Technical Procedures for Updating the National Wetlands Inventory of Northwest Minnesota

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Project Summary

This project, entitled "Updating the National Wetlands Inventory for Minnesota – Northwest Project Area", used geospatial techniques and image interpretation processes to remotely map and classify wetlands in Northwestern Minnesota. The project area included approximately the Northwest quarter of Minnesota. It consists of 1,634 quarter quadrangles (QQ) (408.5 USGS 7.5-minute quadrangle equivalents) across portions of the following nineteen counties: Becker, Clay, Clearwater, Douglas, Grant, Kittson, Lake of the Woods, Mahnomen, Marshall, Norman, Otter Tail, Pennington, Polk, Pope, Red Lake, Roseau, Stevens, Traverse, and Wilkin (Figure 1). Given that the National Wetland Inventory (NWI) update was based on 7.5-minute quadrangle boundaries, portions of these boundaries cross over into areas outside the designated project area. These areas include a small portion of Koochiching County in Minnesota, as well as small portions of South Dakota, North Dakota, and Canada. The total area updated as part of the Northwest Minnesota project area is approximately 20,700 square miles.

The purpose of this project was to update and enhance the Minnesota NWI using recently-acquired, high resolution digital imagery and a variety of high quality ancillary datasets. NWI attributes from "Classification of Wetlands and Deepwater Habitats of the Unites States" (Cowardin et al. 1979) and simplified plant community classifications from "Wetland Plants and Plant Communities of Minnesota and Wisconsin" (Eggers and Reed 1997) are included. A simplified hydro-geomorphic (HGM) classification using codes and descriptors from "Dichotomous Keys and Mapping Codes for Wetland Landscape Position, Landform, Water Flow Path, and Waterbody Type Descriptors: Version 2.0" (Tiner 2011) are also included as an enhancement. The final product is a seamless NWI dataset of the entire project area for inclusion in the National NWI master geodatabase.

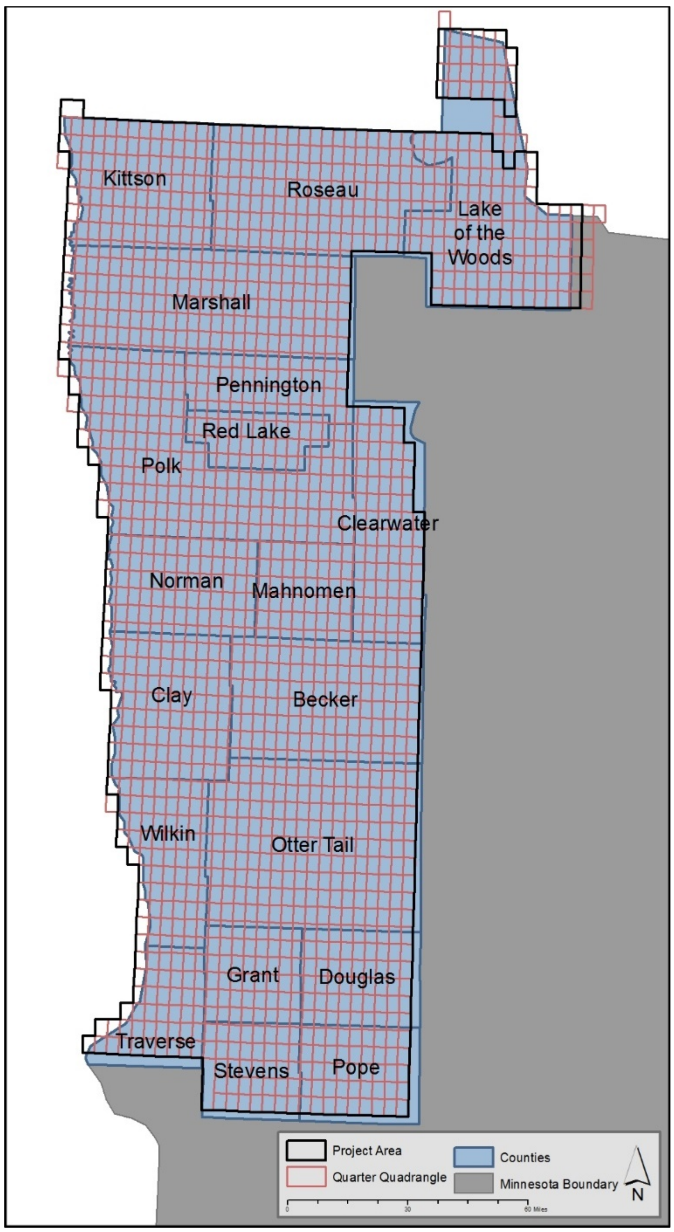


Figure 1. Minnesota NWI Update – Northwest Project Area.

This work resulted in the update of a wetland database that was created between 1980 and 1986 to the date of aerial photography used for this project (2013/14). Improved accuracy was achieved through the utilization of up-to-date GIS software and additional, highly accurate, ancillary datasets that were not available at the time of the previous mapping. The Minnesota Department of Natural Resources (MN DNR) Resource Assessment Program (RAP) personnel supported the project through pre-processing of ancillary datasets, Quality Assurance/Quality Control (QA/QC) support, and project documentation. The QA/QC support for this project provided by RAP included field work for photo-signature convention development, field work for data validation, and on-screen QA/QC review. It is anticipated that RAP's contribution to the project will be distributed with about 25% of their available resources toward data processing and the remaining 75% directed toward QA/QC and project documentation. Total RAP effort was based on RAP's available resources.

Data

The Northwest Minnesota NWI project utilized a variety of data types. Base data consisted of the most current 2013/2014 color-infrared (CIR) air photo imagery (high resolution, leaf-off, 4-band imagery). Ancillary datasets included the following: true color one-meter resolution satellite imagery (National Agriculture Imagery Program [NAIP] source), three-meter Light Detection and Ranging (LiDAR) elevation data (where available), ten-meter digital elevation data (U.S. Geological Survey [USGS]; used in areas where LiDAR is not available), soil data from the Soil Survey Geographic Database (SSURGO), digital topographic maps (digital raster graphic [DRG] format), the Minnesota Restorable Wetland Inventory (RWI), the MN DNR Public Waters Inventory (PWI), statewide data from the National Hydrology Dataset (NHD), surface hydrology (streams and lake), and existing NWI data.

Imagery

Several air photo imagery sources were utilized for this project; these include the most current 2013/2014 CIR and multiple years of true-color imagery from NAIP. The CIR was used as the base, or primary, data source for wetland delineation and classification decisions, while the NAIP imagery provided support in decision-making.

2013/2014 Color Infrared (CIR) Satellite Imagery

The CIR for this project was taken during the spring and has leaf-off, one-meter resolution. It covers the entire project area but can vary in color depending on the time in spring it was taken. There is a relatively small window in the spring, typically two to four weeks, when adequate CIR imagery may be taken; this window is after snow melt and before leaf flush. Depending on when during this two to four-week period the image was taken, some wetlands in the CIR will have red tones and the uplands have gray tones, while in other areas the opposite occurs where the uplands will have red tones and the wetlands have gray tones. Due to the large size of this project area, color variations in the CIR will occur and project mapping conventions will address these and other sources of imagery color hue variables.

National Agriculture Imagery Program (NAIP) Satellite Imagery

In addition to the spring CIR, multiple years of true-color NAIP imagery are available online through a Minnesota GeoSpatial Information Office (MnGeo) Web Mapping Service (WMS). As previously mentioned, this ancillary imagery was utilized as a secondary source to help in wetland delineation and classification decision-making. For example, imagery taken in the spring will not indicate the presence of aquatic bed (AB) wetlands, as the vegetation in those particular wetlands does not appear until later in the growing season. Due to NAIP imagery being taken later in the year, aquatic bed wetlands will appear in the imagery and can thus easily be delineated. Multiple years of NAIP imagery are available from MnGeo; the most recent summer imagery (2015) was the default when an ancillary imagery source was needed for proper wetland delineation and classification.

Soils, Topography, and Bathymetry

Soil Survey Geographic Database (SSURGO)

Two soil datasets were processed as inputs for this NWI update project. Along with providing insight into soil components that are cumulatively 85% (or higher) hydric and amount of organic matter, a series of queries, developed by the MN DNR, were calculated to create a continuous (quantitative) variable map based on a soil's water regime. A water regime value was determined through a concatenation of drainage class, April flood frequency, April pond frequency, and August pond frequency. For example, a soil component with a water regime of seven means the soil is very poorly drained with ponding throughout most of the year, while a water regime of zero means the soils is excessively or well drained with no flooding or ponding.

Table 1. Description of water regime classification used in defining the level of hydrology in soil components (MN DNR 2012).

Water Regime	Description
0	All excessively drained, somewhat excessively drained, and well drained soils as well as udorthents, udipsamments, pits, and gravel. This water regime level also includes moderately well drained soils and somewhat poorly drained soils that do not flood.
1	This water regime level includes moderately well drained soils and somewhat poorly drained soils that do flood at least rarely. (floodplain formations) This is similar to Cowardin's temporarily flooded "A" water regime.
2	Poorly drained and very poorly drained soils that neither flood nor pond. This is similar to Cowardin's saturated "B" water regime.
3	Poorly drained soils that occasionally flood during spring (almost all floodplain formations). Similar to Cowardin's "A" or "C" water regime depending on the length of flooding.
4	Very poorly drained soils with frequent spring flooding, but no ponding (almost all floodplain formations). Similar to Cowardin's seasonal "C" water regime.
5	Very poorly drained soils with frequent spring flooding and spring ponding (almost all floodplain formations). Similar to Cowardin's seasonal "C" water regime.

Water Regime	Description
6	Very poorly drained soils with no flooding, but that do have spring ponding (almost all depressional formations). Similar to Cowardin's seasonal "C" water regime.
7	Very poorly drained soils with ponding throughout most, if not all the year (marsh). Similar to Cowardin's "F" water regime.
8	Map units designated as water (non-soil). Similar to Cowardin "H" water regime.

U.S. Geological Survey (USGS) Topographic Maps (Digital Raster Graphic [DRG])

The USGS 1:24,000 scale topographic map series, also known as DRG, are not only used to verify the presence of hydrologic indicators through wetland symbology (i.e., marsh symbols, intermittent and perennial streams), but they can also be used to determine human-made changes to the landscape, such as new development. These maps also provide ten-foot elevation contours, which can be used for landscape-scale terrain analysis. For this project, the two foot contours and other topographic layers derived from LiDAR were the primary source for elevation analysis, while the DRGs were secondary.

MN DNR Lake Bathymetric Digital Elevation Model (DEM)

The MN DNR Lakes DEM data contain bathymetric data for select lakes throughout the state. The data are in raster format with cell values representing depth. The cell size in most cases is five square meters with some of the larger lakes resampled to ten square meters in order to keep file sizes down to a manageable size. There are a total of 6,096 lakes in the statewide database, of which 534 intersect the Northwest MN project area. This data was used to determine those classifications that are dependent on water depth, mainly the boundary between the limnetic (L1) and littoral (L2) subsystems within the lacustrine Cowardin et al. (1979) system. This supported a more efficient wetland delineation and classification decision-making process.

Light Detection and Ranging (LiDAR) Derived Products

LiDAR Digital Elevation Model (DEM)

In cases where three-meter LiDAR is available, there is both a regular DEM and a hillshade version. The hillshade version is useful for visual interpretation while the regular DEM is used in deriving other elevation data (i.e., contours). All portions of the project area that fell beyond the Minnesota state boundary (i.e., North Dakota, South Dakota, and Canada) did not have LiDAR coverage that could be used for this project (Figure 2).

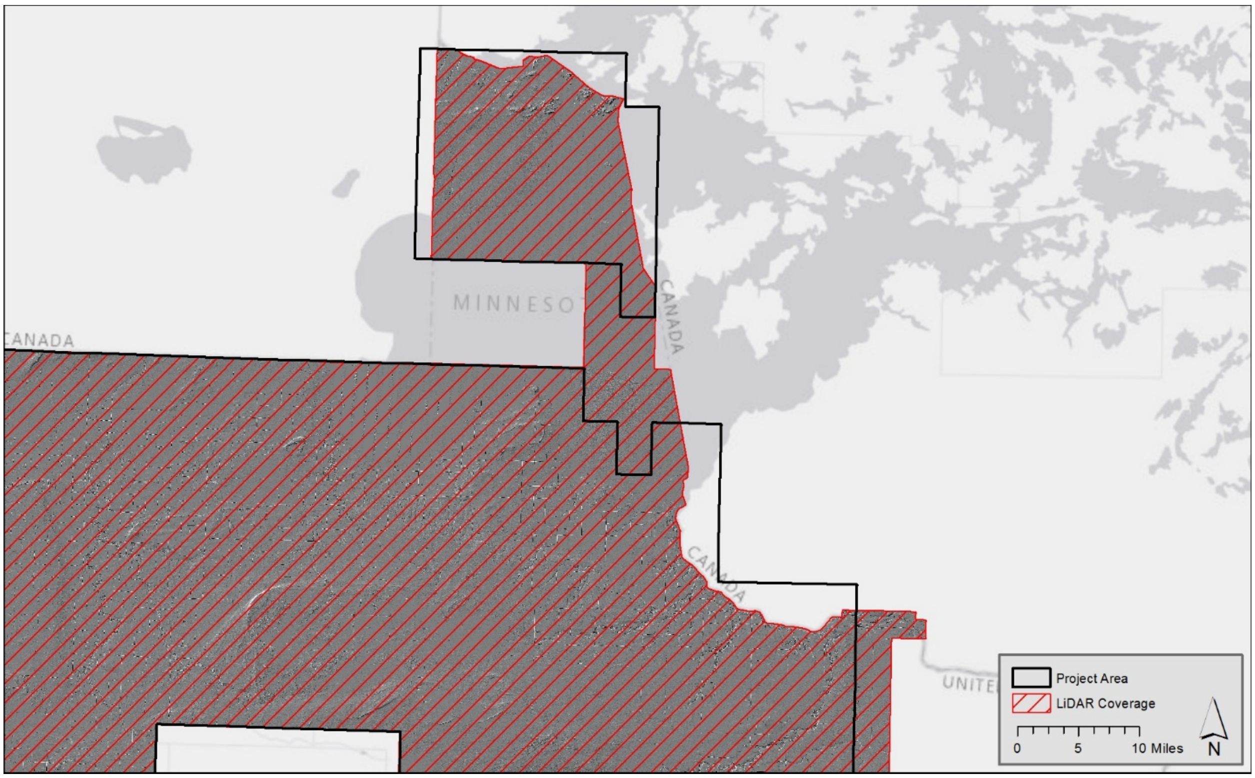


Figure 2. Gaps in LiDAR coverage occur in areas near the Canadian (above graphic), North Dakota, and South Dakota borders.

LiDAR Derived Datasets

Compound topographic index (CTI), Topographic Position Index (TPI), Maximum Vegetation Height, slope, and curvature are all raster datasets derived from the LiDAR data that can be used to aid photointerpretation. LiDAR can also be used to derive vector datasets, such as elevation contours, hydrologic flow networks, and a topographic basins layer, to aid in the classification process.

<u>Compound Topographic Index (CTI)</u>

Compound Topographic Index, also referred to as Topographic Wetness Index (TWI), is a hydrologic index that expresses the wetness of a particular location based on the ratio of upslope catchment area to the slope of a particular location; higher CTI values are more likely to collect water thus indicating the presence or potential of a wetland.

Topographic Position Index (TPI)

Topographic Position Index indicates the shape of the land at a given point by comparing the elevation of that point to the average elevation of the surrounding area. Definition in the size and shape of the surrounding area for the TPI analysis can affect its behavior. Positive TPI values indicate peaks or ridges while negative TPI values indicate valleys or depressions; a value of zero represents either flat areas or saddles. One particular useful application of TPI is for determining the level to which streams are incised into the landscape.

Maximum Height of First Return Points

LiDAR LAS data can provide relative measurements of physical height through the first return points. The maximum height of first return point raster layer generated by the MN DNR can provide insight into vegetation height and can be used to distinguish between forested and scrub-shrub areas. Time of day and year, sun angle, and cloud cover can influence the output intensity, thus this dataset is considered ancillary data and is best used on a local level.

Slope and Curvature

Slope and its derived curvature are both useful in making wetland classification decisions. For example, areas with high slope can often be eliminated from consideration for inclusion as a wetland while gently sloped areas can have saturated soils and are thus considered a potential wetland.

Elevation Contours

Two-foot elevation contours compliment the LiDAR datatset when determining elevation changes in the landscape. For example, when working in floodplains, the contours can help in keeping the delineation from going too far up a slope.

Hydrologic Flow Network

The hydrologic flow network is considered a compliment to existing linear flow network datasets (i.e., NHD, DRG stream display). It is derived from high resolution up-to-date LiDAR data and can be used to detect changes over time in linear flow network datasets. Due to the topographic nature of LiDAR derived products, caution is taken when viewing the hydrologic flow network. The presence of a flow line in the derived data does not necessarily mean that there is normally surface water flow associated with that linear feature.

Topographic Basins

Topographic basins are generated using a fill routine on high resolution DEM data. Basins can be derived to detect shallow and small depressions that fall under the resolution of other spatial layers such as the DRG. Basin mapping is also useful for finding small wetlands under tree canopy. Similar to the hydrologic flow network, LiDAR-derived basins do not necessarily indicate the presence of a wetland. They are useful in determining areas on the landscape where water could potentially pool and contribute to hydric soil development. Imagery signatures and other ancillary datasets are required to confirm the presence or absence of a wetland.

Stochastic Depression Analysis

Stochastic depression analysis uses high-resolution LiDAR data and Whitebox software's Geospatial Analysis Tools to identify depressions that may support wetland types that are normally difficult to detect. This method was successfully used to identify woodland vernal pools in Massachusetts (Wu et al. 2014). In the Northwest Minnesota project area, this layer was useful in locating wetlands under a thick wooded canopy.

National Wetland Inventory Historic Data

The existing NWI data, known as historic data, can aid in decision making. Most of the historic data are over thirty years old and were mapped at a scale of 1:60,000 or smaller using traditional analog photointerpretation methods. This dataset can provide insight into difficult situations where the wetland water regime or vegetation type is difficult to determine with the current ancillary data.

Additional Ancillary Data

Datasets such as public lands, NHD, and the Minnesota PWI are useful in situations where the interpreter needs to understand on a larger scale what is happening on the landscape. The age and scale of the ancillary data varies across the project area, limiting its usefulness in automated processes. In addition, some datasets are derived from information present on other ancillary datasets such as the NHD using the DRG for deriving stream networks.

Data Standards

Data Format

The entirety of this project was conducted in the Environmental Systems Research Institute (Esri) ArcGIS 10.4.1 software. All wetland data reside in a file geodatabase and are in the format of polygon feature classes.

Projection

Updated wetland data were created inside the North American Datum (NAD) 1983 Universal Transverse Mercator (UTM) Zone 15 North projection. In terms of data delivery, the NAD83 UTM Zone 15N was used as the dataset projection to the Minnesota DNR, while NAD83 Albers Equal Area Conic was used as the projection to the U.S. Fish and Wildlife Service (USFWS) and ultimately ended up in the National NWI dataset.

Horizontal Accuracy

Wetland boundaries are coincident with the base imagery. This means that 95% of defined boundaries (e.g., water-land boundaries) occur within 20 feet of the boundary position on the base imagery. This requirement is consistent with the National Map Accuracy Standard for maps with a scale of 1:6,000.

Classification Accuracy

The delivered wetland data meets the classification accuracy goals set in the Federal Geographic Data Commission (FGDC) Wetland Mapping Standard. These accuracy goals include an interpreter's accuracy greater than or equal to 98% for wetland features larger than one-half acre that are visible on the imagery and an overall classification accuracy greater than or equal to 85% for the Cowardin class level. In addition, the delivered wetland maps have a user's accuracy greater than or equal to 92% for wetland features. Evaluation of this goal will be conducted by comparing wetland maps to set validation points developed from an independent analysis conducted by the State of Minnesota and the University of Minnesota. Results from this analysis will be included in the final metadata.

Target Mapping Unit

Wetlands greater than one-half acre are subject to the accuracy assessment goals described above. Any independent wetland features that are less than one-half acre, and visible at a 1:6,000 scale, were mapped but are not subject to the above accuracy standards.

Cartographic Standards

Wetland feature boundaries are represented with a level of detail at the scale of 1:6,000. Features smaller than one-twentieth of an acre (~200 square meters) were not mapped as independent features. Instead they were incorporated into the predominant adjacent class. Upland features were not mapped. In terms of the line work, the wetland feature boundaries were delineated using the Esri ArcGIS standard editing construction tools and should not have a jagged appearance or sharp edges.

Data Verification

The delivered data is logically consistent and topologically complete. It is comprised of simple feature polygons with no overlaps and no gaps between adjacent polygons. A seamless coverage was created through an edge-matching process between all 1,634 quarter quadrangles (QQ) (408.5 USGS 7.5-minute quadrangle equivalents) and to other adjacent Minnesota project areas. The NWI Verification Toolset attribution and topology rules, as well as internal error checking scripts, was again applied to the dataset in order to ensure integrity of the final product.

Metadata Information

Metadata meet the requirements of the Minnesota Geographic Metadata Guidelines. It includes a statement of tested classification accuracy, an error matrix, a full description of the data lineage, and spatial reference information. In addition, a final version of the mapping conventions document that includes all modifications to the mapping procedures was prepared and delivered to MNDNR.

Documentation

Saint Mary's University of Minnesota GeoSpatial Services (GSS) documented their mapping methods and provided this documentation to the MN DNR for approval. If any substantial mapping methods took place, approval by the MN DNR occurred.

Training

GSS ensured that all interpreters working on this project had adequate training both in the office and out in the field. All training documentation and interpreter productivity was kept in records and available for the MN DNR to review if necessary. Interpreters working for GSS could demonstrate proper spatial editing for wetland delineation and had proficient knowledge in wetland classification according to the Cowardin et al. (1979) standards.

Data Management

GeoSpatial Services maintains a secure system to manage input data, intermediate products, and final wetland data with provisions for full data back-up and restoration. All input data not being viewed from the MnGeo Web Mapping Services resides on dedicated network attached storage (NAS) devices. All project work (i.e., created wetland data, ancillary datasets) resides on the GSS project server that is differentially backed up daily with a full back up performed weekly and stored in multiple locations. Data were tracked through a work flow by the project manager (see section "Project Workflow"). Interpreters were given checkouts that were comprised of any number of QQs. Copies of these checkouts were saved at major milestones (i.e., initial editing session, QA/QC approval). Once the final data are delivered, GSS will maintain a copy of the data for at least one year.

Classification

This project classified wetland features using three different classification systems:

- Cowardin Classification (Kloiber and Macleod 2011)
    - Modified from Classification of Wetlands and Deepwater Habitats of the United States by (Cowardin et al. 1979)
- Simplified Hydro-Geomorphic Classification (SHGM) (Kloiber and Macleod 2011)
    - Modified from Landscape Position, Landform, Water Flow Path, and Waterbody Type (LLWW) by (Tiner 2011)
- Simplified Plant Community Classification (SPCC) (Kloiber and Macleod 2011)
    - Modified from Wetland Plants and Plant Communities of Minnesota and Wisconsin by (Eggers and Reed 1997)

Cowardin Classification

Modifications to the Cowardin et al. (1979) classification system, as specified in Kloiber and Macleod (2011), were used to classify all Minnesota wetlands in this project (Table 2). Where appropriate, wetland classifications included a system, subsystem, class, sub-class, water regime, and special modifier. Table 2 below contains the modified Cowardin et al. (1979) classification codes valid for the project. Since the Cowardin et al. (1979) system is the most explicit and highly resolved of all three classifications systems used for this project, it served as the foundation for determining the other two classification systems.

Table 2. Valid Cowardin Classification codes (Kloiber and Macleod 2011).

