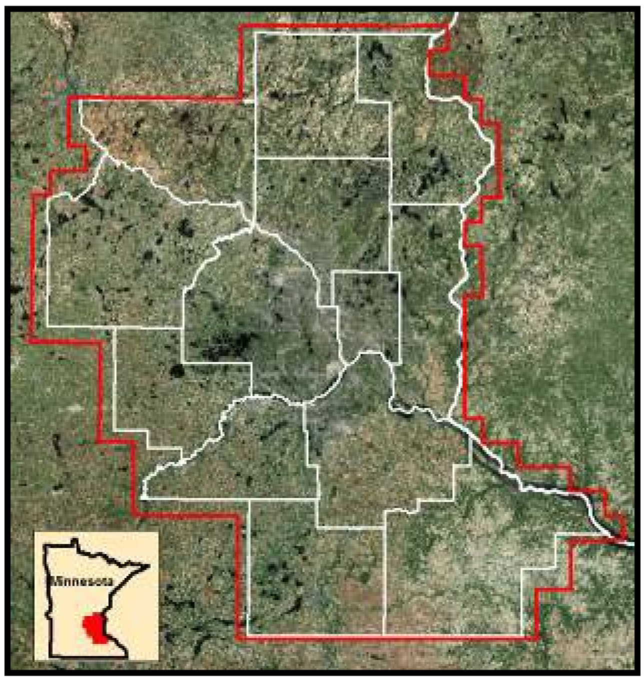
Updating the National Wetland Inventory in East-Central Minnesota

Technical Documentation

MAY 15, 2013



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Minnesota Department of Natural Resources

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1.0 Acknowledgements

Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR). The Trust Fund is a permanent fund constitutionally established by the citizens of Minnesota to assist in the *protection, conservation, preservation, and enhancement of the state's air, water, land, fish, wildlife, and other natural resources.* Currently 40% of net Minnesota State Lottery proceeds are dedicated to building the Trust Fund and ensuring future benefits for Minnesota's environment and natural resources.

Additional funding and support was supplied by the U.S. Fish and Wildlife Service.

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3.0 Introduction

3.1 Project overview

The Minnesota Department of Natural Resources (MDNR) has taken the lead in coordinating a multi-agency effort to update and enhance the National Wetland Inventory (NWI) for Minnesota. Wetland inventories are an essential tool for effective wetland management, protection, and restoration. Such inventories provide baseline information for assessing the effectiveness of wetland policies and management actions. These data are used at all levels of government, as well as by private industry and non-profit organizations for wetland regulation and management, land use and conservation planning, environmental impact assessment, and natural resource inventories. The NWI is the only spatially comprehensive wetland inventory for Minnesota. Yet, there are issues with the original NWI data for Minnesota. First and foremost, the data are about 25 to 30 years out of date. Second, various limitations in the original technology, methodology, and source data resulted in an under representation of very small wetlands, drier-end wetlands, and forested wetlands.

3.2 Project area

The project area consists of 13 counties in east-central Minnesota including: Anoka, Carver, Chisago, Dakota, Goodhue, Hennepin, Isanti, Ramsey, Rice, Scott, Sherburne, Washington, and Wright Counties (Fig. 1). This area is 6,328 square miles, but the updated wetland inventory included complete coverage for all USGS quarter quadrangles that intersect any of these counties (about 7,150 square mile).

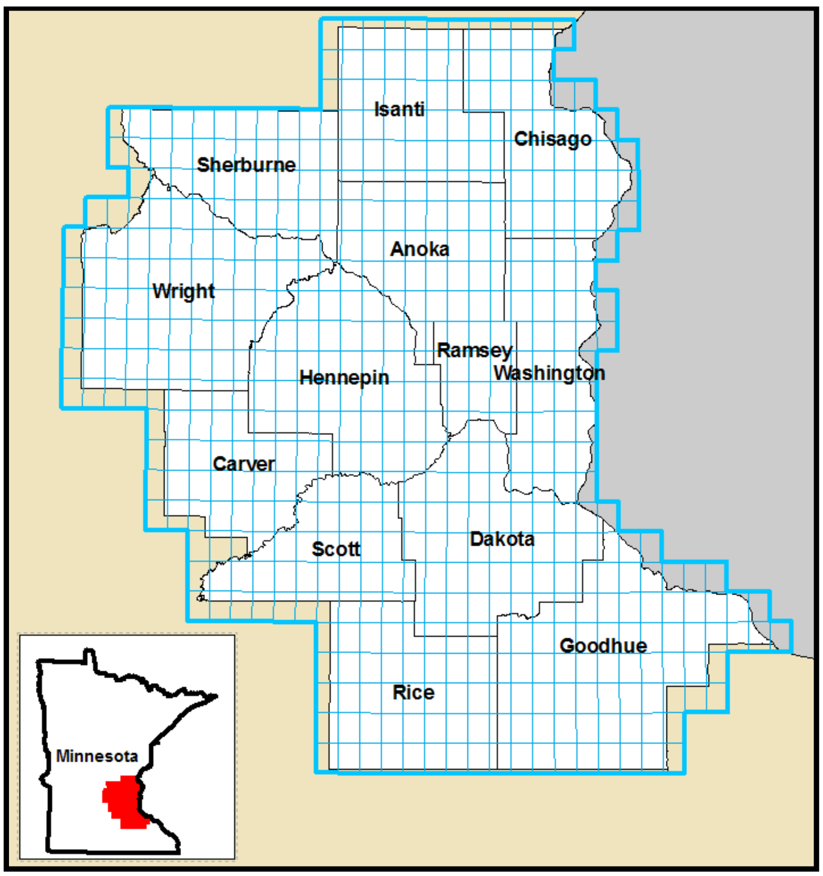


Figure 1: Project area - counties and quarter quadrangles covered

3.3 Project organization

Ducks Unlimited (DU) and the Minnesota Department of Natural Resource's Resource Assessment Office (RA) partnered to perform the NWI update for the east-central project area. DU had primary responsibility for developing the final updated NWI and RA had primary responsibility for the LiDAR and DEM processing as well as assisting with the field data collection.

