Setting Mitigation in the Watershed Context: Demonstration and Description of Colorado's Watershed Approach to Compensatory Wetland Mitigation

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Watershed Approach to Wetland Compensatory Mitigation

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All photos taken by Colorado Natural Heritage Program Staff or Dr. Brad Johnson.

EXECUTIVE SUMMARY

In a comprehensive evaluation of wetland mitigation, the National Research Council (NRC) concluded that "the goal of no net loss of wetlands is not being met for wetland functions" by the U.S. Army Corps of Engineers (ACOE) and U.S. Environmental Protection Agency (EPA)'s mitigation program under Section 404 of the Clean Water Act (CWA). One of the key science recommendations of the NRC was for compensatory mitigation decisions to be made using a "watershed approach." Acknowledging this conclusion, the ACOE and EPA issued a federal rule in April 2008 to increase the effectiveness of compensatory mitigation and called for setting mitigation decisions in the watershed context. While requiring a watershed-scale view of mitigation, the new rule did not provide guidance on how a watershed approach should be implemented. At that time, Colorado lacked the basic capacity to carry out the watershed approach, particularly a lack of spatial data for wetlands and no single guidance document on procedures for applying the watershed approach.

Through this project, we developed a process that would allow the watershed approach to be successfully and consistently implemented across the state. The overarching objective of this project was to demonstrate how the watershed approach can be implemented and used to inform CWA Section 404 decisions. Our approach utilized watershed profiles based on three levels of data availability, regulatory need, and time and resource constraints, from coarse estimates of wetland extent and distribution to highly detailed maps and field data collection. A provisional document, the Colorado Watershed Approach (COWAP), was developed to guide permit applicants through the basic steps of information gathering necessary, based on the level of data available. This type of information, when included with a permit application, will allow regulators to make mitigation decisions within the watershed context. COWAP process will allow local regulators to implement the watershed approach independently, but within a template that fosters consistency across regions.

To serve as an example of how the approach could be implemented start-to-finish, we carried out all three tiers within a specific critical area, the northern Front Range corridor from north of Denver to south Fort Collins.

- Tier 1 wetland profiles were compiled for the current extent and distribution of wetland in the project area and the likely distribution of wetlands pre-settlement based on reference literature and best professional judgment.
- A Tier 2 wetland profile was created by digitizing original NWI maps from the late 1970s. These original NWI maps were coarse and outdated, but provided a rough quantitative estimate of wetland acres. This Tier 2 profile also serves as a historical point of reference for examining change over time.
- A Tier 3 wetland profile was developed through photo-interpretation of the most current air photography available and following the national standards for wetland mapping.
- For both Tier 2 (historical) and Tier 3 (current) profiles, polygons were attributed with a modified hydrogeomorphic (HGM) classification in addition to the standard NWI classification to draw conclusions about functional capacity within the study area.
- To explore watershed needs, change in the wetland profile between the two time periods was quantified by comparing the Tier 2 (historical) and Tier 3 (current) profiles.

- To further inform the geospatial information within the profiles, condition of existing wetlands was assessed using a spatially balanced random sample survey design. Thirty-four wetland sites were selected for sampling and each site was evaluated using the two most prominent wetland assessment methods in Colorado: Functional Assessment of Colorado Wetlands (FACWet) and the Ecological Integrity Assessment (EIA) framework.
- As an added product developed through this study, the two condition assessment methods were compared and contrasted, providing cross validation for both methods and highlighting the strengths and applications for each.

Results from the Fort Range study area highlight the need to understand the current state of wetland resources when deciding what impact mitigation proposals will have on a watershed. Prior to European settlement, the vast majority of wetlands in the north Front Range were tied directly to the rivers and streams and would have been considered riverine wetlands. Groundwater seepage may have created additional slope wetland acres along the base of buttes or significant breaks in slope. The landscape likely supported few natural depressions and even fewer actual lakes. Whether using out of data wetland mapping from the 1970s (the Tier 2 profile) or new, highly detailed mapping based on 2009 imagery (the Tier 3 profile), it was clear that the dominant aquatic resources in the area are now lakes (primarily reservoirs for water storage) and depressional wetlands, most created either intentionally (e.g., stormwater retention ponds, stock ponds, wildlife habitat, etc.) or unintentionally from excess urban and agricultural run-off.

Detailed current mapping (the Tier 3 profile) showed that 8% of the landscape (31,306 acres) is covered by wetlands, riparian areas and waterbodies, but lakes alone make up 42% of those acres. Depressional wetlands, likely uncommon in the study area prior to European settlement, make up the largest wetland type (by HGM Class), with 63% of the acres considered true wetlands. Riverine wetlands, once the dominant type, now have half the acreage of depressional wetlands. A quantitative analysis of change in wetland acreage between the late 1970s and 2009 showed a slight increase in wetland acres (up 12% for wetlands and up 7% for all aquatic resources), but this was driven largely by an increase in depressional wetlands from pond creation.

The profile of wetlands in the study area has implications for future regulatory decision. While depressional wetlands are effective at storm water retention, sediment retention, and nutrient removal/transformation, they are less effective at flood attenuation, streamflow maintenance, transport of sediment and organic material, and support for biodiversity than the riverine wetlands they have replaced. A decrease in the quality of lotic fisheries has been one significant effect of riverine wetland loss. Continued loss of riverine wetlands and the increase of depressional and open water wetlands will further erode the cumulative functional performance of the once defining attribute of the watershed, namely, its riverine arterial system.

While the spatial accounting of wetland acres within a wetland profile is the most basic information needed to carry out the watershed approach, on-the-ground data on wetland condition further fleshes out the picture and highlights wetland types or specific areas within a watershed where wetland impacts should be avoided or where mitigation may be more likely to succeed. To demonstrate how filed data can augment a detailed Tier 3 wetland profile, we conducted a field-based assessment of wetland condition within the demonstration project area. A total of 34 wetlands were sampled in the northern Front Range study area during the summer of 2011 with two assessment methodologies, FACWet and EIA.

To summarize results, sites were classified by the HGM Class, by Ecological System (a vegetation-based classification), and by origin (whether natural or non-natural). A new class was added to both the HGM and Ecological System classifications to describe the prevalence of wet meadows created or sustained by irrigation water. Depressional wetlands were the most common HGM class encountered, with 41% or 14 out of 34 sites. Of these, 13 were classified as non-natural features created by management action, meaning they had formed in a depression on the landscape that held water, but that the water source itself was not natural. Nine wetlands (26%) were sampled in the riverine HGM class. Of these, six were considered natural but altered and three were classified as a non-natural feature created by management action. These non-natural riverine sites were overgrown ditches with established vegetation cover that contained seasonally flowing water, mimicking riverine conditions. Eight wetlands (24%) were sampled within the novel irrigation-fed HGM class. Lastly, there were two lacustrine fringe wetlands and one slope wetland.

Within sampled wetlands, species diversity was relatively high, though a substantial portion of those species were non-native. In total, 233 individual plant taxa were encountered in the 34 sites. Of the 209 species identified to species level, 122 (58%) were native species and 87 (42%) were non-native species. Noxious weeds, an aggressive subset of non-natives, were present in all but two sites. Composite condition scores (a composite of both FACWet and EIA scores) revealed that, overall, aquatic resources in the study area have been subjected to dramatic, ubiquitous alteration. Based on composite scores, 85% of sites had an overall condition of functioning (C) or lower, 41% of sites were at the bottom end of the functioning range (CD) or lower, and one site was found to have been rendered completely non-functional in terms of its wetland habitat characteristics. The field results echoed finding from the mapping, that depressional and non-natural wetlands are now the norm in the study area, but add a richer understanding of the degree of alteration.

The last objective of the study was to compare the FACWet and EIA methods of wetland assessment. While the two methods share similar goals of assessing the condition of wetlands, FACWet aims to measure functional condition (driven by physical processes) and EIA aims to measure biotic condition (the response to cumulative stress). Overall scores from the two methods were remarkably similar, resulting in a correlation coefficient of $r = 0.83$ ($R^2 = 0.69$). However, component scores were often different (i.e., scores for component metrics of landscape, hydrology, physiochemity and vegetation condition). These differences stem from the emphasis of each method and from its methodological roots. FACWet is prescriptive in its approach and focuses on aspects of the wetland that create higher order functions, chiefly hydrology, in order to highlight the causes of (rather than state of) environmental degradation. As such, FACWet grades hydrology more harshly than EIA and weights these variables more heavily. EIA, on the other hand, uses vegetative health, as reflected by composition and structure, to integrate the myriad of environmental effects (some unknowable by an observer) into one tangible aspect of the wetland. EIA, therefore, grades vegetation metrics more harshly than FACWet, and weights these variables more heavily. The result is a highly similar score, but with different underlying messages about the wetland.

The overall results of this project clearly illustrate the power and utility of data for making informed decisions about wetland regulation and management on a watershed scale. The provisional Colorado Watershed Approach guidance document will serve as a valuable tool for all parties involved in wetland mitigation, and we look forward to input from users in the coming year. Lastly, the comparison of assessment methods will clarify the relative strengths and utility of the two major wetland assessment methods currently in use in the state of Colorado.

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1.0 INTRODUCTION

1.1 Watershed Approach to Wetland Mitigation

In a comprehensive evaluation of wetland mitigation through the 1990s, the National Research Council (NRC) concluded that "the goal of no net loss of wetlands is not being met for wetland functions" by the U.S. Army Corps of Engineers (ACOE) and U.S. Environmental Protection Agency (EPA)'s current mitigation program under Section 404 of the Clean Water Act (CWA) (NRC 2001). Acknowledging this conclusion, the ACOE and EPA issued a federal rule in April 2008 (2008 Rule) to increase the effectiveness of compensatory mitigation (ACOE & EPA 2008). The rule is the most recent step in a long history of mitigation policy development and implementation, and it signifies the federal government's intent to make decisions in a more predictable way and using the best available science (Hough and Robertson 2008). One of the key science recommendations of the NRC was for compensatory mitigation decisions to be made using a "watershed approach" (WA). Several facets of the rule are open for interpretation at the ACOE district level, but the general approach involves: a) building program partnerships, b) setting watershed goals, and c) using monitoring and assessment information to inform decision-making based on the established goals (Sumner et al. 2009).

While requiring a watershed-scale view of mitigation, the new mitigation rule did not provide guidance on how a watershed approach should be implemented. Before this project, Colorado lacked the basic capacity to carry out the WA to wetland mitigation. Fundamental impediments to this process included ambiguities about the most effective way to characterize watersheds and how to link site-based information to the greater watershed system. Further exacerbating these issues was a critical lack of the spatial data necessary to place wetlands in a meaningful watershed context. As of only a few years ago, digital National Wetland Inventory (NWI) maps—the national standard for wetland mapping—existed for less than 15% of Colorado[1]. Furthermore, most digital NWI maps that do exist are based on 1970-80s photo-interpretation and do not reflect changes caused by rapid population growth in the past 30 years. In place of reliable spatial data, best professional judgment (BPJ) about a watershed's wetland resources can be a useful starting point, but is inadequate for many applications and is poorly defensible. This situation has led to uncertainty for both regulators and regulated parties on how the rule should be implemented. For successful implementation, all parties need a clear understanding of how the policy will be administered. Without this understanding, mitigation decisions will continue as usual, on a case-by-case basis, and the full intent of the policy may go unrealized.

When this project began, Colorado was at a significant programmatic crossroads from which the WA process could have developed piecemeal, on an ad hoc basis, or it could be applied in a cohesive, uniform fashion coordinated with systematic mapping of wetlands across the state. Ad hoc implementation of the WA was highly undesirable because of the inefficiency and inconsistency it would breed. It was also not realistic to expect that small district offices or local governments would develop and apply the WA in every case where warranted if a process does not exist. To be

[1] Fig. estimated from data available on the U.S. Fish and Wildlife Service's Wetland Mapper webpage in June 2009, http://www.fws.gov/wetlands/Data/Mapper.html. This Fig. has been steadily increasing since 2009, as described further in the report.

applicable across the diverse user population within Colorado, a successful process needed to contend with the various levels of resources, needs, and abilities that exist across the state.

Through this project, we developed a process that would allow the WA to be successfully implemented and applied consistently across the state. The overarching objective of this project was to demonstrate how the watershed approach can be implemented and used to inform CWA Section 404 decisions on compensatory mitigation across the state of Colorado. To contend with the variable requirements and abilities of regulatory districts, local governments and municipalities to carry out the WA, and to make the watershed approach available in a timely fashion, we created a hierarchically-structured process. Our approach utilizes watershed profiles (Johnson 2005; Gwin et al. 1999; Bedford 1996) based on three levels of data availability, regulatory need, and time and resource constraints (Table 1). In application, each tier can be an endpoint or a step toward a more refined tool depending on the particular circumstances. Clear steps and procedures are outlined for all three tiers, and these steps can be put into practice immediately by regulators and the regulated community across Colorado.

Table 1. Three-tiered method to implement the watershed approach.

Tier	Data Source for Profiles	Approx. Timeframe to Develop	Applications and Constraints
1	Coarse data, readily available, high reliance on expert opinion.	5 days	Address Immediate program needs Low priority areas Lower reliability and lack of defensibility
2	Substantial but non-continuous or outdated wetland data available, often varying in quality and intent. Some reliance on expert opinion.	3 – 6 months	Areas facing moderate growth Limited programmatic funding Better reliability/defensibility
3	Targeted wetland survey using aerial photograph interpretation, with ground-truthing.	1 – 3 years	High priority areas Sensitive areas Project with highly impact

To serve as an example of how the approach could be implemented start-to-finish, we carried out all three tiers within a specific critical area, the northern Front Range corridor from north of Denver to south Fort Collins (Fig. 1). The resulting documentation from this study not only provides regulators in the study area with the framework in which to place Section 404 permitting in the watershed context, but also the actual tools, information, and spatial resources to implement the WA at its most detailed level on an immediate basis.

The secondary focus of this study was to facilitate te implementation of the WA outside of the study area by developing Tier 1 or 2 watershed profiles for each of the major river basins in Colorado based on all currently available digital wetlands data. These summaries provide individuals and agencies across Colorado with the basic necessary information to begin using the WA in a short timeframe. Thus our approach has been both intensive and extensive in scope and lays the essential foundation for successful implementation of the WA.

1.2 Project Objectives

The objectives of this project were carried out through the following tasks:

1. All three tiers of data collection to support the watershed approach were carried out in the northern Front Range corridor (Fig. 1). Data collected in this demonstration study area serve as an example for how baseline information on the extent, distribution and condition of wetlands can be assembled to support mitigation decision making under the 2008 Rule. Construction of the wetland profiles included the following steps:

    - Tier 1 wetland profiles were compiled for the current extent and distribution of wetland in the project area and the likely distribution of wetlands pre-settlement based on reference literature and best professional judgment.

    - A Tier 2 wetland profile was created by digitizing original NWI maps from the late 1970s. These original NWI maps were coarse and outdated, but provided a rough quantitative estimate of wetland acres. This Tier 2 profile also serves as a historical point of reference for examining change over time.

    - A Tier 3 wetland profile was developed through photo-interpretation of the most current air photography available and following the national standards for wetland mapping (FGDC 2009).

    - For both Tier 2 (historical) and Tier 3 (current) profiles, polygons were attributed with a modified hydrogeomorphic (HGM: Brinson 1993) classification in addition to the standard NWI classification (Cowardin et al. 1979) to draw conclusions about functional capacity within the study area (*sensu* Tiner 2003).

    - To explore watershed needs, change in the wetland profile between the two time periods was quantified by comparing the Tier 2 (historical) and Tier 3 (current) profiles.

    - To further inform the geospatial information within the profiles, condition of existing wetlands was assessed using a spatially balanced random sample survey design (Detenbeck et al. 2005, Stevens and Olsen 2000). Thirty-four wetland sites were selected for sampling and each site was evaluated using the two most prominent wetland assessment methods in Colorado: Functional Assessment of Colorado Wetlands (FACWet: Johnson et al. 2011) and the Ecological Integrity Assessment (EIA) framework (Faber-Langendoen et al. 2009).

    - As an added product developed through this study, the two condition assessment methods were compared and contrasted, providing cross validation for both methods and highlighting the strengths and applications for each.

2. Guidance for implementing the watershed approach to wetland mitigation in Colorado was developed based on three tiers of data intensity and a series of information gathering steps. The resulting preliminary decision support framework, known as the Colorado Watershed

Approach (COWAP), guides permit applicants through the basic steps of information gathering necessary, based on the level of data available, for regulators to make mitigation decisions within the watershed context This document, included as Appendix A, will allow local regulators to implement the watershed approach independently, but within a template that fosters consistency across regions.

3. All currently available wetland spatial data was compiled to develop Tier 1 or Tier 2 wetland profiles for each of the major river basins in Colorado. These data can be accessed through the recently developed Colorado Wetland Information Center website,[2] which includes summary data for wetland acreage at several spatial scales. These initial wetland profiles can serve as a starting place for regulators to begin implementing the mitigation rule within their districts.

1.3 Report Organization

This report contains a description of work carried out on all three project objectives, but focuses largely on Objective 1, the demonstration of information gathering to support the watershed approach. This objective involved several components, each discussed separately. Following this introduction, Section 2.0 is a description of the demonstration project area, Section 3.0 includes the Tier 2 (historical) and Tier 3 (current) wetland profile and the analysis of wetland change over time, Section 4.0 details the field based wetland condition assessment, and Section 5.0 is the comparison of wetland assessment methods.

Objective 2 resulted in a preliminary decision support framework, known as the Colorado Watershed Approach (COWAP), which can be found in Appendix A of this report. Over the next year, we will seek input and testing of the preliminary COWAP from partners in EPA, ACOE, state and local agencies, and private consultant. This document will eventually be a stand-alone document endorsed by all parties involved in Section 404 mitigation decision making.

As stated above, the work involved in Objective 3 is available on the web at the Colorado Wetland Information Center website.

[2] The Colorado Wetland Information Center can be found at the following web address: www.cnhp.colostate.edu/cwic.

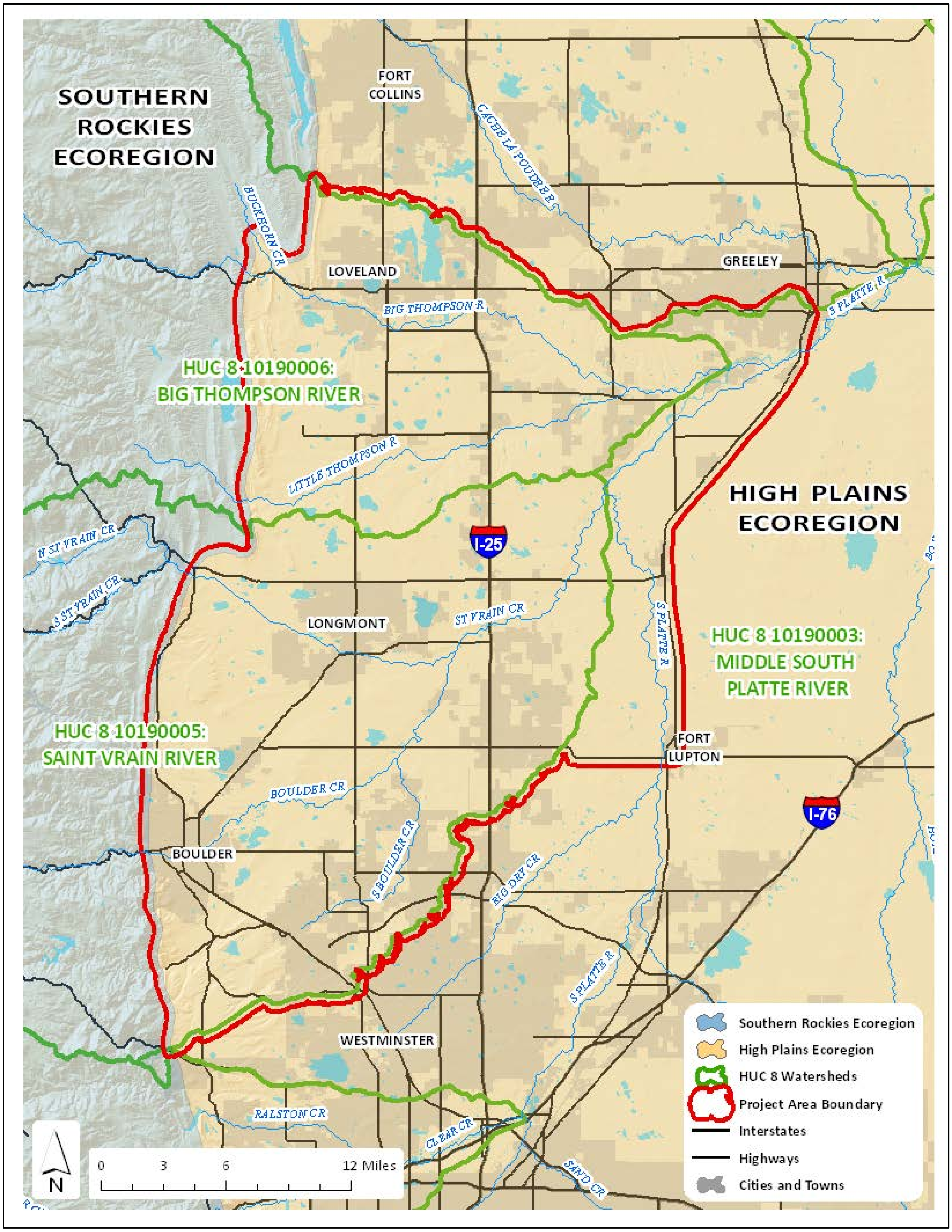


Fig. 1. Northern Front Range demonstration study area. The study area is bound by the Big Thompson and St. Vrain River watersheds and by the High Plains Level 3 Ecoregion. A small portion of the South Platte mainstem was included in wetland mapping, but not in the analyses.

2.0 DEMONSTRATION STUDY AREA

To demonstrate all three tiers of data collection, we focused on the plains portion of two watersheds located in the rapidly urbanizing northern Front Range corridor (Fig. 1), the St. Vrain (HUC 10190005) and Big Thompson (HUC 10190006) river subbasins. Both watersheds are split by the Southern Rockies Level 3 Ecoregion[3] to the west and the High Plains Level 3 Ecoregion to the east, two ecoregions that differ dramatically in terms of topography, natural vegetation, and land use. Following guidance by a multi-agency review team, we defined our study area based on the intersection of HUC 8 river subbasins and Level 3 Ecoregions, the same definition commonly used to define mitigation service areas for mitigation banking in Colorado, and included only the portions of these watersheds within the High Plains Ecoregion. The study area covers 412,699 acres in total, 261,882 (63%) in the St. Vrain watershed and 150,817 (37%) in the Big Thompson.

Within the target watersheds (but beyond the study area), the Southern Rockies Ecoregion is dominated by high elevation coniferous forests on steep mountains and wetlands are generally located within riparian corridors and mountain valleys. Within the study area, in contrast, the High Plains Ecoregion is located at lower elevations and is mostly dominated by grassland with much less topographic relief than the adjacent mountains. Because the area is lower in altitude and not as steep, wetlands can currently be found across a broader range of locations than in the mountains and have distinct vegetation and physical characteristics. Prior to European settlement, however, the vast majority of plains wetlands occurred in association with rivers, streams and other drainages. Elevation within the study area boundary ranges from 4,670–6,610 ft. (1424–2016 m) and the geology is largely sedimentary shale.

Climate within the study area is characterized by relatively warm summers with average high temperatures that approach 90° F and cold winters with average low temperatures of 16° F. Local climates are profoundly affected by differences in elevation, with wide variations occurring over short distances. The majority of available water is derived from snowfall in the mountains during the winter and arrives to the study area in late spring and early summer as snowmelt through creeks and rivers. With annual precipitation averaging less than 20 inches, most natural vegetation outside of riparian corridors is dry prairie grassland. Local climate in the two time periods of photo interpretation used for this study, 1978 and 2009, were very similar with annual precipitation of 23.8 inches and 22.2 inches, respectively, and average temperatures of 50.2° F and 50.8° F, respectively.

Though the study area was dominated by large expanses of short grass prairie prior to settlement, the area is now heavily influenced by land conversion to agriculture and urbanization. Similar to other prairie ecosystems, settlers quickly converted large expanses of land into irrigated and dryland crop systems. Irrigated areas receive water divert water from creeks and rivers in the study area, as well as from major trans-basin diversions that supply water to reservoirs for later distribution and use during the summer. Agricultural crops are composed primarily of feed and forage crops as well as the production of various high value crops. Along with agriculture, urbanization in the Colorado Front Range has been rapid over the past century. The three largest

[3] For more information on EPA or Omernik ecoregions and to download GIS shapefiles, visit the following website: http://www.epa.gov/wed/pages/ecoregions.htm.

cities in the study area, Boulder, Longmont, and Loveland, have collectively grown from under 150,000 people in 1978 to over 250,000 people in 2009. Though much of this urbanization occurs on land that had already been converted from prairie to agriculture, this rapid development has implications for the accurate reflection of historical NWI mapping data to today's landscape. Landownership in the study area is largely private, though cities and counties own a significant amount of land in open space and natural areas (Fig. 2).

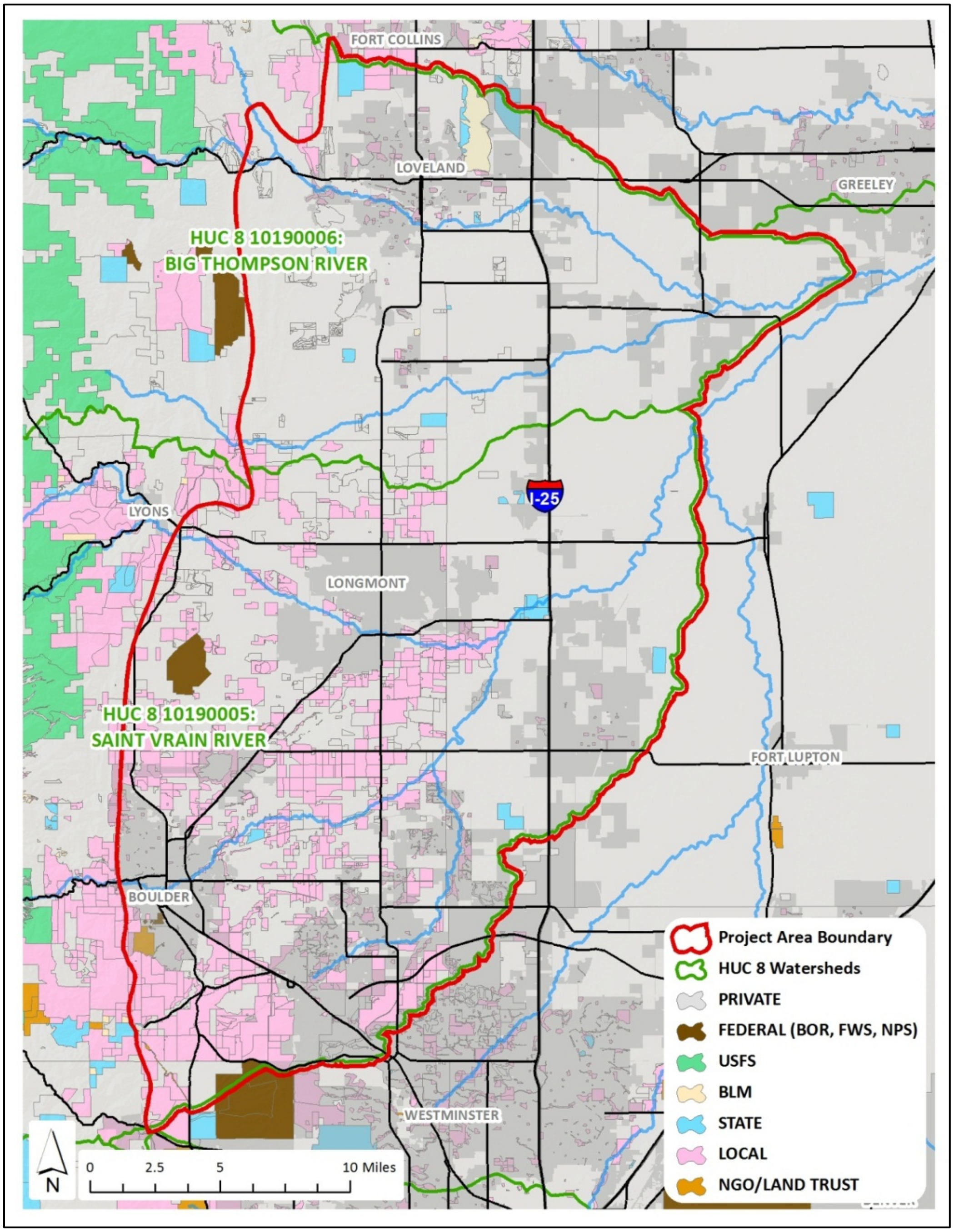


Fig. 2. Land ownership of the northern Front Range study area.

3.0 TIER 1, 2, AND 3 WETLAND PROFILES AND COMPARISON OF WETLAND ACREAGE OVER TIME

A key component of the watershed approach is understanding watershed needs based on the current extent, distribution and classification of wetland acreage within the watershed. This accounting of wetland resources is also called the "wetland profile." The best wetland profiles include up-to-date wetland mapping, attributed with multiple classification systems and augmented with on the ground data. While that level of detail is not available for much of the state, adequate wetland profiles can be developed using various levels of data intensity, as described in Table 1 on page 2.

Wetland profiles can inform effective mitigation decision making, especially when paired with watershed goals. To be most effective, these goals can be developed through a stakeholder-driven watershed planning processes. As an alternative, or to inform the watershed planning process, goal setting can be guided by a historical wetland profile, defined as either the pre-settlement landscape or a specific point in time. Comparing the current and historical profiles can reveal how the extent, distribution and classification of wetlands have changed over time and whether the direction of change is as desired.

To demonstrate how to build wetland profiles based on multiple levels of data, we carried out a multi-step analysis within the northern Front Range demonstration study area. For a Tier 1 profile, we consulted literature regarding wetlands in the study area and produced a coarse overview from existing information and best professional judgement. For a Tier 2 profile, we converted wetland maps created in the 1970s by the U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) program from hard copy paper maps to digital polygons. This Tier 2 profile also served as a historical benchmark from the late 1970s. For a Tier 3 profile, we created newly updated wetland maps for the study area based on 2009 color infrared (CIR) and true color imagery. All new mapping followed the federal standard for wetland mapping (FGDC 2009) and was submitted to NWI for inclusion in the national wetlands dataset. Lastly, we compared the two dataset to quantify how wetlands on the landscape have changed.

3.1 Methods

3.1.1 Wetland Classification Systems

Three classification systems were used within the wetland profile mapping and analysis, specifically the Tier 2 and Tier 3 profiles. The first was NWI's Cowardin classification (Cowardin et al. 1979), which was used to attribute all NWI mapping, both historical and current. The second was the USFWS's classification for riparian mapping (USFWS 2009), created to supplement the Cowardin system. This classification system was only used in the newly updated Tier 3 mapping because it did not exist at the time the original NWI maps were created. The third was the landscape position, landform, water flow path, and waterbody (LLWW) classification (also known as NWIPlus), a modified version of the hydrogeomorphic (HGM) classification (Brinson 1993) developed to describe functional characteristics of NWI mapped wetlands (Tiner 2003). The LLWW system was applied to both Tier 2 (historical) and Tier 3 (current) wetland mapping through a semi-automated process. Detail on all three methods is included below.

NWI's Cowardin Classification: The Cowardin classification (Cowardin et al. 1979) is a hierarchical system that describes wetlands at varying scales of specificity. The classification is based on the following definition of wetlands:

> *"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."*

For the scope of this project and the resolution of data, wetland features have been coded using the first three levels of the hierarchy: system, subsystem and class. In addition to these levels, hydrology and special modifiers were also coded. The result is a 4–6 character alpha-numeric code. Components of the code are used in the northern Front Range demonstration project area described below.[4]

System is the primary division in the classification and divides mapped features into a handful of aquatic resource types (Table 2). The three systems used for Colorado NWI mapping are Riverine (rivers), Lacustrine (lakes) and Palustrine (vegetated wetlands). While the full Cowardin classification includes codes for marine and estuarine systems, they are never found in land-locked Colorado. System is followed (when appropriate) by a numeric subsystem code. After system and subsystem, class identifies the dominate substrate or vegetation structure present (Table 3). Class is represented by a two letter code that follows system and subsystem. Hydrologic regimes describe the duration and timing of flooding and is represented by a single letter character (Table 4). Duration increases from A-H, though B sites are rarely flooded, but have water at or very near the surface consistently. The final component of the code is an optional special modifier, represented by a lowercase letter. Many modifiers are possible, though only a handful of codes were applied in the study area (Table 5). To facilitate generalizations about the mapping data, Cowardin codes were combined into seven broad groups (Table 6), of which five are considered true wetlands and the remaining two are lakes and rivers/streams.

[4] For more detail on the full Cowardin classification, please visit: http://www.fws.gov/wetlands/Data/Wetland-Codes.html.

Table 2: NWI Cowardin system and subsystem codes and interpretation.

System	*Subsystem*	*Code*		*Interpretation*
Riverine		**R**		**Rivers and streams**
	Lower Perennial		2	low gradient, slow moving channels
	Upper Perennial		3	steep, fast moving channels
	Intermittent		4	channels that do not flow year round, including manmade ditches
Lacustrine		**L**		**Lakes (water bodies >20 acres and/or > 2 m deep)**
	Limnetic		1	lake water > 2 m deep
	Littoral		2	lake water < 2 m deep along lake margins
Palustrine		**P**		**Vegetated wetlands (marshes, swamps, bogs, etc.) even if associated with rivers or lakes**

Table 3: NWI Cowardin class codes and interpretation.

Class	*Code*	*Interpretation*
Aquatic Bed	AB	aquatic rooted or floating vegetation
Emergent	EM	herbaceous, non-woody vegetation
Scrub-shrub	SS	low woody vegetation
Forested	FO	trees
Unconsolidated Bottom	UB	habitats with at least 25% cover of particles smaller than stones and less than 30% areal cover of vegetation
Unconsolidated Shore	US	unconsolidated substrates with less than 75% areal cover of stones, boulders or bedrock and less than 30% areal cover of vegetation
Stream Bed	SB	unvegetated surfaces with variable substrate sizes within stream channels

Table 4: NWI Cowardin hydrologic regime codes and interpretation.

Code	*Interpretation*
A	temporarily flooded
B	saturated
C	seasonally flooded
F	semi-permanently flooded
G	intermittently exposed
H	permanently flooded
K	artificially flooded

Table 5: NWI Cowardin special modifier codes and interpretation.

Code	*Interpretation*
f	farmed
h	dammed/impounded
x	excavated

Table 6: NWI attribute groups for summary tables.

NWI Group	*Codes*	*Interpretation*
Herbaceous Wetlands	PEM*	all herbaceous wetlands (e.g., marshes, wet meadows, playas, etc.)
Shrub Wetlands	PSS*	shrub dominated wetlands (e.g. willow stands)
Forested Wetlands	PFO*	tree dominated wetlands (e.g., wet cottonwood stands)
Ponds	PAB*/PUB*	ponds of all kinds, either vegetated or not, but with open water < 2 m (e.g. beaver ponds, stock ponds, golf ponds, etc.)
Other Wetlands	PUS*/Pf	misc. other classes, primarily unvegetated surface (i.e. sparsely vegetated salt flats) and some farmed wetlands (used only rarely)
Lakes and Lakeshores	L*	all lakes and unvegetated lake shores
Rivers / Streams / Canals	R*	all river and stream channels, including manmade ditches, and their associated unvegetated shores (i.e., unvegetated sandbars)

USFWS Classification for Riparian Mapping: In the years since the original Cowardin classification was introduced in the late 1970s, USFWS realized the need to map riparian areas that may not meet the criteria used for mapping wetlands. This need is particularly great in the western U.S. where numerous wildlife species depend on riparian habitats in an otherwise arid landscape. These habitats are moist, can be flooded for short periods of time, and are commonly associated with flowing water. Riparian areas are "wetter" than uplands, but do not always meet the flooding, biological composition or soil criteria to be classified as a wetland. To identify, map, and classify a broad spectrum of non-wetland riparian areas, USFWS issued guidance in a document titled *A System for Mapping Riparian Areas in the Western United States* (USFWS 2009). The definition of riparian used for mapping is:

> *"Riparian areas are plant communities contiguous to and affected by surface and subsurface hydrologic features of perennial or intermitted lotic and lentic water bodies (rivers, streams, lakes, or drainage ways). Riparian areas have one of both of the following characteristics: 1) distinctively different vegetation species than adjacent areas, and 2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian areas are usually transitional between wetland and upland."*

This system is fully integrated into the Cowardin classification scheme and also includes system, subsystem and class. The system is a single unit category of Rp (riparian vegetation) and subsystem defines the water source (Table 7). Class denotes the dominant life form of riparian vegetation. Three of the class codes from the Cowardin classification are used: FO (forested), SS (scrub-shrub), and EM (herbaceous). No water regime or modifiers are applied.

Table 7: USFWS classification for riparian mapping system and subsystem codes and interpretation.

System	*Subsystem*	*Code*		*Interpretation*
Riparian		**Rp**		**Riparian vegetation**
	Lotic		1	associated with flowing water from rivers or streams
	Lentic		2	associated with standing water from lakes

It is important to note that most general definitions of riparian areas do include wetland habitats within the riparian zone. The wettest areas within riparian corridors can meet the wetland criteria, especially at higher elevations. However, riparian areas can include drier areas that are not wetland. The two concepts of wetland and riparian are best conceptualized as two overlapping spheres. There are wetlands within riparian areas, but not all wetlands are riparian and not all riparian areas are wetlands. It is the drier, non-wetland riparian areas that are targeted with the supplemental USFWS riparian mapping standards.

Landscape Position, Landform, Water Flow Path, and Waterbody (LLWW) Classification: While the Cowardin classification is standard for wetland mapping, the hydrogeomorphic (HGM) classification (Brinson 1993) is often used for functional assessments and mitigation planning. Compared to structural vegetation classes of the Cowardin classification, the HGM system places greater emphasis on wetland function stemming from geomorphic setting and hydrology.[5] In 2003, Ralph Tiner with the USFWS NWI program developed a modified version of HGM as a means to expand the coding within NWI wetland mapping (Tiner 2003). The methodology is not a "one -to-one" conversion but rather groups and splits Cowardin codes based on wetland settings and functions.

Though codes in the Cowardin and HGM wetland classification schemes do not have one-to-one corollaries, much of the spatial information critical to the HGM classification is readily available through GIS. Tiner's method uses spatial information about geomorphic setting, water sources and hydrodynamics, which are integral to the HGM classification, and defines classes based on landscape position, landform, water flow path, and waterbody type (LLWW). This approach adds geomorphically relevant information to the NWI mapping without the detail required for a complete HGM classification. The LLWW uses strictly spatial data (position, slope, size) to code wetlands, while the HGM requires other information about water source and groundwater movement not typically available as spatial data.

The LLWW shares some terminology with the original HGM classification and introduces new classes and modifiers. For example, HGM depressional wetlands are roughly equivalent to LLWW basin wetlands. To avoid confusion, the LLWW classification stays away from HGM terminology that is already used in the Cowardin classification. For instance, within Brinson's HGM, wetlands associated with lakes are called lacustrine wetlands. However, in the Cowardin classification, lacustrine features are the actual lakes themselves and not vegetated wetlands on the margins of lakes. In the LLWW, Tiner opts for the word Lentic to describe wetland features associated with lakes. The components of the LLWW method are described below.

[5] For more information on the HGM classification, see Table XX in Section 4.2.

The first split in the LLWW classification divides actual waterbodies from wetland features (Table 8). Because NWI mapping includes waterbodies as well as wetlands, this is easily done by querying the Cowardin system and subsystem. Once waterbodies have been filtered out, the remaining wetland features are assigned a landscape position based on their location in or along a waterbody, in a drainageway, or in isolation (i.e., surrounded by upland) (Table 9). All three waterbodies and the wetlands associated with them are attributed with an additional code that further describes the waterbodies (Table 10). Terrene wetlands do not receive a modifier because they are not associated with a waterbody.

Table 8: LLWW waterbody codes and interpretation.

Waterbody Type	***Code***	***Interpretation***
Deep water	DW	Lakes
River	RV	Larger channels
Streams	ST	Smaller channels

Table 9: LLWW landscape position codes and interpretation.

Landscape Position	***Code***	***Interpretation***
Lentic	LE	wetlands associated with lakes, in HGM terminology this is called Lacustrine
Lotic River	LR	wetlands associated with larger rivers, in HGM terminology this is called Riverine
Lotic Streams	LS	wetlands associated with smaller streams, in HGM terminology this is called Riverine
Terrene	TE	wetlands not associated with either a lake, river, or stream, in HGM terminology this could have various names

Table 10: Additional descriptors for LLWW waterbodies and associated landscape positions.

Applies to	***Code***	***Descriptor***
DW, LE	1	natural lake
	3	damned lake
	4	excavated lake
RV, ST, LR, LS	1	low gradient < 2% slope
	2	middle gradient 2-4% slope
	3	high gradient >4% slope
	4	intermittent

For all wetland features, the next step in the classification is the landform (Table 11). Waterbodies (DW, RV, ST) do not receive a landform code. Landforms are specific to wetland landscape position, meaning not every landform can occur with every landscape position. The final main component of the LLWW system is water flowpath, which describes the primary direction of water flow (Table

12). A handful of additional modifiers can be used, based on existing NWI codes. Ponds can occur in a variety of settings, including in isolated depressions or within backwater channels on river floodplains. Ponds are coded separately within the Cowardin classification and are therefore easy to pull out within the LLWW. Any wetland coded as a pond in the Cowardin system (PUB/PAB) receives a separate pond modifier code (p). The LLWW also takes advantage of the modifier codes within Cowardin system, such as beaver (b), ditched/drained (d), farmed (f), diked/impounded (h) and excavated (x). Because the resulting LLWW codes are long and cumbersome (e.g., LSBATH, TEphBACO, LR2FRTH, etc.), LLWW codes were combined into six HGM-like groups, of which four are considered true wetlands. This is a simplification of the coding system, but should stand as a coarse estimate for HGM functional classes.

Table 11: LLWW landform codes and interpretation.

Landform	*Code*	*Interpretation*	*Applies to*
Island	IL	wetlands located on islands completely surrounded by water in lakes, rivers, or streams	LR
Fringe	FR	very wet wetlands on the margins of lakes, river, or streams	LE, LR
Floodplain	FP	drier wetlands located within the floodplain of rivers and streams	LR
Basin	BA	depressional landforms	LE, LS, TE
Slope	SL	sloping wetlands not associated with a waterbody	TE

Table 12: LLWW waterflow path codes and interpretation.

Waterflow path	*Code*	*Applies to*
Inflow	IN	DW
Outflow	OU	DW
Throughflow	TH	DW, RV, ST, LR, LS, LE
Bidirectional	BI	LE
Isolated	IS	DW, TE
Complex (many wetlands together)	CO	TE

Table 13: LLWW attribute groups for summary tables.

LLWW Group	*Codes*
Depressional	TEBA*, all pond features
Slope	TESL*
Riverine	LR*/ LS*, except pond features
Lacustrine	LE*, except pond features
Lakes and Lakeshores	DW*
Rivers / Streams / Canals	RV*/ST*

In order to bridge the gap between NWI and LLWW without having to code every polygons separately, the Montana Natural Heritage Program (MTNHP) developed a process to crosswalk Cowardin coded wetlands to LLWW (Newlon and Burns 2010a, b). This process was modified by CNHP and extensively documented in Appendix B. Semi-automated queries create and utilize spatial data (slope, position, adjacency, etc.) along with NWI attributes to identify characteristics integral to the LLWW method. This process was applied to both Tier 2 (historical) and Tier 3 (current) NWI datasets to further inform the wetland data. The semi-automated process is far from perfect, and the MTNHP is actively worked on a revised version. However, it does produce a rough estimate of wetland acreage in HGM-like classes.

3.1.2 Tier 1 Wetland Profile of the Northern Front Range

Two coarse Tier 1 wetland profiles were developed based on available literature regarding wetlands in the northern Front Range and best professional judgment. Literature included reports by Dr. David Cooper on wetlands within the study area and similar nearby landscapes (Cooper 1988, 1989); surveys of biological significant wetlands in Larimer and Boulder Counties conducted by CNHP (Doyle et al. 2005; Neid et al. 2009); and recent academic publications (Johnson et al. 2013; Sueltenfuss et al. 2013). The Tier 1 profiles did not estimate actual acres, but relative proportions of wetland types using the HGM classification system. One Tier 1 profile estimated the relative proportion of wetlands that existed prior to European settlement and the second estimated the relative proportion of wetlands that exist today.

3.1.3 Tier 2 (Historical) Wetland Profile of the Northern Front Range

Tier 2 wetland profiles take advantage of easy to access quantitative spatial data, even if out of date. In Colorado, wetlands across the entire state were mapped by the USFWS NWI Program in the 1970s–80s, but these original products were created as hard copy paper maps, not as digital spatial data. In 2008, shortly before the beginning of this project, digital NWI data were available for less than 15% of state. At that time, CNHP and Colorado Parks and Wildlife (CPW) began working with the NWI Program to convert existing paper maps to digital data, essentially doing the work to create Tier 2 profiles for the state. Conversion of existing paper maps is cost-effective and can be completed relatively quickly. CNHP's current process is well documented and is included as Appendix C. Since 2008 and largely through CNHP's efforts, we are slated to have statewide coverage of digital NWI data by the end of 2014.

At the outset of this project, digital NWI mapping was available for only one topographic quad within the demonstration study area. However, paper maps existed for the entire area. These original wetland maps were created in the late 1970s through photo-interpretation of black and white aerial imagery following a provisional draft of the Cowardin classification system. Polygons were mapped at a scale of 1:80,000 directly onto Mylar sheets and transferred to 1:24,000-scale topographic quads. The photo-interpretation was conducted in 1977/78 based on 1975 aerial imagery. This mapping is referred to as 1978 mapping throughout this report.

For this study, geo-rectified scans of the original paper maps for all topographic quads in the study area lacking digital data were converted to digital polygons using an early version of the process developed by CNHP and CPW. This produced a wall-to-wall digital map of wetlands based on 1970s photo-interpretation. Polygons were unchanged and all codes attributed to the polygons were those identified by the original mappers, although outdated water regime codes were translated to the currently used codes. The scale at which the mapping was originally created prohibited identifying narrow polygons < 10 m. Because of this, all narrow features were originally drawn as lines. During the conversion process, these linear features were turned into polygons by buffering traced lines to 10 or 20 m, whichever best matched the feature. The width of these features should not be taken as representative of what the original mapping technicians identified. Once the original NWI mapping was digital, the semi-automated LLWW attribution process was run on the dataset.

The Tier 2 (historical) wetland profile was summarized along with ancillary data sources. Summary statistics include wetland acreage by NWI attribute group, hydrologic regime, extent modified, land ownership, and LLWW attribute group.

3.1.4 Tier 3 (Current) Wetland Profile of the Northern Front Range

To create the most detailed Tier 3 profile of current wetland resources, CNHP used a combination of data sources to map and classify wetland features in the project area. Photo-interpretation was based on 2009 color infrared (CIR) and true color images obtained from the National Agricultural Imagery Program (NAIP). In addition, 2005 NAIP true color images, topographic maps, political maps, Colorado Parks and Wildlife riparian polygons (generated in early 2000s) and original NWI polygons were used to map wetlands. The most recent coding rules of the NWI classification system were used to attribute the polygons. [6] Special modifiers were used more effectively in the new mapping compared to the original mapping, which did not use modifiers. Polygons were also created for riparian features, following the USFWS riparian mapping classification (USFWS 2009). New wetland mapping was conducted on screen in ESRI ArcGIS 9.3 at a scale of 1:4,500, followed the Federal Geographic Data Committee standards for wetland mapping (FGDC 2009), and was reviewed by the NWI Regional Coordinator.

CNHP mapping specialists performed two quality control procedures to ensure the most accurate updated mapping. 1) *On-the-ground field checks:* CNHP photo-interpreters took periodic trips to the study area to ground-truth the image interpretation. This familiarized the interpreters with photo signatures of specific wetland complexes. GPS points and geo-tagged images were utilized to document the location of specific wetland types for reference on the wetland map being created. Public land was accessed by foot and private land was viewed from roadside vantage points.
2) *Final automated check:* To ensure accuracy in coding, a final automated procedure checked the data layer for invalid wetland codes, size limitations and topological errors. Each error flagged was identified and carefully examined using multiple data layers and on-the-ground and in-the-air field truthing to reconcile errors.[7] Once the original NWI mapping was digital, the semi-automated LLWW attribution process was run on the dataset.

The Tier 3 (current) wetland profile was summarized based on the completed digital NWI mapping and ancillary data sources. Summary statistics include wetland acreage by NWI attribute group, hydrologic regime, extent modified, land ownership, and LLWW attribute group.

[6] For more detail on the most recent Cowardin classification, please visit: http://www.fws.gov/wetlands/Data/Wetland-Codes.html.
[7] For information on the NWI Data Verification Procedure, please visit: http://www.fws.gov/wetlands/Data/Tools-Forms.html.

3.1.5 Wetland Change Over Time

The final step in the analysis was to compare the Tier 2 (historical) and Tier 3 (current) datasets and quantify changes in wetland acreage and type over time, as depicted in the mapping. There were several significant differences in mapping methodology between the two time periods. Most notable was the resolution of images and the scale at which the mapping was carried out for the two time periods. This meant that small wetland features were often lumped with surrounding matrix wetlands in the original (historical) mapping (Fig. 3). Secondly, the Cowardin NWI classification has evolved over time and codes are applied differently, particularly since the development of the USFWS supplemental riparian mapping system. Much of the woody vegetation along rivers and streams in the study area is now coded as riparian mapping because they are too dry to be considered true wetlands. But these areas were often coded as PFOA wetlands in the original mapping because they lacked an appropriate code and did not want these large corridors to go unmapped. Given these changes, the challenge was to understand the difference between true landscape change (creation, removal or change in wetland type and acreage) and discrepancy in mapping techniques or image resolution between the two mapping years. Simply comparing raw wetland acres from the two datasets would result in spurious conclusions. Therefore, we examined a subset of polygons along with imagery from both time periods determine why the change in mapping had occurred, whether due to landscape change or mapping methods.

Four primary datasets were used in the analysis: the two wetland mapping dataset and aerial imagery from the two time periods. The black and white aerial images used for the original mapping, flown in the summer of 1975, were not available for this analysis. The next available time period was 1977/78 (coincidentally when the photo-interpretation was conducted). These were purchased, scanned, ortho-rectified, geo-referenced and combine into a single composite overlay for the study area. Some small areas were not available, but the majority of the project area was obtained (Fig. 4a). The dates of the flights ranged from early June 1977 to early September 1978. The images had minimal cloud shadowing and appeared fairly clear. As stated previously, 2009 NAIP color infra-red and true color images were used for the updated interpretation. These were flown over the summer of 2009 (primarily June) and were of good quality as well.

It was not feasible to examine every polygon in the study area, so a random sample approach was taken. The goal of the random sample was to sample across the project area in such a way as to eliminate bias and allow the results to represent a reasonable estimate of change across the entire project area. Sample units for the random selection were sections from the Public Land Survey System selected using the Reversed Randomized Quadrant-Recursive Raster (RRQRR) approach in ArcGIS 9.3 (Theobald et al. 2007). Selected sections were included in the analysis if there was continuous aerial imagery for both time periods and if they contained any wetlands from the either time period. Several sections had to be thrown out because they spanned a gap in the 1978 imagery or because they were on the edge of the study area and did contain any mapped wetlands. In total, 73 selected sections were analyzed and these represented ~10% of the study area (Fig. 4b). Within selected sections, all wetland polygons from both time periods were examined. This analysis was modeled, in part off similar wetland change detection studies carried out by the MTNHP (Vance et al. 2006; Kudray & Schemm 2008; Newlon & Burns 2012a, b).

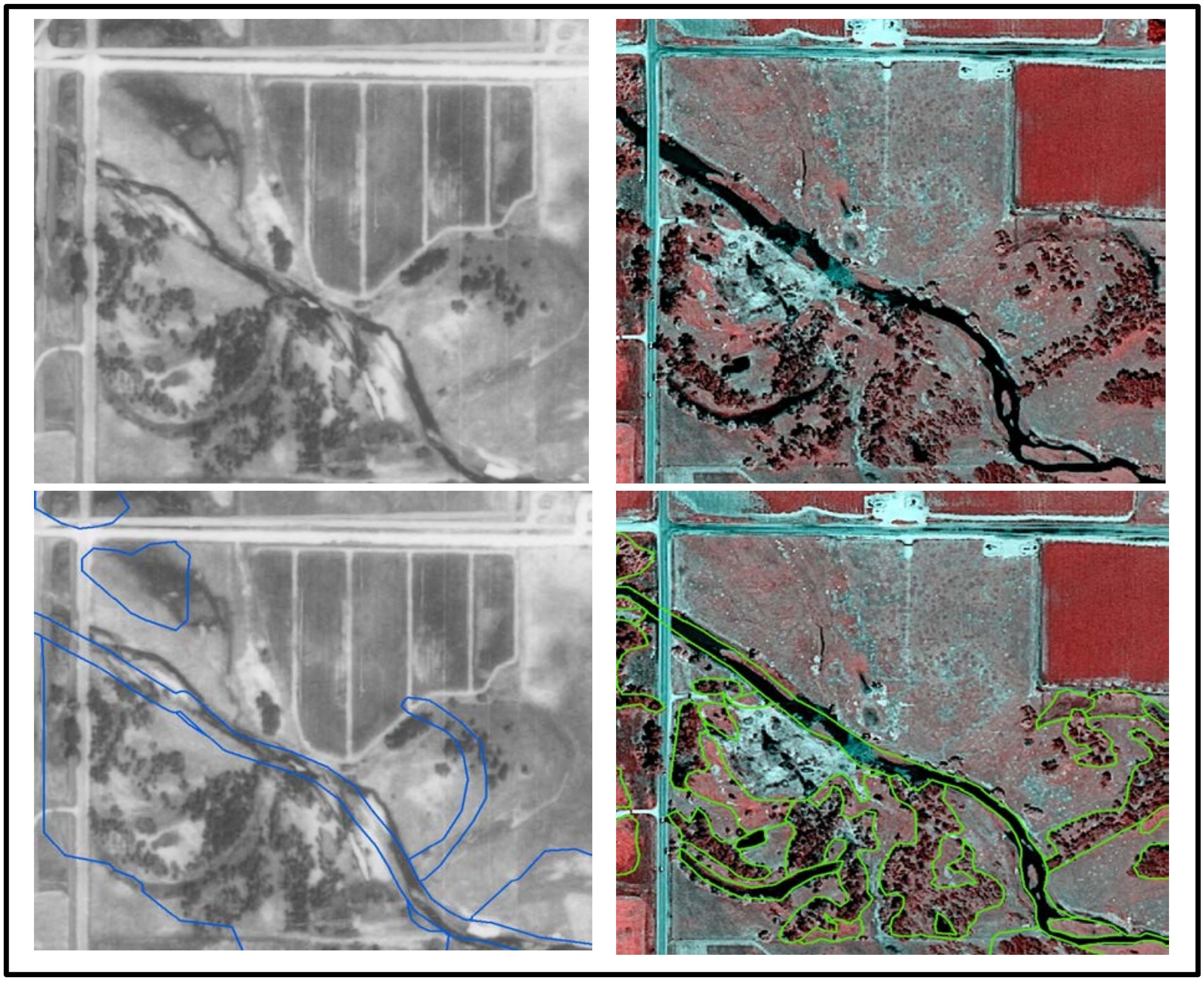


Fig. 3: Resolution and image quality differences between 1978 black and white and 2009 CIR imagery. Viewed at a 1:2,500 scale. Blue and green lines show NWI wetland polygons from 1978 and 2009, respectively.

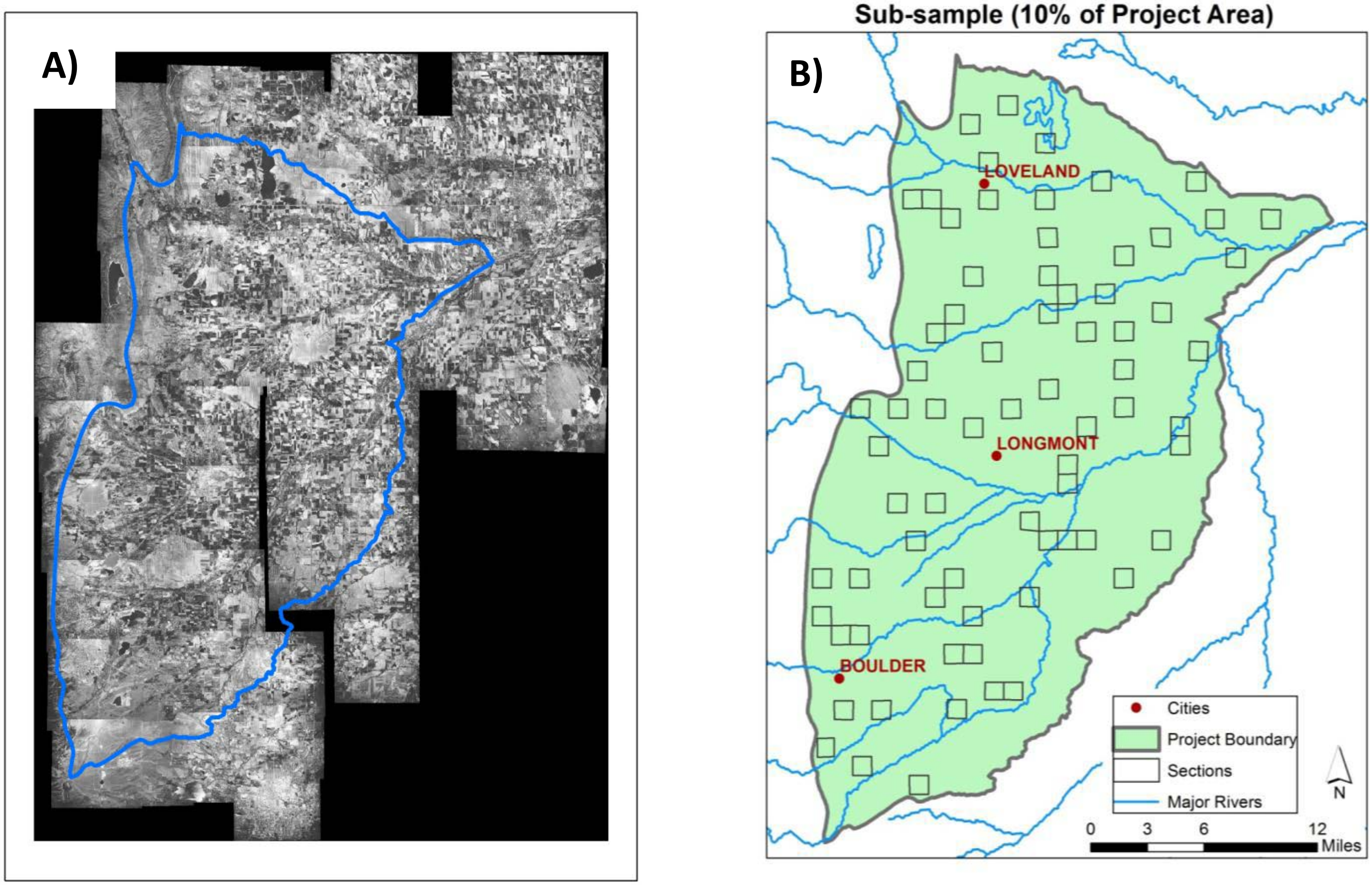


Fig. 4: a) Extent of 1978 black and white aerial imagery used to evaluate the original NWI mapping. b) The 73 sections analyzed within the study area.

To quantify differences in the mapping, the two wetland datasets were combined using the “union” tool in ArcGIS. The “union” of the two datasets created split polygons at all intersections. The number of polygons in the resulting layer was a function of this union and did not reflect the original number of polygons from neither dataset. Therefore, the results are presented in terms of area in acres and not number of polygons. The combined dataset was partitioned into five logical categories that highlight changes in wetland extent between the two mapped years (Table 14; Fig. 5). The names *‘Added’* and *‘Removed’* are only partially suggestive of the origin or fate of a particular wetland polygon in this categorization. The *‘Added 2009 Wetlands’* and *‘Removed 1978 Wetlands’* are the only two categories that kept the original shape of the wetland polygon intact. The remaining three categories were dependent on the intersections and overlapping of 1978 and 2009 wetland polygons and the subsequent divisions, as shown in Fig. 5. The large disparity in imagery quality used to create the original and updated wetland maps required careful criticism to identify when resolution or mapping errors incorrectly suggest the removal or addition of wetland features and acreage.

Table 14. Comparison categories used in the change over time analysis.

Comparison Category	***Interpretation***
Removed 1978 Wetlands	Wetland polygons from the 1978 mapping that did not overlap nor touch any polygon from the 2009 mapping.
Added 2009 Wetlands	Wetland polygons from the 2009 mapping that did not overlap nor touch any polygon from the 1978 mapping.
Overlapping Wetlands	Union polygons that represented overlap between polygons from the 2009 and 1978 mapping. Union polygons were not the entire polygon from either map, but only the areas that overlap.
Remaining 1978 Wetlands	Union polygons that represented components of polygons from the 1978 mapping remaining after the overlap area was removed.
Remaining 2009 Wetlands	Union polygons that represented components of polygons from the 2009 mapping remaining after the overlap area was removed.

Removed 1978 Wetlands: This category examines wetland polygons that were removed from the NWI map between 1978 and 2009. Two possible causes of this disparity between wetland layers included: 1) the landscape was changed such that the wetland no longer exists (e.g., the water source was eliminated or the wetland was filled); or 2) an error of commission was made in the 1978 mapping that was corrected with improved imagery in 2009 (e.g., incorrectly mapping an upland area as wetland). The first cause was directly related to landscape change whereas the second was related to image quality and mapping techniques.

Added 2009 Wetlands: This category examined wetland polygons that were added to the landscape using 2009 imagery that were not mapped in 1978. There were two possible reasons these wetlands were mapped in 2009 and not in 1978: 1) the wetland did not exist in 1978 and was created sometime in the intervening three decades; or 2) the wetland did exist in 1978, but was not mapped due to mapping errors, which can originate from resolution issues (e.g., the wetland was too small), a different interpretation in the NWI code and wetland definition, or general image quality. The addition of riparian mapping also added considerable acreage.

