Wetlands of the Flathead Valley: Change and Ecological Functions

Prepared for:

The Montana Department of Environmental Quality and
The U. S. Environmental Protection Agency

Prepared by:

Karen R. Newlon and Meghan D. Burns

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EXECUTIVE SUMMARY

Although several reports have documented loss in wetland area, few studies have addressed the corresponding change or loss of wetland functions associated with flood control, nutrient retention, and wildlife habitat. Wetlands are valued not for the area they cover but for the ecological functions they perform, so an assessment of the change in cumulative function over time is warranted. This is particularly valuable for those areas experiencing rapid land use changes that have potentially impacted wetland area, distribution, and function. The purpose of this project was to estimate wetland change in the rapidly developing Flathead Valley between 1981 and 2005 and estimate cumulative change in wetland functions. We compared historic National Wetland Inventory (NWI) wetland mapping from 1981 for the Flathead Valley with updated wetland mapping based on 2005 color-infrared aerial photography and added hydrogeomorphic (HGM) modifiers to link wetland type and wetland function.

To analyze wetland change, we compared randomly selected wetlands from the original NWI with new NWI mapping created for this project. We randomly selected 10% of the one-square mile Public Land Survey System sections in each fifth-code hydrologic unit in the study area. Within the sampled area, we compared each wetland polygon in the old mapping to the corresponding wetland polygon in the new mapping, and we assigned a source of change to each polygon. In addition to changes in wetland area, we also examined changes in land cover type within the study area and within a one-kilometer buffer of each wetland polygon. To assess the functions associated with each wetland, we assigned an HGM attribute code to all wetland polygons in both the old and new wetland mapping. These HGM attributes were combined with the NWI classification attributes to yield a combination ranked on a performance scale of 1 (high), 2 (moderate), and 3 (low) for each of ten wetland functions. We used this performance ranking as a weighting factor and multiplied this weighting factor by wetland area to calculate functional units for each wetland function.

We digitized nearly 132,000 acres (53,419 hectares) of wetlands within the study area. Deepwater types associated with Flathead Lake comprised over 75% of the wetland area. As expected, the majority of wetland and riparian habitats (24,255 acres; 9,816 hectares) occurred on private lands within the study area. We observed a slight overall decline of 358 wetland acres (145 hectares) between 1981 and 2005 within the study area, although estimates were highly imprecise. At the fifth-code hydrologic unit level, the greatest decline in estimated wetland area occurred in the Ashley Creek watershed with 1,366 acres (553 hectares) lost. However, most watersheds showed increases in estimated wetland area. Within the wetlands sampled, most wetland changes were attributable to natural causes such as succession. Overall anthropogenic changes in land cover type have been largely changes from Forest and Grassland/Shrub types to Urban and Agriculture types, and the Flathead River-Columbia Falls and Lake Mary Ronan watersheds have seen the largest changes with over 2,405 acres (971 hectares) converted. Land surrounding palustrine emergent wetlands showed the greatest anthropogenic change with 3,160 acres (1,279 hectares) of Open Water, Forest and Grassland/Shrub types converted to Agriculture or Urban cover types.

Deepwater throughflow wetlands consisting of Flathead Lake and associated lentic wetlands comprised the largest hydrogeomorphic type in the Flathead study area, totaling 110,761 acres (44,824 hectares). Wetlands associated with lotic features covered 13,737 acres (5,560 hectares), and terrene wetlands totaled 6,800 acres (2,752 hectares). When examined by watershed, the Flathead Lake watershed contained the largest area of deepwater and lentic wetlands with 60,541 acres (24,500 hectares), and the Flathead River-Columbia Falls watershed had the largest area covered by lotic wetlands with 465 acres (188 hectares) within the study area.

Comparison of wetland functional performance capacities throughout the study area showed a 38.4% loss in hydrologic functions including water

storage, streamflow maintenance, and groundwater recharge. Biogeochemical functions incorporating nutrient cycling, sediment retention, and shoreline stabilization showed a slight increase, whereas functions associated with terrestrial and aquatic habitat, native plant community maintenance, and conservation of wetland biodiversity showed an overall decline of 15.4%. These changes in functional capacity were due to both natural and anthropogenic changes in wetland type and area, as well as changes in mapping conventions between the historic and updated mapping.

Although our analysis showed relatively little overall change in wetland area between 1981 and 2005, we did find changes in wetland functional capacity, particularly in terms of functions related to hydrology and habitat. Additionally, analysis of changes in land cover type around wetlands showed that relatively large areas of forest and grassland/shrub have been converted to agricultural and urban types. These changes have likely affected not only the quality of these wetlands, but also the spatial extent and pattern of wetlands on

the landscape, resulting in a loss of connectivity, reduced water quality, and a reduction in overall wetland integrity.

We emphasize that limitations exist with any wetland mapping effort derived almost exclusively from photointerpretation techniques. Factors such as photo quality, scale, and environmental conditions at the time of photo acquisition can affect mapping accuracy. We also emphasize that the functional capacity ratings assigned to wetlands in this project are only potential capacities, and data on actual functional capacity would require extensive field checking.

This analysis should be considered a preliminary assessment of changes in Flathead Valley wetlands and wetland functional capacity. Data from this analysis can provide very effective conservation tools to identify areas with the potential to perform wetland functions most effectively, allowing natural resource managers and other stakeholders to focus or prioritize their conservation and restoration efforts.

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INTRODUCTION

The U.S. Fish and Wildlife Service has completed several reports on the status and trends of the nation's wetlands (Frayer et al. 1983, Dahl and Johnson 1991, Dahl 2000, 2006). Although these reports underscore the cumulative loss of more than 50% of wetland area in the continental U.S., few studies address the corresponding change or loss of wetland functions associated with flood control, nutrient retention, and wildlife habitat. Because wetlands are valued not for the area they cover but for the ecological functions they perform, an assessment of the change in cumulative wetland function over time is warranted.

Data from the National Wetlands Inventory (NWI) are typically used to analyze changes in wetland area because these data are the most widely available, comprehensive, and standardized wetland mapping products available. The NWI classification system (Cowardin et al. 1979) provides information on wetland characteristics such as water regime, vegetation, and substrate that allow wetlands to be grouped not only for inventory and mapping purposes but also to meet natural resource management objectives. Although these wetland features perform valuable wetland functions such as providing wildlife habitat, NWI descriptions are limited to the individual wetland and provide no information on the wetland within a landscape context. To fully assess wetland functionality, other features must be recognized that describe the external factors influencing wetland function. Several systems have been developed that use hydrology and geomorphology to differentiate among wetland types (see review in Brinson 1993). The hydrogeomorphic (HGM) method of wetland assessment (Brinson 1993) emphasizes the hydrologic and geomorphic controls responsible for maintaining the functional aspects of wetlands, recognizing that some wetlands perform certain functions more effectively than others. In the HGM approach, wetlands are classified based on their geomorphic position, water source, and hydrodynamics.¹ Adding HGM descriptors to each wetland in an

NWI digital database enhances the information about each wetland. In addition to water regime and vegetation, the resulting data record contains information on landscape position, landform, and water flow path. This information can in turn be linked to wetland function, providing a simple way to identify wetlands with the potential to perform various ecological functions (Tiner 2005).

Although HGM applications are largely site specific, based on regional reference conditions, and require substantial field investigations, recent studies in the northeastern U.S. (Tiner 2005) and Colorado (Johnson 2005) illustrate the application of HGM as a tool for initial, coarse-scale characterization and assessment of wetland functions through GIS-based landscape analyses. Once a baseline of wetland functionality is established, a wetland functional profile can be created that estimates wetland functionality at a watershed scale. Comparison of the baseline with current conditions provides information on the status and trends of wetland functions, allowing for recognition of potentially ecologically significant wetlands, prioritization of restoration and protection efforts, and identification of wetlands most effective at performing particular wetland functions.

For areas with historic NWI wetland mapping, the enhancement of NWI digital data with HGM modifiers provides a means of not only estimating change in wetland area but also estimating change in wetland function over time. This is particularly valuable for those areas experiencing rapid land use changes that have potentially impacted wetland area, distribution, and function. In Montana, rapid development in large river valleys has prompted concern over the potential loss of wetlands and their associated wetland functions.

Wetlands are typically concentrated in broad river valleys and riparian areas in Montana. The attractive amenities offered by such areas often encourage rapid population growth, increased

¹ Several regional guidebooks have been developed to assess wetland functions associated with hydrogeomorphic types in areas with similar environmental characteristics (e.g., Hauer et al. 2002).

development, and land conversion. These pressures can have negative impacts on wetland functions including reduced groundwater recharge, increased sediment and nutrient inputs, increased nonnative species, and reduced wildlife habitat. This report focuses on the rapidly developing Flathead Valley. Our objectives were to quantify wetland change in our study area between 1981 NWI wetland mapping and wetland mapping based on 2005 imagery and estimate cumulative change in wetland functions.

STUDY AREA

The study area covers portions of southern Flathead and northern Lake Counties and includes portions of the Northern Rockies and Canadian Rockies Level III Ecoregions (Omernik 1987). The study area is over 925,000 acres (374,000 hectares) and includes portions of 20 fifth-code hydrologic units (HUCs; Figure 1) covering 29 U.S. Geological Survey 1:24,000 topographic quadrangles (Figure 2). These 29 quads comprise the change detection analysis area (CDAA). Outside urban areas, land use is predominantly timber harvest, wildlife habitat, and recreation. Livestock grazing and farming occur in valley locations. The valley formed by the Flathead River is largely private land, whereas the surrounding mountains are predominantly U.S. Forest Service and Plum Creek Timber Company (Figure 3). Much of the CDAA is privately owned (45.9%). The U.S. Forest Service is the second largest land owner with 30%. The largest cities in the CDAA are Kalispell (Flathead County) and Polson (Lake County).

Climate

Regional climate is influenced by Pacific maritime systems and drier continental air masses with cool, cloudy, and wet winters and warm, dry summers. The North Fork and Swan Valleys are cooler and moister than the Flathead Valley and receive more of their annual precipitation as snowfall (Table 1).

Geology, Landform, Soils, and Hydrology

The parent materials in the study area are predominantly sedimentary rocks of the Belt formation. Major rock types include argillite, quartzite, and siltite, with localized areas of limestone. The advances of continental glaciers scoured the low-elevation valleys during the Pleistocene, while alpine glaciers influenced the mountains. Since glacial retreat, valley bottoms have largely been influenced by alluvial processes. Many of the lakes and wetlands occur on glacially influenced landforms such as kettle ponds, outwash plains, and foothill moraines. Alpine glaciers created U-shaped valleys and cirque basins, both of which are favorable for wetland development (Alt and Hyndman 1986).

Several streams and waterbodies within the study area are listed on Montana's 303(d) list of impaired waters. Major impairments include habitat alteration, flow alteration, and bank erosion with siltation and suspended solids being major pollutants. These impaired waters have Total Maximum Daily Load (TMDL) plans to meet water quality standards (Figure 4).

Table 1. Climate data for Polebridge (North Fork of the Flathead), Swan Lake (Swan Valley), and Kalispell (Flathead Valley) from the Western Regional Climate Center (2008).

