Assessing the Natural Range of Variability in Minimally Disturbed Wetlands Across the Rocky Mountains: the Rocky Mountain ReMAP Project

Prepared for:

The U.S. Environmental Protection Agency

Prepared by:

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Executive Summary

In Montana, Wyoming, Colorado and Utah, extremes of mountain climate, high elevations and characteristic geology produce a large range of natural variability within ecological systems. Even under minimal human disturbance regimes, environmental gradients can result in wetlands with very low vegetation cover, low species diversity and unpredictable hydrologic shifts. Documenting the range of variability found under minimally disturbed conditions can help distinguish signal from noise when assessing more altered occurrences, and aid in the calibration of assessment metrics.

The project was a collaboration between the Montana Natural Heritage Program (MTNHP), the Colorado Natural Heritage Program (CNHP) and the Wyoming Natural Diversity Database (WYNDD). It had three objectives: 1) identify reference standards for four wetland ecological systems across four Rocky Mountain ecoregions; 2) assess the range of natural variability of these ecological systems; and 3) produce a regionally standardized Level 1, 2 and 3 method for assessing and monitoring wetland condition, including quality assurance project plans, sampling strategies, and metrics calibrated to the four different wetland ecological systems. This report summarizes our approach, activities, and conclusions.

Objective 1 summarizes the approach we used to identify wetlands in minimally disturbed condition. We built a regional landscape integrity model based on distance from stressors, and used this to select minimally disturbed landscapes. Within this landscape, we used a spatially balance random sampling approach to select a sample of wetlands for assessment. The initial landscape model performed well in terms of identifying sites with minimal disturbance, especially when it was used in conjunction with photointerpretation of more recent imagery. However, our random sampling did not produce equal numbers of all wetland ecological systems included in the study. Marshes were significantly underrepresented, and we think it is likely that our sample did not represent the full range of fens found across the region.

Objective 2 describes the attributes, indicators and metrics we used to determine the range of natural variability found in the minimally disturbed sites we sampled. We found considerable variability in the vegetation of our study sites. Analysis of intensive vegetation plots and derived metrics showed clear patterns of regional and typological variability. The Southern Rockies and Wasatch-Uinta Mountains had consistently higher metric values than the Middle Rockies and Canadian Rockies for all Floristic Quality Assessment (FQA) calculations except exotic species richness. Riparian shrublands had the highest species richness across all Level III Ecoregions, followed by wet meadows. Fens had the lowest species richness in the Middle Rockies, Southern Rockies, and Wasatch-Uinta Mountains, while emergent marshes had the lowest richness in the Canadian Rockies. Riparian shrublands and wet meadows also had the highest Shannon-Wiener diversity indices, whereas marshes had the lowest across all Level III Ecoregions. Results for Floristic Quality Index (FQI) values followed similar patterns, with riparian shrublands and wet meadows having the highest FQI values across Level III Ecoregions. Emergent marshes had the lowest FQI values in all Level III Ecoregions except the Middle Rockies, where fens had the lowest FQI values.

Objective 3 discusses our draft protocol and its performance. Because we were only looking at reference standard sites we could not evaluate

whether or not individual metrics were sensitive to human disturbance. Instead, we wanted level 2 metrics that had either had a consistent value across all wetlands in the study, or metrics whose variable response was easily correlated to specific wetland types. Unlike the Level 3 FQA metrics, which were intended to capture a range of natural variation that could be used to calibrate Level 3 protocols to specific wetland types and ecoregions, any Level 2 metric that had a wide range of unexplained scoring values when applied to reference standard sites was considered unsuitable for inclusion in a future protocol. We saw little variation among sites in terms of landscape context, hydrology, and physiochemical/soil metrics. However, regeneration of native woody species, vertical overlap of vegetation strata, horizontal interspersion of vegetation zones, and number of structural patch types had wide ranges of response, leading us to conclude that these would not be good metrics for detecting the results of human disturbance.

The report concludes with our overall conclusions and recommendations. In particular, we conclude that the random sampling approach used in this study was preferable to targeted sampling of reference wetlands, avoiding the tendency to identify the largest and most diverse examples of wetlands, and thus more accurately capturing the range of diversity. The representativeness of the sites can be used to establish reasonable performance standards for voluntary and compensatory mitigation. Our findings that there are regional and typological differences in the range of natural variability are of particular importance. Marshes, with their low species richness and relatively low FQI scores, do not compensate for the loss of wet meadows or fens. In contrast, if a marsh is an appropriate choice for mitigation and/or restoration, then performance standards for FQA values should be based on what a marsh can be expected to attain, not on values observed in fens. Finally, we lay out a number of suggestions for future study. These include the need for a more nuanced understanding of the geographic and temporal scales at which landscape level disturbances affect wetland integrity; a reevaluation of the appropriate use of structural diversity metrics as an indicator of habitat suitability rather than condition; research into the underlying causes of the regional variability we observed; and further analysis of the factors that drive species richness and diversity at individual wetland sites.

Acknowledgements

This report reflects the collective work of many people. Without Rich Sumner of the Environmental Protection Agency (EPA), the project never would have begun. Joe Rocchio, formerly of the Colorado Natural Heritage Program and now part of the Washington Natural Heritage Program, was the guiding force behind the initial proposal. Tony Olson of the EPA provided guidance and support on GRTS design. Bob Ozretich of the EPA offered helped with QA/QC activities. The Nature Conservancy allowed us to use its Red Canyon Ranch in Wyoming as a field testing site to work out our draft assessment protocols. Those protocols, in turn, incorporate and build on work led by Don Faber-Langendoen of NatureServe and his many collaborators; Josh Collins of the San Francisco Estuary Institute and Martha Sutula of the Southern California Coastal Water Research Project, who pioneered the California Rapid Assessment Method (CRAM); and John Mack, now of Cleveland Metroparks, whose Ohio Rapid Assessment Method (ORAM) has inspired may similar efforts.

The project also benefited greatly from the exchange of information and ideas with EPA scientists involved in the National Wetlands Condition Assessment, which was designed and carried out during the same time period. In particular, we acknowledge the input, advice and other help from Mike Scozzafava, Gregg Serenbetz, Teresa Magee, Mary Kentula, Regina Poeske, Mary Ann Theising, Teresa Magee and Kathleen Drake. We owe particular thanks to Jill Minter and Toney Ott from Region 8 of the EPA, whose support and encouragement over the years were critical to the development of wetland science in the Rocky Mountain West.

In Montana, Colorado and Wyoming, many people participated in the design and implementation of this study. Claudine Tobalske of MTNHP located and put together data layers from four states for the Landscape Integrity Model, which required a great deal of sleuthing and persistence. Cat McIntyre, formerly of the MTNHP, was tireless in planning, coordinating and managing field work in Montana, and offered astute insights into protocol development. Denise Culver of CNHP shared her botanical expertise and experience with the entire team. And of course, this project would never have come to fruition had it not been for the field ecologists who braved bad weather, abandoned roads, deep water and voracious insects to find and assess the study wetlands: Nick Smith, Joe St. Peter, Karissa Ramstead, Tara Luna, Kyla Zaret, Sam Isham, Hannah Varani, Elin Franzen, Cat Sever and Sean Ryder. Sam Isham and Karissa Ramstead also tackled the job of entering all the field data. Tara Luna and Karissa Ramstead combed through the field notes and data to describe the plant communities and to prepare the sentinel site descriptions.

We also thank Neil Snow for his patient editing, and Coburn Currier for formatting the final version. If any errors remain despite the efforts of all these people, they are the authors' alone.

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Table of Contents

List of Figures

List of Tables

List of Tables (Continued)

Project Description

The Rocky Mountain West has a unique geography, population distribution, and concentration of public land ownership. In Montana, Wyoming, Colorado and Utah, extremes of mountain climate, high elevations and characteristic geology produce a large range of natural variability within ecological systems. In previous field projects, we have observed that even under minimal human disturbance regimes, environmental gradients can result in wetlands with very low vegetation cover, low species diversity and unpredictable hydrologic shifts. However, there have been no systematic studies addressing whether, and to what extent, these differences represent natural variability among wetland ecological systems. Because wetland assessment protocols are predicated on an assumption that there are distinct, measurable indicators of wetland condition that will respond in predictable ways to human disturbance, documenting the range of variability found under minimally disturbed conditions can help distinguish signal from noise in more altered occurrences, and aid in the calibration of metrics.

The project was a collaboration between the Montana Natural Heritage Program (MTNHP), the Colorado Natural Heritage Program (CNHP) and the Wyoming Natural Diversity Database (WYNDD). It had three objectives: 1) identify reference standards for four wetland ecological systems across four Rocky Mountain ecoregions; 2) assess the range of natural variability of these ecological systems; and 3) produce a regionally standardized Level 1, 2 and 3 method for assessing and monitoring wetland condition, including quality assurance project plans, sampling strategies, and metrics calibrated to the four different wetland ecological systems. This report summarizes our approach, activities, and conclusions. Objective 1 summarizes the approach we used to identify wetlands in minimally disturbed condition. Objective 2 describes the attributes, indicators and metrics we used to determine the range of natural variability found in the minimally disturbed sites we sampled. Objective 3 discusses our draft protocol and its performance. This is followed by a summary of our overall conclusions and recommendations.

Objective 1. Identify reference standards for four wetland ecological systems across four ecoregions

Background

The Rocky Mountain West is unusual in having an abundance of land that has been withdrawn from (or never available to) intensive human use, thus escaping all but generalized or indirect disturbances (e.g. native ungulate grazing, high-intensity fires caused by suppression of periodic low intensity fires, etc.). In many cases, even landscapes disturbed by grazing or logging have had sufficient time to recover (Stoddard et al. 2006). Therefore, we believed it would be possible to identify a set of wetlands in minimally disturbed condition (MDC) across the region,[5] and describe their biotic and abiotic attributes in such a way that we could determine their natural range of variability. We expected that these minimally disturbed sites would exhibit a range of natural variability even though they have been exposed to widespread anthropogenic change vectors, such as atmospheric deposition, and that these sites could be used to describe reference conditions. A secondary goal was to create a network of well-documented "sentinel" wetlands that could be revisited over time to evaluate impacts of climate change, human land uses, or other natural or anthropogenic factors.

We recognized that some of the variability in wetland attributes is predictable based on wetland type; for example, the calcium-rich groundwater characteristic of rich fens will often result in greater species diversity than is found in wet meadows or marshes (Chadde et al. 1998). Therefore, we decided to do an a priori classification of our target population, both to constrain the variability and to ensure even representation of wetland types. For our typology we chose the ecological system classification developed by NatureServe (Comer et al. 2003).

Ecological systems are groupings of biological communities occurring in similar physical environments, and influenced by similar ecological processes such as flooding, fire, wind, and snowfall. Systems typically occur on a landscape at scales of tens to thousands of acres, and generally persist in a recognizable state for 50 or more years. By integrating biotic and abiotic features, the ecological system concept incorporates elements of the Hydrogeomorphic Method (HGM) and the vegetation-based National Vegetation Classification Standard. Furthermore, ecological systems are mappable units that can be classified from aerial or satellite imagery, and are easily identifiable in the field by land managers, resource specialists, and planners (Comer et al. 2003).

Although over 30 wetland/riparian ecological systems are found in the four states (Montana, Wyoming, Utah and Colorado) included in this study, only six occurred in all states. Although more detailed classification possibilities exist, e.g., the National Vegetation Classification Standard (NVC) macrogroup level (Faber-Langendoen et al. 2009b), and could be used to constrain variability, the relatively small sample size that we anticipated (~100 wetlands) required a coarser classification. Of the six wetland ecological systems occurring in the four states, two were not suitable for inclusion. One (the Rocky Mountain Subalpine Montane Riparian Woodland) occurs only in narrow bands along high

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5 Because human alteration of the landscape has occurred at different times and with different intensity across the U.S. and other parts of the world, it has been suggested that the term "reference condition" has lost its meaning, and should be replaced by a new set of terms more accurately describing the various expected conditions against which an assessed site can be ranked (Stoddard et al. 2006). For example, Minimally Disturbed Condition (MDC) can be used for sites occurring in the absence of significant human disturbance. Such sites exhibit a range of natural variability even though they have been exposed to widespread anthropogenic change vectors, such as atmospheric deposition. Historical Condition (HC) can describe sites at some point in history prior to large-scale change, e.g., European settlement of North America. Least Disturbed Condition (LDC) can indicate sites that are the best in the area or region in terms of physical, chemical, biological, or hydrological properties. Here we continue to use the term "reference condition" to mean "Minimally Disturbed Condition, in accordance with common practice; when we refer to historic or least-disturbed conditions, we will use those terms.

order streams, and typically has little true wetland habitat. The other (Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland) is largely found in the wildland-urban interface, and initial field reconnaissance indicated that we would be unable to find sufficient examples of this system in minimally disturbed areas to meet our goals. The four systems retained in our study were the Rocky Mountain Subalpine-Montane Fen; Rocky Mountain Alpine-Montane Wet Meadow; North American Arid West Emergent Marsh; and Rocky Mountain Subalpine-Montane Riparian Shrubland. See Appendix A for descriptions of these ecological systems.

We further limited our sampling by choosing the four largest and most mountainous Level III ecoregions (Omernik 1987) within our four-state area: The Canadian Rockies, the Middle Rockies, the Wasatch and Uinta Mountains and the Southern Rockies (See Map 1). Level III ecoregions are delineated on the basis of common geology, soils, hydrology, topography, climate, vegetation, water quality, and wildlife.[6]

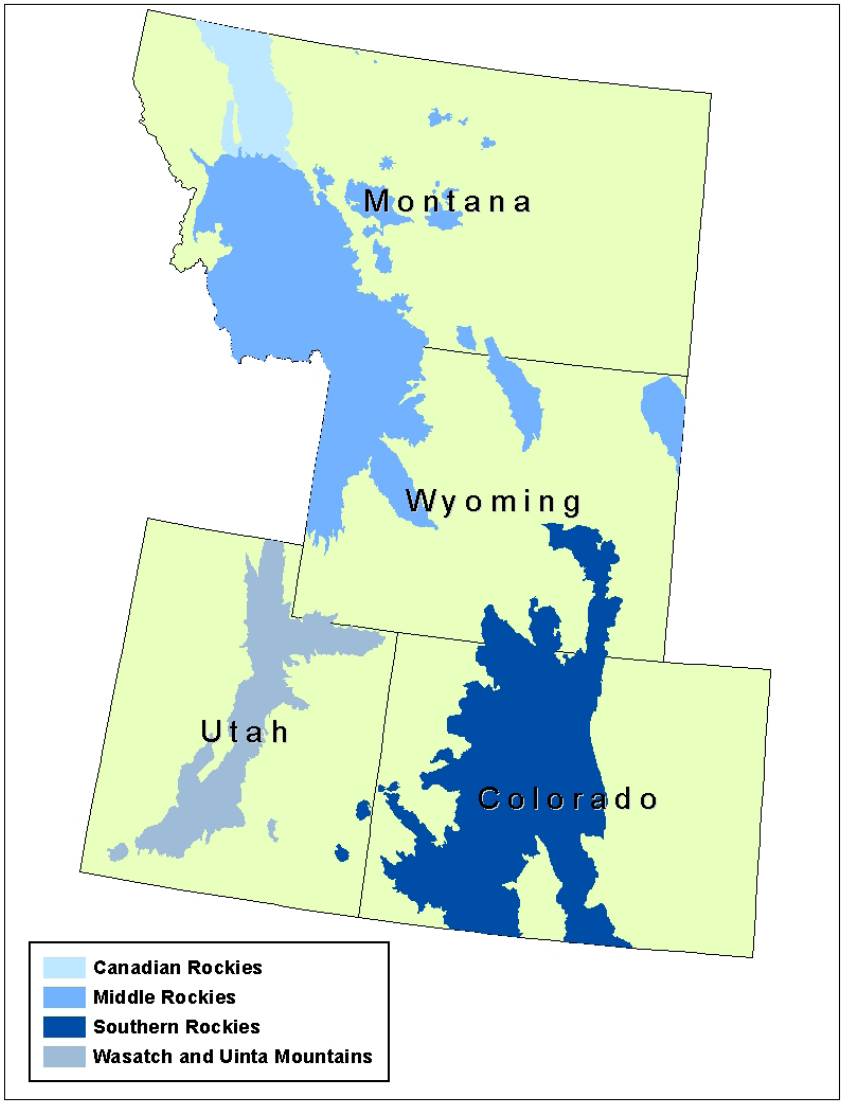

Figure 1. Study ecoregions, Rocky Mountain Remap Project.

6 The National Wetlands Condition Assessment is using the aggregated ecoregions developed for the Wadeable Streams Assessment. This aggregated approach rolls up Level III ecoregions into 9 broad ecoregions. Our four ecoregions roughly correspond to the portions of the "Western Mountains" broad ecoregion lying within the four states of our study area.

Methods

Montana, Colorado and Wyoming all have documented examples of the high quality wetland ecological systems in this study. However, we elected a probabilistic rather than targeted survey approach (Herlihy et al. 2008) because we were concerned that the previously documented sites might be biased to the largest, most diverse, or most interesting examples of the systems, instead of reflecting the range of variability that we believed existed across the region.

We used a two-stage survey design. First, we used a Generalized Random Tessellation Stratification (GRTS) sampling design within the package spsurvey (Kincaid et al. 2009) in the statistical software R (R Development Core Team 2009) to select 50 two mile by two mile grid cells within each Level III Ecoregion, and created a grid of points at 100 meter intervals within each selected cell. The GRTS design is discussed in greater detail under Objective 3. Given our primary interest in describing reference standard wetlands, we needed to limit potential sample sites to minimally disturbed landscapes. Additionally, we needed to ensure that sites were reasonably accessible without excessive travel on foot. To determine the portions of the study area that were most likely to feature minimally disturbed landscapes, a landscape integrity model developed for Montana (Vance 2009) was adopted for the entire project area. This is an inverse weighted distance model premised on the idea that ecosystem processes and functions achieve their fullest expression in areas where human activities have the least impact. In the case of wetlands, it presumes that reference standard wetlands are mostly likely to be found in areas well removed from roads, commercial or industrial development, urban areas, resource extraction sites, or hydrologic modifications. Although GIS data quality varied among the four states, we were able to identify sufficiently comparable data sets to build a Rocky Mountain Landscape Integrity Model that could be used as an initial predictor of minimally disturbed areas. Appendix B includes a list of the parameters and weighting used in the model. We determined which points in our grid fell within the high integrity landscape using Spatial Analyst in ArcGIS 9.3 (ESRI 2008). From the selected points, we eliminated any points not falling on publicly owned lands or were greater than 10 miles from a four-wheel drive road.

We used GRTS to order the remaining points for additional evaluation. We then used aerial photographs in a GIS to visually examine each of these points and determine if it occurred within one of the targeted wetland ecological systems. We also inspected each point to ensure that there were no landscape disturbances (e.g., outfitter camps, heavy livestock use, recent logging or wildfire) that had been undetected in the GIS data layers. Appendix C includes the instructions developed for using the screening parameters and the digital data layers to select sites from aerial photographs. We selected points until we had up to three points representing each wetland system within each grid cell.

Trained field crews navigated with a GPS to the selected sample points. Upon arrival at the point, the crew first conducted a site evaluation to determine if the site met the criteria of the target population. To determine if a wetland was one of the four target ecological systems, crews used a field key developed for wetland and riparian ecological systems of Montana, Wyoming, Utah, and Colorado by the MTNHP and CNHP (Appendix D). Next, field crews determined if the site met the criteria defined for reference standard. These criteria were based on the parameters used in the initial landscape integrity model screening, and acted as a final validation of the model and its assumptions. Table 1 shows the minimum acceptable distance for each disturbance; if any one of these occurred in closer proximity, the site was dropped from the sample.

Once the site was verified, an assessment area (AA) was established,[7] and crews collected site information on field forms following the instructions in the Draft Protocol.[8] After basic site data were recorded, crews assessed the four wetland at-

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[7] The standard AA was half a hectare (5000 square meters) in size; see the Draft Protocol (Appendix E) for more information on non-standard layouts and sizes.

[8] The Draft Protocol is discussed in more detail under Objective 3.

Table 1. Minimum acceptable distance for disturbance in the landscape screening.

Roads and Highways

- 4x4, dirt > 200 m
- local, city > 300 m
- highways > 500 m

Hydrologic Modification

- canals, ditches > 200 m
- reservoirs > 1,000 m downstream
- water right point of use (wells, diversion points, impoundments) > 200 m

Land Cover

- high density residential > 2,000 m
- low density residential / high use recreation > 300 m
- crop agriculture / hay pastures > 500 m
- timber harvest > 2,000 m

Land Use

- abandoned mines / tailings piles > 500 m
- active gravel pit, open pit, strip mining > 1,000 m
- evidence of heavy livestock use > 200 m

tributes examined in this study: landscape context, vegetation, physical-chemical features, and hydrology. In addition to the condition metrics (discussed in detail under Objective 2), each attribute had an associated set of stressor metrics.

For example, crews conducted an assessment of the landscape context in which the site was found and identified stressors within a 500 m envelope. This assessment covered the larger envelope in which the site occurred, and acted as a validation of the site selection methodology, providing a final set of data that could be reviewed during analysis to ensure that the wetland was indeed reference standard. Metrics included landscape connectivity, buffer area and condition and percent natural cover. Crews also identified landscape stressors in and around the site. Disturbance thresholds for the condition assessment were more stringent than for site selection. For example, a dirt road 300 m from the AA did not disqualify a site from inclusion in the sample; however, the road did affect landscape connectivity measurements. Similarly, while a fence near the AA would not affect the site's inclusion in the sample, the fence would be considered as an anthropogenic impact within the buffer if it restricted wildlife movement.

Other landscape context metrics also provided us with an opportunity to verify that the sites retained in the study met the criteria for minimal disturbed condition:

Landscape Connectivity: This metric evaluated the percent unfragmented area within a 500 m envelope surrounding the AA. For non-riparian wetlands, crews identified the largest unfragmented block that contained the AA and estimated its percentage of the total area within the 500 m envelope. For riparian sites, the metric required them to identify the largest unfragmented area within the geomorphic floodplain beginning 500 m above the AA and extending 500 m downstream. Fragmentation occurred whenever connectivity was interrupted, e.g., by heavy grazing, roads, agriculture, residential development or managed recreational sites.

Buffer extent: This was defined as a buffer of at least 30 m in width and at least 5 m in length around the AA. Unpaved, lightly used trails (bike, foot or horse), natural upland habitats, nature parks, lightly grazed rangeland, vegetated swales and ditches, open water and vegetated levees all were considered to be buffering land covers, while land cover types such as corrals, horse paddocks or heavily used trails were not. *Buffer width* was defined as the width of uninterrupted buffer (up to 200 m) around the AA. *Buffer condition* was evaluated within a 200 m envelope surrounding the AA. Condition metrics included the percent native plant cover, evidence of human visitation, and soil disturbances within the buffer area defined by extent and width.

Landscape stressors were ranked based on their scope (amount of the envelope affected) and severity (likelihood that the stressor, if continued, would degrade wetland function or condition). A full list of stressors and scope/severity rankings can be found in the Draft Protocol.

Results

The initial landscape model performed well in terms of identifying sites with minimal disturbance. In Montana, 9% of the sites selected with the model were disqualified based on disturbances detected during aerial photo inspection. Additional sites were disqualified in the field (9 of 45 visited, or 20%). Two of these were disqualified because of heavy livestock grazing and invasive species that were not detectable with the GIS model or the aerial photos. The remaining sites were disqualified for reasons unrelated to disturbance because they did not meet the 0.5 ha minimum sampling size (3); were too deep to be sampleable (2); were not wetlands (2); or, in one case, because the wetland was the same system type as a previously sampled wetland in the same cell.

For the sites that passed all screening the field assessments further validated the relative absence of stressors. In the landscape context assessment, within the 500 m envelope surrounding the AA, nearly all (90%) non-riverine sites (n = 70) had 100% landscape connectivity; one site had 99% connectivity; one site had 95% connectivity; three sites had 90% connectivity; and two sites had 70% connectivity. All riverine sites (22 sites) had 100% landscape connectivity. Similarly, nearly all sites (97%) had a buffer extent of 100%; 96% had a buffer width of at least 187 m. Only one site had a buffer width less than 150 m. Within the 200 m envelope surrounding the AA, 96% of selected sites had > 95% native vegetation cover and < 5% cover of non-native plants.[9] The remaining sites had > 75% native vegetation cover and 5 to 25% cover of non-native plants.

Assessment of stressors affecting the other attributes—vegetation, hydrology, and physicochemical factors— confirmed the identification of the selected sites as minimally disturbed. Tables 2 through 4 list the anthropogenic and environmental stressors considered for each attribute. Each table shows the number of sites at which a particular stressor was observed as well as the range of scope and severity ratings. No hydrology stressors were observed at any wetland site within the project area.

The most common stressors observed across the study area were related to grazing by livestock or native ungulates. Crews examined woody vegetation for evidence of browsing, and looked for soil compaction or pugging, as well as wallows. If ancillary evidence (cowpies, hoofprints, cattle presence) was available, crews noted that cattle were the common grazers. Otherwise, we felt it was impossible to determine what animal (e.g., elk, moose, deer, mountain goats or bighorn sheep) was the dominant herbivore. However, based on the infrequency of cattle evidence, it appears that

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[9] It should be noted that most of the non-native plants in the assessments were nearly ubiquitous, non-native species as dandelion and Kentucky bluegrass; dandelion was, in fact, one of the most commonly encountered species in the study.

Table 2. Landscape context stressors

Stressor	Number of Sites	Range of Scope Ratings	Range of Severity Ratings
Paved roads / parking lots	2	0-1	1
Unpaved Roads (e.g., driveway, tractor trail, 4-wheel drive roads)	8	0-2	1
Domestic or commercially developed buildings	1	1	1
Intensively managed golf courses, sports fields	0	---	---
Gravel pit operation, open pit mining, strip mining	0	---	---
Mining (other than gravel, open pit, and strip mining), abandoned mines	0	---	---
Resource extraction (oil and gas)	0	---	---
Vegetation conversion (chaining, cabling, rotochopping, clearcut)	1	2	1
Logging or tree removal with 50-75% of trees >50 cm dbh removed	0	---	---
Selective logging or tree removal with <50% of trees >50 cm dbh removed	1	0	1
Agriculture – tilled crop production	0	---	---
Agriculture – permanent crop (hay pasture, vineyard, orchard, nursery, berry field)	0	---	---
Agriculture – permanent tree plantation	0	---	---
Haying of native grassland	0	---	---
Recent old fields and other disturbed fallow lands dominated by exotic species	0	---	---
Heavy grazing/browsing by livestock or native ungulates	2	3-4	2
Moderate grazing/browsing by livestock or native ungulates	11	1-4	1-2
Light grazing/browsing by livestock or native ungulates	55	0-4	1
Intense recreation or human visitation (ATV use / camping / popular fishing spot, etc.)	5	0-2	1
Moderate recreation or human visitation (high-use trail)	16	0-3	1-2
Light recreation or human visitation (low-use trail)	27	0-3	1-2
Dam sites and flood disturbed shorelines around water storage reservoirs	0	---	---
Beetle-killed conifers	45	0-4	1-4
Evidence of recent fire (<5 years old)	6	0-4	1-4

Table 3. Vegetation stressors

Stressor	Number of Sites	Range of Scope Ratings	Range of Severity Ratings
Unpaved Roads (e.g., driveway, tractor trail, 4-wheel drive roads)	0	---	---
Vegetation conversion (chaining, cabling, rotochopping, clearcut)	0	---	---
Logging or tree removal with 50-75% of trees >50 cm dbh removed	0	---	---
Selective logging or tree removal with <50% of trees >50 cm dbh removed	0	---	---
Heavy grazing/browsing by livestock or native ungulates	4	1-4	1-3
Moderate grazing/browsing by livestock or native ungulates	6	0-4	1-2
Light grazing/browsing by livestock or native ungulates	53	0-4	1-2
Intense recreation or human visitation (ATV use / camping / popular fishing spot, etc.)	1	1	1
Moderate recreation or human visitation (high-use trail)	1	4	1
Light recreation or human visitation (low-use trail)	0	0-2	1-2
Recent old fields and other disturbed fallow lands dominated by exotic species	0	---	---
Haying of native grassland	0	---	---
Beetle-killed conifers	8	1-4	1-4
Evidence of recent fire (<5 years old)	4	4	4
Other:	3	1-4	1

the most frequent herbivores were native species. Where herbivory occurred, it was mostly light in both scope and severity.

The next most common stressor was light recreation, largely in the form of hiking/horse trails, which was partially an artifact of our decision to select sites with reasonable access. Scope and severity for these stressors were generally low.

Discussion

The approach used to select reference condition wetlands was satisfactory, yielding a set of sites that can be considered minimally disturbed by direct human impacts. Nonetheless, we recognize that the non-human impacts - in particular, native ungulate grazing and beetle-killed conifers - are linked to human manipulation of wildlife populations and to forest management practices. There-

[10] The lack of high resolution mapping such as the NWI mapping also affected our ability to stratify our sampling by ecological system. This is discussed in more detail under Objective 3.

Table 4. Physiochemical stressors

Stressor	Number of Sites	Range of Scope Ratings	Range of Severity Ratings
Erosion	8	0-2	1-3
Sedimentation	8	0-1	1
Current plowing or disking	0	---	---
Historic plowing or disking (evident by abrupt A horizon boundary at plow depth)	0	---	---
Substrate removal (excavation)	0	---	---
Filling or dumping of sediment	0	---	---
Trash or refuse dumping	1	0-1	1
Compaction and soil disturbance by livestock or native ungulates	41	0-4	1-2
Compaction and soil disturbance by human use (trails, ORV use, camping)	5	0-2	1-2
Mining activities, current or historic	0	---	---

fore, few sites, even in the most remote areas, could be considered as reflecting historic condition.

Visually inspecting aerial photos to verify the sites chosen by the model was a critically important factor in the success of our approach, as it substantially reduced the error associated with the data quality of GIS inputs. However, the most difficult obstacle was the lack of National Wetlands Inventory mapping across most of the study area. This required photointerpretation for each cell selected by the GRTS design, which added considerable cost and time to the project.[10] Even in areas where 1980s-era NWI mapping was available, it was incomplete, as older mapping generally excludes riparian woodlands and shrublands unless they experience annual flooding. Moreover, the quality of the imagery available during the first round of NWI mapping resulted in frequent errors concerning flooding regimes, so that it was not possible to create reliable crosswalks between the old NWI mapping and ecological systems. New mapping from 2005 imagery by the MTNHP was more useful, but that only covered parts of Montana.

We caution anyone considering the adoption of this approach in a state without NWI mapping that photointerpretation is a learned skill. In our Results section, we report only Montana's experience with the GIS and photointerpretation process. While all the teams were able to detect landscape impacts on aerial photos, they encountered varying degrees of difficulty determining whether a site was a sampleable wetland. The MTNHP had a cadre of skilled wetland photointerpreters to assist with this project, and although they were more familiar with the Cowardin classification than with ecological systems, they were confident in their ability to identify wetlands, and to crosswalk between systems. By contrast, CNHP and WYNDD staff, who were less experienced with photointerpretation, faced a steep learning curve that required them to do much more field reconnaissance in the initial project stages to verify whether a site qualified as a wetland, and if so, to determine the class into which it fell. Even the MTNHP photointerpreters were not always successful in correctly identifying sites as wetlands or accurately estimating their sizes. Furthermore, all teams found it impossible to determine in advance if open water in wetlands was deeper than our maximum sampleable depth of 1 meter. Therefore, although the methodology we used was successful in screening for impacts around sites, considerable uncertainty was associated with determining whether a potential site was even part of the target population.

Field sampling also was difficult due to a lack of reliable spatial information about roads. Although the data layers for frequently-travelled roads were good, there was no single source of GIS data depicting accessible 4WD roads or pedestrian and horse trails. Many 4WD roads on topographic maps or in the TIGER GIS database were gated and locked, and several of the trails on topographic maps were abandoned, resulting in several false starts for crews. We encourage anyone using a similar approach to locate the best available local data. In Montana, road and trail data were available from Region 1 of the U.S. Forest Service, which made accessibility screening much smoother. However, even those data were not accurate across all National Forests and local districts, and on several occasions crews were unable to locate trailheads or identify critical trail junctions. Similarly, while we had access to high-resolution aerial imagery, trails in wooded areas were difficult to detect.

We recommend initial field reconnaissance whenever possible to ascertain accessibility and to ensure the accuracy of aerial photo interpretation of wetland classes. Study design restricted crews to sampling one example of a given wetland ecological systems per grid cell. However, in aerial photos, it was often difficult to distinguish sedge-dominated fens with open water areas from marshes, or to distinguish between the drier herbaceous peatlands and wet meadows. Consequently, crews sometimes navigated to a site only to discover it was not sampleable within the protocol (e.g., it was the second fen within the grid cell). This extra travel time dramatically reduced the number of sites that were sampled and led to considerable crew frustration. However, field reconnaissance might not always be cost effective, particularly when safety considerations require it be done by a two-person team, or when sites are so remote that several person-days would be added to the project budget. Another solution, which might eliminate some of the problem, would be a modified study design. In smaller areas, where environmental gradients are not as variable as they were across this extremely large study area, it might not be as important to eliminate the risk of spatial autocorrelation. In that case, crews should be allowed to sample more than one wetland of a particular system within a grid cell.

Our approach had other shortcomings that were not anticipated during the study design phase. For example, random sampling did not produce equal numbers of all wetland ecological systems included in the study. Marshes were significantly underrepresented. High-integrity landscapes meeting our suitability screens tend to be clustered at medium-to-high elevations, where edaphic factors and geomorphology do not always support development of marsh wetlands (Baker, 1989). Despite going to our oversample GRTS panels, we were not able to find as many marsh sites as we wanted in any of the four study states. We attempted a targeted approach to marsh site selection in Montana, but although we were able to find marshes that did pass the initial screens, the presence of long-term impacts from historic logging in most cases were such that we did not consider these marshes to represent MDC.

We also note that the study design's emphasis on roadless areas with reasonable access biased the sample towards popular recreation areas and routes. High elevation and low elevation sites were probably underrepresented, as were slope wetlands at the mountain-to-valley transition where public lands typically abut private lands. We also believe that our sample did not represent the full range of fens found across the region. In general, fens are categorized as "extremely rich," "rich" or "poor" (Chadde et al. 1998) based on vegetation composition and water chemistry. Poor fens are generally acidic, and dominated by sphagnum mosses, with a limited number of vascular plants species, while rich and extremely rich fens are more alkaline, and have higher vascular plant cover. Both poor fens and extremely rich fens are uncommon across most of the study area, with most fens having moderate vascular plant diversity and a fairly neutral pH. Although our sample did reflect the relative distribution of these types across the study area, in terms of simple numbers, we did not have enough poor or extremely rich fens to really represent their range of natural variability. Underrepresentation of uncommon types will always be a drawback of probabilistic survey design (Jones 2004).

Despite the success achieved with this model we have not fully evaluated it as a Level 1 assessment tool across the entire condition gradient. In previous work in Montana, Level 1 assessment results did not show strong correlations with Level 2 and 3 results for disturbed sites (Vance 2009, Newlon and Vance 2011). In part this is because roads in the West do not necessarily integrate multiple human stressors to the extent that they do in more populated areas, so that while roadless condition is a strong indicator of a lack of disturbance, road density is not necessarily a predictor of degradation (Vance 2009). However, Lemly et al. (2011) reported correlations between Level 1 and Level 2 scores for wetlands in the Upper Rio Grande, and studies in progress in Montana suggest that where human populations are more concentrated, landscape level disturbance is more predictive of site disturbance. Nonetheless, considerably more work will be necessary to calibrate the Landscape Integrity Model as a true Level 1 assessment tool.

Objective 2. Assess the natural range of variability for these four ecological systems

Background

The concept of natural range of variability reflects the ecological understanding that the climatic, topographic, geological and biogeographic factors that shape ecosystems differ across space and time, and that these differences will lead to disparate expressions of individual wetlands. Although some of these differences can be captured with wetland classification, so that riverine wetlands in the Rocky Mountains are only compared with other riverine wetlands in the Rocky Mountains (e.g., Brinson et al. 1995, Shafer et al. 2007, U.S. Army Corps of Engineers 2010, Williams et al. 2010, Klimas et al. 2011, Nobel et al. 2011), distinct differences may be present even within a wetland class. ,. For example, localized dispersal factors or water chemistry can result in marked differences in plant species composition (Magee et al. 1999, Peterson-Smith et al. 2009). Similarly, natural disturbances such as fire or other ecological processes occur stochastically across the landscape such that individual wetlands may be at dramatically different points in terms of successional dynamics.

This spatial and temporal variability can make it difficult to determine whether the values of the indicators being measured at an assessment site are outside the range of values that occur naturally. In theory, at least, probabilistic sampling schemes will result in assessments being conducted across the full spectrum of human disturbance, eventually producing "an ecological dose-response curve" (Rocchio and Crawford 2011) that links each indicator to each stressor, thus allowing identification of those wetlands in the dataset that can be said to represent a reference standard (Jones 2004). Nevertheless, it has been noted in other contexts that probabilistic sampling tends to underrepresent both undisturbed and highly disturbed occurrences (Fore 2003), so that it may take years of probabilistic sampling before enough reference condition sites are found to accurately portray the variability that exists within and between wetland ecological systems. Therefore, one of the central goals of this project was to identify regionally representative examples of wetlands in Minimally Disturbed Condition (Stoddard et al. 2006) and describe the range of values we measured with a standard assessment protocol.

The Colorado and Montana Natural Heritage Programs have both been developing Level 1, 2, and 3 protocols (Kentula et al. 2007) to evaluate the ecological integrity of wetland ecosystems. These protocols are based on a conceptual model of integrity linking key ecosystem attributes, such as biotic structure and composition, to stressors or other change agents (Karr 1991, Parrish et al. 2003, Andreason et al. 2001, Rocchio 2006, Faber-Langendoen et al. 2008, Hargiss et al. 2008, Lemly and Rocchio 2009). This model is premised on an assumption that key attributes will respond in a measurable and predictable way to stressors and common indicators of response can be assessed through well-crafted metrics. Level 1 metrics operate at a landscape level and tend to focus on the presence of disturbance. Level 2 are rapid, semi-quantitative field metrics and often infer integrity from the absence of disturbance. Level 3 metrics are based on intensive sampling of an attribute or attributes in the field, typically vegetation.

In this study we relied primarily on Level 3 surveys, collecting data to support a floristic quality assessment (FQA). The FQA combines measures of species diversity (including native and exotic species) with measures of individual plant species' tolerance of, and sensitivity to, disturbance (Cronk and Fennessy 2001, Miller and Wardrop 2006). Over the past decade FQA metrics and derived indices such as the Floristic Quality Index have emerged as effective and reliable methods for evaluating wetland condition (Lopez and Fennessy 2002).

We posited that any natural variability within and between minimally disturbed examples of wetland ecological systems would be best detected by a Level 3 approach. Level 1 metrics (e.g., landscape fragmentation, buffer zone intrusions) are designed to detect human impacts rather than natural variability. However, some Level 2 metrics, particularly those related to vegetation structure and topographical complexity, did appear to have potential for capturing variability. For example, wetland assessment metrics often include the abundance, type and interspersion of patches. If values for these metrics vary widely among minimally disturbed wetlands and the variability is linked to wetland class or region, this would be an important factor to consider in designing wetland assessments. By contrast, if the variable responses exist but cannot be linked to wetland class or region, then these metrics may not lend themselves to describing a dose-response relationship between stressors and condition.

Because a related goal of this project was to refine the Level 1, 2 and 3 indicators and methods so that they could be standardized into a regional assessment protocol, we decided to combine the Montana and Colorado Ecological Integrity Assessment (EIA) methods into a full draft protocol (Appendix E), carrying out complete assessments at every site. This allowed us to test the reliability of all metrics, establish baseline values for Level 2 metrics at reference sites, and use selected Level 2 and Level 3 vegetation metrics to fully assess the range of natural variability in our target sites.

Methods

Field sampling: Field crews established an assessment area (AA) of 0.5 ha centered on the selected sample point, gathered site data, and then assessed landscape context, hydrology, vegetation, and physicochemical indicators and stressors at the Level 1 and 2 scales. Detailed accounts of these indicators and stressors can be found in our Draft Field Protocol (Appendix E). For the Level 3 assessment we collected data on vegetation composition and cover using an approach adapted from the flexible-plot method developed by Peet et al. (1998). Each plot measured 20 m x 50 m (1,000 m^2 = 0.1 ha), consisting of ten 10 m x 10 m (100 m^2) modules typically arranged in a 2 x 5 array (Figure 2). The plot was subjectively placed within the AA to maximize abiotic/biotic heterogeneity, capturing micro-site variations produced by hummocks, water tracks, side-channels, pools, wetland edge, and microtopography. Within four of these 100 m2 modules we collected information on multiple ground cover variables including standing water, bare ground, litter, woody debris, and nonvascular plant species. In these intensive modules we identified all vascular plants to species and estimated each species absolute cover for the 100 m2 module.

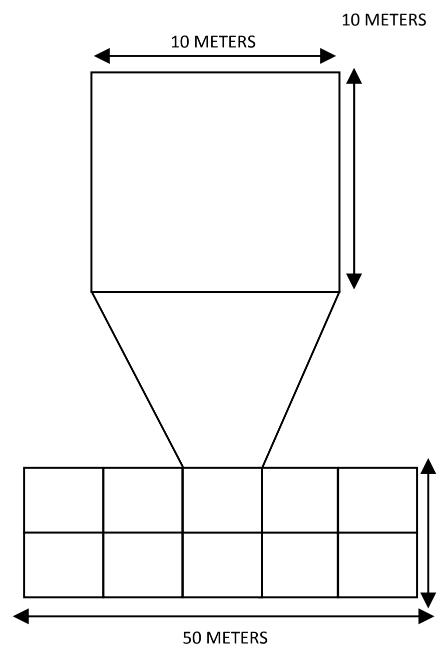


Figure 2. Flexible-plot layout (adapted from Peet et al. 1998).

After sampling each of the intensive modules the field crews walked through the remaining, or residual, modules to document presence of any species not recorded in the intensive modules. Percent cover of these species was estimated over the entire 1,000 m2 plot. We used cover class midpoints to calculate average values for each taxon in each plot. Vegetation sampling was conducted from late June through early September in 2009 and 2010, and from late August through early September of 2011.

At each AA we also dug two to four soil pits 40cm in depth. Pits were located in or near the vegetation plot; the number of pits depended on the heterogeneity of the AA. We collected information on soil texture, the color of the soil matrix and any redoximorphic features, and any hydric soil indicators observed based on the U.S. ACOE Regional Supplement. The depth to saturated soil and free water, if present, were recorded for each pit.

Analysis: In development of FQA metrics, or a Floristic Quality Index (FQI), coefficients of conservatism (C-values) are assigned to taxa identified to species, typically by panels of botanists and ecologists. The C-values reflect the relative tolerance of a species to disturbance, ranging from 0 to 10 (after Andreas et al. 2004). Native species exhibiting high degrees of ecological specificity and sensitivity to disturbance have C-values of 9-10. Native species that are typical of well-established communities that have undergone minimal disturbance have C-values of 6-8. Native species that have some degree of habitat specificity but can tolerate moderate disturbance have C-values of 3-5. Widespread native species that occur in a variety of communities and are common in disturbed sites have values of 1-2. Exotic species are typically given a score of 0. Lower FQI and mean C-values indicate that the site is dominated by plants that are frequently found in disturbed areas, whereas higher values indicate a greater floristic quality (Lopez and Fennessy 2002). Although the FQI is usually computed only for native species it is also useful to calculate an FQI that includes non-native species, as their presence in a site is often a response to a disturbance (Lopez and Fennessy 2002, Miller and Wardrop 2006, Bourdaghs et al. 2006, Milburn et al. 2007).

For species that occurred across the project area we averaged C-values for Colorado (Rocchio 2007) and Montana (Jones 2004) when values differed by less than two. For C-value differences greater than three, a panel of botanists and ecologists from the Montana and Colorado Natural Heritage Programs reassigned C-values.

We calculated multiple vegetation metrics (Appendix F) to support a floristic quality assessment (FQA). Metrics in the FQA included native species richness, non-native species richness, total species richness, mean C-value of all plants, mean C-value of just native plants, and a cover weighted mean C-value for both native species and total species and a Floristic Quality Index (Appendix F for complete list of formulas).

A cover-weighted FQI was also calculated using the relative average cover of a species in the entire plot as a weighting factor (Milburn et al. 2007). The FQI typically is sensitive to species richness, so species poor sites will receive a lower FQI value despite being in or close to a natural state. We therefore calculated an adjusted FQI (Miller and Wardrop 2006) that incorporates a "maximum attainable FQI score" based on the highest possible value, as well as both native and non-native species scores, into the final index. The cover-weighted FQI was also calculated for native species alone and for the adjusted FQI. A cover-weighted adjusted FQI was also produced for each site using the relative average cover of a species in the entire plot as a weighting factor. Finally, we also calculated descriptive statistics and assessed the range and distribution of each metric by examining frequency histograms.

Results

The number of wetlands assessed within each ecological system varied across Level III Ecoregions (Table 5). The average elevation of ecological systems varied by Level III Ecoregion as well, but elevation varied little across ecological systems within a Level III Ecoregion (Table 6). Sites in the Southern Rockies were generally higher; however, given the rule of thumb that treeline rises 100 m in proportion to each degree of latitude southward (Barbour and Billings 2000), the Southern Rockies sites were not as much higher than the Canadian Rockies sites (+/- 10 degrees of latitude apart) as the raw elevation data might suggest.

We found considerable variability in the vegetation of our study sites, both with metrics measured onsite and in the FQA metrics calculated from plot data. This was true for both Level 2 vegetation metrics and Level 3 plot-based metrics[11]. For example, one Level 2 metric assessed vertical overlap

[11] Other Level 2 metrics, most of which are designed to identify response to stressors, did not show much range of variability because our sites were chosen to be as stressor-free as possible.

Table 5. Number of assessed wetlands by Level III Ecoregion and wetland ecological system.

Level III Ecoregion	North American Arid West Emergent Marsh	Rocky Mountain Alpine-Montane Wet Meadow	Rocky Mountain Subalpine-Montane Fen	Rocky Mountain Subalpine-Montane Riparian Shrubland
Canadian Rockies	7	4	7	5
Middle Rockies	10	15	15	11
Wasatch-Uinta Mountains	1	3	4	3
Southern Rockies	3	4	7	6

Table 6. Average elevation (in meters) of wetlands assessed as part of the Rocky Mountain ReMAP project.

Level III Ecoregion	North American Arid West Emergent Marsh	Rocky Mountain Alpine-Montane Wet Meadow	Rocky Mountain Subalpine-Montane Fen	Rocky Mountain Subalpine-Montane Riparian Shrubland
Canadian Rockies	1,532	1,617	1,493	1,320
range	*(941-2,005)*	*(1,169-1,834)*	*(1,111-1,813)*	*(1,050-1,817)*
Middle Rockies	2,339	2,478	2,398	2,475
range	*(1,737-2,922)*	*(1,831-3,308)*	*(1,872-3,003)*	*(1,870-3,161)*
Wasatch-Uinta Mountains	3,343	3,126	3,033	3,105
range		*(2,787-3,361)*	*(2,690-3,347)*	*(2,703-3,325)*
Southern Rockies	3,074	3,185	3,256	3,239
range	*(2,607-3,509)*	*(3,108-3,324)*	*(3,134-3,403)*	*(2,767-3,424)*

of vegetation strata. Some of the variability in the results was explained by differences between ecological systems, with shrublands being the most likely to have overlapping strata and marshes being the least likely. However, even within individual assessment areas, vegetation overlap was variable (Table 7). Another Level 2 metric, horizontal interspersion of vegetation zones, also showed a wide range of variability, as did the metric assessing the number of structural patch types.

When a Level 2 metric uncovers wide variability in minimally disturbed wetlands, its utility for measuring condition comes into question unless the variability is correlated to particular wetland types or regions. In this study we did not see any such correlation. Therefore, we revisited these metrics in the context of our regionally standardized protocol. This will be discussed in more detail under Objective 3.

Table 7. Percent of sites by wetland ecological system with portions of their assessment area comprised of at least three overlapping vertical vegetation strata, two overlapping vertical vegetation strata, and one vertical vegetation stratum, respectively.

Ecological System	≥ 3 overlapping vertical vegetation strata	2 overlapping vertical vegetation strata	1 vegetation strata	Total number of sites
Emergent Marsh	7%	21%	93%	14
Alpine-Montane Wet Meadow	25%	54%	96%	24
Subalpine-Montane Fen	24%	52%	76%	29
Subalpine-Montane Riparian Shrubland	72%	100%	76%	25

The variability in Level 3 metrics, by comparison, did appear to be linked to regional and typological differences in our target population of wetlands. Overall, we encountered 613 vascular plant species across 105 sites. Of these, 564 were identified to species and 49 were identified to genus. Of the 613 total taxa, 228 species were observed only once and another 101 species were observed twice, indicating relatively high species diversity in wetlands across the project area. The average number of species per site was 27 (*range* 2-70 species). *Carex* was the most diverse genus, with 52 species positively identified. The most frequently occurring species was *Carex utriculata*, occurring at 70 of 105 sites. The most frequently encountered species are listed by ecological system and ecoregion in Tables 8 and 9.

Frequency histograms for FQA metrics across all systems and ecoregions show a relatively broad range of values with the exception of metrics related to exotic species (Appendix G), with large standard deviations around the mean. However, when metric values are analyzed by geography and typology, clear patterns of regional and typological variability emerge (Tables 10 and 11). The Southern Rockies and Wasatch-Uinta Mountains had consistently higher metric values than the Middle Rockies and Canadian Rockies for all FQA calculations except exotic species richness, suggesting a strong regional range of natural variability. We also found a strong typological association for most FQA metrics. Riparian shrublands had the highest species richness across all Level III Ecoregions, followed by wet meadows. Fens had the lowest species richness in the Middle Rockies, Southern Rockies, and Wasatch-Uinta Mountains, while emergent marshes had the lowest richness in the Canadian Rockies. Riparian shrublands and wet meadows also had the highest Shannon-Wiener diversity indices, whereas marshes had the lowest across all Level III Ecoregions. Results for FQI values followed similar patterns, with riparian shrublands and wet meadows having the highest FQI values across Level III Ecoregions. Emergent marshes had the lowest FQI values in all Level III Ecoregions except the Mid-

Table 8. Most frequently occurring species by ecological system.

Ecological System	Number of Site	Plant Species	C-Value	Nativity
Emergent Marsh	14	*Carex utriculata*	4	Native
	8	*Calamagrostis canadensis*	6	Native
	7	*Carex aquatilis*	6	Native
	6	*Deschampsia cespitosa*	6	Native
	5	*Salix planifolia*	7	Native
Wet Meadow	18	*Carex aquatilis*	6	Native
	16	*Calamagrostis canadensis*	6	Native
	15	*Pedicularis groenlandica*	8	Native
	14	*Phleum alpinum*	7	Native
	13	*Senecio triangularis*	6	Native
Fen	21	*Carex aquatilis*	6	Native
	21	*Carex utriculata*	4	Native
	12	*Calamagrostis canadensis*	6	Native
	10	*Carex canescens*	8	Native
	10	*Pedicularis groenlandica*	8	Native
	10	*Salix planifolia*	7	Native
Riparian Shrubland	21	*Achillea millefolium*	4	Native
	20	*Calamagrostis canadensis*	6	Native
	18	*Carex aquatilis*	6	Native
	15	*Senecio triangularis*	6	Native
	14	*Carex norvegica*	8	Native

Table 9. Most frequently occurring plant species by Level 3 ecoregion.