System	Subsystem	Class	Subclass	Water Regime	Special Modifier
L	1	UB		H, K	h, x
L	2	UB		F, H, K	b, d, h, x
		AB		F, H, K	b, d, h, x
		EM	2	F, H, K	b, d, h, x
		US		A, C, K	b, d, h, x
		RS		A, C, K	b, d, h, x
		RB		F, H, K	b, d, h, x
P		UB		F, H, K	b, d, h, x
		AB		F, H, K	b, d, h, x
		EM	1	A, B, C, F, K	b, d, f, h, x, q
			2	C, F, H, K	b, d, h, x
		FO	1, 2, 3	A, B, C, F, K	b, d, h, x, q
		SS	1, 2, 3, 4	A, B, C, F, K	b, d, h, x, q
		US		A, C, K	b, d, h, x
		RB		F, H, K	b, d, h, x
		ML		B	d, q
R	2	UB		H	h, x
		AB		H	h, x
		EM	2	F, H	h, x
		US		A, C	h, x
		RS		A, C	h, x
		RB		F, H	h, x
R	3	UB		F, H	h, x
		US		A, C	h, x
		RS		A, C	h, x
		RB		F, H	h, x
R	4	SB		A, C	h, x

Simplified Hydro-Geomorphic Classification (SHGM)

Modifications to the LLWW classification system, as specified in Kloiber and Macleod (2011), were also used to classify all Minnesota wetlands in the project. This simplified hydro-geomorphic system (SHGM) classifies wetlands and water bodies based on landscape position, surface hydrology, and relationship to nearby landscape features including other wetlands and waterbodies. In a similar manner to Cowardin et al. (1979), SGHM uses codes to describe wetland characteristics but it differs from the full LLWW classification in that no special modifiers are applied. In SHGM, and LLWW, a wetland feature can be put into one of two categories: wetlands or waterbodies. A wetland feature coding schema can take two different forms depending on what category the feature is put into. The two schema forms are described below with their descriptive keys.

Wetlands = Landscape Position | Landform | Water Flow Path

SHGM codes for this category are six characters in length. Landscape Position is an uppercase two-letter code that describes whether the wetland is associated with a lake, a river, or surrounded by uplands. Wetlands associated with lakes are defined as lentic (**LE**). Wetlands associated with flowing water are classified as lotic streams (**LS**) or lotic rivers (**LR**), depending upon their size. Wetlands that are surrounded by uplands as part of an isolated basin are classified as terrene (**TE**) (Table 3).

Table 3. SHGM Landscape Position Dichotomous Key (Kloiber and Macleod 2011).

	Landscape Position Dichotomous Key	
1a	Wetland lies along a river, stream, lake, or reservoir, or in-stream pond; or within a relatively flat plain contiguous to a waterbody	2
1b	Wetland does not lie along one of these waterbody types; it is surrounded by upland or borders a pond that is surrounded by upland	Terrene
2a	Wetland lies along a lake or reservoir or within its basin (i.e. the relatively flat plain contiguous to the lake or reservoir)	Lentic
2b	Wetland lies along a river, stream, or in-stream pond	3
3a	Wetland is the source of the river or stream and this watercourse does not flow through the wetland	Terrene
3b	A river or stream flows through or alongside the wetland	4
4a	Wetland is periodically flooded by river or stream	5
4b	Wetland is not periodically flooded by the river or stream	Terrene
5a	River or stream that flows through wetland is represented by a single line on USGS 7.5-minute topographic map	Lotic Stream
5b	River or stream that flows through a wetland is represented by a polygon on USGS 7.5-minute topographic map	Lotic River

Landform is the second portion of the code and is also made up of two uppercase letters. Landform refers to the geomorphic structure on or in which the wetland resides. There are six inland landforms present in Northwest MN. These are slope (**SL**), island (**IL**), fringe (**FR**), floodplain (**FP**), basin (**BA**), and flat (**FL**) (Table 4). The interfluve (IF) landform is not included for this project.

Table 4. SHGM Landform Dichotomous Key (Kloiber and Macleod 2011).

Landform Dichotomous Key		
1a	Wetland occurs on a slope greater than 2%	Slope
1b	Wetland does not occur on a slope greater than 2%	2
2a	Wetland forms an island completely surrounded by water	Island
2b	Wetland does not form an island	3
3a	Wetland occurs in the shallow water zone of a permanent waterbody	Fringe
3b	A river or stream flows through or alongside the wetland	4
4a	Wetland forms a non-vegetated bank or is within the banks of a river or stream	Fringe
4b	Wetland is a vegetated stream bank or is not within the banks	5
5a	Wetland occurs on the active alluvial floodplain along a river	Floodplain
5b	Wetland does not occur on an active floodplain	6
6a	Wetland occurs in a distinct depression	Basin
6b	Wetland occurs on a nearby level landform	Flat

Water flow path refers to how and if the wetland feature is part of the surface hydrology network. Common examples of the water flow path code include inflow (**IN**), outflow (**OU**), and throughflow (**TH**). Wetlands that are not connected to the surface hydrology network are classified as isolated (**IS**) (Table 5).

Table 5. SHGM Water Flow Path Dichotomous Key (Kloiber and Macleod 2011).

Water Flow Path Dichotomous Key		
1a	Wetland is typically surrounded by upland; receives precipitation and runoff from adjacent areas with no apparent outflow	Isolated
1b	Wetland is not geographically isolated	2
2a	Wetland is a sink receiving water from a river, stream, or other surface water source lacking surface water outflow	Inflow
2b	Wetland is not a sink; surface water flows through or out of the wetland	3
3a	Wetland flows out of the wetland, but does not flow into this wetland from another source	Outflow
3b	Water flows in and out of the wetland, or the water table fluctuates due to the presence of a lake or stream	4
4a	Water flows through the wetland through an identifiable channel	Throughflow
4b	Wetland occurs along a lake or reservoir and not along a river or stream; its water levels are subject to the rise and fall of lake or reservoir levels	Bidirectional-Nontidal

Some examples of complete codes in the wetland category are shown below:

LEBABI: This is a basin (**BA**) wetland associated with a lake (**LE**). It has bidirectional flow (**BI**), which is the type of flow associated with fluctuating lake levels.

LSFRTH: This wetland is located on the fringe (**FR**) of a stream (**LS**). It has throughflow (**TH**).

LRFRTH: This wetland is located on the fringe (**FR**) of a river (**LR**). As might be expected for many of these types of wetlands, it has throughflow (**TH**).

TEBAIS: This code refers to a terrene (**TE**) wetland or a wetland surrounded by uplands. It is in a basin (**BA**), and because it is disconnected from the surface hydrology network, it is given the isolated (**IS**) water flow path.

<u>Waterbody = Waterbody | Water Flow Path</u>
SHGM codes for this category are four characters in length. Water Body consists of an uppercase two letter code. Four waterbody types are present in Northwest MN; these are lake (**LK**), river (**RV**), stream (**ST**) and pond (**PD**). When a feature is classified as a water body, there is no landform code applied because the water body can be considered its own landform (Table 6).

Table 6. SHGM Waterbody Dichotomous Key (Kloiber and Macleod 2011).

	Waterbody Dichotomous Key	
1a	Waterbody is predominantly flowing water	2
1b	Waterbody is predominantly standing water	3
2a	Waterbody is represented by a polygonal feature on the USGS 7.5-minute topographic map	River
2b	Waterbody is represented by a linear feature on the USGS 7.5-minute topographic map	Stream
3a	Waterbody is permanently flooded, greater than 6.6 feet deep at low water, and is not associated with a morainal “kettle” or a “bog pond”	Lake
3b	Waterbody is less than 6.6 feet deep at low water, or is associated with a morainal “kettle” or a “bog pond”	4
4a	Waterbody is less than 20 acres is size	Pond
4b	Waterbody is greater than or equal to 20 acres is size	Lake

Water flow path refers to how and if the wetland feature is part of the surface hydrology network. Common examples of the water flow path code include throughflow (**TH**), inflow (**IN**) and outflow (**OU**). Wetlands that are not connected to the surface hydrology network are classified as isolated (**IS**) (See Table 5 above).

Some examples of complete codes under this category are shown below:

> **LKIN**: This water body is a lake (**LK**) with surface water flowing into it, but not out of it; thus inflow (**IN**) is the water flow path.
>
> **PDIS:** This code refers to a water body that is a pond (**PD**) that is isolated (**IS**) from the rest of the surface hydrology network.

Most of the water flow path codes are the same for both wetlands and water bodies. However, there are small differences between them, which makes following the SHGM keys crucial when assigning codes. It should be emphasized that this classification can only consider surface hydrology. Subsurface hydrologic connectivity is not considered because these characteristics cannot be assessed through image interpretation. The SHGM codes that are expected to be found in Northwestern MN are shown in Table 7.

Table 7. Valid Simplified Hydro-Geomorphic (SHGM) Classification codes (Kloiber and Macleod 2011).

Landscape Position Code (Description)	Landform Code (Description)	Water Flow Path Code (Description)	Waterbody Code (Description)
LE (Lentic)	SL (Slope)	VR (Vertical Flow)	LK (Lake)
LR (Lotic River)	IS (Island)	IN (Inflow)	RV (River)
LS (Lotic Stream)	FR (Fringe)	OU (Outflow)	ST (Stream)
TE (Terrene)	FP (Floodplain)	TH (Throughflow)	PD (Pond)
	BA (Basin)	BI (Bidirectional-Nontidal)	
	FL (Flat)		

As previously mentioned, the wetland features created during the Cowardin classification process served as the foundation for creating SHGM data. The wetland feature class had an additional field added to the attribute table which was populated with the proper SHGM codes. The entire procedure for SHGM classification is outlined in the succeeding Project Workflow section below.

Simplified Plant Community Classification (SPCC)

A simplified plant community classification (SPCC) based on a modified version of the Eggers and Reed (1997) classification system was also applied to all wetland features. The attribution inside the feature class was applied as described by Kloiber and Macleod (2011) (Table 8). It should be noted that features classified with the artificially flooded (K) water regime were not included in any of the plant community classes. These were attributed with “N/A” in the SPCC attribute field.

Table 8. Simplified Plant Community Classes (SPCC), cross-referenced to Eggers and Reed (1997)

MN Simplified Plant Community		Eggers and Reed (1997) Plant Community	
Type	**Class**	**Type**	**Class**
1	Seasonally Flooded Basin	16B	Seasonally Flooded Basin
2	Wet Meadow	13A	Sedge Meadow
		15B	Fresh (Wet) Meadow
		15A	Wet to Wet-Mesic Prairie
		14A	Calcareous Fens (Herbaceous Type)
3	Shallow Marsh	13B	Shallow Marsh
4	Deep Marsh	12B	Deep Marsh
5	Shallow Open Water Community	16A	Shallow Open Water Community
6	Peatland	10A	Open Bog (Herbaceous Type)
		7A	Open Bog (Shrub Type)
		4A	Coniferous Bog
7	Shrub Wetland	8B	Shrub-Carr
		8A	Alder Thicket
		7B	Calcareous Fens (ShrubType)
8	Hardwood Wetland	3B	Hardwood Swamps
		3A	Floodplain Forests
9	Coniferous Swamps	4B	Coniferous Swamps
10	Non-Vegetated Aquatic	N/A	N/A

The SPCC attributes were added to the final data after the Cowardin and SHGM classifications were applied, and all delineations were reviewed and approved. In a similar fashion to the addition of the SHGM descriptors, the Cowardin classification and delineation provided the spatial foundation to which the SPCC descriptors were added. A series of SQL database queries based on the relationships defined in Table 9 were used to populate the SPCC descriptor field. The entire procedure for the addition of the SPCC identifiers is outlined in the succeeding Project Workflow section below.

Table 9. Simplified Plant Community Classification (SPCC), Cross-referenced to Cowardin Classification.

Simplified Plant Community Class	Cowardin Codes
Coniferous Bog	PFO2Bq, PFO4Bq
Coniferous Wetland	PFO2B, PFO4B
Deep Marsh	L2EM2G, L2EM2H, PEM2G, PEM2H, R2EM2G, R2EM2H
Hardwood Wetland	PFO1A, PFO1B, PFO1C
Non-Vegetated Aquatic Community	L1UBH, L2RSC, L2USA, L2USC, PUSA, PUSC, R2UBF, R2UBG, R2UBH, R2USA, R2USC, R3UBG, R4SBA, R4SBC, L2UBF, L2UBG, L2UBH, PUBF, PUBG, PUBH
Open Bog	PEM1Bq, PSS1Bq, PSS2Bq, PSS3Bq, PSS4Bq
Seasonally Flooded/Saturated Emergent Wetland	PEM1A, PEM1B
Shallow Marsh	L2EM2F, PEM1C, PEM1F, PEM2F, R2EM2F
Shallow Open Water Community	L1ABH, L2ABF, L2ABG, L2ABH, PABH, R2ABG, R2ABH, PABF, PABG
Shrub Wetland	PSS1A, PSS1B, PSS1C, PSS1F, PSS2B, PSS3B, PSS4B
Artificially Flooded Hardwood Wetland	PFO1K
Artificially Flooded Non-Vegetated Aquatic Community	L1UBK, PUSK, L2UBK, PUBK
Artificially Flooded Shallow Marsh	PEM1K
Artificially Flooded Shallow Open Water Community	L2ABK, PABK
Artificially Flooded Deep Marsh	L2EM2K, PEM2K
Artificially Flooded Shrub Wetland	PSS1K, PSS3K

Project Workflow

Introduction

This project was broadly divided into two phases. The first phase consisted of initial field visits, developing a photo-interpretation guide, and documenting the technical procedures, while the second phase consisted of data production, which can be subdivided into draft data production and final data preparation. Data quality was evaluated with respect to the data standards (please see Data Standards Section above). Field visits were used to correlate photo-signatures and other indicators present in the digital data to the presence and classification of wetlands on the ground. Field visits also helped to identify factors unique to the study area. Draft data were used to prototype the technical procedures and photo-interpretation guide. Once the draft data were approved and the technical procedures were finalized, data production began.

The production work flow is outlined in Figure 3. The workflow was divided into draft data development, and final QA/QC and processing. There are several places in the work flow where the data were assessed against the project standards. If it did not meet the standards, it was revised based on the feedback of the reviewing party.

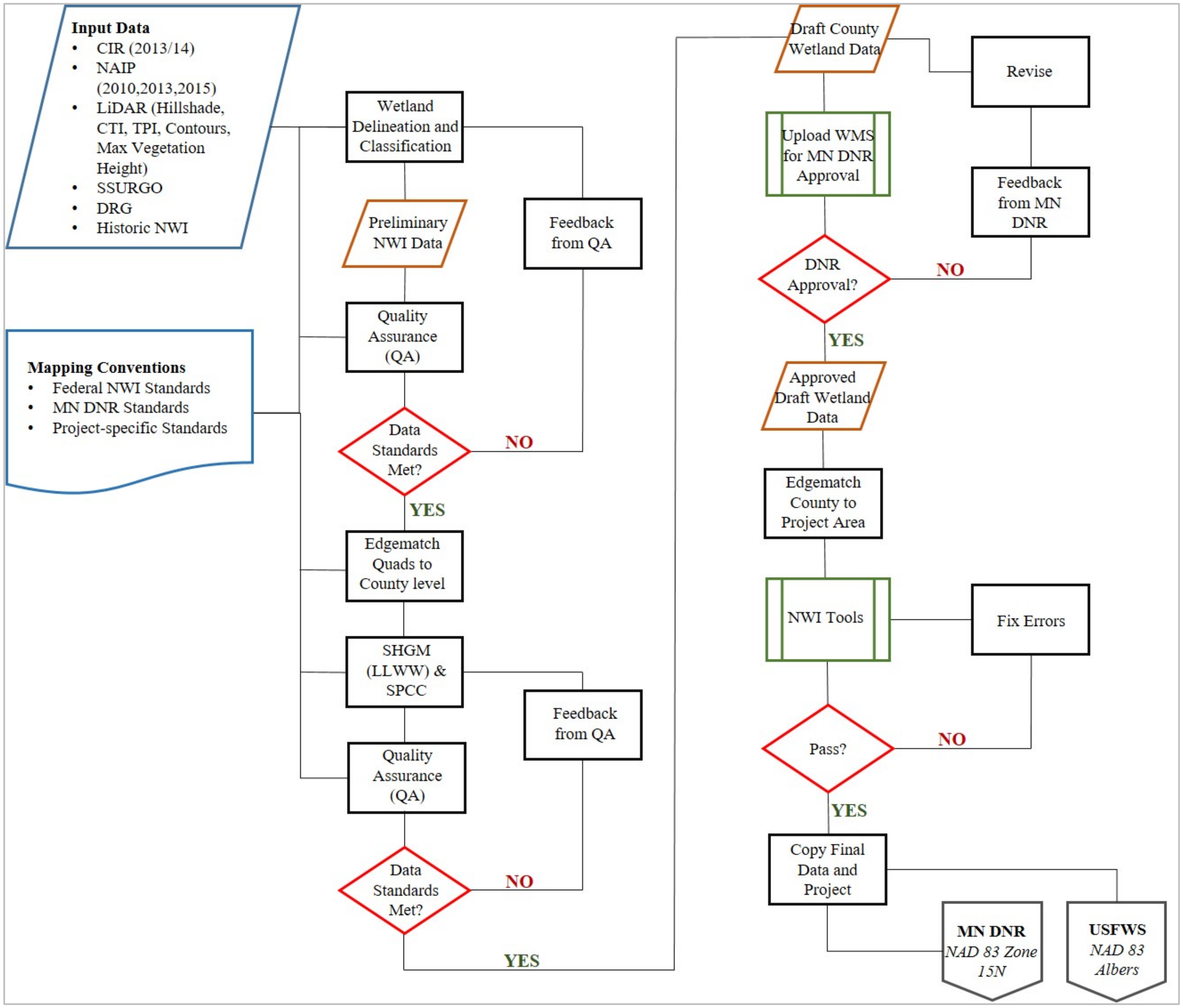


Figure 3. Northwest Minnesota NWI Update Work Flow.

Process Documentation

This document defines the delineation and classification process for this project. The Technical Procedures portion explains the standards and procedures of the project while the Photointerpretation Guide (Appendix A) provides specific direction on particular signatures and classification.

Field Verification and Review

Field verification is a vital part of the photointerpretation process with several objectives:

1. Document commonly occurring signatures and habitats.
2. Document unusual but important signatures.
3. Determine and verify the classification of difficult to distinguish signatures, including distinguishing between upland and wetland.
4. Verification of water regimes.
5. Document variability in photo-signatures due to variability in the imagery and location within the study area (i.e., multiple ecoregions).

Field sites were selected to meet these objectives. The process of selecting sites involved reviewing the imagery and creating points in a feature class of the site locations. The site locations were then used to plan the logistics of each field trip and uploaded to a GPS for navigational purposes. Field visits occurred in the spring after the ground had thawed, but before vegetation leaf flush was complete. This makes it easier to observe conditions on the ground. For sites on public land, formal documentation was possible which could include a collection of a GPS point at the site location, a soil probe test, and completion of a field data sheet which records information like location, ownership, soil test results, vegetation species, etc. Informal documentation was all that could be performed for sites on private land, which consisted of examination of the site from a public right of way. In both cases, ground level photographs documenting the site and notes and/or delineations on hard copy maps were gathered.

Data Production

Data production utilized on-screen digitizing methods, which were the same methods used to generate the draft data. Figure 3 above represents the production workflow and its four stages. Delineation and classification using the FGDC Cowardin Classification system was the first stage and the most labor-intensive portion of data production. This stage occurred at the 7.5-minute quadrangle level. It included initial delineation and attribution by an editor and internal QA/QC by GSS staff, concluding with the edgematching of quad data to the county level. The second stage was assigning SHGM (referred to as “LLWW” in workflow) and SPCC (referred to as “modified plant community classification” in workflow) attributes at the county level. The third stage was the MN DNR draft review phase. At this stage the draft data were submitted by county to MN DNR WMS for review and feedback (external QA/QC). If not approved, GSS incorporated MN DNR’s feedback and resubmitted for review. Once approved, the data moved to the fourth and final stage of processing. The approved county level data were edgematched to create a seamless dataset for the entire project area. The NWI QA/QC tools were applied to the data and any errors were fixed. Upon successful completion of the NWI QA/QC tools, two copies of the data were made, one for the MN DNR (in

NAD83 UTM Zone 15N projection) and another for the USFWS (in NAD83 Albers Equal Area Conic projection) to be put into the nation-wide NWI database.

Software and Data Management

Esri ArcGIS 10.4.1 was the GIS software utilized for this project. A file geodatabase was used to house and organize the wetland data. A hard copy form called a routing sheet was generated for each 7.5-minute quadrangle checkout. The routing sheet was used to document the interpreter's checkout information, hours, and polygons created. The Project Lead and QA/QC Specialist were responsible for assigning checkouts, generating the routing sheet, and maintaining the digital data file structure. Each interpreter had a folder in a working directory. When a new checkout was assigned, a blank file geodatabase holding an empty feature class (titled "CONUS_wet_poly") for wetland data creation, along with a shapefile of the checkout boundary, was put into an interpreter's folder. All edits took place within this file geodatabase. As each stage of production was completed, the Project Lead made a copy of the data which was then stored in a different location to serve as a "snapshot" of the data for that particular stage of production. Once the checkout was approved through the QA/QC process, an additional copy was made in another location in order to segregate completed data from in-process data. This was in addition to GSS' organization-wide data back-up system explained in the previous Data Standards section of this document.

The collateral data for this project resided in two locations: a dedicated NAS device and the MnGeo aerial imagery WMS. The WMS was used for the true color NAIP imagery sources and as a back-up for the Spring 2013/14 CIR. The NAS device was the source for all other collateral data (LiDAR and associated products, DRGs, SSURGO, Lake DEMs) and the primary source for the Spring CIR imagery. By accessing the Spring CIR from the NAS device, GSS was able to apply a standard deviation stretch to the imagery to make the wetland signatures more distinctive. This was not possible when accessing the same data from the WMS. In order to ensure the collateral data were not inadvertently edited, permissions were set on the NAS device so that only the project lead had write privileges.

<u>On-Screen Photointerpretation Process</u>

Delineation & Cowardin Classification

This project used an on-screen, heads-up, digitizing process. This approach takes advantage of the editing tools available through ArcMap to delineate and classify wetland features based on photosignatures in ortho-rectified imagery, and supporting collateral data. The Photointerpretation Guide (Appendix A) explains the specifics of how the source imagery and collateral data were applied to delineate and classify each Cowardin wetland type in the Northwest MN project area.

1. The interpreter started by creating a new ArcMap map document. The first data added to the map document was the blank wetlands file geodatabase in order to ensure the data frame was set to the NAD83 UTM Zone 15 North projection. Imagery and collateral data sources were added next. The end result was an ArcMap window similar to the example in Figure 4. Beyond the initial wetlands file geodatabase, it was up to the interpreter to organize in the

Table of Contents and symbolize the data to their liking; this created a unique editing environment to help optimize productivity.

