extensive beaver activity), and geomorphic regimes. Please see Table 2 in Section 3.2.3 for more information on ecological systems, plant communities, and key processes associated with each wetland landform. Based on our review of available 1930s aerial photography, in which land use modifications like historical dredge mining and flood irrigation are often visible, many of these wetland losses occurred prior to the early 1900s. The conversion of existing wetlands to wetter or drier hydrologic regimes, including flooding by reservoirs, dewatering due to dampened stream peak flows and groundwater withdrawals, irrigation, excavation, and partial drainage, was not included in this analysis.

Over 16,400 acres of potential historical wetlands and upland riparian areas were mapped in the South Platte Headwaters subbasin, with the greatest wetland loss (62% of mapped acres) in sloping wetland complexes, followed by floodplain wetland complexes (31% of mapped acres). Of the 16,200 acres of potential historical wetlands and upland riparian areas mapped in the Arkansas Headwaters subbasin, the majority of wetland losses are concentrated around floodplain wetland complexes (64% of mapped acres), followed by sloping wetlands (34% of mapped acres). While fens account for a relatively minor proportion of the likely historical wetland acres (4% in the Upper South Platte and 2% in the Arkansas Headwaters), fens and mires likely existed in many areas mapped as sloping wetlands and along the margins of some floodplains, similar to their current distribution. Basins occupied the smallest portion of potential historical wetlands, primarily concentrated around kettle ponds and playas with hydrologic and/or land use modification in surrounding areas.

Table 8. Acres of potential historical wetlands within the Toolbox Project Area by type.

<i>Likely Wetland Type</i>	<i>South Platte Headwaters</i>		<i>Arkansas Headwaters</i>		<i>Total Acres</i>
	<i>Acres Mapped</i>	<i>% of Acres Mapped</i>	<i>Acres Mapped</i>	<i>% of Acres Mapped</i>	
Sloping wetlands	10,138	61.8%	5,485	33.8%	15,624
Floodplain wetlands	5,079	31.0%	10,413	64.2%	15,492
Fens	642	3.9%	330	2.0%	972
Basins	550	3.4%	1	0.0%	552
Total	16,410	100.0%	16,229	100.0%	32,639

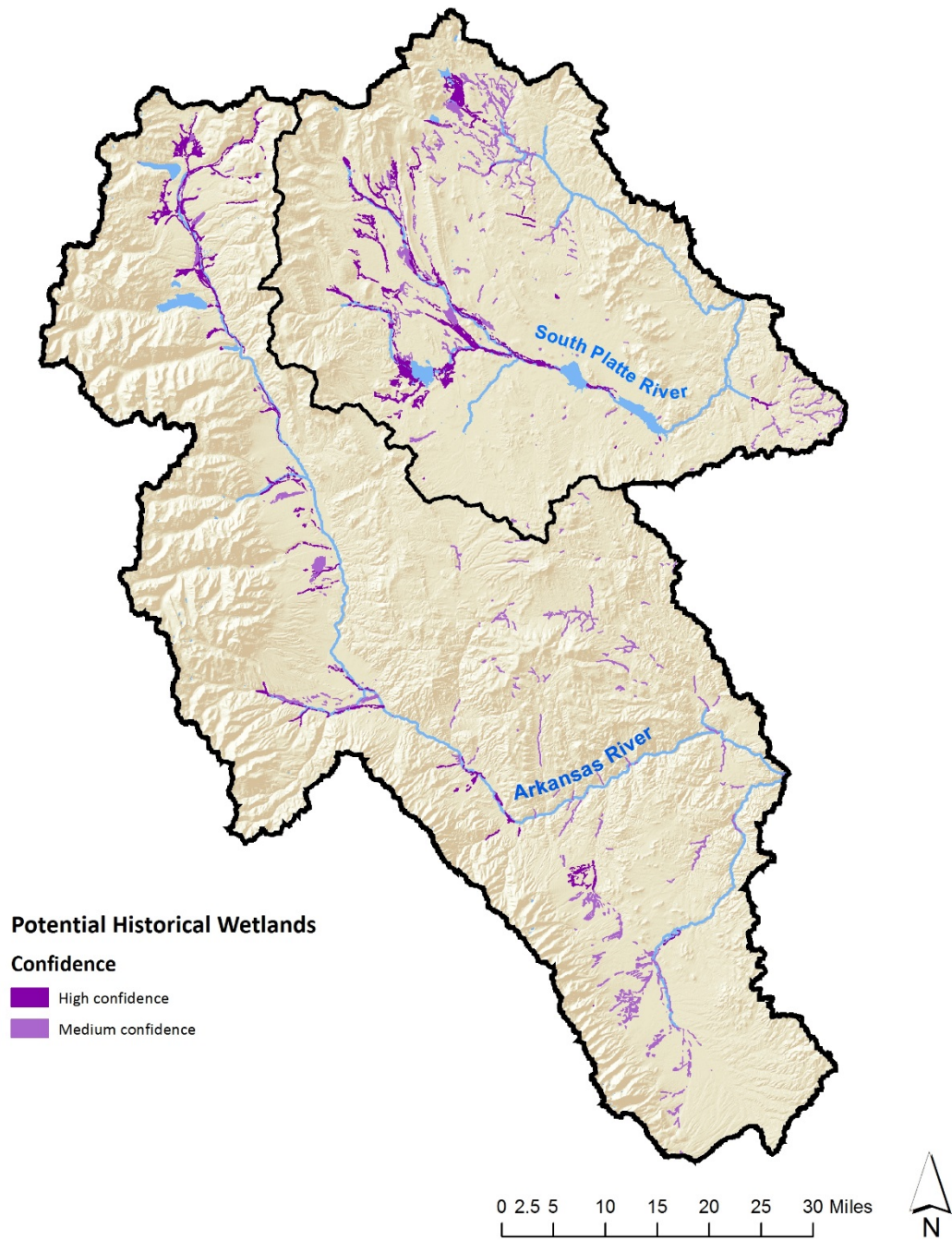


Figure 12. Map of potential historical wetlands within the Toolbox Project Area.

4.4. Updated Landscape Disturbance Index (LDI) Model

Human land use, both past and present, can impact wetland resources by altering hydrologic regimes, shifting plant communities, and disrupting natural soil processes. While some past landscape disturbances can be mitigated through earthwork, soil remediation and vegetation management, others are more permanent, like roads and housing development. Other human land uses, particularly irrigated agriculture, can augment wetland hydrologic inputs, and even create new wetland areas. At a time when natural peak flows have been damped and historical beaver populations dramatically reduced, flood irrigation is a key factor in maintaining wetland acres in many Colorado watersheds. The loss of nearly 90% of formerly irrigated acres in South Park contributed to wetland loss along the floodplains, especially in areas with stream channel incision and reduced lateral floodplain connectivity.

The updated Landscape Disturbance Index (LDI) provides a landscape-scale model of major land use disturbance across the Project Area (Table 9, Figure 13). Fortunately, as high-elevation headwater areas, the majority of both watersheds experiences minimal or low landscape disturbance. Of all wetland and waterbody acres in the Project Area, less than 30% face moderate or high disturbance. Wetlands within the Arkansas Headwaters face higher disturbance than in the South Platte Headwaters, primarily due to the larger human development footprint of cities and towns within the Arkansas Valley. Both watersheds have scattered low disturbance from agriculture and past mining activities.

Table 9. Acres of wetlands and waterbodies within the Toolbox Project Area by watershed and modeled disturbance class.

<i>Disturbance Class</i>	<i>South Platte Headwaters</i>	<i>Arkansas Headwaters</i>	<i>Total Acres</i>
Minimal or Low Disturbance	52,837	48,790	101,627
Moderate Disturbance	11,686	15,952	27,639
High Disturbance	3,074	9,582	12,656
Total	67,596	74,325	141,921

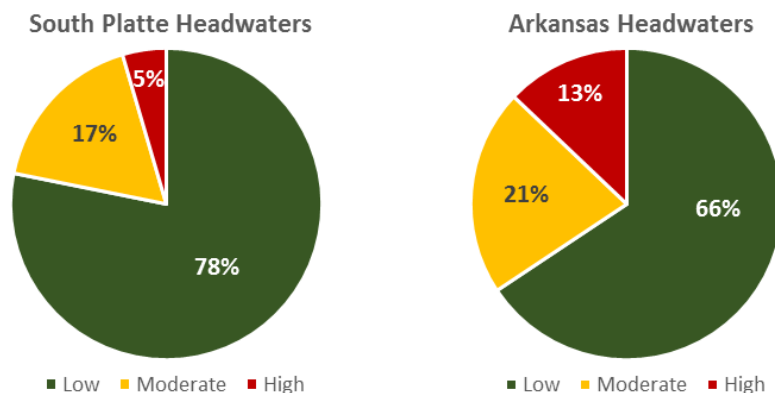


Figure 13. Proportion of wetland and waterbody acres within the Toolbox Project Area by watershed and modeled disturbance class

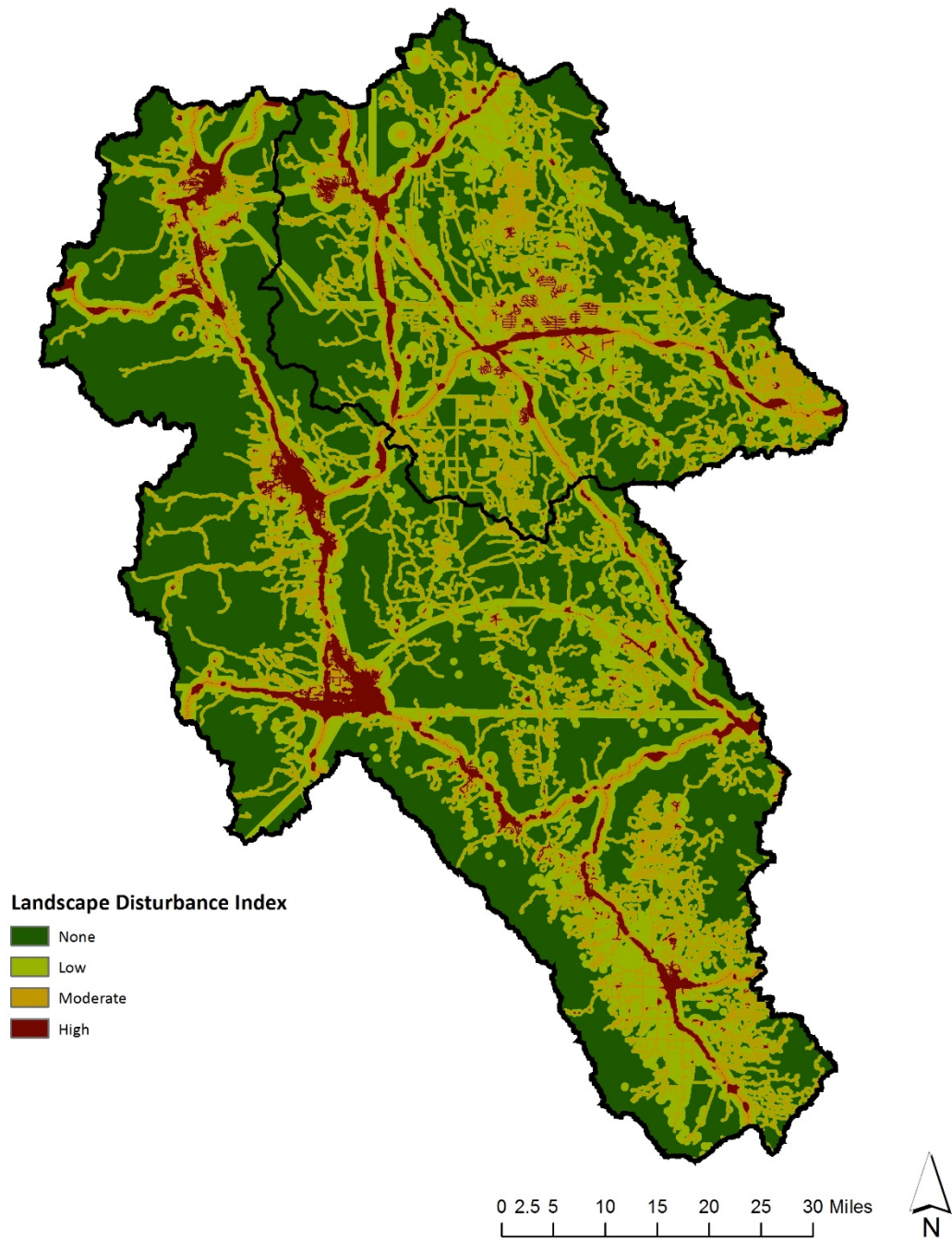


Figure 14. Map of the Landscape Disturbance Index model within the Toolbox Project Area.

5.0 OUTCOMES AND FUTURE DIRECTIONS

While developing the Watershed Planning Toolbox, CNHP actively worked with a variety of partners to ensure that the Toolbox would be useful and intuitive, and that partners could immediately begin using Toolbox components to support conservation and water resource planning and project implementation. We have listened to the needs of our wetland partners, as well as the broader Colorado conservation and water communities, and curated a set of data layers and resources that we hope will encourage more productive conversations around wetland conservation and restoration, as well as integrating wetlands into large-scale planning for future droughts, wildfires, and other statewide habitat conservation, water, human health, and economic concerns. Several ongoing efforts include:

Envision Chaffee County – Citizens of Chaffee County in the Arkansas Headwaters identified several key community priorities related to wetlands, including sustainable recreation, community wildfire planning, and supporting conservation efforts on working lands. Partners involved in the planning effort will be using the Watershed Planning Toolbox to evaluate wetland functions on farms and ranches to support potential future ecosystem services markets and conservation easements, identify sensitive areas for recreation management, and assist in incorporating wetlands into wildfire planning (see below). In November 2018, Chaffee County voters approved a ballot measure to levy an additional sales tax to help implement these three elements of the Envision plan.

Chaffee County Community Wildfire Protection Plan – CNHP is currently collaborating with Chaffee County, the Colorado Forest Restoration Institute at Colorado State University, and a variety of local, state, and federal fire managers to use Toolbox data layers to identify sensitive wetland habitats for targeted pre-fire treatments (e.g., forest thinning around large fen complexes to protect wetlands from post-fire erosion and sediment) and find opportunities to restore floodplain wetland complexes that may provide fire breaks during fires and help trap sediment and attenuate flooding following fires.

Colorado's Wetland Program Plan – CNHP is currently working with state partners that work in or with wetlands to identify statewide wetland priorities and actions. The Toolbox and associated web content have provided a platform for communicating wetland information with our state partners, and we have received valuable input from these partners on various aspects of the Toolbox. We will continue to use the Toolbox as a conversation platform, including discussions on connections between wetlands and wildlife habitat, water quality and water quantity at the subbasin scale.

The Arkansas Headwaters Wetland Focus Area Committee – AHWFAC will continue to utilize and expand upon prioritized restoration areas displayed in the Toolbox. Our partners in the South Platte Headwaters can now view prioritized restoration areas displayed for that portion of the Toolbox Project Area, and we hope that the Toolbox will be useful to the South Platte Headwaters Wetland Focus Area Committee if it becomes active again in the future.

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APPENDIX A: KEYS TO LLWW FOR INLAND WETLANDS OF THE WESTERN UNITED STATES

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Introduction

Wetlands occur in a wide variety of landscape settings across the western United States. 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), which emphasizes vegetation structure, hydroperiod, and certain natural and human modifications (e.g., beaver, excavated, impounded, partly drained, and farmed). This classification has been used by the USFWS National Wetland Inventory (NWI)⁷ since the 1970s to map wetlands across the conterminous U.S. and many outlying areas. The NWI Program now provides a seamless digital dataset of wetlands for nearly the entire nation. The Cowardin classification has proven very effective at characterizing diverse wetlands 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 system groups wetlands based on 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. To assist with the application of the LLWW classification, NWI's Ralph Tiner developed a series of dichotomous keys for LLWW codes (Tiner 2003; Tiner 2011; Tiner 2014) and these keys have been used for landscape-scale assessments of potential wetland functions in several states (e.g., Tiner & Bergquist 2003; Tiner et al. 2013; Stark et al. 2016).

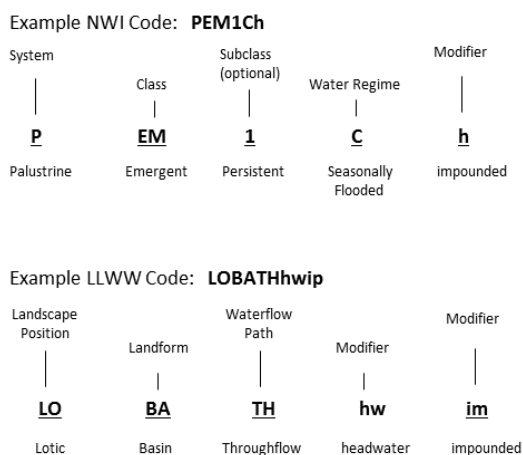
⁷ See the NWI website for more information: <https://www.fws.gov/wetlands/index.html>

The LLWW classification was originally developed in the eastern United States and has primarily been applied to wetlands east of the Great Plains. Wetlands in the western United States differ from eastern wetlands in many respects, due to differences in climate, geography, and common landscape stressors. The following keys are intended to guide the application of the LLWW classification to existing or newly created NWI data throughout the inland portion of the western United States⁸ following basic principles outlined in Tiner (2014). These keys do not apply to marine or estuarine wetlands. Specific aspects of these keys and associated codes are different from those presented in Tiner (2014) to better represent the Western landscape, including wetland types unique to arid and semi-arid climates, and to simplify the application of the classification.

How to Use These Keys

This document focuses on clear definitions for the major components of the LLWW coding system, along with specific modifiers that can be added to further refine the data. The basic structure of the LLWW code presented in this document is two letters for Landscape Position, two letters for wetland Landform OR Waterbody type (streams include an additional numeric character for stream flow duration), and two letters for Water Flow Path. Modifiers are applied at the end of the code as a string, separated with comma if the user desires. The resulting code is a minimum of six characters for the base codes (or seven for streams), with any number of modifiers at the end (Figure 1). All modifiers within this document are optional and can be added through visual inspection or overlays of ancillary data sources. Modifiers are grouped into four main categories: 1) natural characteristics, 2) human-influenced characteristics, 3) hydrologic characteristics, and 4) landscape characteristics.

(A) Wetland Feature Example (i.e., non-waterbody)



(B) Waterbody Feature Example (i.e., lake, pond, stream)

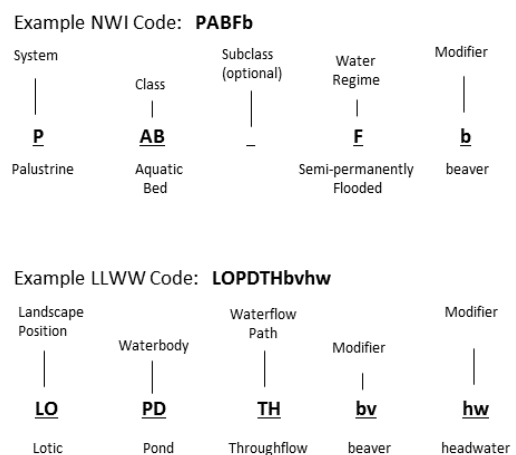


Figure 1. Example LLWW codes for (A) wetland and (B) waterbody features.

⁸ These keys apply to all inland wetlands within the states of AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, and WY.

In a Geographic Information System (GIS) database table, it may be helpful to users of this key to assign each component of the code separately in its own field. A typical table structure may contain fields for:

1. Landscape Position
2. Waterbody Type
3. Landform (optionally, Landform can be combined with Waterbody type, as the two fields are mutually exclusive; a polygon would either receive a Landform or Waterbody type code)
4. Flow Path
5. Modifiers (either one field for all modifiers or, preferably, a series of fields for each individual modifier)

Once all components have been assigned individually, a concatenated field can be populated to show the code as a single string. Alternatively, one field could be used for all the components of an LLWW code (Landscape Position, Landform, Water Flow Path, and modifiers). For example, TEBAVRbv for Terrene, Basin, Vertical Flow, beaver-influenced wetland.

When applying the LLWW classification with these keys, it is useful to assign codes to all waterbodies first, since wetland Landscape Position is directly related to proximity and connection to waterbodies. **Key A** includes all components of waterbody codes. Unlike wetlands, waterbodies are coded first by waterbody type, then by Landscape Position and Water Flow Path. The definition of a waterbody in LLWW is different than the definitions of Lacustrine or Riverine within the Cowardin classification; *it is important* to fully read Key A before applying any codes. See **Figure 1A** for an example of a waterbody code.

Starting with Key B, the remaining keys focus on wetlands. **Key B** is a key to wetland Landscape Position, **Key C** is a key to Landforms and Water Flow Paths for Lotic wetlands, **Key D** is a key to Landforms and Water Flow Paths for Lentic wetlands, and **Key E** is a key to Landforms and Water Flow Paths for Terrene wetlands. Modifiers for natural and human-influenced characteristics are specified throughout the keys under the Landforms to which they are primarily applied. Modifiers for hydrologic characteristics and landscape characteristics are listed separately in **Key F**. See **Figure 1B** for an example of a wetland code.

Sub-Appendix A-1 includes several important notes on applying the LLWW keys in particular situations. **Sub-Appendix A-2** includes an alphabetical list of all modifiers and rules for their application. Please review all modifiers in the Appendix, as not every potential modifier is incorporated into the main keys. Throughout the keys, NWI attribute rules provide guidance on the logical relationships between NWI and LLWW. However, most LLWW codes are not a direct crosswalk from NWI and additional considerations may be required. Within the NWI attribute rules and elsewhere in the document, the percent symbol (%) is used as a wild card signifying that any character could occupy that space in the attribute or code.