Overlap Wetlands: This category examined portions of wetland polygons that existed in both 1978 and 2009 NWI wetland maps. In areas where wetlands were identified in both years, the NWI and LLWW codes for both years were evaluated to determine if the polygons represented the same wetland on the ground, or if it had been converted from one type to another. Differences in NWI or LLWW codes could be derived from errors in coding in either year; changes in the physical landscape through cutting, planting, clearing, flooding, or successional vegetation growth; and the introduction of the riparian codes from USFWS (2009). The limited use of NWI modifiers in 1978 wetland codes compared to the regular application of modifiers in 2009 are not considered a code change, nor were minor changes in hydrologic regimes (e.g., from temporarily flooded to seasonally flooded).

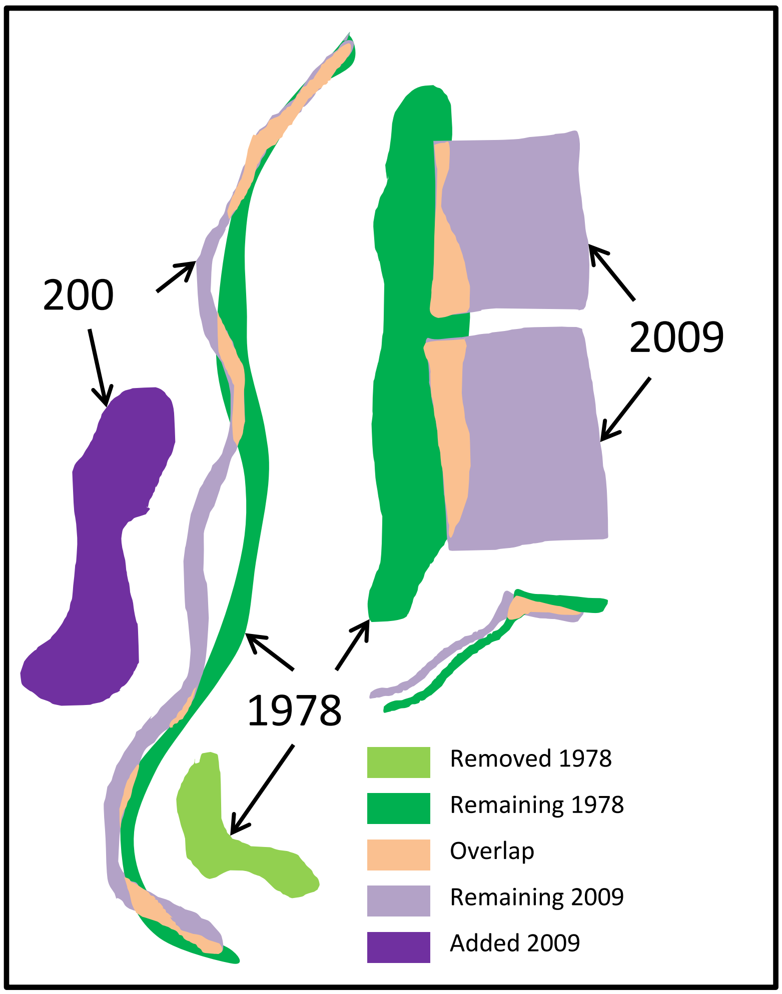


Fig. 5: A simple illustration of the five comparison categories of wetlands. This image shows four original 1978 wetland polygons and five 2009 wetland polygons, but the total unioned polygons is 13.

Remaining 1978 Wetlands: This category examined portions of wetland polygons that were mapped in 1978 but had some part of their extent overlapping with a 2009 wetland polygon. The overlapping portion was considered in the *'Overlap Wetlands'* category while the remaining portion of the 1978 wetland polygon was considered here. Small discrepancies in geo-referencing, and the increased precision of wetland boundary delineation for 2009 wetlands often led to the creation of small areas of *'Remaining 1978 Wetland'* polygons. Even if a pond, for example, had not changed between the two mapping periods, the spatial tolerances of the mapping were different enough to cause some differences (Fig. 6).

Remaining 2009 Wetlands: This category examined portions of wetland polygons that were mapped in 2009 but had some part of their extent overlapping with a 1978 wetland polygon. The overlapping portion was considered in the *'Overlap Wetlands'* category while the remaining portion of the 2009 wetland polygon was considered here. Small discrepancies in geo-referencing, and the increased precision of wetland boundary delineation for 2009 wetlands often led to the creation of small areas of *'Remaining 2009 Wetland'* polygons.

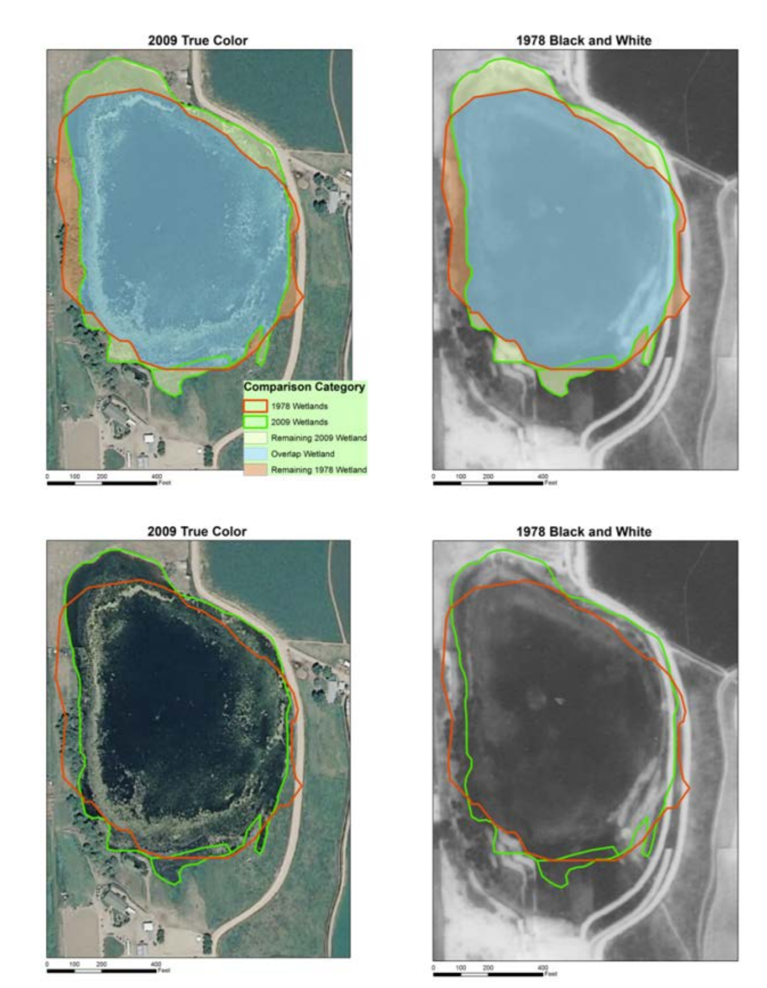


Fig. 6: A wetland polygon showing the discrepancies in mapping between 1978 and 2009 that can develop from a spatial tolerance/resolution origin.

The driving question of the analysis was how much change in the wetland mapping was related to actual landscape change and how much was related to mapping differences. Within each of those larger categories, a number of potential causes were identified (Table 15). Some changes had very discrete causes, such as a shopping center built where a farm pond once existed or the creation of small lakes in an old gravel quarry. Other changes in wetland shape and degree of wetness were more difficult to interpret, such as slight land use changed or more or less efficient irrigation practices. Each polygon that represented either a loss or addition of wetland acreage or a conversion of wetland type was assigned one of the change causes below, observed to be the dominant cause of difference between the datasets. Examples of each cause are included as Appendix D.

Table 15. Potential causes of change between historical and current mapping.

Causes Related to Landscape Change	
Natural Adjustment	In the three decades between the original and updated wetland mapping, there has likely been vegetation succession, shifting channel patterns, sandbar movement, etc. These natural processes are important to note as change because ecological function is often reliant on the vegetation structure. While many channels are confined by human structures to stabilize banks to prevent channel movement, several of the larger channels still have segments with some horizontal mobility to adjust their course. This results in shifted sandbars, split or combined channels, and newly formed oxbow features. Closely linked with channel adjustment, vegetation succession is the shifting of vegetation vertical strata from bare earth to herbaceous to shrub to forest. A time period of 30+ years allows for significant change following disturbance and new land use practices.
Ponds	Ponds can be excavated on the landscape as a water feature for a home, a water source for pasture animals, retention ponds for stormwater management, or for intentional wetland habitat. Bermed draws and swales also act as ponds, impounding water into a still pool. This is common in pasture land. Converted ponds are dug out of the land or bermed in an area where a non-pond wetland had previously been mapped.
Added Irrigation "Wetter"	Agricultural fields in the area have increased their use of irrigation (often pivot systems) to increase crop yield. The application of this water can elevate water tables around the field (especially downslope), which can lead to the creation or augmentation of wetlands. Surface flow from over application can also lead to increased wetland size in swales draining the landscape near fields.
Reduced Irrigation "Drier"	Increased efficiency in irrigation application can have as stark an influence as changes in direct application to wetland size, condition and sustainability. While less often, shifting an agricultural field from irrigated to dryland practices can adversely affect wetlands downslope whose water source was irrigation runoff, elevated ground water, or ground water seepage, causing them to dry out.
Resource Extraction	Gravel pits are common along the larger rivers in the study area. These features are primarily located in floodplains and often result in ponds or lakes after mining activities ceased.
Urban Development	Population increases in the study area have led to increased built structures, roads connecting these structures, and parking lots supporting them. Change due to urban development was loosely defined as dense structures constructed since the 1978 image year.
Rural Development	Population in the study area has also spread into more rural areas, where construction of homes, barns, roads, etc. has been completed on a less intense scale, with more space between buildings and roads. This more sparse development often did not completely eliminate wetlands, but narrowed, confined or otherwise altered the extent or type of wetland.

Other	This category was a catch all for landscape change that does not fit into one of the above categories.
Causes Related to Mapping Methods	
Riparian Attribution	The additional of riparian mapping led to splitting many 1978 wetland polygons (particularly PFOA, PSSA and PEMA) into part wetland and part riparian. This additional mapping also added new areas that did not have wetland characteristics.
Scale	The aerial images from the late 1970s were in black and white with a much coarser resolution than the images from flights in 2009. This resolution directly affected the scale at which wetlands were mapped, both in the minimum mapping until and the degree to which features were aggregated or separated. This is particularly noteworthy for narrow features such as streams, canals and small features such as farm ponds. One aspect of scale was that images and wetland polygons did not match up perfectly, leading to many small inconsistencies.
Interpreter Difference	While it was not possible to communicate with the original wetland mapper as to why a wetland was or was not included or categorized a specific way, clear discrepancies or mistakes were observed between datasets.
Image Quality	The black and white images from the late 1970s had fewer pixel colors to represent the images than did the 2009 color images. This gray scale made it difficult to represent the complexity of some wetland systems. Blurry, cloud shaded, overly dark or washed out images made identify of wetland types and extents difficult.

3.2 Results

3.2.1 Tier 1 Wetland Profile of the Northern Front Range

Prior to European settlement, the landscape of the northern Front Range was dominated by open prairie grassland. A network of rivers and streams, many of which originated high in the mountains, flowed through this open prairie and across the plains, liking together one by one on their path to join the South Platte River. The predominant direction of water flow in the study area was west to east, trending somewhat to the northeast for the Boulder Creek drainage. Most of these rivers and streams meandered across wide floodplains, which are still evident in the region's topography. Along these floodplains, abandoned channels would fill with wetland vegetation until they were flushed through by a major flooding event (Cooper 1988). The vast majority of wetlands in the region was likely tied directly to the rivers and streams and would have been considered riverine wetlands. Groundwater seepage may have created additional slope wetland acres along the base of buttes or significant breaks in slope. The landscape likely supported few natural depressions and even fewer actual lakes. The potential pre-settlement wetland profile, therefor, may have looked like the one presented in Fig. 7.

It is easy to see from aerial imagery that the historical network of rivers and streams in the northern Front Range has been dramatically altered by an even more complex array of ditches, canals and water storage. Instead of flowing west to east, these channels now flow north to south and vice versa, linking agricultural field and open reservoirs that have been dug out of the plains. Based on review of imagery, literature, and best professional judgment, Fig. 8 presents an estimated profile of the distribution of current wetland acreage in the study area. Lakes, primarily

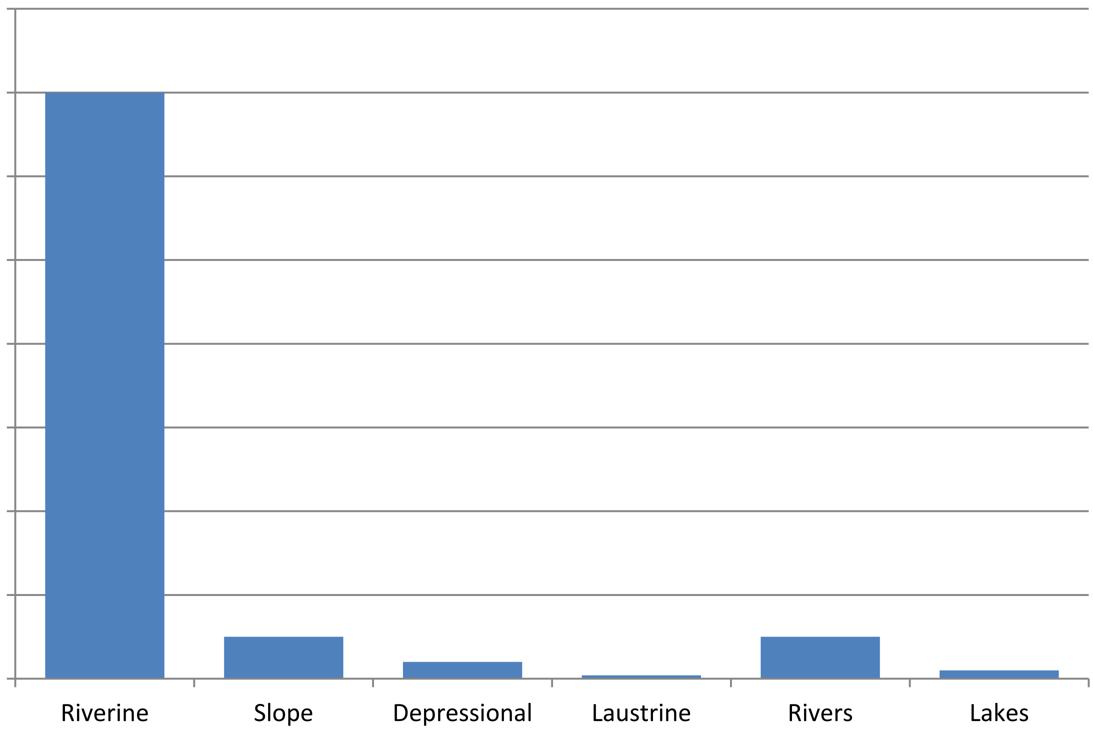


Fig. 7. Tier 1 wetland profile showing the estimated pre-settlement distribution of wetland acres.

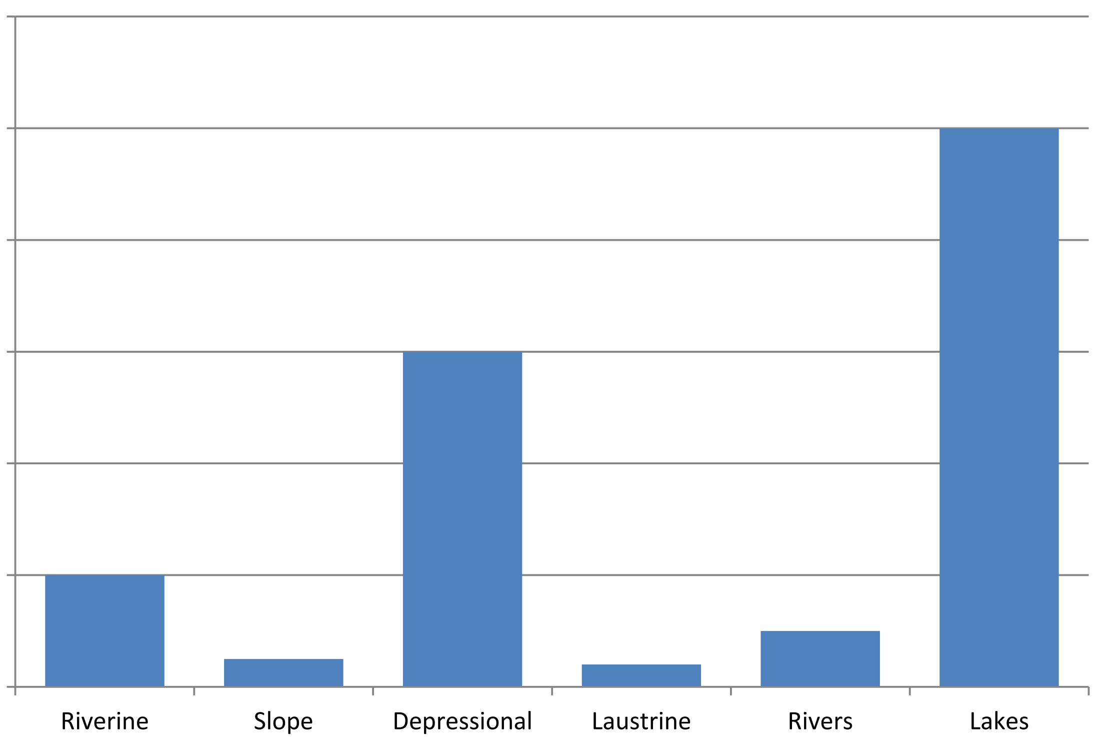


Fig. 8. Tier 1 wetland profile showing the estimated distribution of wetland acres today.

for water storage, are a dominant aquatic resource in this landscape. Second to lake are the large number of smaller open water ponds and vegetated wetlands that form in depressions on the landscape from both urban and agricultural runoff. Previous field studies have shown a direct link between urban and agricultural runoff and a high number of wetlands along Colorado's Front Range (Cooper 1988; Sueltenfuss 2013). Most of these wetlands form in natural depressions or natural swales in the landscape that now trap irrigation return flow, ditch leakage, or urban stormwater due to downslope impoundments like roads. In the current Tier 1 profile, riverine wetlands have been significantly reduced, while lakes and depressional wetlands have been significantly increased.

3.2.2 Tier 2 (Historical) Wetland Profile of the Northern Front Range

Results of the Tier 2 (historical) wetland profile provide a coarse quantification of wetland resources in the northern Front Range study area. The study area itself covers 412,699 acres. Original 1978 NWI mapping contained 29,039 acres of wetlands and water bodies, representing approximately 7% of the total land area (Fig. 9; Table 16). These acres were mapped in 2,461 individual polygons, with a mean polygon size of 11.8 acres.

Wetland Acres by NWI Group: Based on the original 1978 mapping, lakes and rivers comprised 15,804 acres or fully 54% of the total NWI mapped acres (Table 16).[8] Lakes alone accounted for 40% of the mapped acres. Nearly all lakes in the Front Range are artificial, dug for water storage, as gravel pits, or as recreation and aesthetic features. In addition to lakes, rivers, streams and canals covered 4,173 acres or 14% of the total mapped acres. These acres represent natural rivers and streams in the study area (Big Thompson River, St. Vrain Creek, South Boulder Creek and associated tributaries), as well as the intricate network of irrigation canals that criss-cross the area. This number is likely inflated from the original intent of the mapping because all original linear features (features drawn on the original mapping as lines with no defined thickness) were converted to polygons by buffering them out to either 10 or 20 m, likely wider than the mapper would have intended.

With lakes and rivers removed, the 1978 mapping showed 13,235 acres of wetlands, which represents ~3% of the total land area. Among wetland acres, the most significant category was herbaceous wetlands, with 7,965 acres or 60% of mapped wetlands and 27% of all NWI acres. Herbaceous wetlands mapped in the study area primarily represent marshes and wet meadows, with occasional vegetated salt flats or playas. Both forested wetlands and ponds each made up an additional 17% of wetland acres and 8% of all NWI acres. Shrub wetlands made up only 2% of wetland acres and 1% of the overall total.

There were notable differences in the distribution of aquatic resources between the two watersheds included in the study area (Table 16). The Big Thompson watershed, which represents 37% of the study area, contained 40% of the mapped features but only 26% of mapped wetlands. Though total NWI acres were lower in the Big Thompson watershed, acres of lakes were higher, 6,582 vs. 5,049. A greater percentage of the landscape in the Big Thompson was devoted to open water features and these represented a far greater share of the aquatic resources mapped in the

[8] NWI mapping includes deep water bodies, such as lakes and river channels, as well as true wetlands.

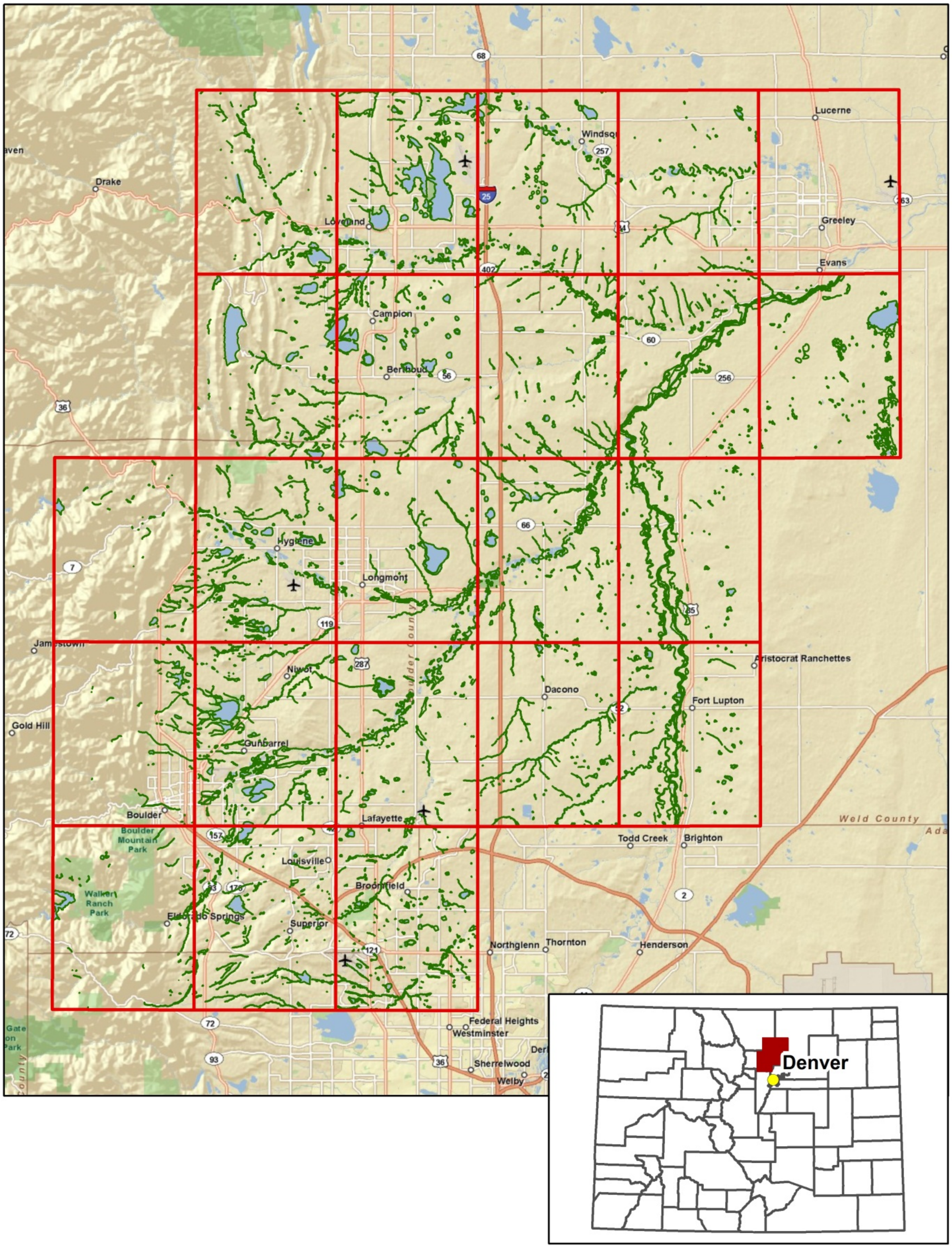


Fig. 9. Original 1978 NWI mapping for the northern Front Range study area.

Table 16. Wetland and waterbody acreage mapped in the northern Front Range study area by 1978 NWI group.

1978 NWI Group	Entire Study Area			Big Thompson Watershed			St. Vrain Watershed		
	All Acres	% Wetlands and Water	% Wetlands	All Acres	% Wetlands and Water	% Wetlands	All Acres	% Wetlands and Water	% Wetlands
Herbaceous Wetlands	7,965	27%	60%	1,728	15%	50%	6,238	36%	64%
Shrub Wetlands	270	1%	2%	50	0%	1%	220	1%	2%
Forested Wetlands	2,250	8%	17%	849	7%	25%	1,402	8%	14%
Ponds	2,266	8%	17%	645	6%	19%	1,621	9%	17%
Other Wetlands	483	2%	4%	170	1%	5%	313	2%	3%
Total Wetlands (excl. Lakes & Rivers)	**13,235**	**46%**	**100%**	**3,441**	**29%**	**100%**	**9,794**	**56%**	**100%**
Lakes and Shores	11,631	40%		6,582	56%		5,049	29%	
Rivers/Streams/Canals	4,173	14%		1,680	14%		2,494	14%	
Total Wetlands & Waterbodies	**29,039**	**100%**	**NA**	**11,702**	**100%**	**NA**	**17,337**	**100%**	**NA**

watershed (50% of all mapped acres vs. only 29% for the St. Vrain). The St. Vrain, in contrast, had more than 3.5 times the acres of herbaceous wetlands as well as over 2.5 times the acres of ponds.

Wetland Acres by LLWW/HGM Group: In order to approximate wetland acreage by HGM class, and to approximate the relative delivery of functions and services associated with those wetlands, we used the LLWW to roll up mapped wetland acres into HGM-like groups (Table 17). Given concerns with the semi-automated process for applying the LLWW codes, these estimates should not be taken as exact numbers. This analysis was focused only on the 13,235 acres of mapped wetland and excluded lakes and rivers. Across the entire study area, and in both watersheds, more than half the mapped acres were classified as riverine. This number largely reflects the inflated linear features, most of which are rivers, streams and canals. In the semi-automated process, wetlands are classified as riverine (lotic river and lotic stream in the LLWW classification) if they are within a certain distance from and river or stream feature. By inflating the acreage of river and stream features, the extent of riverine features is also inflated. Second to riverine, depressional wetlands represent roughly a third of mapped acres and lacustrine fringe wetlands make up 12%. There was remarkable similarity in the proportion of wetlands by LLWW groups between the two watersheds in the study area.

Table 17. Wetland acreage mapped in the northern Front Range study area by 1978 LLWW group.

1978 LLWW Group	Entire Study Area		Big Thompson Watershed		St. Vrain Watershed	
	Acres	% Wetlands	Acres	% Wetlands	Acres	% Wetlands
Depressional	4,520	34%	1,109	32%	3,411	35%
Riverine	7,169	54%	1,976	57%	5,139	53%
Lacustrine	1,530	12%	357	10%	1,173	12%
Slope	16	< 1%	-	-	16	< 1%
Total Wetlands	**13,235**	**100%**	**3,441**	**100%**	**9,794**	**100%**

Wetland Acres by Hydrologic Regime: The most prevalent wetland hydrologic regimes in 1978, according to acreage, were temporarily (38% of acres) and seasonally flooded regimes (45% of acres; Table 18). These hydrologic regimes represent wetlands that are wet for a few weeks to a few months each year, but are typically dry by the end of the growing season. Semipermanently flooded wetlands, which maintain standing water throughout most of the growing season, made up 11% of wetland acreage, while the intermittently exposed regime accounted for 6%. However, when looking across all NWI mapped acres, including lakes and rivers, intermittently exposed became the most common, principally because it was applied to most of the large lakes.

Table 18. Wetland and waterbody acreage mapped in the northern Front Range by 1978 NWI hydrologic regime code.

1978 NWI Code	Hydrologic Regime	All NWI Acres	% All Acres	Wetland Acres Only	% Wetland Acres
A	Temporarily Flooded	5,333	18%	5,043	38%
C	Seasonally Flooded	9,141	31%	5,911	45%
F	Semipermanently Flooded	1,701	6%	1,475	11%
G	Intermittently Exposed	12,865	44%	805	6%
Total		29,039	100%	13,235	100%

Wetland Acres by Extent Modified and Irrigated: The NWI classification includes several modifiers that describe aspects of human and natural alteration. At the time the 1978 mapping was conducted, however, these modifiers were not used as extensively. In fact the only modifier used in the 1978 mapping was the artificially flooded modifier, whose use has changed over the years. This modifier was applied primarily to irrigation channels, which is why 64% of the river, stream, canals category was mapped with this attribute (Table 19). More modern mapping (such and the current wetland profile based on 2009 imagery), would have applied an excavated or impounded modifier to most of the lakes and many ponds in the study area. The lack of modifiers used in the 1978 mapping means we were unable to compare the extent to which wetlands were modified.

Another important aspect of human modification to wetlands is the degree to which they are affected by irrigation. Within agricultural landscapes in the West, wetland acres have developed on historical uplands due to long-term irrigation practices that maintain localized high water tables, either through direct application of flood irrigation on fields, though ponding of excess irrigation water on the margins of fields, or seepage through irrigation ditches (Peck & Lovvorn 2001; Sueltenfuss 2013). In addition, many historically natural wetlands located near irrigated lands are augmented by irrigation flows. While it is difficult to tease apart the differences between these two classes of irrigation-influenced wetlands (wetlands entirely created by irrigation and historically natural wetlands that are influenced by irrigation), it is possible to estimate the extent of wetlands directly receiving irrigation water by overlaying a GIS layer of 1976 irrigated acres (CDSS 2013) with the NWI wetland acres. Within the study area as a whole, 12% of all NWI mapped acres in 1978 were also mapped as irrigated. These acres were primarily herbaceous wetlands (35%) and ditches (40%) (Table 19). Among all herbaceous wetlands, 15% were irrigated and these areas mainly represented flood irrigated hayfields and wetland adjacent to fields receiving irrigation return flows.

While this Fig. is dramatically lower than in some parts of the state (see Lemly & Gilligan 2011 for a discussion of irrigated wetlands in the North Platte River Basin, where 75% of all herbaceous wetlands are irrigated), it likely does not reveal the full impact of irrigation on wetland acreage. Direct flood irrigation is common in the mountain valleys, where water is abundant during spring snowmelt and can irrigate vast acres of valley bottomland by simply spreading the water over a wider floodplain. Flood irrigation in the mountains in many ways mimics natural spring floods, and can lead to standing water for days or even weeks in wet years. Its impact is therefore reflected in the intersection between mapped wetland acres and mapped irrigated lands. On the plains, however, irrigation is conducted more often through center pivots or though carefully time releases that do not lead to extensive flooding. The impact of irrigation on lower elevation wetlands is more likely at the edges of fields, in swales that collect irrigation run-off, or along the edges of leaky ditches. These types of impacts are not adequately captured by comparing the direct overlap of mapped wetlands and mapped irrigated lands. In fact, virtually every lake, pond, waterway, and flooded depressional wetland is part of the basin-wide system of irrigation supply, storage, conveyance, and return flow. In effect, the 10% of NWI acres mapped as irrigated likely grossly underestimates the acreage of wetlands directly tied to or largely influenced by irrigation water.

Table 19. Wetland and waterbody acreage mapped in the northern Front Range by 1978 NWI modifier and extent irrigated. All NWI acres shown, with totals for wetlands only in the last row.

1978 NWI Group	No modifier		Artificially Flooded		Irrigated Wetlands[1]		
	Acres	% of Class	Acres	% of Class	Acres	% of Class	% of Irrigated Wetlands
Herbaceous Wetlands	7,865	99%	100	1%	1,224	15%	35%
Shrub Wetlands	256	95%	14	5%	17	6%	< 1%
Forested Wetlands	2,171	96%	80	4%	279	12%	8%
Ponds	2,263	100%	3	< 1%	361	16%	10%
Other Wetlands	483	100%	-	-	123	25%	4%
Lakes and Shores	11,631	100%	-	-	115	1%	3%
Rivers/Streams/Canals	1,504	36%	2,669	64%	1,389	33%	40%
Wetlands & Waterbodies	26,173	90%	2,866	10%	3,508	12%	100%
Wetlands (excl. Lakes & Rivers)	13,038	99%	197	1%	2,004	15%	71%

[1] Irrigated lands in 1976, from the Colorado Decision Support System (CDSS 2013).

Wetland Acres by Landownership: The final summarization of the wetland profile was to quantify the distribution of ownership. Detailed spatial data for landownership were only available for the current time period (2009) and not for the 1970s. These results illustrate a land ownership summary for a Tier 2 profile (easy to compile, but less accurate), but should not be used to make historical comparisons.

Based on the 1978 mapping, 79% of mapped acres were privately owned (Table 20). This included water bodies as well as wetlands. The share of wetlands and water bodies in private hands was roughly similar to the share of the total land area in private hands (84%). Private landowners held a slightly lower percent (76%) if only wetlands were included, meaning some of the private owned acres were lakes. The only other notable land owners of wetlands and water bodies were cities and counties, both individually and in joint ownership, and special districts, mainly water conservancy districts. With lakes and rivers excluded, the share of wetland ownership by local governments went up to 22%, slightly larger than the 15% of the basin they own. Most of the acreage owned by water conservancy districts were lakes.

Table 20. Wetland and waterbody acreage mapped in the northern Front Range by grouped land owner.

Grouped Owner[1,2]	Total Land Area within Basin		Total 1978 NWI Acres within Basin		Wetland Acres Only	
	Acres	% of Basin	Acres	% of NWI Acres	Acres	% of Wetlands
Federal Lands						
U.S. Fish and Wildlife Service	537	< 1%	21	< 1%	17	< 1%-
Misc. Federal Lands	1,781	< 1%	1	< 1%	1	< 1%-
State Lands						
State Land Board	1,476	< 1%	42	< 1%	12	< 1%
Colorado Parks and Wildlife	1,306	< 1%	280	1%	154	1%
Other						
Cities	31,807	8%	2,527	9%	1,863	14%
Counties	23,490	6%	1,315	5%	885	7%
Joint City / County	4,598	1%	221	1%	183	1%
Special / Metro / School Districts	2,484	1%	1,708	6%	16	< 1%
Non-Governmental Organizations	541	0%	29	< 1%	14	< 1%
Private	344,678	84%	22,895	79%	10,091	76%
Total	**412,699**	**100%**	**29,039**	**100%**	**13,235**	**100%**

[1] Many properties in the basin are owned by one agency but managed by another agency through inter-agency agreements or are owned by private land owners but managed by an agency through easements. Therefore, the numbers of acres owned by a given agency is different than the number of acres managed by that agency. For the purpose of this report, acres are reported by land owner, except in Appendix I, where they are presented by management unit.

[2] Land ownership shown is based on 2009 land ownership and may not reflect ownership in 1978. Detailed GIS data for 1978 land ownership was not available for this analysis.

3.2.3 Tier 3 (Current) Wetland Profile of the Northern Front Range

While the Tier 2 (historical) wetland profile provided coarse baseline estimates of wetland acreage and distribution, the Tier 3 (current) wetland profile developed through photo-interpretation of 2009 imagery provides a far more accurate and precise accounting of aquatic resources in the study area. *NOTE: Numbers for the Tier 3 (current) profile are presented below and contrasted to the Tier 2 (historical) profile, but only in general terms. The more rigorous analysis of change over time is present in Section 3.3.4 The comparison of raw acres does quantitatively separate change in mapping methodology from actual change on the landscape.*

Updated Tier 3 wetland mapping documented 31,306 acres of wetlands, water bodies and riparian areas in the study area (Figs. 10, 11; Table 21), which represents 2,267 more acres than were mapped in 1978. However, with lakes, rivers and riparian areas removed, the 2009 mapping showed only 11,470 acres, which represents 1,765 acres less than was mapped in 1978. The total 2009 NWI mapping covered just over 8% of the total land area, while the wetland acres alone again cover ~3%. The 2009 mapping contained 9,963 individual polygons, with a mean polygon size of 3.2 acres. This was a four-fold increase in the number of polygons and a subsequent reduction in mean polygon size, demonstrating the scale of the 2009 mapping was a much finer resolution.

Wetland Acres by NWI Group: Within the Tier 3 (current) wetland profile, lakes and rivers comprised 15,013 acres, a very similar number to those mapped in 1978, but this number included more acres of lakes and fewer of rivers, streams and canals. The change in river features is logical, since we acknowledged that the process for converting linear features into polygons for the 1978 mapping inflated their numbers. The upward trend in lake acreage has primarily been driven by aggregate mining in the river floodplains and the subsequent use of mine pits for water storage. The 2009 mapping also introduced riparian mapping following the USFWS mapping standards. These new classification categories included 4,823 acres or 15% of the total mapped acres. These acres represent woody and herbaceous vegetation growing on floodplains, along intermittent tributary streams, and along lake shores that are not wet enough to be mapped as wetlands based on the current standards. Some of these acres were likely mapped in 1978, but classified as wetlands with the temporarily flooded regime, while others are newly mapped acres. The addition of riparian mapping is likely the chief reason why the acres of actual wetlands decreased between the two time periods. The largest category of riparian vegetation was riparian forests, with 3,801 acres. In contrast, forested wetlands went from 2,266 acres in the 1978 mapping to only 154 acres in the 2009 mapping, a dramatic difference, but understood in light of the change in mapping methods.

Among true wetlands, herbaceous wetlands were still the largest category, with 6,185 acres or 54% of wetland acres and 20% of all NWI mapped acres. Ponds were a close second, with 4,453 acres or 39% of wetland acres. This was nearly double the acreage of ponds from the 1978 mapping, but the increase is likely related as much to the resolution of the mapping as to any actual change on the landscape. Shrub wetlands represented 568 acres, again double the 1978 estimate, likely related to scale. Forested wetlands, as stated above, included only 154 acres.

The same differences in the distribution of aquatic resources between the two watersheds were evident in the 2009 mapping (Table 21). The Big Thompson watershed still contained only 40% of

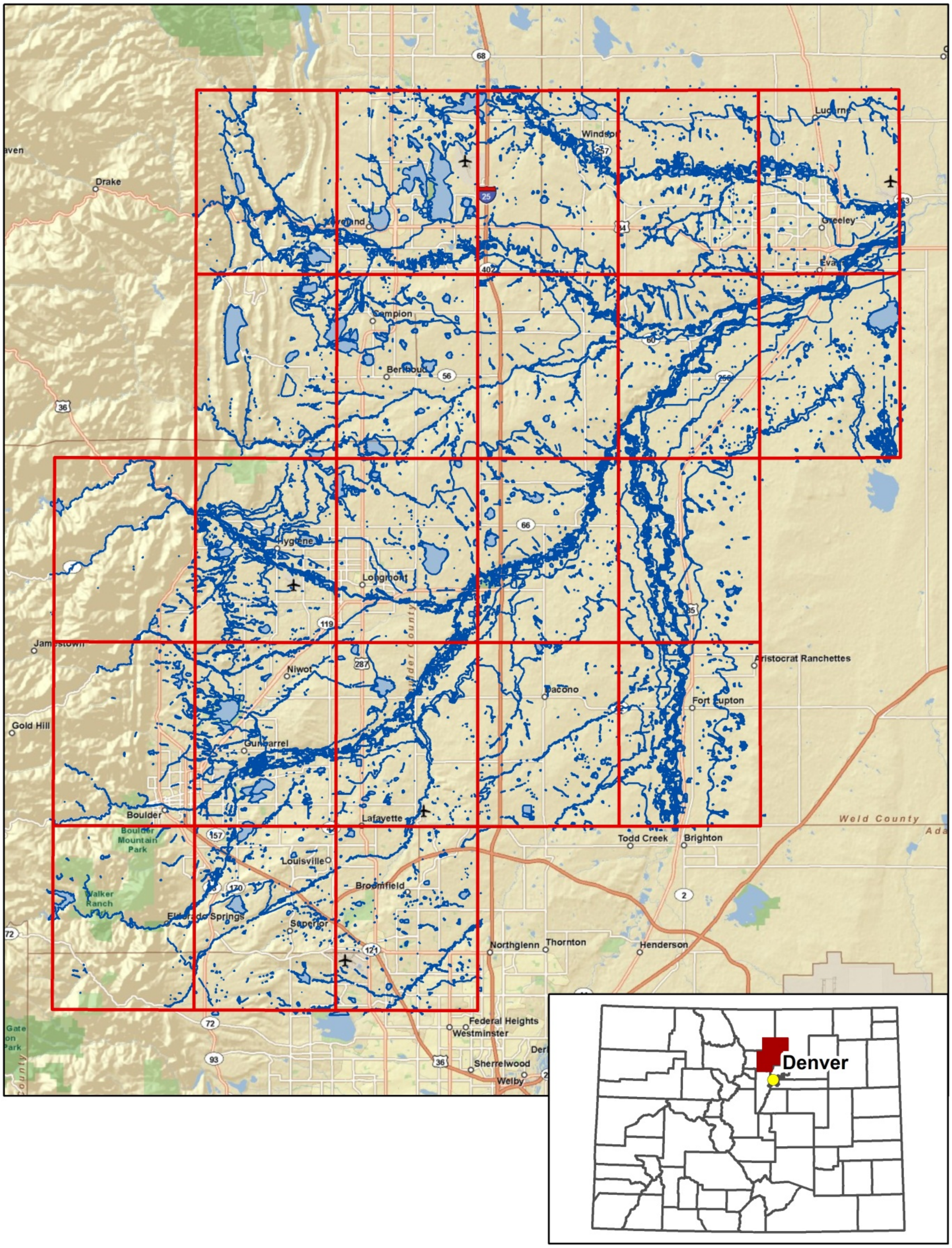


Fig. 10. Updated 2009 NWI mapping for the northern Front Range study area.

Table 21. Wetland, riparian area, and waterbody acreage in the northern Front Range study area by 2009 NWI group.

2009 NWI Group	Entire Study Area			Big Thompson Watershed			St. Vrain Watershed		
	All Acres	% Wetlands Riparian and Water	% Wetlands	All Acres	% Wetlands Riparian and Water	% Wetlands	All Acres	% Wetlands Riparian and Water	% Wetlands
Herbaceous Wetlands	6,185	20%	54%	1,933	15%	53%	4,252	23%	54%
Shrub Wetlands	568	2%	5%	248	2%	7%	321	2%	4%
Forested Wetlands	154	< 1%	1%	86	1%	2%	68	< 1%	1%
Ponds	4,453	14%	39%	1,310	10%	36%	3,143	17%	40%
Other Wetlands	110	< 1%	1%	63	< 1%	2%	47	< 1%	1%
Total Wetlands (excl. Riparian Areas, Lakes & Rivers)	**11,470**	**37%**	**100%**	**3,639**	**29%**	**100%**	**7,831**	**42%**	**100%**
Lakes and Shores	13,206	42%	-	6,626	53%	-	6,580	35%	-
Rivers/Streams/Canals	1,807	6%	-	671	5%	-	1,137	6%	-
Riparian Herb	818	3%	-	237	2%	-	581	3%	-
Riparian Shrub	203	1%	-	43	< 1%	-	160	1%	-
Riparian Forested	3,801	12%	-	1,377	11%	-	2,424	13%	-
Total Wetlands, Riparian Areas & Waterbodies	**31,306**	**100%**	**NA**	**12,593**	**100%**	**NA**	**18,713**	**100%**	**NA**

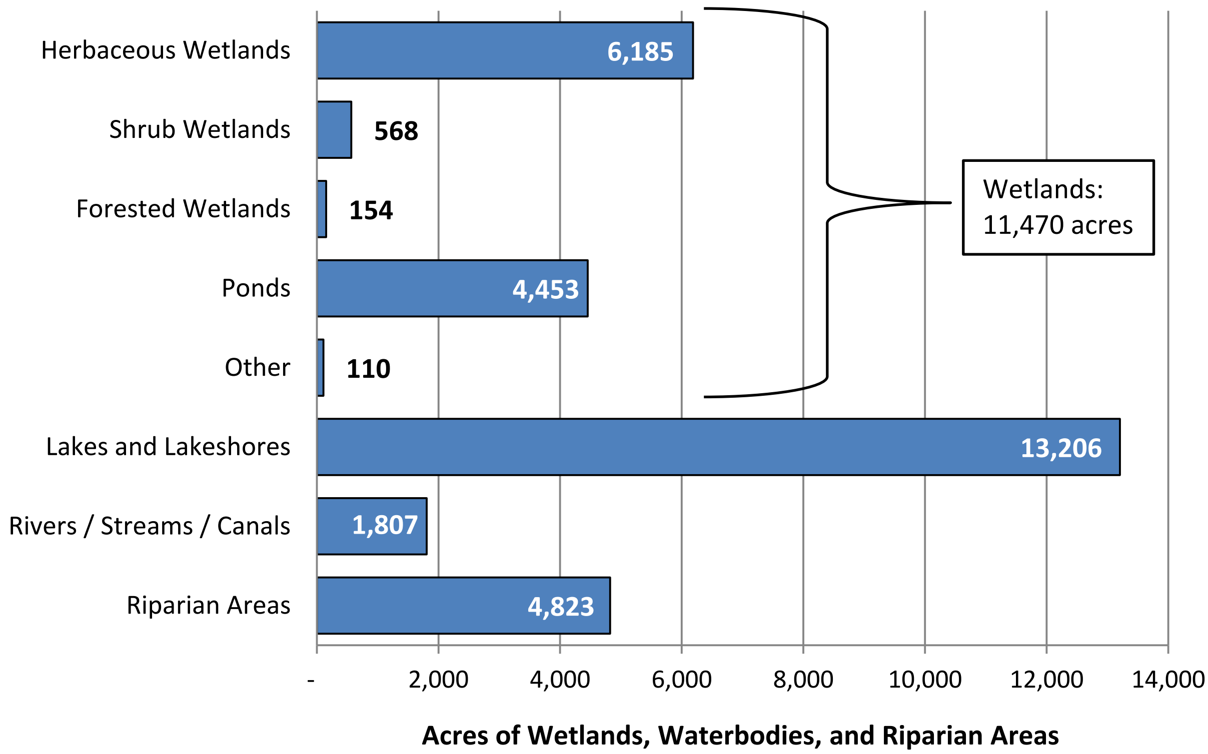


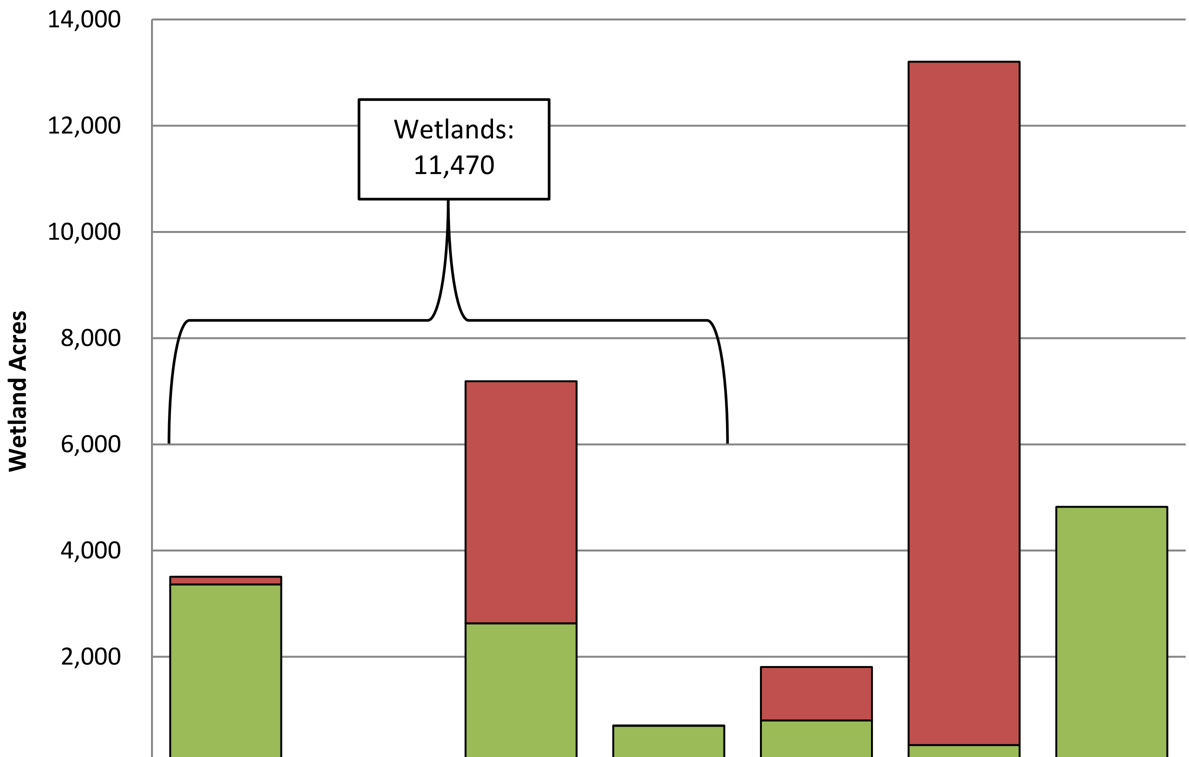
Fig. 11. Wetland, riparian area, and waterbody acreage in the northern Front Range by 2009 NWI group.

the mapped features, but increased its share of the mapped wetlands to 32% because the St. Vrain contained more riparian vegetation. Lakes still made up a greater percentage of the landscape inthe Big Thompson (53% of all mapped acres vs. 35% for the St. Vrain). But in the 2009 mapping, the St. Vrain watershed had roughly 1.5 times the acres of both herbaceous wetlands and ponds, as opposed to the much more imbalanced numbers from the 1978 mapping.

Wetland Acres by LLWW/HGM Group: Comparisons between the Tier 2 (historical) and Tier 3 (current) profiles are most stark in terms of the HGM-like LLWW groups (Table 22; Fig. 12). The numbers from the current profile are more accurate than the historical profile, but probably still not precise, given limitations of the semi-automated process of applying LLWW codes. In the 2009 mapping, depressional wetlands were now the clear dominant features, representing more than 60% of the wetlands acres across the entire study area and in both watersheds. Riverine wetlands dropped to ~30% of wetland acres and lacustrine fringe another ~6%. Slope wetlands are very rare, making up only 1% of mapped wetlands. The increase in depressional features was likely related to both a real increase in pond area and to the higher resolution of the 2009 mapping, which identified many more small-scale pond features. Similarly, loss of riverine habitat in the study area is well documented, but the decrease in acreage indicated by the mapping is inflated by the increased precision of the 2009 mapping of rivers, streams and canals. A majority of depressional wetlands were mapped with an NWI modifier of excavated or impounded, as were almost all lakes. This does not, however, take into account wetlands unintentionally created through urban and agricultural runoff.

Table 22. Wetland acreage mapped in the northern Front Range study area by 2009 LLWW group.

2009 LLWW Group	Entire Study Area		Big Thompson Watershed		St. Vrain Watershed	
	Acres	% Wetlands	Acres	% Wetlands	Acres	% Wetlands
Depressional	7,188	63%	2,199	60%	4,989	64%
Riverine	3,507	31%	1,140	31%	2,367	30%
Lacustrine	705	6%	262	7%	444	6%
Slope	70	1%	39	1%	31	< 1%
Total Wetlands	**11,470**	**100%**	**3,639**	**100%**	**7,831**	**100%**
Lakes	13,206	-	6,626	-	6,580	-
Rivers	1,807	-	671	-	1,137	-
Riparian	4822	-	1657	-	0.13	-
Total Wetlands, Riparian Areas & Waterbodies	**31,306**	**NA**	**12,593**	**NA**	**18,713**	**NA**



	Riverine	Slope	Depressional	Lacustrine	Rivers	Lakes	Riparian
"Modified"	144	-	4,557	3	1,005	12,869	-
"Natural"	3,363	70	2,631	702	802	337	4,823

2009 LLWW Group (approx. HGM Class)

Fig. 12. Wetland acreage mapped in the northern Front Range study area by 2009 LLWW group, split into "natural" and "modified" based on the NWI modifiers. This does not take into account wetlands unintentionally created through urban and agricultural runoff.

Wetland Acres by Hydrologic Regime: When broken down by hydrologic regime, the temporarily flooded regimes still represented 38% of wetland acres (Table 23), but there was a dramatic decrease in acres mapped with the seasonally flooded regime and a stark increase in both semipermanently flooded and intermittently exposed regimes, covering 24% and 29% of wetland acres, respectively. These hydrologic regimes represent wetlands that maintain standing water throughout most or all of the growing season in most years. This is likely also related to the increased number of ponds mapped, as these regimes are common for ponds, both vegetated and unvegetated. These regimes are also used for depressional wetlands with marsh vegetation, which would be mapped as herbaceous (i.e., PEMF). Across all NWI mapped acres, the permanently flooded regime, which is never used for wetlands, was the most common, because it was applied to most of the large lakes.

Table 23. Wetland and waterbody acreage mapped in the northern Front Range study area by 2009 NWI hydrologic regime.

NWI Code	NWI Hydrologic Regime	All NWI Acres	% All Acres	Wetland Acres Only	% Wetland Acres
A	Temporarily Flooded	4,791	15%	4,312	38%
C	Seasonally Flooded	1,971	6%	1,085	9%
F	Semipermanently Flooded	2,833	9%	2,766	24%
G	Intermittently Exposed	4,434	14%	3,306	29%
H	Permanently Flooded	12,455	40%	-	-
N/A	No hydrology regime applied to riparian areas	4,823	15%	-	-
Total		31,306	100%	11,470	100%

Wetland Acres by Extent Modified and Irrigated: Modifiers were used extensively in the 2009 mapping, as opposed to the 1978 mapping where they were essentially ignored. The two modifiers used most often were excavated and dammed/impounded. While both could apply to the same feature, only one was given. In those cases, dammed/impounded trumped excavated, but this should not lead to the conclusion that these features were not also excavated, as many of them were. Nearly 60% of all mapped acres received a modifier in the 2009 mapping (Table 24). The most common was impounded, which represented 38% of all mapped acres and 83% of the lake acres. In additional 20% of ponds were classified as impounded. The excavated modifier was applied to another 15% of lakes, leaving only 3% of lake acres with no modifier. More than three-quarters (77%) of ponds were classified as excavated, leaving only 4% of those acres with no modifier. Over half of river features (56%) were classified as excavated. These features are the intricate network of canals and ditches that interconnect the array of reservoirs, storage ponds and irrigation return flow basins. While modifiers were essentially the rule for lakes, ponds and canals, few acres of herbaceous, shrub or forested wetlands received modifiers.

Irrigation data showed a similar pattern in the 2009 mapping. Across the study area, 9% of NWI mapped acres were also mapped as irrigated. These acres were primarily herbaceous wetlands (60%), but also included riparian areas (riparian forests: 12%; riparian herbaceous: 9%), ponds

Table 24. Wetland acreage in the northern Front Range study area by NWI modifier and extent irrigated. All NWI acres shown, with totals for wetlands only in the last row.

2009 NWI Attribute Group	No modifier		Excavated		Dammed / Impounded		Farmed		Irrigated Wetlands[1]		
	Acres	% of Class	Acres	% of Class	Acres	% of Class	Acres	% of Class	Acres	% of Class	% of Irrigated Wetlands
Herbaceous Wetlands	5,860	95%	130	2%	182	3%	13	< 1%	1,633	26%	60%
Shrub Wetlands	561	99%	6	1%	1	< 1%	-	-	83	15%	3%
Forested Wetlands	151	98%	-	-	3	2%	-	-	-	-	-
Ponds	160	4%	3,422	77%	872	20%	-	-	204	5%	8%
Other Wetlands	35	32%	69	63%	6	6%	-	-	9	< 1%	< 1%
Lakes and Shores	337	3%	1,920	15%	10,949	83%	-	-	4	4%	< 1%
Rivers/Streams/Canals	802	44%	1,005	56%	-	-	-	-	215	2%	8%
Riparian Herb	818	100%	-	-	-	-	-	-	243	30%	9%
Riparian Shrub	203	100%	-	-	-	-	-	-	5	3%	< 1%
Riparian Forested	3,801	100%	-	-	-	-	-	-	317	8%	12%
Wetlands, Riparian Areas & Waterbodies	12,728	41%	6,552	21%	12,013	38%	13	< 1%	2,714	9%	100%
Wetlands (excl. Riparian Areas, Lakes & Rivers)	6,766	59%	3,626	32%	1,064	9%	13	< 1%	1,930	15%	71%

[1] Irrigated lands data from the Colorado Decision Support System (CDSS 2009).

(8%), and ditches (29%) (Table 24). Among all herbaceous wetlands, 26% were irrigated, as were 30% of herbaceous riparian areas. As discussed in the Tier 2 (historical) wetland profile, these estimates of irrigated wetlands still grossly underestimate the acreage of wetlands influenced by irrigation water.

Wetland Acres by Landownership: The Tier 3 profile also shows that most aquatic resources in the study area are still privately owned (Table 25 Local governments, however, together own 21% of all wetland acres, which is larger than the 15% of the basin they own. The only other significant owner of aquatic resources is water conservancy districts, and most of their acreage is lakes.

Table 25. Wetland, water body and riparian acreage in the northern Front Range by grouped land owner.

Grouped Owner[1]	Total Land Area within Basin		Total 2009 NWI Acres within Basin		Wetland Acres Only	
	Acres	% of Basin	Acres	% of NWI Acres	Acres	% Wetlands
Federal Lands						
U.S. Fish and Wildlife Service	537	< 1%	7	< 1%	7	< 1%
Misc. Federal Lands	1,781	< 1%	4	< 1%	-	-
State Lands						
State Land Board	1,476	< 1%	49	< 1%	16	< 1%
Colorado Parks and Wildlife	1,306	< 1%	404	1%	289	3%
Other						
Cities	31,807	8%	2,968	9%	1567	14%
Counties	23,490	6%	1,427	5%	639	6%
Joint City / County	4,598	1%	177	1%	95	1%
Special / Metro / School Districts	2,484	1%	1,761	6%	34	< 1%
Non-Governmental Organizations	541	0%	31	< 1%	11	< 1%
Private	344,678	84%	24,480	78%	1,816	77%
Total	**412,699**	**100%**	**31,306**	**100%**	**2,714**	**100%**

[1] Many properties in the basin are owned by one agency but managed by another agency through inter-agency agreements or are owned by private land owners but managed by an agency through easements. Therefore, the numbers of acres owned by a given agency is different than the number of acres managed by that agency. For the purpose of this report, acres are reported by land owner.

3.2.4 Wetland Change over Time

The change over time analysis focused on ~10% of the study area. Within this subset of the mapping, there were 3,543 acres of wetlands and waterbodies mapped in 1978 and 4,021 acres mapped in 2009 (see Appendix E for detailed results from the change over time analysis). This represents slightly more than 10% of the total mapped polygons in either time period (12% for 1978 and 13% for 2009). *The numbers presented in this analysis, therefore, do not reflect the actual acreage of wetland gain, losses or conversion across the entire study area, but the proportions should be representative.*

Significant changes in mapping methods between the two time periods complicated the analysis. The core question of interest was how much actual change in wetland acreage and type has taken place on the landscape in the past 30 years. To answer that core question, we had to separate changes between the two dataset that were strictly due to mapping methodology and those that were due to actual landscape change. The results below are presented both in terms of NWI attribute groups, which represent the dominant structural component of the vegetation (Table 26; Fig. 13), and LLWW attribute groups, which represent and approximation of functionally based HGM classes (Table 27; Fig. 14).

Between 1978 and 2009, this analysis showed an increase in acres of wetlands, riparian areas, and waterbodies across the study area. Changes in mapping methods accounted for two to three times more gross change in acres than actual landscape changes, which underscores the importance of separating out the two major causes of change. However, the net change in acres was roughly similar between the two causes; of the 478 net acres added to the mapping, 272 were due to landscape factors and 205 were due to mapping methods. Mapping related changes can essentially be ignored when considering the actual change on the landscape, but are critical to understand how the two datasets compare. The overall change in acreage related to landscape changes, therefore, was 272 acres, which represents a 7% increase over the 1978 total (adjusted for mapping changes) for all aquatic resource. For wetland alone (excluding waterbodies and riparian areas), the increase is 179 acres or 12% of the 1978 total.

Wetland Change by NWI Group: The most significant landscape change between the two time periods in terms of NWI groups was the net addition of 147 acres of ponds (Table 26; Fig. 13). This represents an increase of 41% over the 1978 total (adjusted for mapping changes). These acres also represent 54% of the total net change in acres across the study area. There were 191 acres of herbaceous wetlands added between the two time periods, but this was offset by 168 acres lost, for a net change of only 23 acres. Proportionally, landscape changes in both shrub and forested wetlands were notable. Shrub wetlands appear to have increased 34% over the 1978 total. However, given how few acres of shrub wetlands were mapped in either time period, this number is less precise than estimates for other types of wetlands. Likewise, forested wetlands appear to have decreased by 38%, but this number may also be imprecise. Lakes gained additional acreage (net increase of 56 acres), but only by a small percent of their overall area (3% increase).

Table 26. Gross and net change in mapped acres between 1978 and 2009, by NWI attribute group and by landscape vs. mapping change. These changes do not incorporate changes in type.

	2009 NWI Attribution for Added / 1978 NWI Attribution for Lost								
	Herbaceous	*Shrub*	*Forested*	*Ponds*	*Other*	*Lakes*	*Rivers*	*Riparian*	***Grand Total***
Acres Added Since 1978									
Landscape Additions	191	26	3	166	6	83	6	42	522
Mapping Additions	509	37	11	53	2	50	141	278	1,081
Total Acres Added	**700**	**63**	**14**	**219**	**8**	**133**	**147**	**319**	**1,603**
Acres Lost Since 1978									
Landscape Losses	168	-	14	20	11	27	11	-	250
Mapping Losses	345	-	126	48	11	70	275	-	876
Total Acres Lost	**513**	**-**	**141**	**67**	**21**	**97**	**286**	**-**	**1,126**
Net Change									
Net Landscape Change	23	26	-11	147	-5	56	-5	42	272
Net Mapping Change	164	37	-116	5	-9	-20	-134	278	205
Total Net Change	**187**	**63**	**-127**	**152**	**-14**	**36**	**-139**	**319**	**478**
% Actual Change[1]	**2%**	**34%**	**-38%**	**41%**	**-28%**	**3%**	**-2%**	**9%**	**7%**

[1]Final calculation of % actual change is based only on landscape change, which represents real change in wetland acres. This Fig. was calculated by subtracting the landscape change from the 2009 total acres (thereby approximating the total 1978 acres without mapping differences) and dividing the net landscape change by that approximated 1978 total acres.