Station	Polebridge (1933-2000)	Swan Lake (1950-2007)	Kalispell (1896-2006)
MAX TEMP	53.7° F (12.1°C)	55.3° F (12.9°C)	55.5° F (13.1°C)
MIN TEMP	24.6° F (-4.1°C)	29.8° F (-1.2°C)	33.0° F (0.6°C)
HOTTEST	July (79.9° F; 26.6°C), Aug (79.3° F; 26.3°C)	July (81.4° F; 27.4°C), Aug (80.3° F; 26.8°C)	July (81.6° F; 27.6°C), Aug (80.9° F; 27.2°C)
PRECIP	22.0 in (559 mm)	28.5 in (725 mm)	15.2 in (386 mm)
WETTEST	Dec (2.7 in; 70 mm), Jan (2.6 in; 67 mm); June (2.3 in; 57 mm)	Dec (3.4 in; 86 mm), Jan (3.3 in; 84 mm); June (2.9 in; 74 mm)	May (1.6 in; 41 mm), June (2.0 in; 52 mm)
SNOWFALL	108.4 in (2,753 mm)	125.9 in (3,200 mm)	53.3 in (1,354 mm)

MAX TEMP = Average yearly maximum temperature; MIN TEMP = Average yearly minimum temperature;
HOTTEST = Hottest months and maxima; PRECIP = Average annual precipitation; WETTEST = Wettest months;
SNOWFALL = Average total snowfall.

Figure 1. The wetland change detection analysis area for the Flathead Valley.

Figure 2. The topographic quadrangles covered by the wetland change detection analysis area for the Flathead Valley.

Figure 3. Land ownership within the Flathead change detection analysis area.

Figure 4. Streams and waterbodies on the state of Montana's 303(d) list of impaired waters with Total Maximum Daily Load plans.

Vegetation

The lower elevations in the study area are primarily forested with Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) in drier areas, and grand fir (*Abies grandis*), Engelmann spruce (*Picea engelmanni*), and western redcedar (*Thuja plicata*) on more mesic sites. Common species of mid-elevation forests include Douglas-fir, western larch (*Larix occidentalis*), and subalpine fir (*Abies lasiocarpa*), with whitebark pine (*P. albicaulis*) and subalpine fir most common at higher elevations (Sirucek and Bachurski 1995).

The following information on wetland and riparian vegetation communities is taken largely from Greenlee (1999).

Riparian and Palustrine Forested Wetlands

Wetland and riparian forests in the study area include both coniferous and deciduous tree species (Figure 5). Black cottonwood (*Populus trichocarpa*) and spruce (*Picea* spp.) are common on islands and alluvial terraces along the Flathead, Swan, Stillwater, and Whitefish Rivers. Western redcedar and grand fir occur on low elevation tributaries, whereas subalpine fir is found on low gradient streams at higher elevations.

Riparian and Palustrine Scrub-shrub Wetlands

Riparian and wetland scrub-shrub vegetation in the study area occur on terraces along the floodplains of both low and high gradient streams and rivers. They can also be found around beaver ponds and on the fringes of fens and lakes (Figure 6). Drummond's willow (*Salix drummondiana*) is the most common willow with lesser amounts of Bebb's willow (*S. bebbiana*) and Geyer willow (*S. geyeriana*). Active gravel- and sand-bars are dominated by sandbar willow (*S. exigua*). Mountain alder (*Alnus incana*) and redosier dogwood (*Cornus sericea*) are common on high gradient streams. Shrub communities on the

Figure 5. Palustrine forested wetland in the Flathead Valley.

fringes of fens and lakes include mountain alder and alder-leaved buckthorn (*Rhamnus alnifolia*), whereas bog birch (*Betula glandulosa*) is a common shrub on peatlands.

Figure 6. Palustrine scrub-shrub wetland in the Flathead Valley.

Palustrine Emergent Wetlands

Herbaceous emergent vegetation in the study area is found in a variety of settings with several sedge species common, including *Carex lasiocarpa*, *C. utriculata*, *C. vesicaria*, and *C. limosa* occurring on the wettest sites and native grasses such as tufted hairgrass (*Deschampsia cespitosa*) and bluejoint reedgrass (*Calamagrostis canadensis*) common on wet meadow sites (Figure 7).

Figure 7. Saturated palustrine emergent wetland (top) and semi-permanently flooded palustrine emergent wetland (bottom) in the Flathead Valley.

Aquatic Bed

Palustrine, lacustrine, and riverine aquatic bed wetlands occur in littoral (< 2 meters in depth) and limnetic (> 2 meters in depth) zones of ponds and lakes or on the beds of slow-moving perennial streams (Figure 8). Common aquatic plant species include the floating-leaved yellow pond lily (*Nuphar polysepalum*), and submerged

or partially submerged species such as water-milfoil (*Myriophyllum* spp.), common mare's-tail (*Hippuris vulgaris*), and pondweeds (*Potamogeton* spp.).

Figure 8. Palustrine aquatic bed wetland in the Flathead Valley.

Land Use History

Fur traders arriving in the early 19th century found Salish, Pend d'Oreille, and Kootenai villages along the western shores of Flathead Lake (Elwood 1980, McKay 1994, 1997). The first permanent settler came to the Flathead Valley in 1860 (U.S. Bureau of Reclamation 2008). Kalispell, the largest city in the area, was incorporated in 1892, soon after the arrival of the Great Northern Railway. Livestock grazing, agriculture, and timber harvest have been common land uses since European settlement.

Irrigated agriculture began as early as the 1880s in the Ashley Creek area of the Flathead Valley (U.S. Bureau of Reclamation 2008). Large-scale hydroelectric projects in the area include Hungry Horse Dam on the South Fork of the Flathead River, completed in 1952, and Kerr Dam on the Flathead River about five miles southwest of Polson. Kerr Dam began operation in 1938, raising the level of Flathead Lake by 10 feet (3 meters) over the natural lake outlet (PPL Montana 2008).

The populations of both Flathead and Lake Counties have grown steadily throughout the 20th century (Figure 9). Growth has been especially rapid in Flathead County, where the population has

increased by 67% since 1980 (U.S. Census Bureau 2008). Population growth in both Flathead and Lake Counties has outpaced that of both Montana and the nation (Headwaters Economics 2007a, 2007b). Similarly, density of single-family housing

has increased steadily since 1980 (Figure 10). A comparison of increases in water rights permits over the last 150 years illustrates the increased demand on water resources within the Flathead Valley (Figure 11).

Figure 9. Population growth from 1980-2007 in Flathead and Lake Counties. Source: U.S. Census Bureau 2008.

Figure 10. Growth in single-family housing density in Flathead and Lake Counties from 1980-2006. Source: Headwaters Economics 2008.

As of 1950

As of 1980

As of 2007

Figures 11. Water Rights Permits as of 1950, as of 1980, and as of 2007 in the Flathead Valley. Source: Montana Department of Natural Resources and Conservation.

METHODS

Wetland and Riparian Mapping

To analyze wetland change, we compared randomly selected wetlands from the original NWI with new NWI mapping created for this project. To create the new maps, we digitized wetland and riparian areas using ArcGIS 9.2 (ESRI 2006). We used 1:12,000 scale color-infrared aerial photography taken in 2005 along with several ancillary data layers (Table 2) to enhance mapping accuracy. The NWI classification system (Cowardin et al. 1979) was used to classify wetlands. Mapping procedures followed the USFWS National Standards and Quality Components (USFWS 2004a) and the Technical Procedures for Mapping Wetland, Deepwater, and Related Habitats (USFWS 2004b). The National Wetlands Inventory originally delineated wetlands in the study area using 1:58,000 scale color-infrared aerial photography in 1981.

The NWI classification system is a hierarchical approach that classifies wetlands into systems, subsystems, and classes (Appendix 1). Three systems occur in Montana: Palustrine wetlands (e.g., marshes, fens, potholes, wet meadows, willow carrs, forested swamps); Lacustrine wetlands (e.g., associated with waterbodies at least 6.6 feet [2 meters] in depth and/or at least 20

acres [8 hectares] in size); and Riverine wetlands (e.g., occurring within the active channel of a stream or river). Lacustrine and Riverine systems are further classified into subsystems. Lacustrine subsystems include limnetic (> 2 meters in depth) and littoral (< 2 meters in depth). Riverine subsystems occurring in Montana include Lower Perennial, Upper Perennial, and Intermittent. Classes describe the substrate for Lacustrine and Riverine systems, and the vegetation life form (e.g., emergent, scrub-shrub, forested) for Palustrine wetlands. Hydrologic modifiers are applied to each wetland describing the water regime along a continuum from wettest (permanently flooded) to driest (temporarily flooded). Additional modifiers are added to wetlands altered by anthropogenic (e.g., excavated, impounded) and natural (e.g., beaver) influences.

Riparian habitats have never been mapped in Montana. We used the U.S. Fish and Wildlife Service Western Riparian Classification System (USFWS 1997; Appendix 2) to classify riparian areas. Riparian areas typically lack the amount or duration of water present in wetlands, yet are more mesic and vegetation is more vigorous than adjacent uplands. Woody vegetation is the predominant type of riparian habitat mapped (e.g.,

Table 2. Ancillary spatial data layers used in Flathead wetland change analysis.

Data Layer	Data Source	Year
1-meter resolution color-infrared digital orthophotography	National Agricultural Imagery Program	2005
1-meter resolution true color	National Agricultural Imagery Program	2005
1-meter black and white digital orthophoto quarter quadrangles	U.S. Geological Survey	1990
10-meter digital elevation model	U.S. Geological Survey	Various
1:24,000 topographic quadrangle digital raster graphic	U.S. Geological Survey	Various
1:24,000 high resolution National Hydrography Dataset	U.S. Geological Survey	Various
Original National Wetlands Inventory Wetland Mapping	National Wetlands Inventory, U.S. Fish and Wildlife Service	1981
Management and Ownership Boundaries	Montana Natural Heritage Program Stewardship Layer	2008
National Land Cover Dataset	U.S. Geological Survey, Land Cover Institute	2001

riparian shrubland and riparian forest), although herbaceous riparian emergent vegetation may be mapped if the imagery allows for identification of this type. The riparian classification system is similar to the NWI classification system in its hierarchical approach. The riparian classification system has a single system (Riparian), two subsystems (Lotic and Lentic), and three classes (Forested, Scrub-shrub, and Emergent).

Wetland Change Detection

Analysis

Our sampling units were one-square mile Public Land Survey System sections. We randomly selected 10% of the sections in each fifth-code HUC in the study area using the Hawth's Analysis Tools extension for ArcGIS (Beyer 2004). Flathead Lake does not have survey sections delineated, so sections were digitized for this area.

Improved image quality and resolution associated with the 2005 imagery has enhanced our ability to more accurately map wetlands by detecting wetlands potentially excluded in previous mapping efforts. We made every effort to correctly recognize and attribute the sources of wetland change by visually inspecting each wetland polygon in both the old and new wetland mapping within the sampled sections. Within the sampled area, we compared each wetland polygon in the old mapping to the corresponding wetland polygon in the new mapping, and we assigned a source

of change to each polygon based on the USFWS Status and Trends Procedures (2005) with some modifications (Table 3). For example, if a wetland was mapped as palustrine emergent in the old mapping but had been excavated to create a pond, the polygon was attributed as a "New Pond". If the new wetland polygon was classified the same as the old wetland polygon, then the polygon was attributed with "No Change". We also included a "Mapped as Riparian" category because riparian areas were not previously mapped. Wetland changes attributable to interpreter differences or differences in image quality were attributed with "Interpreter Difference" and removed from the analysis. Additionally, we visually inspected all wetlands associated with beaver ponds and all created wetlands (e.g., excavated ponds).