For the most part, LLWW codes should be applied to NWI mapping without further dividing NWI polygons. However, there are times when it may make sense to split NWI polygon so that multiple LLWW codes could be applied to separate areas of one polygon. Before making that decision, the

following points should be considered: 1) first and foremost, the resulting data will not be compliant with NWI data standards (i.e., adjacent polygons will have the same NWI attribute); 2) this could likely have significant effect on the scope of the mapping effort by creating additional work to split individual polygons; 3) there are many situations where the scale of the split is unrealistic to produce (e.g., separating narrow features along edge of a stream to separate Fringe Landforms from Floodplain Landforms). The decision to split NWI polygons rests with the photo-interpreter, who is presumably knowledgeable about wetlands within a project area and the proposed use of the LLWW data. While we caution against splitting NWI polygons, it may be desirable in some instances.

Crosswalk of LLWW Codes to Primary HGM Classes

One goal of producing this regionalized and simplified set of LLWW keys was to make the crosswalk between LLWW and HGM Class more straight-forward. There are only 10 base code combinations resulting from these keys. Those 10 codes are listed below with their crosswalk to primary HGM Classes (**Table 1**). HGM subclasses, which are generally defined by region, can often be derived based on LLWW modifiers and ancillary data sources. One advantage of LLWW is that it includes code combinations that indicate characteristics of more than one HGM Class. For instance, Lotic Basin (LOBA) describes depressions on a floodplain, which have characteristics of both Riverine and Depressional HGM Classes. Another example is Terrene Slope wetlands that occur within a geomorphic floodplain (TESL%fp). These wetland have characteristics of both Riverine and Slope HGM Classes and have been called “Sliverine” wetlands by some practitioners.

Table 1. Base LLWW Codes and Primary HGM Class.

<i>Base LLWW Code</i>	<i>Primary HGM Class</i>	<i>Secondary HGM Class</i>
Lotic Basin (LOBA)	Riverine	Depressional
Lotic Floodplain (LOFP)	Riverine	
Lotic Fringe (LOFR)	Riverine	
Lentic Basin (LEBA)	Lacustrine Fringe	Depressional
Lentic Floodplain (LEFP)	Lacustrine Fringe	
Lentic Fringe (LEFR)	Lacustrine Fringe	
Terrene Basin (TEBA)	Depressional	
Terrene Flats (TEFL)	Flats (Mineral or Organic)	
Terrene Fringe (TEFR)	Depressional	
Terrene Slope (TESL)	Slope	Riverine (if given the <i>fp</i> modifier)

Key A: Waterbodies

Key A begins by assigning waterbody type because waterbodies are often the easiest features to map (and automate in mapping), and the waterbody codes subsequently help determine Landscape Position, wetland Landform, and Water Flow Paths. The definition of a waterbody in LLWW is different than the definitions of the Lacustrine or Riverine System within the Cowardin classification, so *it is important* to fully read **Key A** before applying any codes. Please note that waterbody type occupies the same position in the LLWW code as Landform for wetland and can be populated in its own field in GIS or joined with wetland Landform in one field.

A-1: Waterbody Types

- 1a.** Waterbody has predominantly flowing water (when present) in a channel with defined bed and banks, and is a linear or polygonal feature on a U.S. Geological Survey (USGS) map (1:24,000) or within the National Hydrography Dataset (NHD) **Stream (ST)**
See Appendix A for NOTE 1 on LLWW Rivers and Streams.

Optional distinction between streams and rivers; if not differentiated, use Stream (ST) for all:

- i.** Waterbody is a polygonal feature (width >10 m or 33 ft) on a U.S. Geological Survey (USGS) map (1:24,000) or within the National Hydrography Dataset (NHD) **River (RV)**
NWI Attribute Rules: R1%, R2%, R3% (restricted to F, G, H water regimes), though the defining criteria is that the feature is a polygon within NHD.
- ii.** Waterbody is a linear or polygonal feature on USGS maps or in NHD **Stream (ST)**

*Go to **Key A-2** for River/Stream Flow Duration and Modifiers, **Key A-5** for Waterbody Landscape Position, then **Key A-6** for Waterbody Flow Paths.*

- 1b.** Waterbody has predominantly standing water **2**

- 2a.** Waterbody is permanently flooded and either large in size (>8 ha or 20 acres) or deep even at low water (≥2.5 m or 8.2 ft deep) **Lake (LK)**
*.....NW Attribute Rules: L1%, L2UB%, L2AB% (restricted to F, G, H, K water regimes).
See Appendix A for NOTE 2 on NWI Lacustrine System vs. LLWW Lakes.*

*Go to **Key A-3** for Lake Modifiers, **Key A-5** for Waterbody Landscape Position, then **Key A-6** for Waterbody Flow Paths*

- 2b.** Waterbody is small (<8 ha or 20 acres) and shallow (<2.5 m or 8.2 ft) **Pond (PD)**
.....NW Attribute Rules: PUB%, PAB% (restricted to F, G, H, K water regimes).

*Go to **Key A-4** for Pond Modifiers, **Key A-5** for Waterbody Landscape Position, then **Key A-6** for Waterbody Flow Paths*

A-2: River/Stream Flow Duration

River and streams within the LLWW classification are refined by flow duration, an ecologically important characteristic that affects their ability to support fish and other aquatic life, along with riparian vegetation and terrestrial wildlife. See Appendix A for **NOTE 1** on LLWW Rivers and Streams.

- 1a.** Natural flowing water feature (including features that have flow alteration due to dams and other impoundments, as well as streams and rivers that have been channelized)..... **2**
- 1b.** Flowing water feature (usually a linear and narrow shape) created solely for the purpose of water conveyance and built in an otherwise upland landscape
.....**Artificial Canal or Ditch (RV5/ST5)**
*NWI Attribute Rules: Most R%x features, but check for channelized natural streams.
Also check for vegetated ditches and canals mapped at PEM%x or PSS%x.
See Appendix A for NOTE 3 about artificial ditches vs. excavated and channelized streams*
- 2a.** Water flow is generally year-round.....**Perennial Flow (RV1/ST1)**
NWI Attribute Rules: R(1,2,3)UB%, generally with no 'x' but check for channelized natural streams.
- 2b.** Water flow is not year-round, generally only streams**3**
- 3a.** Water flow occurs for prolonged periods (usually more than a few weeks) and is generally seasonal in nature, lasting for much of the growing season.....
.....**Seasonal Intermittent Flow (ST2)**
*NWI Attribute Rules: R4SBC, generally with no 'x' but check for channelized natural streams.
Also check for vegetated channels mapped at PEM% or PSS%.*
- 3b.** Water flow is less than a few weeks, generally only streams**4**
- 4a.** Water flow occurs for briefer periods (from a few days to a few weeks) during the growing season.....**Temporary Intermittent Flow (ST3)**
*NWI Attribute Rules: R4SBA, generally with no 'x' but check for channelized natural streams.
Also check for vegetated channels mapped at PEM% or PSS%.*
- 4b.** Water flows for brief periods (usually less than a few days) and is tied to precipitation events; flow duration may extend beyond a few days during extremely wet years in arid regions
.....**Ephemeral Flow (ST4)**
*NWI Attribute Rules: R4SBJ, generally with no 'x' but check for channelized natural streams.
Also check for vegetated channels mapped at PEM% or PSS%.*

Further classification of LLWW Rivers and Streams is attributed with optional modifiers. More than one modifier may be applied, if appropriate. Modifiers below are divided into those that define natural characteristics and those that define human-influence characteristics. A polygon could have modifiers from both categories, as well as from Hydrology and Landscape modifiers listed in **Key F**.

Natural modifiers:

- i. Temporary or ephemeral stream in an arid region (*ST4 and ST3 only*); often used with the flashy hydrology modifier (fs)..... *arroyo (ay)*
- ii. River or stream influenced by beaver activity*beaver influenced (bv)*
- iii. River or stream located within a geomorphic floodplain (*all RV and ST features should receive this modifier*)*geomorphic floodplain (fp)*

Human-influence modifiers:

- i. Stream or canal used for agriculture purposes, such as crop production (including hay) or livestock watering.....*agricultural (ag)*
- ii. Natural stream that has been artificially straightened, redirected, or deeply incised from excess erosion..... *channelized (ch)*
- iii. Excavated channel, either natural or artificially dug into the upland landscape.....*excavated (ex)*
- iv. River or stream affected by dam used for hydropower*hydropower (hy)*
- v. Channelized river with a series of locks and dams to aid navigation (*ST1 only*)*lock and dammed (ld)*
- vi. River or stream affected by logging*logged (lg)*
- vii. River or stream affected by mining.....*mining (mn)*
- viii. River or stream modified by known restoration or enhancement activities (e.g., earthwork, planting, vegetation removal, beaver re-introduction, etc.)*restoration site (re)*
- ix. River or stream section with low dam(s) allowing flow during high water periods; often used for low-head hydropower generation or irrigation diversion(s) (*ST1 and ST2 only*)*run of river dammed (rr)*

You've completed the River/Stream Flow Duration Key.

Now go to Key A-5 for Waterbody Landscape Position.

All Rivers and Streams are generally given a Throughflow (TH) Water Flow Path.

See Key F for Hydrology and Landscape Modifiers.

A-3: Lakes

In this version of LLWW keys, all lakes receive the same code (LK). See Appendix A for **NOTE 2** discussing the difference between the NWI Lacustrine System and LLWW Lakes. Further classification of LLWW Lakes is attributed with optional modifiers. More than one modifier may be applied, if appropriate. Modifiers below are divided into those that define natural characteristics and those that define human-influence characteristics. A polygon could have modifiers from both categories, as well as from Hydrology and Landscape modifiers listed in **Key F**. Modifiers for ponds (see next page) may also be used for lakes, if applicable. Also see Appendix B for additional modifiers that may be possible for lakes.

Natural modifiers

Most appropriate for the following NWI Attributes: L1%, L2UB%, L2AB% (restricted to F, G, H water regimes) with no modifier.

- i. Lake influenced by beaver activity*beaver influenced (bv)*
- ii. Lake located within a geomorphic floodplain (up to the approximate 100-year floodplain boundary) *geomorphic floodplain (fp)*
- iii. Lake formed from an oxbow channel on a floodplain.....*oxbow (ox)*
- iv. Shallow lake, often saline, with fluctuating water levels depending on local precipitation patterns and extent of groundwater connection; typically with no natural outlet *playa (pl)*
- v. Lake located within the formerly glaciated Prairie Pothole region; water sources include direct precipitation, runoff from surrounding areas, and groundwater; generally associated with Quaternary glacial deposits such as moraines, glacial valleys, and outwash plains ..*prairie pothole (pp)*
- vi. Lake dominated by inputs from surface runoff, groundwater seepage and precipitation; may be subject to seasonal water level fluctuation; typically with no natural inlet or outlet..... *seepage lake (sl)*

Human-influence modifiers

Most appropriate for the following NWI Attributes: L1%, L2UB%, L2AB% (restricted to F, G, H, K water regimes) with 'h', 'm', or 'x' modifier.

- i. Lake excavated or impounded for mining of sand or gravel.....*gravel (gr)*
- ii. Lake is excavated or impounded.....*impounded (im) or excavated (ex)*
- iii. Dammed lake used for hydropower.....*hydropower (hy)*
- iv. Lake excavated or impounded for coal or hard rock mining, either a quarry lake or lake to capture mining waste*mining (mn)*
- v. Water levels are managed for wildlife (e.g., waterfowl habitat)*wildlife management (wm)*

*You've completed the **Lakes Key**.*
*Now go to **Key A-5** for Waterbody Landscape Position,*
*then **Key A-6** for Waterbody Flow Paths.*

A-4: Pond Subtypes

In this version of LLWW keys, all ponds receive the same code (**PD**). Further classification of LLWW Ponds is attributed with optional modifiers. More than one modifier may be applied, if appropriate. Modifiers below are divided into those that define natural characteristics and those that define human-influence characteristics. A polygon could have modifiers from both categories, as well as from Hydrology and Landscape modifiers listed in **Key F**. Modifiers for lakes (see preceding page) may also be used for lakes, if applicable.

Natural modifiers

Most appropriate for the following NWI Attributes: PUB %, PAB% (restricted to F, G, H water regimes) with no modifiers, except beaver (b).

- i. Pond formed by beaver activity*beaver (bv)*
- ii. Pond located within a peatland matrix (bog if precipitation-dominated or fen if groundwater-dominated)*bog (bg) or fen (fn)*
- iii. Pond contains a floating mat of vegetation*floating mat (fm)*
- iv. Pond located within a geomorphic floodplain (within the approximate 100-year floodplain)
..... *geomorphic floodplain (fp)*
- v. Pond located within a dune field*interdunal (id)*
- vi. Pond located within a formerly glaciated landscape (but not in the Prairie Pothole region) and formed by ice blocks left by retreating glaciers*kettle (kt)*
- vii. Pond formed from an oxbow channel on a floodplain*oxbow (ox)*
- viii. Shallow pond, often saline, with fluctuating water levels depending on local precipitation patterns and extent of groundwater connection *playa (pl)*
- ix. Pond located within the formerly glaciated Prairie Pothole region; water sources include direct precipitation, runoff from surrounding areas, and groundwater; generally associated with Quaternary glacial deposits such as moraines, glacial valleys, and outwash plains ..*prairie pothole (pp)*

Human-influence modifiers

Most appropriate for the following NWI Attributes: PUB%, PAB% (restricted to F, G, H, K water regimes) with 'h', 'm', or 'x' modifier.

- i. Pond used for agriculture or livestock watering*agricultural (ag)*
- ii. Pond used for aquaculture *aquaculture (aq)*
- iii. Pond is excavated or impounded*impounded (im) or excavated (ex)*
- iv. Pond situated within a golf course*golf (gf)*
- v. Pond is excavated or impounded for mining of sand or gravel*gravel (gr)*
- vi. Pond is excavated or impounded for mining of coal or hard rock, either a quarry pond or a pond to capture mining waste*mining (mn)*
- vii. Pond is used to detain or retain stormwater runoff*stormwater (sw)*
- viii. Pond is used for wastewater retention and/or treatment (e.g., oil and gas, domestic) wastewater (ww)
- ix. Water levels are managed for wildlife (e.g., waterfowl habitat)*wildlife management (wm)*

*You've completed the **Ponds Key**.*
*Now go to **Key A-5** for Waterbody Landscape Position,*
*then **Key A-6** for Waterbody Flow Paths.*

A-5: Waterbody Landscape Position

This key characterizes waterbodies based on their proximity to other waterbodies or in relative isolation. Please consider these rules:

- River and streams are generally classified within the Lotic (**LO**) Landscape Position and are not discussed in the key. However, Artificial Canals (**ST5**) can be classified as Terrene (**TE**) at the discretion of the user.
- Lakes can be classified as either Lotic (**LO**) or Terrene (**TE**) based on proximity to the stream network. Please note that lakes are **not** classified as Lentic (**LE**), even though they create the Lentic Landscape Position for associated ponds and wetlands.
- Ponds can be classified as Lotic (**LO**), Lentic (**LE**), or Terrene (**TE**) based on proximity to the stream network or to a large lake.

1a. Lake or pond is adjacent to, within the banks of, or on the *active* (approximately 1-5 year recurrence interval) channel or floodplain of a natural river or stream **and** is periodically flooded by the river or stream or strongly influenced by the alluvial aquifer. This includes reservoirs and other impounded lakes formed within a stream channel, oxbows and other floodplain ponds, and it includes ponds formed by natural depressions or artificial impoundments on ephemeral channels that are flooded when the channel flows and receive no major inputs other than flooding when the channel flows..... **Lotic (LO)**

1b. Lake or pond is not as described.....**2**

2a. Pond is located within the basin formed and influenced by a large lake or reservoir **and** experiences rising and falling water levels as a direct result of the lake or reservoir **Lentic (LE)**

2b. Lake or pond is surrounded by upland (non-hydric soils or filled lands that are now upland), or is located within the geomorphic floodplain of a river or stream **but** is not subject to frequent overbank flow (e.g., lake or pond in a headwater position feeding the stream, at a toe-of-slope on the edge of a stream valley, or on a disconnected upper floodplain terrace); hydrology is maintained primarily by groundwater discharge, surface runoff, precipitation and/or irrigation..... **Terrene (TE)**

The following are optional ways to differentiate the Terrene landscape position; they may be applied if additional data are available. Alternatively, the same information can be conveyed through modifiers, with TE1 = hw, TE2 = fp, and TE3 = no modifier.

- i.** Lake or pond occurs in a headwater position (*see Appendix A for NOTE 9 for a potential method of classifying headwaters*)..... Terrene Headwater (**TE1**)
- ii.** Lake or pond is located within the boundary of the geomorphic (approximately 100-year) floodplain of a river or stream, but is fed primarily by groundwater, surface runoff, and precipitation rather than overbank flow..... Terrene Riparian (**TE2**)
- iii.** Lake or pond occurs in an upland area, and not in a geomorphic floodplain Terrene Non-riparian (**TE3**)

***You've completed the Waterbody Landscape Position Key.**
Now go to Key A-6 for Waterbody Flow Paths.*

A-6: Waterbody Flow Paths

This key characterizes the primary surface Water Flow Path of waterbodies based on their proximity to a waterbody, in a drainageway, or in relative isolation. Please consider these rules:

- River and streams are automatically classified with the Throughflow (TH) flow path, even if the stream is ephemeral or the initiation point of a flow network. Rivers and streams are not discussed in the key.
- Lakes and ponds can be classified by several flow paths, however, please note that only lakes can receive the Throughflow-Bidirectional (TB) flow path.
- For small ponds embedded within wetland complexes, consider the flow path of the entire complex and not the internal paths within the complex.

- 1a. There is an observable perennial or seasonal surface water channel connecting the lake or pond with other waters either upstream or downstream; water may flow out of, into, or through the waterbody. This applies to ponds within natural depressions or artificial impoundments on intermittent channels that are flooded when the channel flows and receive no other major inputs, **but** this does not apply to ponds on floodplains that are not flooded, but connected through shallow alluvial groundwater2
- 1b. There are no observable perennial or seasonal surface water channels connecting the lake or pond with other waters upstream or downstream; surface water does not pass through the waterbody to other waters except through temporary (ST3) or ephemeral (ST4) drainages. Sources of water include non-channelized inputs of snowmelt, precipitation, local surface runoff, groundwater discharge, or shallow alluvial groundwater that is not connected via surface water channels5
- 2a. Waterbody receives surface water from a waterbody at a higher elevation **and** surface water passes through it to another waterbody at a lower elevation3
- 2b. Surface water flows **either out** of the waterbody to waters at a lower elevation **or into** the waterbody from waters at higher elevation; water does not flow through waterbody4
- 3a. Water flows through the waterbody, even if interrupted by small impoundments (e.g., impounded ponds along a stream channel); waterbody is not a lake with periodic raising or lowering of lake levels **Throughflow (TH)**
- 3b. Water flow is through a lake where residence time of water is generally longer and accompanied by periodic raising or lowering of lake levels; this often occurs in large dammed or excavated lakes or lakes situated in historic floodplains that are now separated by man-made or natural levees **Throughflow-Bidirectional (TB)**

- 4a. Water flows out of the waterbody via a river, stream, or ditch, with little or no observable surface water inflow (inflow could be from ephemeral drainages, non-channelized inputs of snowmelt, precipitation, local surface runoff, or groundwater discharge); waterbody serves as a source for surface water **Outflow (OU)**
- 4b. Water flow enters via a river, stream, ditch, or is pumped in, but does not exit the pond, lake or reservoir (outflow could be through ephemeral drainages or groundwater discharge); waterbody serves as a sink for surface water **Inflow (IN)**
- 5a. Waterbody is a large isolated lake and water levels fluctuate due to both rising and falling lake levels and wind-driven wave action **Bidirectional (BI)**
- 5b. Waterbody is a pond or small isolated lake; water levels rise as the pond or lake fills with precipitation, surface runoff, and/or groundwater discharge and lowers as water is evaporated or lost to groundwater seepage; wave action is rare or nonexistent. This can apply to Lotic or Lentic Ponds that lack a dominant surface water connection with a stream or lake but are driven by fluctuation in the aquifer **Vertical Flow (VR)**

*You've completed the **Waterbody Flow Path Key**.*
*Now go to **Key F** for **Hydrology and Landscape Modifiers***

Key B: Wetland Landscape Position

This key allows characterization of wetlands based on their location in or along a waterbody, in a drainageway, or in relative isolation. Wetland Landscape Position should be attributed by analyzing the proximity of each wetland polygon to waterbodies. See Appendix A for **NOTES 4 & 5** for more information on distinguishing Landscape Position.

- 1a.** Wetland is adjacent to, within the banks of, or on the *active* (approximately 1-5 year recurrence interval) channel or floodplain of a natural river or stream **and** is periodically flooded by the river or stream or strongly influenced by the alluvial aquifer. This also includes wetlands formed by natural depressions or artificial impoundments on ephemeral channels that receive no major inputs other than flooding when the channel flows **Lotic (LO)**

See Appendix A for NOTE 4 on Lotic vs. Lentic Landscape Position.

See Appendix A for NOTE 5 on Lotic vs. Terrene Landscape Position.

*Go to **Key C-1** for Lotic Landforms*

*Optionally, use **Key A-2** to add a River and Stream Duration numeral to the Lotic Landscape Position.*

- 1b.** Wetland is not as described **2**

- 2a.** Wetland is located along the shore of a lake or reservoir, within the basin formed by a lake or reservoir, or along a stream flowing through a lake basin **and** wetland experiences rising and falling water levels as a direct result of the lake or reservoir..... **Lentic (LE)**

*Go to **Key D-1** for Lentic Landforms*

- 2b.** Wetland or wetland complex is surrounded by upland (non-hydric soils or filled lands that are now upland), **or** is located within the geomorphic floodplain of a river or stream **but** is not subject to frequent overbank flow (e.g., wetland is in a headwater position feeding the stream, at a toe-of-slope on the edge of a stream valley, or on a disconnected upper floodplain terrace); hydrology is maintained primarily by groundwater discharge, surface runoff, precipitation and/or irrigation..... **Terrene (TE)**

The following are optional ways to differentiate the Terrene landscape position; they may be applied if additional data are available. Alternatively, the same information can be conveyed through modifiers, with TE1 = hw, TE2 = fp, and TE3 = no modifier.

