Technical Procedures for Updating the National Wetlands Inventory of Southern Minnesota

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GeoSpatialServices

Saint Mary's University OF MINNESOTA

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1. Project Summary

This project, entitled "Updating the National Wetlands Inventory for Minnesota: Southern Project Area", used geospatial techniques and image interpretation processes to remotely map and classify wetlands in Southern Minnesota. The project study area included approximately the southern third of Minnesota (Figure 1). It consists of 1,784 quarter quadrangles (446 USGS 7.5 minute quadrangle equivalents) across portions of the following thirty-six counties: Big Stone, Blue Earth, Brown, Chippewa, Cottonwood, Dodge, Faribault, Fillmore, Freeborn, Houston, Jackson, Kandiyohi, Lac qui Parle, Le Sueur, Lincoln, Lyon, Martin, McLeod, Meeker, Mower, Murray, Nicollet, Nobles, Olmstead, Pipestone, Redwood, Renville, Rock, Sibley, Steele, Swift, Wabasha, Waseca, Watonwan, Winona, and Yellow Medicine.

Given that the National Wetland Inventory (NWI) update was based on 7.5 minute quarter quadrangle boundaries, some areas beyond the boundaries of these counties were mapped. Areas outside the county boundaries that were mapped included small portions of Traverse, Stevens, Pope, and Stearns counties in Minnesota, as well as small adjacent portions of the neighboring states of Iowa, South Dakota, and Wisconsin.

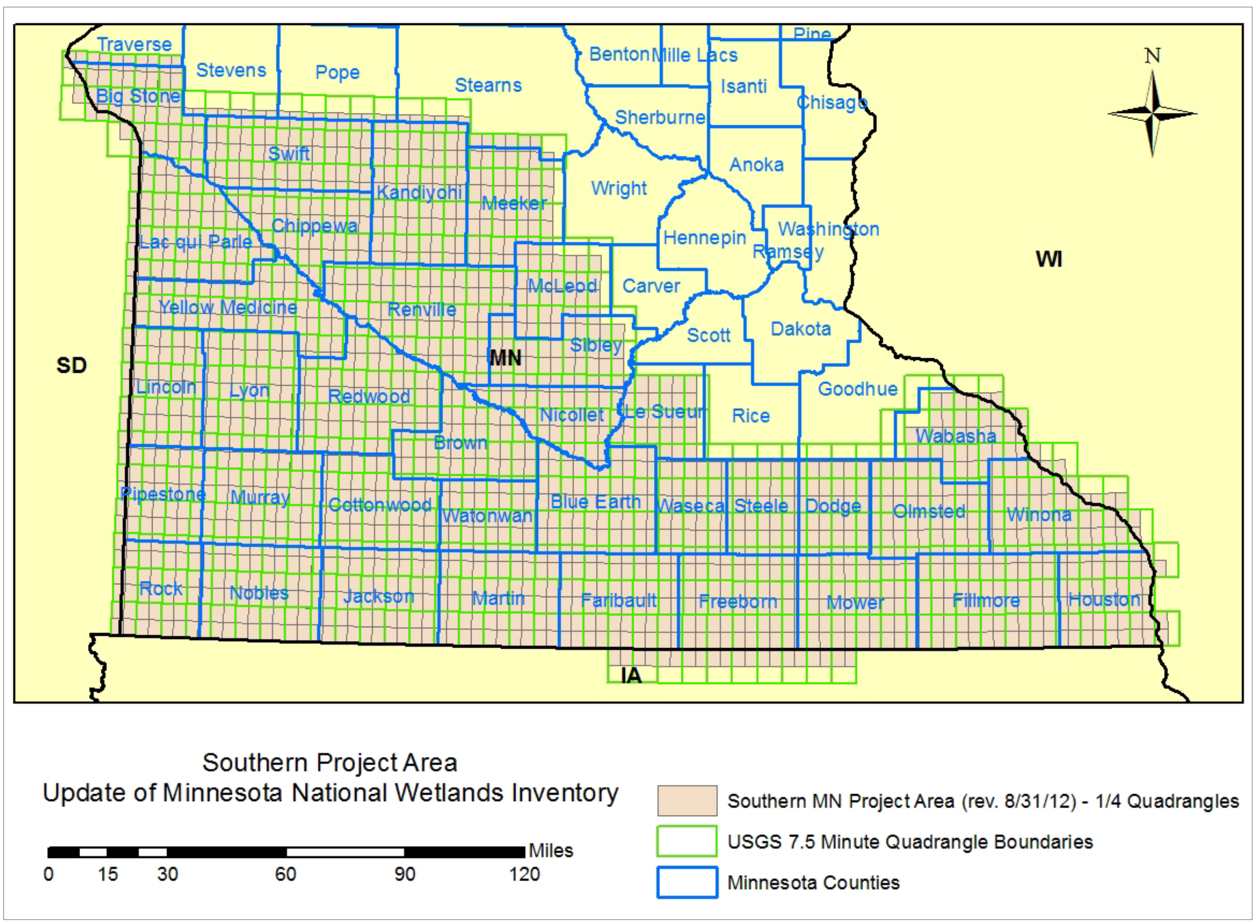


Figure 1. Minnesota NWI Update – Southern Project Area

The purpose of this project was to update and enhance the Minnesota National Wetland Inventory using high resolution digital imagery and a variety of high quality ancillary datasets. Both FGDC Cowardin (Cowardin et. al., 1979) and simplified plant community classifications (Eggers and Reed, 1997) were included. A simplified hydro-geomorphic classification using LLWW codes and descriptors (Tiner, 2003) were included as an additional enhancement. The final product was a seamless NWI dataset of the entire project area for inclusion in the NWI master geodatabase. The work resulted in the update of a 25 to 30 year old wetland database to the current date of photography: spring 2011. Improved accuracy was achieved through the utilization of technologies and additional, highly accurate, collateral datasets that were not available at the time the original NWI mapping was completed.

Minnesota Department of Natural Resources (MN DNR) Resource Assessment Program (RAP) personnel provided support for the project through preprocessing of ancillary datasets, QA/QC reviews, and project documentation. QA/QC reviews for this project provided by RAP included field work for photo-signature convention development, field work for data validation, and on-screen wetland assessment. RAP's contribution to the project was distributed with approximately 25 percent of their available resources toward data processing and the remaining 75 percent directed toward QA/QC and project documentation. Total RAP effort was based on available resources over the project time frame.

2. Data

The Southern Minnesota NWI project utilized a variety of data sources. Base data consisted of several sources of aerial imagery, soils data, USGS topographic map data, LiDAR digital elevation models (DEM), and LiDAR-derived products such as the two-foot derived contours, Compound Topographic Index (CTI) and slope raster.

2.1. Imagery

Several imagery data sources were used for this project: 2011 spring, leaf-off imagery and multiple years of National Agriculture Imaging Program (NAIP) summer imagery. The 2011 spring imagery was acquired as 0.5-meter resolution, 4-band imagery which could be displayed as either a false-color infrared image or a natural color image; the false-color infrared display was the default display for this imagery in this project because it is more useful for wetland mapping. The spring 2011 imagery was simply referred to as the spring color infrared (CIR) imagery throughout this document. Whenever possible, the spring CIR imagery was used as the primary data source for classification and delineation decisions. However, in many cases it was necessary to use NAIP imagery to support decisions where ground conditions make it difficult to correctly classify and delineate based on the CIR imagery alone.

2011 Spring Color Infrared (CIR) Aerial Photography

The spring CIR was the primary imagery source for the NWI update. The challenge of acquiring spring CIR imagery for wetland delineation was that the ideal time window for acquisition is relatively narrow; typically a two to four week period compressed between snow melt and leaf flush. Compounding the challenge was the variability inherent in a study area as large as southern Minnesota. For this reason there were some parts of the study area on the 2011 CIR imagery where wetlands have red tones while the uplands have gray tones, while in other areas the converse applies with uplands having red tones and wetlands having gray tones. Variability in wetness due to precipitation and spring thaw events ranged across the study area as well. Project mapping conventions addressed these and other sources of variability inherent in the imagery.

National Agriculture Imagery Program (NAIP) Aerial Photography

In addition to the spring CIR, there were multiple years of NAIP imagery available online through the Minnesota GeoSpatial Information Office (MnGeo) Web Mapping Service (WMS). Primarily, this imagery was used in specific situations to make or confirm certain wetland classification calls. For example, spring imagery typically does not indicate the presence of aquatic bed (AB) wetlands because the vegetation in these wetlands does not appear on aerial imagery until later in the growing season. Because NAIP is acquired later in the year, aquatic bed wetlands are evident on the imagery and easily delineated. There were multiple years of NAIP imagery available from MnGeo. The 2010 NAIP, being the most recent summer imagery, was the default for making wetland classifications when summer imagery is required.

2.2. Soils, Topography, and Bathymetry

Soil Survey Geographic Database (SSURGO)

The soils data was processed using queries developed by the United States Department of Agriculture, Natural Resources Conservation Service (NRCS) to calculate the hydric percentage of soil components making up each soil map unit. Soil map units containing components that are cumulatively 85% hydric or higher are considered hydric for the purpose of this project. Based on feedback from MN DNR, the hydric percentage queries were refined to include the influence of spring and summer ponding and flood frequency based on queries developed by MN DNR (Kloiber, 2011).

USGS Topographic Maps (DRG)

The USGS 1:24,000 scale topographic map series were used mainly as ancillary data to assist with determination of man-made changes, such as new development, and to verify presence of hydrologic indicators such as marsh symbols, intermittent and perennial streams. These topographic maps also contain elevation contours which are typically used in wetland mapping projects to assess terrain characteristics. For this project, however, the contours and other topographic layers derived from LiDAR based digital elevation models superseded the contour information on the DRG (Digital Raster Graphic).

MN DNR Lake Bathymetric Digital Elevation Model (DEM)

The MN DNR Lakes DEM data contained bathymetric data for select lakes throughout the state. The data was in raster format with cell values representing depth. The cell size in most cases was five meters with some of the larger lakes resampled to ten meters in order to keep file sizes down to a manageable size. There were a total of 6,096 lakes in the statewide database, of which 288 intersect the Southern MN study area. Where it was available, the data was used for determining those classifications that are dependent on water depth, mainly the boundary between the limnetic (L1) and littoral (L2) subsystems within the lacustrine Cowardin system. The manner in which the data was displayed was quickly manipulated making it easy for the photo-interpreter to incorporate it into the decision making process.

2.3. Light Detection and Ranging (LiDAR) Derived Products

LiDAR Digital Elevation Models (DEM)

LiDAR was not available for the entirety of the study area. Portions of the project study area beyond the Minnesota state boundary did not have LiDAR coverage, as shown in Figure 2. Photointerpretation of the areas shown in red on Figure 2 relied solely on imagery data sources, DRG topographic maps, and SSURGO soils.

Where LiDAR was available, there was both a regular DEM and a hillshade version. The hillshade version was useful for visual interpretation while the regular DEM was the basis for geo-processing. There were both one and three meter resolutions available. In most cases the three meter product appeared to be more suitable for visual interpretation. The one meter DEM represented so much detail that it became difficult to differentiate the significant topographic features from micro-topography. Given the mapping scales for this project, micro-topography has little impact upon the wetland classification.

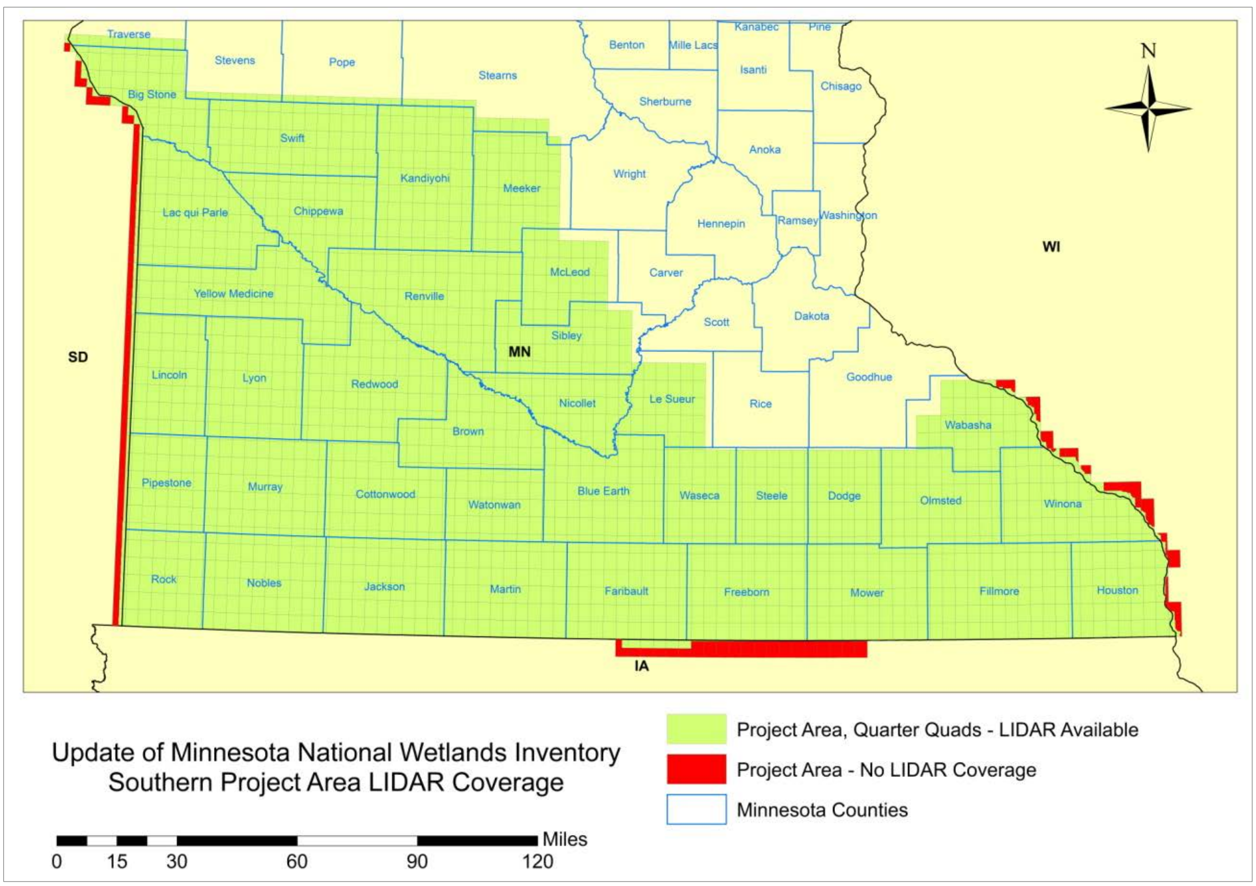


Figure 2. LiDAR Coverage for the Southern MN NWI Update Study Area

LiDAR Derived Datasets

Compound Topographic Index (CTI), Topographic Position Index (TPI), slope, and curvature were all raster datasets derived from the LiDAR data that were used to aid photointerpretation. LiDAR data was used to derive vector datasets to aid in the classification process. Examples of vector features that were derived for further assessment are elevation contours, hydrologic flow networks, and a topographic basins layer.

Compound Topographic Index – CTI, 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 at a particular location. In other words, areas with higher CTI values are more likely to collect water and be or have been wetlands.

Topographic Position Index **–** Topographic Position Index (TPI) is an indicator of the shape of the land at a given point. TPI compares the elevation at a particular point to the average elevation in the neighborhood around it. Positive TPI values indicate peaks or ridges, negative TPI values indicate valleys or depressions. A TPI value near 0 indicates either flat areas or saddles. One particular useful application of TPI is for determining the level to which streams are incised into the landscape. Definition in the size and shape of the neighborhood for the TPI analysis can affect its behavior, depending on the landscape.

Slope and Curvature – Slope and its derivative curvature are both useful in making wetland classification decisions. Highly sloped areas can often be eliminated from consideration for inclusion as a wetland. Where wetlands exist on more gently sloped areas, they are almost always saturated soil wetlands and are classified accordingly.

Hydrologic Flow Network – The hydrologic flow network is similar to features that can be found in layers such as the National Hydrography Dataset (NHD) or the stream data that is displayed on the DRG. Because they are derived from high resolution, current elevation data, they can be used to detect changes over time in the location of linear hydrologic features. These data should be considered a compliment to existing linear flow network datasets (i.e., known streams). LiDAR derived products are purely topographic in nature. In other words, just because a flow line is present in the derived data, it does not necessarily mean there is normally surface water flow associated with that feature.

Topographic Basins – Topographic basins are generated using a fill routine on the DEM. With 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 if derived from the bare-earth LiDAR. Similar to the hydrologic networks, derived basins are purely topographic in nature and by themselves do not necessarily indicate the presence of a wetland. They indicate areas on the landscape where water can potentially pool and contribute to hydric soil development. Imagery signatures or other additional supporting data are required to confirm the presence or absence of a wetland.

2.4. US Fish and Wildlife Service National Wetland Inventory Historic Data

Existing wetland data can be an aid to decision-making, provided the age and accuracy of the data is kept in context. Most of the existing data is over thirty years old and was mapped at a scale of 1:60,000 or smaller. Historic wetland data can be useful in making determinations regarding the nature and extent of temporal changes. This is especially true when combined with some of the older imagery where available.

2.5. Additional Ancillary Data

Examples of additional datasets that were proven useful for wetland mapping included public lands data, the National Hydrography Dataset (NHD), and the Minnesota Public Waters Inventory (PWI). These data were useful in a few special cases and were employed as needed, typically in verifying changes and answering broader “What is going on here?” types of questions. The age and scale of the ancillary data varies across the study area, limiting its usefulness in automated processes. In addition, in some cases, the data was actually derived from information present on other data sources that are already being used, such as the DRG. This was particularly true of the National Hydrography Dataset.

3. Data Standards

3.1. Data Format

The final data are in an ESRI ArcGIS 10.1 File Geodatabase. All wetland data resided and all processing occurred in a polygon feature class.

3.2. Projection

UTM-15N, NAD83, meters and Albers Equal Area Conic Projection, NAD83, meters. Two projections were specified because data delivery consists of two copies. The copy delivered to the Minnesota DNR was in UTM Zone 15 North, NAD 83, while the copy delivered to the US Fish and Wildlife Service (USFWS) was in Albers Equal Area Conic NAD 83 for inclusion in the NWI dataset. All draft data sets were produced using the UTM projection.

3.3. Target Mapping Unit

Wetlands greater than one half an acre in area were subject to the accuracy assessment goals described below; however, wetlands smaller than one half an acre that are visible at 1:6,000-scale were also mapped.

3.4. Horizontal Accuracy

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

3.5. Classification Accuracy

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

3.6. Cartographic Standards

Features and boundary lines were represented with a level of detail that was appropriate for the desired use scale of 1:6,000. Features smaller than one twentieth of an acre in size were not independently mapped; however, they were incorporated into the predominant adjacent class. Upland features are not mapped. In addition, the boundary lines for wetland features did not have an excessive number of vertices or have a jagged, saw-toothed appearance.

3.7. Data Verification

The data was logically consistent and topologically complete. It consisted of simple feature (single part) polygons with no overlaps and no gaps between adjacent polygons. The final data was edgematched across tile boundaries into a seamless coverage. Whenever practical, boundaries were edgematched to data for areas adjacent to the project area. The current version of the NWI verification tool was used in conjunction with internal quality assurance scripts to ensure data integrity, both in terms of delineation and attribution.

3.8. Metadata Information

Metadata for this project met the requirements of the Minnesota Geographic Metadata Guidelines. Metadata information included a tested classification accuracy statement, an error matrix, a full description of the data lineage, and spatial reference information.

3.9. Documentation

Saint Mary's University of Minnesota GeoSpatial Services (GSS) fully documented their mapping methods and provided this documentation to MN DNR for approval. Any substantial method changes required an update to the documentation and were approved by MN DNR.

3.10. Training

GSS ensured that all personnel working on this project had adequate training and kept training records on file for the State to review if necessary. Photo-interpreters working for GSS demonstrated proficiency in wetland mapping prior to conducting work on this project. Training was consistent with "Classification of Wetland and Deepwater Habitats of the United States" (Cowardin et. al. 1979).

3.11. Data Management

GSS maintained a secure system to manage input data, intermediate products, and final wetland maps with provisions for full data back-up and restoration. All input data not being viewed from the MnGeo Web Mapping Service resided on dedicated network attached storage (NAS) devices. All project work resided on the GSS projects server. Work packets were assigned to updaters by geographic area. Data is tracked through the work flow (Figure 3) by the project manager. Copies of the work packet data were saved at major milestones, such as edits completed and QA approved. GSS was to maintain a copy of the data for at least one year after the completion of the project. The GSS project server was differentially backed up daily with a full back up performed weekly and stored in multiple locations.

3.12. Classification

This National Wetland Inventory mapping project classified wetland features using three different classification systems. The data consisted of one attribute table with separate fields for each system. The three systems were the Federal Geographic Data Committee (FGDC) Wetland Mapping Standard (Cowardin et.al.1979), referred to in this document as simply the Cowardin classification, the Simplified Hydro-Geomorphic Classification (adapted from Tiner, 2003), and the Simplified Plant Community Classification (Eggers and Reed, 1997).

3.12.1. Cowardin Classification

Wetlands were mapped and classified according to Cowardin et al. (1979) including the system, subsystem, class, sub-class, water regime, and special modifiers. Modifications to the Cowardin classification, as specified in the document titled, “Supplemental Guidance for the Classification of Wetlands of the National Wetlands Inventory for Minnesota” (Kloiber, 2011), was incorporated to address the specific conditions unique to Minnesota. Table 1 below contains the codes that were valid for the Minnesota NWI Update. Because the Cowardin system is the most explicit and highly resolved of the classifications used in this project, its polygonal features served as the foundation to which the additional Simplified Hydro-Geomorphic Classification and Simplified Plant Community Classification were attached.

Table 1. Valid Cowardin Codes

Valid NWI Cowardin Codes for Southern MN NWI Update					
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	1,2,4	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

3.12.2. *Simplified Hydro-Geomorphic Classification*

In addition to the Cowardin classification, the wetland data also included a set of attributes to describe the hydro-geomorphic setting of wetlands based on the Landscape Position, Landform, Water Flow Path, and Waterbody Type (LLWW) system (Tiner, 2003). This “simplified hydro-geomorphic” classification (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, SHGM uses codes to describe wetland characteristics. The schema is described below and keys are included in the appendix (Section A10). SHGM differs from the full LLWW in that no modifiers are applied. SHGM makes a distinction between wetlands and waterbodies. Wetlands are vegetated, while waterbodies are essentially deepwater habitats. The coding schema can actually take two slightly different forms depending on whether the feature is being classified as a wetland or a waterbody. Vegetated wetlands (e.g. marshes and wet meadows) and non-vegetated substrates that are periodically exposed (e.g. mud flats) are classified using the wetland landscape position and landform codes of the schema. The vertical bars divide the schema into its components.