Figure 4

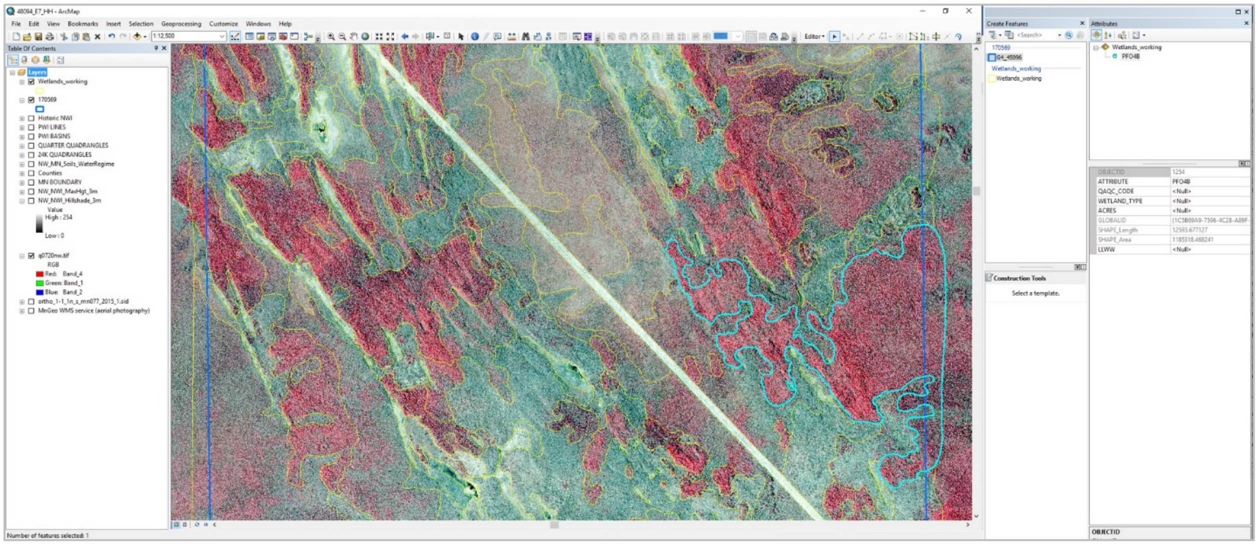
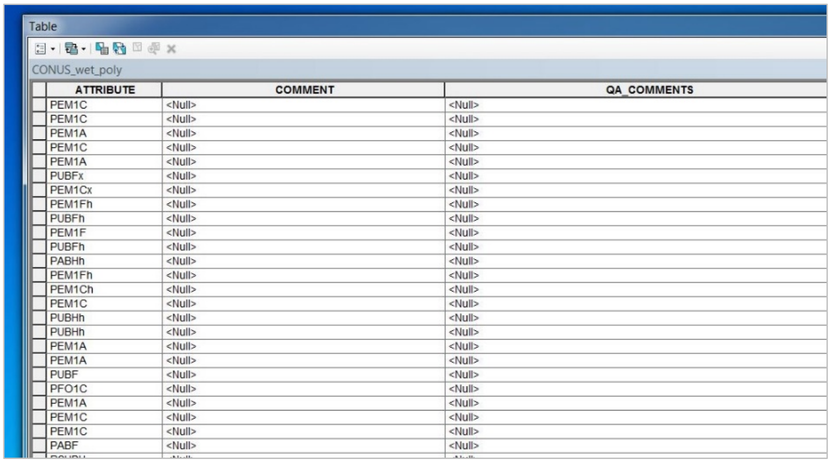


Figure 4. Example ArcMap map document window.

2. To clearly see wetland signatures, the edited wetland feature polygon must be displayed as hollow with a line weight between one-half and one in a line color that contrasts with the background imagery. The CIR must be set to display the red band as band #4, the green band as band #1, and the blue band as band #2. This is a spectral enhancement that allows the use of the near infrared band. A standard deviation stretch of two was also applied to the CIR at this time to help make the wetland signatures, especially emergent signatures, easier to distinguish. Display of the other data layers was at the discretion of the interpreter. However, any display color or technique that interfered with photointerpretation was not allowed, such as non-contrasting colors, and excessively heavy line weights.
3. The entire extent of the assigned checkout was examined for wetlands. This was accomplished through a “mowing the lawn” technique where the interpreter started in the northwest corner of the assigned checkout at the mapping scale of ~1:6,000. This extent was examined for presence of wetlands based on the signatures and other indicators outlined in the Photointerpretation Guide (Appendix A). Where wetlands were found, they were delineated as a polygon feature using the standard ArcMap editing tools.

Wetland classification utilized the Cowardin Classification system and occurred by directly editing the *ATTRIBUTE* field in the CONUS_wet_poly feature class’ attribute table (Figure 5). Wetland classes were assigned as individual wetland polygons were delineated.



Table

CONUS_wet_poly

ATTRIBUTE	COMMENT	QA_COMMENTS
PEM1C	<Null>	<Null>
PEM1C	<Null>	<Null>
PEM1A	<Null>	<Null>
PEM1C	<Null>	<Null>
PEM1A	<Null>	<Null>
PUBFx	<Null>	<Null>
PEM1Cx	<Null>	<Null>
PEM1Fh	<Null>	<Null>
PUBFh	<Null>	<Null>
PEM1F	<Null>	<Null>
PUBFh	<Null>	<Null>
PABHh	<Null>	<Null>
PEM1Fh	<Null>	<Null>
PEM1Ch	<Null>	<Null>
PEM1C	<Null>	<Null>
PUBHh	<Null>	<Null>
PUBHh	<Null>	<Null>
PEM1A	<Null>	<Null>
PEM1A	<Null>	<Null>
PUBF	<Null>	<Null>
PFO1C	<Null>	<Null>
PEM1A	<Null>	<Null>
PEM1C	<Null>	<Null>
PEM1C	<Null>	<Null>
PABF	<Null>	<Null>

Figure 5. Screen shot of CONUS_wet_poly feature class attribute table.

The interpreter was allowed to zoom in to a scale of 1:3,500 if necessary to make edits, but no closer. After all the wetlands in the 1:6,000 extent were found, delineated, and classified, the interpreter panned across the checkout from west to east by one extent with a slight overlap to the previous extent, making sure no areas were missed. The process was repeated for each extent, until the eastern edge of the work area was reached. At this point the interpreter panned south one "row" and started the next pass, moving from east to west. Along the edges of the checkout, the interpreter consulted with the interpreter of the neighboring checkout to help assure consistency across the project area. Any delineation along the edge is overlapped by 100 to 200 meters outside of the work area to expedite edgematching. The panning process continued until the entire checkout had been examined and all wetland features were delineated and classified. At this point the interpreter was required to perform a series of finalization tasks to prepare the checkout for QA/QC.

Interpreter Finalization Tasks

The interpreter checkout finalization tasks were equivalent to the first stages of the QA/QC process. These tasks can be viewed as a "self QA" by the interpreter. Beyond that, it was a vital step in making sure the data being produced met the project standards. The objective of this procedure was to eliminate as many errors and issues as possible before the data were sent to QA/QC. This helped QA/QC focus their efforts on more difficult tasks rather than spending time on mundane, easily addressed issues. After completing photo-interpretation and classification edits, the assigned checkout was finalized by performing the following steps:

1. All CONUS_wet_poly features (edited wetland feature class) were selected and exploded to split any multi-part features into separate polygons. This step may have been repeated multiple times until there were no multi-part features to explode.
2. The CONUS_wet_poly (edited wetland feature class) attribute table was sorted on the *ATTRIBUTE* field in ascending order in order to find null and blank entries. A null or blank entry in the attribute field could occur for a couple reasons. The interpreter may have neglected to assign a classification code to the wetland feature. It could also occur when a "ghost" polygon is created, which means an entry was created in the attribute table, but there is no associated geometry for the feature class. They are created when, inside the attribute table, an interpreter hits the enter key after making an entry. Missing attributes were populated by the interpreter and "ghost" polygons were deleted.

3. The CONUS_wet_poly (edited wetland feature class) attribute table was then sorted on *SHAPE_Area* field in ascending order. The smallest polygons were brought to the top of the attribute table, making it easier for the interpreter to verify whether any polygons less than a quarter-acre (~1,000 square meters) exist. This is mainly to find and address sliver polygons, which were merged with an adjacent polygon, or deleted if not associated with a wetland. In other cases, wetland features less than one-tenth of an acre (~400 square meters) that are part of a complex were merged with the adjacent wetland feature. However, wetland features less than one-tenth of an acre that are easily visible at a scale of 1:6,000 and easily delineated at a scale of 1:3,500 could be retained (i.e., PUBF farm ponds).
4. A check for erroneous attributes was conducted by using “Select by Attribute” on the *ATTRIBUTE* field of the CONUS_wet_poly (editing wetland feature class) table. This was a quick way of getting a list of unique classification code present in the data. Once the Select by Attribute graphical user interface was open (Figure 6), “ATTRIBUTE” was selected in the field list, then the“Get Unique Values” button was selected to populate the values list as shown in the figure. The interpreter reviewed these values and looked for attribution errors. Common errors included invalid attributes (refer to Table 2 for valid attributes), capitalization errors (PeM1A versus PEM1A), missing code components (RUSC versus R2USC), and typographic errors such as using a zero for the letter O (PF01C versus PFO1C). Erroneous attributes were directly edited in the table to fix errors, which may have required looking back to the imagery for verification.

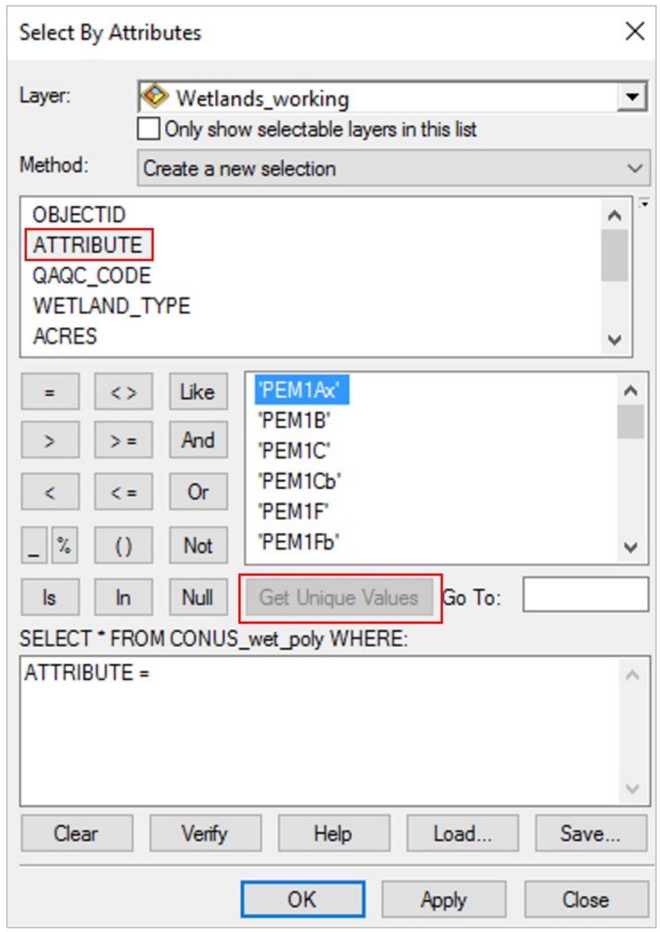


Figure 6. Screen shot of the Select by Attribute graphical user interface.

5. Topology was used to look for geometry issues and at this point, the only rule applied by the interpreter was “must not overlap.” The “must not have gaps” was applied later by the QA/QC specialist. The interpreter then validated topology and fixed errors as many times as needed until all polygon overlaps were corrected.

6. After successfully completing steps 1-5, the checkout was considered complete and ready for QA/QC. The interpreter’s last step was to record their hours, polygons created, and any relevant notes on the routing sheet and return it to the Project Lead.

The checkout was considered complete when all of the above steps had been executed, errors fixed and the finalization tasks all came back error-free. If the steps were not completed, the QA/QC Specialist immediately returned the checkout back to the interpreter to finish all required steps. As a final step before QA/QC, the Project Lead made a backup copy of the data that was stored in a separate folder.

<u>Quality Assurance/Quality Control (QA/QC)</u>

Wetland Delineations and Cowardin Classification

After finalization tasks, the checkout was sent through the QA/QC process. This process was performed by the Project Lead or the QA/QC Specialist.

1. Opening the interpreter’s map document, the Project Lead or QA/QC Specialist verified that all of the interpreter’s finalization tasks had been successfully completed. If not, the checkout was returned to the interpreter to complete the tasks. The map document was saved to a different folder as a separate QA/QC map document.
2. Using the QA/QC map document, the entire checkout was reviewed at a 1:6,000 scale using the “mow the lawn” technique to guarantee the entirety of the checkout was reviewed. QA/QC had the same data available to them that the interpreter had when performing the delineations and classifications. QA/QC was verifying that the data met the standards described above (Data Standards), checking the following:
    a. Accurate delineations – the wetlands boundaries are correct based on signatures and supporting collateral data. No wetlands were omitted. No uplands were included.
    b. Correct Cowardin Classifications – attribute values match photo signatures based on imagery and supporting collateral data. All attributes are valid. There are no nulls, and split classes are applied appropriately.
    c. Line work - smooth with no jagged edges. Feature sizes are in line with the minimum mapping unit guidelines, and there are no multi-part features. There are no incorrect (sliver) gaps between polygons and no polygons that overlap adjacent polygons.
    d. General accuracy and consistency – interpreter has consistently and correctly delineated and classified similar signatures across the checkout; decisions conform to the Northwest MN mapping standards.
3. When issues were identified, QA/QC used the QA_COMMENTS field in the CONUS_wet_poly (edited wetland feature class) attribute table and box graphics in the map document to provide feedback. Not all errors were necessarily identified, but enough were highlighted to illustrate any patterns of errors present in the data. If necessary, QA/QC reviewed the issues with the interpreter and returned the checkout and routing sheet so the interpreter could perform revisions. The interpreter performed the requested revisions, repeated the finalization tasks and gave the checkout and routing sheet back to the Project Lead or QA/QC Specialist to start the QA/QC process again. Generally, it was not the

QA/QC's responsibility to perform revisions to the data; however, if there were just a few isolated errors that were not part of a systematic pattern, QA/QC may have performed the revisions rather than returning it to the interpreter.

4. The checkout was finalized and the finalization tasks and checks were run against the data again by QA/QC. During the topology checks, the data were additionally checked for "must not have gaps" along with "must not overlap". This was accomplished by adding a "universal polygon" around the checkout (Figure 7), adding the "must not have gaps" rule to the topology, and verifying topology. The universal polygon was temporary and was created by drawing a box around the entire work area using the auto-complete editor tool. Addition of the universal polygon allowed the "must not have gaps" topology rule to be applied without creating a large number of false positive errors at wetland/upland boundaries. There may still be false positive "must not have gaps" errors where there are uplands surrounded by wetland. This approach reduced the number of false positives while still locating the true gap errors, many of which were tiny sliver gaps that were difficult to locate in a visual inspection. The topology error inspector was used to locate and resolve the flagged topology errors. False positives were set as exceptions and edits were performed to fix the true errors. Topology was verified again and errors fixed until the data were free of topological errors. The universal polygon was then deleted.
5. A backup copy was created and stored in a different location from the working data. The data were then considered complete in regards to delineation and FGDC classification.

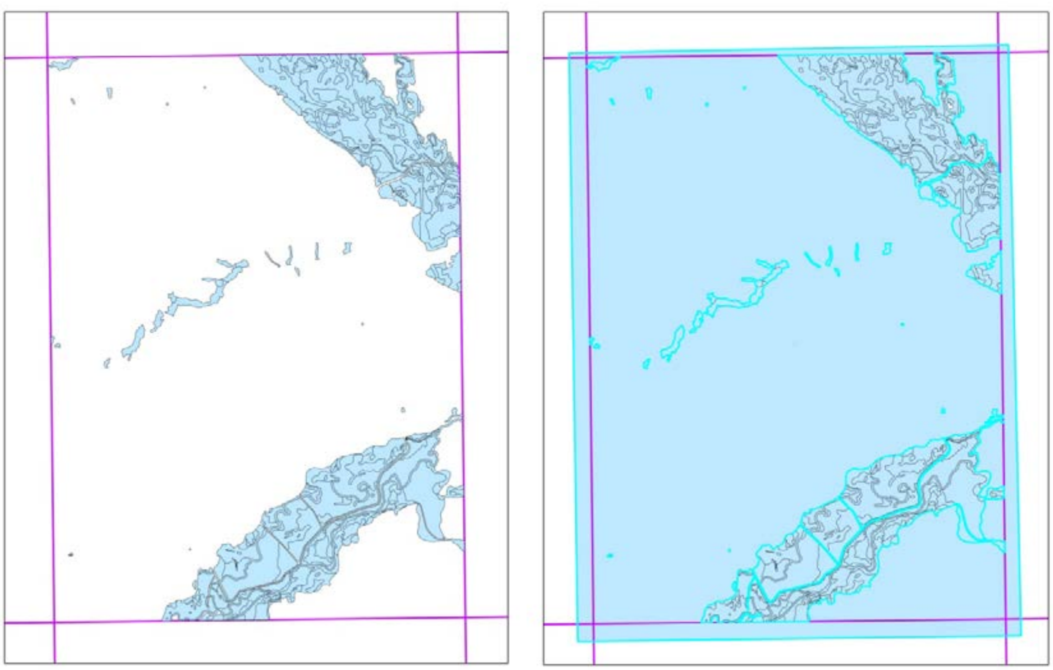


Figure 7. Universal polygon (highlighted in light blue on right) before and after topology.

The Cowardin Classification system served as the foundation for the other classification systems; no additional wetland polygons were created for SHGC or SPCC. It was expected that, with the exception of edgematching, there would be no further geometry edits required of the data.

Edgematching

7.5 Minute Quadrangle Checkouts to County

Since the next production phases of SHDP and SPCC classifications were completed at a landscape level, the 7.5-minute quadrangle checkouts were appended and edgematched into county-wide datasets. Esri Simple Data Loader was utilized to perform the append process. After each checkout was appended, edgematching was performed by panning along the checkout boundaries at a scale of 1:6,000 and using the ArcMap editing tools to merge those wetland polygons that are split by the boundary, creating seamless data. The edits required to both classification and geometry were expected to be minimal, given that both checkouts were edited and QA/QCed to the same standard. Edgematching occured incrementally as checkouts were approved by QA/QC. Checkouts crossing county boundaries were not cut at those boundaries, but included with the county that covered the majority of the checkout.

On-Screen Photointerpretation Process

Simplified Hydro-Geomorphic (SHGM) Classification

Simplified Hydro-Geomorphic Classification is a landscape level classification that is performed at smaller scales (1:10,000 and smaller) than the Cowardin classification; therefore, applying the classification to the seamless county-sized data is reasonable. SHGM attributes were added in a separate field (*SHGM_ATTRIBUTE*) inside the CONUS_wet_poly (edited wetland feature class) attribute table to the county-wide dataset. Using similar panning techniques, the interpreter worked through the county at a scale of 1:10,000. Given the landscape nature of SHGM and its more system-wide focus, the interpreter had latitude to zoom as far in or out as required to make decisions. In most cases the classification scale was between 1:5,000 and 1:20,000. Large complexes of wetland polygons were often classified very similarly, if not identically. Therefore, it is often possible to assign SHGM attributes quickly.

Simplified Plant Community Classification (SPCC)

The Simplified Plant Community Classification is based entirely on the cross-reference relationships between the Cowardin and the SPCC outlined in Table 9. It is a relatively straight forward exercise in using SQL database queries in the ArcMap "Select by Attribute" GUI to first select features based on their Cowardin Classification and then using the ArcMap field calculator to populate the *SPCC_ATTRIBUTE* field in the wetlands geodatabase. Each SPCC class required a separate query, or in some cases a series of queries was more efficient. Figure 8 shows an example of one of the simpler queries, which is for the Hardwood Wetland SPCC class. The data for each county was examined in order to gain an understanding of which Cowardin Classification codes were present to make sure all codes were addressed by the queries.

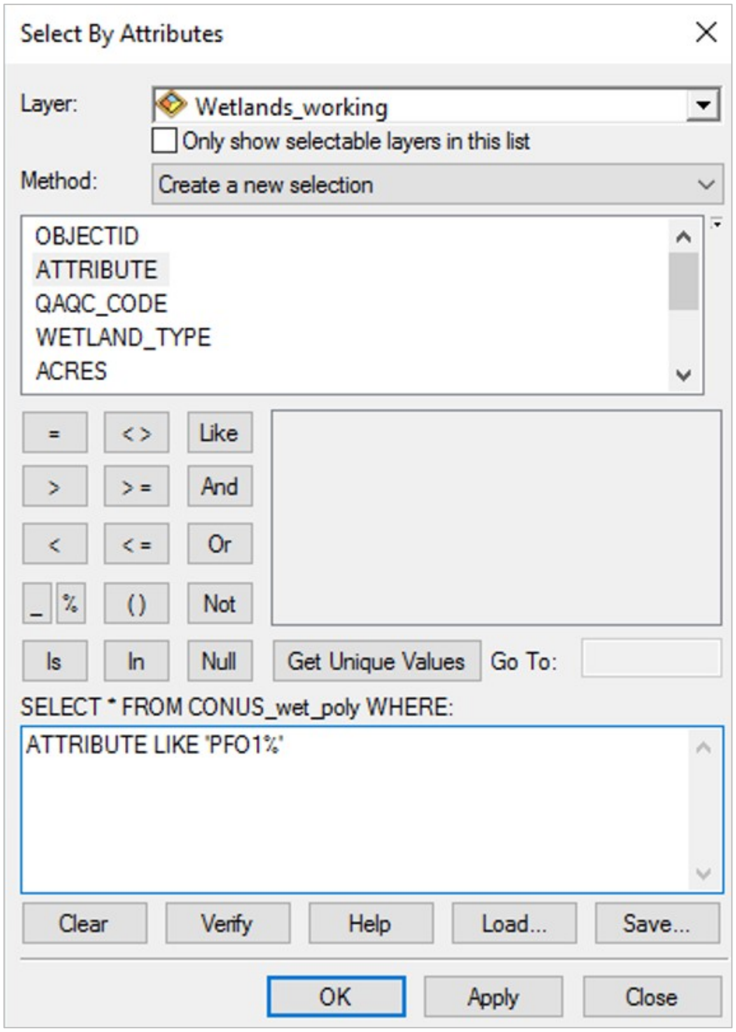


Figure 8. SPCC query for Hardwood Wetland Class.

Draft Data Approval

The QA/QC assessment, as previously described, was repeated on the county-wide data after all classifications (NWI, Wetland Type, and SPCC) were performed. Upon QA/QC approval, the draft county-wide data were then submitted to the MN DNR through a WMS for review. After review, MN DNR either approved the data or provided feedback from which GSS made necessary revisions and resubmitted. It should be noted that changes to the Cowardin Classifications could impact the SHGP and, more likely, the SPCC classification. QA/QC was performed before any resubmissions.

Final Processing

Upon approval by MN DNR, the county-wide data was appended to the project area-wide dataset and edgematched. The end result was a seamless dataset with coverage of the entire Northwest Minnesota project area (refer to Figure 1). The NWI Verification Tool developed by the USFWS NWI Program was then run against the seamless dataset. These tools were not expected to find many errors due to the previous QA/QC checks performed. If any errors were found, the data was revised and the tools run again until all errors were identified and addressed or documented. Upon successful completion of the NWI QA/QC tools, two copies of the data were made for delivery, one to MN DNR (in NAD83 UTM Zone 15N projection) and another to the USFWS (in NAD83 Albers Equal Area Conic projection) to be put into the nationwide NWI database.

Updating the National Wetlands Inventory for Minnesota: Northwest Project Area

Appendix A: Photointerpretation and Classification Guide

September 30, 2018

Saint Mary's University OF MINNESOTA

GEOSPATIAL SERVICES

Introduction

The purpose of the Photointerpretation and Classification Guide is to provide guidance on the application of imagery and collateral data in the photointerpretation process for mapping wetlands within the Northwest Minnesota National Wetlands Inventory Update. Examples of important signatures and guidance on applying available data are provided. This should not be considered an exhaustive list of signatures, but instead provide examples to provide a better basis for consistent delineation and classification of wetlands across the study area.

Seven ecological subsections can be found inside the project area: Agassiz Lowlands, Aspen Parklands, Chippewa Plains, Hardwood Hills, Minnesota River Prairie, Pine Moraines & Outwash Plains, and the Red River Prairie (Figure 9). Tree species common in the northeast portion of the project area include tamarack (*Larix laricina*) and black spruce (*Picea mariana*), which can be found in the large forested bogs.