- i.** Wetland occurs in a headwater position (see Appendix A for **NOTE 9** on a potential method of classifying headwaters) **Terrene Headwater (TE1)**
- ii.** Wetland is located within the boundary of the geomorphic (approximately 100-year) floodplain of a river or stream, but is fed primarily by groundwater, surface runoff, and precipitation rather than overbank flow **Terrene Riparian (TE2)**
- iii.** Wetland occurs in an upland area, and not in a geomorphic floodplain..... **Terrene Non-riparian (TE3)**

*Go to **Key E-1** for Terrene Landforms*

Key C: Lotic Landforms and Water Flow Paths

Lotic wetlands are primarily driven by streamflow, overbank flooding, and rising and falling alluvial groundwater. **Key C-1** defines the classification of Lotic Landforms and includes most commonly used modifiers. **Key C-2** defines the classification of Lotic Water Flow Paths. More than one modifier may be applied, in addition to Hydrology and Landscape modifiers listed in **Key F**. All Lotic polygons should receive the *geomorphic floodplain (fp)* modifier. Also see Appendix B for additional modifiers that may be possible for Lotic Landforms.

C-1: Lotic Landforms

- 1a.** Wetland occurs within or along the banks of a river or stream (often below the bankfull elevation), on the margin of an island in the streams, or on the shore of a pond embedded within a Lotic landscape **and** is either vegetated and semi-permanently flooded or permanently saturated due to this location **or** a non-vegetated shore that is temporarily flooded or wetter (e.g., gravel and sand bars)..... **Fringe (FR)**

*NWI Attribute Rules: P(EM,SS,FO)(F,D) or PUS(A or wetter) or R%US(A or wetter) and adjacent to a Stream/River (RV/ST) or Lotic Pond (LOPD)
See Appendix A for NOTE 6 on Fringe and Island Landforms.*

- i. Wetland formed along the shore of an island within the stream or river channel.....*island (il)*
- ii. Wetland formed along the shore of a pond within an active floodplain*pond fringe (pd)*

- 1b.** Wetland does not occur within or along the banks of a river or stream, along an island in the stream, or on the shore of a Lotic pond.....**3**

- 2a.** Wetland formed in a distinct depression within the floodplain, either a natural depression, such as an abandoned oxbow, or an excavated or impounded depression**Basin (BA)**

- i. Wetland occurs in a distinct depression along a river or stream, including recently active oxbows and meander scars.....*oxbow (ox)*
- ii. Depression formed by beaver activity, may be fully vegetated (PEM1Fb) or recently blown out (PUSCb)..... *beaver pond (bv)*
- iii. Excavated or impounded depression within a floodplain or along a stream channel
.....*impounded (im) or excavated (ex)*

- 2b.** Wetland forms the matrix vegetation on a (approximate) 100-yr floodplain above the bankfull elevation and is fed primarily by overbank flow and alluvial groundwater. This includes narrow vegetated bands along small streams, even if the stream corridor only has a narrow floodplain..... **Floodplain (FP)**

See Appendix A NOTE 7 on Floodplain Landforms.

- i. Wetland is influenced by beaver activity*beaver-influenced (bv)*
- ii. Wetland formed along the shore of an island within the stream or river channel.....*island (il)*

Go to Key C-2 for Lotic Flow Paths

C-2: Lotic Water Flow Paths

- 1a.** Hydrology within the wetland is dominated by surface water inputs from a stream or wetland associated with a stream through overbank flooding or through the alluvial aquifer and surface water outflow is to a stream, wetland, or other waterbody at a lower elevation. By default, all Lotic (LO) Fringe and Floodplain wetlands receive this flow path
..... **Throughflow (TH)**
- 1b.** Wetland lacks a dominant surface water connection with a stream or river; hydrology is driven by fluctuation in the alluvial aquifer in most years, and closely tied to stream or river stage. This flow path is generally reserved for Lotic Basins..... **Vertical Flow (VR)**

*You've completed the **Lotic Landform and Flow Path Keys.***
*Now go to **Key F** for Hydrology and Landscape Modifiers*

Key D: Lentic Landforms and Water Flow Paths

Lentic wetlands are primarily driven by rising and falling lake levels. **Key D-1** defines the classification of Lentic Landforms and includes most commonly used modifiers. **Key D-2** defines the classification of Lentic Water Flow Paths. More than one modifier below may be applied, in addition to Hydrology and Landscape modifiers listed in **Key F**. Also see Appendix B for additional modifiers that may be possible for Lentic Landforms.

D-1: Lentic Landforms

- 1a.** Wetland occurs along the shores of a lake, an island in a lake, or a pond embedded within a Lentic landscape **and** is either vegetated and permanently inundated, semi-permanently flooded or permanently saturated due to this location **or** a non-vegetated shore that is temporarily flooded or wetter **Fringe (FR)**
NWI Attribute Rules: P(EM,SS,FO)(F,D) or PUS(A or wetter) or L2US%(A or wetter) and adjacent to a Lake (LK) or Lentic Pond (TEPD)
See Appendix A for NOTE 6 on Fringe and Island Landforms.
- i.** Wetland formed along the margin of an island within a lake.....*island (il)*
 - ii.** Wetland formed along the outer margin of a Lentic pond.....*pond fringe (pd)*
- 1b.** Wetland does not occur along a shore.....**3**
- 2a.** Wetland occurs in a distinct depression within a Lentic landscape.....**Basin (BA)**
NWI Attribute Rules: Many code combinations could fall within the Landform, but they are generally wetter water regimes.
- i.** Depression formed by beaver activity, may be fully vegetated (PEM1Fb) or recently blown out (PUSCb)..... *beaver pond (bv)*
 - ii.** Excavated or impounded depression within a floodplain or along a stream channel
.....*impounded (im) or excavated (ex)*
- 2b.** Wetland exists in a nearly flat area within a Lentic landscape.....**Floodplain (FP)**
NWI Attribute Rules: Many code combinations could fall within the Landform, but they are generally drier water regimes.
See Appendix A NOTE 7 on Floodplain Landforms.
- i.** Wetland formed along the margin of an island within a lake.....*island (il)*

Go to **Key D-2** for Lentic Flow Paths

D-2: Lentic Water Flow Paths

- 1a. Wetland is associated with a river or stream flowing through the lake basin and is influenced by lake levels, such as wetlands along streams at the delta of a reservoir with fluctuating water levels.....**Throughflow-Bidirectional (TB)**
- 1b. Wetland is not associated with a river or stream flowing through the lake basin.....**2**

- 2a. Water levels fluctuate due to both rising and falling lake levels and wind-driven wave action **Bidirectional (BI)**
- 2b. Water levels rise as the lake fills and lowers as water is evaporated or lost to groundwater seepage; water levels lack a surface water connection to the lake in most years; hydrology is driven by groundwater fluctuations closely tied to lake levels.....**Vertical Flow (VR)**

*You've completed the **Lentic Landform and Flow Path Keys**.
Now go to **Key F** for **Hydrology and Landscape Modifiers***

Key E: Terrene Landforms and Water Flow Paths

Terrene wetlands are primarily driven by precipitation, overland flow, or groundwater discharge. They include wetlands fed by overland flow from the direct application of irrigation water, from excess irrigation run-off, and subsurface seepage from irrigation up-gradient, such as from a field or canal. They can be located far from a waterbody **or** adjacent to a waterbody, but with a separate water source. The water regime of a wetland identified in the NWI code can be useful in separating Terrene Landforms, but visual examination and ancillary data are often needed. **Key E-1** defines the classification of Terrene Landforms and includes most commonly used modifiers. **Key E-2** defines the classification of Terrene Water Flow Paths. More than one modifier may be applied, in addition to Hydrology and Landscape modifiers listed in **Key F**. Also see Appendix B for additional modifiers that may be possible for Terrene Landforms.

E-1: Terrene Landforms

- 1a.** Wetland occurs along the outer margin of a pond or the margin of an island within a pond embedded within a Terrene landscape and is either vegetated and semi-permanently flooded or permanently saturated due to this location **or** a non-vegetated shore that is temporarily flooded or wetter **Fringe (FR)**
Attributes: P(EM,SS,FO)(D,F) or PUS(A or wetter) and adjacent to or within a Terrene Pond (TEPD)
See Appendix A for NOTE 6 on Fringe and Island Landforms.
- ii.** Wetland formed along the margin of an island within a pond *island fringe (if)*
- iii.** Wetland formed along the outer margin of a pond..... *pond fringe (pf)*
- 1b.** Wetland does not occur along the outer margin of a pond or the margin of a pond island **2**
- 2a.** Wetland occurs in a distinct depression, typically round or oblong in shape, and collects water from the surrounding landscape in multiple directions **Basin (BA)**
- i.** Wetland is a floating mat of vegetation extending into or over open water..... *floating mat (fm)*
- ii.** Wetland is peat-accumulating, and has the minimum required organic soil depth (40 cm in the upper 80 cm) to qualify as a bog (precipitation-dominated) or fen (groundwater-dominated) *bog (bg) or fen (fn)*
- iii.** Wetland within the formerly glaciated Prairie Pothole region; water sources include direct precipitation, runoff from surrounding areas, and groundwater; generally associated with Quaternary glacial deposits such as moraines, glacial valleys, and outwash plains *prairie pothole (pp)*
- iv.** Shallow wetland, often saline, with fluctuating water levels depending on local precipitation patterns and extent of groundwater connection *playa (pl)*
- x.** Wetland located within a dune field *interdunal (id)*
- 2b.** Wetland does not occur in a distinct depression **3**

3a. Wetland occurs on a slope (typically >2%, but not always) **and** hydrology is largely influenced by groundwater discharging to the surface (including seepage of irrigation water), groundwater flowing laterally subsurface, or surface water flowing laterally across the site from snowmelt or overland flow (including the direct application of irrigation water)

..... **Slope (SL)**

NWI Attribute Rules: P(EM, SS, FO)(restricted to A, B, C, D, or E water regimes)

- i.** Wetland is peat-accumulating, and has the minimum required organic soil depth (40 cm in the upper 80 cm) to qualify as a bog (precipitation-dominated) or fen (groundwater-dominated)*bog (bg) or fen (fn)*
- ii.** Wetland has accumulation of peat, but not of sufficient depth to qualify as a bog or fen; often interspersed with, or along the margins of a bog or fen*mire (mr)*
- iii.** Wetland is managed as a hay field and/or pasture with grass cover*hayfield (hf)*
- iv.** Wetland is located on a geomorphic (approximately 100-year) floodplain, often at the edge or in some cases filling a narrow valley*geomorphic floodplain (fp)*
- v.** Wetland is located in a narrow valley*stream valley (sv)*
- vi.** Wetland is located at the base of a hill or slope.....*toe-of-slope (ts)*

3b. Wetland exists in a nearly flat area (<2% slope) **and** is fed primarily by precipitation **Flat (FL)**

- i.** Wetland occurs on saline soil, often with obvious salt crust visible*saline (sa)*
- ii.** Wetland is comprised of mineral soils*mineral (ml)*
- iii.** Wetland is peat-accumulating, and has the minimum required organic soil depth (40 cm in the upper 80 cm) to qualify as a bog (precipitation-dominated) or fen (groundwater-dominated)*bog (bg) or fen (fn)*

Go to Key E-2 for Terrene Flow Paths

E-2: Terrene Water Flow Paths

- 1a.** There is an observable perennial or seasonal surface water channel connecting the wetland with waterbodies either upstream or downstream; surface water may flow out of the wetland, into the wetland, **or** through it.....**2**
- 1b.** There are no observable perennial or seasonal surface water channels connecting the wetland and other wetlands or waterbodies upstream or downstream; surface water does not pass through the wetland to other waters except through temporary (**ST3**) or ephemeral (**ST4**) drainages. Sources of water include inputs of snowmelt, precipitation, local surface runoff, or groundwater discharge (including irrigation seepage) and water is lost to evaporation or groundwater recharge. Water movement may not always be in a vertical direction, but this flow path captures all wetlands that are not part of the flowing surface water network **Vertical Flow (VR)**
- 2a** Wetland receives surface water from a stream, other waterbody, or wetland at higher elevation **and** surface water passes through the wetlands to a stream, other waterbody, or wetlands at a lower elevation; a flow-through system **Throughflow (TH)**
See Appendix A for NOTE 8 on common uses of Terrene Throughflow wetlands.
- 2b.** Surface water flows **either** out of the wetland to waters at lower elevations **or** into the wetland from waters at higher elevations via a perennial or seasonal channel; water does not flow through the wetland.....**3**
- 3a.** Surface water flows out of the wetland via a perennial or seasonal channel, with little or no observable surface water inflow (inflow could be from ephemeral drainages, non-channelized inputs of snowmelt, precipitation, local surface runoff, or groundwater discharge). Headwater slope wetland complexes that contribute to stream channel initiation are considered outflow systems in this key **Outflow (OU)**
- 3b.** Surface water flows into the wetland via a perennial or seasonal channel, but does not exit the wetland (outflow could be through ephemeral drainages or groundwater recharge).....
 **Inflow (IN)**

*You've completed the **Terrene Landform and Flow Path Keys.**
 Now go to **Key F** for Hydrology and landscape Modifiers*

Key F: Hydrology and Landscape Modifiers

F-1: Hydrology Modifiers

The following codes are hydrology or flow path modifiers. More than one can be applied. They will occur at the end of the LLWW string along with all other modifiers. These may be applied if additional data are available and/or high resolution imagery and elevation data can allow for consistent interpretation of these features.

- i. Hydrologic regime is artificial, typically through ditches or pumps, or for diked/impounded wetlands along streams where hydrologic connectivity is regulated by water control structures *artificial flow (ar)*
- ii. Hydrologic regime is augmented by large trans-mountain or trans-basin diversions of water (*does not apply to the TE landscape*) *augmented flow (au)*
- iii. Wetland contributes to streamflow (e.g., sloped wetland adjacent to the stream or within a stream valley) *discharge to stream (ds)*
- iv. Hydrologic regime is considered flashy, or surface-runoff dominated, with high variability in the occurrence and magnitude of peak flow events; levels are often rainfall-driven and unpredictable; includes waterbodies in catchments with shallow soil and/or bedrock that are prone to flash flooding, as well as urbanized catchments with a high amount of impervious surfaces..... *flashy (fs)*
- v. Hydrologic regime is primarily groundwater-driven, such that levels are predictable and dominated by stable groundwater inflow for most (if not all) of the year..... *groundwater-driven (gw)*
- vi. Hydrologic regime is strongly influenced by irrigation, either direct application or seepage *irrigation-influenced (ir)*
- vii. Hydrologic regime is intermittent or ephemeral (including inflow driven by short duration precipitation event, including monsoonal events) *temporary intermittent flow (it)*
- x. Hydrologic regime is regulated by major dams or diversions upstream, such that the flow regime has been substantially altered in terms of the timing, frequency, magnitude, and duration of peak and low flows (*does not apply to the TE landscape*) *regulated flow (rf)*
- xi. Hydrologic regime, including mean annual flow and peak flows, is primarily driven by rainfall..... *rainfall (rn)*
- xii. Hydrologic regime, including mean annual flow and peak flows, is primarily driven by snowmelt..... *snowmelt (sn)*
- xiii. Hydrologic regime, including mean annual flow and peak flows, is driven by a mixture of snowmelt and rainfall..... *snow + rain (sr)*
- xiv. Waterbody or wetland is fed by a spring..... *spring-fed (sf)*

F-2: Landscape Modifiers

- i. Waterbody or wetland located above treeline *alpine (al)*
- i. Waterbody or wetland is located within a burn area perimeter *burn area (ba)*
- ii. Waterbody or wetland is located within a beetle kill area *beetle killed forest (bk)*
- iii. Waterbody or wetland is located within a historical or current glacial landscape *glacial (gl)*
- iv. Waterbody or wetland is located in the upper reaches of a watershed and often the source of a stream network (*see Appendix A for NOTE 9 on a potential method of classifying headwaters*) *headwaters (hw)*
- v. Waterbody or wetland is located on permafrost *permafrost (pf)*

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Sub-Appendix A-1: Notes on Applying the LLWW Keys

NOTE 1: LLWW Rivers and Streams. This characteristic may be identified by 1:24,000 U.S. Geological Survey topographic maps, high-resolution National Hydrographic Data (NHD), locally specific hydrography data, high resolution aerial imagery, or field gauge data or observations. While NHD may be used to inform the flow duration classification, the accuracy of NHD should be checked against streamflow data and/or aerial photography to ensure proper attribution. The terms within LLWW are intended to be consistent with NHD, but the resulting data may not be consistent with the NHD lines if the NHD is not accurate for a given area. Further classification of River/Stream Types is attributed with modifiers applied at the end of the River/Stream Type Code. If applying LLWW to newly created NWI mapping which maps Lotic features, these considerations would have already been made in determining NWI codes. Most LLWW rivers and streams will be mapped as Riverine features in NWI; however, there may be vegetated stream channels mapped as PEM% or PSS%. These will be difficult to pull out in an automated application of LLWW, but can be attributed as streams if LLWW attribution is applied at the time of mapping. If these features are not caught as streams in LLWW attribution, they should generally be attributed as Lotic Floodplain wetlands.

NOTE 2: NWI Lacustrine System vs. LLWW Lakes. The LLWW Lake definition is narrower than the Cowardin Lacustrine System. The Cowardin Lacustrine System includes all open waterbodies >8 ha (20 acres), regardless of depth or water permanence, and smaller open waterbodies if the deepest part of the waterbody is >2.5 m deep and the shoreline is formed by wave action or bedrock (USFWS 2015). Within the LLWW classification, all Cowardin Lacustrine Limnetic (L1) features deeper than 2.5 m, and Cowardin Lacustrine Littoral Subsystem (L2) features with relatively permanent water (L2UB or L2AB classes with water regimes of F, G, H or K) are considered Lakes. Polygons with less permanent water (L2US class with water regimes of J, A, or C) are considered wetlands instead of Lakes within LLWW. For instance, L2US polygons on the margin or otherwise associated with a Lake within LLWW are considered Lentic Fringe wetlands. If Cowardin lacustrine features occur as shallow waters that are not associated with a deeper or more permanent lake, they are considered either Terrene or Lotic wetlands depending on the proximity and influence of a stream. For example, a large, intermittently flooded playa lake mapped as Lacustrine Littoral Unconsolidated Shore Intermittently Flooded (L2USJ) in Cowardin because of its size would be considered a Terrene Basin rather than a Lake in LLWW.

NOTE 3: Artificial Ditches vs. Excavated and Channelized Streams. The NWI modifier of 'x' or excavated can be used on a variety of different channel, including ditches constructed within uplands, natural channels converted to ditches, and natural channels excavated or channelized for other purposes (to facilitate transportation or prevent erosion). If possible, these types of excavated system should be separated in LLWW. For ditches constructed with uplands, the LLWW code should be Lotic Artificial Canal Throughflow (LOST5TH). For natural streams used as ditches, the code should be Lotic Stream (appropriate flow duration) Throughflow channelized irrigation-influenced (LOST%THchir). For natural stream channels that are excavated or channelized for other purposes, the code should be Lotic Stream (appropriate flow duration) Throughflow channelized (LOST%ch). In addition, there can be stream that receive excess irrigation runoff, but

are not excavated for water conveyance. Those features would be coded Lotic Stream (appropriate flow duration) Throughflow irrigation-influenced (LOST%THir)

NOTE 4: Lotic vs. Lentic Landscape Position. Lentic wetlands consist of all wetlands in a lake basin (i.e., the depression forming the lake), including lakeside wetlands intersected by streams emptying into the lake and ponds within lake basins. The upstream limit of lentic wetlands is defined by the upstream influence of the lake, which is usually approximated by the limits of the basin within which the lake occurs. Lentic wetlands consist of all wetlands influenced directly by lake levels, including areas that are inundated only during high lake levels. Wetlands contiguous to the lake but at higher elevations and not in the lake basin should not be classified as Lentic; these wetlands should be treated as Terrene Outflow types in most cases. Lentic wetlands may include polygons attributed within the Cowardin Lacustrine Littoral Unconsolidated Shore class (L2US [restricted to J, A, C water regimes]), but only if they are adjacent to or associated with deeper or more permanent waters (i.e., F, G, H water regimes). See note in Key A-1.

NOTE 5: Lotic vs. Terrene Landscape Position. This note includes guidance on three specific situations where defining the break between Lotic and Terrene (or Terrene Riparian) Landscape Positions can be challenging.

- 1) As a rule, wetlands fed by artificial drainageways (i.e., ditches, canals, or stormwater conveyance channels) are considered Terrene. This includes wetland created by irrigation water that may be within or proximate to natural floodplains. The should be coded as Terrene Slope Throughflow irrigation-influenced (TESLTHir) if the irrigation water returns directly to the stream or Terrene Slope Inflow irrigation-influenced (TESLINir) if there is not a clear surface water connection back to the stream. These wetlands may receive a hayfield modifier, if appropriate.
- 2) In some stream valleys, wetlands can alternate between Lotic and Terrene depending on primary water source. Along headwater stream reaches, sloping groundwater-fed wetlands on the edges of the stream often contribute to baseflow. In many cases, the wetlands originate upslope of the geomorphic floodplain, but can extend to the edge of the stream channel. These groundwater-fed wetlands are often mapped with a B or D water regime in Cowardin, while polygons closer to the channel and flooded by the stream are mapped as E, C, or A water regimes. Wetlands located upslope of the floodplain and primarily fed by groundwater should be classified as Terrene Slope Outflow (TESLOU), even if other nearby wetlands are mapped as Lotic Floodplain Throughflow (LOFPTH). While most Terrene Slope wetlands receive an Outflow flow path, some Terrene Slope wetlands can actually fill the stream valley and have flow that is parallel to the valley. In many cases, these wetlands lack a defined channel, but are located in an obvious geomorphic valley and there can be a defined channel both above and below the wetland within the same valley. These Terrene Slope wetlands should receive a Throughflow flow path with a groundwater modifier (TESLTHgw).
- 3) A separate challenging distinction is in dry landscapes dominated by ephemeral drainages. In these landscapes, there are often many small impoundments along the ephemeral drainages created either to capture and retain water during floods or to control erosion.