4.0 Data

4.1 Projection

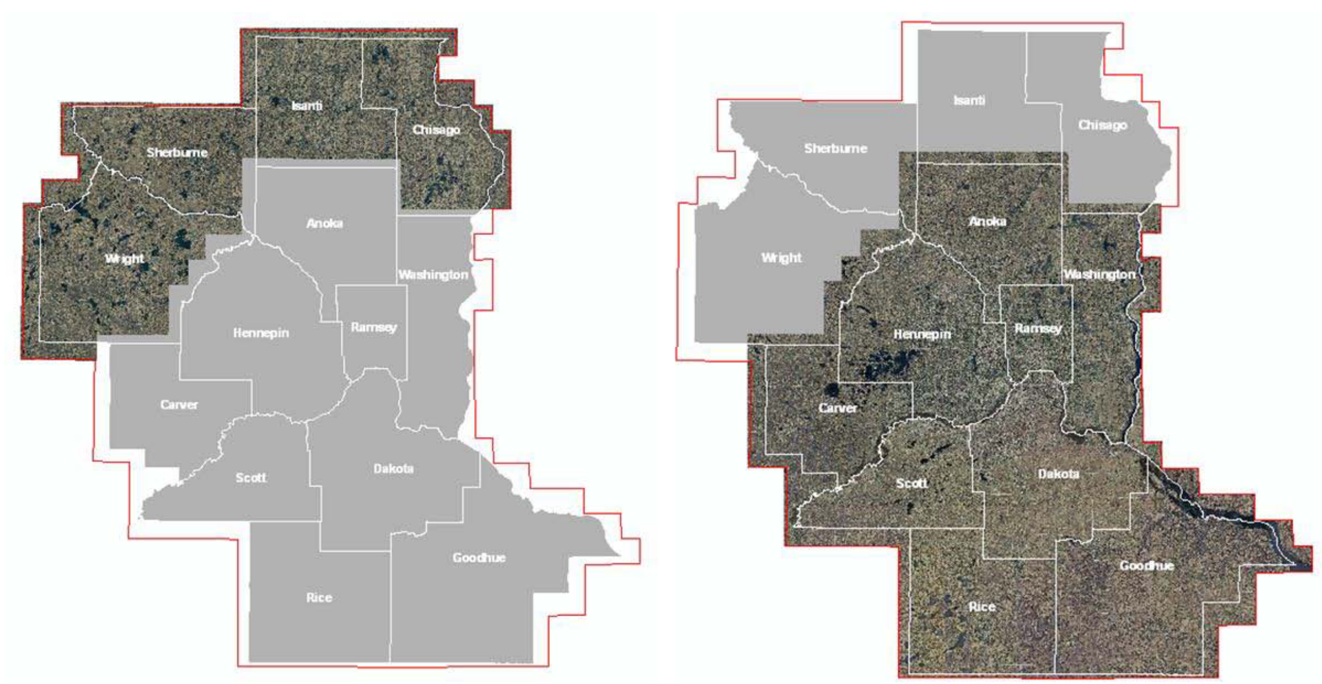
The NWI update for the east-central project area in Minnesota used the UTM projection, Zone 15N and the NAD83 datum. All data layers used this spatial reference. The final products were also projected to Albers Equal Area Conic Projection, NAD83 to conform to the spatial reference set by the U.S. Fish and Wildlife for NWI data.

4.2 Primary data layers

The primary data layers for this project were the layers used in creating the segmentation and wetlands probability layer and/or the photo interpretation process.

4.2.1 Spring Aerial Photos

The primary image data set for the NWI update was the 2010/11 4-band, digital ortho quarter quads, spring leaf-off aerial imagery (http://www.mngeo.state.mn.us/chouse/airphoto/ecmn10.html) (Fig. 2). Eleven of the thirteen counties were flown in 2010, with Rice and Goodhue flown in 2011. Four counties (Wright, Sherburne, Isanti, and Chisago) were flown with a spatial resolution of 50 cm. Seven counties (Carver, Scott, Dakota, Hennepin, Ramsey, Anoka, Rice, Goodhue and Washington) were flown with a spatial resolution of 30 cm.



0.5 meter, 4-band, spring imagery 0.3 meter, 4-band, spring imagery

Figure 2. The spring aerial imagery for the east-central project area.

4.2.2 Summer Aerial Photos

State-wide summer aerial photos have been flown by the Farm Service Agency (FSA) National Agriculture Imagery Program (NAIP) in 2008, 2009, and 2010. The 2008 imagery is 4-band, ortho-rectified imagery, while the 2009 and 2010 imagery is natural color (3-band), ortho-rectified imagery. (http://www.mngeo.state.mn.us/chouse/airphoto/fsa.html)

4.2.3 LiDAR data

LiDAR (Light Detection and Ranging) is an active remote sensing technology that operates on the power of laser light to detect and measure surface features on the earth. This data is particularly valuable for representing the topographical variation across a landscape. In Minnesota, LiDAR data is available for many areas of the state at a spatial resolution of 3 meters. Specifically in the East-Central study area, the LiDAR data currently available was collected in eight counties (Chisago – 2007, Scott – 2003, Dakota – 2005-2006, Hennepin – 2008, Ramsey – 2008, Washington – 2008, Carver – 2005, and McLeod – 2007)(Fig. 3).