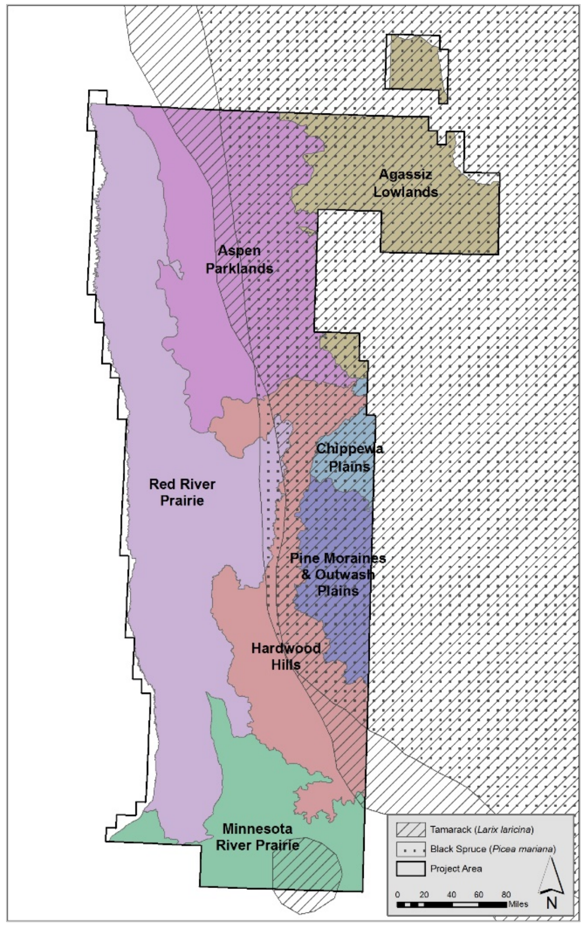


Figure 9. Ecoregion subsections found inside the Northwest MN project area, with range boundaries for tamarack and black spruce species.

Peatlands are dominant inside the Agassiz Lowlands and extend west into the Aspen Parklands. Inside the Aspen Parklands subsection, in areas where agriculture is not present, tall grass prairies exist. Moving further west into the Red River Prairie subsection, relatively flat land supports a dominant land use of agriculture. In more natural areas of the subsection, tall grass prairie is the dominant vegetation type. The Hardwood Hills subsection is defined by steep slopes, high hills, and lakes with oak savannas, tall grass prairies, and oak forests being the dominant vegetation types. The Chippewa Plains subsection is characterized as gently rolling lake plains and till plains, while the Pine Moraines and Outwash Plains subsection is a mix of end moraines, outwash plains, till plains, and drumlin fields. At the southernmost portion of the project area, the Minnesota River Prairie subsection consists largely of rolling ground moraine with tallgrass prairies.

The following pages contain imagery and relevant ancillary data examples of common wetland signatures present in the Northwest MN project area, as well as descriptions of some specific relevant situations, such as large forested bogs and areas of farmland.

Lacustrine System

The lacustrine system refers to lake environments. The following items apply to mapping lacustrine systems:

1. The lacustrine system is divided into two subsystems, limnetic (L1), which refers to deep water habitats and littoral (L2), which refers to shallower habitats.
2. In Northwest Minnesota, valid classes for the littoral (L2) subsystem are unconsolidated bottom (UB), unconsolidated shore (US), rocky shore (RS), rock bottom (RB), aquatic bed (AB) and non-persistent emergent (EM2). Of these, only the UB class is valid in the limnetic system (L1).
3. To be classified as lacustrine, the features must be larger than 20 acres (80,000 square meters) in size. This includes the combined area of the UB, US, RS, RB, AB, and EM2 classes.
4. Wetlands with the characteristics described in 2 and 3, but less than 20 acres in size are considered lacustrine if at least a portion of the boundary is active wave-formed shoreline or bedrock.

L1/L2 Boundaries

Not all characteristics required for classification are easily distinguished from remotely sensed imagery, such as deciding where to divide the lacustrine system between its littoral (L2) and limnetic (L1) subsystems. For this determination, a variety of collateral data and the following protocol were used. The goal is to use the best data that are available to determine the location of the L1/L2 boundary or to determine if the entire basin is L2. If a reliable determination is impossible, the last step of the protocol is to assume the entire basin is L2.

1. Check the MN DNR Hydrography feature class for maximum depth value. This data is the DNR Lakes Data joined to MN DNR fisheries survey maximum depth data. If the value is present and less than eight feet, classify the entire water body as L2.
    a. If the maximum depth is absent, null, or greater than or equal to eight feet proceed to step 2 below. A cutoff of eight feet was chosen since it is impossible to determine from the location and shape of area with depths ranging from six and one-half to eight feet. Also, in many cases the maximum depth may only occur at one location.
2. If the maximum depth in the MN DNR Hydrography layer is null or greater than or equal to eight feet, the Minnesota DNR Lake Bathymetry DEM data will be utilized where available to find the two-meter depth contour, or possibly provide information to indicate if the entire lakebed is less than two meters in depth. Lake Bathymetry data are grouped in folders by county, and it may require some trial and error to find the data for the particular lake in question. After the data is located and added to the ArcMap document, it needs to be classified and symbolized to show the two-meter (6.5 foot) contour line. This is done by classifying the data into two classes and specifying a class break of -6.5 feet, with the deeper class (≤ -6.5 feet) symbolized with a dark color (represents L1) and the shallower class (> -6.5 feet) with a light color (represents L2) (Figure 13). This data is available for 288 lakes

within the study area. All L1/L2 areas greater than two meters deep and larger than 0.1 acres (400 square meters) in size will be mapped.

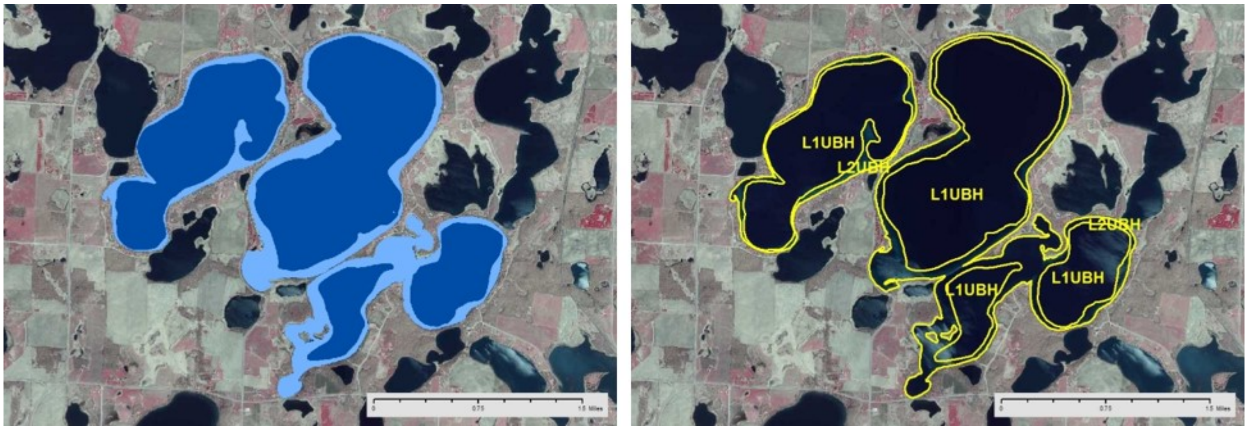


Figure 10. Symbolized Lake DEM data with a 6.5-foot class break (left) can help determine L1UBH/L2UBH boundaries for a lacustrine environment (right).

3. In the absence of bathymetry DEMs, the DRG will be the next choice for determining the L1/L2 boundary. If the feature is not present as a water body on the DRG, it will be classified as L2 if the signature indicates open water (UB) in all of the imagery and it meets the 20-acre size criteria for lacustrine. If it is not present as a water body on the DRG or does not exhibit open water on **<u>all</u>** imagery (2013/14 CIR, 2015 NAIP, 2013 NAIP, 2010 NAIP), it will be classified as palustrine.
4. If the feature is present as a water body on the DRG and if bathymetric contours are present, the 5- foot contour will serve as a guide to visually interpolate the 2 meter (6.5 foot) contour based on the approximate shape of the lake basin as shown in Figure 14.

Figure 11. Lake contours on the DRG can help in determining the L1/L2 boundaries.

5. In the absence of contours, spot soundings on the DRG will serve as the guide for visual interpolation as shown in Figure 15.

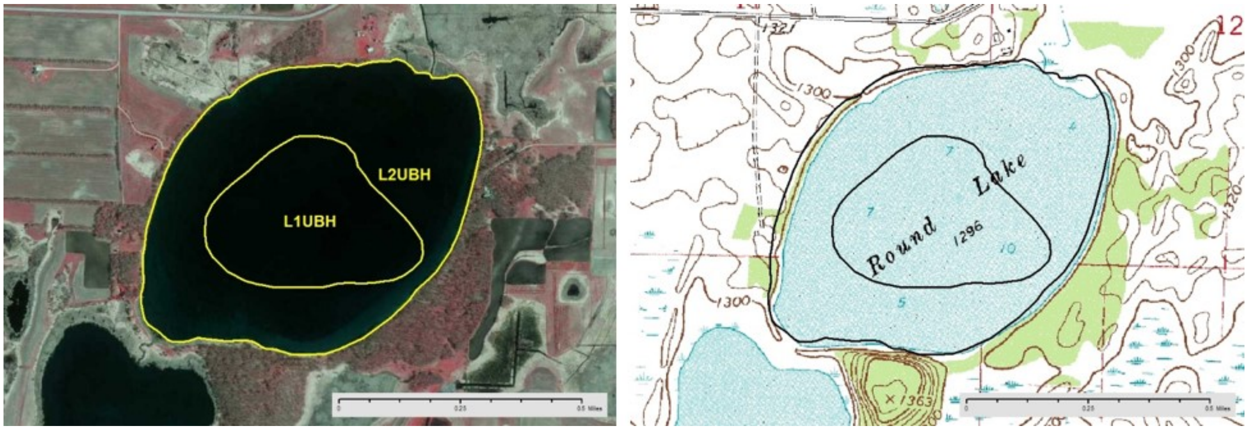


Figure 12. Utilizing DRG spot soundings for determining L1/L2 boundaries.

6. In the absence of both bathymetric contours and spot soundings on the DRG, a company called Navionics developed a web application that visually displays lake depth contours (Navionics 2018). This web application can be used as a side-by-side comparison for determining the L1/L2 boundaries of a lake, similar to a DRG (Figure 16).

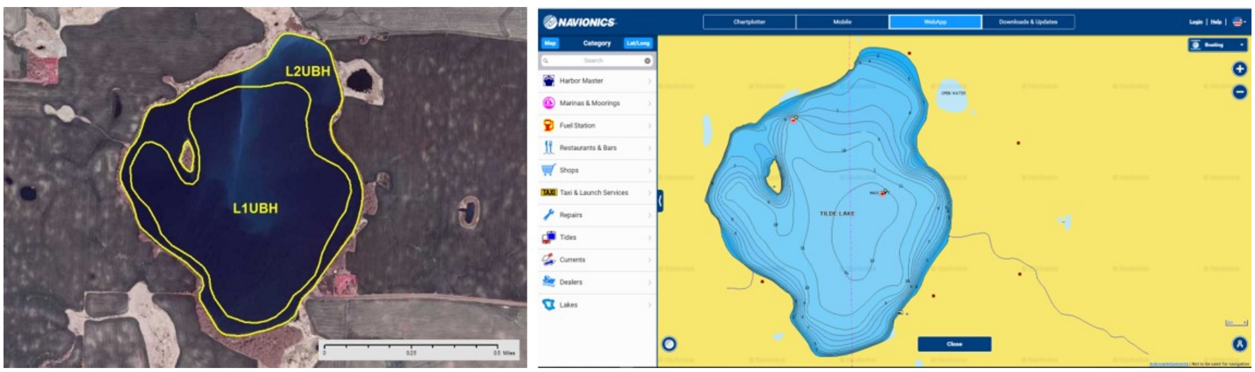


Figure 13. Lake depth contours from Navionics can be used to determine L1/L2 boundaries (Navionics 2018).

7. If previous steps do not result in a valid determination, visual cues on the imagery and other cues on the DRG will be used to attempt a determination. This includes, but is not limited to, visual evidence of submerged vegetation, shallow water signatures, infrastructure, etc. Lack of recreational infrastructure and presence of an undeveloped natural shoreline indicate L2.
8. If all the above steps do not lead to a determination, the L1/L2 boundary in the historical NWI will be assumed to be correct.
9. If all the above steps do not lead to a determination and there is no historic NWI, the entire water body will be classified as L2.

L1UBH

System: Lacustrine

Subsystem: Limnetic

Class: Unconsolidated Bottom

Water Regime: Permanently Flooded

L1UBH features are deep zones in natural lakes that are more than two meters (6.5 feet) deep (Figure 10**)**. In Northwest Minnesota, they occur in natural depressions as well as dammed river channels. Typical photosignatures are flat with dark blue to almost black tones on the Spring CIR and/or NAIP imagery. Additionally, they will also present with dark green to brown tones on the true color NAIP. Sometimes glare will cause a bright white signature, and wind-blown areas will present with some roughness. Flat brown signatures will also occur if imagery was acquired at a time of high turbidity such as after a precipitation or melting event.

Collateral data include imagery, LiDAR DEM, and DRGs. Where available, the MN DNR lake DEMs are used within the protocol defined above (L1/L2 Boundaries) to find those areas that are greater than 2 meters (6.5 feet) in depth. The presence of a hydrologically enforced water body on the LiDAR DEM is also an indication of L1UB.

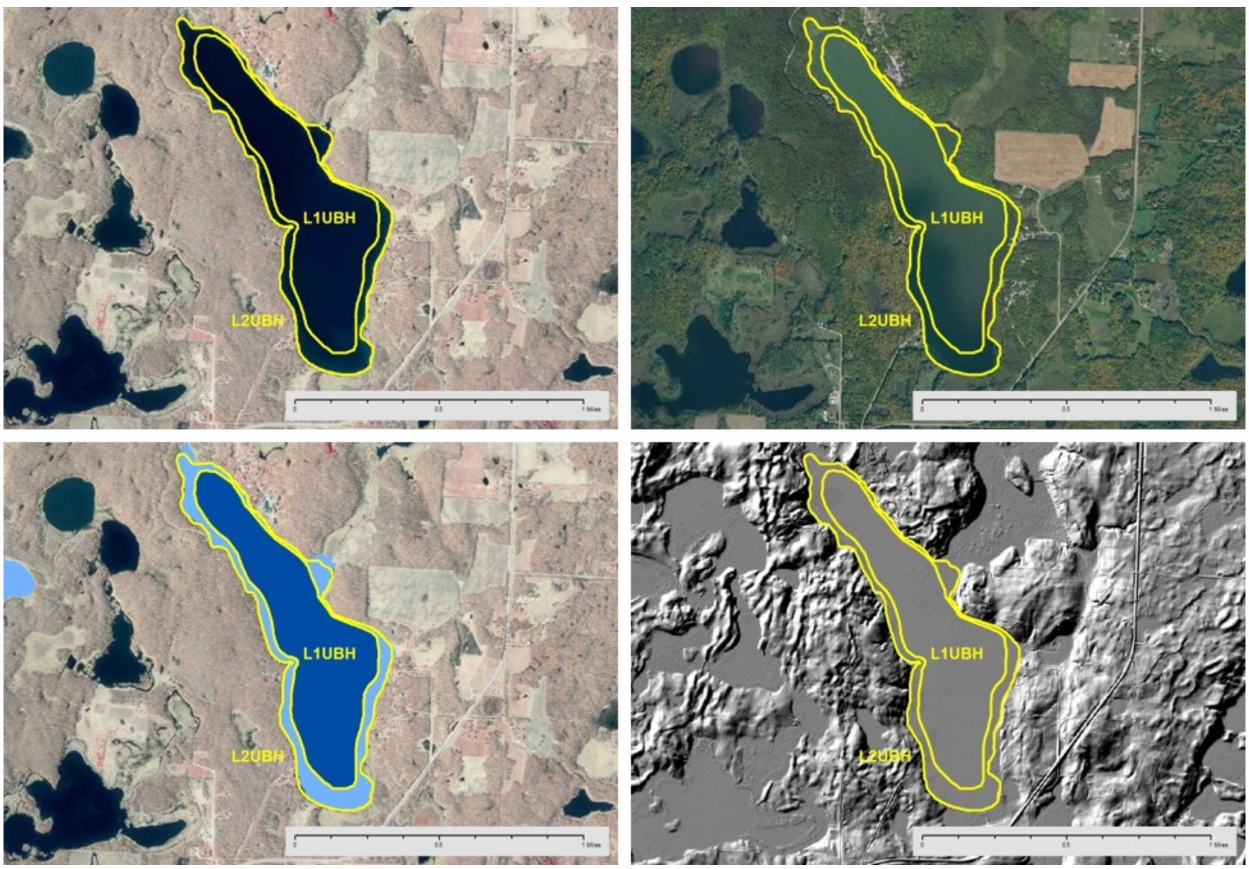


Figure 14. L1UBH/L2UBH signature example; 2013/14 Spring CIR (upper left), 2015 NAIP (upper right), MN DNR Lake DEM (lower left), 3-meter LiDAR hillshade (lower right).

L2ABH

System: Lacustrine

Subsystem: Littoral

Class: Aquatic Bed

Water Regime: Permanently Flooded

L2ABH features are those open water areas that are less than two meters (6.5 feet) in depth and are covered by at least 50% floating vegetation such as duckweed (*Lemna* spp.). They often occur along the edges and in sheltered areas of lacustrine basins (Figure 11). L2ABH signatures are not present on the Spring CIR because the signatures do not present themselves until later in the growing season. Typical signatures on the true-color NAIP are flat in texture and bright green in tone, although in some cases they present as flat dark brown. The location of the aquatic bed in the imagery can vary considerably from year to year, in which case the 2015 NAIP takes priority in defining boundaries.

Collateral data include imagery and DRG. Additionally, where available, the MN DNR lake DEMs are used within the protocol defined above (L1/L2 Boundaries) to find those areas that are less than 2 meters (6.5 feet) in depth.

Figure 15. L2ABH signature example; 2013/14 Spring CIR (left) and 2015 NAIP (right).

L2UBF
System: Lacustrine
Subsystem: Littoral
Class: Unconsolidated Bottom
Water Regime: Semi-Permanently Flooded

L2UBF features are those open water areas that are less than 2 meters (6.5 feet) in depth and semi-permanently flooded. They normally occur in basins that are entirely less than two-meters deep. Aquatic bed wetlands are often associated with them. In Northwest Minnesota, they typically occur in natural depressions. Typical photosignatures are flat in texture and blue/black in tone on the Spring CIR, but are often lighter than similar signatures for L1UBH. On the true color NAIP imagery, signatures are again flat, but tend to lighter brown or green in tone (Figure 12).

Collateral data includes imagery and DRGs. The main indication, if any, on the DRG is marsh symbols. Secondary indicator is a depression rather than a blue water body on the DRG. The presence of a hydrologically enforced water body on the LiDAR DEM is also an indicator, but may not occur as often as for an L1UBH. Additionally, where available, the MN DNR lake DEMs are used within the protocol defined above (L1/L2 Boundaries) to find those areas that are less than 2 meters (6.5 feet) in depth.

L2ABF

System: Lacustrine

Subsystem: Littoral

Class: Aquatic Bed

Water Regime: Semi-Permanently Flooded

L2ABF features are those open water areas that are less than 2 meters (6.5 feet) in depth and are covered by at least 50% floating vegetation such as duckweed. They often occur along the edges and in sheltered areas of lacustrine basins, but are also likely to occur in irregular patterns as compared to L2ABH (Figure 12). L2ABF signatures are typically not present on the Spring CIR because the signatures do not present themselves until later in the growing season. Typical signatures on the true-color NAIP are flat in texture and bright green in tone, although in some cases they present as mottled tan or brown. The location of the aquatic bed on the imagery may vary considerably from year to year, in which case the 2015 NAIP takes priority in defining boundaries.

Collateral data include imagery and DRG. A water body is likely not present on the DRG, but there may be marsh symbols or a depression. Where available, the MN DNR lake DEMs are used within the protocol defined above (L1/L2 Boundaries) to find those areas that are less than two meters (6.5 feet) in depth.

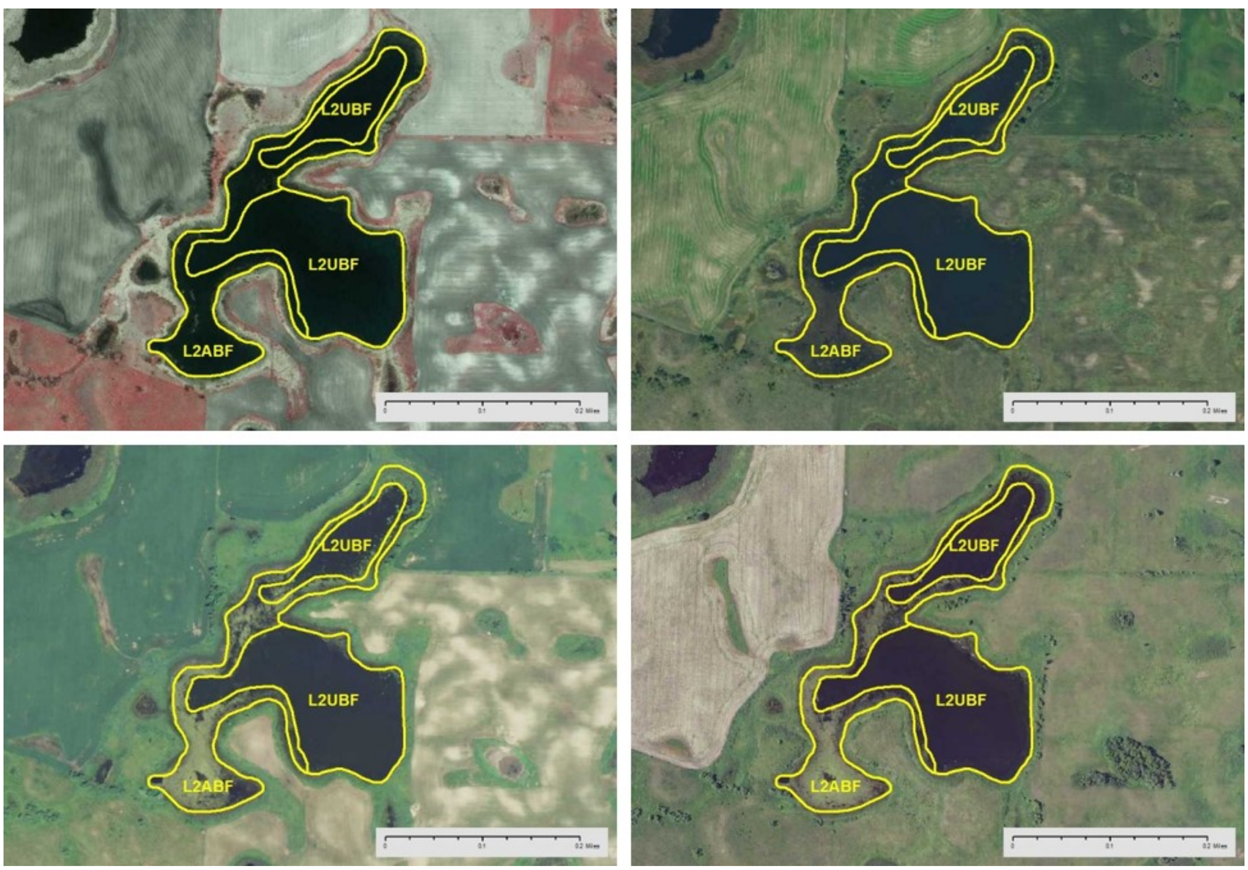


Figure 16. L2UBF/L2ABF signature example; 2013/14 CIR (upper left), 2015 NAIP (upper right), 2013 NAIP (lower left), 2010 NAIP (lower right).