These impoundments are often mapped as PUSAh or PEMAh in Cowardin. If there is no other obvious water source other than periodic flows of the ephemeral channel, they should be considered Lotic rather than Terrene. They are often classified as Lotic Basin Throughflow impounded temporary-intermittent (LOBATHimit).

NOTE 6: Fringe Landform and the Island modifier. Fringe wetlands are those occurring directly on the margins, shores, or banks of waterbodies and are directly and frequently influenced by the waterbody. They may also occur along the margins of islands within a waterbody or along a pond in any Landscape position. Vegetated Fringe wetlands must be very wet (see NWI Attribute Rules in the key) and border a permanent waterbody (e.g., floating mat vegetation, either rooted below the water surface or floating above the water surface, or emergent marsh vegetation along the shores of a lake or pond). Non-vegetated Fringe, such as sand bars, may occur along intermittent shores. Islands are any vegetated wetlands that occur on an island completely surrounded by water within a river, stream, lake, or pond. In the original Tiner LLWW keys, islands were called out as a separate Landform, yet there are places where a polygon met the criteria for a Fringe Landform and was located on an island, complicating the attribution. For the purposes of this classification, island has been converted to a modifier and any polygon on any type of island (fully wetland or a mix of wetland and upland, Fringe or Floodplain Landforms) receive the island (il) modifier, which simplifies the classification. Similarly, the key includes an optional pond modifier (pd) to signify that the Fringe is along the margin of a pond. No modifier is needed for Fringe Landforms on the outer shores or a lake (LEFR) or banks of a river or stream (LOFR). In addition, sections of marsh divided by ditching that are completely surrounded by water in the ditches are not considered Island for this classification.

NOTE 7: Floodplain Landforms. For the purpose of this classification, the term Floodplain is used for both Lotic and Lentic Landscape Positions. In both Landscape Positions, Floodplains represent the landform and associated vegetation that is influenced by streams or lakes, but is not on the immediate margins of the waterbody (Fringe) or within a distinct depression (Basin). In the original Tiner keys, the Flats Landform is used for Lentic landscapes. In this key, we have chosen to reserve the Flats Landform exclusively for the Terrene landscape to be most consistent with the HGM Class of Flats. Lotic Floodplain areas may be verified by consulting local and regional floodplain mapping, or using soil surveys and locating alluvial soils (e.g., Fluvaquents and Fluvents, or soils with Fluvaquentic subgroups). While active floodplains are considered part of the Lotic landscape, not all wetlands within the larger geomorphic floodplain are considered part of the Lotic landscape. Terrene wetlands with a groundwater source that originates outside the floodplain may occur along the edges of the floodplain or even fill a narrow stream valley. These would be considered Terrene with a floodplain modifier (TE%fp) or Terrene Riparian, if differentiated. These wetlands may still experience flooding in extreme events, but their primary water source is not the stream or alluvial aquifer. In some cases, wetlands on the historical geomorphic floodplain may be intentionally cut off from floodwater by dikes or levees.

NOTE 8: Terrene Throughflow wetlands. There are three common reasons for Terrene Throughflow wetlands. Also see **NOTE 5** above about distinguishing the Lotic vs. Terrene Landscape Position.

- 1) Irrigation-influenced wetlands, including flood irrigated hayfields, where water is diverted from a waterbody, typically a stream or reservoir, passes over the irrigated field, and returns to the stream in a contiguous surface flow path. In most instances, these sites would be classified as TESLTHfir.
- 2) Groundwater-fed wetlands that occur within a narrow stream valley and are fully integrated within adjacent Lotic Floodplain wetlands should be classified as TESLTHsvgw.
- 3) Wetlands with shallow bedrock or soil with perennial or seasonal overland flow from groundwater discharge, snowmelt, or other surface runoff upslope, including features like wetland basins and ponds nested in slope wetland complexes with a C or wetter NWI hydrologic regime indicating overland flow.

NOTE 9: Method for Classifying Headwater. There is no precise definition for the word headwaters, as it is relative to the scale of watershed under consideration and how the stream network is classified and mapped. For the purpose of this key, we recommend the following method for classifying headwater waterbodies and wetlands. Intersect all NWI polygons by HUC10 watersheds. Calculate the mean elevation of each HUC10 watershed and of each intersected NWI polygon. All NWI polygons with a mean elevation greater than the mean elevation of their HUC10 watershed should be considered headwaters.

Sub-Appendix A-2: LLWW Modifiers

Table 1: List of all LLWW modifiers used within the Western U.S. LLWW Keys, arranged alphabetically.

Code	Name	Description	Category
<i>ag</i>	<i>agricultural</i>	Waterbody or wetland used for agricultural purposes, such as crop production (including hay) or livestock watering.	Human-Influence
<i>al</i>	<i>alpine</i>	Waterbody or wetland is located above treeline	Landscape
<i>aq</i>	<i>aquaculture</i>	Waterbody or wetland used for aquaculture	Human-Influence
<i>ar</i>	<i>artificial flow</i>	Hydrologic regime is artificial, typically controlled through ditches or pumps or hydrologic connectivity is regulated by water control structures (e.g., diked/impounded wetlands along streams)	Hydrology
<i>au</i>	<i>augmented flow</i>	Hydrologic regime is augmented by large trans-mountain or trans-basin diversions of water	Hydrology
<i>ay</i>	<i>arroyo</i>	Temporary or ephemeral stream in an arid region (<i>ST3 and ST4 only</i>)	Natural
<i>ba</i>	<i>burn area</i>	Waterbody or wetland is located within a burn area perimeter	Landscape
<i>bg</i>	<i>bog</i>	Wetland (or waterbody within a wetland) is peat-accumulating, has the minimum required organic soil depth to qualify as a peatland (40 cm in the upper 80), and saturation is maintained by precipitation	Natural
<i>bk</i>	<i>beetle killed forest</i>	Waterbody or wetland is located within a beetle kill area	Landscape
<i>bv</i>	<i>beaver</i>	Waterbody or wetland formed or influenced by beaver activity	Natural
<i>ch</i>	<i>channelized</i>	River or stream has been artificially straightened or redirected or deeply incised from excess erosion	Human-Influence
<i>dr</i>	<i>partially drained</i>	Waterbody or wetland is partially drained	Human-Influence
<i>ds</i>	<i>discharge to stream</i>	Wetland contributes to streamflow (e.g., sloped wetland adjacent to the stream or within a stream valley)	Hydrology
<i>ex</i>	<i>excavated</i>	Waterbody or wetland is excavated	Human-Influence
<i>fm</i>	<i>floating mat</i>	Floating mat of vegetation extending into or over open water; can be used for the vegetation itself and the waterbody containing the vegetation	Natural
<i>fn</i>	<i>fen</i>	Wetland (or waterbody within a wetland) is peat-accumulating, has the minimum required organic soil depth to qualify as a peatland (40 cm in the upper 80), and saturation is maintained by groundwater discharge	Natural
<i>fp</i>	<i>geomorphic floodplain</i>	Waterbody or wetland is located within a geomorphic floodplain (up to the approximate 100-year floodplain boundary), even if fed by water sources outside the floodplain	Natural

Code	Name	Description	Category
<i>fs</i>	<i>flashy</i>	Hydrologic regime is considered flashy, or surface-runoff dominated, with high variability in the occurrence and magnitude of peak flow events; levels are often rainfall-driven and unpredictable; includes waterbodies in catchments with shallow soil and/or bedrock that are prone to flash flooding, as well as urbanized catchments with a high amount of impervious surfaces	Hydrology
<i>gf</i>	<i>golf</i>	Waterbody or wetland is located within a golf course	Human-Influence
<i>gl</i>	<i>glacial</i>	Waterbody or wetland is located within a historical or current glacial landscape	Landscape
<i>gr</i>	<i>gravel</i>	Waterbody or wetland is excavated or impounded for mining of sand or gravel	Human-Influence
<i>gw</i>	<i>groundwater-driven</i>	Hydrologic regime is primarily groundwater-driven, such that levels are predictable and dominated by stable groundwater inflow for most (if not all) of the year	Hydrology
<i>gz</i>	<i>grazed</i>	Wetland shows obvious signs of intensive grazing by livestock or native ungulates	Human-Influence
<i>hf</i>	<i>hayfield</i>	Wetland is managed as a hay field and/or pasture with grass cover	Human-Influence
<i>hs</i>	<i>hot-spring</i>	Waterbody or wetland is influenced by a geothermal spring (can be warm to hot)	Natural
<i>hw</i>	<i>headwater</i>	Waterbody or wetland is located in the upper reaches of a watershed and often the source of a stream network	Landscape
<i>hy</i>	<i>hydropower</i>	River, stream or lake is dammed for hydropower generation	Human-Influence
<i>id</i>	<i>interdunal</i>	Waterbody or wetland located within a dune field	Natural
<i>il</i>	<i>island</i>	Waterbody or wetland located on land completely surrounded by water within either a lake, pond, or stream (not formed by ditches that encircle the wetland)	Natural
<i>im</i>	<i>impounded</i>	Waterbody or wetland is impounded	Human-Influence
<i>ir</i>	<i>irrigation-influenced</i>	Hydrologic regime is strongly influenced by irrigation, either direct application or seepage	Hydrology
<i>it</i>	<i>temporary-intermittent flow</i>	Hydrologic regime is temporarily intermittent or ephemeral (including inflow driven by short duration precipitation event, including monsoonal events). Cowardin water regimes of A or J.	Hydrology
<i>kt</i>	<i>kettle</i>	Lake, pond, or wetland located within a formerly glaciated landscape (but not in the Prairie Pothole region) and formed by ice blocks left by retreating glaciers	Natural
<i>ld</i>	<i>lock and dammed</i>	Channelized river with a series of locks and dams to aid navigation (<i>ST1 and ST2 only</i>)	Human-Influence
<i>lg</i>	<i>logged</i>	Waterbody or wetland is subject to or within the perimeter of recent timber harvest area, particularly clear-cutting or other large-scale timber harvests	Human-Influence
<i>ml</i>	<i>mineral</i>	Wetland is comprised of mineral soils, within an emphasis on mineral soil flats rather than any mineral soil wetland	Natural

Code	Name	Description	Category
<i>mn</i>	<i>mining</i>	Waterbody or wetland is excavated or impounded for mining of coal or hard rock (e.g., quarry pond or pond to capture mining waste)	Human-Influence
<i>mr</i>	<i>mire</i>	Wetland has accumulation of peat, but not of sufficient depth to qualify as a bog or fen; often interspersed with, or along the margins of a bog or fen	Natural
<i>ox</i>	<i>oxbow</i>	Lake, pond, or wetland is located in a distinct depression within the floodplain of a river or stream, including recently active oxbows and meander scars	Natural
<i>pd</i>	<i>pond fringe</i>	Wetland formed along the shore of a pond	Natural
<i>pf</i>	<i>permafrost</i>	Waterbody or wetland is located on permafrost	Landscape
<i>pl</i>	<i>playa</i>	Shallow lake, pond, or wetland with fluctuating water levels depending on local precipitation patterns and extent of groundwater connection; typically with no natural outlet; can be saline or not	Natural
<i>pp</i>	<i>prairie pothole</i>	Lake, pond, or wetland located within the formerly glaciated Prairie Pothole region; water sources include direct precipitation, runoff from surrounding areas, and groundwater; generally associated with Quaternary glacial deposits such as moraines, glacial valleys, and outwash plains	Natural
<i>re</i>	<i>restoration site</i>	Waterbody or wetland has been modified by known restoration or enhancement activities (e.g., earthwork, planting, vegetation removal, beaver re-introductions, etc.); requires site-specific data to apply	Human-Influence
<i>rf</i>	<i>regulated flow</i>	Hydrologic regime is regulated by dam(s) or diversion(s) upstream, such that the flow regime has been substantially altered in terms of the timing, frequency, magnitude, and duration of peak and low flows (does not apply to the TE landscape)	Hydrology
<i>rn</i>	<i>rainfall</i>	Hydrologic regime, including mean annual flow and peak flows, is primarily driven by rainfall	Hydrology
<i>rr</i>	<i>run of river dammed</i>	River or stream section with low dam(s) allowing flow during high water periods; often used for low-head hydropower generation or irrigation diversion(s) (<i>ST1 and ST2 only</i>)	Human-Influence
<i>sa</i>	<i>saline</i>	Lake, pond, or wetland that occurs on saline soil, often with obvious salt crust visible	Natural
<i>sf</i>	<i>spring-fed</i>	Hydrologic regime includes inputs from a natural spring	Hydrology
<i>sl</i>	<i>seepage lake</i>	Lake dominated by inputs from surface runoff, groundwater seepage and precipitation; may be subject to seasonal water level fluctuation; typically with no natural inlet or outlet	Natural
<i>sn</i>	<i>snowmelt</i>	Hydrologic regime, including mean annual flow and peak flows, is primarily driven by snowmelt	Hydrology
<i>sr</i>	<i>snow + rain</i>	Hydrologic regime, including mean annual flow and peak flows, is driven by a mixture of snowmelt and rainfall	Hydrology

Code	Name	Description	Category
<i>sv</i>	<i>stream valley</i>	Slope wetland located in a narrow valley	Natural
<i>sw</i>	<i>stormwater</i>	Waterbody or wetland is used to detain or retain stormwater runoff	Human-Influence
<i>ts</i>	<i>toe-of-slope</i>	Slope wetland located at the base of a hill or slope	Natural
<i>wm</i>	<i>wildlife management</i>	Waterbody or wetland is managed for wildlife (e.g., waterfowl habitat); includes the management of water levels	Human-Influence
<i>ww</i>	<i>wastewater</i>	Waterbody or wetland is used for wastewater retention and/or treatment (e.g., oil and gas, domestic)	Human-Influence

Table 2: Natural and human-influence modifiers and rules for their application with wetland polygons. X = common application, o = less common application, gray cells = not applicable.

Code	Name	Wetland Types (Landscape Position and Landform)									
		LOBA	LOFP	LOFR	LEBA	LEFP	LEFR	TEBA	TEFL	TEFR	TESL
Natural: Modifiers that further refine the classification based on natural characteristics											
ay	arroyo	X	X								
bg	bog				X	X	X	X	X	X	X
bv	beaver	X	X	X	X	X	X	X	X	X	X
fn	floating mat	X		X	X		X	X		X	
fn	fen	o	o	o	o	o	o	X	X	X	X
fp	geomorphic floodplain	X	X	X	X	X	X	X	X	X	X
hs	hotspring	o	o	o	o	o	o	X		X	X
id	interdunal				X	X	X	X		X	X
il	island	X	X	X	X	X	X	o		X	o
kt	kettle				X			X			
ml	mineral								X		
mr	mire	X	X	X	o	o	o	X	X	X	X
ox	oxbow	X		X				X		X	
pd	pond fringe			X			X			X	
pl	playa							X		X	
pp	prairie pothole				X	X	X	X		X	
sa	saline	o	o	o	X	X	X	X	X	X	X
sv	stream valley										X
ts	toe-of-slope										X
Human-Influence: Modifiers that further refine the classification based on human-derived characteristics											
ag	agricultural	X	o	o	X	o	o	X	X	X	X
aq	aquacultural	X		o	X		o	X		o	
ch	channelized	X	X	X							
ex	excavated	X	o	o	X	o	o	X	o	o	o
gf	golf							X	X	X	X
gr	gravel	X	X	X	X	X	X	X	X	X	X
gz	grazed	X	X	X	X	X	X	X	X	X	X
hf	hayfield		X					X	X	X	X
im	impounded	X	X	X	X	X	X	X		X	
lg	logged	X	X	X	X	X	X	X	X	X	X
mn	mining	X	X	X	X	X	X	X	X	X	X
dr	partially drained	X	X		X	X		X	X	X	X
re	restoration site	X	X	X	X	X	X	X	X	X	X
sw	stormwater							X	X	X	X
ww	wastewater							X	X	o	o
wm	wildlife management	X	X	X	X	X	X	X	X	X	X

Table 3: Natural and human-influence modifiers and rules for their application with waterbody polygons. X = common application, o = less common application, gray cells = not applicable.

Code	Name	Waterbodies						
		ST1	ST2	ST3	ST4	ST5	LK	PD
Natural: Modifiers that further refine the classification based on natural characteristics								
ay	arroyo			X	X			
bg	bog						X	X
bv	beaver	X	X	X	X	X	X	X
fm	floating mat						X	X
fn	fen						o	X
fp	geomorphic floodplain	X	X	X	X	X	X	X
hs	hotspring	o	o	o	o	o	o	X
id	interdunal						X	X
il	island							X
kt	kettle						X	X
mr	mire						o	X
ox	oxbow						X	X
pl	playa							X
pp	prairie pothole						X	X
sa	saline						X	X
Sl	seepage lake						X	
Human-Influence: Modifiers that further refine the classification based on human-derived characteristics								
ag	agricultural	o	o	o	o	X	o	X
aq	aquacultural					o	o	X
ch	channelized	X	X	X	X	X		
ex	excavated	o	o	o	o	X	X	X
gf	golf						o	X
gr	gravel						X	X
hy	hydropower	X	X			X	X	X
im	impounded						X	X
ld	lock and dammed	X					X	
lg	logged	X	X	X	X	X	X	X
mn	mining	X	X	X	X	X	X	X
dr	partially drained						X	X
re	restoration site	X	X	X	X	X	X	X
rr	run of river dammed	X	X					
sw	stormwater					X		X
ww	wastewater							X
wm	wildlife management						X	X

Table 4: Hydrology modifiers and rules for their application with waterbody and wetland polygons and by flow path. X = common application, o = less common application, gray cells = not applicable.

Code	Name	Wetland Polygons										Waterbody Polygons						Flow Path							
		LOTIC			LENTIC			TERRENE																	
		BA	FP	FR	BA	FP	FR	BA	FL	FR	SL	ST 1	ST 2	ST 3	ST 4	ST 5	LK	PD	BI	TB	TH	IN	OU	VR	
Hydrology: Modifiers specific to hydrologic regime and flow path																									
ar	artificial flow	X	X	X	X	X	X	X		X	X					X	X	X		X	X	X	X		
au	augmented flow	X	X	X	X	X	X					X	X	X			X	X		X	X				
ds	discharge to stream							X		X	X					X	X	X			X		X		
fs	flashy	X	X	X				X		X			X	X	X			X			X				
gw	groundwater-driven	o	o	o	X	X	X	X		X	X		o	o			X	X	X		X		X	X	
ir	irrigation-influenced	o	o	o	o	o	o	X		X	X						X			X	X				
it	temporary intermittent flow	X	X											X	X			X			X				
rf	regulated flow	X	X	X	X	X	X					X	X	X			X	X		X	X				
rn	rainfall	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
sf	spring-fed	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
sn	snowmelt	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
sr	snow + rain	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table B-5: Landscape modifiers are applicable across all polygons.

<i>Code</i>	<i>Name</i>
<i>Landscape: Modifiers that can be applied to large areas of the landscape using ancillary data sources</i>	
<i>al</i>	<i>alpine</i>
<i>bk</i>	<i>beetle killed forest</i>
<i>ba</i>	<i>burn area</i>
<i>gl</i>	<i>glacial</i>
<i>hw</i>	<i>headwater</i>
<i>pf</i>	<i>permafrost</i>

APPENDIX B: 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 C.

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.

Aquatic Invertebrate Habitat

Aquatic invertebrates, including insect larvae, inhabit a variety of wetland habitats from bare areas with flowing water in the mountains to vegetated areas with standing water in the plains. Larval and adult invertebrates provide a critical food source for fish (including trout and other recreationally important species), amphibians, reptiles, migratory shorebirds, wading birds, ducks and other waterfowl, mammals, and other wetland-dependent species, and often help break down leaves, woody material, algae, and other material in streams and other aquatic environments. Depending on the duration of standing water, and other habitat characteristics like water chemistry and vegetation type, each wetland or waterbody may host an entirely different, yet diverse community of aquatic invertebrates. The types of invertebrates present in a wetland or waterbody are often used as an indicator of water quality (temperature, dissolved oxygen, etc.), and other habitat characteristics like the degree to which the natural hydrologic regime (including the magnitude, duration, frequency, rate of rise and recession, and variability in flows or water levels) has been altered by human water management.

Supporting Information for Model Development

In a review of aquatic invertebrate habitat preferences by Batzer and Wissinger (1996), invertebrates were found to inhabit a wide variety of habitats, from seasonally flooded systems to permanently flooded areas. Whiles and Goldowitz (2005) documented higher macroinvertebrate species diversity and productivity in intermittent and perennial wetlands. The only factors documented as consistently reducing habitat quality included sedimentation, and insecticides and herbicides in agricultural areas (Batzer and Wissinger 1996). Gleason et al. (2003) also observed impacts from sedimentation, including a 99.7% decrease in invertebrate emergence in soils from wetland basins in the Prairie Pothole region with sediment deposition depths as low as 0.5 cm.

Flow reduction, and the associated decrease in instream habitat diversity, is generally associated with decreased invertebrate species richness, though abundance may increase or decrease and degree of community alteration depends on the level of surface water diversions and other flow reductions (e.g., Rader and Belish 1999; McKay and King 2006; Dewson et al. 2007). Lammert and Allan (1999) found that assemblages of aquatic macroinvertebrates were strongly associated with local habitat drivers/conditions and that bed substrate size had a strong correlation with nearly every measure of macroinvertebrate community composition that they evaluated. Altered flow and sediment regimes are tightly coupled.

Mining activity, including dissolved metals and suspended sediments in downstream areas, had a strong negative correlation with overall macroinvertebrate biological integrity in a study of 86 different randomly located Colorado Rocky Mountain stream reaches (Griffith et al. 2005). Stream water containing elevated heavy metals in Colorado has been found to influence the composition and productivity of benthic invertebrate communities, and reduce the abundance of sensitive species at moderate to high metal concentrations (e.g., Clements 1994; Carlisle and Clements 2003). Caddisflies and other macroinvertebrates have demonstrated a similar sensitivity to acidic (low pH) water (Courtney and Clements 1998), which is often associated with mining pollution in the Rocky Mountains.