Landscape Position | Landform or Water Body | Water Flow Path

Landscape Position is a two letter code that describes whether the wetland is associated with a lake, 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 upland as part of an isolated basin are classified as terrene (**TE**). Landform is the second portion of the code which refers to the geomorphic structure on or in which the wetland resides. There are six inland landforms present in Southern MN. These are slope (**SL**), island (**IS**), fringe (**FR**), floodplain (**FP**), basin (**BA**), and flat (**FL**). In SHGM, any deepwater habitat is considered to be a water body and is classified using the waterbody type codes and attributed into the landform code. The water body coding schema consists of an uppercase two letter code. Four waterbody types are present in Southern MN; these are lake (**LK**), river (**RV**), stream (**ST**), and pond (**PD**). When a feature is classified as a water body it is considered to be its own landform. The next component of the code is Water Flow Path which applies to both wetlands and water bodies as defined by SHGM. Water flow path refers to how and if the feature is part of the surface hydrology network. Common examples of the water flow path code include bidirectional flow (**BI**), in flow (**IN**), through flow (**TH**), out flow (**OU**). Wetlands that are not connected to the surface hydrology network are classified as isolated (**IS**). Most of the water flow path codes are the same for both wetlands and water bodies. However, there are some small differences between them so the keys in Section A10 need to be followed 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 or available remotely-sensed geographic data products.

SHGM codes are either six characters in length for wetlands or four characters in length for waterbodies. Some examples of complete codes 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 a located on the fringe (**FR**) of a stream (**LS**). It has through flow (**TH**).

LRFPTH – 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 through flow (**TH**).

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

LELKIN – 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.

TEPDIS – This code refers to a water body that is a pond (**PD**) that is isolated (**IS**) from the rest of the surface hydrology network.

The SHGM codes that are expected to be found in Southern MN are shown in Table 2 below. Refer to Section A10 for the dichotomous keys used to apply these codes.

Table 2. SHGM Codes

Simplified Hydro-Geomorphic Classification (SHGM) Descriptors for The Southern MN NWI Update adapted from Tiner, 2003					
Landscape Position		Landform		Water Flow Path	
Code	Description	Code	Description	Code	Description
LE	Lentic	SL	Slope	IS	Isolated
LR	Lotic River	IS	Island	IN	Inflow
LS	Lotic Stream	FR	Fringe	OU	Outflow
TE	Terrene	FP	Floodplain	TH	Throughflow
		BA	Basin	BI	Bidirectional-Nontidal
		FL	Flat		
Waterbody					
Code	Description				
LK	Lake				
RV	River				
ST	Stream				
PD	Pond				

The wetland features created during the Cowardin Classification process served as the foundation for creating SHGM data. The wetland data had an additional field added to the attribute table which was populated with the SHGM codes. Waterbodies as well as wetlands were classified using the SHGM system. The entire procedure for SHGM classification is outlined in the succeeding Project Workflow section.

3.12.3. Simplified Plant Community Classification

A simplified plant community classification (SPCC) based on a modified version of the Eggers and Reed (1997) classification system was applied to all wetland features. The attributes were applied as described by the supplemental guidance document provided by the MN DNR (Kloiber, 2011). Table 3 below illustrates the codes that were applied in the Southern Minnesota NWI Update and their corresponding classes in Eggers and Reed. It should be noted that the peatland and bog attributes have been left in although it is not likely that there will be large areas or numbers of them in the Southern Minnesota project area.

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 4 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 of this document.

Table 3. Simplified Plant Community Classes Cross-Referenced to Eggers and Reed

MN Simplified Plant Community to Eggers and Reed Plant Community Southern MN NWI Update Cross Reference Table			
MN Simplified Plant Community		Eggers and Reed 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	Calcerous 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	Calcerous Fens (Shrub Type)
8	Hardwood Wetland	3B	Hardwood Swamps
		3A	Floodplain Forests
9	Coniferous Swamps	4B	Coniferous Swamps
10	Non-Vegetated Aquatic Community	-	N/A

Table 4. Simplified Plant Community to Cowardin Cross-Reference

Simplified Plant Community to Cowardin Classifications Southern Minnesota NWI Update Cross Reference Table				
Simplified Plant Community Classes				
Seasonally Flooded Basin	Wet Meadow	Shallow Marsh	Deep Marsh	Shallow Open Water Community
PEM1A	PEM1Bb	PEM1C	PABF	L2UBF
	PEM1Bd	PEM1F	PEM2F	L2UBH
	PEM1Bh		PEM2H	L2ABF
	PEM1Bx			L2ABH
				L2EM2F
				L2EM2H
				PUBF
				PUBH
				PABH
				R2ABH
				R2EM2F
				R2EM2H
Simplified Plant Community Classes				
Peatland	Shrub Wetland	Hardwood Wetland	Coniferous Swamps	Non-Vegetated Aquatic Community
PMLBq	PSS1A	PFO1A	PFO2A	L1UBH R2RSA
PEM1Bq	PSS1B	PFO1B	PFO2Bb	L2RSA R2RSC
PSS2Bq	PSS1C	PFO1C	PFO2Bd	L2RSC R2USA
PSS3Bq	PSS2A		PFO2Bh	L2USA R2USC
PSS4Bq	PSS2Bb		PFO2Bx	L2USC R3RBF
PFO2Bq	PSS2Bd		PFO2C	L2RBF R3RBH
PFO4Bq	PSS2Bh		PFO4A	L2RBH R3UBF
	PSS2Bx		PFO4Bb	PRBF R3UBH
	PSS2C		PFO4Bd	PRBH R3RSA
	PSS4A		PFO4Bh	PUSA R3RSC
	PSS4Bb		PFO4Bx	PUSC R3USA
	PSS4Bd		PFO4C	R2RBH R3USC
	PSS4Bh			R2UBH R4SBA
	PSS4Bx			R4SBC
	PSS4C			

4. Project Workflow

4.1. Introduction

The project can be broadly broken down into phases. The first phase consisted of initial field visits, developing a photo-interpretation guide, and documenting the technical procedures. The second phase was data production, which can be further subdivided into draft data production and final data preparation. Data quality was evaluated with respect to the data standards (Section 3). These were based on existing standards for NWI data and state specific standards provided by MN DNR. 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. Sample data were used to prototype the technical procedures and photo-interpretation guide. Once the sample data were approved and the technical procedures were finalized, data production began.

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

4.2. Process Documentation

This document, as well as the Photointerpretation Guide (Appendix A), define the delineation and classification process for the Southern MN wetland mapping project. The Technical Procedures document explains the standards and procedures of the project. The Photointerpretation Guide provides specific direction on particular signatures and classification. Both of these documents were treated as working drafts, allowing for amendments as the project proceeded.

4.3. Field Verification and Review

Field verification is a vital part of the photointerpretation process. There were several objectives of this verification, they included:

1. Documentation of commonly occurring signatures and habitats;
2. Documentation unusual but important signatures;
3. Determination and verification of the classification of difficult to distinguish signatures, including distinguishing between upland and wetland;
4. Verification of water regimes;
5. Documentation of the 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 shapefile or geodatabase feature class of the site locations. The site locations were then used to plan the logistics of the field trip and uploaded to a GPS for navigational purposes. Field visits were focused during the spring after the ground thawed, but before vegetation leaf flush was complete. This made it easier to observe conditions on the ground. For sites on public land, formal documentation of the site was possible. Formal documentation included the collection of a GPS point at the site location, a soil probe test, and completion of a field data sheet which recorded location, ownership, soil test results, vegetation species, etc. For sites on private land only informal documentation was completed. Informal documentation typically consisted of examination of the site from a public right of way. In both cases (public and private sites), ground level photographs documenting the site and notes and/or delineations on hard copy maps were gathered.

4.4. Data Production

Data production involved on-screen digitizing methods using ESRI's ArcGIS 10.1 software where ArcMap was the editing platform. Work packets were assigned based on geographic area. Figure 3 graphically represents the production workflow. Delineation and classification using the FGDC Cowardin system was the first and most labor intensive stage of data production. This stage occurred at the 7.5 minute quadrangle level. The second phase was the assigning of the LLWW and SPCC attributes to the data. This occurred at the county level. The third phase was the MN DNR draft review phase. At this stage the draft data was submitted in individual county-level data packages to MN DNR via a web mapping service (WMS) for review and feedback. When approved the data moved to the final stages of processing. If the County-level data was not approved GSS incorporated MN DNR's feedback into the final geodatabase. The fourth and final stage was edgematching and final data generation. The approved county-level data was edgematched to create a seamless data set for the entire study area. The NWI QA tools were applied to the data and any errors were fixed. Upon successful completion of the NWI tool runs, two copies of the data were made, one for submission to MN DNR and one to the USFWS NWI database, each in their preferred projection.

4.4.1. Software and Data Management

ESRI ArcGIS 10.1 was the GIS software platform utilized in this project. The file geodatabase data structure was used for the wetland data. A hard copy form referred to as a "routing sheet" was generated for each 7.5 minute quadrangle work packet. The routing sheet contained all of the information the updater needed to create an ArcMap document (.mxd) for the assigned work area as well as provided a place for tracking other pertinent information such as the time to complete edits. The project lead was responsible for assigning work packets, generating the routing sheet, and maintaining the digital data file structure. Each updater had a folder in a working directory (location on the shared server). The project lead created a blank geodatabase in this working folder for each work packet assigned. All edits took place within this 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 and it served as a "snapshot" of the data for that particular stage of production. Once the work packet was approved by QA, an additional copy was made in another location in order to segregate completed data from in-process data. This was done as a data security measure in addition to GSS' organization-wide data back-up system.

The collateral data for this project resided in two locations, a dedicated network attached storage (NAS) device and the MN Geo aerial imagery web mapping service (WMS). The WMS was used for the true-color NAIP imagery and as a back-up for the Spring, 2011, false-color infrared imagery. 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 we are able to apply a standard deviation stretch (an option in the symbology tab for rasters in ArcMap ArcGIS 10.1) 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 was not inadvertently edited, permissions were set on the NAS device so that only the project lead had write privileges.

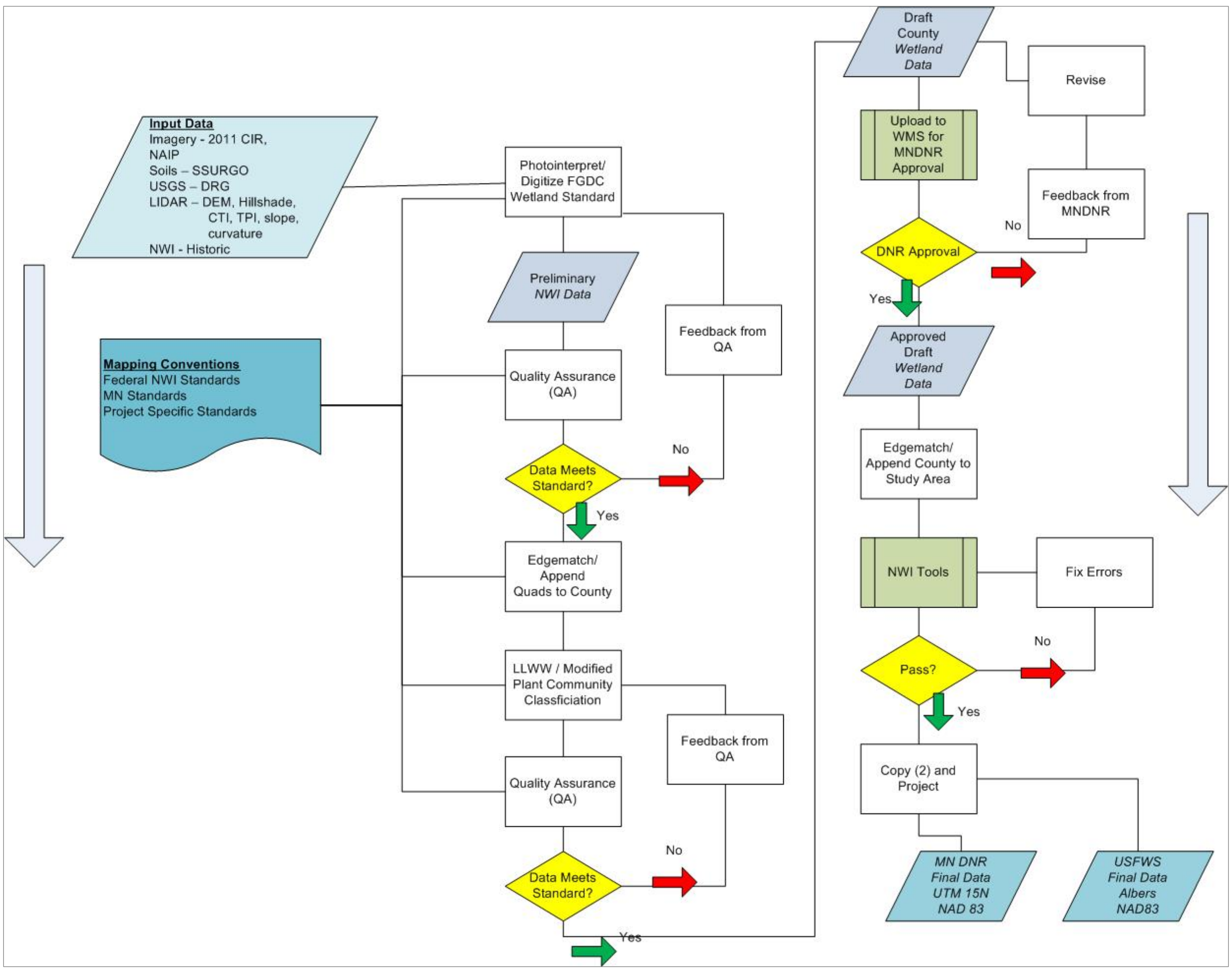


Figure 3. Southern MN NWI Update Work Flow

4.4.2. On-Screen Photointerpretation Process –Delineation & Cowardin Classification

This project involved an on-screen, heads-up, digitizing process, utilizing the editing tools available ArcMap, to delineate and classify wetland features based on photo signatures in ortho-rectified imagery, and supporting collateral data. The Photointerpretation Guide (Appendix A) explains the specifics of how the source imagery and collateral data are applied to delineate and classify each Cowardin wetland type in the Southern MN study area.

1. The updater started by creating a new ArcMap map document (.mxd). The first data added to the .mxd was the blank wetlands geodatabase in order to ensure the data frame is set to UTM Zone

15 North, NAD 83. Imagery data sources and the collateral data sources were added next. The end result was an ArcMap window similar to the example in Figure 4.

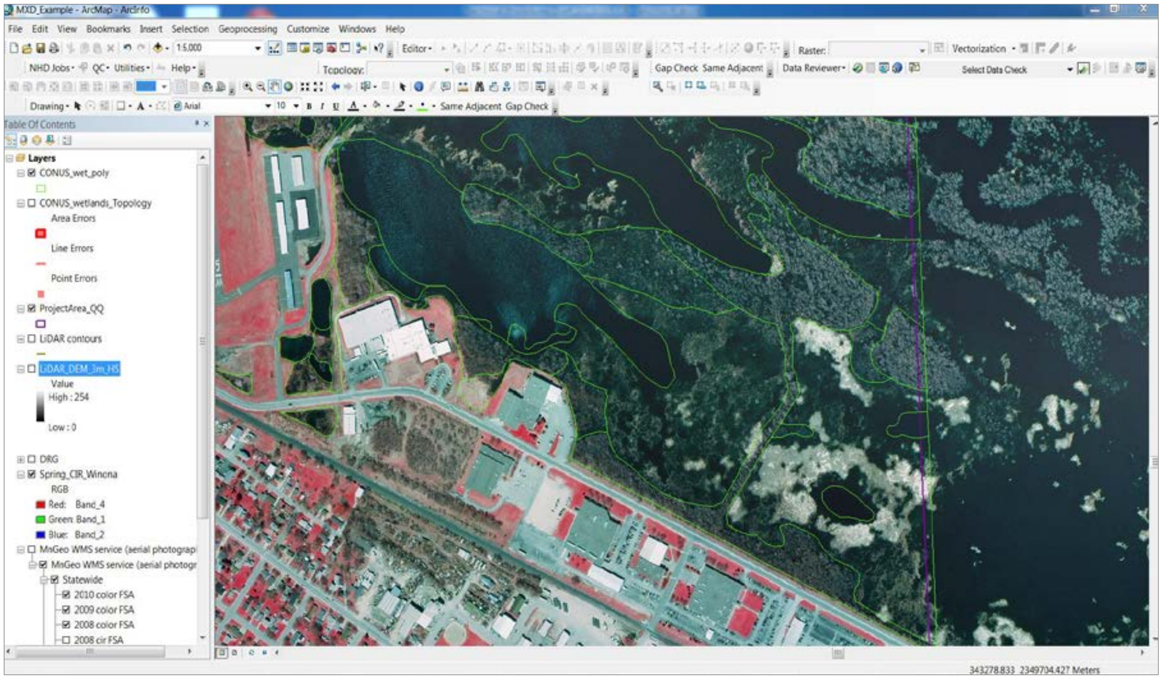
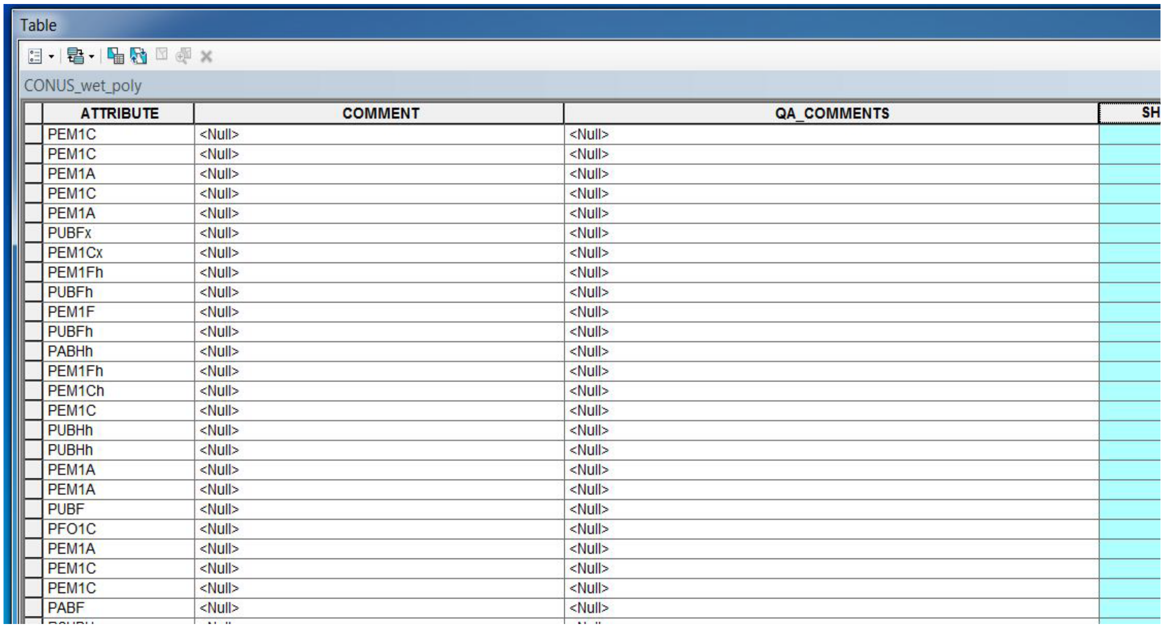


Figure 4. Typical ArcMap .mxd Window

2. To clearly see signatures, the wetland polygons were displayed as hollow with a line weight between 0.5 and 1 in a line color that contrasted 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 allowed the use of the near infrared band. A standard deviation stretch of 2 was also applied to the CIR to help make the wetland signatures, especially emergent signatures, easier to distinguish. Display of the other data layers was at the discretion of the updater. However, any display color or technique that interferes with photointerpretation was not allowed, such as non-contrasting colors, and excessively heavy line weights.

3. The entire extent of the assigned work area was examined for wetlands. This was accomplished by systematic scanning the entire extent at a 1:6,000 geographic scale. 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.

4. Wetland classification utilized the Cowardin system and occurred by directly editing the *ATTRIBUTE* field in the CONUS_wet_poly feature class’ attribute table (Figure 5).



ATTRIBUTE	COMMENT	QA_COMMENTS	SH
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. CONUS_wet_poly Feature Class, Attribute Table

The editor 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 updater panned across the map sheet 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 updater panned south one “row” and started the next pass moving from east to west. Along the edges of their assigned area the updater consulted with the updater of the neighboring work area to assure consistency across the study area. Any delineation along the edge was overlapped by 50 – 100 meters outside of the work area to expedite edgematching. The panning process continued until the entire work area was examined and the wetland features were delineated and classified. At this point the updater was required to perform a series of finalization tasks to prepare the work packet for quality assurance.

4.4.3. On-Screen Photointerpretation Process – Updater Finalization Tasks

The updater work packet finalization tasks were essentially the first stages of the quality assurance (QA) process. These tasks can be viewed as a “self QA” by the updater. It was a vital step in making sure the data being produced met the project standards. The objective of this procedure is to eliminate as many errors and issues with the data as possible before the data were sent to QA. This helped QA to 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 work area (quarter quad, quadrangle etc.) was finalized by performing the following tasks:

1. The CONUS_wet_poly attribute table was sorted on the *ATRIBUTE* field in ascending order in order to find null and blank entries. A Null or blank entry in the attribute field occurs for a couple of reasons. The updater may have neglected to assign a value to the feature. It also occurs when a “ghost” polygon is created. A “ghost” polygon has an entry in the attribute table, but has no associated geometry in the feature class. They typically are created because of computer issues

such as momentary network service interruptions that occur in the middle of creating or reshaping a polygon. Missing attributes were populated by the updater and “Ghost” polygons were deleted.

2. All polygon features were selected and exploded to split any multi-part features into separate polygons. This step was repeated until no multi-part features were available to explode.

3. The CONUS_wet_poly attribute table was sorted on *SHAPE_Area* in ascending order. The smallest polygons were at the top of the table, making it easier for the updater to verify any polygons less than a quarter-acre (~1,000 square meters) should exist. This was 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, features less than one-tenth of an acre (~400 square meters) that were part of a complex were merged with the adjacent feature. However, 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 can be retained, (i.e., PUBF farm ponds).

4. A check for erroneous attributes was conducted by selecting by attribute on the *ATTRIBUTE* field of the CONUS_wet_poly table. This was a quick way of getting a list of attributes present in the data. Once the Select by Attribute graphical user interface (GUI) was open (Figure 6), first click on “ATTRIBUTE” in the field list (red arrow) then click the “Get Unique Values” button which will populate the values list as shown in the figure. This will most likely require scrolling through the list. Common errors include invalid attributes (refer to Table 1 for valid attributes), capitalization errors (PeM1A versus, PEM1A), missing code components (RUSC vs. R2USC), and typographic errors such as using a zero (0) for the letter O (PF01C vs. PFO1C). The attributes are directly edited in the table to fix errors, and may require looking back to the imagery to rectify errors.

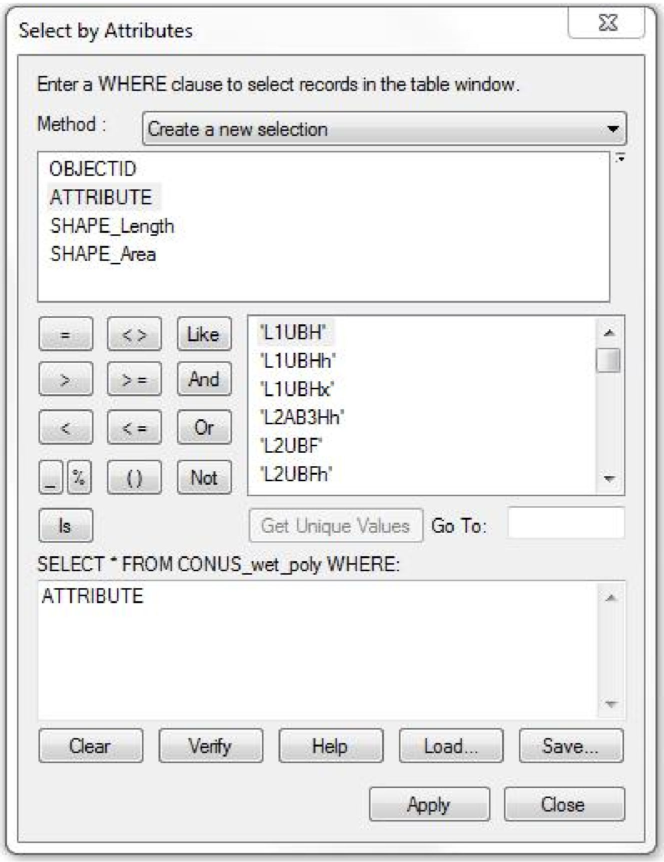


Figure 6. Select by Attribute GUI.