Riverine System

The riverine system refers to stream and river environments that have flowing water. The following factors should be considered for riverine environments in the project area:

1. The riverine system has three subsystems that are defined by the gradient of the stream or the frequency of the presence of surface water. These subsystems include:
    a. Lower Perennial (R2) **–** Low gradient (gentle elevation change) defined by slow-moving water with sand or mud substrates. This subsystem tends to be associated with developed floodplains through which the main flow meanders if left in its natural state. Valid classes are UB, US, AB, EM2, RS, and RB.
    b. Upper Perennial (R3) **–** High gradient (steep elevation change) defined by fast-moving water and substrates such as gravel, cobble, or bedrock that do not erode in a higher energy environment. This system typically contains little to no floodplain with little meandering. The non-vegetated classes UB, US, RS, and RB are valid for this subsystem.
    c. Intermittent (R4) **–** This subsystem applies to channels that do not carry water all of the time. In times of no flow, surface water, if present, is likely to be in isolated pools. The only valid class is streambed (SB).
2. Streams greater than or equal to 4.6 meters (15 feet) in width are mapped. Wherever possible, stream networks are mapped to avoid a series of disconnected polygons that are actually part of the same stream. However, there are cases with the smallest streams where tree cover makes it impossible to consistently and accurately map these features. In those cases, what is visible is mapped, even if it results in a disjointed river network.
3. Riverine systems are not split where they pass under bridges if collateral data indicates connectivity.
4. Features are classified based on the substrate or vegetation in the channel, not what is present on the edges of the channel.

R2UBH

System: Riverine
    Subsystem: Lower Perennial
        Class: Unconsolidated Bottom
            Water Regime: Permanently Flooded

R2UBH features are low gradient rivers. They are normally associated with well-developed floodplains and exhibit meanders and evidence of meander scars in surrounding floodplain areas. Surrounding floodplain areas may be in their natural state, but are often drained for agriculture. Typical photosignatures are flat with dark blue to almost black tones on the Spring CIR or NAIP imagery (Figure 17). They will also present with dark green to brown tones on the true color NAIP, depending on the turbidity level of the water. In rare instances, a bright white signature due to glare will be present. R2UBH features vary greatly in size; therefore, sinuosity and supporting collateral data are the best indicators of the R2 system.

Collateral data include imagery, LiDAR DEM, and DRGs. Both the DRG and the LiDAR products indicate gradient. R2UBH attributes are often represented as polygon features on the DRG, however the smallest R2UBH features may be represented as a solid blue line.

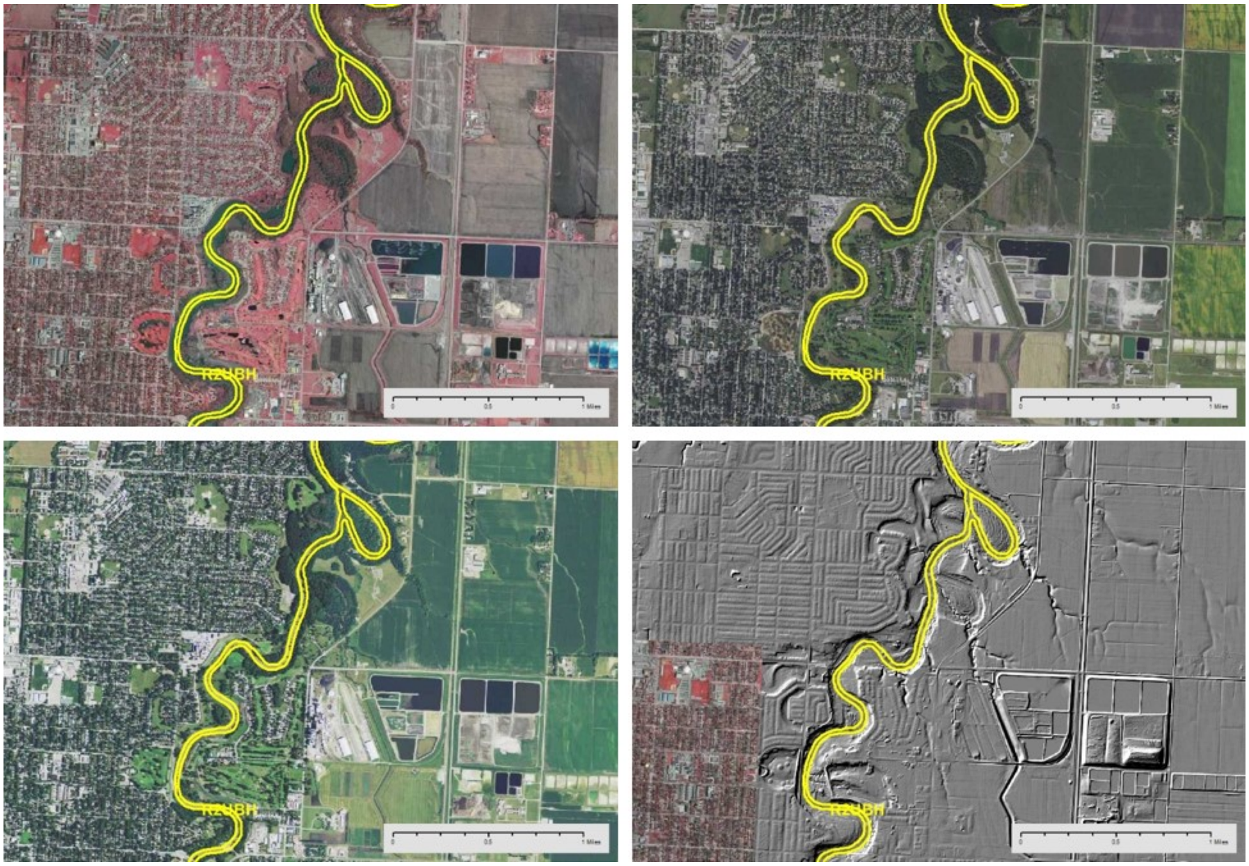


Figure 17. R2UBH signature example; 2013/14 CIR (upper left), 2015 NAIP (upper right), 2013 NAIP (lower left), and 3-meter LiDAR hillshade (lower right).

R2UBHx

System: Riverine

Subsystem: Lower Perennial

Class: Unconsolidated Bottom

Water Regime: Permanently Flooded

Special Modifier: Excavated

R2UBHx features are low gradient rivers whose natural course has been altered through excavation. They are normally associated with well-developed floodplains but do not exhibit meanders, because they have been channelized into straight sections. It should be noted that, over time, channelized R2 rivers will revert back to their natural state and the channel will begin to meander. There is often evidence of past meanders in the surrounding areas. Surrounding floodplain areas are often drained for agriculture. Typical photosignatures are identical to a natural R2UBH, flat with dark blue to almost black tones on the Spring CIR or NAIP imagery (Figure 18). They will also present with dark green to brown tones on the true color NAIP, depending on the turbidity of the water. In rare instances, a bright white glare signature will be present. R2UBHx features vary greatly in size, but natural R2UBH sections are often connected by channelized R2UBHx sections within the same river system.

Collateral data include imagery, LiDAR DEM, and DRGs. Both the DRG and the LiDAR products indicate gradient. R2UBHx rivers are often represented as polygon features on the DRG, but the smallest R2UBHx features may be represented as a solid blue line.

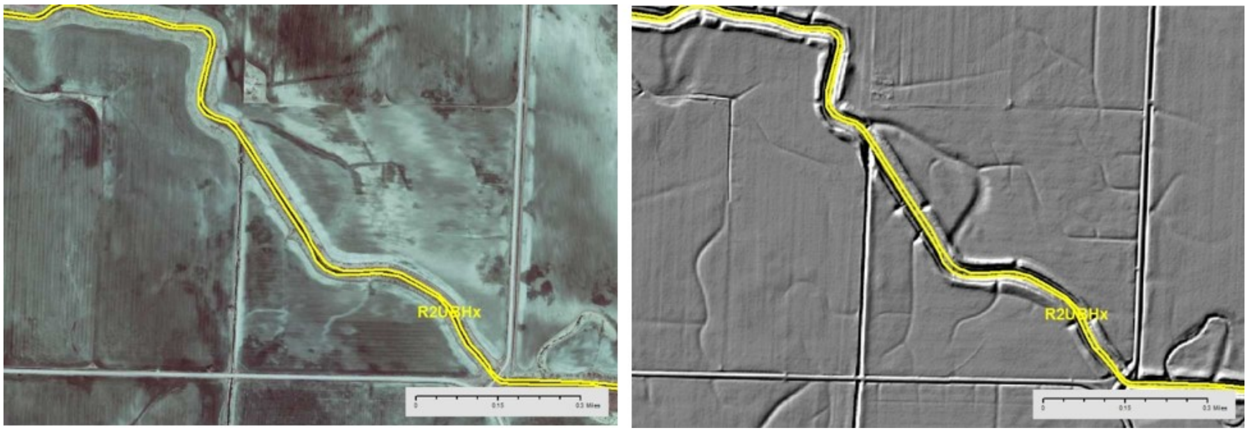


Figure 18. R2UBHx signature example; 2013/14 CIR (left) and 3-meter LiDAR hillshade (right).

Palustrine System

The palustrine system refers to wetlands that are dominated by persistent emergent, scrub-shrub, or forested vegetation, or lacking vegetation and are less than 20 acres (80,000 square meters) in basins with a maximum depth of less than 2 meters. The following factors should be considered for palustrine environments in the project area:

1. No subsystem is applied to the palustrine system.
2. Valid classes include: unconsolidated bottom (UB), unconsolidated shore (US), aquatic bed (AB), emergent (EM), scrub-shrub (SS), forest (FO), rock bottom (RB), and moss-lichen (ML).
3. Subclasses will be applied to the EM, SS, and FO classes with valid attributes listed in Table 2.
4. Valid water regimes for each class are also listed in Table 2.
5. Special modifiers will be applied based on the valid lists in Table 2.
6. The PEM1Af attribute will only be applied to farmed wetlands meeting a specific set of circumstances as described below (Farmed Wetlands). Features where hydrophytic vegetation is dominant will not be classified as farmed.
7. Palustrine wetlands can exist as inclusions within lacustrine basins and riverine floodplains.
8. Wetlands larger than 20 acres can be classified as palustrine if vegetated and the maximum depth of the basin is less than 2 meters.

PUBH

System: Palustrine

Class: Unconsolidated Bottom

Water Regime: Permanently Flooded

PUBH features are open water, pond environments. Photosignatures are the normal open water signatures: flat, with dark blue to almost black tones on the Spring CIR or NAIP imagery (Figure 20). They will also present dark green to brown tones on the true color NAIP, depending on the turbidity level of the water. In rare instances, a bright white signature due to glare will be present. To be classified as PUBH, it must be flooded in all but the most extreme drought. For Northwest Minnesota, this means flooded on all three years of NAIP imagery, and the 2013/14 Spring CIR.

Collateral data include imagery, LiDAR DEMs and DRGs. The DRG will often show a water body if the PUBH is a natural, well-established wetland. The LiDAR should show a flat, hydro-enforced, flooded basin.

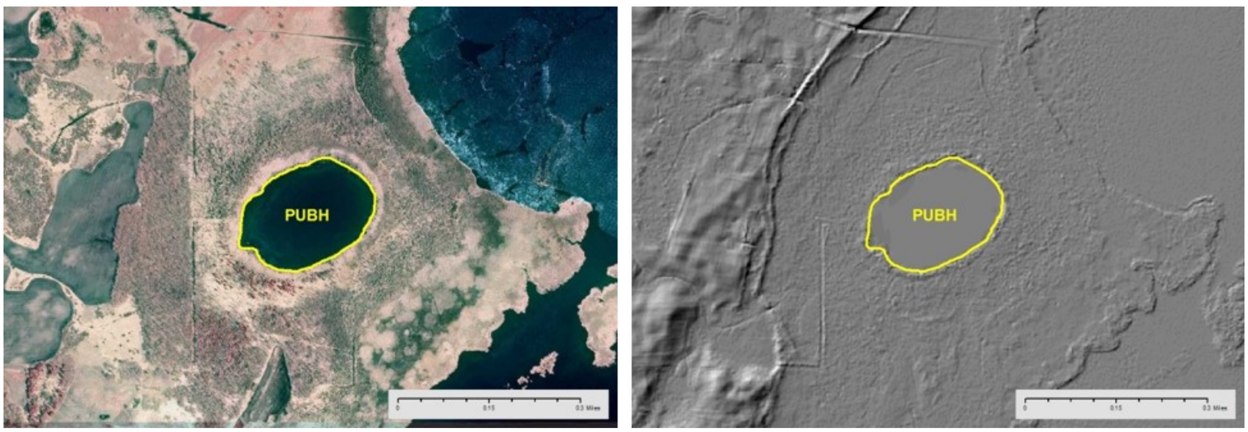


Figure 19. PUBH signature example; 2013/14 CIR (left) and 3-meter LiDAR hillshade (right).

PUBF

System: Palustrine

Class: Unconsolidated Bottom

Water Regime: Semi-Permanently Flooded

PUBF features are open water, pond environments. They often occur as open water portions of marsh basins associated with cattail marshes and aquatic bed wetlands. Photosignatures are the normal open water signatures, flat with dark blue to almost black tones on the Spring CIR or NAIP imagery (Figure 21). They will also present with dark green to brown tones on the true color NAIP, depending on the turbidity level of the water. In rare instances, a bright white signature due to glare will be present. To be classified as PUBF, it must exhibit the open water signature on a majority of the three years of NAIP imagery, and especially on the 2015 NAIP. They tend to be smaller in size than PUBH wetlands.

Collateral data include imagery, LiDAR DEMs, and DRGs. The DRG will often show marsh symbols for these features. The LiDAR should show a flat flooded basin.

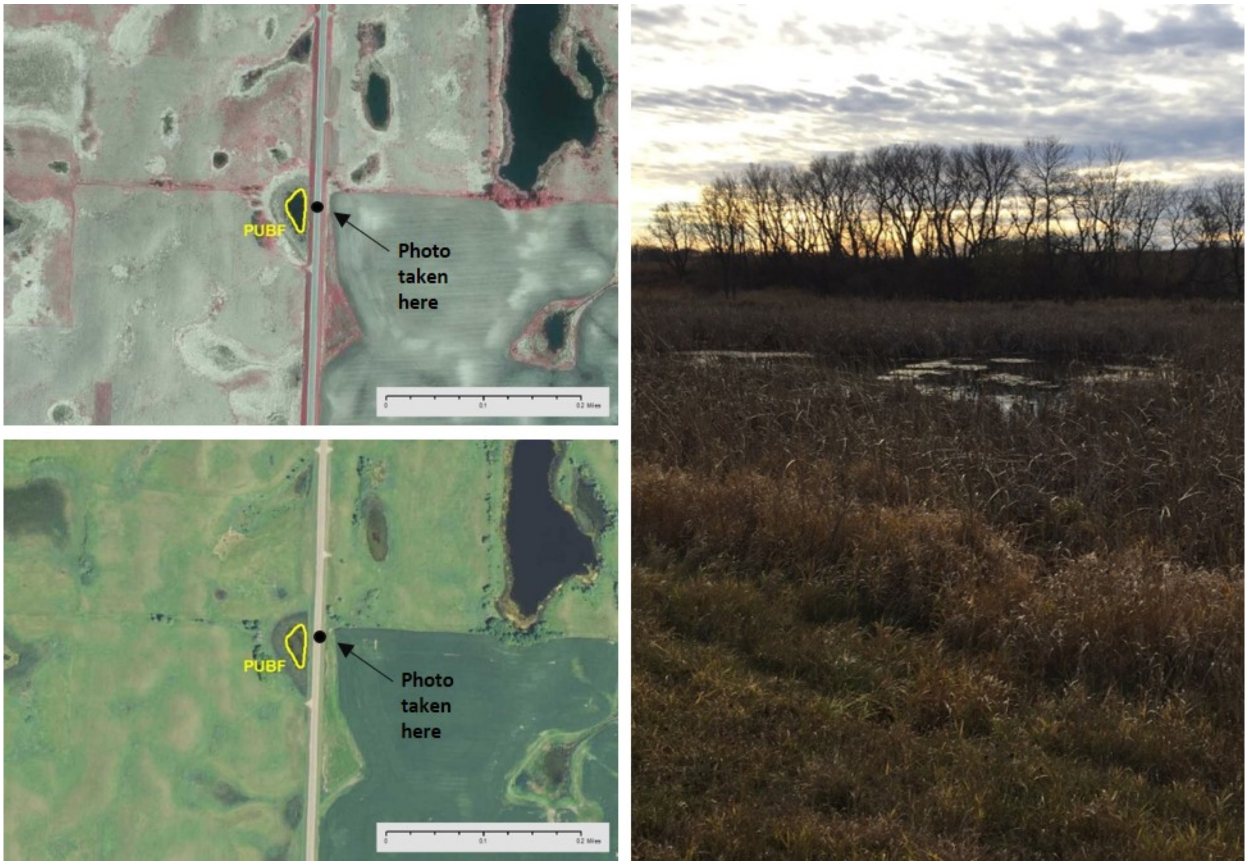


Figure 20. PUBF signature example; 2013/14 CIR (upper left), 2013 NAIP (lower left), ground-level oblique (right).

PUBFx

System: Palustrine

Class: Unconsolidated Bottom

Water Regime: Semi-Permanently Flooded

Special Modifier: Excavated

PUBFx features are open water, pond environments that have been gouged, blasted, dug, or suctioned through artificial means. They may be intentionally created wetlands as is the case on golf courses and ornamental ponds in residential developments, or they may be the incidental result of other activity such as mining. Photosignatures are the typical open water signatures, flat with dark blue to almost black tones on the Spring CIR or NAIP imagery (Figure 22). They will also present with dark green to brown tones on the true color NAIP, depending on the turbidity level of the water. Depending on substrate, these wetlands can also show as a lighter blue when the water is shallow enough that sunlight is reflected off a sandy substrate. In rare instances, a bright white signature due to glare will be present. These wetlands will often have regular polygonal shapes, such as rectangular or square. Semi-permanently flooded (PUBF) wetlands tend to be smaller and often shallower than their permanently flooded (PUBH) counterparts. To be classified with the semi-permanently flooded “F” water regime, it must be flooded in at least two out of three NAIP images. To be classified with the excavated “x” modifier, there should be evidence of digging, such as a pile of fill in the immediate vicinity of the wetland. Evidence of mining is another indicator, in which case the visible water is actually the exposed surface of the water table.

LiDAR is the primary collateral data for making the excavated determination. Evidence of excavation such as fill piles, or gravel pits are easily identified on the LiDAR hillshade, and if large enough, on the LiDAR contours. The DRG often will not show these features if they were recently created, however, gravel pits are often marked on the DRG.

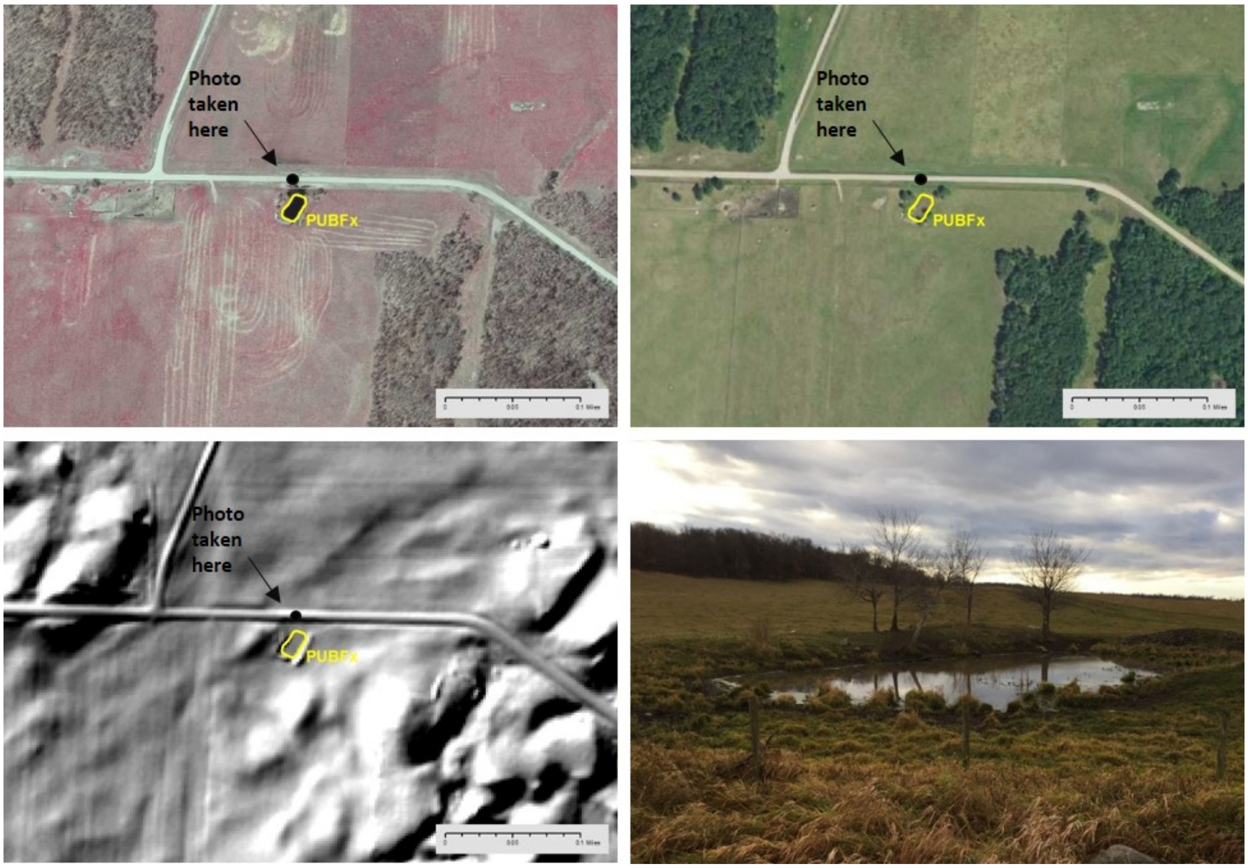


Figure 21. PUBFx signature example; 2013/14 CIR (upper left), 2015 NAIP (upper right), 3-meter LiDAR hillshade (lower left), ground-level oblique (lower right).

PUBKx

System: Palustrine

Class: Unconsolidated Bottom

Water Regime: Artificially Flooded

Special Modifier: Excavated

This classification is reserved for open water features associated with sewage treatment ponds, industrial cooling ponds, fish hatcheries or any other situation where the water level is altered using siphons or pumps. Photosignatures when flooded are the typical open water signatures, flat with dark blue to almost black tones on the Spring CIR or NAIP imagery, but often other signatures will be present if a pond has been pumped down (Figure 23). In a majority of cases, they will have regular geometric shapes and be surrounded by a dike system. The surrounding land use also provides clues to their existence. Sewage treatment ponds are often in or near urban areas, and fish hatcheries will tend to be near cold water streams. Large manure storage pits are near large farms. In cases where artificially flooded features are larger than 20 acres in size, they should be classified as L2UBKx.

LiDAR and the DRG are the primary collateral data for identifying these wetlands. Any associated dike system or regular polygonal shape is easily identified on the LiDAR hillshade. The DRG is useful because sewage treatment ponds and fish hatcheries are often identified. However, given the age of the DRGs, this is not always the case because newer facilities will not be present.