Wetland water regimes can change annually, so we analyzed wetland change to the class level only. We estimated the difference in area between old and new mapping using the spsurvey package for Spatial Survey Design and Analysis (Kincaid et al. 2008) in R 2.8.0 (R Core Development Team 2008). We estimated wetland change for the entire study area and for each fifth-code HUC.

In addition to changes in wetland area, we also examined changes in area of land cover types between 1992 and 2001 using the National Land Cover Database Change Product (Vogelmann et al. 2001) for the entire study area (Table 4). We assessed land cover change around wetlands by

Table 3. Change categories assigned to sampled wetland polygons.

Code	Type	Description
AG	Agriculture	Land used for the production of food/fiber. Often evidenced by geometric patterns.
RD	Rural Development	Non-intensive land use and sparse building density.
UD	Urban Development	Land is predominantly covered by structures (high building density).
NC	No Change	No change in wetland attribute.
NA	Natural	Change in wetland class due to natural changes in seral stage (e.g., PEM succeeding to PSS).
RE	Resource Extraction	Oil and gas, mining, wind farm.
OT	Other	Areas in transition (filled, drained), but final land use is undetermined at date of imagery.
IN	Interpreter differences	Wetland change due to interpreter error, differences in imagery, etc.
PD	New pond	Pond created by either excavation or impoundment.
RP	Mapped as Riparian	Wetland mapped as riparian in new mapping.

calculating the change in land cover type area within a one-kilometer buffer of each wetland polygon using the Thematic Raster Summary tool in Hawth's Analysis Tools (Beyer 2004).

Wetland Functional Performance

To assess the functions associated with each wetland, we analyzed the landscape position, landform, waterbody type, and water flow paths for each wetland. We used an HGM attribute coding approach developed by Tiner (2003, 2005) and modified by the Montana Natural Heritage Program. This approach has been demonstrated

in previous wetland analyses (Vance et al. 2006, Kudray and Schemm 2008, Vance 2009) but has been further refined for this study (Appendices 3 and 4). We assigned an HGM attribute code to all wetland polygons in both the old and new wetland mapping. These HGM attributes were combined with the NWI classification attributes to yield a combination ranked on a performance scale of 1 (high), 2 (moderate), and 3 (low) for each of ten wetland functions (water storage, streamflow maintenance, groundwater recharge, nutrient cycling, sediment retention, shoreline stabilization, native plant community maintenance, terrestrial habitat, aquatic habitat, and conservation

Table 4. National Land Cover Database land cover types.

Land Cover Type	Definition
Forest	Areas dominated by trees generally greater than 5 meters tall that make up more than 20% of total vegetation cover; includes Deciduous Forest, Evergreen Forest and Mixed Forest.
Grassland/Shrub	Includes grassland areas dominated by graminoid or herbaceous vegetation and shrub/scrub areas dominated by shrubs less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation; includes true shrubs, young trees in an early successional stage, or trees stunted due to harsh environmental conditions.
Agricultural Land	Cultivated crops are described as areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and perennial woody crops such as orchards and vineyards. This class also includes all land being actively tilled. Pasture/Hay is described as grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle.
Wetlands	Areas where forest or shrub land vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water and/or areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Perennial Ice/Snow	All areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.
Open Water	All areas of open water, generally with less than 25% vegetation or soil cover.
Urban	Includes developed open spaces with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses such as large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes. Also includes developed, low, medium, and high intensity with a mixture of constructed materials and vegetation, such as single-family housing units and highly developed areas where people reside or work in large numbers such as apartment complexes, row houses, and commercial/industrial areas.
Barren	Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

of wetland biodiversity; Appendix 5). We used this performance ranking as a weighting factor and multiplied this weighting factor by wetland area to calculate functional units for each wetland function (see Tiner 2005). This method does not account for actual wetland functional performance but rather ranks potential wetland functional performance based on presumed functioning condition. Rationale for wetland functional performance rankings can be found in Vance et al. (2006) and Kudray and Schemm (2008).

RESULTS

We digitized nearly 132,000 acres (53,419 hectares) of wetlands within the change detection analysis area. Deepwater types associated with Flathead Lake comprised over 75% (100,698 acres; 40,750 hectares) of the wetland area. Palustrine emergent wetlands covered the second largest area with over 12,168 acres (4,924 hectares; Figure 12).

As expected, the majority of wetland and riparian habitats (24,255 acres; 9,816 hectares) occurred on private lands within the CDAA. Palustrine emergent wetlands comprised the largest acreage with over 8,727 acres (3,532 hectares; Figure 13). On public lands, over 8,129 acres (3,290 hectares) were mapped, with lands owned by the U. S. Fish

Figure 12. National Wetland Inventory (NWI) wetlands mapped using 2005 color-infrared aerial photography. Deepwater habitats (L1UB) associated with Flathead Lake are not included (See Appendix 1 for NWI codes).

Figure 13. Acreage of wetland and riparian types mapped on private lands within the Flathead change detection analysis area.

and Wildlife Service having the most wetlands (Figure 14).

Wetland Change Detection

Analysis

We observed a slight overall decline of 358 wetland acres (145 hectares) between 1981 and 2005 within the study area, although estimates were highly imprecise (Table 5). At the fifth-code hydrologic unit, the greatest decline in estimated wetland area occurred in the Ashley Creek watershed with 1,366 acres (553 hectares) lost (Table 6). The Whitefish River and Logan Creek watersheds also showed declines in estimated wetland area of 91 acres (37 hectares) and 37 acres (15 hectares), respectively. All other watersheds showed increases in estimated wetland area, with the Lake Mary Ronan watershed showing the largest increase of 659 acres (267 hectares). The Sullivan Creek watershed contained

no mapped wetlands. We could not estimate wetland change for the Middle Swan River, Middle Fork Flathead River-Harrison Lake, Middle Fork Flathead River-Lake McDonald, Pleasant Valley Fisher River, and Upper Stillwater River watersheds because only one section was sampled within each of these watersheds.

Within the wetlands sampled, most wetland changes were attributable to natural causes such as succession (Figure 15). Additionally, 199 acres (81 hectares) mapped as wetland in the sampled 1981 mapping were mapped as riparian in the new wetland mapping. Almost 163 acres (66 hectares) of beaver-created wetlands have been lost since the 1981 mapping (Figure 16). Created wetlands have also decreased across the study area, with diked/impounded palustrine emergent wetlands showing the largest decline. This decline was due possibly to drying of these sites.

Figure 14. Acreage of all combined wetland and riparian types mapped on public lands within the Flathead change detection analysis area. Wetlands and riparian areas mapped on lands owned by City Government, Montana Department of Transportation, Confederated Salish and Kootenai Tribal Lands, and the U. S. Department of Defense totaled 39 acres (16 hectares) and are not displayed on this graph.

Table 5. Changes in wetland area within the Flathead change detection analysis area (in acres) generalized by NWI wetland type between 1981 and 2005.

NWI Attribute Code	1981			2005			Estimated Wetland Change	
	Estimated Acres	Standard Error	95% Confidence Limits	Estimated Acres	Standard Error	95% Confidence Limits		
L1UB	124,938.1	30,783.9	64,602.7	125,152.4	30,441.1	65,489.0	184,815.8	214.3
L2AB	5,294.1	1,588.9	2,180.0	3,257.2	1,214.4	877.0	5,637.5	-2,036.8
L2UB	none mapped	none mapped	none mapped	119.9	112.4	-100.4	340.3	—
L2US	none mapped	none mapped	none mapped	83.9	50.6	-15.2	182.9	—
PAB	2,413.5	583.4	1,270.0	1,630.9	325.1	993.7	2,268.1	-782.5
PEM	15,538.7	3,748.2	8,192.3	17,223.4	3,061.6	11,222.7	23,224.1	1,684.7
PFO	1,100.2	667.7	-208.3	69.3	37.0	-3.2	141.8	-1,031.0
PSS	4,186.6	1,108.8	2,013.4	2,283.9	455.2	1,391.7	3,176.1	-1,902.7
PUB	1.4	1.4	-1.3	82.3	75.5	-65.6	230.2	80.9
PUS	none mapped	none mapped	none mapped	389.0	321.1	-240.4	1,018.4	—
R2UB	559.8	394.1	-212.6	7,494.3	2,933.3	1,745.1	13,243.5	6,934.5
R2US	397.3	397.3	-381.4	829.1	388.3	68.0	1,590.2	431.8
R3UB	4,692.9	1,575.4	1,605.3	1,526.7	619.8	311.9	2,741.5	-3,166.2
R3US	1,635.0	774.6	116.9	341.6	174.5	-0.4	683.6	-1,293.4
All Wetlands	160,757.6	30,717.5	100,552.4	160,400.1	30,862.3	99,911.2	220,889.0	-357.5

Table 6. Changes in wetland area within the Flathead change detection analysis area (in acres) by fifth-code hydrologic unit generalized by NWI wetland type between 1981 and 2005.

Fifth-Code Hydrologic Unit	NWI Attribute Code	1981				2005				Estimated Wetland Change
		Estimated Acres	Standard Error	95% Confidence Limits	Estimated Acres	Standard Error	95% Confidence Limits			
Flathead Lake	L1UB	61,594.7	7,382.4	47,125.4	76,063.9	61,607.5	7,325.2	47,250.3	75,964.6	12.8
	L2AB	7.8	7.8	-7.5	23.2	0.0	0.0	0.0	0.0	-7.8
	PEM	none mapped	none mapped	none mapped	none mapped	9.5	9.5	-9.1	28.0	—
	All Wetlands	61,602.5	7,375.4	47,147.1	76,058.0	61,616.9	7,316.7	47,276.4	75,957.5	14.4
Upper Little Bitterroot River	L1UB	1,702.9	1,327.2	-898.3	4,304.2	1,945.9	1,432.2	-861.2	4,752.9	243.0
	L2AB	1,429.6	729.0	0.7	2,858.4	994.9	498.5	17.9	1,972.0	-434.6
	PAB	15.7	15.7	-15.1	46.6	7.5	7.5	-7.2	22.1	-8.3
	PEM	477.7	469.6	-442.6	1,398.0	615.1	504.8	-374.4	1,604.5	137.4
	PSS	131.3	71.0	-7.8	270.4	69.3	34.9	1.0	137.7	-62.0
	All Wetlands	3,493.6	1,871.5	-174.6	7,161.8	3,632.7	1,794.1	116.3	7,149.0	139.1
Lake Mary Ronan	L1UB	20,972.7	12,750.5	-4,017.8	45,963.1	21,242.4	12,821.9	-3,888.0	46,372.8	269.7
	L2AB	203.9	192.5	-173.4	581.2	0.0	0.0	0.0	0.0	-203.9
	PAB	197.0	131.1	-59.9	454.0	81.8	65.1	-45.7	209.4	-115.2
	PEM	1,131.1	589.8	-24.9	2,287.1	1,758.2	825.2	140.9	3,375.6	627.1
	PSS	129.6	83.7	-34.4	293.6	211.0	162.2	-107.0	528.9	81.4
	All Wetlands	22,634.3	12,676.8	-2,211.7	47,480.4	23,293.4	12,716.0	-1,629.5	48,216.4	659.1
Upper Hungry Horse Reservoir	L1UB	147.7	147.7	-141.8	437.2	154.8	154.8	-148.6	458.1	7.1
	L2UB	none mapped	none mapped	none mapped	none mapped	0.6	0.6	-0.5	1.7	—
	PAB	26.8	10.4	6.5	47.1	23.2	6.1	11.4	35.1	-3.6
	PEM	2.6	2.6	-2.4	7.5	4.1	2.0	0.1	8.0	1.5
	All Wetlands	177.1	156.6	-129.9	484.0	182.6	162.4	-135.6	500.9	5.6