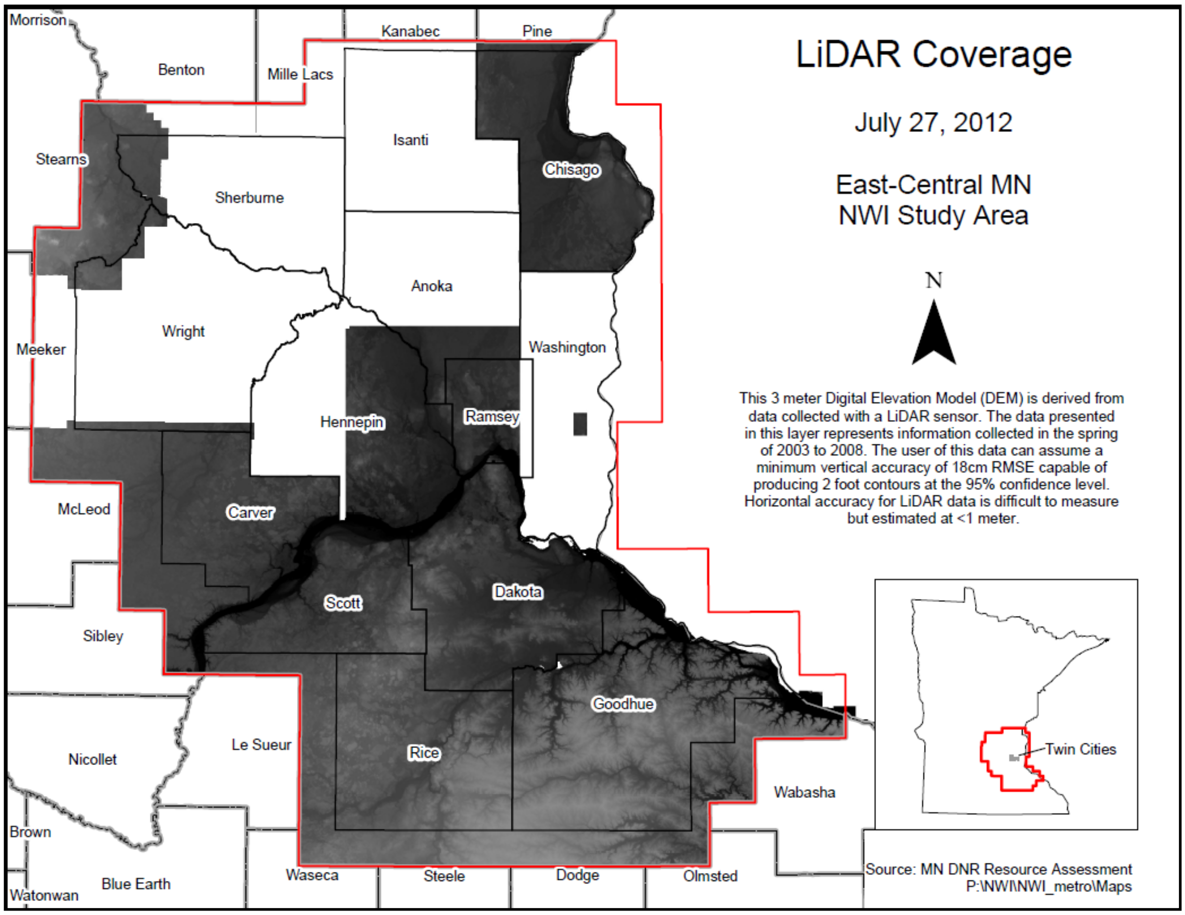


Figure 3. The LiDAR and NED coverage for the east-central project area.

4.2.4 Digital Elevation Model (DEM)

A Digital Elevation Model is a type of raster layer that represents the landscape in three dimensions, providing the x,y, and z characteristics at regular intervals. Each cell of the raster has a value corresponding to the surface elevation at that point on the landscape. DEMs in this analysis allow for systematic analysis of the relationships between elevation and other landscape characteristics. In the East-Central study area, the DEMs were derived from two different datasets. Since LiDAR (3 meter) is not available for the entire study area at the time of the analysis, the National Elevation Dataset (10 meter) was used to supplement (Fig. 3).

4.2.5 Palsar RADAR data

PALSAR L-band radar data was acquired through a data grant from the Alaska Satellite Facility (ASF) DAAC and AADN data pool. The data grant program is collaboration between ASF and NASA that offers free access to PALSAR upon approval of proposal. Thirteen single date scenes were acquired to cover the east-central Minnesota project area through the data grant program. The scenes available were a combination of single and dual polarization during spring and mostly leaf-off seasonal window (Table 1 and Fig. 4).

Table 1. The Palsar L-band RADAR scenes acquired for the east-central project area.

Palsar Scene ID	Path Number	Frame Number	Beam Mode	Start Time
ALPSRP124590870	165	870	FBD	MAY-27-2008 04:31:35
ALPSRP124590880	165	880	FBD	MAR-27-2008
ALPSRP122840890	167	890	FBD	MAY-15-2008 04:36:21
ALPSRP229470900	164	900	FBD	MAY-16-2010 04:33:54
ALPSRP229470890	164	890	FBD	MAY-16-2010 04:33:45
ALPSRP229470880	164	880	FBD	MAY-16-2010 04:33:37
ALPSRP229470870	164	870	FBD	MAY-16-2010 04:33:29
ALPSRP225240900	165	900	FBS	APR-17-2010 04:36:18
ALPSRP225240890	165	890	FBS	APR-17-2010 04:36:10
ALPSRP221010900	166	900	FBS	MAR-19-2010 04:38:41
ALPSRP221010890	166	890	FBS	MAR-19-2010 04:38:33
ALPSRP221010880	166	880	FBS	MAR-19-2010 04:38:25
ALPSRP221010870	166	870	FBS	MAR-19-2010 04:38:17

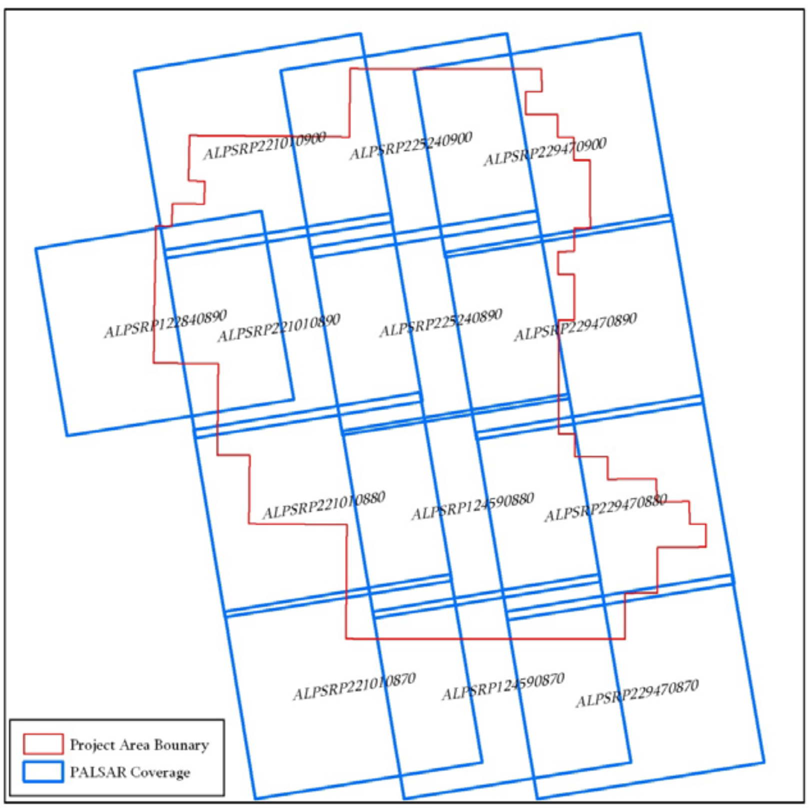


Figure 4. The Palsar L-band RADAR imagery for the east-central project area.

4.2.6 SSURGO Soils Data

The Natural Resources Conservation Service (NRCS) produces soils maps in GIS format (Soil Survey Geographic (SSURGO)) from the original soil survey maps. These maps can be very useful in identifying wetlands using various combinations of attributes contained within the SSURGO database. The SSURGO database was available for the entire east-central Minnesota project area. http://soils.usda.gov/survey/geography/ssurgo/description.html

4.3 Ancillary data layers

The ancillary data layers were used for creating the training data for the wetlands probability layer and for assisting with the photo interpretation. A separate training data set was collected by the University of Minnesota for the final wetlands assessment.