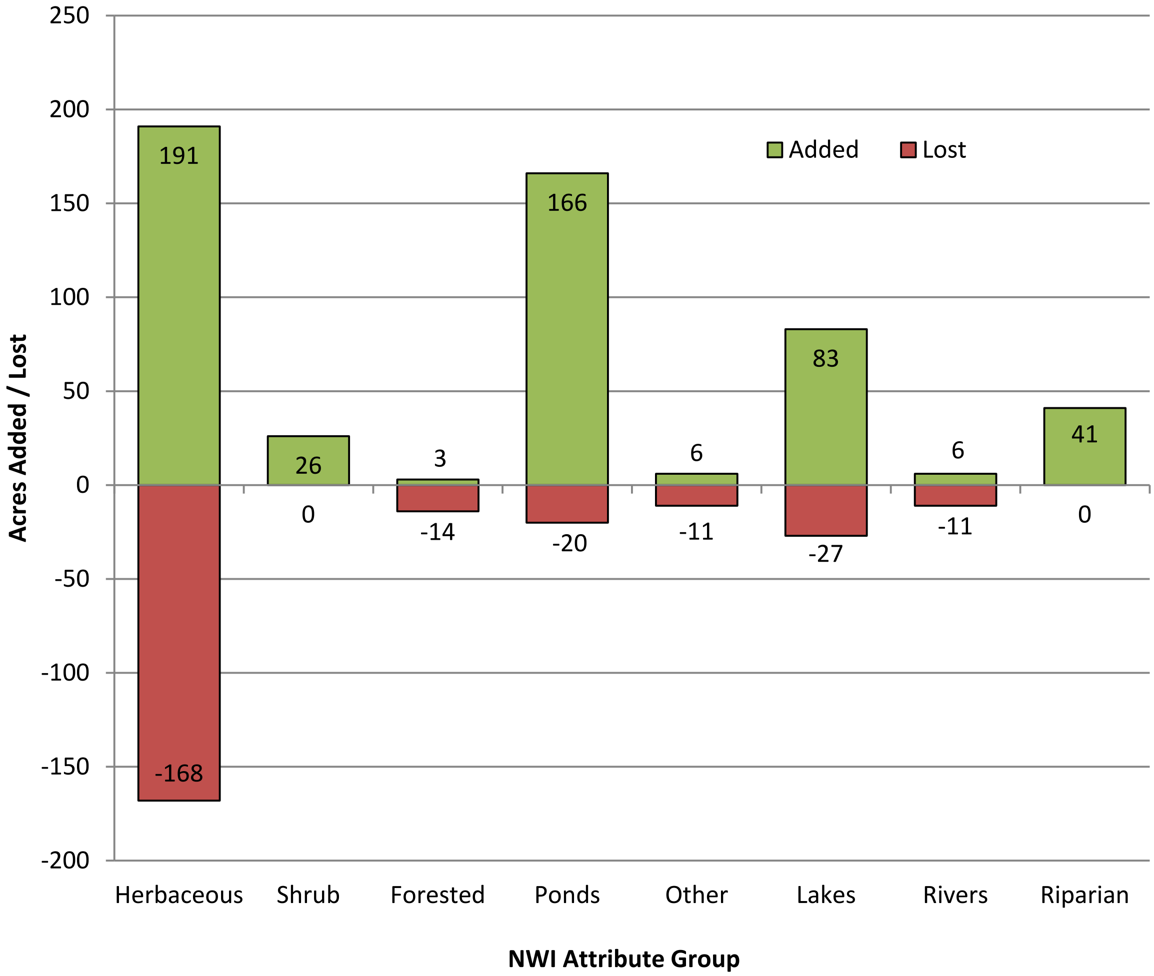


Fig. 13. Gross changes in wetland acres by NWI attribute group. These changes do not incorporate changes in type.

Wetland Change by LLWW/HGM Group: When viewed by LLWW group, the gross and net landscape changes between the two time periods reveal and even stronger trend (Table 27; Fig. 14). Depressional wetlands increased 214 acres (276 added and 62 lost). This represented a 29% increase in acreage over the 1978 total (adjusted for mapping changes) and accounts for the vast majority of net acres gained (79% of total net landscape change). If waterbodies and riparian acres are excluded, the net change in wetland acres was only 179 (less than the 214 acres gained by depressional wetlands), meaning that depressional gains were offset by losses of other wetland types. There was a net loss of 32 acres of riverine wetlands (103 added and 135 lost), which represented a 6% decline in riverine wetlands, and a net loss of 7 acres of lacustrine wetlands, a 4% loss of that type. The analysis did show gains of 4 slope wetland acres, which represents a 29% increase in that type, but the few acres mapped overall likely make that number imprecise.

Table 27. Gross and net change in mapped acres between 1978 and 2009, by NWI attribute group and by landscape vs. mapping change.

	2009 NWI Attribution for Added / 1978 NWI Attribution for Lost							
	Dep	*Riv*	*Lacust*	*Slope*	*Lakes*	*Rivers*	*Riparian*	***Grand Total***
Acres Added Since 1978								
Landscape Additions	276	103	9	4	83	6	41	522
Mapping Additions	306	234	59	12	50	141	278	1,081
Total Acres Added	**582**	**337**	**68**	**17**	**133**	**147**	**319**	**1,603**
Acres Lost Since 1978								
Landscape Losses	62	135	16	-	27	11	-	250
Mapping Losses	95	369	66	-	70	275	-	876
Total Acres Lost	**156**	**504**	**82**	**-**	**97**	**286**	**-**	**1,126**
Net Change								
Net Landscape Change	214	-32	-7	4	56	-5	41	272
Net Mapping Change	211	-135	-7	12	-20	-134	278	205
Total Net Change	**426**	**-167**	**-14**	**17**	**36**	**-139**	**319**	**477**
% Actual Change[1]	**29%**	**-6%**	**-4%**	**29%**	**3%**	**-2%**	**9%**	**7%**

[1]Final calculation of % actual change is based only on landscape change, which represents real change in wetland acres. This Fig. was calculated by subtracting the landscape change from the 2009 total acres (thereby approximating the total 1978 acres without mapping differences) and dividing the net landscape change by that approximated 1978 total acres.

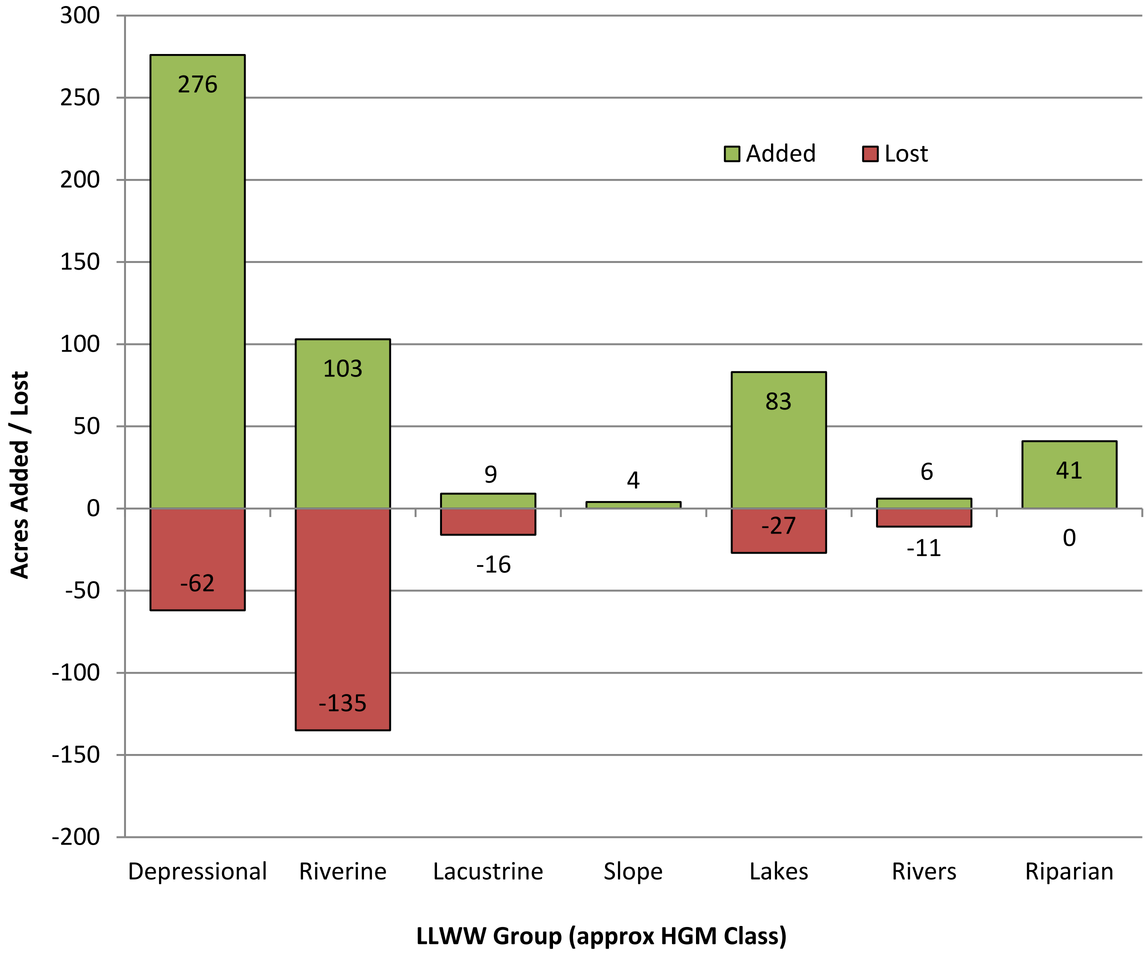


Fig. 14. Gross changes in wetland acres by NWI attribute group. These changes do not incorporate changes in type.

Wetland Conversion: In addition to acres lost and gained, nearly 500 acres that were mapped in both time periods were converted from one wetland type to another (Table 28). More than half of converted acres were related to mapping changes. Notable among those, 128 acres that had been mapped as forested wetlands (80% of the forested wetlands originally mapped) were converted to another type, mainly to riparian forest. Other significant mapping changes included 22 acres of rivers converted to riparian forest along with 12 acres of rivers and 17 acres of lakes converted to herbaceous wetlands due to improved scale and resolution of the mapping along river corridors. Another 31 acres of lakes were converted to ponds to better reflect the intended definitions of both types. Major conversion attributed to actual landscape change included 49 acres of herbaceous wetlands converted to ponds and ponds converted to lakes, both indicative of a trend towards more open water in the study area.

Table 28. Converted wetland acres, by original 1978 NWI attribute group and resulting 2009 NWI attribute and broken down by landscape vs. mapping changes. All acres in this table were mapped in both years, but were attributed with a different NWI attribute group.

		2009 NWI Attribution										
		Herbaceous[1]	*Shrub*	*Forested*	*Ponds*	*Other*	*Lakes*	*Rivers*	*Rip Herb*	*Rip Shrub*	*Rip Forested*	***Total Acres Converted***
Landscape Change												
1978 NWI Attribution	*Herbaceous*[1]	9	16	1	49	1	6	3	< 1	< 1	7	**92**
	Forested	2	3	-	2	-	11	9	< 1	1	-	**29**
	Ponds	1	< 1	-	-	-	20	-	-	-	-	**22**
	Other	3	< 1	-	5	-	-	-	-	-	-	**8**
	Lakes	16	< 1	-	6	2	-	-	< 1	-	3	**27**
	Rivers	8	7	1	2	-	< 1	5	4	3	19	**49**
Mapping Change												
1978 NWI Attribution	*Herbaceous*[1]	2	2	< 1	9	-	13	3	3	-	7	**39**
	Forested	18	3	-	1	-	3	3	5	1	95	**128**
	Ponds	5	< 1	-	-	-	-	1	-	-	1	**6**
	Other	< 1	-	-	1	-	-	-	-	-	-	**1**
	Lakes	17	6	< 1	31	-	-	< 1	3	1	2	**59**
	Rivers	12	1	< 1	1	-	-	1	2	< 1	22	**40**
Total Acres Converted		**93**	**39**	**3**	**107**	**2**	**53**	**25**	**17**	**6**	**155**	**499**

[1] For the most part, code changes within NWI attribute type were not considered conversions if they were changes in hydrologic regime or modifiers. However, changes from the temporarily flooded regime to the permanently flooded regime were considered significant enough to be considered a conversion. This only occurred within herbaceous wetlands.

Causes of Wetland Gains, Loss and Conversion: The reason for change was evaluated for all acres gained, lost and converted (Table 29; Fig. 15). For acres actually added to the landscape, the most common reason attributed to new acres was pond creation, accounting for 39% of all added acres. The second most common cause for new acres was added irrigation, which includes an array of land use changes that add extra water to the landscape. Natural adjustments, resource extraction, and other miscellaneous causes also contributed 10–14% of new acres each. Half of acres lost from the landscape were attributed to rural development, which includes low density growth outside the major cities in the study area. Development within the cities accounted for another 13% of wetland acres lost, while reduced irrigation accounted for 10%. The most common cause for wetlands converted from one type to another (not including mapping related conversions) was natural adjustment. This category included shifts in channel morphology and natural vegetation succession. Second to natural causes was pond conversion, generally the digging out of an existing wetland to form one with more open water.

The primary driver behind acres added due to changing mapping methods was interpreter difference, meaning the wetland was present in 1978, but was not mapped by the original interpreter. It is difficult to truly separate this from wetlands missed due to scale, which was the second most important factor for acres added. The new riparian attribution accounted for 15% of acres added. Acres lost between the two time periods due to mapping methods was almost entirely due to interpreter difference or scale. Riparian attribution was the major driver behind conversions due to mapping changed, followed by scale and interpreter difference.

Table 29. Detailed cause of wetland acres added lost and converted.

	Acres Added		***Acres Lost***		***Acres Converted***	
Landscape Change						
Pond Conversion/Creation	203	39%	< 1	< 1%	62	27%
Added Irrigation "Wetter"	132	25%	< 1	< 1%	26	11%
Reduced Irrigation "Drier"	-	-	25	10%	11	5%
Natural Adjustment	70	13%	6	2%	99	44%
Resource Extraction	64	12%	12	5%	14	6%
Urban Development	2	< 1%	32	13%	1	1%
Rural Development	< 1	< 1%	127	51%	< 1	< 1%
Other	52	10%	49	19%	14	6%
Total	**522**		**250**		**228**	
Mapping Change						
Riparian Attribution	163	15%	-	-	112	41%
Scale	343	32%	485	55%	90	33%
Interpreter Difference	550	51%	381	43%	66	24%
Image Quality	26	2%	10	1%	4	1%
Total	**1081**		**876**		**272**	
Grand Total	**1603**		**1126**		**499**	

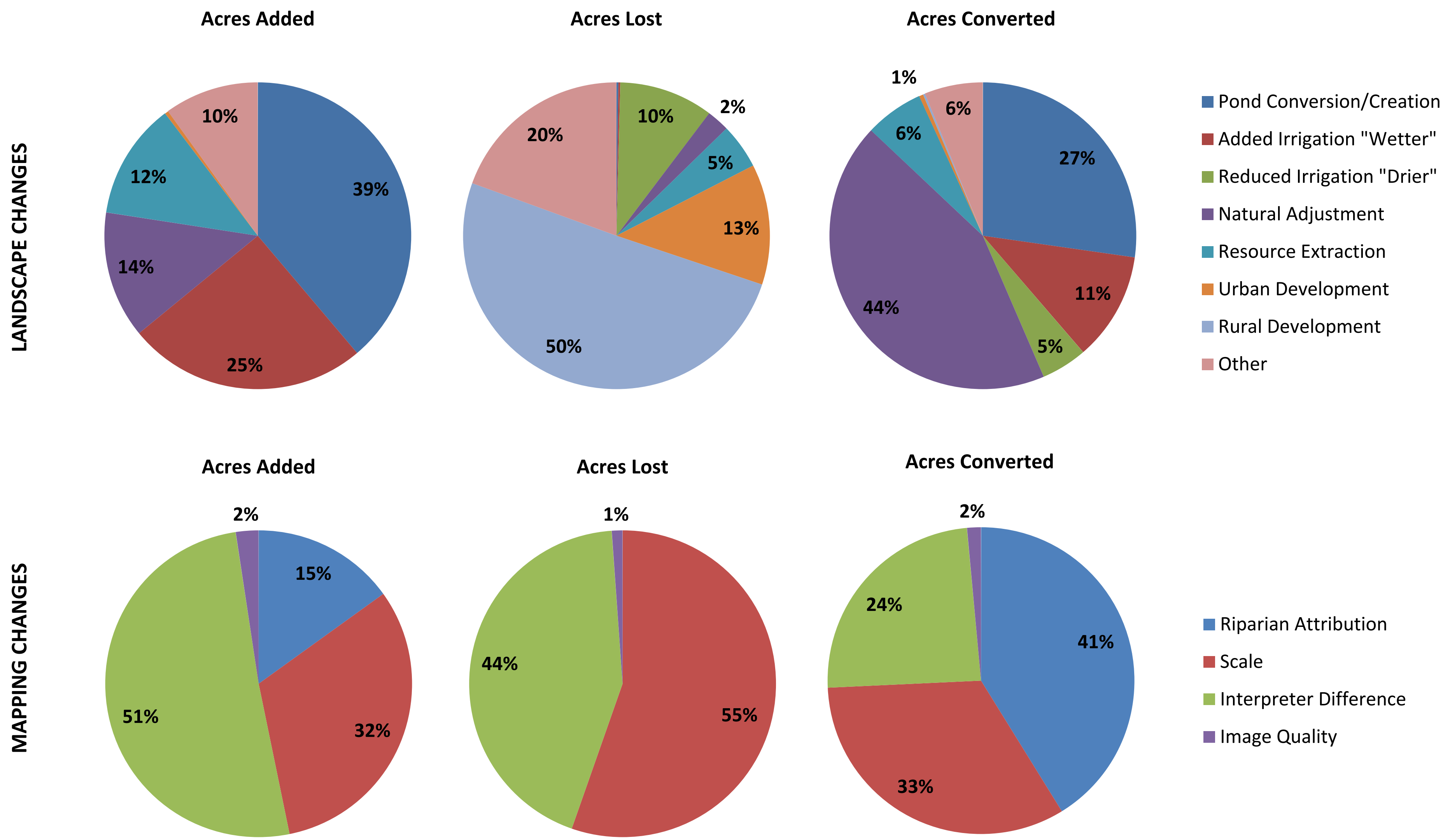


Fig. 15. Detailed cause of wetland acres added, lost and converted.

3.3 Discussion

The wetland profiles and change over time analysis presented for the northern Front Range study area reveal major trends in the aquatic resource base, and these trends have significant implications for wetland mitigation. The most significant trend is the shift from a landscape where aquatic resources were once closely linked to river and stream systems to one now dominated by open water, both large lakes and many small ponds. The bulk of this change occurred even before the benchmark of our Tier 2 historical wetland profile in the late 1970s, but the direction of change has continued in the past three decades.

This trend signifies a change in the functions and services performed by the aquatic resource base in the study area. The predominant depressional wetlands are effective at storm water retention, sediment retention, and nutrient removal/transformation, but they are less effective at flood attenuation, streamflow maintenance, transport of sediment and organic material, and support for biodiversity than the riverine wetlands they have replaced. A decrease in the quality of lotic fisheries has been one significant effect of riverine wetland loss. Continued loss of riverine wetlands and the increase of depressional and open water wetlands will further erode the cumulative functional performance of the once defining attribute of the watershed, namely, its riverine arterial system.

Regulatory wetland mitigation mandated under Section 404 of the Clean Water Act, when carried out based on the watershed approach, provides an opportunity to move the current wetland profile in a direction that can add to the functional performance of the watershed rather than continue to degrade it. The wetland profiles constructed for the Front Range study area allow one clear watershed need to be identified. That is, riverine wetlands and the functions they provide have been grossly disproportionately impacted in the region. Consequently, any increase the acreage or condition of riverine wetlands in this study area would be interpreted as improving the wetland profile. In the context of mitigation planning and federal review, mitigation targeting riverine habitats may be viewed as the most ecologically preferable based on the wetland profile analysis.

This demonstration also shows the relative ease and usefulness of creating wetland profiles with three tiers of data intensity. All three tiers resulted in a similar picture of the watersheds, but with increased data intensity, the picture becomes clearer and more precise. Colorado's ultimate goal should be to create statewide coverage of digital wetland mapping based on the most recent air photography available, ideally no more than 10 years old. But short of that goal, Colorado is approaching a significant milestone of having the original 1970s and 1980s NWI maps converted to digital data for the entire state. This will allow for the development of Tier 2 wetland profiles for all watersheds across the state.

4.0 FIELD STUDY OF WETLAND CONDTION WITHIN THE NORTHERN FRONT RANGE

While the spatial accounting of wetland acres within a wetland profile is the most basic information needed to carry out the watershed approach, on-the-ground data on wetland condition further fleshes out the picture and highlights wetland types or specific areas within a watershed where wetland impacts should be avoided or where mitigation may be more likely to succeed. To demonstrate how filed data can augment a detailed Tier 3 wetland profile, we conducted a field-based assessment of wetland condition within the demonstration project area.

4.1 Introduction to Colorado Wetland Assessment Methods

Numerous wetland assessment methods have been developed across the country in the past 20 years. Bartoldus (1999) and Fennessy et al. (2004) provide early reviews of assessment methods, though many more have been developed in the intervening years. Assessment methods can be broken down in two ways: 1) intensity of data collection and 2) whether they focus on functional condition or biotic condition.

Level 1-2-3 Approach: EPA´s National Wetlands Monitoring Workgroup has endorsed the concept of a Level 1, 2, 3 approach to monitoring that defines three levels of data collection intensity. Level 1 (landscape assessment) relies on coarse, landscape scale inventory information, typically gathered through remote sensing and preferably stored in, or convertible to, a geographic information system (GIS) format. Level 2 (rapid assessment) is at the specific wetland site scale, using relatively simple, rapid protocols. Level 3 (intensive site assessment) uses intensive research-derived, multi-metric indices of biological integrity.[9] Nearly all assessment methods in use today fit within one or more levels of this paradigm.

Functional vs. Biotic Condition: The difference between assessment methods that evaluate functional condition vs. biotic conditional is largely based on the purpose and intended use of the method. Functional assessments focus on physical drivers or processes, such as hydrology and geomorphology. They aim to evaluate the current ability of a wetland to perform certain understood functions typical of a wetland in its class. They are often used to quantify the potential change in functional capacity if certain actions are carried out, such as impacts by development, restoration activities, or changes in hydrologic regime. Functional assessments are carried out by measuring, estimating, or otherwise quantifying variables associated with one or more ecosystem functions. Functions normally fall into one of three major categories: 1) hydrologic (e.g., storage of surface water), 2) biogeochemical (e.g., removal of elements and compounds), and 3) physical habitat (e.g., topography, depth of water, number and size of trees) (EPA 1998).

Biotic assessments, on the other hand, focus on the biological response to cumulative stressors over many years. While some stressors may be evident to an observer, others may not. However, the biota within that wetland reflect the long term cumulative effect of all stressors placed on the wetland and can serve as indicators of its overall health. Biologically based condition assessments

[9] For more information, see http://www.epa.gov/owow/wetlands/pdf/techfram.pdf.

aim "to evaluate a wetland's ability to support and maintain a balanced, adaptive community or organism having a species composition, diversity, and functional organization comparable with that of minimally disturbed wetlands within a region." (EPA 1998). They are typically carried out by measuring or quantifying certain aspects of wetland assemblages (i.e., plant, invertebrate, or faunal communities) along with associated wetland attributes.

Colorado Assessment Methods: Within Colorado, two primary assessment methods have been developed for wetlands at the rapid assessment level (Level 2). The first is the Functional Assessment of Colorado Wetlands (FACWet), developed by Dr. Brad Johnson with funding from the Colorado Department of Transportation (Johnson et al. 2011).[10] FACWet is a functionally based condition assessment method that focuses on physical drivers of wetland processes in an effort to highlight the causes of degradation. The FACWet method has been endorsed by the U.S. Army Corps of Engineers (ACOE) and is now required to accompany all Section 404 permits for wetland impacts or mitigation plans.

The second major assessment method is based on the Ecological Integrity Assessment (EIA) framework developed by NatureServe[11] and ecologist from several Natural Heritage Programs across the country (Faber-Langendoen et al. 2008; Faber-Langendoen et al. 2012).[12] Colorado-specific EIA protocols have been developed and refined by CNHP with funding from EPA Region 8 and Colorado Parks and Wildlife (Rocchio 2006a-g; Lemly & Rocchio 2009; Lemly et al 2011; Lemly and Gilligan 2012). The EIA method is an ecologically based condition assessment method that focuses on the biological response to disturbance, but also evaluates underlying processes. In addition to rapid assessment methods, CNHP has developed two intensive (Level 3) biotic condition assessment methods: the Floristic Quality Assessment (FQA: Rocchio 2007b) and vegetation indices of biotic condition (VIBIs) for three wetland types (Lemly & Rocchio 2009b; Rocchio 2007a). Though the FQA can be viewed as a Level 3 method because it requires botanical knowledge, it is used in a more rapid form as part of Colorado's Level 2 EIA protocol, as carried out in this project.

While FACWet focuses on the impact of stressor and their influence on process, EIA incorporates several quantitative biotic metrics (e.g., % non-native species, noxious weeds, FQA metrics), that reveal the biological response to those stressors. FACWet is highly effective at identifying root causes of degradation, while EIA tracks the biotic response. Both are essential tools for management of Colorado's wetland resource. More information on the FACWet, EIA and FQA methods is provided below and throughout this report.

4.1.1 Functional Assessment of Colorado Wetlands (FACWet)

FACWet is an information framework and stressor-based rapid assessment method, founded on hydrogeomorphic (HGM) theory and classification. In overall structure, it is strongly influenced by the California Rapid Assessment Methodology (CRAM: CWMW 2012). In approach, FACWet is the formalization of an investigative process in which evidence is gathered to support a best

[10] For up-to-date information on FACWet, see the webstie: http://rydberg.biology.colostate.edu/FACWet.
[11] NatureServe is a non-profit conservation organization whose mission is to provide the scientific basis for effective conservation action. For more information about NatureServe, see their website: www.natureserve.org.
[12] For up-to-date information on Colorad's EIA, see the website: http://www.cnhp.colostate.edu/cwic.

professional judgment on the condition of eight ecological forcing factors (i.e., "state variables") that control wetland functioning. State variables are organized in three attribute classes:

- Buffer & Landscape Context
- Hydrology
- Abiotic & Biotic Habitat

The evaluator's summary opinion on each state variable's condition is represented by a numeric score that corresponds to a letter grade based on the academic grading scale of A-F (Table 20). Letter grades, in turn, are intended to convey information about functional condition – an A indicates reference standard condition with little or no detectable human impact and an F indicates the highest degree of impact and nonfunctional condition.

Once each variable is scored, FACWet then relates state variable condition to functional capacity. Functional capacity is a relative index that gauges the departure from the expected level of functioning exhibited by the reference standard. The evidence supporting a rating will commonly be a best professional assessment of the effect of visibly detectable stressors or their indicators, reinforced with readily obtained information available from web-based sources or GIS. Information from quantitative investigations of ecological condition can be directly incorporated into a FACWet evaluation if circumstances should warrant additional rigor. FACWet provides the framework within which to place all of the information gathered during project permitting, mitigation planning or monitoring.

Table 30. FACWet grading scale and associated definitions.

Score Range	***Letter Grade***	***Narrative Condition Category***	***Interpretation***
1.00 – 0.90	**A**	**Reference Standard**	Pristine or nearly so. Supports highest level of sustainable functioning.
<0.90 – 0.80	**B**	**Highly Functioning**	Stressors detectably alter the variable's form in minor ways. The variable still retains its essential qualities and supports a high level of ecological function.
<0.80 – 0.70	**C**	**Functioning**	Obvious alteration and degradation of the variable, but it still supports basic, natural, passive wetland functioning.
<0.70 – 0.60	**D**	**Functionally Impaired**	Major ecologically harmful alterations to the variable. Active management commonly required to support maintenance of wetland characteristics.
<0.60	**F**	**Non-Functioning**	Massive deleterious alteration of the variable. The level of alteration generally results in an inability of the variable to support wetland conditions or it otherwise makes the area biologically-unsuitable.

4.1.2 Ecological Integrity Assessment (EIA) Framework

The EIA framework also shares characteristics of established wetland assessment methods, such as CRAM and the Ohio Rapid Assessment Method (ORAM: Ohio EPA 2001). The EIA framework evaluates wetland condition based on a multi-metric index. Biotic and abiotic metrics are selected to measure the integrity of key wetland attributes within four major categories:

- Landscape Context
- Biotic Condition
- Hydrologic Condition
- Physiochemical Condition.

EIA is also a reference-based approach; metrics are rated according to deviation from our current understanding of the natural range of variability (i.e., reference standard) expressed in wetlands from the time of pre-European settlement to today. Reference standard is ideally determined using the range of variability observed in wetlands with no or minimal human disturbance (i.e., reference wetlands) that exist on the landscape today. Where field data are lacking or no reference condition wetlands remain, information from the literature is also used to define reference standard. The further a metric deviates from its natural range of variability (reference standard), the lower the rating it receives.

EIA metrics are both quantitative and qualitative and thresholds are defined by numeric and narrative criteria. Each metric is rated on a letter grade scale (typically A–D, but occasionally A–E) that translates into a point value of 5, 4, 3, 1 (or 5, 4, 3, 2, 1). Once metrics are rated, scores are rolled up into the four major categories using a weighted algorithm. Scores for these four categories are then rolled up into an overall EIA score. For ease of communication, category scores and the overall EIA score are converted back to ranks following the ranges shown in Table 31. The scores and ranks can be used to track change and progress toward meeting management goals and objectives.

Table 31. Overall EIA scores and ranks and associated definitions.

Score Range	*Rank*	*Narrative Condition Category*	*Interpretation*
5.0 – 4.5	**A**	**Excellent / Reference Condition** **(No or Minimal Human Impact)**	Wetland functions within the bounds of natural disturbance regimes. The surrounding landscape contains natural habitats that are essentially unfragmented with little to no stressors; vegetation structure and composition are within the natural range of variation, nonnative species are essentially absent, and a comprehensive set of key species are present; soil properties and hydrological functions are intact. Management should focus on preservation and protection.
<4.5 – 3.5	**B**	**Good / Slight Deviation from Reference**	Wetland predominantly functions within the bounds of natural disturbance regimes. The surrounding landscape contains largely natural habitats that are minimally fragmented with few stressors; vegetation structure and composition deviate slightly from the natural range of variation, nonnative species and noxious weeds are present in minor amounts, and most key species are present; soils properties and hydrology are only slightly altered. Management should focus on the prevention of further alteration.
<3.5 – 2.5	**C**	**Fair / Moderate Deviation from Reference**	Wetland has a number of unfavorable characteristics. The surrounding landscape is moderately fragmented with several stressors; the vegetation structure and composition is somewhat outside the natural range of variation, nonnative species and noxious weeds may have a sizeable presence or moderately negative impacts, and many key species are absent; soil properties and hydrology are altered. Management would be needed to maintain or restore certain ecological attributes.
<2.5	**D**	**Poor / Significant Deviation from Reference**	Wetland has severely altered characteristics. The surrounding landscape contains little natural habitat and is very fragmented; the vegetation structure and composition are well beyond their natural range of variation, nonnative species and noxious weeds exert a strong negative impact, and most key species are absent; soil properties and hydrology are severely altered. There may be little long term conservation value without restoration, and such restoration may be difficult or uncertain.

4.1.3 Floristic Quality Assessment (FQA)

The FQA approach to assessing ecological communities is based on the concept of species conservatism. The core of the FQA method is the use of "coefficients of conservatism" (C-values), which are assigned to all native species in a flora following the methods described by Swink and Wilhelm (1994) and Wilhelm and Masters (1996). C-values range from 0 to 10 and represent an estimated probability that a plant is likely to occur in a landscape relatively unaltered from pre-European settlement conditions. High C-values are assigned to species which are obligate to high-quality natural areas and cannot tolerate habitat degradation, while low C-values are assigned to species with a wide tolerance to human disturbance. Generally, C-values of 0 are reserved for non-native species. The proportion of conservative plants in a plant community provides a powerful and relatively easy assessment of the integrity of both biotic and abiotic processes and is indicative of the ecological integrity of a site (Wilhelm and Ladd 1988). The most basic FQA index is a simple average of C-values for a given site, generally called the Mean C, though more complex indicies can be calculated.

The FQA provides a unique approach to ecological monitoring and assessment that moves beyond simple measures of species richness and abundance and provides an estimate of the quality of native plants at a site (Herman et al. 1997). Under the assumption that plants effectively integrate spatial and temporal human impacts to ecological systems, FQA indices provide a cost-effective means of assessing ecological condition. FQA indices also provide consistent, quantitative measures of floristic integrity, can be used in any plant community, do not require extensive sampling equipment (only a competent botanist), and can be applied to existing data sets. FQA indices are included as a component of the Colorado EIA protocols, but they can also be used as stand-alone measures of biotic condition.

4.2 Methods

4.2.1 Survey Design and Site Selection

Target Population: The target population for this field study was all wetlands within the northern Front Range study area. The target population for field sampling did not include deep water lakes, river and stream channels, or non-wetland riparian areas, though we report the acreage of these features in the wetland profiles (see Section 3.0). Minimum size criteria of 0.1 hectares in area and 10 m in width were also implemented. For safety reasons, we excluded wetland area with water > 1 m deep from field sampling.

The operational definition used in this project was the USFWS definition used for NWI mapping (Cowardin et al. 1979):

> *"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."*

The USFWS definition is different than the definition of wetland used by the ACOE and the EPA for regulatory purposes under Section 404 of the Federal Clean Water Act (ACOE 1987):

> *"[Wetlands are] those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions."*

The primary difference between the two definitions is that the Clean Water Act definition requires positive identification of all three wetland parameters (hydrology, vegetation, and soils) while the USFWS definition requires only one to be present. It is important to note that wetlands surveyed through this study may or may not be classified as jurisdictional wetlands under the Clean Water Act and that NWI mapped boundaries should not be interpreted as wetland delineations, though they are often similar.

Standard wetland identification and delineation techniques were used to determine inclusion in the target population. We relied heavily on materials produced by the ACOE and the Natural Resources Conservation Service (NRCS), such as the *Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Western Mountains, Valleys, and Coast Region* (ACOE 2008) and the *Indicators of Hydric Soils in the United States* (NRCS 2010). However, we only needed positive identification of one or two parameters, not all three.

Classification/Subpopulations: The target population was classified in the field into subpopulations based two different classification systems: hydrogeomorphic (HGM) and Ecological Systems. Because elements within the sample frame (NWI polygons) were not attributed with either system *a priori*, these subpopulations were not part of the survey design. Through initial field testing, we found that the HGM-like LLWW attribution described in Section 3.0 was too coarse to use as a proxy for HGM classes in the field. We therefore relied on field-based classification for summarizing results.

The HGM classification system groups wetlands according to hydrologic characteristics and geomorphic position (Brinson 1993). Hydrologic and geomorphic "controls" are responsible for maintaining many of the functional aspects of wetland ecosystems. These hydrogeomorphic characteristics include geomorphic setting, water source, and hydrodynamics. By classifying wetland according to the hydrologic and geomorphic "controls," the HGM classification groups wetlands into classes that perform a similar suite of functions. Sites were classified by HGM following the key in Appendix F. Four of the original five HGM classes within Colorado were found in the study area (Table 32).

Table 32. HGM Classes found in the northern Front Range.

HGM Class	***Interpretation***
Riverine	Wetlands occurring in floodplains and riparian corridors in association with stream channels. Dominant water sources are overbank or backwater flow from the channel. Flow is horizontal and unidirectional.
Lacustrine Fringe	Wetlands adjacent to lakes where the water elevation of the lake maintains the water table in the wetland. Flow is bidirectional, meaning water levels rise and fall with lake levels and with wave action.
Depressional	Wetlands formed in topographic depressions (i.e., closed elevation contours) that allow the accumulation of surface water by ponding or saturation to the surface. Potential water sources are precipitation, overland flow, or groundwater flow from adjacent uplands. Flow is from higher elevations toward the center of the depression.

Slope	Wetlands found in association with the discharge of groundwater to the land surface or saturated overland flow and no channel formation. Dominant source of water is groundwater or interflow discharging at the land surface. Flow is downslope unidirectional.
Novel Irrigation-Fed	Wetlands created or sustained by surface or subsurface flow from irrigation and irrigation canals. Flow is downslope unidirectional.

The Ecological System classification (Comer et al. 2003) is a component of the International Vegetation Classification System (Grossman et al. 1998; Faber-Langendoen et al. 2009), developed by NatureServe and the Natural Heritage Network. It provides a finer scale of resolution and focuses more on vegetation composition than either the HGM classification system (Brinson 1993) or the USFWS Cowardin classification (Cowardin et al. 1979), but is a coarser-scale than individual plant associations. The Ecological System approach uses both biotic (structure and floristics) and abiotic (hydrogeomorphic template, elevation, soil chemistry, etc.) criteria to define units. These classes allow for greater specificity in developing conceptual models of natural variability and the thresholds that relate to stressors. Sites were classified by Ecological System following the key in Appendix G. Four Ecological Systems were found in the study area (Table 33).

Table 33. Wetland Ecological Systems found in the northern Front Range.

Ecological System
Rocky Mountain Alpine-Montane Wet Meadow
Rocky Mountain Lower Montane Riparian Woodland and Shrubland
North American Arid West Emergent Freshwater Marsh
North American Arid West Irrigated Wet Meadow

A new class was added to both the HGM and Ecological System classifications to describe the prevalence of wet meadows created or sustained by irrigation water. The new HGM class was called '*Novel Irrigation-Fed'* and the new Ecological System was called '*Western North American Irrigated Wet Meadow.'* These wetlands were outside the historical range of variability for both hydrologic, geomorphic, and vegetation characteristics within the study area and do not fit cleanly within either classification system. Within the HGM classification, irrigation-fed wet meadows could be seen as a variation on the slope class, and have been described as such by pervious authors (Cooper 1998; Adamus 2004). However, they differ from the classic description of a slope wetland because they are not associated with natural groundwater discharge. Within the Ecological System classification, irrigation-fed wet meadows could be seen as a variation of Rocky Mountain Alpine-Montane Wet Meadows, but they are outside the typical elevation range for that system and are dominated by non-native grass species. Historically, wet meadows within the study area were likely confined to small patches within the vegetated mosaic of river and stream floodplains or in few localized areas with true groundwater discharge. Irrigated wet meadows can occur in a variety of landscape positions not associated with alluvial flow or natural groundwater.

In addition to the two primary classification systems, all sites were also classified into three subclasses based on an approximation of the site's origin (Table 34). These subclasses were determined by examining the landscape position, proximity to irrigation canals and other non-nature water sources, and knowledge of site history. Taken together, the three classifications effectively separate the sampled wetlands into meaningful groups.

Table 34. Wetland origin classification used for the northern Front Range demonstration study.

Wetland Origin
1) Natural feature with minimal alteration
2) Natural feature, but altered or augmented
3) Non-natural feature created by management action

Sample Size: The initial target was to sample 30–40 wetlands, of which 34 wetlands were sampled in the summer of 2011.

Sample Frame: A sample frame is the spatial representation of the target population from which sample points are selected. The sample frame for this study was based on the newly updated NWI mapping (Tier 3 wetland profile). From the NWI dataset, we eliminated polygons that represented deep water lakes, river and stream channels, and non-wetland riparian areas. To build the final sample frame, all area within the included NWI polygons was converted into a 10-meter grid of potential sample points. A 10-meter grid was chosen as the smallest sample unit possible under the constraints of computer processing time and file size, but ensured that even small polygons would include points. Target sample points were selected from within this grid of points and not from polygon centroids because of extreme variation in the size of individual polygons. Therefore, wetlands sampled represent a portion of wetland area, not of individual wetlands.

Selection Criteria: The study employed a one-stage survey design stratified by HUC8 river subbasins (watersheds). Half the target sample points were selected in the St. Vrain watershed and half in the Big Thompson watershed. Target sample points were selected using the Reversed Randomized Quadrant-Recursive Raster (RRQRR) approach in ArcGIS 9.3 (Theobald et al. 2007).

4.2.2 Field Methods

One objective of this demonstration study was to compare Colorado's two leading wetland assessment methods: the FACWet method and the EIA framework (see Section 5.0 for a detailed description of the comparison). For this project, FACWet Version 2.0 was carried out by Dr. Brad Johnson and Colorado-specific EIA protocols were carried out by CNHP Wetland Ecologist Laurie Gilligan. All wetlands were sampled using the rapid assessment (Level 2) version of the EIA protocols. Vegetation data were collected with a timed, plotless sampling design. To maintain independence between the two methods, there was no discussion while these two methods were applied. However, the vegetation data was collected jointly. See Johnson et al. (2011) for the FACWet field form and Appendix I for EIA field form used during the 2011 field season.

Defining the Wetland Assessment Area (AA): Randomized sampling relies on the identification and establishment of an assessment area (AA) within the target wetland population. An AA is the boundary of the wetland (or portion of the wetland) targeted for sampling and analysis. Sample points were randomly selected from the sample frame within areas presumed to meet the target population. Before any sampling occurred, all points were screened in the office to remove sites that were clearly non-target. Once in the field, the target status of each point was verified or the point was rejected. To accommodate slight inaccuracies within the sample frame and variable precision of GPS receivers, we were able to shift up to 60 m from the original target point in order to establish an AA within a sampleable target wetland.

At each sample point determined to meet the target population, an AA was defined as all wetland area of the same HGM class and Ecological System in a 0.1–0.5 ha area surrounding the target point. Where possible, the AA was delineated as a 40 m radius circle around the point (0.5 ha). However, the size and shape of the AA could vary depending on site conditions with the overall goal of establishing an AA of 0.1–0.5 ha and at least 10 m wide within the same HGM class and Ecological System. If the AA was not a circle, the perimeter of the AA was walked with a GPS to record the boundary. During data processing, the actual area of each AA was delineated in GIS based on GPS data and field notes in order to calculate the area sampled. Prior to field visits, two field maps were made for each targeted sample point. The field maps outlined the potential AA boundary (40 m radius circle around the sample point) and a 100-m and 500-m radius envelope around the AA..

Once the AA was established, standard site variables were collected from each sample location. This included:

- UTM coordinates at four locations around the AA
- Elevation, slope, and aspect
- Place name, county, and land ownership
- HGM classification
- Ecological System classification
- Cowardin classification
- Vegetation zones within the AA
- Description of onsite and adjacent ecological processes and land use
- Description of general site characteristics and a site drawing
- At least four photos were taken at each site along the edge of the AA looking in towards the site (Fig. 16).
- Additional photos were taken as need to document the wetland and surrounding landscape.

Fig. 16. Example AA photos from northern Front Range wetlands.

Functional Assessment of Colorado Wetlands (FACWet): For every sampled wetland, the FACWet Version 2.0 field form was filled out by Dr. Brad Johnson according to the standard methodology. FACWet variables used in the northern Front Range demonstration study are summarized in Table 35. FACWet scoring formula is described in more detail in Section 5.0 and in Johnson et al. (2011).

Table 35. FACWet attributes and state variable used for the northern Front Range demonstration study.

Attribute	*Variable Number*	*State Variable Name*
Buffer & Landscape Context	V1	Habitat Connectivity - Neighboring Wetland Habitat Loss
	V2	Habitat Connectivity - Migration/Dispersal Barriers
	V3	Buffer Capacity
Hydrology	V4	Water Source
	V5	Water Distribution
	V6	Water Outflow
Abiotic & Biotic Habitat	V7	Geomorphology
	V8	Chemical Environment
	V9	Vegetation Structure and Complexity

Ecological Integrity Assessment (EIA): For every sampled wetland, a Level 2 rapid EIA field form was filled out by CNHP Wetland Ecologist Laurie Gilligan according to HGM Class and Ecological System. EIA metrics used in the northern Front Range demonstration study are shown in Table 36. Metric narrative ratings and scoring formulas are included as Appendix I

Table 36. EIA categories, attributes, and metrics used for the northern Front Range demonstration study.

Ecological Categories	*Key Ecological Attributes*	*Metrics*
Landscape Context	Landscape Connectivity	Landscape Fragmentation Riparian Corridor Continuity[1]
	Buffer	Buffer Extent Buffer Width Buffer Condition
Biotic Condition	Species Composition	Relative Cover Native Plant Species Absolute Cover Noxious Weeds Absolute Cover Aggressive Native Species Mean C

Ecological Categories	Key Ecological Attributes	Metrics
	Community Structure	Regeneration of Native Woody Species[2] Litter Accumulation Structural Complexity
Hydrologic Condition	Hydrology	Water Source Alteration to Hydroperiod Hydrologic Connectivity Bank Stability[1]
Physiochemical Condition	Physiochemistry	Water Quality – Turbidity / Pollutants Water Quality – Algal Growth Substrate / Soil Disturbance

[1] Metric recorded in Riverine HGM wetlands only.
[2] Only applied to sites where woody species are naturally common.

Vegetation Data Collection: Vegetation data were collected in a plotless sample design. All species present within the AA were identified and listed on the field form and the overall cover within the AA was visually estimated using the following cover classes (Peet et al. 1998).

1 =	trace (one or two individuals)	6 =	>10–25%
2 =	0–1%	7 =	>25–50%
3 =	>1–2%	8 =	>50–75%
4 =	>2–5%	9 =	>75–95%
5 =	>5–10%	10 =	>95%

The search for species was limited to no more than one hour to minimize the amount of time spent at the site. Nomenclature for all plant species followed Weber and Wittman (2001a,b) and all species were recorded on the field form using the fully spelled out scientific name. Any unknown species were entered on the field form with a descriptive name and all unknown species were collected for later identification. The only species not collected were those identified as or suspected to be federally or state listed species.

4.2.3 Data Management

To efficiently store and analyze collected data, all data forms were entered into electronic spreadsheets and databases at the completion of the field season. FACWet variables were entered into a spreadsheet designed to calculate FACWet functional capacity indices and overall FACWet scores. EIA metrics and vegetation data were entered into a Microsoft Access™ database designed to calculate EIA and FQA scores. Within the EIA/FQA database, a pre-defined species list was used for species entry to eliminate spelling errors. Unknown or ambiguous species (e.g., *Carex* sp.) were entered into the database, but not included in data analysis. The species table from the Colorado FQA (based on Rocchio 2007 and regularly updated) was used as the pre-defined species list and to populate life history traits, wetland indicator status, and C-values for each species. Primary species nomenclature follows Weber and Wittmann (2001a,b) and all names are cross-referenced to nationally accepted names in the U.S. Department of Agriculture's PLANTS National Database[13].

4.2.4 Data Analysis

For all sampled wetlands, scores were calculated separately for both the FACWet and EIA methods. To discuss condition of northern Front Range wetlands in general, FACWet and EIA scores were combined to produce a composite condition score. In addition, vegetation data were used to calculate FQA metrics for all sites. One FQA metric (Mean C) was included in the Biotic Condition category of the EIA protocol, but also represents the single strongest measures of biotic wetland condition (Lemly and Rocchio 2009) and is presented separately.

To create composite scores, letter grades were simply combined. When there was agreement between the two methods, a single grade resulted (e.g., "B"). When there was a disparity in grades, an intermediate grade consisting of two letters was assigned (e.g., "BC"). This letter grade scheme follows that used in some academic institutions, such as the University of Wisconsin. The two-letter grade format accomplishes two things. First, it creates three intermediate condition categories that provide additional resolution of patterns in wetland condition. Second, it highlights instances when there was disagreement between evaluation grades. Intermediate grades are only produced when scores differ between the evaluation methods. The two different scores that make up the intermediate grade category are the two grades assigned in the evaluation.

Although each method has its own approach to condition rating, combining scores was a useful approach to condition assessment, since each emphasizes different, but complementary aspects of wetland condition. Section 5.0 provides a detailed comparison of the two methods, explaining the relationship between the methods' grades and highlighting the similarities and differences between them. In brief, however, ignoring borderline cases, there was a 91% correspondence in the composite condition grades between FACWet and EIA. Thus, in terms of condition assessment, letter grades are essentially equivalent between the two methods; however, it is important to understand that FACWet relates condition on functional grounds, whereas EIA emphasizes biotically-based criteria for condition, thus the information extracted from each and its use is different between the methods.

Both FACWet and EIA letter grades are tied to categories called condition classes, which range from reference standard at the high end (A), to non-functional or low integrity at the low end (F in FACWet and D or E in EIA). As such, condition class names provide handy, concise descriptive narratives about the state of the wetland's functional and biotic condition. Because of their utility, these terms will often be used to describe the combined implications of FACWet and EIA grades, to convey an easily understandable sense of condition. In doing so, however, it must be understood that each functional condition class also implies an equivalent level of ecological integrity and vice versa. For instance, the term highly functional should also be taken as implying a high level of functional as well as biological integrity.

[13] PLANTS National Database can be accessed at the following website: http://plants.usda.gov. National nomenclature in the Colorado FQA is based on a download from the website in January 2008.

4.3 Results of Condition Assessment

4.3.1 Classification of Sampled Wetlands

A total of 34 wetlands were sampled in the northern Front Range study area during the summer of 2011 (Fig. 17). Fifteen were sampled in the Big Thompson River subbasin (44%) and 19 in the St. Vrain River subbasin (56%). All sites were classified by two primary classification systems (HGM and Ecological Systems) and an additional sub-classification of origin (Tables 37, 38; Figs. 18, 19).

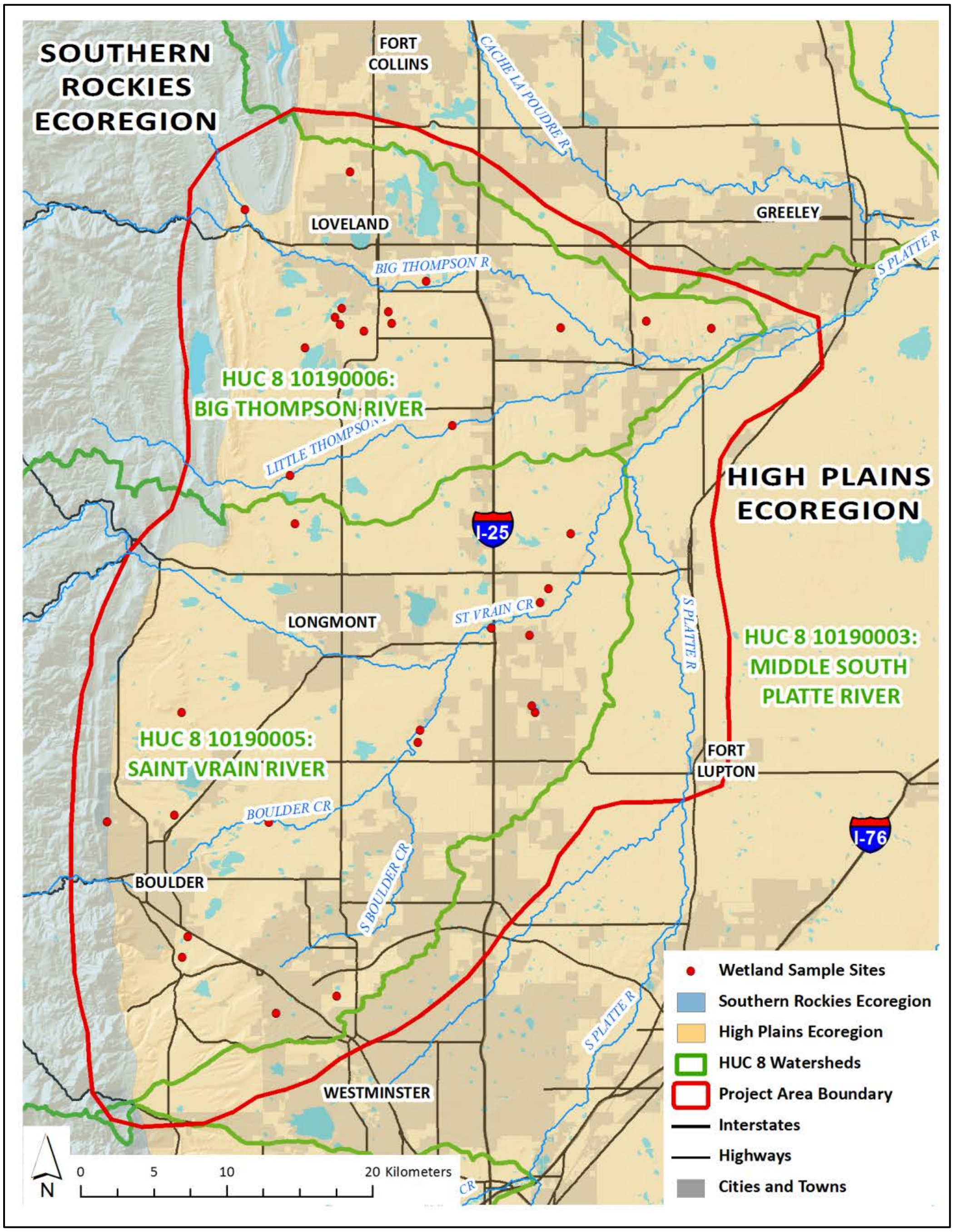


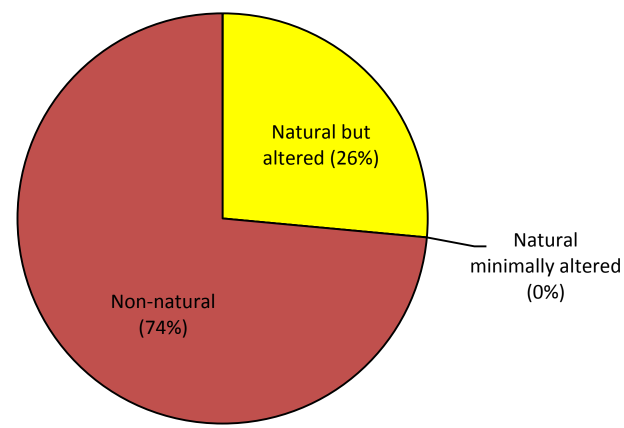
Fig. 17. Wetlands sampled in the northern Front Range study area.

Table 37. HGM and Ecological System classification of wetlands sampled in the northern Front Range demonstration study.

Ecological System / Origin	*HGM Class*					*Total*	*% of Total*
	Depressional	*Riverine*	*Novel Irrigation-Fed*	*Lacustrine Fringe*	*Slope*		
Arid West Emergent Marsh	**14**	**3**		**1**		**18**	**53%**
2) Natural feature, but altered or augmented	1	1				2	6%
3) Non-natural feature created by management action	13	2		1		16	47%
Lower Montane Riparian Woodland and Shrubland		**6**		**1**		**7**	**21%**
2) Natural feature, but altered or augmented		5				5	15%
3) Non-natural feature created by management action		1		1		2	6%
Arid West Irrigated Wet Meadow			**8**			**8**	**24%**
2) Natural feature, but altered or augmented			1			1	3%
3) Non-natural feature created by management action			7			7	21%
Alpine-Montane Wet Meadow					**1**	**1**	**3%**
2) Natural feature, but altered or augmented					1	1	3%
Total	**14**	**9**	**8**	**2**	**1**	**34**	**100%**
% of Total	**38%**	**26%**	**26%**	**6%**	**3%**	**100%**	

Table 38. Origin sub-classification of wetlands sampled in the northern Front Range demonstration study.

Origin	*Count*	*% of Total*	*Chart Color*
1) Natural feature with minimal alteration	0	0%	n
2) Natural feature, but altered or augmented	9	26%	n
3) Non-natural feature created by management action	25	74%	n
Total	**34**	**100%**	



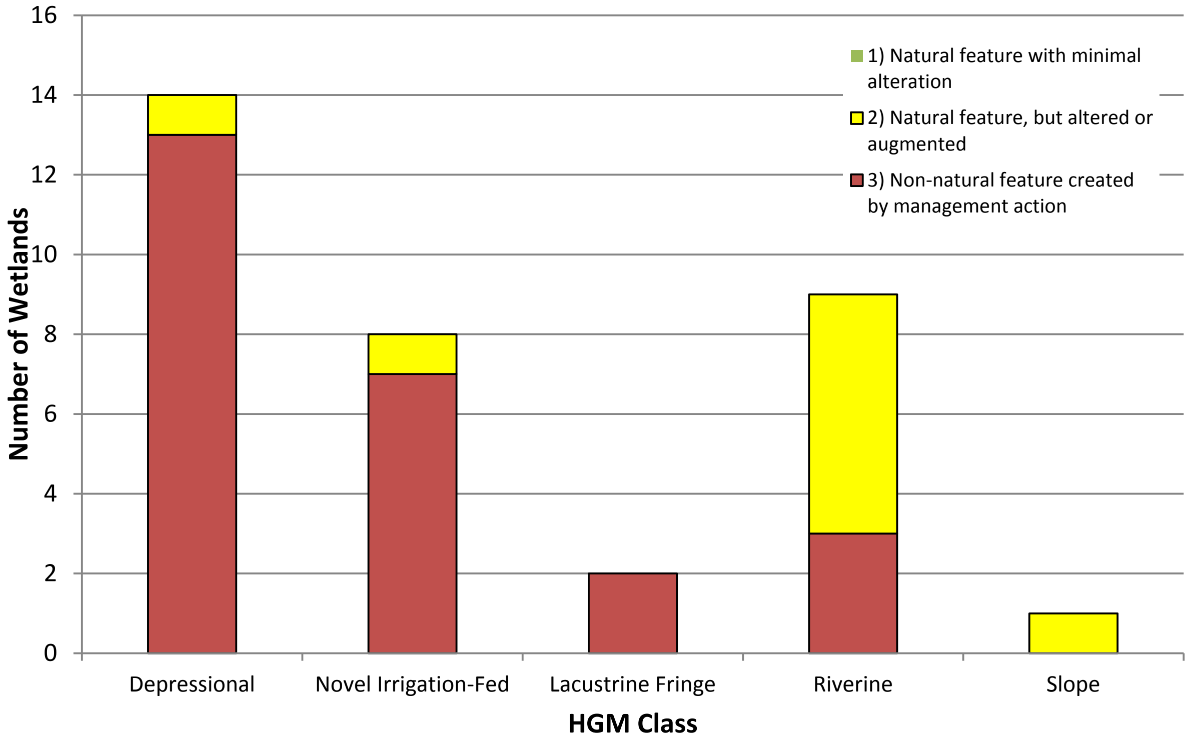


Fig. 18. HGM and original classification of sampled wetlands.

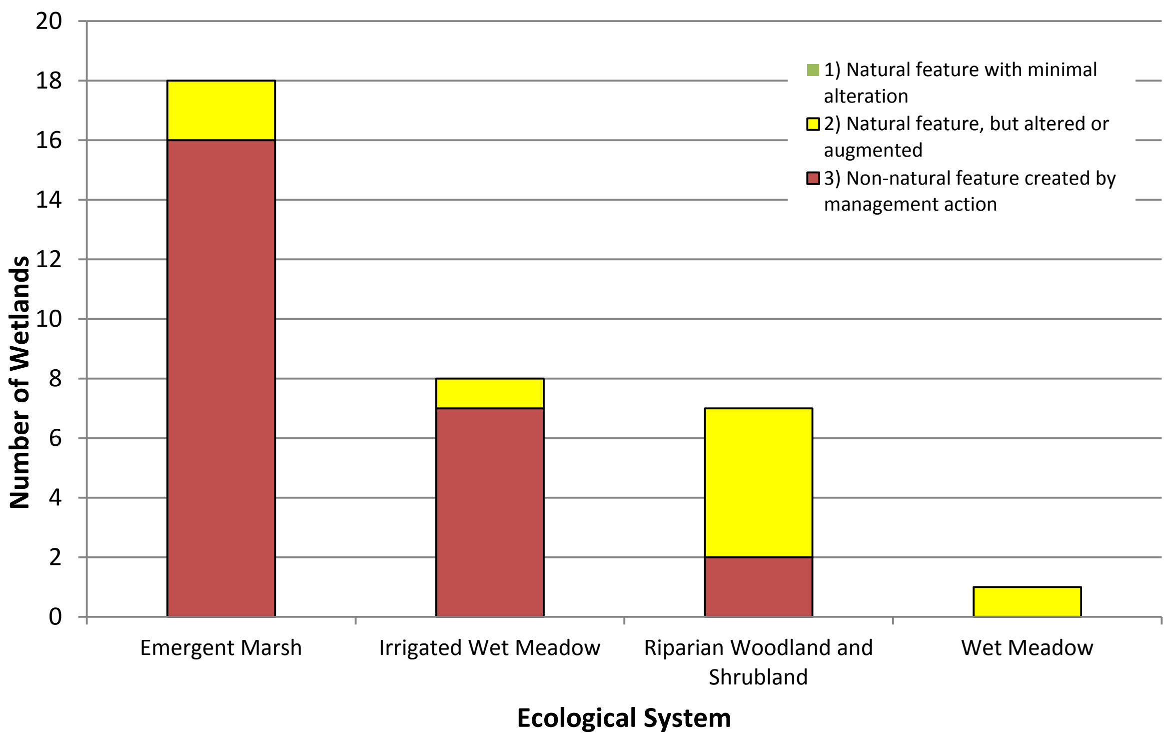


Fig. 19. Ecological System and original classification of sampled wetlands.

Depressional wetlands (Fig. 20) were the most common HGM class encountered, with 41% or 14 out of 34 sites. All 14 were classified as the arid west emergent marsh Ecological System. Of these, 13 were classified as non-natural features created by management action, meaning they had formed in a depression on the landscape that held water, but that the water source itself was not natural. These sites were either intentionally created wetlands for wildlife habitat, wetland mitigation, or storm water retention or they were unintentionally created from the impounded of either irrigation or storm water run-off. Non-natural depressional wetlands formed the largest single subclass of all wetlands sampled. One remaining depressional wetland was classified as a natural feature, but altered or augmented. This was a site that was located in what appeared to be a natural isolated depression (apparent on all old topo maps) that may have been a playa or other depressional wetland originally. Today, however, the hydrology of the site is maintained by ditch leakage. Whether the site was truly a natural wetland is impossible to know without further research.