Ecoregion	Number of Site	Plant Species	C-Value	Nativity
Canadian Rockies	14	*Carex utriculata*	4	Native
	14	*Potentilla gracilis*	4	Native
	11	*Petasites frigidus*	8	Native
	10	*Equisetum fluviatile*	6	Native
	9	*Calamagrostis canadensis*	6	Native
	9	*Fragaria virginia*	5	Native
Middle Rockies	34	*Carex aquatilis*	6	Native
	30	*Carex utriculata*	4	Native
	26	*Calamagrostis canadensis*	6	Native
	20	*Senecio triangularis*	6	Native
	19	*Phleum alpinum*	7	Native
Wasatch-Uinta Mountains	11	*Carex aquatilis*	6	Native
	10	*Salix planifolia*	7	Native
	8	*Calamagrostis canadensis*	6	Native
	8	*Rhodiola rhodantha*	8	Native
	7	*Deschampsia cespitosa*	6	Native
	7	*Pedicularis groenlandica*	8	Native
	7	*Veronica wormskjoldii*	7	Native
	7	*Viola macloskeyi*	8	Native
Southern Rockies	18	*Carex norvegica*	8	Native
	15	*Carex aquatilis*	6	Native
	14	*Caltha leptosepala*	7	Native
	14	*Deschampsia cespitosa*	6	Native
	13	*Calamagrostis canadensis*	6	Native
	13	*Salix planifolia*	7	Native

dle Rockies, where fens had the lowest FQI values. The box plots in Figure 3 show the typology by ecoregion scores on selected metrics.

Discussion

In our protocol, as in most wetland assessment approaches, Level 1 metrics evaluate human disturbance rather than natural variability. For example, metrics focus on fragmentation of natural cover by human impacts rather than looking at the structure and composition of the natural cover in the landscape envelope. Because the emphasis is on disturbance, there is no “natural” variability.

Level 2 metrics assess indicators that are believed to be sensitive to disturbance. If these metrics work as they should, there will be little variability in scores between and among minimally disturbed sites. The exception to this would be in metrics that are predicted to vary between different wetland systems. In this project, as expected, Level 2 metrics generally showed consistency across the study area, except for number of vegetation strata, degree of horizontal interspersion, and patchiness. However, in the case of these metrics, the range of variability occurs both between and within wetland ecosystems. For example, even in the case of riparian shrublands, which had the highest likelihood of overlapping vegetation strata, there were more sites with a single stratum (76%) than with three or more strata (73%). We discuss the implications of this under Objective 3.

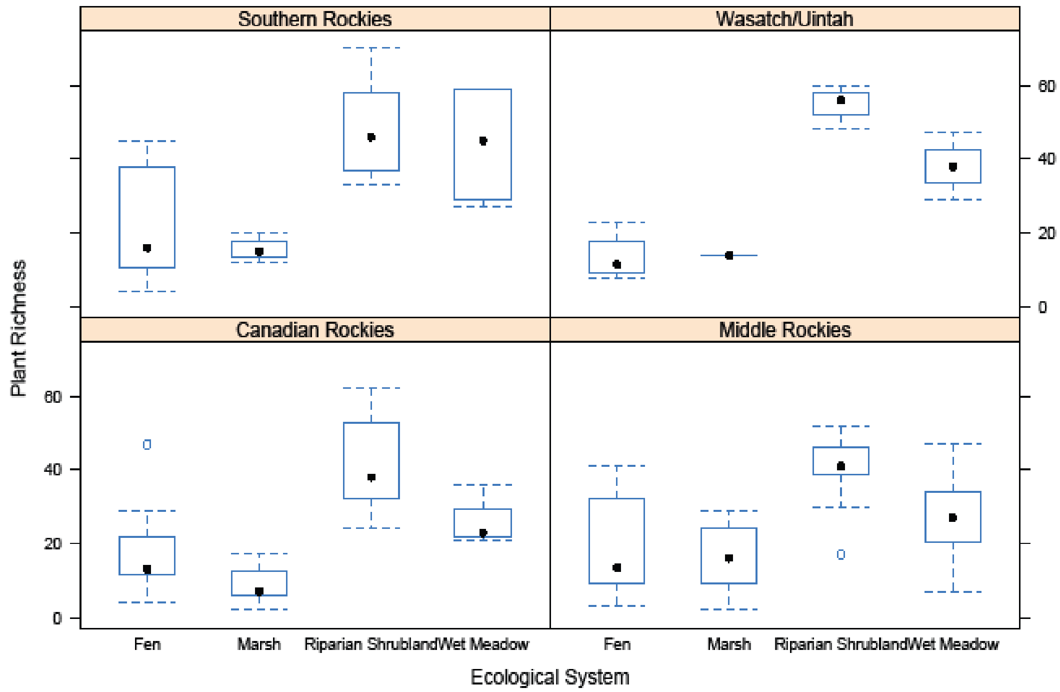
We did find a substantial range of variability in Floristic Quality Assessment metrics. FQA metrics are in wide use as a “gold standard” for Level 3 assessment because of their well-documented sensitivity to human disturbance (Lopez and Fennessy 2002, Andreas et al. 2004, Miller and Wardrop 2006, Bourdaghs et al. 2006, Milburn et al. 2007, McIntyre et al. 2011) and their relative ease of ap-

Table 10. Means and standard deviations of all Floristic Quality Assessment (FQA) metrics by wetland ecological system.

FQA Metric	Fen $n = 29$		Wet Meadow $n = 24$		Emergent Marsh $n = 14$		Riparian Shrubland $n = 25$	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total species richness	19	13	30	13	13	7	41	12
Native species richness	18	13	29	13	13	7	39	11
Non-native species richness	1	1	1	1	0	1	1	1
% Non-native species	2%	4%	4%	4%	1%	3%	3%	3%
Mean C-value of all species	6.32	0.57	6.03	0.62	5.89	0.58	6.06	0.69
Mean C-value of native species	6.48	0.59	6.26	0.48	5.94	0.50	6.26	0.54
Cover-weighted Mean C-value of all species	6.06	1.01	5.73	0.84	5.04	0.60	5.98	0.84
Cover-weighted Mean C-value of native species	6.13	1.08	5.89	0.85	5.05	0.60	6.11	0.71
FQI of all species	25.60	9.60	32.26	8.75	20.40	6.96	38.26	7.46
FQI of native species	25.98	9.78	32.90	8.59	20.52	6.96	38.92	7.35
Cover-weighted FQI of all species	24.62	10.03	30.52	8.48	17.46	6.25	37.53	7.10
Cover-weighted FQI of native species	24.56	9.94	30.85	8.72	17.42	6.23	37.78	6.73
Adjusted FQI	64.06	5.67	61.52	5.33	59.14	5.31	61.65	6.10
Adjusted cover-weighted FQI	60.61	10.47	57.87	8.68	50.29	6.02	60.18	7.62

Table 11. Means and standard deviations of all Floristic Quality Assessment (FQA) metrics by Level III Ecoregion.

FQA Metrics	Canadian Rockies $n = 18$		Middle Rockies $n = 43$		Southern Rockies $n = 20$		Wasatch-Uinta Mountains $n = 11$	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total species richness	23	17	25	13	31	18	30	18
Native species richness	22	16	24	12	30	17	29	18
Non-native species richness	1	1	1	1	1	1	1	1
% Non-native species	3%	4%	3%	4%	2%	3%	1%	2%
Mean C-value of all species	5.87	0.44	5.96	0.61	6.35	0.57	6.64	0.71
Mean C-value of native species	6.08	0.36	6.16	0.55	6.49	0.50	6.72	0.63
Cover-weighted Mean C-value of all species	5.46	0.74	5.73	1.00	6.01	0.75	6.21	1.02
Cover-weighted Mean C-value of native species	5.56	0.85	5.87	1.00	6.06	0.74	6.26	0.99
FQI of all species	26.29	10.32	28.58	8.60	33.94	11.87	34.30	12.42
FQI of native species	26.92	10.72	29.11	8.71	34.33	11.91	34.57	12.55
Cover-weighted FQI of all species	24.70	10.58	27.37	8.70	32.39	12.17	32.73	13.25
Cover-weighted FQI of native species	24.72	10.57	27.64	8.78	32.36	12.35	32.77	13.18
Adjusted FQI	59.87	3.80	60.62	5.62	64.20	5.25	66.81	6.68
Adjusted cover-weighted FQI	54.70	8.07	57.84	9.97	59.95	7.48	62.20	9.98



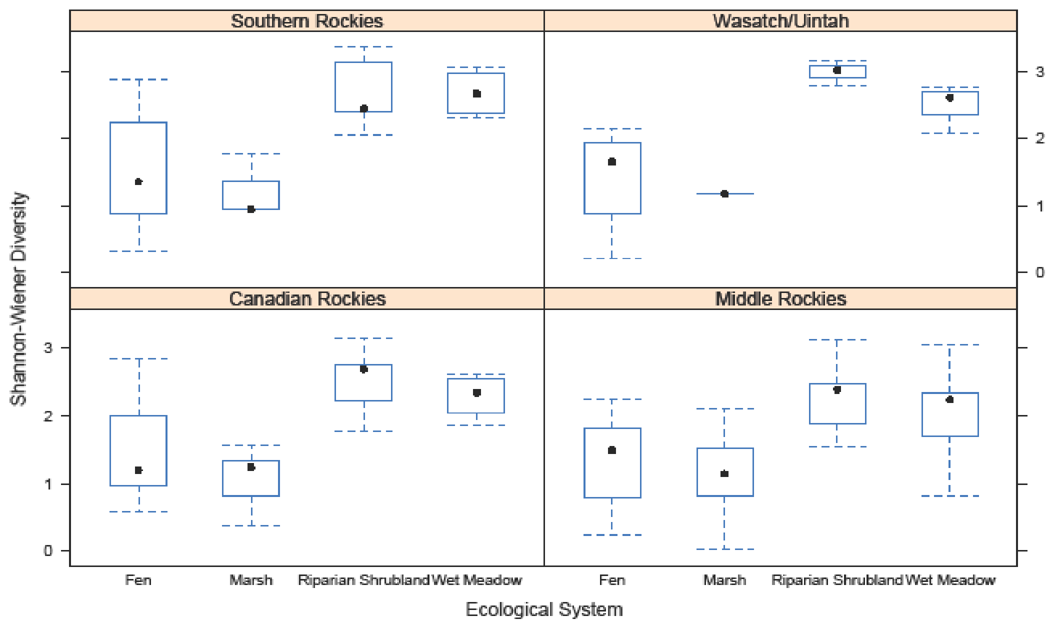


Figure 3. Box plots summarizing a) plant species richness, b) Shannon-Wiener Diversity, and c) floristic quality index (FQI-see Appendix F for equation) across Level III Ecoregions and ecological systems. In each box plot the dot is the mean, the bottom and top of the box are the lower and upper quartiles, and the whiskers are the minimum and maximum values.

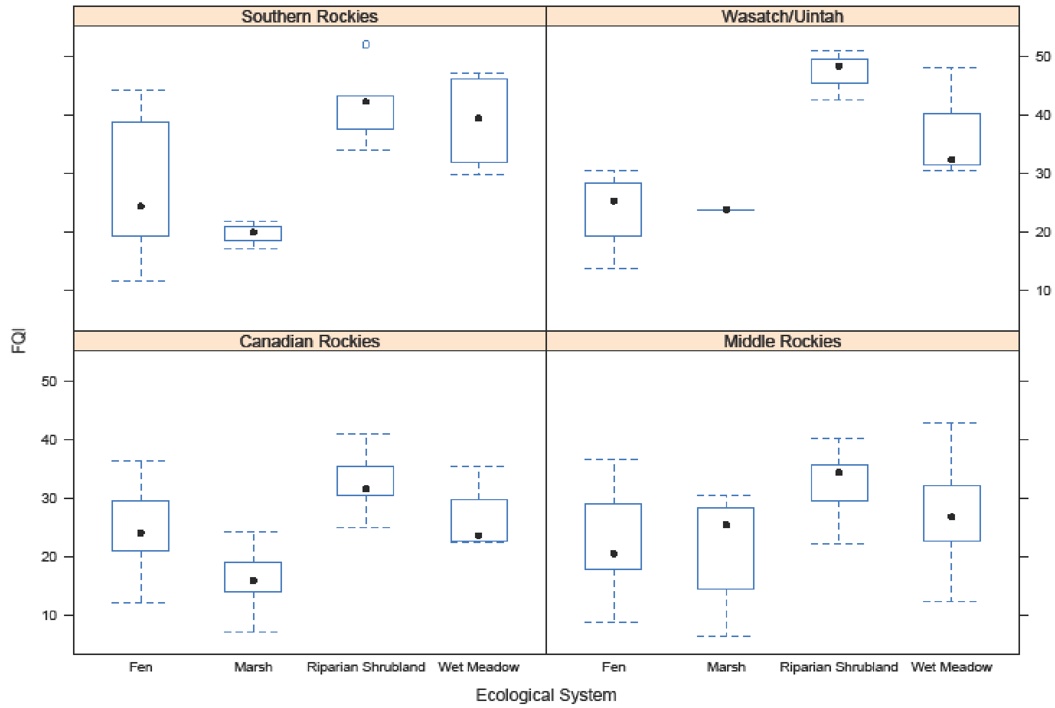


Figure 3. Box plots summarizing a) plant species richness, b) Shannon-Wiener Diversity, and c) floristic quality index (FQI-see Appendix F for equation) across Level III Ecoregions and ecological systems. In each box plot the dot is the mean, the bottom and top of the box are the lower and upper quartiles, and the whiskers are the minimum and maximum values.

plication. Although several researchers have evaluated FQA metrics in individual states and/or for individual wetland types, we are unaware of other studies that have examined FQA scores across such a large study area using an *a priori* classification such as we use here.

Two patterns were apparent here: First, the regional pattern, with higher FQA scores observed in the Southern Rockies and Wasatch-Uinta Mountains compared to the Middle Rockies and Canadian Rockies; and second, the typological pattern with higher values seen in riparian shrublands and fens across all regions.[12] The regional pattern may be explained by the fact that species diversity increases along a north-to-south gradient between the North Pole and the equator (Hildebrand 2004). Almost 11 degrees of latitude separate our northernmost and southernmost study sites. The Southern Rockies have approximately 3,625 recognized native vascular plant species (Snow 2009), whereas Montana has only 2,262 (Mincemoyer 2012). Given the influence of species diversity measures on floristic quality assessment scores, regional differences in FQA scores are expected when one region is floristically richer than another.[13]

12 The sample size was too small for a statistically meaningful comparison of FQA values for wetland type by region.

13 We have considered the possibility that regional differences arise from the initial assignments of coefficients of conservatism values. As noted in the Methods section, when species on both the Colorado and Montana vascular plant lists had different C of C values, we averaged the values, or, when the difference was more than 3, we assigned new values. However, if only one state had assigned a C of C value to a species, that value was used in the study. On average, Montana's C of C assignments for vascular plants are lower than Colorado's (5.25 vs. 5.99). For the 27 cases where there was a difference of more than 3 in the assigned C of C value, the average Colorado value was 7.04, while the average value assigned by Montana was 4.23. It may be, then, that species endemic to the Southern Rockies had slightly more "generous" C of C values than those found only in the Northern or Middle Rockies. As noted by Bourdaghs et al. (2006), coefficients of conservatism –and indeed "floristic quality" in general – are not inherent ecosystem properties. The subjectivity involved in assigning C of C values may thus account for some regional differences in FQA scores. This possibility needs to be explored in more depth.

The typological variability observed in this study, which is repeated across the study ecoregions, confirms earlier observations by Rocchio (2006, 2007), who found that *a priori* ecological system classification explained more variation in his reference plots than HGM or soil-based classifications. Because the ecological systems classification incorporates both hydrologic and vegetation characteristics we believe it is also preferable to Cowardin-based classification for these purposes. At the system-class level, wet meadows and fens (and some marshes) are all generally classified as Palustrine Emergent; only their water regime would distinguish them. However, fens and wet meadows separate out quite distinctly on the FQA metrics.

In Lemly and Rocchio's (2009) development of a Vegetation Index of Biotic Integrity (VIBI) for headwater wetlands in Colorado, ordination of vegetation data further suggested that fens be further subdivided into two categories, representing fens and "extremely rich fens," while wet meadows separated into riparian wet meadows and slope wet meadows.[14] Our results showed a wide range of values for species richness and the FQI for both wet meadows and fens in the Southern Rockies. While insufficient data points existed to make an independent conclusion that separate reference standards were warranted for subtypes of wet meadows and subtypes of fens, that range of values, coupled with the earlier work, seem to support this.

By contrast, we saw less variability in the richness or FQI values within fens or within wet meadows in the Canadian Rockies. Indeed, FQI values for fens in the Canadian Rockies are so similar to FQI values for wet meadows that we could make a case for using the same FQI reference standard across the two systems. We expect this is because most of the sampled fens in the Canadian Rockies were sedge-dominated and lacked a diverse forb component. While extremely rich fens do sometimes occur in this area they are not common and so had little impact on our FQI scores. If we were to analyze a larger sample of fens (or wet meadows) and ordinate vegetation data we might find distinct subtypes within each system. However, this was not apparent in our sample.

Another option for identify subtypes would be teasing out expected FQA metric values based on plant dominance; preliminary community analysis of fens in the Middle Rockies suggested that *Carex aquatilis*-dominated sites had significantly higher FQA metric scores than sites dominated by other *Carex* communities. However, a full analysis of community dominance influence on FQA metrics was beyond the scope of this study and may be more appropriate in the context of research than protocol development.

14 Lemly and Rocchio did not encounter classic sphagnum-dominated "poor" fens in their study.

Objective 3. Produce a regionally standardized method for assessing and monitoring wetland condition, including quality assurance project plans, sampling strategies, and metrics calibrated to the different wetland ecological systems.

Background

Although many individual agencies and tribes across the Rocky Mountain West have adopted Rapid Assessment Methods (RAMs) or use HGM-derived approaches for wetland assessment, only the Colorado and Montana Natural Heritage Programs have been developing Level 1-2-3 Ecological Integrity Assessment (EIA) protocols. One of our goals was to standardize methods used in the two Heritage Programs and make them available for adoption by other interested agencies, tribes and private stakeholders, thereby enabling comparison among results from different states.

As discussed earlier, both Colorado and Montana relied on a conceptual model of ecological integrity that links key ecosystem attributes, such as biotic structure and composition, to stressors or other change agents (Karr 1991, Parrish et al. 2003, Andreason et al. 2001, Rocchio 2006, Faber-Langendoen et al. 2008, Hargiss et al. 2008, Lemly and Rocchio 2009). This conceptual model is premised on an assumption that key attributes will respond in a measurable and predictable way to these stressors, and that there will be common indicators of response that can be assessed through well-crafted condition metrics. When coupled with metrics that evaluate the scope and severity of stressors, these response metrics will allow inferences about the relationship between stressors and effects (Tierney et al. 2009). This conceptual model formed the basis for the draft[15] protocol developed in this study.

Metrics can be applied at three different levels of intensity depending on the purpose and design of the data collection effort (Brooks et al., 2004, Kentula 2007, Wardrop et al. 2007). Level 1 Remote Assessments rely on Geographic Information Systems (GIS) and remote sensing data to obtain information about landscape integrity and the distribution and abundance of ecological types in the landscape or watershed. By combining land cover data with similar datasets that identify and depict roads, water features, and topography, Level 1 approaches can produce synoptic maps that broadly predict wetland impairment (Brooks et al. 2004).[16] Level 2 Rapid Assessments are generally field-based, focusing on physical or biological attributes that can be measured by one or two people during a half day in the field and a maximum of half a day in the office (Fennessy et al. 2007). These methods typically combine qualitative and narrative-based ratings with quantitative or semi-quantitative ratings. Level 3 Intensive Assessments generally use quantitative, plot-based protocols, and may include detailed surveys of vegetation, collection of water and soil samples for chemical analysis, and sampling of algae and phytoplankton (McIntyre et al. 2011). Because Level 3 assessments are time-consuming and costly, their use is often restricted to detailed assessments and documentation of particularly important sites that will be visited over a period of time to evaluate status and trends. Level 3 assessments can also be used to validate and calibrate the results of Level 1 and 2 assessments.

Our overarching goal in protocol and indicator development was to establish a reasonably rapid assessment approach (i.e., Level 2 method) that trained crews could use across a wide range of

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[15] One of the objectives in this study was to evaluate the usefulness of individual metrics based on their field performance; therefore, the protocol used in field data collection was considered to be a draft, subject to revision after data analysis.

[16] The term Level 1 is also sometimes used to describe landscape patterns that can be evaluated in the field, such as the presence of roads or human structures (Faber-Langendoen et al. 2008).

wetlands. However, while we understand the need for methods that can be carried out in less than a day and do not require special skills, we were not convinced that rapid assessments without detailed vegetation data collection can provide the level of detail needed to draw robust conclusions about wetland condition. We were also concerned that Level 2 crew members who lack botanical knowledge may miss indicators of disturbance that a plant ecologist or botanists would see immediately. Therefore, we were willing to sacrifice some speed for greater accuracy and precision and aimed for an integrated Level 2-3 approach that a trained botanist and one other person could implement in the field in six hours or less.

We note here that this study was not intended to yield a set of metrics that are fully calibrated to the entire spectrum of human disturbance for each system in each ecoregion. Rather, we were looking for metrics that have a reliable and consistent signal when applied to minimally disturbed wetlands.

Methods

Site selection

We used a generalized random tessellation stratified (GRTS) procedure for discrete objects with reverse hierarchical randomization (Stevens 1997) to select sites. Spatially balanced sampling has several advantages (Stevens and Jensen 2007). First, it accounts for the spatial patterning inherent in ecological systems, as sites in close proximity tend to share similar environmental characteristics. Second, spatially balanced sampling reduces the likelihood that multiple, proximate sites are included in the sample, which can result in the collection of redundant information. Finally, it allows for an increase or decrease in the number of samples selected without compromising the spatial balance of the design.

A spatially balanced sampling approach typically is used in aquatic resource surveys to estimate the condition of resources or the cumulative amount of wetland area representing any given condition across an area of interest (e.g., watershed). Although our objectives focused on describing the natural range of variability to describe reference standard for specific ecological systems, it is also critical to capture the spatial patterning inherent in different system types when trying to represent the full condition gradient. The GRTS method also ensures that the sample was well distributed over the extent of the resource. Additionally, it is important to retain the ability to add or remove sites from the sample while maintaining spatial balance, either because a site may not prove to be within the target population, or because access is impossible or denied.

Stratification within a GRTS approach depends on the objectives of the survey. In national surveys, particularly those with a water quality component, survey design and selection of reference sites account for regional environmental variables by clustering geographic data to identify regions with similar climate, geology and hydrology. We attempted to use multivariate analysis to cluster 6th code HUCs in the study area into distinct groups with similarities in hydrology, geology, climate, dominant land cover, elevation, etc., using both hierarchical and non-hierarchical cluster approaches. However, we did not find any statistically meaningful clusters. The use of Level III ecoregions was suggested by EPA statistician Tony Olsen.

We used the GRTS script within the package spsurvey (Kincaid et al. 2009) in the statistical software R (R Development Core Team 2009) to select 50 two mile by two mile grid cells within each Level III Ecoregion, and created a grid of points at 100 meter intervals within each selected cell. Once we eliminated points that did not meet our criteria (e.g., on public land, accessible by foot, within a high-integrity landscape), we used GRTS to order the remaining points for additional evaluation. We then used aerial photographs in a GIS to visually examine each of these points and determine if it occurred within one of the targeted wetland ecological systems. We selected points until we had at least three points representing each wetland system within each grid cell. This was done to minimize travel time between cells.

Metric selection

Potential metrics were identified from previous efforts that used either expert knowledge, data-based calibration, or a combination of the two. These were then filtered through selection criteria to determine suitability for this study:

a) useful at multiple spatial scales and across broad geographical gradients;

b) unambiguous, well grounded in natural history, and ecologically relevant;

c) relevant and understandable for managers, decision-makers, and the public;

d) flexible but mutually exclusive;

e) feasible to implement and measure; and

f) predicted to be responsive to stressor-induced change.

We selected four key attributes of wetlands that are generally agreed to define and reflect condition: landscape context, vegetation, hydrology, and soils/physiochemical factors. For each attribute we identified the factors which can be seen as indicators of condition.

Landscape context describes the larger habitat matrix in which a wetland occurs. Measures of landscape connectivity assess whether the landscape pattern facilitates or hinders the movement of species between habitat patches (Haig et al. 1998, Lehtinen et al. 1999, Naugle et al. 2001, Taylor et al. 2003). Buffers operate at a smaller spatial scale and perform both habitat and wetland protection functions. Therefore, we selected landscape connectivity, buffers and human land uses as our indicators of landscape context. Landscape context was measured at all three levels of assessment.

Vegetation data are relatively easy to collect and can be used to derive many other metrics and indices (U.S. Environmental Protection Agency 2011). In an undisturbed setting vegetation will have a structure and composition characteristic of the wetland type and location and there will be evidence of regeneration. This characteristic structure and composition reflects local environmental conditions, including climate and geology, and integrates species interactions and local (non-human) disturbance factors. We collected vegetation data at both Level 2 and Level 3. Our Level 3 plot sampling approach is described in detail under Objective 2. We used plot data collected from our field surveys to calculate floristic quality assessment metrics.

Wetland hydrology affects all other wetland functions (Zeller 2000). Water chemistry and hydroperiod, both a function of water source, drive plant species distribution and abundance (Goslee et al. 1997, Kurtz et al. 2007). Unfortunately, wetland hydrology is the most difficult attribute to evaluate in a single site visit. Therefore, most wetland assessment methods approximate hydrologic conditions through qualitative indicators, e.g., evidence of inundation and sources of inflow or outflow, which some critics contend do not accurately reflect wetland hydrology (Ehrenfeld 2002). While we recognize that full instrumentation and repeated site visits would be needed to thoroughly describe wetland hydrology, we were committed to methods that would yield the best results in a "snapshot-in-time" visit. Wetland hydrology was assessed at Levels 1 and 2.

Soils were our primary physiochemical attributes and filled some of the gaps left by our hydrologic indicators. Soil characteristics are useful indicators of the frequency, duration, and seasonality of hydrology in wetlands (Bisel-Machung et al. 1996). For example, morphological changes occurring in saturated soils include accumulation of organic matter on the wetland surface, low chroma color, and formation of redoximorphic features (Richardson and Vesprakas 2001, Brooks et al. 2005). Matrix chroma can therefore be used as an indicator of soil saturation. We selected several metrics to capture soil indicators, including depth of organic layer, soil texture, soil color, and depth of standing water below ground surface. We also added metrics for structural patch composition and distribution (e.g., rocks, woody debris, animal mounds). Because regional soils maps are too generalized to yield good information at Level 1, soils were only assessed at Levels 2 and 3.

Each attribute also included metrics to evaluate stressors. While the site selection approach was intended to eliminate most stressors, we recognized that there would be circumstances in which some stressors would be present, but not with the scope

Attribute	Level Assessed	Indicator	Example Metrics
Landscape Context	1,2	Connectivity	% unfragmented landscape within 500m
		Buffer	Extent, width and condition of buffer
		Surrounding Land Use	% natural cover within 100m
Vegetation	2,3	Structure	Vertical/horizontal interspersion
		Composition	% native; floristic quality index
		Regeneration	Age classes present; browse
Hydrology	1,2	Water Source	Inflow and outflow
		Hydroperiod	Evidence of inundation
		Water Quality	Algal blooms, turbidity
Soils/Physiochemical	2,3	Soil structure	Depth, layers, redox features
		Texture	% organic, dominant texture
		Physical structure	Patch type and distribution

and severity to exclude the site from consideration. It was important to document these "acceptable" stressors and to find a way to verify the absence of stressors as a quality assurance method. Stressors included both human (e.g., resource extraction, logging, roads) and nonhuman (e.g., beetle-killed conifers, recent fires) factors. For a complete list of stressors, refer to the field forms included in the Protocol (Appendix E). For all stressors, we included scope and severity ratings (Table 12). Stressors were primarily evaluated at Levels 2 and 3.

The raw field data were transferred from paper into a Microsoft Access database. We used plot data collected from the Level 3 assessments and numeric criteria assessed in the field to calculate descriptive statistics, and assessed the range and distribution of each metric by examining frequency histograms. Correlation matrices using Spearman's correlation coefficients were used to investigate relationships and to evaluate any redundancy among metrics.

Quality assurance/quality control

We drafted a quality assurance project plan to help ensure data integrity throughout the study. This was submitted to the EPA, and based on their feedback, was revised and resubmitted. Additional quality control measures included a joint protocol tested by all project investigators, a site visit by EPA staff at the beginning of field sampling to observe crews using the protocol, and annual reports to the EPA detailing quality control issues.

Table 12. Scope and severity ratings for all stressors

Scope of Disturbances	
5	Pervasive – Affects nearly all (>75%) of the buffer or AA.
4	Large – Affects most (>50-75%) of the buffer or AA.
3	Moderate – Affects much (>25-50%) of the buffer or AA.
2	Restricted – Affects some (>10-25%) of the buffer or AA.
1	Small – Affects a small (1-10%) portion of the buffer or AA.
0	Nil – Little or no observed effect (<1%) on the buffer or AA.
Severity of Disturbances	
4	Extreme – likely to extremely degrade, destroy, or eliminate the wetland.
3	Serious – likely to seriously degrade or reduce wetland function or condition.
2	Moderate – likely to moderately degrade or reduce wetland function or condition.
1	Slight – likely to only slightly degrade or reduce wetland function or condition.

Results

As discussed earlier, wetland ecological systems were not represented uniformly across the study area using a GRTS approach. Marshes were underrepresented, and despite going to our oversample, we were unable to identify enough marshes for sampling using a random approach. However, we believe this was due to stratification by high-integrity landscape units rather than random sampling per se.

Metric performance at Level 2 was generally good. Because we were only looking at reference standard sites we could not evaluate whether or not individual metrics were sensitive to human disturbance. Instead, we wanted level 2 metrics that had either had a consistent value across all wetlands in the study, or metrics whose variable response was easily correlated to specific wetland types. Unlike the Level 3 FQA metrics, which were intended to capture a range of natural variation that could be used to calibrate Level 3 protocols to specific wetland types and ecoregions, any Level 2 metric that had a wide range of unexplained scoring values when applied to reference standard sites was considered unsuitable for inclusion in a future protocol. We saw little variation among sites in terms of landscape context, hydrology, and physio-chemical/soil metrics, which was expected. These indicators, while couched in terms of condition, generally reflect degrees of disturbance. Because our sites were undisturbed we expected values for these metrics to be comparable. All sites had only natural water sources and no anthropogenic outlets or impediments; all but one site had either no visual evidence of turbidity or only slightly cloudy water with no obvious source of sedimentation. The one site with cloudy water due to sedimentation was attributable to runoff from a nearby steep slope. Similarly, all but two sites had clear water with minimal algal growth or algal growth limited to small, localized areas of the wetland. One site had extensive algal mats but no obvious causal factors. One site had large patches of algal growth observed in a portion of the AA, but again, no reason for the growth was evident. Eighty-three percent of sites had intact soils and little or no trash or refuse, whereas 15% had intact or moderately disrupted soils, moderate or lesser amounts of trash, or minor intensity of human visitation or recreation. Only one site had moderate or extensive soil disruption, moderate or greater amounts of trash, or moderate intensity of human use; this was due to an abandoned two-track road and evidence of light recreation.

Several metrics that did show a range of variability are discussed individually below.

Regeneration of Native Woody Species

This metric pertained primarily to riparian shrublands. Most (76%) riparian shrublands had all age classes of woody species present. One site had the middle age groups absent, but all other age classes present. Twenty percent of sites had stands comprised mainly of mature individuals with all other age classes absent. The confounding factor for this metric was browsing. Although these were all reference standard sites, estimates of the extent of browsing by native ungulates ranged from 10 to 70%.

Vertical Overlap of Vegetation Strata

Results for this metric varied widely, although for most herbaceous sites, a single vegetation stratum, or two overlapping strata, dominated the AA (Table 13). Across the study area, riparian shrubland sites consistently had a portion of their AA comprised of multiple vegetation strata, but they were also consistent in having a portion of their AA comprised of a single vegetation strata. By contrast, few marshes had overlapping strata. The underlying assumption of this metric, that sites with a higher degree of ecological integrity have more structural complexity, is not corroborated by our data. Wet meadows, fens and riparian shrublands had highly variable responses, unrelated to any human or natural impacts.

Horizontal Interspersion of Vegetation Zones

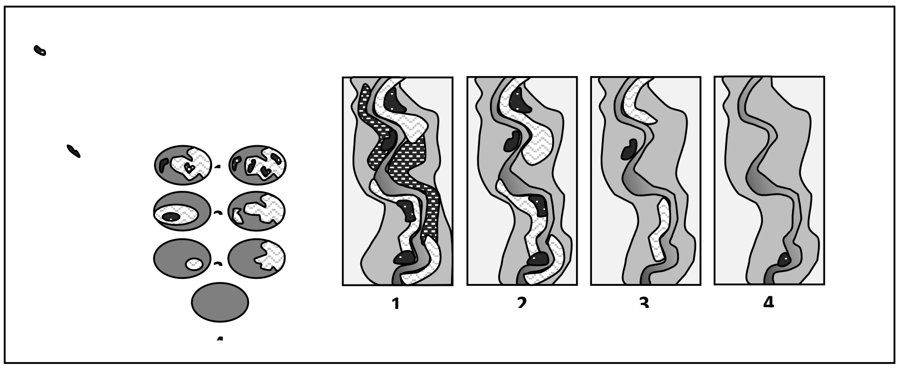
The degree of horizontal interspersion of vegetation zones was assessed using the following categories and diagram (Figure 4):

- N1/R1: High degree of horizontal interspersion: AA characterized by a very complex array of nested or interspersed vegetation zones with no single dominant zone.

Table 13. Number of sites and percentage classes of assessment area with one vegetation stratum, two overlapping vegetation strata, or three or more overlapping vegetation strata.

Percent of AA with three or more overlapping strata	Number of Sites	Percent of AA with two overlapping vegetation strata	Number of Sites	Percent of AA with one vegetation strata	Number of Sites
>=75	4	>=75	8	>=75	44
<75 to 50	2	<75 to 50	11	<75 to 50	10
<50 to 25	4	<50 to 25	11	<50 to 25	11
<25 to 5	13	<25 to 5	23	<25 to 5	12
<5	9	<5	3	<5	0

Figure 4. Horizontal interspersion of vegetation zones diagram



- N2/R2: Moderate degree of horizontal interspersion: AA characterized by a moderate array of nested or interspersed vegetation zones with no single dominant zone.
- N3/R3: Low degree of horizontal interspersion: AA characterized by a simple array of nested or interspersed vegetation zones. One zone may dominate others.
- N4/R4: No horizontal interspersion: AA characterized by one dominant vegetation zone.

In general, riparian shrublands had the highest degree of horizontal interspersion (Table 14). Emergent marshes had low to no horizontal interspersion. Most wet meadow sites also showed low to no horizontal interspersion, although about a third were split between high and moderate interspersion. Fens ranged primarily from moderate, low, to no horizontal interspersion. No clear ecoregional patterns were evident.

Structural Patch Types

Many rapid assessment methods have metrics dealing with patch number and/or patch interspersion. The metrics assume that high quality wetlands are naturally patchy and that patchiness is lost as human disturbance intensifies. However, in our study, the number of structural patch types by ecological system varied widely and showed no strong patterns (Table 15.)

We also investigated the correlation between the number of structural patches at a site and the FQA metrics calculated for that site. Correlations were generally weak (Table 16), with only FQI metrics having moderate correlations with the number of patch types. We consider this metric to be too variable to retain for Level 2 condition assessments.

Floristic quality assessment metrics

We found redundancy (r > 0.8) for several FQA metrics across all ecological systems indicating that several of the metrics related to FQA may not nec-

Table 14. Number of sites by wetland ecological system and their corresponding degree of horizontal interspersion of vegetation zones.

	Ecological System			
Degree of Horizontal Interspersion	North American Arid West Emergent Marsh	Rocky Mountain Alpine-Montane Wet Meadow	Rocky Mountain Subalpine-Montane Fen	Rocky Mountain Subapline-Montane Riparian Shrubland
N1/R1	0	4	2	10
N2/R2	2	4	8	2
N3/R3	6	9	8	6
N4/R4	5	6	6	7

Table 15. Number of sites (n), average number of patch types (± 1 SD), and range.

North American Arid West Emergent Marsh	Rocky Mountain Alpine-Montane Wet Meadow	Rocky Mountain Subalpine-Montane Fen	Rocky Mountain Subapline-Montane Riparian Shrubland
n = 14	n = 24	n = 29	n = 35
3 (1), 1 - 6	4 (2), 1 - 8	4 (2), 1 - 9	5 (3), 0 - 12

Table 16. Pearson's correlation coefficients relating the number of structural patch types present at a site with FQA metrics.

Variables	**Pearson's correlation coefficient**
Number of patch types	1.00
Total species richness	0.37
Native species richness	0.37
Non-native species richness	0.04
% Non-native species	-0.01
Mean C-value of all species	0.21
Mean C-value of native species	0.24
Cover-weighted Mean C-value of all species	0.17
Cover-weighted Mean C-value of native species	0.19
FQI of all species	0.41
FQI of native species	0.41
Cover-weighted FQI of all species	0.38
Cover-weighted FQI of native species	0.39
Adjusted FQI	0.22
Adjusted cover-weighted FQI	0.20

essarily provide additional information (Appendix H). For example, both total species richness and native species richness are strongly correlated with the FQI metrics. In contrast, the mean C-value of all species, while still positively correlated with Adjusted Cover-weighted FQI (r=0.7), may be worth retaining for its potential sensitivity to human disturbance.

Discussion

Stratification based on Level III ecoregions was useful in this study, and allowed us to tease out significant geographic variability in FQA metric scores. However, while ecoregions, biomes or hydrologic landscape units (Winter 2001) are valuable stratifying parameters for national or regional studies, additional research is needed to determine the best biogeographic stratification unit over smaller geographies. It should be noted, too, that it is sometimes desirable to stratify by political boundaries and/or ownership, depending on the study questions being asked, especially in areas with large tracts of public land where managers are prepared to address findings.

Probabilistic sampling in this study did not produce sufficient examples of each target population to fully assess the range of natural variability in each wetland ecological system. As noted earlier, this was largely a result of our landscape integrity model limiting us to higher-elevation areas where marshes are less common. However, this could be an issue whenever a probabilistic study design is used by researchers hoping to find a definite number of an uncommon class of wetlands. In the Middle Rockies, for example, Rocky Mountain Conifer Swamp ecosystems occur infrequently; any attempt to find a fixed number of these with probabilistic sampling would be unlikely to succeed unless the sample frame was extremely large. Even then, the number of the uncommon type found through the sampling would be in proportion to their frequency in the whole population.

This was another area in which we were challenged by the lack of wetland mapping. Although both Landfire and ReGAP maps use ecological systems as mapping units, the small size of most Rocky Mountain wetlands means they are either unmapped or incorrectly mapped at the 30 m resolution used in these map products. Had wetland mapping been available with its higher degree of spatial accuracy and precision, stratification based on ecological systems could have been crosswalked between the Cowardin classification and the ecological systems classification. However, such crosswalking has challenges even for experienced photointerpreters. For example, while the Palustrine Emergent Saturated (PEMB) class often indicates a fen, fens with predominantly herbaceous vegetation – the most frequently encountered in our study – are often given a "Seasonally Flooded" (PEMC) water regime, as are many very wet meadows. While it was important to use the ecological system classification to capture the range of natural variability, we suggest that large-scale probabilistic surveys are best reserved for populations where a clear sampling frame – e.g., the USFWS's Status and Trends plots, or wetland maps for the entire area of interest – is clearly defined, even if that means accepting that frame's classification scheme (e.g., the Cowardin classification). The additional steps involved in creating the sampling frame, selecting the grids, photointerpreting them, screening them, and then verifying the selected site's type in the field, all add substantial time and cost to the project.

This study used a Level 1 tool for initial screening of sites, selecting the sites that were most likely to be in minimally disturbed condition. In assessments of ambient condition it would be inappropriate to stratify selection based on a priori determinations of human landscape context. However, we think our Landscape Integrity Model could be used in a metric development context to establish preliminary condition strata for sampling, although much more research is needed to identify how individual landscape stressors affect wetland condition, and the scale at which they operate. When we applied a targeted approach to finding marshes, we were able to meet almost all of the landscape criteria in our screen, but many of our sites were less than 2 kilometers (the cutoff distance in our model) from an earlier timber harvest. Even when harvest had been completed ten or twenty years before and roads had been decommissioned, we noted impacts on the buffer and assessment area, particularly a high percentage of exotics and tolerant native species.[17] Unfortunately, not enough sites were available to establish a distance from logging at which these impacts diminish (e.g. 500 m, 1000 m), nor were we able to identify a time frame over which logging impacts dissipate. These and similar questions will need to be examined before a Level 1 tool can be a reasonable alternative to field-based sampling.

Many Level 2 condition metrics are designed to detect the results of some unseen (or past) stressor or disturbance, e.g., evidence of turbidity or sheen in water that is not explained by visible natural factors such as landslides. Because sites were chosen for their minimally disturbed state, we cannot address the performance of these metrics beyond noting that they did not vary in any important way. Therefore, we will retain most of the metrics chosen for our protocol until they can be tested across a full disturbance gradient. However, some metrics were frequently found in Level 2 protocols have such a high degree of "noise" that they should not be relied on as signals. In particular, structural complexity metrics, such as regeneration of woody species, overlapping vegetation strata, horizontal interspersion, and number of patches all had a high range of natural variability. While some of this variability can be constrained with classification –for example, riparian shrublands were the most likely to have multiple strata– too much variability remains. This is not to say that the metrics should be abandoned. For example, we observed that some of the lack of woody regeneration in riparian shrublands was attributable to high levels of native ungulate browsing. In a management or restoration context this might provide valuable information about the success of exclusion fences. However, without an ability to distinguish between browsing by native ungulates and domestic livestock, this metric is not useful for tracking anthropogenic change. The other metrics that measured vegetation structure were not noticeably influenced by wildlife and were too variable, even within specific systems, to be useful. We suggest that additional research to investigate whether other structurally based metrics are similarly variable. For example, the protocol did not include a microtopography or roughness metric, although such metrics have been proposed in other assessment tools (e.g., Collins et al. 2008). The lack of signal found in our study for structural metrics may extend to similar metrics; however, this remains to be documented.

We want to stress that even metrics with a wide range of response may have some utility in wetland assessment. A well-established principle of conservation biology holds that larger and more complex habitats, islands, ecosystems, or conservation areas have more habitat available to more species, and are better able to withstand and recover from disturbance, than are smaller and more simple areas (MacArthur and Wilson 1967). As a simple matter of fact, wet meadows and riparian shrublands with multiple overlapping natural strata or high patchiness may be "better" than more simple sites, at least insofar as their habitat value is concerned. If the objective of wetland condition assessments is to identify wetlands that are in good condition and have high habitat values, then there is a reason to retain these metrics. However, if wetland assessments are only intended to report on the ambient condition of wetlands, with the intention of measuring or monitoring the consequences of human activities, then the values from structural diversity metrics should not be included in overall assessment scoring, as they are not a reliable signal of disturbance.

Our Level 3 vegetation metrics were able to parse out both ecoregional and typological variability in reference standard wetlands. The sample size per wetland ecosystem per ecoregion is too small to establish a definitive range of values that can be expected in reference quality wetlands in each region; other reference standard sites might have higher or lower metric values. However, we believe that these values can be used to validate and calibrate other FQA metrics from similar wetlands being assessed in the study area, whether by individual state programs or the NWCA.

Because we have only reference standard wetlands in this study, we are not recommending that

[17] Because they represented such a departure from reference standard, we excluded these sites from our analysis.

redundant metrics (e.g. total and native species richness) be discarded at this time; it could be that one or both of these metrics is more sensitive to human disturbance than the overall adjusted cover-weighted FQI. However, this should be a focus of analysis for the NWCA dataset and other Rocky Mountain surveys.

Finally, while Level 1, 2 and 3 assessment metrics in this study are discussed as though they were distinct and even severable from one another, we want to emphasize that this was not true. Because our sample only had reference standard wetlands we were unable to identify and calibrate any thresholds for Level 2 metrics. For example, one Level 2 metric requires calculations of buffer width and extent. Because almost all sites had a buffer extent of close to 100% and a buffer width of 150m or more, we had no way to measure the correlation between loss of buffer and FQA metrics.[18] Similarly, in the absence of human disturbance, we were unable to identify the metrics that are most sensitive to human disturbance. Ideally, the three assessment levels should be nested; while Level 1 assessments can stand alone under circumstances where a quick, desktop summary is needed, Level 2 assessments should be complemented by Level 1 assessments, and Level 3 assessments should include the full suite of Level 1 and Level 2 metrics as well, including disturbance metrics. A full wetland assessment needs to be multimetric in nature, so that changes in FQA metrics can be linked to observable disturbances that are within the control of land managers.

[18] These analyses are, however, part of the work currently being done by both the MTNHP and the CNHP in other wetland research projects.

Summary and Recommendations

This study achieved its main objectives: to identify reference standard examples of four wetland ecological systems across the Canadian Rockies, Middle Rockies, Wasatch-Uinta Mountains and Southern Rockies; to describe the range of natural variability found between systems and between ecoregions; and to develop methods, approaches and protocols that can be used for assessment of ambient condition. As a result of the study,

- Region 8 states and tribes have access to a landscape integrity model that can be used as is or adapted to identify areas where high-quality reference sites are likely to be found;
- There are tested field protocols, field forms, keys, crosswalks and a QAPP that can be used or adapted by states and tribes;
- There is a documented reference standard for floristic quality in Rocky Mountain Subalpine-Montane Fens; Rocky Mountain Alpine-Montane Wet Meadows; North American Arid West Emergent Marshes; and Rocky Mountain Subalpine-Montane Riparian Shrublands;
- The strengths and limitations of GRTS-based probabilistic sampling for identification of reference sites have been evaluated;
- There are over 100 documented reference sites representing a range of natural variability for the four ecological systems in Montana, Wyoming, Utah and Colorado that can be used for long-term monitoring and/or future protocol development.

The strength of this study, we believe, lies in its probabilistic sampling design. As Heritage Programs, we tend to focus on those landscapes and populations that The Nature Conservancy describes as "the last of the least and the best of the rest" (Moore 2011). For example, NatureServe's ecological integrity scorecard describes A-ranked sites in these terms:

> Occurrence is believed to be, on a global or range-wide scale, among the highest quality examples with respect to major ecological attributes functioning within the bounds of natural disturbance regimes. Characteristics include: the landscape context contains natural habitats that are essentially unfragmented (reflective of intact ecological processes) and with little to no stressors; the size is very large or much larger than the minimum dynamic area; vegetation structure and composition, soil status and hydrologic function are well within natural ranges of variation; exotics (non-natives) are essentially absent or have negligible negative impact; and, a comprehensive set of key plant and animal indicators are present (Faber-Langendoen et al. 2009).

The distinction between "the highest quality examples" and "sites in minimally disturbed condition" may appear semantic at first inspection, but when the actual data from our study are examined, it becomes evident that many of our randomly chosen sites are small and not especially diverse. Some may barely cover a "minimum dynamic area", may be fairly transitory as landscape elements, and probably would not be chosen as "the best of the rest." However, because many of the wetlands in our ambient condition surveys were themselves not "the highest quality examples" of their kind even in their undisturbed state, to assess them against that standard is misleading. By identifying the real range of variability found in minimally disturbed landscapes, this study offers a set of reference standard wetlands that can form the basis for assessments that make sense to all end-users, not just conservation professionals.

We also believe that the sites described in this study can be used to establish reasonable performance standards for voluntary and compensatory mitigation. Here, our findings that there are regional and typological differences in the range of natural variability are of particular importance. Marshes, with their low species richness and relatively low FQI scores, do not compensate for the loss of wet meadows or fens. In contrast, if a marsh is an appropriate choice for mitigation and/

or restoration, then performance standards for FQA values should be based on what a marsh can be expected to attain, not on values observed in fens. Similarly, while wetlands in the Canadian Rockies ecoregion may occasionally be highly diverse, with populations of endemic species having very high C o f C scores, this study shows that these are not the norm; in general, wetlands in that ecoregion appear to have lower FQA scores than do wetlands in the Southern Rockies, and performance standards should reflect that.

This study also identifies a number of questions for future work. Notably:

- We used best professional judgment to establish minimum acceptable distances to a number of potential disturbances. Results indicated that disturbances beyond that distance were not impacting our sites. However, from a management perspective it is important to understand the geographic (and temporal) scales at which these disturbances do have an impact. For example, our sites were all at least 500 m from a highway and 2,000 m from any timber harvest. Would we see impacts on wetlands from a highway 250 m away? A past timber harvest 1,000 m away?

- We found that Level 2 metric values for vertical overlap of vegetation strata, horizontal interspersion of vegetation zones, and the number of structural patch types varied widely within and between wetland types, with no apparent correlation to disturbance. If, however, structural complexity is important from a habitat perspective, or to provide more inherent resistance or resilience should disturbance occur, what is the best way to measure and document it?

- The study showed clear bioregional variation in floristic quality metric scores. Is this best explained by a latitudinal diversity gradient? Do state-specific Coefficients of Conservatism vary enough from state to state to influence FQA values? If so, does this reflect a biogeographic reality (i.e., a genuine difference in tolerance to disturbance for species in one state vs. another) or is it an artifact of subjectively assigning those values? In either case, how do we compare wetland condition across regions? Does this call for developing regional or national Coefficients of Conservatism?

- Within individual wetland classes, what are the factors that drive natural variability of species richness and diversity? What are the factors that operate between wetland classes? We observed that wet meadows and riparian shrublands have some of the highest FQA values across our study region. Wet meadows and riparian shrublands tend to have more variable flooding regimes than fens or marshes. Are there unmeasured hydrologic variables that account for observed differences in richness and diversity?

Finally, this study, while separate from the National Wetlands Condition Assessment and the rotating basin assessments being carried out in Colorado and Montana, is conceptually linked to them. In addition to establishing a reference standard against which condition can be assessed, this study also presents an opportunity to begin evaluating the results of those assessments at multiple geographic scales. By establishing reference standards for these four wetland systems, and identifying regional variation, this study makes it much easier to extract the “dose-response curve” for human disturbance and wetland condition from other survey work. It establishes a framework within which data from Montana can be meaningfully compared to data from Colorado. Absent the finding that reference standard wetlands in northern Montana have lower FQA values than those in the Southern Rockies, it would have been easy to conclude that all assessed wetlands in northern Montana were just in “worse” shape than their southern counterparts. In the future, we would like to see more opportunities for collaboration that focus on other parts of Montana, Wyoming and Colorado, particularly the plains and grassland areas.