Table 6. Changes in wetland area within the Flathead change detection analysis area (in acres) by fifth-code hydrologic unit generalized by NWI wetland type between 1981 and 2005. (Continued)

Fifth-Code Hydrologic Unit	NWI Attribute Code	1981			2005			Estimated Wetland Change
		Estimated Acres	Standard Error	95% Confidence Limits	Estimated Acres	Standard Error	95% Confidence Limits	
Lower Swan River	L1UB	8,516.9	8,516.9	-8,175.9	8,254.9	8,254.9	-7,924.4	24,434.3
	L2AB	0.0	0.0	0.0	591.4	591.4	-567.7	1,750.5
	L2US	none mapped	none mapped	none mapped	43.3	43.3	-41.5	128.0
	PAB	183.3	180.1	-169.7	25.1	16.9	-8.0	58.2
	PEM	605.0	322.4	-27.0	732.7	262.9	217.3	1,248.0
	PFO	65.6	65.6	-63.0	0.0	0.0	0.0	0.0
	PSS	97.7	97.7	-93.8	5.1	5.1	-4.9	15.2
	R2UB	273.2	273.2	-262.2	144.9	144.9	-139.1	428.9
	All Wetlands	9,676.1	8,454.1	-6,893.7	9,754.1	8,890.8	-7,671.5	27,179.7
								78.0
Lower Hungry Horse Reservoir	L1UB	67.8	67.8	-65.1	76.7	76.7	-73.6	226.9
	PEM	35.1	23.9	-11.7	23.5	13.0	-1.9	48.9
	PSS	none mapped	none mapped	none mapped	23.1	23.1	-22.2	68.4
	R3UB	223.2	223.2	-214.3	358.7	358.7	-344.3	1,061.7
	All Wetlands	326.1	187.4	-41.2	481.9	310.9	-127.4	1,091.3
								155.8

Table 6. Changes in wetland area within the Flathead change detection analysis area (in acres) by fifth-code hydrologic unit generalized by NWI wetland type between 1981 and 2005. (Continued)

Fifth-Code Hydrologic Unit	NWI Attribute Code	1981			2005			Estimated Wetland Change	
		Estimated Acres	Standard Error	95% Confidence Limits	Estimated Acres	Standard Error	95% Confidence Limits		
Flathead River- Columbia Falls	L1UB	0.0	0.0	0.0	0.0	11.9	-11.4	35.2	11.9
	L2AB	1,566.5	938.4	-272.7	3,405.6	433.6	-37.0	904.1	-1,132.9
	PAB	993.1	427.4	155.5	1,830.7	882.5	405.1	1,360.0	-110.6
	PEM	6,177.7	2,161.6	1,941.1	10,414.2	6,666.5	2,738.2	10,594.8	488.9
	PFO	984.2	652.6	-294.8	2,263.1	25.5	-19.4	70.5	-958.6
	PSS	1,882.4	746.0	420.2	3,344.7	1,007.2	427.3	1,587.1	-875.2
	PUB	0.0	0.0	0.0	0.0	75.2	-72.2	222.6	75.2
	PUS	none mapped	none mapped	none mapped	none mapped	9.9	-9.5	29.2	—
	R2UB	0.0	0.0	0.0	0.0	7,068.5	1,775.6	12,361.5	7,068.5
	R2US	397.3	397.3	-381.4	1,175.9	829.1	112.5	1,545.6	431.8
Whitefish River	R3UB	4,075.6	1,402.9	1,326.1	6,825.2	551.5	-245.7	1,348.7	-3,524.2
	R3US	1,470.8	738.0	24.4	2,917.1	111.0	-106.5	328.5	-1,359.8
	All Wetlands	17,547.5	3,706.3	10,283.4	24,811.7	17,672.4	10,035.0	25,309.7	124.8
	L1UB	4,718.4	4,673.4	-4,441.3	13,878.1	4,740.7	-4,434.6	13,916.0	22.3
	L2AB	284.3	284.3	-272.9	841.4	0.0	0.0	0.0	-284.3
	L2US	none mapped	none mapped	none mapped	none mapped	8.0	-2.5	18.4	—
	PAB	208.0	99.9	12.1	403.9	131.6	14.3	248.9	-76.4
	PEM	521.4	316.2	-98.3	1,141.1	692.4	-36.6	1,421.3	170.9
	PSS	77.4	63.0	-46.1	200.9	124.0	-3.0	251.1	46.6
	R3UB	0.0	0.0	0.0	0.0	42.9	-41.2	127.1	42.9
R3US	78.8	78.8	-75.6	233.2	66.3	-63.6	196.1	-12.5	
All Wetlands	5,888.3	4,586.0	-3,100.1	14,876.7	5,797.8	-3,385.6	14,981.3	-90.5	

Table 6. Changes in wetland area within the Flathead change detection analysis area (in acres) by fifth-code hydrologic unit generalized by NWI wetland type between 1981 and 2005. (Continued)

Fifth-Code Hydrologic Unit	NWI Attribute Code	1981			2005			Estimated Wetland Change	
		Estimated Acres	Standard Error	95% Confidence Limits	Estimated Acres	Standard Error	95% Confidence Limits		
Ashley Creek	L1UB	4,252.1	3,846.1	-3,286.0	4,322.8	3,898.0	-3,317.1	11,962.8	70.7
	L2AB	597.8	415.7	-216.9	478.2	330.4	-169.3	1,125.8	-119.6
	L2UB	none mapped	none mapped	none mapped	7.1	7.1	-6.8	21.0	—
	L2US	none mapped	none mapped	none mapped	25.3	25.3	-24.2	74.8	—
	PAB	159.5	121.7	-79.1	177.5	110.5	-39.0	394.0	18.0
	PEM	3,670.5	2,739.1	-1,698.0	2,312.0	1,431.8	-494.2	5,118.2	-1,358.5
	PFO	32.4	26.9	-20.3	41.5	28.7	-14.8	97.8	9.1
	PSS	263.2	100.5	66.2	169.2	83.4	5.8	332.6	-94.1
	PUB	1.4	1.4	-1.3	7.1	7.1	-6.8	21.0	5.7
	PUS	none mapped	none mapped	none mapped	10.8	6.9	-2.8	24.3	—
Finley Point	R2UB	none mapped	none mapped	none mapped	63.2	63.2	-60.7	187.1	—
	R3UB	none mapped	none mapped	none mapped	21.8	21.8	-21.0	64.7	—
	All Wetlands	8,976.9	4,806.2	-443.1	7,611.2	4,244.4	-707.6	15,930.1	-1,365.7
	L1UB	6,995.9	6,995.9	-6,715.8	20,707.7	7,041.7	-6,759.8	20,843.1	45.8
	PAB	12.4	0.4	11.7	13.2	20.0	-7.4	47.4	7.6
Logan Creek	PEM	165.6	165.6	-158.9	490.0	163.8	-149.1	493.1	6.4
	All Wetlands	7,173.9	6,830.8	-6,214.2	20,562.0	7,233.7	-6,274.1	20,741.4	59.8
	PAB	40.8	31.9	-21.7	103.3				-40.8
	PEM	987.6	837.7	-654.3	2,629.4	1,163.8	-727.3	3,054.9	176.2
	PSS	189.8	173.7	-150.6	530.2	153.0	-56.8	362.7	-36.8
	R2UB	286.7	286.7	-275.2	848.5				-286.7
	R3UB	85.4	85.4	-82.0	236.5	236.5	-227.0	700.1	151.1
	All Wetlands	1,590.3	1,362.2	-1,079.4	4,260.1	1,553.3	-1,003.5	4,110.1	-37.1

Table 6. Changes in wetland area within the Flathead change detection analysis area (in acres) by fifth-code hydrologic unit generalized by NWI wetland type between 1981 and 2005. (Continued)

Fifth-Code Hydrologic Unit	NWI Attribute Code	1981			2005			Estimated Wetland Change
		Estimated Acres	Standard Error	95% Confidence Limits	Estimated Acres	Standard Error	95% Confidence Limits	
	L1UB				410.2	410.2	-393.8 1,214.2	410.2
	L2AB	1,140.6	632.7	-99.5 2,380.7				-1,140.6
	L2UB	none mapped	none mapped	none mapped none mapped	112.3	112.3	-107.8 332.3	—
Lower	PAB	303.6	209.4	-106.9 714.1	196.6	106.6	-12.4 405.5	-107.0
Stillwater	PEM	1,279.1	615.8	72.1 2,486.1	1,734.0	679.3	402.6 3,065.3	454.9
River	PSS	158.6	102.7	-42.7 359.9	81.6	63.4	-42.7 205.9	-77.0
	PUS	none mapped	none mapped	none mapped none mapped	368.4	316.5	-252.0 988.8	—
	R2UB	none mapped	none mapped	none mapped none mapped	217.7	148.2	-72.8 508.1	—
	All Wetlands	2,881.9	1,150.2	627.6 5,136.2	3,120.7	1,099.9	964.9 5,276.6	238.9
North Fork	PEM	9.4	9.4	-9.0 27.8	16.1	16.1	-15.5 47.7	238.9
Flathead	PSS	14.2	14.2	-13.6 41.9	20.9	20.9	-20.0 61.7	6.7
River-Camas	R3UB	100.0	100.0	-96.0 296.0	96.9	96.9	-93.0 286.7	6.7
Creek	R3US	51.8	51.8	-49.7 153.2	59.3	59.3	-56.9 175.5	-3.2
	All Wetlands	175.3	156.5	-131.4 482.0	193.1	160.9	-122.3 508.5	7.5

Figure 15. Types of wetland changes (in acres) between 1981 and 2005 in the Flathead change detection analysis area.

Figure 16. Changes in naturally modified (beaver) and created wetlands (in acres) between the 1981 and 2005 in the Flathead change detection analysis area.

Overall anthropogenic changes in land cover type have been largely changes from Forest and Grassland/Shrub types to Urban and Agriculture types (Figure 17). The Flathead River-Columbia Falls and Lake Mary Ronan watersheds have seen the largest changes with 2,405 acres (971 hectares) of Forest and Grassland/Shrub

converted to Agriculture and Urban types (Table 7). Land within a one-kilometer buffer of palustrine emergent wetlands showed the greatest anthropogenic change with 3,160 acres (1,279 hectares) of Open Water, Forest, and Grassland/Shrub types converted to Agriculture or Urban cover types (Table 8).

Figure 17. Overall changes in land cover type (in acres) between 1992 and 2001 to Urban (top) and Agriculture (bottom) from the National Land Cover Database Change Product.

Table 7. Changes in land cover type (in acres) between 1992 and 2001 from the National Land Cover Database Change Product by fifth-code hydrologic unit.