4.3.1 Metropolitan Mosquito Control District wetland layer

The Metropolitan Mosquito Control District monitors and controls mosquito, tick, and other potential disease-causing insect populations across the metropolitan St. Paul and Minneapolis area. MMCD maintains detailed data of the location, size, and type of potential breeding grounds across an approximately 2,800 mi^2 area. Breeding area types are based on wetness and vegetation type and are defined in Table 2 (adapted from MMCD metadata). Nearly all of the sites are visited by MMCD field staff. MMCD data is available in polygon format. (http://www.mmcd.org/)

Table 2: Wetland types as documented by MMCD

<table>
<tr><td rowspan="3">1. Temporary water; usually well-drained during much of the growing season</td><td>1.1 Open field, usually grass</td></tr>
<tr><td>1.2 Woodland pool or floodplain forest; could produce both spring and summer mosquitos</td></tr>
<tr><td>1.3 Woodland pool, only spring mosquitoes produced</td></tr>
<tr><td rowspan="3">2. Temporary water; typically dries out at some time during the year but may stay waterlogged.</td><td>2.1 - Reed canary grass, predominantly. No cattail</td></tr>
<tr><td>2.2 - Sedge meadow, predominantly. No cattail</td></tr>
<tr><td>2.3 - Assorted aquatic plants (not cattail, not predominantly reed canary grass or sedge)</td></tr>
<tr><td rowspan="2">3. Temporary water; wet or waterlogged most of year in wet years, may dry out in midsummer or dry years</td><td>3.1 - Majority reed canary grass and sedge, remainder mostly cattail</td></tr>
<tr><td>3.2 - Majority cattail, remainder reed canary grass and sedge</td></tr>
<tr><td rowspan="4">4. Permanent water, usually ca. 3 ft deep</td><td>4.1 - Vegetative band mostly canary grass and sedges; perm. open water area less than area covered by vegetation</td></tr>
<tr><td>4.2 - Vegetative band mostly cattails or broadleaf plants; open water area less than area covered by vegetation</td></tr>
<tr><td>4.3 - Majority of site is open water; narrow band of cattail, grass, sedge or other vegetation</td></tr>
<tr><td>4.4 - Majority open water; steep banks, very little emergent vegetation (ex: golf hazards, "duck ponds")</td></tr>
</table>

5. Permanent water ca. 10 ft. deep, may contain game fish	5.1 - Most vegetation grass and sedge, some cattail; open water area less than area covered by vegetation
	5.2 - Mostly cattails and/or broadleafs, some grass or sedge; open water area less than area covered by vegetation
	5.3 - Majority of site is open water; narrow bands of cattail, grass, sedge or other vegetation
	5.4 - Shallow pond or reservoir that does not contain game fish (including panfish)
6. Shrub swamp; usually waterlogged during growing season.	6.0 - (only type used)
7. Wooded swamp	7.0 - Usually tamarack
8. Bog	8.1 - Poorly drained, wet spongy ground rich in plant residue
	8.2 - Floating mat

4.3.2 Native Plant Communities

The Minnesota County Biological Survey collects information on high-quality, native plant communities. The Minnesota County Biological Survey locates higher quality native plant communities using aerial photo interpretation followed by field survey of selected sites. These native plant communities can be downloads in GIS format from the Minnesota DNR data deli (http://deli.dnr.state.mn.us/metadata.html?id=L250000040201).

4.3.3 Minnesota Wetland Monitoring Survey

The MN DNR Resource Assessment monitors wetlands throughout the state using 5,000 1-mi^2 plots as part of a broader wetland monitoring program. The classification used in the plots is shown in Table 3.

Table 3: Name, codes, and definitions for the wetland and non-wetland classifications

Code	***Habitat Name***	***General Description***
Deepwater class: delineate to 1-acre minimum *		
DW	Deepwater	Lakes, reservoirs, rivers, streams
Wetland classes: delineate to 1-acre minimum *		
FO	Forested wetland	Forested swamp
SS	Shrub swamp	Woody shrub or small tree marshland
EM	Emergent wetlands	Marshes, wet meadows, and bogs
AB	Aquatic bed	Wetlands with floating and submerged aquatics
UB	Unconsolidated bottom	Open water wetland, shore beaches and bars
CW	Cultivated wetland	Wetlands in agricultural fields
Wetland modifier		
m	Manmade	DW, UB, AB or EM of artificial origin
Upland habitats: delineate to 5-acre minimum		
U	Urban	Cities, incorporated developments

R	Rural development	Non-urban developed areas, infrastructure
A	Agricultural	Cultivated lands and managed upland pasture
S	Silvicultural	Forest stands of planted trees, plantations – including hybrid poplar
N	Natural	Unplanted forest, grassland, Shrubland, old fields
O	Other	All uplands not otherwise classed
Emergent Wetlands Subclasses		
IN	Inundated	Usually larger than 3 acres and are frequently associated with other fringing wetland classes or water regimes in the transition to upland habitats
SE	Seasonal	Typical in glaciated depressional basins or are frequently associated with inundated emergent wetlands or stream systems.
SA	Saturated	Typical water regime in lowland flats with little topographic gradient and also wetlands associated with ground water seepage faces located on slopes.
TE	Temporary	Typical in small (usually less than 3 acres) wetlands in glaciated regions, particularly agricultural regions, though small temporary basins do occur in upland forested regions

4.3.4 U.S. Fish and Wildlife Service National Wetland Inventory

The U.S. Fish and Wildlife Service's National Wetland Inventory (NWI) data is also available for Minnesota, but is about 25 to 30 years old. The data can be downloaded from the NWI web site: http://www.fws.gov/wetlands/ .

5.0 Cowardin Classification System guidance for Minnesota

The primary classification system used for the National Wetland Inventory (NWI) was described by Cowardin et al. (1979). All wetland classification definitions for the 2010 update of the Minnesota NWI follows Cowardin et al. (1979) and Dahl et al. (2009) unless otherwise noted below. The following section describes the valid codes and descriptions of the Cowardin classification system as applied to the 2010 Minnesota NWI update. A full list of valid codes is provided in Table 4. For examples of the NWI classes and how they were interpreted, please see the Photo Interpretation Guide for the 2010 Minnesota NWI Update (Ducks Unlimited 2012).

Table 4: Valid codes for NWI update of Minnesota

System	Subsystem	Class	Subclass	Water Regime	Special Modifier
L	L1	UB		H, K	h, x
L	L2	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
		EM	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	R2	UB		H	h, x
		AB		H	h, x
		US		A, C	h, x
		EM	2	F, H	h, x
		RS		A, C	h, x
		RB		H	h, x
					h, x
R	R3	UB		F, H	h, x
		US		A, C	h, x
		RS		A, C	h, x
		RB		F, H	h, x
R	R4	SB		A, C	h, x

5.1 Cowardin classes

The Cowardin classification system is a hierarchical system developed to standardize the classification of wetlands and deepwater habitats of the United States. At the highest level are five systems: marine, estuarine, riverine, lacustrine, and palustrine. Only three of these systems are relevant to the inland wetlands found in Minnesota: riverine, lacustrine, and palustrine. Santos and Gauster (1993) included a list of valid Cowardin wetland types for Minnesota in their regional user's guide to the National Wetland Inventory Maps.