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Appendix A. Brief Descriptions of Ecological Systems Covered in This Study

Brief descriptions of Ecological Systems covered in this study.

Rocky Mountain Subalpine-Montane Fens (hereinafter "fens") occur infrequently throughout the Rocky Mountains from Colorado north into Canada. They are confined to specific environments defined by groundwater discharge, soil chemistry, and peat accumulation. Fens form at low points in the landscape or near mountain-to-valley transitions where groundwater intercepts the soil surface. Groundwater inflows maintain a fairly constant water level year-round, with water at or near the surface most of the time. Constant high water levels lead to accumulation of organic material, usually greater than 40 centimeters (15 inches), except on sites underlain by limestone bedrock. In addition to peat accumulation and perennially saturated soils, extremely rich and iron fens have distinct soil and water chemistry, with high levels of one or more minerals such as calcium, magnesium, or iron. Fens are among the most floristically diverse of all wetland types, supporting a large number of rare and uncommon bryophytes and vascular plant species, and provide habitat for uncommon mammals, mollusks and insects. Fens usually occur as a mosaic of herbaceous and woody plant communities. The surrounding landscape may be ringed with other wetland systems: fens often grade into marshes, wet meadows or riparian shrublands, and can be surrounded by conifer swamps or wet to mesic coniferous forests.

Rocky Mountain Alpine-Montane Wet Meadows are found at moderate to high elevations throughout the Rocky Mountains, dominated by herbaceous species found on wetter sites with very low-velocity surface and subsurface flows. This system typically occurs in cold, moist basins, seeps and alluvial terraces of headwater streams or as a narrow strip adjacent to alpine lakes. Wet meadows are typically found on flat areas or gentle slopes, but may also occur on sub-irrigated sites with slopes up to 10 percent. In alpine regions, sites are typically small depressions located below late-melting snow patches or on snowbeds. The growing season may only last for one to two months. Soils of this system may be mineral or organic. In either case, soils show typical hydric soil characteristics, including high organic content and/or low chroma and redoximorphic features. This system often occurs as a mosaic of several plant associations, often dominated by graminoids such as tufted hairgrass (*Deschampsia caespitosa*), and a diversity of montane or alpine sedges. High elevation bluegrasses (*Poa arctica* and *Poa alpina*) are often present. Moisture for these wet meadow community types comes from groundwater, stream discharge, overland flow, overbank flow, and precipitation. Salinity and alkalinity are generally low due to the frequent flushing of moisture through the meadow. Depending on the slope, topography, hydrology, soils and substrate, intermittent, ephemeral, or permanent pools may be present, and standing water may be found during some or all of the growing season, with water tables typically remaining at or near the soil surface. Fluctuations of the water table throughout the growing season are not uncommon, although wet meadows are rarely subjected to high disturbance events such as flooding. On drier sites supporting the less mesic types, the late-season water table may be one meter or more below the surface. Soils typically possess a high proportion of organic matter, but this may vary considerably depending on the frequency and magnitude of alluvial deposition. Organic composition of the soil may include a thin layer near the soil surface. Soils may exhibit gleying and/or mottling throughout the profile.

North American Arid West Emergent Marshes are found throughout the arid and semi-arid regions of North America, often in depressions surrounded by an upland matrix of mixed prairie, shrub steppe, or steppe vegetation. Natural marshes occur in and adjacent to ponds and prairie potholes, as fringes around lakes or oxbows, and along slow-flowing streams and rivers as riparian marshes. Marshes are classified as either seasonal or semipermanent based on the dominant vegetation found in the deepest portion of the wetland; vegetation is representative of the hydroperiod. A central shallow marsh zone dominated by graminoids and sedges characterizes seasonal wetlands, while semipermanent wetlands are continually inundated, with water depths up to 2 meters (6.5 feet) and a deeper central marsh zone dominated by cattails (*Typha* species) and bulrushes (*Schoenoplectus* species). Water chemistry may be alkaline or semi-alkaline, but the alkalinity is highly variable even within the same complex of wetlands. Marshes have distinctive soils that are typically mineral, but can also accumulate organic material. Soils characteristics reflect long periods of anaerobic conditions. Wet-drought year climatic cycles, often in 10 to 20 year cycles, influence the ecological communities in these systems. During this climatic cycle, wetlands go through a dry marsh, regenerating marsh, degenerating marsh and a lake phase that is regulated by periodic drought and deluge. During drought periods, seeds from annuals and perennials germinate and cover exposed mud flats, but when precipitation floods the depressions, the annuals drown and the perennials survive, regenerating the marsh. Over a series of years, perennials dominate and submersed and floating-leaved hydrophytes return. After a few years of the regenerating phase, emergent vegetation begins to decline and eventually the marsh reverts to an open water system. Muskrats may play an important role in the decline of emergent vegetation in some of these systems.

Rocky Mountain Subalpine-Montane Riparian Shrublands are found at montane to subalpine elevations of the Rocky Mountains. Shrubs dominate this seasonally flooded system, with total shrub cover ranging from 20 to 100 percent. Shrublands occur as linear bands of shrub vegetation lining streambanks and alluvial terraces in narrow to wide, low-gradient valley bottoms and floodplains with sinuous stream channels. Flooding creates and destroys sites for the establishment of vegetation through the transport and accumulation of coarse sediment. Sediment accumulating in these systems can form gravel bars at or near the surface of the river, creating bands of mixed vegetation that occupy different stages of succession (Melanson and Butler, 1991). Ground water seepage from snowmelt may create shallow water tables or seeps that vegetation depends on for a portion of the growing season. This system often occurs as a mosaic of multiple communities that are shrub and herb dominated. Vegetation structure varies depending on latitude, elevation and climate. Flooding in these systems influences vegetative communities by transporting sediments and creating establishment sites for colonization. Many plants in these high-energy systems that experience large disturbances from floods have acquired adaptive traits. Some have flexible, resilient stems and specialized cells to hold oxygen so that they can survive large flood events. These species also have reproductive adaptations such as water-dispersed seeds and are able to sprout quickly from flood damaged stumps. In sites where there is prolonged disturbance, willow coverage will decrease, resulting in a more open canopy. Herbaceous vegetation will transition to a grass-dominated system. Shrubland riparian systems are important for bank stabilization, organic inputs to the adjacent stream, shade cover and wildlife habitat values.

Appendix B. Parameters and Weighting used in Landscape Integrity Model

The Landscape Integrity Model used in our initial screening was built from the following GIS data layers:

Roads:
We used the road data from Tiger 2008 (ftp://ftp2.census.gov/geo/tiger/TIGER2008) across the entire region.

Data were downloaded, merged, projected to Albers Equal Area Conic Projection, and assigned to one of three classes:

g) Highways: MTFCC S1100 (primary road); and S1200 (secondary road) if the secondary road name contains “Hwy” or “Highway”. Also S1630 (ramp).
h) Four-wheel-drive roads: MTFCC S1500 (vehicular trail) and S1740 (private road for service vehicles: logging, oil field, ranches, etc). Also S1640 (service drive usually along a limited access highway) if they were actually logging roads (Name = ‘’).
i) Other roads: MTFCC S1200 (if name does not contain “US Hwy”), S1400 (local neighborhood road, rural road, city street), S1780 (parking lot road), and S1640 that are not logging roads (service drive usually along a limited access highway; name attribute is filled).

Each shapefile was buffered and converted to a grid. Scores were assigned to pixels (see Table C-1).

Hydrology:
Artificial flow: From the National Hydrography Dataset (NHD) High resolution data (http://nhd-geo.usgs.gov/metadata/nhd_high.htm), we selected FTYPE 336

Impaired waters: Data were downloaded on a state-by-state basis from the EPA site (http://ep-amap32.epa.gov/radims/). Metadata was found at:
http://www.epa.gov/waters/data/303D_metadata.xml

We also downloaded data for facilities that discharge to water (points): http://www.epa.gov/waters/data/PCS_metadata.xml

Theses layers (points, lines and polygons) were buffered and converted to a grid.

Wetland violations (section 404): These data were downloaded from EPA region 8 webpage:
http://www.epa.gov/Region8/gis/index.html#2
http://www.epa.gov/Region8/gis/data/r8_404.html

Points were buffered and converted to a grid.

Land cover:
Our based layers for land cover came from the Northwest ReGAP (MT and WY) and Southwest ReGAP (CO and UT):

http://www.gap.uidaho.edu/Northwest/data.htm
http://earth.gis.usu.edu/swgap/landcover_download.html

We used the following land cover classifications to build our land cover/land use categories:

Urban: NW ReGAP codes 22, 23 and 24 (low, medium, and high intensity developed); SW ReGap codes 111 and 112 (low and medium-high intensity developed). Clumps of pixels smaller than 5 pixels were removed using the Eliminate command in Erdas Imagine. All pixels within 100m of a highway were also removed. Finally, remaining pixels were shrunk by 1 pixel, to remove isolated, non-highway roads pixels.

Agriculture: NW ReGap codes 81 and 82 (hay/pasture and cropland); SW ReGap code 114 (agriculture). Clumps of pixels smaller than 5 pixels were removed using the Eliminate command in Erdas Imagine.

Timber harvest: NW ReGap codes 8601, 8602 and 8603 (harvested, grass, shrub and tree regeneration); SW ReGap code 123 (logged). Clumps of pixels smaller than 5 pixels were removed using the Eliminate command in Erdas Imagine.

Each grid was expanded and scores were assigned to pixels.

Mining:
In addition to ReGAP mining pixels (ESLF 31 and 8498 for MT, ESLF 117 for UT and CO, pixel groups smaller than 11 removed), point locations of active and/or abandoned mines were obtained from a variety of sources:
http://nris.mt.gov/nsdi/nris/deq_abandoned_mines.html
http://mining.state.co.us/GIS%20Data.htm
GNIS data from Daniel Smith, Utah DNR (danielsmith@utah.gov)
http://mrdata.usgs.gov/mineral-resources/active-mines.html

After being assigned scores and weights, the grids were stacked into a global integrity grid with values ranging from 10,000 (highest integrity) to 38,925 (lowest integrity):

Pixels with the highest possible integrity: [(>200m 4-wheel drive: 15%, >300m local roads: 35%, >500m highways: 50%) * 35%] + [(>2000m urban: 40%, >500m crop agriculture: 40%, >2000m timber harvest: 20%) * 35%] + [(>200m artificial flow: 25%, >200m water right pt of use: 50%, >200m section 404: 25%) * 20%] + [(>150m abandoned mines: 100%) * 10%) =
[(15 + 35 +50)*35] + [(40 + 40 + 20)*35] + [(25 + 50 + 25)*20] + [100*10] = 10,000

Pixels with the lowest possible integrity: [(<100m 4-wheel drive: 15%, <100m local roads: 35%, <100m highways: 50%) * 35%] + [(<500m urban: 40%, <200m crop agriculture: 40%, <500m timber harvest: 20%) * 35%] + [(<100m artificial flow: 25%, <100m water right pt of use: 50%, <100m section 404: 25%) * 20%] + [(<60m abandoned mines: 100%) * 10%) =
[(3*35 + 4*35 + 5*50)*35] + [(5*40 + 5*40 + 5*20)*35] + [(3*25 + 3*50 + 3*25)*20] +
[(100*3)*10] = 43,825

Table B-1.

Category	Buffer distance (meters)	Score	Weight
Roads			**35%**
4-wheel drive (15%)	0-100	3	
	100.01-200	2	
	>200.01	1	
Local roads, city streets (35%)	0-100	4	
	100.01-200	3	
	200.01-300	2	
	>300.01	1	
Highways (50%)	0-100	5	
	100.01-200	4	
	200.01-300	3	
	300-500	2	
	>500.01	1	
Land Cover			**35%**
Urban (40%)	0-500	5	
	500.01-1000	4	
	1000.01-1500	3	
	1500.01-2000	2	
	>2000.01	1	
Crop agriculture (40%)	0-200	5	
	200.01-300	4	
	300.01-400	3	
	400.01-500	2	
	>500	1	
Timber harvest (20%)	0-500	5	
	500.01-1000	4	
	1000.01-1500	3	
	1500.01-2000	2	
	>2000.01	1	
Hydrology			**20%**
Artificial flow (25%)	0-100	3	
	100.01-200	2	
	>200.01	1	
Water right point of use (50%)	0-100	3	
	100.01-200	2	
	>200.01	1	
Section 404 permit (25%)	0-100	3	
	100.01-200	2	
	>200.01	1	
Land use			**10%**
Abandoned mines (100%)	0-60	3	
	60.01-150	2	
	>150.01	1	

Appendix C. Screening Process for Site Selection in the Rocky Mountain ReMAP Project

Essential GIS layers:
Digital Raster Graphic (topographic map)

NAIP or other aerial image

Land Ownership and Designation

Cells and Points

Other Useful Layers:

Wetland layers

Landscape-scale vegetation layers (ReGAP, Landfire, etc.)

County and state boundaries, roads, trails, river, lakes

The Cell Attribute Table:
The following fields were added to the cell attribute table: <*Include*>, <*Dom_Owner*>, and <*Comments*>

<*Include*> is marked "yes," "no," or "maybe" depending on whether points have been selected within that cell and the confidence of those selections. The "maybe" designation is reserved for cells that need careful consideration before spending travel time.

<*Dom_Owner*> contains information of who manages the land, (i.e. Private, USFS, BLM, etc).

<*Comment*> includes information about the first two designations and any other relevant information. This contains the reasoning behind the "yes," "no," or "maybe" inclusion.

The Point Attribute Table:
The following fields have been added to the point attribute table: <*Selected*>, <*EcolSyst*>, <*EcolSyst2*>, <*Confidence*>, and <*Comments*>

<*Selected*> can be only "yes" or "no"; a decision must be made.

<*EcolSyst*> and <*EcolSyst2*> can be marked as ONLY ONE Ecological System type: "Marsh," "Fen," "Wet Meadow," "S-M Rip Shrub," "S-M Rip Wood," "LM Rip Wood & Shrub," or "n/a" (not analyzed). "S-M Rip Wood" is no longer a target system, but can still be included as a secondary designation.

"n/a" should be used only for points that have a selection of "no." Every point with a selection of "yes" must also have a designation in <*EcolSyst*>, even if <*EcolSyst2*> is left blank.

We have two EcolSyst fields for points that are wetlands, but there remains some question as to which type. <*EcolSyst*> is reserved for the most probable type. <*EcolSyst2*> can be left blank if the first designation is clear.

Points can have a selection of "no" but still have an <*EcolSyst*> designation if the site is too small to sample, or if confidence is too low to sample, or another reason indicated in <*Comments*>.

<*Confidence*> is marked "high," "medium," or "low." A "high" designation indicates that the point is clearly a sample able wetland, even if there is question as to what <*EcolSyst*> designation to use. A "me-

dium" designation indicates some doubt as to whether the point should be visited or not. A "low" designation indicates a larger amount of doubt, a second opinion is needed.

<*Comment*> can include any useful information, and examples are "on private land," "not a wetland," "site too small to sample," "is this a wetland or a cloud?" etc.

Do not leave the <Comment> column blank for points where <Selected> is "no." These are easily filled in for most points using the Field Calculator in GIS and can be surprisingly helpful. Examples include "on private land" or "upland area, not wetland."

Methods:
Each cell/point must eventually be designated with information in every added column (except perhaps <*EcolSyst2*>.

It is most efficient to first look at the Land Ownership layer so that points on private land can be discarded immediately.

Use the DRG layer to identify the best potential sites on public land. Go to these points first at a ~1:2,000 resolution).

Use the aerial image to confirm wetland presence.

Use wetland data if available, and surrounding vegetation data to further strengthen decisions to select points. These data are sometimes too coarse but sometimes very useful.

Use the measuring tool to confirm that potential points are within 20 m of a wetland that is wider than 20 m and at least 0.10 ha in area.

Lastly, navigate through the cell at a 1:5,000 looking for other unexpected potential wetlands.

Be critical and try to only select points that will probably be confirmed, but also be consistent across cells, and for all points.

Finally, use county, road, river and stream layers when locating the cells within the landscape.

To make sure that selected points occur within a landscape context that meets our criteria of High Integrity, the following thresholds have been set. Selected points must be at least the stated minimum distance from the following potential stressors.

Distance from Roads

4x4, dirt >200 m

local, city >300 m

highways >500 m

Hydrologic Modification

canals, ditches >200 m

reservoirs >1,000 m (only if wetland is downstream)

water right point of use (wells, diversion points, impoundments) >200 m

Land Cover

high density residential >2,000 m

low density residential / high use recreation >300m

crop agriculture / hay pastures >500 m

timber harvest >2,000 m

Land Use

abandoned mines / tailings piles >500 m

active gravel pit, open pit, strip mining >1,000 m

evidence of livestock >200 m

APPENDIX D. FIELD KEY

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 mosaic 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 mosaic 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 tree cover). This system occurs as either a narrow band of shrubs lining the streambank of steep V-shaped canyons *or* as a wide, extensive shrub stand (sometimes referred to as a shrub carr) on alluvial terraces in low-gradient valley bottoms. 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, 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. This example of the system has the same species composition as the riverine example of this system and is dominated by species of *Salix*, *Alnus*, or *Betula*. .... **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**

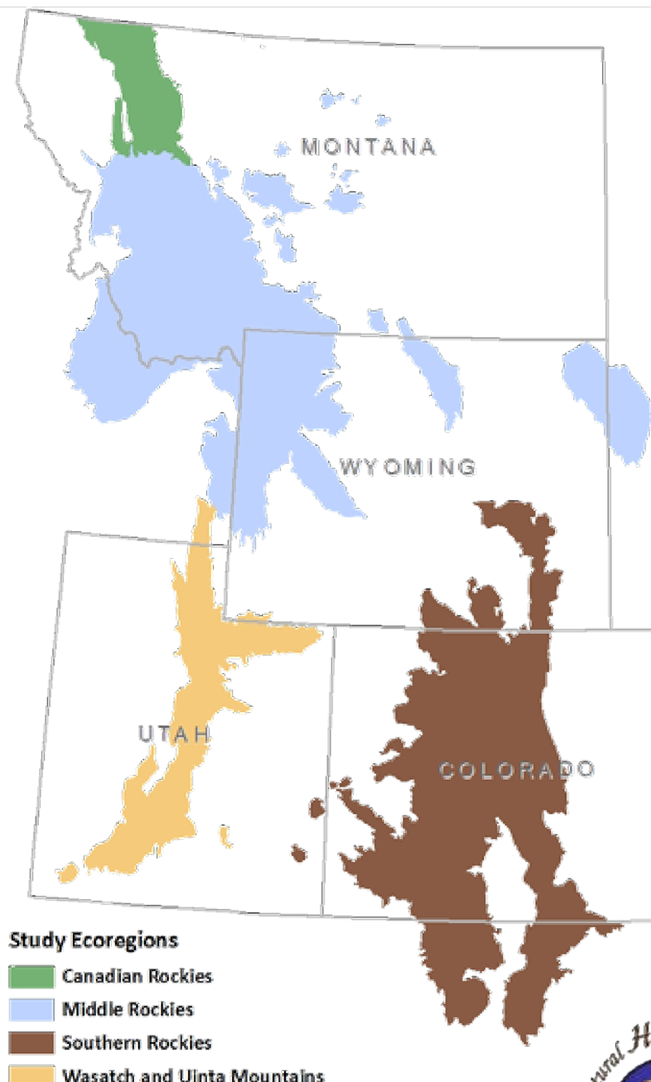
6a. Depressional wetlands occurring in areas of alkaline to saline clay soils with hardpans. Salt encrustations can occur on the surface. Species are typically salt-tolerant such as *Distichlis spicata*, *Puccinellia* spp., *Leymus* sp., *Poa secunda, Salicornia* spp., and *Schoenoplectus maritimus*. 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. 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, Schoenplectus*, *Typha*, *Juncus*, *Carex*, *Potamogeton*, *Polygonum*, and *Phalaris*. ....**Western North American Emergent Marsh**
7b. Herbaceous wetlands associated with a high water table or overland flow, but typically lack 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). Site *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). Wetlands in this system have less than 40 cm of peat (organic soil) accumulation. 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**

APPENDIX E. DRAFT PROTOCOL

Rocky Mountain REMAP
Wetland Condition Assessment
2010 Field Manual



United States Environmental Protection Agency

Montana Natural Heritage Program

Natural Heritage Program COLORADO

Wyoming Natural Diversity Database

Rocky Mountain REMAP Wetland Condition Assessmnt 2010 Field Manual

Compiled by:
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Table of Contents

Rocky Mountain REMAP Field Manual

Section 1: Introduction to the Rocky Mountain REMAP Project

This field manual documents protocols for the Rocky Mountain Wetland Condition Assessment project funded through the U.S. Environmental Protection Agency's (EPA) Regional Assessment and Monitoring Program (REMAP). This project is a collaborative effort by the Montana Natural Heritage Program (MTNHP), the Colorado Natural Heritage Program (CNHP), and the Wyoming Natural Diversity Database (WYNND) to develop a standardized approach to assessing wetland condition in the mountain ecoregions of U.S. EPA Region 8. The work we are doing will also further the objectives of the National Wetland Condition Assessment (NWCA) scheduled for 2011 by providing an opportunity to field test proposed metrics and protocols.

The Rocky Mountains have a unique geography, population distribution, and concentration of public land ownership. In Montana, Wyoming, Colorado and Utah, mountain areas receive as much as ten times the relative effective precipitation than do the eastern plains. The extremes of mountain climate, high elevations and characteristic geology produce a large range of natural variability among wetlands. Even under minimal human disturbance regimes, environmental gradients can result in wetlands with very low vegetation cover, low species diversity and unpredictable hydrologic shifts. Moreover, there are distinct ecoregional differences within the Rocky Mountain States. For example, southern areas are subjected to monsoonal weather patterns during the summer months, while northern areas are generally dry after June. To date, there have been no systematic studies addressing whether, and to what extent, these differences might affect natural variability among wetland ecological systems.

Many of the wetland assessment protocols in use across the country have been designed for areas with more moderate climates and have not been tested or calibrated in mountain ecoregions. Even though researchers from Colorado, Montana and Wyoming have been extensively involved in developing ecoregion-specific assessment protocols and methods, field testing and calibration of indicators and metrics is still ongoing. While informal collaborative networks exist, there has not been the kind of systematic cooperation and information sharing that will be necessary for consistent and effective assessment and monitoring across the region. This project addresses the need for such cooperation by bringing researchers from all three states together to collaborate on a standardized regional protocol and to evaluate, calibrate and validate the tools being developed for the National Wetland Condition Survey.

Field work for the Rocky Mountain REMAP project focuses on establishing a baseline reference standard condition. By describing the natural variability associated with reference condition wetlands, the response of these wetlands to human-induced disturbances is more easily understood. In other words, it becomes easier to separate the signal (response to human disturbance) from noise (natural variability) when sampling wetlands across a human disturbance gradient. It follows that, if ecological response to stressors can be identified, then better informed restoration, management, and protection projects can be implemented.

Practically speaking, natural variability is difficult to define empirically since long-term ecological data as well as data on conditions prior to European settlement are rarely available (Swetnam et al. 1999). In ecological and biological assessments, the concept of "reference standard" sites may have several meanings. At one extreme, it means sites that have been minimally disturbed by human activities, while at the other it means "best attainable condition" (Stoddard et al. 2006). Typically, minimally disturbed sites are found only in near-pristine areas managed as wilderness or in similar remote and wild areas (Herlihy et al. 2008). In broad regional or national assessment contexts, selection of "minimally disturbed" as a reference standard may be inappropriate, simply because the types of sites found in these remote, often high-elevation areas may be biologically dissimilar to sites in less extreme locations, even in the absence of human disturbance. However, in the Rocky Mountain West, we expect that minimally disturbed examples of most wetland ecological systems can be found across the range of abiotic gradients occurring in the area. Therefore, we will use the concept of Minimally Disturbed Condition (MDC). This is the biotic condition of sites in the absence of significant human disturbance. Stoddard et al. (2006) consider the MDC to be the "best approximation or estimate of biotic integrity." Recognizing that most sites have likely been exposed to some minimal human stressor (e.g. atmospheric contaminants), the definition incorporates the disclaimer of "significant" human disturbances. The natural variation of the MDC provides a baseline from which ecological indicators can be assessed to determine their comprehensiveness, sensitivity, and their ability to distinguish highly impacted from reference standard sites.

Natural variability occurs both within wetland classes (e.g. wet meadows may occur at alpine and lower montane elevations, leading to differences in plant diversity and productivity) and between different wetland classes (e.g. fens differ in hydrology, soils, and plant communities from freshwater marshes). To constrain the breadth of natural variability between wetlands in some way, wetlands are generally classified into discrete types. Common wetland classification systems include the Cowardin system (Cowardin et al. 1979), the hydrogeomorphic (HGM) system (e.g. Hauer et al. 2002), the National Vegetation Classification Standard (NVC) and the ecological systems classification (Comer et al. 2003). For the purpose of our study, we will use the ecological systems classification. This is a spatially explicit, mappable, mid-scale classification that integrates finer-scale plant communities (e.g. associations and alliances) with natural dynamics, soil types, hydrology, and landscape setting. Individual wetland ecological systems can also be crosswalked to the hydrogeomorphic (HGM) classification system and the Cowardin system using field indicators. We have chosen to use ecological systems as our primary classification system for several reasons: first, substantial work has already been completed in Colorado and, to a lesser degree, in Montana to identify the key ecological attributes and indicators of wetland ecological systems; second, comprehensive land cover maps using ecological systems as map units are now available throughout the Rocky Mountain West; third, they integrate the abiotic and hydrologic approach of the HGM with the vegetation and landform approach of the Cowardin system; and fourth, they are at once broad enough and narrow enough to capture the range of natural variability in wetlands while organizing it into similar and manageable conceptual units.

We have identified four wetland ecological systems common to mountainous regions of all four states in the project area:

- North American Arid West Emergent Marsh
- Rocky Mountain Subalpine-Montane Fen
- Rocky Mountain Alpine-Montane Wet Meadow
- Rocky Mountain Subalpine-Montane Riparian Shrubland

This project will identify the key ecological attributes of each ecological system, identifying the range of natural variability (if any) that can be expected for each attribute at reference standard sites. We expect to identify a minimum of twenty reference standard examples of each ecological system. These will not necessarily be evenly distributed among the ecoregions or states in the study—Utah's Wasatch and Uinta Mountains do not have the same fen density as the Northern Rocky Mountains, for example—but we are aiming for a broad regional spread.

Section 2: Elements of the Study Design

We will use a three-step approach to identifying reference sites: identification of landscape units; screening for high-integrity areas with reasonable access; and selection of sites using a Generalized Random Tessellation Stratified (GRTS) sampling design.

2.1. Stratification across Level III Ecoregions

The Rocky Mountain West[1] is an area characterized by rugged landscapes, climatic extremes, and rivers with snowmelt-driven hydrographs. Within the study area, seven Omernik Level III ecoregions reflect differences in physiography, geology, vegetation, climate, soils, land use and hydrology (Omernik 1987). However, within these broad ecoregions, there is still considerable variability in biotic and abiotic factors. We know that this variability affects the distribution of wetland ecological systems in the Rocky Mountain West. Playas, for example, are primarily found in the Southern Rockies. Northern Rocky Mountain Vernal Pools tend to be more frequent in Montana. Therefore, it follows that even when we see wetland ecological systems occurring in all four states in the study area, there may be significant regional differences in relevant ecological attributes as a result of environmental variables such as precipitation, temperature, geology, etc. For the purpose of the Rocky Mountain REMAP project, we will use EPA Level III ecoregions as a grouping unit and will focus on four ecoregions (Figure 1):

- Canadian Rocky Mountains
- Middle Rocky Mountains
- Southern Rocky Mountains
- Wasatch and Uintah Mountains

2.2. Screening for high quality sites with reasonable access.

To identify areas in minimally disturbed condition, we adapted a landscape integrity model developed for Montana (Vance 2009). This is an inverse weighted distance model premised on the idea that ecosystem processes and functions achieve their fullest expression in areas where human activities have the least impact. In the case of wetlands, it presumes that reference standard wetlands are mostly likely to be found in areas well-removed from roads, commercial or industrial development, urban areas, resource extraction sites, or hydrologic modifications. When tested on a set of rapid assessments carried out in Montana's mountain ecoregions, the model was able to accurately assign A-ranks (on an A, B, C, or D scale) in 75% of the cases. Where measured rank differed, it was generally due to factors that were not included the model, such as high-use backcountry recreation sites or timber harvest activities on federal lands. In most cases, these factors can be identified visually from aerial photography. Although GIS data quality may vary among individual Rocky Mountain states, we have identified sufficient comparable data sets to build a Rocky Mountain Landscape Integrity Model that can be used as an initial predictor of minimally disturbed areas.

Minimally disturbed areas will, of course, include many areas with no reasonable access. Because our goal is to identify reference standard sites that can be used in subsequent studies and research, we will limit our search area to locations within 2 miles of a maintained footpath or trail (areas near roads will, by definition, fall outside the MDC criterion). We will also limit the area by ownership, selecting locations on public land,

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[1] The "Rocky Mountain West" is a broad geographic concept that includes the four states in the study area as well as Idaho, and sometimes Nevada, New Mexico and Arizona. We use the term to refer to the Rocky Mountain States in EPA Region 8: Montana, Wyoming, Colorado and Utah.

again with the intention of maintaining access over time. To delineate this search area, we will obtain GIS layers of footpaths and trails from each National Forest, National Park, and other managed resource area (wildlife refuges, state parks, etc). If there are high-integrity areas with no GIS layers for trails, we will hand-delineate trails from aerial photographs.

Figure 1. Four Level III Ecoregions included in the Rocky Mountain REMAP Project.

2.3. Selection of sites

Our target population will be all examples of the four wetland ecological systems within the accessible, high-integrity area identified in step 2. We will lay a 2 mile by 2 mile grid of cells over the area and use a Generalized Random Tessellation Stratified (GRTS) sampling design to choose potential sample grid cells (Stevens 1997; Stevens and Olsen 1999; Stevens and Olsen 2004), stratifying by landscape unit (e.g. ecoregions). After the potential sample grid cells are chosen using GRTS, each will be sequentially evaluated to determine if it contains wetlands (using National Wetland Inventory mapping where available and digital orthophotos when not available). We will also determine whether there are human disturbances within the sample grid that were not identified in the GIS; if this is the case, the sample grid square will be skipped.

Within all non-disturbed grid cells, we will lay a grid of points at 100 m intervals in each direction. These points will be ordered using GRTS and we will evaluate each point in the order assigned by GRTS. Each GRTS point that falls within a wetland will be coded as one of the six ecological systems; wetlands that are not within one of the six target ecological systems (e.g.conifer swamps, vernal pools, etc) will be disregarded. We will continue to evaluate points in the GTRS order until we have selected up to five examples of each wetland ecological system that occurs in the cell. Our goal will be to visit at least one example of each wetland type in each cell, but we will draw oversamples in case we are unable to access sample sites. GRTS sampling will be carried out in ArcGIS and R–package spsurvey.

Section 3: Introduction to Field Sampling Protocols

Field protocols used in this project draw from methods under development at CNHP and MTNHP through previous and concurrent EPA funding and are based on the Ecological Integrity Assessment (EIA) framework (Faber-Langendoen *et al.* 2008, Lemly and Rocchio 2009), which also borrow from established wetland assessment methods such as the California Rapid Assessment Method for Wetlands (Collins *et al.* 2008) and the Ohio Rapid Assessment Method (Ohio EPA 2001). Because the goal of the Rocky Mountain REMAP project is to gather detailed, Level 3 data at high quality, reference condition sites, the field protocols focus on quantitative data that will inform qualitative assessments using the EIA framework. Where possible, REMAP methods also draw heavily from the EPA's upcoming National Wetland Condition Assessment (NWCA) scheduled for 2011. One stated goal of the REMAP project is to collect reference data in support of the NWCA. However, because the NWCA methods have been under development during the course of the REMAP study, the protocols do not match exactly. In addition, NWCA sampling will entail laboratory analysis of many parameters that will not be collected in this REMAP project.

Section 4: Site Evaluation Guidelines

The basis of this study is the identification and establishment of an assessment area within one of four target Ecological Systems. Sample points have been randomly selected throughout the study area within areas that are presumed to meet the target population. Field crews will navigate to the sample points using GPS coordinates given to them by their State field coordinator. Before any sampling can occur, the crew must verify that the sample point is within 60 m of the target population. If so, the field crew will begin sampling and carry out all protocols necessary for that Ecological System. If not, the field crew must reject the point and move on to the next point within the cell. There are three elements to determining the target population and suitability for sampling: 1) the site must be a wetland at least 0.1 ha in size with minimal water > 1 m deep; 2) the wetland must be one of four target Ecological Systems; and 3) the site must meet minimum criteria for reference condition based on distance to potential disturbances.

When evaluating the area around a point, the crew may use the **2010 REMAP Site Evaluation Form.** Crews can fill out one page of this form at a sample point if all area surrounding the point is homogeneous, or they can fill out multiple pages surrounding a sample point to capture different potential wetland areas**.** This form is not necessary to fill out if there is an obvious wetland at or near the point. Much of the information on the evaluation form is repetitive to information on the actual field form. However, the Site Evaluation Form can be useful in two different scenarios. 1) **Site evaluation on the day of sampling:** If the crew is uncertain whether the area meets the target population, they can fill out the Site Evaluation Form at various locations at and surrounding the sample point. This form is a useful place to take notes and track whether locations qualify as target. Once a suitable wetland area is encountered, the crew can begin data collection and the Site Evaluation Form will be kept with the final data forms and returned to the State field coordinator. If a suitable wetland area is not encountered within 60 m of the sample point, the Site Evaluation Form will document why a point was rejected. 2) **Site evaluation during reconnaissance visits:** If the crew has time to recon sample points before actually conducting the sampling, the Site Evaluation Form can be filled out at sample points to document which are suitable for sampling and which are not. This information can then be used to plan the actual sampling schedule.

Wetland Determination
Upon arrival at a sample point, the first question that the crews must answer is whether or not there is wetland area ≥ 0.1 ha in size at the point or within 60 m of the point. Deep water > 1 m may be present within the wetland, but no sampling will occur in water > 1 m deep for safety reasons. Suitable wetland area must be ≥ 0.1 ha in size with < 10% water > 1 m deep within the area targeted for sampling.

For the purpose of the REMAP project, wetland is defined based on the U.S. Fish and Wildlife Service (USFWS) definition (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."*

Crews will use established protocols developed by the U.S. Army Corps of Engineers (ACOE) to determine whether the site is a wetland. Each crew will carry with them *at all times* the ACOE *Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Western Mountain, Valleys, and Coast Region* (ACOE 2008). Wetland determinations are based on three lines of evidence: hydrophytic vegetation, hydric soils, and wetland hydrology. However, in contrast to the ACOE methodology, crews do not have to find all three criteria because the USFWS definition only requires one of the three. The best lines of evidence to use are the dominance of hydrophytic vegetation and the presence of hydric soils. Wetland hydrology alone can be used only if the crew are certain the hydrology is long term and not present due to recent weather.

Ecological System Classification
If there is wetland area at or within 60 m of the sample point, the crew must then determine if any of that wetland area is one of the four target Ecological Systems. To determine the Ecological System classification, crews will use the Field Key to Wetland and Riparian Ecological Systems of Montana, Wyoming, Utah, and Colorado (**Appendix A**) and Ecological Systems Descriptions for Target Ecological System in Colorado and Montana (**Appendix B**). The four target Ecological Systems are:

- North American Arid West Emergent Marsh
- Rocky Mountain Subalpine-Montane Fen
- Rocky Mountain Alpine-Montane Wet Meadow
- Rocky Mountain Subalpine-Montane Riparian Shrubland

Crews should pay particular attention to size criteria listed in the key when dealing with mixed vegetation. Wetlands can occur as mosaics of herbaceous and woody vegetation, but any given patch must meet a certain size to be considered an occurrence of a separate Ecological System.

Reference Condition Criteria

If wetland area is one of the four target Ecological Systems and meets the required size, the crew must then determine if the site meets the criteria defined for reference condition sites. The wetland must meet minimum distances from the following stressors:

Roads and Highways

- 4x4, dirt > 200 m
- local, city > 300 m
- highways > 500 m

Hydrologic Modification

- canals, ditches > 200 m
- reservoirs > 1,000 m downstream
- water right point of use (wells, diversion points, impoundments) > 200 m

Land Cover

- high density residential > 2,000 m
- low density residential / high use recreation > 300 m
- crop agriculture / hay pastures > 500 m
- timber harvest > 2,000 m

Land Use

- abandoned mines / tailings piles > 500 m
- active gravel pit, open pit, strip mining > 1,000 m
- evidence of heavy livestock use > 200 m

Section 5: Describing and Establishing the Assessment Area

5.1. Location and General Information

On the **2010 Rocky Mountain REMAP Wetland Condition Assessment Field Form**, the top section contains general information about the site. This information can be filled out once the crew determines that a suitable wetland area is located at or near the sample point. The following guidance will assist in filling out this section of the form.

Point Code: The code of the original sample point. This code starts with a three letter acronym for the Level 3 Ecoregion (CRM = Canadian Rocky Mountains, MRM = Middle Rocky Mountains, SRM = Southern Rocky Mountains, WUM = Wasatch and Uintah Mountains). The second part of the point code is three-digit number for the grid cell. The last part of the code is a five digit number for the sample point itself. As an example, a point code might be SRM-603-01133.

Site Name: This is a name given to the site by the field crew. This name can be anything the crew wants (excluding inappropriate language) and should reflect the location of something memorable that happened or was observed during sampling. The name could be something like Spring Creek Shrubland or could be Dizzy Cloud Fen. It is helpful to include the Ecological System at the end of the name.

Date: Date of sampling, written as month, day, year (e.g., July 12, 2010 or 7/12/2010).

Surveyors: The first initial and last name of field crew members sampling the site (e.g., J. Lemly, C. McIntyre).

Weather Conditions: The general weather on the day of sampling. It is helpful to know whether sampling was done in sunny weather or rainy weather, either of which may impact sampling in one way or another. If the weather changes dramatically during the course of a sample day, make sure to note that on the field form. This will help explain why the sampling was cut short in the event of extreme weather.

Level 3 Ecoregion: Check the Level 3 Ecoregion being sampled.

State: Check the State in which the wetland occurs.

Ecological System: Check the Ecological System targeted in the survey. This information will also occur with more detail on the following page under classification, but is included here on the first page for ease of managing the forms.

General Location: A brief phrase describing the general location of the site, usually a creek name or other landmark from the USGS topo map (e.g., Spring Creek, Mt Emmons, Beaver Meadows).

County: The County in which the wetland occurs.

General Ownership: A general description of the land ownership, using the following short abbreviations and others where applicable:

- USFS = U.S. Forest Service
- BLM = Bureau of Land Management
- NPS = National Park Service

Specific Ownership: A more specific description of the land ownership, such as Rio Grande National Forest, Mt Zirkel Wilderness, Glacier National Park, etc.

USGS Quad Name: The name of the USGS quad, found on the lower right-hand corner of the quad. Field crews should *always* carry the USGS quads with them in the field.

USGS Quad Code: May also be written on the lower right-hand corner of the quad, but if not, leave blank.

Directions to Point and Access Comments: A brief description of how the crew accessed the point, generally starting from a major road or trailhead. Should include approximate mileage traveled on dirt roads, trails, and off trail navigation.

5.2. Establishing the Assessment Area

The assessment area (AA) represents the sample point that was defined by the random sample survey design. Proper placement of the AA is crucial because it defines the area for most the data collection. Before heading into the field, crews should examine aerial photos of the points within a given cells and should strategize the most likely placement of the AA based on observed wetland features surrounding the point. Once in the field and the area surrounding the point has been identified to be suitable for sampling (see Site Evaluation Guidelines above), the crew will establish the AA to bound further sampling. The edge of the AA can be up to

60 m from the original point, but the AA must be located in the closest possible suitable wetland area from the original point.

AA establishment follows these general principles, in this order of priority:

- The AA should be established in *only one* target Ecological System. (Make sure to follow size criteria within the Ecological System Key. Small patches of herbaceous or shrubby vegetation do not necessarily mean multiple Ecological Systems. Changes in dominant soil type, however, can mean multiple Ecological Systems.)
- The AA should be 0.5 ha (5000 m^2) where possible, but can be as small as 0.1 ha (1000 m^2) if necessary.
- The maximum AA length is 200 m, regardless of shape.
- The minimum AA width is 20 m, regardless of shape.
- The AA should contain no more than 10% water > 1 m deep. This included water in a stream channel. The AA can cross and contain a stream channel that is < 1 m deep (or the depth considered safe to wade by the field crew, which may be different for different crew members and at different stream velocities). The AA *should not* cross streams that are too deep to wade.
- The AA should contain no more than 10% upland inclusions.
- The AA should be as close to the sample point as possible.

Before establishing an AA, the crew should take a **GPS waypoint at the original sample point**. This waypoint is written in the center of the first page of the field form. If the AA is centered on the sample point, this waypoint can also be written below for AA-Center. If the AA is not centered on the sample point, a new GPS point will be taken at the approximate AA center. *Make sure to note the UTM Zone of all GPS waypoints!*

Standard AA Layout – 40-m radius circle

The standard AA is a 40-m radius circle surrounding the point. If the wetland area is not located exactly at the point, the 40-m radius circle may be shifted so that the edge of the AA is up to 60 m from the sample point. If the AA is not centered on the sample point, a GPS point will be taken at the approximate AA center and recorded as AA-Center. To layout and mark the AA, two options may be used.

1. In open vegetation, one crew member will stand at the center of the AA holding the end of a 50-m tape. The second crew member will walk north from the center of the AA carrying the 50-m tape spool until they reach 40 m. Once they reach 40 m, the second crew member will walk in a circle, flagging the boundary of the AA with either pin flags or flagging tape. At least eight flags should be marked on the perimeter, one at each of the cardinal directions (N, E, S, W) and one at each of the ordinal directions (NE, SE, SW, NW). More points along the boundary may be marked to aid in visualizing the boundary of the AA, as the crew deems appropriate.

2. If vegetation is dense or difficult to walk through with a 50-m tape, the GPS unit may be used to layout the AA. A GPS point must first be taken at the center of the AA (either the original sample point or the new AA center). Once the center point is taken, the crew can use the "GO TO" function on the GPS unit and walk away from the center point heading north until they are 40 m from the point. They can then walk in a circle around the point, always keeping their distance from the center at 40 m, but moving either clockwise or counter clockwise around the point. At least eight flags should be marked on the perimeter, one at each of the cardinal directions (N, E, S, W) and one at each of the ordinal directions (NE, SE, SW, NW). More points along the boundary may be marked to aid in visualizing the boundary of the AA, as the crew deems appropriate.

Alternate AA Layout 1 – Rectangle

If a 40-m radius circle does not fit within the wetland area, crews may decide to use a rectangular shape to mark out the AA. Rectangle dimensions should reflect the target AA size of 0.5 ha (5000 m^2). For example, a square AA should be 71 m on each side (71 x 71 = 5041). If the wetland is 50 m wide, the rectangle should be 50 x 100 m. The *maximum* length of a rectangular AA is 200 m and the minimum width is 20 m. Beyond 200 m length, the wetland may be highly variable and too difficult to assess in one visit. Less than 20 m width is too difficult to establish the vegetation plot. Rectangular AAs may be centered on the point or the their edges may be up to 60 m from the point, depending on the wetland area. Rectangular AAs should only be used where the wetland area is generally straight and the size of the AA is not compromised by bends in the wetland boundary. The AA boundary may be marked out using either the 50-m tape or the GPS unit in a manner similar to that listed above for circular AAs. The boundary of the AA should be flagged as often as necessary so the boundary is easy to visualize. GPS waypoints should be taken at each of the four corners of rectangular AAs and their coordinates should be written down on page 1 of the field form under AA-1, AA-2, AA-3, and AA-4.

Alternate AA Layout 2 – Freeform shape

If the wetland area is smaller than 0.5 ha *or* if the wetland is larger than 0.5 ha, but the wetland boundaries contain numerous bends that complicate AA establishment, the shape of the AA can be determine by the wetland or Ecological System boundaries themselves or can be ovoid in shape. This is considered a freeform AA shape. If the wetland or Ecological System occurrence is small, the entire wetland will become the AA. If the wetland is larger but oddly shaped, the crew must first estimate the general dimensions of the wetland using the aerial photos provided and strategize about the best way to lay out a 0.5 ha (5000 m^2) AA. Based on this estimate, the crew will walk the perimeter of the AA with the GPS in TRACK mode, flagging the edges as they walk. Once the perimeter is walked and the shape completed, the GPS unit will calculate the area of the shape and the crew can adjust one edge if need be to create a 0.5 ha AA. The GPS track will be saved on the GPS unit and named by the point code (e.g., SRM-603-01133).

Once the AA is established, the crew will check off the dimensions of the AA on the field form and whether the point is one of the following:

- Within target population (AA centered at point)
- Within target population (AA *not* centered at point)
- Within 60 m of target population (AA shifted, point outside)

The crew should make any notes necessary to describe how the AA was established and the reasoning behind the AA shape in the box for **AA Placement and Dimensions Comments**. This will be particularly important for freeform AAs in the event that the GPS track is lost.

5.3. Photos of the Assessment Area

For every AA, regardless of shape, **four photographs** will be taken on the edge of the AA looking in. The photos can be taken while walking the perimeter of the AA, if both crew members are walking the edge at the same time (i.e., if they are using the GPS unit to establish the boundary). If one crew member is holding the end of the 50-m tape, the crew must take the photos once the AA boundary is established. It is essential that two people participate in taking the photographs.

A **photo placard** will be held in all four of the official AA photo (Figure 2). Photo placards will be placed in the very corner of the photo, taking up only a small portion of the frame, with as little arm or body visible as possible. The point code should be written on in full on the first line of the placard (e.g., SRM-603-01133). The second line of the placard will contain the aspect that the photo is facing and the location of the photo (e.g., 140°/AA-4; 300°/AA-1; 90°/AA-1). Aspect should be rounded to the nearest 5 degrees in all photo points (note first photo in example below should be rounded to 140°). *Make sure to set the declination of your compass.* Date should be written as month / day / 2010 (e.g., 7/7/2010; 6/24/2010).

Figure 2. Example AA photos. Note placement of photo placard in corner and information written on placard.

For each of the four photos taken, the crew will **record the photo number** on the field form (AA-1, AA-2, AA-3, AA-4) and the aspect that the photo is taken. The photo number is visible on the camera's screen when it is placed in view or playback mode and when data about the photos are shown. *Remember that the photo number is NOT the sequential number based on the count of photos taken since the camera was last erased. The photo number often starts with a three digit number, a dash, and then a four or five digit number. Only the last four or five digit number is necessary to write down on the form. Each State field coordinator should ensure that the crews are familiar with the actual photo number. If sequential numbers are written on the field form, this data will be meaningless.* In addition to the photo number, the crew will take a **GPS waypoint at each photo** location. These will also be recorded on the field form under GPA Coordinates of Target Point and Assessment Area. **Additional photos** will be taken as need to document the wetland and surrounding landscape. These do not need to contain the placard, but should be noted on the form with a GPS waypoint and comment. Additional details based on the AA layout are explained below.

For a standard 40-m radius circle AA, the photographs will be taken facing the cardinal directions (N, E, S, W). The order of the photos does not matter. Waypoints should be taken along with the photos.

For a rectangular AA, the photos will be taken at the four corner points looking in at an angle across the AA. If AA establishment took place before taking photos, the four GPS waypoints will have already been taken because they mark the corners of the AA. If photos are taken during AA establishment, the GPS points and photos will be taken at the same time. For long skinny rectangular AAs, two additional AA photos can be taken on the long sides of the AA looking across, since the end corner points will be located in two close sets of points separated from each other by a long distance. These photos should be noted as additional photos and GPS waypoints should be taken.

For freeform AAs, the four photos and GPS waypoints should be taken at evenly spaced intervals in locations that best fit the shape of the AA. Where possible, these can be placed on the cardinal directions, but do not need to be. If the shape is ovoid, the photos should be at the approximate ends and sides.

5.4. Environmental Description and Classification of the Assessment Area

The top of the second page of the field form contains environmental descriptors and classification information. Guidance is given below. For any environmental descriptor or classification where there is doubt, ambiguity, or further explanation is necessary, use the comment field at the bottom of the page.

GPS Elevation: One elevation reading for the AA, taken from the GPS unit. It may be useful to write the elevation on the front of the form when taking waypoints of the AA. If not, turn the unit on again and record the elevation.

Topographic position: Pick one from the list below that best matched the site.

Slope	Intermediate slope position, not the toe of the slope but actually on a sloping face. (Low, mid or high slope.)
Toeslope	Outermost gently inclined surface at base of a slope. In profile, commonly gentle and linear and characterized by alluvial deposition. (Alluvial toeslope.)
Channel wall	Sloping side of above a channel. (Bank.)
Channel bed	Bed of single or braided watercourse commonly barren of vegetation and formed of modern alluvium. (Narrow valley bottom, gully arroyo.)
Low level	Valley floor or shoreline representing the former position of an alluvial plain, lake, or shore. (Terrace, low flat.)
Basin floor	Nearly level to gently sloping, bottom surface of a basin. (Depression.)

Slope and Aspect 1 and 2: The field form contains two places to record slope for assessment areas that have two general slopes (e.g., for a riparian area, the wetland might slope down to the river channel and might also slope with the general gradient and direction of the river.) The first slope and aspect are mandatory, the second set are optional. Both are recorded in degree, not percent. Slope is measured either with a clinometer or a compass; aspect is measured with a compass. *Make sure to set the declination on your compass.*

Ecological System: Select the Ecological System targeted in the survey. This information also occurs on the first page of the form, but here there is a place to note the percent of the AA occupied by upland inclusions and areas of deep water > 1 m. Circle High, Med, or Low to denote confidence in classification and explain in the comments section below.

Cowardin Classification: Record the appropriate Cowardin classification codes, using the definitions provided in **Appendix C**. The Cowardin classification should be applied to patched larger than 0.1 ha (1000 m^2), but no smaller. This area should also upland inclusions. The final total of percentages should equal 100% of the AA. Circle High, Med, or Low to denote confidence in classification and explain in the comments section below.

HGM Class: Select the appropriate HGM Class using the key provided in **Appendix D.** Try to pick only one dominant HGM Class. Circle High, Med, or Low to denote confidence in classification and explain in the comments section below. *Note that additional classification and metrics apply to AAs in the Riverine HGM Class.*

5.5. Riverine Specific Classification of the Assessment Area

Specific classification is applied to AAs in the Riverine HGM class. Some Riverine Class AAs will include the channel or be located adjacent to a channel. Others may be in a floodplain, but not located near the channel. Answer all questions possible based on available evidence in a surrounding the AA. These questions should be answered based on best professional judgment and do not require exact measurements.

Confined vs. Unconfined Valley Setting: Streams in confined (Figure 3) and unconfined (Figure 4) settings behave very differently. There are two pieces of information necessary to determine whether a stream is in a confined or unconfined setting. This first is bankfull width, the second is valley width. It is not necessary to measure either one precisely in order to make a determination about confined or unconfined status of a stream. Estimate these widths as precisely as is necessary to determine whether the valley width is greater or less than 2x the bankfull width. **Bankfull width** is the width of a stream channel at the point where over-bank flow begins during a flood event. Bankfull indicators may include: the lower limit of perennial vegetation, stain lines, moss or lichen, a change in particle size, etc. Valley width is the width of the topographic floodplain, the extent of the area where water could easily flood. In confined valley setting, valley width is less than 2x bankfull width. In unconfined valley settings, valley width is greater than 2x bankfull width. See Figure 5 for a graphical illustration of these components.