Fig. 20. Depressional wetlands sampled in the northern Front Range (sites #13407 and #11576).

Nine wetlands were sampled in the riverine HGM class (Fig. 21). Of these, six were considered natural but altered. The hydrology of nearly all streams and rivers along the Front Range has been modified by upstream water retention and diversions, which clearly impacts associated riverine wetlands, often leading to steeply incised banks and disconnected floodplains. Five of the natural riverine wetlands were riparian woodland and shrublands and one was an arid west emergent marsh located in a backwater area still subject to flooding events. Three riverine wetlands (two marshes and one riparian woodland and shrubland) were classified as a non-natural feature created by management action. These sites were overgrown ditches with established vegetation cover that contained seasonally flowing water, mimicking riverine conditions. Natural riverine wetlands occur on floodplains and along stream channels where they are tightly connected to flowing water and seasonal flooding events. The dynamic can be somewhat replicated by ditches themselves, leading to the split between natural and non-natural features.

Fig. 21. Riverine wetlands sampled in the northern Front Range, a natural riverine wetland (left: site #4778) and an overgrown ditch (right: site #4337).

Eight wetlands were sampled within the novel irrigation-fed HGM class (Fig. 22). All eight were classified as irrigated wet meadows. These were herbaceous wetlands that lacked significant standing water and were dominated by graminoides, often non-native grasses and weeds. The hydrology of these sites depended on irrigation waters, either through direct flood irrigation, indirect return flows, or ditch seepage. One site within the novel irrigation-fed subclass was classified as natural but altered because it was located on the historical floodplain of Boulder Creek and was likely a wetland in the past; however it would have been tied to flow from the creek or subsurface alluvial water within the floodplain. At the time of field sampling, the site appeared to be sustained by direct irrigation through lateral ditches. The other seven irrigation-fed sites were considered non-natural features because they appeared in landscape positions that likely did not support wetlands historically.

Fig. 22. Novel irrigation-fed wetlands sampled in the northern Front Range (sites #5189 and #11452).

Lastly, there were two lacustrine fringe wetlands and one slope wetland (Fig. 23). The two lacustrine fringe wetlands were both non-natural features formed on the margins of constructed reservoirs. One contained significant cover of woody species (chiefly plains cottonwood = *Populus deltoides* ssp. *monilifera* and green ash = *Fraxinus pennsylvanica* var. *lanceolata*) and was classified as a riparian woodland and shrubland. The other was classified as an arid west emergent marsh. The one true slope wetland was located at the edge of a butte and had a thick histic epipedon (8- to 16-inch layer of organic matter on the surface of a mineral soil). This soil feature is characteristic of long-term saturation and is a good indicator of natural ground water. This site also received irrigation water, but it was not fully sustained by irrigation. The origin, therefore, was classified as natural but altered and the Ecological System was classified as a natural wet meadow.

Fig. 23. A lacustrine fringe marsh wetland (left: #6437) and the one true slope wetland (right: #11013) sampled in the northern Front Range.

In all, 25 of the 34 wetlands were classified as non-natural features (Table 38). This represents 74% of the sites sampled. Another nine (26%) were classified as natural features, but altered or augmented. No wetlands were considered natural features with minimal alteration.

4.3.2 Characteristics of Northern Front Range Wetland Vegetation

Within sampled wetlands, species diversity was relatively high, though a substantial portion of those species were non-native. In total, 233 individual plant taxa were encountered in the 34 sites. This number includes 24 taxa identified only to the genus or family level because they were found either early or late in the season and lacked the floristic parts necessary for identification. Of the 233 total taxa, 143 were only encountered only once or twice, indicating that additional surveys would likely add many more species to the overall total. The average number of species per site was 28, and ranged from 8 to 43. Rushes (*Juncus* spp.) and sedges (*Carex* spp.) were the most diverse genera found in sampled wetlands, with 13 and 12 individual species, respectively.

Of the 209 species identified to species level, 122 (58%) were native species and 87 (42%) were non-native species.[14] Noxious weeds, an aggressive subset of non-natives, were present in all but two sites.[15] In total, 18 different noxious weeds were encountered, though none were A List species designated for immediate eradication (Table 39). The most common noxious weed was Canada thistle (*Breea arvensis* = *Cirsium arvense*), which was found in 28 of the 34 sites. Other common noxious weeds included: Russian olive (*Elaeagnus angustifolia*), found in 17 sites; field bindweed (*Convolvulus arvensis*), found in 9 sites; and common teasel (*Dipsacus fullonum*) and broadleaved or perennial pepperweed (*Cardaria latifolia = Lepidium latifolium*), both found in 7 sites. Aggressive native species were also considered problematic in 12 sites. Aggressive natives include cattails (*Typha* spp.), which can dominate sites with excess nutrients, reed canarygrass (*Phalaroides arundinacea = Phalaris arundinacea*)[16] and giant reed (*Phragmites australis*).

Table 39. Noxious weed species encountered in northern Front Range wetlands.

Scientific Name	Common Name	Occurrences	Noxious Weed List
Breea arvensis (=Cirsium arvense)	Canada thistle	28	List B
Elaeagnus angustifolia	Russian olive	17	List B
Convolvulus arvensis	field bindweed	9	List C
Cardaria latifolia (=Lepidium latifolium)	broadleaved or perennial pepperweed	7	List B
Dipsacus fullonum	common teasel	7	List B
Anisantha tectorum (=Bromus tectorum)	cheatgrass	5	List C
Carduus nutans	musk thistle	5	List B
Cardaria draba	whitetop	4	List B
Arctium minus	lesser burdock	2	List C
Cichorium intybus	chicory	2	List C
Cirsium vulgare	bull thistle	2	List B
Hesperis matronalis	dames rocket	2	List B
Tamarix ramosissima	saltcedar	2	List B
Acroptilon repens	hardheads	1	List B
Conium maculatum	poison hemlock	1	List C
Cynoglossum officinale	gypsyflower	1	List B
Sonchus arvensis	field sowthistle	1	List C
Sonchus uliginosus	common sowthistle	1	List C

Canada thistle was not only the most common noxious weed encountered, but was also the most common species overall (Table 40). The top 25 most common species included 9 non-native and 15

[14] For the purpose of this project, native status was defined based on Weber and Wittmann (2001) and is specific to Colorado. Several species considered native to North America are considered non-native to Colorado by Weber and Wittmann.

[15] For the purpose of this project, noxious weeds were defined based on the Colorado Department of Agriculture's Noxious Weed list from 2010. For more information, see: http://www.colorado.gov/cs/Satellite/ag_Conservation/CBON/1251618874438.

[16] There are both native and non-native ecotypes of *Phalaroides arundinacea.* The non-native, Eurasian ecotype is naturalized in the northern U.S. and can spread aggressively. It is thought that the Colorado populations are likely the Eurasian ecotype, but may also contain the native ecotype. Since the native status is uncertain and the ecotypes are difficult to distinguish in the field, for the purpose of this project, *Phalaroides arundinacea* is considered an aggressive native species.

native species. The final taxon on the most common list was the genus Chenopodium, which includes both native and non-native species that can be difficult to identify to the species level. None of the top 25 species had a C-value higher than 5, indicating that all of the species commonly encountered either thrive in disturbed conditions or tolerate disturbance. Only 16 out of the entire 233 species encountered in the study area had C-values higher than 6, and each of these was found only a few times. The most common species included primarily obligate (OBL), facultative wetland (FACW) and facultative (FAC) species, but also one upland (UPL) species (smooth brome = *Bromopsis inermis*) and six facultative upland (FACU) species.

Table 40. Twenty-five most common plants encountered in northern Front Range wetlands.

Scientific Name	Common Name	Occurrences	Native Status	C-Value[1]	Wetland Indicator Status[2]
Breea arvensis	Canada thistle	28	Non-native	0	FACU
Eleocharis macrostachya	pale spikerush	26	Native	3	OBL
Rumex crispus	curly dock	24	Non-native	0	FAC
Typha angustifolia	narrowleaf cattail	22	Non-native	0	OBL
Schoenoplectus lacustris ssp. *acutus*	hardstem bulrush	22	Native	3	FAC
Asclepias speciosa	showy milkweed	22	Native	3	OBL
Schoenoplectus pungens	common threesquare	21	Native	4	OBL
Chenopodium sp.	goosefoot	20	Unknown	--	--
Phalaroides arundinacea	reed canarygrass	19	Native	2	FACU
Taraxacum officinale	common dandelion	19	Non-native	0	FACW
Critesion jubatum	foxtail barley	18	Native	2	FAC
Typha latifolia	broadleaf cattail	18	Native	2	FACW
Lactuca serriola	prickly lettuce	18	Non-native	0	OBL
Elaeagnus angustifolia	Russian olive	17	Non-native	0	FACU
Juncus arcticus ssp. *ater*	mountain rush	16	Native	4	FACW
Carex praegracilis	clustered field sedge	15	Native	5	FACW
Populus deltoides ssp. *monilifera*	plains cottonwood	14	Native	3	FAC
Bromopsis inermis	smooth brome	14	Non-native	0	UPL
Festuca arundinacea	tall fescue	12	Non-native	0	FACU
Mentha arvensis	wild mint	12	Native	4	FACW
Distichlis stricta	saltgrass	12	Native	4	FACW
Salix exigua	narrowleaf willow	11	Native	3	FACU
Carex nebrascensis	Nebraska sedge	11	Native	5	OBL
Bassia sieversiana	burningbush	11	Non-native	0	FACW
Pascopyrum smithii	western wheatgrass	10	Native	5	FACU

[2] C-values are from the Floristic Quality Assessment for Colorado (Rocchio 2007).

[1] Wetland Indicator Status based on the 2012 National Wetland Plant List for the Great Plains Region (Lichvar 2012). OBL = obligate wetland species, almost always occurs in wetlands; FACW = facultative wetland species, usually occurs in wetlands, but may occur in non-wetlands; FAC = facultative species, occurs in wetland and non-wetlands; FACU = facultative upland species, usually occurs in non-wetlands, but may occur in wetlands; UPL = obligate upland species, almost never occurs in wetlands.

4.3.3 Floristic Quality Assessment

Floristic Quality Assessment (FQA) metrics were calculated for all 34 sites based on the vegetation data collection. The overall average Mean C was 2.15. Mean C values for sampled wetlands ranged from 0.78–3.71, with most values between 1.50 and 3.00 (Fig. 24). On the whole, Mean C values for northern Front Range wetlands were very low compared to sites sampled through other projects at higher elevations in other regions of the state (Lemly et al. 2011; Lemly 2012; Lemly & Gilligan 2012). For example, the average Mean C value observed in the North Platte River Basin in north central Colorado was 5.46 (range 2.77–7.08) and in the Rio Grande Headwaters River Basin in south central Colorado was 4.41 (range 1.55–7.50). Both of these basins contained significant high elevation areas under public land management, as well as rural agricultural lands.

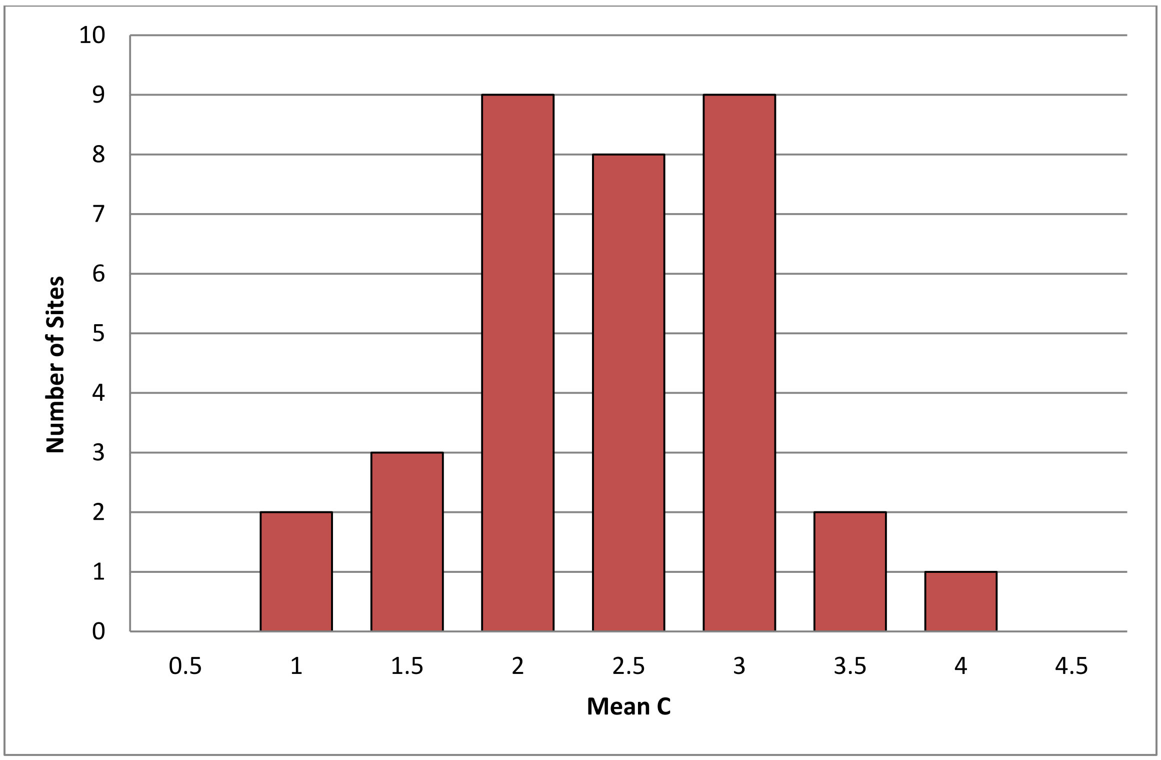
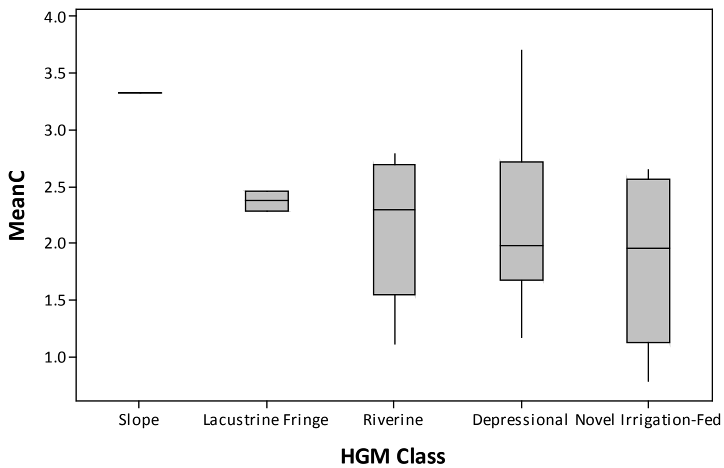


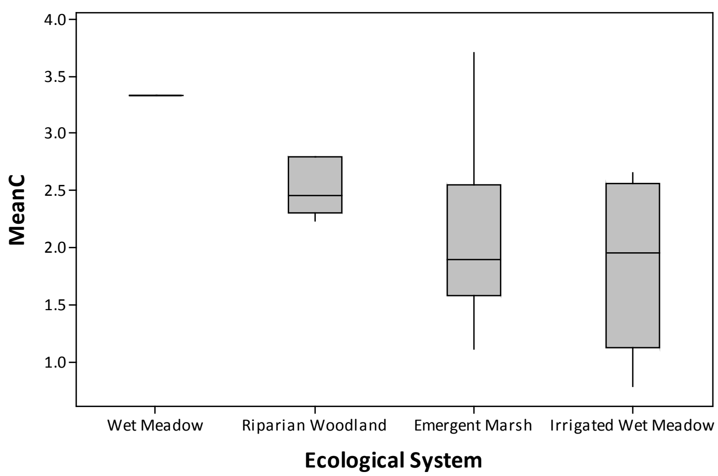
Fig. 24. Distribution of Mean C values for all sampled wetlands. Number under each bar represents the upper bound of the bin.

The range of Mean C values varied by HGM, Ecological System, and wetland origin (Fig. 25). Interestingly, the highest Mean C sampled (3.71) was at a non-natural, depressional, emergent marsh, the City of Boulder's Marshall Mitigation Bank. Though non-natural, this site is managed for wetland vegetation and is located within open space lands. While this was the highest value seen in the study area, it still received the a C rank for the individual Mean C metric within the EIA, meaning the vegetation quality based on that metric alone was only considered fair. In general, depressional wetlands and emergent marshes both showed a wide range of Mean C values and averages of 2.20 and 2.07, respectively. However, these categories include the Marshall Mitigation Bank, which is an anomaly for the study area. If that one site is removed, the averages drop to 2.09 and 1.98, respectively.

The average for riverine sites was 2.14, but this included both the natural riparian areas and the overgrown ditches. The average for riparian woodlands was 2.51 and the spread is much narrower than for all riverine sites. The novel irrigation-fed HGM class and the irrigated wet meadows, essentially the same set of wetlands, had an average Mean C of 1.88. The two lacustrine fringe wetlands (one marsh and one riparian woodland) both had similar Mean C values that averaged to 2.37. The one true slope wet meadow also had one of the highest Mean C values among sampled wetlands (3.33). As the sole representative of both slope wetlands and natural wet meadows, this site made both of those wetland classes rise to the top of average Mean C values by class. When grouped by origin, the natural sites had distinctly higher scores than the non-natural sites, especially if the Marshall Mitigation Bank was removed (not shown). Across the board, it cannot be emphasized enough that these Mean C scores are very low and represent degraded vegetation communities.

In addition to Mean C, the FQA methodology includes a number of different indices that can be evaluated to gauge biotic condition. Table 41 shows means and standard deviations for the ten different FQA indices by Ecological System. The additional indices vary by their inclusion or exclusion of non-native species, the use of cover–weighting to emphasize dominant species, and incorporation of species richness into the equation. For northern Front Range wetlands, each of the FQA indices shows a similar pattern to the general Mean C data presented above. While the values for Mean C calculated with only native species are higher than with all species, they also hover around 4.0, which is low compared to data from wetlands in other regions of the state. Cover-weighted Mean C averages, which give more weight to the C-values of species with high cover, are even lower. The average cover-weighted Mean C of emergent marshes is 1.1, an incredibly low value. This indicates the dominant species are non-natives (which have a C-value of 0) or are native species with very low C-values.





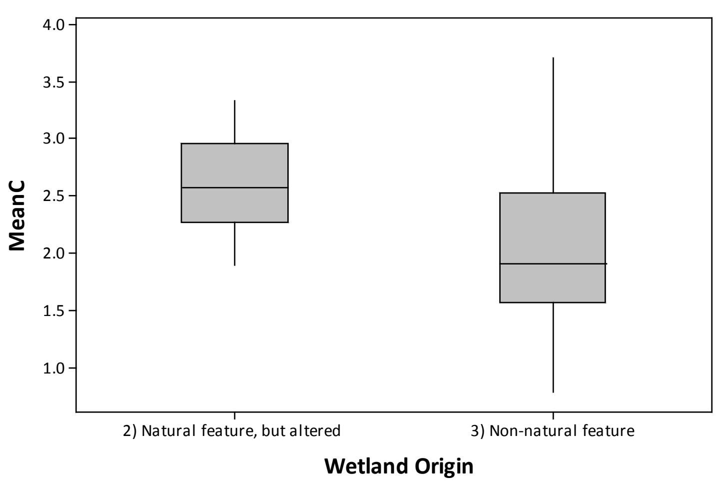


Fig. 25. Range of Mean C scores by HGM Class, Ecological System, and wetland origin. Boxes represent 75th percentile to 25th percentile. Horizontal line represents the median. Whiskers extend to 95th and 5th percentiles and stars are outliers.

Table 41. Means and standard deviations of all FQA metrics by Ecological System.

FQA Indices	Riparian Woodlands *n* = 7		Emergent Marsh *n* = 18		Irrigated Wet Meadows *n* = 8		Wet Meadow *n* = 1
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Value SD=n/a**
Total species richness	35	6	26	9	24	7	34
Native species richness	20	5	12	4	11	6	24
Non-native species richness	13	2	12	6	12	3	9
% Non-native	39%	4%	45%	15%	54%	16%	27%
Mean C of all species	2.5	0.2	2.1	0.7	1.9	0.7	3.3
Mean C of native species	4.2	0.2	3.7	0.4	4.0	0.4	4.6
Cover-weighted Mean C of all species	2.0	1.0	1.1	0.8	2.4	1.2	4.4
Cover-weighted Mean C of native species	3.9	0.7	3.3	0.6	4.0	0.6	4.7
FQI of all species	14.2	2.5	9.6	2.9	9.2	4.3	19.1
FQI of native species	18.3	2.7	12.9	2.9	13.1	4.3	22.5
Cover-weighted FQI of all species	11.7	6.6	5.3	3.8	11.5	6.1	25.1
Cover-weighted FQI of native species	17.0	4.0	11.5	2.8	12.6	3.6	22.8
Adjusted FQI	32.3	2.0	27.6	6.0	27.1	6.4	39.1
Cover-weighted adjusted FQI	29.8	5.2	24.7	6.4	26.3	5.2	39.8

4.3.4 Composite Condition Assessment

Examination of composite condition scores reveals that, overall, aquatic resources in the study area have been subjected to dramatic, ubiquitous alteration (Fig. 26). Based on composite scores, 85% of sites had an overall condition of functioning (C) or lower, 41% of sites were at the bottom end of the functioning range (CD) or lower, and one site was found to have been rendered completely non-functional in terms of its wetland habitat characteristics.

While these grades are low, it is important to note that this survey did not, nor could not, include the vast number of historical wetlands in the study area that have been rendered non-functioning or completely removed through land use change (changes in hydrology, direct filling, etc.). Remote identification and mapping of such habitats is at best difficult and generally impossible. Thus, the actual number of the most impaired or eradicated aquatic habitats is much higher than was detected by this field study.

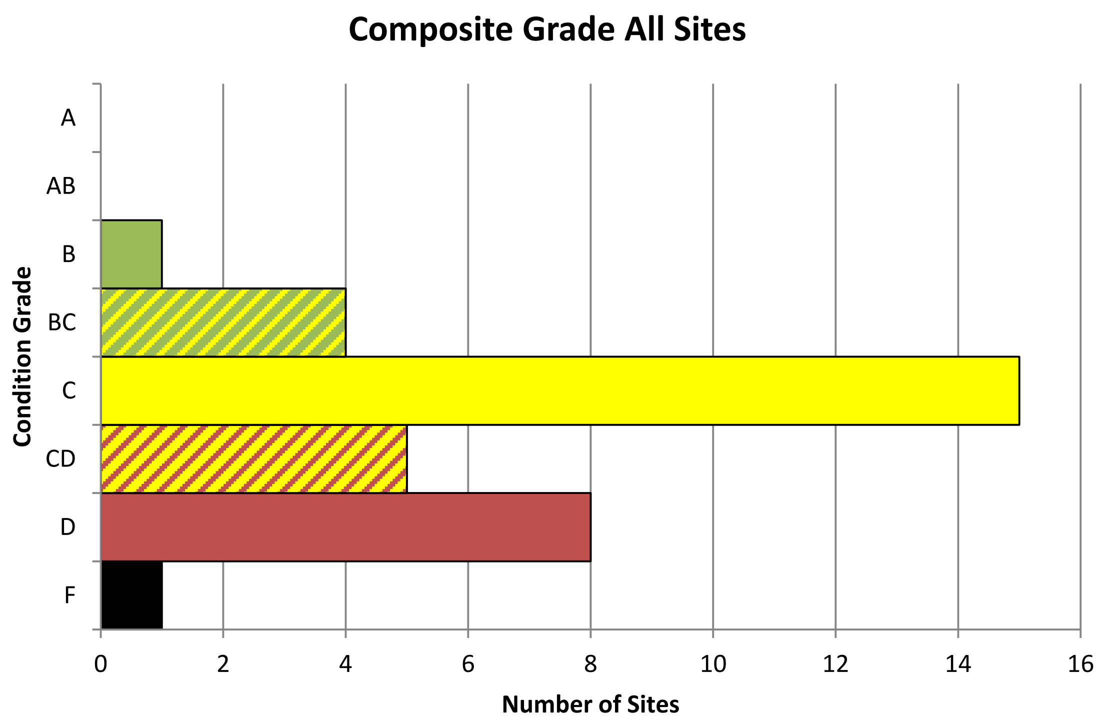


Fig. 26. Distribution of condition grades across all sites. Grades are a composite of FACWet grades and EIA ranks.

<u>*Composite Scores by HGM Class:*</u> While depressional wetlands were rare in the Front Range's natural (pre-settlement) landscape, they are now the most common type of aquatic system (see Section 3.0). The majority of these wetlands have an overall condition in the functioning (C) range, indicating they perform basic wetland functions and retain wetland vegetation, but there is a significant departure from reference conditions (Fig. 27). Thirty-six percent of the depressional sites (n=5) sampled exhibited a functionally and biotically impaired condition (D).

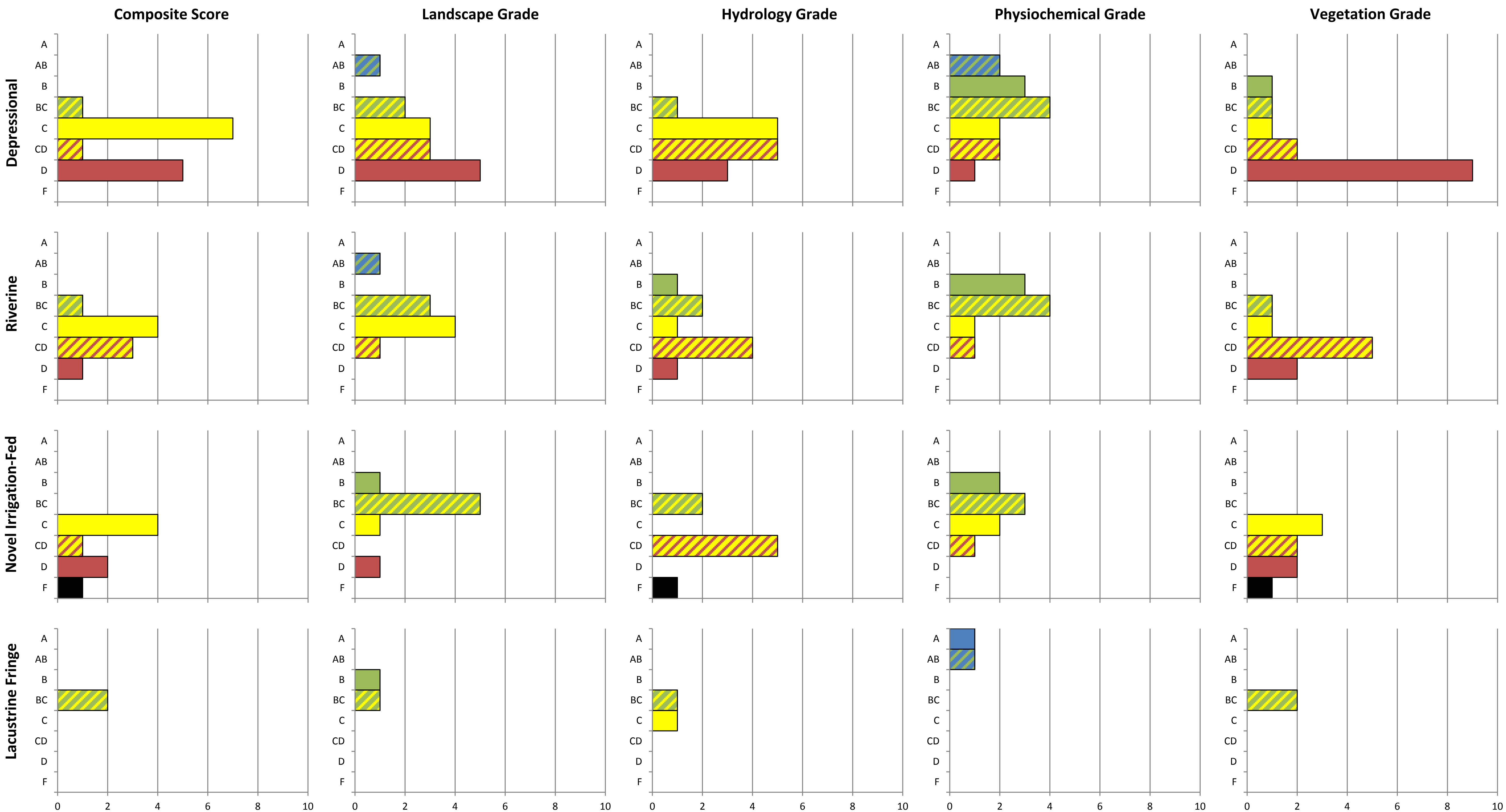


Fig. 27. Category condition grade distributions for wetlands as grouped HGM class. The one slope wetland is not shown. Grades are a composite of FACWet and EIA condition grades.

Riverine and novel irrigation-fed wetlands show the same basic trend in overall condition as described for depressional wetlands, except that no novel irrigation-fed wetland attained a condition better than functioning (C). This is not surprising since most of these habitats developed incidentally as an artifact of water conveyance, irrigation return flow or ditch leakage. These habitats could be described as “weedy”, in the sense that they spring up voluntarily and tend to have poor ecological condition. Although their condition is poor, these sites are taken as extremely important providers of ecosystem services, particularly water quality improvement and provision of wildlife habitat.

The two lacustrine fringe sites evaluated were in comparatively good condition being intermediate between functioning and highly functioning. Both sites occurred on properties managed as natural areas close to the foothills. Because of the small number of lacustrine fringe sites included in this sample population it is unclear if the condition of these sites is truly indicative of reservoir habitats in general. Our observations suggest that habitat quality in reservoir fringe wetlands sites decreases along a west to east gradient, as water becomes increasingly exposed to agricultural and urban runoff and effluent.

There was one slope wetland site evaluated and it was judged to be in highly functioning (B) condition. This site was an anomaly both in terms of its relatively high condition and its habitat characteristics, which very much resembled a high elevation fen site, replete with mounded springs and water tracks (Fig. 28). Because of the rarity of slope wetlands in the study area, the overall condition of those habitats cannot be determined from this study.

Fig. 28. View east down an elongated spring mound (brown vegetation at center) in the slope wetland at site #11013.

Composite condition grades provide a useful picture of overall wetland health, but examination of the key ecological drivers of condition – parameterized in the variables and metrics of FACWet and EIA – yields insights into which specific aspects of wetlands are most impaired and into the causes of their degradation. EIA scoring takes metric scores and combines them to produce four Metric Category grades: *Landscape, Hydrology, Physiochemistry* and *Vegetation*. FACWet on the other hand combines variable scores to produce condition indices for functions, or functional capacity indices, the scores of which are then converted to grades. To make the results of the two methods comparable, the FACWet variables were grouped according to the EIA structure and averaged to produce “Attribute Category” scores that were the FACWet counterpart the EIA Metric Categories. This score was then converted to a letter grade according to the FACWet grading scale. The process of equating the methods is fully described in Section 5.0.

Landscape Condition by HGM Class: The landscape of the Colorado Front Range plains has seen a dramatic shift in land uses. Over the past 30 years, population in the region has nearly doubled and with that growth has come inevitable urbanization, infrastructure expansion and water management. All of these changes create significant stresses on the remaining natural habitats, particularly those that are part of the aquatic system.

Depressional wetlands were generally set in highly altered landscapes, being commonly surrounded by row crop agriculture, urban developments, or parks (Fig. 29). Oil and natural gas develop was very common in the vicinity of depressional wetlands. One depressional wetland sampled was part of the City of Boulder's Marshall Mitigation Bank and was sited in a well-managed open space. This landscape condition was rated as highly functional by FACWet and even reference standard by EIA. However, for most depressional wetlands, landscape modification was a major contributor to the impairment of habitat condition, being a source of sediment, eutrophied water, weeds and chemical toxicants. Landscape condition likely imposes a strong limit on the overall condition any wetland in the region can attain.

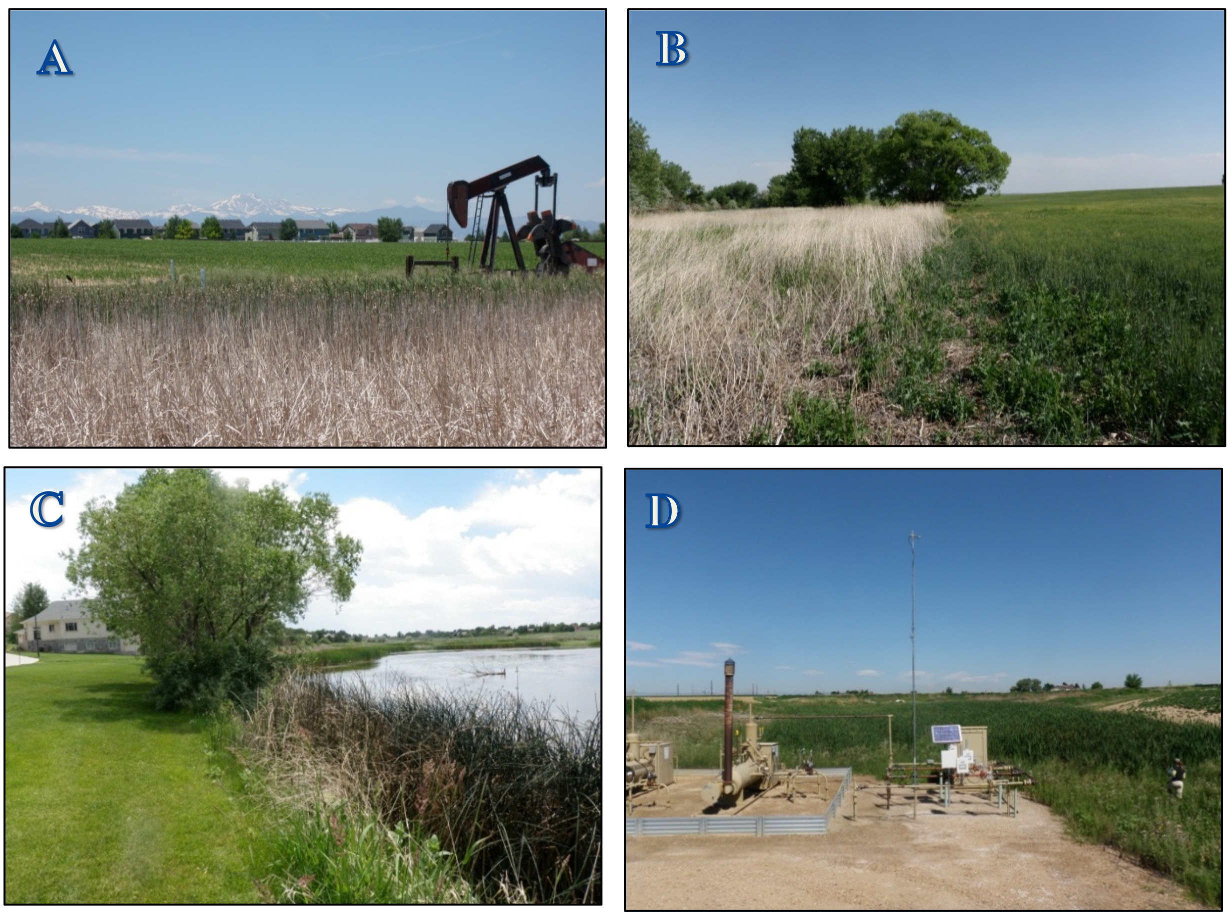


Fig. 29. Typical landscape settings for depressional wetlands. In photo A, row crop agriculture and oil development provide an unhealthy buffer to urbanization (site #2537). In photo B, row crop agriculture edges right up to the wetland (at left), which serves as a catch basin for irrigation runoff (site # 3295). In photos C, residential developments and parks are commonly associated with the ubiquitous depressional wetlands that occur on the fringe of small reservoirs (site #2584). Natural gas pads were frequently placed at the edge of depressional wetlands (site # 13376).

The landscape surrounding one riverine site, which was again sited on City of Boulder Open Space Land (Windhover property, site #4229), was rated highly (Fig. 30); however, most riverine wetlands were found in in agricultural settings, typically involving row cropping, but often with functioning buffers which helped ameliorate some of the ecological stressors emanating from the land uses. The landscapes holding the novel irrigated wetlands ranged in condition from highly functional to functioning impaired with most being at the higher end of the range. Most of these wetlands were found in rural landscapes used for horse grazing or hay production (Fig. 31). As previously mentioned, both lacustrine fringe sites were held in managed open space which accounts for the high marks for landscape condition they received (Fig. 32). The single slope wetland was located on a large property used for low intensity agriculture including haying and light grazing (Fig. 28).

Fig. 30. In the photograph to the left, the City of Boulder's Windhover property (site #4229), provided a contiguous landscape setting for the wetland. The photograph at right shows a more typical setting for riverine wetlands in the study area. Here the wetland at site #6040, was an irrigation ditch flanked by agricultural development.

Fig. 31. Typical landscape setting and appearance of novel irrigation-fed wetlands (sites #8280 and 21272).

Fig. 32. The photograph at right shows the character of a riparian woodland lacustrine fringe wetland, which is managed as a state wildlife area. The photograph at right shows the well managed landscape setting of the lacustrine fringe wetland at site #6437.

Hydrologic Condition by HGM Class: The entire Front Range study area is marked by pervasive and profound hydrologic alteration. Massive trans-divide water diversions bring millions of acre feet of water to the region from Colorado's western slope, and that water is moved across the landscape both in constructed aqueducts as well as natural channels. The water is held in thousands of reservoirs across the region and distributed across the landscape in a perplexing network of irrigation ditches. In fact, in a region which naturally held few ponds not in association with stream channels, and virtually no large lakes, the region is now dotted with water bodies at a density approaching that of the prairie pothole region (Fig. 33).

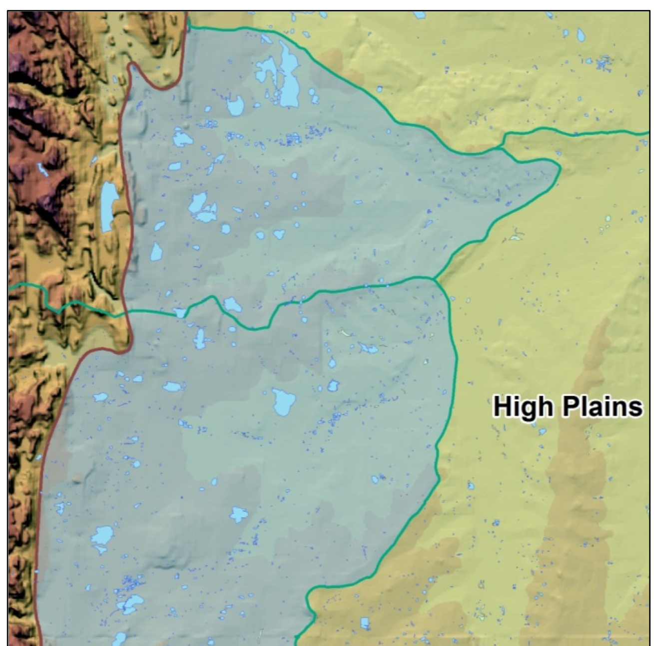


Fig. 33. A shade relief map of the Front Range study area showing the distribution and density of water bodies. Essentially all of these features are human

Overall, depressional wetlands showed the most hydrologic impairment, with only six of the 14 depressional sites having hydrologic regimes rated as functional or better (≥C) (Fig. 27). Three sites were graded solidly as functionally impaired (D), while five additional depressional wetlands had artificial, actively managed water sources that FACWet rated as functionally impaired (D) and EIA rated as functioning (C), which accounts for the five intermediate CD grades. This same difference in grading criteria appeared when the hydrologic condition of novel irrigation-fed wetlands was evaluated.

The hydrology of riverine wetlands has also been strongly altered. For these wetlands, management of stream flow regime is a universal stressor, but degradation of channel morphology is also a widespread issue. Deleterious changes to stream channels such as incision and over-widening (Fig. 34) further decrease the capacity of the stream to flood its adjacent wetlands.

Novel irrigation-fed wetlands were as common in this survey as riverine wetlands. At all of these sites, hydrology is controlled by active management, but the goal of that management is not the support of wetland habitat, instead it is crop production, water delivery, or grazing support. Perhaps the best way to describe the hydrology at these sites is that they receive an adequate amount of water to support hydric conditions, however, the hydrologic regimes are more or less arbitrary with regard to ecological requirements.

Hydrology of the lacustrine sites was split between function (C) and the intermediate BC grade. Though non-natural, these sites were well management for water levels. Hydrology at the one slope wetland appeared to be in highly functional condition (B), being altered only by some moderate internal ditching and redistribution.

These findings suggest that the vast majority of wetlands in the Front Range study area are hydrologically impaired and often times significantly so. The majority of impacts can be directly tied to urban and agricultural water development, which is ubiquitous. The hydrology at every single wetland site surveyed was influence by management either on-site or upstream to some degree.

Fig. 34. Site #4788 on Buckhorn Cr. showing a deeply entrenched channel morphology that prevents overbank flooding in all but the most extreme events.

Physiochemical Condition: The three most common wetland types (depressional, riverine and novel irrigation-fed) showed similar patterns in physiochemical condition. Grades of physiochemical condition in depressional wetlands essentially followed a normal distribution. The one high condition depressional site was again the Marshall Mitigation Bank. The grade distributions of riverine and novel irrigation-fed wetlands are similar in shape to normal, except they are truncated at the B grade.

Physiochemical condition evaluation considers water chemistry, along with soil chemistry in FACWet, and it assesses the condition of the physical environment, including soil disturbance in EIA and geomorphology in FACWet. The most widely detected stressor on water chemistry was nutrient enrichment and eutrophication caused primarily by agricultural runoff, but also urban runoff and effluent, and livestock grazing. This stressor was particularly prevalent and severe in depressional wetlands (Fig. 35)

Given the overall setting of these wetlands, physiochemical grades in the highly functioning and even borderline reference standard are at first surprising, but commonly soil disturbance was minor and the geomorphology of these sites appropriate for the wetland type, such as in the ubiquitous marshy depressions. These positive characteristics drove scores up in a number of cases.

Fig. 35. Eutrophication was the norm in depressional wetlands, with water quality generally degrading in an east trending gradient (sites #185 and 3709, left and right).

The lacustrine fringe and slope wetlands all had highly rated physiochemical conditions (Fig. 27) with minimal stressor effects on the variables and metrics. The normal water chemistry stressors present at other sites were not nearly as evident at these sites. In the case of the reservoirs, they are both located near the western edge of the study area above most or all of the agricultural development that prevail slightly to their east. In the case of the slope wetland, it receives groundwater that is presumably high quality. These sites also had physical conditions that were little impaired by stressors.

Vegetation Condition by HGM Class: A wetland's physical environment ultimately sets the limit on the condition of vegetation and degraded wetland vegetation condition was the rule rather than exception in the study area. The vegetation of Front Range wetlands has responded predictably to the region's land use changes, hydrologic alterations, and chemical degradations described in the sections above. Vegetation composition of the wetlands was discussed in detail in Section 4.2, but in relation to the condition assessment, 11 of the 14 depressional wetlands had vegetation conditions described as borderline functioning (CD) or functionally impaired (D; Fig. 27). This condition was typically manifested as homogenized marsh vegetation dominated by aggressive natives such as cattails or reed canary grass. The one depressional marsh with vegetation in exceptionally good condition (B) was the Marshall Mitigation Bank. Five sites, of a mix of types, were rated as the intermediate grade BC, indicating one grade of a B and one a C. In several of these cases the FACWet grade was borderline, but in every case where there was a grade discrepancy FACWet graded the vegetation condition higher. This is because that method keys less off species composition than EIA, focusing more on the functional or structural components of the wetland vegetation. Wetland vegetation structure was commonly in better condition than was species composition, because of the prevalence of exotic and/or invasive species. The differences in vegetation scoring between the two methods are covered in additional detail in Section 5.0.

Relationship between Condition and Wetland Origin: Only nine of the 34 wetlands evaluated were natural features of the landscape. The remaining 25 wetlands were created intentionally or unintentionally. Seven of the natural wetlands were riverine sites, one was an unusual slope wetland, and the final one was a depression inferred to have originally been a natural playa that now has its hydrology augmented by leakage from Lake Ditch (site #2584). It is difficult to know for certain whether this site was truly a natural wetland or not.

Created wetlands were impounded depressions, novel irrigation-fed meadows, riverine irrigation ditches, and the two lacustrine reservoir fringes. Three of the created wetlands actually achieved borderline highly functional condition overall (Fig. 36). These sites were the Marshall Mitigation Bank (site #1429) and the two reservoir fringes (sites #2840 and 6437), but the majority were borderline or solidly functionally impaired. The condition of natural wetlands was not much better than the created wetlands, with the majority of sites falling in the C or functioning category. Other site conditions grades were assigned evenly amongst the grades B to D.

Other than the three higher quality created sites previously mentioned, created sites were generally located in more intensively used landscapes than natural wetlands and 14 of them (41%) had hydrologic conditions that were borderline functioning impaired or worse (Fig. 37). Hydrologic condition in natural wetlands was fairly evenly distributed amongst the B to D conditional classes. Physiochemical grades of created sites were fairly normally distributed, with a range from A to D. Natural sites on the other hand all had physiochemical conditions judged to be in the borderline highly functional (BC) to highly functional (B) range.

Given the status of the physical environment in and surrounding most of the created wetlands, it is not surprising that vegetation condition at 19 of the 25 sites was assessed to be in borderline functionally impaired condition or worse. Vegetation condition in natural wetlands was hardly better than in the created habitats, however. The highest quality vegetation, which was in borderline highly functional condition, occurred at the slope wetland (site #11013), the playa with ditch-augmented hydrology (site #2584) and a riverine site on the Little Thompson (site #9148). In general the vegetation of created wetlands was strongly dominated by aggressive natives, most notably cattails and reed-canary grass.

These finding reveal strong patterns in wetland condition degradation in the Front Range study area. Most commonly, habitat condition was judged to be in the C range, thereby indicating that habitats were still providing baseline functions and biotic habitat support, but not much more. The condition of the Front Range wetlands does not diminish their importance. The eutrophied conditions, the sediment deposition and prevalence of aggressive wetland species, all provide direct evidence of the invaluable role these ecosystems play in an urbanizing landscape. If these wetlands do not exist to retain and mitigate these stressors, they will migrate into our rivers and streams and our water supply.

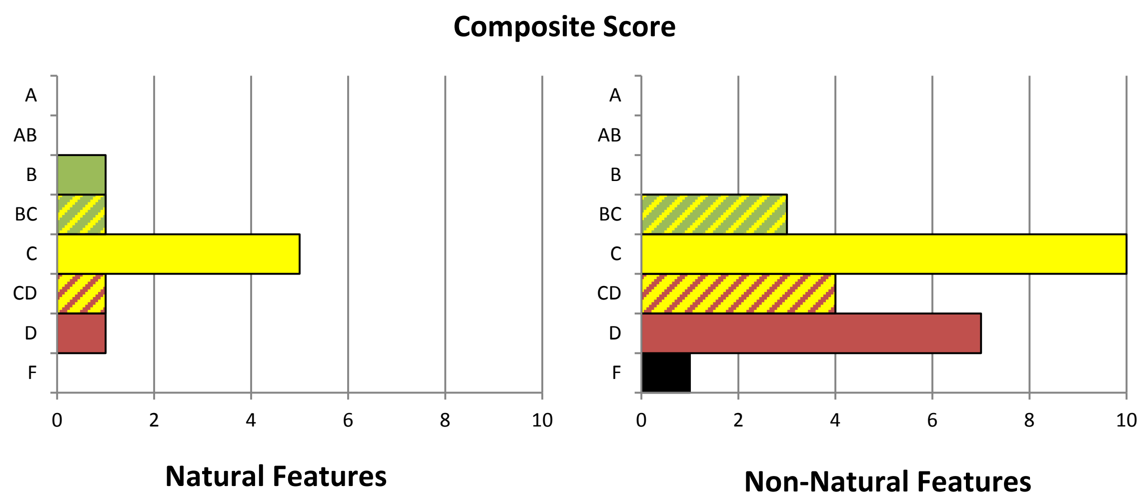


Fig. 36. Composite overall condition grades for wetlands grouped according to their origin; that is, whether they were natural features of the landscape or created by humans. Grades are a composite of FACWet and EIA condition grades.

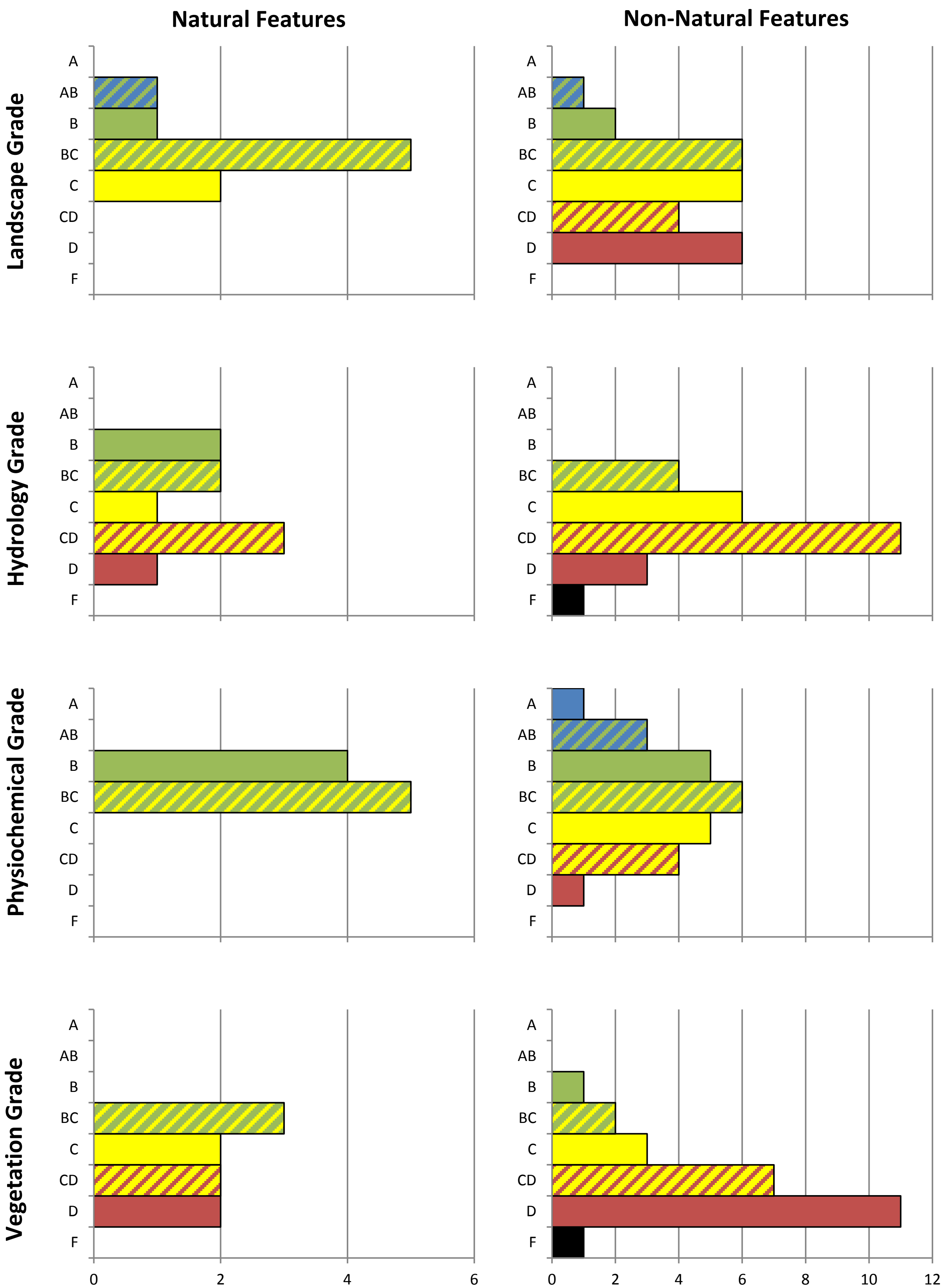


Fig. 37. Composite category condition grade distributions for wetlands grouped according to their origin; that is, whether they were natural features of the landscape or created by humans. Grades are a composite of FACWet and EIA condition grades.

4.4 Discussion

These findings have four implications for mitigation planning and application of the watershed approach in the region. First, if a project proposes to impact a wetland of a type other than riverine (or slope), it will likely be impacting a human-created system. The relevance of this fact to mitigation planning is that the same type of wetland can very likely be creatable elsewhere in the landscape; that is, in-kind mitigation should have a high chance of success. The second implication of this study for mitigation is that the regional setting defines a rather strict limit on the level of functioning a site can attain. In this study area, the Marshall Mitigation Bank likely illustrates the practical maximum level of condition a *created* site could achieve (BC). This bank site can reach a relatively high level of condition because it is intensively managed by a proactive agency, the City of Boulder Open Space and Mountain Parks Department, and it is set in a large property managed as natural area by the same department. Less intensely managed created mitigation should not be expected to attain a condition higher than the banks. Truly, given the degree of water management, even when mitigation involves restoration of historical riverine wetland habitat, achieving a highly functioning (B) level of condition would require significant effort, but it is likely attainable given the right circumstances. The reality of mitigation projects purporting a high degree of ecological condition should be scrutinized closely.

The value of placing mitigation in the watershed of impact is underscored by the observations made during this survey. Wetlands associated with urban and agricultural settings perform a critical ecosystem services, despite their poor condition. Exporting mitigation out of the region, perhaps to a less developed portion of the watershed, or worse out of the watershed altogether, extinguishes a portion of the watershed's ability to provide the extremely valuable services. Although, the Front Range does not need any additional poor quality wetlands, replacing a poor quality wetland on-site or nearby to the impact using a low-cost mitigation option could be a valid approach if the mitigation plan also included the purchase of bank credits, for instance.

The number of depressional wetlands has dramatically increased with development and these wetlands and water bodies are deemed valuable to society, for reasons such as water storage, waterfowl habitat and fishing. This survey has convincingly shown that the condition of the majority of these sites is significantly degraded. Thus in terms of wetland profiles and watershed needs, this finding suggests that one watershed need exhibited by the Big Thompson and St. Vrain watersheds is the need for rehabilitation of depressional wetlands. It is important to highlight one distinction. From an ecological standpoint, additional, created depressional wetlands are not desirable, particularly if they are not very well managed and high quality. Another watershed need suggested by this study is for improvement and expansion of riverine habitat, which has been disproportionately impacted by land use changes and water development. Mitigation projects targeting riverine wetlands do the most to maintain and improve the fundamental natural characteristics of the watershed, which were centered around the arterial network of rivers and streams.

5.0 COMPARISON OF WETLAND ASSESSMENT METHODS

Calibration, testing and validation of wetland assessment methods is a critical, if commonly omitted, step in their development. Both FACWet and EIA have undergone various levels of calibration and validation during their development (Lemly and Rocchio 2009a; Johnson *in prep*). FACWet has also been subjected to peer review, widespread trial application in training workshops, and several years of in-program use by the U.S. Army Corps of Engineers (ACOE). EIA is seeing increasing use by management agencies, especially in ambient monitoring initiatives. As these two assessment methods are currently the most common approaches to rate wetland condition in the region, and their use is growing, it is important to compare and validate the similarities and differences between the methods' scoring processes. During the field study described previously (Section 4.0), both FACWet and EIA were applied independently at each site. The duplicative evaluation was done to allow comparative study of the two methods, further verify each method's calibration, and provide additional validation of the approaches.

Although the specific wetland attributes evaluated vary somewhat between FACWet and EIA, both methods score wetland condition based on deviation from reference standard (pristine) condition, and neither method incorporates societal values into the scoring process (i.e., scoring does not rank wetlands based on the ecosystem services most beneficial to humans). Therefore, the meaning of final ranks or grades should ideally be consistent across the assessment methodologies –A's should be A's in both methods and F's in FACWet should be D's or E's in EIA. Therefore, examining the congruency between the two methods' grading scales is fundamental to compare evaluation results in actual practice. Dual application of the assessment methods facilitates an evaluation of their precision and a test of the validity of their ratings. Coincident ratings between the methods provide support that the rating is reasonable. Inconsistent ratings between the methods can be examined and the causes of divergence in ranks can be revealed. The information obtained by this scrutiny can then identify ways the two methods can be improved, and identify whether one assessment method or another is preferable to achieve a project's goals.

The goal of this portion of the study was three-fold. We sought to assess the correlation of scores and the consistency in grades between the two assessment methods and to identify the cause of any inconsistencies. We also aimed to uncover the potential biases or emphases of each method because this might influence when and how either approach is employed during actual implementation. In addition, multiple evaluations also provide complete replication of evaluation, which serves as a robust QA/QC measure.

5.1 Methods

5.1.1 Similarities and Differences between FACWet and EIA

Structure and Component Metrics: There are many structural parallels between FACWet and EIA. Each is structured around a three-tiered model of wetland condition. At the highest structural tier, FACWet breaks wetland condition into three component "Attributes": 1) *Landscape and Buffer Condition,* 2) *Hydrology* and 3) *Biotic/Abiotic Habitat*. At this high tier, EIA uses the term "Categories" and includes four: 1) *Landscape Context,* 2) *Hydrologic Condition,* 3) *Physiochemical*

Condition and 4) *Vegetation Condition.* In the methods' second structural tier, each Attribute or Category is broken down into "Variables" (FACWet) or "Key Ecological Attributes" (EIA). Finally, variables and key ecological attributes may be differentiated into "Sub-variables" (FACWet) or "Metrics" (EIA). Table 42 provides a key to the synonymy in terminology between the two methods.

Table 42. A key to terminology equivalencies between FACWet and EIA.

Structural Level	FACWet	EIA
Tier 1	Attribute	Category
Tier 2	Variable	Key Ecological Attribute
Tier 3	Sub-variable	Metric

If the FACWet *Biotic and Abiotic Habitat* attribute is parsed into its component parts (i.e., biotic variables considered separately from abiotic variables), the Tier 1 and 2 organization of both methods is very similar (Table 43). In Table 43, FACWet variables have been listed to show the approximate corresponding metric in EIA. Although many are similar in name, the FACWet variables differ from EIA metrics in important ways that will be discussed later, but this arrangement does illustrate that the methods both consider a very similar menu of wetland characteristics. Brief synopses of FACWet and EIA metrics are included in Table 44 and Table 45.[17]

Table 43. A structural comparison of FACWet and EIA. The tier 1 components of the two assessment methods are shaded. Below each tier 1 heading are the variables or key ecological attributes which are included within it. FACWet's Biotic and Abiotic Habitat Attribute has been split into its component parts to produce a structure comparable to EIA.

FACWet Structure	EIA Structure
Landscape and Buffer Condition	**Landscape Context**
Barriers to Migration and Dispersal *Buffer Condition* *Wetland and Riparian Habitat Loss (eliminated from analysis)*	*Landscape Connectivity* *Buffer*
Hydrology	**Hydrologic Condition**
Water Source	*Water Source*
Water Distribution	*Hydroperiod*
Water Outflow	*Hydrologic Connectivity*
Abiotic Habitat	**Physiochemical Condition**
Geomorphology	*Soil Disturbance*
Water and Soil Chemical Environment	*Water Quality*
Biotic Habitat	**Vegetation Condition**
Vegetation Structure and Complexity	*Vegetation Species Composition*
	Community Structure

[17] For up-to-date information on FACWet, see the website: http://rydberg.biology.colostate.edu/FACWet. For up-to-date information on Colorado's EIA, see the website: http://www.cnhp.colostate.edu/cwic.

Table 44. FACWet variable names and descriptions of data recorded.

State Variable	Variable Description
Landscape and Buffer Condition	
V1: Habitat Connectivity - Neighboring Wetland Habitat Loss	Percent natural wetland/riparian habitat remaining of the total that should be present in absence of anthropogenic effects (existing acreage + lost acreage) in 500m radius zone surrounding AA boundary
V2: Habitat Connectivity - Migration/Dispersal Barriers	Qualitative rating of the degree to which AA has become isolated from existing neighboring wetland and riparian habitat by artificial barriers that inhibit migration or dispersal
V3: Buffer Capacity	Extent and width of buffer landcovers at least 5 m wide, and qualitative rating of buffer condition and of surrounding land use in 250m radius zone surrounding AA
Hydrology	
V4: Water Source	Qualitative rating if up-gradient water supply is controlled or passive; if hydroperiod is natural, erratic, or lacking; and of degree of stressor influence on natural hydrodynamics
V5: Water Distribution	Qualitative rating of whether water distribution is natural within the AA, or uneven due to alterations (e.g., fill, ditches)
V6: Water Outflow	Qualitative rating down-gradient dynamics; if there is direct connection to associated channels, outlets, and aquifers, or if connection is impeded or stopped
Abiotic Habitat	
V7: Geomorphology	Qualitative rating if geomorphology is natural and complex (gradual elevation changes, microtopographic variation, floodplain connection); or if grade is unnatural, entrenched, or lacking natural heterogeneity and microtopography
V8: Chemical Environment	Qualitative rating of visual indicators of chemical stress in AA indicating: nutrient enrichment, unnatural sediment/turbidity, toxic contamination, temperature stress, and landscape alterations that affect redox potential
Biotic Habitat	
V9: Vegetation Structure and Complexity	Qualitative rating of ecosystem-appropriate levels of tree, shrub, herb, and aquatic vertical structure and horizontal interspersion

Table 45. EIA metric names and descriptions of data recorded to assess metric condition.