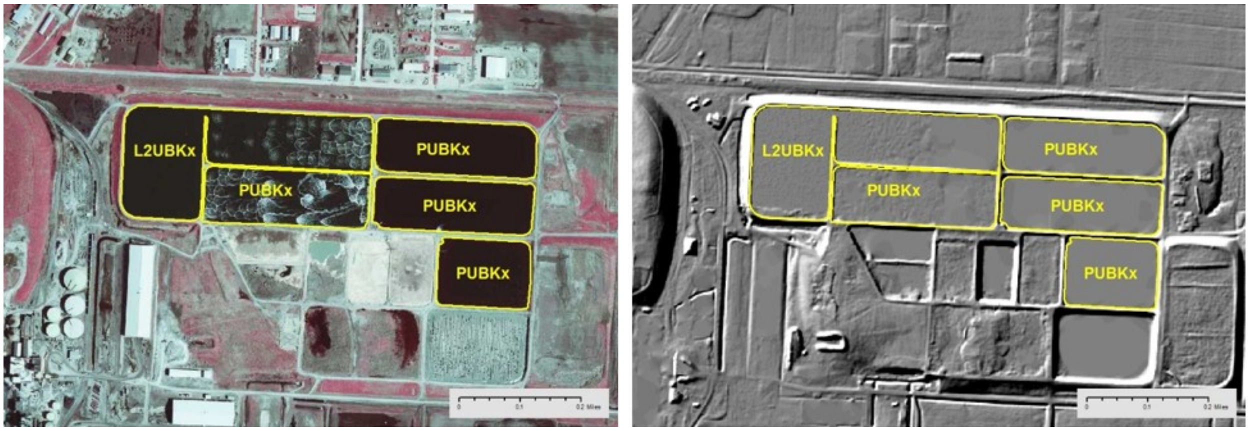


Figure 22. PUBKx signature example; 2013/14 CIR (left), 3-meter LiDAR hillshade (right).

PABH

System: Palustrine

Class: Aquatic Bed

Water Regime: Permanently Flooded

PABH features are permanently inundated open water areas that are less than two meters (6.5 feet) in depth, not part of a lacustrine basin, and covered by at least 50 percent floating vegetation such as duckweed. They can occur as stand-alone wetlands but are often part of larger palustrine wetlands complexes. Figure 24 is an example of a PABH wetland occurring in a relatively isolated morainal basin. PABH signatures are not present on the Spring CIR because the signatures do not present themselves until later in the growing season. Typical signatures are flat in texture and bright green in tone on the true-color NAIP, although in some cases they present as flat dark brown. The location of the aquatic bed on the imagery can vary considerably within a wetland complex from year to year, in which case the 2015 NAIP takes priority in defining boundaries.

Collateral data include LiDAR and DRG. LiDAR will often show the presence of surface water. The DRG will likely show open water or marsh symbols.

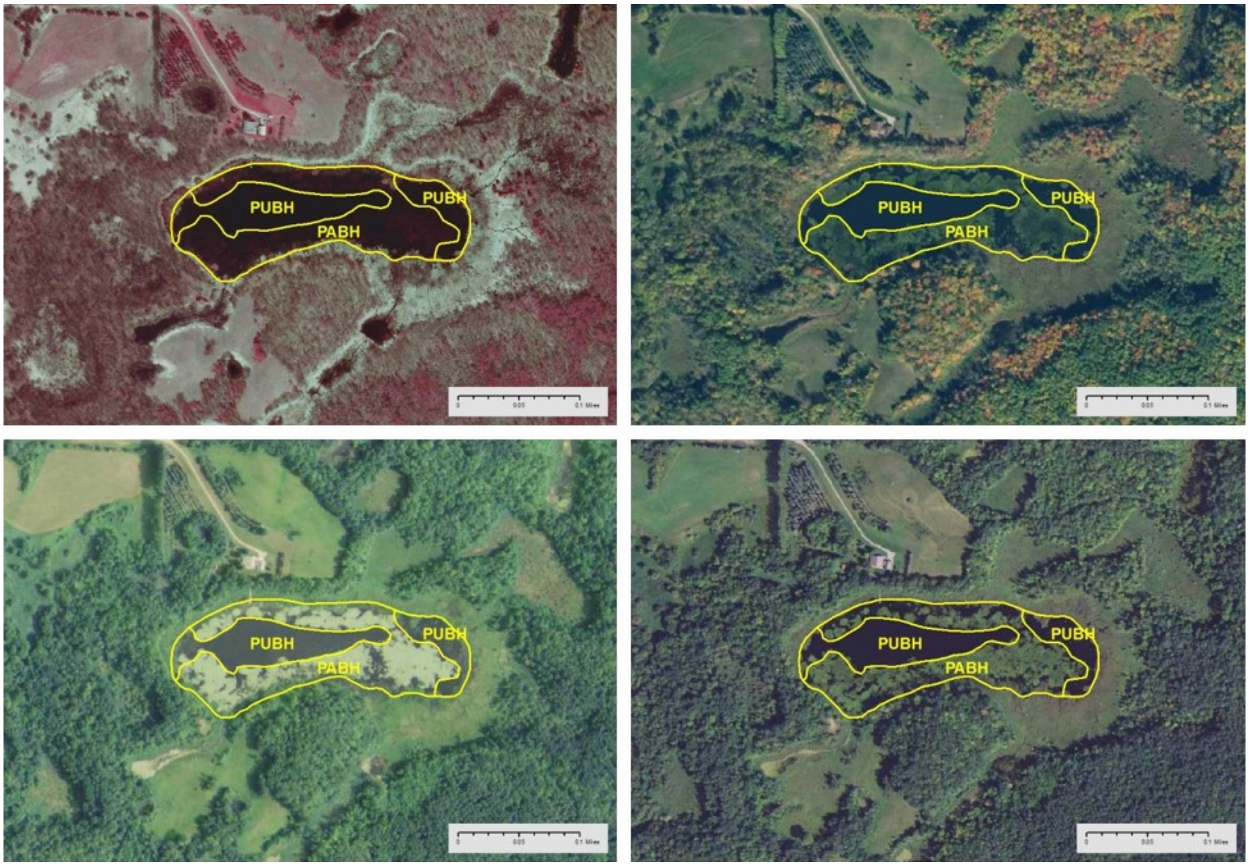


Figure 23. PABH signature example; 2013/14 CIR (upper left), 2015 NAIP (upper right), 2013 NAIP (lower left), 2010 NAIP (lower right).

PABF

System: Palustrine

Class: Aquatic Bed

Water Regime: Semi-Permanently Flooded

PABF features are open water areas that are less than 2 meters (6.5 feet) in depth, nearly always inundated, not part of a lacustrine basin, and covered by at least 50% floating vegetation. They can occur as stand-alone wetlands, but are often the aquatic bed portion of a semi-permanently flooded wetland complex and are therefore often associated with PEM1F and PEM1C wetlands (Figure 25). PABF signatures are not present on the Spring CIR because the signatures do not present themselves until later in the growing season. Typical signatures are flat in texture and bright green in tone on the true-color NAIP, although in some cases they present as flat dark brown. The location of the aquatic bed on the imagery can vary considerably within a wetland complex from year to year, in which case the 2015 NAIP takes priority in defining boundaries. Special modifiers should be added as indicated by the imagery and collateral data.

Collateral data include LiDAR and DRG. LiDAR will often show the presence of surface water. The DRG will most likely have marsh symbols or open water, but in rare cases there will be no indication on the DRG.

Figure 24. PABF signature example; 2013/14 CIR (upper left), 2015 NAIP (upper right), 2013 NAIP (lower left), ground-level oblique (lower right).

PEM1F

System: Palustrine

Class: Emergent

Subclass: Persistent

Water Regime: Semi-Permanently Flooded

PEM1F wetland features are dominated by persistent emergent vegetation and have standing water for the majority of the growing season in most years. Species common in PEM1F wetlands include cattail (*Typha* spp.), and bulrush (*Scirpu*s spp.). They are often located on the edges of lacustrine basins or within large river floodplains, but they can occur in isolated basins. On the imagery, the signature has a rough, spiky texture with small tendrils or patches of open water intermixed. Tone on the CIR can vary from light gray to darker browns and grays to almost black, depending on the thickness of the vegetation and the presence of standing water beneath it. Muskrat houses are also an indicator of PEM1F. Photosignatures on the NAIP tend to also exhibit a rough texture, but with green or brown tones (Figure 26). Aquatic bed signatures will often be present intermixed with the emergent vegetation on the NAIP.

Collateral data primarily include the DRG, SSURGO soils and LiDAR DEM. Marsh symbols are often present on the DRG. Soils will be hydric and the LiDAR DEM will indicate a basin, without a hydrologically enforced water surface.

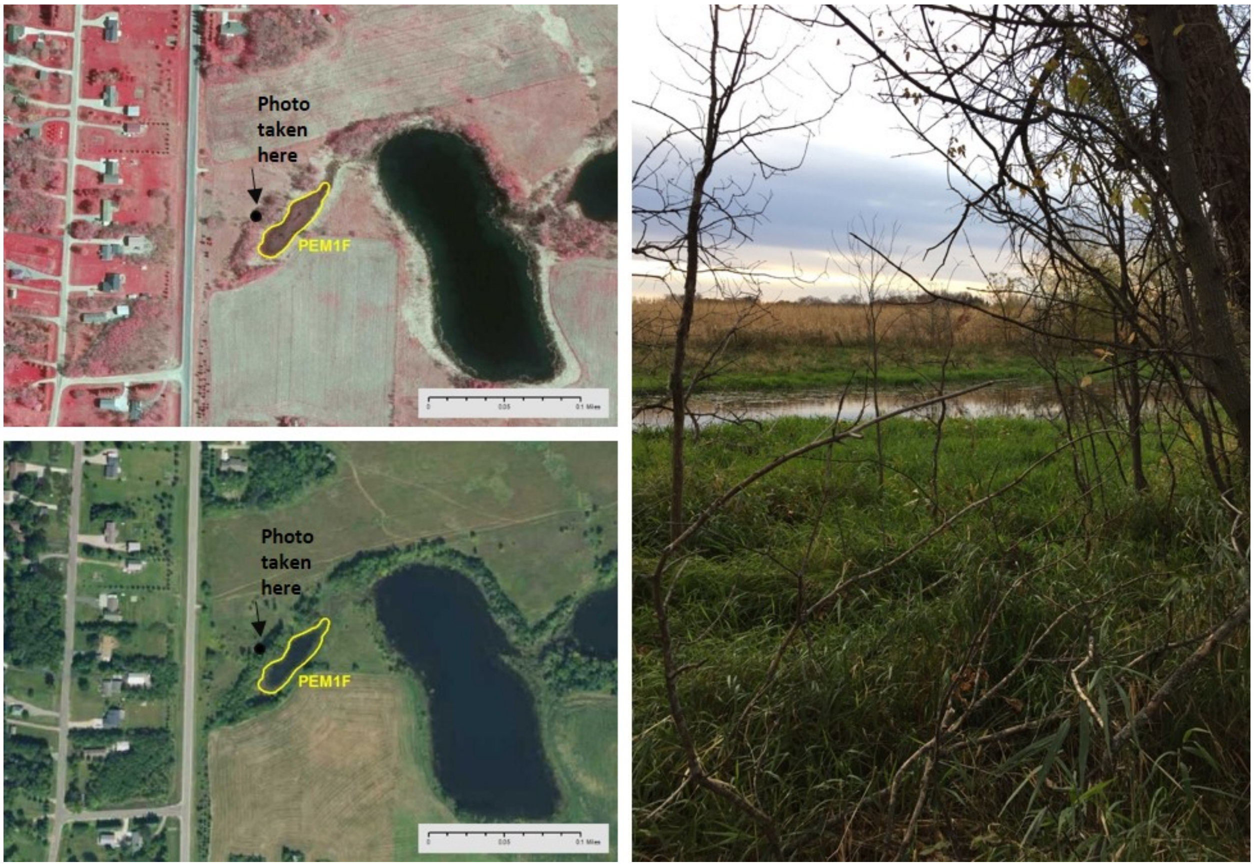


Figure 25. PEM1F signature example; 2013/14 CIR (upper left), 2015 NAIP (lower left), ground-level oblique (right).

PEM1C

System: Palustrine
Class: Emergent
Subclass: Persistent
Water Regime: Seasonally Flooded

PEM1C wetland features are dominated by persistent emergent vegetation and regularly have standing water early in the growing season but may not have surface water later in the growing season. When surface water is not present, the soil is often saturated very near the surface. Reed canary grass (*Phalaris arundinacea*) is a common species present in these wetlands. They occur in a variety of locations, but tend to occur on seasonally flooded basins, including meander scars. Photosignatures tend to have a puffy texture, with tone varying significantly depending on the amount of surface water present at imagery acquisition. The typical signature on CIR imagery is a light gray to white in tone, but where surface water is present may be much darker (Figure 27). Photosignatures on the NAIP tend to also have a puffy texture with a deeper green tone than surrounding temporarily flooded wetlands or uplands. Hybrid cattail (*Typha x glauca*), which will tolerate dry conditions, will also grow in PEM1C wetlands and will exhibit a very similar signature to cattails growing in a PEM1F wetland, but will be much denser without any open water or aquatic bed pockets present, and muskrat houses will not be present.

Collateral data primarily include the DRG, SSURGO soils, and LiDAR DEM. Marsh symbols might be present on the DRG, but are not as likely as for semi-permanently flooded wetlands. Hydric soils are highly likely to be present. The LiDAR DEM and contour lines will, in a majority of cases, show a basin. There generally will not be any indication of a hydrologically enforced water surface on the LiDAR DEM.

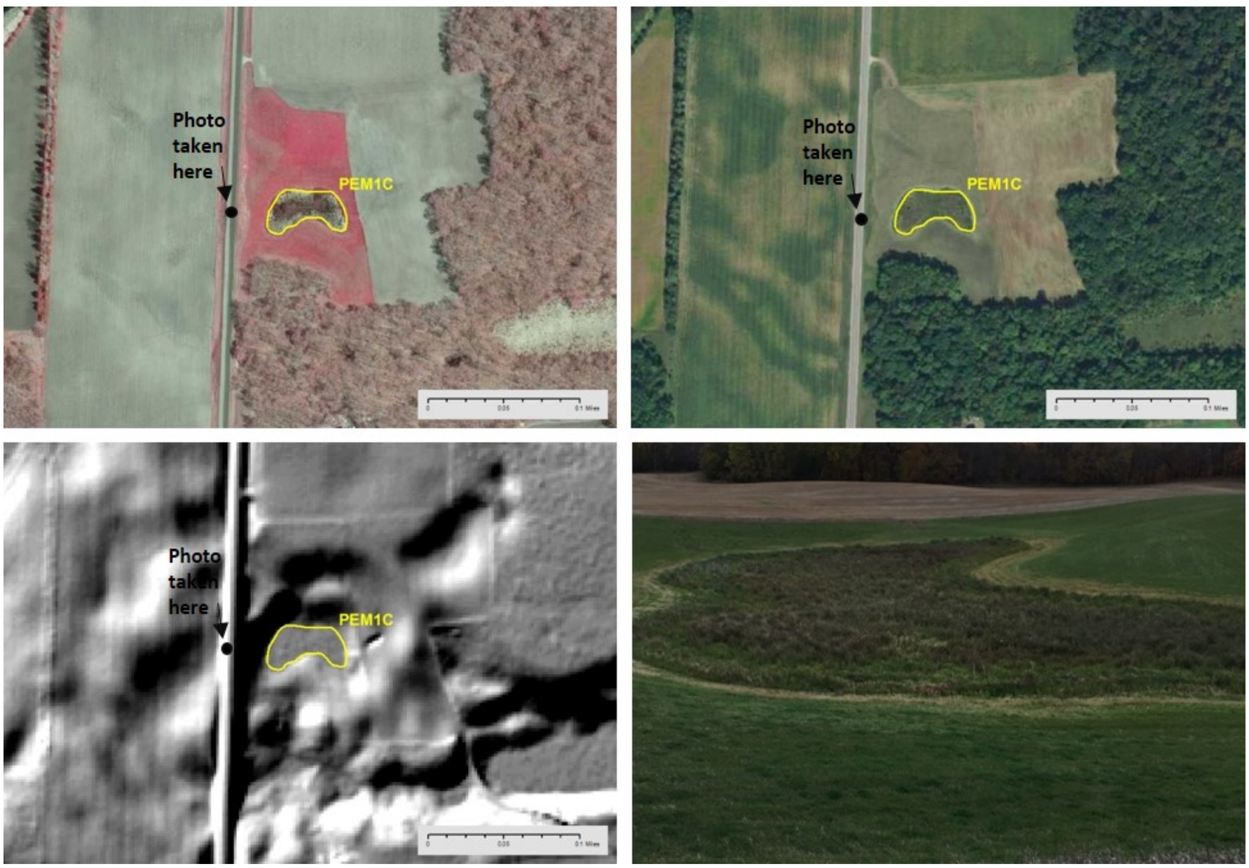


Figure 26. PEM1C signature example; 2013/14 CIR (upper left), 2015 NAIP (upper right), 3-meter LiDAR hillshade (lower left), ground-level oblique (lower right).

PEM1A

System: Palustrine

Class: Emergent

Subclass: Persistent

Water Regime: Temporarily Flooded

PEM1A wetlands are dominated by persistent emergent vegetation and have surface water for only a short time during the growing season, generally two weeks or less. The soil is not usually saturated very near the surface when surface water is absent. Both wetland and upland plants are often present in these wetlands. Due to its ability to thrive in both wet and dry environments, reed canary grass is a common species present in these wetlands. They most often occur in relatively flat areas, but do occur on the edges of wetland basins. Photosignatures tend to be smoother than PEM1C wetlands. Tones on the CIR tend to be darker gray or white tones (Figure 28) or, on some imagery for the Northwest MN project, pink to red in tone. Tones on the true-color NAIP imagery tend to be a lighter green as compared to PEM1C wetlands.

Collateral data primarily include the LiDAR DEM and SSURGO. The LiDAR DEM will show a relatively flat area, including raised shelf structures along drainage ways. SSURGO will often indicate hydric soils, but this is not as sure of an indicator as for wetter PEM1 wetlands.

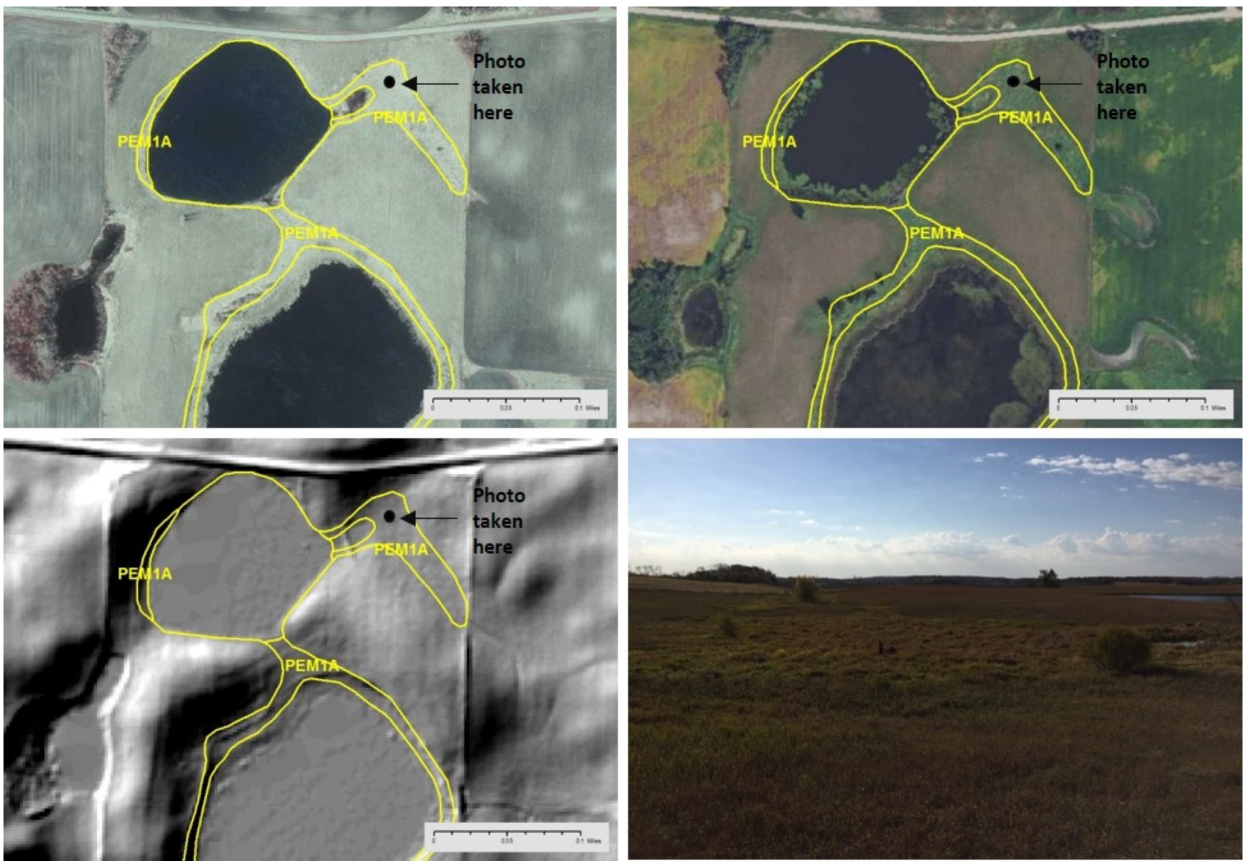


Figure 27. PEM1A signature example; 2013/14 CIR (upper left), 2015 NAIP (upper right), 3-meter LiDAR hillshade (lower left), ground-level oblique (lower right).

PSS1C

System: Palustrine

Class: Scrub-Shrub

Subclass: Broad-Leaved Deciduous

Water Regime: Seasonally Flooded

PSS1C wetland features are dominated by deciduous woody vegetation less than 20 feet tall. In many cases, they are transitional successional communities between emergent and forested stages, but there are some mature communities made up of scrub-shrub vegetation. There is regularly standing water early in the growing season, but there may not be surface water present later in the growing season. When surface water is not present, the soil is often saturated very near to the surface. Both bushy shrub species and juvenile trees are included in this class. Examples of the former include willow (*Salix* spp.), red osier dogwood (*Cornus sericea* ssp. *sericea*), and the invasive buckthorns (*Rhamnus* spp.). Examples of the latter include the saplings of American elm (*Ulmus americanus*) and green ash (*Fraxinus pennsylvannica*). They occur in a variety of locations, but tend to occur in seasonally flooded basins, including meander scars (Figure 29). Photosignatures have a fine, rough, stippled texture without distinct tree crowns. The typical signature on CIR imagery is a light gray, white or brown on CIR acquired earlier in the growing season and pink to red on later CIR. Photosignatures on the NAIP tend to have a similar pattern, with green to deep green tones. The leaf-on conditions of the NAIP also produce more distinct shadows, which provide a visual cue to the height of the vegetation. The NAIP imagery is probably most useful for making the PSS1 determination.

Collateral data primarily include SSURGO soils and the LiDAR DEM. Hydric soils are highly likely to be present. The LiDAR DEM and contour lines will depict a basin or meander scar in most cases. There will not be any indication of a hydrologically enforced water surface on the LiDAR DEM.

Figure 28. PSS1C signature example; 2013/14 CIR (upper left), 2015 NAIP (upper right), 2013 NAIP (lower left), ground-level oblique (lower right).

PFO1C

System: Palustrine

Class: Forested

Subclass: Broad-Leaved Deciduous

Water Regime: Seasonally Flooded

PFO1C wetlands are dominated by trees adapted for life in wet conditions. Vegetation greater than 20 feet in height distinguishes these wetlands from PSS1 wetlands. There is regularly standing water early in the growing season, but there may not be surface water later in the growing season. When surface water is not present, the soil is often saturated very near to the surface. Examples of species present in these wetlands include black willow (*Salix nigra*), silver maple (*Acer saccharinum*), and eastern cottonwood (*Populus deltoides*). They occur in seasonally flooded basins (Figure 30), including meander scars in smaller river floodplains. Large areas of PFO1C wetlands occur in the floodplains of major rivers as well. They can also occur on fringes of larger palustrine and lacustrine basins. Photosignatures have a coarse, rough, stippled texture. An indication of PFO1 wetlands are distinct tree crowns. Large cottonwoods in particular are easily distinguished on the imagery. The typical signature on CIR imagery is a gray or brown for CIR acquired earlier in the growing season and pink to red on later CIR. Photosignatures on the NAIP tend to have a similar pattern, with green to deep green tones. The leaf-on conditions of the NAIP also produce more distinct shadows, which provide a visual cue to the height of the vegetation. The NAIP imagery is probably most useful for distinguishing PFO1 wetlands from PSS1 wetlands, especially where the spring imagery was acquired before leaf out.