Hydrologic Regime: Select perennial, intermediate, or ephemeral based on best professional judgment and evidence observed onsite.

Wadable vs. Non-wadable stream: Note whether the AA is located on both sides of a wadable stream (< 1 m deep), on one side of a non-wadable stream, or is located on one side of a stream but not adjacent to the channel.

Figure 3. Example of a confined valley setting.

Figure 4. Example of an unconfined valley setting.

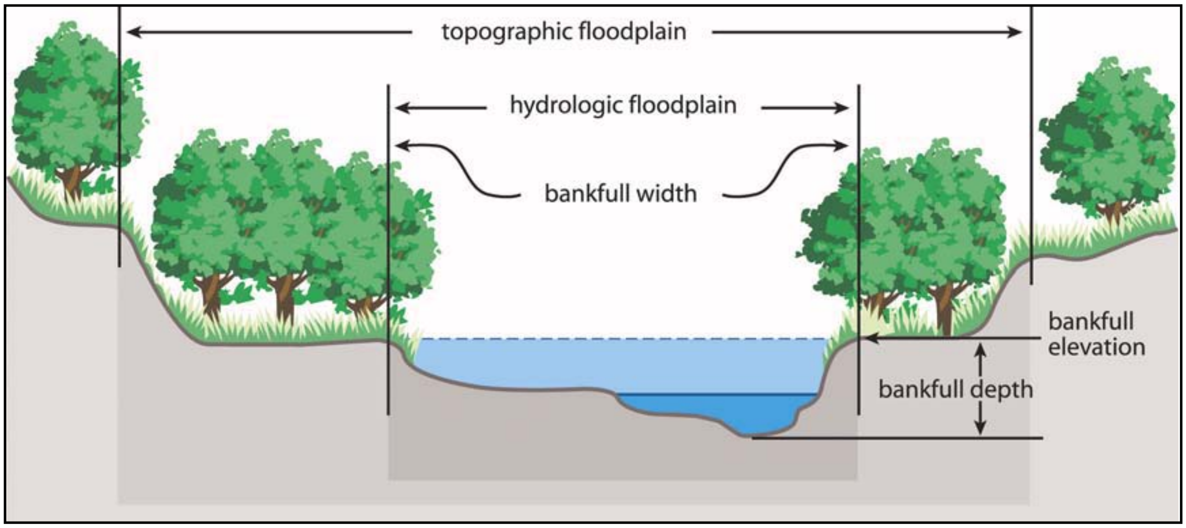

Figure 5. Graphical illustration of bankfull width and the topographic floodplain.

5.6. Vegetation Zones within the Assessment Area

Identify and describe the major vegetation zones within the AA. Vegetation zones often consist of more than one plant species, but some zones can be mono-specific. A vegetation zone should be described if it meets the following rules:

1a. The plant zone is dominated by a stratum distinctly different from the stratum that dominates other plant zones; OR
1b. The plant zone is dominated by the same stratum as other plant zones, BUT each plant zone is dominated by different species AND the average height of the dominant species differs by > 1 m (e.g., *Typha latifolia* vs. *Juncus balticus*).
2. The plant zone makes up more than 5% of the AA (e.g., 250 m^2 for an AA of 0.5 ha).
3. Each individual patch of the plant zone is greater than 10m^2.

For each zone identified, note the physiognomy of the dominant stratum, the dominant species (one or two, use abbreviates if need to fit more than one species on the form), and the percent of the AA it occupies. Percents should total 100% of the AA. Use the following major physiognomic classes:

- Forest/Woodland (trees or shrubs > 5 m tall occupy > 30% cover)
- Shrubland (shrubs 0.5–5 m tall occupy > 30% cover)
- Dwarf Shrubland (shrubs < 0.5 m tall occupy > 30% cover)
- Herbaceous (e.g., graminoides, forbs, ferns dominate)
- Nonvascular (bryophytes, cryptogrammic crusts dominate)
- Submerged / Floating (rooted or floating aquatics dominant, this does not include emergent veg)
- Sparsely Vegetated (including bear ground or vegetation cover < 5 %)

5.7. Assessment Area Drawing and Description

Provide a drawing of the assessment area, including major vegetation zones, direction of drainage into wetland, soil pit placement, and vegetation plot placement. Anthropogenic features like culverts, berms, or impoundments should also be included in the sketch. Also, indicate any major vegetation zones on the aerial photo of the AA.

For the assessment area description and comments, describe the wetland type, dominant vegetation, general location, any notable feature about the wetland that may not have been captured in the classification or other information on the first two pages. Also note surrounding vegetation and land use. This is the best place to sum up the major characteristics of the site in paragraph form.

Section 6: Landscape Context Assessment

1a. Landscape Connectivity: This metric measures the percent of unfragmented landscape within 500 meters of the AA (non-riverine) or the degree to which the riverine corridor above and below a floodplain area exhibits connectivity with adjacent natural systems (riverine). Use either metric 1a. or metric 1b. depending on the HGM class.

1a. Non-riverine wetlands: The intensity of human activity in the landscape often has a proportionate impact on the ecological processes of natural systems. The percentage of altered landscape (e.g., anthropogenic patches) provides an indirect estimate of connectivity among natural ecological systems. To assess this metric, estimate the percent unfragmented area within a 500 meter envelope surrounding the AA. Identify the largest unfragmented block *that contains the AA* and estimate its percentage of the total area within the 500 m envelope. Well traveled dirt roads count as fragmentation, but hiking trails can be included in unfragmented blocks. Estimate the landscape connectivity and enter the percent on the form.

1b. Riverine wetlands (where the channel is within or adjacent to the AA): For Riverine wetlands, landscape connectivity is the continuity of the riparian corridor 500 m upstream and 500 m downstream of the AA. Of special concern is the ability of wildlife to enter the riparian area at any place within 500 m of the AA and to move easily through adequate cover along the riparian corridor from either upstream or downstream. Refer to maps provided to estimate the percent of anthropogenic, non-buffer patches within the riparian corridor (the width of the geomorphic floodplain) 500 m upstream and downstream of the AA. Anthropogenic patches include heavily grazed pastures, roads, bridges, urban/industrial development, agriculture fields, and utility right-of-ways. To determine, identify any non-buffer patches (Table 1) within the riparian corridor both upstream and downstream of the AA. Record their lengths in the table provided on the field form and sum all patches. Specify if the patch occurs on the right or left bank (R/L). *For one-sided AAs,* only consider one side of the channel.

1b, 1c, and 1d. Buffer Index: This metric calculates the overall area and condition of the buffer immediately surrounding the AA using three measures: percent of AA with buffer (buffer extent), average buffer width, and buffer condition. Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland (Table 1).

1b. Buffer Extent: This metric can be assessed first using aerial photography but must be verified in the field. Visually estimate the total percentage of the AA perimeter that adjoins land cover types that provide buffer functions (Table 1). To be considered as a buffer, a suitable land cover type must be at least 30 m wide. For Riverine wetlands, do not include the area immediately upstream or downstream as part of the buffer. Only consider areas on one side of the channel or the other. If the AA only represents one side of a channel, only consider the buffer on that side of the channel. Enter the estimate in the space provided on the form.

1c. Buffer Width: This metric can be assessed first using aerial photography but must be verified in the field. Where buffers exist, visually estimate the average distance between the edge of the AA and the edge of the buffer at eight evenly spaced intervals (up to 200 m from the AA). For Riverine wetlands, do not include the area immediately upstream or downstream as part of the buffer. Only consider areas on one side of the channel or the other. If the AA only represents one side of a channel, only consider the buffer on that side of the channel. See Table 2 for land covers included and excluded from buffers. Enter the estimates in the table on the form and calculate the average.

1d. Buffer Condition: Check one statement from *each* column on the form that best describes the buffer condition. Only consider buffer areas from 1b and 1c above.

Table 1. Land covers that should be included and excluded from wetland buffer calculations.

Examples of Land Covers Included in Buffers	**Examples of Land Covers Excluded from Buffers**
• Additional wetland/riparian area • Natural upland habitats • Nature or wildland parks • Bike trails • Foot trails • Horse trails • Open rangeland with light grazing • Swales and ditches • Open water • Vegetated levees	• Commercial developments • Residential developments • Paved roads • Dirt roads • Railroads • Parking lots • Fences that interfere with the movements of wildlife • Sound walls • Intensive agriculture (row crops, orchards, vineyards) • Dryland farming • Horse paddocks, animal feedlots • Rangeland with intensive grazing • Lawns • Golf courses • Sports fields • Urbanized parks with active recreation • Paved or heavily used pedestrian/bike trails (frequent traffic)

1e. Natural Cover within a 100 m Envelope: The complexity and composition of surrounding vegetation can help to buffer a wetland from potential impacts. Using the table on the form, estimate the total percent of natural cover within a 100 m envelope of the AA, then break that percent down by the various types listed. Estimate the total combined cover then wetland and upland covers separately. This measure applies to the entire 100 m envelope and not just buffer land covers.

1f. Landscape Stressors within a 500 m Envelope: Stressors within the landscape can have a strong effect on wetlands. Using the table on the form, estimate the scope and severity of each landscape stressor within a 500 m envelope of the AA. See Table 2 for scope and severity ratings.

Table 2. Scope and severity ratings for all stressor categories.

Scope of Disturbances	
5	Pervasive – Affects nearly all (>75%) of the buffer or AA.
4	Large – Affects most (>50-75%) of the buffer or AA.
3	Moderate – Affects much (>25-50%) of the buffer or AA.
2	Restricted – Affects some (>10-25%) of the buffer or AA.
1	Small – Affects a small (1-10%) portion of the buffer or AA.
0	Nil – Little or no observed effect (<1%) on the buffer or AA.
Severity of Disturbances	
4	Extreme – likely to extremely degrade, destroy, or eliminate the wetland.
3	Serious – likely to seriously degrade or reduce wetland function or condition.
2	Moderate – likely to moderately degrade or reduce wetland function or condition.
1	Slight – likely to only slightly degrade or reduce wetland function or condition.

Section 7: Vegetation Assessment

7.1. Determining Placement of the Vegetation Plot

Intensive assessments involve the collection of plant species cover and composition data. The vegetation plot used for the REMAP project is adapted from the flexible-plot method developed by Peet *et al.* (1998). The entire plot measures 20 m x 50 m (1,000 m^2 = 0.1 ha). The plot is comprised of ten 10 m x 10 m modules (100 m^2 = 0.01 ha). In general, an AA area consisting of a 0.5 ha circular plot will hold a standard vegetation plot, consisting of a two by five array of ten 10 m x 10 m modules (Figure 6). For the purposes of the REMAP project, we are only measuring vegetation in **four intensive** modules.

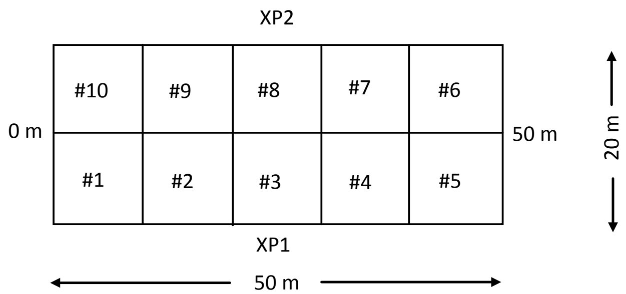

Figure 6. Schematic of the 20 m x 50 m vegetation plot with a two by five array of ten 10 m x 10 m modules. Note the location of the 0 and 50 m ends and XP1 and XP2 for cross plot waypoints and photos.

The location and layout of the vegetation plot within the AA is based on the AA size and site characteristics. In most AAs, a single standard vegetation plot will be used to assess the vegetation of the AA. For situations where AAs are not 0.5 hectare circular plots, alternate plot configurations may be required, such as changing the shape of the plot array. The plot will be subjectively placed within the AA to maximize abiotic/biotic heterogeneity. Capturing heterogeneity within the plot ensures adequate representation of local micro-variations produced by such things as hummocks, water tracks, side-channels, pools, wetland edge, micro-topography, etc. in the floristic data. The **following guidelines** will be used to determine plot locations within the AA[2]:

- The plot should be located in a representative area of the AA which incorporates as much microtopographic variation as possible.
- If the AA is homogeneous and there is no direction or orientation evident in the vegetation, the plot should be centered within the AA and laid out either N-S or E-W using the second hand on a watch to determine which direction (00–29 seconds = N-S orientation; 30–59 seconds = E-W orientation). Simply look at the watch and the first number you see will determine the orientation. This ensures the decision is made in a random fashion.
- If the AA is not homogeneous, is oddly shaped, or is directional (i.e. follows a stream), the plot should be oriented so it adequately represents the wetland features. In the case of a riparian area, this may mean along the stream bank or cutting across the stream obliquely.
- If the wetland has an irregular shape and the 20 m x 50 m plot does not "fit" within the AA, the 2 x 5 array of modules can be restructured to accommodate the shape of the AA. For example, a 1 x 5 array

[2] Many of the guidelines are based on (Mack 2004a; Mack 2004b).

of 100-m^2 modules can be used for narrow, linear areas and a 2 x 2 array of 100-m^2 modules can be used for small, circular sites.

- The plot should attempt to capture the range of diversity within the AA, but should avoid crossing over into the upland. No more than 10% of the plot should be in upland areas beyond the wetland. If end modules do cross into the upland, these should not be sampled as intensive modules.
- If a small patch of another wetland type is present in the AA (but not large enough to be delineated as a separate ecological system type), the plot should be placed so that at least a portion of the patch was in the plot.

Detailed examples of how to place the vegetation plot based on these rules are provided in Figures 7 through 13 to aid in decision making. These diagrams show examples of how to locate standard or alternate plots within different kinds of AAs based the placement rules described above. Alternate plot configurations are used only when the standard plot will not fit into the AA. Note for clarity that the leading text for each diagram, or set of related diagrams, begins with the plot placement rule. The symbols depicted in the legend below are used in all of the plot placement diagrams (Figure 6). All diagrams and accompanying text courtesy of Teresa Magee, US EPA Office of Research and Development, Corvallis, Oregon.

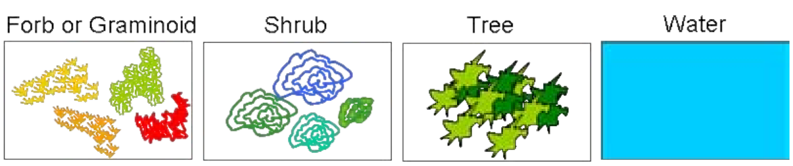

Figure 7. Legend for Figures 8 through 13.

Standard plot, centered in AA for homogeneous vegetation or mosaic. When the vegetation and abiotic features are homogeneous or distributed in a uniform or random mosaic pattern, a standard plot should be centered in the AA (Figure 8). For example, shrub-scrub, cattail marsh, grass-sedge wetlands, wet prairie, fen, forest communities, etc.

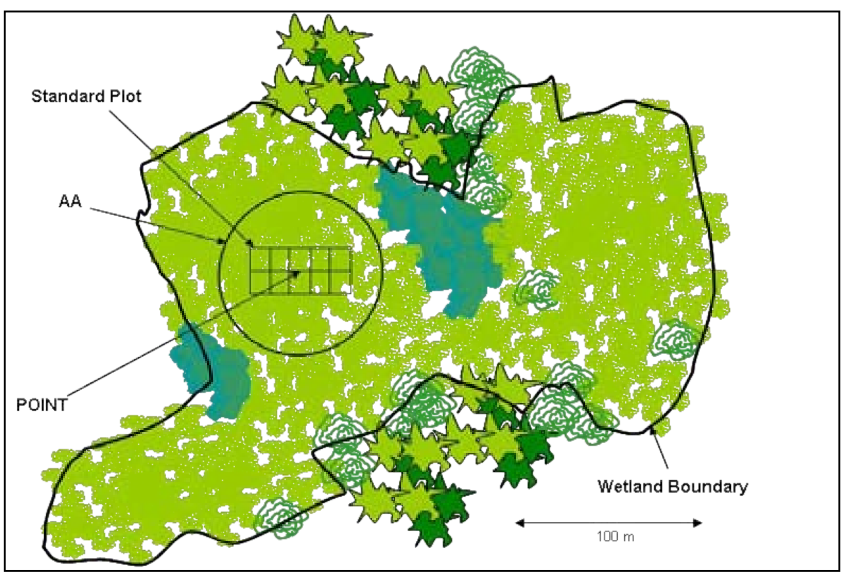

Figure 8. Standard plot centered in AA in homogeneous or mosaic vegetation.

Standard plot, placed within AA to include as many vegetation or community patch types as possible. When the vegetation is organized in distinct patches, lay out the plot so that it proportionally represents patch types for the AA as much as possible (Figure 9). Example situations include patches of shrub-scrub or trees in emergent wetlands, a variety of distinct emergent or shrub plant communities interspersed in the AA, etc.

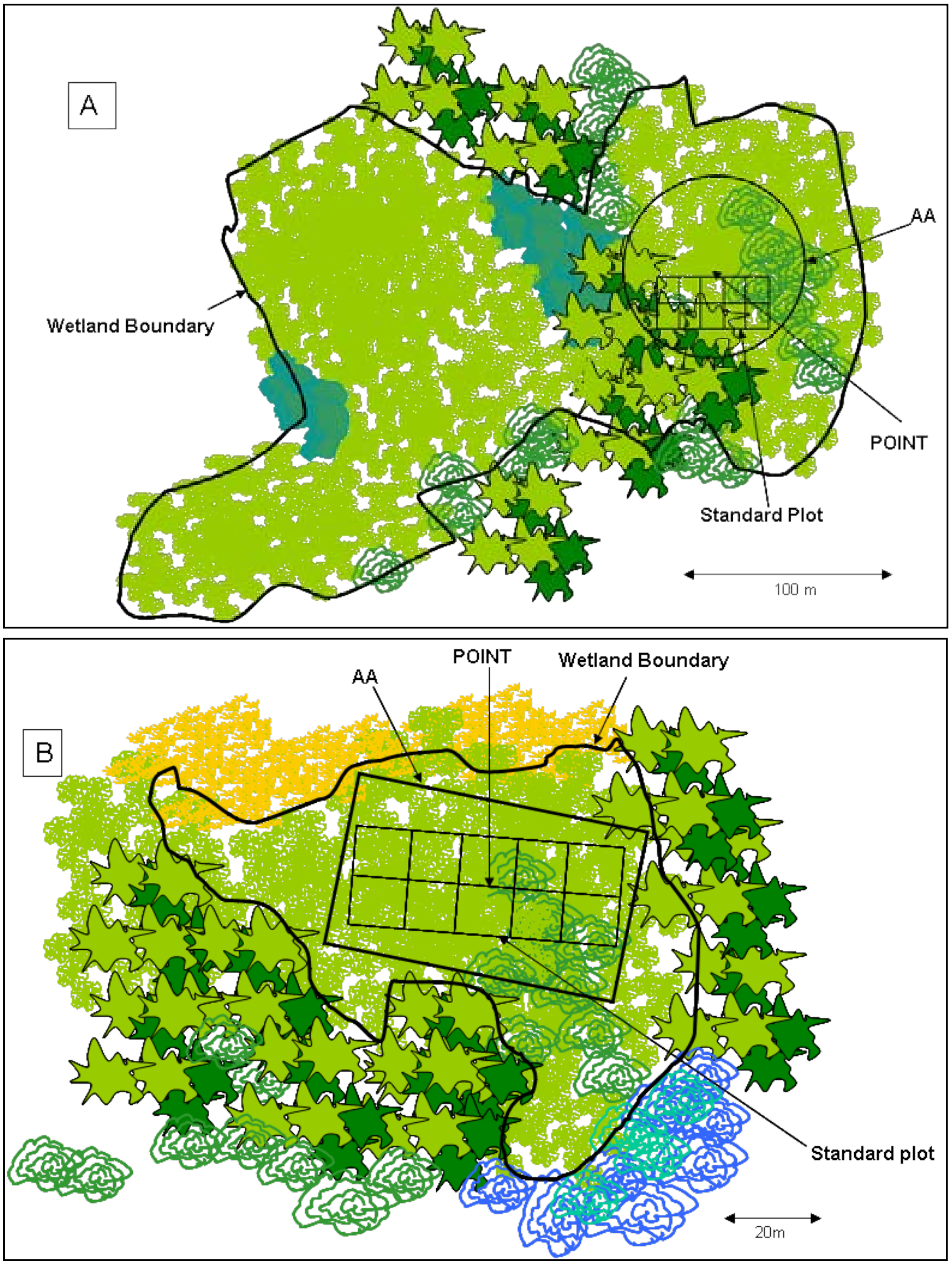

Figure 9. Standard plot placed in AA to include multiple vegetation or community patches.
A = Circular AA, B= Rectangular AA.

Standard plot, placed within AA so long axis parallels primary environmental gradient or is perpendicular to vegetation zonation. If the AA occurs along an environmental gradient, like a lake shore or the zones of a marsh, lay out the standard vegetation plot so the long axis follows the gradient and cuts across multiple vegetation zones. In the examples below, the vegetation plot is lay out so the long axis captures the gradient from close to the lake edge to farther from the lake edge (Figure 10) or from high marsh to low marsh (Figure 11).

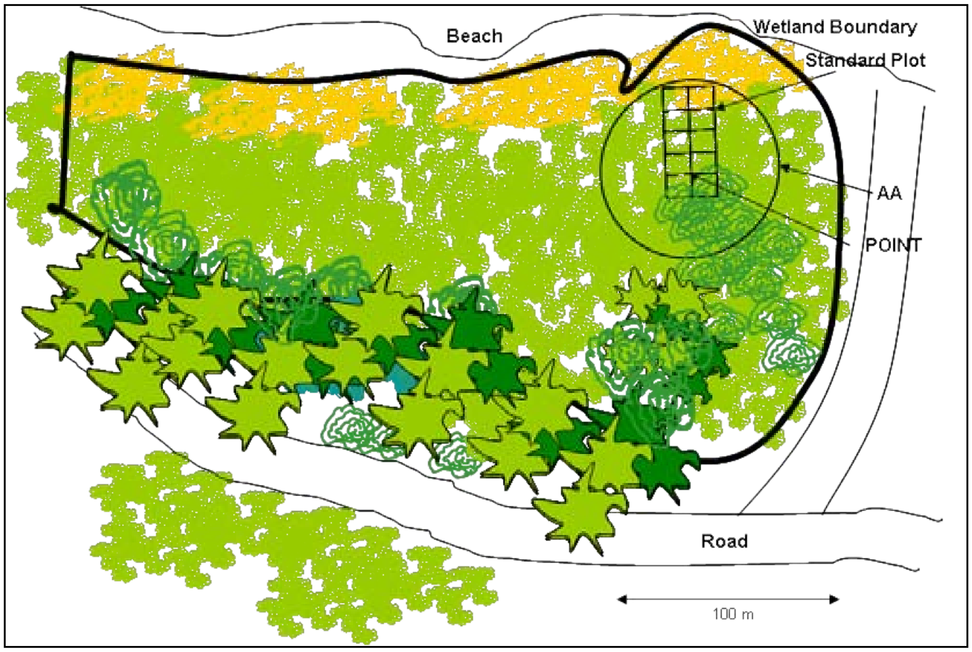

Figure 10. Standard plot placed in AA so long axis of plot parallels primary environmental gradient.

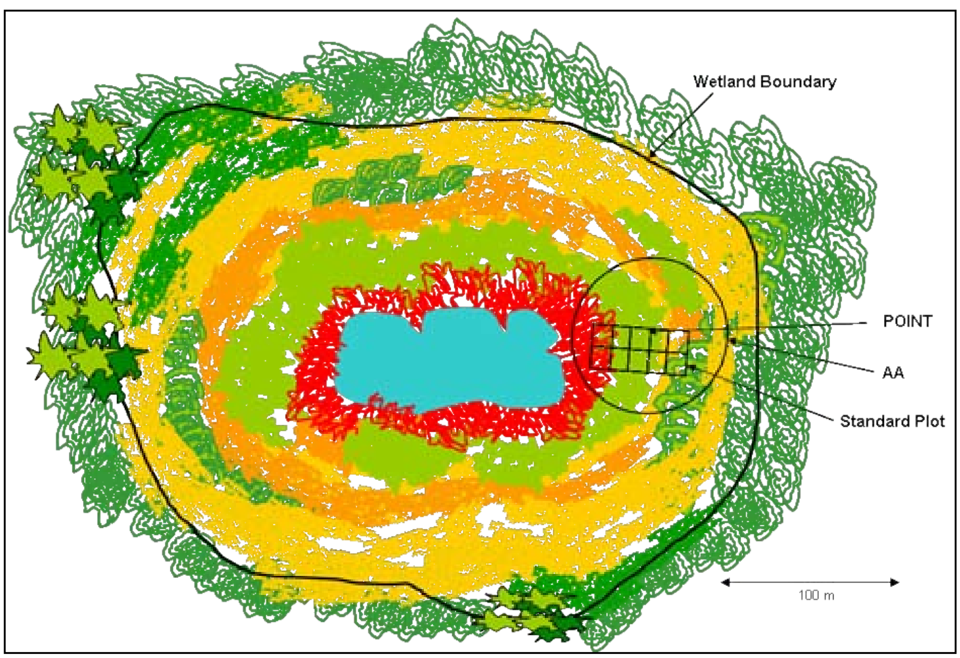

Figure 11. Standard plot placed in AA with long axis of plot perpendicular to vegetation zonation.

Placement of an alternate plot within the AA. If the AA has an irregular shape (e.g., long narrow riparian strip, lake edge, wetland smaller than 0.1 ha) that is incompatible with the standard plot configuration, an alternate plot configuration must be selected. For example, modules may be placed individually or in groupings other than the 2 x 5 array of the standard plot. Modules may be disarticulate to fit in a free-form shaped AA (Figure 12) or arranged as one long row in a narrow riparian area (Figure 13). To facilitate comparisons among AAs, the number of modules making up a standard plot or any alternate plot configuration should, normally, be the same (four 100-m^2 intensive modules and up to ten modules in total) so that equal levels of sample effort are maintained across AAs.

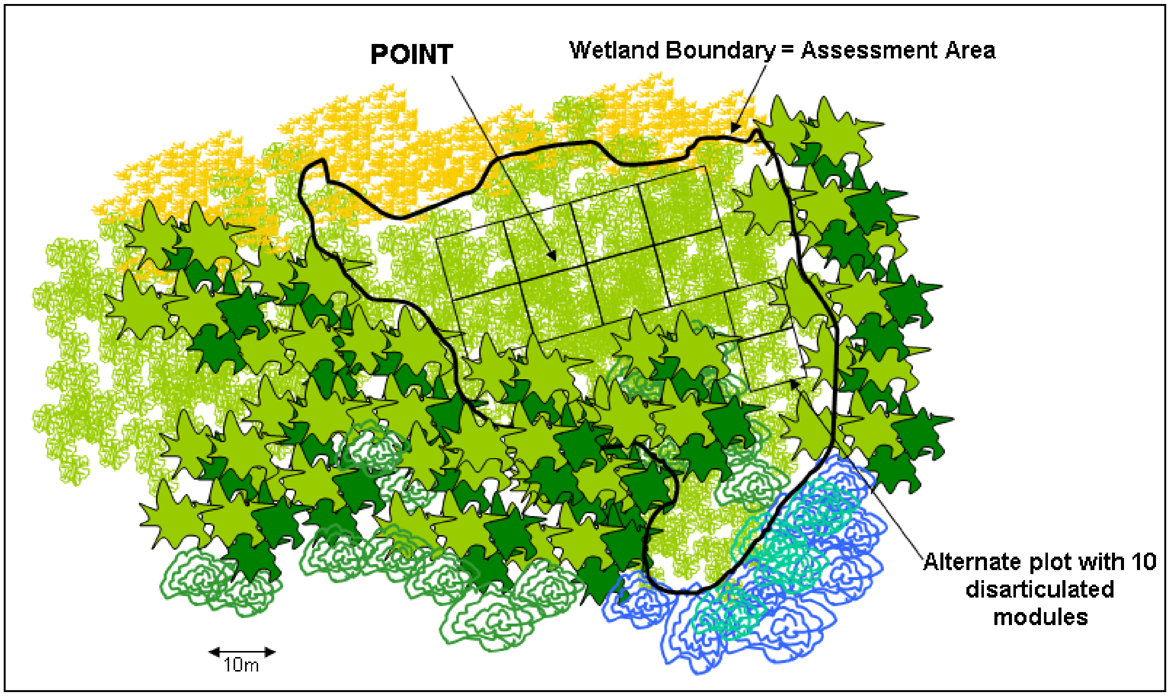

Figure 12. Alternate plot placed in AA that is the boundary of wetland that is < 0.1 ha. For this situation, the alternate plot configuration is defined by arranging as many 100-m^2 modules as will fit into the shape of AA, which is equivalent to the wetland boundary.

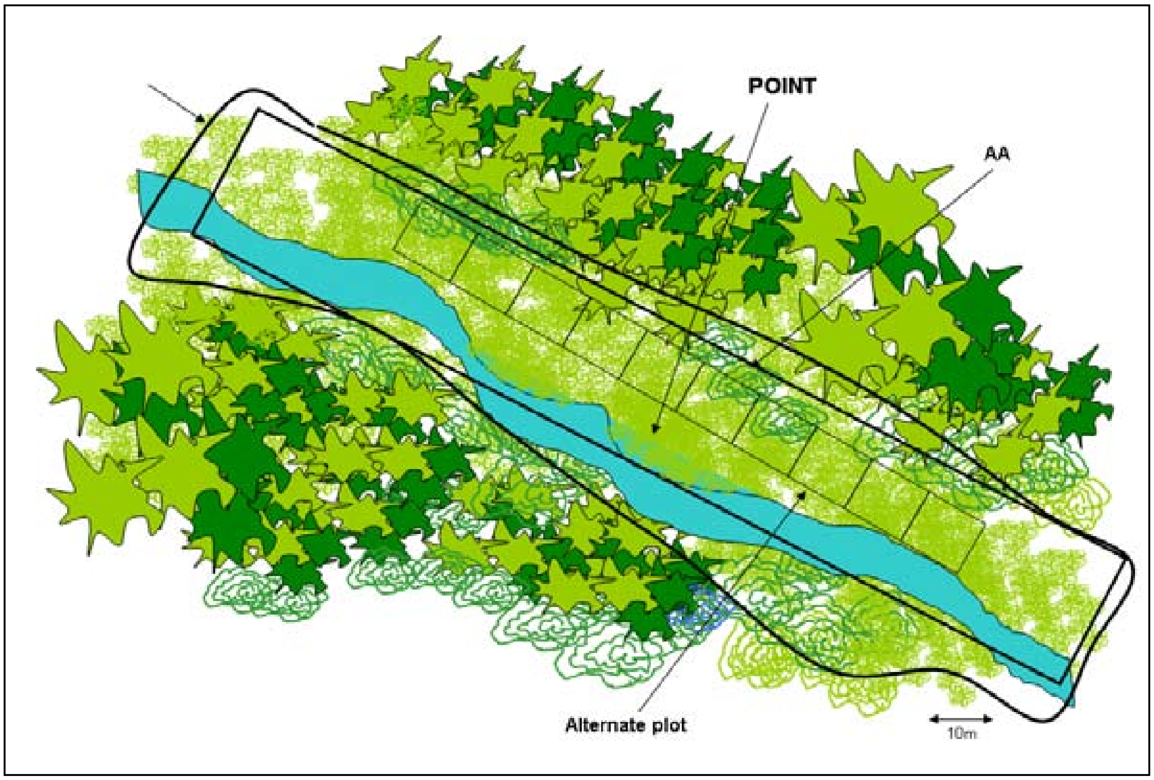

Figure 13. Alternate Plot placed in rectangular AA in a narrow riparian wetland.

7.2 Laying Out and Documenting the Vegetation Plot

To lay out the vegetation plot, begin by stretching the **50-m tape down the center line of the plot**. One crew member will hold the end of the 50-m tape and the second will walk in the direction both crew members decide best captures the vegetation. It will be easy to walk a straight line in open vegetation, but in dense woody vegetation, this will require constant checking to ensure the line is straight and on bearing. The tape should then be staked in place with landscaping staples.

Once the center line is established, the **10-m rope will be used to mark out the modules**. Starting at one end of the tape, one crew member holds the end of the 10-m rope on the center line while the other walks out perpendicular to the center line. The direction of this 10-m line should be check by the crew member along the center line. Once at 10 m and perpendicular to the center line, the second crew member will place a pin flag or use flagging tape to mark the corner of the plot. Both crew members can then walk down length of the plot, one crew member along the center line and one 10 m from the center line, and flag the boarders of the plot at 10-m intervals. This is easy in open vegetation, but in dense woody vegetation, the second crew member may have to return to the center line and walk along the center line until the next 10-m interval. Pin flags or flagging tape should be used both along the center line and along the outside edge to mark the modules. After one side of the plot is laid out, the crew then walks back towards the beginning, laying out the second side of the plot.

Once the vegetation plot is laid out, **GPS waypoints and photos** should be taken of the plot in four locations: the 0 m end, the 50 m end and two cross plot locations called XP1 and XP2. These photos and waypoints should be taken in a manner consistent with the AA photographs (see Section 5.3 and Figure 2). Additional photos can be taken of the vegetation plot, but must be recorded on the field form with notations about their location, either using a GPS waypoint or noting the module being photographed.

After taking photos and waypoints, the crew will decide which four of the ten modules will be selected for **intensive sampling**. If the vegetation is homogeneous, intensive modules will be #s 3, 7, 9, and either 1 or 5, giving the broadest spread of modules. If there are patches in the vegetation, the crew can decide which should be sampled to best capture the range of vegetation. Crew members should note any pertinent information about the plot layout on the form, including whether the plot was a standard 20 x 50 m plot was used or whether an alternative configuration was needed. Crews should circle the intensive models selected on the provided graphic. Lastly, crews should document whether the plot is representative of vegetation within the AA and why the specific location was chosen.

7.3. Vegetation Plot Ground Cover and Vertical Strata

Within each of the four intensive modules, in depth information on the ground cover and vertical vegetation strata will be recorded. This page comes before the species table within the field form, but is easier to fill out after the module has been searched for species. The reason it is presented first is so the two pages of the species table are facing each other, which is much easier for use in the field. There are several aspects of ground cover to record per module. Guidance is provided below.

Cover of standing water of any depth, vegetated or not: This field is for any and all water within the module, whether it is 0.5 cm or 70 cm deep. Using the cover classes provided at the top of the form, estimate total cover of water. This total cover will then be broken down the two ways.

Cover of shallow vs. deep standing water, average depth of both classes: These fields are to separate the cover of shallow standing water (< 20 cm or 0.2 m) from the cover of deep standing water (>20 cm or 0.2 m). Using the cover classes provided, estimate the cover of both depth categories separately. For each depth category, take up to four measurements of the water (in cm) and average those measurements to record the average depth of shallow water and the average depth of deep water. Both pieces of information will fit in one cell, separate by the slash.

Cover of open water with no vegetation, with emergent vegetation, and with submerged or floating vegetation: These fields are to separate the cover of standing water into three categories, water with no vegetation, water dominated by emergent vegetation, and water dominated by submerged or floating aquatic vegetation. There will likely be places where both emergent and floating vegetation occurs in the same water. Try to include areas dominated by one or the other. Using the cover classes provided, estimate the cover of the three classes separately.

Cover of bare ground: Cover of bear ground will be estimated using cover classes for three separate categories of bare ground: 1) soil, sand, or sediment; 2) gravel or cobble ~2–250 mm in diameter; and 3) bedrock, rock, or boulders > 250 mm in diameter.

Cover of litter: Cover of little will be estimated using cover classes. This includes litter than is hidden beneath vegetation. In some cases, this is an easy estimate. In cases where dense herbaceous vegetation covers the plot, this is more difficult to determine, as this year's herbaceous vegetation may be completely intermixed with litter from previous years. Litter can also include standing dead herbaceous vegetation, particularly annual vegetation, which would become litter once it fell over.

Depth of litter: This is an average of the depth (in cm) of litter at four locations where litter occurs. The litter should not be matted down first, but should reflect the height at which it occurs naturally.

Predominant litter type: Select the predominant litter type (C = coniferous, E = broadleaf evergreen, D = deciduous, S = sod/thatch, F = forb). Sod/thatch is used for graminoid litter.

Cover of standing and downed woody debris: The cover of woody debris is estimated based on whether it is standing or downed, and the diameter either at breast height or the average diameter of the debris. To differentiate down debris from standing debris, use the 45° rule. If a tree is leaning more that 45° from upright, it is considered downed woody debris. If it is leaning less that 45° from upright, it is considered a standing dead tree or snag.

Cover of nonvascular species: The cover of non-vascular species ground will be estimated using the cover classes. For each species group, make sure to look underneath vegetation. The cover of these species groups is often underestimated because people do not look for them hiding among the leaves of graminoids or under shrubs. Microalgae refers only to large algae like *Chara* spp. and not to single celled algae.

Vertical vegetation strata: The overall cover and average height class of each vertical stratum will be estimated for the module. This is best done after all species have been identified and cover estimated. Any given stratum can have up to 100% cover, but the overlaps within the stratum are ignored. The following strata, which are based on both life form and height classes, will be used.

T1 = Dominant canopy trees (> 5 m and > 30% cover)
T2 = Sub-canopy trees (> 5 m but < dominant canopy height) or trees with sparse cover
S1 = Tall shrub s 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)
HT = Herbaceous total
H1 = Graminoids
H2 = Forbs
H3 = Ferns and fern allies
AQ = Submerged or floating aquatics

7.4. Vegetation Plot Species Table

Floristic measurements including presence/absence and abundance (i.e.., cover) of all vascular plant species will be made within the four intensive modules. Sampling will begin in one 1-m^2 corner of the module to focus the field crew's search. Once all species in that corner have been identified, the crew can move throughout the entire module and each species identified will receive a check (√) or a one (1) in the "Presence" column if it is encountered in the module. **Nomenclature** for all plant species will follow the accepted standard for the State, which will be decided by the State field coordinator. All species will be recorded on the field form using the fully spelled out scientific name.

Any **unknown species** will be entered on the field form with a descriptive name. If the genus of the species is known, the descriptive name should include the genus name (e.g., Carex sp. or Aster sp). The descriptive name should also include some identifiable characteristics to distinguish multiple unknown species from the same genus (Carex sp. elongate back head or Carex sp. clustered brown head). If the genus is not known, the descriptive name should include any descriptors necessary (fuzzy round basal leaves or purple united corolla). All unknown species will be collected by the field crew either when the species is encountered or at the end of the vegetation plot. If the species is not collected until the end of the plot, a marker or pin flag should be left to mark the spot of the unknown species for later collection. Even if the species appears to be unidentifiable, the crew should still collect. The crew may find the same species further developed at a later site and can compare the further developed specimen with the earlier voucher. *The only species the crew should not collect are those identified as or suspected to be* ***federally or state listed species.*** All crew members should be aware of the listed species in their State and should document occurrences with photographs.

All collected unknown species will receive a **collection number**, which will be a running sequential series of numbers that starts at every site. This collection number will be written on the field form in the column "Coll #". This number will also be written on a piece of tape along with the Point Code ID (e.g., SRM-603-01133) and the date of collection. Fully written out, this tag will look like: SRM-603-01133 #4 6/25/10. The piece of tape can be folded over slightly at both ends so that is does not completely stick to itself for ease of removal. All unknown species should be properly collected for later identification and should include portions of the roots, stems, leaves, flowers, and fruits to the full extent possible. Proper collection technique will be demonstrated in field training.

When all species within a module have been identified, cover will be visually estimated for the module using the following cover classes (Peet *et al*. 1998). The visual aid provided in Figures 14 and 15 for estimating cover can be helpful in the field.

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

Though noting presence in the first module may seem redundant (every species on the list will be within the module), this column will be increasingly important as the crew moves on to the second, third, and forth modules. Starting with the second module, the crew will record each of the species from the first module that they encounter in the second module by placing a check (√) or a one (1) in the "Presence" column. The crew may also add to the species list if additional species are encountered in the second module. This will also receive a mark in the "Presence" column. Once the crew feels confident that all species have been identified, the marks in this column will give the crew a list to use when estimating cover for the module.

After sampling each of the intensive modules, the **remaining (i.e. residual) modules** will be walked through to document presence of any species not recorded in the intensive modules. Percent cover of these species will be estimated over the entire 1000-m^2 plot.

Strata should be noted on the field form in the "Stratum" column for species that can occur in different strata (primarily woody species), but is not necessary for species that can occupy only one stratum (like a graminoid or forb species). **For woody species,** identify and estimate the cover of seedlings, saplings, and mature individuals separately if they occur in different strata. This helps determine the extent of regeneration.

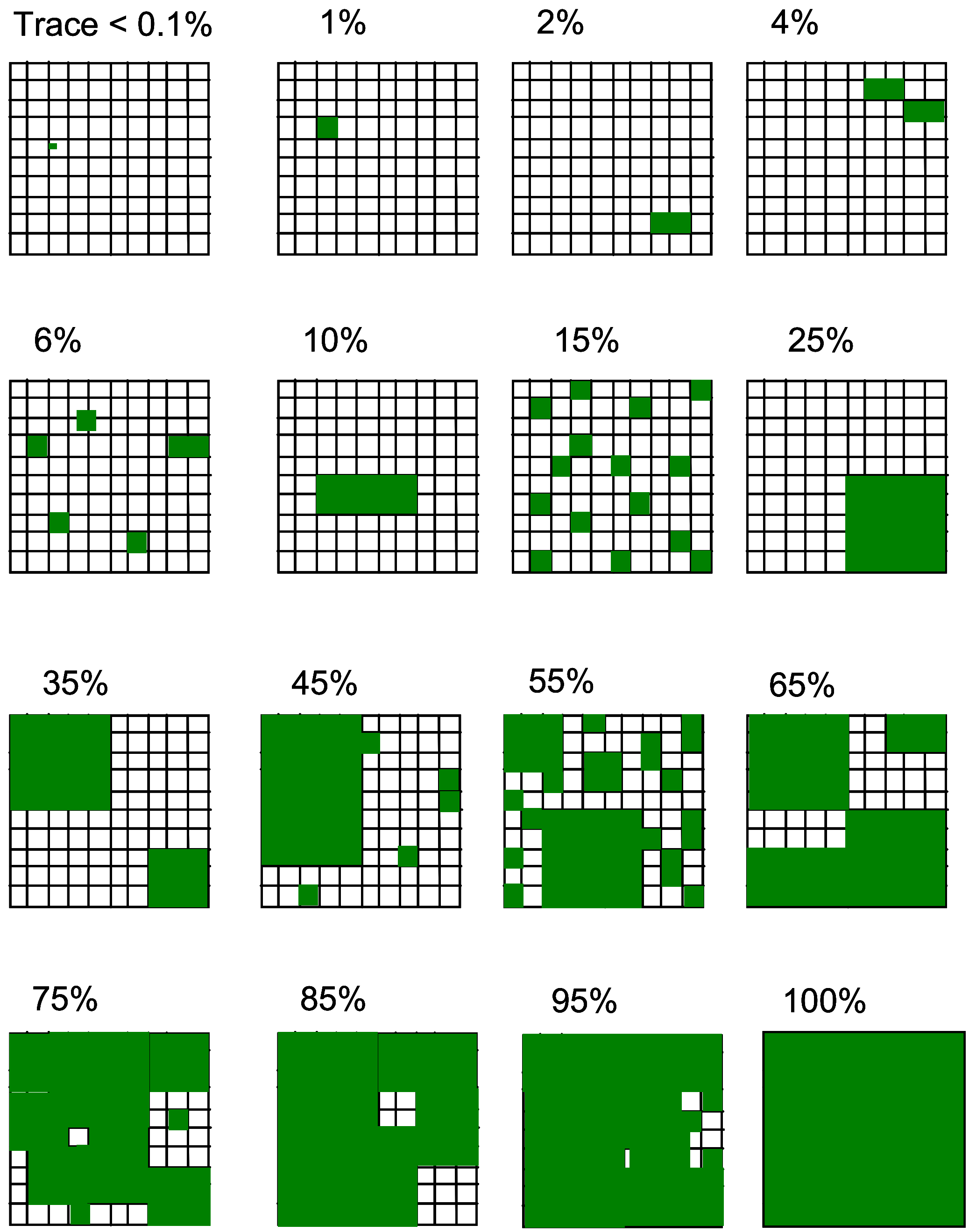

Chart 1. Examples of Percent Cover Estimates. Each large square = 100 m^2 module, grid squares = 1 m^2 (i.e., one grid square = 1% cover in a module), shaded areas represent cover of a vegetation stratum or of an individual species.

Figure 14. Examples of percent cover estimate.

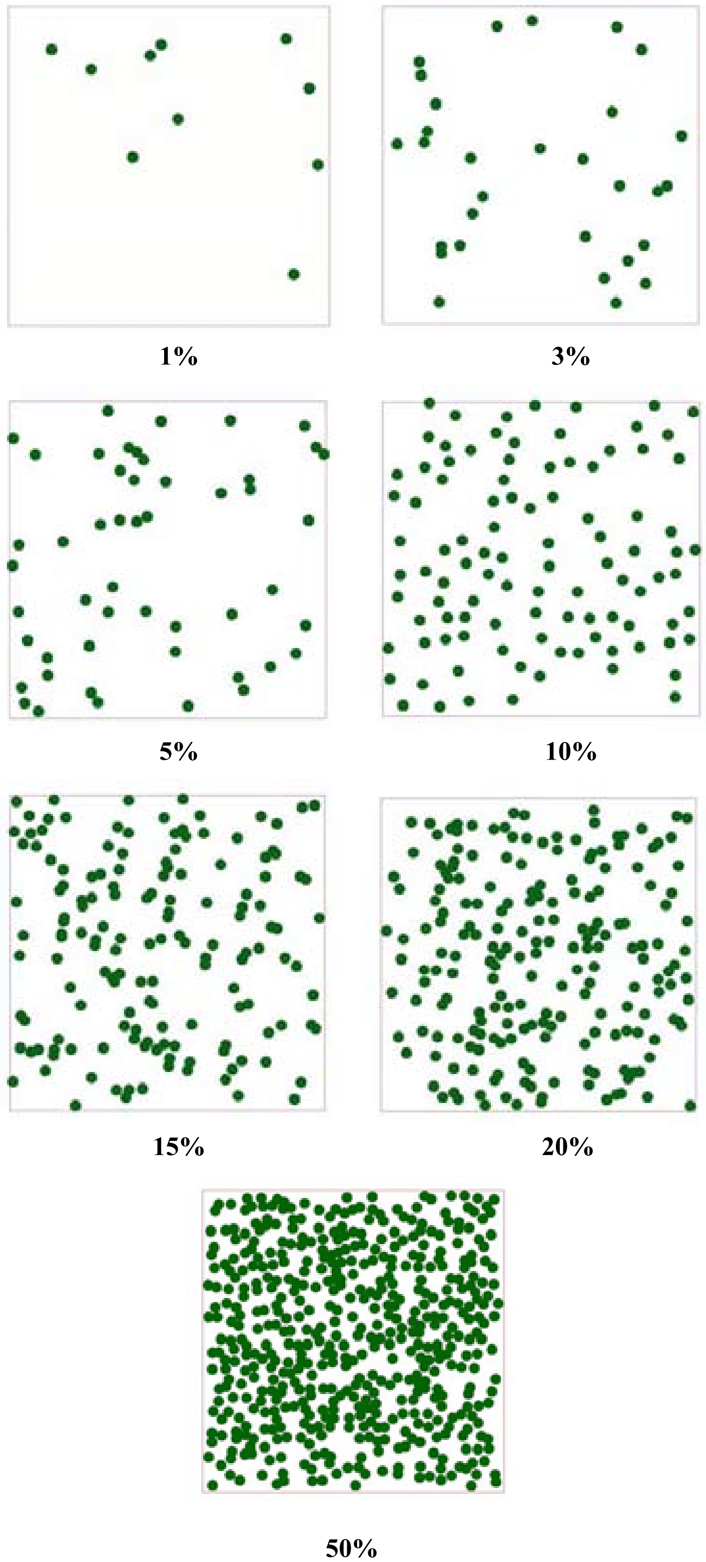

Figure 15. Examples of percent cover estimate.

7.5. Additional Vegetation Metrics

2a. Regeneration of Native Woody Species: Select the statement on the form that best describes the regeneration of native woody species within the AA. This is a place to give a more qualitative assessment of regeneration.

2b. Extent of Browse on Woody Species: Estimate the extent of browse on woody species throughout the entire AA. Using the table provided on the form, estimate browse on each species separately. Only include woody species with >5% cover within the AA. After estimating individual species, estimate the extent of browse on all woody species together.

2c. Vertical Overlap or Vegetation Strata: Based on the strata listed on the preceding page, estimate the percent of the AA with vertically overlapping strata. Each strata must cover >5% of the AA to be counted. Enter percents in the space provided on the form. The four values should total 100%.

2d. Horizontal Interspersion of Vegetation Zones: Refer to diagrams below (Figure 16) and circle the code that best describes the horizontal interspersion of vegetation zones within the AA. Use the vegetation zones identified on page 2 of the field form. Rules for defining vegetation zones are on page 10 of this field manual. Along with vegetation zones, include zones of open water when evaluating interspersion.

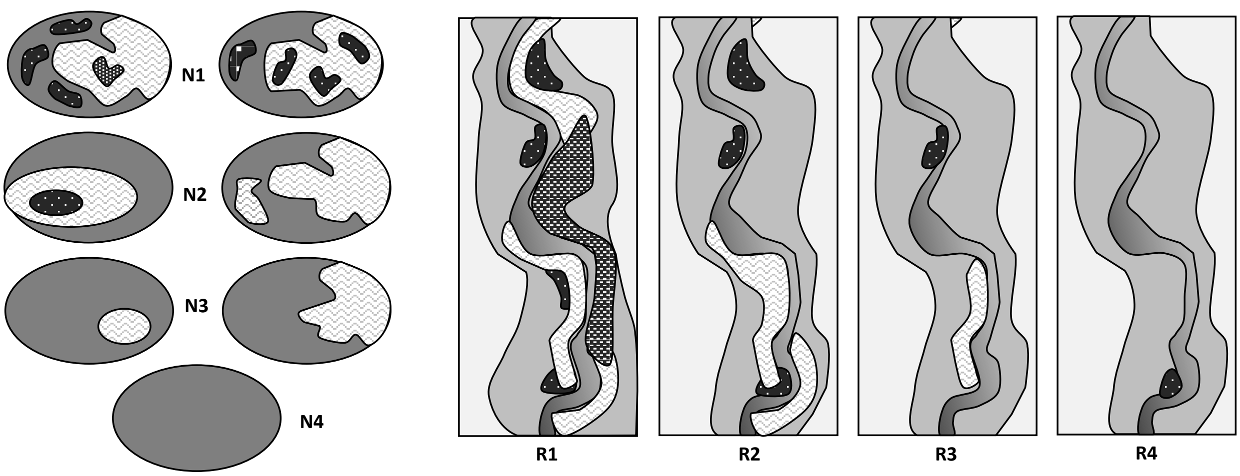

Figure 16. Diagrams of various levels of horizontal interspersion.