Within the riverine and lacustrine systems, there are subsystems. Minnesota has lower perennial rivers, upper perennial rivers, and intermittent streams for riverine subsystems. There are no tidal riverine systems. There are also two lacustrine subsystems, limnetic and littoral. The palustrine system has no subsystems. Within each of these systems and subsystems there are several classes that are defined either on the dominant vegetation (e.g. scrub-shrub and forested) or the dominant substrate (e.g. unconsolidated bottom). Additional details of the classification system including the definition of each system, subsystem, class, and subclass can be found in Cowardin et al. (1979) and Dahl et al. (2009).

Valid classes for the remaining systems and subsystems were derived from Cowardin et al. (1979). These wetland classes are listed in Table 5.

General guidance for wetland classes:

- All wetland polygons will be classified to the Cowardin class level.
- Estuarine and marine systems and the tidal riverine system will not be used.
- Use of subclasses will be limited to emergent, scrub-shrub, and forested wetlands and must be identified for these classes (section 5.2).
- Only the systems, subsystems, and classes listed in Table 2 should be used for the NWI update.
- Mixed classes are allowed as specified by Dahl et al. (2009), but should be minimized (section 5.1.1).

Table 5: Valid classes for NWI update of Minnesota

System	Subsystem	Class	Code
Lacustrine	Limnetic	Unconsolidated Bottom	L1UB
	Littoral	Rock Bottom	L2RB
		Unconsolidated Bottom	L2UB
		Aquatic Bed	L2AB
		Rocky Shore	L2RS
		Unconsolidated Shore	L2US
		Emergent	L2EM
Palustrine		Rock Bottom	PRB
		Unconsolidated Bottom	PUB
		Aquatic Bed	PAB
		Unconsolidated Shore	PUS
		Moss-Lichen	PML
		Emergent	PEM
		Scrub-Shrub	PSS
		Forested	PFO
Riverine	Lower Perennial	Rock Bottom	R2RB
		Unconsolidated Bottom	R2UB
		Aquatic Bed	R2AB
		Rocky Shore	R2RS
		Unconsolidated Shore	R2US
		Emergent	R2EM
	Upper Perennial	Rock Bottom	R3RB
		Unconsolidated Bottom	R3UB
		Rocky Shore	R3RS
		Unconsolidated Shore	R3US
	Intermittent	Streambed	R4SB

5.1.1 Mixed classes

Mixed classes should be avoided if possible (areas of homogenous classes should be delineated as separate polygons). In cases where the classes are interspersed without clear spatial definition of the classes, the mixed classes should be limited to: FO/SS, FO/EM, SS/EM, UB/SS, and AB/SS with no reciprocals.

5.2 Wetland subclass

The historical application of the Cowardin subclasses in the Minnesota NWI is inconsistent with current guidance. Some historical subclasses such as subclass 5 for palustrine emergent wetlands were used in Minnesota, but have been abandoned in recent guidance or re-purposed (Dahl et al. 2009). In addition, many of the subclasses are difficult to reliably determine using remote sensing data. For this reason, the federal wetlands mapping standard (FGDC 2009) only requires subclasses for the emergent, scrub-shrub, and forested classes.

General guidance for subclasses:

- Subclasses will be only be used for scrub-shrub, forested, and emergent wetland classes and must be identified for these classes.
- Whenever possible, the most specific subclass, such as broad-leaved deciduous (PFO1) should be used instead of the more generic subclasses, such as deciduous (PFO6).
- There are no broad leaved evergreen tree species in Minnesota, so that subclass (PFO3) should not be used. However, there are broad-leaved evergreen shrub species (PSS3).
- Based on discussions of the technical advisory committee, sub-class 5 (dead) for both scrub-shrub wetlands and forested wetlands should be avoided. Wetlands should be classified based on the dominant (>30% cover) living life form or substrate.
- Valid subclasses for the Minnesota NWI are in Table 6.
- Mixed subclasses on forested and scrub-shrub classes should be avoided if possible (section 5.2.1)

Table 6: Subclasses for the NWI update of Minnesota

Class	Subclass
Emergent	1-Persistent 2-Nonpersistent
Scrub-Shrub	1-Broad-leaved deciduous 2-Needle-leaved deciduous 3-Broad-leaved evergreen 4-Needle-leaved evergreen 6-Deciduous* 7-Evergreen*
Forested	1-Broad-leaved deciduous 2-Needle-leaved deciduous 4-Needle-leaved evergreen 6-Deciduous* 7-Evergreen*

* The more specific subclasses will be used whenever possible.

5.2.1 Mixed subclasses

Mixed subclasses on forested and scrub-shrub should be avoided if possible (areas of homogenous subclasses should be delineated as separate polygons). In cases where the classes are interspersed without clear spatial definition of the subclasses, the mixed classes should be limited to: 1/2, 1/3, 1/4, 2/4 and 3/4 with no reciprocals.

5.3 Water regime modifier

To fully describe wetlands and deepwater habitats, one must apply certain modifiers at the class level or lower. The water regime modifier describes the hydrologic characteristics of the wetland including the frequency and duration of inundated or saturated conditions. Because detailed hydrologic records are seldom available, the assignment of water regime modifiers relies on interpretation of water levels from images taken at various times as well as interpretation based on the plant communities.

There are some differences in water regime definitions between various guidance documents (Cowardin et al. 1979; Santos and Gauster 1993; Dahl et al. 2009). The Minnesota NWI update will use the water regimes A, B, C, F, H, and K as defined by Dahl et al. (2009). There are no tidal or sub-tidal water regimes. The Minnesota NWI update will also not use the E water regime (seasonally flooded – saturated) due to its potential overlap with the C water regime. The Intermittently Flooded (J) water regime is generally considered to only occur in the western United States. This water regime is also excluded from the Minnesota NWI update. In addition, due to the difficulty in determining the difference between Intermittently Exposed (G) and Permanently Flooded (H) with limited temporal data, the G class will not be used.

Given the limited temporal data (typically only one spring image and maybe just a few relatively recent summer images), it will be difficult to classify water regime on the basis of water observation alone. Instead, it will be important to make inferences based on plant community, landscape position, and other factors. Fortunately, Cowardin et al. (1979) simplifies this task somewhat by restricting the water regimes for each class to only a few possibilities. In addition, water regimes are further restricted somewhat by regional wetland characteristics. For example, Cowardin allows for forested wetlands to have all water regimes except sub-tidal regimes. However, Minnesota does not have any tree species that can tolerate permanent or semi-permanent flooding (like Cypress). This is confirmed by the statistics for water regimes in the original NWI for Minnesota.