Temporary ponds (drying out each year) may support fewer aquatic macroinvertebrate species, but maintain species richness, rarity, and community composition (e.g., Collinson et al. 1995; Whiles and Goldowitz 2005). Created, or managed agricultural wetlands, including ponds and standing water in fields, and grazed pastures, often support diverse aquatic invertebrate populations (e.g., Colwell and Dodd 1995; Taft and Haig 2005; Davis and Bidwell 2008; Ruggiero et al. 2008). A study in France found that 40% of regional aquatic macroinvertebrate species, including several rare species, were found in agricultural ponds. Discing/plowing may reduce habitat quality, and diversity for macroinvertebrates (e.g., Davis and Bidwell 2008).

Based on the literature review, we used NWI water regime, LLWW modifiers for regulated flow and mining, LLWW landforms (basins), and average LDI scores to rank wetland polygons as having a high or moderate potential to provide aquatic invertebrate habitat. LDI scores were used to filter out ponds with a high likelihood of impaired water quality (heavy metals, low pH, pesticides, sediment, etc.) or soil disturbance, including tilled agricultural fields, mining ponds and some urban stormwater features.

Assumptions and Data Limitations

Aquatic invertebrate assemblages are generally dictated by factors that occur on smaller scales than NWI-level wetland mapping, and factors like ponding frequency and timing that may vary from year to year. Many small wetlands also fall below the minimum mapping threshold for NWI.

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; Plaunty 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.

Amphibian Habitat (models shown in Supporting Habitat Information in the Toolbox Mapper)

Wetlands provide critical breeding, foraging, and overwintering habitat for Colorado's 17 species of native amphibians. All of Colorado's amphibians require temporary or permanent standing water for breeding habitat, but many species spend the remainder of the year in adjacent terrestrial habitats. Some species, or individuals of a species, retain juvenile characteristics (neotenic larvae) and spend multiple years in standing water. Colorado's frogs, toads, and salamanders consume a variety of aquatic and terrestrial organisms for food, from aquatic insects, worms, crustaceans, mollusks, and other invertebrates to small vertebrates and sometimes algae and plants.

Amphibians have highly absorbent skin, and are particularly sensitive to water quality, including the presence of excess nutrients (eutrophication), pesticides and other synthetic chemicals, along with land use/management adjacent to the full range of habitats that they utilize throughout the year. Boreal toad populations have also been greatly reduced by the chytrid fungus (*Batrachochytrium dendrobatidis*), which is widespread across the toad's Colorado range. Many of the state's amphibians, including boreal toads and the state's only salamander (barred tiger salamander), are also restricted to narrow elevation or temperature ranges.

Model Development

Two CNHP inductive suitable habitat models are included for CPW Tier 1 amphibians, including the northern leopard frog and boreal toad. Model descriptions are taken directly from Fink and Siemers (2015).

Boreal toad (Southern Rocky Mountain population; *Anaxyrus boreas boreas*)

This is a Maxent (v. 3.3.3e) inductive model. CNHP EORs were used as known locations for the species. The model is based on 120 EORs, which were translated into 652 input points. 522 input points used for training, 130 for testing. Training AUC is 0.954, test AUC is 0.951. Model results with a value of 0.15 (15% probability of occurrence) or greater were retained, based on model performance statistics and expert review. The output extent was modified with a mask to limit extent to known range. This model was reviewed by Colorado zoology and wildlife professionals in 2011. Model variables include growing degree days, distance to water, elevation, summer precipitation, vegetation type, and landforms.

Northern leopard frog (*Lithobates pipiens*)

This is a Maxent (3.3.3e) inductive model. CNHP Element Occurrence Records (EORs) were used as known locations for the species. The model is based on 63 EORs and 646 Observations, which were translated into 846 species presence points. 631 input points were used for training and 157 for testing. Training AUC is 0.883, test AUC is 0.879. Model results with a value of 0.7 (70% probability of occurrence) or greater were retained, based on model performance statistics and expert review. No other modifications were made. This model was reviewed by Colorado zoology and wildlife professionals in 2011. Model variables include distance to water, elevation, vegetation type, distance to wetlands, and landforms.

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 mg/cm³ 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.

Temperature Regulation

Many of Colorado’s fish and other aquatic organisms occupy narrow thermal niches within streams and waterbodies. Water temperatures that are too high in the summer and fall can often lead to trout and other cold water fish mortality and increased susceptibility to disease, as well as allowing competition from non-native fish species. Wetlands help maintain low surface water temperatures during the growing season in several key ways. First, many headwater wetlands are subsurface flow-through systems (including wetlands that intercept seeps and springs) that augment summer and fall base flows with cool groundwater. Second, wetlands collect and store surface water (including snowmelt), often in the subsurface, which can then be slowly released to streams and other waterbodies throughout the growing season. Finally, trees, shrubs, and other dense wetland vegetation can physically shade surface water—especially on smaller streams. Riparian forested wetlands and shrublands (including willow carrs and lowland willow thickets) often provide dense shade over surface water.

Supporting Information for Model Development

Wetlands identified as having high potential to provide temperature regulation included headwater and snowmelt-driven wetlands that discharge to streams, fens and other groundwater-fed (discharge) wetlands that have a connection to streams, and forested riparian wetlands immediately adjacent to an intermittent or perennial stream or river. Wetlands identified as having a moderate potential to provide temperature regulation included other shrublands and woody plant communities along streams, including beaver-influenced wetland complexes.

Assumptions and Data Limitations

The model provides a landscape-scale assessment of potential temperature regulation, based on fundamental processes (e.g., likely groundwater discharge) and mappable landscape attributes. We acknowledge that this model does not capture site-scale spatial or temporal variations in temperature regulation, including the duration of snowmelt in mountain systems, degree of stream shading by trees and other riparian vegetation, and the amount of groundwater vs. surface water in a given wetland’s water budget.

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.

Flood Attenuation

Many types of wetlands store and delay water during rain storms or spring snowmelt; lowering and delaying peak flows and extending the overall duration of elevated stream flow. These wetlands can help save human lives and property downstream, buffer aquatic ecosystems from extreme peak flows, and store water during drier periods following floods. Wetlands with the greatest potential to attenuate flood flows include floodplain wetlands, and basins and ponds with available water storage capacity during peak runoff or flooding. Some headwater wetlands, including slope wetlands that are saturated during runoff or flooding events, may increase flood peaks during larger storm events, but delay surface runoff with vegetation during smaller storms.

Supporting Information for Model Development

Terrene wetland basins (with available storage capacity) and dry wetland soils (when peak precipitation occurs) have greater water storage potential during rainfall events (vs. wetlands that are saturated during rainfall or runoff events). Wetlands with little to no available storage capacity are more likely to generate runoff (e.g., Acreman and Holden 2013). Lindsay et al. (2004) observed that in glacially-influenced headwater catchments with bedrock-controlled basins (often with

organic soils) and abundant depressional and valley-bottom wetlands, bottomland wetland area (i.e., wetlands at, or within 10 m of a valley bottom landscape position), total wetland basin volume, total wetland area (and wetland area as a percent of catchment area), and gentle slopes were all moderately to strongly associated with peak flow attenuation. Interactions between wetland types, antecedent soil moisture, and wetland surface water connectivity were found to be critical to the ability of catchments to attenuate flood flow (Lindsay et al. 2004).

Floodplain wetlands and upland riparian areas that are not within the main channel (or the approximate floodway) have a high potential for storing flood flows (e.g., Bullock and Acreman 2003, in a review of 439 wetland water quantity studies), especially wetlands with woody vegetation (Acreman and Holden 2013). Artificially elevated water elevations (e.g., flood-irrigated areas or artificially impounded basins and ponds) and features like levees that disconnect stream channels and floodplains reduce flood storage capacity (Acreman and Holden 2013).

Wetlands ranked as providing a moderate flood attenuation function included floodplain wetlands and upland riparian areas not included in the “high” rank, along with features like beaver complexes that provide water storage during both peak flows and low flows (e.g., Wegener et al. 2017), but may have limited additional water storage capacity during a flood. The flood attenuation potential of beaver complexes is dependent on a variety of factors such as density of beaver dams, degree of valley confinement, peak flow magnitude, dam construction material (e.g., large wood vs. finer sediment), and available surface water storage capacity.

Other wetlands queried for moderate flood attenuation potential included wetlands with vegetation capable of impeding overland flow in headwater, precipitation-fed areas that have the potential to reduce flood peaks during lower-magnitude precipitation events (Acreman and Holden 2013). This query was restricted to gently sloping wetlands (less than 2% slopes).

Assumptions and Data Limitations

The flood attenuation rankings in this model are not intended to serve as a substitute for FEMA floodplain maps or more detailed evaluations of flood routing and water storage (e.g., hydraulic modeling using high-resolution LiDAR-derived digital elevation models and field survey verification). The ability of wetlands to store and delay peak flows is highly dependent on factors like antecedent soil moisture conditions (or surface water storage), and these factors are often highly variable over space and time. Many of Colorado’s peak flow or flood events occur either during spring snowmelt, or during the summer and fall (e.g., flash flooding). Wetlands that are wet from the spring into early to mid-summer may have sufficient storage capacity for summer and fall rain.

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.

Stream Flow Maintenance

Headwater wetlands collect and store water from precipitation, snowmelt, surface runoff, and groundwater seeps and springs that is then discharged to streams and rivers during the growing season, or throughout the year. Often, wetlands help maintain stream base flows and cool water temperatures into the late summer and fall. These base flows sustain fish and other aquatic organisms, along with human water uses from fishing and whitewater boating to drinking water and irrigation.

Supporting Information for Model Development

Base flow in many Colorado streams is often a combination of local and regional groundwater discharge (Winter 1999). Wetlands identified as augmenting base flows in streams and rivers include many groundwater-dependent ecosystems with hydrologic regimes that are dominated by subsurface lateral flow of groundwater. While these wetlands are not “generating” base flow, they often serve as critical intermediaries that store and delay groundwater moving through them, maintain low water temperatures, and maintain or improve the quality of water passing through them (e.g., Owen and Otton 1995).

Headwater wetlands with a seasonally or permanently saturated (e.g., fens) or wetter hydrologic regime, and outflows to streams or rivers or a stream discharge modifier were ranked as having a high potential to maintain base flows.

Beaver-influenced wetlands provide in-stream/floodplain low-flow attenuation (via water storage, raising the water table, and altering hydraulic gradients) upstream and downstream of dams (e.g., Hammerson 1994; Westbrook et al. 2006; Wegener et al. 2017), and were ranked as having moderate potential to maintain base flows.

Assumptions and Data Limitations

This model does not account for variability in the volume and timing of wetland discharge to streams, including the volume of water contributed per wetland area. It can be assumed that large wetland complexes are likely to provide more stream flow maintenance than small wetlands.

Groundwater Recharge

Groundwater recharge, or downward flow of water through the soil to replenish groundwater aquifers, is a commonly cited wetland function that varies spatially and temporally due to factors like subsurface geology, soil type, surface water depth, depth to impermeable soil or rock layers, regional and local groundwater flow gradients, and wetland water source(s) and outflow(s), and evapotranspiration rates (surface water evaporation + transpiration by plants). Many of Colorado’s wetlands are groundwater discharge systems, as opposed to recharge-dominated systems, during all or part of the year. Select Colorado wetlands recharge local alluvial aquifers during all or part of the year (e.g., floodplain wetlands, many beaver complexes, and some irrigated wetlands), or other local and regional aquifers during spring snowmelt (e.g., kettle ponds) or summer monsoons (e.g., playas).

Supporting Information for Model Development

Kettle ponds have been documented to provide groundwater recharge in spring and early summer (Johnson and Steingraeber 2007). Some mountain lakes and ponds collect snowpack and snowmelt runoff and provide focused recharge along their margins, leading to temporary or relatively permanent water table mounding and enhanced groundwater percolation (e.g., Winter 1999). Seepage lakes, by definition, provide groundwater recharge. Increasing lake depth can also lead to increased seepage (to groundwater) (Winter 1999). While we currently lack data to confirm the presence of true seepage lakes, we can identify waterbodies with the potential for seepage, including waterbodies in glacial terrain and waterbodies lacking distinct intermittent or perennial inflows and outflows.

Streams, rivers, floodplain wetlands fed by stream flow/overbank flow (e.g., Acreman and Holden 2013) and irrigated areas (along with delivery ditches and canals) on unconsolidated alluvium, glacial outwash, and basin-fill deposits may recharge groundwater—particularly in late spring and early summer following peak snowmelt (e.g., Watts 2005; Watts et al. 2014). Beaver complexes may enhance groundwater recharge to the alluvial aquifer due to increased extent and depth of surface water, as well as lateral connectivity between streams and floodplains (e.g., Westbrook et al. 2006).

Playas in the Southern High Plains may have locally high recharge rates (12.7-82 mm/yr; Nativ and Riggio 1989), though recharge rates may be highly variable and most playa hydrologic studies reporting recharge have been conducted in New Mexico and Texas (e.g., Wood and Sanford 1995; Gurdak and Roe 2010). Playas providing groundwater recharge tend to be less saline (evaporite minerals) than playas that receive groundwater discharge (Rosen 1994). Recharge rates for Colorado playas need further field research.

Assumptions and Data Limitations

Groundwater recharge is a complex process, and many wetlands and waterbodies have a combination of groundwater recharge and discharge depending on water source (including snowpack), spatial location, underlying soil and geologic formations, and time of year. Groundwater recharge is not well-studied in Colorado wetlands. Our identification of wetlands and waterbodies with the potential to provide groundwater recharge does not include the potential magnitude (volume), or duration of recharge.

Bank and Shoreline Stabilization

Vegetated wetlands help to minimize waterbody shoreline and stream bank erosion from wave action and flowing water by providing structural stability for soil and sediment, and hydraulic (surface) roughness. The ability of wetlands to stabilize banks and shorelines depends on many environmental factors, including vegetation density, rooting depth, strength and structural complexity of vegetation (e.g., multi-layered vegetation canopies with a mixture of woody and emergent herbaceous plants), soil and/or sediment composition and structure, amount and distribution of bare soil and sediment, degree of soil and plant disturbance (e.g., from livestock or wild ungulate grazing), and the degree of alteration of the natural flow regime (streams), surface water levels (lakes and ponds), or wave action.

Supporting Information for Model Development

Vegetated fringe wetlands or riparian wetlands along stream channels with woody plant communities provide bank and shoreline stabilization (e.g., Johnson 1994). Grasses such as switchgrass (*Panicum* sp.) have been documented to have higher root strength than trees and shrubs, given their high root area ratio, but may provide less bank stability under wetter soil conditions (as opposed to drier conditions) than woody vegetation (Simon and Collison 2002). Increased stream bank strength from vegetation is also a key driver of stream meandering in streams and rivers with gravel bed/coarse bed material (e.g., Gran and Paola 2001; Braudrick et al. 2009). A study of wet meadow vegetation (dominated by sedges and rushes) along a low-gradient mountain stream in California (average width = 30 m; average depth = 1 m; channel slope = 0.001) found that sedges and other graminoids were associated with reduced bank erosion by a factor of 10 (relative to upland vegetation; Micheli and Kirchner 2002a) and stream banks vegetated with wetland graminoids were around five times stronger than banks colonized by xeric vegetation (Micheli and Kirchner 2002b).

Vegetated fringe wetlands or riparian wetlands along stream channels with aquatic bed plant communities (e.g., Gran and Paola 2001) were ranked as having moderate potential to stabilize banks and shorelines.

Assumptions and Data Limitations

The mapping used to evaluate bank and shoreline stabilization lacks detailed information on soil and sediment erodibility, hydraulics, or plant rooting characteristics. In addition to data and mapping limitations, the model assumes healthy, relatively dense vegetation that provides physical retention 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 wetlands to retain soil and sediment along banks and shorelines will likely be reduced.

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APPENDIX C: 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 (see Appendix A)
- 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 B 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 <= 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*

Aquatic Invertebrate Habitat

High potential to provide aquatic invertebrate habitat (AqInvert_Fn = 1)

- *Select by Attribute, Create a new selection:* Hydro IN ('C', 'D', 'E', 'F', 'G', 'H') AND rf IS NULL AND mi IS NULL AND AveLDI <= 250
 - *Assign AqInvert_Fn = 1 to selected features*

Moderate potential to provide aquatic invertebrate habitat (AqInvert_Fn = 2)

- *Select by Attribute, Create a new selection:* Hydro IN ('C', 'D', 'E', 'F', 'G', 'H') AND mi IS NULL AND AveLDI <= 500 AND AqInvert_Fn IS NULL
 - *Assign AqInvert_Fn = 2 to selected features*
- *Select by Attribute, Create a new selection:* LLWW_Landform = 'BA' AND Hydro = 'A' AND AqInvert_Fn IS NULL
 - *Assign AqInvert_Fn = 2 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*

Temperature Regulation

High potential to provide temperature regulation function (TempR_Fn = 1)

- *Select by Attribute, Create a new selection: (hw = 'hw' OR sn = 'sn') AND (LLWW_Flowpath IN ('OU', 'TH') OR sd = 'sd')*
- *Select by Attribute, Remove from current selection: LLWW_Waterbody LIKE 'ST%'*
 - *Assign TempR_Fn = 1 to selected features*
- *Select by Attribute, Create a new selection: (fn = 'fn' OR gw = 'gw') AND (LLWW_Flowpath IN ('OU', 'TH') OR sd = 'sd') AND TempR_Fn IS NULL*
- *Select by Attribute, Remove from current selection: Hydro = 'X' (specific to South Platte dataset)*
 - *Assign TempR_Fn = 1 to selected features*
- *Select by Location, Select features from: Target [Wetland Layer], Source [NDHFlowlines_Perenn_Intermit]. Spatial selection method: Intersect the source layer feature. Apply a search distance: 10 m.*
 - *Assign TempR_Fn = 1 to selected features*
- *Select by Attribute, Select from current selection: fp = 'fp' AND Class LIKE 'FO%' AND TempR_Fn IS NULL*
 - *Assign TempR_Fn = 1 to selected features*

Moderate potential to provide temperature regulation function (TempR_Fn = 2)

- *Select by Attribute, Create a new selection: Class IN ('FO', 'FO1', 'FO4', 'SS1') AND (LLWW_Landscape = 'LO' OR (LLWW_Landscape IN ('LE', 'TE') AND Hydro IN ('C', 'E', 'F', 'G', 'H')))) AND TempR_Fn IS NULL*
 - *Assign TempR_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*

Flood Attenuation

High flood attenuation potential ($FloodAt_Fn = 1$).

- *Select by Attribute, Create a new selection:* LLWW_Landscape = 'TE' AND (LLWW_Landform = 'BA' OR LLWW_Landform = 'SL') AND AveSlope <= 2 AND TPI <=2.5 AND Hydro IN ('A', 'B', 'C', 'E', 'J')
 - *Assign FloodAt_Fn = 1 to selected features*
- *Select by Attribute, Create a new selection:* fp = 'fp' AND (LLWW_Landform IN ('BA', 'FP') OR (LLWW_Waterbody = 'PD' AND ex IS NULL AND im IS NULL)) AND Class IN ('SS1', 'FO', 'FO1', 'FO4') AND Hydro IN ('A', 'B', 'C', 'E', 'F', 'J')
 - *Assign FloodAt_Fn = 1 to selected features*

Moderate flood attenuation potential ($FloodAt_Fn = 2$):

- *Select by Attribute, Create a new selection:* (fp = 'fp' AND (LLWW_Landform IN ('BA', 'FP')) OR LLWW_Waterbody = 'PD' OR bv = 'bv') AND FloodAt_Fn IS NULL
 - *Assign FloodAt_Fn = 2 to selected features*
- *Select by Attribute, Create a new selection:* LLWW_Landscape = 'TE' AND hw = 'hw' AND LLWW_Flowpath IN ('OU', 'TH') AND Class IN ('EM1', 'FO', 'FO1', 'FO4', 'SS1') AND AveSlope <= 2 AND FloodAt_Fn IS NULL
 - *Assign FloodAt_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 → 1, Sed_FnHiQ = 1 → 2, Both field = 1 → 3

Streamflow Maintenance

High potential to maintain base flows (BaseQ_Fn = 1)

- *Select by Attribute, Create a new selection:* (hw = 'hw' AND (LLWW_Flowpath = 'OU' OR sd = 'sd')) AND Hydro IN ('B', 'C', 'D', 'E', 'F', 'G', 'H')
 - *Assign BaseQ_Fn = 1 to selected features*
- *Select by Attribute, Create a new selection:* fn = 'fn' AND dr IS NULL AND LLWW_Flowpath <> 'VR' AND BaseQ_Fn IS NULL
 - *Assign BaseQ_Fn = 1 to selected features*

Moderate potential to maintain base flows (BaseQ_Fn = 2)

- *Select by Attribute, Create a new selection:* bv = 'bv' AND LLWW_Flowpath <> 'VR' AND BaseQ_Fn IS NULL
 - *Assign BaseQ_Fn = 2 to selected features*
- *Select by Attribute, Create a new selection:* LLWW_Landform = 'SL' AND (LLWW_Flowpath = 'OU' OR sd = 'sd') AND Hydro IN ('B', 'C', 'D', 'E', 'F', 'G', 'H') AND BaseQ_Fn IS NULL
 - *Assign BaseQ_Fn = 2 to selected features*
- *Select by Attribute, Create a new selection:* LLWW_Landform = 'SL' AND LLWW_Flowpath <> 'VR' AND fp = 'fp' AND ir IS NULL AND Hydro IN ('B', 'C', 'D', 'E', 'F', 'G', 'H') AND BaseQ_Fn IS NULL
 - *Assign BaseQ_Fn = 2 to selected features*

Groundwater Recharge

Recharge of the alluvial aquifer (GWRech_Fn = 1)

- *Select by Attribute, Create a new selection: bv = 'bv'*
 - *Assign GWRech_Fn = 1 to selected features*
- *Select by Location, Select features from: Target [Wetland Layer], Source [Alluvial Aquifer]. Spatial selection method: Intersect the source layer feature.*
- *Select by Attribute, Remove from current selection: LLWW_Waterbody LIKE 'ST%' OR GWRech_Fn IS NOT NULL*
- *Select by Attribute, Remove from current selection: Hydro = 'X' (specific to South Platte dataset)*
 - *Assign GWRech_Fn = 1 to selected features*

Recharge of non-alluvial groundwater (GWRech_Fn = 2)

- *Select by Attribute, Create a new selection: LLWW_Landscape = 'TE' AND (LLWW_Landform = 'BA' OR LLWW_Waterbody IN ('LK', 'PD')) AND LLWW_Flowpath = 'VR' AND GWRech_Fn IS NULL*
 - *Assign GWRech_Fn = 2 to selected features*
- *Select by Attribute, Create a new selection: (kt = 'kt' OR (pl = 'pl' AND sa IS NULL) OR pp = 'pp') AND GWRech_Fn IS NULL*
 - *Assign GWRech_Fn = 2 to selected features*

Bank and Shoreline Stabilization

High potential to stabilize banks and shorelines (BnkShr_Fn = 1)

- *Select by Attribute, Create a new selection: (LLWW_Landform = 'FR' AND Class IN ('SS1', 'FO', 'FO1', 'FO4'))*
 - *Assign BnkShr_Fn = 1 to selected features*
- *Select by Attribute, Create a new selection: LLWW_Landscape = 'LO' AND LLWW_Landform = 'FP' AND Class IN ('SS1', 'FO', 'FO1', 'FO4')*
- *Select by Location, Select features from: Target [Wetland Layer, select from selected features], Source [Wetland Layer with ST1, ST2, ST3, ST4 selected]. Spatial selection method: Intersect the source layer feature.*
 - *Assign BnkShr_Fn = 1 to selected features*

Moderate potential to stabilize banks and shorelines (BnkShr_Fn = 2)

- *Select by Attribute, Create a new selection: LLWW_Landform = 'FR' OR (LLWW_Landscape = 'LO' AND LLWW_Landform = 'FP') AND Class IN ('AB', 'EM1')*
- *Select by Location, Select features from: Target [Wetland Layer, select from selected features], Source [Wetland Layer with ST1, ST2, ST3, ST4 selected]. Spatial selection method: Intersect the source layer feature.*
 - *Assign BnkShr_Fn = 2 to selected features*

APPENDIX D: METADATA FOR LANDSCAPE DISTURBANCE INDEX (LDI)

Description:

Abstract:

This is the sixth edition of the landscape integrity/disturbance layer for the state of Colorado. This layer supersedes integ_2_2015 and previous versions. Note that this is not just an update, but a refinement of both data inputs and methods. As such it should NOT be directly compared with previous versions and under no circumstances should be treated as representing "change over time" with previous versions. Hence the change in title from "Landscape Integrity Layer" to "Landscape Disturbance Index" (LDI).