2e. Vegetation Stressors within the AA: Specific stressors within a wetland can have impact wetland vegetation. Using the table on the form, estimate the scope and severity of each vegetation stressor within the AA. See Table 2 on page 13 of this manual for scope and severity ratings.

Section 8: Hydrology Assessment

8.1. General Hydrology Metrics for All Wetland Types

3a. Water Inflow: Water inflow encompasses the forms or places of direct inputs of water to the AA. Inputs of water affecting conditions during the *growing season* are especially important because these strongly influence structure and composition of wetland plant and animal communities. The water source metric, therefore, focuses on conditions that affect *growing season* hydrology.

Natural water sources include precipitation, groundwater discharge, and flooding of the AA due to naturally high flows, seasonal runoff, etc. Examples of unnatural sources include storm drains that empty directly into the AA or into an immediately adjacent area. Identify all *major* water sources feeding the AA during the growing season in the table provided on the form. Rank the top sources (up to three) as 1, 2, 3. Mark all others present as 4 and those not present as NA. For discrete inlets (stream channels, springs, ditches, etc.), count the number of each within the AA and a 100 m envelope of the AA. Enter NA for those not present. Mark all inlets on the aerial photo and those within the AA on the site sketch. If there is an indication that inflow during the growing season is controlled by artificial water sources, please explain in comments.

3b. Water Outflow: Whether or not water can leave the wetland and where is goes can also influence the wetland composition and structure. Identify all *major* pathways through which water leaves the AA during the growing season in the table provided on the form. Rank the top pathways (up to three) as 1, 2, 3. Mark all others present as 4 and those not present as NA. For discrete outlets (stream channels, culverts, ditches, etc.), count the number of each within the AA and a 100 m envelope of the AA. Enter NA for those not present. Mark all outlets on the aerial photo and those in the AA on the site sketch. If there is an indication that outflow is modified by anthropogenic disturbance, please explain in comments.

3c. Indicators of Inundation at Seasonal High Water: The characteristic frequency and duration of inundation or saturation of a wetland during a typical year is a major driver of species composition. Depressional, Lacustrine, and Riverine wetlands can have daily variations in water height that are governed by diurnal increases in evapotranspiration and seasonal cycles that are governed by wet season rainfall and runoff. Slope wetlands that depend on groundwater may have relatively slight seasonal variations in hydroperiod. Walk the AA and identify all indicators of inundation at seasonal high water. Mark all indicators present with a check. Mark those absent with NA. Refer to the *ACOE Regional Supplement* for indicator descriptions. Use only indicators from the B group within the *Regional Supplement.* Based on the height of the indicators, estimate the percent of the AA that is covered in standing water at the seasonal high (up to 100% of the AA) as well as the percent of the AA that is covered with surface water at the time of sampling.

3d. Surface Water Turbidity: Select the statement on the form that best describes the turbidity of surface water within the AA.

3e. Algal Growth: Select the statement on the form that best describes algal growth within surface water in the AA.

3f. Hydrology Stressors within 500 m of the AA: Hydrology stressors can occur at scales far larger than the 0.5 ha AA. For that reason, hydrology stressors should be identified when possible, from the entire 500 m envelope. Certain stressors have more effect upstream tan downstream, while others are more damaging downstream. Using the table on the form, estimate the scope and severity of each hydrology stressor within a 500 m envelope of the AA. See Table 2 on page 13 of this manual for scope and severity ratings.

8.2. Riverine Specific Hydrology Metrics

Two additional metrics will be collected in Riverine wetlands, where possible. The first is channel stability and the second is entrenchment ratio. Channel stability can be filled out for AAs in Riverine wetlands that include a channel or are adjacent to a channel. The stream does not have to be waded to assess many of the variables in this metric. Entrenchment ration should only be measured in AAs that include a wadable channel.

3g. Channel Stability: This metric assesses the degree of channel aggradation (i.e., net accumulation of sediment on the channel bed such that it is rising over time) or degradation (i.e., net loss of sediment from the bed such that it is being lowered over time). Every stable riverine channel tends to have a particular form in cross section, profile, and plan view that is in dynamic equilibrium with the inputs of water and sediment. If these supplies change enough, the channel will tend to adjust toward a new equilibrium form. An increase in the supply of sediment, relative to the supply of water, can cause a channel to aggrade (i.e., the elevation of the channel bed increases), which might cause simple increases in the duration of inundation for existing wetlands, or complex changes in channel location and morphology through braiding, avulsion, burial of wetlands, creation of new wetlands, spray and fan development, etc. An increase in water relative to sediment might cause a channel to incise (i.e., the bed elevation decreases), leading to bank erosion, headward erosion of the channel bed, floodplain abandonment, and dewatering of riparian habitats. For most riverine systems, chronic incision (i.e., bed degradation) is generally regarded as more deleterious than aggradation because it is more likely to cause significant decreases in the extent of riverine wetland and riparian habitats.

There are many well-known field indicators of equilibrium conditions, or deviations from equilibrium, that can be used to assess the existing mode of behavior of a channel and hence the degree to which its hydroperiod can sustain wetland and riparian habitats. To evaluate this metric, visually survey the AA for field indicators of aggradation or degradation given on the form. Check "Y" for all those observed and "N" for those not observed. Add any further explanation in the comments section.

3h. Channel Entrenchment: Entrenchment is a field measurement calculated as the flood-prone width divided by the bankfull width. Bankfull width is the channel width at the height of bankfull flow. The flood-prone channel width is measured at the elevation of twice the maximum bankfull depth. The process for estimating entrenchment is outlined in Table 3 below and illustrated in Figure 17.

Table 3. Steps for estimating entrenchment ratio.

1. Estimate bankfull width.	This is a critical step requiring experience. 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).

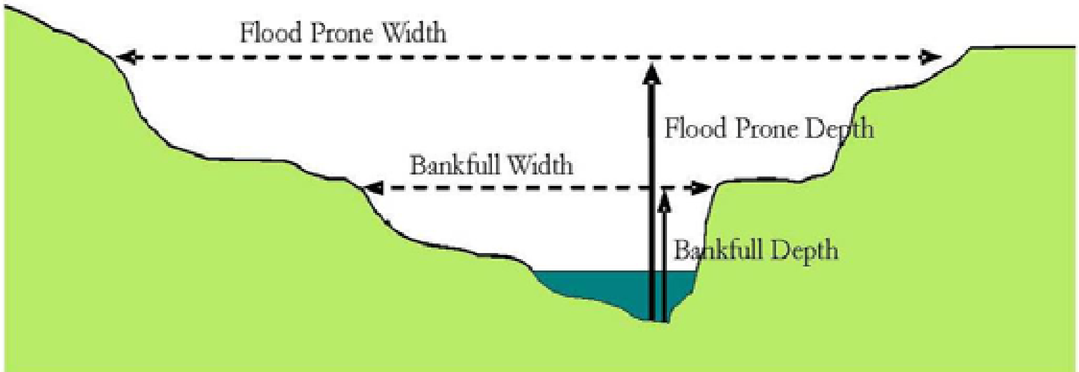

Figure 17. Elements of calculating entrenchment ration. Illustration from Collins *et al.* 2008. California Rapid Assessment Method for Wetlands v 5.0.2

Section 9: Physiochemical Assessment

9.1. Physiochemical Metrics

4a. Structural Patch Types within the AA: Using the worksheet on the form, mark all structural patch types that occur within the AA. Check "Y" for all those observed and "N" for those not observed. See Table 4 for patch type definitions. For patch types present in the AA, estimate their overall cover class in the AA. Photos and comments are optional, but very helpful.

4b. Surface Water Turbidity: Select the statement on the form that best describes the turbidity of surface water within the AA.

4c. Sediment Deposition: Walk the AA and estimate the extent of fresh sediment covering the AA, regardless of source. Enter the estimate in the space provided on the form.

4d. Physiochemical Stressors within the AA:. Using the table on the form, estimate the scope and severity of each physiochemical stressor within the AA. See Table 2 on page 13 of this manual for scope and severity ratings.

Table 4. Descriptions of physical patch types potentially found within the AA.

Patch Type	Description
Open water - river / stream	Areas of flowing water associated with a sizeable channel.
Open water - tributary / secondary channels	Areas of flowing water entering the main channel from a secondary source.
Open water – swales on floodplain or along shoreline	Swales are broad, elongated, vegetated, shallow depressions that can sometimes help to convey flood flow to and from vegetated floodplains. They lack obvious banks, regularly spaced deeps and shallows, or other characteristics of channels. Swales can entrap water after flood flows recede. They can act as localized recharge zones and they can sometimes receive emergent groundwater.
Open water - oxbow / backwater channels	Areas that hold stagnant or slow moving water from that has been partially or completely disassociated from the primary river channel.
Open water - rivulets / streamlet	Areas of flowing water associated with a small, diffuse channel. Often occurring near the outlet of a wet meadow or fen or at the very headwaters of a stream.
Open water - pond or lake	Medium to large natural water body.
Open water - pools	Areas that hold stagnant or slow moving water from groundwater discharge but are not associated with a defined channel.
Open water - beaver pond	Areas that hold stagnant or slow moving water behind a beaver dam.
Active beaver dams	Debris damming a stream, clearly constructed by beaver (note gnawed ends of branches).
Beaver canals	Canals cut through emergent vegetation by beaver.
Debris jams / woody debris in channel	Aggregated woody debris in stream channel deposited by high flows.
Pool / riffle complex	Deep, slow-moving pools alternating with shallow, fast-moving riffles along the relatively straight course of a stream or river.
Point bars	A low ridge of sediment (sand or gravel) formed on the inner bank of a meandering stream.
Interfluves on floodplain	The area between two adjacent streams or stream channels flowing in the same general direction.
Bank slumps or undercut banks in channel or along shoreline	A bank slope is the portion of a stream or other wetland bank that has broken free from the rest of the bank but has not eroded away. Undercuts are areas along the bank or shoreline of a wetland that have been excavated by waves or flowing water.
Adjacent or onsite seeps/springs	Localized point of emerging groundwater, often on or at the base of a sloping hillside.
Animal mounds or burrows	Many vertebrates make mounds or holes as a consequence of their forage, denning, predation, or other behaviors. The resulting disturbance helps to redistribute soil nutrients and influences plant species composition and abundance.
Mudflats	An accumulation of mud of the edge of shallow waters, such as a lake or pond. Often intermittently flooded and exposed.
Salt flats / alkali flats	Dry open areas of fine grained sediment and accumulated salts. Often wet in the winter months or with heavy precipitation.
Hummock / tussock	In fens, a mound composed of organic material (peat) either created by *Sphagnum,* other moss, or formed by sedges and grasses that have a tussock growth habit as they raise themselves on a pedestal of persistent rhizomes and roots.
Water tracks / hollows	In fens, a depression found between hummocks or mounds which remains permanently saturated or is inundated with slow moving surface water.
Floating mat	Mats of peat held together by roots and rhizomes of sedges. Floating mats are found along the edges of ponds and lakes and are slowing encroaching into open water. The mats are underlain by water and/or very loose peat.
Marl/Limonite beds	Marl is a calcium carbonate precipitate often found in calcareous fens. Limonite forms in iron fens when iron precipitates from the groundwater incorporating organic matter.

8.2. Soil Profile Descriptions and Groundwater Chemistry

At least two soil pits will be dug within the AA. The pits should be placed in or near the vegetation plot within vegetation types captured by the plot. If the vegetation and soil surface appears relatively homogenous, only two pits are necessary. If there is variability within the vegetation and soil, up to four soil pits should be dug to capture the range of variation within the site. If the pit is dug within the vegetation plot, mark the module number of the form. If the pit is dug outside the vegetation plot, take a GPS waypoint and record the waypoint number. Mark all soil pits on the map. The pits can be dug before or after the vegetation plot is conducted depending on the flow of the sampling day.

Soil pits should be dug with a 40-cm sharp shooter shovel. The pit should be only slightly larger than the width of the soil on all sides to minimize disturbance to the ground surface. Pits will be dug to one shovel length depth (35 to 40 cm) when possible. The core removed should be set down next to the pit, taking care to keep all horizons intact and in order. A bucket auger can be used to examine the soil deeper in the profile if needed to find hydric soil indicators. It is difficult to dig soil pits in areas with deep standing water. Concentrate on areas near the water's edge if standing water is a significant part of the AA.

Following guidance in the *ACOE Regional Supplement* and the National Resources Conservation Service (NRCS) Field Indicators of Hydric Soils in the United States (NRCS 2010), identify and describe each distinct layer in the soil pit. It is not necessary to name the layers with horizon designations unless you feel comfortable with soil taxonomy. Measure and record the depth of each distinct layer. For each layer, record the following information: 1) color (based on a Munsell Soil Color Chart) of the matrix and any redoximorphic concentrations (mottles and oxidized root channels) and depletions; 2) the soil texture (using Appendix F); and 3) any specifics about the concentration of roots, the presence of gravel or cobble, or any usual features to the soil. Based on the characteristics, identify which, if any, of the hydric soil indicators occur at the pit. See Appendix G for notes on hydric soil indicators commonly found in the Rocky Mountain region. If soil survey information is known for the assessment area, write down the soil survey unit name and note whether the pit matched the soil survey description.

Groundwater parameters will be measures in pits where groundwater is visible. Allow the pit to sit at least 15 minutes and up to one hour before measuring groundwater parameters. Once the pit has equilibrated as much as possible, measure the distance to saturated soil and to free water. Saturated soil can be identified by a sheen on the soil surface or water seeping an oozing into the pit. Free water is an approximation of the groundwater table, but in some cases may not represent the true groundwater table because it can take many hours for the water table to equilibrate. If free water is not observed, note whether the pit is dry or if it appears to be slowly filling. If groundwater is evident in the pit, take a pH, EC, and temperature reading using a handheld meter. Be sure to calibrate the meter periodically and keep the electrode clean at all times. A small squirt bottle is helpful to carry in the field to keep the electrode clean before and after using it.

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Example Field Forms

1. **2010 ROCKY MOUNTAIN REMAP SITE EVALUATION FORM**
2. **2010 ROCKY MOUNTAIN REMAP WETLAND CONDITION ASSESSMENT FIELD FORM**

2010 ROCKY MOUNTAIN REMAP SITE EVALUATION FORM

REMAP POINT CODE: ___________________________________ **SURVEY DATE:** __________________________ **PAGE** _______ **OF** _______

GPS COORDINATES AND PHOTOS

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

Photo #s:

DOMINANT PLANT SPECIES — **Dominance of hydrophytic vegetation** ☐ Yes ☐ No

List dominant species in each stratum. Refer to ACOE *Regional Supplement* for guidance on determining dominance.

SOIL PROFILE DESCRIPTION — **Presence of hydric soils** ☐ Yes ☐ No

Depth (cm)	Matrix Color (moist)	Redox Concentrations Color (moist)	%	Redox Depletions Color (moist)	%	Texture / Remarks
_______	______________	______________	________	_____________	________	____
_______	______________	______________	________	_____________	________	____
_______	______________	______________	________	_____________	________	____
_______	______________	______________	________	_____________	________	____

SITE HYDROLOGY — **Evidence of wetland hydrology** ☐ Yes ☐ No

List any indicators of wetland hydrology. Refer to ACOE *Regional Supplement* for guidance on indicators.

ECOLOGICAL SYSTEM AND HGM CLASSIFICATION

Ecological System Conf: High Med Low

____ SM Riparian Shrubland ____ Fen ____ Other:

____ Freshwater Marsh ____ Wet Meadow ____ Not wetland

HGM Class Conf: High Med Low

____Riverine ____Lacustrine

____Depressional ____ Slope

REFERENCE CONDITION CRITERIA — **Does site meet reference condition criteria?** ☐ Yes ☐ No

Roads and Highways

- 4x4, dirt >200 m
- local, city >300 m
- highways >500 m

Hydrologic Modification

- canals, ditches >200 m
- reservoirs >1,000 m (only if wetland is downstream)
- water right point of use (wells, diversion points, impoundments) >200 m

Land Cover

- high density residential >2,000 m
- low density residential / high use recreation >300 m
- crop agriculture / hay pastures >500 m
- timber harvest >2,000 m

Land Use

- abandoned mines / tailings piles >500 m
- active gravel pit, open pit, strip mining >1,000 m
- evidence of heavy livestock use >200 m

COMMENTS ON SITE EVALUATION

2010 ROCKY MOUNTAIN REMAP WETLAND CONDITION ASSESSMENT FIELD FORM

LOCATION AND GENERAL INFORMATION

Point Code: ______________________________ Site Name: ____

Date: _______________ Surveyors: _______________________________ Weather Conditions: ____________________________

Level 3 Ecoregion	State	Ecological System
____Can Rockies ____South Rockies	____Montana ____Colorado	____Wet Mdw ____Rip Shrub
____Mid Rockies ____Wasatch/Uintah	____Wyoming ____Utah	____Marsh ____Fen

General Location: ____ County: _________________________________

General Ownership: ____________________ Specific Ownership: ____

USGS Quad Name: ____ USGS Quad Code: __________________________

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 (+/-): _____________

Point is:	Dimensions of AA:
____Within target population (AA centered at point)	____40 m radius circle
____Within target population (AA *not* centered at point)	____Rectangle, width_______ length:_______
____Within 60 m of target population (AA shifted, point outside)	____Other, describe below and take a GPS Track

AA-Center WP #: _________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): _____________

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:

Point Code__________________

ENVIRONMENTAL DESCRIPTION AND CLASSIFICATION OF ASSESSMENT AREA

GPS Elevation (m): ____________ Topographic Position (see manual for list): ____

Slope 1 (deg): ________________ Aspect 1 (deg): ________________ Comment: ____

Slope 2 (deg): ________________ Aspect 2 (deg): ________________ Comment: ____

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

____ Subalpine-Montane Riparian Shrubland

____ North American Arid West Emergent Marsh

____ Subalpine-Montane Fen

____ Alpine-Montane Wet Meadow

____ Upland inclusion (% of AA: ______)

____ Open water > 1 m deep (% of AA: ______)

Cowardin Classification (see manual for list) Conf: High Med Low

Code	% of AA	Code	% of AA

HGM Class (see manual for key and pick *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 Bankfull Width (m): ________________________________

Estimated Valley Width (m): __________________________________

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

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

Hydrologic Regime Conf: High Med Low

____Perennial (streams that hold water throughout the year; water in channel ~80% of the time)

____Intermittent (stream that holds water during wet portions of the year; water in channel 10–80% of the time)

____Ephemeral (channel that holds water only during and immediately after rain events; water in channel <10% of the time)

Wadable vs. Non-wadable Stream:

AA represents: ______ Two sides of wadable stream ______ One side of non-wadable stream with channel ______ One side without channel

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

Zone 1 Physiognomy ____________________________ Dom spp: ____ % of AA: ___________

Zone 2 Physiognomy ____________________________ Dom spp: ____ % of AA: ___________

Zone 3 Physiognomy ____________________________ Dom spp: ____ % of AA: ___________

Zone 4 Physiognomy ____________________________ Dom spp: ____ % of AA: ___________

Zone 5 Physiognomy ____________________________ Dom spp: ____ % of AA: ___________

ENVIRONMENTAL AND CLASSIFICATION COMMENTS

Point Code__________________

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:

Point Code__________________

1. LANDSCAPE CONTEXT ASSESSMENT

1a. LANDSCAPE CONNECTIVITY: *NON-RIVERINE WETLANDS*

For non-riverine wetlands, estimate the **landscape connectivity** 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 and small ditches can be included in unfragmented blocks. Enter the estimate in the space provided at right. →	

1a. LANDSCAPE CONNECTIVITY: *RIVERINE WETLANDS*

For riverine wetlands, estimate the **landscape connectivity** within 500 m upstream and downstream of the AA. To determine, identify any non-buffer patches (see field manual, Table XX) within the riparian corridor both upstream and downstream of the AA. Record their length in the tables to the right and sum all patches. Specify if the patch occurs on the right or left bank (R/L). *For one-sided AAs,* only consider one side of the channel.	***Upstream*** (R / L) Length (m) _______ _______________ _______ _______________ _______ _______________ _______ _______________ _______ _______________ *Total:* _______________	***Downstream*** (R / L) Length (m) _______ _______________ _______ _______________ _______ _______________ _______ _______________ _______ _______________ *Total:* _______________	*Upstream:* _________ *Downstream:* _________ *Total length:* _________

Landscape connectivity comments:

1b. BUFFER EXTENT

Estimate the **extent of buffer land cover** surrounding the AA (see field manual, Table XX, for buffer land covers). Each segment must be ≥ 30 m wide and ≥ 5 long. *For riverine wetlands,* do not include the area immediately upstream or downstream within the channel. *For one-sided AAs*, only consider one side of the channel. Enter the estimate in the space provided at right. →	

1c. BUFFER WIDTH

Estimate the **buffer width** (up to 200 m from AA) at eight evenly spaced intervals where buffer land cover exists. *For riverine wetlands,* do not include the area immediately upstream or downstream within the channel. *For one-sided AAs*, only consider one side of the channel.	1: ____________ 2: ____________ 3: ____________ 4: ____________	5: ____________ 6: ____________ 7: ____________ 8: ____________	*Average width:* ____________

1d. BUFFER CONDITION

Check one statement from *each* column that best describes the **buffer condition**. Only consider buffer areas from 1b and 1c above.

___ Abundant (>95%) cover native vegetation and little or no (<5%) cover of non-native plants.

___ Substantial (75–95%) cover of native vegetation and low (5–25%) cover of non-native plants.

___ Moderate (50–75%) cover of native vegetation.

___ Low (>50%) cover of native vegetation.

___ Intact soils and little or no trash or refuse.

___ Intact or moderately disrupted soils, moderate or lesser amounts of trash, OR minor intensity of human visitation or recreation.

___ Moderate or extensive soil disruption, moderate or greater amounts of trash, OR moderate intensity of human use.

___ 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 at all.

Buffer comments:

Point Code__________________

1e. NATURAL COVER WITHIN A 100 M ENVELOPE

Using the table below, estimate the percent cover of each **natural cover type within a 100 m envelope** of the AA. This measure applies to the entire 100 m envelope and not just buffer land covers. Estimate the total combined cover then wetland and upland cover separately.

Natural Cover Type	*Total % Cover*	*Upland % Cover*	*Wetland % Cover*
Total natural cover (breakdown by type below, note dominant species by type)			
Deciduous forest			
Coniferous forest			
Broadleaf evergreen forest			
Mixed forest type			
Shrubland			
Perennial herbaceous			
Annual herbaceous or bare (generally weedy and disturbed)			

Natural cover comments (if different, note the dominant upland vegetation surrounding the entire wetland):

1f. LANDSCAPE STRESSORS WITHIN A 500 M ENVELOPE

Using the table below, estimate the scope and severity of each **landscape stressor within a 500 m envelope** of the AA. See the field manual for scope and severity ratings.

Landscape stressor categories	*Scope*	*Severity*
Paved roads, parking lots, railroad tracks		
Unpaved roads (e.g., driveway, tractor trail, 4-wheel drive roads)		
Domestic or commercially developed buildings		
Intensively managed golf courses, sports fields		
Gravel pit operation, open pit mining, strip mining		
Mining (other than gravel, open pit, and strip mining), abandoned mines		
Resource extraction (oil and gas)		
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		
Agriculture – tilled crop production		
Agriculture – permanent crop (hay pasture, vineyard, orchard, nursery, berry field)		
Agriculture – permanent tree plantation		
Haying of native grassland		
Recent old fields and other disturbed fallow lands dominated by exotic species		
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)		
Dam sites and flood disturbed shorelines around water storage reservoirs		
Beetle-killed conifers		
Evidence of recent fire (<5 years old)		
Other:		

Landscape stressor comments:

Point Code__________________

2. VEGETATION ASSESSMENT

VEGETATION PLOT

GPS COORDINATES OF VEGETATION PLOT (NAD 83 UTM Zone ________)

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

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

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

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

PHOTOS OF VEGETATION PLOT

0 m Photo #: _____________ Aspect: _____________

XP 1 Photo #: _____________ Aspect: _____________

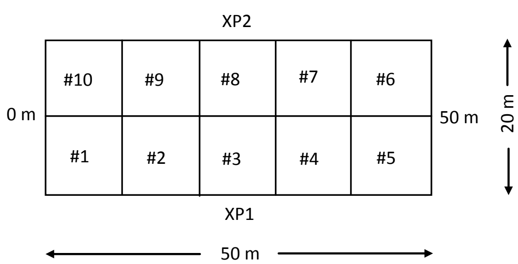
50 m Photo #: _____________ Aspect: _____________

XP 2 Photo #: _____________ Aspect: _____________

Additional AA Photos and Comments:

LAYOUT OF VEGETATION PLOT

Plot layout (circle intensive modules and note any changes to the plot layout, i.e. 1x5 or 2x2 plot)



Plot representativeness (discuss decisions for placement and whether the plot is representative of AA)

Point Code___________________

VEGETATION PLOT GROUND COVER AND VERTICAL STRATA					
Module →					**R**
Cover Classes 1: trace **2:** 0–<1% **3:** 1–<2% **4:** 2–<5% **5:** 5–<10% **6:** 10–<25% **7:** 25–<50% **8:** 50–<75% **9:** 75–<95% **10:** >95%					
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 Class (unless otherwise noted) →	**C**	**C**	**C**	**C**	**C**
Ground Cover					
Cover of standing water of any depth, vegetated or not					
Cover of shallow standing water < 0.2 m / average depth shallow water (cm)	/	/	/	/	/
Cover of deep standing water > 0.2 m / average depth deep water (cm)	/	/	/	/	/
Cover of open water with no vegetation					
Cover of water with emergent vegetation					
Cover of water with submerged or floating aquatic vegetation					
Cover of bare ground – soil / sand / sediment					
Cover of bare ground – gravel / cobble (~2–250 mm)					
Cover of bare ground – bedrock / rock / boulder (>250 mm)					
Cover of litter					
Depth of litter (cm) – average of 4 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 macroalgea (all cover, including under vegetation or litter cover)					

Height / Cover →	**H**	**C**	**H**	**C**	**H**	**C**	**H**	**C**	**H**	**C**
Vertical Vegetation Strata										
(T1) Dominant canopy trees (> 5 m and > 30% cover)										
(T2) Sub-canopy trees (> 5 m 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)										
(HT) Herbaceous total										
(H1) Graminoids										
(H2) Forbs										
(H3) Ferns and fern allies										
(AQ) Submerged or floating aquatics										

Point Code__________________

Vegetation Plot Species Table: For each intensive module, list all species within and overhanging the module and estimate percent cover for the module. List any species found in the remaining modules in the residual "R" column and estimate percent cover for the entire plot. Mark intensive modules on map for reference.

For woody species, estimate seedling, sapling, and mature trees/shrubs separately if they occur in different strata. Use strata codes from previous page.

	#10	#9	#8	#7	#6	
0 m						50 m
	#1	#2	#3	#4	#5	

VEGETATION PLOT SPECIES TABLE												
		Module →									**R**	
		Presence / Cover →	**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**
Cover Classes 1: trace 2: 0–<1% 3: 1–<2% 4: 2–<5% 5: 5–<10% 6: 10–<25% 7: 25–<50% 8: 50–<75% 9: 75–<95% 10: >95%												
Stratum	**Species**	**Coll #**										

Point Code___________________

VEGETATION PLOT SPECIES TABLE												
		Module →									**R**	
		Presence / Cover →	**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**
Cover Classes 1: trace **2:** 0–<1% **3:** 1–<2% **4:** 2–<5% **5:** 5–<10% **6:** 10–<25% **7:** 25–<50% **8:** 50–<75% **9:** 75–<95% **10:** >95%												
Stratum	**Species**	**Coll #**										

Point Code__________________

2a. REGENERATION OF NATIVE WOODY SPECIES

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

____ All age classes of native woody riparian species present OR woody species are naturally uncommon or absent.

____ Middle age group(s) absent. Other age classes (mature individuals/saplings and seedlings) well represented.

____ Seedlings, saplings, and middle age groups absent. Stand comprised mainly of mature individuals.

____ Woody species predominantly consist of decadent or dying individuals or AA has >20% canopy cover of Russian Olive and/or Salt Cedar.

Regeneration comments:

2b. EXTENT OF BROWSE ON WOODY SPECIES

Estimate the **extent of browse on woody species** throughout the entire AA. Using the table below, estimate each species separately. Only include woody species with >5% cover within the AA. After estimating individual species, estimate the extent of browse on all woody species together.

Species	*% Cover in AA*	*% Browsed*
All woody species		

Extent of browse comments:

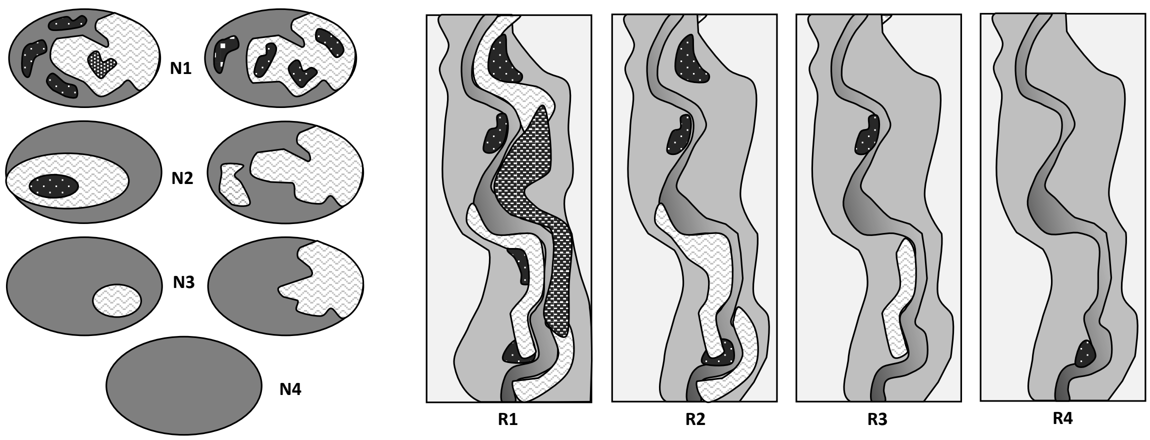
2c. VERTICAL OVERLAP OF VEGETATION STRATA

Estimate the percent of the AA with **vertically overlapping strata**. Each strata must cover >5% of the AA. See field manual for definition of strata by height and life form. Enter percents in the space provided at right. Four values should total 100%.	Percent of AA that supports 3 or more overlapping of strata.	
	Percent of AA that supports 2 overlapping strata.	
	Percent of AA with only one stratum.	
	Percent of AA with open water, bare ground, or sparsely vegetated.	

Vertical overlap comments:

2d. HORIZONTAL INTERSPERSION OF VEGETATION ZONES

Refer to diagrams below and circle the code that best describes the **horizontal interspersion of vegetation zones** within the AA. Rules for defining vegetation zones are on page X 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.	**N1**	**R1**
	Moderate degree of horizontal interspersion: AA characterized by a moderate array of nested or interspersed vegetation zones with no single dominant zone.	**N2**	**R2**
	Low degree of horizontal interspersion: AA characterized by a simple array of nested or interspersed vegetation zones. One zone may dominate others.	**N3**	**R3**
	No horizontal interspersion: AA characterized by one dominant vegetation zone.	**N4**	**R4**



Horizontal interspersion comments:

2e. VEGETATION STRESSORS WITHIN THE AA

Using the table below, estimate the scope and severity of each **vegetation stressor within the AA**. See the field manual for scope and severity ratings.

Vegetation stressor categories	*Scope*	*Severity*
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:

Point Code__________________

3. HYDROLOGY ASSESSMENT

3a. WATER INFLOW

Identify all *major* **water sources feeding the AA** during the growing season in the table below. Rank the top sources (up to three) as 1, 2, 3. Mark all others present as 4 and those not present as NA. For discrete **inlets** (stream channels, springs, ditches, etc.), count the number of each within the AA and a 100 m envelope of the AA. Enter NA for those not present. Mark all inlets on the aerial photo and those within the AA on the site sketch. If there is an indication that inflow during the growing season is controlled by artificial water sources, please explain in comments.

Sources:

_____ Overbank flooding from adjacent channel
_____ Alluvial storage / hyporheic flow
_____ Natural surface (overland) flow
_____ Groundwater discharge
_____ Snowmelt
_____ Precipitation
_____ Urban run-off / culverts
_____ Irrigation run-off / ditches
_____ Pipes (directly feeding wetland)
_____ Other:

Count of Discrete Inlets:

_____ Stream channels
_____ Visible spring sources
_____ Culverts
_____ Ditches
_____ Pipes
_____ Other:

Water inflow comments:

3b. WATER OUTFLOW

Identify all *major* **pathways through which water leaves the AA** during the growing season in the table below. Rank the top pathways (up to three) as 1, 2, 3. Mark all others present as 4 and those not present as NA. For discrete **outlets** (stream channels, culverts, ditches, etc.), count the number of each within the AA and a 100 m envelope of the AA. Enter NA for those not present. Mark all outlets on the aerial photo and those in the AA on the site sketch. If there is an indication that outflow is modified by anthropogenic disturbance, please explain in comments.

Pathways:

_____ Channelized flow (headwater wetland)
_____ Recharge to adjacent stream
_____ Non-channelized flow to contiguous wetland area
_____ Culverts under roadways / trails
_____ Ditches established to drain wetland
_____ No natural outlet
_____ Natural outlet blocked / bermed
_____ Other:

Count of Discrete Outlets:

_____ Channels
_____ Culverts
_____ Ditches
_____ Other:

Water outflow comments:

3c. INDICATORS OF INUNDATION AT SEASONAL HIGH WATER

Walk the AA and identify indicators of inundation at seasonal high water. Mark all indicators present with a check. Mark those absent with NA. Refer to the *ACOE Regional Supplement* for indicator descriptions. Based on the height of the indicators, estimate the percent of the AA that is covered in standing water at the seasonal high.

Indicators:

_____ Water marks / stains (B1)
_____ Sediment deposits (B2)
_____ Drift deposits (B3)
_____ Algal mats or crust (B4)
_____ Iron deposits (B5)
_____ Surface soil cracks (B6)
_____ Sparsely vegetated concave surfaces (B8)
_____ Water stained leaves (B9)
_____ Salt crust (B11)
_____ Aquatic invertebrates (B13)
_____ Other:

Extent of surface water:

Current _____________

Seasonal high ____________

Indicators of inundation comments:

3d. SURFACE WATER TURBIDITY

Select the statement that best describes the **turbidity of surface water** within the AA.

____ No visual evidence of turbidity.

____ Water is slightly cloudy, but there is no obvious source of sedimentation.

____ Water is cloudy, but the bottom is still visible. Sources of sedimentation or other inputs are apparent (identify in comments below).

____ Water is milky and/or muddy. The bottom is no longer visible. There are obvious sources of sedimentation or other inputs (identify in comments below).

Surface water turbidity comments:

3e. ALGAL GROWTH

Select the statement that best describes **algal growth** within surface water in the AA.

____ Water is clear with minimal algal growth.

____ Algae is limited to small and localized areas of the wetland. Water may have a greenish tint or cloudiness.

____ Algal growth occurs in large patches throughout the AA. Water may have a moderate greenish tint or sheen.

____ Algal mats are extensive, blocking light to the bottom. Water has a strong greenish tint, sheen, or turbidity. The bottom is difficult to see.

Algal growth comments:

3h. HYDROLOGY STRESSORS WITHIN A 500 M ENVELOPE

Using the table below, estimate the scope and severity of each **hydrology stressor within a 500 m envelope of the AA**. If known alteration occurs further upstream than 500 m, please explain in comments below. See the field manual for scope and severity ratings.

Hydrology stressor categories	*Scope*	*Severity*
Upstream dam / reservoir		
Upstream impoundment / stock pond		
Upstream spring box diverting water from wetland		
Pumps, diversions, ditches that move water *out of* the wetland		
Downstream berms, dikes, levees that hold water in the wetland		
Weir or drop structure to impound water and control energy of flow		
Pumps, diversions, ditches that move water *into* the wetland		
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:		

Hydrology stressor comments:

Point Code__________________

3. RIVERINE SPECIFIC HYDROLOGY ASSESSMENT

3g. CHANNEL STABILITY: ***FILL OUT FOR RIVERINE WETLAND AAs THAT INCLUDE A CHANNEL OR ARE ADJACENT TO A CHANNEL***

Walk the AA for field indicators of channel equilibrium, aggradation or degradation listed in the table below. Check "Y" for all those observed and "N" for those not observed.

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 may be declining in stature or vigor, and/or riparian trees and shrubs may be falling into the 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.

Channel stability comments:

Point Code__________________

3h. ENTRENCHMENT RATIO: ***FILL OUT FOR RIVERINE WETLAND AAs THAT INCLUDE A WADABLE CHANNEL***				
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 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*
6. Estimate bankfull width.	This is a critical step requiring experience. 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.			
7. 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).			
8. Estimate flood prone height.	Double the estimate of maximum bankfull depth from Step 2.			
9. 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.			
10. Calculate entrenchment.	Divide the flood prone width (Step 4) by the max bankfull width (Step 1).			
11. Calculate average entrenchment	Average the results of Step 5 for all three cross-sections and enter it here.			
Entrenchment ratio comments:				

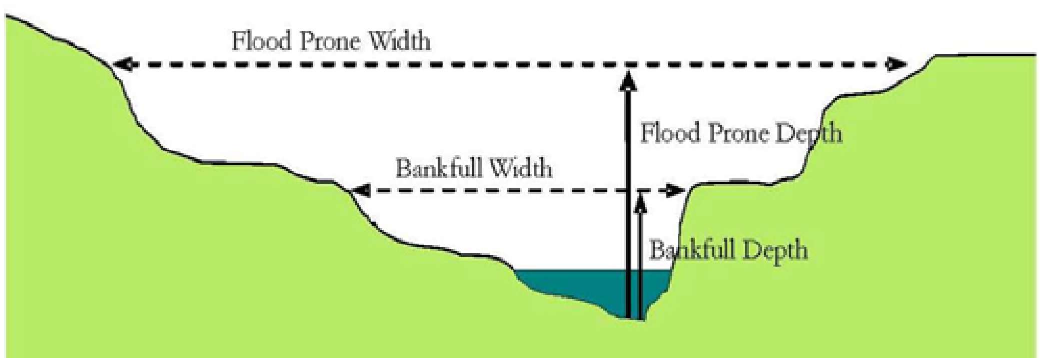


Illustration from Collins *et al.* 2008. California Rapid Assessment Method for Wetlands v 5.0.2

Point Code__________________

4. PHYSIOCHEMICAL ASSESSMENT

4a. STRUCTURAL PATCH TYPES WITHIN THE ASSESSMENT AREA

Using the following worksheet, mark all **structural patch types** that occur within the AA. Check “Y” for all those observed and “N” for those not observed. See the field manual for patch type definitions. For patch types present in the AA, estimate their overall cover class in the AA. Photos and comments are optional, but very helpful.

Cover Classes 1: trace 2: 0–<1% 3: 1–<2% 4: 2–<5% 5: 5–<10% 6: 10–<25% 7: 25–<50% 8: 50–<75% 9: 75–<95% 10: >95%

Patch type	*Present in AA? Y N*	*Cover within AA*	*Photos*	*Comments*
Open water - river / stream	□ □			
Open water - tributary / secondary channel	□ □			
Open water - swales on floodplain or along shoreline	□ □			
Open water - oxbow / backwater channel	□ □			
Open water - rivulets / streamlet	□ □			
Open water - pond or lake	□ □			
Open water - pools	□ □			
Open water - beaver pond	□ □			
Active beaver dam	□ □			
Beaver canal	□ □			
Debris jams / woody debris in channel	□ □			
Pools in stream	□ □			
Riffles in stream	□ □			
Point bar	□ □			
Interfluve on floodplain	□ □			
Bank slumps or undercut banks in channel or along shoreline	□ □			
Adjacent or onsite seep / spring	□ □			
Animal mounds or burrows	□ □			
Mudflat	□ □			
Salt flat / alkali flat	□ □			
Hummock / tussock	□ □			
Water tracks / hollow	□ □			
Floating mat	□ □			
Marl / Limonite bed	□ □			
Other:	□ □			
Other:	□ □			

Structural patch types comments:

4b. SUBSTRATE / SOIL SURFACE INTEGRITY

Select the statement that best describes **substrate / soil surface integrity** within the AA.

____ No soil surface disturbance is observed or soil is naturally bare.

____ Minimal soil surface disturbance is observed, primarily due to native ungulate use (light game trails, wallows) or light flood deposition.

____ Moderate soil surface disturbance is observed due to native ungulates, flood deposition, frost heave, or other natural processes.

____ Significant soil surface disturbance is observed. Cause may be natural or anthropogenic. (Please explain in comments below.)

Substrate / soil comments:

4c. SEDIMENT DEPOSITION

Walk the AA and estimate the extent of fresh sediment covering the AA, regardless of source. Enter the estimate in the space provided at right. →	

Sediment deposition comments:

4d. PHYSIOCHEMICAL STRESSORS WITHIN THE AA

Using the table below, estimate the scope and severity of each **physiochemical stressor within the AA.** See the field manual for scope and severity ratings.

Physiochemical stressor categories	*Scope*	*Severity*
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		
Other:		

Physiochemical stressor comments:

Point Code__________________

SOIL PROFILE DESCRIPTION – SOIL PIT 1 **Module # or 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, note if pit appeared to be filling slowly or if it appears dry.

SOIL PROFILE DESCRIPTION – SOIL PIT 2 **Module # or 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, note if pit appeared to be filling slowly or if it appears dry.

SOIL PROFILE DESCRIPTION – SOIL PIT 3 **Module # or 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 Depletions Color (moist)	%	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, note if pit appeared to be filling slowly or if it appears dry.

SOIL PROFILE DESCRIPTION – SOIL PIT 4 **Module # or 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 Depletions Color (moist)	%	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, note if pit appeared to be filling slowly or if it appears dry.

Appendices

APPENDIX A: 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 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 B: Ecological Systems Descriptions for Target Ecological System in Colorado and Montana

The following Ecological System Descriptions were prepared by CNHP and MTNHP. Descriptions for Colorado include Rocky Mountain Alpine-Montane Wet Meadow and Rocky Mountain Subalpine-Montane Riparian Shrubland. Descriptions for Montana include all four target systems. The descriptions can also be applied to Wyoming and Utah, but should be done so with a knowledge of local flora and ecology.

Rocky Mountain Alpine-Montane Wet Meadow Ecological System Description for the state of Colorado NatureServe Identifier: CES306.812

Summary: Moderate- to high-elevation herbaceous-dominated wet meadows are found throughout the Rocky Mountains and Intermountain regions. Occurrences in Colorado range in elevation from montane to alpine (2,130–3,960 m or 7,000–13,000 ft). These types occur as large meadows in montane or subalpine valleys, as narrow strips bordering ponds, lakes, and streams, and near seeps and springs. They are typically found on flat areas or gentle slopes, but may also occur on sub-irrigated sites with slopes up to 10%. In alpine regions, sites typically are small depressions located below late-melting snow patches or on snowbeds. Soils of this system are mineral but may have large amount of organic matter. Soils show typical hydric soil characteristics, including high organic content and/or low chroma and redoximorphic features. This system often occurs as a mosaic of several plant associations, and may be found adjacent to a variety of willow shrublands. Wet meadows are often dominated by graminoids, although forb cover may be substantial in areas at higher elevations. Characteristic species at the highest elevations include mountain sedge (*Carex scopulorum*), sheep sedge (*C. illota*), hair-like sedge (*C. capillaris*), black alpine sedge (*C. nigricans*), Drummond's rush (*Juncus drummondii*), marsh marigold (*Caltha leptosepala*), and brook saxifrage (*Saxifraga odontoloma*). At subalpine to upper montane elevations, water sedge (*Carex aquatilis*), and beaked sedge (*C. utriculata*), either separately or in combination, form a broadly distributed characteristic community. Other common species of this zone include smallwing sedge (*C. microptera*), analogue sedge (*C. simulata*), tufted hairgrass (*Deschampsia cespitosa*), fewflower spikerush (*Eleocharis quinqueflora*), bluejoint reedgrass (*Calamagrostis canadensis*), heartleaf bittercress (*Cardamine cordifolia*), tall fringed bluebells (*Mertensia cilliata*), arrowleaf ragwort (*Senecio triangularis*), elephanthead lousewort (*Pedicularis groenlandica*), and large leaf avens (*Geum macrophyllum*). At mid to lower montane elevations woolly sedge (*Carex pellita*), Nebraska sedge (*C. nebrascensis*), clustered field sedge (*C. praegracilis*), common spikerush (*Eleocharis palustris*), and mountain rush (*Juncus balticus* var. *montanus*) are typical dominants.

Environment: In Colorado, this system is largely confined to the Southern Rocky Mountains, a landscape of generally high topographic relief shaped by the effects of glaciation and the movement of water. Elevations are usually between 7,000–13,000 ft, and are found in a variety of settings including: large open meadows in high montane valleys; openings in willow carrs or subalpine coniferous forests; small to moderate size patches in very shallow, still to slow-moving water; on saturated soils near low-order streams, lakes, and backwater areas of larger rivers; as narrow strips bordering ponds and streams at lower elevations; or in and near running water of small streams, seeps, and springs. Hydrologic regime is a key factor defining wet meadows and distinguishing them from other wetland types. Wet meadows occur were the soil is seasonally saturated and may be seasonally flooded, but high water tables do not persist throughout the growing season as they do in fens. Though wet meadows can be found in riparian corridors and on floodplains, they generally do not experience the high velocity surface flows, scouring, and sediment deposition that occurs in the active riparian zone. Wet meadows have more stable water tables than marshes and do not experience deep inundation, though fluctuations throughout the growing season are not uncommon. Water tables are typically high early in the growing season and draw down by the end of the season (Gage and Cooper 2007). On drier sites supporting the less mesic vegetation, the late-season water table may be one meter or more below the surface.

Moisture for wet meadow community types comes from groundwater, stream discharge, overland flow, overbank flow, and precipitation. Wet meadows in the alpine are closely associated with snowmelt and typically not subjected to high disturbance events such as flooding, while seasonal flooding is more common in the montane. Salinity and alkalinity are generally low due to the frequent flushing of moisture through the meadow. Depending on the slope, topography, hydrology, soils and substrate, open water pools or standing water may be present and may be intermittent, ephemeral, or permanent. Soils typically possess a high proportion of organic matter, but this may vary considerably depending on the frequency and magnitude of alluvial deposition and water table depth. Organic composition of the soil often includes a thin layer near the soil surface. Because high water tables do not persist throughout the growing season, organic matter accumulation in wet meadows is always less than 40 cm. Soils may exhibit gleying and/or mottling throughout the profile.

Vegetation: Community composition of wet meadows varies with elevation. This system is characterized by an herbaceous layer dominated by perennial graminoids, especially sedges. Significant forb cover may be present in some areas, especially at higher elevations. Alpine-montane wet meadows in Colorado commonly occur as part of a riparian or wetland mosaic, and may be found interspersed with patches of planeleaf willow (*Salix planifolia*), barrenground willow (*S. brachycarpa*), Wolf's willow (*S. wolfii*), Booth's willow (*S. boothii*), mountain willow (*S. monticola*), or *S. geyeriana* (Geyer's willow) shrublands. In many situations, however, these communities form large, essentially shrubless meadows, which may be a mosaic of herbaceous types.

The graminoid herbaceous layer may form a scattered to dense overstory. Characteristic graminoid species at the highest elevations include mountain sedge (*Carex scopulorum*), sheep sedge (*C. illota*), hair-like sedge (*C. capillaris*), black alpine sedge (*C. nigricans*), and Drummond's rush (*Juncus drummondii*). At subalpine to upper montane elevations, water sedge (*Carex aquatilis*), and beaked sedge (*C. utriculata*), either separately or in combination, form a broadly distributed characteristic community. In perennially saturated environments at higher elevations, instances of these herbaceous communities can have significant organic matter accumulation and would therefore be classified as within the Rocky Mountain Subalpine-Montane Fen system. Other common graminoids of this zone include smallwing sedge (*C. microptera*), analogue sedge (*C. simulata*), tufted hairgrass (*Deschampsia cespitosa*), fewflower spikerush (*Eleocharis quinqueflora*),and bluejoint reedgrass (*Calamagrostis canadensis*). Tufted hairgrass grasslands often occur on drier margins. At mid to lower montane elevations, woolly sedge (*Carex pellita*), Nebraska sedge (*C. nebrascensis*), clustered field sedge (*C. praegracilis*), common spikerush (*Eleocharis palustris*), and mountain rush (*Juncus balticus* var. *montanus*) are typical dominants. These lower montane species also form communities of the North American Arid West Emergent Marsh system.

In the alpine to upper subalpine, marsh marigold (*Caltha leptosepala*) is the most widespread and characteristic dominant forb, while brook saxifrage (*Saxifraga odontoloma*) forms a less frequent, but easily recognized alpine community as well. At subalpine to montane elevations, combinations of heartleaf bittercress (*Cardamine cordifolia*), tall fringed bluebells (*Mertensia cilliata*), and/or arrowleaf ragwort (*Senecio triangularis*) form a common forb type within the matrix. Forb cover is variable and may also include elephanthead lousewort (*Pedicularis groenlandica*), large leaf avens (*Geum macrophyllum*), American speedwell (*Veronica americana*), alpine leafy bract aster (*Symphyotrichum foliaceum* var. *foliaceum*), western mountain aster (*Symphyotrichum spathulatum* var. *spathulatum*), stinging nettle (*Urtica dioica*), willowherb (*Epilobium* spp.), fringed grass of Parnassus (*Parnassia fimbriata*), American bistort (*Polygonum bistortoides*), and field horsetail (*Equisetum arvense*).

Twenty-one plant alliances have been described for these systems in Colorado. These include:

- *Betula nana* Seasonally Flooded Shrubland Alliance
- *Calamagrostis canadensis* Seasonally Flooded Herbaceous Alliance
- *Caltha leptosepala* Saturated Herbaceous Alliance
- *Cardamine cordifolia* Saturated Herbaceous Alliance
- *Carex (lachenalii, capillaris, illota)* Seasonally Flooded Herbaceous Alliance
- *Carex (utriculata, rostrata)* Seasonally Flooded Herbaceous Alliance
- *Carex aquatilis* Seasonally Flooded Herbaceous Alliance
- *Carex nebrascensis* Seasonally Flooded Herbaceous Alliance
- *Carex nigricans* Seasonally Flooded Herbaceous Alliance
- *Carex pellita* Seasonally Flooded Herbaceous Alliance
- *Carex praegracilis* Seasonally Flooded Herbaceous Alliance
- *Carex saxatilis* Temporarily Flooded Herbaceous Alliance
- *Carex scopulorum* Seasonally Flooded Herbaceous Alliance
- *Carex simulata* Saturated Herbaceous Alliance
- *Carex vesicaria* Seasonally Flooded Herbaceous Alliance
- *Dasiphora fruticosa* Temporarily Flooded Shrubland Alliance

- *Deschampsia cespitosa* Seasonally Flooded Herbaceous Alliance
- *Eleocharis palustris* Seasonally Flooded Herbaceous Alliance
- *Eleocharis quinqueflora* Seasonally Flooded Herbaceous Alliance
- *Juncus balticus* Seasonally Flooded Herbaceous Alliance
- *Saxifraga odontoloma* Temporarily Flooded Herbaceous Alliance

Dynamics: Communities associated with this ecological system are adapted to soils that may be flooded or saturated throughout the growing season. They may also occur on areas with soils that are only saturated early in the growing season, or intermittently during heavy convective storms in summer. Most appear to be relatively stable types, although in some areas these may be impacted by intensive livestock grazing.