Fifth-code Hydrologic Unit	Open Water to Urban	Open Water to Agriculture	Forest to Urban	Forest to Agriculture	Grassland/Shrub to Urban	Grassland/Shrub to Agriculture
Ashley Creek	7.78	18.90	31.80	213.28	16.90	307.79
Finley Point	0.00	0.00	4.23	65.16	4.23	1.33
Flathead Lake	0.00	0.00	0.00	6.89	1.33	0.00
Flathead River-Columbia Falls	8.45	28.02	78.28	490.38	24.91	868.23
Good Creek	0.00	8.90	17.79	312.69	14.23	143.89
Lake Mary Ronan	0.00	0.00	50.71	886.91	0.00	5.78
Logan Creek	0.00	0.00	6.23	18.90	10.67	10.01
Lower Hungry Horse Reservoir	0.00	0.00	7.34	8.90	1.11	17.79
Lower Stillwater River	38.92	60.05	69.39	134.55	8.67	298.68
Lower Swan River	0.00	0.00	0.00	4.67	0.00	8.23
Middle Fork Flathead River-Harrison Lake	0.00	0.00	0.00	12.90	0.00	8.01
Middle Fork Flathead River-Lake McDonald	0.00	0.00	1.56	3.56	1.56	12.68
Middle Swan River	0.00	0.00	0.44	100.08	0.00	0.00
North Fork Flathead River-Camas Creek	0.00	0.00	20.02	10.90	8.45	3.11
Pleasant Valley Fisher River	0.00	0.00	0.00	37.81	0.00	0.00
Upper Hungry Horse Reservoir	0.00	0.00	7.34	6.23	6.45	3.34
Upper Little Bitterroot River	0.00	0.00	0.00	48.26	0.00	5.78
Upper Stillwater River	0.00	7.12	3.56	24.91	29.80	142.78
Whitefish River	0.00	0.00	5.56	28.02	13.79	189.70

Table 8. Changes in land cover type (in acres) between 1992 and 2001 from the National Land Cover Database Change Product for generalized Cowardin wetland types.

NWI Attribute Code	Open Water to Urban	Open Water to Agriculture	Forest to Urban	Forest to Agriculture	Grassland/ Shrub to Urban	Grassland/ Shrub to Agriculture
L1UB	0.0	0.0	34.0	338.3	6.7	128.3
L2UB	0.0	0.0	0.0	0.0	2.4	1.6
PAB	19.3	15.8	62.5	143.7	26.0	135.2
PEM	22.2	43.6	163.7	1,583.2	79.2	1,267.9
PFO	0.0	0.0	0.0	18.7	0.0	4.9
PSS	6.2	3.6	11.1	154.1	5.3	213.1
PUB	0.0	0.0	0.0	14.2	0.0	0.7
PUS	0.0	0.0	2.7	0.0	0.0	1.1
R2UB	2.7	40.0	15.1	37.4	2.0	102.7
R2US	0.0	0.0	0.0	7.1	0.0	5.8
R3UB	0.0	0.0	3.8	58.3	2.4	21.6
R3US	0.0	0.0	2.0	10.7	13.3	50.0
Rp1EM	0.0	0.0	0.0	0.0	0.0	0.0
Rp1FO	0.0	0.0	6.9	39.1	3.1	93.2
Rp1SS	4.7	20.0	2.4	10.2	1.6	1.1

Wetland Functional Performance

Deepwater throughflow wetlands consisting of Flathead Lake and associated lentic wetlands comprised the largest hydrogeomorphic type in the Flathead CDAA, totaling 110,761 acres (44,824 hectares; Table 9). Wetlands associated with lotic features covered 13,737 acres (5,560 hectares), and terrene wetlands totaled 6,800 acres (2,752 hectares). When examined by watershed, the Flathead Lake watershed contained the largest area of deepwater and lentic wetlands with 60,541 acres (24,500 hectares), and the Flathead River-Columbia Falls watershed had the largest area covered by lotic wetlands with 465 acres (188 hectares) within the CDAA (Table 10).

Comparison of wetland functional performance capacities throughout the Flathead CDAA showed a 38.4% loss in hydrologic functions that included water storage, streamflow maintenance, and groundwater recharge. Biogeochemical functions incorporating nutrient cycling, sediment retention, and shoreline stabilization showed a slight increase, whereas functions associated with terrestrial and aquatic habitat, native plant community maintenance, and conservation of wetland biodiversity showed an overall decline of 15.4% (Table 11). To some degree, estimated changes in functional capacity were due to several factors including image quality, photointerpretation, and interpreter differences. We address this in greater detail in the Discussion below.

Table 9. Hydrogeomorphic types mapped (in acres) within the Flathead change detection analysis area.

Landscape Position/ Waterbody Type	Landform	Water Flow Path	Area
Deepwater		Inflow	2,821.4
		Isolated	335.8
		Outflow	229.0
		Throughflow	99,255.7
River			2,351.4
Stream			616.9
Lentic	Basin	Bidirectional	111.3
		Isolated	81.6
		Throughflow	3,213.8
		Inflow	26.1
	Fringe	Bidirectional	3,185.2
		Throughflow	1,431.6
		Isolated	3.0
	Island	Throughflow	66.5
Lotic River	Floodplain	Throughflow	2,855.7
	Fringe	Throughflow	1,443.0
	Basin	Throughflow	498.8
	Island	Throughflow	321.2
Lotic Stream	Basin	Throughflow	8,064.1
	Island	Throughflow	2.5
	Fringe	Throughflow	551.6
Terrene	Island	Throughflow	0.1
	Basin	Inflow	351.8
		Isolated	3,855.7
		Outflow	476.7
		Throughflow	332.8
	Slope	Inflow	26.4
		Isolated	1,393.7
		Outflow	258.6
		Throughflow	45.4
	Fringe	Inflow	9.1
		Isolated	25.1
		Outflow	25.6

Table 10. Hydrogeomorphic types mapped (in acres) with the Flathead change detection analysis area by fifth-code hydrologic unit.

Landscape Position/ Waterbody Type	Landform	Water Flow Path	Fifth-Code Hydrologic Unit				
			Ashley Creek	Finley Point	Flathead Lake	Flathead River- Columbia Falls	Good Creek
Deepwater		Inflow	214.7				
		Isolated					
		Outflow					
		Throughflow	2,195.8	78.2	60,541.0	150.3	
Lentic	Basin	Bidirectional					
		Isolated					
		Throughflow	10.4		0.0	211.1	
	Fringe	Inflow					
		Bidirectional	20.3			63.7	
		Throughflow	1.0			57.7	
	Island	Isolated					
Lotic River		Throughflow					0.3
		Throughflow					
		Throughflow					
		Throughflow					
		Throughflow					
Lotic Stream		Throughflow					
		Throughflow					
		Throughflow					
		Throughflow					
Terrene		Throughflow					
		Throughflow					
		Throughflow					
		Throughflow					
Terrene	Basin	Throughflow					
		Inflow	0.7			0.2	
		Isolated	13.4	8.4		85.1	5.7
		Outflow	0.7			0.7	
	Slope	Throughflow	1.5				
		Inflow					
		Isolated	7.6	1.2		24.1	4.3
		Outflow	0.3			1.9	1.7
	Fringe	Throughflow	1.6				
		Inflow					
		Isolated				18.5	
		Outflow					

Table 10. Hydrogeomorphic types mapped (in acres) with the Flathead change detection analysis area by fifth-code hydrologic unit. (Continued)

Landscape Position/ Waterbody Type	Landform	Water Flow Path	Fifth-Code Hydrologic Unit				
			Lake Mary Ronan	Logan Creek	Lower Hungry Horse Reservoir	Lower Stillwater River	Lower Swan River
Deepwater		Inflow					
		Isolated					0.4
		Outflow					
		Throughflow	1,586.0			36.4	24.4
Lentic	Basin	Bidirectional					
		Isolated				28.2	
		Throughflow	24.3			18.4	6.5
		Inflow					
	Fringe	Bidirectional				10.0	107.6
		Throughflow	2.1				22.3
		Isolated					
	Island	Throughflow					0.9
Lotic River	Floodplain	Throughflow		90.6	2.0	0.8	11.0
	Fringe	Throughflow					
	Basin	Throughflow					0.1
	Island	Throughflow			1.6		
Lotic Stream	Basin	Throughflow	61.9		0.4	40.7	5.3
	Island	Throughflow					
	Fringe	Throughflow					
Terrene	Island	Throughflow					
	Basin	Inflow					
		Isolated	6.6	2.9		91.2	11.9
		Outflow		12.1			
		Throughflow					
	Slope	Inflow					
		Isolated	2.3	1.7		20.1	
		Outflow		2.7			
		Throughflow					
	Fringe	Inflow					
		Isolated					
		Outflow					

Table 10. Hydrogeomorphic types mapped (in acres) with the Flathead change detection analysis area by fifth-code hydrologic unit. (Continued)

			Fifth-Code Hydrologic Unit		
Landscape Position/ Waterbody Type	Landform	Water Flow Path	Middle Fork Flathead River-Lake McDonald	Middle Swan River	North Fork Flathead River- Camas Creek
Deepwater		Inflow Isolated Outflow Throughflow			
Lentic	Basin	Bidirectional Isolated Throughflow Inflow		45.7	
	Fringe	Bidirectional Throughflow Isolated		16.3	
	Island	Throughflow			
Lotic River	Floodplain	Throughflow	44.4		
	Fringe	Throughflow	24.1		
	Basin	Throughflow	3.7		
	Island	Throughflow	3.3		
Lotic Stream	Basin	Throughflow			
	Island	Throughflow			
	Fringe	Throughflow			0.9
Terrene	Island	Throughflow			
	Basin	Inflow Isolated Outflow Throughflow			
	Slope	Inflow Isolated Outflow Throughflow			
	Fringe	Inflow Isolated Outflow			

Table 10. Hydrogeomorphic types mapped (in acres) with the Flathead change detection analysis area by fifth-code hydrologic unit. (Continued)

			Fifth-Code Hydrologic Unit							
Landscape Position/ Waterbody Type	Landform	Water Flow Path	Upper Hungry Horse Reservoir	Upper Little Bitterroot River	Upper Stillwater River	Whitefish River				
Deepwater		Inflow	25.7	722.2		3,307.2				
		Isolated								
		Outflow								
		Throughflow								
Lentic	Basin	Bidirectional		70.0		3.0				
		Isolated								
		Throughflow								
		Inflow								
	Fringe	Bidirectional		133.8						
		Throughflow								
		Isolated								
		Throughflow								
Island	Throughflow									
Lotic River	Floodplain	Throughflow								
	Fringe	Throughflow								
	Basin	Throughflow								
	Island	Throughflow								
Lotic Stream	Basin	Throughflow	1.4	6.4		14.9				
	Island	Throughflow				0.6				
	Fringe	Throughflow				3.4				
Terrene	Island	Throughflow	1.6	2.2	8.0	15.0				
		Inflow								
	Basin	Isolated					0.9			
		Outflow								
		Throughflow								
		Throughflow								
	Slope	Inflow					2.6	12.2		
		Isolated								
		Outflow								
		Throughflow								
	Fringe	Inflow								
		Isolated								
		Outflow								
		Outflow								

Table 11. Predicted change in wetland functional capacity between 1981 and 2005 within the Flathead change detection analysis area.