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
- * Utility lines (electrical transmission only)
- * 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 \Rightarrow 500 are High impact. Suggested classification of values:

Value range	Level of Impact
0	None (or Minimal)
> 0 - < 250	Low
250 - < 500	Moderate
\geq 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 allows.

Supplemental Information:

The model is based on distance decay functions for each input threat. The method of using distance decay is based on work by Tuffly and Comer (2005a and b), however the equations and parameters used are our own. We used modifications of an s-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 required 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/Med	500	gradual	LANDFIRE 1.3 & NLCD 2014
Development - Low	300	gradual	LANDFIRE 1.3 & NLCD 2014
Agriculture - Tilled	300	moderate-abrupt	CropScape 2015 & SWReGAP 2004
Agriculture - Untilled	100	moderate-abrupt	CropScape 2015 & SWReGAP 2004
Roads - Primary/Secondary	500	moderate	TIGER/Line 2015
Roads - Local/Primitive	300	abrupt	TIGER/Line 2015
Oil & Gas Wells - Active	400	moderate	COGCC 2016
Oil & Gas Wells - Inactive	200	moderate/abrupt	COGCC 2016
Transmission lines	200	moderate/abrupt	Sagemap 2004
Wind turbines	200	abrupt	USGS 2015
Solar farms	200	abrupt	USGS 2011
Surface Mines - Active	500	moderate	CO-DRMS 2015
Surface Mines - Inactive	300	moderate	CO-DRMS 2015

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

Where:

Decay Function | Cut off Distance | Equation

Abrupt | 250 m | $(1 / (1 + \text{Exp}(((\text{Distance} / 100) - 1) * 5))) * \text{Weight}$

Moderate-Abrupt | 600 m | $(1 / (1 + \text{Exp}(((\text{Distance} / 100) - 2.5) * 2))) * \text{Weight}$

Moderate | 1250 m | $(1 / (1 + \text{Exp}((\text{Distance} / 100) - 5))) * \text{Weight}$

Gradual | 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

Time Period of Content:

Time Period Information: 20161213

Currentness Reference: Publication date

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 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.

Citation:

Originator: Colorado Natural Heritage Program

Publication Date: 12/13/2016

Landscape Disturbance Index Layer for Colorado

Edition: 12_2016

Geospatial Data Presentation Form: raster digital data

Publication Place: Fort Collins, CO

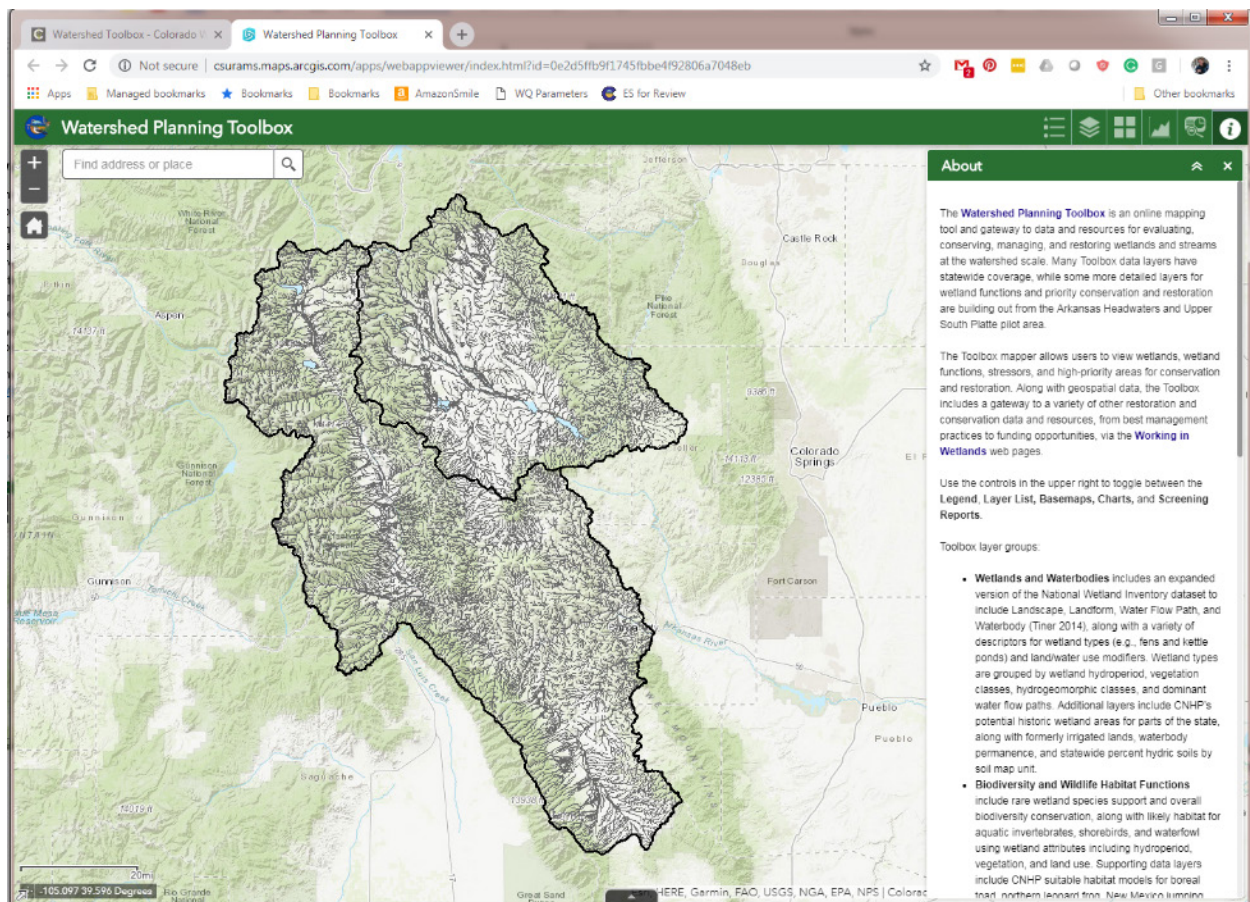
Publisher: Colorado Natural Heritage Program

APPENDIX E: QUICK GUIDE FOR TOOLBOX MAPPER

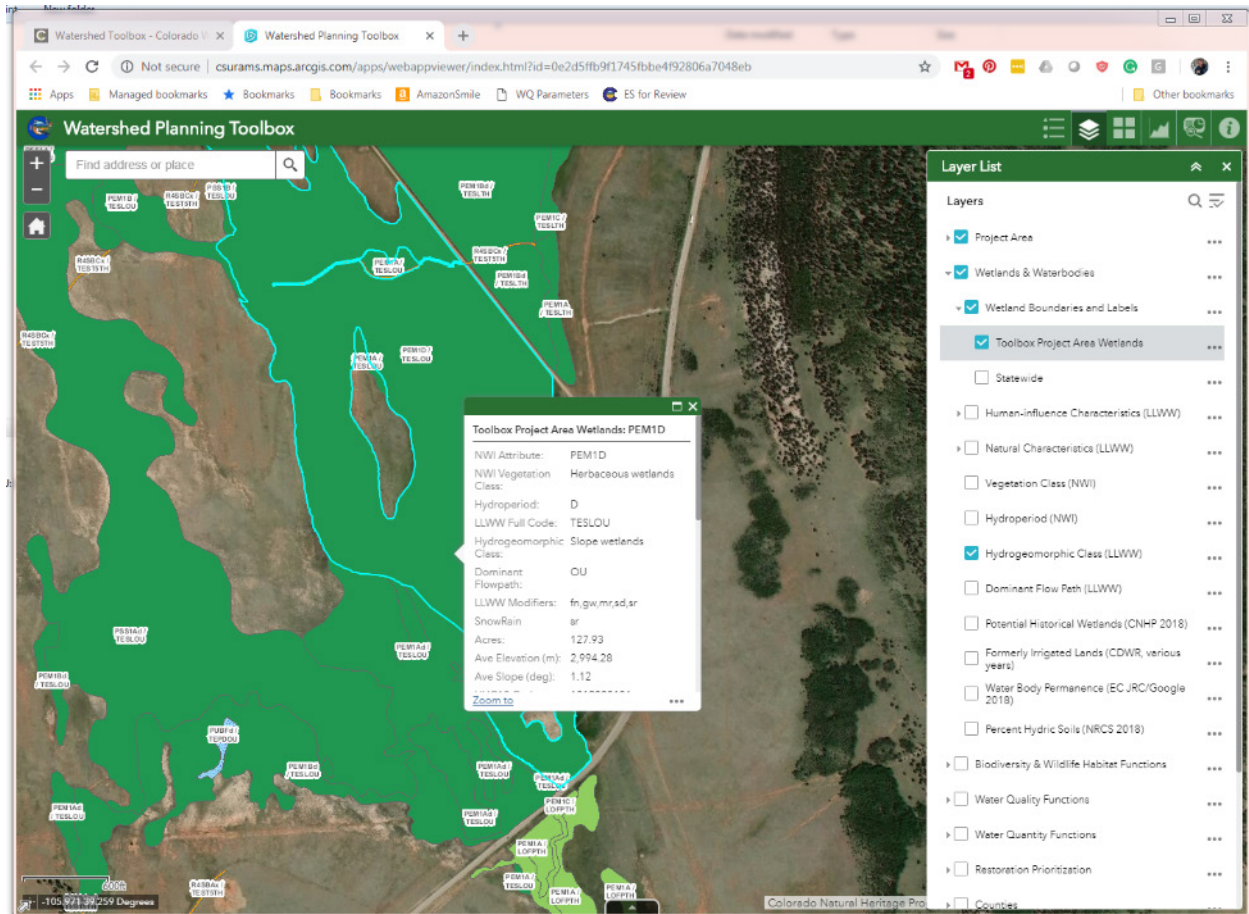
The Watershed Planning Toolbox, released in 2018 by the Colorado Natural Heritage Program, is a comprehensive resource for incorporating wetlands and streams into watershed planning, restoring wetlands to improve watershed health, and identifying opportunities for wetland conservation. Many Toolbox data layers have statewide coverage, while some more detailed layers for wetland functions and priority conservation areas are building out from the Arkansas Headwaters and Upper South Platte Project Area. The Toolbox includes an interactive mapping platform that allows users to view wetlands, streams, likely wetland functions, ecological stressors, and high-priority sites for conservation and restoration at the landscape scale. Supporting information for the Watershed Planning Toolbox is available via the **Colorado Wetland Information Center (CWIC)**, including the **Working in Wetlands** pages (<https://cnhp.colostate.edu/cwic/work/>) that contain information on wetland conservation, restoration, best management practices, regulations, and funding and technical support.

The **Watershed Planning Toolbox mapper** can be found in CWIC under the **Data & Tools** tab (<https://cnhp.colostate.edu/cwic/tools/toolbox/>).

Once you've loaded the mapper, the "About" panel on the right side of the screen has an overview of the Toolbox mapper, including the different layer groups, and a few potential Toolbox uses.



At any point, you can zoom in and select (click on) a given wetland polygon to get more information about the wetland, including basic information like size (acres) and slope, human-influenced and natural wetland characteristics, and whether the wetland likely provides any of the 15 mapped wetland functions.




By expanding the wetland information window, you can view all available attributes.

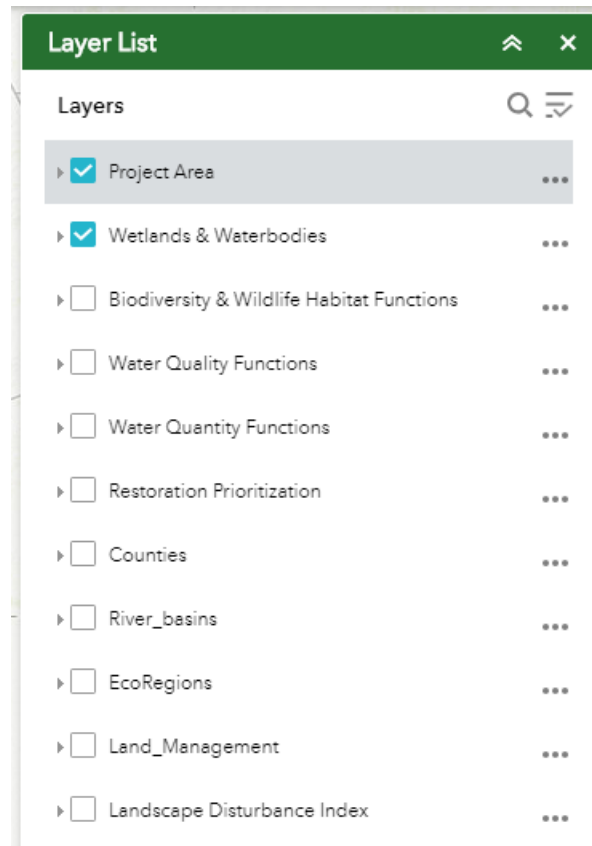
Toolbox Project Area Wetlands: PEM1D	
NWI Attribute:	PEM1D
NWI Vegetation Class:	Herbaceous wetlands
Hydroperiod:	D
LLWW Full Code:	TESLOU
Hydrogeomorphic Class:	Slope wetlands
Dominant Flowpath:	OU
LLWW Modifiers:	fn,gw,mr,sd,sr
SnowRain	sr
Acres:	127.93
Ave Elevation (m):	2,994.28
Ave Slope (deg):	1.12
HUC10 Code:	1019000101
Biodiversity Conservation:	Rare species, moderate landscape condition
Aquatic Invert Habitat:	Moderate
Shorebird Habitat:	
Wildfowl Habitat:	
Nitrogen Removal:	
Phosphorus Uptake:	Moderate
Heavy Metal Removal:	High
Carbon Storage:	
Temperature Regulation:	High
Surface Water Storage:	
Flood Attenuation:	
Sediment Capture:	Frequent flooding
Streamflow Maintenance:	High
Groundwater Recharge:	Recharge of alluvial and floodplain aquifers
Bank & Shore Stabilization:	


By selecting the icons in the upper right corner of the window, you can view the legend for selected layers, all available layers, different options for basemaps, charts for several wetland attributes, a screening option to view wetland information in a specific area, and additional information.

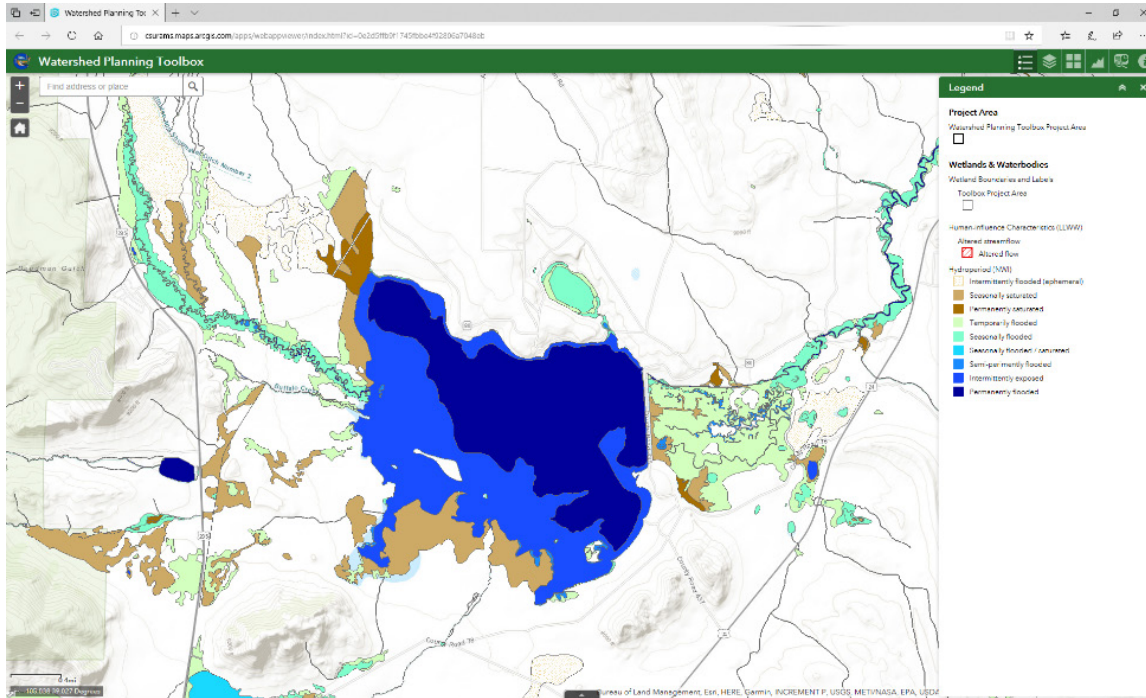


Legend Layer Basemap Chart Screening
 About
 List Gallery

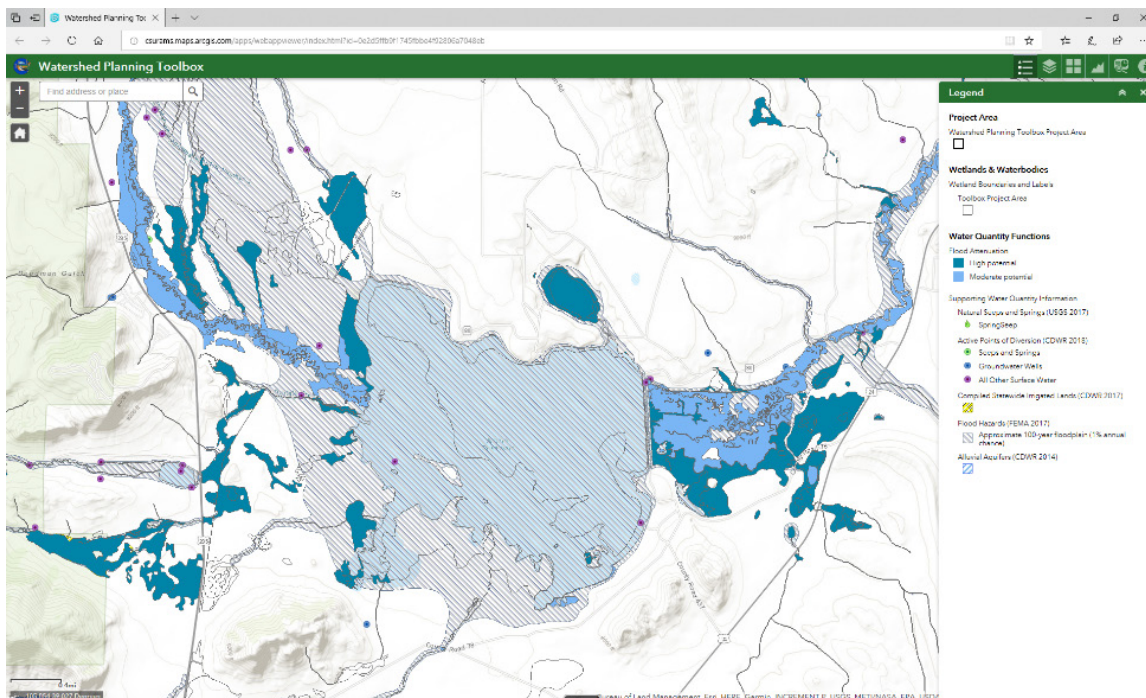
The **Layer List**  icon allows you to explore the 11 different root layer groups, which contain 82 different layers that can be turned on and off. Many of the groups contain primary CNHP layers along with supporting publicly available data layers from other organizations. Some layers are statewide, and others are currently limited to the initial Toolbox Project Area. The source and date for each layer is provided in the layer list and legend. For the best viewing experience and loading time, we recommend turning off layers that you are not currently viewing, and only trying to view one or two wetland functions or wetland and waterbody layers at the same time (since one layer may cover another layer).