5. Topology was used to look for line work issues. At this stage the only topological rule applied was "must not overlap." The "must not have gaps" rule was be applied by the QA analyst. The updater validated topology and fixed errors. The topology was validated again and errors fixed. The process was repeated until overlaps were fixed.

6. After successfully completing steps 1-5, the work packet was considered complete and ready for QA. The updaters' last step was to record their time and any relevant notes on the routing sheet and return it to the project lead.

The work packet was considered complete when all of the above tasks were executed, errors fixed and the finalization tasks all came back error free.

4.4.4. Quality Assurance – Wetland Delineations and Cowardin Classification

After finalization, the work packet was sent through the quality assurance process. This process was performed by the project lead and/or senior photointerpreter, referred to here as the QA analyst.

5. Opening the updater's .mxd, the QA analyst verified that all of the updater finalization tasks were successfully completed; if they were not, the work packet was returned to the updater to complete the tasks. The .mxd was saved to a different folder as a separate QA .mxd.

6. Using the QA .mxd, the entire work area was reviewed at a 1:6,000 scale using a systematic horizontal panning technique to guarantee 100% of the work area was checked. QA analysts had the same data available to them as the updater had when performing the delineations; however they had the option to utilize additional tools and techniques to make wetland interpretation calls in unclear situations. QA Analysts verified that the data meets the standards described in this document, checking the following:

    a. Accurate delineations – the wetlands boundaries were correct based on signatures and supporting collateral data. No wetlands were omitted. No uplands were included.

    b. Correct Cowardin classifications – attribute values matched photo signatures based on imagery and supporting collateral data. All attributes were valid. There are no NULLS, and split classes were applied appropriately.

    c. Line work - smooth with no jagged edges. Feature sizes were in line with the minimum mapping unit guidelines, and there were no multi-part features. There were no incorrect (sliver) gaps between polygons and no polygons that overlap adjacent polygons.

    d. General accuracy and consistency – updater consistently and correctly delineated and classified similar signatures across the work area and the updater's decisions conformed to the Southern MN mapping standards.

7. When issues were identified, QA Analysts uses the QA_COMMENTS field in the attribute table and box graphics in the .mxd to provide feedback. Not all errors were necessarily identified, but enough were identified to illustrate any patterns of errors present in the data. If necessary, QA Analysts reviewed the issues with the updater and return the work packet so the updater can perform revisions. The updater performed the requested revisions, repeated the finalization tasks and gave the work packet back to QA to start the QA process again. Generally, it is not QA Analysts' 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 Analysts performed the revisions rather than return it to the updater.

8. The work packet was finalized. The finalization tasks and checks were run against the data again by QA. During the topology checks, the data was additionally checked for gaps. This was accomplished by adding a "universal polygon" around the work area (Figure 7), adding the "must not have gaps" rule to the topology and verifying topology. The universal polygon is temporary and is created by drawing a box around the entire work area using the auto-complete editor tool.

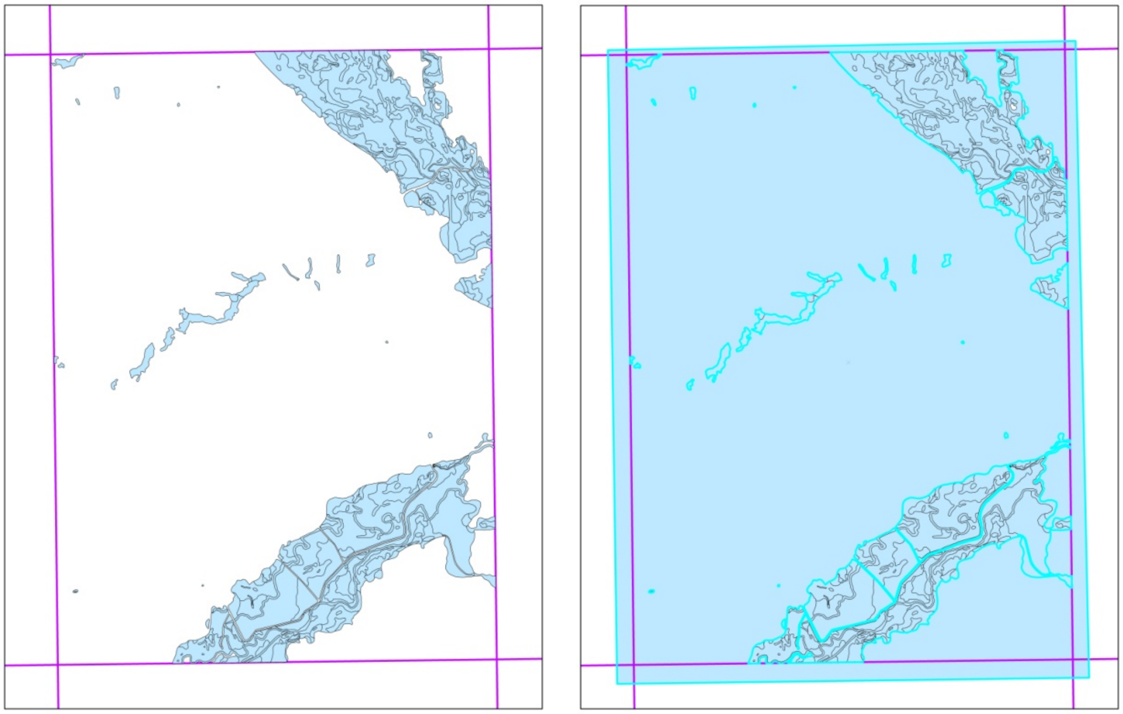


Figure 7. Universal Polygon before and after; highlighted polygon in right hand graphic is the "universal polygon."

9. 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. After this there were many times false positive "must not have gaps" errors where there are uplands surrounded by wetland. However, this approach reduced the number of false positives while still locating the true gap errors, many of which were tiny sliver gaps that were often too 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 was free of topological errors. The universal polygon was then deleted.

10. A backup copy was created and stored in a different location from the working data. The data was then considered complete in regards to delineation and FGDC classification.

Because the Cowardin Classification system is the most specific and results in the most highly resolved data, the spatial features serve as the foundation for the other classification systems. At this point, it was expected that, with the exception of edgematching, no further geometry edits would be required.

4.4.5. Edgematching – 7.5 Minute Quadrangle Work Packets to County

Since the next production phases of LLWW and Simplified Plant Community (SPCC) classifications were landscape level classifications that can be performed at smaller geographic scales, the 7.5 minute quadrangle work packets were appended and edgematched into county-wide data sets. The ESRI Simple Data Loader was utilized to perform the append process. After each work packet was appended, edgematching was performed by panning along the work packet boundaries at a scale of 1:6,000 and using the ArcMap editing tools to merge those areas that were split by the boundary, creating seamless data. Edgematching occurs incrementally as work packets are approved by QA Analysts. Work packets crossing county boundaries were not cut at those boundaries, but included with the county that covered the majority of the work packet.

4.4.6. On-Screen Photointerpretation Process – SHGM Classification

SHGM is a landscape level classification that is performed at smaller scales (1:10K and smaller) than the Cowardin classification; therefore, applying the classification to the seamless county sized data was reasonable. SHGM attributes were added in a separate field to the county wide data, not in a separate dataset. Again, using the panning techniques described in the Cowardin classification section, the updater works through the county at a scale of 1:10,000. Given the landscape nature of SHGM and its more system-wide focus the updater has latitude to zoom as far in or out as required to make decisions. In most cases the classification scale is between 1:5,000 and 1:20,000. The *SHGM_ATTRIBUTE* field stores the classification code in the attribute table. Since the line work is not edited, classification occurs at landscape scale. Large complexes of wetland polygons are often classified very similarly, if not identically. It is possible to assign SHGM attributes quickly.

4.4.7. Simplified Plant Community Classification – A Query Process

The Simplified Plant Community Classification (SPCC) is based entirely on the cross-reference relationships between the Cowardin and the SPCC outlined in Table 4. It was a relatively straight forward exercise in using SQL database queries in the ArcMap “Select by Attribute” GUI to first select those 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 for efficiency. Figure 8 shows an example of one of the simpler queries, which is for the Hardwood Wetland SPCC class. The data for each county needed examination in order to gain an understanding of which Cowardin codes are present to make sure all codes are addressed by the queries.

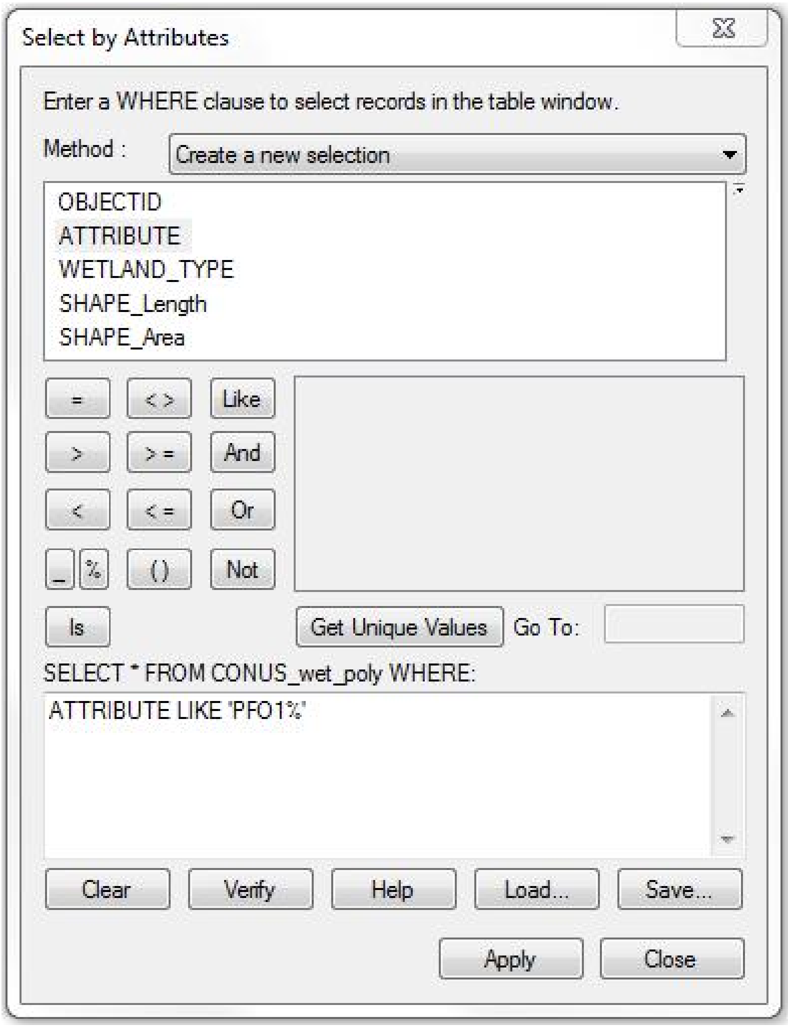


Figure 8. SPCC Query for Hardwood Wetland Class.

4.5. Draft Data Approval

The QA assessment, as described previously, was repeated on the county-wide data after all classifications were performed. Upon QA approval, the draft county wide data were then submitted to the MN DNR through a Web Mapping Service (WMS) served over the internet by GSS for review. After review, MN DNR approved data or some cases provided feedback for GSS to make necessary revisions and resubmit. Similar to the internal QA previously performed, the process is repeated until the data are approved.

4.6. Final Processing

Upon approval by MN DNR, the county data was appended to the study area wide dataset and edgematched. The end result was a seamless dataset with coverage of the entire Southern Minnesota NWI Update study area (Figure 1). The national NWI Verification Tool developed by the USFWS NWI Program was run against the data. These tools did not find many errors, because the internal QA processes previously performed were designed to find and fix the same errors as the NWI tools. When errors were found, the data was revised and the tools run again until all errors have been identified and addressed or documented. Upon successful completion of the NWI tool run, two copies were generated; one copy, for submittal to MN DNR, remained in UTM 15N, NAD83, the other copy was projected to Albers, NAD83 and submitted to the USFWS for inclusion in the nationwide NWI dataset.

5. References

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Kloiber, Steve and MacLeod, Robb (2011). Supplemental Guidance for the Classification of Wetlands for the Update of the National Wetland Inventory for Minnesota. Minnesota Department of Natural Resources.

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

Appendix A: Photointerpretation and Classification Guide

Updating the National Wetlands Inventory for Minnesota: Southern Project Area

June 28, 2013

GeoSpatialServices

Saint Mary's University OF MINNESOTA

A1. Introduction

The purpose of this document is to provide guidance on the application of imagery and collateral data in the photointerpretation process for mapping wetlands within the Southern 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 the examples are intended provide a basis for consistent delineation and classification of the majority of wetlands across the study area.

The study area has portions of three ecological sections within it. These ecological sections include: Paleozoic Plateau, Minnesota and NE Iowa Morainal, and North Central Glaciated Plains. The North Central Glaciated Plains make up approximately 70% of the study area, with the balance divided evenly between the Minnesota and NE Iowa Morainal and the Paleozoic Plateau ecological sections. In the western portion of the study area, the North Central Glaciated Plains are relatively flat to gently rolling hills. Moving eastward, the Minnesota and NE Iowa Morainal is made up of level plains and low irregular hills associated with edges of past glaciation. Moving yet further east toward the Mississippi River, the Paleozoic Plateau is a highly dissected upland plateau characterized by broad steep sided ridges divided by broad valleys exhibiting dendritic drainage patterns. Generally, local relief increases moving from west to east.

The entire study area is heavily impacted by agriculture. Generally, tilled areas become more fragmented moving west to east across the study area because of the changes in local relief across the landscape. In the western sections wetlands are often identified on the imagery because they are not tilled. While in the eastern sections lack of tillage is not as likely to indicate wetland presence due to the steep and irregular grades that are more common in these areas.

The following pages contain imagery (i.e., aerial photography) and relevant collateral geospatial data examples of common wetland signatures present in the Southern MN project area as well as descriptions of some specific relevant situations (e.g., large river floodplains). The examples are organized where possible by Cowardin system. The objective of this document is to provide photointerpretation examples relevant to the Southern MN project area. Please refer to Cowardin (1979) for more detailed explanations of the classification system.

A2. 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 Southern 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.

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. See Figure A1. In Southern Minnesota, they occur in natural depressions as well as dammed river channels. Typical photo signatures are flat with dark blue to almost black tones on the Spring CIR 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, DEMs, and DRGs. Additionally, where available, the MN DNR lake DEMs are used within the protocol defined below in Section A3 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.

L2UBH

System: Lacustrine
  Subsystem: Littoral
    Class: Unconsolidated Bottom
      Water regime: Permanently Flooded

L2UBH features are those open water areas that are less than two meters (6.5 feet) in depth and permanently flooded. They often occur along the edges of L1UBH features, but shallow open water areas of lakes may be entirely classified as L2UBH if they are shallower than 2 meters (Figure A1). In Southern Minnesota they occur in natural depressions as well as dammed river channels. Typical photo signatures are identical to the photo signatures for L1UBH. Sometimes it is present with slightly lighter tones or rougher textures which are indications of shallower water. Collateral data is the primary source for determining the L1/L2 boundary.

Collateral data include imagery, LiDAR, DEMs, and DRGs. Additionally, where available, the MN DNR Lake DEMs are used within the protocol defined below in Section A3 to find those areas that are less than two meters (6.5 feet) in depth. A hydrologically enforced water body on the LiDAR DEM is also an indication that can help define the outer boundary of these wetlands.

Figure A1. L1UBH/L2UBH Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, and 2008 NAIP.

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 (Lemnaceae). They often occur along the edges and in sheltered areas of lacustrine basins (Figure A1). 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 2010, true-color NAIP are flat in texture and bright green in tone, although in some cases they present as flat dark brown on the 2010, true-color NAIP. The location of the aquatic bed imagery can vary considerably from year to year, in which case the 2010 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 below in Section A3 to find those areas that are less than 2 meters (6.5 feet) in depth.

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 Southern Minnesota, they typically occur in natural depressions. Typical photo signatures are flat in texture and blue to 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 A2).

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 below in Section A3 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. See Figure A2. 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 2010, 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 seems to vary considerably from year to year, in which case the 2010 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. Additionally where available, the MN DNR Lake DEMs are used within the protocol defined below in Section A3 to find those areas that are less than two meters (6.5 feet) in depth.

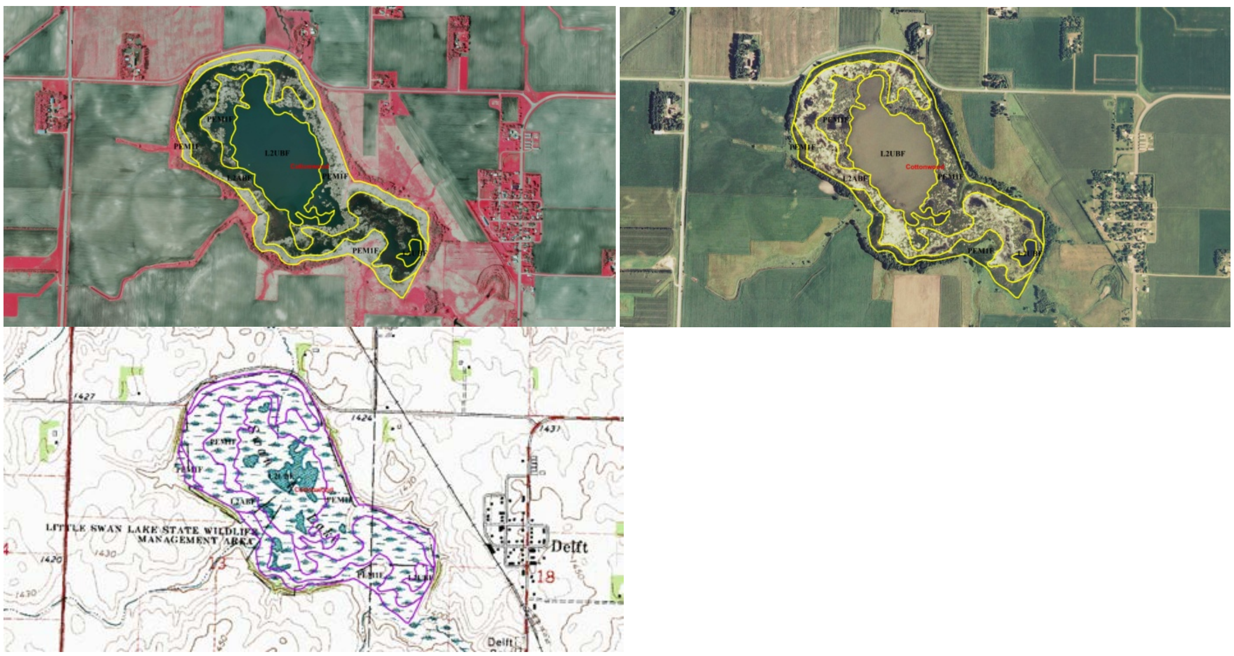


Figure A2. L2UBF/L2ABF Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, and DRG.

A3. L1/L2 Boundaries

Not all characteristics required for classification are easily distinguished from remotely sensed imagery. Deciding where to divide the lacustrine system between its littoral (L2) and limnetic (L1) subsystems is a prime example. For this determination a variety of collateral data and the following protocol is used. Most lakes in the Southern Minnesota project area are relatively shallow, so the protocol first attempts to identify the lake as entirely L2. If that doesn’t provide enough information, the goal is to use the best data that are available to determine the location of the L1/L2 boundary or determine 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. See Figure A3 for an example. This feature class is located on the GSS server at: S:\Hydro\Max_Depth_data_MNDNR_Hydro\DNR Hydrography_Southern_MN.gdb.

Table

DNR_Hydro_Southern_MN

USCLASS	LAKE_NAME	ALT_NAME	LAKE_CLASS	REGION	CTY_NAME	FSH_OFFICE	REDIG_SRC	SRCVERSION	ACRES	SHORE_MI	UTM_X	UTM_Y	Depth_Max
421	Coombs		0	0	Meeker		ORIG DLG	2004.07.08.1	106.909551	2.923912	378313.044236	3095.994285	<Null>
111	Coon Creek Marsh		0	0	Lyon		ORIG DLG	2004.07.08.1	304.039915	4.201317	256653.978624	3053.461919	<Null>
421	Copeman Pond		0	0			PWI	2011.09.22.1	0.363483	0.090184	569610.621894	3012.678681	<Null>
421	Corabelle		43	4	Murray	Windom	2004 FSA	2007.08.23.1	106.230821	1.544265	274930.918304	3021.112408	6
421	Cory		0	4	Lac Qui Parle	Ortonville	2004 FSA	2007.09.07.1	92.081596	2.007516	249585.688041	3093.374034	5
421	Cottonwood		43	4	Lyon	Spicer	2010 FSA	2012.01.11.1	382.598909	3.74877	287314.416345	3071.97528	7
421	Cottonwood		43	4	Cottonwood	Windom	2004 FSA	2007.06.26.1	154.971442	3.471262	331384.973105	3020.144807	10
109	Cottonwood		0	0			PWI	2011.09.22.1	492.829472	4.69295	250055.582029	3050.158004	<Null>
421	Cottonwood		0	4	Blue Earth	Waterville	2004 FSA	2007.05.22.1	125.995687	1.756045	431295.325923	3023.6352	5
421	Cottonwood		0	0	Watonwan		ORIG DLG	2004.07.08.1	91.763787	1.534521	360229.717628	3031.287109	<Null>
610	Cottonwood		0	0			PWI	2011.09.22.1	116.729475	1.808265	382321.225826	3061.619205	<Null>
108	Craven Detention		0	0			PWI	2011.09.22.1	9.839677	0.778149	575281.805026	3021.845567	<Null>
421	Creek		0	0	Martin		ORIG DLG	2004.07.08.1	145.47221	2.076098	368709.273328	3011.57256	<Null>
421	Crook		0	0	Kandiyohi		ORIG DLG	2004.07.08.1	67.703259	2.140611	329837.080316	3126.055444	<Null>
421	Crook		0	0	Pope		ORIG DLG	2004.07.08.1	17.78441	1.008154	327884.805293	3126.365044	<Null>
421	Crook		0	4	Kandiyohi	Spicer	2010 FSA	2012.01.13.1	318.023516	5.025605	334798.521282	3114.926257	<Null>
610	Crooked		0	0			PWI	2011.09.22.1	246.142662	6.181223	272030.177123	3036.565589	<Null>
610	Crooked		0	0			PWI	2011.09.22.1	120.921557	3.649756	354679.016519	3106.444047	<Null>

1045 (1 out of 5536 Selected)

Figure A3. Maximum Depth Example for Cory Lake, Lac qui Parle County.

2. If the maximum depth is absent, null, or greater than or equal to eight feet proceed to step 2. 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.