General guidance for water regime:

- Water regime modifiers will be applied to all wetland polygons.
- Only the A, B, C, F, H, and K water regimes as defined by Dahl et al. (2009) will be used in Minnesota.
- The (E) water regime from Dahl et al. (2009) will not be used. Instead, it will be incorporated into the (C) water regime.
- Due to the potential difficulty of reliably separating F, G, and H water regimes without long-term hydrologic records, the G water regime will not be used. Instead wetlands with more permanent water regimes will be classified as either semi-permanently flooded (F) or permanently flooded (H).
- The (J) water regime will not be used.
- Water regimes for each valid Cowardin class are listed in Table 7, with most-likely water regimes indicated by the abbreviation “ML”.

Table 7: Water regime modifiers for the NWI update of Minnesota

	Water Regime					
Cowardin Class	**A**	**B**	**C**	**F**	**H**	**K**
L1UB					ML	P
L2UB				P	ML	P
L2AB				P	ML	P
L2EM				P	ML	P
L2US	ML		P			P
L2RS	ML		P			P
L2RB				P	ML	P
PUB				P	ML	P
PAB				P	ML	P
PEM	P	P	ML	P	P	P
PFO	P	ML	ML	P		P
PSS	P	ML	ML	P		P
PUS	ML		P			P
PRB				P	ML	P
PML		ML				
R2UB					ML	
R2AB					ML	
R2US	ML		P			
R2EM				ML	P	
R2RS	ML		P			
R2RB					ML	
R3UB				P	ML	
R3US	ML		P			
R3RS	ML		P			
R3RB				P	ML	
R4SB	ML		P			

* The most-likely water regimes are indicated by "ML". Possible, but not-likely, water regimes are indicated by "P".

5.4 Special modifier

Special modifiers were used extensively in the original NWI and will be used in the NWI update (Table 8). The most commonly used special modifier in the original NWI for Minnesota was the (d) modifier for partly drained or ditched. Many of Minnesota's wetlands are partly drained or ditched and this characteristic is readily interpretable from most aerial imagery. The application of special modifiers for beaver impacts and excavated wetlands were also frequently used. As with the partly drained wetlands, these characteristics are readily identifiable from aerial photos. Diked and impounded wetlands can be photo-interpreted, but oftentimes ancillary data such as the impoundment structures GIS database from the DNR Division of Waters may be needed to identify these features.

Little used modifiers include the modifiers for farmed, artificial substrate, and spoils. The farmed modifier was little used at least in part due to policy decisions not to map most farmed wetlands in the original NWI for Minnesota. The current policy is to map these farmed wetlands, where they exist. The typical farmed wetland in Minnesota is usually a depression that is wet in the spring and it shows signs of cultivation. It may be cropped during the summer, but crop stress is often evident. Please see the Photo Interpretation Guide for the 2010 Minnesota NWI Update for examples of identifying farmed wetlands. Based on discussions with the technical advisory committee, the spoils modifier (s) will not be used in the NWI update for Minnesota. In addition, the artificial modifier (r) will not be used in the NWI update for Minnesota. Wastewater ponds will be coded as PUBKh.

A new modifier is proposed specifically for the Minnesota NWI update. Wetlands that have peatland (bog/fen) signatures (typical vegetation may include Sphagnum, Leatherleaf, Sedges, Black Spruce, and Tamarack) should be assigned the (q) modifier. Peatlands are readily identifiable from color-infrared imagery (Hop et al. 2000).

Guidance for special modifiers:

- Special modifiers will be applied using the definitions provided by Dahl et al. (2009), except that the special modifier for spoils (s) and artifical (r) will not be used.
- Farmed wetlands will be identified whenever possible using the guidance in the Photo Interpretation guide.
- An additional special modifier will be added and applied to indicate peatlands (based on the presence of Sphagnum peat mat or other peatland indicators).
- Do not use the r (artificial) special modifier.
- Wastewater stabilization ponds will be coded PUBKh.

Table 8: Valid special modifiers for the NWI update of Minnesota

Special Modifiers
Beaver (b)
Partly drained/ditched (d)
Farmed (f)
Diked/impounded (h)
Peatland (q)
Excavated (x)

5.5 Water chemistry modifier issues

The water chemistry modifiers were virtually ignored in the original NWI for Minnesota. Only four polygons were associated with water chemistry modifiers. Certain peatlands identified with the special modifier (q) are likely to be acidic, but pH cannot be reliably determined from remote sensing data. Therefore, water chemistry modifiers will not be applied for the NWI update for Minnesota.

5.6 Soil modifier issues

The original NWI did make some use of the soils modifiers, but their use was inconsistent. The most reliable mapped information on soils in Minnesota is from the USDA Soil Survey Geographic (SSURGO) Data. Application of soil modifiers in the absence of additional field work would be no better than simply relying on SSURGO. Therefore, soil modifiers will also not be applied to the NWI update for Minnesota.

6.0 Training data

The Random Forest™ classification process requires training data as input for the classification process. The training data consists of point locations of known wetland and upland types. Each location is classified according to the classification scheme list in section 5. The initial training data for the east-central project area was aggregated from on-the-ground field work and ancillary data. In total, 3350 points were used in the initial training data set. The breakdown by system and subsystem is shown in Table 9, with a breakdown by full code in Table 10. 510 sites were visited during field work, 1967 were chosen from ancillary datasets, and an additional 873 were identified by DU staff from aerial imagery. As each quarter quad is updated, additional training data will be merged with the initial training data to create a more robust training data set.

Table 9: Breakdown of training points by system

Classification		Total
Palustrine:		
	Forested	359
	Scrub-Shrub	103
	Emergent	1029
	Aquatic Bed	311
	Unconsolidated Bed	547
Lacustrine:		
	Aquatic Bed	18
	Unconsolidated Bed	39
Riverine:		
	Unconsolidated Bed	22
Upland:		796