EIA Metric	Metric Description
Landscape Context	
Landscape Fragmentation[1]	% of unfragmented, natural landscape in the 500m radius zone surrounding AA (Assessment Area) boundary
Riparian Corridor Continuity[1,2]	% natural habitat 500m upstream and downstream of AA
Buffer Extent[1,3]	% of AA boundary adjoined by least 5m width of buffer landcover
Buffer Width[1,3]	Average buffer landcover width surrounding AA (max width assessed = 200m)

EIA Metric	Metric Description
Buffer Condition[1,3]	Buffer landcovers up to 200m radius surrounding AA: 1) % of buffer vegetation that is native, and 2) Qualitative rating of soil disruption and/or anthropogenic use in buffer
Hydrologic Condition	
Water Source	Qualitative rating of if water sources in and up to 200m upstream from AA are natural, influenced or regulated by irrigation or anthropogenic effects, exposed to point-source pollutants, or if water source has been eliminated
Hydroperiod	Qualitative rating of naturalness of hydroperiod (extent of inundation, saturation, and proper seasonality) in AA; GIS maps and water use models verify field ratings of upstream alteration
Hydrologic Connectivity	Qualitative rating of alteration to natural lateral movement of waters surrounding AA
Bank Stability[2]	Qualitative rating of if channel and streambanks are characterized by equilibrium conditions, aggraded or degraded, or hardened
Physiochemical Condition	
Water Quality – Turbidity / Pollutants[4]	Qualitative rating of visual evidence of pollutants or unnatural turbidity in water
Water Quality – Algal Growth[4]	Qualitative rating of algal infestation in water
Substrate / Soil Disturbance	Qualitative rating of anthropogenic soil/substrate disturbance (eg: grazing effects, fill, unnatural compaction or sedimentation)
Vegetation Condition	
Relative Cover Native Plant Species	If all plant cover in AA totals to 100% (adjusting total % cover of all species to account for overlap where >1 species occurs), relative % of this cover that is native
Absolute Cover Noxious Weeds	% cover of each Colorado state-listed noxious weed species in AA
Absolute Cover Aggressive Native Species	% cover of *Typha* spp., % cover *Phalaroides arundinaceae*, and % cover of *Phragmites australis* in AA
Mean C	Average C-value of all plants assigned a C-value in AA
Regeneration of Native Woody Species[5]	Qualitative rating of if AA contains all age-classes of woody species, is missing age-classes, or is becoming colonized by noxious woody species
Litter Accumulation	Qualitative rating of if litter accumulation in AA is normal, excessive, or lacking
Structural Complexity	Qualitative rating of physiognomic and abiotic complexity, and regularity and dominance of abiotic/biotic patches

[1] Field Assessment is verified by GIS analysis using aerial photography and by evaluation of mapped stressors (e.g., proximity and influence of ditches, oil/gas wells, mines).
[2] Metric only recorded in Riverine HGM wetlands.
[3] Landcover types that were called buffer were similar if not equal between EIA and FACWet methods.
[5] Metric only recorded in wetlands with surface water.
[4] Metric only applied to naturally woody wetlands.

Variable/Metric Scoring and Point Scale: In both methods, variables and metrics are primarily scored during field assessment, although in-office GIS analysis can confirm or adjust the field score as needed for many metrics. In routine application of either method, field scores are assigned by the evaluator using qualitative assessment and best professional judgment. The only explicitly quantitative data collected is vegetation data compiled during EIA evaluations.

One significant difference between the two assessment methods is the point scale used to score variables and metrics. FACWet variables are graded on a 100-point percentage scale. The score assigned to each variable is equivalent to the academic grading scale, with scores between 0.90–1.00 representing a variable impacted by minimal stress from the landscape, meaning related functions should perform at or near reference standard capacity. Variables in this range would receive an 'A' grade (see Table 30 on page 52). The exact score within this range (any value between 0.90–1.00) is up to the individual evaluator. On the low end, variable scores below 0.60 translate to an 'F' grade, which represents variables that are highly stressed. FACWets scores are routinely broken into 5 letter grades (A, B, C, D, and F).

Conversely, EIA metrics assess condition using a 4 or 5 rank scale for each metric, representing how much the metric deviates from reference condition based on numeric (quantitative) or descriptive (qualitative) threshold criteria (see Appendix I). Instead of a precise 100-point grading scale, EIA metric ranks and their associated scores are more categorical, but with the same ultimate meaning as the FACWeat letter grades in that they parallels an academic assessment scale,. The number of points assigned to each EIA metric depends on the rank, an 'A' rank is scored 5 points, and a 'D' or 'E' rank is scored 1 point. Most metrics are scored with only four ranks (A, B, C, D = 5, 4, 3, 1), but EIA metric occasionally include five ranks (A, B, C, D, E = 5, 4, 3, 2, 1). In either case, the lowest rank is still scored 1 point. There is no score of 2 if only four ranks are considered.

Roll-up Scoring Formulas: In both methods, variable or metric scores are combined to rate a higher order aspect of the wetland. In FACWet, variable scores are used to rate the wetland's ability to perform seven functions (Table 46), relative to a naturally functioning wetland of the same hydrogeomorphic type. Functional condition is parameterized by Functional Capacity Indices (FCIs; Fig. 38). Each FCI consists of a weighted average of the variable scores that are the primary drivers of the function in question. The weightings in the FCIs are intended to account for the relative importance of the variable to the function under consideration. In FACWet, the overall functional condition of the site is rated by averaging the seven FCIs to come up with a score that is a composite weighted average (Fig. 39). One of the important outcomes of this scoring approach is that the tier 1 "Attribute" level of organization is irrelevant to FACWet scoring, and merely a conceptual and organizational aid.

In contrast, EIA's metric scores are used to generate a conditional score for each of the tier 1 "Categories" to which they belong. EIA weights each metric score to produce a composite score for each category (Fig. 40). As in FACWet, the weighting is intended to represent the relative influence of the metric on the overall condition of the category. To create an overall wetland condition score, the category scores are weighted and summed (Fig. 41). Weights reflect the influence that each metric and category have on overall wetland condition. Full explanation of EIA metric thresholds and scoring is included in Appendix I. See Table 31 on page 54 for ranges and interpretation of overall EIA scores.

The differences in the ways variables and metrics are combined to characterize condition is one of the fundamental differences between the two methods and it has significant ramifications on scoring, as will be described in the Results section (Section 5.2).

Table 46. Summary of FACWet functions and controlling variables (after Berglund and McEldowney 2008).

Function	Controlling variables
1. Support of characteristic wildlife habitat	V1, V2, V3,V9
2. Support of characteristic fish/aquatic habitat	V4,V 5,V 6,V7, V8
3. Flood attenuation	V3, V4, V5, V6, V7, V9
4. Short- and long-term water storage	V1, V4, V5, V6, V7
5. Water quality	V5, V7, V8
6. Sediment retention/shoreline or bank stabilization	V3, V7, V9
7. Production/food web support	V1, V6, V7, V8, V9

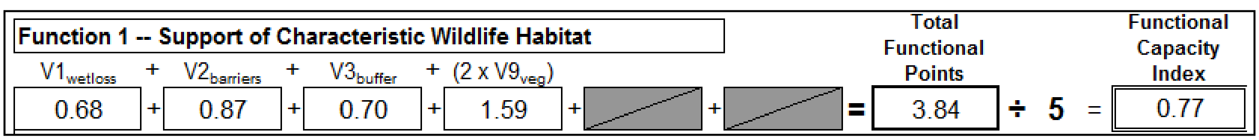


Fig. 38. An example of a FACWet Functional Capacity Index formula taken from the FACWet data forms, including data from site #185. Greyed boxes are simply placeholders.

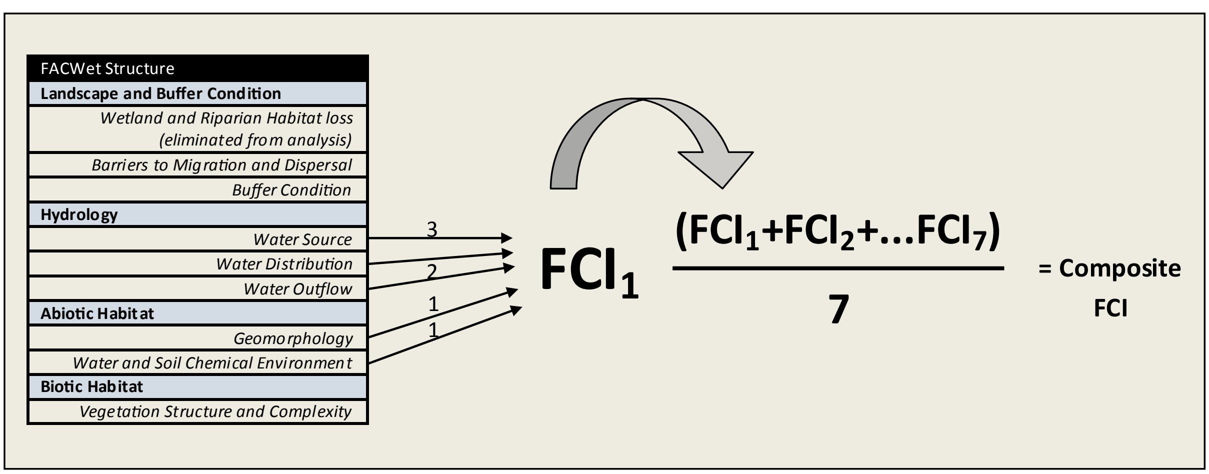


Fig. 39. A schematic representation of FACWet's scoring process. Select variables are weighted and averaged to form a Functional Capacity Index (FCI). There are seven FCIs in FACWet. The seven FCIs are average to generate a composite FCI score.

$\boldsymbol{Landscape\ Context\ \ Category} = (Landscape\ Conectivity\ x\ 0.4) + (Buffer\ x\ 0.6)$, where the Buffer Ecological Attribute includes three metrics and is defined as:

$$Buffer = \sqrt{\left(\sqrt{(buffer\ extent\ x\ buffer\ width)}x\left(\frac{buffer\ vegetation + buffer\ soil\ disturbance}{2}\right)\right)}$$

"Buffer Extent and Width Metrics" "Buffer Condition Metric"

Fig. 40. An example of condition scoring in EIA using the Landscape Context Category to illustrate the process. In EIA, metric scores are combined as arithmetic or harmonic means or both (as here). After all of the Categories are calculated using similar formulas, they are weighted according to the formula at the bottom of the box and summed to generate an overall rating of site condition.

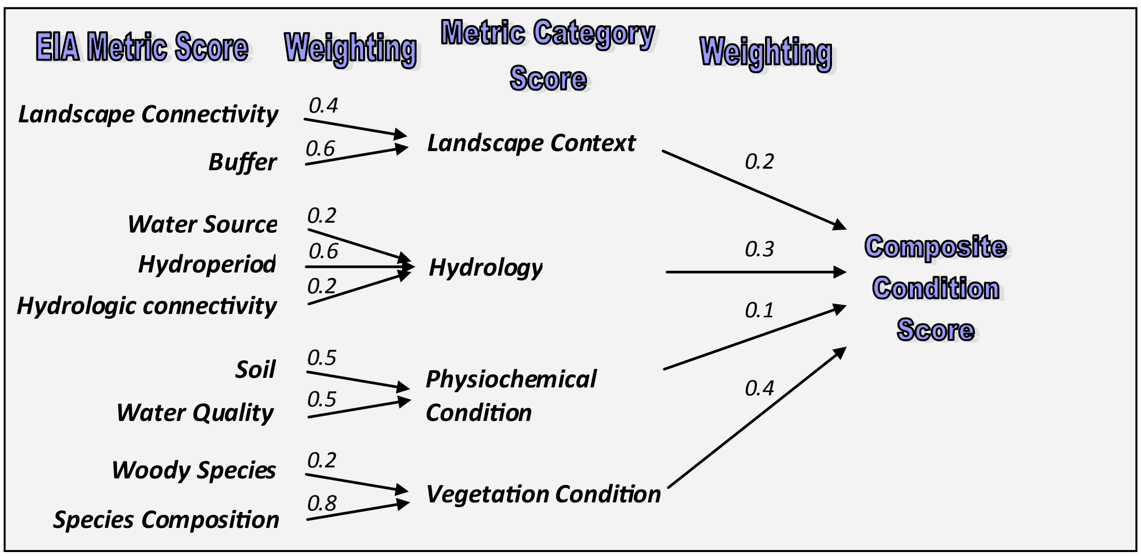


Fig. 41. A schematic representation of the EIA scoring process. Scores from the metrics in each category are weighted and summed. Category weights are then themselves weighted and summed to produce Composite Condition Score.

5.1.2 Comparative Analysis

The condition scores obtained from the FACWet and EIA methods were compared in order to gauge the correspondence between scores, detect methodological biases and identify potential sources of inaccuracy in both methods. As explained above, the ratings in FACWet and EIA consist of a numerical score and a categorical letter grade (or rank). The relationship between continuous scores was explored using linear regression. Both methods generate a readily comparable composite condition score, but below this summary level there is structural incongruity between the methods. In EIA, interpretative emphasis is placed on the four category scores, whereas in FACWet the primary attention is placed upon the nine variable scores. Variables and metrics are not directly comparable because they generally do not consider the same aspect of the wetland. Also, the weighting algorithms used to combine metric scores into category scores has a significant influence on the category scores and overall EIA wetland score. Comparatively, the variables included in each FCI influence how a function is scored and the overall composite FCI score.

To make the methods scores comparable on a level equivalent to EIA's four condition categories (*Landscape Context, Hydrologic Condition, Physiochemical Condition* and *Vegetation Condition*), the aggregation of FACWet variables was altered. Table 43 on page 88 shows how a slight rearrangement of the tier 1 organization of FACWet makes the methods' structures essentially congruent at that level. Since FACWet does not normally generate scores for its "Attributes," the variable scores in each attribute were averaged to arrive at the attribute's score. Taking a simple average was found to be the most parsimonious approach to developing ad hoc FACWet attribute scores through trial of a number of alternative approaches. Evaluation score where standardized to facilitate comparison using the formula:

$$Standardized\ Score = \frac{(\mu - x)}{\sigma}$$

Where μ is the average score across all sites, x is the score of the target site, and σ is the sample standard deviation.

The correspondence in letter ratings between the two methods was also evaluated. FACWet letter grades can be viewed just like EIA's; that is, as a relative categorical ranking. One issue with this type of a categorical letter grade comparison is that category and overall EIA scores are only broken down into four category ranks while FACWet has five attribute grades. That artifact can result in EIA 'D' ranks that parallel FACWet's low 'D' or 'F' grades, and EIA 'C' ranks that parallel a FACWet 'C' to high 'D' grade.

During preliminary analyses it was discovered that FACWet's variable for 'Neighboring Wetland and Riparian Habitat Loss,' was problematic in the setting of the urbanizing Front Range Plains. This is because in predominantly upland areas that naturally lack wetland habitat, the variable's scoring rules constrain it to be rated highly. This rule was intentionally built into FACWet, however, in the Front Range setting it was misleading and obviously inflated the scores of degraded wetlands set in predominately upland settings. Consequently, this variable was not considered in any comparative analysis. This discovery led to the modification of FACWet in its third version that was informed by this study.

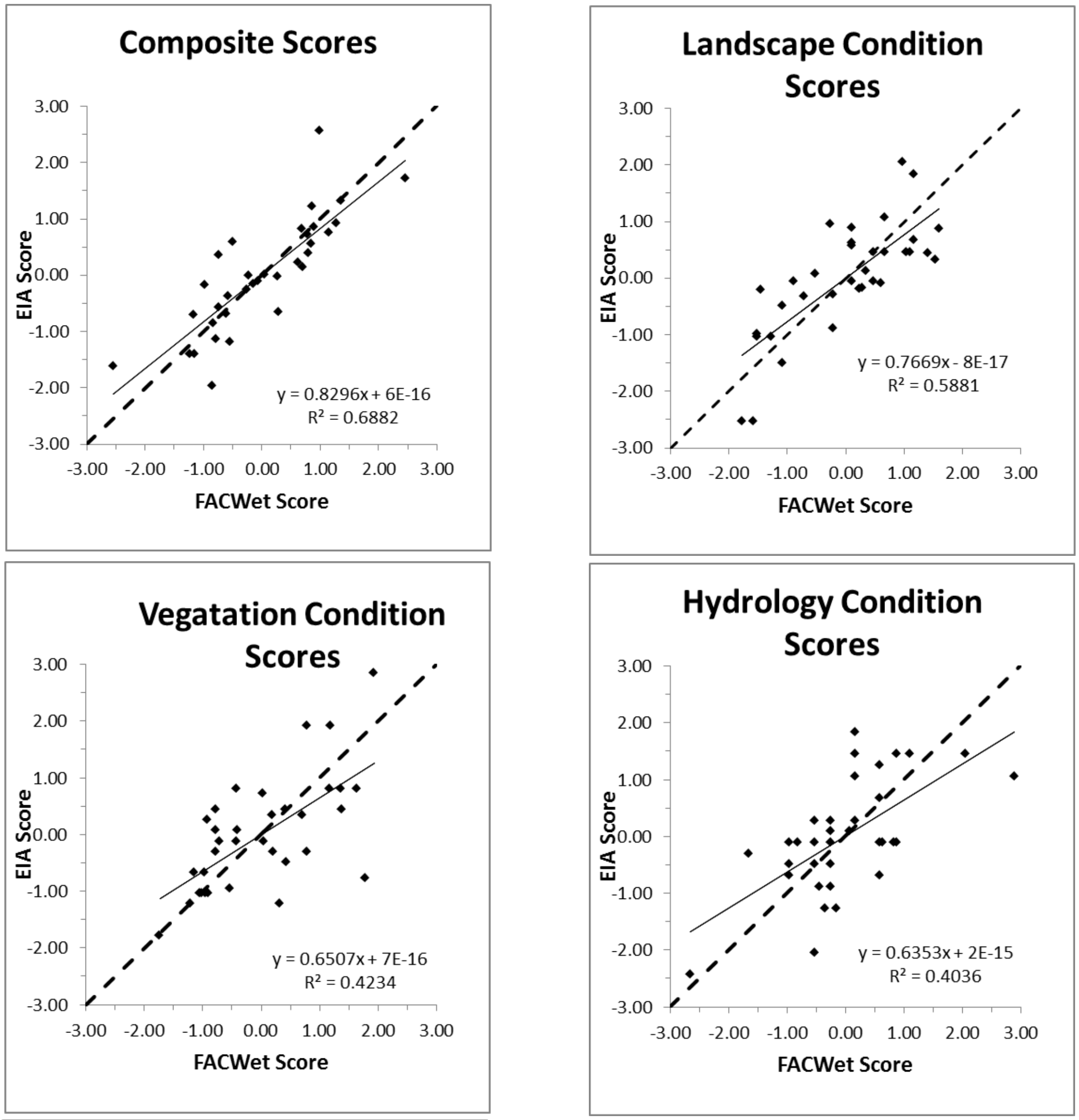
5.1.3 Field Survey Approach

Field evaluations were performed as independently as possible. Upon arrival at a survey site, evaluators would tour the wetland to identify assessment area boundaries and identify its major features. After that step, evaluations were undertaken without further discussion according to methodological guidelines. The one exception was that vegetation data were collected together, as these do not factor directly into FACWet.

5.2 Results

5.2.1 Comparison of Evaluation Scores

There was a significant, positive relationship between FACWet and EIA scores in every case (Fig. 42). The highest correlation was between FACWet and EIA *Composite Condition* scores, which had a



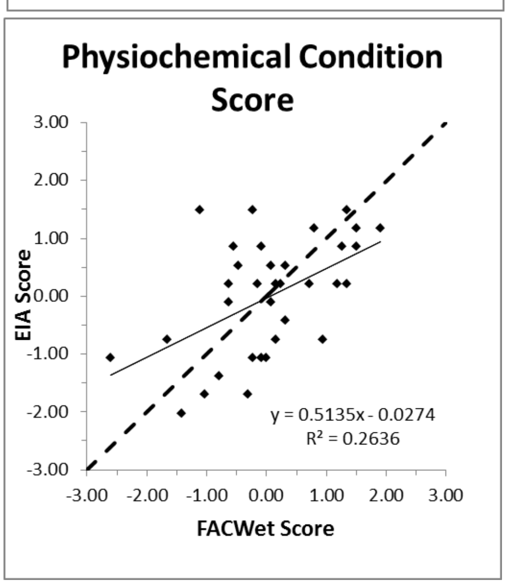
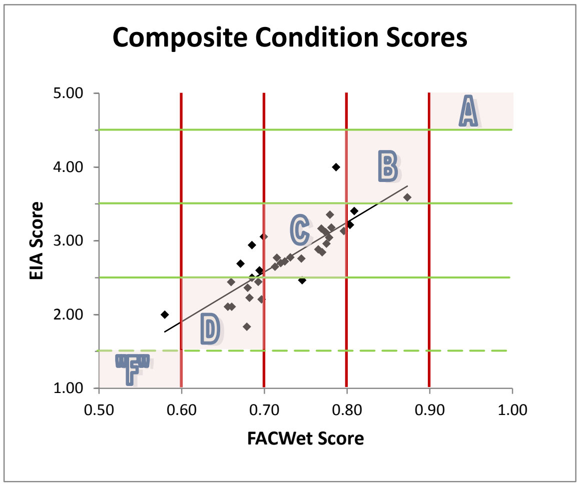
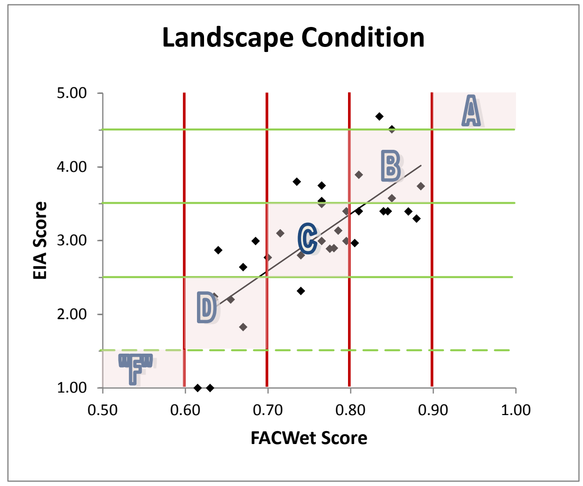
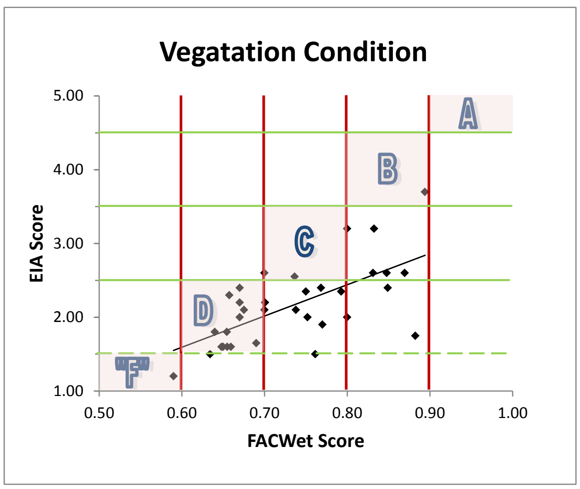
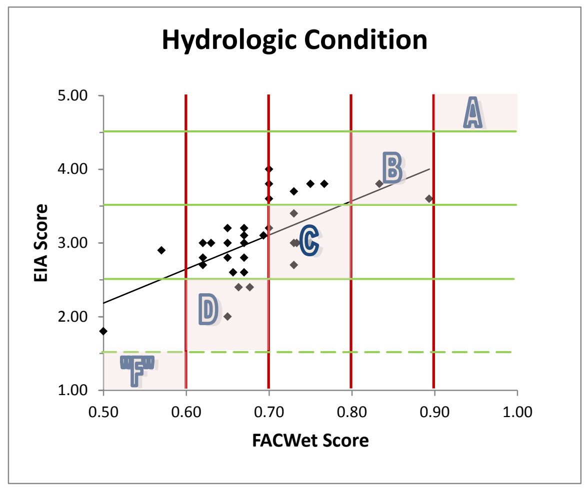


Fig. 42. A comparison of condition scores derived through FACWet and EIA. Scores have been standardized to facilitate comparison. The dashed line represents equality in score. Points above the line indicate that EIA scored condition higher, and conversely when they are below. The solid line is a regression line showing the actual relationship between scores. The regression formula a R^2 value are provided on each plot.









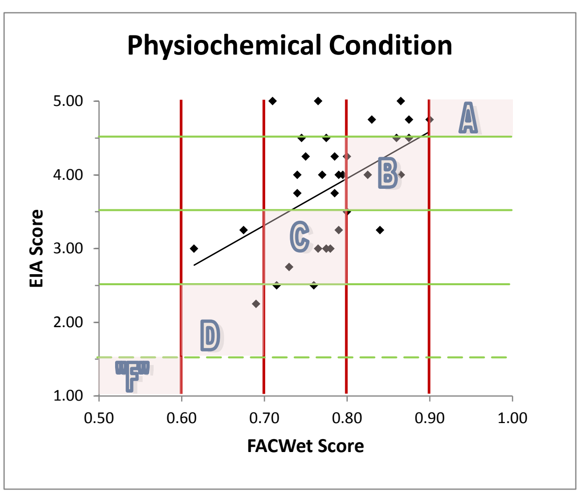


Fig. 43. Regressions of raw assessment scores, indicating the letter grade score ranges for each method.

correlation coefficient (r) of 0.83 ($R^2 = 0.69$). The plot shows one clear outlier, which is the Marshall Mitigation Bank. If this site is removed, the correlation rises to 0.88 ($R^2 = 0.77$). The next highest correlation was between *Landscape Condition* scores (r = 0.77). For these scores there was essentially an even split between whether FACWet rated a site more highly than EIAand vice versa. Thus there does not appear to be a systematic bias of either method. In fact, the variables and metrics used to generate the landscape condition scores are quite similar, so this is not a surprising finding. Therefore, much of the disparities in scoring landscape condition can likely be directed at minor emphasis of the various variables and metrics and differences in evaluator interpretation.

Hydrology Condition and *Vegetation Condition* scores had essentially the same correlation, with r-values of 0.63 and 0.65, respectively. Interestingly, though, the methods behave in almost exact opposition to one another. FACWet rate hydrology appreciably lower than EIA at about two-thirds of sites, while EIA scored vegetation lower in about the same proportion.

The lowest correlation was between *Physiochemical Condition* scores (r = 0.51). In the majority of cases, EIA rated condition lower, but there was not a strong trend in this regard. The comparatively low correlation is not surprising because there is the least amount of similarity between the variables or metrics used to describe physiochemical condition. While the methods' treatment of water chemistry is comparable, FACWet's soil chemistry variable assesses different landscape stressors than EIA's soil disturbance metric. In FACWet, when a soil's oxidation-reduction regime is altered by hydrologic impacts, the variable score drops accordingly. This was a common situation encountered and a primary cause of FACWet scoring physiochemical condition lower than EIA. Conversely, favorable scores for FACWet's geomorphology variable tended to be the driving agent when FACWet rated physiochemical condition higher than EIA. There is not a high congruence between what the FACWet geomorphology variable and EIA soil disturbance metric are evaluating in the wetland.

5.2.2 Comparison of Categorical Grades/Ranks

In both FACWet and EIA, condition scores are converted to letter grades/ranks that represent classes of condition. The score thresholds defining grade cut offs are, therefore, critically important. Scores do not have inherent meaning apart from the scale to which they are tied.

In this comparison, letter grades/ranks that did not match between FACWet and EIA were called a categorical disagreement. Considering the two method's *Composite Condition* grades, there were only eight cases of categorical disagreement (out of 34), or 73% agreement (Fig. 43). In all cases, the maximum departure from scores was one letter grade. Also considering the difference in four vs. five-rank scales between the two methods, this agreement supports the consistency of overall wetland condition ratings across methods. FACWet graded sites lower in five of those cases. Three of the eight cases of categorical disagreement resulted from completely borderline (0.70 or 0.80) FACWet scores, where a 1% change in FACWet score (in the appropriate direction, i.e., from 0.70 to 0.69) would have resulted in categorical agreement. Three other cases had composite FACWet scores within 2% of the scoring threshold that would have resulted in agreement. One disagreement resulted from the differing low end scores (D vs. F). Dismissing these cases, there was over 91% consistency amongst the two method's composite site scores. Moreover, in one additional case (site #4788), FACWet graded the site more harshly than EIA because the evaluation was based on wetland jurisdictional criteria. The site did not have wetland hydrology or vegetation and so was downgraded. The EIA evaluation, on the other hand, evaluated the site as a riparian zone, making wetland criteria irrelevant. Thus, this discrepancy was simply the result of an intentional difference in evaluation perspective. The number of borderline cases highlights the importance of examining the actual scores, relative to the grading thresholds. Simply doing so raises the achieved agreement between the two method's 18%, because the small scoring differences of 2% or less are trivial and below either method's level of practical resolution.

In the eight cases of categorical disagreement between *Composite Condition,* there was no single variable/metric that was consistently the root of discrepancy. In each of these cases where there was a disparity in *Hydrology Condition* grades (n = 5), the FACWet grade was always lower by one letter grade. In almost every instance, this was because the site was supported by managed hydrology, which automatically assigns it a D grade (or lower) for all FACWet hydrology variables. The EIA 'water source' metric scores entirely managed hydrology as a C (3 points), and sites where hydrology was eliminated as a D (1 point). However, the EIA scoring process sums each hydrology metric independently, so managed hydrology with a 'water source' metric score of C can get a better score if the water conveyance flows naturally within the AA (i.e., if the 'hydrologic connectivity' metric = A or B). This exemplifies how the final summary formula, combined with specific site attributes assessed for each metric/variable, can create divergence between scores and methods. As with the numeric scores, *Physiochemical Condition* was graded the least consistently between methods and there was disagreement on this score in all eight cases of disagreement between *Composite Condition*. At seven of these sites, FACWet rated the variable lower by one grade. *Vegetation Condition* had the fewer scoring discrepancies (n = 5), and one of these was due to the lowest grade definition (D vs. F). At each of these five sites, EIA graded vegetation condition lower than FACWet.

The grades assigned to the variable or metric categories across all of the sites were also examined. In this analysis, site #5189 was removed since variables at that site generally received "F" grades, a grade which EIA does not have. There was 51% (17/33) congruence between *Landscape Condition* grades, with two borderline cases and three more within 2%. Ignoring these threshold cases, the precision goes up to 67% (22/33) and all disagreements were within one grade. Which method rated the landscape more highly was evenly split, thus neither has a clear bias.

There was only 36% (12/33) agreement in *Hydrology Condition* grades. Dropping the one threshold case, correspondence goes up to 39% (13/33). FACWet rated hydrology lower in every instance of disagreement. This was because of FACWet and EIA score actively managed water sources differently. In cases where there was a disparity in hydrology grade between the two methods, grades were within one of each other, except in the case of the one riparian site evaluated (site #4788), which lacked wetland hydrologic conditions, as described above. FACWet evaluated hydrology as non-functional ("F"), whereas EIA graded it "C". The disparity in rating at this site makes sense given the aim of each method. FACWet has a strong regulatory bent and it was specifically applied in a regulatory-like fashion during this study. The riparian wetland had been reduced to a non-jurisdictional status in terms of hydrology, secondary to surrounding land use change and water management. Consequently, the site received an "F" grade for hydrology. With FACWet, an implied historical reference was used; that is, the site was evaluated relative to what it had been (presumably an actual wetland). The EIA evaluation on the other hand used a habitat-based reference; that is, the site's habitat was evaluated in comparison to high quality examples of that type of riparian habitat. A habitat-based reference like this could have been used for the FACWet evaluation as, but was not in order to stay consistent with how the method was used at the other evaluation sites. Thus, the difference in hydrology grades at this site was somewhat artificial.

There was a 42% (14/33) agreement between *Physiochemical Condition* grades, with one borderline and three cases within 2%. Disregarding these threshold scores, the correspondence in grades goes up to 54% (18/34). In almost every case of disparity, the FACWet score was lower. There are three apparent causes of grade disparities. The EIA does not assess geomorphology using the same data and metric/variables as FACWet does. EIA lumps mechanical geomorphic alterations (fill, compaction, tilling and resulting sedimentation, etc.) together with grazing and other biotic effects into the one soil metric, called 'substrate/soil disturbance.' Thus geomorphic alterations, such as well vegetated levees, are assessed differently between the FACWet and EIA methods.

The second cause of disparities in grading *Physiochemical Condition* is the inclusion of a 'soil chemistry' sub-variable in FACWet, as described in the previous section. Hydrologic stressors are evaluated, amongst other stressors, in this FACWet variable. This finding illuminates another basic difference between the methods that exist because of their intended applications and fundamental approaches. To be consistent with regulatory applications and wetland delineations, FACWet must evaluate the soil environment in reference to environmental policy, which includes criteria for hydric soil conditions. Soil pits were not dug in this study for either FACWet or EIA methods, but presence of hydric indicators can be inferred from hydrologic stressors using FACWet methods. EIA methods do not penalize a soil/physiochemical score for lacking hydric soils, but rather this is considered in scoring the EIA hydrology metrics.

The last probable source of disparity in *Physiochemical Condition* grades was evaluator bias. Water chemistry metrics were almost always rated more highly by the EIA evaluator than by the FACWet one. This highlights the difficulty of evaluating water chemistry using field indicators alone. It is a fundamentally subjective pursuit, but fortunately one easily addressed through analytical means if circumstances should warrant additional accuracy. At the moment, cost, time, and lack of infrastructure for wetland water quality analysis and standards development can be prohibitive to incorporating water quality measurements into rapid wetland condition assessments. However, the inconsistency in water quality scores across the two rapid assessment methods highlights a need for studies that compare Level 3 (quantitative) wetland water quality data to wetland condition assessment data, which could inform rapid assessment water quality criteria and scoring consistency.

Grades for *Vegetation Condition* were 48% (16/33) correspondent between FACWet and EIA. When two borderline cases were removed this percentage went up to 54% (18/33). In every case of disparity, EIA graded vegetation lower than FACWet. EIA includes very specific quantitative metrics on the vegetation community composition based on species data recorded in the site. EIA metrics consider information such as 'native species' and 'noxious weeds,' as well as structural considerations like 'regeneration of woody species.' FACWet's one vegetation variable solely emphasized vegetation structure and does not take species composition into account. This leads to far harsher scores in the EIA method than FACWet, particularly in these heavily impacted Front Range wetlands.

5.3 Discussion

The results of this comparative study of FACWet and EIA yields significant insights into how each method behaves under the breadth of wetland habitats in the Colorado Front Range plains, it uncovered inherent methodological differences, and it provided a verification of the methods' calibration on an ambitious scale. These analyses allowed a deconstruction of the methods that revealed their inner workings, and exposed how the underlying philosophies of wetland condition evaluation used in method development colors the approach.

To understand why each approach works the way it does, the history of each needs to be explored. EIA has grown from its roots in vegetative Indices of Biotic Integrity (IBIs) and from Natural Heritage Network[18] methodology. As the name implies, IBIs come from a biotically-based assessment paradigm formalized by Karr (1981) in the 1980s and 90s. Forty percent of the EIA wetland score stems from biotic data and the other sixty percent are summarized from the qualitative assessment of landscape condition, hydrology, and physiochemistry. In contrast, FACWet uses no biotic data to score a wetland. Rather, the foundation of FACWet, is hydrogeomorphic (HGM) theory, established by Brinson (1993). FACWet, like HGM, evaluates wetlands on functional grounds. The development of each school of thought occurred almost perfectly along agency lines, with the EPA championing biotically-based approaches and the ACOE forwarding functionally-based approaches that champion hydrology.

The defining attribute of the biotic assessment paradigm is that plants are "phytometers" that reflect the quality of the local environment. That is, vegetative health, as reflected by composition and structure, integrates the myriad of environmental effects into one tangible aspect of the wetland. In a purely biotic approach, there is no need to evaluate the environmental causes of impairment, because the condition of the vegetation reflects the condition of the wetland as a whole. Biotically-based approaches have the advantage that vegetation health does in fact reflect overall wetland health, and vegetation structure and composition respond to factors to which the evaluator may be oblivious. Biotically-based assessment methods can be thought of as being "top down" in perspective (Fig. 44), in which a higher-order feature of the wetland is used as an indicator of impairment of basic elements of the wetland, such as hydrology or water chemistry. Biotically-based approaches are inherently symptomatic in the way in which they approach condition assessment; that is, determining the health of the wetland is the focus rather than determining the underlying causes of ill health. Symptomatic evaluation is the main goal of ambient monitoring, thus the school of thought based on biotic assessment fit well with EPA's programmatic needs, leading to EPA's involvement in assessment tool development.

[18] The Natural Heritage Network is the network of global Natural Heritage Programs that all collect data on biologically significant plants, animals and natural communities using similar methodology. NatureServe is the umbrella organization over the Natural Heritage Network: http://www.natureserve.org/.

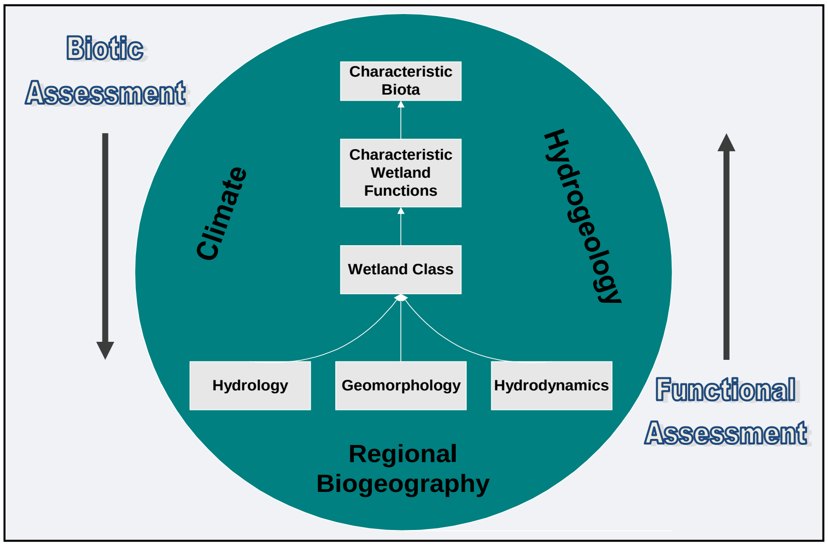


Fig. 44. Schematic representation of the top-down and bottom-up approaches used in assessment. Functional condition assessment evaluates the basic physical attributes, to imply biotic condition. Biotic assessments do just the opposite.

EIA incorporates substantial evaluation of physical aspects of the wetland, however, its lineage still flavors its fundamental approach – EIA leverages the power of vegetation to resolve ecological degradation. This fact can most plainly be seen in the weights applied to the metric category scores (Table 47). Vegetation is the most highly weighted category score (0.4), out weighing the keystone environmental driver of wetland condition, hydrology (0.3). This weighting strategy implies that vegetation condition carries more ecological information than any other factor, which is consistent with highlighting the state of environmental degradation (rather than the cause). Although vegetation composition provides a powerful indication of wetland condition, the challenge in applying biotic assessment methods is the high technical proficiency in plant taxonomy that is needed to produce reliable results.

Functionally-based evaluation methods such as HGM and FACWet can be considered to be "bottom up" (Fig. 44) and prescriptive in their approach. These methods focus on aspects of the wetland that create higher order functions, including the maintenance of characteristic vegetation. Highlighting the causes of (rather than state of) environmental degradation is the focus of functional methods, while the specific ramifications of impacts, such as changes in species composition, are assumed. This confers the advantage of relieving the evaluator of the need for a high level of taxonomic proficiency, opening them up to a broader audience, but limiting the interpretation of the end state of degradation expressed through vegetation.

Identification of the causes of impairment is a fundamental task of compensatory mitigation and the CWA specifically protects wetland functions. Therefore, functionally-based approaches such as HGM best fit the needs to the ACOE's role in administering the CWA and they became favored by the agency. FACWet grew from this heritage and its physically-based emphasis FACWet can be clearly seen when the overall weight of each variable in the composite FCI is calculated (Table 48). As can be seen, the hydrology attribute receives the largest weight of 0.51. That is, to FACWet keys off of hydrologic condition in the same way that EIA does with vegetation. In the FACWet school of thought, hydrology conveys the most information about a site, and is favored for a site-specific evaluation. If the variables in the FACWet biotic and abiotic habitat attribute are arranged according to EIA as they were in this study's analyses, the weighting scheme of the two methods can be compared (Table 49). This table makes FACWet's focus on hydrologic and geomorphic factors clear.

Table 47. The weight of each EIA metric is provided in the right column. The weight is the proportion of influence of each metric has on the entire wetland score.

Category	Metric Name	Weight in Overall Wetland Score
Landscape Context	Landscape Fragmentation	0.08 (0.02 if Riverine HGM)
	Riparian Corridor Continuity	NA (0.06 if Riverine HGM)
	Buffer Extent	((Buffer Extent*Buffer Width)$^{1/2}$)*Buffer Condition)$^{1/2}$=0.12
	Buffer Width	
	Buffer Condition	
	Total Category Weight	**0.20**
Vegetation Condition	Relative Cover Native Plant Species	0.08
	Absolute Cover Noxious Weeds	0.08 (NA if score better than aggressive natives)
	Absolute Cover Aggressive Native Species	NA (0.08 if score worse than noxious weeds)
	Mean C	0.16
	Regeneration of Native Woody Species	0.04 (NA if naturally herbaceous wetland)
	Litter Accumulation	0.02 (0.04 if naturally herbaceous wetland)
	Structural Complexity	0.02 (0.04 if naturally herbaceous wetland)
	Total Category Weight	**0.40**
Hydrology	Water Source	0.06
	Hydroperiod	0.18 (0.15 if Riverine HGM)
	Hydrologic Connectivity	0.06
	Bank Stability	NA (0.03 if Riverine HGM)
	Total Category Weight	**0.30**
Physiochemical Condition	Water Quality – Turbidity / Pollutants	0.025 (NA if no surface water)
	Water Quality – Algal Growth	0.025 (NA if no surface water)
	Substrate / Soil Disturbance	0.05 (0.10 if no surface water)
	Total Category Weight	**0.10**

Table 48. The total weight of each variable in the Composite FCI is provided in the right column. The total weight equals the total number of times the variable was used across all seven FCIs. Dividing this number by the sum of all variable weights provides an equivalent weighting factor as represented in Table 47.

Attribute	Variable Number	Variable Name	Total Weight in the Composite FCI
Buffer & Landscape Context	Variable 1:	Habitat Connectivity – Neighboring Wetland Habitat Loss	0 (or 2)
	Variable 2:	Habitat Connectivity – Migration/Dispersal Barriers	1
	Variable 3:	Buffer Capacity	3
		Total Attribute Weight	4 (or 6)
Hydrology	Variable 4:	Water Source	6
	Variable 5:	Water Distribution	8
	Variable 6:	Water Outflow	8
		Total Attribute Weight	22
Abiotic and Biotic Habitat	Variable 7:	Geomorphology	7
	Variable 8:	Chemical Environment	3
	Variable 9:	Vegetation Structure and Complexity	7
		Total Attribute Weight	17
		Total Weight in FCI formula	43 (or 45)

Table 49. A comparison of the weights used to produce Composite Wetland Condition scores

FACWet Attribute / EIA Category	EIA Weight	FACWet Weight
Landscape	0.20	0.09
Hydrology	0.30	0.51
Physiochemistry	0.10	0.23
Vegetation	0.40	0.16

The important thing to note is that both types of methods evaluate **wetland condition.** FACWet does so based primarily on physical and functional rationale, while EIA does so with a focus on biotic criteria. Methods that assess function relative to a reference standard, as FACWet and the HGM approach do (Smith et al. 1995), are evaluations of *functional condition*. Changes in vegetation are assumed to be related to function. Methods such as EIA, IBIs, and Coefficients of Conservatism (FQA) provide assessments of *biotic condition*. The synthetic qualities of vegetation in its response to physical perturbation allow many of the details of environmental condition to be assumed.

There are some methods such as the Washington State Wetland Function Assessment Method (Hruby 2000) that consider functioning in absolute terms, such as the volume of water stored or the rate of some processes performed. Such methods do not assess condition. They are yet another vein of assessment, with a distinctly different school of thought than employed by condition assessments. Thus, in discussing wetland assessments the relevant distinction is whether a method is based on *functional condition* or *biotic condition* and whether it considers *relative* or *absolute* measures, not whether it is *functional* or *conditional*, as is routinely done. This latter distinction is misplaced.

The high correlation between FACWet and EIA composite scores and the even much higher correspondence in the overall grades assigned by the methods (Figs. 42, 43) are direct evidence that both methods, despite their differing biotic/ functional lineages, seek to uncover the same essential attribute of the wetland – holistic condition, or what is commonly referred to as ecological health. In the vast majority of cases, FACWet and EIA provide the same overall answer about the condition of the wetland. This provides strong support for the validity of each method. If two methods purport to evaluate condition or health, then ultimately they should agree on what that condition is. FACWet and EIA do just that, and thus they corroborate one another's validity. But agreement should not be taken as methodological equivalency – each has a distinct way of codifying the condition of natural habitat that has resulted from its evolutionary heritage.

Composite condition scores were more highly correlated than were any of underlying variable or metric categories. Initially this may seem puzzling, because how could composite scores be more similar than the variable/metric categories that comprise them? This pattern, however, turns out to be a precise illustration of the points made above. Physiochemical scores were not particularly well correlated. This is because the methods are asking different questions of the physiochemical environment and seeking to extract different information from this aspect of wetland habitat. The scattering of points in the regression does not necessarily indicate inaccuracy or disagreement, rather a divergence in approach.

The relationship between vegetation and hydrology scores and final weightings create the dramatic tightening of correlations and allowing agreement on overall site condition in the end. FACWet had a strong tendency to score hydrology lower than EIA, and whenever there was a disparity in grades FACWet assigned the lower one. Conversely, EIA tended to score vegetation lower, and in cases where vegetation grades differed, EIA always assigned the lower grade. This finding provides a direct illustration of the influence lineage has one method character and is a clear demonstration of the effect that each method's philosophical approach has on scoring. FACWet judges the effects of hydrologic alteration more harshly than does EIA, because it stems from a functionally and physically-based paradigm. EIA does the same thing, for the same reason, for vegetation. These *Vegetation* and *Hydrology* categories are used in the exact same manner by the methods, and as such the score differences offset each other to a very high degree. In the end, the only reason that the methods finally arrive at the same answer, is that the weighting strategy remained consistent with the paradigm from which it was built. EIA weights vegetation most highly, that is, it implies that in its paradigm vegetation condition provides the most information about wetland health. FACWet weights hydrology most heavily following the same logic. If EIA, for instance, was unresolved in its philosophy and employed a physically-biased weighting scheme, such as FACWet's, to calculate composite condition scores, the method would report condition erroneously.

Despite the fact that scoring differences are largely compensated for the two methods weighting schemes, the question of why hydrology and vegetation scores differed systematically remains. As the category metric scores were lower when evaluated by the respective assessment method that specializes in that category, the possibility arises that the condition of wetlands in this study area should be rated even worse than they currently are with the current methods. However, first and foremost, score divergence is readily attributable to the different approaches to condition assessment, the methods used, and applications for which they were designed.

In this study, the typical reason that hydrology scores were lower in FACWet than in EIA is that FACWet rates the hydrologic condition of wetlands with actively managed hydrology low. Aside from its empirical validity, this scoring criterion was developed in direct response regulatory policy and the goals of compensatory mitigation. A requirement of mitigation is that it must function in perpetuity. Since mitigation supported by actively managed hydrology is known to fail at a very high rate, it follows that in regulatory applications, the hydrology of actively managed sites should be graded severely. EIA on the other hand, has developed more in response to the needs of management applications and ambient monitoring programs. From that standpoint, it does not make sense for the method to penalize managed wetlands, since evaluating the effectiveness of active management is often the specific purpose of the assessment. Being more tolerant of actively managed hydrology makes the method more sensitive to other consequences of management actions. It is likely that if the interpretation of hydrology were simply made consistent between the two methods, a majority of the grade disagreements would be resolved.

Similarly, the differences in vegetation scores result from the individual emphases of each method. Specifically, EIA emphasizes floristic composition, both the nativeness of species and their affinity for, or relative dependence on, undisturbed habitat. Floristic emphasis is necessary for methods using a top-down, phytometric approach such as EIA does. In FACWet on the other hand, vegetation is viewed more in terms of its physical influence on habitat condition and the way it influences characteristic wetland functions, such as sediment retention, flood attenuation, or wildlife habitat. For example, when woody exotic species such as Russian olive are present at a site, FACWet scores are expected to be higher than EIA's in acknowledgement of the functional roles the trees play, such as their ability to mediate thermal regimes, stabilize shorelines, and provide wildlife habitat. These trees, which commonly invade after a native woody canopy has been removed, play the same functional role as the native species, if perhaps not to the same high degree. Again, this functional emphasis is more in line with the goals of the CWA, whereas floristic emphasis if EIA may serve the needs of management applications better, since it engenders the ability to track species and shifts in species composition which could be the manifestation of large-scale, long-term environmental alteration such as climate change.

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APPENDIX A: A Provisional Colorado Watershed Approach to Compensatory Wetland Mitigation Planning and Decision Making Framework

ABSTRACT

The Colorado Watershed Approach (COWAP) is a provisional methodology developed to address the mitigation planning requirements of the 2008 Rule. In particular, the COWAP is an approach to guide applicants towards planning mitigation that minimizes the risk of cumulative watershed impacts. It is designed to help permit applicants plan mitigation that is compliant with federal regulations and to effectively convey project facts and information to regulators. COWAP is intended to assist federal regulators in communicating agency preferences to applicants, reviewing permit information, easing the decision making process, and facilitating explanation of the decision rationale.

The COWAP is structured as a hierarchical information framework, embedded with the tools needed to obtain the information to fill the framework. To a large degree, the COWAP is an articulation of current practices used in federal mitigation review, but it places activities such as wetland boundary delineation and functional assessment into a watershed-based perspective. The COWAP is designed in response to the mitigation project review factors described in a joint-agency Training Syllabus for a Watershed Approach to Project Review.

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INTRODUCTION

The main body of this report describes the acquisition of data and application of tools designed to help in the administration of §404 of the Clean Water Act (CWA); particularly during the planning and review of compensatory mitigation. This appendix describes a ***Provisional Colorado Watershed Approach to Compensatory Wetland Mitigation Planning and Decision Making Framework***. The provisional Colorado Watershed Approach (COWAP) is intended to assist permit applicants plan compensatory mitigation that is in compliance with current federal policy and in step with regulatory agency requirements.

The COWAP identifies the critical ecological facts of a mitigation project which the applicant must know in order to plan appropriate mitigation and regulators must understand in order to make an informed permit review. The COWAP leads the applicant through a five-step information gathering process. At each step keystone questions are posed about the circumstances of the impact site, mitigation site and/or surrounding watershed. The COWAP provides the applicant with an approach to acquire the information needed to answer each question using the integrated suite of tools available in Colorado.

The COWAP is largely a framework which is used to organize, relate and convey the information that is typically obtained during mitigation planning, including wetland boundary delineation and functional assessment. It goes on, however, to use the power of the watershed wetland profiles, described in previous sections of this report, to relate site-level project circumstances to their watershed-level context. The project facts revealed during the information gathering process are summarized in the COWAP with "yes/no" question responses or tabular matrices that provide a readily understandable overview of the most ecologically important aspects of the proposed plan.

Through its question-based format, the COWAP conveys regulatory emphases and preferences to the applicant, and it provides insight into how information acquired during the permitting process, such as wetland size, is put into use during mitigation plan review.

A COWAP summary and its supporting documentation is intended to facilitate information transfer to regulatory agencies by spotlighting the most important ecological facts of a proposed mitigation plan. The COWAP's summary structure is designed to assist regulators with efficient permit review and to structure information delivery. Widespread use of the COWAP would lend considerable consistency to mitigation plans submitted to regulatory agencies.

This document is divided into two sections: The Introduction and the COWAP Procedure. The Introduction section includes background information on the development of the COWAP as well as its technical and policy underpinnings. The COWAP Procedure section is broken down into five subsections each covering one of the steps in the COWAP information gathering process.

Background on COWAP Development

In a comprehensive evaluation of wetland mitigation through the 1990s, the National Research Council concluded that "the goal of no net loss of wetlands is not being met for wetland functions" by the ACOE and EPA's administration of the CWA mitigation program (NRC 2001). Acknowledging this conclusion, ACOE and EPA issued a federal rule in April 2008 to increase the effectiveness of compensatory mitigation under the §404 of the CWA program (ACOE & EPA 2008). The 2008 joint-agency Final Rule on Compensatory Mitigation for Impacts to Aquatic Resources ("2008 Rule") is the most recent step forward in a long history of mitigation policy development and implementation, and it signifies the federal government's intent to make decisions in a more predictable way using the best available science (Hough and Robertson 2008). One of the key science recommendations of the National Research Council (2001) was for compensatory mitigation decisions to be made using a "watershed approach". Several important facets of the rule are open for interpretation at the ACOE district level, but the general approach involves: a) building program partnerships, b) recognizing watershed needs and goals, and c) using monitoring and assessment information to inform decision-making based on the established needs and goals (Sumner et al. 2011). While requiring a watershed-scale view of mitigation, the new mitigation rule does not provide guidance on what a watershed approach should entail or how one should be implemented.

In response to the 2008 Rule, a joint agency team was assembled to develop a watershed approach to mitigation planning and decision making in the ACOE's Denver Office of the Omaha District. The team included representatives from EPA Region 8, EPA's Office of Research and Development, ACOE's Denver Regulatory Office, CDOT, CSU, and CNHP. The joint agency team produced a brief 'training syllabus' that outlined the principles of the watershed approach in Colorado.

The training syllabus was built on the following principles (**m**odified from Sumner et al. 2010):

1. All permit decisions must comply with applicable provisions of Section 404 of the federal Clean Water Act (40CFR part 230), including those which require the permit applicant to take all appropriate and practical steps to avoid and minimize adverse impacts to waters of the United States.

2. Mitigation should be located where it will help protect or restore the health and condition of aquatic resources within a watershed or other appropriate area within an ecological landscape. This principle is also expressed in terms of mitigation meeting "watershed needs" and "watershed goals." The two terms are synonymous.

3. Mitigation must be sited in a location capable of supporting the desired wetland type and condition.

4. A "wetland landscape profile" or "watershed profile" provides a relatively simple way of characterizing watersheds and identifying watershed needs.

5. Wherever possible, existing watershed and environmental planning information should be analyzed in advance of mitigation to:
   - determine the location of relatively intact, natural areas in a watershed,
   - identify those areas for preservation and protection, and

- identify nearby degraded areas that are amenable to enhancement, restoration or establishment, and that would contribute to the sustainability of natural areas and the overall health of a watershed's aquatic resources.

6. When watershed and environmental planning information is not readily available, project impact sites and mitigation sites can be evaluated using knowledge of basic landscape principles and watershed management goals (e.g., Principle #2 above).

7. Assessment results may indicate that on-site mitigation is appropriate when:
   - the wetland at the impact site is of measurable significance to the ecological condition of the watershed;
   - the on-site mitigation opportunities have a high likelihood of successfully replacing the functions lost at the impact site; and
   - the mitigation is consistent with watershed goals.

8. A watershed approach may be used to justify use of more than one mitigation site to provide compensation for an impacted wetland. For example, it may be ecologically advantageous and consistent with a watershed profile and watershed goals to restore or enhance different types of wetlands at multiple locations.

9. The watershed approach underscores the concept that existing mitigation "compensation ratios" must take into account wetland acreage, as well as wetland condition and wetland rates of function. Wetland abundance, along with ecosystem condition and landscape position, controls the delivery of ecosystem services.

10. Use of a watershed approach may sometimes result in mitigation wetlands that are of different types (e.g., hydrogeomorphic wetland type) and/or that provide different levels of functions than impacted wetlands. This may be preferable if assessment shows that the "out-of-kind" mitigation fits within the broader watershed profile and would better address watershed needs. This situation commonly occurs in urban or urbanizing areas.

The training syllabus codifies these mitigation principles into seven *Review Factors.*

- Impact site description
- Impact site condition
- Mitigation category (*e.g.*, re-establishment, rehabilitation, establishment or preservation)
- Mitigation consistency with watershed profile
- Mitigation site suitability – Landscape review
- Mitigation site suitability – Field review
- Mitigation performance over time

Review Factors generally include a number of supporting questions, who's "yes/no" or short answers are used to summarily describe the most important ecological facts of a mitigation plan. *Review Factors* are intended to be used by regulatory staff during mitigation plan review, to help identify and spotlight ecologically-risky or otherwise sub-optimal aspects of a proposed project.

The training syllabus was formally transmitted from EPA Headquarters to the ACOE Denver Regulatory Office in June 2010, to initiate in-program trials of its approach.

The COWAP is built directly from the training syllabus. The training syllabus's *Review Factors* indicate which ecological aspects of a project may be scrutinized during federal review of a mitigation plan. It also provides general guides for interpreting *Review Factor* responses based on policy preferences. It does not, however, document any procedures for actually gathering the information needed to document and answer *Review Factor* questions. The COWAP describes a process for acquiring all the information called for by the *Review Factors*. The COWAP defines a distinct role for each tool used in Colorado's regulatory program in answering keystone mitigation planning questions, and it allows this information to be placed in the context of the surrounding landscape and watershed.

When using COWAP in mitigation planning, the end result is a completed project information questionnaire form. The form includes all of the *Review Factor* questions contained in the training syllabus augmented with tabular matrices for some types of information such as FACWet scores.

Authority

The COWAP is a tool designed in collaboration with federal regulatory agencies, but this does not imbue the method with any legal standing nor does it imply formal approval or its endorsement by any of the agencies involved. Following the COWAP procedure provides no assurance that a permit application will receive a favorable decision under federal review.

Improving the Effectiveness of Compensatory Mitigation

The idea behind compensatory mitigation is simple – offset the effects of unavoidable wetland impacts by improving, creating or preserving comparable wetland habitat elsewhere. The policy goal of wetland mitigation is to assure "no-net-loss" of wetland acreage and function within a given watershed. Actually achieving this ideal has proved challenging, however, and attempts to do so have been prone to an unacceptably high rate of failure. Given this fact, the mitigation process becomes a matter of balancing mitigation "risks" with "assurances" (Fig. 1). "Risk" here refers to the potential of a permitted action to result in a net decrease in wetland functioning through loss of area, diminishment of condition, change in wetland functional signature, or any combination of these circumstances. Assurances may take on a number of forms including financial provisions to cover future work in the event of unacceptable performance, increased compensation ratios, or elevating ecological condition requirements.

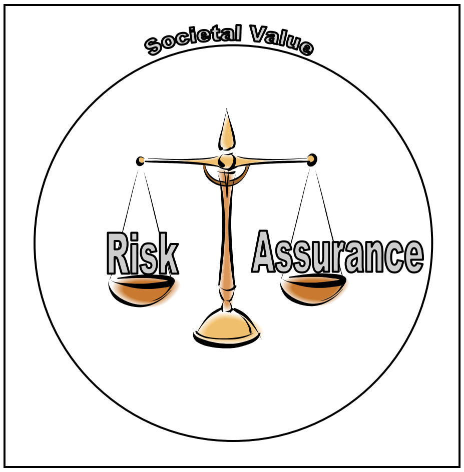

Fig. 1. The balance between the ecological risk associated with a project and assurance of success is evaluated in light of perceived societal value.

Best mitigation practices come about by minimizing risk. Generally speaking, best practices in mitigation include: targeting an ecologically-appropriate wetland type for re-establishment, rehabilitation, establishment or preservation; explicitly stating design and success criteria; and siting mitigation in a location appropriate for its hydrogeomorphic type and in a landscape setting that has the potential to passively support required wetland functioning. Minimization of risk allows a corresponding reduction in the weight of necessary assurances. Viewing the mitigation process in terms of risk minimization guides it towards a conclusion that is least damaging to the environment and provides the most efficient means for the permit applicant to meet federal regulatory requirements.

In terms of the CWA, watershed-scale risk is manifested as the potential of a permitted project to create cumulative impacts to the aquatic ecosystem and to the ecosystem services it provides, most notably water quality maintenance. The CWA cannot achieve its purpose of controlling cumulative impacts unless permitting and mitigation is placed in the context of the watershed, but it is critical to understand that when considering mitigation planning at a watershed-scale, the qualities of the impact and proposed mitigation site must not be ignored.

Different types of wetlands perform different functions or the same functions to differing degrees. The functions performed by wetlands within a watershed integrate to produce ecosystem services. Consequently, the overall abundance and distribution of wetland types in the watershed dictate the portfolio of ecosystem services provided by the watershed; that is, wetland functions are a product of individual wetlands, while ecosystem services are products of whole landscapes or watersheds (Fig. 2). The COWAP uses this relationship to create a linkage between site level evaluations and overall watershed-scale functioning of the watershed's aquatic system to inform mitigation planning and review.

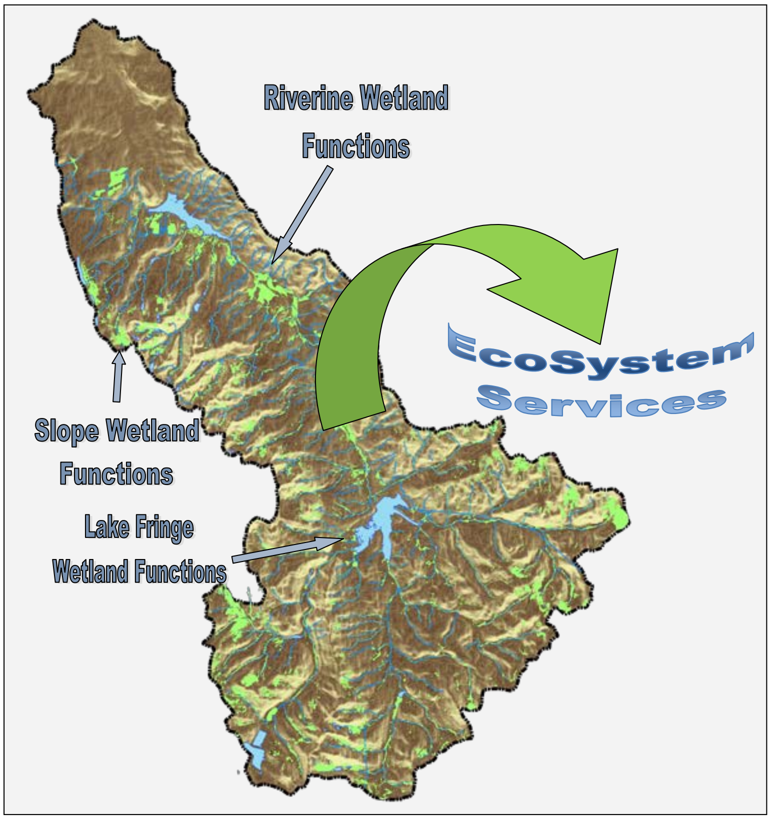

Fig. 2. A representation of the relationship between the abundance and diversity of wetland types and the ecosystem services provided by the watershed.

Until recently, the means of explicitly achieving the watershed-scale goals of the CWA have not been technically feasible. In lieu of a direct approach to watershed-scale cumulative impacts management, regulatory agencies in Colorado (and elsewhere) have tended to depend on a policy of designating 1:1 ratios and in-kind, on-site mitigation; the logic underlying this practice being that if impacted wetlands are replaced with equivalent habitats, the ecological integrity of the watershed should be maintained.