3. If the maximum depth in the MN DNR Hydrography (step 1) 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 the entire lakebed is less than two meters in depth. The data is located on the GSS server at: S:\Hydro\MN_DNR_Lake_DEMs\<county name>\mndnrdata\dowlknum\. Each folder at this location contains the data for one 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. The deeper class is symbolized with a dark blue and the shallower class with a light green. The boundary is digitized with the blue areas classified as L1 and the green areas as L2. If the entire basin is shown in light green it is classified as L2. This data is available for 288 lakes within the study area. Figure A4 illustrates both the symbolized lake DEM and the digitized boundary. All areas greater than two meters deep and larger than 0.1 acres (400 square meters) in size will be mapped.

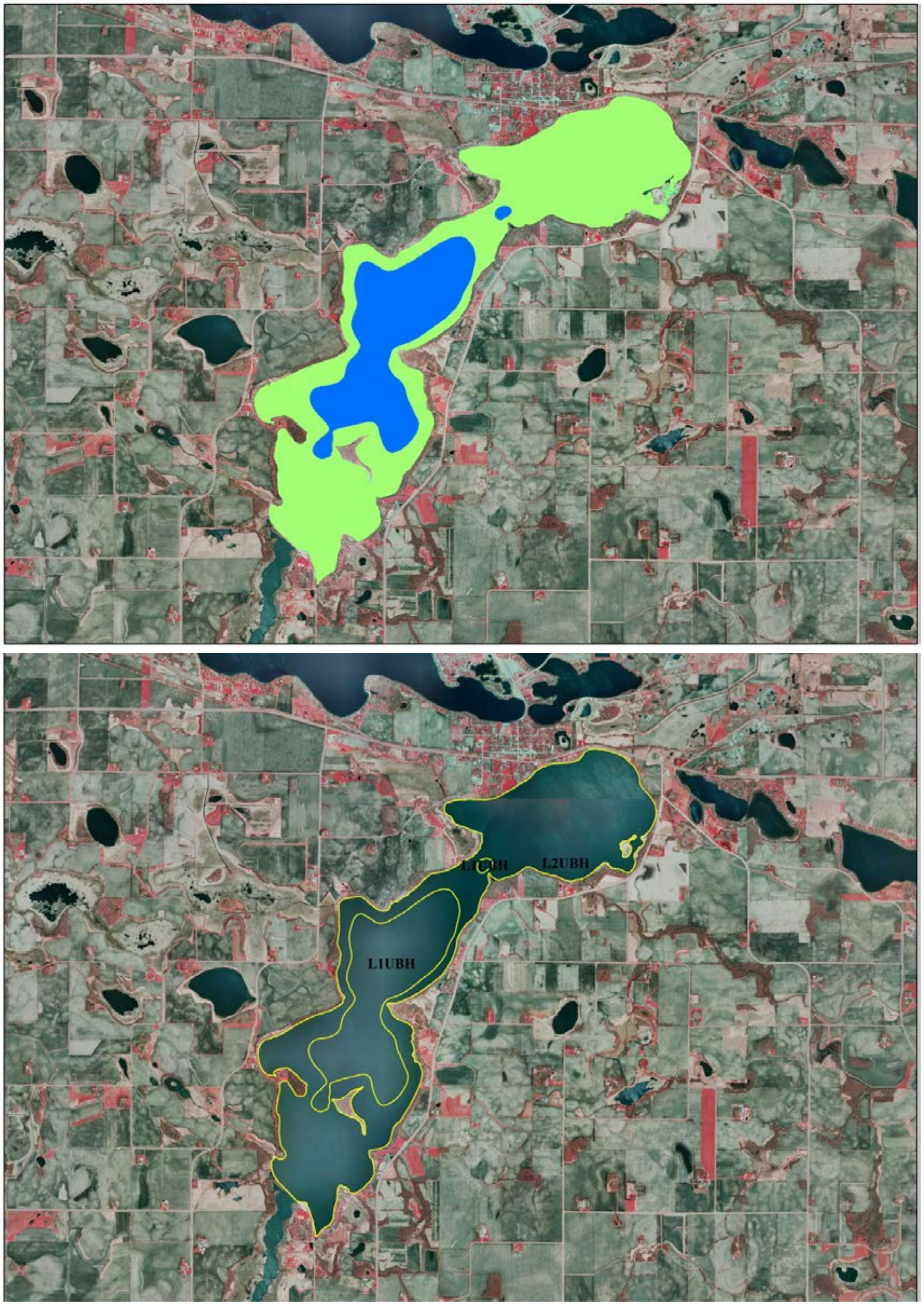


Figure A4. Lake DEM Example. Top: Symbolized Lake DEM with 6.5 foot class break, Bottom: Digitized boundaries, Background Imagery: 2011 Spring CIR.

4. 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 **all** imagery (2011 CIR, 2010 NAIP, 2009 NAIP, 2008 NAIP), it will be classified as palustrine.

5. 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 A5.

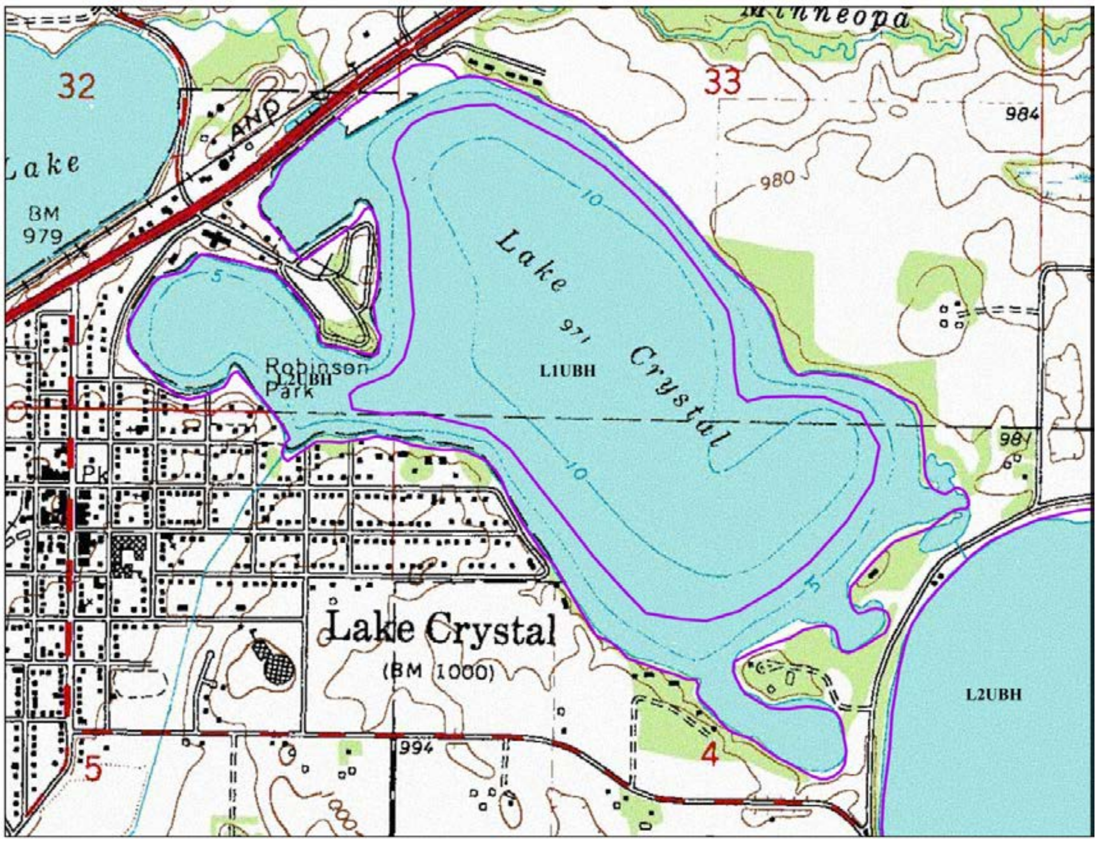


Figure A5a. DRG Contour Example.

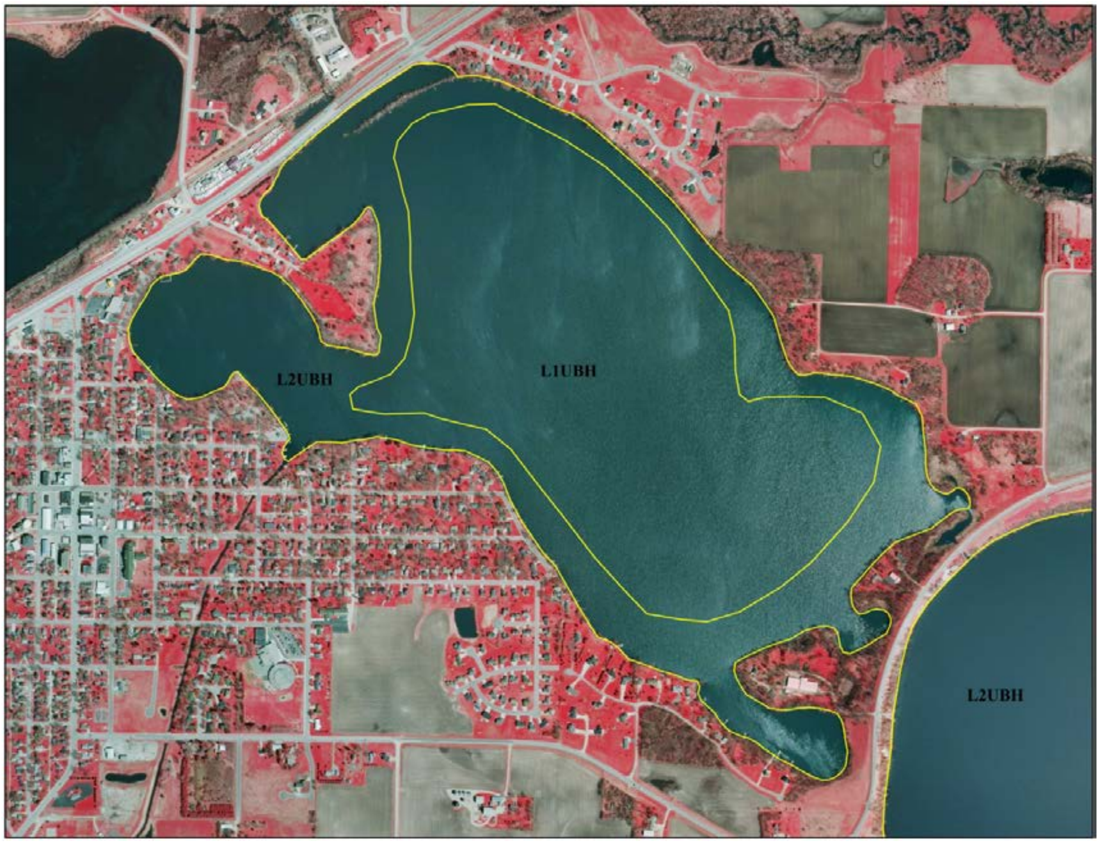


Figure A5b. DRG Contour Example. Background Imagery: Spring 2011 CIR.

6. In the absence of contours, spot soundings on the DRG will serve as the guide for visual interpolation as shown in Figure A6.

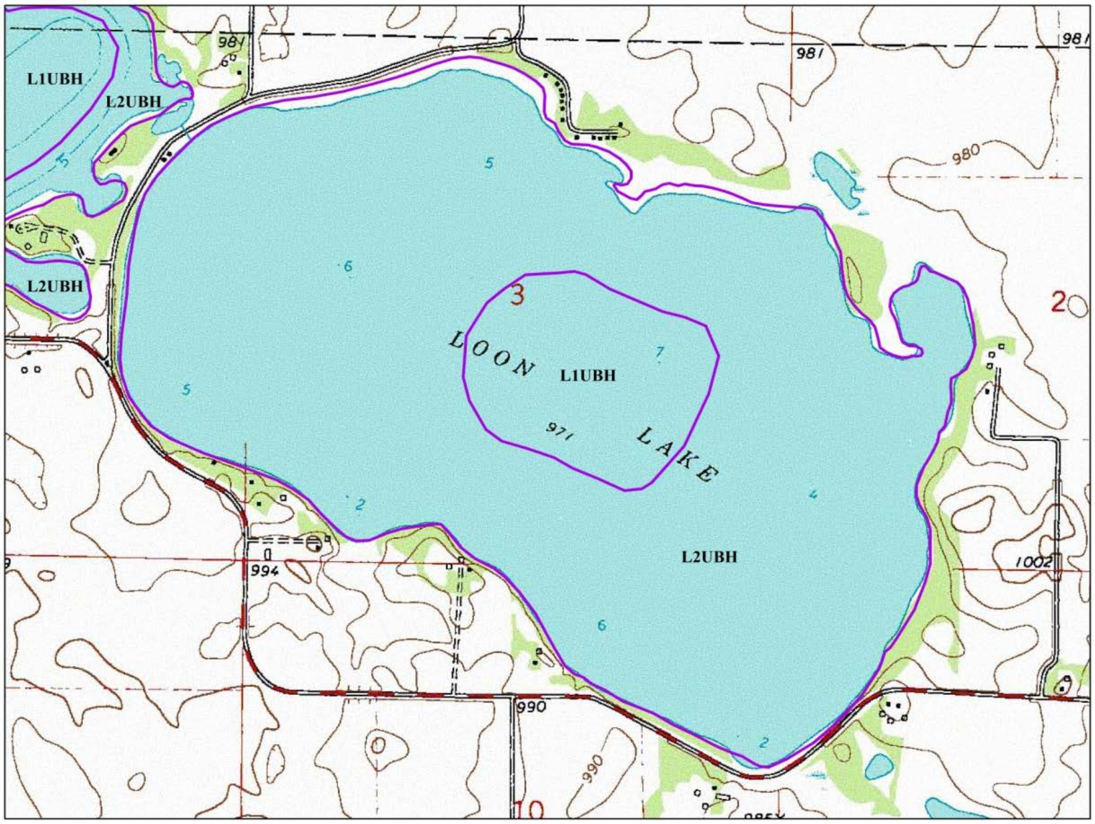


Figure A6. DRG Spot Sounding Example.

7. In the absence of both bathymetric contours and spot soundings on the DRG the MN DNR Lake Finder website (https://www.dnr.state.mn.us/lakefind/index.html) will be searched for the lake in question. If a scanned .pdf map of the lake is available, it will provide the data for visually interpolating the two meter contour (Figure A7).

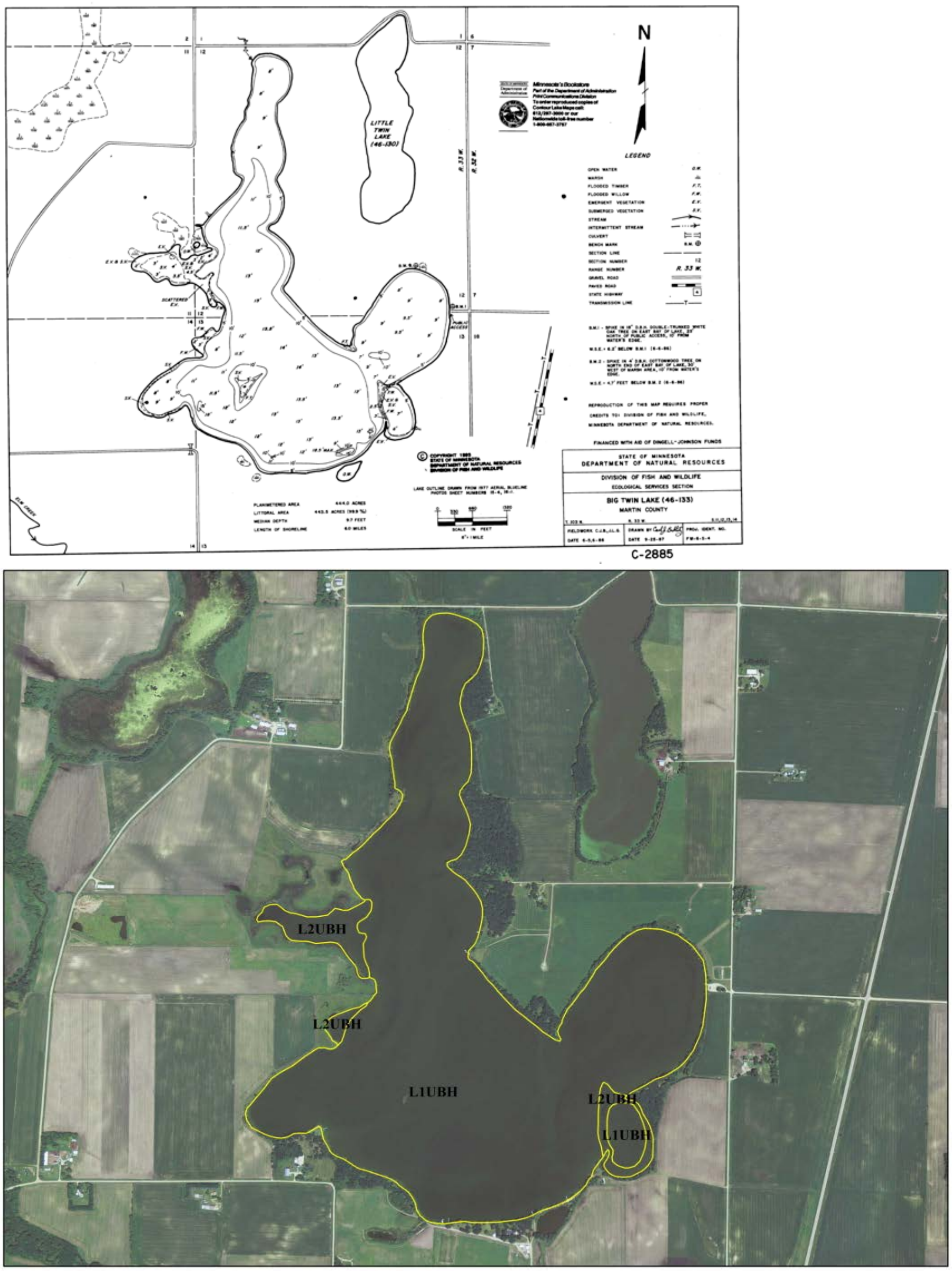
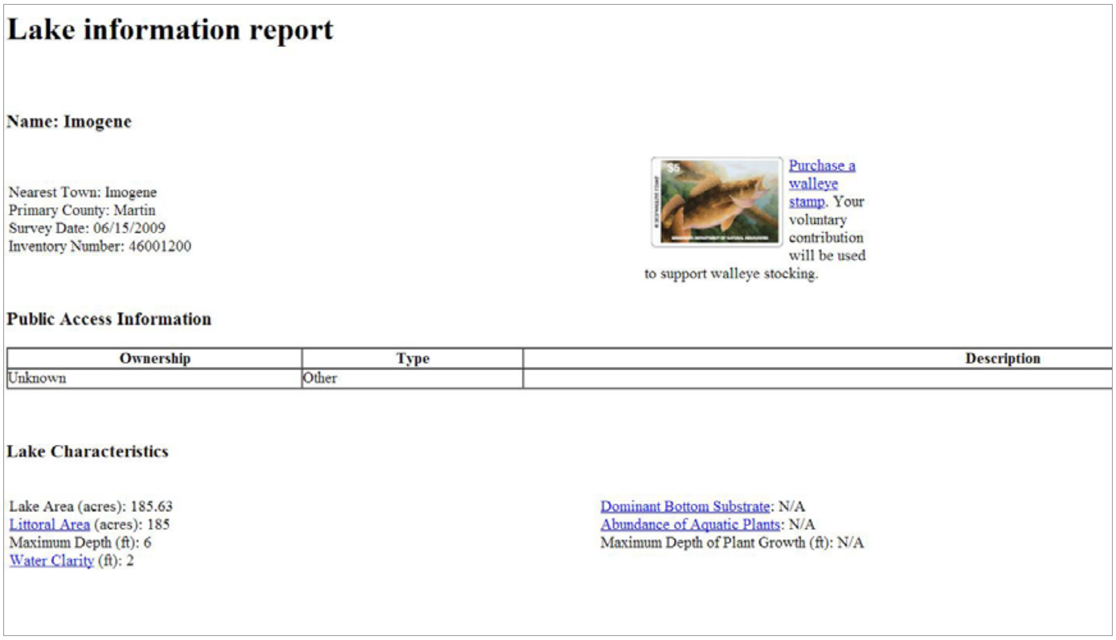


Figure A7. MN DNR Lake Finder .pdf Example.

8. In the absence of a .pdf map, the lake characteristics on the lake finder website will be consulted to determine the maximum depth of the lake. Any lake with a maximum depth of less than eight feet will be entirely classified as L2. An example of the LakeFinder information page for Lake Imogene in Martin County is shown below (Figure A8). In this case, the entire lake basin would be classified as L2 since the maximum depth is less than eight feet. A cutoff of eight feet was chosen for identical reasons to the first step of this protocol.



Lake information report

Name: Imogene

Nearest Town: Imogene
Primary County: Martin
Survey Date: 06/15/2009
Inventory Number: 46001200

Purchase a walleye stamp. Your voluntary contribution will be used to support walleye stocking.

Public Access Information

Ownership	Type	Description
Unknown	Other	

Lake Characteristics

Lake Area (acres): 185.63
Littoral Area (acres): 185
Maximum Depth (ft): 6
Water Clarity (ft): 2

Dominant Bottom Substrate: N/A
Abundance of Aquatic Plants: N/A
Maximum Depth of Plant Growth (ft): N/A

Figure A8. LakeFinder Information Page Example. Lake Imogene, Martin County.

9. 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, and etc. Lack of recreational infrastructure and presence of an undeveloped natural shoreline indicate L2.

10. 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.

11. If all the above steps do not lead to a determination and there is no historic NWI present, the entire water body will be classified as L2.

A4. 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 study area:

1. The riverine system has three sub systems 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 15 feet (5 meters) 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 photo signatures are flat with dark blue to almost black tones on the Spring CIR or NAIP imagery (Figure A9). Additionally, 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, DEMs, and DRGs. Both the DRG and the LiDAR products indicate gradient. Additionally, R2UBH attributes are often represented as polygon features on the DRG, however the smallest R2UBH features may be represented as a solid blue line.