Function	1981 Functional Units	2005 Functional Units	Predicted % Change in Functional Capacity
<i>Hydrology</i>			
Water Storage	234,922.8	211,310.1	-10.1
Streamflow Maintenance	236,254.2	212,592.6	-10.0
Groundwater Recharge	89,614.3	73,147.8	-18.4
<i>Biogeochemical</i>			
Nutrient Cycling	193,539.8	202,264.6	4.5
Sediment Retention	121,675.3	133,173.7	9.5
Shoreline Stabilization	236,781.0	213,047.8	-10.0
<i>Habitat</i>			
Native Plant Community Maintenance	232,431.2	211,603.2	-9.0
Terrestrial Habitat	231,751.4	211,355.1	-8.8
Aquatic Habitat	120,405.7	134,568.6	11.8
Conservation of Wetland Biodiversity	234,264.4	212,244.1	-9.4

DISCUSSION

Our analysis showed relatively little overall change in wetland area between 1981 and 2005. Yet differences in land area alone do not adequately convey the cumulative change and potential loss of wetland functions, as this and other studies have shown (Syphard and Garcia 2001, Tiner 2005). Wetlands in the Flathead Valley have experienced a loss in functional capacity, particularly in terms of functions related to hydrology and habitat. Additionally, analysis of changes in land cover type around wetlands showed relatively large areas of forest and grassland/shrub have been converted to agricultural and urban types. These changes have likely affected not only the quality of these wetlands, but also the spatial extent and pattern of wetlands on the landscape, resulting in a loss of connectivity, reduced water quality, and a reduction in overall wetland integrity.

General Limitations of the Study

Limitations exist with any wetland mapping effort derived almost exclusively from photointerpretation techniques (Tiner 2005). Factors such as photo quality, scale, and environmental conditions at the time of photo acquisition can affect mapping accuracy. Similarly, comparisons between historic and updated wetland mapping are also limited by differences in imagery and mapping scale. Technological advances associated with mapping techniques have greatly increased our capacity to capture more detailed information. Additionally, temporarily and seasonally flooded wetlands that typically dry out by the end of the growing season may be difficult to reliably separate from upland areas.

Limitations also exist with wetland functional assessments based solely on photointerpretation and best professional judgment. We emphasize the functional capacity ratings assigned to wetlands in this project are only potential capacities. Data on actual functional capacity would require extensive field checking. The estimated changes in functional capacities may also be, in part, a byproduct of changes in mapping conventions, specifically the addition of the riparian classification system. Palustrine forested

and palustrine scrub-shrub wetlands associated with lotic features, which are most effective at performing hydrologic and habitat functions, may have been overmapped in the 1981 NWI wetland mapping. Our wetland change analysis revealed some wetlands originally mapped as palustrine forested and palustrine scrub-shrub wetlands were mapped as riparian forest and riparian scrub-shrub in the new mapping, so this reduction in mapped wetland area influenced our estimated changes in functional capacity. Because riparian areas were not mapped in the original mapping effort, many forested and scrub-shrub areas along streams and rivers were mapped as wetland rather than excluded completely. Additionally, it is often difficult to distinguish between palustrine and riparian types based on aerial imagery alone, and the original wetland mapping had only cursory ground-truthing. In addition to differences in photointerpretation, the dynamic nature of lotic systems naturally influences the type, location, and extent of floodplain wetlands and changes can be expected over multiple decades. However, anthropogenic factors such as dams, riprap, and increased water demands have almost certainly impacted the hydrology of these floodplain wetlands.

Additionally, this assessment does not consider the condition of the adjacent uplands or the wetland itself, two factors critical to assessing the integrity of the wetland. Wetland function depends largely on wetland type (Brinson 1993), but we could not evaluate the effect changes in wetland type between 1981 and 2005 have had on changes in wetland function. Thus, extensive ecological integrity assessments are required to fully capture the condition and functional capacity of wetlands in the study area.

This analysis should be considered a preliminary assessment of changes in Flathead Valley wetlands and wetland functional capacity. Although this analysis provides general information on the ability of wetlands in the area to perform certain functions, it does not assess differences in functional capacity among wetlands of similar type and function.

Despite these limitations, data from this analysis can provide very effective conservation tools. For example, detailed wetland and riparian maps can be used to identify areas with the potential to perform wetland functions most effectively, allowing natural resource managers and other stakeholders to focus or prioritize their conservation and restoration efforts. Accurate, digital wetland data at a watershed scale can also provide the foundation for initiation and tracking of watershed restoration and monitoring efforts, as well as a method to inform watershed councils, local planners, land managers, and other stakeholders about the types and location of wetlands within the Flathead Valley and the functions they perform.

LITERATURE CITED

- Alt, D., and D.W. Hyndman. 1986. Roadside geology of Montana. Mountain Press Publishing Company, Missoula, MT. 427 pp.
- Beyer, H.L. 2004. Hawth's Analysis Tools for ArcGIS. Available at <http://www.spatial ecology.com/htools>.
- Brinson, M.M. 1993. A hydrogeomorphic classification for wetlands. Technical Report WRP-DE-4, Waterways Experiment Station, Army Corps of Engineers, Vicksburg, Mississippi.
- Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Washington, D.C. FWS/OBS-79/31.
- Dahl, T.E. 2000. Status and trends of wetlands in the conterminous United States 1986 to 1997. U.S. Fish and Wildlife Service, Washington, D.C.
- Dahl, T.E. 2006. Status and trends of wetlands in the conterminous United States 1998 to 2004. U.S. Fish and Wildlife Service, Washington, D.C.
- Dahl, T.E., and C.E. Johnson. 1991. Status and trends in the conterminous United States, mid-1970's to mid-1980's. U.S. Fish and Wildlife Service, Washington, D.C.
- Elwood, H.E. 1980. Kalispell and the upper Flathead Valley. Thomas Printing, Inc., Kalispell, Montana.
- ESRI. 2006. ArcGIS 9.2. ESRI Corporation, Redlands, California.
- Frayser, W.E., T.J. Monahan, D.C. Bowden, and F.A. Graybill. 1983. Status and trends of wetlands and deepwater habitats in the conterminous United States, 1950's to 1970's. Colorado State University, Fort Collins, Colorado.
- Greenlee, J.T. 1999. Ecologically significant wetlands in the Flathead, Stillwater, and Swan River Valleys. Unpublished report to the Montana Department of Environmental Quality. Montana Natural Heritage Program, Helena, Montana. 192 pp.
- Hauer, F.R., B.J. Cook, M.C. Gilbert, E.J. Clairain, and R.D. Smith. 2002. A regional guidebook for applying the hydrogeomorphic approach to assessing wetland functions of riverine floodplains in the Northern Rocky Mountains. ERDC/EL TR-02-21, U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.
- Headwaters Economics. 2007a. A socioeconomic profile, Flathead County, Montana. Produced by the Economic Profile System. Headwaters Economics, Bozeman, Montana.
- Headwaters Economics. 2007b. A socioeconomic profile, Lake County, Montana. Produced by the Economic Profile System. Headwaters Economics, Bozeman, Montana.
- Johnson, B. 2005. Hydrogeomorphic wetland profiling: an approach to landscape and cumulative impacts analysis. EPA/620/R05/001. U.S. Environmental Protection Agency, Washington, D.C.
- Kincaid, T., T. Olsen, D. Stevens, C. Platt, D. White, and R. Remington. 2008. spsurvey: Spatial Survey Design and Analysis. R package version 2.0. <http://www.epa.gov/nheerl/arm/>
- Kudray, G.M., and T. Schemm. 2008. Wetlands of the Bitterroot Valley: Change and ecological functions. Report to the Montana Department of Environmental Quality. Montana Natural Heritage Program, Helena, Montana. 32 pp. plus appendices.

- McKay, K.L. 1994. Trails of the past: historical overview of the Flathead National Forest, Montana, 1800-1960. USDA Forest Service, Flathead National Forest, Kalispell, Montana. 351 pp.
- McKay, K.L. 1997. Looking back: a pictorial history of the Flathead Valley, Montana. A Northwest Montana Historical Society Publication. The Donning Company Publishers. 224 pp.
- Omernik, J.M. 1987. Ecoregions of the conterminous United States. Map (scale 1:7,500,00). *Annals of the Association of American Geographers* 77:118-125.
- PPL Montana. 2008. Kerr Dam. <http://www.pplmontana.com/producing+power/power+plants/Kerr+Dam.htm>. Accessed December 2008.
- R Development Core Team. 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL <http://www.R-project.org>.
- Sirucek, D.A., and V.C. Bachurski. 1995. Riparian landtype survey of the Flathead National Forest area, Montana. USDA Forest Service, Flathead National Forest, Kalispell, Montana.
- Syphard, A.D., and M.W. Garcia. 2001. Human- and beaver-induced wetland changes in the Chickahominy River Watershed from 1953 to 1994. *Wetlands* 21:342-353.
- Tiner, R.W. 2003. Dichotomous keys and mapping codes for wetland landscape position, landform, water flow path, and waterbody type descriptions. U.S. Fish and Wildlife Service, National Wetlands Inventory Program, Northeast Region, Hadley, Massachusetts. 44 pp.
- Tiner, R.W. 2005. Assessing cumulative loss of wetland functions in the Nanticoke River Watershed using enhanced National Wetlands Inventory data. *Wetlands* 25:405-419.
- U.S. Bureau of Reclamation. 2008. Hungry Horse Project. <http://www.usbr.gov/dataweb/html/hungryho.html>. Accessed December 2008.
- U.S. Census Bureau. 2008. State & County QuickFacts, Montana. <http://quickfacts.census.gov/qfd/states/30000.html>. Accessed December 2008.
- U.S. Fish and Wildlife Service. 1997. A system for mapping riparian areas in the western United States. U.S. Fish and Wildlife Service., Washington, DC. 15 pp.
- U.S. Fish and Wildlife Service. 2004a. National standards and quality components for wetlands, deepwater, and related habitat mapping. U.S. Fish and Wildlife Service, Arlington, VA. 19 pp.
- U.S. Fish and Wildlife Service. 2004b. Technical procedures for mapping wetland, deepwater, and related habitats. U.S. Fish and Wildlife Service, Branch of Habitat Assessment, Arlington, Virginia. 46 pp.
- U.S. Fish and Wildlife Service. 2005. Technical procedures for wetlands status and trends. U.S. Fish and Wildlife Service, Branch of Habitat Assessment, Arlington, Virginia. 61 pp.
- Vance, L.K. 2009. Geographically isolated wetlands and intermittent/ephemeral streams in Montana: Extent, distribution, and function. Report to the Montana Department of Environmental Quality and the U.S. Environmental Protection Agency. Montana Natural Heritage Program, Helena, Montana. 33 pp.
- Vance, L.K., G.M. Kudray, and S.V. Cooper. 2006. Crosswalking National Wetland Inventory attributes to hydrogeomorphic functions and vegetation communities: a pilot study in the Gallatin Valley, Montana. Report to the Montana Department of Environmental Quality and the U.S. Environmental Protection Agency. Montana Natural Heritage Program, Helena, Montana. 37 pp plus appendices.

Vogelmann, J.E., S.M. Howard, L. Yang, C.R. Larson, B.K. Wylie, and J.N. Van Driel. 2001. Completion of the 1990's National Land Cover Data Set for the conterminous United States, Photogrammetric Engineering and Remote Sensing 67:650-662.

Western Regional Climate Center. 2008. Western U.S. climate historical summaries. (<http://www.wrcc.dri.edu/Climsum.html>). Desert Research Institute, Reno, Nevada. Accessed November 2008.