While on the surface reasoning behind this approach seems sound, in application both theoretical and practical problems have been identified. There are four primary problems underlying such an approach to mitigation planning: 1) there is no upfront accounting for the risk of underperformance or failure; 2) conditions at the impact site ("on-site") are commonly unable to support mitigation with the necessary type of functioning and level of quality; 3) in highly modified landscapes, in-kind replacement can replicate previous impacts to the watershed's aquatic system and perpetuate watershed dysfunction; and 4) mitigation goals and success criteria were commonly based on vegetative habitat criteria and not characteristics that dictate functional capacity. The first two issues occur at the site level but have potential ramifications for the watershed. The second two directly affect watershed functioning. Each of these issues is discussed briefly below.

Relative to the first two issues listed above, the 2001 National Research Council study clearly shows that most mitigation underperforms relative to stated goals or fails outright. The reasons for poor success are many, but the common causes are inappropriate site selection, poor implementation, inappropriate landscape position/water source given goals, surrounding land uses impose limitations on condition, unrealistic performance expectations, and ill-defined goals and success criteria. In our framework such factors are categorized as "risk increasers"; therefore, one of the primary goals of mitigation planning should be to eliminate these and other risky planning elements.

The third problem with past mitigation practices has been that in-kind mitigation, in particular when conducted on-site, can perpetuate or exacerbate historical watershed alternations and cumulative impacts. This problem has two causes. First, wetlands in highly developed landscapes are commonly human-made and possess functional signatures far different than the original wetlands that may have existed at the site (see main report for an example). To illustrate this point, consider the common situation involving depressional wetlands on the plains east of the Front Range. The vast majority of these wetlands were created by aggregate mining in river corridors (Fig. 3). Depressional wetlands have a strongly divergent functional signature from the riverine wetlands they tend to replace. For instance, depressional wetlands emphasize retentive functions such as storage of surface water and materials, and they form more or less discrete oases of habitat. Riverine wetlands, on the other hand, function as the arterial network of the watershed, transporting water and materials through the watershed and forming continuous corridors of habitat. Thus, substitution of depressional wetlands for riverine ones constitutes an alteration of watershed-scale aquatic functioning. The way in which functional replacement of wetlands can affect watershed-scale functioning can easily be envisioned when the practice is as prevalent as it is in areas such as the Front Range plains. In-kind mitigation of derived wetlands perpetuates these watershed alterations and may not be desirable under a variety of circumstances.

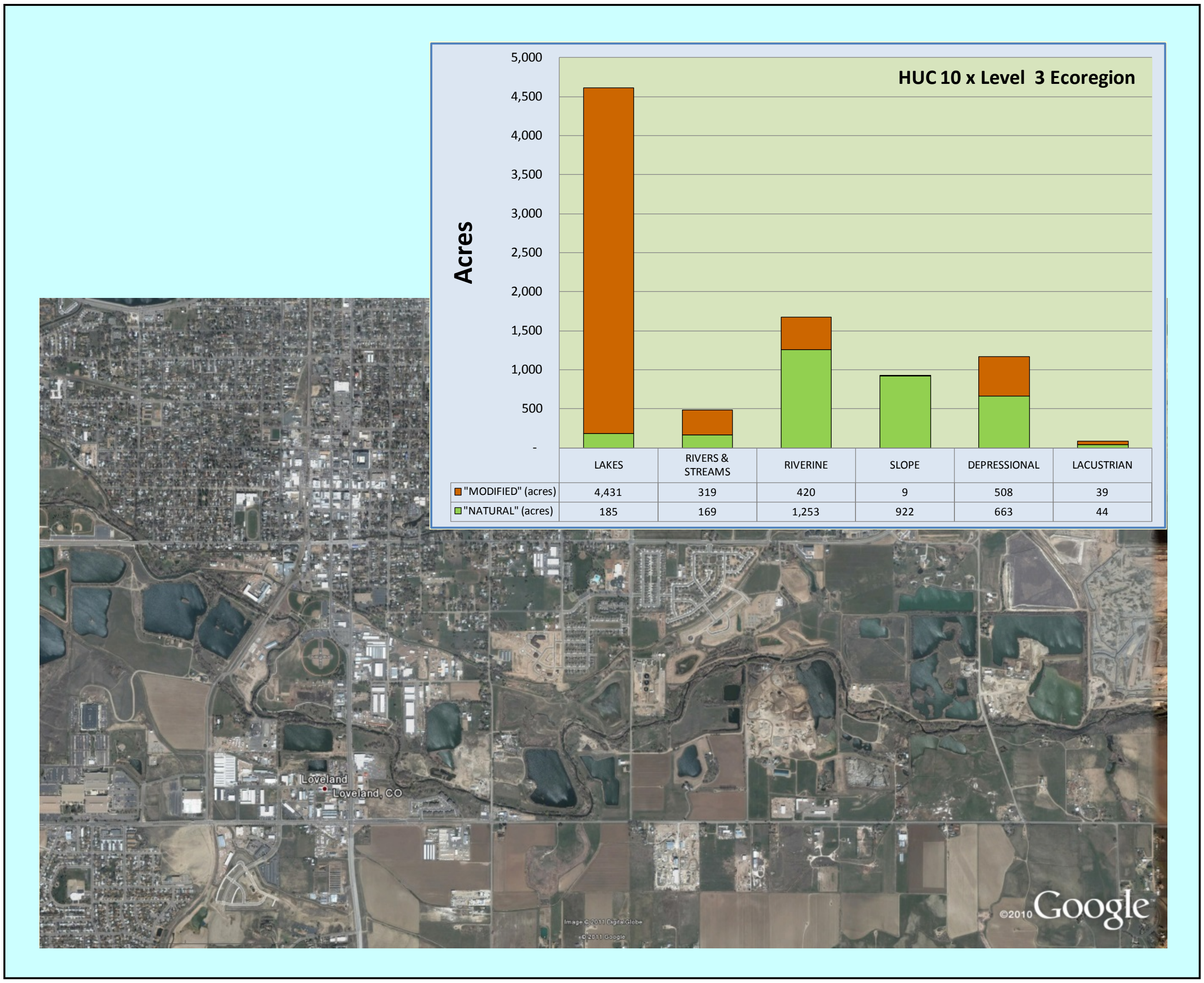

Fig. 3. In urban landscapes along the Front Range, riverine wetlands are commonly converted to depressions and open water systems. The graph is a wetland profile of the Big Thompson Watershed, showing the number of acres of each wetland type and the proportion of that wetland area that is generally created vs. of natural origin. The aerial image shows the Big Thompson River corridor as it runs through the Town of Loveland, CO.

The final issue with past mitigation practices seems at first trivial, but actually has far reaching implications. Mitigation goals are commonly based strictly on vegetative habitat criteria, in particular using the descriptions and higher levels of classification included in the U.S. Fish and Wildlife Service's "Cowardin classification" (Cowardin et al. 1979), such as "Palustrine Shrub-scrub" or "Palustrine Emergent." The critical issue here is that there is only a weak correspondence between vegetation structure and the functions performed by the wetland or the relative rate at which various functions are performed (excepting some wildlife habitat functions). For instance, continuing the above example, using the Cowardin classification could result in a shrub-scrub wetland associated with a riverine system being replaced with shrub-scrub wetland associated with a depression. Because of the disparate functions exhibited by the impacted site and the mitigation, such action would not offset of *functional* loss of the impact.

The COWAP and its comprehensive assessment tool kit are designed to address all of these identified problems associated with mitigation planning and review prior to the advent of the 2008 Rule.

Aims and Goals of the COWAP

COWAP provides a means of placing mitigation planning in the watershed context in accordance with the 2008 Rule. The goal of the 2008 Rule, and therefore of COWAP, is to improve the effectiveness of compensatory mitigation. The COWAP framework systematically links proposed unavoidable wetland impacts to their watershed ramifications, and then to the type and placement of mitigation that would best offset those impacts (Fig. 4).

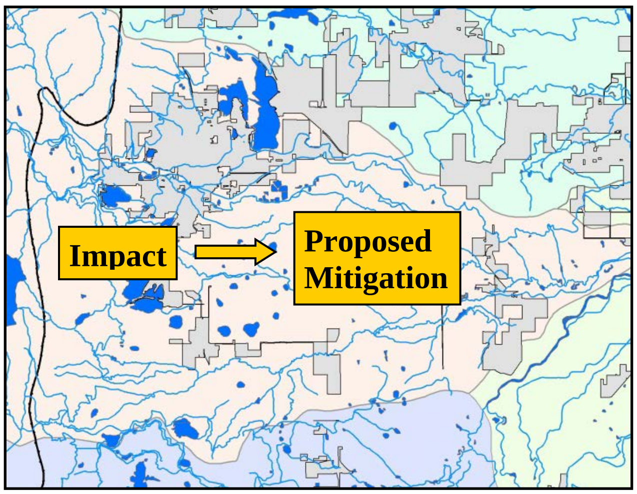

Fig. 4. In the COWAP, mitigation planning and review is placed in the watershed context.

Successful communication of current mitigation policy to permit applicants is an important goal of the COWAP. Mitigation planning is often an inefficient and frustrating process because permit applicants commonly have little upfront information on regulatory objectives and procedures, which may even vary Corps district to Corps district. COWAP addresses these issues by clearly articulating a mitigation planning process that is visible to both regulators and permit applicants. The process is flexible so it can meet the widely varying needs across the state, but is intended to engender consistency, bolster efficiency, and increase understanding of best mitigation practices, emphasizing their use during the planning phase. The COWAP is also aimed at aiding in mitigation planning and permit review by:

- Providing guidance on information needs and best practices in mitigation planning.
- Assembling a coherent strategy for obtaining information based on assessment tools existing in Colorado.
- Constructing a concise summary of key points of the mitigation proposal to highlight the relative merits and drawbacks of a mitigation proposal.
- Providing an information framework within which to organize information and apply it during risk assessment, assigning assurances, and decision making.
- Providing a means and rationale to explain permitting requirements and decisions.

Previously in Colorado, the watershed context of mitigation was mainly implied during mitigation planning. In the COWAP, watershed considerations are brought to the forefront of the planning and decision making process. This watershed approach includes tools to aid mitigation planning and review taking into consideration the following project attributes:

- The type of impact relative to watershed condition and watershed goals.
- The benefit of proposed mitigation towards maintaining or achieving watershed condition or goals.
- The hydrologic and geomorphic setting of the proposed mitigation and contributing area.
- Land use surrounding the mitigation.

Importantly, COWAP is intended to be practically applicable in the day-to-day administration of the CWA and not overly burdensome on applicants either. The approach simply provides a list of clear and concise questions about the impact site, proposed mitigation site and the surrounding watershed that are given a “yes”, “no” or otherwise very short answer. Each answer has risk factors or a preference assigned to it. This summary format confers several advantages. First, the planning questions convey to the applicant both the important considerations to take into account when planning mitigation and also what policy preferences are; that is, mitigation planning actions which are considered low risk. The second advantage of the COWAP framework is that it provides a concise summary of the most important facts of a mitigation plan, which can otherwise be lost in voluminous project documentation. From this summary, a reviewer can choose specific avenues of inquiry and delve into increasing project detail in a controlled fashion. Despite their brevity, COWAP’s short-answer responses convey a great deal of essential project information, in a manner that is quickly interpretable.

It is important to understand that the COWAPs short-answers are simply capstones which may be founded on a great deal of data and information. In the COWAP, conclusions are placed upfront of potentially lengthy rationales and explanations. The amount and intensity of investigation backing COWAP responses can be wholly tailored to project circumstances, from best professional judgment to detailed quantitative study. Another way of looking at this is that COWAP is a **weight-of-evidence** approach.

It also must be understood that the COWAP does not produce any type of decision or even a numerical index. The COWAP highlights the minimal scope of information that is needed to successfully plan mitigation a watershed context, it provides a process for obtaining that information, and a framework to aid in the organization and interpretation of summary information. This systemization of process and information delivery is intended to aid communication of project aims and methods to agencies, and to assist agencies in reviewing proposed plans, making permit decisions, and explaining rationales.

Life Cycle of a Mitigation Project

While every mitigation project is unique, there is a commonality in the general process and typically a minimal number of questions need to be answered in order for regulators to make an informed review of a mitigation proposal. Fig. 5 provides a flow model of a generic mitigation project life cycle, which includes three major phases: 1) planning, 2) implementation and 3) effectiveness evaluation. Each of these phases includes one or more components which themselves may entail several steps. The COWAP deals exclusively with the planning phase of the mitigation process. Being foundational, the outcomes of this step should generally influence all later aspects of the project life cycle.

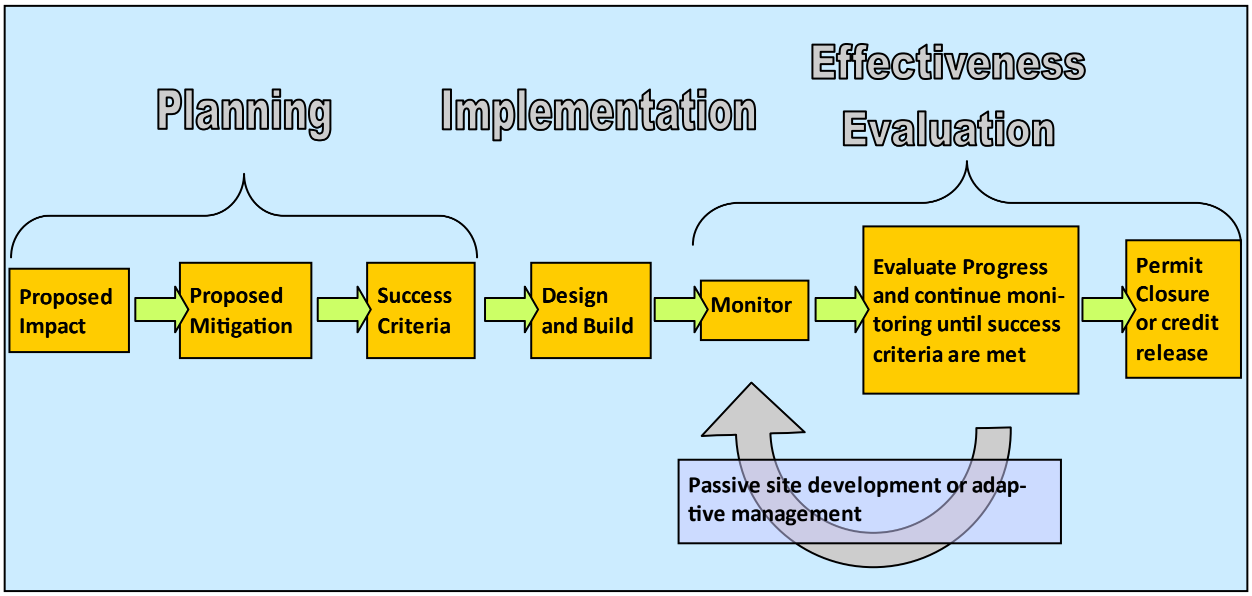

Fig. 5. Step-wise breakdown of the generic components of a mitigation project life cycle. The project life cycle is broken down into three stages: 1) planning, 2) implementation and 3) effectiveness evaluation. In the planning stage, an impact is proposed and then mitigation to offset that impact is planned. Finally success criteria based on the mitigation targets are designated. The planning stage generally includes the permit review procedure. Given permit approval, implementation commences, including the execution of the regulated action and the construction of required mitigation or purchase of bank credits. Following mitigation construction, monitoring and performance evaluation ensue. Based on monitoring results adaptive management may be prescribed, or the site may be allowed to develop passively if progress is satisfactory. Once the attainment success criteria has been confirmed the permit is closed or banking credits are released.

The Mitigation Planning Phase

The COWAP breaks down mitigation planning into three basic tasks: 1) information gathering, 2) decision making and 3) reconciliation or permit denial (Fig. 6). It is the applicant's responsibility to provide regulators with the information they need to undertake an informed review of a permit. It is the regulator's challenge to interpret the information. COWAP is designed to aid in both of these pursuits by guiding the applicant's information gathering activities to ensure that the most important aspects of a project are sufficiently characterized, and providing an organizational framework within which to place that information.

The information gathering phase, that is the focus of the COWAP, is broken down into five steps (Fig. 6). Each step addresses a major keystone question. Adequately answering keystone questions may require answering several supporting questions as well. For instance, in the *'Impact Site Assessment'* step, the keystone question posed is: "What wetland resources would be impacted by the proposed action?" Sufficiently answering that question requires that additional questions be answered about the size, type and functional condition of the impact site. The information obtained to answer these questions is then applied in subsequent planning steps and is ultimately used to inform the decision making process.

The culmination of mitigation planning with the COWAP is a completed questionnaire (Appendix A.1) on the facts of a proposed mitigation plan, supported by a project-appropriate level of documentation justifying questionnaire responses.

The completed COWAP is intended to feed into the second step of the planning process which is comprised of permit/mitigation plan review and decision making. Decision making falls to regulatory agencies, presumably the ACOE in most cases. As explained above, COWAP informs permit review and decision making by identifying ecologically risky aspects of a mitigation plan.

Mitigation risk is described as the risk that proposed mitigation will not successfully compensate for impacts because it will perpetuate or contribute to watershed-scale cumulative impacts and will fail to meet the stated policy goal of "no-net-loss." Risk assessment and permit review may or may not result in a final decision at this point. A proposed mitigation plan could be accepted or rejected outright, but perhaps more often, the project enters the third and final stage of the planning process: reconciliation or denial. This phase is a joint undertaking between regulatory agencies and the permit applicant involving communication of risk concerns and the negotiation of solutions or assurance. This process parallels the logic of 404 (b)(1) guidelines by attempting to eliminate ecological risk, minimize it, or provide assurance that any impact resulting from unavoidable risks will be remedied.

The five steps in the information gathering phase are detailed in the following section on the COWAP process. Each step lists a keystone question that should be addressed, recommended tools for obtaining answers to the question, and the ecologically preferential response based on associated risks. As indicated previously, various methodologies can be employed to answer mitigation planning questions. The COWAP provides one coherent strategy for answering the questions using wetland profiles in conjunction with wetland boundary delineation and functional assessment using FACWet.

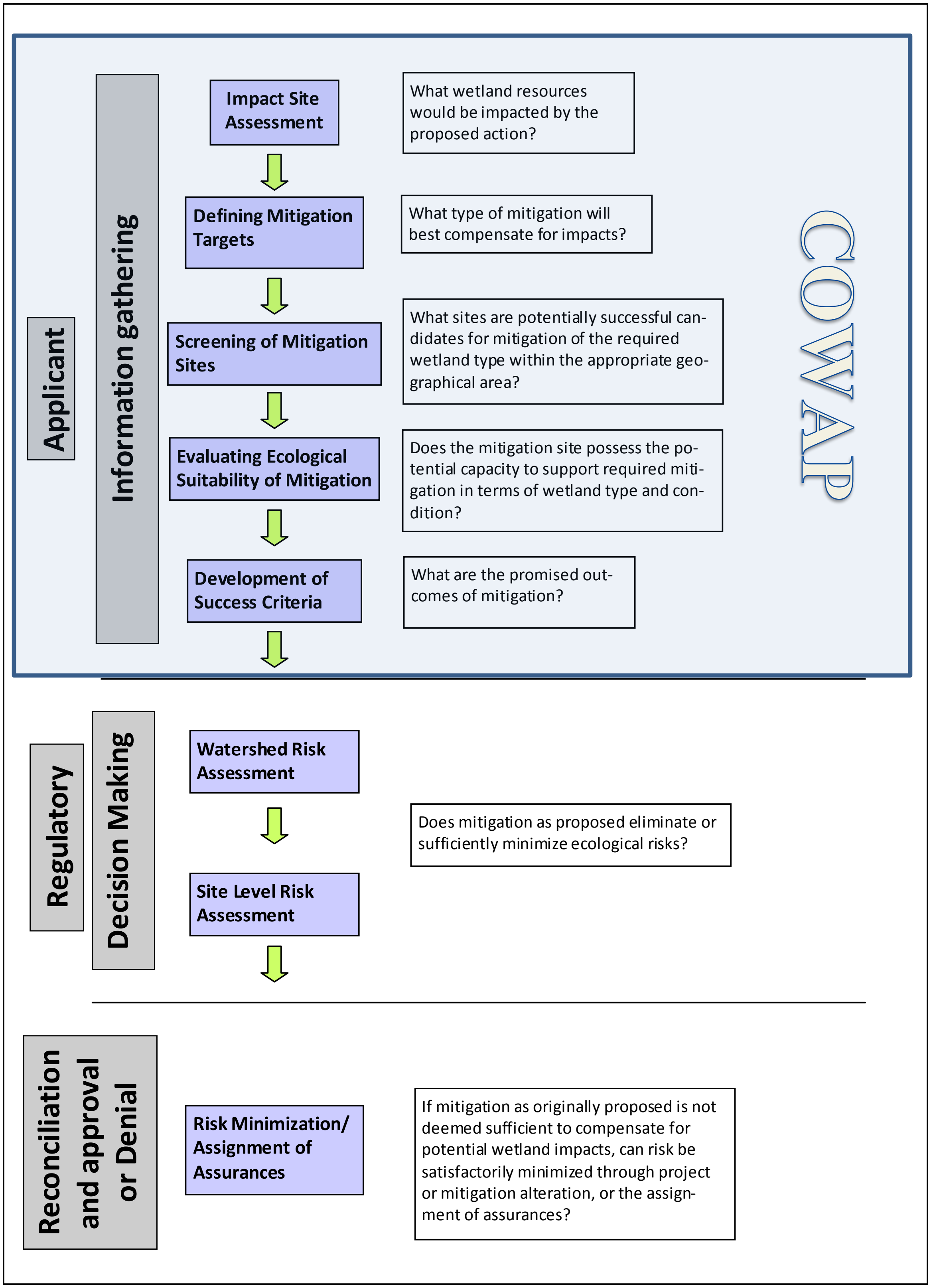

Figure 1. Flow diagram of the mitigation planning and review process, including the three major phases and their component steps. To the right of the steps are the keystone questions that need to be answered. COWAP's focus is on the information gathering phase, which supports later phases.

THE COWAP PROCESS

Mitigation plans answer what are often times implied questions about the facts of a project. In the COWAP, information is obtained in direct response to keystone questions that, in effect, walk the user through each step of the mitigation planning process. At each step, guidance is given on how to obtain the information required to answer each question, although other tools may be used as well.

Detailed mitigation planning documents provided with permit applications can describe the way in which information was compiled. Such documentation should also include the rationale for question responses. The findings of the information gathering phase are summarized using the COWAP evaluation questionnaire (Appendix A.1) and this information is subsequently intended to be used to support decision making.

STEP 1. IMPACT SITE DESCRIPTION

Keystone Question:
What wetland resources would be impacted by the proposed action?

Supporting Questions:
- *What is the extent of wetland impacts?*
- *What type of wetland (HGM Class) is involved?*
- *Are there known special status species that occur on site?*

This step involves wetland boundary delineation and application of the Functional Assessment of Colorado Wetlands (FACWet: Johnson et al. 2012), or a comparable method, to provide information about the impact site. Impact site assessment supplies the basic information on the areal extent of proposed impacts, the type of wetland involved (including water source, geomorphic setting, and vegetation structure), and the condition of the resource. Table 1 provides a list of information items required in this step along with their intended usage. Information compiled from this step is entered into Table 2.

Aerial Extent of Impact
The standard practice in Colorado is that mitigation is approved at a minimum of a 1:1 ratio. That is, mitigation must improve at least the amount of wetland that would be impacted by an authorized action. Determination of the areal extent of a potential wetland impact serves two purposes. First, it informs regulators, and possibly the public, as to the magnitude of proposed impacts. Second, it sets the minimum area requirement for mitigation. Note that mitigation plans that include significant risk factors may require mitigation above a minimum value to ensure no net loss of wetland functioning. This is determined by regulatory agencies.

Table 1. Information items needed to complete the first step of the mitigation planning process, including their intended usage.

Information Item	Usage
Areal extent of impact	This information is used to gauge the magnitude of impacts and determine the minimal amount of mitigation.
Type of wetland involved	The watershed-scale ramifications of the impact are considered based on the identified wetland type and the watershed's wetland profile. This information helps identify risks in achieving mitigation success and determines what constitutes in-kind mitigation.
Condition of the resource	The present condition of the impact site helps set the target condition and performance criteria of the proposed mitigation, influences risk determination, and serves as the benchmark from which to gauge environmental lift brought by mitigation actions mitigation lift.

The Type of Wetland Involved

The type of wetland that will be impacted has a number of ramifications for mitigation site selection, risk assessment and decision making. Some wetlands, such as fens or alpine wetlands, can be very difficult to restore or impossible to create. Knowing the type of wetland that would be impacted by the authorized action also informs evaluation of the watershed-scale significance of the action. For example, in research described in earlier sections of this report, depressional wetlands were found to be the most common type, their numbers greatly inflated by land use changes and water management, and most examples were in poor condition. Conversely, only one slope wetland was identified, implying that that type of wetland and the functions it provides is rare in the landscape.

The relative commonness and/or watershed-scale condition of various wetland types is illustrated by wetland profiles. For example, in the case of the northern Front Range, a project proposing impacts to a slope wetland might be viewed as substantially riskier than one impacting a depressional wetland. The loss of that wetland type would produce a relatively large reduction in functions provided to the watershed and the opportunities to mitigate those losses appear to be extremely limited. Relatedly, identifying the type of wetland that would be impacted sets the criteria for what would be considered in-kind mitigation, however, this use of the information does not imply that in-kind mitigation is the best type in every situation. The 2008 Rule makes provisions for using out-of-kind mitigation, but determining the type of wetland that would be impacted provides a benchmark for determining what sort of mitigation would be in-kind and what would be out-of-kind.

The primary classification used in the COWAP is the hydrogeomorphic (HGM) classification (Brinson 1993). Other classifications can be used to describe vegetation and habitat, but HGM classes must be primary. Using classifications such as the Cowardin classification (Cowardin 1979) or the National Vegetation Classification System does not provide any assurance that wetland functions will be replaced by mitigation and this is a primary requirement of the CWA. All HGM classes present within the impact site should be identified separately with their corresponding area and condition class. Appendix A.2 provides a key to HGM classes in Colorado.

The Condition of the Resource

The condition of the wetland resource that would be impacted by a regulated action is key information that lends insight into the potential mitigability of proposed impacts and helps set targets for the necessary condition that must be achieved at the mitigation site in order to successfully compensate for authorized impacts. This information will be used to create mitigation performance and success criteria in Step 5.

To determine condition, a FACWet evaluation is performed at the proposed impact site. The findings of the FACWet evaluation are summarized by providing the FACWet Composite Score and associated condition class, as defined in Table 3. Generally, projects proposing impacts to high quality sites (condition grades of A or B) are considered “risky” because of the documented difficulty of developing highly functioning mitigation.

Table 2. Description of key impact site characteristics.

Impact Site Descriptor	Response
Amount of Impact	
Impact Site HGM Class	
Additional Classification	
Occurrence of Special Status Resource?	Yes No Unknown
Impact Site FACWet Composite Score	
Impact Site Functional Condition Class	

Table 3. Functional condition classes and associated FACWet composite scores.

FACWet Composite Score	Condition Grade	Functional Condition Class
0.8 – 1.0	A – B	Reference standard – highly functional
0.7 – <0.8	C	Functional
<0.7	D – F	Functionally impaired – non-functional

STEP 2. DEFINING MITIGATION TARGETS

Keystone Question:
What is the most ecologically-preferable mitigation and how does proposed mitigation compare?

Supporting Questions:
- *From Step 1, what wetland type (HGM Class) would be impacted by the proposed project?*
- *Based on the watershed wetland profile and watershed needs, is in-kind mitigation ecologically preferable?*
- *If the ecologically preferable mitigation type is not in-kind, what type of wetland mitigation would best improve watershed condition as illustrated by the wetland profile?*
- *What type of wetland (HGM Class) is being proposed for mitigation?*
- *Is the proposed mitigation wetland type the ecologically-preferable one?*

The goal of this step is to first identify the most-ecologically preferable wetland type (HGM Class) for mitigation and then to select the target mitigation type. This allows easy identification of the risk factors associated with a selected target wetland type. This step may commonly be performed in coordination with regulatory agencies, however, it is ultimately the responsibility of the permit applicant to propose a mitigation plan and then for regulators, and often the public, to weigh its relative merits.

A specific wetland type should be identified as the target for mitigation prior to identifying the actually property at which the mitigation will occur. This is actually a very important shift in emphasis resulting from the 2008 Rule. Previously, the preference for on-site mitigation, in effect, put property selection ahead of wetland type selection. This led to mitigation being constructed in inappropriate landscape settings that could not support the desired level or type of wetland functioning.

The easiest way to select a target wetland type is to first determine whether in-kind mitigation appears to be the most ecologically preferable. To do so, first consider the type of wetland being impacted in comparison to the watershed's wetland profile and watershed needs and goals. If the impact wetland is of a type that has been disproportionately impacted in the watershed, either through degradation in habitat condition brought on by land use change or outright destruction, then in-kind mitigation is likely the most ecologically-preferable option. Mitigation involving improvements of that type of wetland would be said to improve the watershed wetland profile.

If the impact wetland is an exotic type in the profile, out-of-kind mitigation may be the most ecologically-preferable option. The accompanying Front Range study provides an excellent example of the way in which ecologically-preferable mitigation options can be identified using wetland profiles. In the Front Range profile, riverine wetlands have been strongly, disproportionately impacted in the watershed. Depressional wetlands have proliferated, but they tend to be in poor condition. Therefore, in this watershed, the ecologically-preferable type of mitigation for riverine wetland impacts would be in-kind. Out-of-kind mitigation, particularly if it targets creation of a depressional wetland, would degrade the profile and so would probably not be ecologically-preferable. In cases in which the impact wetland type is depressional, in-kind mitigation may not be the most ecologically-preferable option. In particular, establishment (creation) of additional, low quality depressional wetland would be the least ecologically-preferable option.

Identifying or evaluating the merits of a proposed mitigation wetland type is carried out by addressing five basic questions (Table 4). There may be reasons to target a wetland type for mitigation that is not the most ecologically-preferable, but completing this step identifies preferences and signals when a proposed mitigation plan deviates from the preferred alternative.

Table 4. Five questions used to identify whether the proposed mitigation wetland type is the ecologically-preferable one, given the impact wetland type and watershed condition.

Question	Response	
1. What type of wetland (HGM Class) would be impacted by the proposed project?		
2. Based on the watershed wetland profile and watershed needs, is in-kind mitigation ecologically preferable?	YES	NO
3. If the ecologically-preferable mitigation type is not in-kind, what type of wetland mitigation would best improve watershed condition as illustrated by the wetland profile?		
4. What type of wetland (HGM Class) is targeted by the proposed mitigation?		
5. Is the proposed mitigation wetland type the ecologically-preferable one?	YES	NO

STEP 3. LANDSCAPE-LEVEL SCREENING OF WETLAND MITIGATION SITES

Keystone Question:
What options exist for successful mitigation of the required wetland type within the appropriate geographical area?

Supporting Questions:
- *Where can mitigation be located geographically?*
- *What general features should a candidate mitigation site possess?*

The goal of Step 3 is to identify promising candidate mitigation sites within an appropriate geographical proximity to the impact site. Step 3 is a preliminary screening step generally carried out remotely as an "in-office" exercise. This step may be skipped if only a small number of candidate sites are known to exist, and those will be surveyed on the ground.

The screening of mitigation sites is a systematic vetting process that filters out sites that do not meet selection criteria (Fig. 7). The intention of this step is to single out the most ecologically-preferable mitigation site options, and/or document the shortcomings of suboptimal alternatives. The most ecologically-preferable candidate mitigation sites are those which have the highest probability of achieving success criteria and that possess a minimum of risk factors. The screening process is illustrated in Fig. 7 within the bounds of the Colorado, understanding that state boundaries may not be relevant in practice, since watersheds cross state lines. The first selection criterion depicted in Fig. 7 was defined in Step 2 of the COWAP, when the target mitigation type was determined. This criterion eliminates from further consideration all potential mitigation areas which are incapable of supporting the target wetland type, for any reason.

The second criterion is one of geographic proximity to the proposed impact. The second screening factor only allows consideration of sites within a certain geographic range of the proposed impact site. In mitigation banking scenarios, this geographic range is the bank service area. In non-banking situations, this would be the appropriate geographical range as determined by regulatory staff. COWAP uses the intersection of watersheds and ecoregion boundaries to define the geographical extent of this filter. The standard parameters used to set a geographical range are HUC 8 watersheds and Level 3 Ecoregions. Setting the geographical range for mitigation using these parameters has been a common practice in Colorado, and is perhaps the most common way that bank service areas are set across the country. HUC 10s and/or Level 4 Ecoregions may be appropriate in some cases.

In practice the applicant usually applies the wetland type and geographic filters simultaneously to develop the basic mitigation site search image. For example, in a search for slope wetland mitigation sites the South Platte Headwaters watershed/Southern Rockies Ecoregion might form the basic search image.

The third filter is applied to each of the sites identified in the steps above. In this step, landscape and site-level factors are considered to rule out the remaining inappropriate sites. These screening factors are described in the form of six simple yes/no questions (Table 6). In each case, an answer of "no" indicates a condition of mitigation risk. In complex mitigation scenarios, screening filters could literally take the form of an algorithm in a GIS, but generally this step will be undertaken "manually," identifying a population of potential sites using various geographic and data resources and then applying the screening questions.

The final output of the screening process is a list of candidate mitigation site alternatives which, optimally, represent the most ecologically-preferable options or otherwise the available mitigation options. In practice, suboptimal sites may be included within the final candidate pool for various reasons. The deficits (risk factors) inherent in these options are cataloged by the COWAP and will be weighed during the decision making process. Candidate sites may also be eliminated from the final list for practical reasons, such as ownership. Of the list of candidate mitigation sites, one or more top candidates are selected for further review in Step 4.

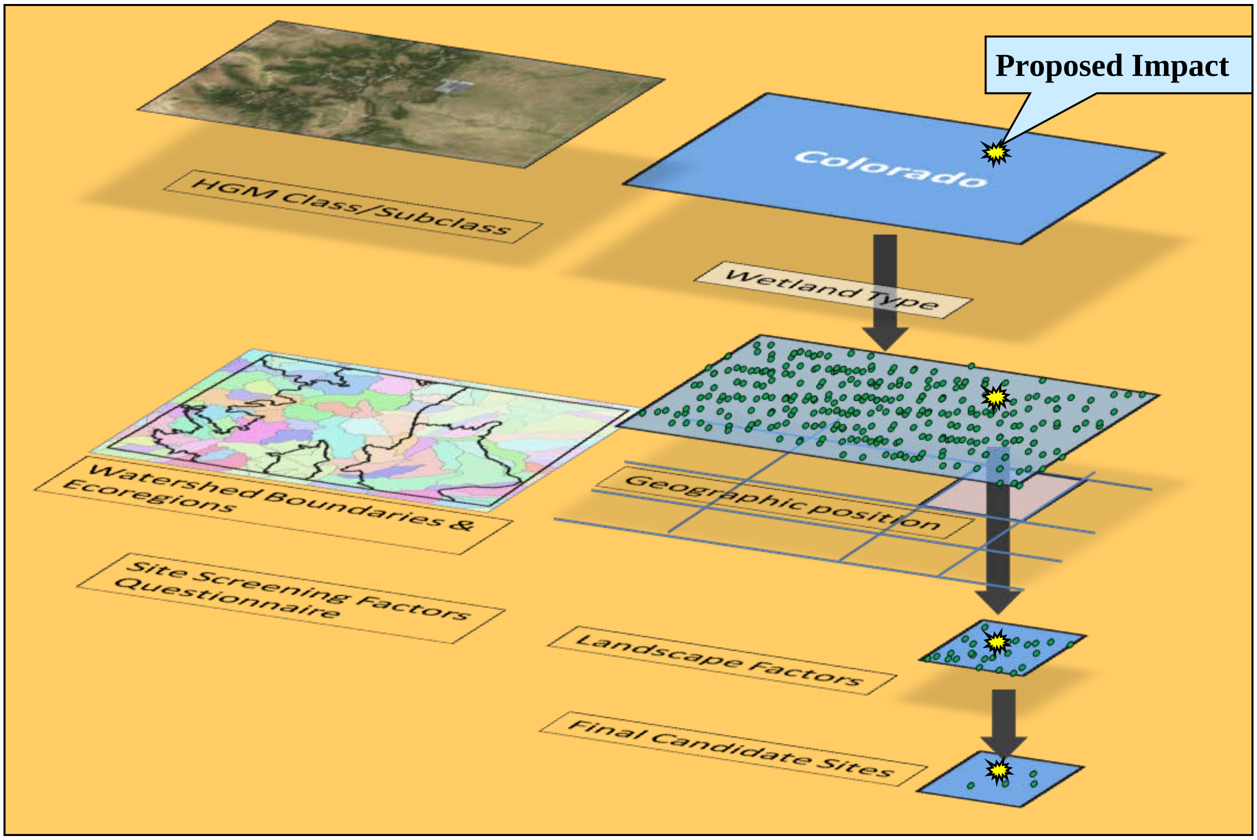

Fig. 7. The mitigation site screening process employs a series of filters to eliminate undesirable sites from contention. The series of diagrams on the right illustrate the generic screening process. On the left, diagrams indicate the actual screening criteria in COWAP. In this model, search criteria begin broad but become successively more refined. The three filters that are applied in site screening are based on the target wetland type, geographic proximity to the proposed impact, and landscape factors. See text for additional details.

Table 6. Factors used in the landscape-level assessment of potential wetland mitigation sites.

Landscape Review Indicators	Yes	No
1. Does the contributing area to the proposed mitigation site contain mostly natural land and aquatic resources in relatively good condition?		
2. Does the project watershed area contain a prevalence of the wetland type being proposed for mitigation?		
3. Is the proposed mitigation site in proximity to an appropriate type of water source needed to support a desired HGM type of wetland?		
4. Does the proposed mitigation site possess hydric soils or is its substrate in relatively good condition?		
5. Is there an adequate buffer area to sustain the proposed mitigation site?		
6. Is the proposed mitigation site in close proximity to a significant natural area?		

STEP 4. EVALUATING SITE-LEVEL ECOLOGICAL SUITABILITY FOR COMPENSATORY MITIGATION

Keystone Question:
How suitable is the proposed mitigation site for supporting the required wetland type and at the necessary condition?

Supporting Questions:
- *Is the proposed mitigation site located within an appropriate landscape setting to support the target wetland type and level of condition?*
- *Is the category of proposed mitigation appropriate given site location?*
- *Can the primary stressors affecting the proposed mitigation site be remediated?*

The questions posed in this step are answered using FACWet or other appropriate method. The COWAP is structured around FACWet, if a different assessment method is used the tables presented below will need to be modified accordingly. In this step a FACWet evaluation is performed at one or more of the most promising candidate sites. The scores and information generated by the FACWet is used to answer questions and populate the information matrices included as Tables 7 – 9.

Answering the first question posed in the box above involves confirming the assessment of factors presented in Table 6 of Step 3 and evaluating the hydrogeomorphic attributes of the mitigation site pre- and post-build, in light of characteristics that define the target HGM class. This summary is documented in Table 7. In making such comparisons, it is very important to understand that COWAP does not evaluate the technical feasibility of a specific method of wetland improvement. ***If the post-build condition of mitigation does not have the fundamental defining characteristics of the target HGM class, then the mitigation will not replace the wetland functions lost through a federally-authorized action.***

The category of mitigation (Table 8) is important since it is often used to set compensation ratios, which when multiplied by the extent of impacts defines the areal requirement of mitigation. The category of mitigation is determined from the composite site score generated through the pre-build FACWet evaluation (Table 8). In Table 8, the level of preference is provided for each mitigation category. Re-establishment is generally the most preferred form of mitigation, since it has a higher chance of success than establishment (creation), and it typically provides the potential for mitigation to induce a higher degree of environmental lift than rehabilitation.

The final question as to whether, or to what degree, the primary stressors can be remediated is evaluated by examining the information compiled during the FACWet assessment. The applicant lists the primary stressors affecting each FACWet variable called for in Table 9, and responses are given as to whether each would be remediated through mitigation. This simple format helps to highlight which stressors will remain after mitigation and may identify disjuncts between proposed mitigation plans and realistically achievable outcomes.

Table 7. A matrix of hydrogeomorphic factors and mitigation site condition, aimed at identifying inconsistencies between predicted post-build site characteristics and those of the target HGM class. Answers of "no" identify areas of mitigation risk.

				Is the Post-build condition the same as the target HGM Class?	
Attribute	**Mitigation Site (Pre-Build)**	**Mitigation Site (Post-Build)**	**Target HGM Class (or Subclass)**	**Yes**	**No**
Water Source					
Geomorphic Setting					
Hydrodynamics					
Organic Soils or Forested Wetland Present?					

Table 8. A table converting FACWet scores to mitigation categories.

FACWet Score	Mitigation Category	Preference Ranking
1.0 – 0.85	Preservation	Only in exceptional circumstances
<0.85 – 0.65	Rehabilitation	High preference
0.65 – 0.50	Re-establishment	Highest preference
<0.50	Establishment	Lowest preference – riskiest option

Table 9. The primary stressors affecting each FACWet variable are recorded and put to the question of whether, or to what degree, each would be remediated through mitigation.

FACWet Variable	Primary Stressors	Is the stressor(s) remediable through mitigation action?		
		Yes	Partially	No
Habitat Connectivity				
Contributing Area				
Water Source				
Water Distribution				
Water Outflow				
Geomorphology				
Soil and Water Chemical Environment				
Vegetation Structure and Complexity				

STEP 5. DESIGNATION OF DESIGN GOALS AND SUCCESS CRITERIA

Keystone Question:
What are the desired and promised outcomes of mitigation?

Supporting Questions:
- *What are the project's design goals?*
- *What specific criteria define success?*

Design goals summarize the treatments that will be applied to a mitigation site. They constitute the proposed solutions to the stressors affecting a site. Performance criteria are narrative and quantitative benchmarks that define mitigation success. The design goals and performance criteria of each project are unique, but the FACWet framework provides a useful way to structure them. FACWet version 3.0 provides a discussion about performance criteria in the FACWet framework, including an actual example. That section of the FACWet manual (whose development was also part of this project) was excerpted and is included next.

Structuring Design Goals and Performance Criteria Using the FACWet Framework
Once a mitigation site has been selected and baseline conditions documented, the next phase is to plan the project by identifying ecological goals and setting specific design objectives according to a guiding image. In this task, a road map is laid out to describe how the stated objectives are going to be met and how progress will be demonstrated along the way (Table 10). Ecological goals are generally described in terms of the habitat type and functional improvements that would result from the mitigation project. The goals should be clear about whether the project is restoration of an historic wetland, enhancement or protection of an existing wetland, or establishment of new wetland habitat. Ecological goals are formally mandated in CWA regulation through permit conditions stipulating whether mitigation is to be in-kind or out-of-kind with reference to the habitat which would be impacted by a regulated action.

The approach that will be taken to meet ecological goals is made clear in a set of design objectives. FACWet provides a practical way to make design objectives explicit by identifying which variables can be targeted for improvement by particular treatments and specifically how much improvement can be expected. Based on the intended or predicted ecological responses, an expected score range is set for each target variable and this can ultimately be used to summarize mitigation goals (Table 7; Target Condition Class/Score Range). Design objectives and performance criteria define the character or behavioral limits for target variables that would qualify as meeting scoring range conditions. As such, performance criteria become site-specific replacements for FACWet's rapid assessment scoring guidelines. Performance criteria are agreed upon rules and these can be used to describe performance criteria in compensatory mitigation as required under 40 CFR 230.96.

Ultimately, the performance criteria will be used to create a monitoring plan to track project success. The final phase of mitigation project planning is to define specific monitoring parameters that will be used to evaluate performance of the project by assessing the condition of target variables relative to performance criteria.

Table 10. An example of a FACWet-based summary of ecological goals, design objectives, performance criteria, and monitoring parameters used to gauge mitigation success on the Four-mile Fen project.

Variable	Target Functional Class/Score Range	Design Objectives and Performance Criteria	Monitoring Parameters Used to Demonstrate Compliance and Success
Habitat Connectivity	Reference Standard (0.9 – 1.0)	Maintenance of historical land use	Evaluation of aerial photography. Field survey if necessary
Contributing Area	Reference Standard (0.9 – 1.0)	Maintenance of historical land use	As above.
Water Source	Reference Standard (0.9 – 1.0)	Utilization of the natural water source for the wetland (springs)	16 data logging groundwater wells demonstrate functioning of wetland water source
Water Distribution	Reference Standard (0.9 – 1.0)	*Fen wetland* – 66% growing season water table at or above 30 cm, with an avg. depth 37 cm *Mineral* soil wetland – 12.5 to 47% of growing season water table at or above 30cm, with an avg. depth of 50 cm	As variable 4, with 12 additional manually read wells
Water Outflow	Reference Standard (0.9 – 1.0)	Re-establish groundwater outflow characteristics	As in variables 4 and 5, including three flow stations in the ditch (pre-construction)
Geomorphology	Reference Standard (0.9 – 1.0)	Filling of the ditch and removal of its berm Microtopographical improvement Soil surface recovery	69 permanent transects sampled annually and annual survey of 154 benchmarks
Chemical Environment	Reference Standard (0.9 – 1.0)	Restoration of the characteristic redox environment and improvement of soil chemistry characteristics	Annual soil chemistry analysis at 32 plots. Monitoring 30 soil redox probes.
Vegetation Structure and Complexity	Highly Functioning (0.8 – 0.9)	Trend toward or achievement of reference conditions Species Richness within range of reference Weedy and invasives (<10%)	Visual estimation of vegetation coverage by species within 32 5-meter diameter, permanent vegetation plots and 10 transects across the filled ditch.

Table 10 illustrates the use of FACWet for defining ecological goals, design objectives, performance criteria, and monitoring parameters using an example from a mitigation bank. Ecological goals are made explicit in the second column of the table which defines a target value for each variable listed in the first column. This highlights the specific ecological processes which are targeted for remediation, and predicted outcome of mitigation actions. The third column defines the specific design objectives and performance criteria used for appraising project success. These criteria are essentially the trigger that signals when the mitigation project has successfully met its objectives. The last column in the table lists the specific parameters or metrics that will be measured to objectively monitor project progress.

In the mitigation bank example, the site was determined to be impaired owing to degradation caused by a ditch and intensive cattle grazing. At the planning stage, the guiding image for mitigation is described, which in this example includes restoration of historic wetland condition by removing identified stressors. The design goals included filling the ditch to recreate the pre-existing soil profile and restore the Water Distribution and managing livestock with exclusionary fencing and a grazing management plan. The ecological goals, as outlined in the second column, are to restore the condition of Variables 1-7 to *reference standard* condition (score ≥ 0.90) and Variable 8 to the level of highly functional (score ≥ 0.80). In the third and fourth columns the specific project objectives are laid out as design goals and performance criteria along with the identification of monitoring parameters relevant to each variable. It is important that the monitoring plan is devised in the planning stage, prior to any construction. Looking at Water Distribution, for instance, one of the specific performance criteria is for the water table within fen areas to be within 30 cm of the surface for at least 66% of the time during the growing season. The table indicates that this objective will be monitored by measuring the hydrographs at 28 sites equipped with groundwater wells. The project is considered successful in terms of water distribution once this criterion has been demonstrated using these prescribed monitoring parameters.

APPENDIX A.1: COWAP BASIC MITIGATION PLAN QUESTIONAIRE

The COWAP questionnaire tables described in the text are arranged according to the Train Syllabus on the Watershed Approach *Review Factor* they inform during the decision making process.

Review Factor 1 – Impact Site Description
Enter the information requested in the table.

Impact Site Descriptor	Response
Amount of Impact	
Wetland type	
Occurrence of special status resource?	Yes No Unknown

Review Factor 2 – Impact Site Condition
*Enter the **impact wetland's** FACWet score in the condition category cell that holds the score range in which the impact wetland's score falls.*

	Impact Site Condition		
	Good/excellent (0.8 – 1.0)	Fair (0.7 – 0.8)	Poor (<0.7)
Impact Site FACWet Composite Score			

Review Factor 3 – Mitigation Category
Enter the mitigation wetland's FACWet score in the mitigation category cell that holds the score range in which the mitigation wetland's score falls.

Mitigation Site Composite FACWet Score	FACWet Score	Mitigation Category	Preference Ranking
	1.0 – 0.85	Preservation	Only in exceptional circumstances
	<0.85 – 0.65	Rehabilitation	High preference
	0.65 – 0.50	Re-establishment	Highest preference
	<0.50	Establishment	Lowest preference – riskiest option

Review Factor 4 – Mitigation Consistency with Watershed Profiles

The table below is used to identify the most ecologically-preferable type of wetland for mitigation given the wetland impact type and the watershed condition as portrayed through a wetland profile. The relative preference for the varying circumstances of a mitigation plan are provided in the table below.

Question	Response	
1). What type of wetland (HGM Class) would be impacted by the proposed project?		
2). Based on the watershed wetland profile and watershed needs, is in-kind mitigation ecologically-preferable?	YES	NO
3). If the ecologically-preferable mitigation type is not in-kind, what type of wetland mitigation would best improve watershed condition as illustrated by the wetland profile?		
4). What type of mitigation wetland (HGM Class) is being proposed?		
5). Is the proposed mitigation wetland type the ecologically-preferable one?	YES	NO

Mitigation Type	Ecological Preference
In-kind and improves or maintains wetland profile or watershed goals	Highest
Out-of-kind and improves wetland profile	High
In-kind, maintains derived condition of watershed or does not work toward watershed goals	Low
Out-of-kind, no benefit to profile or movement of profile away from desired goals	Undesirable

Review Factor 5 – Mitigation Site Suitability – Landscape Review

Provide answers to the six questions posed in the table

Landscape Review Indicators	Yes	No
1. *Does the contributing area to the proposed mitigation site contain mostly natural land and aquatic resources in relatively good condition?*		
2. Does the project watershed area contain a prevalence of the wetland type being proposed for mitigation?		
3. *Is the proposed mitigation site in proximity to an appropriate type of water source needed to support a desired HGM type of wetland?*		
4. Does the proposed mitigation site possess hydric soils or is its substrate in relatively good condition?		
5. *Is there an adequate buffer area to sustain the proposed mitigation site?*		
6. Is *the proposed mitigation site in close proximity to a significant natural area?*		

Review Factor 6 – Mitigation Site Suitability – Field Review

Fill out the table below by entering the mitigation wetland's water source, geomorphic setting, hydrodynamics, and soil and canopy status as they exist prior to mitigation and as they are predicted to exist after mitigation is completed. Provide the characteristic status of each wetland attribute in the target HGM class. The possible answers are provided with HGM attribute. For each wetland attribute, answer whether the post-build mitigation site will possess the characteristics of the target HGM class. Answers of "no" indicate significant risk factors and may signal that mitigation has been misclassified.

				Is the Post-build condition the same as the target HGM Class?	
Attribute	**Mitigation Site (Pre-Build)**	**Mitigation Site (Post-Build)**	**Target HGM Class (or Subclass)**	**Yes**	**No**
Water Source (Surface, Ground or Precipitation)					
Geomorphic Setting (Floodplain, depression, associated with sloping terrain, lake or reservoir Fringe)					
Hydrodynamics (unidirectional, vertical, bidirectional)					
Organic Soils or Forested Wetland Present? (yes, no)					

Review Factor 7 – Mitigation Performance over Time

Provide the target FACWet composite FCI score along with the corresponding functional condition class in the first column. In the second column provide the specific design objectives and performance criteria that will indicate the attainment of that FACWet condition class. Every variable should have a performance criterion associated with it, even if it will not be targeted by mitigation actions. For variables that would not be affected by mitigation, "maintenance of existing conditions" may be an acceptable performance criterion. The third column contains the list of monitoring parameters that will be used to document mitigation performance.

Variable	Target Functional Condition Class/Score Range	Design Objectives and Performance Criteria	Monitoring Parameters Used to Demonstrate Compliance and Success
Habitat Connectivity			
Contributing Area			
Water Source			
Water Distribution			
Water Outflow			
Geomorphology			
Chemical Environment			
Vegetation Structure and Complexity			

APPENDIX B: CNHP LLWW Coding Procedures

CNHP LLWW Coding Procedures

Updated 5-18-2012

ArcGIS SQL protocol and procedures for converting Cowardin Wetland Classification codes into LLWW Classification codes to obtain HGM style information. The procedure is designed to be mutually exclusive in the end product. With few selective overwriting of values related to inferred relative importance.

Notes that will aid in reading this procedure:

- wetlands = spatial layer of wetland polygons created and coded to NWI classification.
- '' two single quotes in a query indicate there has been no value entered
- Blue_text = Output files
- Red_text = Input Files
- Green text = Field names in attribute tables
- % allows for a variety of characters to be present. Example: a query for "PUB%" could yield: PUBF, PUBG, PUBH, PUBGx, PUBFx, PUBGh, etc.

Step #	***Action***	***Included NWI Codes***
1	Run Slope using 10m DEM	***Spatial Analyst>Slope***: percent_rise *INPUT*: 10m_dem *OUTPUT*: 10m_slope
2	Reclassify into greater than and less than 4% slope.	***Spatial Analyst>Reclass>Reclassify***: *INPUT*: 10m_slope *RECLASSIFICATION:* 0-4 = 1, 4-1000 = 2 *OUTPUT*: slope_recl
3	Convert reclassified slope into polygons	***Conversion Tools>Raster>Raster to Polygon***: *INPUT*: slope_recl *OUTPUT*: slope_polys
4	Select and export polygons less than 4%	***Select by Attributes***: *VALUE* = 1 *EXPORT DATA*: flat_area
5	Add fields to wetland_polygon table	**Waterbody** (text), **Gradient** (short int), **Lake_Mod** (short int), **Water_Flow** (short int), **Pond** (text), **Spec_Mod** (text), **Landform** (text), **Flow_Path** (text)

A: Waterbody Classification		
DW	Select all lakes	***L1UB%***
LE	Select all lakeshores and shallow lake features	***L2US%, L2UB%***
RV	Select all rivers	***R2UB% OR R3UB%***
ST	Select all streams	***R4%***
LE	Select all features that "touch the boundary of DW"	Select from selected features "Waterbody" = ''
LE	Select all features "within a distance of 20m OF DW"	Select from selected features "Waterbody" = ''
LR	Select all features that "touch the boundary of RV"	Select from selected features "Waterbody" = ''
LR	Select all features "within a distance of 20m of RV"	Select from selected features "Waterbody" = ''
LS	Select all features that "touch the boundary of ST"	Select from selected features "Waterbody" = ''

LS	Select all features "within a distance of 10m of ST"	Select from selected features "Waterbody" = ''
LR	Select all features "within a distance of 10m of Perennial streams" (1:24k bluelines)	Select from selected features "Waterbody" = ''
LS	Select all features "within a distance of 5m of Intermittent streams, stream connectors, canals, ditches" (1:24k bluelines)	Select from selected features "Waterbody" = ''
LS	Select all Rp1 features.	Select from selected features "Waterbody" = ''
TE	Select all features with "Waterbody" = ''	
B: Lake Modifier		
3	Classify impounded lakes with the "h" modifier as 3	***L1UB%h, L2UB%h***
4	Classify excavated lakes with the "x" modifier as 4	***L1UB%x, L2UB%x***
1	Classify natural lakes without a modifier as 1	***L1UBG, L1UBH, L2UBG, L2UBH***
3	Features that share a boundary with lakes that have a LM of 3, give LM of 3 also.	
4	Features that share a boundary with lakes that have a LM of 4, give LM of 4 also.	
1	Features that share a boundary with lakes that have a LM of 1, give LM of 1 also.	
C: Special Modifiers		
b	Select all features with beaver modifier (b)	***%b***
h	Select all features with impounded modifier (h)	***%h***
x	Select all features with excavated modifier (x)	***%x***
d	Select all features with drained modifier (d)	***%d***
f	Select all features with farmed modifier (f)	***%f***
D: Pond Modifier		
p	Select all pond features	***PAB%, PUB%***
E: Landform Type		
IL	Identify islands in lakes	Select all DW features and select by location any feature "completely within"
FR	Select all shore features	***L2US%***
FR	Select all PEMF's that "touch the boundary of DW", lakes	***PEMF%***
FR	Select all PEMF's that "touch the boundary of p", ponds	***PEMF%***
FR	Select all lentic Riparian features (Rp2)	***Rp2%***
FP	Select all LR and LS waterbodies	Select from selected features "Landform" = ''
FP	Select all lotic riparian features (Rp1)	***Rp1%***
FP	Select all RV and ST waterbodies	
BA	Select all ponds (p)	Select from selected features "Landform" = ''
FP_ba	Select all ponds (p)	Select from current selection "Landform" = 'FP'
BA	Select all features with 'x' and 'h' and 'f' modifiers	Overwrite other features
BA	Select all features that intersect [flat_area]	Select from selected features "Landform" = ''
SL	Select all features that intersect [flat_area]	Reverse selection. Select from selected features "Landform" = ''
F: Flow Path		
TH	Select all rivers and streams	***RV, ST***

BI	Select all shore features	***L2US%***
BI	Select all water regime F's AND are FR landforms	
TH	Select all LE features	Select from selected features "Flow_Path" = ''
TH	Select all dammed lakes	***L1%h, L2%h***
IN	Select all natural lakes, "Lake_mod" = '1'	Select from selected features "Flow_Path" = ''
TH	Select all LR and LS waterbodies	Select from selected features "Flow_Path" = ''
	Buffer the wetlands by 20m	***Analysis Tools>Proximity>Buffer***: *INPUT*: wetlands *OUTPUT*: wetlands_20m *Linear Unit*: 20
	Create topology with "Must not overlap" rule	
IS	Validate topology and select features from error report, then reverse the selection.	Select from selected features "Flow_Path" = ''
CO	Select features "Flow_Path" = ''	
G: Water Source		
SF	Select all DW and shore features	***L1%, L2US%, PUS%***
OV	Select features with "centroid within" Riparian area AND "centroid within" 20m of RV features	Select from selected features "Water_Srce" = ''
OV	Select features with "centroid within" Riparian area AND "touching the boundary" RV features	Select from selected features "Water_Srce" = ''
OV	Select features with "centroid within" Riparian area AND "centroid within" 10m of ST features	Select from selected features "Water_Srce" = ''
OV	Select features with "centroid within" Riparian area AND "touching the boundary" ST features	Select from selected features "Water_Srce" = ''
PP	Select all TE features WITH "landform" = 'BA'	Select from selected features "Water_Srce" = ''
GW	Select all "Landform" = 'SL'	Select from selected features "Water_Srce" = ''
SF	Select features "Water_Srce" = ''	

APPENDIX C: CNHP Wetland Mapping Procedures

COLORADO NATURAL HERITAGE PROGRAM WETLAND MAPPING PROCEDURES

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Version Date: March 29, 2013

Scope of Document

This document was prepared by the Colorado Natural Heritage Program (CNHP), a research unit of the Warner College of Natural Resources and Colorado State University. It describes procedures used by CNHP to map wetlands in Colorado. All wetland mapping conducted by CNHP is in collaboration with the U.S. Fish and Wildlife Service (USFWS)'s National Wetlands Inventory (NWI) Program and follows the Federal Geographic Data Committee (FGDC)'s most recent standards for wetland mapping (FGDC 2009).

There are two primary types of wetland mapping carried out by CNHP:

1) Conversion of original NWI paper maps to digital polygonal data. The original NWI paper maps were produced in the 1970s and 1980s and are currently available as either hard copy paper maps or scanned images, but are not available as digital polygonal data. CNHP works in partnership with the NWI program to convert these hard copy maps to geo-referenced digital polygonal data. Polygons and attributes are not updated or corrected in this process, except in cases where the original attribute is now considered an invalid code. When converting original NWI mapping, CNHP is responsible for the accurate representation of the original mapping in a digital form, but not for the accuracy of how well the data represent wetlands on the ground.

2) Creation of new, updated digital NWI maps delineated in ArcGIS and based on the most recent aerial photography available. When delineating newly updated NWI maps, CNHP is responsible for all aspects of accuracy and precision.

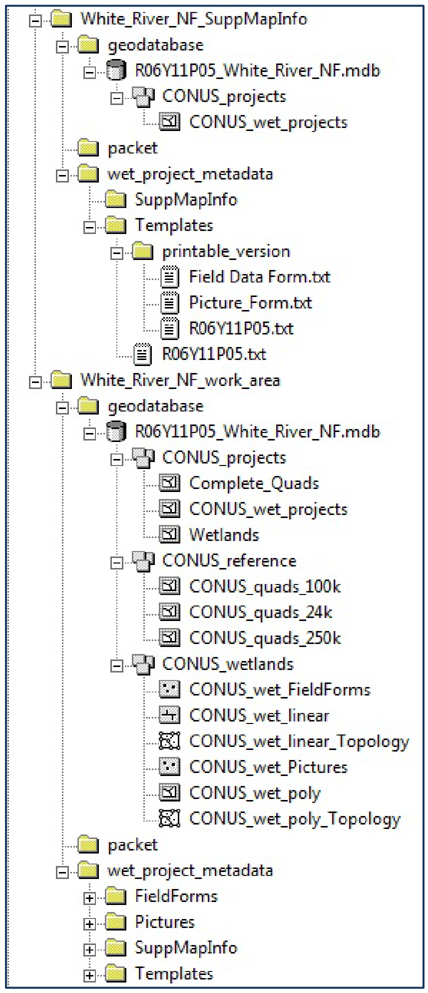
This document is primarily intended as an internal communication tool for CNHP's Wetland Mapping Specialists. Certain sections, therefore, may lack background information of interest to external readers. More information is available upon request.

Funding for CNHP's wetland mapping projects has come from a variety of partners, including U.S. Environmental Protection Agency (EPA), U.S. Forest Service (USFS), Bureau of Land Management (BLM), and National Academy of Science (NAS)'s Transportation Research Board (TRB). Non-Federal matching support has come from Colorado Parks and Wildlife (CPW), Great Outdoor Colorado (GOCO), Colorado Department of Transportation (CDOT), and Colorado Water Conservation Board (CWCB).

Table of Contents

A. Project Check-out/Prep Work

1. ***Checkout Project Area from NWI:*** Choose the quads in the project area. Merge and dissolve into a single polygon shape. Submit to Regional NWI Coordinator Kevin Bon (Kevin_Bon@fws.gov). Kevin will reply with a "Checkout Packet" which will include documentation, a database with the checkout area, any existing wetland shapes and supplemental layers. Below is a view of the file structure in ArcCatalog.