Non-native species can displace native species, alter hydrology, alter structure, and affect food web dynamics by changing the quantity, type, and accessibility to food for fauna (Zedler and Kercher 2004). Wetland dominated by non-native, invasive species typically support fewer native animals (Zedler and Kercher 2004). Wet meadows are susceptible to invasion by many non-native species, especially pasture grasses such as Kentucky bluegrass (*Poa pratensis*) and timothy (*Phleum pratense*) as well as exotics species common to other wetland types such as Canada thistle (*Cirsium arvense*) and dandelion (*Taraxacum officinale*). Reed canary grass (*Phalaris arundinacea*) and giant reed (*Phragmites communis*) are also common exotics in wet meadows. Native increasers such as mountain rush (*Juncus arcticus*), wild iris (*Iris missouriensis*), silverweed (*Argentea anserina*), and shrubby cinquefoil (*Dasiphora floribunda*) often increase with overgrazing and or changes in the water table (Cooper 1990; Johnson 1996).

Range: This system is found throughout the Rocky Mountains and Intermountain West regions, ranging in elevation from montane to alpine (1,000–3,600 m). In Colorado, this system occurs throughout the mountainous portion of the state. Similar occurrences at lower elevations (below 2,130 m or 7,000 ft.) and those not in the Southern Rocky Mountain ecoregion are likely to belong to the North American Arid West Emergent Marsh system.

Cowardin Wetland Classification:

System: Palustrine
Class: Emergent Wetland
Subclass: Persistent
Water regime: Seasonally, temporarily, or intermittently flooded, or (less commonly), saturated.

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Rocky Mountain Alpine-Montane Wet Meadow
Ecological System Description for the state of Montana
Natureserve Identifier: CES306.812

Summary: These moderate-to-high-elevation systems are found throughout the Rocky Mountains and Intermountain regions, dominated by herbaceous species found on wetter sites with very low-velocity surface and subsurface flows. Occurrences range in elevation from montane to alpine (1000-3600 m). This system typically occurs in cold, moist basins, seeps and alluvial terraces of headwater streams or as a narrow strip adjacent to alpine lakes (Hansen et al., 1996). They are typically found on flat areas or gentle slopes, but may also occur on sub-irrigated sites with slopes up to 10%. In alpine regions, sites typically are small depressions located below late-melting snow patches or on snowbeds. The growing season may only last for one to two months. Soils of this system may be mineral or organic. In either case, soils show typical hydric soil characteristics, including high organic content and/or low chroma and redoximorphic features. This system often occurs as a mosaic of several plant associations, often dominated by graminoids such as tufted hairgrass (*Deschampsia caespitosa*), and a diversity of alpine sedges such as small-head sedge (*Carex illota*), small-winged sedge (*Carex microptera*), black alpine sedge (*Carex nigricans*), Holm's Rocky Mountain sedge (*Carex scopulorum*) shortstalk sedge (*Carex podocarpa*) and Payson's sedge (*Carex paysonis*). Drummond's rush (*Juncus drummondii*), Merten's rush (*Juncus mertensianus*), and high elevation bluegrasses (*Poa arctica* and *Poa alpina*) are often present. Forbs such as arrow-leaf groundsel (*Senecio triangularis*), slender-sepal marsh marigold (*Caltha leptosepala*), and spreading globeflower (*Trollius laxus*) often form high cover in these meadows. Wet meadows are tightly associated with snowmelt and are usually not subjected to high disturbance events such as flooding.

Environment: Moisture for these wet meadow community types comes from groundwater, stream discharge, overland flow, overbank flow, and precipitation. Salinity and alkalinity are generally low due to the frequent flushing of moisture through the meadow. Depending on the slope, topography, hydrology, soils and substrate, intermittent, ephemeral, or permanent pools may be present. Standing water may be present during some or all of the growing season, with water tables typically remaining at or near the soil surface. Fluctuations of the water table throughout the growing season are not uncommon, however. On drier sites supporting the less mesic types, the late-season water table may be one meter or more below the surface. Soils typically possess a high proportion of organic matter, but this may vary considerably depending on the frequency and magnitude of alluvial deposition. Organic composition of the soil may include a thin layer near the soil surface. Soils may exhibit gleying and/or mottling throughout the profile.

Vegetation: A variety of plant communities are found within this system in Montana. Many alpine wet meadows throughout the state are dominated by tufted hairgrass (*Deschampsia caespitosa*), forming a dense stand of tussocks. The *Deschampsia caespitosa* Temporarily Flooded Herbaceous Alliance has been found at elevations as high as 10,100 ft, but is much more common at lower elevations where it often occupies low gradient areas and slopes less than 15 percent facing north to northeast (Cooper et al., 1997). This alliance is thought to be found in relatively undisturbed sites (Hansen et al., 1996), while more disturbed sites are dominated by Kentucky bluegrass (*Poa pratensis*), fowl bluegrass (*Poa palustris*), redtop (*Agrostis stolonifera*) and Baltic rush (*Juncus balticus*).

In southwestern Montana, wet meadow communities are dominated by species more characteristic of the Middle Rocky Mountains ecoregion, such as Holm's Rocky Mountain sedge (*Carex scopulorum*, Cooper et al, 1999). Drier sites, especially those where soils and/or hydrology have been disturbed, may be characterized by Baltic rush and clustered field sedge communities (*Juncus balticus-Carex praegracilis).* In the Northern Rocky Mountains, shortstalk sedge (*Carex podocarpa*) or Payson's sedge (*Carex paysonis*) are dominant (Lesica, 2002), often found on slopes that range from zero to eight percent where the growing season lasts only for one to two months. In these northern occurrences, other common graminoids include small-head sedge (*Carex illota*), lens sedge (*Carex lenticularis*), smallwing sedge (*Carex microptera*), black alpine sedge (*Carex nigricans*), beaked sedge (*Carex utriculata*), Drummond's rush (*Juncus drummondii*), Merten's rush (*Juncus mertensianus*), arctic bluegrass (*Poa arctica*), and alpine bluegrass (*Poa alpina*). Common forbs include woolly pussytoes (*Antennaria lanata*), spreading globeflower (*Trollius laxus*), slender-sepal marsh marigold (*Caltha leptosepala*), arrow-leaf groundsel (*Senecio triangularis*), elephant's head (*Pedicularis groenlandica*), small flowered anemone (*Anemone parviflora*), alpine bistort (*Polygonum viviparum*), Buek's groundsel (*Packera subnuda*), and Rocky Mountain goldenrod *(Solidago multiradiata*). Sibbaldia (*Sibbaldia procumbens*) often occurs in open areas within the turf or open peat. At more montane elevations, extensive shrubby cinquefoil (*Dasiphora fruticosa*) shrublands are frequently found adjacent to this system.

Thirty-five plant alliances have been described for this system in Montana. These include:

- *Betula nana* Seasonally Flooded Shrubland Alliance
- *Calamagrostis canadensis* Seasonally Flooded Herbaceous Alliance
- *Calamagrostis stricta* Temporarily Flooded Herbaceous Alliance
- *Caltha leptosepala* Saturated Herbaceous Alliance
- *Carex (lachenalii, capillaris, illota*) Seasonally Flooded Herbaceous Alliance
- *Carex (rostrata, utriculata*) Seasonally Flooded Herbaceous Alliance
- *Carex aperta* Saturated Herbaceous Alliance
- *Carex aquatilis* Seasonally Flooded Herbaceous Alliance
- *Carex nebrascensis* Seasonally Flooded Herbaceous Alliance
- *Carex nigricans* Seasonally Flooded Herbaceous Alliance
- *Carex pellita* Seasonally Flooded Herbaceous Alliance
- *Carex praegracilis* Seasonally Flooded Herbaceous Alliance
- *Carex saxatilis* Temporarily Flooded Herbaceous Alliance
- *Carex scopulorum* Seasonally Flooded Herbaceous Alliance
- *Carex simulata* Saturated Herbaceous Alliance
- *Carex spectabilis* Herbaceous Alliance
- *Carex vesicaria* Seasonally Flooded Herbaceous Alliance
- *Dasiphora fruticosa* Temporarily Flooded Shrubland Alliance
- *Deschampsia caespitosa* Saturated Herbaceous Alliance
- *Deschampsia caespitosa* Seasonally Flooded Herbaceous Alliance
- D*eschampsia caespitosa* Temporarily Flooded Herbaceous Alliance
- *Eleocharis (palustris, macrostachya*) Seasonally Flooded Herbaceous Alliance
- *Equisetum fluviatile* Semi-permanently Flooded Herbaceous Alliance
- *Geum rossii* Herbaceous Alliance
- *Glyceria (grandis, striata*) Seasonally Flooded Herbaceous Alliance
- *Glyceria borealis* Semi-permanently Flooded Herbaceous Alliance
- *Heracleum maximum* Temporarily Flooded Herbaceous Alliance
- *Juncus balticus* Seasonally Flooded Herbaceous Alliance
- *Juncus drummondii* Herbaceous Alliance
- *Juncus parryi* Herbaceous Alliance
- *Poa palustris* Semi-natural Seasonally Flooded Herbaceous Alliance
- *Senecio triangularis* Temporarily Flooded Herbaceous Alliance
- *Trollius laxus* Saturated Herbaceous Alliance
- *Valeriana sitchensis* Herbaceous Alliance

Dynamics: Communities associated with this ecological system are adapted to soils that may be flooded or saturated throughout the growing season. They may also occur on areas with soils that are only saturated early in the growing season, or intermittently during heavy convective storms in summer. Most appear to be relatively stable types, although in some areas these may be impacted by intensive livestock grazing.

Range: This system is found throughout the Rocky Mountains and Intermountain West regions, ranging in elevation from montane to alpine (1000-3600 m). In Montana, high-elevation wetlands are found in the colder and wetter mountains of the Beartooth-Absaroka range and in northwestern Montana.

Cowardin Wetland Classification:
System: Palustrine
Class: Emergent Wetland
Subclass: Persistent
Water regime: Seasonally, temporarily, or intermittently flooded, or (less commonly), saturated.

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Rocky Mountain Subalpine-Montane Riparian Shrubland Ecological System Description for the state of Colorado NatureServe Identifier: CES306.832

Summary: This riparian system is a seasonally flooded shrubland found at montane to subalpine elevations in Colorado (2,280–3,410 m or 7,500–11,200 ft). These are short to tall willow, or occasionally birch, alder, or other shrub dominated communities of subalpine and montane lower order streams and slopes. Community structure is variable, and may appear as narrow to wide bands of shrub vegetation lining streambanks and alluvial terraces, or as extensive carrs (willow shrublands) of valley bottoms and slopes. These shrublands are typical of ex-glaciated valleys of higher elevations in Colorado. At subalpine elevations (above 9,000 ft), short shrub communities dominated by planeleaf willow (*Salix planifolia*), barrenground willow (*Salix brachycarpa*), Wolf's willow (*Salix wolfii*), or bog birch (*Betula nana*) are characteristic and widespread throughout the mountain ranges of the southern Rockies. With the transition to montane zone elevations, taller willows and shrubs become dominant. Drummond willow (*Salix drummondiana*) is found at low subalpine to upper montane elevations, while Geyer's willow (*Salix geyeriana*) and/or mountain willow (*Salix monticola*) dominate a broad variety of associations ranging from the mid subalpine to lower montane zones. In the lower montane, non-willow tall shrubs such as thinleaf alder (*Alnus tenuifolia*), water birch (*Betula occidentalis*), red-osier dogwood (*Cornus sericea*), and tall-willow species including Bebb willow (*Salix bebbiana*), strapleaf willow (*S. liguifolia*), and shining willow (*S. lucida*) may dominate associations within this system. The herbaceous layer may be graminoid or forb dominated, and include many of the species that are also common in riparian forests and woodlands of similar elevations.

Environment: This riparian system consists of seasonally flooded shrublands found at montane to subalpine elevations of the Rocky Mountains. In Colorado, this system typically occurs at elevations between 2,280–3,410 meters (7,500–11,200 feet). This system can occur as narrow to wide bands of shrub vegetation lining streambanks and alluvial terraces, or as extensive carrs (willow shrublands) of valley bottoms and slopes. The distribution of this systems in Colorado has been greatly influenced by the history of glaciation in the Southern Rocky Mountains. Many high elevation river valleys (known locally as "parks") experienced glaciation during the Pleistocene; terminal moraines extend to about 2,550 m in the north and 3,000 m in the southern part of the region (Baker 1987, 1989; Windell et al. 1986). High elevation streams of the glaciated (U-shaped) valleys are low-gradient and typically dominated by riparian shrublands. Though most commonly associated with distinct riparian corridors, this system can also occur as dense, low shrublands on broad, open slopes in the subalpine and alpine. In these instances, the shrub wetlands are fed by snowmelt and groundwater discharge that eventually accumulates into channelized flow downslope, forming the very headwaters of mountain streams.

Alluvial soils within riparian shrublands are of variable thickness and texture and often exhibit redoximorphic features such as mottling and gleying, indicating a fluctuating water table. Organic matter is also of variable thickness and the depth and degree of decomposition varies according to the stability of the water table, quality of detritus, and soil temperatures. However, shrub wetlands with 40 cm or greater organic matter accumulations are indicative of permanent saturation from groundwater input and not fluvial processes and should be classified as Rocky Mountain Subalpine-Montane Fens.

Vegetation: These are short to tall willow, or occasionally birch, alder, or other shrub dominated communities of subalpine and montane lower order streams and slopes. The structure of vegetative communities in these systems varies depending on latitude, elevation and climate. At subalpine elevations (above 9,000 ft), short shrub communities dominated by planeleaf willow (*Salix planifolia*), barrenground willow (*Salix brachycarpa*), wolf willow (*Salix wolfii*), or bog birch (*Betula nana*) are characteristic and widespread throughout the mountain ranges of the southern Rockies. Instances of these short shrub communities with greater than 40 cm of organic matter accumulation are equally as common as mineral soil occurrences, but belong to the Rocky Mountain Subalpine-Montane Fen system. With the transition to lower, montane zone elevations, taller willows and shrubs become dominant. Drummond willow (*Salix drummondiana*) is found at low subalpine to upper montane elevations, while Geyer's willow (*Salix *geyeriana*) and/or mountain willow (*Salix monticola*) dominate a broad variety of associations ranging from the mid subalpine to lower montane zones. In the lower montane, non-willow tall shrubs such as thinleaf alder (*Alnus tenuifolia*), water birch (*Betula occidentalis*), red-osier dogwood (Cornus sericea), and tall-willow species including Bebb willow (*Salix bebbiana*), strapleaf willow (*S. liguifolia*), and shining willow (*S. lucida*) may dominate associations within this system, or, at even lower elevations, belong to the Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland system.

The herbaceous layer may be graminoid or forb dominated, and include many of the species that are also common in riparian forests and woodlands of similar elevations. Wet meadow or emergent marsh community types may occur as inclusions in this system. Common graminoids include water sedge (*Carex aquatilis*), beaked sedge (*C. utriculata*), smallwing sedge (*C. microptera*), woolly sedge (*C. pellita*), fowl mannagrass (*Glyceria striata*), bluejoint reedgrass (*Calamagrostis canadensis*), smallflowered woodrush (*Luzula parviflora*), mountain rush (*Juncus balticus* var. *montanus*), slimstem reedgrass (*Calamagrostis stricta*), tufted hairgrass (*Deschampsia cespitosa*), American mannagrass (*Glyceria grandis*), and rough bentgrass (*Agrostis scabra*). Common forbs include Jacob's ladder (*Polemonium* sp.), tall fringed bluebells (*Mertensia ciliata*), willowherb (*Epilobium* sp.), common cowparsnip (*Heracleum maximum*), starry false lily of the valley (*Maianthemum stellatum*), bluntseed sweetroot (*Osmorhiza depauperata*), angelica (*Angelica* spp.), monkshood (*Aconitum columbianum*), Parry's clover (*Trifolium parryi*), American bistort (*Polygonum bistortoides*), alpine bistort (*P. viviparum*), heartleaf bittercress (*Cardamine cordifolia*), Fendler's meadow-rue (*Thalictrum fendleri*), marsh marigold (*Caltha leptosepala*), elephanthead lousewort (*Pedicularis groenlandica*), Rocky Mountain hemlock parsley (*Conioselinum scopulorum*), Porter's licorice root (*Ligusticum porteri*), alpine meadow-rue (*Thalictrum alpinum*), common yarrow (*Achillea millefolium*), American vetch (*Vicia americana*), Richardson's geranium (*Geranium richardsonii*), arrowleaf ragwort (*Senecio triangularis*), Fendler's cowbane (*Oxypolis fendleri*), Virginia strawberry (*Fragaria virginiana*), largeleaf avens (*Geum macrophyllum*), Fendler's waterleaf (*Hydrophyllum fendleri*), brook saxifrage (*Saxifraga odontoloma*), subalpine larkspur (*Delphinium barbeyi*), bedstraw (*Galium* spp.), field horsetail (*Equisetum arvense*), scouringrush horsetail (*Equisetum hyemale*), and felwort (*Swertia perennis*).

Nineteen plant alliances have been described for these systems in Colorado. These include:

- *Alnus incana* Seasonally Flooded Shrubland Alliance
- *Alnus incana* Temporarily Flooded Shrubland Alliance
- *Betula nana* Seasonally Flooded Shrubland Alliance
- *Betula occidentalis* Seasonally Flooded Shrubland Alliance
- *Betula occidentalis* Temporarily Flooded Shrubland Alliance
- *Cornus sericea* Temporarily Flooded Shrubland Alliance
- *Dasiphora fruticosa* Temporarily Flooded Shrubland Alliance
- *Salix bebbiana* Temporarily Flooded Shrubland Alliance
- *Salix boothii* Temporarily Flooded Shrubland Alliance
- *Salix brachycarpa* Seasonally Flooded Shrubland Alliance
- *Salix drummondiana* Temporarily Flooded Shrubland Alliance
- *Salix geyeriana* Seasonally Flooded Shrubland Alliance
- *Salix geyeriana* Temporarily Flooded Shrubland Alliance
- *Salix ligulifolia* Temporarily Flooded Shrubland Alliance
- *Salix monticola* Temporarily Flooded Shrubland Alliance
- Salix planifolia Seasonally Flooded Shrubland Alliance
- Salix planifolia Temporarily Flooded Shrubland Alliance
- Salix wolfii Seasonally Flooded Shrubland Alliance
- Salix wolfii Temporarily Flooded Shrubland Alliance

Dynamics: Riparian shrubland development is driven by the magnitude and frequency of flooding, valley and substrate type, and beaver activity. Seasonal and episodic flooding erodes and deposits sediment resulting in complex patterns of soil development that exerts a strong influence on the distribution of riparian vegetation (Gregory et al. 1991; Poff et al. 1997). Bare alluvium provides suitable substrate for the germination of willow seedlings and is a critical patch type for continued regeneration of riparian shrublands (Poff et al. 1997;

Woods 2001). Valley geomorphology and substrate dictate the types of riparian shrublands which typically develop. For example, thinleaf alder (*Alnus incana*), Drummonds willow (*Salix drummondiana*), and red-osier dogwood (*Cornus sericea*) are often dominant shrublands on steep and/or gravelly streams whereas a variety of willows (*Salix* sp.) occupy more gently sloped streams with finer sediment or peat substrates. However, riparian shrublands in the Southern Rocky Mountains are most commonly found in wide glaciated valleys or open parks where they often occupy a substantial portion of the valley floor.

Beaver have historically been an important hydrogeomorphic driver of Rocky Mountain Subalpine-Montane Riparian Shrublands. The activities of beaver create a heterogeneous complex of wet meadows, marshes and riparian shrublands and increases species richness on the landscape. The continuing consequences of wholesale removal of beaver from many streams during the height of the fur trade are evident, but largely unquantified.

Community composition is also influenced by land use. In sites where there is prolonged disturbance, willow coverage will decrease resulting in a more open canopy. Herbaceous vegetation is likely to include more non-native species such as Kentucky bluegrass (*Poa pratensis*) and timothy (*Phleum pratense*) as well as exotics species common to other wetland types such as Canada thistle (*Cirsium arvense*) and dandelion (*Taraxacum officinale*). Native increasers such as mountain rush (*Juncus arcticus*), tufted hairgrass (*Deschampsia cespitosa*), and shrubby cinquefoil (*Dasiphora floribunda*) often invade shrublands that have been artificially drained (Cooper 1990; Johnson 1996). Although these species are native, they can be indicative of disturbance if they dominate areas previously occupied by willows and sedges.

Range: This system is found throughout the Rocky Mountain cordillera from New Mexico north into Montana. In Colorado, this system is found throughout the Rocky Mountains at elevations between 2,280–3,410 meters (7,500–11,200 feet).

Cowardin Wetland Classification:

System: Palustrine
Class: Scrub Shrub
Subclass: Broadleaved deciduous
Water regime: Temporarily to seasonally flooded

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Rocky Mountain Subalpine-Montane Riparian Shrubland Ecological System Description for the state of Montana Natureserve Identifier: CES306.832

Summary: This riparian system is a seasonally flooded shrubland found at montane to subalpine elevations of the Rocky Mountains. Shrubs dominate this system, with total shrub cover from 20 to 100 percent. Tree cover is less than 15 percent, and shrubs dominate over the herbaceous species. This system consists of narrow bands of shrub vegetation lining streambanks and alluvial terraces in narrow to wide, low-gradient valley bottoms and floodplains with sinuous stream channels. Floristically similar communities area also found around seeps, fens, and isolated springs on hillslopes away from valley bottoms. Along the low-order streams most commonly associated with this system, high-energy flow events are common, driven by thunderstorms, rain-on-snow events, or rapid snowmelt. Flooding from these events constantly creates and destroys sites for the establishment of vegetation , by eroding, transporting and depositing coarse sediment (Melanson and Butler, 1991). Sediments create gravel bars at or near the surface of the river, where vegetation colonizes. Over time, this creates bands of mixed vegetation representing different stages of succession (Melanson and Butler, 1991). In both streambank and hillslope systems, ground water seepage from snowmelt may create shallow water tables or seeps that vegetation depends on for a portion of the growing season.

This system often occurs as a mosaic of multiple shrub and herbaceous communities. The structure of vegetation communities in these systems can vary depending on latitude, elevation and climate. In Montana, these systems are usually dominated by willows, including Drummond willow (*Salix drummondiana*), Bebb willow (*Salix bebbiana*), planeleaf willow (*Salix planifolia* ssp. *planifolia*), undergreen willow (*Salix commutata*), Idaho willow (*Salix wolfii*), Booth willow (*Salix boothi*) and Geyer's willow (*Salix geyeriana*). Typical herbaceous vegetation found in the understory includes beaked sedge (*Carex utriuculata*), bluejoint reedgrass (*Calamagrostis canadensis*), and northern reedgrass (*Calamagrostis stricta*). Generally, the upland vegetation surrounding these riparian systems are conifer-dominated forests. Shrubland riparian systems are functionally important for bank stabilization, for providing organic inputs to the adjacent stream, and for their shade cover and wildlife habitat values.

Environment: This riparian system is a seasonally flooded shrubland found at montane to subalpine elevations of the Rocky Mountains. In Montana, this system typically occurs at elevations between 1,750 to 2,693 meters (5,740 to 8,830 feet). This system consists of narrow bands of shrub vegetation lining streambanks and alluvial terraces in narrow to wide, low-gradient valley bottoms and floodplains with sinuous stream channels. This system is also typical around seeps, fens, and isolated springs on hillslopes away from valley bottoms.

Vegetation: The structure of vegetative communities in these systems varies depending on latitude, elevation and climate. For example, in southwest Montana, Drummond willow (*Salix drummondiana*) occupies higher elevations while Geyer's willow (*Salix geyeriana*) and Booth willow (*Salix boothi*) are found at more intermediate elevations. In the northwest region of Montana, Geyer's and Booth willow are barely present and Drummond's willow dominates most riparian areas (Hansen et al, 1995). Bebb willow (*Salix bebbiana*), planeleaf willow (*Salix planifolia* ssp.*planifolia*), undergreen willow (*Salix commutata*) and Idaho willow (*Salix wolfii*) are frequent associates. Barclay's willow (*Salix barclayi*), shortfruit willow (*Salix brachycarpa*) and grayleaf willow (*Salix glauca*) become common at higher subalpine elevations. Sageleaf willow (*Salix candida*) is indicative of fens and occurs in association with other willow species to form the shrub dominated carr layers within fen systems. Water birch (*Betula occidentalis*) or resin birch (*Betula glandulosa*) may also be present within these shrublands.

The dominant graminoid vegetation in the herbaceous stratum of these shrubland riparian systems includes bluejoint reedgrass (*Calamagrostis canadensis*), northern reedgrass (*Calamagrostis stricta*) and beaked sedge (*Carex utriculata*). Common forbs include dwarf fireweed (*Chamerion latifolium*), field mint (*Mentha arvensis*), glaucous willowherb (*Epilobium glaberrimum*), western mountain aster (*Symphyotrichum* *spathulatum*), and tiny trumpets (*Collomia linearis*). Sharptooth angelica (*Angelica arguta*), starry solomon's seal (*Maianthemum stellatum*), sweet-cicely (*Osmorhiza* species), common cowparsnip (*Heracleum maximum*), clasp-leaf twistedstalk (*Streptopus amplexifolius*) and green false hellebore (*Veratrum viride*) are frequent at higher elevations. When these systems occur in conjunction with rich fen-carr shrublands, graminoid and forb species diversity will be much higher.

Flooding in these systems influences plant communities by transporting sediments and creating colonization sites. Many plants in these high-energy systems have developed adaptive traits to withstand flooding, notably flexible, resilient stems and specialized oxygen-holding cells. Similarly, many have reproductive adaptations like water-dispersed seeds and the ability to sprout quickly from damaged stumps.

Community composition is also influenced by land use. Sites that are overly browsed will become dominated by Bebb willow (*Salix bebbiana*), a shrub that is more resilient to heavy grazing. In sites where there is prolonged disturbance, willow coverage will decrease resulting in a more open canopy. Herbaceous vegetation will transition to a grass dominated system including fowl bluegrass (*Poa palustris*), Kentucky bluegrass (*Poa pratensis*) and field horsetail (*Equisetum arvense*).

Twenty-five plant alliances have been described for these systems in Montana. These include:

- *Acer glabrum* Temporarily Flooded Shrubland Alliance
- *Alnus incana* Seasonally Flooded Shrubland Alliance
- *Alnus incana* Temporarily Flooded Shrubland Alliance
- *Alnus viridis* ssp. *sinuata* Temporarily Flooded Shrubland Alliance
- *Betula nana* Seasonally Flooded Shrubland Alliance
- *Betula occidentalis* Seasonally Flooded Shrubland Alliance
- *Betula occidentalis* Temporarily Flooded Shrubland Alliance
- *Cornus sericea* Temporarily Flooded Shrubland Alliance
- *Dasiphora fruticosa* Temporarily Flooded Shrubland Alliance
- *Salix bebbiana* Temporarily Flooded Shrubland Alliance
- *Salix boothii* Seasonally Flooded Shrubland Alliance
- *Salix boothii* Temporarily Flooded Shrubland Alliance
- *Salix candida* Seasonally Flooded Shrubland Alliance
- *Salix commutata* Seasonally Flooded Shrubland Alliance
- *Salix drummondiana* Seasonally Flooded Shrubland Alliance
- *Salix drummondiana* Temporarily Flooded Shrubland Alliance
- *Salix geyeriana* Seasonally Flooded Shrubland Alliance
- *Salix geyeriana* Temporarily Flooded Shrubland Alliance
- *Salix glauca* Temporarily Flooded Shrubland Alliance
- *Salix lucida* Temporarily Flooded Shrubland Alliance
- *Salix lutea* Seasonally Flooded Shrubland Alliance
- *Salix lutea* Temporarily Flooded Shrubland Alliance
- *Salix planifolia* Seasonally Flooded Shrubland Alliance
- *Salix wolfii* Seasonally Flooded Shrubland Alliance
- *Salix wolfii* Temporarily Flooded Shrubland Alliance

Dynamics: Stochastic flood events and variable fluvial conditions are crucial to the development of establishment sites for riparian plants as well as acting as a primary control on plant succession. Steep gradients and high-energy flows controlled by precipitation and hydrological events lead to flood-driven transportation of coarse sediments. The alternating scouring and deposition of sediments constantly creates and destroys plant habitat (Melanson and Butler, 1991). Over time, this creates bands of mixed vegetation representing different stages of succession (Melanson and Butler, 1991**).** Increasing vegetation traps even more sediment so that the size and height of the gravel bar increases (Melanson and butler, 1990). Eventually, the gravel bar will be sufficiently achored by vegetation to withstand or deflect flood flows, directing the force of the water at the opposite banks, where erosion of sediments will occur.

Range: This system is found throughout the Rocky Mountain cordillera from New Mexico north into Montana. In Montana, this system is found throughout the Rocky Mountains at elevations between 1,750 to 2,693 meters (5,740 to 8,830 feet). This system also occurs in the isolated island mountain ranges of central and eastern Montana and in mountainous areas of the Intermountain West.

Cowardin Wetland Classification:
System: Palustrine
Class: Scrub Shrub
Subclass: Broadleaved deciduous
Water regime: Temporarily to seasonally flooded

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Rocky Mountain Subalpine-Montane Fen
Ecological System Description for the state of Montana
Natureserve Identifier: CES306.831

Summary: Subalpine-montane fens occur infrequently throughout the Rocky Mountains from Colorado north into Canada. They are confined to specific environments defined by groundwater discharge, soil chemistry, and peat accumulation. This system includes poor fens, rich fens and extremely rich fens. Fens form at low points in the landscape or near slopes where groundwater intercepts the soil surface. Groundwater inflows maintain a fairly constant water level year-round, with water at or near the surface most of the time. Constant high water levels lead to accumulation of organic material. In addition to peat accumulation and perennially saturated soils, the extremely rich and iron fens have distinct soil and water chemistry, with high levels of one or more minerals such as calcium, magnesium, or iron.

Fens are among the most floristically diverse of all wetland types, supporting a large number of rare and uncommon bryophytes and vascular plant species, as well as providing habitat for uncommon mammals, mollusks and insects. In Montana, 17 vascular plant species of concern inhabit fens. Many more uncommon plant species are also confined to fens. Fens also help maintain stream water quality through denitrification and phosphorus absorption

Fens usually occur as a mosaic of several plant associations dominated by sedges (*Carex* species), spikerushes (*Eleocharis* species), and rushes (*Juncus* species). Bryophyte diversity is generally high and includes sphagnum (*Sphagnum* species). In rich and extremely rich fens, forb diversity is equally high, often supporting many species of orchids such as bog orchid species (*Plantanthera* species), giant helleborine orchid (*Epipactis gigantea*), one leaf orchid (*Ameorchis rotundifolia*), sparrow's egg ladyslipper (*Cypripedium passerinum*) and small yellow ladyslipper (*Cypripedium parviflorum*). Buckbean (*Menyanthes trifoliata*), beautiful shooting-star (*Dodecatheon pulcherrinum*), elephant head (*Pedicularis groenlandica*), arrow-grass (*Triglochin palustris*), and Siberian chives (*Allium schoenoprasum*) are commonly represented in rich and extremely rich fens. The surrounding landscape may be ringed with other wetland systems, e.g., riparian shrublands known as carrs, or a variety of upland systems from grasslands to wet forests or forest swamps. Riparian carr shrublands, dominated by willow and bog birch (*Salix* species-*Betula nana*) are usually present. In Montana, sage leaf willow (*Salix candida*) is indicative of the carr environment within a fen. Fens are found in scattered locations in the western Great Plains along the Rocky Mountain Front, in the Rocky Mountains and the small isolated central mountain ranges, and at higher elevations on the Beartooth Plateau in the southern portion of the state.

Environment: The montane-subalpine fen ecological system is a small-patch system comprised of mountain wetlands that support a unique ecology of rare plants not found in other types of wetlands. These fens are confined to specific environments defined by groundwater discharge, soil chemistry, and peat accumulation of at least 40 cm. However, peat accumulations in areas overlain by gravel, cobble or bedrock may be less than 40 cm. Fens form at low points in the landscape or near slopes where groundwater intercepts the soil surface. Groundwater inflows maintain a fairly constant water level year-round, with water at or near the surface most of the time. Constant high water levels lead to accumulations of organic material. Rich and extremely rich fens are found in areas underlain by limestone. Water chemistry ranges from only slightly acidic to alkaline and is usually distinctly calcareous. Marl deposits (precipitated calcium carbonates) are common in these systems. Tufa deposits or terraces can be seen in some rich fens and are composed of virtually pure calcium carbonate at the soil surface, formed by continuous discharge and evaporation of calcite saturated groundwater. In northwestern Montana, pH values usually range from 5.9 to 8.4 (Chadde et al., 1998). Poor fens are more common in the northern Rocky Mountains and occur in areas overlain by non-calcareous bedrock such as argillites and granite. These are usually flat, acidic, and saturated to the surface, sometimes with standing water.

Fens develop sucessionally through lake-filling, flow-through succession or paludification. Lake filling occurs in depressions and is often characterized by the presence of floating mats and a ring of carr vegetation on the out margin of the peatland. Flow-through fens are the most common in the northern Rocky Mountains. They occur along streams, slopes and benches with a constant inflow and outflow of calcium-rich water. They are characterized by a series of linear hummocks oriented perpendicular to the slope. Carr shrubland is well developed in flow-through fens due to well-aerated, nutrient-rich water near the inflow and outflow zones.. Usually there is an open, nutrient- poor community in the central portion of the fen. Paludification occurs when fens expand due to a rise in the water table caused by peat accumulation. This process is most often observed near seeps and springs or adjacent to closed basin peatlands where peat accumulation causes wetter conditions along the outer edges. Higher water tables kill existing trees. In the northern Rocky Mountains, this sucessional process is limited due to prolonged summer droughts; however it may be seen in some fen systems at higher elevations.

In northwestern Montana, fens occur at montane to subalpine elevations, generally ranging from 762 to 1,676 m (2,500-5,500 feet), and are characterized by mosaics of plant communities. In southern Montana, subalpine and alpine fens potentially occur at higher elevations (Heidel and Rodemaker 2008). These communities typically occur in seeps and wet sub-irrigated meadows in narrow to broad valley bottoms. Surface topography is typically smooth to concave with lake-fill peatlands or with slopes ranging from 0 to 10 percent in flow-through fens. Soils within this system are organic histosols with 40 cm or more of organic material if overlying a mineral soil. Organic histosols may be any depth, however, if overlying bedrock, cobbles or gravels. Histosols range in texture from clayey-skeletal to loamy-skeletal and fine-loams.

Vegetation:
Floristically, rich and extremely rich fens are the most diverse of all peatland types in the Rocky Mountains. Extremely rich fens are characterized by high species diversity and a mosaic of plant communities. In contrast, poor fens have scattered vascular plant cover but are characterized by a nearly continuous cover of mosses.

The sedge layer is often dominated by beaked sedges (*Carex utriculata* or *Carex rostrata*), water sedge (*Carex aquatilis*), mud sedge (*Carex limosa*), woolyfruit sedge (*Carex lasiocarpa*), spikerush (*Eleocharis species*) cottongrass (*Eriophorum species*), rushes (*Scirpus* species and *Trichophorum* species) and bulrushes (*Shoenoplectus* species). Other species include Buxbaum's sedge (*Carex buxbaumii*), northern bog sedge (*Carex gynocrates*), bristly-stalked sedge (*Carex leptalea*), pale sedge (*Carex livida*), poor sedge (*Carex paupercula*), yellow sedge (*Carex flava*), hair sedge (*Carex capillaris*), silvery sedge (*Carex canescens*), lens sedge (*Carex lenticularis*), Baltic rush (*Juncus balticus*), northern rush (*Juncus alpino-articulatus*), dagger leaf rush (*Juncus ensifolius*), threadleaf rush (*Juncus filiformis*), common spike rush (*Eleocharis palustris*), few flowered spike rush (*Eleocharis pauciflora*), simple bog sedge (*Kobresia simpliciuscula*), tufted clubrush (*Trichophorum pumilum*), alpine clubrush (*Trichophorum alpinum*), green keeled cottongrass (*Eriophorum viridicarinatum*), and slender cottongrass (*Eriophorum gracile*). Three-way sedge (*Dulichium arundinaceum*), flatstem spikerush (*Eleocharis tenuis*), and beaked spikerush (*Eleocharis rostellata*) are found west of the Continental Divide. Common grasses include bluejoint reedgrass (*Calamagrostis canadensis*), tufted hairgrass (*Deschampsia cespitosa*), and fringed brome (*Bromus ciliatus*).

Common forbs within the open, sedge-dominated fen community include showy pussytoes (*Antenarria pulcherrima*), bog orchid (*Plantanthera* species), buckbean (*Menyanthes trifoliata*), elegant death camas (*Zigadenus elegans*), grass-of-parnassus (*Parnassia* species), beautiful shooting-star (*Dodecatheon pulcherrinum*) elephant head (*Pedicularis groenlandica*), arrow-grass (*Triglochin palustris*), and Siberian chives (*Allium schoenoprasum*). At subalpine elevations, common butterwort (*Pinguicula vulgaris*) often occurs near seeps or springs, in areas where there is marl accumulation or on tufa deposits or terraces.

Many species of concern or uncommon species are indicators of fen systems. Northern bog violet (*Viola nephrophylla*) is a common forb fen indicator throughout Montana. West of the Continental Divide, Kalm's lobelia (*Lobelia kalmii*) and bulblet-bearing water hemlock (*Cicuta bulbifera*) are found exclusively in fens. In Montana, yellow widelip orchid (*Liparis loeselii*) is found exclusively in fens. Other orchids such as giant helleborine orchid (*Epipactis gigantea*) are found in open sedge-dominated portions of the fen system, while one leaf orchid (*Ameorchis rotundifolia*), sparrow's egg ladyslipper (*Cypripedium passerinum*) and small yellow ladyslipper (*Cypripedium parviflorum*) occur on raised sphagnum hummocks that form around trees and shrubs near the perimeter of the fen. These species are found almost exclusively in fens or forest habitats bordering fens.

In Montana, wet, floating *Sphagnum*-dominated mats are associated with open water edges or depressional areas of fen systems. Bryophyte floating mats consist of *Meesia triquetra* and *Scorpidium* species, and Magellan's peatmoss (*Sphagnum magellanicum*) and brown peatmoss (*Sphagnum fuscum*). The bryophyte floating mat supports a very minor component of sedges such as mud sedge (*Carex limosa*), and small sedges such as grape sedge (*Carex aurea*), softleaf sedge (*Carex disperma*), inland sedge (*Carex interior*) and cottongrass species (*Eriophorum* species). Species of concern and fen indicators such as pale laurel (*Kalmia polifolia*), rannoch rush (*Scheuchzeria palustris*) and sundews (*Drosera* species) occur on these floating mats. Buckbean (*Menyanthes trifoliata*) is a late seral species from the sedge mat phase and is often present on these floating mats.

Fens are frequently bordered by willow-bog birch (*Salix* species-*Betula nana*) dominated carrs. Carr shrubland is well developed in flow-through fens due to well-aerated nutrient-rich water near the inflow and outflow zones or the perimeter of basin fens. Sageleaf willow (*Salix candida)* is an indicator species, and sometimes the dominant willow species, especially in prairie fens. Other willow species include Bebb's willow (*Salix bebbiana*), Drummond's willow (*Salix drummondiana*), plane-leaf willow (*Salix planifolia*), wolf willow (*Salix wolfii*), and undergreen willow (*Salix commutata*) in the subalpine systems. Autumn willow (*Salix serrissima*) is found in fen-carr shrublands east of the Continental Divide near the Canadian border. Other common carr shrubs include alder (*Alnus* species), alder buckthorn (*Rhamnus alnifolia*), shrubby cinquefoil (*Dasiphora fruticosa*), and western Labrador tea (*Ledum glandulosum*). Engelmann spruce (*Picea engelmannii*) is the frequent conifer species associated with fens and forested fen margins of these systems (Hansen and others, 1996).

Associations: *Carex utriculata* Herbaceous Vegetation, *Carex lasiocarpa* Herbaceous Vegetation, *Carex limosa* Herbaceous Vegetation, *Carex simulata* Herbaceous Vegetation, *Carex utriculata* Perched Wetland Herbaceous Vegetation, *Betula nana / Carex* spp. Shrubland, *Salix candida / Carex utriculata* Shrubland

Ten plant alliances have been described for these systems in Montana. These include:

- *Betula nana* Seasonally Flooded Shrubland Alliance (A.995)
- *Carex (rostrata, utriculata)* Seasonally Flooded Herbaceous Alliance (A.1403)
- *Carex aquatilis* Seasonally Flooded Herbaceous Alliance (A.1404)
- *Carex buxbaumii* Seasonally Flooded Herbaceous Alliance (A.1413)
- *Carex lasiocarpa* Seasonally Flooded Herbaceous Alliance (A.1415)
- *Carex limosa* Seasonally Flooded Herbaceous Alliance (A.1416)
- *Carex simulata* Saturated Herbaceous Alliance (A.1469)
- *Dulichium arundinaceum* Seasonally Flooded Herbaceous Alliance (A.1398)
- *Salix candida* Seasonally Flooded Alliance (A.1002)

Species of Concern associated with this system: One leaf orchid (*Ameorchis rotundifolia*), creeping sedge (*Carex chordorrhiza*), beaked sedge (*Carex rostrata*), English sundew (*Drosera angelica*), linear leaf sundew (*Drosera linearis*), crested woodfern (*Dryopteris cristata*), beaked spikerush (*Eleocharis rostellata*), giant helleborine orchid (*Epipactis gigantea*), Macoun's fringed gentian (*Gentianopsis macounii*), hiker's gentian (*Gentianopsis simplexi*), slender cottongrass (*Eriophorum gracile*), pale laurel (*Kalmia polifolia*), simple bog sedge (*Kobresia simpliciuscula*), yellow widelip orchid (*Liparis loeselii*), autumn willow (*Salix serrisissima*), bluntleaf pondweed (*Potamogeton obtusifolius*), rannoch rush (*Scheuchzeria palustris*), tufted rush (*Trichophorum cespitosum*), lesser bladderwort (*Utricularia minor*).

Dynamics: Mountain fens act as natural filters, cleaning ground and surface water. Fens also act as sponges by absorbing heavy precipitation, then slowly releasing it downstream, minimizing erosion and recharging groundwater systems. The persistent groundwater and cold temperatures allow organic matter to accumulate (forming peat),which allows classification of wetlands within this system as fens. Peat accumulates at the rate of 8 to 11 inches per 1000 years, making peatlands a repository of 10,000 years of post-glacial history.

Range: This system occurs infrequently throughout the Rocky Mountains from Colorado north into Canada. In Montana, small fens are found in scattered locations in the plains and the small isolated mountain ranges of the central part of the state. The Swan, Stillwater and Flathead valleys have numerous rich and extremely rich fen systems due to the prevalence of limestone bedrock in the Whitefish, Mission, and Swan mountain ranges. Similarly, rich and extremely rich fens are found along the limestone-rich Front Range east of the Continental Divide. East of the Continental Divide, both small (20 acres or less) and a few large rich and extremely rich prairie fens occur on the extreme western Great Plains bordering the Rocky Mountain Front. Further south in western Montana, poor fen systems are more common in the Bitterroot, Lolo, and Beaverhead ranges. Similarly, poor fens are found in the granitic, isolated central Montana island ranges and the Beartooth plateau in southern Montana.

Isolated Wetland: Partially to completely isolated

Cowardin Wetland Classification:

System: Palustrine
Class: Emergent
Water regime: Saturated

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APPENDIX C: National Wetland Inventory Classification
Modified from Cowardin *et al.* 1979

Cowardin System:

Palustrine (P): All wetlands sampled within the REMAP project will fall under the Palustrine Cowardin System because they are vegetated. This system includes all wetlands dominated by trees, shrubs, and emergent, herbaceous vegetation. Wetlands lacking vegetation are also included in this system if they are less than 8 hectares (20 acres) and have a depth less than 2 meters (6.6 feet) in the deepest portion of the wetland.

Cowardin Classes:

Aquatic Bed (AB): Wetlands with vegetation that grows on or below the water surface for most of the growing season.

Emergent (EM): Wetlands with erect, rooted herbaceous vegetation present during most of the growing season.

Scrub-Shrub (SS): Wetlands dominated by woody vegetation that is less than 6 meters (20 feet) tall. Woody vegetation includes tree saplings and trees that are stunted due to environmental conditions.

Forested (FO): Wetland is dominated by woody vegetation that is greater than 6 meters (20 feet) tall.

Unconsolidated Bottom (UB): Wetlands that have a muddy or silty substrate with at least 25% cover.

Unconsolidated Shore (US): Wetlands with less than 75% areal cover of stones, boulders, or bedrock AND with less than 30% vegetative cover AND are irregularly exposed due to seasonal or irregular flooding and subsequent drying.

Cowardin Water Regime Modifiers (in order from driest to wettest):

Intermittently Flooded (J): The substrate is usually exposed, but surface water is present for variable periods without detectable seasonal periodicity. Weeks, months, or even years may intervene between periods of inundation.

Temporarily Flooded (A): Surface water is present for brief periods during the growing season, but the water table usually lies well below the soil surface for most of the season. Plants that grow both in uplands and wetlands are characteristic of the temporarily flooded regime.

Saturated (B): The substrate is saturated to the surface for extended periods during the growing season, but surface water is seldom present. This modifier is applied to fen like areas with stable water tables regardless of their connectivity.

Seasonally Flooded (C): Surface water is present for extended periods especially early in the growing season, but is absent by the end of the season in most years. When surface water is absent, the water table is often near the land surface.

Semi-permanently Flooded (F): Surface water persists throughout the growing season in most years. When surface water is absent, the water table is usually at or very near the land surface.

Intermittently Exposed (G): Surface water is present throughout the year except in years of extreme drought. This is applied to large ponds and shallow lakes where the water does not appear likely to dry up.

Permanently Flooded (H): Water covers the land surface throughout the year in all years. Vegetation is composed of obligate hydrophytes. Mostly applied to deepwater habitats such as lakes where there is no chance drying.

Cowardin Special Modifiers

Beaver (b): This modifier describes wetlands that are formed within and adjacent to streams by beaver activity.

Excavated (x): This modifier describes wetlands that were created through the excavation of soils.

Partially ditched/drained (d): This modifier describes manmade alterations to wetlands including ditches.

Diked/impounded (h): This modifier describes manmade alterations to wetlands where impoundments or dikes have been added.

Farmed (f): This modifier describes wetlands that have been altered due to farming practices.

Examples of Palustrine System:

To classify Palustrine wetlands, we combine the codes for the system, class, and water regime. The following are examples of types of wetlands and how they would be coded for wetland mapping purposes.

1. Cattail marsh that has standing water for most of the year: **PEMF**
2. A prairie pothole dominated by grasses and sedges that is only wet at the beginning of the growing season: **PEMA**
3. A fen in the subalpine zone: **PEMB**
4. A small shallow pond that has lily pads and other floating vegetation and holds water throughout the growing season: **PABF**
5. A small shallow pond with less than 30% vegetation and a muddy substrate that holds water for most of the year: **PUBF**
6. A wetland dominated by willows adjacent to a stream that is only periodically flooded: **PSSA**

APPENDIX D: Field Key to the Hydrogeomorphic (HGM) Classes of Wetlands 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**

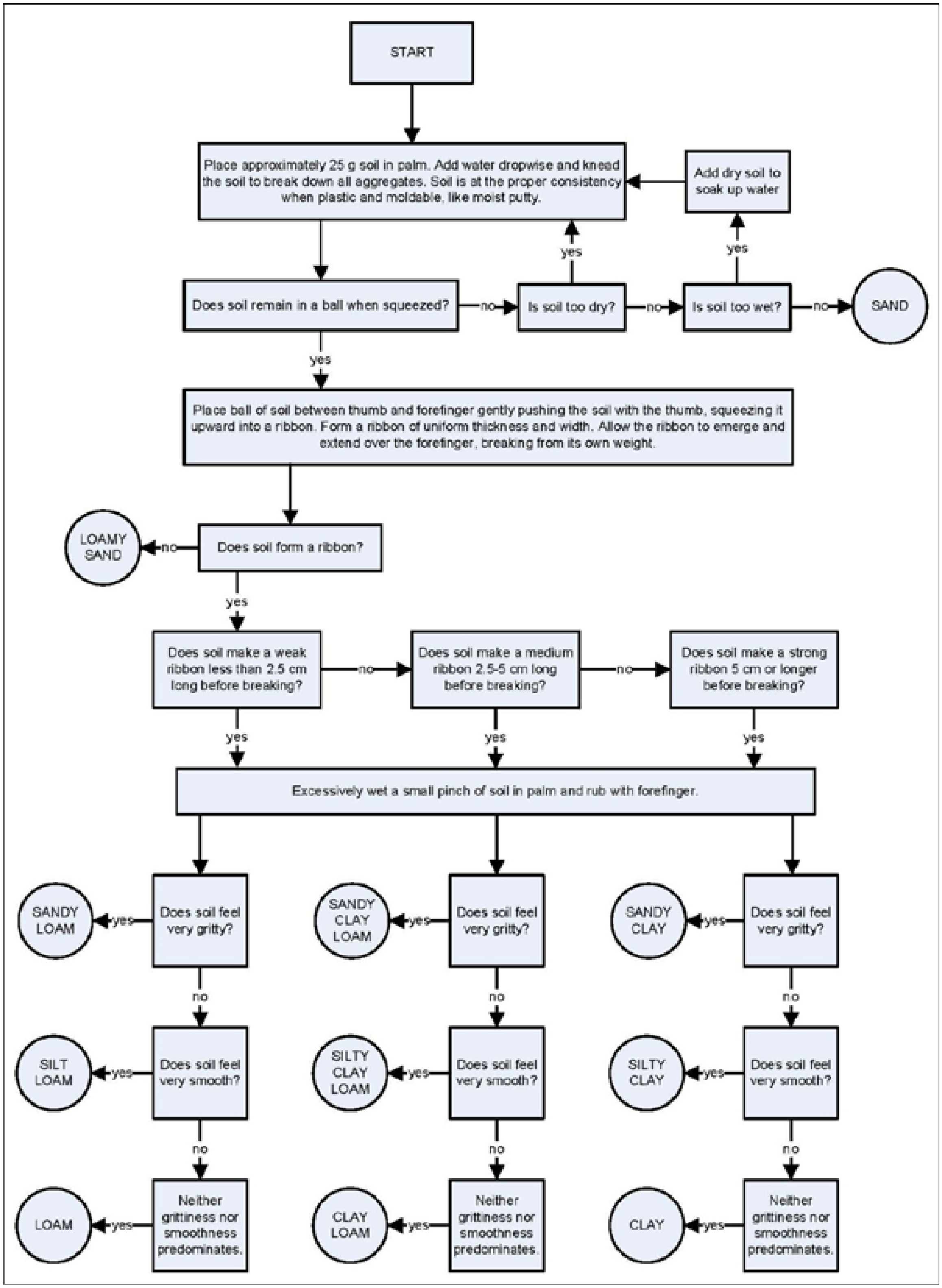
3a. Entire wetland unit meets ***all*** of the following criteria: a) wetland unit is in a valley, floodplain, or along a stream channel where it is inundated by overbank flooding from that stream or river; b) overbank flooding occurs at least once every two years; and c) wetland does not receive significant 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 meets ***all*** of the following criteria: 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**

4b. Wetland does not meet all of the above criteria. 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**

APPENDIX E: Soil Texture Flowchart



APPENDIX F: Notes on Hydric Soil Indicators for the Mountain West

All Soil Types

A1. Histosol: Organic soil material **≥ 40 cm** think within the top **80 cm**.