**APPENDIX A. CLASSIFICATION OF WETLANDS AND DEEPWATER
HABITATS OF THE UNITED STATES (COWARDIN ET AL. 1979)**

[illegible]

Classification of Wetlands and Deepwater Habitats of the United States
Cowardin ET AL. 1979 as modified for National Wetland Inventory Mapping Convention

WETLANDS AND DEEPWATER HABITATS CLASSIFICATION

MODIFIERS			
In order to more adequately describe the wetland and deepwater habitats one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy. The named modifier may also be applied to the ecological system.			
WATER REGIME		WATER CHEMISTRY	
Non-Tidal		Soil	
A Temporally Flooded	H Permanent Flooded	Coastal Salinity	pH Modifiers for all Fresh Water
	I Intermittently Flooded		
B Saturated	K Artificially Flooded	Inland Salinity	a Acid
	L Subtidal		
C Seasonally Flooded	M Irregularly Exposed	0 Fresh	t Circumneutral
	N Regularly Exposed		
D Seasonally Flooded Well Drained	P Irregularly Flooded	6 Mesohaline	1 Alkaline
	Y Saturated/Seasonal/Temporary		
E Seasonally Flooded Saturated	Z Seasonal	0 Fresh	
	U Unknown		
F Seasonally Flooded			
G Intermittently Exposed			

NOTE: Italicized terms were added for mapping by the National Wetlands Inventory program.

**APPENDIX B. CLASSIFICATION OF RIPARIAN SYSTEMS
(USFWS 1997)**

**APPENDIX C. FLOWCHART FOR HYDROGEOMORPHIC (HGM)
CODING OF WETLAND POLYGONS**

**APPENDIX D. KEY TO HYDROGEOMORPHIC (HGM) MODIFIERS,
ADAPTED FROM TINER (2003)**

Key A-1: Key to Wetland Landscape Position

1. Wetland is completely surrounded by upland (non-hydric soils)..... **Terrene**
Go to couplet 'd' below
1. Wetland is not surrounded by upland but is connected to a waterbody or other wetland.....**2**
2. Wetland is located in or along a lake or reservoir (permanent waterbody where standing water is typically deeper than 6.6 feet or larger than 20 acres), including streamside wetlands in a lake basin**Lentic**
Go to couplet 'a' below

Note: Lentic wetlands consist of all wetlands in a lake basin (i.e., the depression containing the lake), including lakeside wetlands intersected by streams emptying into the lake. The upstream limit of lentic wetlands is defined by the upstream influence of the lake, which is usually approximated by the limits of the lake basin. Streamside lentic wetlands are designated **Throughflow**, thereby emphasizing the stream flow through these wetlands.
2. Wetland does not occur along a lake or reservoir**3**
3. Wetland is located in a river or stream (including in-stream ponds), within its banks, or on its floodplain **and** is periodically flooded by the river or stream.....**4**
3. Wetland is not located in a river or stream or on its floodplain OR wetlands along streams are NOT subject to frequent overflows..... **Terrene**
4. Wetland is the source of a river or stream, but there is **no channelized flow** through the wetland **Terrene**
4. Wetland is located in a river or stream, within its banks, or on its floodplain**5**
5. Wetland is associated with a river (mapped as a 2-lined watercourse on 1:24,000 U.S.G.S. topographic map) or its floodplain..... **Lotic River**
Go to Modifiers 'b', 'c', and 'd' below
5. Wetland is associated with a stream (single-line watercourse on 1:24,000 U.S.G.S. topographic map) or its floodplain..... **Lotic Stream**
Go to Modifiers 'b', 'c', and 'd' below
 - a. Wetland is associated with a natural water body.....**Natural Lake**
 - a. Wetland is associated with a waterbody created by a dammed river valley..... **Dammed River Valley**
 - a. Wetland is associated with a waterbody created by another obstruction..... **Other Dammed Lake**
 - a. Wetland is associated with a waterbody that has been excavated..... **Excavated Lake**

Slope Modifiers

- b. Water flow is generally slow with extensive floodplain development (Cowardin's Lower Perennial Subsystem) **Low Gradient**
- b. Water flow is moderate to fast with little to some floodplain development (Cowardin's Upper Perennial Subsystem).....**Middle Gradient**
- b. Water flow is rapid due to steep gradient with little or no floodplain development (Cowardin's Upper Perennial Subsystem)**High Gradient**

Water Flow Modifier

- c. Water flow is intermittent or ephemeral (as indicated on the high resolution National Hydrography Dataset)..... **Intermittent**

Other Special Modifiers

- d. Wetland is modified by a beaver dam.....**Beaver**
- d. Wetland is modified by a ditch or has been partially drained..... **Partially Drained/Ditch**
- d. Wetland has been farmed..... **Farmed**
- d. Water flow or wetland modified by dam, dike, or impoundment.....**Dammed/Diked/Impounded**
- d. Wetland or waterbody has been modified by excavation.....**Excavated**
- d. Wetland forms a waterbody less than 6.6 feet deep or smaller than 20 acres. This includes in-stream ponds**Pond**

Key B-1: Key to Landforms

- 1. Wetland hydrology is largely influenced by groundwater discharge to the surface (can occur on nearly flat landscapes) **or** wetland occurs on a slope of at least 4% **Slope**
- 1. Wetland hydrology is influenced by a number of sources**2**
- 2. Wetland occurs on an island..... **Island**
- 2. Wetland does not occur on an island.....**3**
- 3. Wetland occurs with the banks of a river or stream or along the shores of a pond, lake, or island **and** is either (1) vegetated **and** at least saturated or semi-permanently flooded **or** (2) a non-vegetated bank or shore that is temporarily or seasonally flooded **Fringe**
- 3. Wetland does not occur along a bank or shore.....**4**
- 4. Wetland occurs on a floodplain of a Lotic River..... **Floodplain**
- 4. Wetland does not occur on a floodplain of a Lotic River.....**5**
- 5. Wetland exists in a distinct depression in various landscape positions **Basin**
- 5. Wetland receives virtually no groundwater discharge (playa).....**Flat**

Key C-1: Key to Water Flow Paths

1. Water levels fluctuate due to lake influences or variable river levels, but water does not flow through the wetland **Bidirectional**
1. Wetland is not influenced by fluctuating water levels.....**2**
2. Wetland receives surface or groundwater from a watercourse, other waterbody, *or* from another wetland at a higher elevation *and* surface or groundwater passes through it to a watercourse, other waterbody, *or* another wetland at a lower elevation..... **Throughflow**
2. Water does not pass through the wetland to other wetlands or waters.....**3**
3. Wetland is in a closed depression (based on closed elevation contours) or flat areas where water comes from surface water runoff and/or groundwater discharge. Isolated wetlands *lack channelized surface water inflow and outflow* **Isolated**
3. Wetland is not hydrologically or geographically isolated.....**4**
4. Wetland exists in a sink where no outlet exists, yet water enters via an intermittent or perennial stream or from a wetland at a higher elevation**Inflow**
4. Wetland receives no surface or groundwater inflow from a wetland or other permanent waterbody at a higher elevation *and* water is discharged from the wetland to a watercourse, waterbody, or other wetland at a lower elevation **Outflow**

Key D-1: Key to Waterbody Types

1. Waterbody is predominantly flowing water**2**
1. Waterbody is predominantly standing water.....**3**
2. Waterbody is a polygonal feature on a U.S.G.S. topographic map (1:24,000)..... **River**
2. Waterbody is a linear feature on a U.S.G.S. topographic map (1:24,000)..... **Stream**
Go to couplets 'b', 'c', and 'd' below
3. Waterbody is permanently flooded and deep (> 6.6 feet) **Deep Water**
Go to couplet 'a' below
 - a. Waterbody is created by a dammed river valley **Dammed River Valley**
 - a. Waterbody is created by another obstruction **Other Dammed Lake**
 - a. Waterbody has been excavated **Excavated Lake**
 - a. Waterbody is natural.....**Natural Lake**

Slope Modifiers

- b. Water flow is generally slow with extensive floodplain development (Cowardin's Lower Perennial Subsystem) **Low Gradient**
- b. Water flow is moderate to fast with little to some floodplain development (Cowardin's Upper Perennial Subsystem) **Middle Gradient**
- b. Water flow is rapid due to steep gradient with little or no floodplain development (Cowardin's Upper Perennial Subsystem) **High Gradient**

Water Flow Modifier

- c. Water flow is intermittent or ephemeral (as indicated on the high resolution National Hydrography Dataset) **Intermittent**

Other Special Modifiers

- d. Water flow is dammed..... **Dammed**

**APPENDIX E. RELATIVE FUNCTIONAL PERFORMANCE LEVELS FOR
WETLANDS CLASSIFIED WITH NATIONAL WETLAND INVENTORY
(NWI) AND HYDROGEOMORPHIC (HGM) CODES.**

**(A RANK OF “1” INDICATES A HIGH PERFORMANCE LEVEL;
A RANK OF “2” INDICATES A MODERATE PERFORMANCE LEVEL;
AND A RANK OF “3” INDICATES A LOW PERFORMANCE LEVEL)**