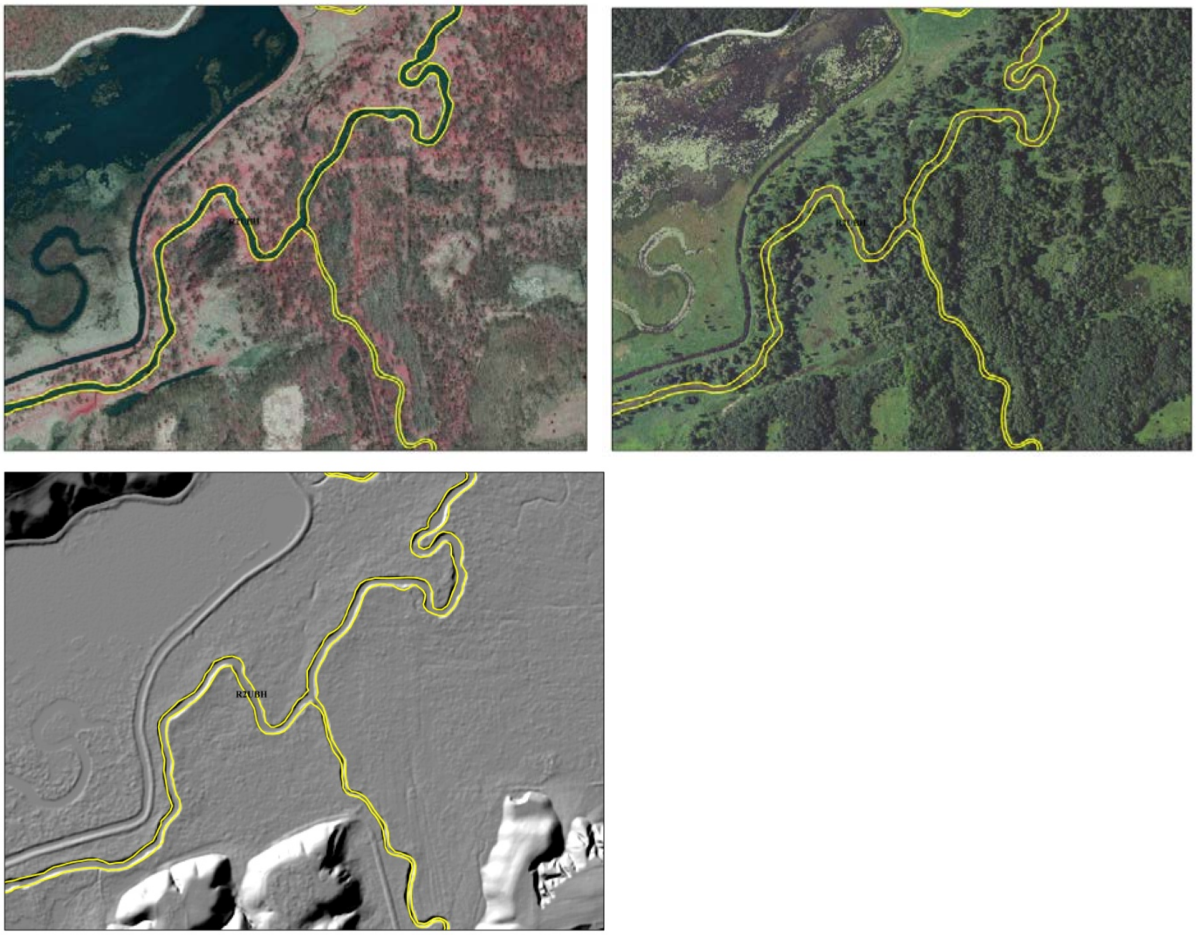


Figure A9. R2UBH Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, and LiDAR DEM.

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 photo signatures are identical to a natural R2UBH, flat with dark blue to almost black tones on the Spring CIR or NAIP imagery (Figure A10). Additionally, 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, DEMs, and DRGs. Both the DRG and the LiDAR products indicate gradient. Additionally, 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 A10. R2UBHx Signature Example. Left to right: 2011 Spring Imagery (CIR), 2010 NAIP.

R2USC

System: Riverine

Subsystem: Lower Perennial

Class: Unconsolidated Shore

Water regime: Seasonally Flooded

R2USC features are sand, mud, or gravel bars associated with low gradient rivers. They form through deposition of sediment, often on the inside of curves in the river channel (Figure A11). Typical photo signatures are smooth with tone varying from white to tan for sand, and gray to black for mud. Gravel bars tend to exhibit a slightly rougher texture, but often appear relatively smooth with tan to gray tones. The key indicators are the smooth texture and position in relation to the river channel. These features are often colonized quickly by vegetation, so the 2010 NAIP should be used to determine their extent. Once vegetation has established itself to greater than or equal to 30% areal coverage the feature is no longer unconsolidated shore and should be classified as palustrine with the appropriate class; (i.e., emergent, scrub-shrub, forested).

Collateral data include primarily the LiDAR, DEMs, and DRGs, mainly to indicate gradient.

Figure A11. R2USC Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, and Ground Level Oblique Example.

R2ABH(h)

System: Riverine

Subsystem: Lower Perennial

Class: Aquatic Bed

Water regime: Permanently Flooded

(Special Modifier): Impounded

R2ABH features occur in low gradient rivers where there is flow present, but not so much flow that floating vascular plants are unable to become established. Indicators of flow present are adjacency to R2UBH wetlands, lack of palustrine emergent, scrub-shrub, or forested wetland on the boundary, and the presence of small "stringy" openings in the floating bed. They typically occur in large river backwater areas or along the edges of the main channel. R2ABH signatures are not present on the Spring CIR (Figure A12) because the signatures do not present themselves until later in the growing season. For this reason, the NAIP imagery is the primary data source for these wetlands. Typical signatures are flat in texture and bright green in tone, although in some cases they present as flat dark brown on the true color NAIP. The location of the aquatic bed boundaries vary considerably from year to year, in which case the 2010 NAIP takes priority in defining boundaries. The wetlands in the examples shown below are in the Mississippi River floodplain and are thus assigned the impounded "h" special modifier by convention.

Collateral data primarily include the DRG, LiDAR, and DEMs. Because they occur on the surface of the water, they are flat on the LiDAR DEM, as their location typically falls below the breakline used for hydrologic enforcement of the LiDAR data. DRGs will have open water in most cases, but in cases of aquatic bed wetlands with well-established boundaries, there may be marsh symbols.

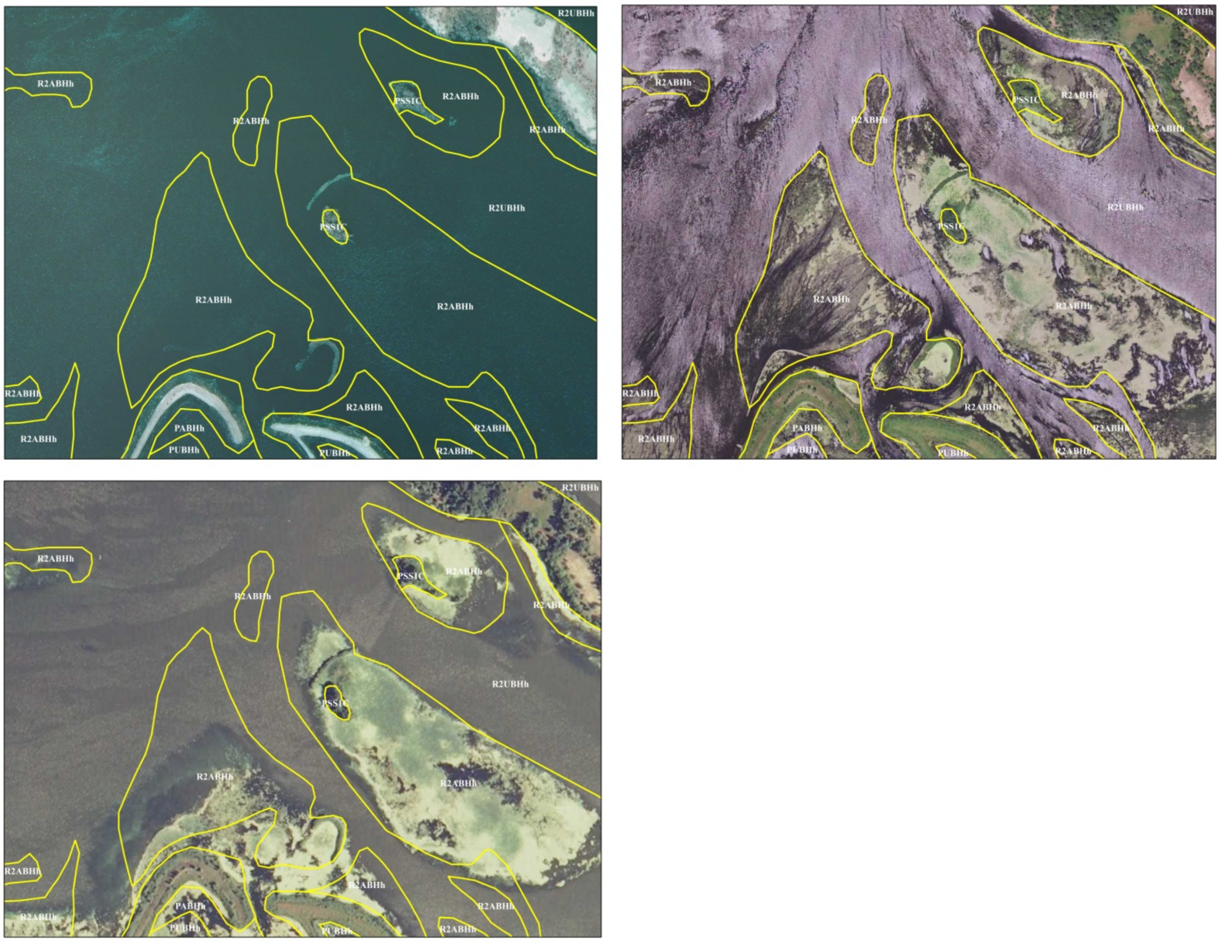


Figure A12. R2ABH Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, and 2009 NAIP.

R2EM2H(h)

System: Riverine

  Subsystem: Lower Perennial

    Class: Non-Persistent Emergent

      Water regime: Permanently Flooded

        (Special Modifier): Impounded

R2EM2H wetland features occur in low gradient rivers where there is flow present, but not so much flow that plants are unable to become established. Indicators of flow presence are adjacency to R2UBH wetlands, and lack of palustrine emergent, scrub-shrub, or forested wetland on the boundary. This is the only example of the emergent class that occurs in the riverine system for Southern Minnesota. The wetlands are wild rice (*Zizania aquatica*) beds. They typically occur in large river backwater areas or along the edges of the main channel. R2EM2H signatures are not present on the Spring CIR (Figure A13) because the signatures do not present themselves until much later in the growing season. For this reason, the fall 2011 color imagery for East Central and Southeast Minnesota should be the primary data source where it is available. Typical signatures are sparse, clumpy, greens and browns on the fall color imagery.

Signatures are much less pronounced on the NAIP photography, but could best be described as a "smoky" green to brown signature. These wetlands in the examples shown below are in the Mississippi River floodplain and are thus assigned the impounded "h" special modifier by convention.

Collateral data primarily include the DRG, LiDAR, and DEMs. Because these wetlands occur in flooded areas, their location typically falls below the breakline used for hydrologic enforcement of the LiDAR data and will appear flat and smooth on the LiDAR DEM. DRGs will have open water in most cases.

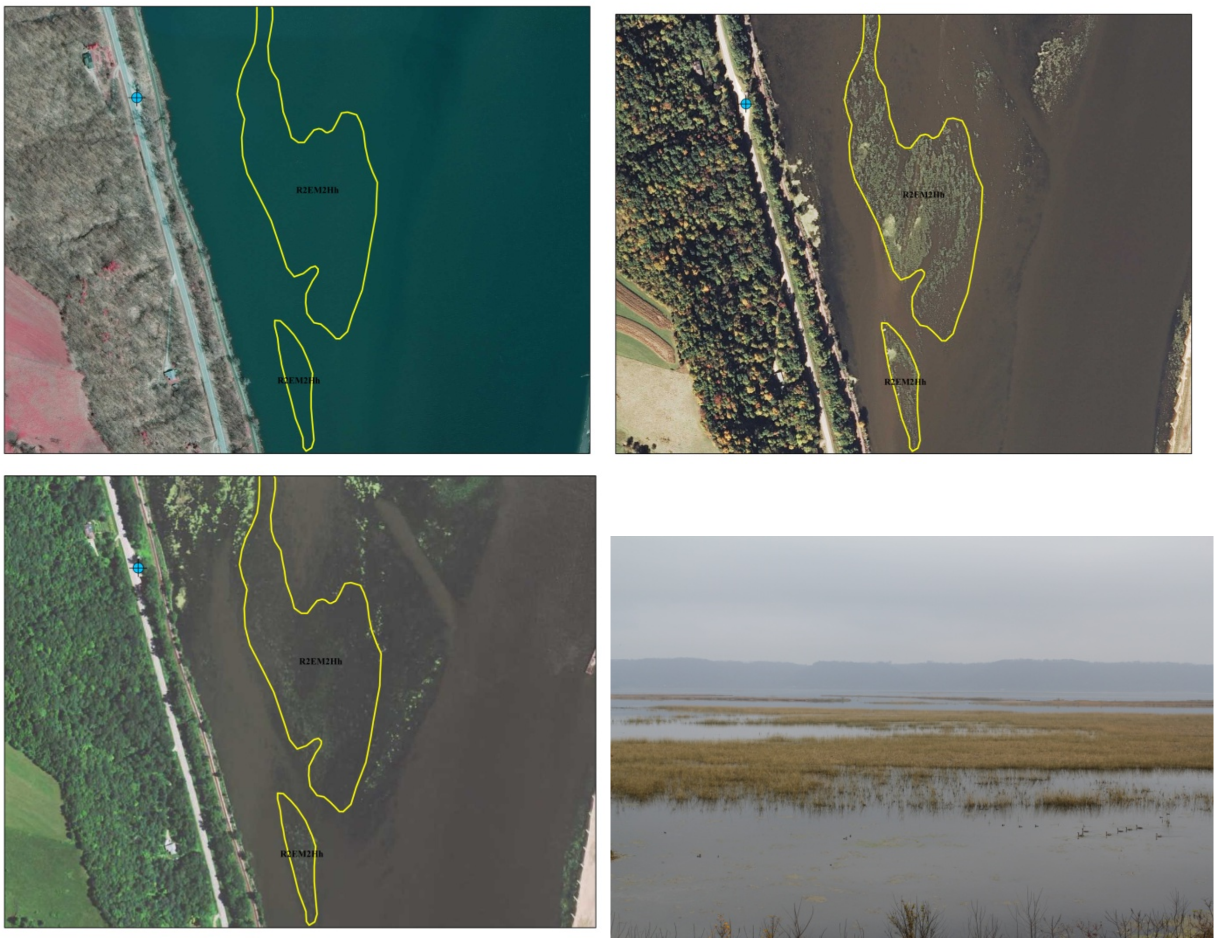


Figure A13. R2EM2H Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2011 fall imagery, 2010 NAIP, and ground level oblique from blue marker looking east.

R3UBH

System: Riverine
- Subsystem: Upper Perennial
  - Class: Unconsolidated Bottom
    - Water regime: Permanently Flooded

R3UBH features are high gradient rivers. They typically have little or no floodplain, and are cold water streams that will support trout and other cold water species. They often have a rapids, riffle, and pool structure. If any meanders occur, they are typically limited because the stream is often contained by surrounding bedrock. Substrates also tend to be heavier aggregate such as cobble and gravel because finer sediments do not stay in place with the high energy flow that is present. Typical photo signatures are flat with dark blue to almost black tones on the Spring CIR or NAIP imagery (Figure A14). Additionally, they will also present with dark green to brown tones on the true color NAIP, depending on the turbidity of the water. They tend to be narrow and are often difficult to see under tree cover; therefore the Spring CIR is the best indicator of their presence and location. Collateral data include the LiDAR, DEMs, and DRGs. Both the DRG and the LiDAR products indicate gradient. Additionally, R3UBH rivers are often represented as solid line on the DRG.

Figure A14. R3UBH Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, LiDAR Hillshade and ground level oblique from blue marker looking south.

R4SBC

System: Riverine
    Subsystem: Intermittent
        Class: Streambed
            Water regime: Seasonally Flooded

R4SBC features only carry surface water in their channels at certain times of the year or after precipitation or melting events. They can occur on high or low gradient areas, but are more common in high gradient areas in Southern MN. They have no floodplain, and in high gradient areas the substrate consists of heavier sediments such as gravel and cobble. Typical photo signatures are white to light gray tones on the Spring CIR and tan tones on the NAIP imagery (Figure A15). The texture of the signature varies depending on the substrate, with larger cobble appearing rougher and finer sediments such as sand or mud appearing smooth. They tend to be narrow and are often difficult to see under tree cover; therefore the Spring CIR and the LiDAR is the best indicator of their presence and location. Collateral data include the LiDAR DEMs and DRGs. Both the DRG and the LiDAR products indicate gradient. Note the DRG contours (20 foot contour interval) on the DRG in Figure A15.

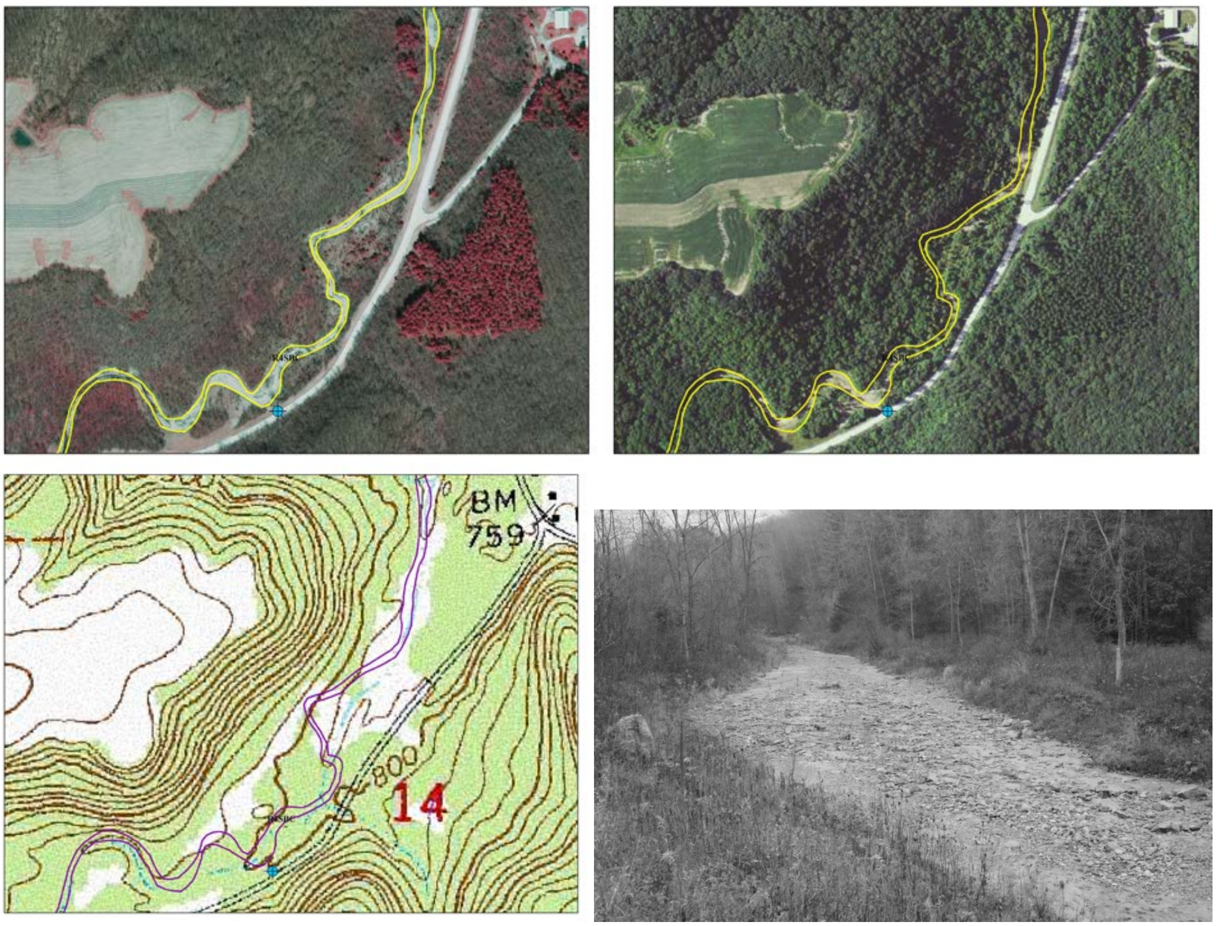


Figure A15. R4SBC Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, DRG, and black & white ground level oblique from blue marker toward WNW.

A5. Palustrine System

The palustrine system refers to wetlands dominated by persistent emergent, scrub-shrub, or forested vegetation or lacking vegetation, those wetlands 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 study 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 1.

4. Valid water regimes for each class are also listed in Table 1.

5. Special modifiers will be applied based on the valid lists in Table 1.

6. The PEM1Af attribute will only be applied to farmed wetlands meeting a specific set of circumstances as described below (Section A6). 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. Photo signatures are the normal open water signatures: flat, with dark blue to almost black tones on the Spring CIR or NAIP imagery (Figure A16). Additionally, 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 PUBH, it must be flooded in all but the most extreme drought. For Southern Minnesota, this means flooded on all three years of NAIP imagery, and the 2011Spring 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.

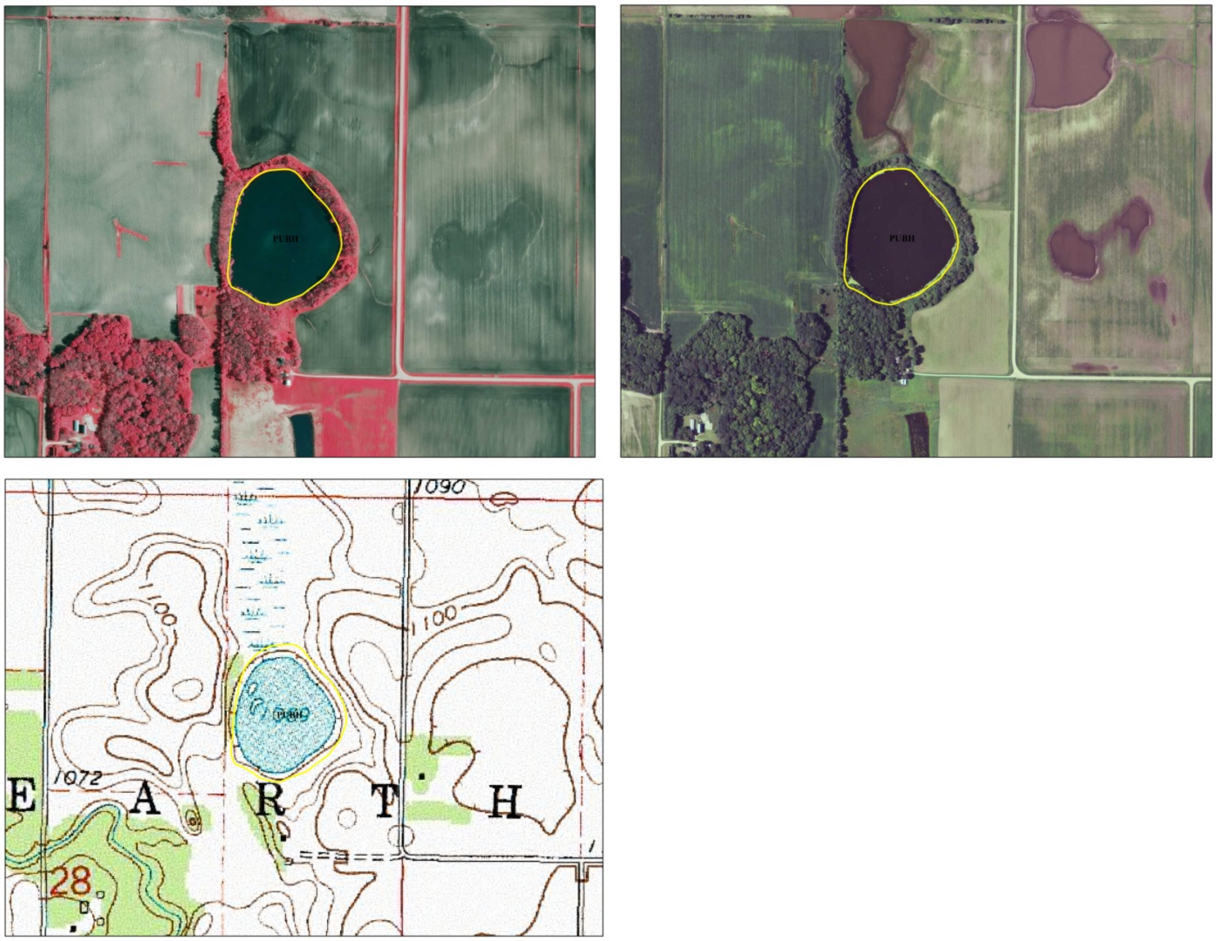


Figure A16. PUBH Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, and DRG.