Collateral data primarily include SSURGO soils and the LiDAR DEM. Hydric soils are highly likely to be present. The LiDAR DEM and contour lines will typically indicate a basin, meander scars, or flood plain boundaries.

Figure 29. PFO1C signature example; 2013/14 CIR (upper left), 2015 NAIP (upper right), 3-meter LiDAR hillshade (lower left), ground-level oblique (lower right).

PFO1A

System: Palustrine

Class: Forested

Subclass: Broad-Leaved Deciduous

Water Regime: Temporarily Flooded

Similar to PFO1C, PFO1A wetlands are dominated by trees adapted for life in wet conditions. Vegetation greater than 20 feet in height distinguishes these wetlands from PSS1 wetlands. They typically are only flooded for one or two weeks during the growing season. Examples of species present in these wetlands include black willow (*Salix nigra*), silver maple (*Acer saccharinum*), and Eastern cottonwood (*Populus deltoides*). They occur primarily on flat locations, which is the main distinguishing characteristic from PFO1C wetlands (Figure 31). They also occur on fringes of larger palustrine and lacustrine basins. Photosignatures have a course, rough, stippled texture. An indication of PFO1 wetlands are distinct tree crowns. Large cottonwoods in particular are easily distinguished on the imagery. The typical signature on CIR imagery is a gray or brown for CIR acquired earlier in the growing season and pink to red on later CIR. Photosignatures on the NAIP tend to have a similar pattern, with green to deep green tones. The leaf-on conditions of the NAIP also produce more distinct shadows, which provide a visual cue to the height of the vegetation. The NAIP imagery is probably most useful for distinguishing PFO1 wetlands from PSS1 wetlands, especially where the spring imagery was acquired before leaf out.

Collateral data primarily include SSURGO soils and the LiDAR DEM. Hydric soils are likely to be present. The LiDAR DEM and contour lines will typically indicate a flat or very gently sloping area.

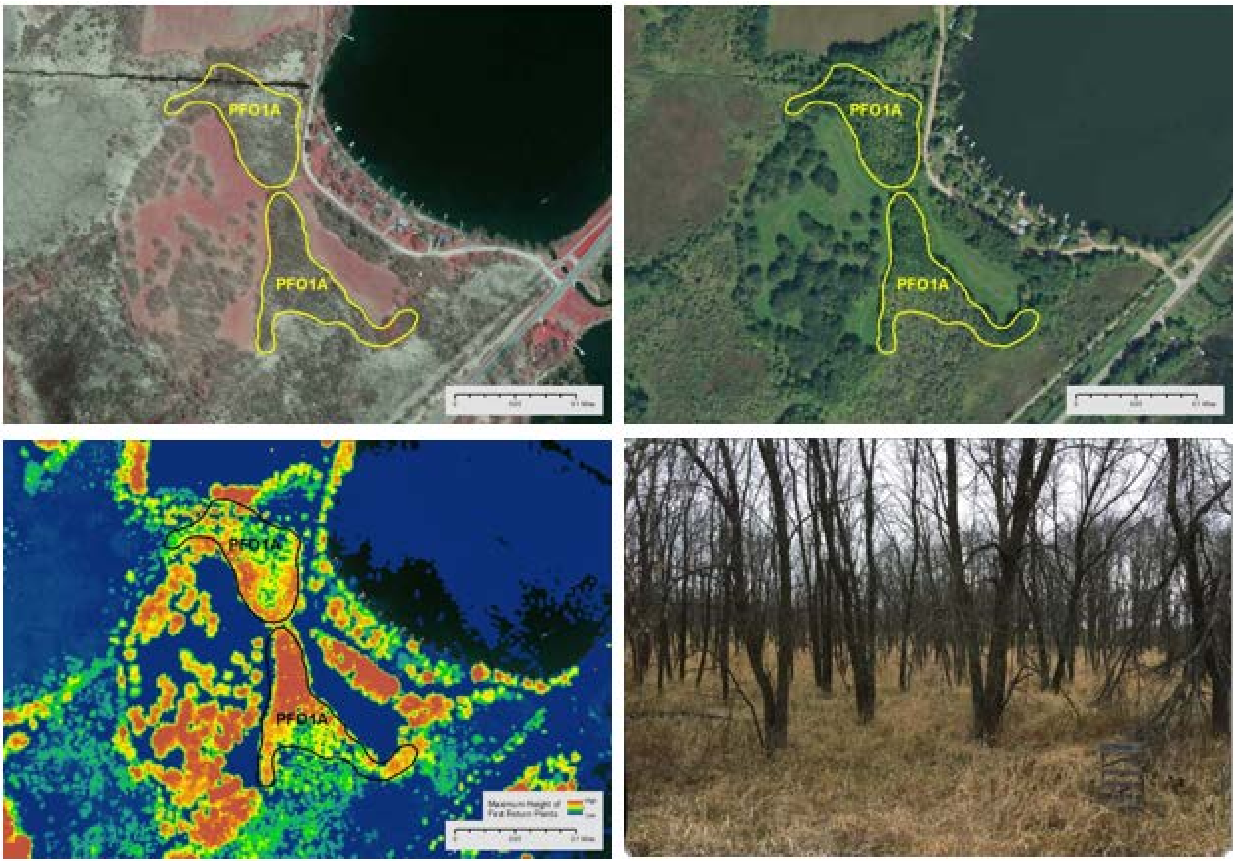


Figure 30. PFO1A signature example; 2013/14 CIR (upper left), 2015 NAIP (upper right), maximum height of first return points (lower left), ground-level oblique (lower right).

B (Saturated) Water Regime

The saturated water regime rarely floods, but has wet, saturated soil to the surface for extended periods during the growing season. Unlike other wetland types, which tend to have hydrology dominated by surface water, saturated wetlands exist primarily due to ground water sources. The following wetland types all have the B water regime assigned to them.

<u>PSS2B</u>

System: Palustrine

  Class: Scrub-Shrub

    Subclass: Needle-Leaved Deciduous

      Water Regime: Saturated

PSS2B wetlands are defined by the presence of needle-leaved deciduous trees, such as small-form tamarack. Saturation occurs throughout the entire year and can sometimes flood when precipitation is high. Photosignatures appear light pink (Figure 32) due to the needle-leaved deciduous trees starting to bud in the spring CIR. The maximum height of first return points data can provide insight into the height of the vegetation; vegetation in PSS2B wetlands will appear shorter than vegetation in PFO2B wetlands.

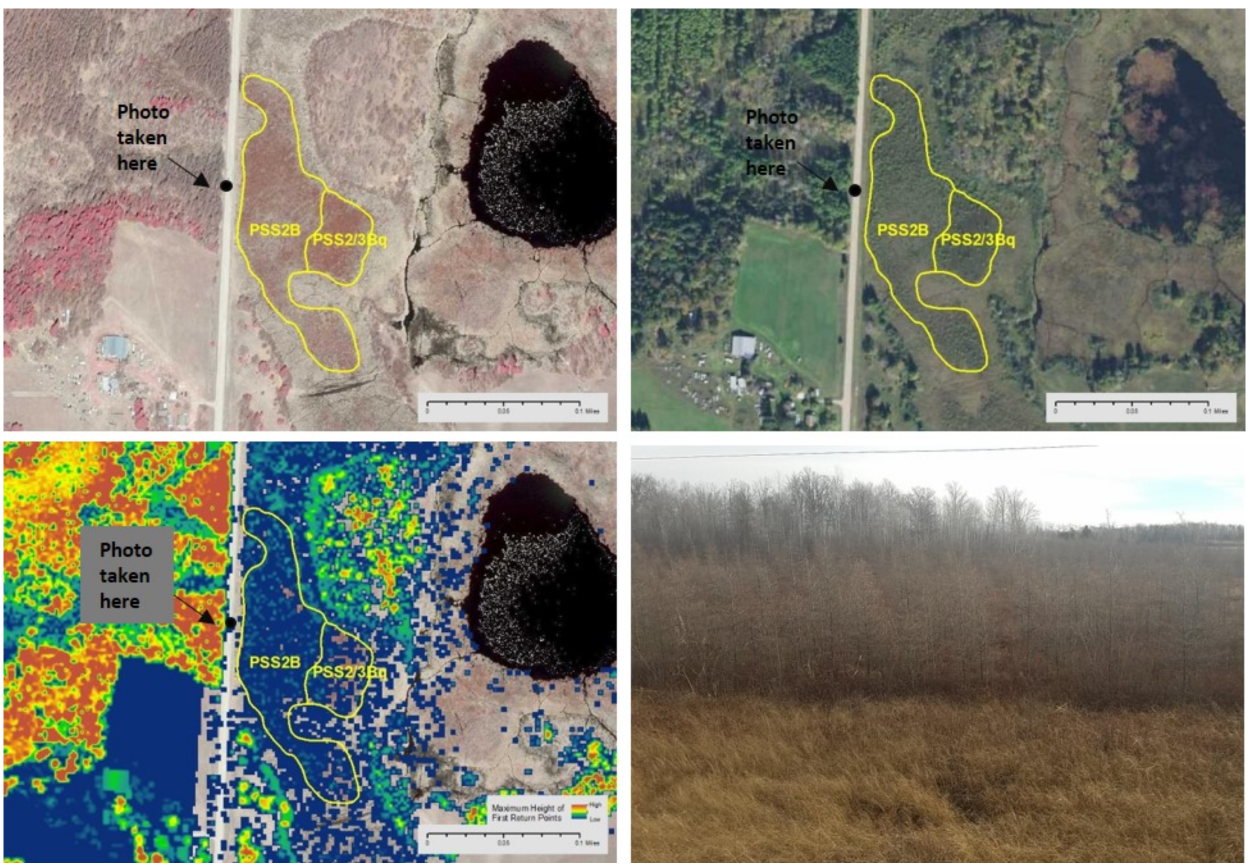


Figure 31. PSS2B signature example; 2013/13 CIR (upper left), 2015 NAIP (upper right), maximum height of first return points (lower left), ground-level oblique of small-form tamarack (lower right).

PFO2B

System: Palustrine

Class: Forested

Subclass: Needle-Leaved Deciduous

Water Regime: Saturated

Defined by species such as full-grown tamarack trees, PFO2B wetlands are saturated all of the time and can have standing water if an increase in precipitation occurs. Photosignatures in the spring CIR can appear light-gray to pink depending on what time in the spring the CIR was generated (Figure 33). Full-grown tamarack trees will appear pink/red before other deciduous trees, which will have predominately a tone of gray due to their leaves not budding yet in the spring, but not as red as needle-leaved evergreen trees (PFO4), which hold their needles all year around. The maximum height of first return points data can provide insight into the height of the vegetation; vegetation in PFO2B wetlands will appear taller than vegetation in PSS2B wetlands.

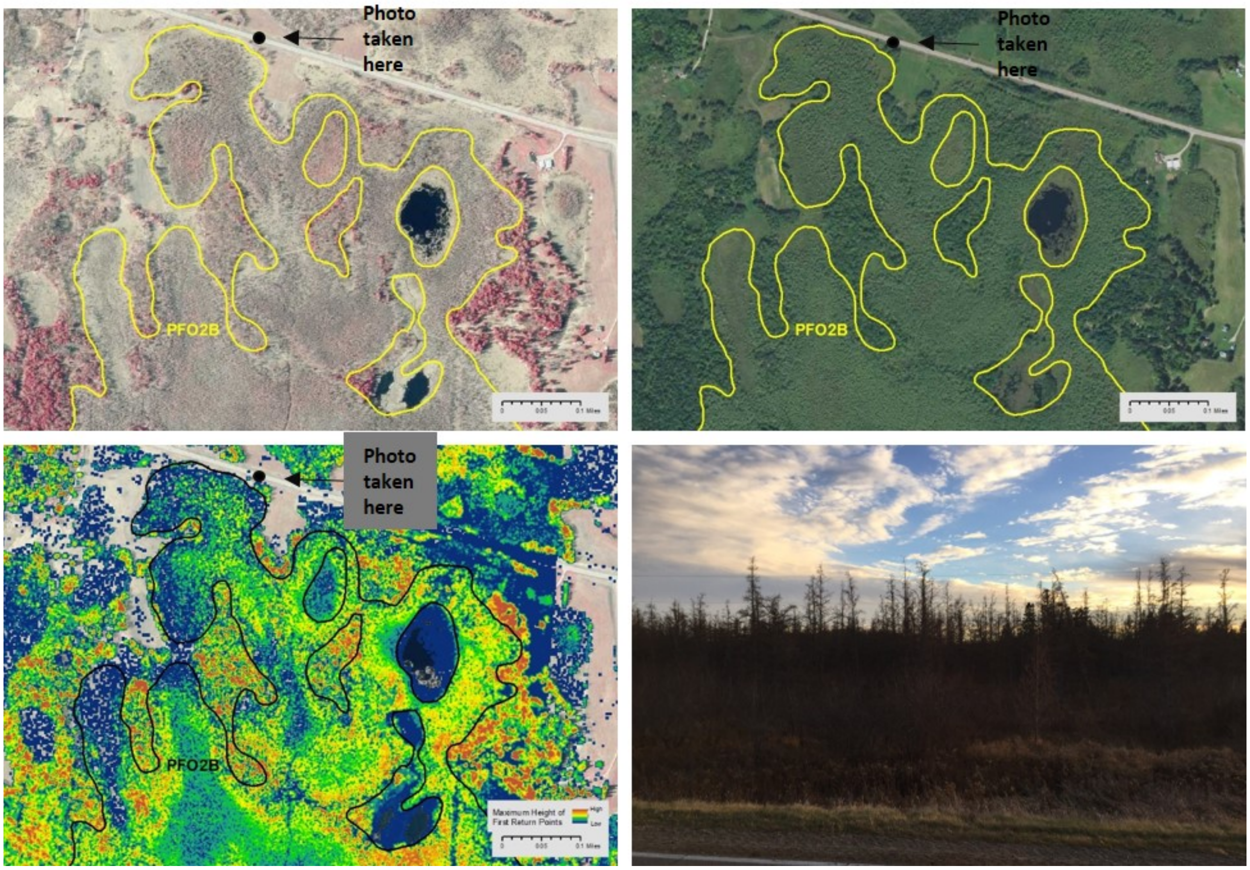


Figure 32. PFO2B signature example; 2013/14 CIR (upper left), 2015 NAIP (upper right), maximum height of first return points (lower left), ground-level oblique of full-grown tamarack (lower right).

PSS3B

System: Palustrine

Class: Scrub-Shrub

Subclass: Broad-Leaved Evergreen

Water Regime: Saturated

Broad-leaved evergreen shrubs, such as bog rosemary (*Andromeda polifolia*) and leatherleaf (*Chamaedaphne calyculata*), are vegetation that can be found in the PSS3B wetland type. Photosignatures appear light pink similar to PSS2B wetlands, yet have a smoother texture compared to the rougher looking PSS2B (Figure 34).

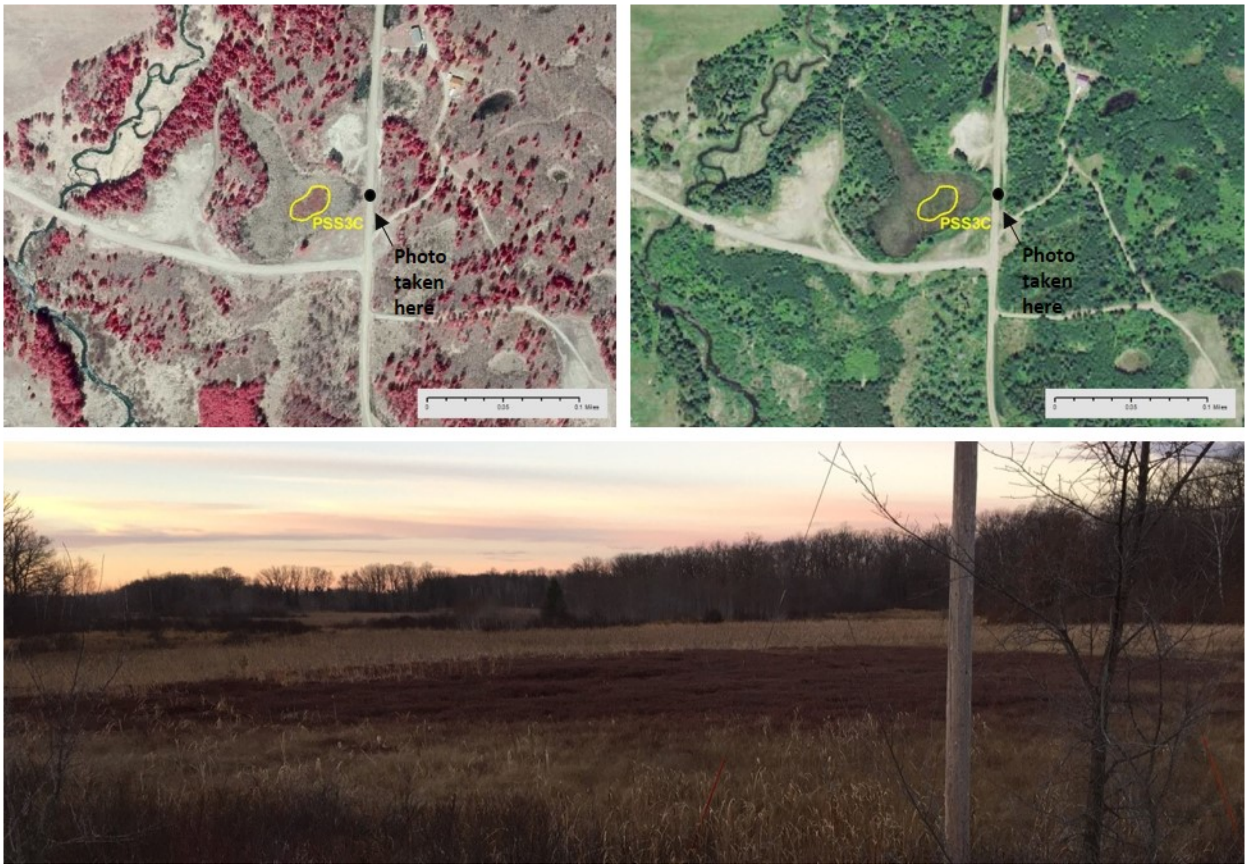


Figure 33. PSS3B signature example; 2013/14 CIR (upper left), 2013 NAIP (upper right), ground-level oblique of leatherleaf (bottom).

<u>PSS4B</u>

System: Palustrine

Class: Scrub-Shrub

Subclass: Needle-Leaved Evergreen

Water Regime: Saturated

PSS4B wetlands are defined by the presence of needle-leaved evergreen trees, such as small-form black spruce. Saturation occurs throughout the entire year and can sometimes flood when precipitation is high. Tamarack (PSS2B) and black spruce (PSS4B) can be difficult to distinguish from one another; a deciding factor can be the amount of red wetland signature. Black spruce will appear a brighter red while tamarack can appear light pink or gray due to their needles starting to bud in the spring. To differentiate PSS4B and PFO4B, the maximum height of first return points data can provide insight; vegetation in PSS4B wetlands will appear shorter than vegetation in PSS4B wetlands (Figure 35).

PFO4B
System: Palustrine
Class: Forested
Subclass: Needle-Leaved Evergreen
Water Regime: Saturated

Tamarack (PFO2B) and black spruce (PFO4B) can be difficult to distinguish from one another; a deciding factor can be the amount of red wetland signature and the density of the vegetation. Like mentioned above, tamarack can appear light pink due to their needles starting to bud in the spring. Black spruce will appear bright red and appear denser because they retain their needles year-round. To differentiate PFO4B from PSS4B, the maximum height of first return points data can provide insight; vegetation in PFO4B wetlands will appear taller than vegetation in PSS4B wetlands (Figure 35).

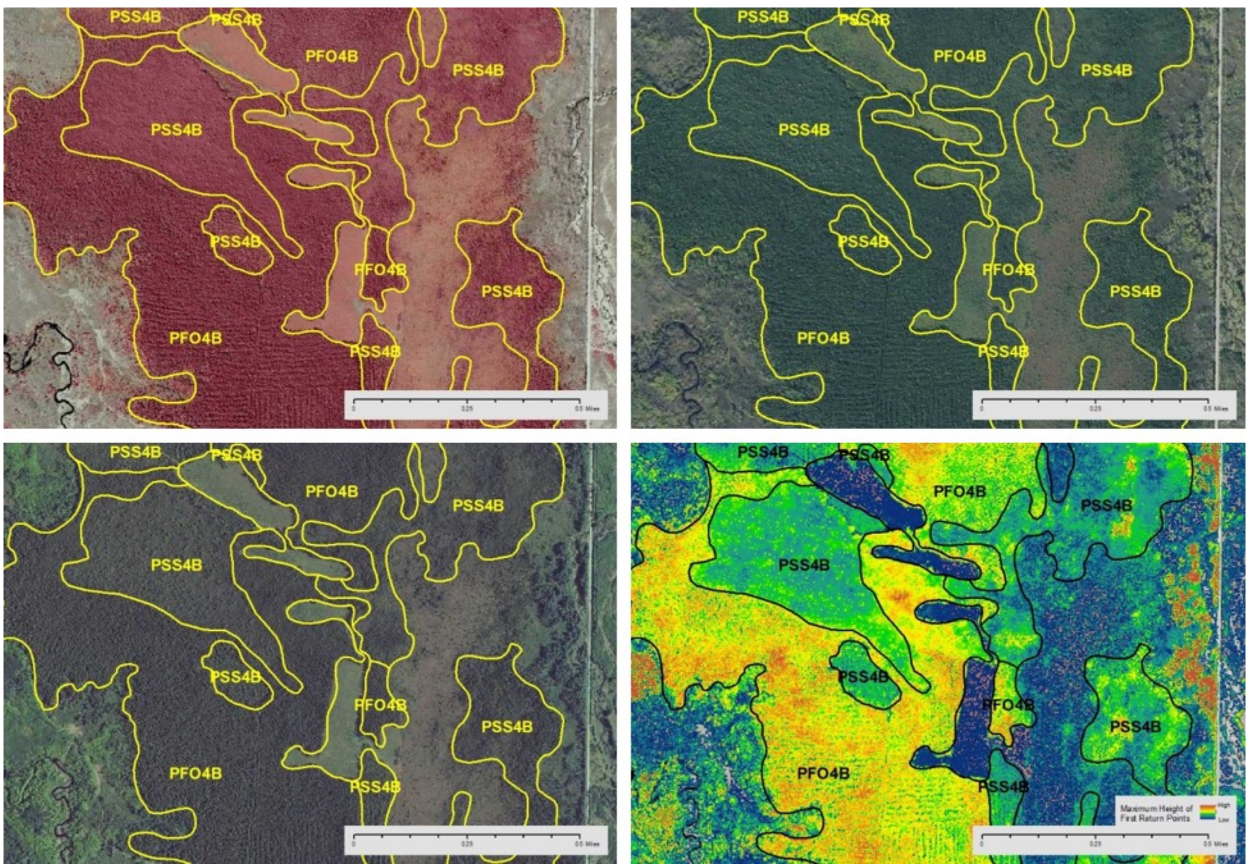


Figure 34. PSS4B and PFO4B signature examples; 2013/14 CIR (upper left), 2015 NAIP (upper right), 2010 NAIP (lower left), maximum height of first return points (lower right).

Mixed Wetland Classes

In situations where it is difficult to delineate separate vegetation classes, mixed classes are used to classify wetlands that have an even mixture of two vegetation classes. Below are a few examples of what could be encountered during this NWI update in Northwest Minnesota.