The **Legend**  icon allows you to view the symbols for all selected layers. In the following example, altered flow and wetland hydroperiod are selected from the Wetlands and Waterbodies layer list.

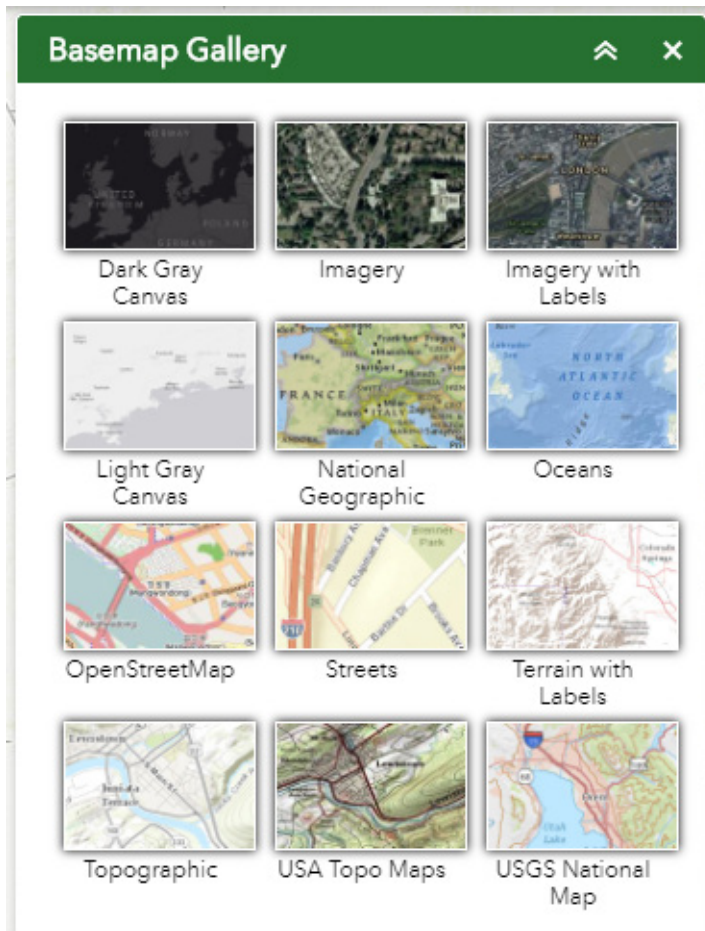


In the next example, some of the Water Quantity functions are selected, along with supporting data layers.

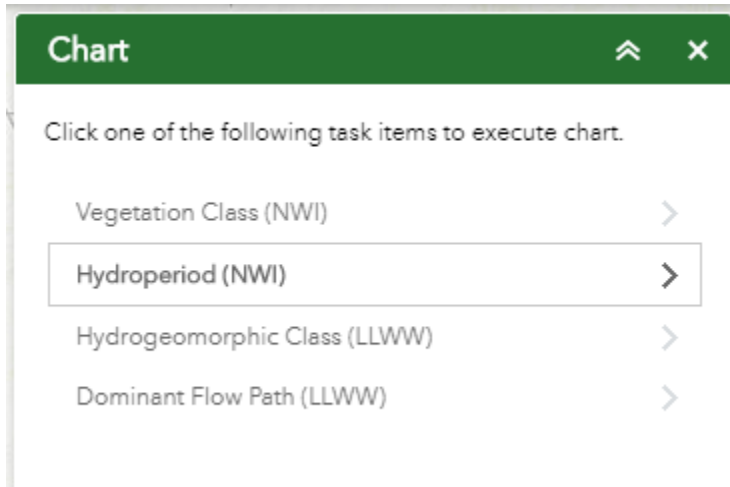




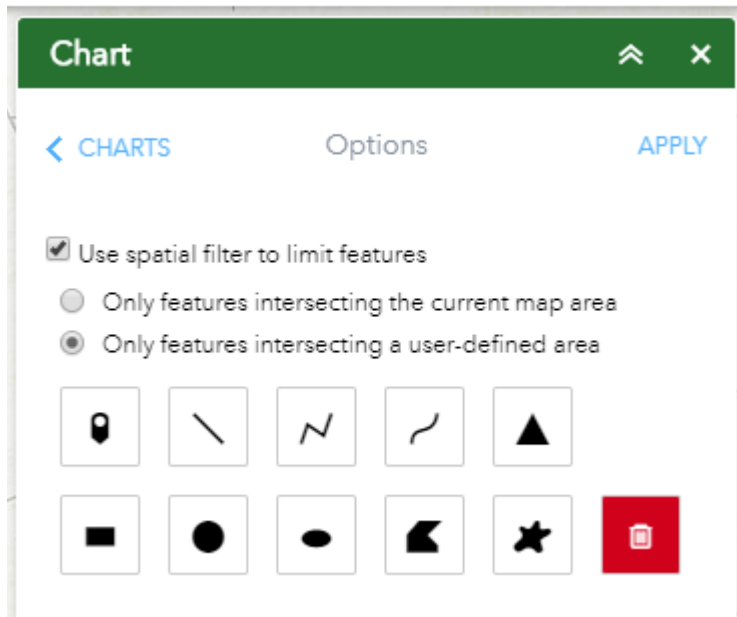
The **Basemap Gallery** icon allows you to choose from a variety of basemaps, including aerial imagery, topographic, and street maps.




The **Chart** icon allows you to create summary charts for several wetland attributes.



By clicking on an attribute, you can then choose to use spatial filter to limit features (recommended) for either the current map extent shown on your screen or a user-defined area. By hovering over the user-defined area icons, you can see each of the 10 different options—from a simple circle to a freehand polygon. Once you have selected a user-defined area, click “Apply” in the upper right corner of the box go generate results.



The **Screening**  icon allows you to select an area of interest (place, user-drawn, or uploaded shapefile) and summarize wetland data for that area. An optional buffer distance is also included. If you do not have ArcGIS software, but have a zipped shapefile, you can still upload and view the shapefile in the Toolbox mapper. Once you click “Report” to generate a report of wetlands that meet the screening criteria, data for selected wetlands can be viewed in the mapper (see red arrow below), exported in a CSV file format, or printed as a Screening Report that includes a map and summary table.

Watershed Planning Toolbox

Find address or place

Screening

Area of Interest

Placename Draw Shapefile

Search for a location

Fairplay, CO, USA

Buffer distance (optional)

Show results within

0.25 Miles

Report Start Over

Search result

Fairplay, Colorado

Zoom to

Screening

Report

Back Area: 125.38 acres

Wetlands (11)

NWI Attribute: PUBGh
 NWI Vegetation Class: Ponds and impoundments
 Hydroperiod: G
 LLWW Full Code: LOPDTH
 Hydrogeomorphic Class: Ponds
 LLWW Landscape Position: LO
 LLWW Waterbody: PD
 LLWW Landform: No Data
 LLWW Flowpath: TH
 LLWW Modifiers: fp,im,m,r,rsr
 Snow or Rain: sr
 Acres: 5.19
 Ave Elevation (m): 3018.98
 Ave Slope (deg): 1.8
 HUC10 Code: 1019000101
 Biodiversity Conservation: No Data
 Aquatic Invert Habitat: No Data
 Shorebird Habitat: No Data
 Wildfowl Habitat: High
 Nitrogen Removal: High
 Phosphorus Uptake: Moderate
 Heavy Metal Removal: High
 Carbon Storage: No Data
 Temperature: No Data

Upload Shapefile to include in analysis Upload

An example of a basic screening report for the buffered search above is provided below.

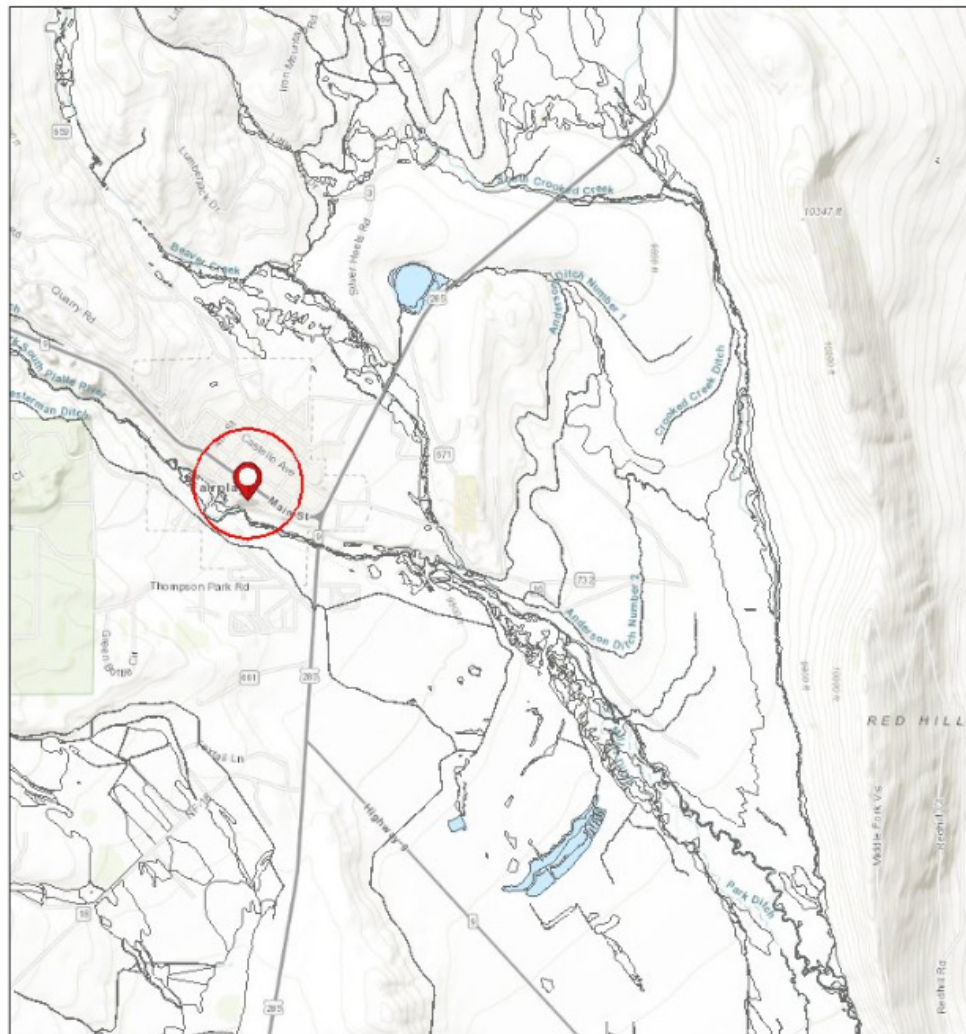


Screening Report

Area of Interest (AOI) Information

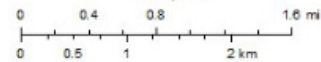
Area : 125.38 acres

Nov 20 2018 10:27:26 Mountain Standard Time

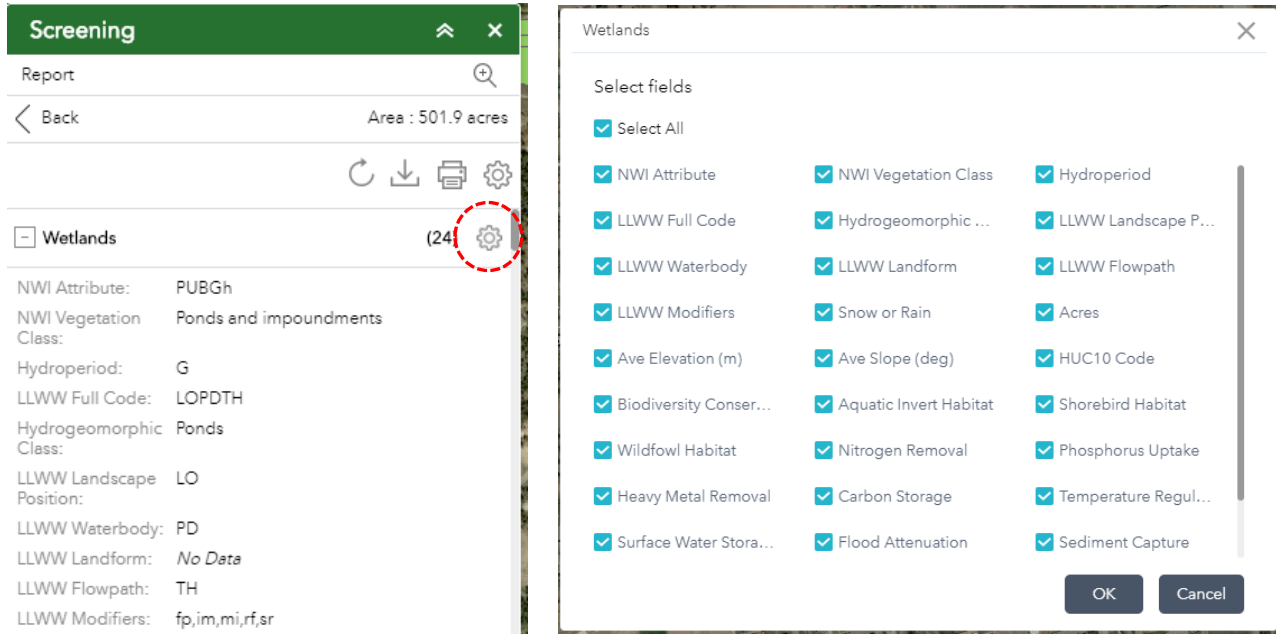


- Watershed Planning Toolbox Project Area
- Toolbox Project Area Wetlands

1:48,149



By default, the results from the screening tool include all available attributes. If you want to screen for specific attributes, you can click on the “Choose attributes to display” button (shown with a red circle below), which will open a new window with options to check/uncheck boxes for all available attribute fields.



APPENDIX F: WATERSHED PLANNING TOOLBOX MAPPER

DATA LAYER GUIDE

Watershed Planning Toolbox Mapper layer groups, and layers with extent, source, date, and description.

<i>Layers by Group</i>	<i>Primary</i>	<i>Supporting</i>	<i>Statewide</i>	<i>Source</i>	<i>Date</i>	<i>Description</i>
Wetlands and Waterbodies						
Human-influence Characteristics						
Altered streamflow	x			CNHP	2018	Hydrologic regime is regulated by dam(s) or diversion(s) upstream, such that the flow regime has been substantially altered in terms of the timing, frequency, magnitude, and duration of peak and low flows (does not apply to wetlands nested in the landscape)
Excavated wetlands and waterbodies	x		(x)	CNHP	2018	Waterbody or wetland is excavated
Impounded wetlands and waterbodies	x		(x)	CNHP	2018	Waterbody or wetland is impounded
Partially drained wetlands	x		(x)	CNHP	2018	Waterbody or wetland is partially drained
Wetlands within irrigated lands	x		(x)	CNHP	2018	Hydrologic regime is strongly influenced by irrigation, either direct application or seepage
Wetlands within mine areas	x		(x)	CNHP	2018	Waterbody or wetland is excavated or impounded for mining of coal or hard rock (e.g., quarry pond or pond to capture mining waste)
Natural Characteristics						
Alpine wetlands	x		(x)	CNHP	2018	Wetlands, waterbodies, and streams above treeline
Beaver wetlands	x		(x)	CNHP	2018	Wetlands and streams influenced by beaver activity (including flooding and saturation)
Fen wetlands	x		(x)	CNHP	2018	Wetland (or waterbody within a wetland) is peat-accumulating, and has the minimum required organic soil depth to qualify as a peatland (40 cm in the upper 80 cm of the soil profile), and saturation is maintained primarily by groundwater discharge
Mire wetlands (adjacent to fens)	x			CNHP	2018	Wetland has accumulation of peat, but not of sufficient depth to qualify as a bog or fen; often interspersed with, or along the margins of a bog or fen
Headwater wetlands	x		(x)	CNHP	2018	Waterbody or wetland is located in the upper reaches of a watershed and often the source of a stream network
Kettle ponds and basins	x		(x)	CNHP	2018	Lake, pond, or wetland located within a formerly glaciated landscape (but not in the Prairie Pothole region) and formed by ice blocks left by retreating glaciers
Playa wetlands	x		(x)	CNHP	2018	Shallow lake, pond, or wetland basin with fluctuating water levels depending on local precipitation patterns and extent of groundwater connection; typically with no natural outlet; can be saline or not

Layers by Group	Primary	Supporting	Statewide	Source	Date	Description
Natural Characteristics (continued)						
Riparian corridors	x			CNHP	2018	Wetlands at the interface between uplands and streams, rivers, and lakes
Snow permanence	x		(x)	CNHP	2018	Wetlands symbolized by snow persistence (from intersections with western U.S. snow zones, GIS files from Moore, C., S. Kampf, B. Stone, E. Richer. 2014. A GIS-based method for defining snow zones: application to the western United States. Geocarto International, DOI 10.1080/10106049.2014.885089. Available at: https://www.nrel.colostate.edu/investigator/stephanie-kampf-homepage/stephanie-kampf-projects/
Vegetation Class (NWI)	x		(x)	CNHP	2018	Wetlands mapped by Cowardin vegetation classes.
Hydroperiod (NWI)	x		(x)	CNHP	2018	Wetlands mapped by Cowardin water regimes.
Hydrogeomorphic Class (LLWW)	x			CNHP	2018	NWI wetlands mapped by grouped landscape, landform, water flow path, and waterbody associations
Dominant Flow Path (LLWW)	x			CNHP	2018	Wetlands mapped by their primary surface water connection to downstream/downslope wetlands, streams, and other waterbodies.
Potential Historical Wetlands	x			CNHP	2018	Potential historical wetland areas, mapped using SSURGO soil map units, topographic data, known wetlands, and some field soil samples
Formerly Irrigated Lands		x		CDWR	Various	"Buy and dry" areas, where water rights have been transferred to other areas, inferred from state irrigated lands data (limited to South Park)
Water Body Permanence	x		x	EC JCR/Google	2018	Global Surface Water Explorer map of the spatial and temporal distribution of lakes, ponds, and other surface waterbodies
Percent Hydric Soils		x	x	NRCS	2018	SSURGO soil map units with hydric soil components, symbolized by percent hydric soil(s) in each map unit
Biodiversity and Wildlife Habitat Functions						
Biodiversity Conservation	x			CNHP	2018	Rare species and ecosystems, and general biodiversity support, by landscape condition (using CNHP's Landscape Disturbance Index)
Aquatic Invertebrate Habitat	x			CNHP	2018	Wetlands and waterbodies with high or moderate potential to provide aquatic invertebrate habitat
Shorebird Habitat	x			CNHP	2018	Wetlands and waterbodies with high or moderate potential to provide shorebird habitat
Waterfowl Habitat	x			CNHP	2018	Wetlands and waterbodies with high or moderate potential to provide waterfowl habitat
Supporting Habitat Information						
New Mexico Jumping Mouse Distribution Model		x	x	CNHP	2015	Potential New Mexico jumping mouse habitat (southern Colorado)
Boreal Toad Distribution Model		x	x	CNHP	2015	Potential boreal toad habitat

Layers by Group	Primary	Supporting	Statewide	Source	Date	Description
Supporting Habitat Information (continued)						
Northern Leopard Frog Distribution Model		x	x	CNHP	2015	Potential northern leopard frog habitat
Southwestern Willow Flycatcher Distribution Model		x	x	CNHP	2015	Potential Southwestern Willow Flycatcher habitat
Western Yellow-Billed Cuckoo Distribution Model		x	x	CNHP	2015	Potential Western Yellow-Billed Cuckoo habitat
Important Bird Areas		x	x	Audubon Rockies	2018	Areas identified by the Audubon Society and other bird conservation partners as critical to state, regional, and international bird conservation; areas are linked to descriptions
Bird Habitat Conservation Areas		x	x	IWJV	2005	Bird habitat conservation areas identified by the Intermountain West Joint Venture
Gold Medal Streams		x	x	CPW	2017	Streams with high-quality recreational fisheries
Gold Medal Lakes		x	x	CPW	2017	Lakes with high-quality recreational fisheries
Barriers to Fish Passage		x	x	NFHP	2012	National Anthropogenic Barriers Database points, including dams and other fish passage barriers
Tier 1 Fish Species by Watershed		x	x	CPW	2016	HUC10 watersheds designated in the State Wildlife Action Plan as habitat for Tier 1 priority fish species, including a variety of sensitive, threatened, and endangered fish; watersheds are symbolized by number of priority fish and species occupying each area can be found in the attributes table
Water Quality Functions						
Nitrogen Uptake and Transformation	x			CNHP	2018	Wetlands and waterbodies with high or moderate potential for nitrogen uptake and removal
Phosphorus Removal and Storage	x			CNHP	2018	Wetlands and waterbodies with high or moderate potential for phosphorus removal and storage
Metal Removal and Storage	x			CNHP	2018	Wetlands and waterbodies with high or moderate potential for metal removal and storage
Carbon Sequestration and Storage	x			CNHP	2018	Wetlands with high or moderate potential to store carbon (soil and biomass)
Temperature Regulation	x		(x)	CNHP	2018	Wetlands with high or moderate potential to regulate surface water temperatures
Supporting Water Quality Information						
Oil and Gas Wells		x	x	COGCC	2018	Oil and gas location data, including wells, from the Colorado Oil & Gas Conservation Commission. Data are updated daily on the COGCC data download page
Permitted Mines		x	x	CDNR	2018	Permitted mines, active construction permits, and active hard rock permits
Stream Outstanding Waters		x	x	CDPHE	2018	Streams with the highest level of protection from regulated activities under Colorado's surface water antidegradation regulation