A2. Histic Epipedon: Organic soil material **≥ 20 cm** thick above a mineral soil layer. Aquic conditions or artificial drainage *required,* but can be assumed if hydrophytic vegetation and wetland hydrology are present.

A3. Black Histic: Very dark organic soil material **≥ 20 cm** thick that starts **within 15 cm** of soil surface. Color: hue = 10YR or yellower; value ≤ 3; chroma ≤ 1. Aquic conditions or artificial drainage *not required. Rare in our region.*

A4. Hydrogen Sulfide: Rotten egg odor within **30 cm** of the soil surface due to the reduction of sulfur. Most commonly found in areas that are permanently saturated or inundated; almost never at the wetland boundary.

A11. Depleted Below Dark Surface: Depleted (colorless) layer **≥ 15 cm** that starts **within 30 cm** of the soil surface. Color: chroma ≤ 2. Redox features required if color = 4/1, 4/2, 5/2. Layers above must be dark. See Table 1 for specifics.

A12. Thick Dark Surface. Depleted (colorless) layer **≥ 15** cm that starts **below 30 cm** of the soil surface. Color: chroma ≤ 2. Redox features required if color = 4/1, 4/2, 5/2. Layers above must be dark. See Table 1 for specifics. *Not common in our region.*

For the remaining indicators, unless otherwise indicated, all mineral layers above the indicators must have a dominant chroma of ≤ 2 or the layers with dominant chroma of > 2 must be < 15 cm thick.

Sandy Soil Types Sandy soil indicators are generally shallower and thinner than loamy/clayey soil indicators.

S1. Sandy Mucky Mineral: A layer of mucky modified sandy soil material **≥ 5 cm** starting **within 15 cm** of the soil surface. *Limited in our region,* but found in swales associated with sand dunes.

S4. Sandy Gleyed Matrix: Gleyed matrix that occupies **≥ 60%** of a layer starting **within 15 cm** of the soil surface. No minimum thickness required. Gley colors are not synonymous with grey colors. They are found on the Gley page. *Rare in our region;* only found where sandy soils are almost continuously saturated.

S5. Sandy Redox: Redox features in a depleted (colorless) layer **≥ 10 cm** that starts **within 15 cm** of the soil surface. Color: chroma ≤ 2. See Table 1 for specifics. *Most common indicator in our region of the wetland boundary for sandy soils.*

S6. Stripped Matrix: A layer starting **within 15 cm** of the surface in which iron/manganese oxides and/or organic matter has been stripped and the base color of the soil material is exposed. Evident by faint, diffuse splotchy patterns of two or more colors. Stripped zones are ≥ 10% and ~1–3 cm in diameter.

Loamy / Clayey Soil Types Loamy/clayey soil indicators are generally deeper and thicker than sandy soil indicators.

F1. Loamy Mucky Mineral: A layer of mucky modified loamy or clayey soil material **≥ 10 cm** starting within 15 cm of the soil surface. Difficult to tell without testing.

F2. Loamy Gleyed Matrix: Gleyed matrix that occupies **≥ 60%** of a layer starting **within 30 cm** of the soil surface. No minimum thickness required. Gley colors are not synonymous with grey colors. They are found on the Gley page.

F3. Depleted Matrix: Depleted (colorless) layer **≥ 5 cm** thick **within 15 cm** *or* **≥ 15 cm** thick w**ithin 30 cm** of the soil surface. Color: chroma ≤ 2. Redox features required if color = 4/1, 4/2, 5/2. See Table 1 for specifics. *Most common indicator at wetland boundaries.*

F6. Redox Dark Surface: A dark surface layer with **redox features.** Depth and location: **≥ 10 cm** thick entirely **within 30 cm of** the mineral soil. Matrix color and redox features: matrix value ≤ 3 and chroma ≤ 1 with ≥ 2% distinct, prominent redox concentrations OR matrix value ≤ 3 and chroma ≤ 2 with ≥ 5% distinct, prominent redox concentrations. The chroma can be higher with more redox features. *Very common indicator to delineate wetlands,* though difficult to see in soils with high organic matter.

F7. Depleted Dark Surface: A dark surface layer with **redox depletions.** Depth and location: **≥ 10 cm** thick entirely **within 30 cm of** the mineral soil. Matrix color and redox depletions: matrix value ≤ 3 and chroma ≤ 1 with ≥ 10% redox depletions OR matrix value ≤ 3 and chroma ≤ 2 with ≥ 20% redox depletions. The chroma can be higher with more redox depletions. Redox depletions themselves should have value ≥ 5 and chroma ≤ 2. *Rare in our region.*

F8. Redox Depressions: A layer **≥ 5 cm** thick entirely **within 15 cm** of soil surface with ≥ 5% distinct or prominent redox concentrations in closed depressions subject to ponding. *No color requirement for the matrix soil, but only applies to depressions in otherwise flat landscapes.*

Table 1. Comparison of indicators with depleted matrices and redox features.

	A11	***A12***	***F3***	***S5***
Depleted matrix extent	≥ 60%	≥ 60%	≥ 60%	≥ 60%
Depleted matrix color	chroma ≤ 2	chroma ≤ 2	chroma ≤ 2	chroma ≤ 2
Redox requirements	≥ 2% distinct or prominent redox concentrations ***if matrix color is*** 4/1, 4/2, 5/2	≥ 2% distinct or prominent redox concentrations ***if matrix color is*** 4/1, 4/2, 5/2	≥ 2% distinct or prominent redox concentrations ***if matrix color is*** 4/1, 4/2, 5/2	≥ 2% distinct or prominent redox concentrations
Starting within	< 30 cm	≥ 30 cm	see below	> 15 cm
Min thickness	15 cm or 5 cm if fragmental soil material	15 cm	**5 cm** within 15 cm of soil surface OR **15 cm** within 25 cm of soil surface	10 cm
Color of layers above	***loamy/clayey*** value ≤ 3 chroma ≤ 2 ***sandy material*** value ≤ 3 chroma ≤ 1 70% coated with organic material	***all types to 30cm*** value ≤ 2.5 chroma ≤ 1 ***all types below 30 cm and above depleted matrix*** value ≤ 3 chroma ≤ 1 ***all sandy material*** 70% coated with organic material	no requirements	no requirements

APPENDIX G: First Aid and Safety in the Field

First Aid Considerations and Common Field Ailments

First: If you have the time and resources take a Wilderness First Aid (1 day) or Wilderness First Responder (week) course.

Second: In any accident scenario (injury or just a flat tire) remain calm and **make sure the scene around you is safe** (before attempting to help someone make sure the bear is not going to get you too or the car will not fall on top of you as you jack it up).

Third: Pay attention to how far you are from help or your vehicle, this can have a huge impact on an injury or weather scenario. (*Always take a GPS point of the location of your vehicle before heading out into the field.*) Pay attention to the weather, sun exposure etc.

First Aid/Safety List

In your Pack:

- **Your car keys, ID, emergency contact info, insurance card**
- Sun hat and sun screen
- Rain coat/pants
- Plenty of water and food for the time you'll be out **plus** time you may be out given an injury or other change of plans
- Map and Compass (GPS units run out of batteries and lose signals)
- Whistle or radio for signaling others in the group or nearby
- Lighter or matches
- Firestarter (e.g., cotton balls soaked in Vaseline stored in a film canister)
- Tape and Gauze (Quick-clot is a new super gauze)
- Mole skin and bandaids
- Needle and thread
- Tweezers
- Anti-biotic ointment
- Painkillers (make sure they do not dehydrate or compromise your ability to get out of your situation)
- Knife/leatherman type tool
- Salt and sugar packets (especially if low blood sugar is an issue)
- Other meds or allergy equipment (epi-pen) you may want or need
- Water purification (iodine one 8ppm tab per quart or filter)
- Headlamp
- Bandana (can double as triangular bandage)
- Reflective blanket or emergency bag

In the Vehicle:

- Full size spare tire
- Jack and all the parts to the jack (including knowledge of how to use the jack)
- Lug nut wrench
- More food, water, coffee etc.
- Sleeping bag, warm clothes

- More sun block
- More mole skin
- Cell phone or radio

Heat Exhaustion and Heatstroke

It can get hot in Colorado, even at the higher elevations. Physical exertion at high temperatures can lead to **heat exhaustion** - becoming dehydrated increases the chances of it. Insufficient water in your body inhibits sweating, and you won't cool down to the degree that you would otherwise.

Symptoms of heat exhaustion include rapid breathing, high pulse rate, heavy sweating, paleness, fatigue, muscle cramps, dizziness, moderately elevated temperature, headache and nausea. When it gets more severe the symptoms may include vomiting and fainting. Some of the less severe symptoms also commonly accompany heavy physical exertion. You have to listen to your body. One good (usually early) sign that you are pushing yourself too hard is if you start feeling a little dizzy or woozy. If so, take a break and let your body recoup before resuming physical activity.

If someone does appear to have heat exhaustion, have the person lay down in the shade (if possible), rest with their feet raised a few inches and drink some water.

If heat exhaustion symptoms are ignored and the person keeps on with their physical exertion, the problem can become more severe and lead to **heatstroke**. This is life-threatening. With heatstroke the ability of the brain to regulate body temperature ceases -- the person's temperature can go up to 104 F or higher.

Heatstroke symptoms can include confusion, highly elevated temperature, strong rapid pulse, delirium, seizures and unconsciousness.

If someone appears to have heatstroke you should do the following: remove some clothing and cool the person with water and by fanning them. If there is a stream or pond nearby, put them in it to cool them down. After the person appears to be getting better (with their temperature having dropped to about 101 F) have the person assume the first aid recovery position. Get medical attention for the person as soon as possible even if they appear to be recovering. Heatstroke involves a serious a disruption of normal body functions, and a victim can appear to be recovering, and then go into a dangerous relapse.

Hypothermia ("exposure")

Hypothermia relates to drops in human body temperature to levels at which physical and mental abilities deteriorate. The process is progressive and can lead to death. It is not the same thing as "freezing" -- many instances of hypothermia in Colorado occur at temperatures around 50 degrees Fahrenheit. Hypothermia is a modern term for a condition that used to be referred to as "exposure".

The root cause of hypothermia is simple: loss of body heat at a higher rate then it is created. The loss of body heat is caused by things like low surrounding temperatures, wet clothes that have lost their insulation properties, and wind creating wind-chill affects on the body. Your clothes can get wet from rain or body perspiration. The inability of the body to make up for heat loss is amplified by factors like fatigue, dehydration and lack of food.

Hypothermia goes through several stages defined by body temperature and symptoms. First, there is mild hypothermia which occurs at body temperature ranging down to 96 F. Typical symptoms are involuntary shivering and the loss of the ability to do complex motor functions. The person can still walk and converse.

Next comes moderate hypothermia, with body temperature ranging from 95 to 93 F. Symptoms include dazed consciousness, loss of fine motor coordination (particularly in the hands), slurred speech, violent shivering and strange behavior (including taking their clothes off). Severe hypothermia occurs with body temperature in the 92 to 86 F range, and is life threatening. Symptoms include waves of shivering, inability to walk, taking a fetal position to conserve heat, muscle rigidity and a major drop in pulse rate.

Victims of advanced hypothermia can appear dead but in fact still be alive with imperceptibly slow rates of breathing and pulse. The best way to deal with hypothermia is to get the victim into dry clothes, give them warm drinks and food, and put them in a sleeping bag, possibly with another person to speed up their warming. Get advanced hypothermia victims to a medical professional (MD or EMT) as fast as possible, even if they look like a goner - they may be revivable with the right procedures.

Altitude adjustment and altitude sickness

Gaining altitude has physiological effects on everyone. However, the effects vary considerably among individuals and do not seem to correlate very much with physical condition, sex or age. A young well conditioned athlete could find himself more set back by a substantial rise in altitude than some inactive out of shape person.

Altitude affect is such that a fit person used to running several miles daily, who then comes up to a location 5000 feet higher than they are used to, may become exhausted after a half-mile of their usual running workout. A week to several weeks may have to pass at the new higher altitude before the usual level of performance ability exists again.

What causes this change? Two physiological factors have been identified as resulting from altitude gain. The first and most obvious effect is caused by a reduction in concentration of oxygen in the air breathed. Going from sea level to 12,000 feet results in a reduction of oxygen concentration of about 40 percent. It takes time for the body to adjust to this reduction. The other factor involves leakage of fluid from the capillaries into the lungs and brain.

These physiological effects result in two considerations: a reduction in physical stamina and the potential for developing altitude sickness. Given time for adjustment, the body will compensate by such methods as producing more red blood cells, increasing the pressure in pulmonary arteries, increasing the production of certain enzymes and deeper breathing.

Loss of physical stamina with altitude gain is easily detected. The symptom is feeling tired after a relatively small amount of physical exertion. The cure is to be at high-altitude until your body can make the necessary adjustments, and to take it easy until then. In a practical way, this temporary loss of stamina can lead to bad results if you are on a hike, and you are the only one suffering from altitude associated weakness. The best thing you can do is to be honest with yourself and the others and slow down and take necessary rests before (not after) you drive yourself to physical exhaustion. If you start feeling woozy - don't be ashamed to take a break. It's harder for the body to regain strength after you drive yourself to near collapse.

Altitude sickness

The medical profession recognizes several types of altitude sickness. They go by the names of acute mountain sickness, high altitude pulmonary edema and high-altitude cerebral edema. Mostly, they are due to fluid buildups in the lungs or brain. It's not important for a hiker to be able to diagnose and differentiate between them. Some of the symptoms associated with one or more of these altitude sicknesses are listed below. If you or a member of your party have some of these after a gain of substantial altitude, the best first step is to come down and lose at least 1000 to 2000 feet of altitude. Return to town as soon as possible and get medical attention.

Some general altitude sickness symptoms: Headache, dizziness, fatigue, shortness of breath, respiratory symptoms worsening at night, loss of appetite, nausea, disturbed sleep, tightness in the chest, persistent productive cough bringing up white, watery, or frothy fluid, mental confusion, loss of coordination, disorientation, loss of memory, hallucinations, psychotic behavior, coma.

(From http://www.hence-forth.com/Colorado_Hiking/1_Hiking_topics/safety.htm)

4x4 Driving Techniques

The Basics

Wear Seatbelts: Put on your seatbelt, and instruct passengers to put them on as well. A good belt will help restrain you when driving difficult terrain, and can save your life in case of a rollover or other accident.

Lock the Hubs: the first thing to do when you get in the dirt is to put the transfer case in four-wheel drive and lock the hubs—if your vehicle is so equipped. With all four wheels hooked together, your control is increased, braking is improved, and you won't get stuck as fast when you make a mistake. This also spreads the tractive force over four tires instead of two, minimizing breakage of drivetrain parts. However, with practice, flipping back and forth between 2WD and 4WD can be advantageous for turning, sliding, and other advanced maneuvers, but it's best to learn while in four-wheel drive.

Use 4 Low: Using low range in the transfer case is important. In low range the available power is greater, and the speed with which you can drive is diminished. By driving slowly over obstacles rather than pretending you're in a SUV commercial and flying over them, you're more likely to make it to the other side instead of breaking your rig or yourself. Going downhill is also easier in low range, as compression braking from the engine is increased. This allows you to stay off the brake more often for optimum control.

Hold the Wheel: While gripping the steering wheel, make sure that your thumbs aren't wrapped around it. If the wheel should suddenly whip around from a tire hitting a rock, your thumbs won't get broken or mangled.

Listen to the car: Turn your stereo off, so you can hear what your vehicle is telling you. The sounds of slipping tires, scraping metal, and engine rpm can all help you be a better driver, but not if you can't hear them. Just like drinking and driving, distractions from what is happening with your vehicle can distract you at the wrong time.

Know the car: Know your rig inside and out. This means being familiar with all of the controls in the cab, as well as how to use them for what purpose. On the outside, make a mental note of what hangs down underneath, and what side the front differential is on so you won't bang the underside on obstacles.

Don't ride the clutch: Staying off the clutch unless you need it is important in many situations. While automatic-equipped 4x4s can have an easier time crawling over things, a manual transmission rig is capable of outdoing an auto as long as the clutch isn't always used. Try driving with your feet on the floor for practice, and see what your rig can do. Once you push in the clutch you've unhooked the drivetrain, and only your brakes will be holding you on a hill.

Lower tire pressure: Consider lowering your tire pressure according to the terrain and speed. Tire pressure lower than the manufacturer's recommendations can provide greater tire traction, flexibility, flotation, and smoother ride. Because the tire will tend to spread out at lower pressures, a bigger footprint is formed, but the tire is more susceptible to sidewall damage. Never air down farther than what you are comfortable with, and remember to air them back up before you hit the pavement.

Get a spotter: If you're unsure of what you're doing while driving an obstacle, ask someone to spot you over the tough areas. An experienced spotter can be your best ally and can make you look like a pro. Remember, though, that you as the driver are the one in command, and it's your decision to trust the spotter or not.

Study the area: Watch the driver in front of you and see how he makes it through. You can learn a lot on what to do and what not to do. Get out and walk the trail or examine the obstacle before you drive through. This allows you to get a mental picture of where you will place your tires before you go. Just as a golfer examines the green before that game-winning putt, you need to know what's ahead of you so you don't get into trouble. Walk ahead and look back; the view is different from the other direction, and other features of the terrain become apparent.

Hills and Dirt

Climbing hills and going back down them is older even than four-wheeling. Usually a steady speed with momentum is adequate, depending on the surface. An occasional blip of the throttle can bump you over some ledges, but rarely will a full-throttle attack do much more than break stuff.

When climbing or descending a hill, keep straight up or down, and don't turn around on the side of a hill. The propensity to roll is far greater, and any stored inertia can send the rig tumbling. Know when to quit and how to back down in a straight line.

The steering seems much more sensitive (and backwards) when you are backing down a hill, and miscues and rolls are common. If you traverse a side hill and are off camber, you need to go slowly to prevent sudden shift of vehicle or cargo weight. A rock on the high side or a hole on the low side can tend to tip you in the wrong direction, as in downhill.

Likewise, spinning the tires on a loose surface when on a side hill breaks traction, causing gravity to pull you off the trail and possibly over the edge. Descending a hill is best done in the lowest gear, for maximum compression braking. Even automatic transmissions will have some compression braking, and a light foot on the brakes is better than locking them up and sliding.

The tires must be rolling to have control, so if you start to slide you need to give it a little gas and be easy on the brake pedal. Easy movements of the steering wheel can help you keep directional control, while whipping the wheel can cause the tires to slide sideways, right into what you are trying to avoid.

Rocks

Lowering the air pressure and going slowly is the best recommendation for rocky trails or hard-core rockcrawling. Tires should be placed on top of the rocks, which allows the axle and undercarriage to avoid hitting the boulders. On IFS rigs or Hummers, for example, the available clearance in the center of the undercarriage is sometimes better, but straddling rocks can still get you stuck in any case.

Your lowest speed that keeps your momentum going is usually the best. If you go too fast you end up bashing and crashing while hurting your rig and generally getting stuck. Rockcrawling is truly the home of elegant driving as coined by the late great Granville King. By making this activity a true art form of fluid motion like a mechanical ballet, a greater amount of obstacles can be scaled with less damage to yourself and the vehicle.

Likewise, raw power and speed can jet you over the boulders, but the hopping and flopping action of bashing and crashing your way through a canyon of boulders is in no sense of the word elegant, and it'll cost you more in the long run. One way to stay in control with an automatic transmission is to use one foot on the brake and one on the gas. On a stick-equipped rig the engine compression braking gives you greater control, but using the two-foot method on an auto will mimic this action.

Sand

Higher gears are great for sand, as speed and momentum keeps you flying on top rather than sinking in. Depending on the type of sand—from fine to coarse and from wet to dry—different speeds and gears may need to be used. Usually, spinning the tires is needed since wheel speed is a factor to keep on top of the sand. Lowering air pressure and running wide tires help in the flotation department as well.

Sand dunes can have steep drop-offs and other obstacles, so being alert is extremely important. If you're climbing a sand hill and realize you've run out of engine power, downshift quickly, and floor it without losing momentum. This is where automatic transmissions excel—virtually instant downshifts with no loss of momentum. Shifting a manual truck usually means the momentum is gone before the clutch is ever let back out. Side hilling in the sand or running a bowl is great if you have enough speed and power, but turn downhill as soon as you start to bog down. Point your ride straight down, and if the nose starts to go sideways give it a little gas to straighten it out.

Water Crossings

Driving through water can be as hazardous as any other terrain. The swift current, unknown bottom conditions, and possibility of engine damage can ruin a nice 4x4 outing. Check the depth and bottom conditions before you attempt to drive across a stream. Look to see where others have made it, and imagine what happens if your rig floats or gets washed downstream.

Cross streams and rivers at an angle upstream to prevent the force of the water from pushing the vehicle downstream. This helps you keep going in a more controlled manner without getting moved downstream. Know where your engine air intake is, and be sure that it is not lower than the deepest part of the stream you are crossing. Many new vehicles have the air intake lower than the front bumper or in the fender. If water gets into the cylinders of a running engine it will hydrolock the engine, stopping it cold, and probably damaging the engine. Avoid spinning tires when they are wet, as wet rubber cuts as easily on sharp rocks.

Mud

Different consistencies of mud call for different styles of driving. Some mud responds to fast driving with a lot of wheelspin, while others may do better with a slower gate with just enough spin to clean out the tires.

Like in snow, skinny tires can dig down to the hard stuff, while wide flotation tires can keep you on top of the goo. Regardless of what the mud is like, a steady forward progress is needed. In other words, keep your momentum up. If you get off the gas, you can risk losing the momentum needed to traverse the slop. Be aware that spinning the tires while stopped may get you going, but quite often you'll simply dig down and get stuck to the gills.

It's always easier to extricate your 4x4 from deep mud before it's resting on the framerails. So if the rig's not moving forward as you spin tires, it's probably going down. Don't be afraid to back out of a sticky situation either; the ruts are already there and you may escape without getting stuck.

Hiking during hunting season

During field work you should be aware of the potential for hunting on the lands in which you are working. The best thing to do is to be aware of the hunting dates and to wear orange when necessary.

Working around wildlife

Black Bears

The following is from the Yosemite National Park Website, (http://www.nps.gov/yose/wilderness/bsafety.htm).

"Never approach a bear regardless of its size. If you encounter a bear, act immediately: throw small stones or sticks toward the bear from a safe distance. Yell, clap hands, and/or bang pots together. If there is more than one person, stand together to present a more intimidating figure, but do not surround the bear. Use caution if you see cubs, as a mother may act aggressively to defend them.
"When done immediately, these actions have been successful in scaring bears away. Never try and retrieve anything once a bear has it."

The group Citizens for Responsible Wildlife Management has a good web page with tips for handling a bear encounter. Check it out if you want more information.
(http://www.responsiblewildlifemanagement.org/bear_safety.htm)

Mountain Lions

The following is from the Yosemite National Park Website, (http://www.nps.gov/yose/wilderness/bsafety.htm).

Although lion sightings and attacks are rare in the area, they are possible, as is injury from any wild animal. We offer the following recommendations to increase your safety: Avoid walking alone, especially around dawn and dusk. Be aware of your surroundings and how you appear if you are being stalked.

"What should you do if you meet a mountain lion?"

Never approach a mountain lion, especially one that is feeding or with kittens. Most mountain lions will try to avoid confrontation. Always give them a way to escape. Don't run. Stay calm. Hold your ground or back away slowly. Face the lion and stand upright. Do all you can to appear larger. Grab a stick. Raise your arms. If the lion behaves aggressively, wave your arms, shout and throw objects at it. The goal is to convince it that you are not prey and may be dangerous yourself. If attacked, fight back!

"Generally, mountain lions are calm, quiet, and elusive. The chance of being attacked by a mountain lion is quite low compared to many other natural hazards. There is, for example, a far greater risk of being struck by lightning than being attacked by a mountain lion."

Moose

The following is from the Alaska Department of Fish and Game website, (http://alaska.org/anchorage/advice-moose-courtesy.htm).

Moose Courtesy

- Never feed moose
- Give moose at least 50 feet. If it doesn't yield as you approach, give it the trail. (Either retreat or walk way around.)
- If its ears lay back or its hackles (the hairs on its hump) rise, it's angry or afraid and may charge; back off pronto
- Moose kick with their front as well as hind feet
- Don't corner moose into fences or houses
- If a moose charges, get behind a tree. You can run around the trunk faster than the gangly creature.
- Never get between a cow and her calf

The following is from the Wrangell-St. Elias National Park and Preserve website, (http://www.nps.gov/wrst/planyourvisit/moose-safety.htm).

Moose aren't inherently aggressive, but will defend themselves if they perceive a threat. When people don't see moose as potentially dangerous, they may approach too closely and put themselves at risk.

Give Moose plenty of room! Enjoy viewing them from a distance. Cow moose are extremely defensive of their young so use extra caution around cows with calves.

In the summer months, moose blend in well to their environment and can be surprisingly hard to see for such large animals. They are likely to stand their ground even when they hear people approaching, so pay close attention to your surroundings, especially in prime moose habitat such as willow thickets or around streams or ponds.

If you do find yourself close to a moose: If it hasn't detected you yet, keep it that way. If it knows you're there, talk to it softly and move away slowly. Don't be aggressive – you want to convince the moose that you aren't a threat. If you think the moose is going to charge you, take cover or run away.

Watch for signs that the moose is upset. If its ears are laid back and hackles are up it is likely to charge. Most of the time, when a moose charges it is a 'bluff', or warning for you to get back – a warning you should take very seriously! Once a moose bluff charges it is already agitated. If possible, get behind something solid (*like a tree or a car*).

Unlike with bears, it is okay to run from a moose. They usually won't chase you and if they do, it's unlikely that they'll chase you very far. If a moose knocks you down, curl up in a ball and protect your head with your arms and keep still. Fighting back will only convince the moose that you may still be a threat. Only move once the moose has backed off to a safe distance or it may renew its attack.

Snakes

(From: http://lomalindahealth.org and http://www.hence-forth.com/Colorado_Hiking/ and http://www.fs.fed.us/r8/boone/safety/critters/snakes.shtml)

Wear boots not sandals or running shoes when hiking - the higher the boot tops the better. Wear long trousers instead of shorts. Bare legs increase the probability of a successful strike. Loose trousers might result in a strike to the wrong spot, or a deflected strike.

Use a hiking stick. Often, the first thing to come close to a rattler will be your stick instead of your leg. When stepping over a log or a fallen tree you can plant the stick first and perhaps stir up the snake before exposing your leg. The snake's first strike may be at the stick versus your leg.

When you come across a rattlesnake that has been startled and is rattling, the first thing to do is stop and hold still, visually locate the snake, let the snake calm down, then move away from it to at least ten feet. Next, take a look around just to make sure there aren't any others nearby, but stay aware of the original snake's location and movements. Then work out a safe route around it, and leave. Unless there is some overriding reason to do it, don't mess around with the snake - that is actually how most bites occur.

Basic first-aid measures for rattlesnake bites:

If you are bitten by a snake, get away from it as fast as you can to avoid any further bites.

You should try not to panic and minimize activity if possible. However, if you are alone in the wilderness or far from access to medical care, you may have to hike out to the nearest phone.

Use a cell phone to call for help or send somebody out, or hike out using a slow measured pace with a crutch if necessary. In some cases the most sensible approach will be to notify a medical facility of what has happened (if you can) and to arrange for an EMT vehicle to meet you at the trail head, perhaps with antivenin. The sooner the MD's know they will need antivenin the better - not all medical facilities have it on hand. It is highly desirable to get medical attention within two hours of the bite.

Keep the injured body part motionless and just below heart level.

Remove jewelry and tight-fitting clothes in anticipation of severe swelling.

Do not cut across fang marks and do not try to suck out the venom with your mouth or a suction device. This could lead to complications and infections. Cutting the bite wounds is NOT RECOMMENDED as this increases damage to the tissue and has not been shown to be beneficial.

A tourniquet is not recommended because it could cut off circulation. However, an ace wrap and splint may delay the time to death in the rare event of a fatal bite, but could risk further injury to an arm or leg. If the victim won't be able to reach medical care within 30 minutes, as will normally be the case in a hiking situation, then slow the venom movement from the bite area by applying a bandage wrap 2 to 4 inches above the bite. This is NOT a tourniquet - it should not cut off the flow of blood - the band should be loose enough to slip a finger under it.

Do not take aspirin or ibuprofen after snakebite. Many snake venoms can thin the blood and these medicines may compound this effect, leading to bleeding.

Other first aid that does not help or that is potentially more harmful than the snakebite includes applying electric shock, drinking alcohol, and placing ice directly on the wound. Avoid further injury by staying away from the snake.

Mosquitoes and West Nile virus

(From: http://www.hence-forth.com/Colorado_Hiking/)

The West Nile virus problem is best dealt with by reducing the number of mosquito bites by wearing long sleeved shirts and trousers. Spraying DEET on your clothes and skin works well in keeping mosquitoes and other bugs away. You can also like to wear a baseball cap sprayed with DEET which seems to keep the mosquitoes away from my face and neck. It should be applied to skin and clothing only -- keep it out of open wounds, scrapes, eyes, nostrils or mouth.

If you use a water bladder and tube instead of water bottles - avoid spraying DEET on the end of your drinking tube.

The following info is taken from the CDC's rundown on West Nile virus.

Most people who are infected with the West Nile virus will not have any type of illness.

It is estimated that 20% of the people who become infected will develop West Nile fever with mild symptoms including fever, headache, and body aches, occasionally with a skin rash on the trunk of the body and swollen lymph glands.

It is estimated that about 0.67 percent (less than 1 out of 100) of persons infected with the West Nile virus will develop the severe form of the disease. The symptoms of severe infection (West Nile encephalitis or meningitis) include headache, high fever, neck stiffness, stupor, disorientation, coma, tremors, convulsions, muscle weakness, and paralysis.

If you become ill after outdoor activities and bites, make certain that your physician knows this, and can therefore factor this in when ordering tests and making diagnoses.

Ticks

(From: http://www.hence-forth.com/Colorado_Hiking/)

Ticks attach themselves to humans and other animals in order to feed on blood. They are small roundish dark insects that can cause illness in humans due to viruses and bacteria that they may input to the host during feeding. Using DEET cuts down on the odds of getting ticks on you. There are two types of tick caused illness in Colorado and both are rare.

Rocky Mountain Spotted Fever is a bacterial illness which can be life-threatening. The early symptoms are headaches, fever, nausea, abdominal pain, lethargy and a rash which develops on the extremities and spreads to the entire body. It is a rare disease with only a couple of cases reported yearly.

Colorado Tick Fever is a viral illness which is not life-threatening. It's symptoms are headaches, fever, nausea, abdominal pain, and lethargy. These symptoms last four or five days, followed by an apparent recovery. Then the symptoms return for a few more days. Total recovery usually takes several weeks. The disease is not life-threatening and infection results in lifelong immunity.

If you become ill after being outdoors, and especially if you have had ticks on your body, let your physician know of the possibility of tick disease exposures so it can factored in when ordering tests and making diagnoses.

As with the case for mosquitoes, the best defense is long sleeved shirts and trousers and DEET. Look over your body for any ticks and remove them with tweezers by carefully grasping the tick's head as close to your skin as possible. Pull the tick straight out, using firm, steady pressure. Another method is to use a credit card or knife blade to carefully sweep down and force the tick's head out of your skin. The idea is to get the tick's head out of your flesh without exposing the ticks fluids to your blood. Don't prick, heat, smother or crush the tick. These methods may cause the tick to regurgitate into the bite wound which increases the chance of infection.

Hanta Virus

(From: http://www.cdc.gov/ncidod/diseases/hanta/hps/noframes/FAQ.htm)

What is hantavirus pulmonary syndrome (HPS)?
Hantavirus pulmonary syndrome (HPS) is a deadly disease caused by hantaviruses. Rodents can transmit hantaviruses through urine, droppings, or saliva. Humans can contract the disease when they breathe in aerosolized virus.

Who is at risk of contracting HPS?
Anyone who comes into contact with rodents that carry hantavirus is at risk of HPS. Rodent infestation in and around the home remains the primary risk for hantavirus exposure. Even healthy individuals are at risk for HPS infection if exposed to the virus.

Which rodents are known to be carriers of hantavirus that cause HPS in humans?
In the United States, deer mice, cotton and rice rats (in the Southeast), and the white-footed mouse (in the Northeast), are the only known rodent carriers of hantaviruses causing HPS.

How is HPS transmitted?
Hantavirus is transmitted by infected rodents through urine, droppings, or saliva. Individuals become infected with HPS after breathing fresh aerosolized urine, droppings, saliva, or nesting materials. Transmission can also occur when these materials are directly introduced into broken skin, the nose or the mouth. If a rodent with the virus bites someone, the virus may be spread to that person, but this type of transmission is rare.

Can you contract HPS from another person?
HPS in the United States cannot be transmitted from one person to another. You cannot get the virus from touching or kissing a person who has HPS or from a health care worker who has treated someone with the disease. In addition, you cannot contract the virus from a blood transfusion in which you receive blood from a person who survived HPS.

Can you contract HPS from other animals?
Hantaviruses that cause HPS in the United States are only known to be transmitted by certain species of rodents. HPS in the United States is not known to be transmitted by farm animals, dogs, or cats or from rodents purchased from a pet store.

How long can hantavirus remain infectious in the environment?
The length of time hantaviruses can remain infectious in the environment is variable and depends on environmental conditions, such as temperature and humidity, whether the virus is indoors or outdoors or

exposed to the sun, and even on the rodent's diet (which would affect the chemistry of its urine). Viability for 2 or 3 days has been shown at normal room temperature. Exposure to sunlight will decrease the time of viability, and freezing temperatures will actually increase the time that the virus remains viable. Since the survival of infectious virus is measured in terms of hours or days, only active infestations of infected rodents result in conditions that are likely to lead to human hantavirus infection.

How do I prevent HPS?
Seal up rodent entry holes or gaps with steel wool, lath metal, or caulk. Trap rats and mice by using an appropriate snap trap. Clean up rodent food sources and nesting sites and take precautions when cleaning rodent-infested areas.

What are the recommendations for cleaning a rodent-infested area?

Put on rubber, latex, vinyl or nitrile gloves.

Do not stir up dust by vacuuming, sweeping, or any other means.

Thoroughly wet contaminated areas with a bleach solution or household disinfectant.
Hypochlorite (bleach) solution: Mix 1 and ½ cups of household bleach in 1 gallon of water.

Once everything is wet, take up contaminated materials with damp towel and then mop or sponge the area with bleach solution or household disinfectant.

Spray dead rodents with disinfectant and then double-bag along with all cleaning materials. Bury, burn, or throw out rodent in appropriate waste disposal system. (Contact your local or state health department concerning other appropriate disposal methods.)

Disinfect gloves with disinfectant or soap and water before taking them off.

After taking off the clean gloves, thoroughly wash hands with soap and water (or use a waterless alcohol-based hand rub when soap is not available).

Can I use a vacuum with HEPA filter to clean up rodent-contaminated areas?
HEPA vacuums are not recommended since they blow air around and may create aerosols.

How do I clean papers, books, and delicate items?
Books, papers, and other items that cannot be cleaned with a liquid disinfectant or thrown away should be left outdoors in the sunlight for several hours or in an indoor area free of rodents for approximately 1 week before final cleaning. After that time, the virus should no longer be infectious. Wear rubber, latex, or vinyl gloves and wipe the items with a cloth moistened with disinfectant.

I do not want to bleach my clothes or stuffed animals; is there anything else I can do?
Wash clothing or stuffed animals in the washing machine using hot water and regular detergent. Laundry detergent can break down the virus's lipid envelope, rendering it harmless. Machine dry laundry on a high setting or hang it to air dry in the sun. CDC does not recommend simply running the clothing through the dryer without washing first.

How do I clean rugs, carpets and upholstered furniture?
Disinfect carpets and upholstered furniture with a disinfectant or with a commercial-grade steam cleaner or shampoo.

What precautions should I take if I think I have been exposed to hantavirus?
If you have been exposed to rodents or rodent infestations and have symptoms of fever, deep muscle aches, and severe shortness of breath, see your doctor immediately. Inform your doctor of possible rodent exposure so that he/she is alerted to the possibility of rodent-borne diseases, such as HPS.

Lightning

July and August can bring heavy afternoon rainstorms with lightning. Plan to hike on the dunes in morning or evening to avoid these storms, and to avoid the hot mid-day sand surface. See the NOLS lightning guide on the following pages for in depth information on lightning.

Safety Information - Lightning

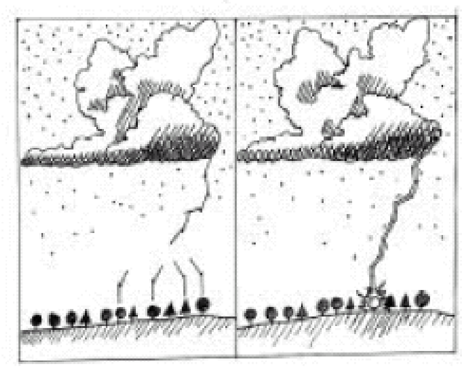
NOLS Backcountry Lightning Safety Guidelines

John Gookin,, NOLS Curriculum Manager

This paper discusses the phenomenon of lightning as it typically happens; how to seek relative safety when caught in a backcountry lightning storm; typical lightning injuries; some tips on teaching lightning risk management in the backcountry; an overview of first aid, and incident reporting guidelines. It can not be emphasized enough, that **being outdoors exposes us to random lightning hazard, no matter what actions we take.**

How Does Lightning Strike?

Lightning strikes fast: the whole process usually takes a few milliseconds. Stepped leaders leave a cumulonimbus cloud and some leaders move toward the ground. They appear as many branches, but only 1-2 branches will reach the ground. Approximately every 50 meters[1] a new step leaves each leader and heads in a fairly random direction. If a leader gets 100m from the ground, positively charged streamers start rising from the closest grounded objects towards the negatively charged leader. As soon as the leader is close enough to a streamer[2], it shoots directly to that streamer and "blazes a trail" for a significant charge (a return stroke) to shoot from the ground to the cloud[3]. This leader search distance concept is important to understand to avoid direct strikes.



Illustrations by Rob MacLean

Figure 1 Left: a stepped leader moves down in 50 m steps and multiple streamers rise from tall objects near the leader.
Right: a single return stroke from a tree is the most obvious part we see.
Note the leader connected with the streamer that happened to be closest to it during the final step.

Most ground strikes occur immediately below a cumulonimbus cloud. Rarely, a bolt of lightning can move horizontally and strike somewhere "out of the blue" (out of the blue sky) as far as 10 miles (16km) away. These horizontal strikes are rare and unpredictable, so they shouldn't affect our decisions.

Using the 50 m search distance of stepped leaders (see above) lightning tends to hit the closest object within range at the end of the last step. Lightning tends to hit elevated sharp terrain features like mountain tops. Lightning tends to hit tall trees in open areas, with objects twice as high receiving roughly 4X the strikes[4]. Lightning tends to hit bushes in the desert if the bush is sticking up higher than the flat ground around it. Lightning tends to hit a boat on the water, especially if it has a tall mast. Lightning can still hit flat ground or water, but more randomly than it hits elevated objects.

Even a few less feet of height can make a difference in improving your odds of NOT being the struck object. This is why the first part of getting into the lightning position is lowering yourself down to decrease your height.

Lightning tends to hit long electrical conductors. Metal fences, power lines, phone lines, handrails, measuring tapes, bridges and other long metallic objects can concentrate currents. Wet ropes also conduct current and should be treated with the same respect as wires. Longer objects tend to concentrate more current and reach more strike points.

How Can Lightning Hurt Us?

Lightning throws an ensemble of deadly and injurious threats our way. All of these effects happen in the same few milliseconds, but none of the threats linger after each strike.

Direct strike: this means the stepped leader connected with a streamer coming out of your body, then the return stroke passed through you or over your body's surface. The return stroke is the most significant electrical event of a lightning strike and has a typical current of 30,000 amps[5] (household current is 15 amps). You greatly reduce the chances of receiving a direct strike by being inside a substantial building or a metal-topped vehicle. In the backcountry you should avoid high places and open ground and assume the lightning position[6] to decrease risk.

Streamer Currents: fast high current pulses are launched from the tops of many elevated objects near each leader as it approaches the ground (see Fig.1.) These are launched in response to the tremendously high electric field that exists, momentarily under each tip of the stepped leader. Since the tips of several or many leaders may approach the ground at about the same time, you do not have to be very near the actual ground strike point to be involved in a streamer current. Streamer currents, while much smaller than the return stroke current, are still large enough to cause injury or death to humans. You suppress the tendency to launch streamer currents from your person by crouching into a tight ball as close to the ground as possible. You avoid this possibility by avoiding high locations.

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[1] Yards and meters can be used interchangeably. One meter = 1.1 yards.
[2] This "strike distance" can vary by 10X according to Uman in The Lightning Discharge, 1987.
[3] Return strokes of the opposite polarity tend to occur at the end of storms and under collapsed anvils. In some areas, multiple ground strike points in the same flash are common.
[4] "Towers, Lightning & Human Affairs." LG Byerley 3rd, WA Brooks, RC Noggle & KL Cummins. 11th Intl Conf on Atmospheric Electricity. 1999.
[5] Figures vary from 1-200kA, with most strikes in the 10-50kA range.
[6] This has formerly been called the lightning "safety" position and is explained later in this paper.

Ground Currents: ground currents occur with each strike and cause roughly half of all lightning injuries. Ground currents are driven by the enormous potential differences[7] that appear in the Earth near the ground strike point. Typical lightning-to-ground strikes inject roughly 30,000 amps into the Earth: since the Earth resists electrical flow, large potential differences will appear in the ground all around the strike point. How far the current flows varies wildly since strike current and ground conductance easily vary by orders of magnitude. But the closer you are to the direct strike, the stronger the ground current. If you are standing with your legs separated, if you are on all fours, if you are in a prone position on the ground, or if you are touching a long metallic object, you maximize your exposure to potential differences that arise from ground currents. The potential difference that appears between your legs or across your prone body can drive significant currents through and over your body. You can minimize your exposure to ground potential differences and ground currents by: keeping your feet close together, by NOT getting in a prone position, by assuming the lightning position on additional insulation such as a foam pad, and by not removing your shoes with thick rubber soles. These actions can help minimize the amount of ground current going through your body, but some experts think these efforts are moot compared to getting to a safer location. We need to be careful that we don't give students a false sense of security by getting in this defensive position.

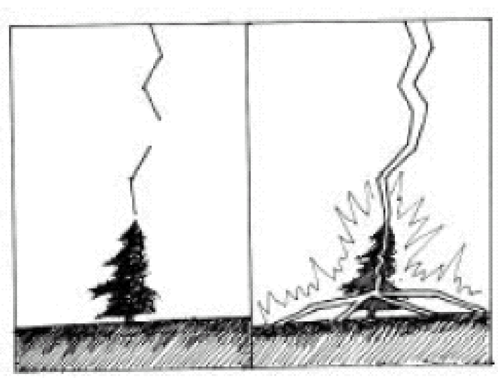

Figure 2: Left: tree with a streamer and a stepped leader.
Right: tree with return stroke, surface arcs, and electrostatic field.

Surface Arcs: high current surface arcs appear to be associated with some fraction of all cloud-to-ground discharges, during the return stroke. They appear in photographs as bright arcs of light radiating from a strike point like spokes of a wheel, in the air just above the ground's surface. (See figure 2.) These long hot horizontal currents have been measured up to 20 meters in length and may get longer. If you are in the path of a surface arc you are likely to conduct some of the surface arc current through or over your body. Since surface arcs emanate from the base of trees struck by lightning, **never seek shelter near a tree.**

[7] Potential difference: if your feet are touching the ground in two different spots, each has a certain electrical **potential** based on the current flowing there. But it is the **difference** between these potentials that will drive current in one foot and out the other.

Radiation: the visible, infrared and ultraviolet radiation near the strike point can damage your vision.

Sound: the thunder pulse can damage hearing temporarily and possibly permanently.

Electrostatic Field Changes: there is a large change in the electrostatic field out to 30m from the ground strike point. If you are standing, then you maximize the voltage across your body, which in turn maximizes currents that pass through and over your body. It takes very little current to interrupt heart function. Minimizing your height by assuming the lightning position is one way to minimize the field change across the length of your body.

Corona: During any stage of a thunderstorm, the electrostatic field can be enhanced enough around grounded objects to cause brush or point discharge (corona). At night, you may be able to see corona as a faint glow from sharp rock outcrops or the tops of bushes or trees — sometimes even from the fingers of your outstretched hand. You may hear corona as a sizzling or buzzing sound. Even if you can't see or hear corona, you might smell ozone, one of the chemical products of point discharge in air. Ozone has an irritating, acrid "swimming pool" smell.

On land it is unusual to have optimum conditions for sensing corona. If you feel hairs on your head, leg or arms tingling and standing on end, you are in an extremely high electric field. If you or any member of your group experiences any of these signs, it should be taken as an indication of immediate and severe danger. The response to any of these signs should be to instantly (seconds matter) drop and move away from all packs, remove metal shoe fittings, spread out, and adopt the lightning position. Do not ignore these signs and do not try to run to safety, unless safety is literally seconds away. If any of these signs are detected, the probability of a close discharge is high and every effort should be made to minimize injuries and the number of injured.

How Can We Reduce Lightning Risk In The Backcountry?

Backcountry lightning safety data is sparse, so these suggestions are "best hunches" by experts who study lightning safety. Random circumstance is a significant factor in where lightning might strike, meaning that these behaviors help reduce your "Las Vegas" odds of lightning injury, but can never make you safe. If you need to stay safe, you need to remain indoors in well protected buildings.

There are things you can do to reduce risk during a thunderstorm, but you can never get as safe as you could be in town. Ron Holle of the National Severe Storm Lab uses a 10-scale for lightning safety. (Going into a modern building and avoiding metal is as safe as it gets at 10, being in a hard-topped car is a 5, sitting on a steel tower on a mountaintop is a 0.) Ron thinks backcountry precautions only move you up .1 on this scale. Other scientists say they think these precautions move you up 4 points on Ron's 10-scale. Some risk reduction factors, like taking off a metallic belt buckle, might reduce burns but have little to do with avoiding becoming a fatality from a direct strike or ground currents. But there are five actions that can reduce your risk, in order:

- **time visits to high risk areas with weather patterns**

- **find safer terrain if you hear thunder**
- **avoid trees**
- **avoid long conductors**
- **get in the lightning position.**

Timing activities with safe weather requires knowledge of typical and recent local weather patterns. There is no such thing as a surprise storm. You need to set turnaround times that will get you off of exposed terrain before storms hit. You need to observe the changing weather and discuss its status with your group. Logistical problems en route should alter whether you complete the paddle or the climb, not whether you get exposed during a storm.

Begin your turnaround if you hear thunder (which means lightning is one to ten miles away.) In calm air you can hear thunder for about ten miles. In turbulent air you can hear the thunder for about five miles[8]. In a driving storm you may only hear it out to one mile. Some parties in rain storms have been struck before they heard any thunder at all.

Safer terrain in the backcountry can decrease your chances of being struck. High pointed terrain attracts lightning to the high points, and even to the terrain around it. Avoid peaks, ridges, and significantly higher ground during an electrical storm. If you have a choice, descend a mountain on the side that has no clouds over it, since strikes will be rare on that side until the clouds move over it. Once you get down to low rolling terrain, strikes are so random you shouldn't worry about terrain as much. If you are exposed to lightning, you need to get in the lightning position as soon as possible, which obviously means you stop moving to safer terrain at that point. Many people have died while upright and walking to safer terrain, but no one has died while stopped in the lightning position. Move to safer terrain as soon as you hear thunder, not when the storm is upon you.

Tents may actually increase the likelihood of lightning hitting that spot if they are higher than nearby objects. Metal tent poles conduct ground current and may generate streamers. Use your understanding of terrain and lightning to select tent sites that may reduce your chances of being struck or affected by ground current. If you are in a tent in "safer terrain" and you hear thunder, you at least need to be in the lightning position. But if your tent is in an exposed location, such as on a ridge, in a broad open area, or near a tall tree, you need to get out of the tent and get into the lightning position before the storm starts, and stay out until it has passed. It would be wise to anticipate additional hazards of getting out of tents in the dark of night during a storm. Determine a meeting spot, have rain gear and flashlights accessible, and have a plan for managing the group during this time.

In gently rolling hills the lower flat areas are probably not safer than the higher flat areas because none of the gentle terrain attracts leaders. Strikes are random in this terrain. Look for a dry ravine or other significant depression to reduce risk.

Wide open ground offers high exposure during an electrical storm. Avoid trees and bushes that raise above the others, since the highest objects around tend to generate streamers. Your best bet is to look for an obvious ravine or depression before the storm hits, but when the cloud is over you, spread out your group at 50' intervals to reduce multiple injuries and assume the lightning position.

Naturally wet ground, like damp ground next to a stream, isn't any more dangerous than dry ground, so don't worry about this. It used to be said that wet ground was more dangerous, because it conducted more ground current, but wet ground actually dissipates ground current faster. Neither wet nor dry is considered more dangerous than the other. Standing *in* water should be avoided.

Dry snow is an insulator, but wet snow is a conductor. This should make travel on dry snow safer than on bare ground, because it will be harder for a person to generate streamers or conduct ground current.

Figure 3: terrain with streamers and a stepped leader. Where do you think the strike will occur?

Avoid cave entrances. Small overhangs can allow arcs to cross the gap. Natural caves that go well into the ground can be struck, either via the entrance or through the ground: cavers should avoid being inside a cave, near an entrance, during a thunderstorm[9]. You should never be anywhere near any metal handrail, wire or cable during a storm. People who have been shocked standing in water deep inside caves cite weak charges, indicating that deep within a cave is safer than being on the surface. If you are near an entrance during electrical activity, don't stand in water, avoid metal conductors, and avoid bridging the gap between ceiling and floor. Move quickly through the entrance (in or out) to minimize the time of your exposure. If you are stopped waiting for others near an entrance area, assume the lightning position.

Boaters should start to get off of the water as soon as they hear thunder. There are no reported incidents of lightning accidents on rivers in canyons, probably because the higher terrain above the canyon attracts the leaders. But there is ample lightning injury data for boaters on rivers in flat terrain, on lakes, and on the ocean. When you get to shore, look for protective terrain to wait out the storm. Be especially cautious of trees at the edge of the water because they might be the tallest objects around the body of water. Boats that can't get off the water in lightning-

[8] Use the 5 sec/ mile (3sec/km) flash-bang rule to measure the distance in ideal conditions, but this can distract people from the big picture.