Table 10: Breakdown of training points by full classification

FULL_CODE	FREQUENCY	FULL_CODE	FREQUENCY	FULL_CODE	FREQUENCY
L1UBH	17	PEM1F	109	PSS1A	41
L2ABG	5	PEM1Fd	4	PSS1B	15
L2ABH	13	PEM1Fh	1	PSS1C	37
L2UBH	21	PEM1Fx	9	PSS1Cd	4
L2UBHx	1	PFO1/2B	2	PSS2Bq	2
PAB/EM2F	2	PFO1/2Bd	1	PSS3Bq	4
PABF	87	PFO1/EM1A	13	PUBF	60
PABFx	61	PFO1/EM1B	4	PUBFh	2
PABG	9	PFO1/EM1C	19	PUBFx	215
PABGx	7	PFO1/SS1A	11	PUBG	9
PABH	117	PFO1/SS1C	12	PUBGx	10
PABHh	9	PFO1A	174	PUBH	104
PABHx	21	PFO1Ad	12	PUBHh	25
PEM1A	239	PFO1B	51	PUBHx	114
PEM1Ad	44	PFO1Bq	1	PUBKh	8
PEM1Af	51	PFO1C	91	R2UBH	22
PEM1Ax	16	PFO1Cd	11	U - Ag	264
PEM1B	42	PFO2B	5	U - FO1	86
PEM1Bd	8	PFO2Bq	9	U - FO4	34
PEM1Bq	7	PFO4A	1	U - Open	79
PEM1Bx	5	PFO4B	1	U - Rec	25
PEM1C	398	PSS1/EM1A	16	U - Res	84
PEM1Cd	57	PSS1/EM1B	8	U - Road	62
PEM1Cq	13	PSS1/EM1C	36	U - Urban	162
PEM1Cx	26	PSS1/EM1Cd	5		

6.1 Field data collection

Field training data for photo interpretation projects is extremely important in order to guide the interpretation. The field training data for the east-central project area served three purposes: 1) provided experience for the staff members updating the Minnesota NWI in the local wetland identification and classification, 2) gathered images for use in a guidebook for wetland photo interpretation, and 3) collected training data for the creation of a potential wetlands layer using a Random Forest™ classification. Within the project area, 12 quads with wetlands representative of those found in the project area were selected for field verification (Fig. 5). These quads included urban, residential, and rural areas.

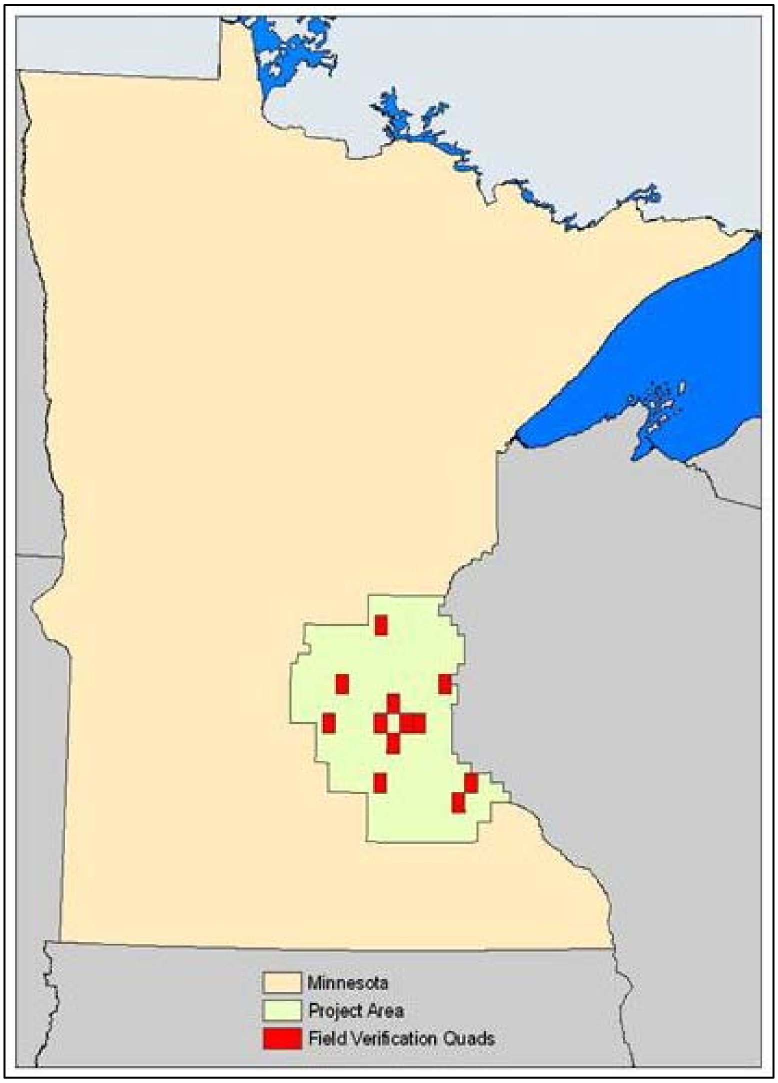


Figure 5: Location of quads within project area

6.11 Field training data selection

A frequency table was created of wetland types across the 12 field training quads. Wetlands were randomly flagged for field sampling in proportion to the frequency of that wetland class across all 12 quads, with the exception of rarely occurring wetland types, which were all flagged for field sampling.

6.12 Field training database

During the field data collection process, information on each site was simultaneously recorded on field data sheets and entered into the NWI photo file geodatabase. Direction of photo, wetland classification, collector's name and organization, date, and additional comments were recorded for each site. Additionally, the photos will be attached to the point layer and kept in a separate SDE geodatabase.

6.13 Field data results

During the four day period, 503 sites were visited. An additional seven were visited at an earlier date, for a total of 510 sites (Fig. 6). All sites were entered into DU's NWI geodatabase and will be used to assist in the classification process and photo interpretation of the NWI product. Metadata (information describing the dataset) was also created for the field training data geodatabase. The field training data geodatabase (points, attributes and site photos) were delivered to the MN DNR and U.S. Fish and Wildlife Service and to be archived with the official NWI data for future reference.