PUBHh

System: Palustrine

Class: Unconsolidated Bottom

Water regime: Permanently Flooded

Special Modifier: Impounded

PUBHh features are open water, pond environments that are the result of surface water pooling behind a man-made structure such as an earthen dike, They normally occur as the result of a valley being dammed. Photo signatures are the normal open water signatures, flat with dark blue to almost black tones on the Spring CIR or NAIP imagery (Figure A17). Additionally, 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. These wetlands will often have a straight boundary on the edge formed by the structure causing the impoundment. To be classified with the permanently flooded "H" water regime, it must be flooded in all but the most extreme droughts. For Southern Minnesota, this means flooded on all three years of NAIP imagery, and the spring, 2011 CIR. If the feature is not flooded in all three years of imagery it should be classified with the semi-permanently flooded "F" water regime.

To be classified with the impounded “h” modifier, the structure causing water to pool must have been built with that intention. By convention, roads do not cause impoundments.

LiDAR is the primary collateral data for making the impounded determination. Dams are easily identified on the LiDAR hillshade. The DRG often will not show these features if they were recently created, but will likely show the valley before it was dammed.

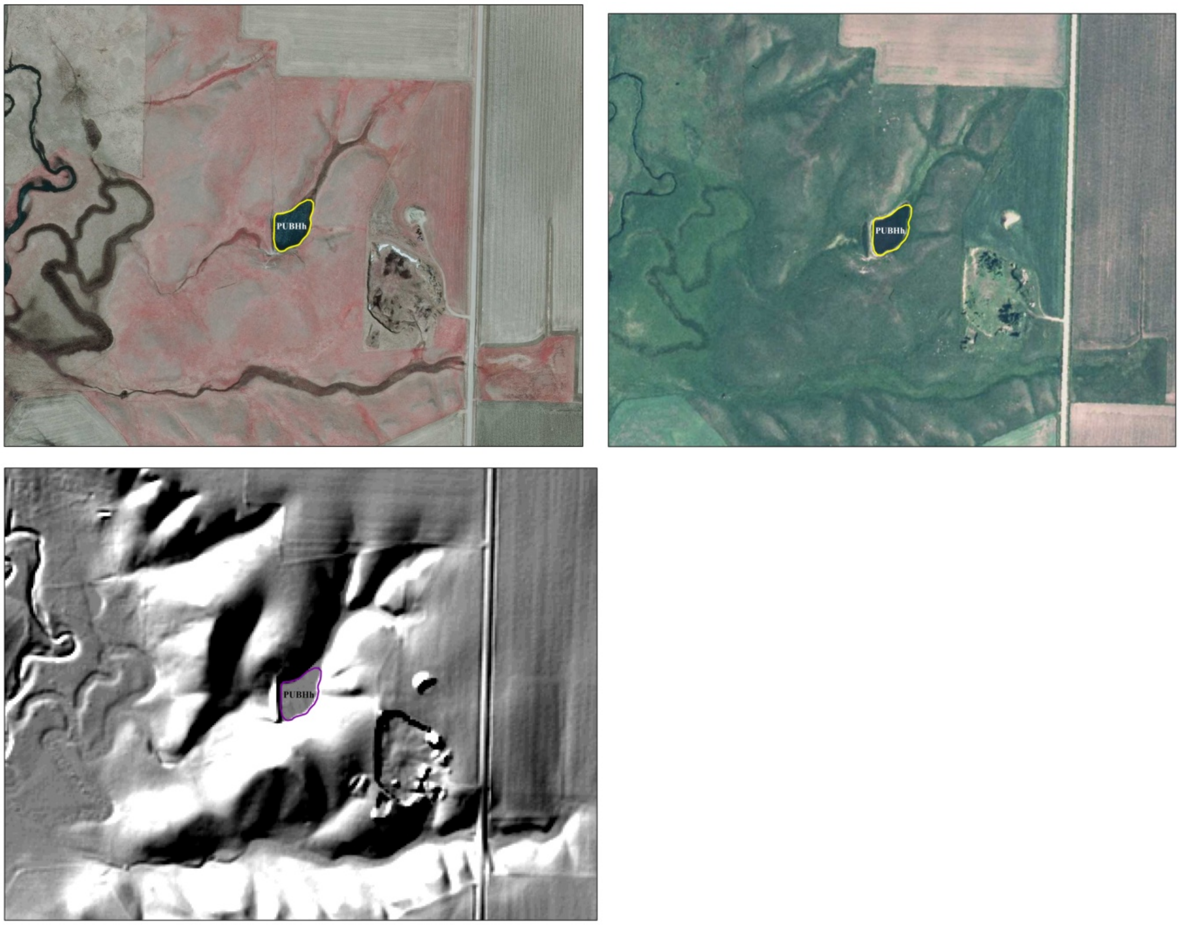


Figure A17. PUBHh Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2009 NAIP, and LiDAR Hillshade.

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. Photo signatures are the normal open water signatures, flat with dark blue to almost black tones on the Spring CIR or NAIP imagery (Figure A18). Additionally, 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 2 out of 3 years of NAIP imagery, and especially on the 2010 NAIP. Generally, 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.

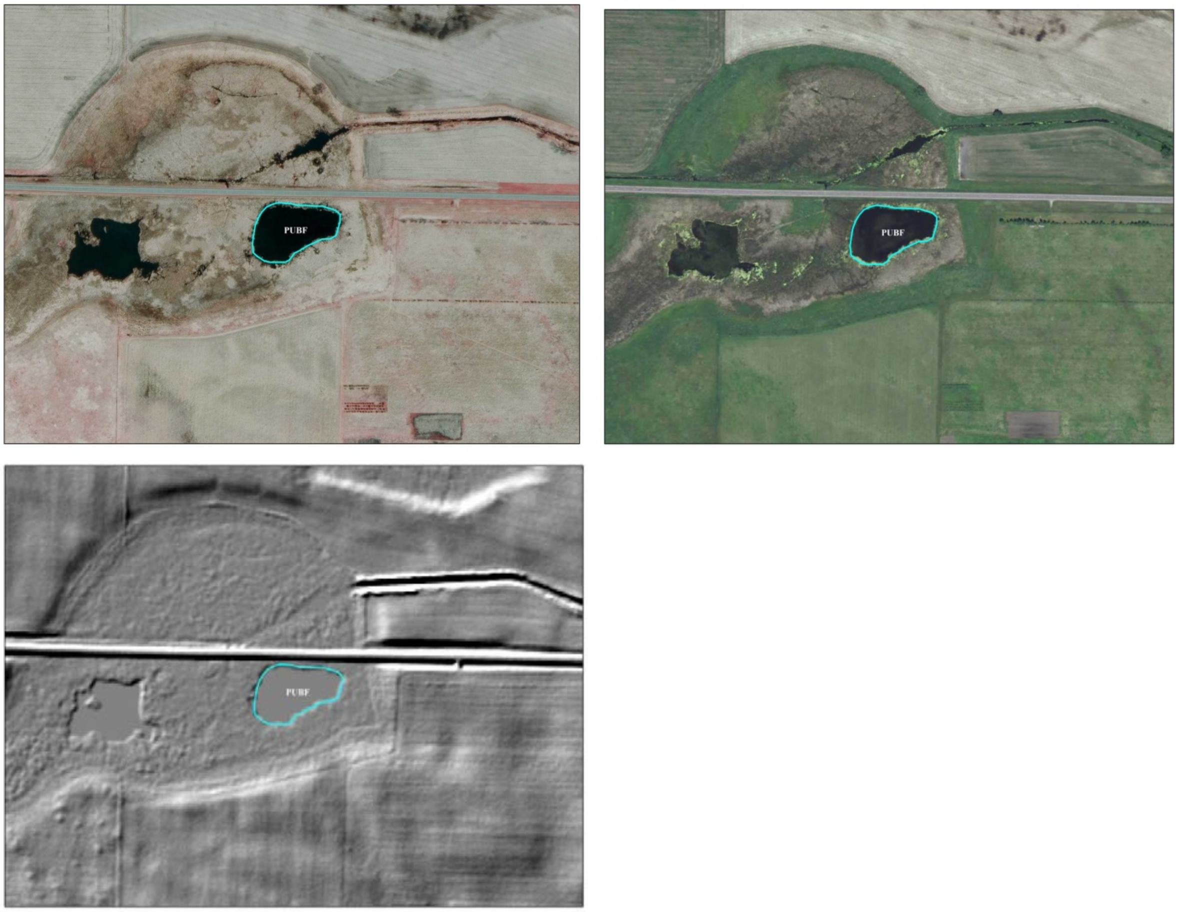


Figure A18. PUBF Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, and LiDAR Hillshade.

PUBFx

System: Palustrine

Class: Unconsolidated Bottom

Water regime: Semi-Permanently Flooded

Special Modifier: Excavated

PUBFx features are open water, pond environments created by digging. 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. Photo signatures are the normal open water signatures, flat with dark blue to almost black tones on the Spring CIR or NAIP imagery (Figure A19).

Additionally, they will also present 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 PUB wetlands tend to be smaller and often shallower than their Permanently Flooded counterparts. To be classified with the semi-permanently flooded "F" water regime, it must be flooded at least two out of three NAIP images. To be classified with the excavated "x" modifier, there should be evidence of excavation 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, 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.

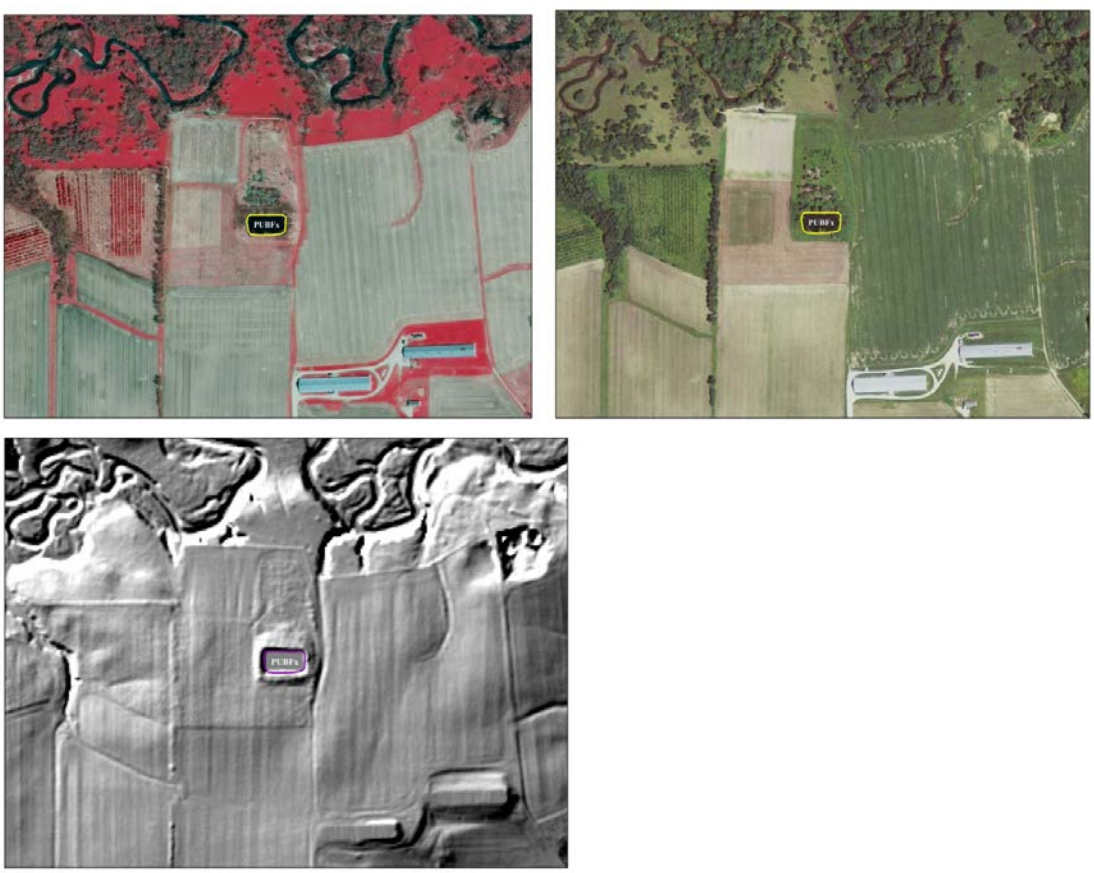


Figure A19. PUBFx Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, and LiDAR Hillshade.

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. Photo signatures when flooded are the normal 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 A20). 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 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.

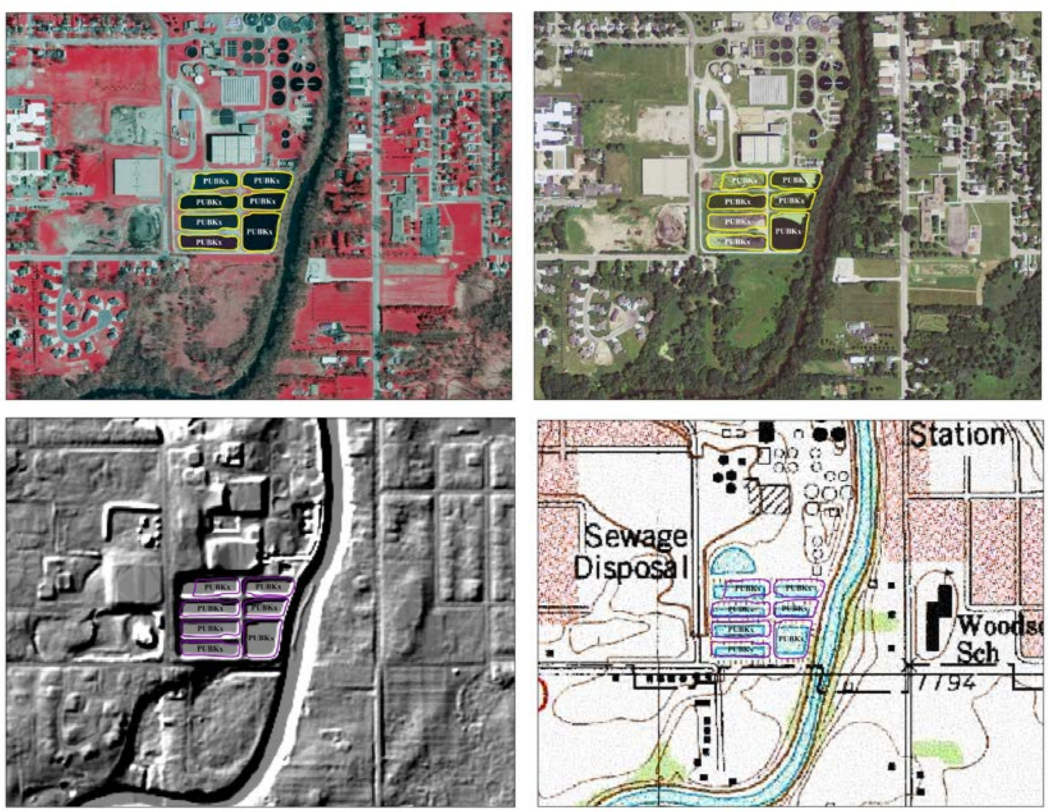


Figure A20. PUBKx Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, DRG, and LiDAR Hillshade.

PABH

System: Palustrine

Class: Aquatic Bed

Water regime: Permanently Flooded

PABH features are those open water areas that are less than two meters (6.5 feet) in depth, not part of a lacustrine basin, and are 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 A21 is an example of the former, 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 varies considerably within a wetland complex from year to year, in which case the 2010 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.

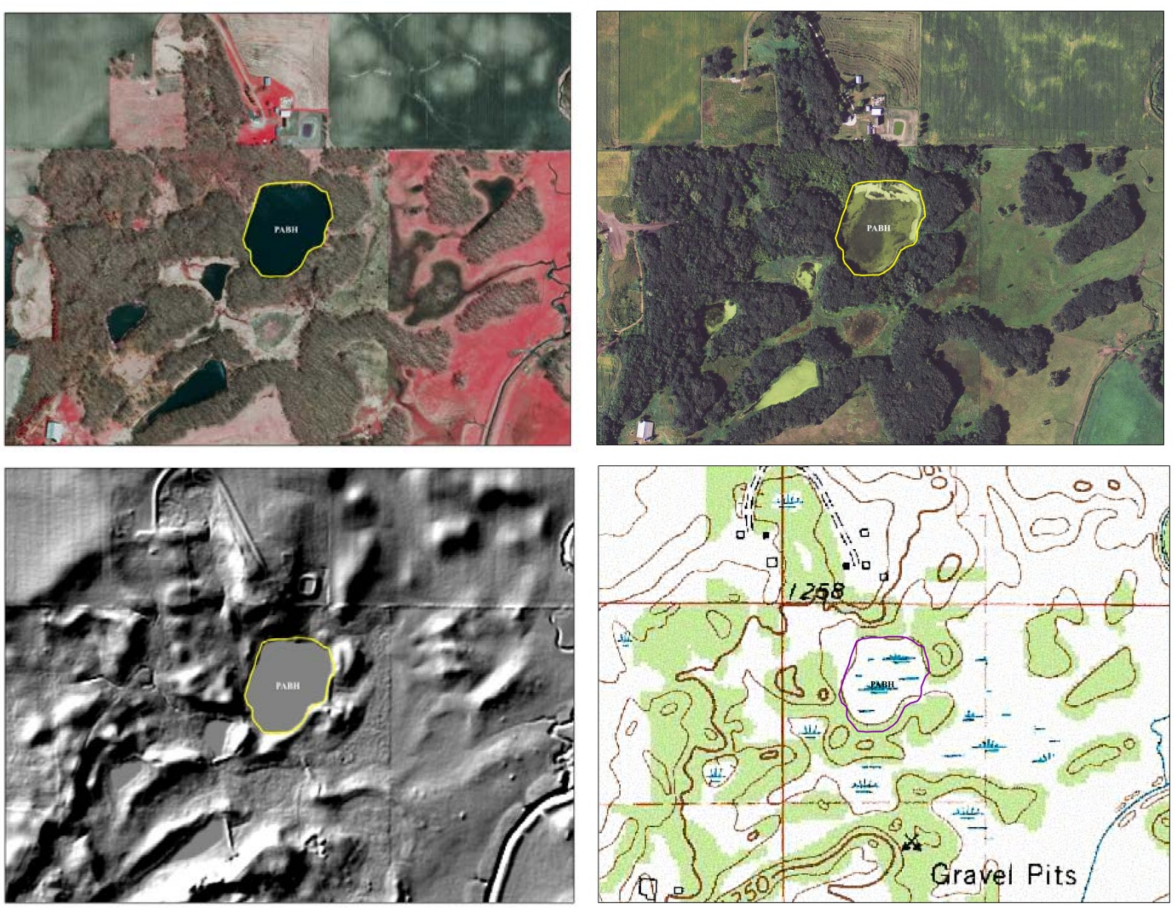


Figure A21. PABH Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, DRG, and LiDAR Hillshade.

PABF

System: Palustrine

Class: Aquatic Bed

Water regime: Semi-Permanently Flooded

PABF 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. 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 A22). 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 varies considerably within a wetland complex from year to year, in which case the 2010 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 mave marsh symbols or open water, but in rare cases there will be no indication on the DRG.

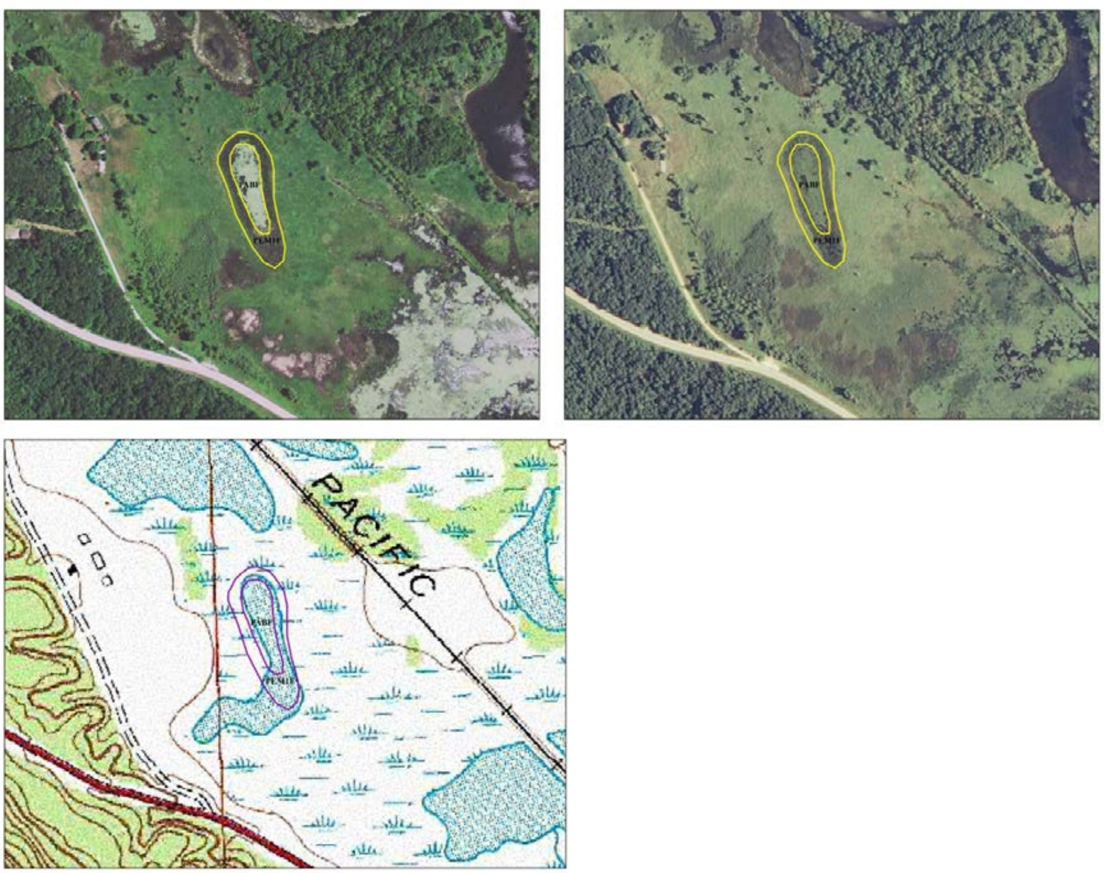


Figure A22. PABF Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, and DRG.

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 on most years. Species common in PEM1F wetlands include cattail (*Typha*), and bulrush (*Scirpus*). 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. Photo signatures on the NAIP tend to also exhibit a rough texture, but with green or brown tones (Figure A23). 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.