PSS1/EM1B

System: Palustrine

Class: Scrub-Shrub/Emergent

Subclass: Broad-Leaved Deciduous/Persistent

Water Regime: Saturated (Figure 36)

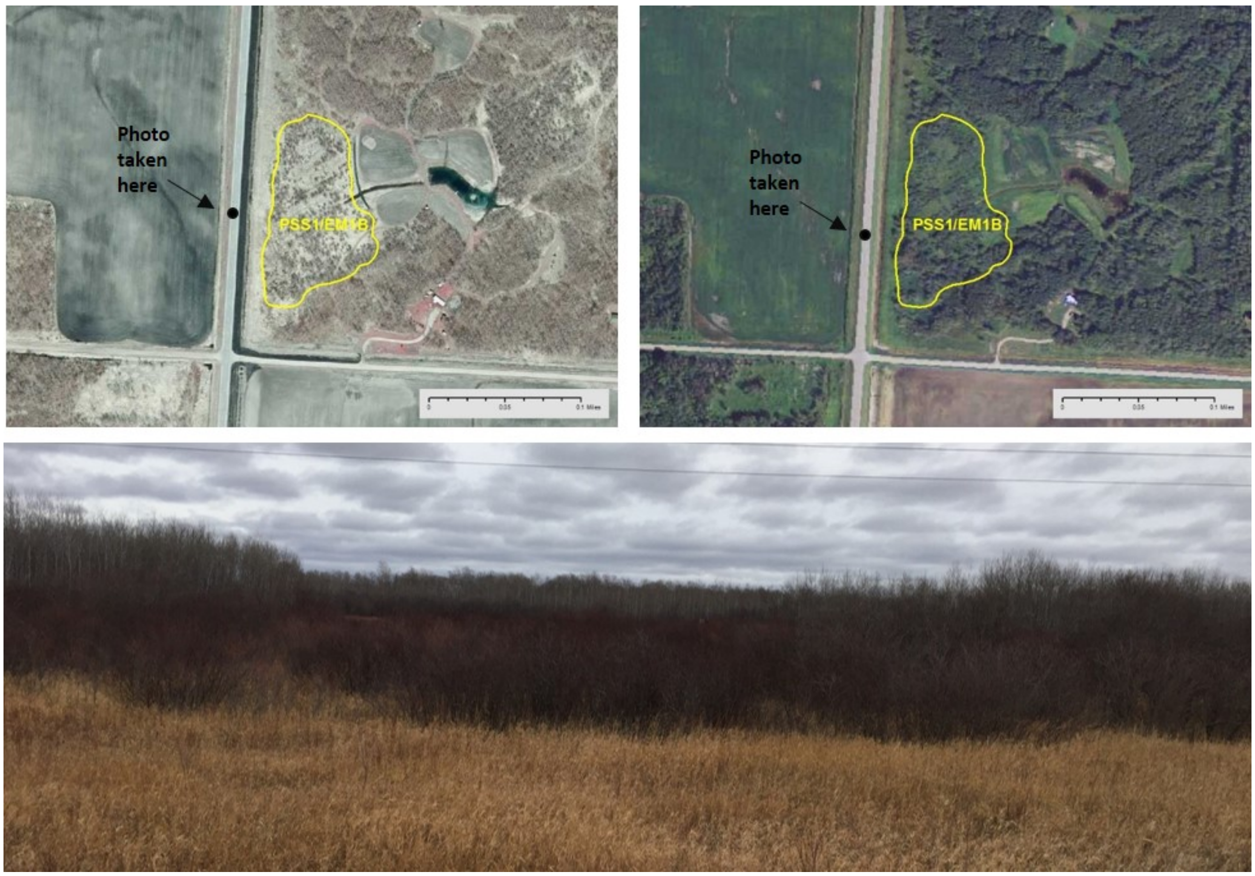


Figure 35. PSS1/EM1B signature examples; 2013/14 CIR (upper left), 2010 NAIP (upper right), ground level oblique (bottom).

PFO1/SS1B

System: Palustrine

Class: Forested/Scrub-Shrub

Subclass: Broad-Leaved Deciduous

Water Regime: Saturated (Figure 37)

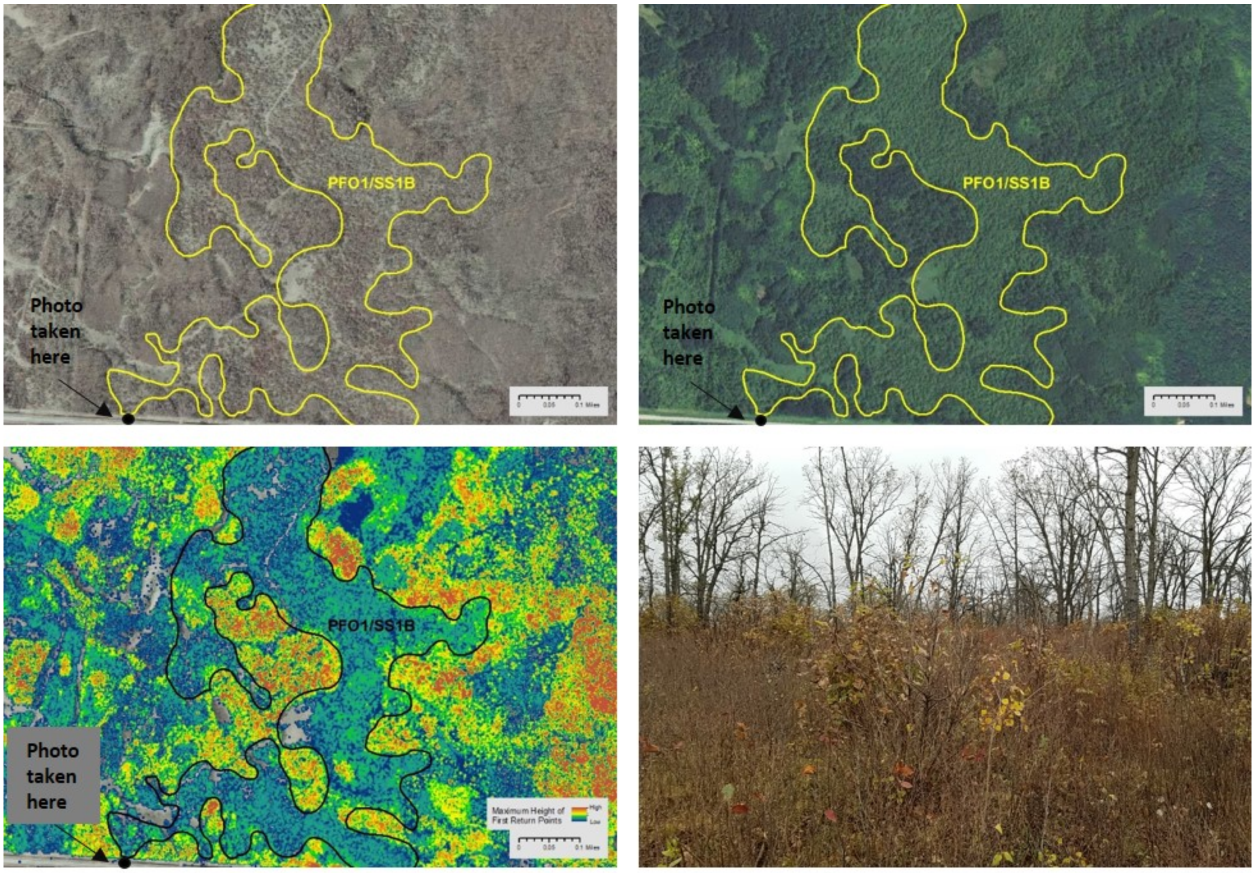


Figure 36. PFO1/SS1B signature examples; 2013/14 CIR (upper left), 2013 NAIP (upper right), maximum height of first return points (lower left), ground level oblique (lower right).

Farmed Wetlands

Farmed wetlands will be designated by the PEM1Af classification. The main distinguishing factor between a farmed wetland and a wetland that happens to be located within an agricultural area is the presence/absence of hydrophytic vegetation. If a wetland contains hydrophytic vegetation, it should be classified using the previously defined protocols. If there is no hydrophytic vegetation present and it meets the conditions outlined below, it should be mapped as a farmed wetland (PEM1Af):

1. Inundation (standing water) or evidence of heavy saturation on the 2013/14 Spring CIR, and,
2. Evidence of crop stress, drown out, or otherwise altered crop pattern on at least 2 out of the 3 NAIP (2015, 2013, 2010) images.

Generally, soil signatures will be dark in comparison to the surrounding area and can sometimes have a thin white border around at least part of the area. The white is crop chaff and debris that was floating on standing water and was blown to one side by the wind before the water drained away. Farmed wetlands will only occur in depressions and other low level areas. The LiDAR hillshade is helpful in identifying these areas. Figure 38 below illustrates the difference between areas that should be considered for mapping as PEM1Af (“PEM1Af”) and areas that should not be considered (“NOT

PEM1Af”). When determining boundary locations, the “average” location of crop stress/drown out/disturbance should be used, not necessarily the dark soil signature boundary on the CIR imagery.

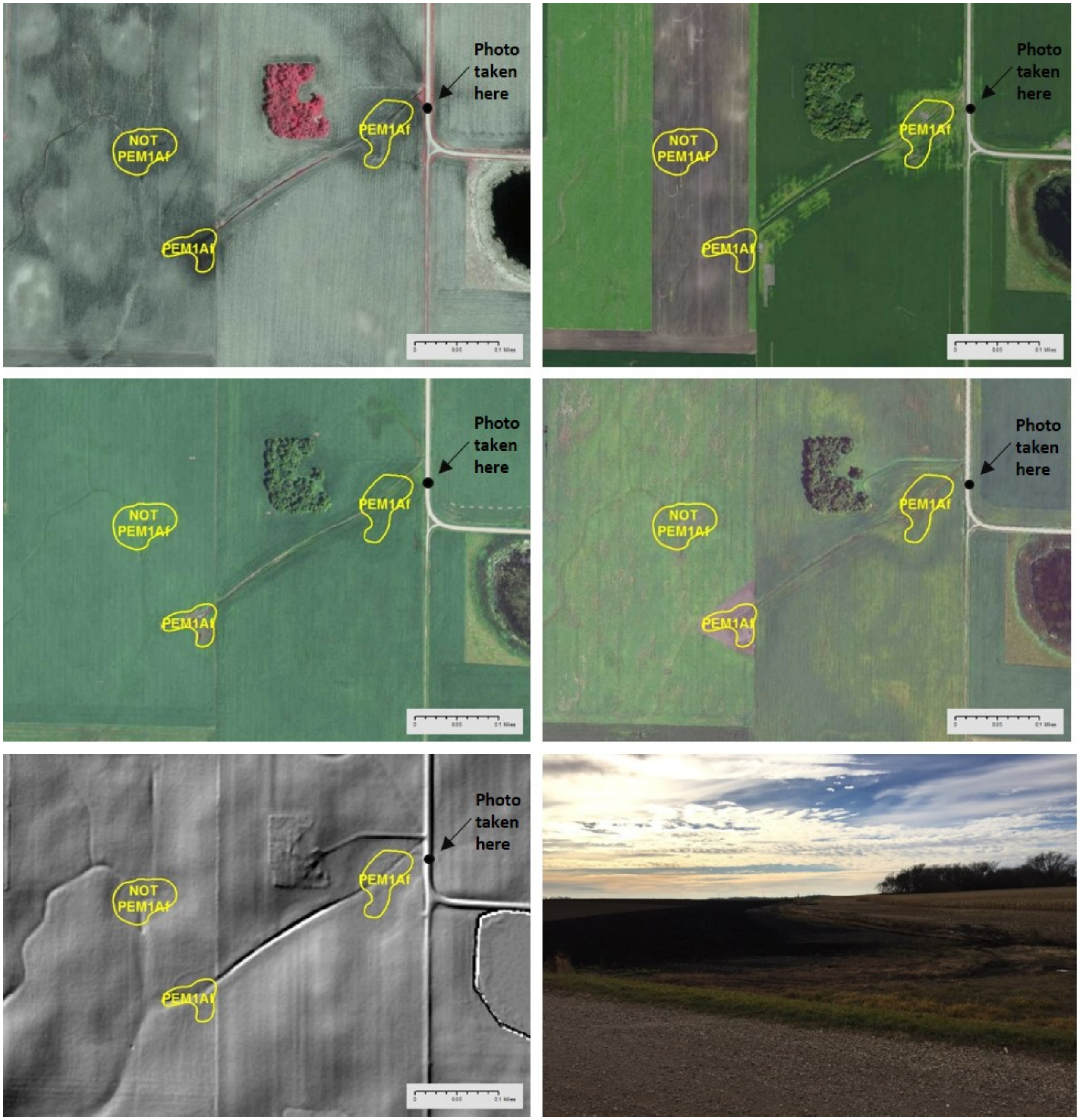


Figure 37. PEM1Af signature example; 2013/14 CIR (upper left), 2015 NAIP (upper right), 2013 NAIP (center left), 2010 NAIP (center right), 3-meter LiDAR hillshade (lower left), ground-level oblique of PEM1Af not farmed in 2016 (lower right). Notice the two PEM1Af wetlands have soil scarring 2 out of 3 NAIP years while the polygon labeled “NOT FARMED” does not have 2 out of 3 years of soil scaring.

Partially Drained/Ditched Wetlands

The partly drained (“d”) special modifier is applied to those areas where the water level has been artificially lowered due to ditching or drain tile, but still have enough soil moisture to support hydrophytes. If soil moisture has been lowered to the point that it no longer supports hydrophytes, it is no longer classified as wetland. In the historic NWI data, the partly drained modifier was used more frequently than the previously mentioned farmed (“f”) special modifier and should not be relied upon as an indicator of current conditions. The “d” modifier should be used in situations like the example below (Figure 39). When there is a ditch or drain tile associated with a wetland, a determination must be made as to whether the ditch/tile is draining out of the wetland or into the wetland. In this case, the contours indicate the ditch is pulling water from the wetland and the “d” modifier should be used. Additional indications include the wetland is getting smaller in extent and/or drier in terms of water regime over time, as compared to the historic NWI data.

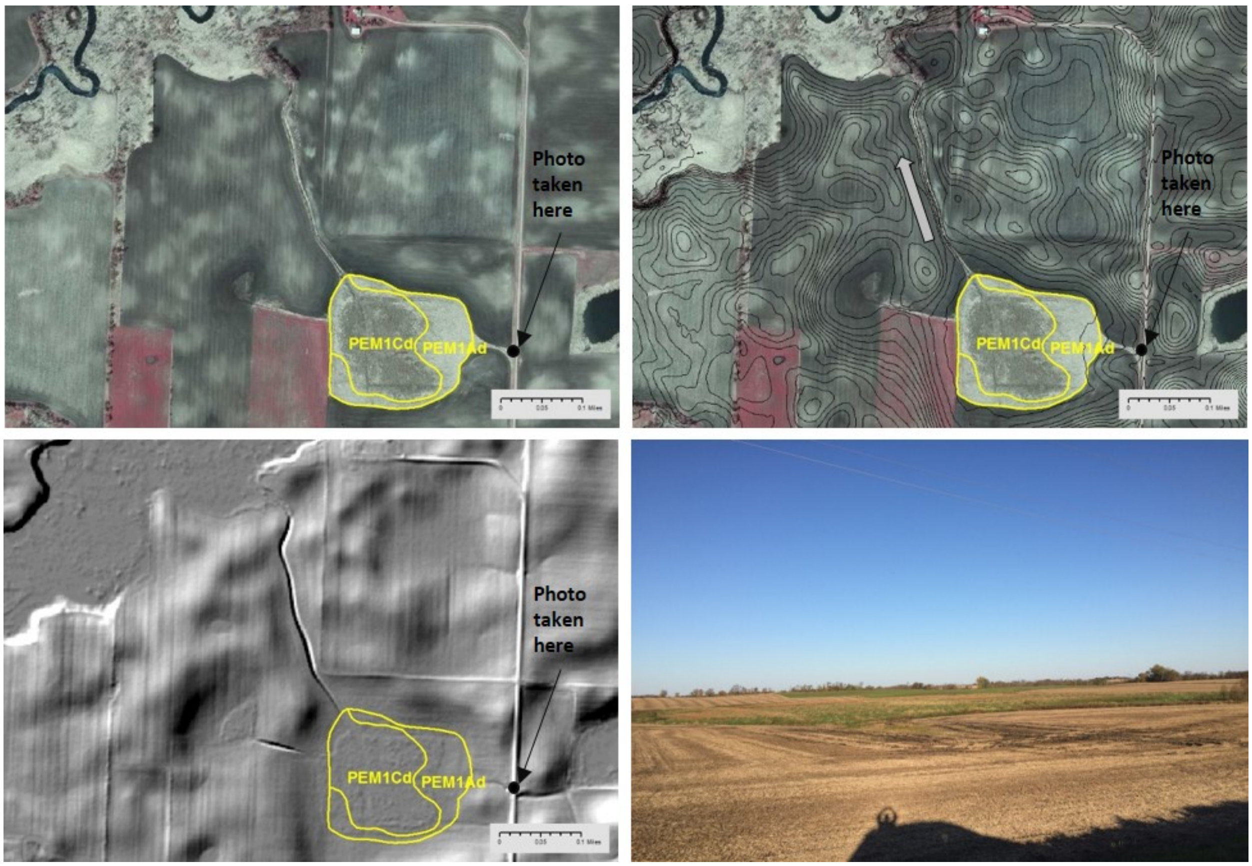


Figure 38. Drained wetland signature example; 2013/14 CIR (upper left), 2013/14 CIR with 2-foot contours (upper right), 3-meter LiDAR hillshade (lower left), ground-level oblique (lower right).

Peatland Wetlands

For this particular project, peatlands can be found in the northeast corner of the project area. In terms of the Cowardin Classification, wetlands that are considered peatlands receive the “q” modifier and can cross all classes (PEM, PSS, and PFO). They will always be assigned the “B” water regime due to their ability to hold water. Tree species such as tamarack (see PFO2B above) and black spruce or shrub species such as leatherleaf that are found growing on a bed of sphagnum moss are considered peatlands and will be classified appropriately (Figure 40).

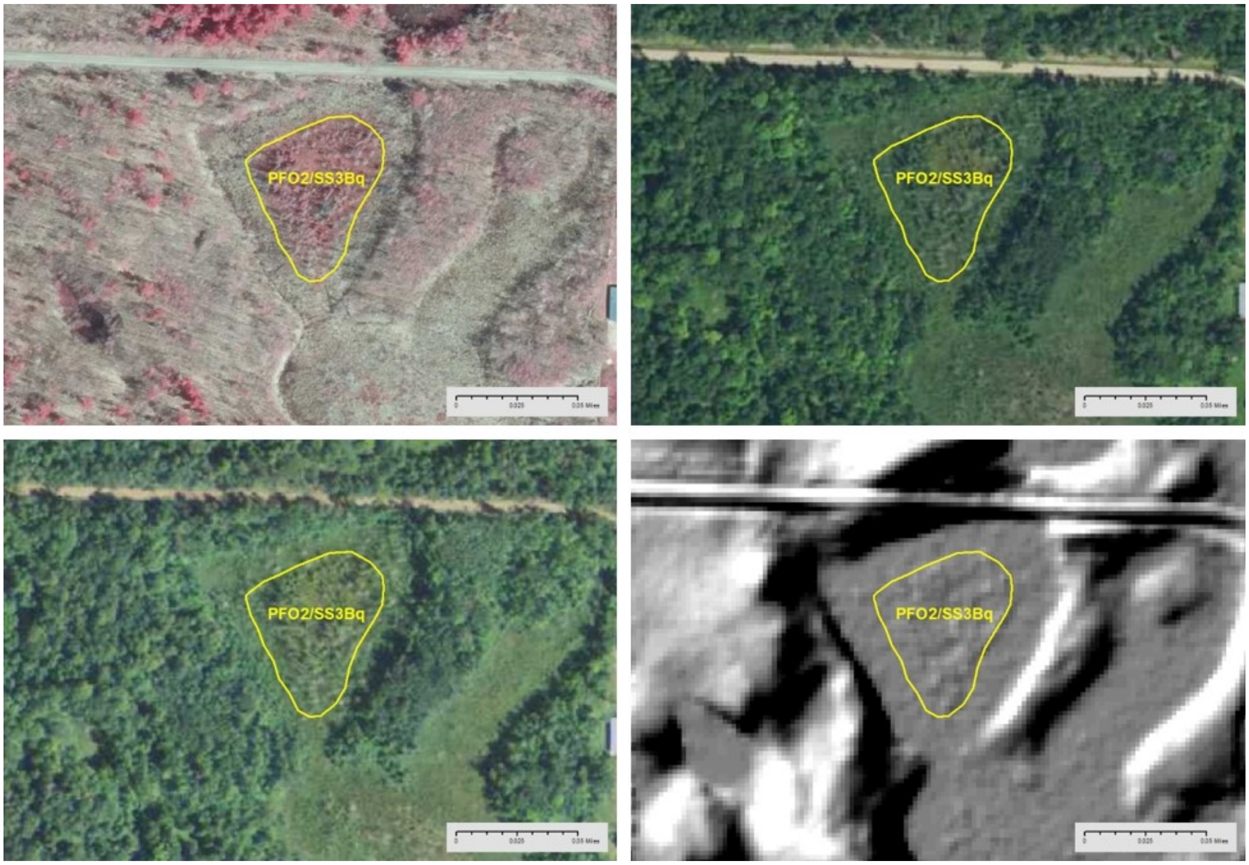


Figure 39. Inside this basin, a peatland signature (PFO2/SS3Bq) can be found with the presence of tamarack and a broad-leaved evergreen shrub, like leatherleaf.

Unusual Signatures

These signatures are documented in the interest of reducing confusion when they are encountered. In some cases, they mimic other wetland signatures.

Ice

On the Spring CIR imagery, there are a few examples of winter ice still present on lakes and ponds. The example below (Figure 41) shows a pocket of ice on Lake of the Woods in Lake of the Woods County. The 2010 NAIP also shown below indicates a lacustrine unconsolidated bottom (UB) classification. Where ice is present, the NAIP imagery is the primary image source.

Figure 40. Lake ice example on Lake of the Woods; 2013/14 CIR (left) and 2015 NAIP (left).

Peat Harvesting

Northern Minnesota supports a peat industry that produces and harvests peat for horticultural purposes (e.g., greenhouse use). In aerial imagery, peat harvest areas often appear unnatural in shape and may show a series of straight lines from machinery operations (Figure 41). These areas are mapped as PEM1B, with an excavated (x) modifier added once an area was harvested.

Figure 41. Peat harvest example, 2013/14 CIR; note unnatural geometric shapes and lines from machinery in some areas.

Wild Rice Plantations

Northern Minnesota also supports wild rice farming, where rice is cultivated in purposely flooded fields. Like peat harvest areas, wild rice plantations often appear unnatural in shape. They will appear totally or partially flooded on spring CIR, since wild rice is a non-persistent plant, but are usually green on NAIP imagery. These areas are mapped as PEM2Kx (non-persistent emergent vegetation, artificially flooded, excavated).

Figure 42. Wild rice plantation example, 2013/14 CIR; note unnatural shapes and black or dark blue (flooded) color.

Beaver activity

Beavers are "ecosystem engineers", capable of manipulating the vegetation and hydrology of their habitat. In the Northwest Minnesota project area, beavers have converted some forested areas to meadows and their damming activity has created ponds or made wetlands even wetter (e.g., A to C or C to F). The graphics below show an area cleared of trees by beavers (upper wetland) and a more recently dammed area (lower wetland), where felled trees are still visible and the dam is seen as a straight line at the top of the pond (Figure 43).

Figure 43. Example of beaver activity in 2013/14 CIR (left) and 2010 NAIP (right). The beaver dam and felled trees are visible in the CIR of the lower right wetland.

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