2. ***Identifying Priorities/Intermediate Deadlines:*** These must be known early in the planning stages before mapping begins. Once the project area is divided into sets (see below) it can be very confusing to split sets or complete single quads for an intermediate data request. If priority areas or intermediate deadline exist (i.e., if the sponsor requests a certain set of the data before the entire project is complete) these should be flagged and the project area should be divided accordingly.

3. ***Aerial Imagery for New Mapping Updates:*** New mapping updates will be based on the most current digital aerial photography available. In most cases, this imagery will be obtained from the USDA Farm Service Agency, Aerial Photography Field Office in Salt Lake

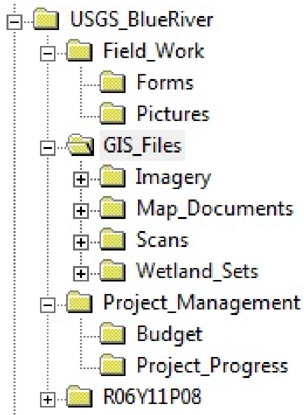
City, Utah (http://www.apfo.usda.gov). In special circumstances, imagery may be provided by a project sponsor for a specific project area. The imagery used must be color infra-red (CIR) and must meet all requirements stated in the FGDC standard for wetland mapping (FGDC 2009). The minimum imagery needed to perform new mapping updates is CIR imagery for the year the wetland mapping is being updated to, and CIR imagery for one other year. Two or more additional years is preferable, as having multiple years available (such as a drought year and wet year) supports more accurate water regime determination.

4. ***Tracking Project Progress:*** Progress on each mapping project is tracked in an Excel spreadsheet. Several template versions are located on the CNHP Server at P:\Wetland_Mapping\SupportFiles\Project_Progress_Templates. Three types exist: 1) Double_Scan_Quads, 2) Single_Scan_Quads and 3) New_Mapping_Updates. Slightly different intermediate steps warrant multiple versions. Projects with quads in more than one of these statuses should have the quads broken up and worked on separately and progress recorded in each respective spreadsheet. An additional, Full_Project_Progress spreadsheet should be created to track overall progress.

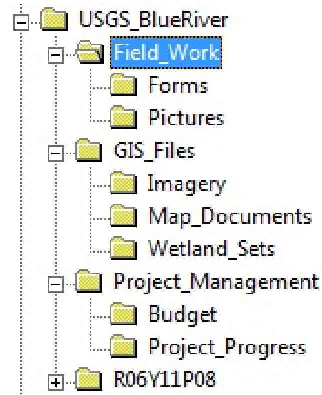
5. ***Dividing Project Area:*** It is usually not feasible to work continuously on a single feature class for a project area; therefore, the quads within the project area are divided into "sets".
    a. When converting original NWI maps to digital polygons, blocks can be made up of four quads in a 2x2 square. A 4x1 linear set can also be created. There is no difference between the two and often the overall project area will determine the correct set structure. Working with more than 4 quads can be very cumbersome and more densely populated quads may want to be divided into smaller sets.
    b. When delineating new wetland features, quads should be dealt with singularly.

6. ***Naming Conventions/File Structure:*** The standard file structure below shows an Old-Digital Conversion project and a New Mapping Update project. The only difference between these two structures is the addition of a "GIS_Files/Scans" folder to hold rasters of NWI maps, if available.

Old-Digital Conversion



New Mapping Update



Daily work should be complete on a local drive (C:\temp) and copied back to the proper location on the P:\ drive at the end of the day. Additional daily or AT LEAST weekly backups should be completed to a third (external) drive. Backup files should be named explicitly with a date (e.g., “Backup\USGS_BlueRiver\7_17_2011”). Naming conventions for the wetland files produced during the procedure:

“ProjectCode”_Set_”#”_wetlands_pre_attribution.shp (after Step 3)
“ProjectCode”_Set_”#”_wetlands_post_attribution.shp
“ProjectCode”_Set_”#”_wetlands_qaqced.shp (ready to be merged)
“Project”_merged_wetlands (post merging)
“Project”_checked_wetlands (after topology and script run)

“ “ are values that change with the set or project.

B. Overview of CNHP ArcGIS Method for Digital Conversion

CNHP uses the ArcScan extension for ArcGIS 10.x to convert rasters (scanned data) into digital vector data. The steps below represent the conceptual process taken to convert raster NWI data into vector data. More detail on each step is spelled out in the following section.

1. Project rasters into NAD83: Albers projection. Extract the data within each individual quad and mosaic 4 to 6 quads worth of data into a set.
2. Use the ArcScan extension to generate vector lines on all the visible lines on the mosaicked raster.
3. Inspect lines that represent linear features (rivers and streams) and merge line segments into complete continuous lines that accurately represent linear wetland features.
4. Attribute the linear features with their NWI wetland code, and populate a field with buffer distance values that correspond to the desired width of linear features.
5. Convert all enclosed features into polygons.
6. Buffer the linear features using the values in the Buffer Distance field.
7. Copy the buffered lines into the feature class created in step 5.
8. Attribute all features with NWI wetland codes.
9. Run topology and QAQC tests as described in Section F and make necessary changes.

C. Work Flow for Digital Conversion of Original NWI Mapping, using ArcScan extension

1. Copy the GDB "Wetlands_Domain.gdb" from P:\Wetland_Mapping > SupportFiles into the appropriate set folder.

2. Load quad TIFFs for the defined set to your map document.

3. For each TIFF:

    - Project in Albers (Data Management Tools > Projections and Transformations > Raster > Project Raster) with the output landing in the geodatabase in the set folder mentioned in step 1.

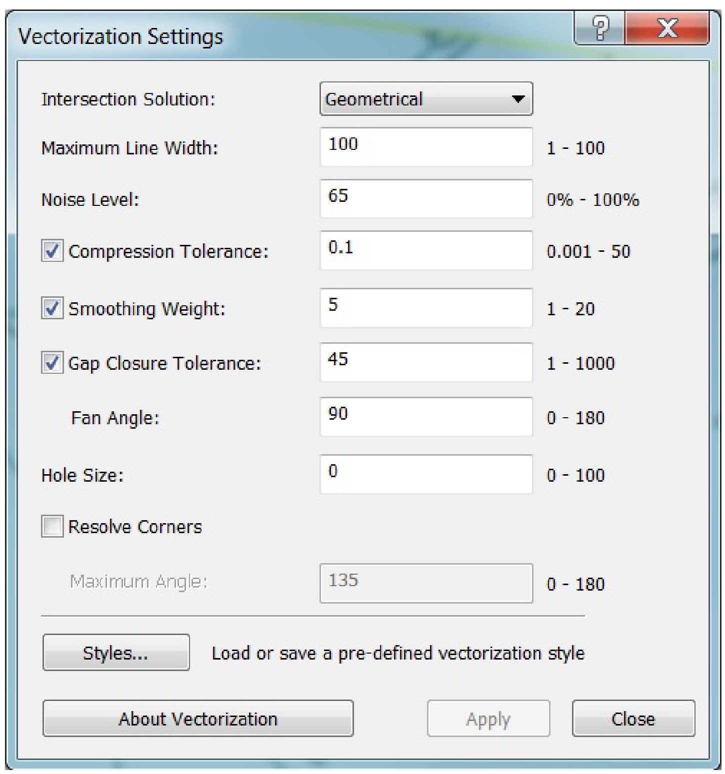
    - Extract each Tiff individually by highlight the quad boundary and extracting by mask (Spatial Analyst Tools > Extraction > Extract by mask).

4. Mosaic rasters together (Data Management > Raster > Raster Dataset > Mosaic to New Raster). Output location should be the GDB in the set folder. Number of bands = 1.

5. Add the 'Lines' blank linear feature class from the GDB to the map.

6. Start an editing session on the linear feature class created in the previous step.

7. Enter the following "vectorization settings" In the ArcScan toolbar drop down menu:



8. Select "Generate Features" under the Vectorization dropdown. Uncheck the box that says "Generate polygons where the maximum line width setting is exceeded." Make sure the mosaic raster is in the ArcScan Raster selection.

9. Examine all linear features to ensure they are smooth and continuous. Manually draw or correct any linears missed or misrepresented during automated processing and merge necessary segments. Once a linear is merged and correct, enter the corresponding code into the "Attribute" attribute field.

10. Close any open polygon lines within the feature class or along the edges.

11. Once you are confident the feature line work is correct, use it to create polygons (Data Management > Features > FeaturetoPolygon). Save the feature class as "ProjectCode_set_XX_pre_attribution" in the GDB.

12. Export all attributed linears to the GDB. Name the output "linears_for_buff_set_X".

13. Enter the correct buffer width for the following categories in the "Buff_Dist" field:
    - Palustrines = 3m (6m)
    - Riverine Perennial (R2/3) = 4m (8m)
    - Riverine Intermittent (R4) = 3m (6m)
    - Lacustrine = 4m (8m)

14. Buffer the "linears_for_buff_set_X" using the "Buffer_Width" field (Analysis > Proximity > Buffer). Name the output 'Linears_Buffered_set_X'.

15. Copy and paste 'linears_buffered_set_X' into the 'ProjectCode_set_XX_pre_attribution' feature class.

16. Add, merge, and correct all polygons.

17. After saving edits and closing your map document, copy your geodatabase to the appropriate folder in P:Wetland_Mapping and name it (ex. 'SRLCC_set_28_wetlands_pre_attribution')

18. In ArcCatalog, apply the domain "Attribute" to the "ProjectCode_set_XX_pre_attribution" feature class. If you notice any common attributes that exist in the current set but are not included in the attribute domain, add those values to the domain.

19. Attribute polygons.

20. QAQC data as outlined in Section F.

D. Process for Attributing Digitally Converted Data

CNHP often uses the help of student work studies, interns and volunteers to attribute the digitally converted original NWI data. The following steps should be taken to ensure correct attribution.

1. Navigate the map document (.mxd) that has been prepared for you and open it. In the table of contents, locate the shapefile you will be editing. It will be named something similar to: "SP_set_32_pre_attribution.shp"

2. Check to make sure the attribution table of this item is ready to edited. Depending on the project you are working on, you will need either a field named Attribute (text, 20 characters) or Old_Code (text, 20 characters). If the field you need is not in the shapefile's table, you can add it by clicking "Adding Field" in the table window's dropdown list.

3. Click on the editor toolbar dropdown list and choose "Start Editing." The next dialog box prompts you to indicate which layer you will be editing, choose the shapefile identified in step 1. If the editor toolbar is not already displayed in your ArcMap, you can add it using Customize > Toolbars > Editor.

4. Check to be sure that snapping is turned on for the layer you are editing. (Editor > Snapping > Snapping window). You may need to check the "use old style snapping" in the editor options if the snapping window is not an available choice.

5. Make sure your display properties are set up to make editing easy. You want the field you are editing to be the displayed label field, and layer visibility should be at about 35% transparency so you can see the raster layer underneath the shapefile you are editing. For symbology I usually go with "Lake" colored because the outline provides nice contrast.

6. Start filling in the "Attribute" (or Old_Code) field. You can type this into the table directly, or open the attributing window by clicking "Attribute" on the editor toolbar. You can use the wetland code handout to understand what the codes mean. All codes are letters, with the exception that riverine and lacustrine systems have a number after their first letter (ie R4SBC).

7. An important rule of wetland mapping is that **no two features with the same attribute can touch each other**. Sometimes a single feature will be incorrectly split by the automated processes that we use to create them – in that case the appropriate solution is to merge the pieces. I set my merge function to Insert as a hotkey, but it can be set to any key, or choosen from the editor dropdown menu. Sometimes the solution to this problem is not so simple – perhaps a linear feature splits a polygon, but that linear feature was overlooked.

   **When in doubt, just attribute a polygon with "??" so it can be reviewed later.

8. Reshape polygons that do not accurately represent the shape on the CONUS scan vectors.

9. When done attributing a shapefile, save edits and stop editing. Save and close the map document, and let me know that set is done.

D. Work Flow for New Mapping Updates

1. Prepare ¼ quad images with mosaic method of choice.

2. Create a line shapefile to add features to.

3. Map smaller streams, channel, canals and linear features, then buffer to the appropriate amount.

4. Create a polygon shapefile to add features to.

5. Begin mapping large water bodies and rivers.

6. Attribute NWI wetland codes (Cowardin et al., 1979) as you go, keeping the following in mind:

    - Map to the image, not historic or predicted.
    - Be conscious of mowing changing the intensity of vegetation signatures.
    - Be conscious of haying changing the texture and color.
    - "Farmed" modifier describes tiled agriculture, not pastureland or mowed areas.

7. Use the Montana Natural Heritage Program's method of applying LLWW descriptors in a semi-automated fashion to areas of 8-12 quads at a time. The application of LLWW descriptors will be done in a manner consistent with Ralph Tiner's 2003 Dichotomous Keys and *Mapping Codes for Wetland Landscape Position, Landform, Water Flow Path, and Waterbody Type Descriptors* (Tiner, 2003).

8. Once finished, save as quad name, copy to the project folder on P: and turn over to other mapper for QAQC'ing.

9. Important things to keep in mind:

    - Examine the wetlands for consistent alignment with features on the imagery.
    - Examine for correct System/Subsystem (mostly lakes and rivers).
    - Examine for correct Class (look for shadows denoting trees and shrubs, look carefully at smaller ponds for aquatic vegetation, and larger lakes for rings of aquatic vegetation).
    - Examine for correct Water Regime (use several dates if possible) compare with reference sites of field visits.
    - Examine for correct Modifiers (only put modifier if confident).
    - Look at large riparian systems carefully for matrix and isolated wetland pockets.

E. Riparian Classification Information Sheet

Riparian Features – Riparian features are mapped at the same time as wetland features. The USFWS defines riparian features as "contiguous to and affected by… lotic and lentic water bodies (rivers, streams, lakes or drainage ways)". The have either distinctly different vegetation (species) or significantly more robust growth. These areas are transitional between uplands and wetlands and can be considered to have a less predictable flooding regime and is often drier than an "A" water regime from NWI.

It is important to consider subsurface flow as well. Sandy washes, wooded draws, etc are affected by collection of water during storm events and/or water tables closer to the surface.

Residential areas can be trickier, as runoff from lawn watering, impervious surfaces, etc often elevate water tables in these areas. Look at the type of tree and proximity to water feature. Golf courses contain many trees and well watered vegetation but are not likely Rp.

Coding: Class is defined by the tallest life form that composes at least 30% of the area. No modifiers are applied to the riparian code. Tilled fields, even those close to rivers and streams are not mapped as riparian.

System	**Rp** (Riparian)		
SubSystem	**1** (lotic-flowing)	**2** (lentic – standing)	
Class	**EM** (emergent)	**SS** (scrub-shrub)	**FO** (forested)

Examples: Rp1FO, Rp1SS, Rp2FO

Common settings: *Rp1SS* – shrubby draw or drainage, often interrupted with drier herbaceous patches or by locations of incision. Shrubs can be dense or not. Often very narrow and linear in appearance. These will often be mapped as a linear feature then buffered out to the appropriate width.

Rp1EM – often along larger R4's with terraces. Often the same type of vegetation as the surround area, but much more robust. Channel scars and swales will usually be and NWI wetland code PEMA or PEMC, so one needs to look broadly.

Rp1EM/Rp1FO – matrix of herb/tree pockets in a larger floodplain. Look closely at denser pockets and the overall % cover to decide a class. Must choose one, DO NOT USE MIXED CODE.

Rp2FO – a ring of trees along a lake with a waterlevel that appears to fluctuate. Look closely at the understory (if visible) to determine if it's really Rp or NWI code PFOA.

F. QA/QC Procedures

CNHP uses the Wetland Data Verification Toolset developed by the U.S. Fish and Wildlife Service National Wetlands Inventory. The tool and its supporting document is available at: http://www.fws.gov/wetlands/Data/Tools-Forms.html

This toolset contains an ArcGIS 10 toolbox with 6 QAQC tests, a geodatabase containing a complete list of all currently valid NWI wetland codes and a PDF set of instructions. All data must clear these tests (or have justifications provided for records that get flagged as errors but are in fact correct) to be accepted by the NWI.

F1. QAQC Work Flow for All Mapping Projects

1. **Run topology (rule: features must not overlap), correct all errors**

2. **Run the "NWI Wetlands Data Verification Toolset version 1206, database version 1110" tool in a custom toolbox:**
   http://www.fws.gov/wetlands/Data/tools/Wetlands-Data-Verification-Toolset-Installation-Instructions-and-User-Information.pdf

3. **QAQC Code description:** Shows up in the form "NNNNNN". "N" means no error.
   C – incorrect wetland code
   U – sliver uplands*
   A – adjacent polygons with same attribute, this test also catches multipart features
   S – sliver wetlands, less than 0.1 acres *
   L – L1 or L2 < 20 acres *
   P – PUB or PAB > 20 acres *
   O – overlapping polygons (topology should render this test moot)

   ** indicates this test is "optional" in the sense that there can be polygons that are correct but not slivers, there can be Lakes less than 20 acres, etc.*

4. **Visual Scan -** new mapping only, see following section F5 for procedure.

F2. Description of the Verification Tests

A brief description of each of the verification functions is provided below.

Code "C" - Incorrect Wetland Codes: This model identifies wetland polygons with incorrect wetland codes, or null or blank values in the 'attribute' field. Bad wetland code and wetland code synonym summary tables are created and stored with your wetlands file geodatabase. The model changes the first character of QAQC_Code = 'C' if the wetland code is bad.

Code "U" - Sliver Uplands: This model identifies upland islands or holes in wetlands that are less than 0.01 acres. These may be actual upland features but are identified as errors as they are typically errors in wetland delineation. The model changes the fourth character of QAQC_Code = 'U', in wetland polygons adjacent to the upland sliver.

Code "A" - Adjacent Wetlands: This model identifies wetland polygons that are adjacent to other wetland polygons with the same 'attribute' and changes the second character of QAQC_Code = 'A'. Adjacent wetlands with the same attribute are not allowed and need to be corrected. This test also highlights multi-part features, which need to be corrected.

Code "S" Sliver Wetlands: This model identifies wetland polygons less than 0.01 acres and changes the third character of QAQC_Code = 'S'. These wetland features exceed the minimum mapping standard for wetlands and should be reviewed. Actual wetland features flagged as sliver wetlands can be justified as correct in the comments field of the QAQC_Summary table.

Code "L" or" P" - Lake and Pond Size: This model identifies Lakes that are less than 20 acres in size and Ponds that are greater or equal to 20 acres in size. It changes the fifth character of QAQC_Code ='L' for small lakes or 'P' for large ponds. These may or may not be errors and can be justified based on water depth of the identified waterbody or small lake portions on the edge of the mapping project area. Comments can be added to the 'comments' field of the QAQC_Summary table for those wetland features flagged that are valid based on depth requirements outlined in the wetlands mapping standards.

Code "O" - Overlapping Wetlands: This model identifies overlapping wetland polygons and changes the sixth character of QAQC_Code = 'O'. The overlapping portions of these polygons are stored in your wetlands file geodatabase as an Overlapping_Polygons feature class to assist in locating these features. This model does not validate topology of the wetlands file geodatabase. The CONUS_wet_poly_Topology layer in your wetlands file geodatabase can be validated using the topology toolbar in ArcMap and also to view the errors. This model and the wet_poly_topology identify the same errors and either can be used. Overlapping wetland features are not allowed in the dataset.

F3. Code Updates

Some wetland codes were used in the original NWI maps that are no longer considered valid. These out of date codes are found on Colorado NWI maps uncommonly, but often enough that CNHP developed a standardized method for conversion. Codes can be checked for validity using the Wetland Code Interpreter available here: http://www.fws.gov/wetlands/Data/Wetland-Codes.html

The following rules have been used to update these out of date codes to valid codes:

Old Classes:

OW = UB
BB or FL = US

Old Water Regimes

D = C
W = A
Y = B, C, or A (usually C)
Z = G, H (P usually gets G, L usually gets H)

F4. QAQC Notes

Water Regimes Available for Each Class (red = default for P systems):

EM – Emergent	Water Regimes = A, B, C, F, G, H, or J
SS – Shrub/Scrub	Water Regimes = A, B, C, F, G, H, or J
FO – Forested	Water Regimes = A, B, C, F, G, H, or J
UB – Unconsolidated Bottom	Water Regimes = H, G, or F
AB – Aquatic Bed	Water Regimes = H, G, F or C
US – Unconsolidated Shore	Water Regimes = C, B, A or J

PAB/PUB and LAB/LUB: Ensure that only lakes and ponds with "apparent" aquatic vegetation are labeled as PAB. Be aware that flooded shrubs can look like aquatic vegetation. Be sure to examine both 2005 and 2009 images.

PEMC/PEMF: Can be confusing in that some PEMF (especially bulrush) can look pale. Examine 2005 true color image. PEMF's are usually very dark.

Rp1SS/PSSA: PSSA needs to be wet and should be in proximity to other wet areas. Along streams Rp1SS is most common unless back channels, etc. suggest wetter conditions.

CANALS: Be aware of the 10m minimum distance. Larger canals can be labeled R4SB but smaller ones not. If a canal is shallow and significantly vegetated at a swath of 10m and appears to be significantly wet, it could be labeled as a PEM.

DONUTS: Be aware for areas where wetlands form inset, concentric circles to ensure that the inner polygon is "clipped" to remove that area from the larger polygon when analysis is completed.

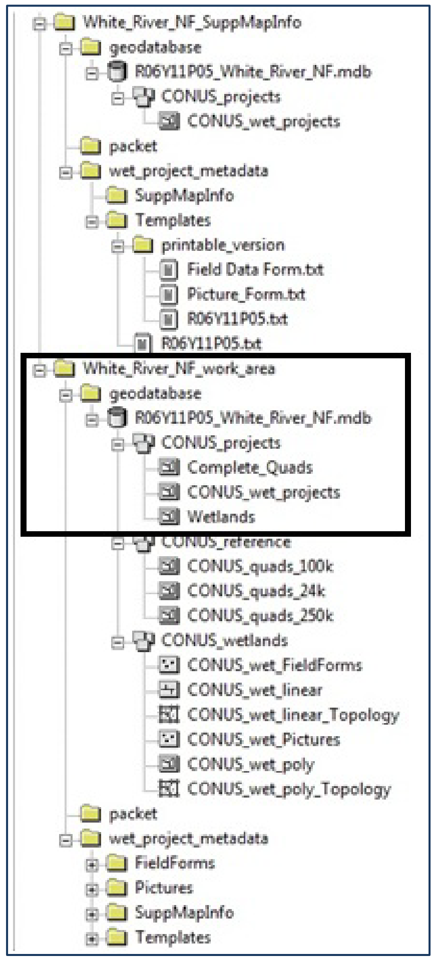
F5. QA/QC Procedures: Visual Inspection on New Mapping

Goal: 100% of features visually inspected by a wetland mapper who did not create the dataset.

1. Examine the wetlands for consistent alignment with features on the imagery.
2. Examine for correct System/Subsystem (mostly lakes and rivers).
3. Examine for correct Class (look for shadows denoting trees and shrubs, look carefully at smaller ponds for aquatic vegetation, and larger lakes for rings of aquatic vegetation).
4. Examine for correct Regime (use several dates if possible) compare with reference sites of field visits.
5. Examine for correct Modifiers (only put modifier if confident).
6. Look at large riparian systems carefully for matrix and isolated wetland pockets.

G. Project Check-in/Data Storage

1. ***Check in Project Area to NWI*** – Import the files properly into the geodatabase provided in the materials originally received from the NWI. The created data should be submitted in the part of the file structure indicated below by the black box. "Complete_Quads" indicates the actually area that was mapped as a feature class of the quads. "Wetlands" is the feature class that contains the attributed wetland polygons. A third feature class could be added for New Mapping Updates if riparian features were mapped. This would be called "Riparian" and be located in the same subfolder.



2. ***Internal CNHP Wetlands Database*** – For data sharing on relevant projects, an internal geodatabase of wetlands for the State of Colorado will be maintained. After wetland mapping projects are delivered to the client and delivered to the NWI, they will be imported into the Colorado_Wetlands.gdb. The imported wetlands will need to be merged with the existing wetlands. If the imported data is an update, any existing wetland polygons should be clipped by quad boundary and exported with a logical file name. We do not want to delete older mapping, but it should not be included in the internally distributed layer. This dataset will be located at G:\Colorado\Wetlands. The date will be in the file or folder name

such that the most current data can be accessed. No more than 3 copies will exist at any given time in the folder, older copies will be deleted.

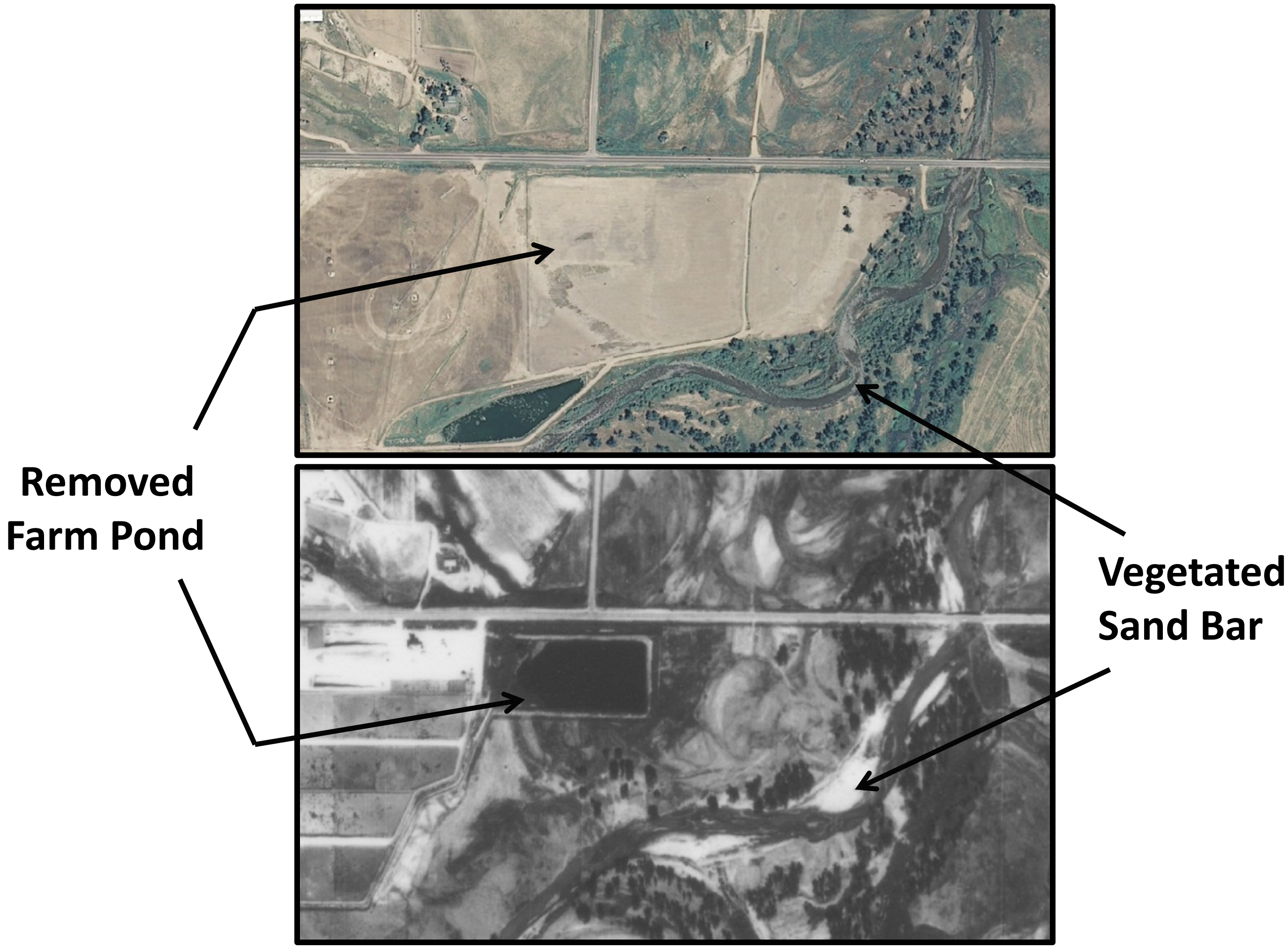
H. References

Tiner, R.W. 2003. Dichotomous Keys and Mapping Codes for Wetland Landscape Position, Landform, Water Flow Path, and Waterbody Type Descriptors. U.S. Fish and Wildlife Service, National Wetlands Inventory Program, Northeast Region, Hadley, MA. 44 pp.

Cowardin et al. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service, Washington D.C.

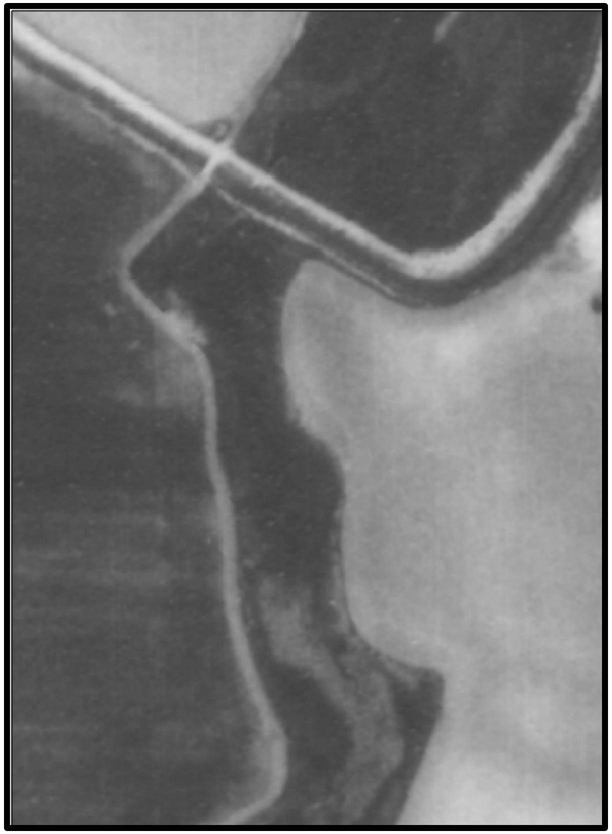
APPENDIX D: Examples of Image Analysis from Wetland Change Over Time Analysis

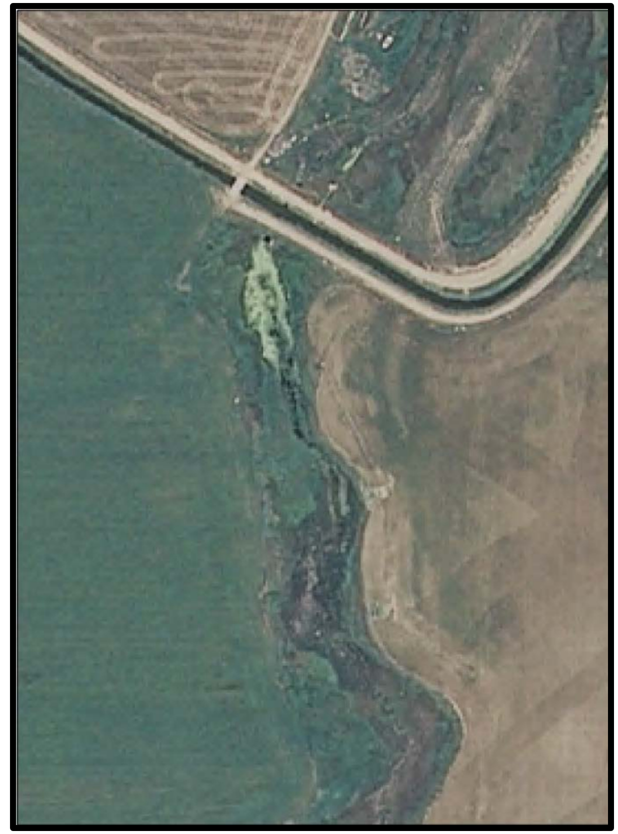
Natural Channel Adjustment and Vegetation Succession



Rural Development

Image Quality – dark



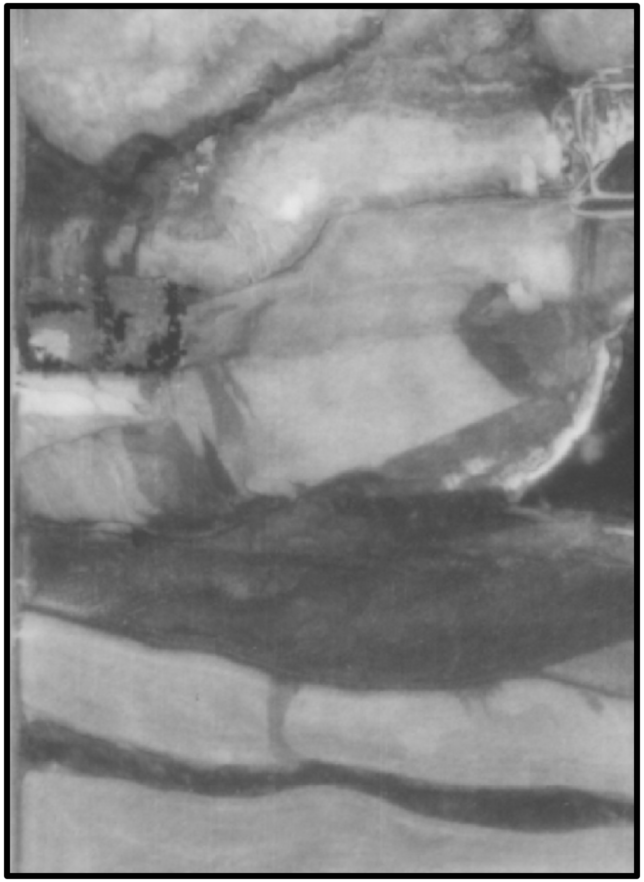


No Change

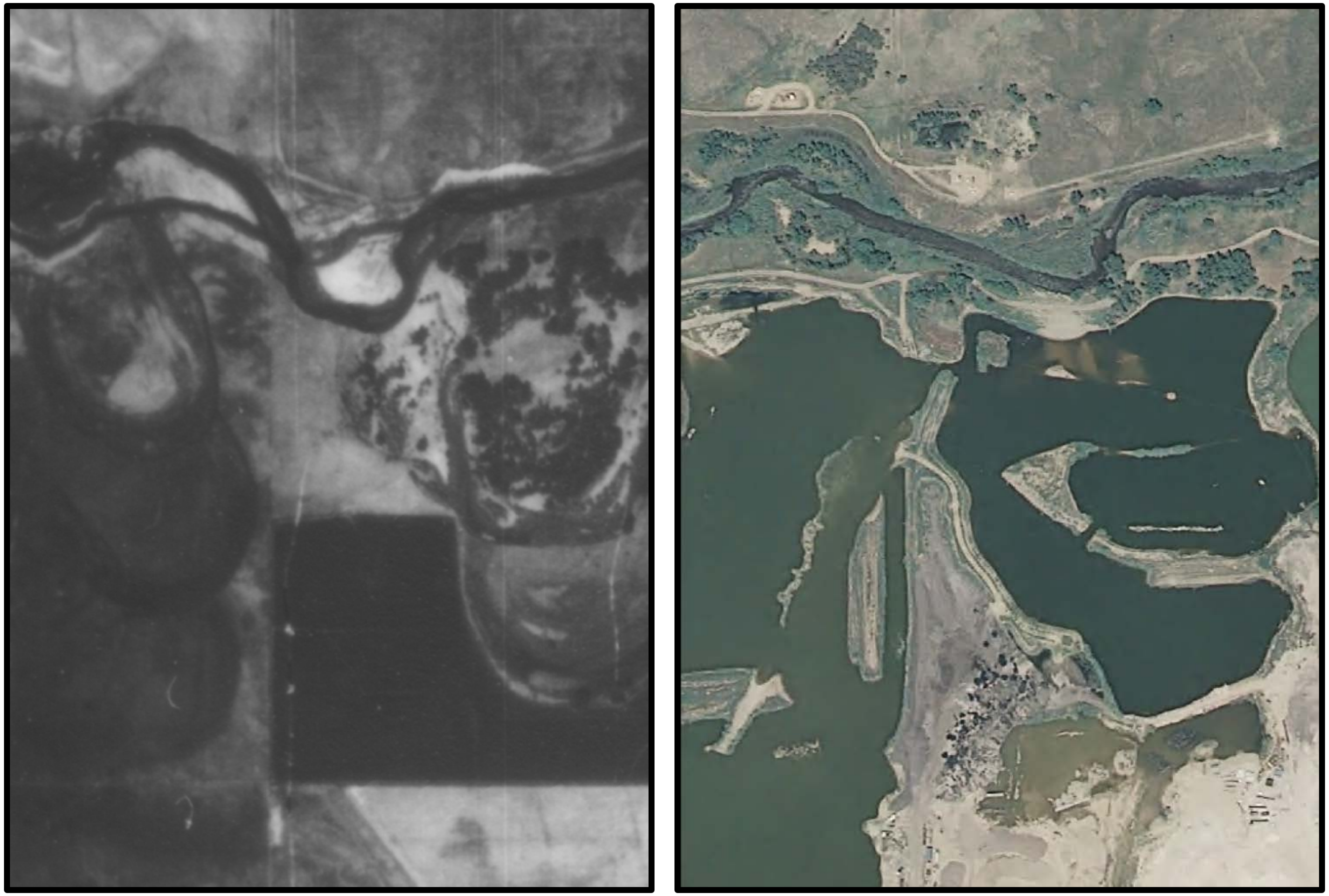
New Pond

Added Irrigation

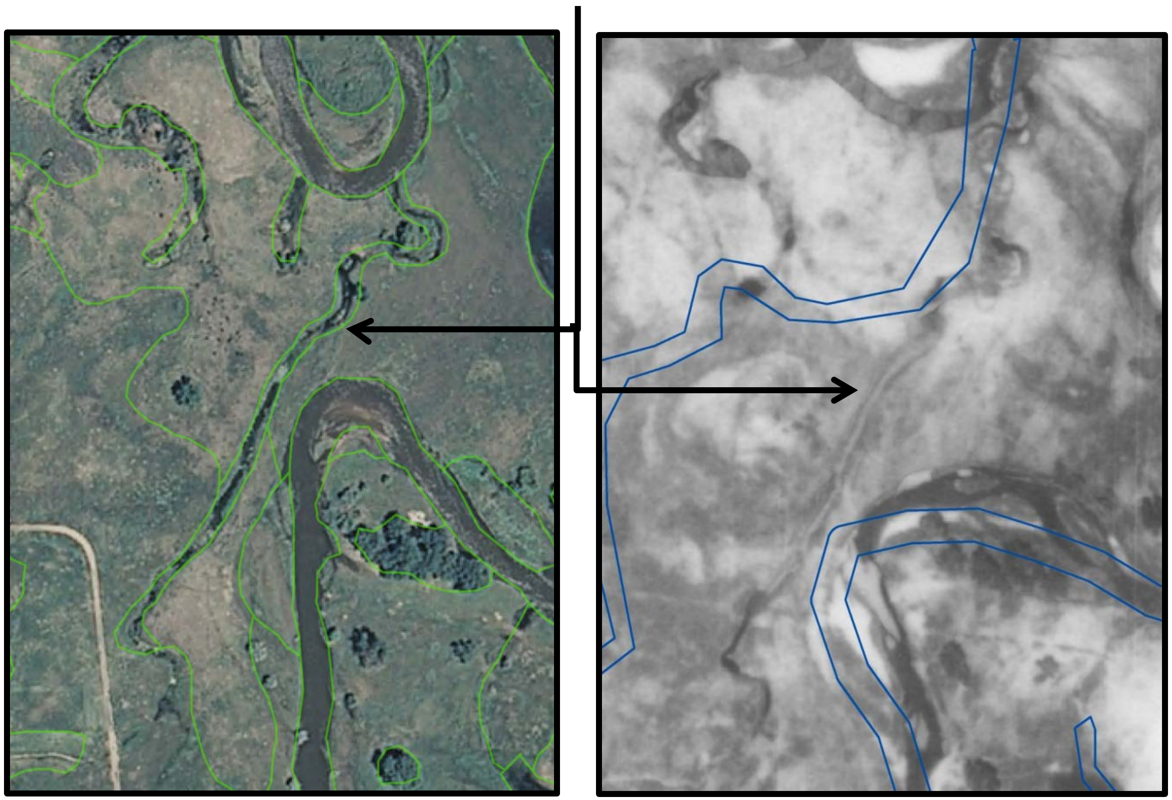
Reduced Irrigation



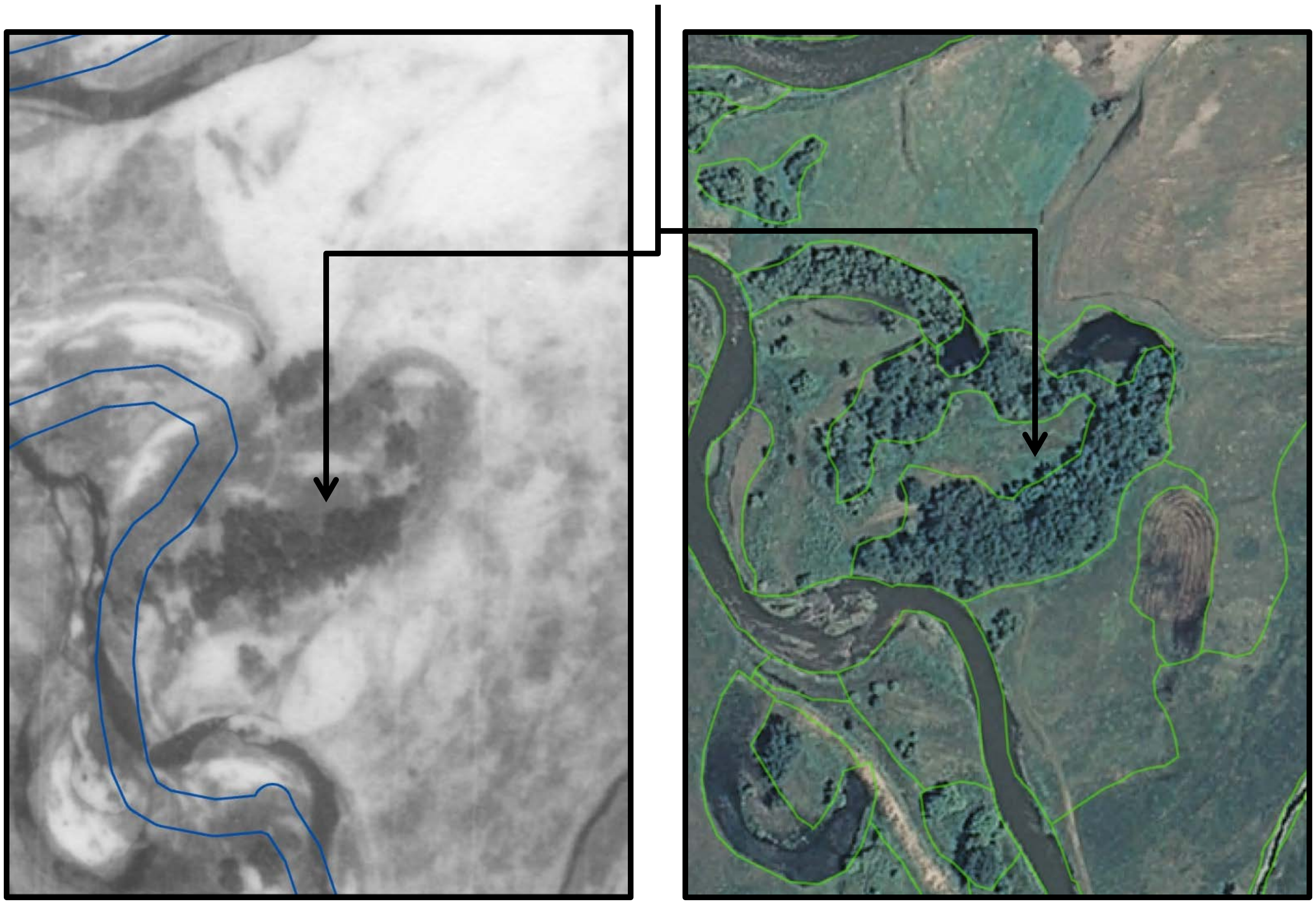
Resource Extraction – Gravel Pit



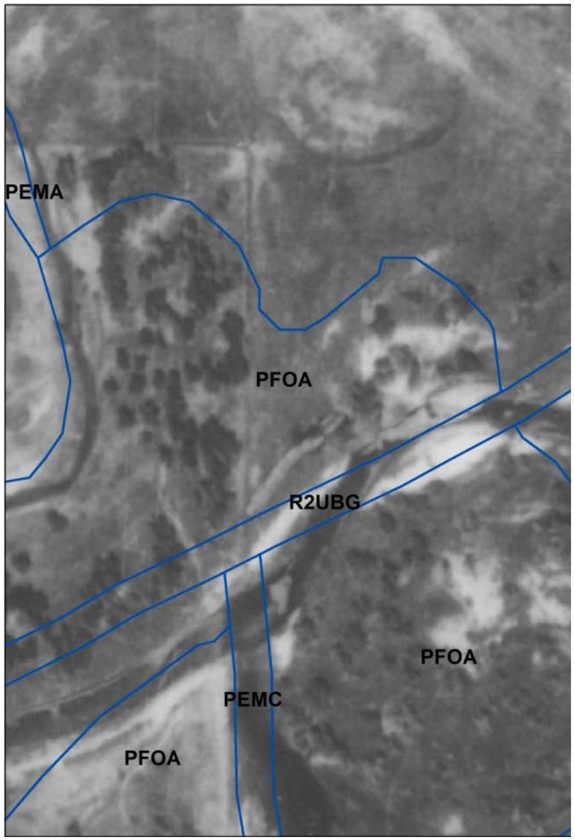
Scale – feature too narrow

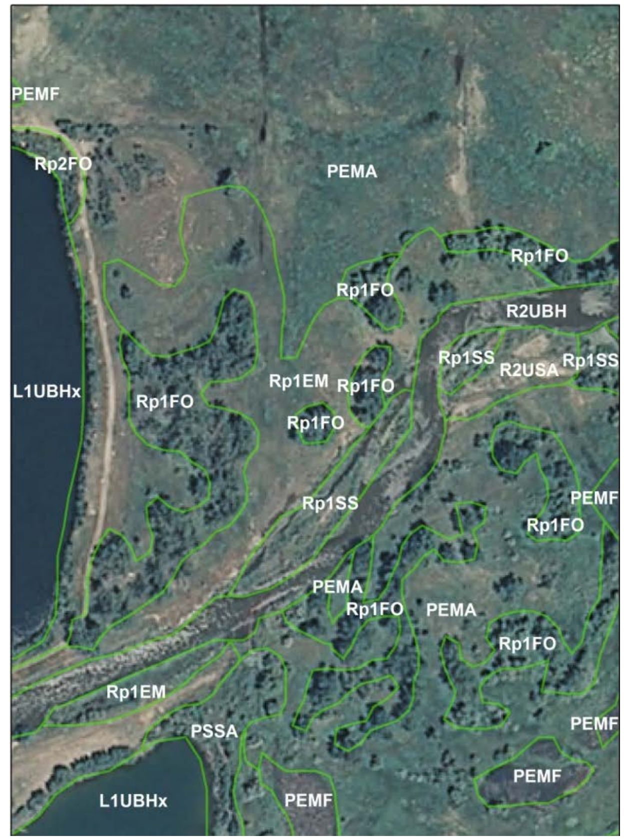


Interpreter Difference – missed wetland feature



Riparian Code Changes





APPENDIX E: Detailed Data Tables for Wetland Change Over Time Analysis

Table E-1. Summary of change over time analysis by NWI attribute group, including acres mapped in both years and acres mapped exclusively in 1978 or 2009. Grey shaded boxes represent acres mapped in both years with the same NWI attribute group. Acres mapped in both years but not in shaded boxes represent acres with a change in NWI attribute group (converted acres), from either landscape change or mapping change. Acres mapped in one time period and not the other are divided between landscape change and mapping change.

Acres Mapped in Both Years		***2009 NWI Attribution***											***Acres Lost Since 1978***			***1978 Grand Total***
		Herb	*Shrub*	*Forest*	*Ponds*	*Other*	*Lakes*	*Rivers*	*Rip Herb*	*Rip Shrub*	*Rip Forest*	*Total*	*Land Losses*	*Map Losses*	*Total*	
1978 NWI Attribution	*Herbaceous*	209	18	1	58	1	19	6	3	< 1	14	**330**	168	345	**513**	**843**
	Forested	20	6	1	3	-	14	12	5	1	95	**159**	14	126	**141**	**300**
	Ponds	6	< 1	-	177	-	20	1	-	-	1	**204**	20	48	**67**	**272**
	Other	3	< 1	-	5	3	-	-	-	-	-	**11**	11	11	**21**	**33**
	Lakes	33	6	< 1	37	2	1,485	< 1	3	1	5	**1,571**	27	70	**97**	**1,668**
	Rivers	20	8	1	4	-	< 1	59	6	3	41	**142**	11	275	**286**	**428**
	Total	**291**	**39**	**4**	**284**	**5**	**1,538**	**78**	**17**	**6**	**155**	**2,418**	**250**	**876**	**1,126**	**3,543**
Acres Added Since 1978																
Landscape Additions		191	26	3	166	6	83	6	2	3	36	**522**				
Mapping Additions		509	37	11	53	2	50	141	76	7	195	**1,081**				
Total		**700**	**63**	**14**	**219**	**8**	**133**	**147**	**78**	**10**	**231**	**1,603**				
2009 Grand Total		**991**	**103**	**18**	**503**	**13**	**1,672**	**225**	**95**	**16**	**386**	**4,021**				

Table E-2. Summary of change over time analysis by LLWW attribute group, including acres mapped in both years and acres mapped exclusively in 1978 or 2009. Grey shaded boxes represent acres mapped in both years with the same LLWW attribute group. Acres mapped in both years but not in shaded boxes represent acres with a change in LLWW attribute group (converted acres), from either landscape change or mapping change. Acres mapped in one time period and not the other are divided between landscape change and mapping change. Only wetland acres are included; lakes, rivers and riparian areas are removed.

Acres Mapped in Both Years		***2009 LLWW Attribution***								***Acres Lost Since 1978***			***1978 Grand Total***
		Dep	*Riv*	*Lacust*	*Slope*	*Lakes*	*Rivers / Stream*	*N/A*	*Total*	*Land Losses*	*Map Losses*	*Total*	
1978 LLWW Attribution	*Depressional*	213	6	< 1	< 1	20	1	7	**247**	62	95	**156**	**404**
	Riverine	88	115	2	1	13	18	106	**343**	135	369	**504**	**846**
	Lacustrine	25	7	57		19		6	**114**	16	66	**82**	**197**
	Lakes	47	< 1	30		1,485	< 1	9	**1,571**	27	70	**97**	**1,668**
	Rivers / Streams	9	23	1		0	59	50	**142**	11	275	**286**	**428**
	Total	**382**	**151**	**90**	**1**	**1,538**	**78**	**178**	**2,418**	**250**	**876**	**1,126**	**3,543**
Acres Added Since 1978													
Landscape Additions		276	103	9	4	83	6	42	**522**				
Mapping Additions		306	234	59	12	50	141	278	**1,081**				
Total		**582**	**337**	**68**	**17**	**133**	**147**	**319**	**1,603**				
2009 Grand Total		**964**	**488**	**158**	**18**	**1,672**	**225**	**498**	**4,021**				

APPENDIX F: Field Key to Hydrogeomorphic Classes in the Rocky Mountains

1a. Entire wetland unit is flat and precipitation is the primary source (>90%) of water. Groundwater and surface water runoff are not significant sources of water to the unit .... **Flats HGM Class**

1b. Wetland does not meet the above criteria; primary water sources include groundwater and/or surface water **2**

2a. Entire wetland unit meets ***all*** of the following criteria: a) the vegetated portion of the wetland is on the shores of a permanent open water body at least 8 ha (20 acres) in size; b) at least 30% of the open water area is deeper than 2 m (6.6 ft); c) vegetation in the wetland experiences bidirectional flow as the result of vertical fluctuations of water levels due to rising and falling lake levels. .... **Lacustrine Fringe HGM Class**

2b. Wetland does not meet the above criteria; wetland is not found on the shore of a water body, water body is either smaller or shallower, OR vegetation is not effected by lake water levels **3**

3a. Entire wetland unit meets ***all*** of the following criteria: a) wetland unit is in a valley, floodplain, or along a stream channel where it is inundated by overbank flooding from that stream or river; b) overbank flooding occurs at least once every two years; and c) wetland does not receive significant inputs from groundwater. **NOTE:** *Riverine wetlands can contain depressions that are filled with water when the river is not flooding such as oxbows and beaver ponds.* .... **Riverine HGM Class**

3b. Wetland does not meet the above criteria; if the wetland is located within a valley, floodplain, or along a stream channel, it is outside of the influence of overbank flooding or receives significant hydrologic inputs from groundwater. **4**

4a. Entire wetland unit is located in a topographic depression in which water ponds or is saturated to the surface at some time during the year. **NOTE:** *Any outlet, if present, is higher than the interior of the wetland.* .... **Depressional HGM Class**

4b. Wetland does not meet all of the above criteria. Instead, wetland meets part or all if the following : a) wetland is on a slope (slope can be very gradual or nearly flat); b) groundwater is the primary hydrologic input; c) water, if present, flows through the wetland in one direction and usually comes from seeps or springs; and d) water leaves the wetland without being impounded. **NOTE:** *Small channels can form within slope wetlands, but are not subject to overbank flooding. Surface water does not pond in these types of wetlands, except occasionally in very small and shallow depressions or behind hummocks (depressions are usually < 3ft diameter and less than 1 foot deep).* .... **Slope HGM Class**

Adapted from:

- Hruby, Tom. (2004) *Washington State Wetland Rating System for Eastern Washington - Revised.* Publication #04-06-15. Washington State Department of Ecology, Olympia, Washington.
- Williams, H. M., A. J. Miller, R. S. McNamee, and C. V. Klimas. (2010) *A Regional Guidebook for Applying the Hydrogeomorphic Approach to the Functional Assessment of Forested Wetlands in Alluvial Valleys of East Texas.* ERCD/EL TR-10-17. Army Corps of Engineers, Engineer Research and Development Center, Wetlands Regulatory Assistance Program. 144 p.

APPENDIX G: Field Key to Wetland and Riparian Ecological Systems of Montana, Wyoming, Utah, and Colorado

1a. Wetland defined by groundwater inflows and peat (organic soil) accumulation of at least 40 cm. Vegetation can be woody or herbaceous. If the wetland occurs within a mosaic of non-peat forming wetland or riparian systems, then the patch must be at least 0.1 hectares (0.25 acres). If the wetland occurs as an isolated patch surrounded by upland, then there is no minimum size criteria. .... **Rocky Mountain Subalpine-Montane Fen**

1b. Wetland does not have at least 40 cm of peat (organic soil) accumulation or occupies an area less than 0.1 hectares (0.25 acres) within a mosaic of other non-peat forming wetland or riparian systems **2**

> **2a.** Total woody canopy cover generally 25% or more within the overall wetland/riparian area. Any purely herbaceous patches are less than 0.5 hectares and occur within a matrix of woody vegetation. Note: Relictual woody vegetation such as standing dead trees and shrubs are included here........ **GO TO KEY A: Woodland and Shrubland Ecological Systems**
>
> **2b.** Total woody canopy cover generally less than 25% within the overall wetland/riparian area. Any woody vegetation patches are less than 0.5 hectares and occur within a matrix of herbaceous wetland vegetation **3**

3a. Total vegetation canopy cover generally 10% or more .... **GO TO KEY B: Herbaceous Ecological Systems**

3b. Total vegetation canopy cover generally less than 10% .... **GO TO KEY C: Sparse Vegetation**

KEY A: Woodland and Shrubland Ecological Systems

1a. Woody wetland associated with any stream channel, including ephemeral, intermittent, or perennial (Riverine HGM Class) **2**

1b. Woody wetland associated with the discharge of groundwater to the surface or fed by snowmelt or precipitation. This system often occurs on slopes, lakeshores, or around ponds. Sites may experience overland flow but no channel formation. (Slope, Flat, Lacustrine, or Depressional HGM Classes) **9**

> **2a.** Riparian woodlands and shrublands of the montane or subalpine zone (refer to lifezone table) **3**
>
> **2b.** Riparian woodlands and shrublands of the plains, foothills, or lower montane zone (refer to lifezone table) **4**

3a. Montane or subalpine riparian woodlands (canopy dominated by trees). This system occurs as a narrow streamside forest lining small, confined low- to mid-order streams. Common tree species include *Abies lasiocarpa*, *Picea engelmannii*, *Pseudotsuga menziesii*, and *Populus tremuloides*.......... **Rocky Mountain Subalpine-Montane Riparian Woodland**

3b. Montane or subalpine riparian shrublands (canopy dominated by shrubs with sparse or no tree cover). Within the Riverine HGM Class, this system occurs as either a narrow band of shrubs lining streambanks of steep V-shaped canyons *or* as a wide, extensive shrub stand on alluvial terraces in low-gradient valley bottoms (sometimes referred to as a shrub carr). Beaver activity is common within the wider occurrences. Species of *Salix*, *Alnus*, or *Betula* are typically dominant.......... **Rocky Mountain Subalpine-Montane Riparian Shrubland**

> **4a.** Riparian woodlands and shrublands of the foothills or lower montane zones of the Northern, Middle, and Southern Rockies, Wyoming Basin, Wasatch and Uinta Mountains, and Great Basin **5**

4b. Riparian woodlands and shrublands of the Northwestern or Western Great Plains of eastern Montana, central Wyoming, or northeastern Colorado **7**

5a. Foothill or lower montane riparian woodlands and shrublands associated with mountain ranges of the Northern Rockies in northwestern Montana. This type *excludes* island mountain ranges east of the Continental Divide in Montana. *Populus balsamifera* ssp. *trichocarpa* is typically the canopy dominant in woodlands. Other common tree species include *Populus tremuloides*, *Betula papyifera*, *Betula occidentalis*, and *Picea glauca*. Shrub understory species include *Cornus sericea*, *Acer glabrum*, *Alnus incana*, *Oplopanax horridus*, and *Symphoricarpos albus*. Areas of riparian shrubland and open wet meadow are common .... **Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland**

5b. Foothill or lower montane riparian woodlands and shrublands of other mountain regions **6**

6a. Foothill or lower montane riparian woodlands and shrublands associated with mountain ranges of the Southern and Middle Rockies, Wyoming Basin, and Wasatch and Uinta Mountains. This type also includes island mountain ranges in central and eastern Montana. Woodlands are dominated by *Populus* spp. including *Populus angustifolia*, *Populus balsamifera* ssp. *trichocarpa*, *Populus deltoides*, and *Populus fremontii*. Common shrub species include *Salix* spp., *Alnus incana*, *Crataegus* spp., *Cornus sericea*, and *Betula occidentalis*........ **Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland**

6b. Foothill or lower montane riparian woodlands and shrublands associated with mountain ranges of the Great Basin in Utah. Woodlands are dominated by *Abies concolor*, *Populus angustifolia*, *Populus balsamifera* ssp. *trichocarpa*, *Populus fremontii*, and *Pseudotsuga menziesii*. Important shrub species include *Artemisia cana*, *Betula occidentalis*, *Cornus sericea*, *Salix exigua*, *Salix lutea*, *Salix lemmonii*, and *Salix lasiolepis*........ **Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland**

7a. Woodlands and shrublands of draws and ravines associated with permanent or ephemeral streams, steep north-facing slopes, or canyon bottoms that do not experience flooding. Common tree species include *Fraxinus* spp., *Acer negundo*, *Populus tremuloides*, and *Ulmus* spp. Important shrub species include *Crataegus* spp., *Prunus virginiana*, *Rhus* spp., *Rosa woodsii*, *Symphoricarpos occidentalis*, and *Shepherdia argentea*. .... **Western Great Plains Wooded Draw and Ravine**

7b. Woodlands and shrublands of small to large streams and rivers of the Northwestern or Western Great Plains. Overall vegetation is lusher than above and includes more wetland indicator species. Dominant species include *Populus balsamifera* ssp. *trichocarpa*, *Populus deltoides*, and *Salix* spp. **8**

8a. Woodlands and shrublands of riparian areas of medium and small rivers and streams with little or no floodplain development and typically flashy hydrology........ **Northwestern/Western Great Plains Riparian**

8b. Woodlands and shrublands of riparian areas along medium and large rivers with extensive floodplain development and periodic flooding .... **Northwestern/Western Great Plains Floodplain**

9a. Woody wetland associated with small, shallow ponds in northwestern Montana. Ponds are ringed by trees including *Populus balsamifera* ssp. *trichocarpa*, *Populus tremuloides*, *Betula papyrifera*, *Abies grandis*, *Abies lasiocarpa*, *Picea engelmannii*, *Pinus contorta*, and *Pseudotsuga menziesii*. Typical shrub species include *Cornus sericea*, *Amelanchier alnifolia*, and *Salix* spp. .... **Northern Rocky Mountain Wooded Vernal Pool**

9b. Woody wetland associated with the discharge of groundwater to the surface, or sites with overland flow but no channel formation. **10**

10a. Coniferous woodlands associated with poorly drained soils that are saturated year round or seasonally flooded. Soils can be woody peat but tend toward mineral. Common tree species include *Thuja plicata*, *Tsuga heterophylla*, and *Picea engelmannii*. Common species of the herbaceous understory include *Mitella* spp., *Calamagrostis* spp., and *Equisetum arvense* .... **Northern Rocky Mountain Conifer Swamp**

10b. Woody wetlands dominated by shrubs **11**

11a. Subalpine to montane shrubby wetlands that occur around seeps, fens, lakes, and isolated springs on slopes away from valley bottoms. This system can also occur within a mosaic of multiple shrub- and herb-dominated communities within snowmelt-fed basins. Vegetation dominated by species of *Salix*, *Alnus*, or *Betula.* Within Slope, Flat, Lacustrine, or Depressional HGM Classes, this system has a similar species composition as occurrences within the Riverine HGM Class, but occurs in different landscape settings ....**Rocky Mountain Subalpine-Montane Riparian Shrubland**

11b. Lower foothills to valley bottom shrublands restricted to temporarily or intermittently flooded drainages or flats and dominated by *Sarcobatus vermiculatus* ....**Inter-Mountain Basins Greasewood Flat**

KEY B: Herbaceous Wetland Ecological Systems

1a. Herbaceous wetlands of the Northwestern Glaciated Plains, Northwestern Great Plains, or Western Great Plains regions of eastern Montana, central Wyoming, or northeastern Colorado.. **2**

1b. Herbaceous wetlands of other regions.. **5**

2a. Wetland occurs as a complex of depressional wetlands within the glaciated plains of northern Montana. Typical species include *Schoenoplectus* spp. and *Typha latifolia* on wetter, semi-permanently flooded sites, and *Eleocharis* spp., *Pascopyrum smithii*, and *Hordeum jubatum* on drier, temporarily flooded sites...**Great Plains Prairie Pothole**

2b. Wetland does not occur as a complex of depressional wetlands within the glaciated plains of Montana**3**

3a. Depressional wetlands in the Western Great Plains with saline soils. Salt encrustations can occur on the surface. Species are typically salt-tolerant such as *Distichlis spicata*, *Puccinellia* spp., *Salicornia* spp., and *Schoenoplectus maritimus*...**Western Great Plains Saline Depression Wetland**

3b. Depressional wetlands in the Western Great Plains with obvious vegetation zonation dominated by emergent herbaceous vegetation, including *Eleocharis* spp., *Schoenoplectus* spp., *Phalaris arundinacea*, *Calamagrostis canadensis*, *Hordeum jubatum*, and *Pascopyrum smithii* **4**

4a. Depressional wetlands in the Western Great Plains associated with open basins that have an obvious connection to the groundwater table. This system can also occur along stream margins where it is linked to the basin via groundwater flow. Typical plant species include species of *Typha*, *Carex*, *Schoenoplectus*, *Eleocharis*, *Juncus*, and floating genera such as *Potamogeton*, *Sagittaria*, and *Ceratophyllum*.. ....**Western Great Plains Open Freshwater Depression Wetland**

4b. Depressional wetlands in the Western Great Plains primarily within upland basins having an impermeable layer such as dense clay. Recharge is typically via precipitation and runoff, so this system typically lacks a groundwater connection. Wetlands in this system tend to have standing water for a shorter duration than Western Great Plains Open Freshwater Depression Wetlands. Common species include *Eleocharis* spp., *Hordeum jubatum*, and *Pascopyrum smithii* ....**Western Great Plains Closed Depression Wetland**

5a. Small (<0.1 ha) depressional, herbaceous wetlands occurring within dune fields of the Great Basin, Wyoming Basin, and other small inter-montane basins.. ....**Inter-Mountain Basins Interdunal Swale Wetland**

5b. Herbaceous wetlands not associated with dune fields **6**

6a. Depressional wetlands occurring in areas with alkaline to saline clay soils with hardpans. Salt encrustations can occur on the surface. Species are typically salt-tolerant such as *Distichlis spicata*, *Puccinellia* spp., *Leymus* sp., *Poa secunda*, *Salicornia* spp., and *Schoenoplectus maritimus*. Communities within this system often occur in alkaline basins and swales and along the drawdown zones of lakes and ponds. ....**Inter-Mountain Basins Alkaline Closed Depression**

6b. Herbaceous wetlands not associated with alkaline to saline hardpan clay soils. **7**

7a. Wetlands with a permanent water source throughout all or most of the year. Water is at or above the surface throughout the growing season, except in drought years. This system can occur around ponds, as fringes around lakes and along slow-moving streams and rivers. The vegetation is dominated by common emergent and floating leaved species including species of *Scirpus*, *Schoenoplectus*, *Typha*, *Juncus*, *Carex*, *Potamogeton*, *Polygonum*, and *Nuphar*. .... **Western North American Emergent Marsh**

7b. Herbaceous wetlands associated with a high water table or overland flow, but typically lacking standing water. Sites with *no channel formation* are typically associated with snowmelt and not subjected to high disturbance events such as flooding (Slope HGM Class). Sites *associated with a stream channel* are more tightly connected to overbank flooding from the stream channel than with snowmelt and groundwater discharge and may be subjected to high disturbance events such as flooding (Riverine HGM Class). Vegetation is dominated by herbaceous species; typically graminoids have the highest canopy cover including *Carex* spp., *Calamagrostis* spp., and *Deschampsia caespitosa* .... **Rocky Mountain Alpine-Montane Wet Meadow**

KEY C: Sparsely Vegetated Ecological Systems

1a. Sites are restricted to drainages with a variety of sparse or patchy vegetation including *Sarcobatus vermiculatus*, *Ericameria nauseosa*, *Artemisia cana*, *Artemisia tridentata*, *Grayia spinosa*, *Distichlis spicata*, and *Sporobolus airoides*. .... **Inter-Mountain Basins Wash**

1b. Sites occur on barren or sparsely vegetated playas that are intermittently flooded and may remain dry for several years. Soil is typically saline, and salt encrustrations are common. Plant species are salt-tolerant and can include *Sarcobatus vermiculatus*, *Distichlis spicata*, and *Atriplex* spp. .... **Inter-Mountain Basins Playa**

Table G-1. General life zones found in Colorado, Montana, Wyoming, and Utah. Note that elevations at which a life zone begins and ends is dependent upon latitude, aspect, and topographic variation.