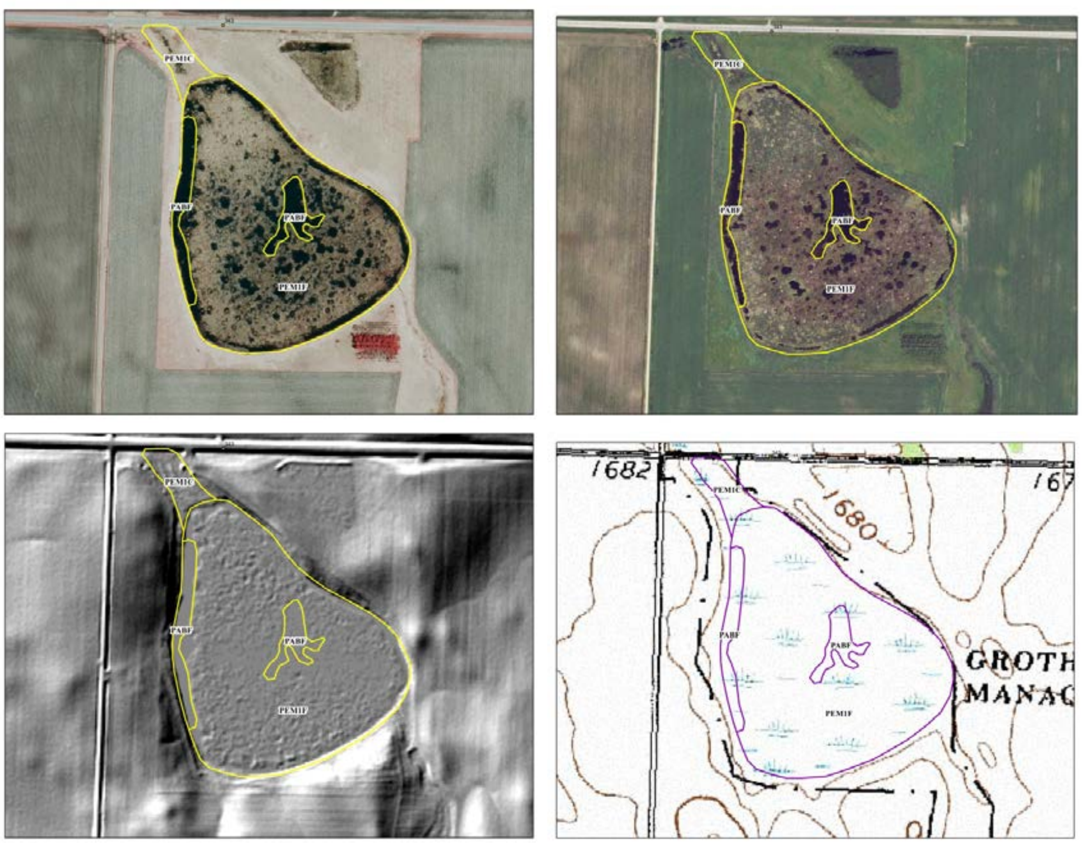


Figure A23. PEM1F Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, DRG, and LiDAR Hill shade.

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 including meander scars. Photo signatures 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 A24). Photo signatures on the NAIP tend to also have a puffy texture with a deep green tone compared to the surrounding temporarily flooded wetlands or uplands. Hybrid cattail, which will tolerate dry conditions, will also grow in PEM1C wetlands. They exhibit a similar signature to cattails growing in a PEM1F wetland. Muskrat houses will not be present and vegetation will be much denser without any open water or aquatic bed pockets 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.

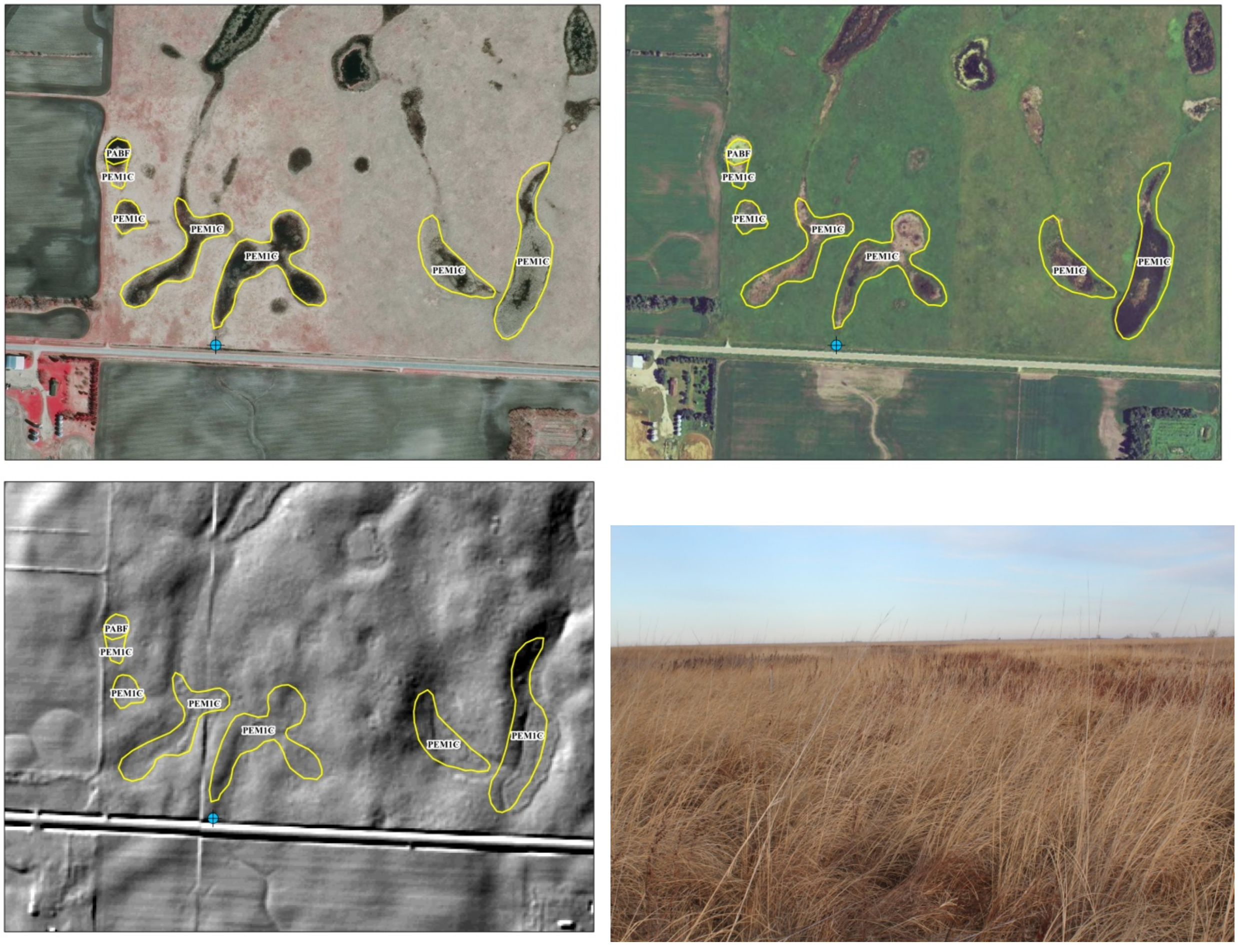


Figure A24. PEM1C Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, ground level oblique - looking north from blue marker, and LiDAR Hillshade.

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 generally 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. Photo signatures tend to be smoother than PEM1C wetlands. Tones on the CIR tend to be darker gray tones than PEM1Cs or, on some imagery for the Southern MN project, pink to red in tone (Figure A25). 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.

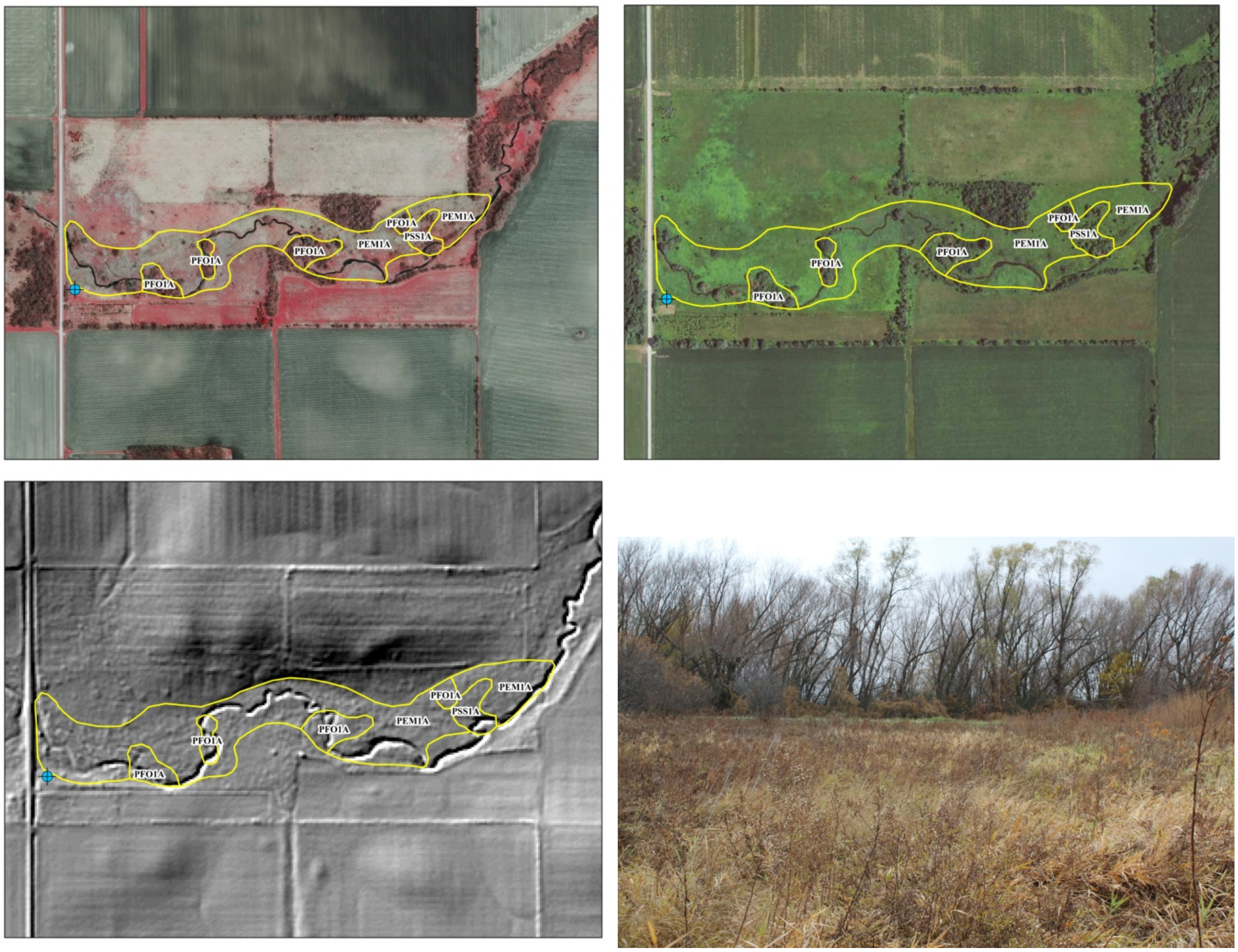


Figure A25. PEM1A Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, ground level oblique - looking east from blue marker, and LiDAR Hillshade.

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 succession 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*), red osier dogwood

(*Cornis stolonifera*), and the invasive, buckthorn (*Rhamnus*). 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 A26). 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. Photo signatures 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.

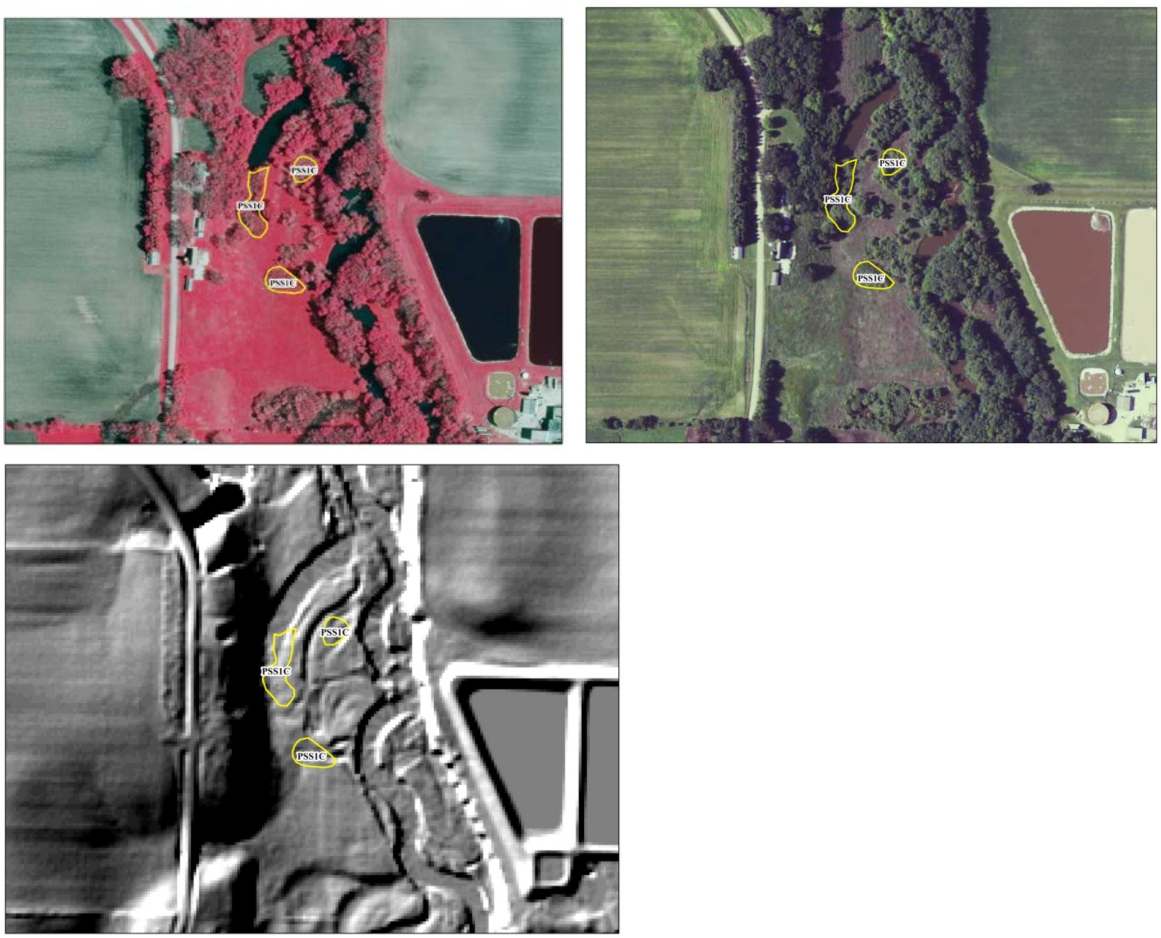


Figure A26. PSS1C Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, and LiDAR Hillshade.

PSS1A

System: Palustrine

Class: Scrub-Shrub

Subclass: Broad-Leaved Deciduous

Water regime: Temporarily Flooded

PSS1A wetlands are dominated by deciduous woody vegetation less than 20 feet tall. In many cases they are transitional succession communities between emergent and forested stages, but there are some mature communities made up of scrub-shrub vegetation. They typically are only flooded for one or two weeks during the growing season. Both bushy shrub species and juvenile trees are included in this class. Examples of the former include willow, red osier dogwood, and the invasive, buckthorn. Examples of the latter include the saplings of American elm and green ash. They occur primarily in relatively flat locations which is the main distinguishing characteristic from PSS1C wetlands (Figure A27). Photo signatures are identical to PSS1C wetlands with 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. Photo signatures 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. The DRG will most likely not provide an indication of these wetlands. Hydric soils are not as likely to be present as in PSS1C wetlands, but are present in a majority of cases. The LiDAR DEM and contour lines will, in a majority of cases, show a flat area without a well-defined basin boundary, such as a floodplain flat. There will not be any indication of a hydrologically enforced water surface on the LiDAR DEM.

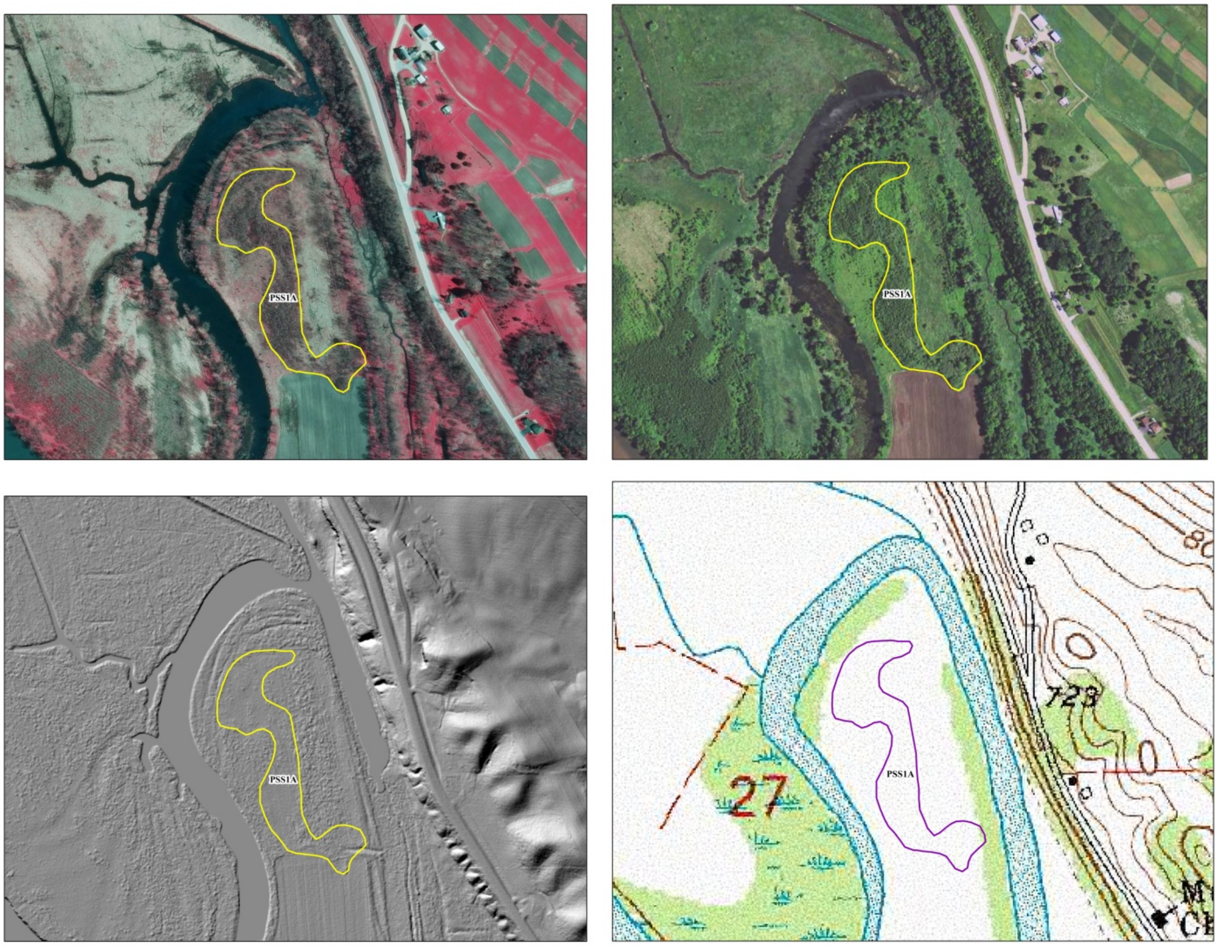


Figure A27. PSS1A Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, DRG, AND LiDAR Hillshade.

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 A28), including meander scars in smaller river floodplains. Large areas of PFO1C wetlands also occur in the floodplains of major rivers. They can also occur on fringes of larger palustrine and lacustrine basins. Photo signatures 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. Photo signatures 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 A28. PFO1C Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, ground level oblique from blue marker looking north, and 2009 NAIP.

PFO1A

System: Palustrine

Class: Forested

Subclass: Broad-Leaved Deciduous

Water regime: Temporarily Flooded

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 A29). They also occur on fringes of larger palustrine and lacustrine basins. Photo signatures 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. Photo signatures 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.

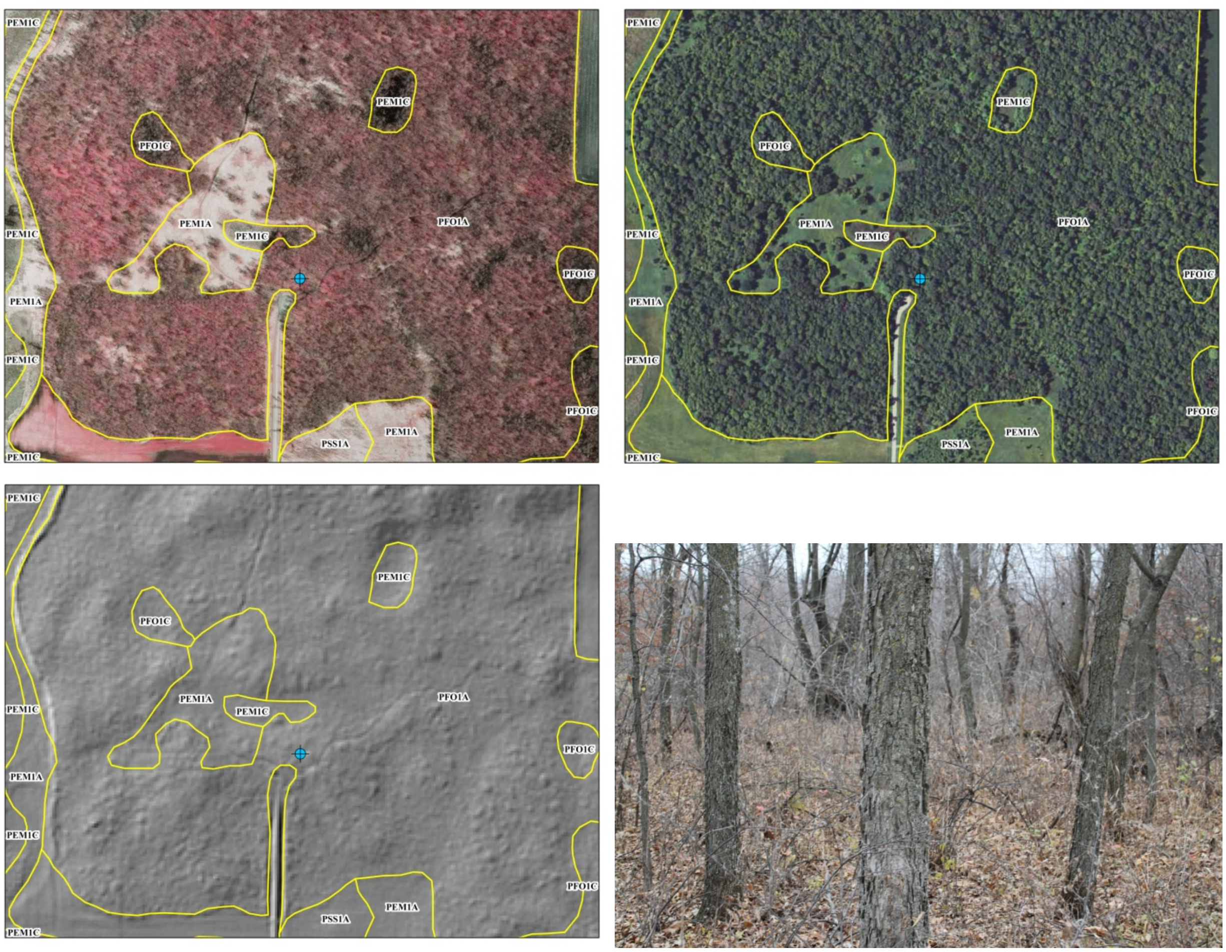


Figure A29. PFO1A Signature Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, ground level oblique from blue marker looking north, and LiDAR Hillshade.