NWI Code	HGM Code	Acres	Water Storage	Streamflow Maintenance	Groundwater Recharge	Nutrient Cycling	Sediment Retention	Shoreline Stabilization	Native Plant Community Maintenance	Terrestrial Habitat	Aquatic Habitat	Conservation of Wetland Biodiversity
L1UBG	DW1IS	0.4	3	3	1	2	2	3	3	3	1	3
L1UBG	DW1TH	40.0	3	3	1	2	1	3	3	3	1	3
L1UBH	DW1IN	214.7	3	3	1	2	1	3	3	3	1	3
L1UBH	DW1IS	3.7	3	3	1	2	2	3	3	3	1	3
L1UBH	DW1OU	25.7	3	3	1	2	1	3	3	3	1	3
L1UBH	DW1TH	7785.8	3	3	1	2	1	3	3	3	1	3
L1UBHh	DW2TH	60856.1	3	3	1	3	2	3	3	3	2	3
L2ABG	LE1BATH	44.3	3	3	1	1	1	3	1	1	1	2
L2ABG	LE1FRBI	143.6	3	3	3	1	1	3	1	1	1	2
L2ABH	LE1FRBI	161.5	3	3	3	1	1	3	1	1	1	2
L2ABG	LE1FRIS	33.7	3	3	3	1	1	3	1	1	1	2
L2ABG	LE1FRTH	419.9	3	3	3	1	1	3	1	1	1	2
L2ABH	LE1HLTH	0.9	3	3	3	1	1	3	1	1	1	2
L2UBH	LE1FRBI	28.3	3	3	3	2	1	3	3	3	1	3
L2ABGh	LE2FRBI	1.0	3	3	3	2	3	3	3	3	2	3
L2USA	LE1BATH	0.2	2	3	1	2	3	3	3	3	2	3
L2USA	LE1FRBI	2.0	2	3	3	2	3	3	3	3	2	3
L2USC	LE1BAIS	28.2	2	3	1	2	3	3	3	3	2	3
PABF	LE1pBATH	3.6	2	3	1	1	1	3	1	1	1	2
PABF	LE2pBATH	0.8	2	3	1	1	1	3	1	1	1	2
PABF	LR1pBATH	24.8	2	2	1	1	1	3	1	1	1	2
PABF	LS14pBATH	9.0	2	3	3	1	2	3	1	1	1	2
PABF	LS1pBATH	0.6	2	2	1	1	1	3	1	1	1	2
PABF	TEpBAIN	0.2	2	3	2	1	1	3	1	1	1	2
PABF	TEpBAIS	8.2	2	3	2	1	2	3	1	1	1	2
PABF	TEpBAOU	0.8	3	3	2	1	1	3	1	1	1	2
PABFb	LR1bpBATH	3.7	2	2	1	1	1	3	1	1	1	2
PABFb	LS1bpBATH	0.6	2	2	1	1	1	3	1	1	1	2
PABFb	LS3bpBATH	3.7	2	2	2	1	1	3	1	1	1	2
PABFh	LR1hpBATH	1.7	3	2	3	2	1	3	3	2	2	3
PABFh	LS14hpBATH	3.6	3	3	3	2	2	3	3	2	2	3
PABFh	LS3hpBATH	6.3	3	3	3	2	2	3	3	2	2	3
PABFh	TEhpBAIS	0.2	3	3	3	2	3	3	1	2	2	2
PABFx	LR1xpBATH	0.1	3	3	3	2	2	3	3	2	2	3
PABFx	LS24xpBATH	0.3	3	3	3	2	3	3	3	2	2	3
PABFx	LS2xpBATH	0.2	3	3	3	2	2	3	3	2	2	3
PABFx	TExpBAIN	0.3	3	3	3	2	2	3	3	2	2	3
PABFx	TExpBAIS	3.8	3	3	3	2	3	3	3	2	2	3
PABG	LE1pBATH	0.2	2	3	1	1	1	3	1	1	1	2
PABG	LR1pBATH	4.9	2	2	1	1	1	3	1	1	1	2
PABG	LS1pBATH	2.3	2	2	1	1	1	3	1	1	1	2
PABG	LS34pBATH	3.4	2	3	3	1	3	3	1	1	1	2
PABG	LS3pBATH	3.8	2	2	2	1	1	3	1	1	1	2
PABG	TEpBAIS	44.0	2	3	2	1	2	3	1	1	1	2
PABGb	TEbpBAIS	2.8	2	3	2	1	2	3	1	1	1	2
PABG	TEpBAOU	0.8	3	3	2	1	1	3	1	1	1	2
PABGx	LR1xpBATH	3.3	3	3	3	2	2	3	3	2	2	3
PABGx	LS34xpBATH	0.6	3	3	3	2	2	3	3	3	2	3
PABGx	TExpBAIS	1.5	3	3	3	2	3	3	3	2	2	3
PABH	TEpBATH	16.4	2	3	2	1	1	3	1	1	1	2
PEMA	LE1BATH	120.9	2	3	1	2	1	3	3	3	3	3
PEMA	LR1FPTH	156.9	2	2	1	2	1	3	3	3	3	3
PEMA	LS14BATH	90.9	2	3	3	2	3	3	3	3	3	3
PEMA	LS1BATH	8.9	2	2	1	2	1	3	3	3	3	3
PEMA	LS1HLTH	0.1	2	2	3	2	1	3	3	2	2	3
PEMA	LS24BATH	85.7	2	3	3	2	3	3	3	3	3	3
PEMA	LS2BATH	30.9	2	2	2	2	1	3	3	3	3	3
PEMA	LS34BATH	12.4	2	3	3	2	3	3	3	3	3	3
PEMA	LS3BATH	23.3	2	2	2	2	1	3	3	3	3	3
PEMA	TEBAIS	104.4	1	3	1	1	2	3	3	3	3	3
PEMA	TEBAOU	12.7	3	3	1	2	1	3	3	3	3	3
PEMA	TEBATH	1.5	2	3	1	2	1	3	3	3	3	3
PEMA	TESLIS	4.8	3	3	1	1	2	3	3	3	3	1
PEMB	LS3FRTH	0.8	3	2	3	1	1	3	1	1	1	1
PEMB	LS34FRTH	4.0	3	3	3	1	3	3	1	1	3	1
PEMB	TESLIN	5.7	3	3	2	1	1	3	1	1	3	1
PEMB	TESLIS	43.8	3	3	2	1	2	3	1	1	3	1
PEMB	TESLOU	6.3	3	3	2	1	1	3	1	1	3	1

NWI Code	HGM Code	Acres	Water Storage	Streamflow Maintenance	Groundwater Recharge	Nutrient Cycling	Sediment Retention	Shoreline Stabilization	Native Plant Community Maintenance	Terrestrial Habitat	Aquatic Habitat	Conservation of Wetland Biodiversity
PEMC	LE1BATH	184.4	2	3	1	2	1	3	3	3	3	3
PEMC	LR1FPTH	41.2	2	2	1	2	1	3	3	3	3	3
PEMC	LS14BATH	22.5	2	3	3	2	3	3	3	3	3	3
PEMC	LS24BATH	0.2	2	3	3	2	1	3	3	3	3	3
PEMC	LS2BATH	1.4	2	2	2	2	1	3	3	3	3	3
PEMC	LS1BATH	24.7	2	2	1	2	1	3	3	3	3	3
PEMC	LS34BATH	11.3	2	3	3	2	3	3	3	3	3	3
PEMC	LS3BATH	4.5	2	2	2	2	1	3	3	3	3	3
PEMC	TEBAIN	1.5	1	3	1	1	1	3	3	3	3	3
PEMC	TEBAIS	60.7	1	3	1	1	2	3	3	3	3	3
PEMC	TEBAOU	1.4	3	3	1	2	1	3	3	3	3	3
PEMC	TESLIS	21.9	2	3	1	1	2	3	3	3	3	1
PEMC	TESLOU	0.3	3	3	1	2	1	3	3	3	3	1
PEMCd	LS14dBATH	94.0	3	3	3	3	2	3	3	3	3	3
PEMCd	LS1dBATH	16.2	3	3	3	3	2	3	3	3	3	3
PEMCd	LS24dBATH	1.9	3	3	3	3	2	3	3	3	3	3
PEMCh	LE2hBATH	9.1	3	3	3	3	2	3	3	3	3	3
PEMCh	LE2hILTH	0.3	3	3	3	3	2	3	3	3	3	3
PEMCh	TEhBAIS	0.8	3	3	3	3	3	3	3	3	3	3
PEMF	LE1FRTH	97.5	3	3	3	1	1	3	1	1	1	1
PEMF	LR1FPTH	13.0	3	2	1	1	1	3	1	1	1	1
PEMF	LR1FRTH	24.2	3	2	3	1	1	3	1	1	1	1
PEMF	LR1ILTH	3.6	3	2	3	1	1	3	1	1	1	1
PEMF	LS14BATH	19.8	2	3	3	1	1	3	1	1	1	2
PEMF	LS1BATH	1.5	2	2	1	1	1	3	1	1	1	2
PEMF	LS34BATH	1.9	2	3	3	1	1	3	1	1	1	2
PEMF	LS14FRTH	0.6	3	3	3	1	3	3	1	1	1	1
PEMF	LS1FRTH	0.2	3	2	3	1	1	3	1	1	1	1
PEMF	TEBAIS	14.1	2	3	2	1	2	3	1	1	1	1
PEMF	TEFRIS	18.5	2	3	3	1	2	3	1	1	1	1
PEMF	TESLIS	0.9	2	3	2	1	2	3	1	1	1	1
PEMFb	LS16BATH	1.2	2	2	1	1	1	3	1	1	1	1
PEMFh	LE2FRTH	1.9	3	3	3	2	1	3	3	2	2	3
PEMFh	TEhBAIS	0.2	3	3	3	2	3	3	3	2	2	3
PFOA	LE1BATH	0.2	1	3	1	2	1	1	2	1	2	1
PFOA	LR14FPTH	0.3	1	3	1	2	1	1	2	2	2	1
PFOA	LR1FPTH	96.4	1	2	1	2	1	1	2	1	2	1
PFOA	LS1BATH	1.7	1	2	1	2	1	1	2	1	2	1
PFOA	TEBAIS	2.2	1	3	1	1	2	3	2	2	2	1
PFOA	TESLTH	1.6	2	3	1	2	1	3	2	2	2	1
PFOA	TESLIS	2.2	2	3	1	1	2	3	2	2	3	1
PSSA	LE1BATH	6.7	1	3	1	2	1	2	2	1	2	3
PSSA	LE2BATH	3.1	1	3	1	2	1	2	2	1	2	3
PSSA	LR1FPTH	105.7	1	2	1	2	1	2	2	1	2	3
PSSA	LR1ILTH	9.3	1	2	3	2	1	2	2	1	2	3
PSSA	LS14BATH	14.0	1	3	3	2	3	2	2	2	2	3
PSSA	LS1BATH	20.3	1	2	1	2	1	2	2	1	2	3
PSSA	LS1ILTH	0.5	1	2	3	2	1	2	2	1	2	3
PSSA	LS2BATH	5.7	1	2	1	2	1	2	2	1	2	3
PSSA	LS34BATH	8.0	1	3	3	2	3	2	2	2	2	3
PSSA	LS3BATH	4.3	1	2	2	2	1	2	2	1	2	3
PSSA	TEBAIS	1.5	1	3	1	1	2	3	2	2	2	3
PSSA	TEBAOU	1.0	3	3	1	2	1	3	2	2	3	3
PSSA	TEBATH	5.1	1	3	1	2	1	2	2	2	3	3
PSSA	TESLIS	6.5	1	3	1	1	2	3	2	2	3	1
PSSA	TESLOU	0.3	3	3	1	2	1	3	2	2	3	1
PSSB	TESLIS	5.7	2	3	1	1	2	3	1	2	2	1
PSSB	LS34BATH	1.1	2	3	3	1	1	2	1	2	1	2
PSSC	LE1BATH	16.7	1	3	1	2	1	2	2	1	2	3
PSSC	LR1FPTH	17.9	1	2	1	2	1	2	2	1	2	3
PSSC	LS1BATH	0.5	1	2	1	2	1	2	2	1	2	3
PSSC	LS14BATH	2.7	1	3	3	2	1	2	2	2	2	3
PSSC	LS2BATH	8.7	1	2	2	2	1	2	2	1	2	3
PSSC	LS34BATH	1.2	1	3	3	2	3	2	2	2	2	3
PSSC	LS3BATH	4.0	1	2	2	2	1	2	2	1	2	3
PUBFb	TEhpBAIS	0.5	3	3	3	3	3	3	3	3	3	3
PUBFx	TExpBAIS	6.0	3	3	3	3	3	3	3	3	3	3
PUSA	LS14BATH	0.9	3	3	3	3	3	3	3	3	2	3
PUSC	TEBAIN	0.5	1	3	1	2	3	3	3	3	2	3

NWI Code	HGM Code	Acres	Water Storage	Streamflow Maintenance	Groundwater Recharge	Nutrient Cycling	Sediment Retention	Shoreline Stabilization	Native Plant Community Maintenance	Terrestrial Habitat	Aquatic Habitat	Conservation of Wetland Biodiversity
PUSC	TEBAIS	4.5	1	3	1	2	3	3	3	3	2	3
PUSC _x	TE _x BAIS	7.4	3	3	3	3	3	3	3	3	3	3
R2UBH	RV1	369.2	3	3	3	2	2	3	3	3	1	3
R2USA	LR1FRTH	66.8	2	2	3	3	3	3	3	3	2	3
R2USA	LR1ILTH	15.1	2	2	3	3	3	3	3	3	2	3
R2USC	LR1FRTH	73.9	3	1	3	3	3	3	3	3	2	3
R3USA	LR1FRTH	24.1	2	2	3	3	3	3	3	3	2	3
R3USA	LR1ILTH	18.9	2	2	3	3	3	3	3	3	2	3
R3USA	LS1FRTH	3.4	2	2	3	3	3	3	3	3	2	3
R3UBH	RV1	2703.0	3	3	3	2	2	3	3	3	1	3
R3USC	LR1FRTH	146.6	3	1	3	3	3	3	3	3	2	3
R3USC	LR1ILTH	36.3	3	1	3	3	3	3	3	3	2	3
R3USC	LS1FRTH	12.0	3	1	3	3	3	3	3	3	2	3