[9] This is anecdotal data from Cavers' Digest.

prone areas should have lightning protection: see this website http://www.cdc.gov/niosh/nasd/docs/as04800.html

Avoid trees because they are taller than their surroundings. Tall trees are especially adept at generating streamers that attract strikes. If you need to move through a forest while seeking safer terrain, stay away from the tree trunks as you move. You should also avoid open areas that are 100 m wide or wider. Lone trees are especially dangerous: the laws of probability say you are hundreds of times safer in a forest with hundreds of trees than you are near a lone tree in an open space.

"Cone of protection" from trees and cliffs is an arguable concept and has no place in lightning safety education anymore. Lightning has been photographed striking 100 m from 200 m towers, and surface arcs have been photographed exactly where "cones of protection" inferred we were all safe. Instead we need to teach the 50 m leader search distance concept (see the first paragraph of this paper.) If someone is within 50 m of a significantly higher object, they have a greatly reduced chance of being struck directly. You can still be struck, especially indirectly, but the chances are reduced. The 50 m concept works best with cliffs and other steep terrain that provide protection without directing the strike toward you. The 50 m concept does not work well for trees because the base of the tree may send out surface arcs. (see figure 2)

Avoid long conductors. Lightning currents tend to pass in long electrical conductors — particularly ones that are on or near the surface of the Earth. Metal fences, power lines, phone lines, railway tracks, handrails, measuring tapes, bridges, and other metal objects can carry significant lightning current even if these objects are at some distance from the lightning ground strike point. Near the ground strike point of a lightning discharge, wet ropes can conduct lethal currents. During a thunderstorm, wet, extended ropes should be regarded as equivalent in risk and danger to metal wires.

Assume the lightning position[10] when at risk. This will reduce the chances of getting a direct strike and it may reduce the other effects of lightning, but it offers no guarantees. Some scientists argue that it only moves you up to 0.1 on the 10-scale; others argue that it is much more valuable because the data says that no one in this position has ever been hurt. This position includes squatting (or sitting) and balling up so you are as low as possible without getting prone. Wrap your arms around your legs, both to offer a safer path than your torso for electrons to flow from the ground, and to add enough comfort that you will choose to hold the position longer. Close your eyes.

Figure 4: The lightning position: squat or sit, ball up, put feet together, wrap arms around legs.

[10] We used to call this the lightning SAFETY position, but this name easily allows the illusion of safety.

While the prone position is lower, being spread out increases potential for ground current to flow through or across you. Keep your feet together so you don't create potential for current to flow in one foot and out the other. If you have any insulated objects handy, like a foam pad or a soft pack full of clothes, sit on them. Avoid backpacks with frames since the frame may concentrate current. Don't touch metallic objects like ice axes, crampons, tent poles or even jewelry. You won't get a warning that a strike is imminent because the lightning event from cloud to ground and back occurs faster than you can blink an eye, so stay in the lightning position until the storm passes. The lightning position reduces the chances of lightning injuring you as badly as if you were standing, but is no substitute for getting to safer terrain or structure if it is immediately available. A dangerously close strike actually offers a moment of opportunity to move, while the electrical field rebuilds itself. But in wide open country or gentle rolling terrain there are no simple terrain advantages, so use this position to reduce exposure. If you are concerned enough to assume the lightning position, you should have your group dispersed at least 50' apart to reduce the chances of multiple injuries.

Ground current may spontaneously trigger your leg muscles to jump while in the lightning position, so take care to avoid being near hazards when you drop into this position.

Anecdotal injury data shows that persons with metal cleats on their shoes are more prone to injury. So take crampons off while in the lightning position. But if taking crampons off will slow your descent from a hazardous spot, leave them on to reach safer terrain faster, since terrain is a much better protector than the lightning position is.

The Effects Of Lightning Strikes On Humans

There are three ways lightning hurts us:

1. Electrical shock
2. Secondary heat production
3. Explosive force[11].

Neuro-electrical Damage: Current through the torso or brain can stop the heart or stop breathing. Hearts often restart themselves quickly, but it can take the breathing control center longer to recover. Cardiac or respiratory arrest that isn't restarted quickly will eventually cause anaerobic conditions that make recovery problematic. Current through the tissues can also lead to numbness, paralysis or other nervous system dysfunction.

Burns: Lightning victims can get burned from the high current electricity that turns into heat in conductors that resist its flow. Strike victims can get linear burns from head to feet along the skin, punctate (spotted) burns, or feathering skin marks (not really burns) from the charge flowing over their skin. They can get secondary burns from metallic objects like belt buckles and jewelry that heat up from the current. Burns can also occur from lightning-ignited clothing.

[11] Cooper, Mary Ann, MD. Ch 7: Lightning Injuries. In Paul Auerbach MD's Wilderness Medicine: Management Of Wilderness And Environmental Emergencies, 3rd ed. 1995.

Large entry and exit burn wounds from lightning strikes are rare. Most victims have a flashover effect (current travels over their skin) that saves them from the more severe wounds: these people can get linear or punctate burns or feathering patterns. But flashover can also travel into orifices, which may explain the many ear and eye problems that result from lightning strikes.

Wet people may carry more current over their skin, instead of through their bodies, reducing their injuries. It is not suggested that you intentionally get wet in case you are struck, but it does mean you shouldn't be scared that being wet will increase the risk for you.

Trauma: The explosive force of lightning can result in direct or indirect trauma resulting in fractures or soft tissue injuries. Watch for explosive injuries at the feet. The high current can also trigger significant muscle spasms that can fracture bones.

Psychological Effects: Electrical injury can injure the brain. Immediate problems may include altered consciousness, confusion, disorientation or amnesia. Long term problems may include anything from headaches and distractibility to persistent psychiatric disorders and dementia[12].

First Aid For Lightning Victims

Medical aspects of lightning injury are covered in "NOLS Field Medical And Drug Protocols 2000" and in Ch 4 of the NOLS Wilderness First Aid[13] text 3rd ed. The following overview does not supercede those documents.

All patients require a complete body survey and careful evaluation for head, spinal, long bone, or cardiac injuries; peripheral pulses and sensory and motor status should be assessed. Check the skin for small hidden burns. The patient in cardiopulmonary arrest may require prolonged CPR, especially **respiratory support** if spontaneous pulse and blood pressure return. *Unlike normal triage protocols*, first attention and resources should be directed to those who appear dead and those requiring immediate support of airway and breathing. Any patient who has shown any signs and symptoms of lightning injury should be evacuated for further evaluation and treatment.

Teaching Lightning Risk Management

Teaching backcountry lightning safety has the risk that our students will defer to these techniques when civilization offers significantly better options. There are two things we can do to mitigate this possibility.

1) When we are in town, if lightning hazards present themselves, it is important that we model the reaction to seek safety in buildings or vehicles[14]. Once inside, we need to avoid pipes, wires and other metallic objects that could conduct a strike. If you aren't sure whether to "do the drill," err on the side of caution for the sake of having your students practice the routine. Just like CPR, emergency actions are best learned in the kinesthetic mode rather than an intellectual one, so they will be more memorable in times of stress.

2) We can easily teach non-wilderness lightning safety techniques during a wilderness program, since the intown choices are so simple and so effective. Getting in a modern building or inside a car during an electrical storm are the only reasonable options when they are available. Indeed, we can use the relative ease of good choices while in town, and the comparatively high risk of backcountry options, to help our backcountry students default on the side of conservatism when it comes to getting up peaks by noon, getting off the water, choosing safe campsites and generally avoiding exposed terrain when storms threaten us.

Record Keeping For Lightning Incidents

Normal near-miss forms need to be completed quickly to accurately document any near miss. Near misses are used to inform others what hazards to be careful of, and to help predict accident types. Any lightning incident also needs a record of actions taken to avoid the hazard before the incident, weather observations, and thunder and lightning observations before the incident. You should sketch who was where relative to surrounding terrain and vegetation, with estimated distances, heights and elevations, a North arrow, and at least one definitive landmark. If you have time for a detailed sketch, measure using paces that you can convert to meters later. Be sure to record people who were and were not injured by the strike. A precise record of the time[15] and location of the ground strike may help lightning scientists give you some data about that actual strike[16].

Thank you to Mary Ann Cooper MD, Ron Holle, Martin Uman and others for their tremendous contributions to the field and to this collection of information. Lightning scientists do not all agree on these adaptations of their careful scientific studies. Any misrepresentation or maladaptation of their material is my fault, not theirs. JTG

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[12] "Behavioral Consequences of Lightning and Electrical Injury". Margaret Primeau, Ph.D., Gerolf H. Engelstatter, Ph.D. and Kimberly K Bares, M.S. Seminars in Neurology, V15, N3, Sept 1995.

[13] Schimelpfenig & Lindsey, NOLS Wilderness First Aid, 3rd ed, Stackpole, 2000.

[14] See http://www.uic.edu/~macooper/faq1.htm for recommendations of the Lightning Safety Group.

[15] Check watches to the nearest second, then calibrate them with an atomic clock, available at any Radio Shack.

[16] The National Lightning Data System records most strikes in the continental US. Buy data at www.lightningstorm.com

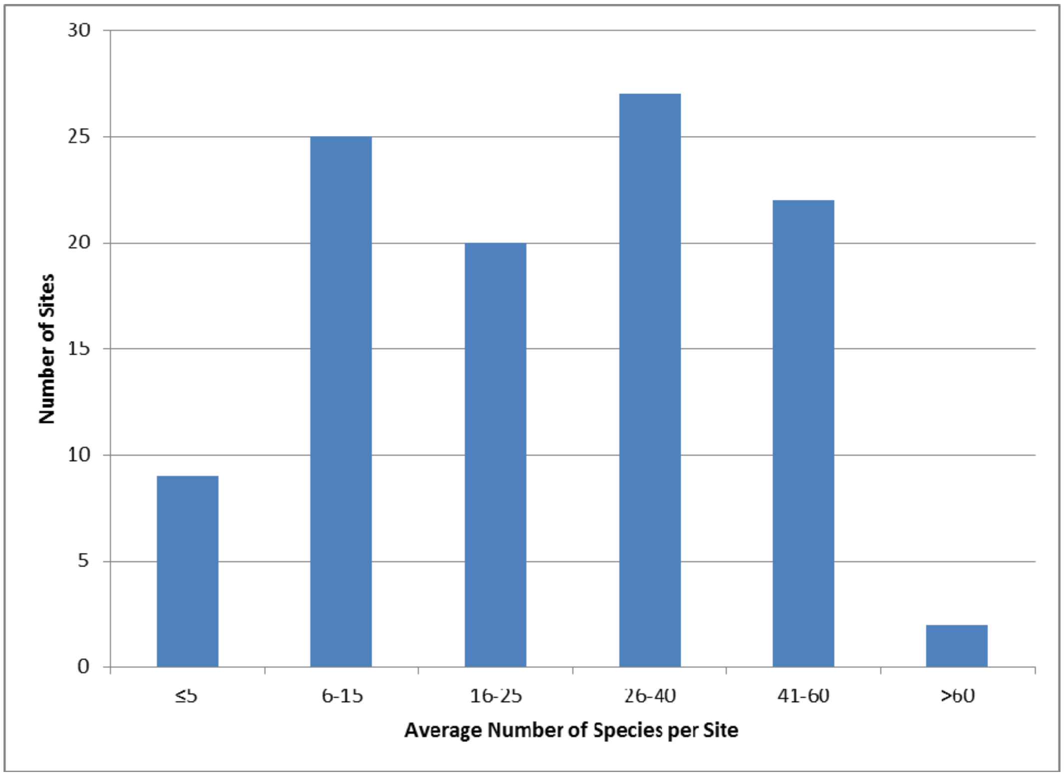
Appendix F. Terminology, Description, and Calculation of the Floristic Quality Assessment Metrics

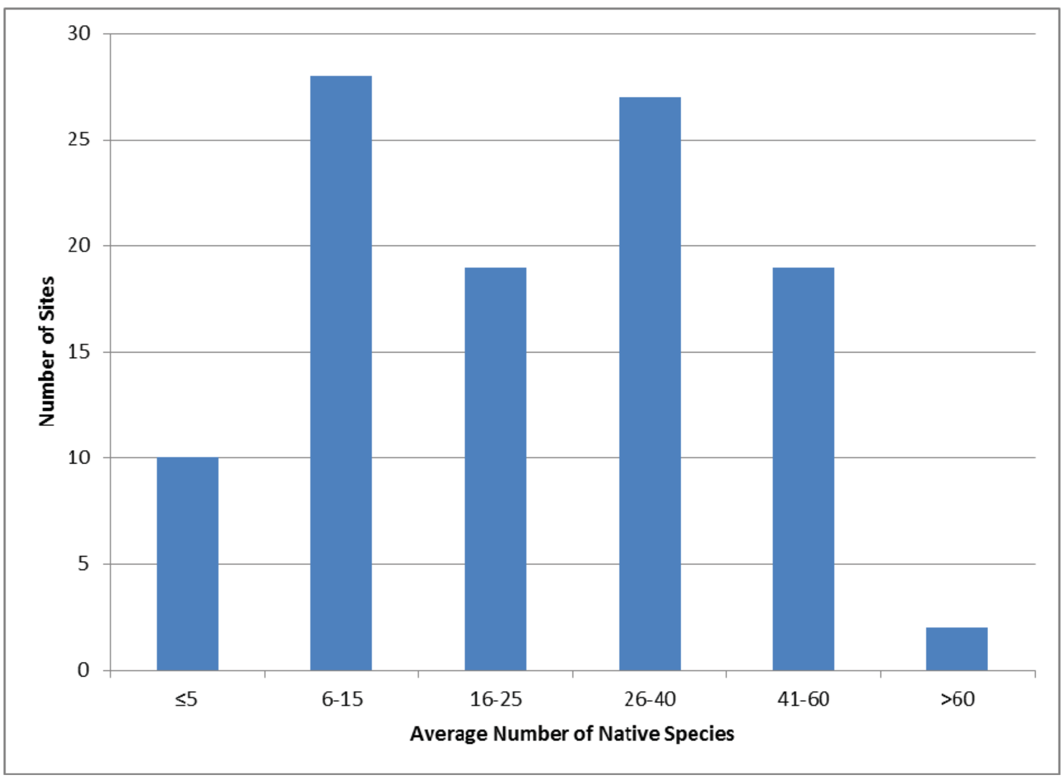
N_n = count of native species, N_a = count of all species, N_e = count of non-native species, C_i = index of conservatism for the i^{th} species, x_i = percent cover for the i^{th} species.

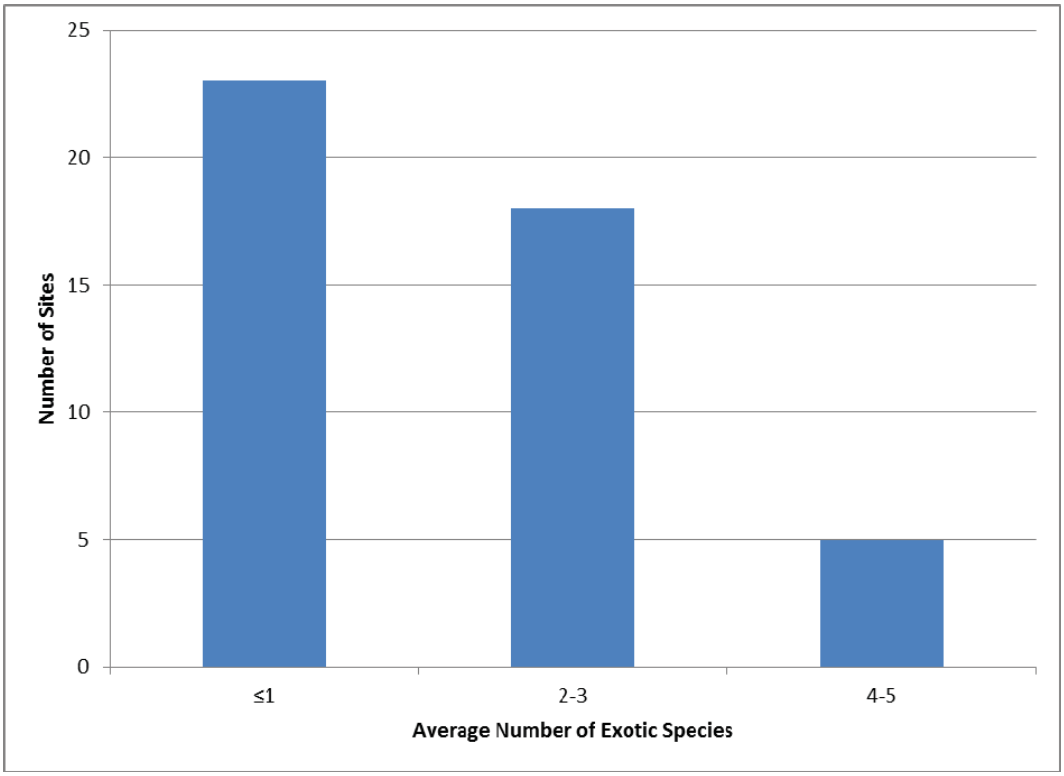
Indices	Description	Calculation
Species richness	Number of plant species observed	N_a
Native species richness	Number of native plant species observed	N_n
Non-native species richness	Number of non-native plants	N_e
Percent non-native species	Number of native plants divided by the number of all plants multiplied by 100	$(N_n/N_a)(100)$
Mean C	Average C-value of all plants	$\sum_{i=1}^{n} C_i \Big/ N_a$
Mean C$_{nat}$	Average C-value of only the native plants	$\sum_{i=1}^{n} C_i \Big/ N_n$
Cover-weighted Mean C	Sum of each species C-value multiplied by its cover values, then divided by the sum of cover values for all species	$\sum_{i=1}^{n} x_i C_i \Big/ \sum_{i=1}^{n} x_i$
Cover-weighted Mean C$_{nat}$	Sum of each native species C-value multiplied by its cover values, then divided by the sum of cover values for native species	$\sum_{i=1}^{n} x_i C_i \Big/ \sum_{i=1}^{n} x_i$
FQI	Mean C of all plants multiplied by the square-root of number of all plants	$\left(\sum_{i=1}^{n} C_i \Big/ N_a\right)\sqrt{N_a}$
FQI$_{nat}$	Mean C of native plants multiplied by the square-root of number of native plants	$\left(\sum_{i=1}^{n} C_i \Big/ N_n\right)\sqrt{N_n}$
Cover-weighted FQI	Cover-weighted Mean C for all species multiplied by the square-root of all species	$\left(\sum_{i=1}^{n} x_i C_i \Big/ \sum_{i=1}^{n} x_i\right)\sqrt{N_a}$
Cover-weighted FQI$_{nat}$	Cover-weighted Mean C for native plants multiplied by the square-root of native plants	$\left(\sum_{i=1}^{n} x_i C_i \Big/ \sum_{i=1}^{n} x_i\right)\sqrt{N_n}$
Adjusted FQI	Mean C of native plants divided by 10 multiplied by square-root of native plants divided by the square-root of number of all plants multiplied by 100	$\dfrac{\left(\sum_{i=1}^{n} C_i \Big/ N_n\right)}{10} \dfrac{\sqrt{N_n}}{\sqrt{N_a}}(100)$
Adjusted cover-weighted FQI	Cover-weighted Mean C for native plants divided by 10 multiplied by square-root of native plants divided by the square-root of number of all plants multiplied by 100	$\dfrac{\left(\sum_{i=1}^{n} x_i C_i \Big/ \sum_{i=1}^{n} x_i\right)}{10} \dfrac{\sqrt{N_n}}{\sqrt{N_a}}(100)$

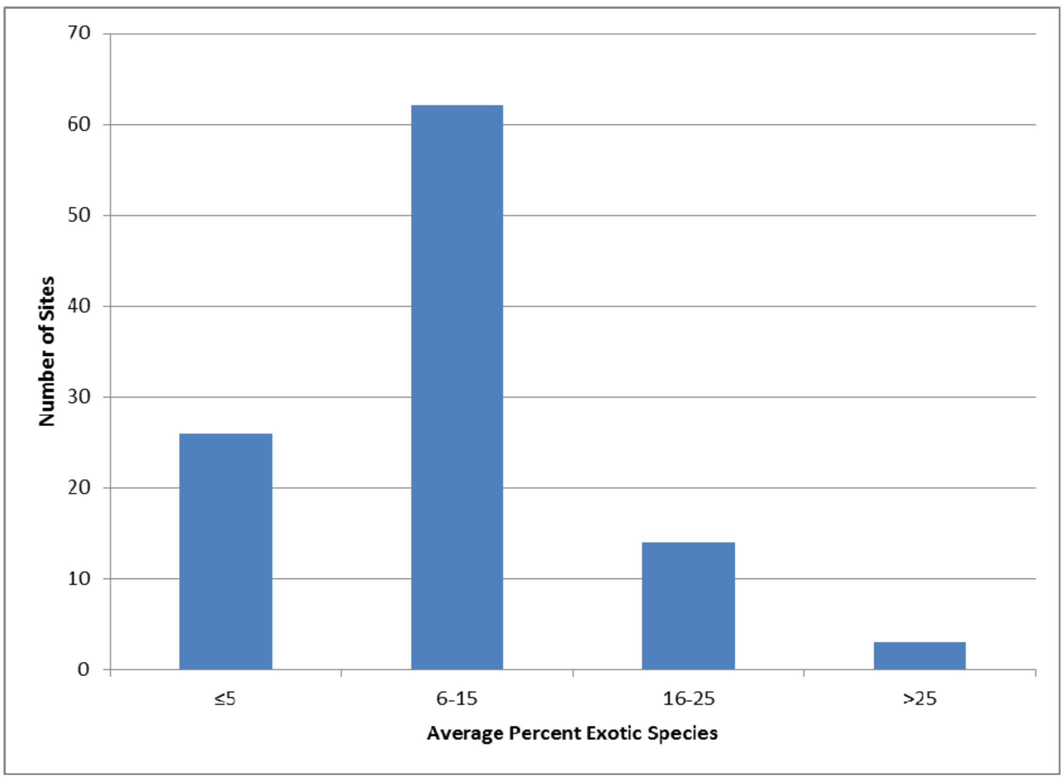
Appendix G. Frequency Histograms

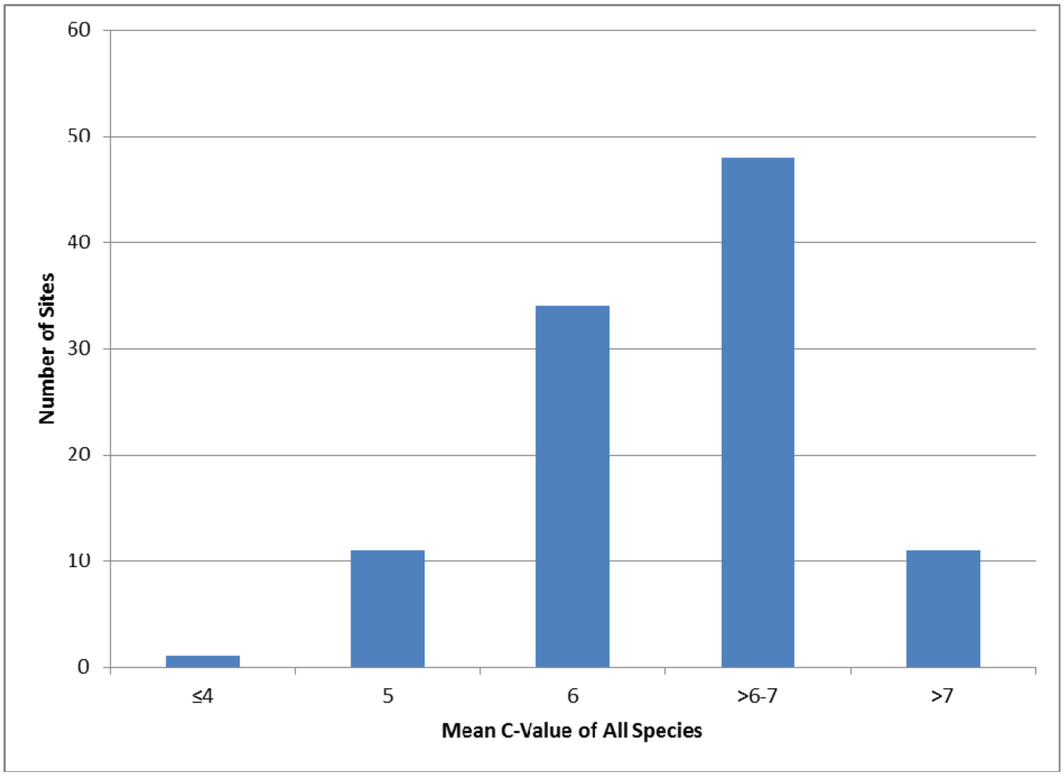
These histograms depict the floristic quality assessment metrics for wet meadows, fens, emergent marshes, and riparian shrublands assessed as part of the project.

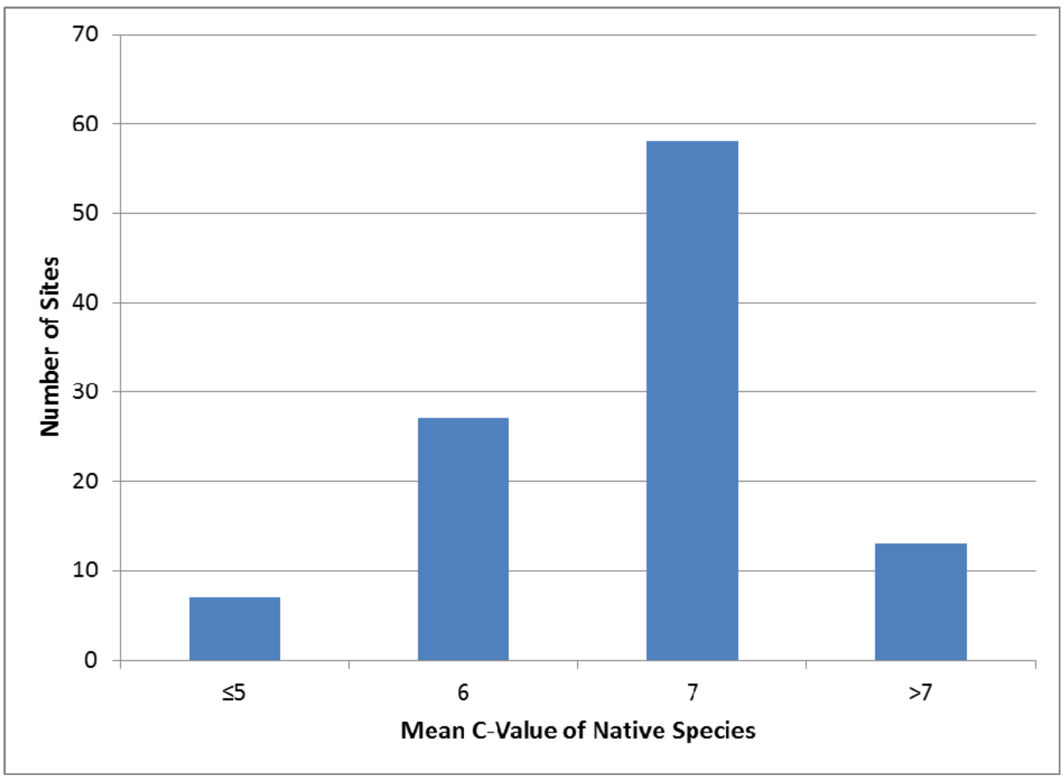


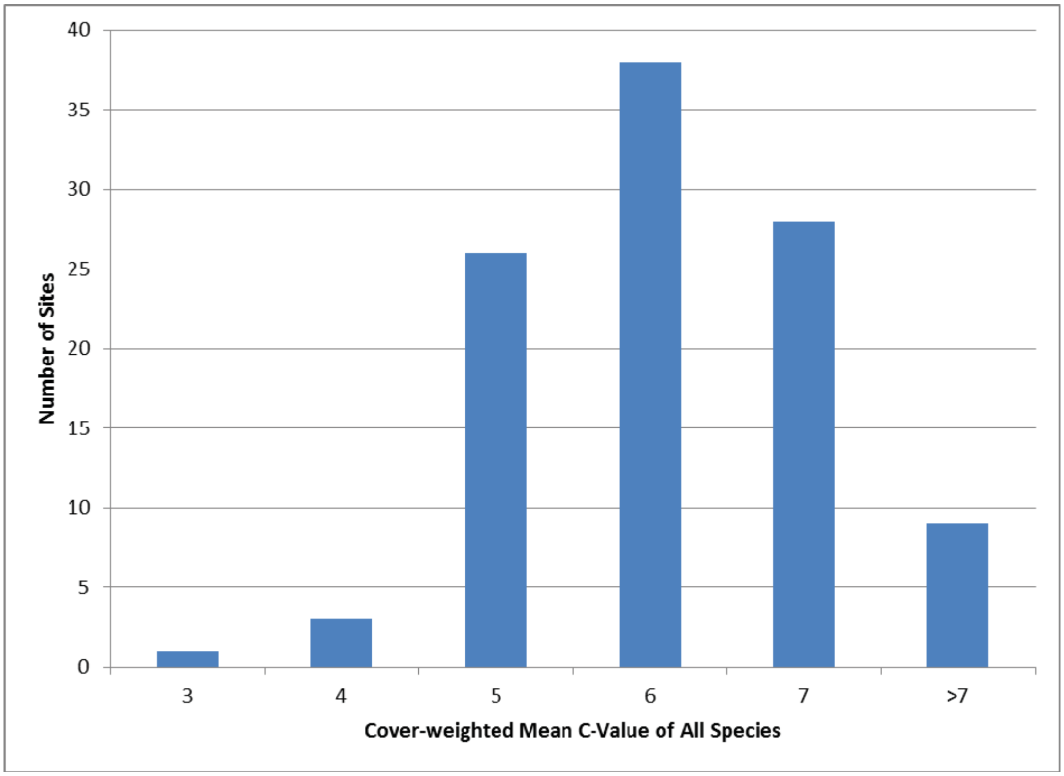


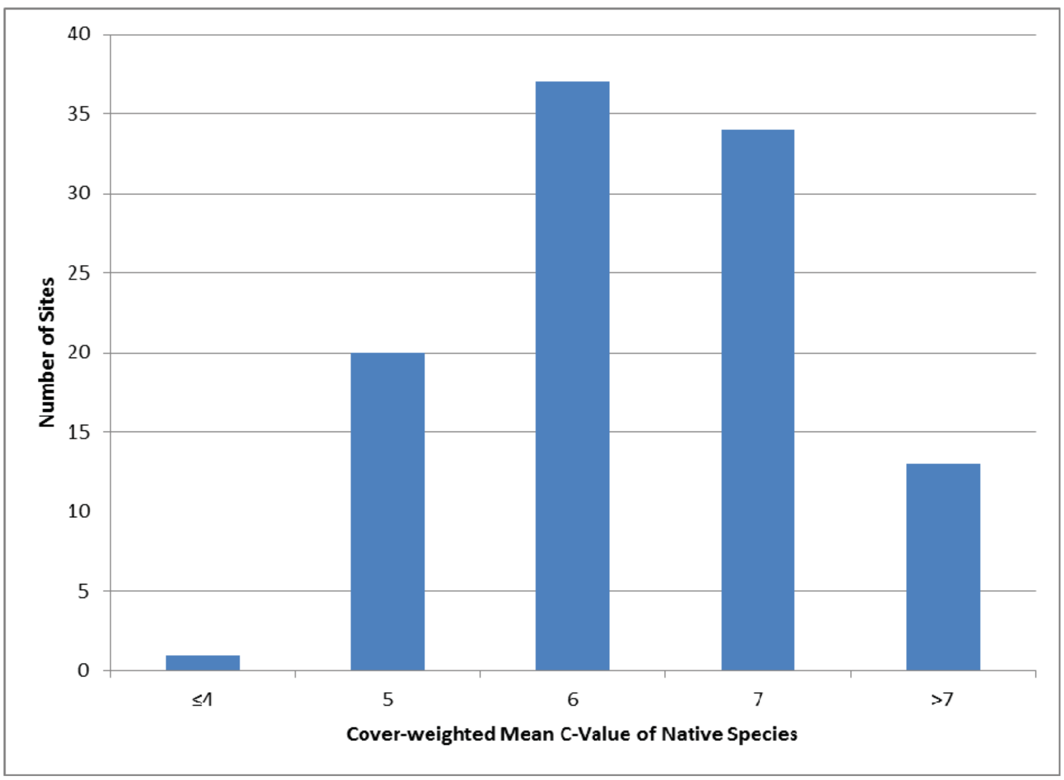

25
20
15
10
5
0
Number of Sites
≤1
2-3
4-5
Average Number of Exotic Species

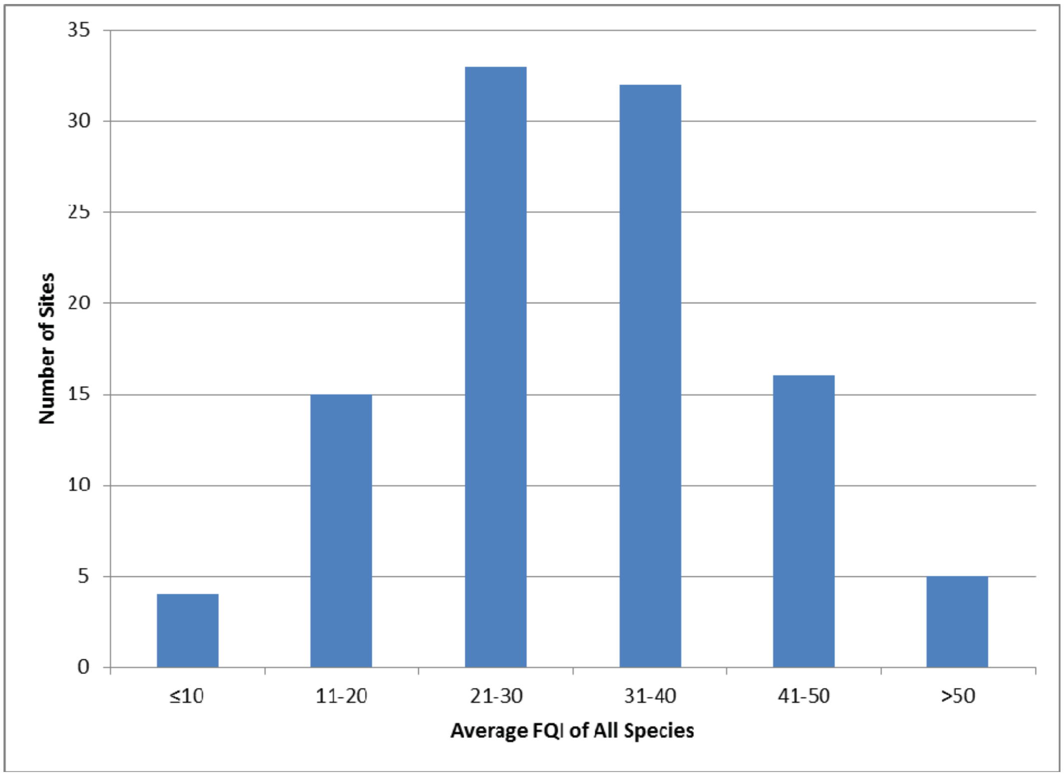

70
60
50
40
30
20
10
0
Number of Sites
≤5
6-15
16-25
>25
Average Percent Exotic Species

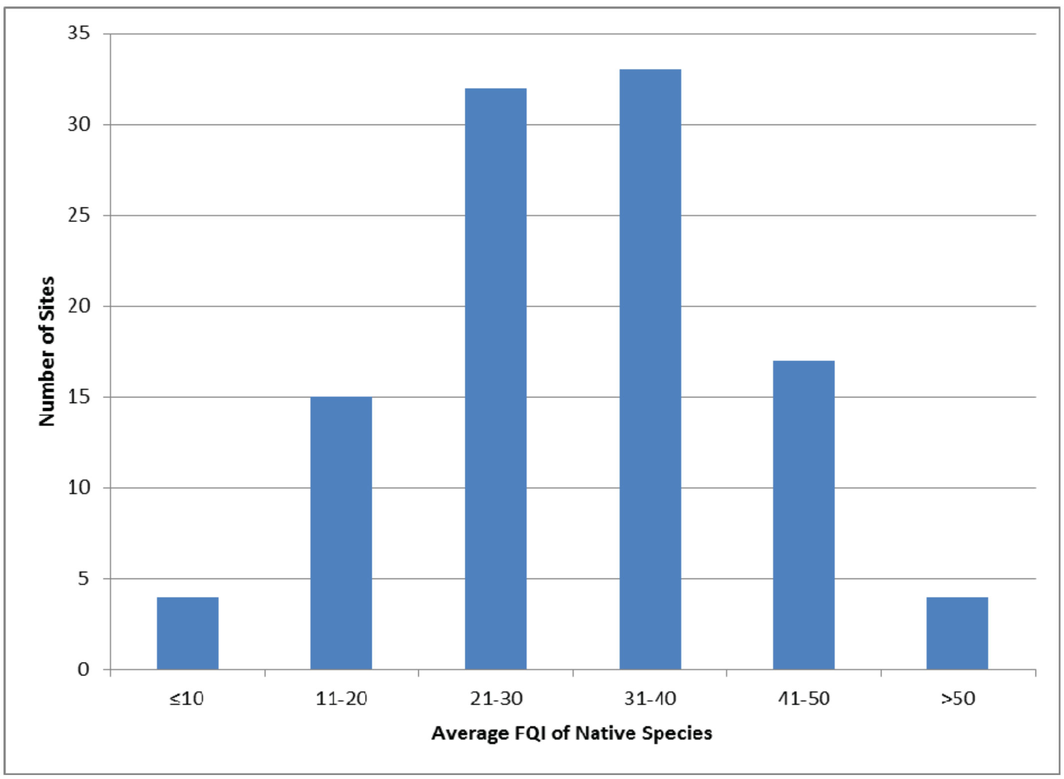

60
50
40
30
20
10
0
Number of Sites
≤4
5
6
>6-7
>7
Mean C-Value of All Species

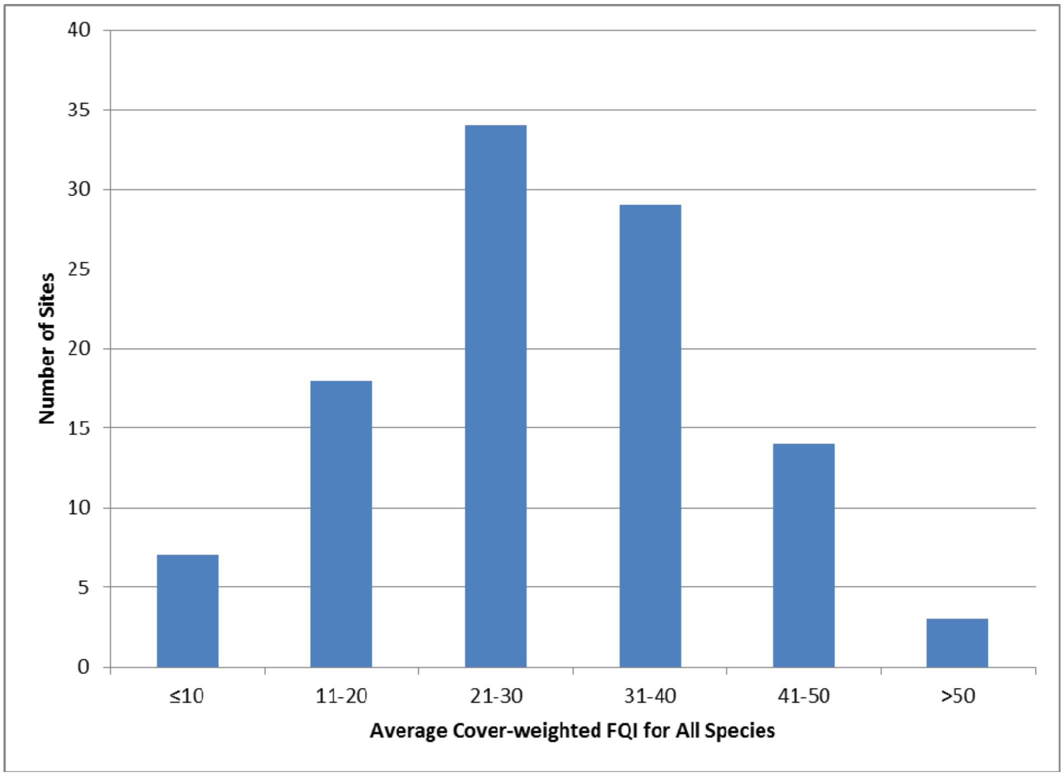

70
60
50
40
30
20
10
0
Number of Sites
≤5
6
7
>7
Mean C-Value of Native Species

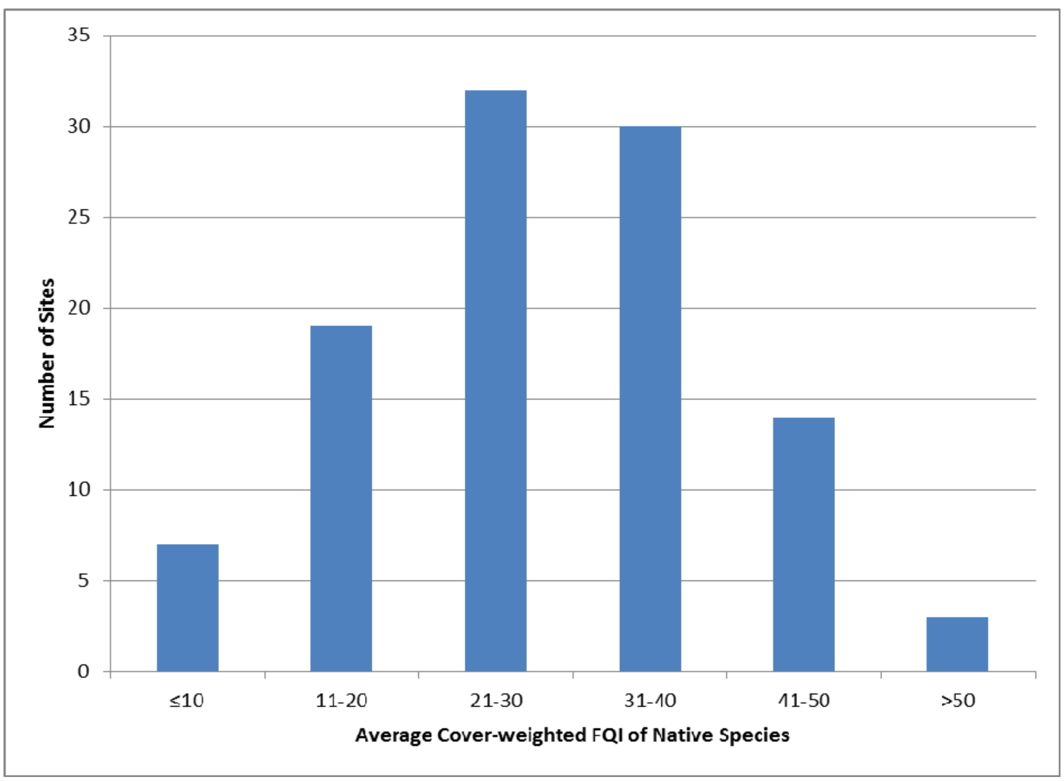

40
35
30
25
20
15
10
5
0
Number of Sites
3
4
5
6
7
>7
Cover-weighted Mean C-Value of All Species

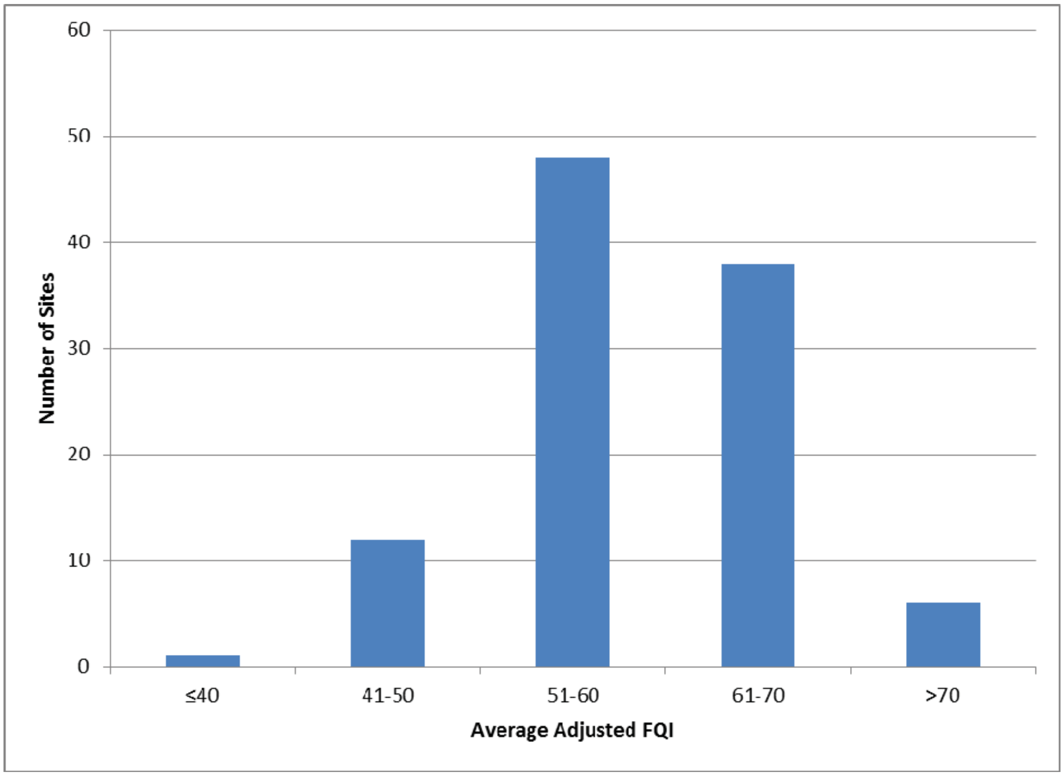

40
35
30
25
20
15
10
5
0
Number of Sites
≤4
5
6
7
>7
Cover-weighted Mean C-Value of Native Species

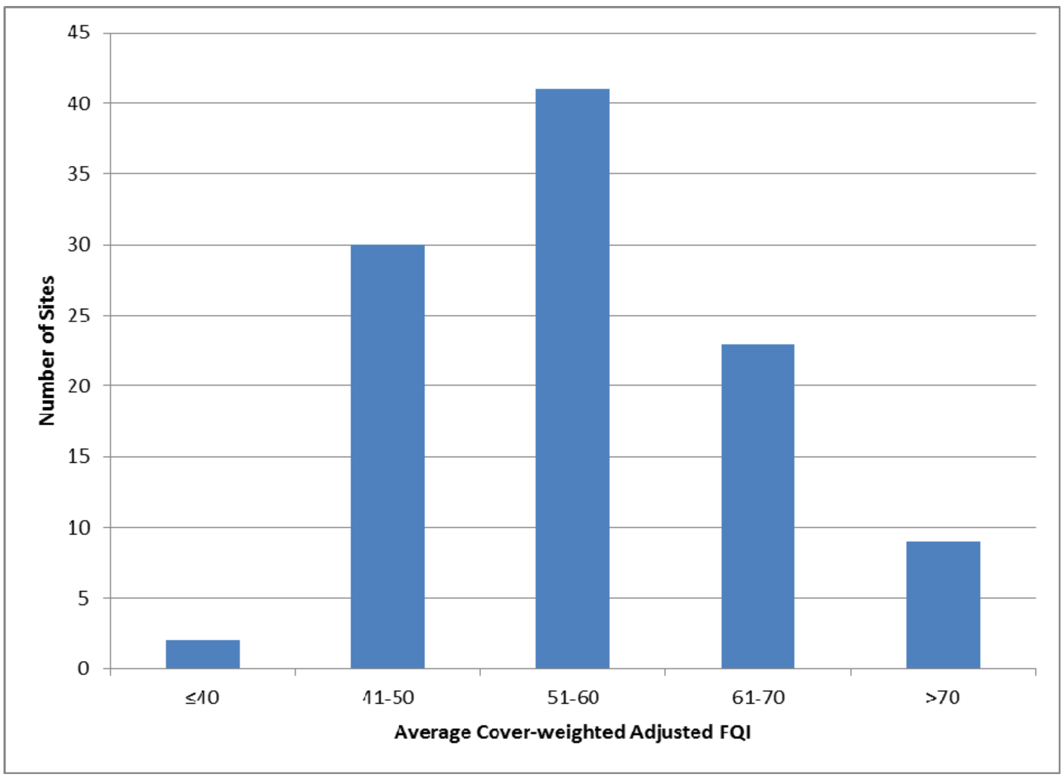

35
30
25
20
15
10
5
0
Number of Sites
≤10
11-20
21-30
31-40
41-50
>50
Average FQI of All Species


35
30
25
20
15
10
5
0
Number of Sites
≤10
11-20
21-30
31-40
41-50
>50
Average FQI of Native Species


40
35
30
25
20
15
10
5
0
Number of Sites
≤10
11-20
21-30
31-40
41-50
>50
Average Cover-weighted FQI for All Species


35
30
25
20
15
10
5
0
Number of Sites
≤10
11-20
21-30
31-40
41-50
>50
Average Cover-weighted FQI of Native Species


60
50
40
30
20
10
0
Number of Sites
≤40
41-50
51-60
61-70
>70
Average Adjusted FQI


45
40
35
30
25
20
15
10
5
0
Number of Sites
≤40
41-50
51-60
61-70
>70
Average Cover-weighted Adjusted FQI

Appendix H. Redundancy Test of Pearson Correlation Coefficients Among FQA Metrics

Variable correlations > 0.8 are shown in bold.

	Total species richness	Native species richness	% Non-native species	Mean C-value of all species	Mean C-value of native species	Cover-weighted Mean C-value of all species	Cover-weighted Mean C-value of native species	FQI of all species	FQI of native species	Cover-weighted FQI of all species	Cover-weighted FQI of native species	Adjusted FQI	Adjusted cover-weighted FQI
Total species richness	1.00												
Native species richness	**0.99**	1.00											
% Non-native species	0.16	0.09	1.00										
Mean C-value of all species	0.05	0.07	-0.17	1.00									
Mean C-value of native species	0.12	0.13	-0.08	**0.95**	1.00								
Cover-weighted Mean C-value of all species	0.12	0.14	-0.11	0.62	0.65	1.00							
Cover-weighted Mean C-value of native species	0.18	0.18	0.06	0.58	0.65	**0.91**	1.00						
FQI of all species	**0.95**	**0.96**	0.06	0.31	0.36	0.30	0.33	1.00					
FQI of native species	**0.96**	**0.97**	0.04	0.28	0.34	0.28	0.32	**0.99**	1.00				
Cover-weighted FQI of all species	**0.91**	**0.91**	0.08	0.30	0.36	0.48	0.50	**0.96**	**0.95**	1.00			
Cover-weighted FQI of native species	**0.92**	**0.92**	0.07	0.28	0.35	0.44	0.51	**0.96**	**0.96**	**0.99**	1.00		
Adjusted FQI	0.13	0.17	-0.35	**0.91**	**0.93**	0.65	0.57	0.36	0.36	0.37	0.36	1.00	
Adjusted cover-weighted FQI	0.18	0.20	-0.12	0.61	0.66	**0.95**	**0.97**	0.36	0.35	0.52	0.52	0.65	1.00