PEM1/SS1/FO1B

System: Palustrine

Classes: Emergent/Scrub-Shrub/Forested

Subclasses: Persistent/Broad-Leaved Deciduous/Broad-Leaved Deciduous

Water regime: Saturated

PEM1/SS1/FO1B wetland features are grouped together for the purpose of discussion because the photo signatures are very similar to the previously defined wetlands with the same class. The defining factor for these wetlands is their water regime. The saturated water regime rarely floods, but has saturated soil to the surface for extended periods during the growing season. Unlike the other wetland types which tend to have hydrology dominated by surface water, saturated wetlands exist primarily due to ground water sources such as springs and seeps. Due to this characteristic, they are often located on slopes, where springs reach the surface. The example below (Figure A30) is Nelson Fen in Southeast Minnesota. The blue circles in the LiDAR example illustrate the locations that likely have springs coming to the surface. The contours show the relatively high slope of the area, and hydric soils are shown in transparent blue against the CIR imagery. Because this example is a state natural area, this shows the appearance of a natural saturated wetland. In cases where there is human disturbance, the wetlands might be much smaller and are more likely to have emergent vegetation, often in a triangular fan shape on a slope, not unlike the shape of the depressions highlighted on the LiDAR example.

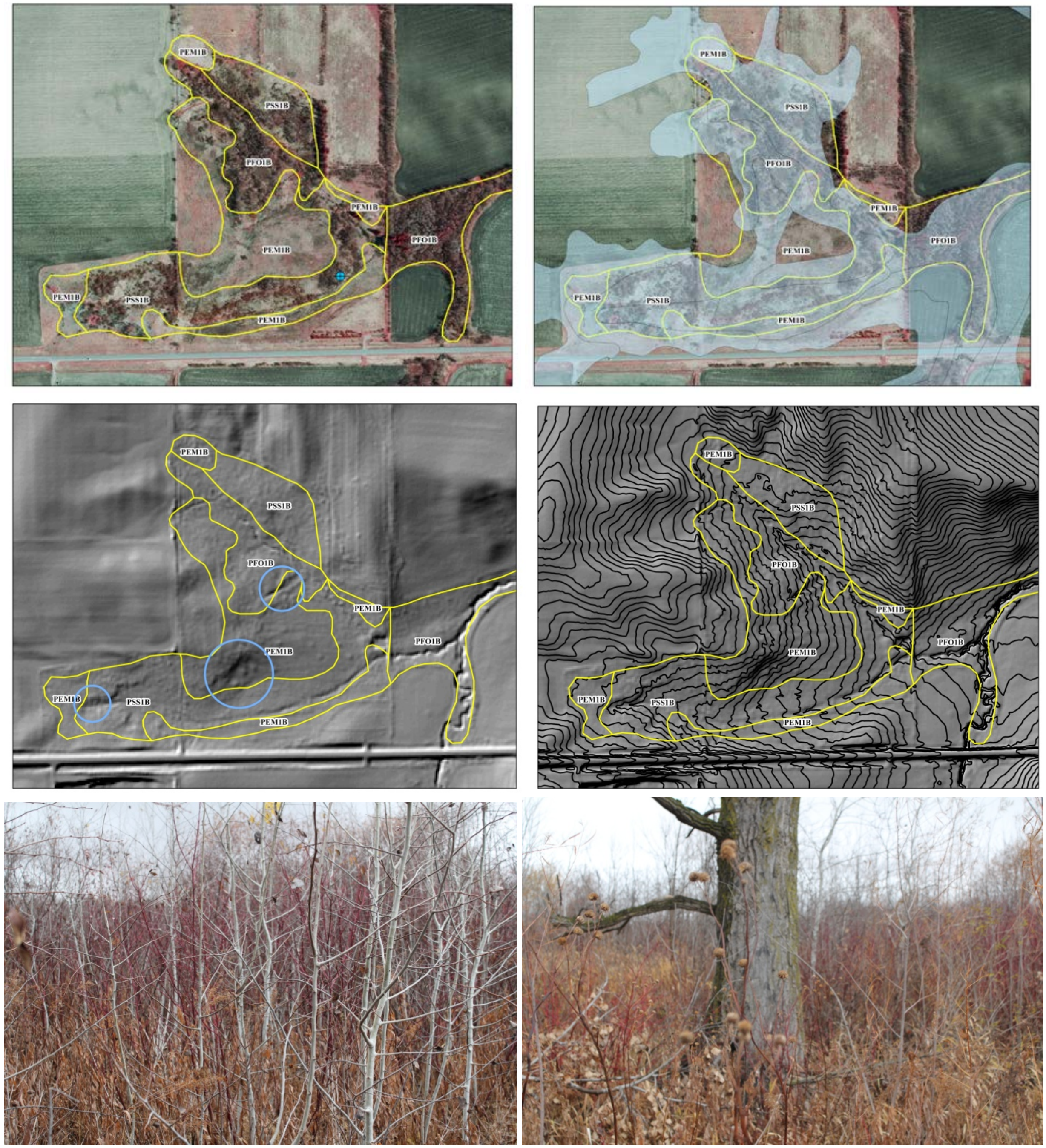


Figure A30. Saturated Wetland Signature Example. Top to Bottom. Left to Right: 2011 Spring Imagery (CIR), 2011 Spring (CIR) with SSURGO soils (85% hydric) in blue, LiDAR Hillshade with spring areas highlighted by blue circles, LiDAR Hillshade with contours, ground level oblique looking north from blue marker, and ground level oblique looking west from blue marker.

A6. Farmed Wetlands

Farmed wetlands will be designated by the PEM1Af classification. A distinction needs to be drawn between a farmed wetland and a wetland that happens to be located within an agricultural area. The presence/absence of hydrophytic vegetation is the distinguishing factor. 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 (Figure A31) on the 2011 Spring CIR, and,

2. Evidence of crop stress, drown out, or otherwise altered crop pattern on at least 2 out of the 3 NAIP (2010, 2009, 2008) images.

Generally, soil signatures will be dark in comparison to the surrounding area. These may 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. The example below illustrates the difference between areas that should be considered for mapping as PEM1Af (green arrows) and areas that should not be considered (red arrows). The yellow arrow represents the limit of what should be considered for mapping. The additional examples illustrate the multiple years of NAIP, as well as the LiDAR DEM for the area. 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.

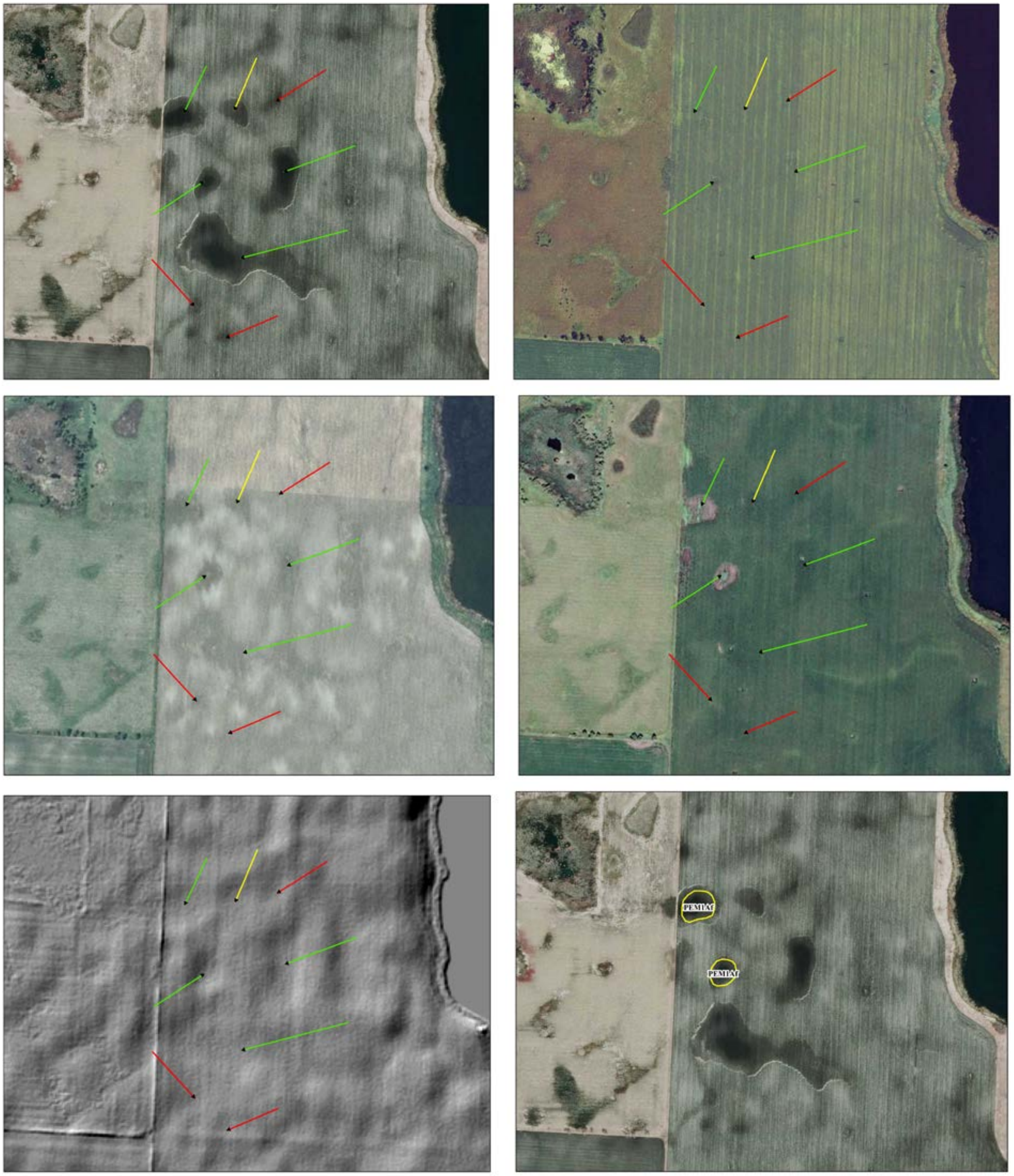


Figure A31. Farmed Wetland Signature Example. Top to Bottom. Left to Right: 2011 Spring Imagery (CIR), 2010 NAIP, 2009 NAIP, 2008 NAIP, LiDAR Hillshade, and 2011 Spring CIR with PEM1Af delineations. Arrows show examples to illustrate which soil signatures need to be considered for inclusion as farmed wetlands, green – must be considered, yellow – limit of what should be considered and red – should not be considered for inclusion.

A7. Mississippi River Floodplain

Due to the unique and dynamic nature of the Mississippi River, some conventions have been adopted to ensure consistent delineation and classification. The correct attribution for the Mississippi River main channel and other open water flowing back channels is R2UBH. Even though it is likely that the upper reaches of many pools (lock and dam tailwater areas) are more likely to behave as a naturally flowing river rather than impounded, this has been adopted as convention. The 2010 NAIP imagery will again serve as the primary imagery source. Areas exhibiting UB, US, AB, and EM2 signatures will be classified based on flow regime. In other words, areas exhibiting evidence of flow, mainly an upstream inlet and a downstream outlet, will be classified as R2, while areas that do not have evidence of flow (i.e. a single or no connection to a flowing area) will be classified as lacustrine littoral (L2) if larger than 20 acres and palustrine (P) if less than 20 acres. Interpretation decisions will have to be made for those UB, AB, and EM2 wetlands adjacent to R2 features as to whether there is enough flow present to classify the feature as riverine. This only applies to the UB, US, AB, and EM2 Cowardin classes. A good starting point would be to classify these features as riverine if more than 50 percent of their boundary is shared with a riverine wetland, but this might not hold true in all cases, and ultimately decisions should be based on the flow geometry. EM1, FO, and SS signatures will all be classified as palustrine. It is recognized that at certain times of the year the entire floodplain experiences flow; hence, the need to rely on the NAIP summer imagery. Figure A32 shows an example from the Mississippi River floodplain. The blue areas have been classified as riverine and the green areas as palustrine.

Figure A32. Mississippi River Floodplain Example. Top: 2010 NAIP, Bottom: Updated NWI with riverine in blue and palustrine in green, no color are upland inclusions.

A8. Application of the Partly Drained Special Modifier

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 existing NWI data, the partly drained modifier seems to have been overused, and should not be relied upon as an indicator of current conditions. In some cases wetlands located in natural floodplains were given the “d” modifier. The “d” modifier should be used in situations like the example below (Figure A33). 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 dryer in terms of water regime over time, as compared to the existing NWI data (orange in the example).

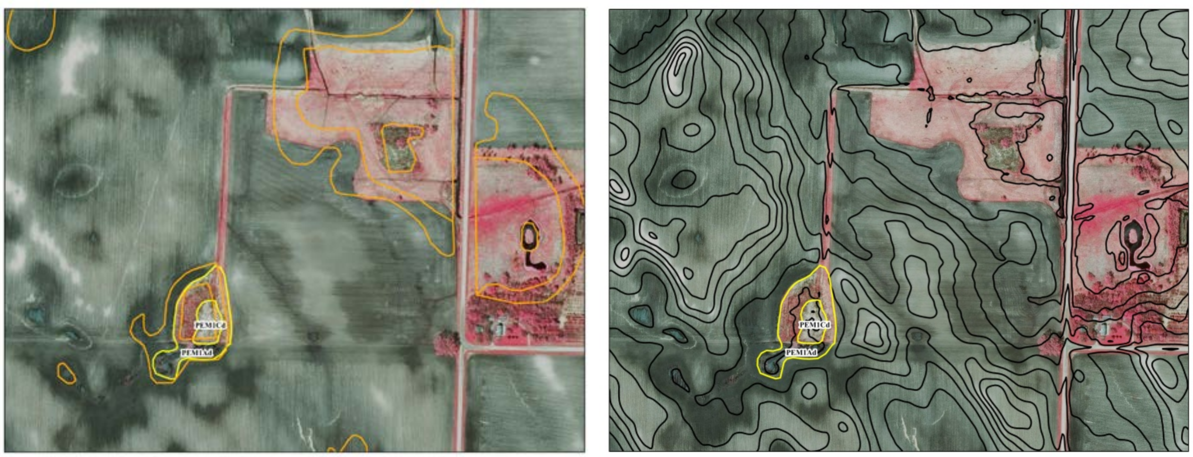


Figure A33. Partly Drained /Ditched Example. Left: Spring CIR with existing NWI in orange and updated delineation in yellow, Right: Spring CIR with LiDAR contours.

A9. Unusual Signatures

These signatures are documented in the interest of reducing confusion when they are encountered. In both 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 A34) shows a pocket of ice on Shetek Lake in Murray County. At first glance the signature might be confused with unconsolidated shore or maybe aquatic bed. However, there is a bluish tinge to the ice and a white shell ice signature along its outer boundary. 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.

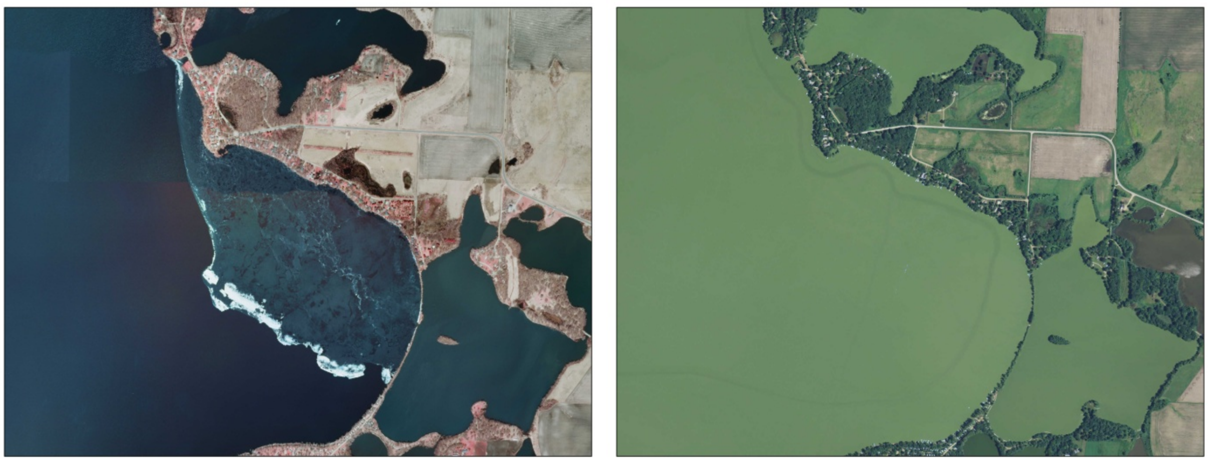


Figure A34. Lake Ice Example. Left: 2011 Spring CIR, Right: 2010 NAIP.

Gray Upland Signatures

There are some upland signatures on a few of the Spring CIR flight lines that mimic the smooth, gray PEM1A signature. An example is shown below in Figure A35. In this example, at first glance the gray areas might appear to be wetland, but they are actually high points of land sticking out along a drainage way. The deeper reds and reddish browns on the valley floor are, however, wetlands. The LiDAR is valuable for making this determination, and the true-color NAIP is also useful for finding wetlands in this situation. The ground level photograph is from the blue dot looking to the southeast.

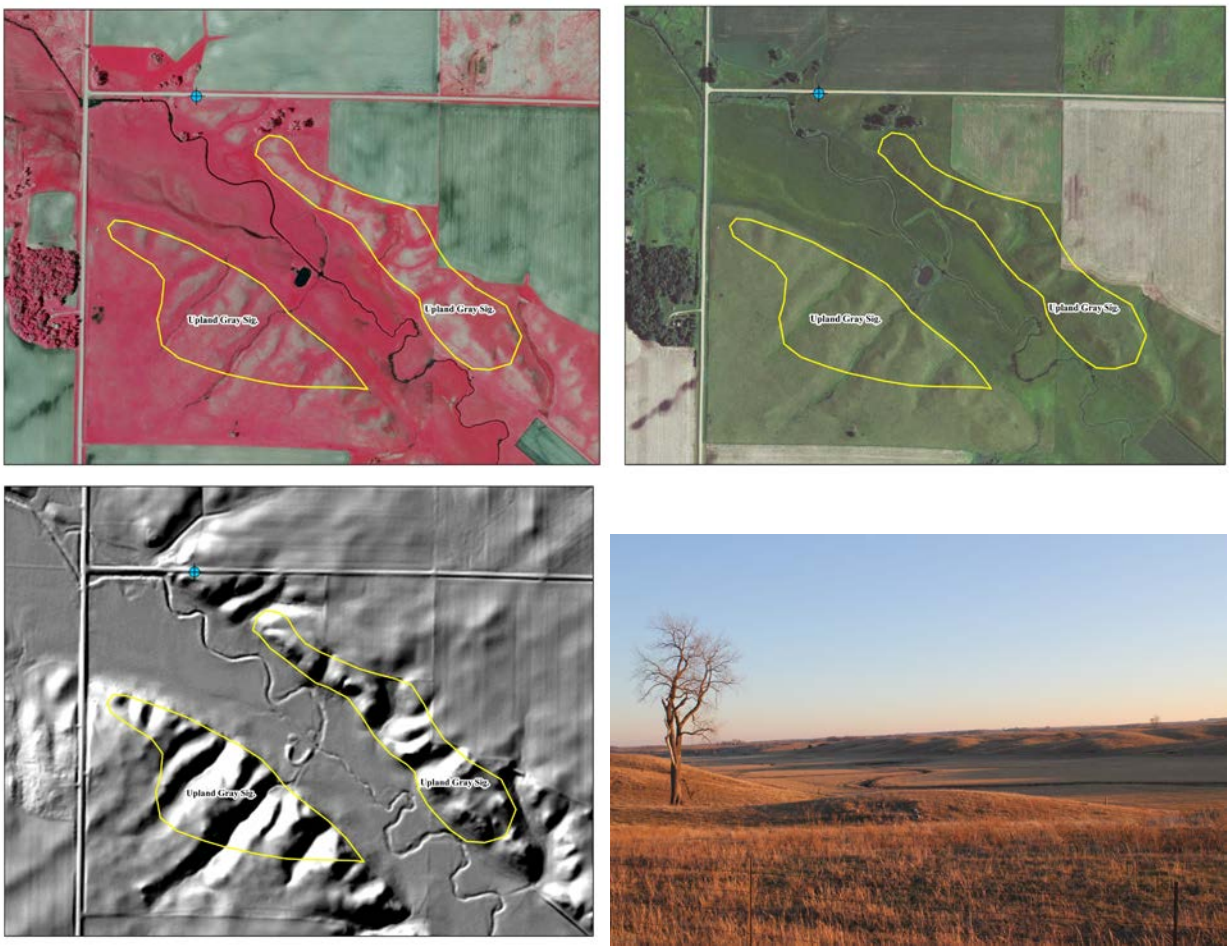


Figure A35. Gray Upland Signatures Example. Clockwise from upper left: 2011 Spring Imagery (CIR), 2010 NAIP, ground level oblique from blue marker southeast, and LiDAR Hillshade.

A10. Simplified Hydro-Geomorphic Classification Dichotomous Keys

The Simplified Hydro-Geomorphic Classification (Kloiber, 2011) is adapted from the U.S. Fish and Wildlife Service's Landscape Position, Landform, Waterflow Path, and Waterbody Descriptors (Tiner, 2003). These keys are simplified versions of the full LLWW and therefore only include those codes relevant to the Southern MN study area.

Table A1. SHGM Landscape Position Dichotomous Key

Landscape Position Dichotomous Key		
1a	Wetland lies along a river, stream, lake, reservoir, or in-stream pond; or witin a relatively flat plain contiguous to a waterbody	2
1b	Wetland does not lie along a 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 a 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 periodicallly 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 wetland is represented by a polygon on USGS 7.5 minute topographic map	**Lotic River**

Table A2. SHGM Landform Dichotomous Key

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	Wetlnad occurs ona nearly level landform	**Flat**

Table A3. SHGM Water Flow Path Dichotomous Key for Wetlands

Water Flow Path for Wetlands 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 outlflow	**Inflow**
2b	Wetland is not a sink; surface water flows through or out of the wetland	3
3a	Water 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 level are subject to the rise and fall of lake or reservoir levels	**Bidirectional-Nontidal**

Table A4. SHGM Water Body Dichotomous Key

Waterbody Type 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 and 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 in size	**Pond**
4b	Waterbody is greater than or equal to 20 acres in size	**Lake**

Table A5. SHGM Water Flow Path Dichotomous Key for Waterbodies

Water Flow Path for Waterbodies Dichotomous Key		
1a	Water flows out of the waterbody via a river, stream or ditch, with little or no inflow (inflow could be from intermittent streams or ground water only)	**Outflow**
1b	Waterflow is not so	2
2a	Water enters the waterbody from a river, stream, or ditch, flows through it and continues to flow downstream	**Throughflow**
2b	Water low is not throughflow	3
3a	Water flows in and out of the waterbody through the same channel; it does not flow through the waterbody	**Bidirectional-Nontidal**
3b	Water flow is not bidirectional	4
4a	Water flows enters viw a river, stream, or ditch, but does not exit the pond, lake or reservoir; waterbody serves as a sink for water	**Inflow**
4b	No apparent channelized inflow, source of water is by precipitation or underground sources.	**Isolated**

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