	Colorado		Montana		Wyoming		Utah	
Life Zone	Elevation range (feet)	Dominant vegetation	Elevation range (feet)	Dominant vegetation	Elevation range (feet)	Dominant vegetation	Elevation range (feet)	Dominant vegetation
Foothills - Lower Montane	<5,500-8,000	Gambel oak, pinon-juniper, sagebrush in foothills to ponderosa pine, Douglas-fir in lower montane	<4,000-6,000	bunchgrasses, ponderosa pine, juniper, sagebrush	>5,000-6,000	bunchgrasses, ponderosa pine, juniper, sagebrush	<5,500-8,000	pinyon-juniper woodlands, oak-maple shrublands.
Montane	8,000-9,500	Douglas-fir, lodgepole pine, aspen	>4,500-7,600	Douglas-fir, spruce, cedar, lodgepole pine	6,000-7,600	Douglas-fir, spruce, lodgepole pine	8,000-9,500	lodgepole pine, ponderosa pine, aspen, Douglas-fir
Subalpine	9,500-11,500	subalpine fir, Engelmann spruce	5,000-8,800	subalpine fir, Engelmann spruce	7,600-10,000	subalpine fir, Engelmann spruce	>9,500	spruce-fir
Alpine	>11,500	grassland/tundra	>6,000-8,800	grassland/tundra	>10,000	grassland/tundra	>11,200	grassland/tundra

APPENDIX H: EIA Field Form Used for the Northern Front Range Wetland Condition Assessment

2011 CNHP RAPID WETLAND CONDITION ASSESSMENT FIELD FORM

LOCATION AND GENERAL INFORMATION

Point Code: ____________________ Site Name: ____ LEVEL 2 ASSESSMENT

Date: _________________________ Surveyors: ____

General Location: ____ County: ____________________________________

General Ownership: _____________________ Specific Ownership: ____

Directions to Point and Access Comments:

GPS COORDINATES OF TARGET POINT AND ASSESSMENT AREA (NAD 83 UTM Zone ________)

Point WP #: __________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): ______________

Elevation (m):	Slope 1 (deg):	Aspect 1 (deg):
Point is: ____Within target population ____ Not within target population, but within 60 m of target population	AA is: ____ Centered at point ____ Not centered at point, but includes point ____ Shifted, point outside	Dimensions of AA: ____40 m radius circle ____Rectangle, width______ length:______ ____Other, describe and take a GPS Track

AA-Center WP #: __________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): ______________
(Circle AAs Only)

AA-1 WP #: __________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): ______________

AA-2 WP #: __________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): ______________

AA-3 WP #: __________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): ______________

AA-4 WP #: __________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): ______________

AA-Track Track Name: ____ Comments: ____

AA Placement and Dimensions Comments:

PHOTOS OF ASSESSMENT AREA (Taken at four points on edge of AA looking in. Record WPs of each photo in table above.)

AA-1 Photo #: ______________ Aspect: ______________

AA-2 Photo #: ______________ Aspect: ______________

AA-3 Photo #: ______________ Aspect: ______________

AA-4 Photo #: ______________ Aspect: ______________

Additional AA Photos and Comments:

(Note range of photo numbers and explain particular photos of interest)

Point Code___________________

ENVIRONMENTAL DESCRIPTION AND CLASSIFICATION OF ASSESSMENT AREA

Non-target Inclusions

% AA with > 1m standing water: _______________

% AA with upland inclusions: _________________

Wetland origin

____ Natural feature with minimal alteration

____ Natural feature, but altered or augmented by modification

____ Non-natural feature created by management action

Ecological System (see manual for key and rules on inclusions and pick *only one*) Conf: High Med Low

Cowardin Classification (pick *one each*) Conf: High Med Low

System and Class:		Water Regime:		Modifier (optional):	
____ PEM	____ PAB	____ A	____ F	____ b	____ h
____ PSS	____ PUB	____ B	____ G	____ x	____ f
____ PFO	____ PUS	____ C	____H	____ d	

HGM Class (pick *only one*) Conf: High Med Low

____Riverine*	____Lacustrine Fringe
____Depressional	____ Slope
____ Flats	____ Unknown

**Specific classification and metrics apply to the Riverine HGM Class*

RIVERINE SPECIFIC CLASSIFICATION OF THE ASSESSMENT AREA

Confined vs. Unconfined Valley Setting

Estimated Valley Width (m): __________________________________

Estimated Bankfull Width (m): ________________________________

____Confined Valley Setting (valley width < 2x bankfull width)

____Unconfined Valley Setting (valley width ≥ 2x bankfull width)

AA Proximity to Channel

______ AA includes the channel and both banks

______ AA is adjacent to or near the channel (< 50 m) and evaluation includes one or both banks

______ AA is > 50 m from the channel and banks were not evaluated

Stream Depth at Time of Survey (if evaluated)

______ Wadeable

______ Non-wadeable

BIOTIC AND ABIOTIC ZONES WITHIN THE ASSESSMENT AREA (See manual for rules and definitions. Mark each zone on the site sketch.)

Zone 1	Life Form / Type__________________________	Dom spp: ____	% of AA: ___________
Zone 2	Life Form / Type__________________________	Dom spp: ____	% of AA: ___________
Zone 3	Life Form / Type__________________________	Dom spp: ____	% of AA: ___________
Zone 4	Life Form / Type__________________________	Dom spp: ____	% of AA: ___________
Zone 5	Life Form / Type__________________________	Dom spp: ____	% of AA: ___________

ENVIRONMENTAL AND CLASSIFICATION COMMENTS

** Include reason for medium or low confidence on classification**

Is AA representative of larger wetland (note if AA is entire wetland):

ASSESSMENT AREA DRAWING

Add north arrow and approx scale bar. Document vegetation zones, inflows and outflows, and indicate direction of drainage. Include sketch of vegetation plot and soil pit placement.

ASSESSMENT AREA DESCRIPTION AND COMMENTS

Note wildlife species observed:

VEGETATION PLOT GROUND COVER AND VERTICAL STRATA			
	Module →	R	
Cover Classes 1: trace **2:** <1% **3:** 1–<2% **4:** 2–<5% **5:** 5–<10% **6:** 10–<25% **7:** 25–<50% **8:** 50–<75% **9:** 75–<95% **10:** >95%			
	Cover Class (unless otherwise noted) →	C	
Ground Cover			
	Cover of water (any depth, vegetated or not, standing or flowing)		
Set 1 (sum= 100%)	Cover of shallow water <20 cm / Mean depth of most shallow water (cm)	/	
	Cover of deep water >20 cm / Mean depth of most deep water (cm)	/	
Set 2 (sum= 100%)	Cover of open water with no vegetation		
	Cover of water with submergent or floating aquatic vegetation		
	Cover of water with emergent vegetation		
	Cover of exposed bare ground* – soil / sand / sediment		
	Cover of exposed bare ground – gravel / cobble (~2–250 mm)		
	Cover of exposed bare ground – bedrock / rock / boulder (>250 mm)		
	Cover of litter (all cover, <u>including under water or vegetation</u>)		
	Depth of litter (cm) – average of 4 non-trampled locations where litter occurs		
	Predominant litter type (C = coniferous, E = broadleaf evergreen, D = deciduous, S = sod/thatch, F = forb)		
	Cover of standing dead trees (>5 cm diameter at breast height)		
	Cover of standing dead shrubs or small trees (<5 cm diameter at breast height)		
	Cover of downed coarse woody debris (fallen trees, rotting logs, >5 cm diameter)		
	Cover of downed fine woody debris (<5 cm diameter)		
	Cover bryophytes (all cover, including under vegetation or litter cover)		
	Cover lichens (all cover, including under vegetation or litter cover)		
	Cover algae (all cover, including under vegetation or litter cover)		
*Bare ground has no vegetation/litter/water cover.			
Height Classes 1: <0.5 m **2:** 0.5–1m **3:** 1–2 m **4:** 2–5 m **5:** 5–10 m **6:** 10–15 m **7:** 15–20 m **8:** 20–35 m **9:** 35–50 m **10:** >50 m			
	Cover / Height →	C	H
Vertical Vegetation Strata (Live or very recently dead with leaves/needles/herbaceous)			
	(T1) Dominant canopy trees (>5 m and > 30% cover)		
	(T2) Sub-canopy trees (> 5m but < dominant canopy height) or trees with sparse cover		
	(S1) Tall shrubs or older tree saplings (2–5 m)		
	(S2) Short shrubs or young tree saplings (0.5–2 m)		
	(S3) Dwarf shrubs or tree seedlings (<0.5 m; includes short <u>Vaccinium sp,</u> etc.)		
	(HT) Herbaceous total		
	(H1) Graminoids		
	(H2) Forbs		
	(H3) Ferns and fern allies		
	(AQ) Submergent or floating aquatics		

Point Code__________________

VEGETATION PLOT SPECIES TABLE

Cover Classes 1: trace 2: <1% 3: 1–<2% 4: 2–<5% 5: 5–<10% 6: 10–<25% 7: 25–<50% 8: 50–<75% 9: 75–<95% 10: >95%

Coll #	Scientific Name or Pseudonym (if repeated/common pseudonym, mark with *)	Cover Class	Photo #'s

VEGETATION PLOT SPECIES TABLE

Cover Classes 1: trace **2:** <1% **3:** 1–<2% **4:** 2–<5% **5:** 5–<10% **6:** 10–<25% **7:** 25–<50% **8:** 50–<75% **9:** 75–<95% **10:** >95%

Coll #	Scientific Name or Pseudonym (if repeated/common pseudonym, mark with *)	Cover Class	Photo #’s

Point Code__________________

SOIL PROFILE DESCRIPTION – SOIL PIT 1 **Time pit dug: __________** **Time water depth observed: __________** **Photo #s __________** **GPS Waypoint ______________ (mark on site sketch)**

Soil survey unit: ______________________________ Soil pit matches soil survey unit? ☐ Yes ☐ No Explain in comments.

Depth to saturated soil (cm): ____________ Depth to free water (cm): _____________ ☐ Not observed* Groundwater pH: ______________ EC: ______________ Temp: ______________

Horizon (optional)	Depth (cm)	Matrix Color (moist)	Redox Concentrations Color (moist)	Redox Concentrations %	Redox Depletions Color (moist)	Redox Depletions %	Texture	Remarks
________	_______	______________	______________	________	_____________	________	______________	______________________________
________	_______	______________	______________	________	_____________	________	______________	______________________________
________	_______	______________	______________	________	_____________	________	______________	______________________________
________	_______	______________	______________	________	_____________	________	______________	______________________________
________	_______	______________	______________	________	_____________	________	______________	______________________________

Hydric Soil Indicators: See field manual for descriptions and check all that apply to pit.

____Histosol (A1)
____Histic Epipedon (A2/A3)
____Mucky Mineral (S1/F1)
____Hydrogen Sulfide Odor (A4)
____Gleyed Matrix (S4/F2)
____Depleted Matrix (A11/A12/F3)
____Redox Concentrations (S5/F6/F8)
____Redox Depletions (S6/F7)

Comments:

*If free water is not observed in pit, circle: A. Pit is filling slowly OR B. Pit appears dry

SOIL PROFILE DESCRIPTION – SOIL PIT 2 **Time pit dug: __________** **Time water depth observed: __________** **Photo #s __________** **GPS Waypoint ______________ (mark on site sketch)**

Soil survey unit: ______________________________ Soil pit matches soil survey unit? ☐ Yes ☐ No Explain in comments.

Depth to saturated soil (cm): ____________ Depth to free water (cm): _____________ ☐ Not observed* Groundwater pH: ______________ EC: ______________ Temp: ______________

Horizon (optional)	Depth (cm)	Matrix Color (moist)	Redox Concentrations Color (moist)	Redox Concentrations %	Redox Depletions Color (moist)	Redox Depletions %	Texture	Remarks
________	_______	______________	______________	________	_____________	________	______________	______________________________
________	_______	______________	______________	________	_____________	________	______________	______________________________
________	_______	______________	______________	________	_____________	________	______________	______________________________
________	_______	______________	______________	________	_____________	________	______________	______________________________
________	_______	______________	______________	________	_____________	________	______________	______________________________

Hydric Soil Indicators: See field manual for descriptions and check all that apply to pit.

____Histosol (A1)
____Histic Epipedon (A2/A3)
____Mucky Mineral (S1/F1)
____Hydrogen Sulfide Odor (A4)
____Gleyed Matrix (S4/F2)
____Depleted Matrix (A11/A12/F3)
____Redox Concentrations (S5/F6/F8)
____Redox Depletions (S6/F7)

Comments:

*If free water is not observed in pit, circle: A. Pit is filling slowly OR B. Pit appears dry

Point Code__________________

LEVEL 2 ECOLOGICAL INTEGRITY ASSESSMENT FOR SOUTHERN ROCKY MOUNTAIN WETLANDS

1. LANDSCAPE CONTEXT METRICS – Check the applicable box.

1a. LANDSCAPE FRAGMENTATION		
Select the statement that best describes the **landscape fragmentation** within a 500 m envelope surrounding the AA. To determine, identify the largest unfragmented block *that includes the AA* within the 500 m envelope and estimate its percent of the total envelope. Well-traveled dirt roads and major canals count as fragmentation, but hiking trails, hayfields, fences and small ditches can be included in unfragmented blocks (see definitions).	Intact: AA embedded in >90–100% unfragmented, natural landscape.	
	Variegated: AA embedded in >60–90% unfragmented, natural landscape.	
	Fragmented: AA embedded in >20–60% unfragmented, natural landscape.	
	Relictual: AA embedded in ≤20% unfragmented, natural landscape.	

1b. RIPARIAN CORRIDOR CONTINUITY *(RIVERINE WETLANDS ONLY)*		
For riverine wetlands, select the statement that best describes the **riparian corridor continuity** within 500 m upstream and downstream of the AA. To determine, identify any non-buffer patches (see definitions) within the riparian corridor (natural geomorphic floodplain) both upstream and downstream of the AA. Estimate the percentage of the riparian corridor they occupy. *For AAs on one side of a very large river channel (~20 m width),* only consider the riparian corridor on that side of the channel.	Intact: >95–100% natural habitat within the riparian corridor both upstream and downstream.	
	Variegated: >80–95% natural within the riparian corridor both upstream and downstream.	
	Fragmented: >50–80% natural habitat within the riparian corridor both upstream and downstream.	
	Relictual: ≤50% natural habitat within the riparian corridor both upstream and downstream.	

Landscape fragmentation and riparian corridor continuity comments:

1c. BUFFER EXTENT		
Select the statement that best describes the **extent of buffer land cover** surrounding the AA. To determine, estimate the percent of the AA surrounded by buffer land covers (see definitions). Each segment must be ≥ 25 m wide and ≥ 5 long. *For AAs on one side of a very large river channel (~20 m width),* only consider the buffer on that side of the channel.	Buffer land covers surround >100% of the AA.	
	Buffer land covers surround >75–<100% of the AA.	
	Buffer land covers surround >50–75% of the AA.	
	Buffer land covers surround >25–50% of the AA.	
	Buffer land covers surround ≤25% of the AA.	

1d. BUFFER WIDTH

Select the statement that best describes the **buffer width**. To determine, estimate width (up to 200 m from AA) at eight evenly spaced intervals. *For AAs on one side of a very large river channel (~20 m width),* only estimate buffer width on that side of the channel.

1: ____________ 5: ____________	Average buffer width is >200 m	
2: ____________ 6: ____________	Average buffer width is >100–200 m	
3: ____________ 7: ____________	Average buffer width is >50–100 m	
4: ____________ 8: ____________	Average buffer width is >25–50 m	
Average width: ______________________	Average buffer width is ≤25 m OR no buffer exists	

1e. BUFFER CONDITION

Select the statement that best describes the **buffer condition**. Select one statement per columns. Only consider the actual buffer measured in metrics 1c and 1d.

Abundant (≥95%) relative cover native vegetation and little or no (<5%) cover of non-native plants.		Intact soils, little or no trash or refuse, and no evidence of human visitation.	
Substantial (≥75–95%) relative cover of native vegetation and low (5–25%) cover of non-native plants.		Intact or moderately disrupted soils, moderate or lesser amounts of trash, OR minor intensity of human visitation or recreation.	
Moderate (≥50–75%) relative cover of native vegetation.		Moderate or extensive soil disruption, moderate or greater amounts of trash, OR moderate intensity of human use.	
Low (<50%) relative cover of native vegetation OR no buffer exists.		Barren ground and highly compacted or otherwise disrupted soils, moderate or greater amounts of trash, moderate or greater intensity of human use, OR no buffer exists.	

Buffer comments:

1f. LANDSCAPE STRESSORS AND ONSITE AND SURROUNDING LAND USE (For use in the Human Disturbance Index)

Using the table below, estimate the percent of each **landscape stressor within a 500 m envelope** of the AA. Independent percentages can overlap (e.g., light grazing can occur along with moderate recreation). In addition, estimate the cumulative % of land uses within the 500 m envelope and the AA. Start at the top of the list and only record the most severe stressor in areas where two or more land uses overlap. The total for both cumulative columns should = 100%.

Landscape stressor/ land use categories	*Independent % within 500 m Envelope*	*Cumulative % of Land Use within 500 m Envelope*	*Cumulative % of Land Use within AA*
Paved roads, parking lots, railroad tracks			
Domestic or commercially developed buildings			
Gravel pit operation, open pit mining, strip mining			
Unpaved roads (e.g., driveway, tractor trail, 4-wheel drive roads)			
Mining (other than gravel, open pit, and strip mining), abandoned mines			
Resource extraction (oil and gas wells and surrounding footprint)			
Agriculture – tilled crop production			
Intensively managed golf courses, sports fields, urban parks, expansive lawns			
Vegetation conversion (chaining, cabling, rotochopping, or clear-cutting of woody veg)			
Heavy grazing/browse by livestock or native ungulates			
Intense recreation or human visitation (ATV use / camping / popular fishing spot, etc.)			
Logging or tree removal with 50-75% of trees >50 cm dbh removed			
Agriculture – permanent crop (hay pasture, vineyard, orchard, tree plantation)			
Dam sites and flood disturbed shorelines around water storage reservoirs			
Recent old fields and other disturbed fallow lands dominated by non-native species			
Moderate grazing/browse by livestock or native ungulates			
Moderate recreation or human visitation (high-use trail)			
Selective logging or tree removal with <50% of trees >50 cm dbh removed			
Light grazing/browse by livestock or native ungulates			
Light recreation or human visitation (low-use trail)			
Haying of native grassland (land not dominated by non-native hay grasses)			
Fallow with no history of grazing or human use in past 10 years (primarily native veg)	**NA**		
Natural area / land managed for natural vegetation	**NA**		
Beetle-killed conifers		**NA**	**NA**
Evidence of recent fire (<5 years old, still very apparent on vegetation, little regrowth)		**NA**	**NA**
Other:			

Landscape stressor comments:

1g. NATURAL COVER WITHIN A 100 M ENVELOPE (Supplemental Information)

Using the table below, estimate the percent cover of each **natural cover type within a 100 m envelope** of the AA. Natural cover is not restricted to native vegetation; it could contain a mix of native and non-native vegetation. This measure applies to the entire 100 m envelope and not just buffer land covers. Estimate the total combined cover and wetland and upland cover separately.

Natural Cover Type	*Total % Cover*	*Upland % Cover*	*Wetland % Cover*
Total non-natural cover (development, row crops, feed lots, etc).			
Total natural cover (breakdown by type below)			
A. Deciduous forest			
B. Coniferous forest			
C. Mixed forest type (neither deciduous nor coniferous trees dominate)			
D. Shrubland			
E. Perennial herbaceous (includes passively managed hay)			
F. Annual herbaceous or disturbed bare (generally weedy)			
G. Naturally bare (open water, rock, snow/ice)			

Natural cover comments (and note the dominant species from above):

A.

B.

C.

D.

E.

F.

G.

2. *VEGETATION CONDITION METRICS – Check the applicable box.*

2a-d. VEGETATION COMPOSITION

Vegetation composition metrics will be calculated out of the field based on the species list and cover values. To aid data interpretation, provide comments on composition and **list noxious species identified in field:**

2e. REGENERATION OF NATIVE WOODY SPECIES

Select the statement that best describes the **regeneration of native woody species** within the AA.

Woody species are naturally uncommon or absent.	**N/A**
All age classes of desirable (native) woody riparian species present.	
Age classes restricted to mature individuals and young sprouts. Middle age groups absent.	
Stand comprised of mainly mature species.	
Woody species predominantly consist of decadent or dying individuals or AA has >5% canopy cover of Russian Olive and/or Salt Cedar.	

Regeneration comments:

2f. BROWSE ON WOODY SPECIES

Select the statement that best describes the **extent of browse on woody species** within the AA. Pay more attention to second year or older stems as heavily browse individuals may produce large or prolific resprouts each year as a response to winter browse pressure.	Woody species are naturally uncommon or absent	**N/A**
	<5% of stems are browsed.	
	5–25% of stems are browsed.	
	25–50% of stems are browsed.	
	>50% of stems are browsed.	

Browse comments:

2g. HERBACEOUS / DECIDUOUS LITTER ACCUMULATION

Select the statement that best describes **herbaceous and/or deciduous litter accumulation** within the AA.

AA characterized by moderate amount of fine or coarse litter. New growth is more prevalent than previous years'. Litter and duff layers in pools and topographic lows are thin. Organic matter is neither lacking nor excessive.	
AA characterized by small amounts of litter with little plant recruitment OR litter is somewhat excessive.	
AA lacks litter OR litter is extensive and limiting new growth.	

Herbaceous / deciduous litter accumulation comments:

2h. STRUCTURAL PATCH TYPES WITHIN THE ASSESSMENT AREA

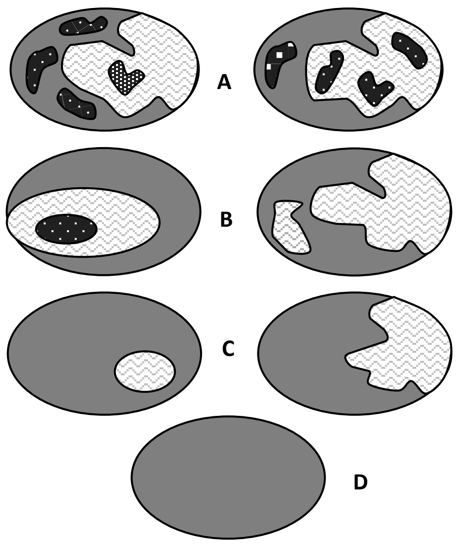
Using the following worksheet, mark all structural patch types that occur within or adjacent to the AA. Check all those that occur and record photo numbers if taken. See the field manual for patch type definitions.

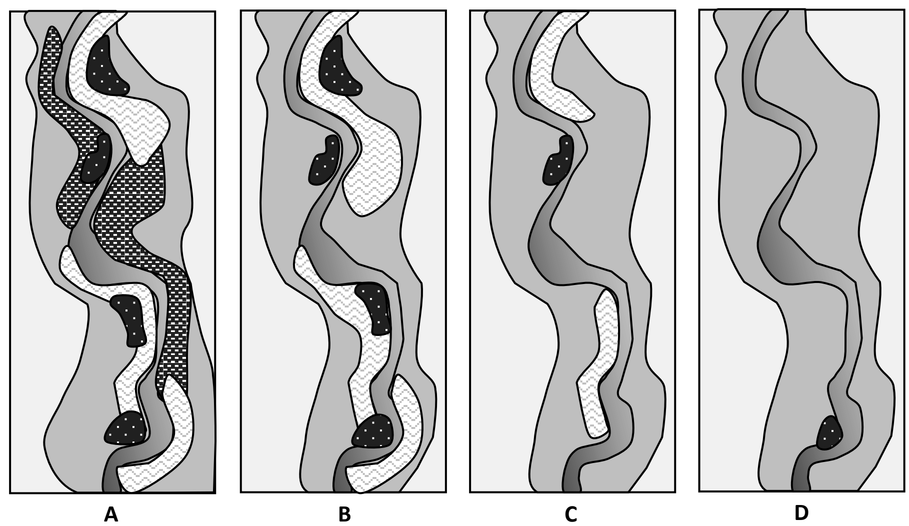
Patch type	*Photo #'s*	*Patch type*	*Photo #'s*
Open water - river / stream		Point bar	
Open water - tributary / secondary channel		Interfluve on floodplain	
Open water - oxbow / backwater channel		Bank slumps or undercut banks in channel or along shoreline	
Open water - rivulets / streamlet / small channel		Adjacent or onsite seep / spring	
Open water - ditch or canal		Animal mounds or burrows	
Open water - pond or lake (>1000 m^2)		Mudflat	
Open water - pools (<1000 m^2)		Salt flat / alkali flat	
Open water - beaver pond		Hummock / tussock (naturally formed)	
Active beaver dam		Water tracks / hollow	
Beaver canal		Floating mat	
Debris jams / woody debris in channel		Marl / Limonite bed	
Pools in stream		Other:	
Riffles in stream		Other:	

Structural patch types comments:

2i. HORIZONTAL INTERSPERSION OF VEGETATION ZONES

Refer to diagrams below and select the statement that best describes the **horizontal interspersion of biotic and abiotic zones** within the AA. Rules for defining zones are in the field manual. Include zones of open water when evaluating interspersion.	High degree of horizontal interspersion: AA characterized by a very complex array of nested or interspersed vegetation zones with no single dominant zone.	
	Moderate degree of horizontal interspersion: AA characterized by a moderate array of nested or interspersed vegetation zones with no single dominant zone.	
	Low degree of horizontal interspersion: AA characterized by a simple array of nested or interspersed vegetation zones. One zone may dominate others.	
	No horizontal interspersion: AA characterized by one dominant vegetation zone.	





Horizontal interspersion comments (note if interspersion is not related to wetland integrity such as in *Carex*-dominated fens):

2j. VEGETATION STRESSORS WITHN THE AA

Using the table below, estimate the independent scope of each vegetation stressor within the AA. Independent scopes can overlap (e.g., light grazing can occur along with moderate recreation). ***Scope rating: 1 = 1–10%, 2 = >10–25%, 3 = >25–50%, 4 = >50–75%, 5 = >75%.***

Vegetation stressor categories	*Scope*
Unpaved Roads (e.g., driveway, tractor trail, 4-wheel drive roads)	
Vegetation conversion (chaining, cabling, rotochopping, clearcut)	
Logging or tree removal with 50-75% of trees >50 cm dbh removed	
Selective logging or tree removal with <50% of trees >50 cm dbh removed	
Heavy grazing/browse by livestock or native ungulates	
Moderate grazing/browse by livestock or native ungulates	
Light grazing/browse by livestock or native ungulates	
Intense recreation or human visitation (ATV use / camping / popular fishing spot, etc.)	
Moderate recreation or human visitation (high-use trail)	
Light recreation or human visitation (low-use trail)	
Recent old fields and other disturbed fallow lands dominated by exotic species	
Haying of native grassland	
Beetle-killed conifers	
Evidence of recent fire (<5 years old)	
Other:	

Vegetation stressor comments:

3. *PHYSIOCHEMICAL METRICS – Check the applicable box.*

3a. SUBSTRATE / SOIL DISTURBANCE	
Select the statement below that best describes **disturbance to the substrate or soil** within the AA.	
No soil disturbance within AA. Little bare soil OR bare soil areas are limited to naturally caused disturbances such as flood deposition or game trails OR soil is naturally bare (e.g., playas). No pugging or soil compaction.	
Minimal soil disturbance within AA. Some amount of bare soil, pugging, or compaction present due to human causes, but the extent and impact is minimal. The depth of disturbance is limited to only a few inches and does not show evidence of ponding or channeling water. Any disturbance is likely to recover within a few years after the disturbance is removed.	
Moderate soil disturbance within AA. Bare soil areas due to human causes are common and will be slow to recover. There may be pugging due to livestock resulting in several inches of soil disturbance. ORVs or other machinery may have left some shallow ruts. Damage is not excessive and the site will recover to potential with the removal of degrading human influences and moderate recovery times.	
Substantial soil disturbance within AA. Bare soil areas substantially degrade the site due to altered hydrology or other long-lasting impacts. Deep ruts from ORVs or machinery may be present, or livestock pugging and/or trails are widespread. Water, if present, would be channeled or ponded. The site will not recover without restoration and/or long recovery times.	
Substrate / soil comments and photo #'s:	

3b. WATER QUALITY - SURFACE WATER TURBIDITY / POLLUTANTS	
Select the statement that best describes the **turbidity or evidence or pollutants** in surface water within the AA.	
No visual evidence of degraded water quality. No visual evidence of turbidity or other pollutants.	
Some negative water quality indicators are present, but limited to small and localized areas within the wetland. Water is slightly cloudy, but there is no obvious source of sedimentation or other pollutants.	
Water is cloudy or has unnatural oil sheen, but the bottom is still visible. Sources of water quality degradation are apparent (identify in comments below). *Note: If the sheen breaks apart when you run your finger through it, it is a natural bacterial process and not water pollution.*	
Water is milky and/or muddy or has unnatural oil sheen. The bottom is difficult to see. There are obvious sources of water quality degradation (identify in comments below). *Note: If the sheen breaks apart when you run your finger through it, it is a natural bacterial process and not water pollution.*	
Surface water turbidity / pollutants comments and photo #'s:	

3c. WATER QUALITY - ALGAL GROWTH	
Select the statement that best describes **algal growth** within surface water in the AA.	
Water is clear with minimal algal growth.	
Algal growth is limited to small and localized areas of the wetland. Water may have a greenish tint or cloudiness.	
Algal growth occurs in moderate to large patches throughout the AA. Water may have a moderate greenish tint or sheen. Sources of water quality degradation are apparent (identify in comments below).	
Algal mats are extensive, blocking light to the bottom. Water may have a strong greenish tint and the bottom is difficult to see. There are obvious sources of water quality degradation (identify in comments below).	
Algal growth comments and photo #'s: If naturally occurring algae is present, describe and record % of total algae that is due to natural processes.	

3d. PHYSIOCHEMICAL STRESSORS WITHIN THE AA
Using the table below, estimate the independent scope of each physiochemical stressor within the AA. Independent scopes can overlap (e.g., soil compaction can occur with trash or refuse). ***Scope rating: 1 = 1–10%, 2 = >10–25%, 3 = >25–50%, 4 = >50–75%, 5 = >75%.***

Physiochemical stressor categories	*Scope*
Erosion	
Sedimentation	
Current plowing or disking	
Historic plowing or disking (evident by abrupt A horizon boundary at plow depth)	
Substrate removal (excavation)	
Filling or dumping of sediment	
Trash or refuse dumping	
Compaction and soil disturbance by livestock or native ungulates	
Compaction and soil disturbance by human use (trails, ORV use, camping)	
Mining activities, current or historic	
Obvious point source of water pollutants (note source in comments)	
Non-point sources of water pollutants, such as agricultural fields, urban runoff, feedlots, etc.	
Other:	
Physiochemical stressor comments:	

4. ***HYDROLOGY METRICS – Check the applicable box.***

4a. WATER SOURCES / INPUTS

Select the statement below that best describes the **water sources** feeding the AA during the growing season. Check off all *major* water sources in the table to the right. If the dominant water source is evident, mark it with a star.	______ Overbank flooding ______ Alluvial / hyporheic flow ______ Groundwater discharge ______ Precipitation ______ Snowmelt	______ Natural surface flow ______ Irrigation run-off / ditches ______ Urban run-off / culverts ______ Pipes (directly feeding wetland) ______ Other:

Sources are precipitation, groundwater, natural runoff, or natural flow from an adjacent freshwater body, or the AA naturally lacks water in the growing season. There is no indication that growing season conditions are controlled by artificial water sources.	
Sources are mostly natural, but also obviously include occasional or small effects of modified hydrology (e.g., developed land or irrigated agricultural land that comprises less than 20% of the immediate drainage basin within about 2 km upstream of the AA, presence of a few small stormdrains or scattered homes with septic systems). No large point sources or dams control the overall hydrology.	
Sources are primarily from anthropogenic sources (e.g., urban runoff, direct irrigation, pumped water, artificially impounded water, or another artificial hydrology). Indications of substantial artificial hydrology include developed or irrigated agricultural land that comprises more than 20% of the immediate drainage basin within about 2 km upstream of the AA, or the presence of major drainage point source discharges that obviously control the hydrology of the AA.	
Natural sources have been **eliminated** based on the following indicators: impoundment of all wet season inflows, diversions of all dry-season inflows, predominance of xeric vegetation, etc.	
Water source comments :	

4b. HYDROPERIOD

Select the statement below that best describes the **hydroperiod** within the AA (extent and duration of inundation and/or saturation). Search the AA and 500 m envelope for hydrologic stressors (see list below). Use best professional judgment to determine the overall condition of the hydroperiod.

Hydroperiod is characterized by natural patterns of filling or inundation and drying or drawdowns.	
Hydroperiod filling or inundation patterns deviate slightly from natural conditions due to presence of stressors such as small ditches or diversions, berms or roads at/near grade, pugging, or minor flow additions.	

Hydroperiod filling or inundation and drying patterns deviate moderately from natural conditions due to presence of stressors such as 1-3ft deep ditches or diversions, two lane roads, roads with culverts adequate for stream flow, moderate pugging, or moderate flow additions.	
Hydroperiod filling or inundation and drawdown of the AA deviate substantially from natural conditions from high intensity alterations such as a 4-lane highway, large dikes, > 3ft diversions or ditches capable of lowering water table, large amount of fill, artificial groundwater pumping, or heavy flow additions.	
Hydroperiod comments :	

4c. HYDROLOGIC CONNECTIVITY

Select the statement below that best describes the **hydrologic connectivity**. *Rating criteria is different for naturally isolated fens than for other wetlands.*

Rising water has unrestricted access to adjacent areas without levees or other obstructions to the lateral movement of flood waters and no artificial connectivity with the surrounding water bodies. Channel, if present, is not entrenched (see entrenchment ratio on following page).	
Unnatural features such as levees or road grades limit the amount of adjacent transition zone or the lateral movement of floodwaters, relative to what is expected for the setting, but limitations exist for <50% of the AA boundary. Restrictions may be intermittent along the margins of the AA, or they may occur only along one bank or shore. Channel, if present, is somewhat entrenched. If naturally isolated fen, non-natural connectivity (i.e. ditching) can cause drying.	
The amount of adjacent transition zone or the lateral movement of flood waters to and from the AA is limited, relative to what is expected for the setting, by unnatural features such as levees or road grades, for 50–90% of the boundary of the AA. Flood flows may exceed the obstructions, but drainage out of the AA is probably obstructed. Channel, if present, is moderately entrenched. If fen, peat body is drying.	
The amount of adjacent transition zone or the lateral movement of flood waters is limited, relative to what is expected for the setting, by unnatural features such as levees or road grades, for >90% of the boundary of the AA. Channel, if present, is severely entrenched. If fen, peat body is drying substantially.	

Hydrologic connectivity comments:

4d. HYDROLOGY STRESSORS WITHIN A 500 M ENVELOPE

Using the table below, mark the severity of each **hydrology stressor within a 500 m envelope of the AA**. Mark whether the stressor is present upstream/slope or downstream/slope of the AA. If known alteration occurs further upstream than 500 m, please explain in comments below.

Hydrology stressor categories	*Upstream / Upslope*	*Downstream / Downslope*
Dam / reservoir		
Impoundment / stock pond		
Spring box diverting water from wetland		
Pumps, diversions, ditches that move water *out of* the wetland		
Pumps, diversions, ditches that move water *into* the wetland		
Berms, dikes, levees that hold water in the wetland		
Weir or drop structure that impounds water and controls energy of flow		
Observed or potential agricultural runoff		
Observed or potential urban runoff		
Flow obstructions into or out of wetland (roads without culverts)		
Dredged inlet or outlet channel		
Engineered inlet or outlet channel (e.g., riprap)		
Other:		
Other:		

Hydrology stressor comments:

5. OPTIONAL RIVERINE HYDROLOGY METRICS (use when channel is within ~50 m)

5a. RIVERINE CHANNEL STABILITY

Select the statement below that best describes **channel stability** within or near the AA. To determine, visually survey the AA for field indicators of channel equilibrium, aggradation or degradation listed in the table below. Check "Y" for all that apply and "N" for those not observed. Use best professional judgment to determine the overall channel stability.

Condition	Y	N	*Field Indicators*
Indicators of Channel Equilibrium	☐	☐	The channel (or multiple channels in braided systems) has a well-defined usual high water line or bankfull stage that is clearly indicated by an obvious floodplain, topographic bench that represents an abrupt change in the cross-sectional profile of the channel throughout most of the site.
	☐	☐	The usual high water line or bank full stage corresponds to the lower limit of riparian vascular vegetation.
	☐	☐	Leaf litter, thatch, wrack, and/or mosses exist in most pools.
	☐	☐	The channel contains embedded woody debris of the size and amount consistent with what is available in the riparian area.
	☐	☐	There is little or no active undercutting or burial of riparian vegetation.
	☐	☐	There is little evidence of recent deposition of cobble or very coarse gravel on the floodplain, although recent sandy deposits may be evident.
	☐	☐	There are no densely vegetated mid-channel bars and/or point bars.
	☐	☐	The spacing between pools in the channel tends to be 5-7 channel widths.
	☐	☐	The larger bed material supports abundant periphyton.
Indicators of Active Aggradation	☐	☐	The channel through the site lacks a well-defined usual high water line.
	☐	☐	There is an active floodplain with fresh splays of sediment covering older soils or recent vegetation.
	☐	☐	There are partially buried tree trunks or shrubs.
	☐	☐	Cobbles and/or coarse gravels have recently been deposited on the floodplain.
	☐	☐	There is a lack of in-channel pools, their spacing is greater than 5-7 channel widths, or many pools seem to be filling with sediment.
	☐	☐	There are partially buried, or sediment-choked, culverts.
	☐	☐	Transitional or upland vegetation is encroaching into the channel throughout most of the site.
	☐	☐	The bed material is loose and mostly devoid of periphyton.
Indicators of Active Degradation	☐	☐	The channel through the site is characterized by deeply undercut banks with exposed living roots of trees or shrubs.
	☐	☐	There are abundant bank slides or slumps, or the banks are uniformly scoured and unvegetated.
	☐	☐	Riparian vegetation declining in stature or vigor, and/or riparian trees and shrubs may be falling into channel.
	☐	☐	Abundant organic debris has accumulated on what seems to be the historical floodplain, indicating that flows no longer reach the floodplain.
	☐	☐	The channel bed appears scoured to bedrock or dense clay.
	☐	☐	The channel bed lacks fine-grained sediment.
	☐	☐	Recently active flow pathways appear to have coalesced into one channel (i.e. a previously braided system is no longer braided).
	☐	☐	There are one or more nick points along the channel, indicating headward erosion of the channel bed.

RATING CRITERIA FOR ALL RIVERINE WETLANDS	
Most of the channel within or near the AA is characterized by equilibrium conditions, with little evidence of aggradation or degradation. Streambanks dominated (>90% cover) by stabilizing plant species, including trees, shrubs, herbs.	
Most of the channel within or near the AA is characterized by some aggradation or degradation, none of which is severe, and the channel seems to be approaching an equilibrium form. Streambanks have 70–90% cover of stabilizing plant species, but some bare areas occur.	
There is evidence of severe aggradation or degradation of most of the channel within or near the AA or the channel is artificially hardened through less than half of the AA. Streambanks have 50–70% cover of stabilizing plant species within several bare areas.	
The channel is concrete or otherwise artificially hardened through most of the AA. Streambanks have <50% cover of stabilizing plant species.	

Channel stability comments: (note if channel is unstable due to beaver or natural processes)

5b. RIVERINE ENTRENCHMENT RATIO (optional guide for if stream may be entrenched)

Using the following worksheet, calculate the average **entrenchment ratio** for the channel. The steps should be conducted for each of three cross sections located in or adjacent to the AA at the approximate mid-points along straight riffles or glides, away from deep pools or meander bends. *Do not attempt to measure this for non-wadeable streams!*

Steps	*Replicate cross-sections* →	*1*	*2*	*3*
1. Estimate bankfull width.	If the stream is entrenched, the height of bankfull flow is identified as a scour line, narrow bench, or the top of active point bars well below the top of apparent channel banks. If the stream is not entrenched, bankfull stage can correspond to the elevation of a broader floodplain with indicative riparian vegetation. Estimate or measure the distance between the right and left bankfull contours.			
2. Estimate max bankfull depth.	Imagine a line between right and left bankfull contours. Estimate or measure the height of the line above the thalweg (the deepest part of the channel).			
3. Estimate flood prone height.	Double the estimate of maximum bankfull depth from Step 2.			
4. Estimate flood prone width.	Imagine a level line having a height equal to the flood prone depth from Step 3. Note the location of the new height on the channel bank. Estimate the width of the channel at the flood prone height.			
5. Calculate entrenchment.	Divide the flood prone width (Step 4) by the max bankfull width (Step 1).			
6. Calculate average entrenchment	Average the results of Step 5 for all three cross-sections and enter it here.			

RATING CRITERIA FOR CONFINED RIVERINE WETLANDS		RATING CRITERIA FOR UNCONFINED RIVERINE WETLANDS	
Entrenchment ratio >2.0.		Entrenchment ratio >2.2.	
Entrenchment ratio 1.6–2.0.		Entrenchment ratio 1.9–2.2.	
Entrenchment ratio 1.2–1.5.		Entrenchment ratio 1.5–1.8.	
Entrenchment ratio <1.2.		Entrenchment ratio <1.5.	

Entrenchment ratio comments:

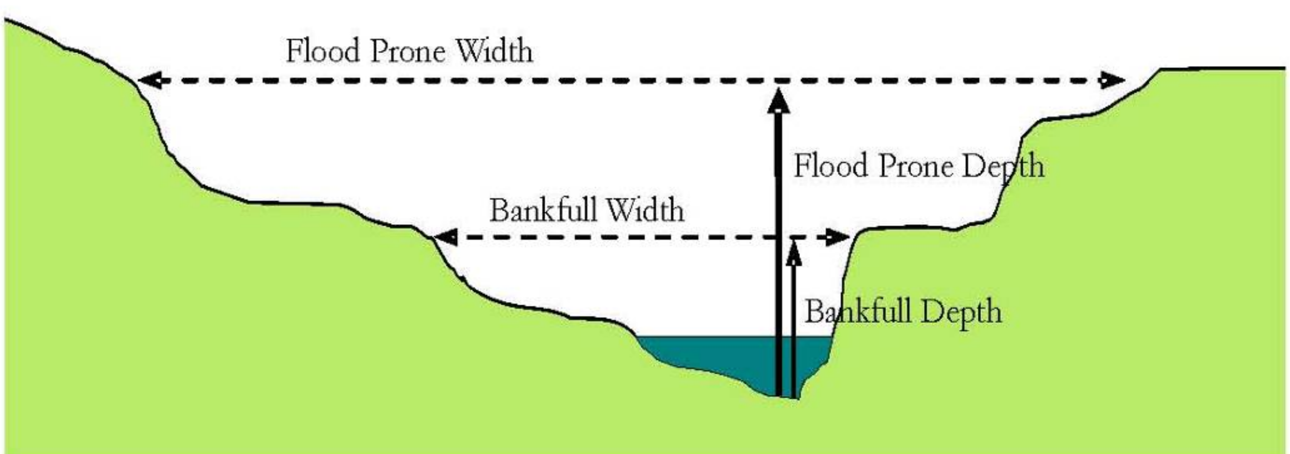


Illustration from Collins *et al.* 2008. California Rapid Assessment Method for Wetlands v 5.0.2

APPENDIX I: EIA Metric Rating Criteria and Scoring Formulas Used for the Northern Front Range

Table D1. Ecological Integrity Assessment (EIA) metric rating criteria and scoring formulas for the northern Front Range.

<table>
<tr><th rowspan="11">LANDSCAPE CONTEXT</th><th>Key Ecological Attribute</th><th>Indicator / Metric</th><th colspan="5">Metric Rating Criteria</th></tr>
<tr><th colspan="2">Rank / Score</th><th>A / 5</th><th>B / 4</th><th>C / 3</th><th colspan="2">D / 1 –OR– D / 2 and E / 1</th></tr>
<tr><th colspan="2">Interpretation</th><th>Reference (No or Minimal Human Impact)</th><th>Slight Deviation from Reference</th><th>Moderate Deviation from Reference</th><th colspan="2">Significant Deviation from Reference</th></tr>
<tr><td rowspan="2">Landscape Connectivity</td><td>1a. Landscape Fragmentation within 500 m</td><td>Embedded in >90% unfragmented, natural landscape.</td><td>Embedded in >60–90% unfragmented, natural landscape.</td><td>Embedded in >20–60% unfragmented, natural landscape.</td><td colspan="2">Embedded in ≤20% unfragmented, natural landscape.</td></tr>
<tr><td>1b. Riparian Corridor Continuity within 500 m[1]
RIVERINE ONLY</td><td>>90% natural habitat upstream and downstream</td><td>>60–90% natural habitat upstream and downstream</td><td>>20–60% natural habitat upstream and downstream</td><td colspan="2">≤20 natural habitat upstream and down-stream</td></tr>
<tr><td rowspan="4">Buffer</td><td>1c. Buffer Extent</td><td>Buffer at least 5 m wide surrounds 100% of AA</td><td>Buffer at least 5 m wide surrounds >75–<100% of AA</td><td>Buffer at least 5 m wide surrounds >50–75% of AA</td><td>Buffer at least 5 m wide surrounds >25–50% of AA</td><td>Buffer at least 5 m wide surrounds ≤25% of AA</td></tr>
<tr><td>1d. Buffer Width</td><td>Average buffer width is >200 m</td><td>Average buffer width is >100–200 m</td><td>Average buffer width is >50–100 m</td><td colspan="2">Average buffer width is ≤50 m or no buffer exists</td></tr>
<tr><td>1e. Buffer Condition – Vegetation</td><td>Abundant (>95%) cover native vegetation, little or no (<5%) cover of non-native plants, intact soils.</td><td>Substantial (75–95%) cover of native vegetation, low (5–25%) cover of non-native plants.</td><td>Moderate (25–50%) cover of non-native plants.</td><td colspan="2">Dominant (>50%) cover of non-native plants.</td></tr>
<tr><td>1f. Buffer Condition – Soils</td><td>Intact soils with little-no trash, negligible intensity of human use.</td><td>Intact or moderately disrupted soils, moderate –lesser trash, OR minor intensity of human use.</td><td>Moderate-extensive soil disruption, moderate of greater amounts of trash, OR moderate intensity of human use.</td><td colspan="2">Barren ground and highly compacted or disrupted soils, moderate-greater amounts of trash, moderate-greater intensity of human use, OR no buffer.</td></tr>
</table>

[1] Metric used for Riverine HGM wetlands only

	Key Ecological Attribute	Indicator / Metric	Metric Rating Criteria				
		Rank / Score	**A / 5**	**B / 4**	**C / 3**	**D / 1 –OR– D / 2 and E / 1**	
		Interpretation	**Reference (No or Minimal Human Impact)**	**Slight Deviation from Reference**	**Moderate Deviation from Reference**	**Significant or Severe Deviation from Reference**	
BIOTIC CONDITION	**Community Composition**[1]	*2a. Relative Cover Native Plant Species*	Relative cover native plants > 99%	Relative cover native plants >95-99%	Relative cover native plants >80-95%	Relative cover native plants >50-80%	Relative cover native plants ≤50%
		2b. Absolute Cover Noxious Weeds	Absolute cover noxious weeds = 0%	Absolute cover noxious weeds >0-3%	Absolute cover noxious weeds >3-10%	Absolute cover noxious weeds >10% noxious	
		2c. Absolute Cover Aggressive Native Species	<10% cattail or <5% reed canary grass or giant reed grass	10-25% cattail or 5-10% reed canary grass or giant reed grass	>25-50% cattail or 10-25% reed canary grass or giant reed grass	>50% cattail or >25% reed canary grass or giant reed grass	
		2d. Mean C[2] *Riparian Areas and Fens* *Wet Meadows* *Saline Wetlands & Marshes*	 Mean C > 6.0 Mean C > 6.0 Mean C > 4.5	 Mean C > 5.5-6.0 Mean C > 5.5-6.0 Mean C > 4.0-4.5	 Mean C >5.0-5.5 Mean C >4.0-5.5 Mean C >3.0-4.0	 Mean C >4.5-5.0 Mean C >3.0-4.0 Mean C >2.0-3.0	 Mean C ≤ 4.0 Mean C ≤ 3.0 Mean C ≤ 2.0
	Community Structure	*2e. Regeneration of Native Woody Species*[3]	All age classes present (N/A if woody sp. naturally uncommon/absent)	No middle age groups, others present	No young-middle age groups, mature present	Woody sp. mainly decadent and dying or >5% cover Tamarisk or Russian Olive	
		2f. Litter Accumulation	Moderate litter and duff and organic matter, neither lacking nor excessive.		Small amounts of litter with little plant recruitment, or excessive litter.	AA lacks litter completely, or excessive litter that limits new growth.	
		2g. Structural Complexity	Horizontal structure consists of a very complex array of nested and/or interspersed, irregular biotic and abiotic patches with no single dominant patch type.	Horizontal structure consists of a moderate array of biotic and abiotic patches with no single dominant patch type.	Horizontal structure consists of a simple array of biotic and abiotic patches.	Horizontal structure consists of one dominant patch type and thus has relatively no interspersion.	

[1] All community composition metrics calculated from the vegetation data not derived from field for rank scores. Final thresholds are different from those shown on the field form.
[2] Mean C thresholds apply to specific Ecological Systems.
[3] Only applied to sites with where woody species are naturally common.

HYDROLOGIC CONDITION[1]	Indicator / Metric	Metric Rating Criteria			
	Rank / Score	A / 5	B / 4	C / 3	D / 1
	Interpretation	Reference (No or Minimal Human Impact)	Slight Deviation from Reference	Moderate Deviation from Reference	Significant Deviation from Reference
	3a. Water Source	Sources are precipitation, groundwater, natural runoff, or natural flow from an adjacent freshwater body, or the AA naturally lacks water in the growing season. There is no indication that growing season conditions are controlled by artificial water sources.	Sources are mostly natural, but also obviously include occasional or small effects of modified hydrology (e.g., developed land or irrigated agricultural land that comprises less than 20% of the immediate drainage basin within about 2 km upstream of the AA, presence of a few small storm drains or scattered homes with septic systems). No large point sources or dams control the overall hydrology.	Sources are primarily from anthropogenic sources (e.g., urban runoff, direct irrigation, pumped water, artificially impounded water, or another artificial hydrology). Indications of artificial hydrology include developed or irrigated agricultural land that comprises more than 20% of the immediate drainage basin within about 2 km upstream of the AA, or the presence of major drainage point source discharges that obviously control the hydrology.	Natural sources have been eliminated based on the following indicators: impoundment of all wet season inflows, diversions of all dry-season inflows, predominance of xeric vegetation, etc.
	3b. Hydrologic Connectivity	Rising water has unrestricted access to adjacent areas without levees or other obstructions to the lateral movement of flood waters, if stream present, not entrenched.	Unnatural features such as levees or road grades limit the lateral movement of floodwaters, relative to what is expected for the setting, but limitations exist for <50% of the AA boundary. Restrictions may be intermittent along the margins of the AA, or they may occur only along one bank or shore. If stream present, slightly entrenched.	The lateral movement of flood waters to and from the AA is limited, relative to what is expected for the setting, by unnatural features such as levees or road grades, for 50–90% of the boundary of the AA. Flood flows may exceed the obstructions, but drainage out of the AA is probably obstructed. If stream present, moderately entrenched.	The lateral movement of flood waters is limited, relative to what is expected for the setting, by unnatural features such as levees or road grades, for >90% of the boundary of the AA. If stream present, very entrenched.
	3c. Alteration to Hydroperiod *NON-RIVERINE ONLY*	Hydroperiod is characterized by natural patterns of filling or inundation and drying or drawdowns with no alterations.	Filling and drying patterns deviate slightly from natural conditions due to presence of stressors such as small ditches or diversions, berms or roads at/near grade, pugging, or minor flow additions.	Filling and drying patterns deviate moderately from natural conditions due to presence of stressors such as 1-3ft deep ditches or diversions, two lane roads, roads with culverts adequate for stream flow, moderate pugging, or moderate flow additions.	Filling and drying patterns deviate substantially from natural conditions due to high intensity alterations such as a 4-lane highway, large dikes, > 3ft diversions or ditches capable of lowering water table, large amount of fill, artificial groundwater pumping, or heavy flow additions.
	3d. Upstream Water Retention *RIVERINE ONLY*	<5% of watershed drains to water storage facility.	5–20% of watershed drains to water storage facility.	20–50% of watershed drains to water storage facility.	>50% of watershed drains to water storage facility.

[1] Hydrology metrics are different for Riverine HGM and Non-Riverine HGM wetlands.

HYDROLOGIC CONDITION[1]	*3e. Water Diversions and/or Additions* *RIVERINE ONLY*	No upstream or onsite water diversions or additions present.	Few diversions/additions present or impacts minor relative to contributing watershed size. Minor impact to local hydrology.	Many diversions/additions present or impact moderate relative to contributing watershed size. Major impact to local hydrology.	Diversions/additions very numerous or impacts high relative to contributing watershed size. Local hydrology drastically altered.
	3f. Bank Stability *RIVERINE ONLY*	Most of the channel through the AA is characterized by equilibrium conditions, with little evidence of aggradation or degradation. Streambanks dominated (>90% cover) by stabilizing plant species, including trees, shrubs, herbs.	Most of the channel through the AA is characterized by some aggradation or degradation, none of which is severe, and the channel seems to be approaching an equilibrium form. Streambanks have 70–90% cover of stabilizing plant species.	There is evidence of severe aggradation or degradation of most of the channel through the AA or the channel is artificially hardened through less than half of the AA. Streambanks have 50–70% cover of stabilizing plant species.	The channel is concrete or otherwise artificially hardened through most of the AA. Streambanks have <50% cover of stabilizing plant species.
	3g. Beaver Activity[2] *RIVERINE ONLY*	Active or recent beaver sign present. Beaver currently active within the area.	Only old beaver sign present. No evidence of recent or new beaver activity despite available food resources and habitat. (Score = 3)		No beaver sign present.

[1] Hydrology metrics are different for Riverine HGM and Non-Riverine HGM wetlands.
[2] Only applied to sites with where beaver activity is expected.

PHYSIOCHEMICAL CONDITION	*4a. Water Quality*	No visual evidence of degraded water quality. No visual evidence of turbidity or other pollutants.	Some negative water quality indicators are present, but limited to small and localized areas within the wetland. Water is slightly cloudy, but there is no obvious source of sedimentation or other pollutants.	Water is cloudy or has unnatural oil sheen (natural bacterial sheens break apart upon contact), but the bottom is still visible. Sources of water quality degradation are apparent.	Water is milky and/or muddy or has unnatural oil sheen (natural bacterial sheens break apart upon contact). The bottom is difficult to see and there are obvious sources of water quality degradation.
	4b. Algal Growth	Water is clear with minimal algal growth.	Algal growth is limited to small and localized areas of the wetland. Water may have a greenish tint or cloudiness.	Algal growth occurs in moderate to large patches throughout the AA. Water may have a moderate greenish tint or sheen. Sources of water quality degradation are apparent.	Algal mats are extensive, blocking light to the bottom. Water may have a strong greenish tint and the bottom is difficult to see. There are obvious sources of water quality degradation.
	4c. Substrate / Soil Disturbance	No apparent modifications.	Past modifications, but recovered; OR recent but minor modifications.	Recovering OR recent and moderate modifications.	Recent and severe modifications.

EIA Scoring Formulas:

Non-Riverine HGM Wetlands

Landscape Context Score: $(1a * 0.4) + ([(1c*1d)^{1/2} * (1e + 1f)/2]^{1/2} * 0.6)$

Biotic Condition Score: $(2a * 0.2) + ([2b \text{ OR } 2c^{1}] * 0.2) + (2d * 0.4) + (2e^{2} * 0.1) + (2f^{2} * [0.05 \text{ OR } 0.1]) + (2g^{2} * [0.05 \text{ OR } 0.1])$

Hydrologic Condition Score: (3a * 0.2) + (3b * 0.2) + (3c * 0.6)

Physiochemistry Condition Score: (4a * 0.25) + (4b * 0.25) + (4c * 0.5)

Riverine HGM Wetlands

Landscape Context Score: $(1a * 0.1) + (1b * 0.3) + ([(1c*1d)^{1/2} * (1e + 1f)/2]^{1/2} * 0.6)$

Biotic Condition Score: $(2a * 0.2) + ([2b \text{ OR } 2c^{1}] * 0.2) + (2d * 0.4) + (2e^{2} * 0.1) + (2f^{2} * [0.05 \text{ OR } 0.1]) + (2g^{2} * [0.05 \text{ OR } 0.1])$

Hydrologic Condition Score: $(3a * 0.2) + (3b * 0.2) + ([3d*3e]^{1/2} * 0.4) + (3f^{3} *[0.1 \text{ OR } 0.2]) + (3g^{3} * 0.1)$

Physiochemistry Condition Score: (4a * 0.25) + (4b * 0.25) + (4c * 0.5)

Overall EIA Score

(Landscape Context Score * 0.2) + (Biotic Condition Score * 0.4) + (Hydrologic Condition Score * 0.3) + (Hydrologic Condition Score * 0.1)

[1] Lowest value from 2b or 2c is used.
[2] If 2e is NA, use 0.1 for 2f and 2g weights.
[3] If 3g is NA, use 0.2 for 3f weight.

Overall Score to Rank Conversion:

A = 4.5 – 5.0
B = 3.5 – <4.5
C = 2.5 – <3.5
D = 1.0 – <2.5s