Layers by Group	Primary	Supporting	Statewide	Source	Date	Description
Supporting Water Quality Information (continued)						
Stream Water Quality 303(d) Categories		x	x	WQCD	2018	Stream segments mapped by degree of attaining numeric or narrative water quality standards for designated uses, as required by Section 303(d) of the Clean Water Act
Lake Outstanding Waters		x	x	CDPHE	2018	Lakes with the highest level of protection from regulated activities under Colorado's surface water antidegradation regulation
Lake Water Quality 303(d) Categories		x	x	WQCD	2018	Lakes mapped by degree of attaining numeric or narrative water quality standards for designated uses, as required by Section 303(d) of the Clean Water Act
Mine Tailings (SSURGO)		x	x	NRCS	2018	SSURGO soil map units corresponding with mine tailings, dumps, and other mining-associated features
Environmental Hazard Mine Areas		x	x	USFS	2016	Abandoned and inactive mine areas identified by the Colorado Geological Survey and USFS as posing an environmental hazard, to be prioritized for reclamation
Nonpoint Source Pollution (319) Watershed Plans		x	x	CDPHE	2018	Existing and recent watershed plans to address nonpoint source pollution such as nutrients from agricultural land and residential areas, oil and other chemicals from urban runoff, and sediment from soil and stream bank erosion
Water Quantity and Geomorphic Functions						
Surface Water Storage	x		(x)	CNHP	2018	Wetlands and waterbodies likely to provide long-term or seasonal surface water storage
Flood Attenuation	x			CNHP	2018	Wetlands and waterbodies with high or moderate potential to delay and store surface runoff and peak stream flow
Sediment Capture and Retention	x			CNHP	2018	Wetlands and waterbodies likely to provide sediment capture and retention during frequent, low intensity precipitation/runoff/flood events, high intensity precipitation/runoff/flood events, or both types of events
Stream Flow Maintenance	x			CNHP	2018	Wetlands and waterbodies with high or moderate potential to maintain late summer and early fall base flow in streams
Groundwater Recharge	x		(x)	CNHP	2018	Wetlands and waterbodies likely to recharge alluvial or non-alluvial groundwater aquifers
Bank and Shoreline Stabilization	x			CNHP	2018	Wetlands with high or moderate potential to stabilize stream banks and waterbody shorelines
Supporting Water Quantity Information						
Natural Seeps and Springs		x	x	USGS	2017	Points of natural groundwater discharge
Active Points of Diversion		x	x	CDWR	2018	Active surface water and groundwater diversion points (associated with water rights)
Decreed Instream Flow Stream and River Reaches		x	x	CDWR	2018	Stream reaches with State-decreed minimum flows
Decreed Lake Levels		x	x	CDWR	2015	Lakes with State-decreed minimum levels
Compiled Statewide Irrigated Lands		x	x	CDWR	2016/2017	Extent of irrigated areas, including flood, sprinkler, and drip irrigation systems
Flood Hazards		x	x	FEMA	2017	Approximate 100-year floodplains (1% annual chance of flooding)

Layers by Group	Primary	Supporting	Statewide	Source	Date	Description
Supporting Water Quantity Information (continued)						
Alluvial Aquifers		x	x	CDWR	2014	Approximate extent of unconfined groundwater aquifers on alluvial deposits (formed by streams, rivers, and other flowing water)
Historic Fire Perimeters		x	x	USGS	2018	Recent burn area perimeters from the Geospatial Multi-Agency Coordination (GeoMAC) database, from 2010 to present
Wetland Restoration and Conservation Prioritization						
Park County Wetland Restoration Priority Areas	x	x		Eco-Metrics	2016	High- and medium-priority wetland restoration areas in Park County, from the Park County Wetland a Stream Inventory (Beardsley 2016)
Arkansas Headwaters Restoration Priority Areas	x			CNHP and AHWFAC	2018	Prioritized potential wetland and stream restoration areas, ranked by feasibility and potential ecological lift
Playas Prioritized for Restoration		x		PLJV	2014	Playas in the Great Plains with very high, high, medium, and low priority for restoration, as identified by the Playa Lakes Joint Venture
Playas Prioritized for Wind Energy Avoidance				PLJV	2014	Playas in the Great Plains with very high, high, medium, and low priority for wind energy avoidance, as identified by the Playa Lakes Joint Venture
Wetland Potential Conservation Areas	x		x	CNHP	2018	Areas supporting rare aquatic-dependent species and ecosystems, identified for potential conservation and/or management actions
U.S. Army Corps of Engineers Regions		x	x	USACE	2008	Regions used by the Corps of Engineers for supplemental wetland delineation guidance and wetland plant indicator status
Other Supporting Information						
Counties		x	x	CDOT	2010	All Colorado Counties
River Basins		x	x	USGS	2017	Colorado river basins (HUC 6) and subbasins (HUC 8)
Ecoregions		x	x	EPA	2013	EPA Level III and IV Ecoregions
Land Management		x	x	COMap	2018	Land ownership and management via the COMaP v10 Map Service, grouped by private, federal, state, local, and NGO/land trust management
Landscape Disturbance Index (LDI)		x	x	CNHP	2018	Degree of landscape disturbance, from none/minimal to high, based on land use, energy development, and natural resource extraction layers

APPENDIX G: SUPPORTING WEB CONTENT

CNHP created new web content to support the Toolbox, including 6 new pages and 2 revised and reorganized pages within the Colorado Wetland Information Center (CWIC) website. We've provided a brief description of each page and sample screen captures for some of the key elements on each page below. The full website can be found at: <https://cnhp.colostate.edu/cwic/>

Why Are Wetlands Important? provides a photo and collapsible description of each of the 15 functions mapped in the Toolbox, and is referenced in many of the other Working in Wetlands web pages.

The screenshot shows the Colorado Wetland Information Center website. The header includes the logo and navigation links: About CWIC, Wetland Types, Wetland Condition, Working in Wetlands, Data & Tools, Library, and CNHP Home. The main content area is titled 'Colorado Wetland Functions' and includes a list of 15 functions with circular icons. Below this list are two detailed sections: 'Conservation of Biodiversity' and 'Amphibian Habitat', each featuring a circular image and a 'Read more' link.

Colorado Wetland Functions

Wetlands provide a large number of functions across the state. We've provided summaries for some of the most well-documented wetland functions below.

Click a link below for details.

- Conservation of Biodiversity
- Amphibian Habitat
- Aquatic Invertebrate Habitat
- Shorebird Habitat
- Waterfowl Habitat
- Bank and Shoreline Stabilization
- Flood Attenuation
- Groundwater Recharge
- Sediment Capture and Retention
- Stream Flow Maintenance
- Carbon Sequestration and Storage
- Metal Removal and Storage
- Nitrogen Uptake and Transformation
- Phosphorus Removal and Storage
- Temperature Regulation

Conservation of Biodiversity [Back to top](#)

Wetlands are located at the interface between terrestrial and aquatic environments, and are often hotspots for a diverse array of terrestrial and aquatic wildlife and plants, including rare species. 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.

[Read more](#)

Amphibian Habitat [Back to top](#)

Wetlands provide breeding, foraging, and overwintering habitat for Colorado's 17 species of native amphibians. All of Colorado's amphibians require temporary or permanent standing water for breeding habitat, but many species spend the remainder of the year in adjacent terrestrial habitats.

[Read more](#)

Working in Wetlands is the landing page for state-level and regional resources related to wetland conservation, restoration, regulations, best management practices, and funding and technical support.

The screenshot shows the Colorado Wetland Information Center website. The top navigation bar includes links for 'About CWIC', 'Wetland Types', 'Wetland Condition', 'Working in Wetlands', 'Data & Tools', 'Library', and 'CNHP Home'. The 'Working in Wetlands' dropdown menu is open, listing 'Overview', 'Conservation', 'Restoration', 'Regulation', 'Best Management Practices', and 'Funding and Technical Support'. The main content area features an 'Overview of Working in Wetlands' section with a list of key points:

- Wetlands are wet! Many common practices in agriculture and development don't work in wetlands because of factors like seasonal or permanent flooding and saturated soil.
- Wetlands have special **legal protections** intended to protect their habitats and protect water quality downstream.
- Wetlands host plant and animal communities that are adapted to flooded and anaerobic soil conditions. Many of these communities require a specific set of chemical and physical conditions, such as saline or mineral-rich soils.

 Below this is a paragraph explaining that due to their hydrology, wetlands often have strong connections to surface runoff, groundwater aquifers, streams, and other waterbodies. These hydrologic conditions create unique ecological communities, but make wetlands vulnerable to local and regional hydrologic modifications, sedimentation and other pollution from surrounding land use. Working in Wetlands provides land owners and managers with tools and resources to **conserve, restore, protect, and manage** wetlands and all of the **ecological functions** they provide across Colorado's diverse landscapes.

On the right side of the page, there are two sidebar sections:

- Working in Wetlands**: A list of links including Overview, Conservation, Restoration, Regulation, Best Management Practices, and Funding and Technical Support.
- Related Topics**: A list of links including Wetland Reports, PCA Reports, County Survey Reports, Field Guides and Apps, Field Manuals, Educational Resources, and Watershed Toolbox.

At the bottom of the page, there is a photograph of a scenic wetland landscape with a pond surrounded by dense evergreen trees and a grassy foreground.

Wetland Conservation provides information on the importance of conserving Colorado's wetlands, and resources to support conservation.



Getting Involved in Wetland Conservation

[Back to top](#) ↑

Interested in helping with or learning more about wetland conservation? Please see our [Funding and Technical Support](#) page for resources and opportunities to conserve, restore, and learn more about wetlands in Colorado!

Colorado also has 6 Wetland Focus Area Committees (FACs), which include stakeholders ranging from private landowners to federal land management agencies and nongovernmental organizations. CPW hosts a map of the [FAC regions](#), as well as contact information for each committee.



Incorporating Wetlands into Watershed Planning

[Back to top](#) ↑

Watershed Plans

Is there an existing watershed plan that includes your area of interest? Find out via the CNHP [Watershed Planning Toolbox Mapper](#) or [Colorado Watershed Assembly's Watershed Reports and Plans](#).

The [EPA Handbook for Developing Watershed Plans to Restore and Protect our Waters](#) is also a useful resource for groups looking to create and implement watershed plans for water quality or water resource protection.

Watershed Groups

The Colorado Watershed Assembly maintains an [interactive mapping tool](#) that allows users to see watershed groups and soil conservation districts in each of the major river basins across the state.

Wetland Restoration and Enhancement contains an outline of key restoration steps and questions for successful projects, along with supporting photos and links to restoration resources ranging from the NRCS Web Soil Survey to statewide native plant revegetation guidance and nurseries.

Restoration and Enhancement

Click a link below for details.

- ✔ Site Selection and Prioritization
- ✔ Site Evaluation
- ✔ Creating a Restoration Plan
- ✔ Site Preparation
- ✔ Selecting Plants and Finding Plant Materials
- ✔ Implementation
- ✔ Monitoring and Adaptive Management

Wetlands and streams are the organs and circulatory system of Colorado's watersheds—storing, transforming, and transporting water, sediment, nutrients, and organisms from the Rocky Mountain alpine to the plains. Since Colorado became a state in the late 1800s, we have lost approximately 50% of our state's original wetland area through drainage, fill, or excavation. With each acre of wetland loss, we have lost associated habitat, water quality, and water storage functions.

Through the process of **ecological restoration**, or "assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (Society for Ecological Restoration), many land owners and managers are attempting to bring back the ecological functions that wetlands once provided across our state. *Whether you are a rancher, a consultant, or a federal land manager, you can help conserve and restore Colorado wetlands and streams!*

Both **voluntary** and **compensatory** (e.g., mitigating for impacts to existing wetlands) restoration projects often follow a step-wise process starting with goal setting and site selection and ending with monitoring and adaptive management. We've provided an outline for this process, along with links to supporting documents and web pages for more information.



Working in Wetlands

- Overview
- Conservation
- Restoration
- Regulation
- Best Management Practices
- Funding and Technical Support

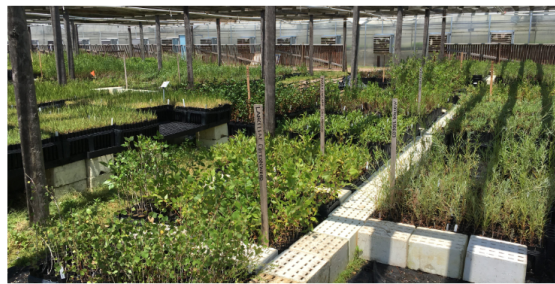
Related Topics

- Wetland Reports
- PCA Reports
- County Survey Reports
- Field Guides and App
- Field Manuals
- Educational Resources
- Watershed Toolbox

Selecting Plants and Finding Plant Materials

[Back to top](#) ↑

Whether you are interested in planting native plants on your property, or restoring a large wetland complex, we've included resources to help you find out what to plant, where to purchase plants, and how to propagate and care for native plants as they become established.




Ecological Systems and Plant Communities

If you are interested in how your site fits into the larger landscape, the [Field Key to Wetland and Riparian Ecological Systems of Colorado](#) is an excellent place to start when looking at nearby least-altered wetland sites to use as a reference.

For more detailed information on Colorado's wetland plant communities, please see the [Field Guide to the Wetland and Riparian Plant Associations of Colorado](#). Once you have identified one or more plant communities that are appropriate for your restoration site, [The Field Guide to Colorado's Wetland Plants: Identification, Ecology and Conservation](#) provides detailed information on Colorado's wetland plant species, from plant ID to how plants are used by wildlife. Regional wetland plant guides are also available for the [Great Plains](#), [Southern Rocky Mountains](#), and [Western Valleys and Plateaus](#). The Colorado Native Plant Society is also an excellent resource for learning about CO native plants, including a variety of checklists, keys, and habitat information on their [Colorado Plants and Habitats page](#).

Wetland Regulation includes photos, figures, links to regulatory agencies (and contact information), and topics relevant to wetland work in Colorado (including new content for regulatory issues like water rights, and floodplains).

 Colorado Wetland Information Center

[About CWIC](#) |
 [Wetland Types](#) |
 [Wetland Condition](#) |
 [Working in Wetlands](#) |
 [Data & Tools](#) |
 [Library](#) |
 [CNHP Home](#)

Wetland Regulations

Wetlands help us all by maintaining clean water, providing habitat, helping buffer downstream areas from floods, and supporting recreation and other tourism in Colorado. Given their important role in our watersheds, wetlands are directly and indirectly protected by a series of state, federal, and sometimes local regulations. Whether you are restoring wetlands, or planning to impact a wetland as part of a construction project or permanent development, there are several key considerations for working in Colorado's wetlands. **Before you begin work**, consider the following items listed below.

Click a link below for details.

<ul style="list-style-type: none"> Will You Be Impacting Wetlands or Downstream Waters? Compensatory Mitigation vs. Voluntary Restoration Water Law 	<ul style="list-style-type: none"> Floodplains and Floodways Impacts to Water Quality and Quantity Federal Regulations and Incentives State Regulations Local Regulations
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Will You Be Impacting Wetlands or Downstream Waters? [Back to top](#) ↑

When working in wetlands, including habitat restoration, you may still be impacting existing wetlands—even if your project will result in a net gain in the condition of the plant community or ecological functions.

Examples of wetland impacts

- [Temporary fill in wetland areas](#)
- [Soil disturbance](#)
- [Damage or removal of native wetland vegetation](#)

Another important consideration is how your project will impact areas downslope or downstream. Please see the [Best Management Practices for Wetlands](#) page for more information on avoiding wetland impacts during construction, and other land management activities.


Working in Wetlands

- [Overview](#)
- [Conservation](#)
- [Restoration](#)
- [Regulation](#)
- [Best Management Practices](#)
- [Funding and Technical Support](#)

Related Topics


- [Wetland Reports](#)
- [PCA Reports](#)
- [County Survey Reports](#)
- [Field Guides and App](#)
- [Field Manuals](#)
- [Educational Resources](#)
- [Watershed Toolbox](#)

Wetland Best Management Practices provides a new portal for wetland BMPs, grouped by general BMP guidance, and guidance by wetland type and land use (with linkages between related BMPs). We plan to regularly update this page as new BMP literature and data become available.

 Colorado Wetland Information Center

[About CWIC](#) |
 [Wetland Types](#) |
 [Wetland Condition](#) |
 [Working in Wetlands](#) |
 [Data & Tools](#) |
 [Library](#) |
 [CNHP Home](#)

Wetland Best Management Practices



Click a link below for details.

- [General Wetland BMP Guidance](#)
- [Guidance by Wetland Type](#)
- [Land Use Specific Guidance](#)

Wetlands perform critical water quality, water quantity, and habitat functions in the landscape. In Colorado, surface water and groundwater feeding every municipal water system passes through wetlands, and more than 75% of wildlife species depend on wetlands for all or part of their life cycle.

Wetland **Best Management Practices (BMPs)** are actions that help protect wetlands and the functions they provide from temporary or permanent human disturbance. The optimal size and design of wetland buffers and other BMPs depends on factors like surrounding land use, vegetation, topography, hydrology, and habitat requirements for wetland-associated species.

Questions to consider when planning for and designing wetland BMPs:

- How is the wetland impacted by existing disturbance, and/or how will the wetland be impacted by a proposed disturbance?
- Can the disturbance be avoided or minimized?
- What are the objectives for the BMP, in terms of protecting the wetland? Examples include preserving/improving water quality within the wetland, limiting invasion of non-native species, and protecting wildlife habitat.
- What is the landscape position and hydrologic context of the wetland?
- What is the lifespan of the BMP (permanent or short-term)?
- How will the BMP(s) be operated and maintained to ensure that wetlands are protected for the

Working in Wetlands

- [Overview](#)
- [Conservation](#)
- [Restoration](#)
- [Regulation](#)
- [Best Management Practices](#)
- [Funding and Technical Support](#)

Related Topics

- [Wetland Reports](#)
- [PCA Reports](#)
- [County Survey Reports](#)
- [Field Guides and App](#)
- [Field Manuals](#)
- [Educational Resources](#)
- [Watershed Toolbox](#)


General Wetland BMP Guidance

[Back to top](#) ↑

We've provided a starting point for a variety of wetland BMPs, from buffers to wildlife. Please stay tuned for more BMPs in the future, or contact CNHP at the link at the bottom of this page if you know of new or existing BMPs for Colorado wetlands that we've missed.

Click a link below for details.


- [Wetland Buffers](#)
- [BMPs for Plants](#)
- [Wetland Wildlife BMPs](#)
- [Aquatic Nuisance Species and Noxious Weeds](#)
- [Climate Change](#)



Wetland Buffers

- ✔ The Environmental Law Institute's [Planner's Guide to Wetland Buffers for Local Governments](#)
- ✔ The City of Boulder's [Wetland Protection Program Best Management Practices](#)
- ✔ [Update on Wetland Buffers: The State of the Science](#) from the Washington Department of Ecology, provides a review of wetland buffers for preventing common pollutants like phosphorus and sediment from entering wetlands, as well as protecting wetland wildlife.


[Back to General Wetland BMP Guidance](#) ↑



BMPs for Plants




- ✔ For plant-specific guidance, the [USDA Fact Sheets & Plant Guides page](#) provides detailed information by species, including many BMPs related to grazing, fire, and other land management.
- ✔ The searchable [USDA Fire Effects Information System](#) also provides comprehensive plant information by species, including BMPs.
- ✔ Many Colorado wetlands host rare plants, and have unique needs for managing noxious weeds. The CO Department of Agriculture and CNHP have developed [Recommended Best Management Practices for Managing Noxious Weeds on Sites with Rare Plants](#).

Funding and Technical Support for wetland conservation and restoration – provides a growing list of funding opportunities for different scales and types of wetland and stream restoration, grouped by project themes (e.g., water quality improvement), along with links to groups doing wetland conservation and restoration-related work in Colorado.

 Colorado Wetland Information Center

[About CWIC](#) |
 [Wetland Types](#) |
 [Wetland Condition](#) |
 [Working in Wetlands](#) |
 [Data & Tools](#) |
 [Library](#) |
 [CNHP Home](#)

Funding and Technical Support

Click a link below for details.

- Funding for Wetland and Stream Conservation and Restoration
- General watershed and habitat restoration funding
- Invasive species control and management
- Statewide, regional, or basin-wide water work
- Water quality
- Wildlife habitat
- Wetland conservation on working lands
- Getting Involved in Wetland Conservation and Restoration
- Watershed Groups by River Basin

Working in Wetlands

- Overview
- Conservation
- Restoration
- Regulation
- Best Management Practices
- Funding and Technical Support


Related Topics

- Wetland Reports
- PCA Reports
- County Survey Reports
- Field Guides and App
- Field Manuals
- Educational Resources
- Watershed Toolbox

Funding for Wetland and Stream Conservation and Restoration

Depending on the objectives of your restoration project, you may be eligible for a variety of funding opportunities at the state and national level. We've provided a list of wetland and watershed restoration and conservation funding opportunities in Colorado, grouped by types of project objectives and eligibility. Please also see a list of **nonprofit organizations and watershed groups** below, many of which provide funding and/or technical support for wetland-related work.

General watershed and habitat restoration funding



- Colorado Water Conservation Board **Watershed Restoration Grant Program**
- Great Outdoors Colorado **Habitat Restoration Grants**
- The Colorado Watershed Assembly maintains a **list of funding opportunities**, including many sources specific to

Getting Involved in Wetland Conservation and Restoration Back to top ↑

Looking for help with your restoration project, or interested in learning and volunteer opportunities related to wetlands and streams? We've provided a list of state, national, and regional organizations who are actively involved in conserving and restoring wetlands and streams in Colorado.



Land Trusts Back to top ↑

Land trusts play a critical role in helping landowners with voluntary land conservation across Colorado, including wetlands and riparian areas surrounding streams. The Colorado Coalition of Land Trusts