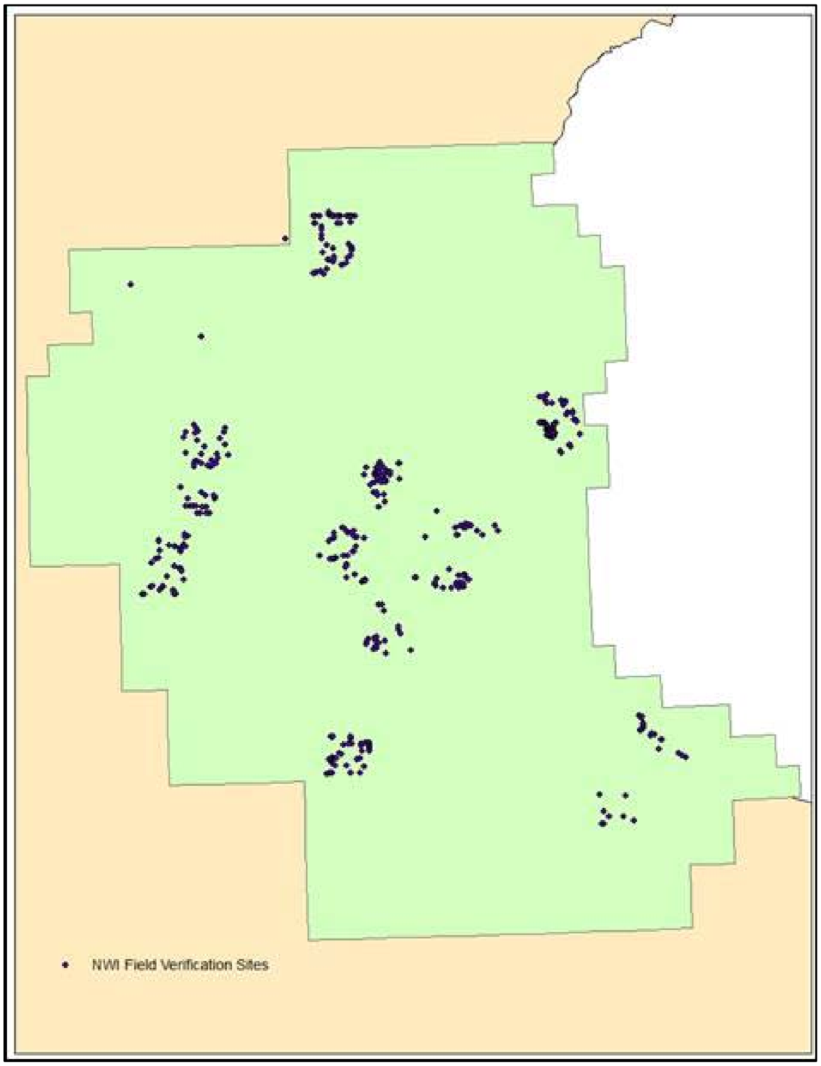


Figure 6: Field sites visited for this project

6.2 Additional Ancillary Data for Training Data

Existing data sets as well as photo interpretation of upland classes were used to supplement the field data for the initial training data input into the random forest classification.

6.21 Metropolitan Mosquito Control District (MMCD)

The MMCD polygon features were converted to point features by calculating the centroid of each polygon. The point data was clipped to the test quad boundaries, bringing the number of features down from over 57,000 to 6,562. These points informed the interpreter of the approximate wetness of each area, providing a more accurate assessment of the potential water regime for a site. The MMCD data was used to supplement areas within the 12 reference quads that were lacking training data. The MMCD sites selected were classified according to NWI standards and were included in the final dataset of training points. There were 1,140 MMCD points included in the final training data.

6.22 Native Plant Communities

The Minnesota DNR provided data from the 2003 Minnesota County Biological Survey (MCBS) of native plant communities. The polygon features were converted to point features by calculating the centroid of each polygon and clipped to the test quad boundaries. The points were classified according to NWI standards and were included in the final dataset of training points, with 288 of these points included in the final reference data.

6.23 Minnesota Wetland Monitoring Survey

The MN DNR Resource Assessment provided shapefiles covering the 53 plots that intersected the test quads used for training data. There were anywhere from 2 to 366 features per plot. The centroid of each polygon was calculated; from the resulting point file, representative points were classified by NWI type and included in the final reference data file. 539 points (of 2,273 within the test quads) from the wetland monitoring survey plots were included in the final file.

6.3 Additional training points

In addition to the training points from field data and Minnesota DNR data, Ducks Unlimited staff used aerial imagery to identify an additional 873 training points. The majority of these points were chosen for distinguishing different upland land types: agriculture, upland forest (deciduous and coniferous), open upland, recreation, residential, roads, and urban land cover. The rest of the points were chosen to provide more examples for less common wetland classes.

The final set of point features used as training data is shown in Figure 7.

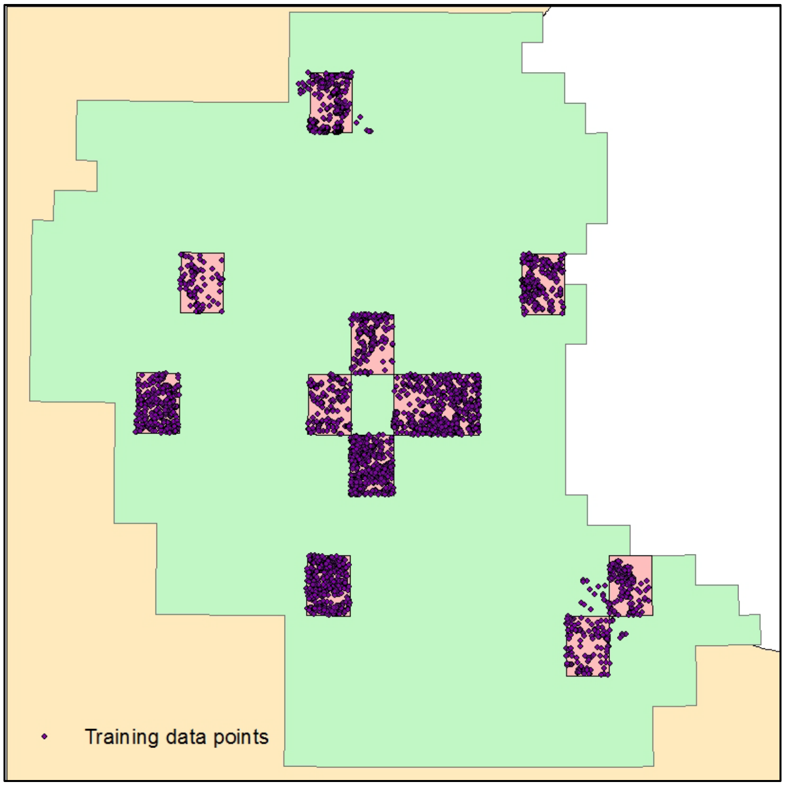


Figure 7: Training points used as reference data

7.0 Data processing

7.1 Spring Aerial Photos

The Minnesota NWI update project conducted by Ducks Unlimited and the MN DNR Resource Assessment group utilized two resolutions of imagery (30cm and 50cm pixel resolution) for image interpretation and segmentation for the purpose of wetland delineation and labeling for incorporation into the updated NWI database. After considerable difficulty in identifying a set of image segmentation parameters that would produce comparable results in both image resolutions, a solution was proposed which entailed resampling (coarsening) the 30cm resolution data to the same spatial resolution as the 50cm data available for the majority of the project area. The 30cm imagery was retained and used for photo-interpretation tasks but for the purposes of automated image analysis the resampled data allowed for a single unified set of processing algorithms to be applied across the entire project area.

In order to ensure the resampling step would not compromise the quality of the final database a small evaluation was developed to test alternative resampling methods with respect to the image segmentation process. The resampling evaluation yielded visual and segmentation results similar to the imagery acquired and delivered at 50cm resolution (50cm base). Therefore, the 30cm data was resampled to 50cm for the purposes of image segmentation for this project.

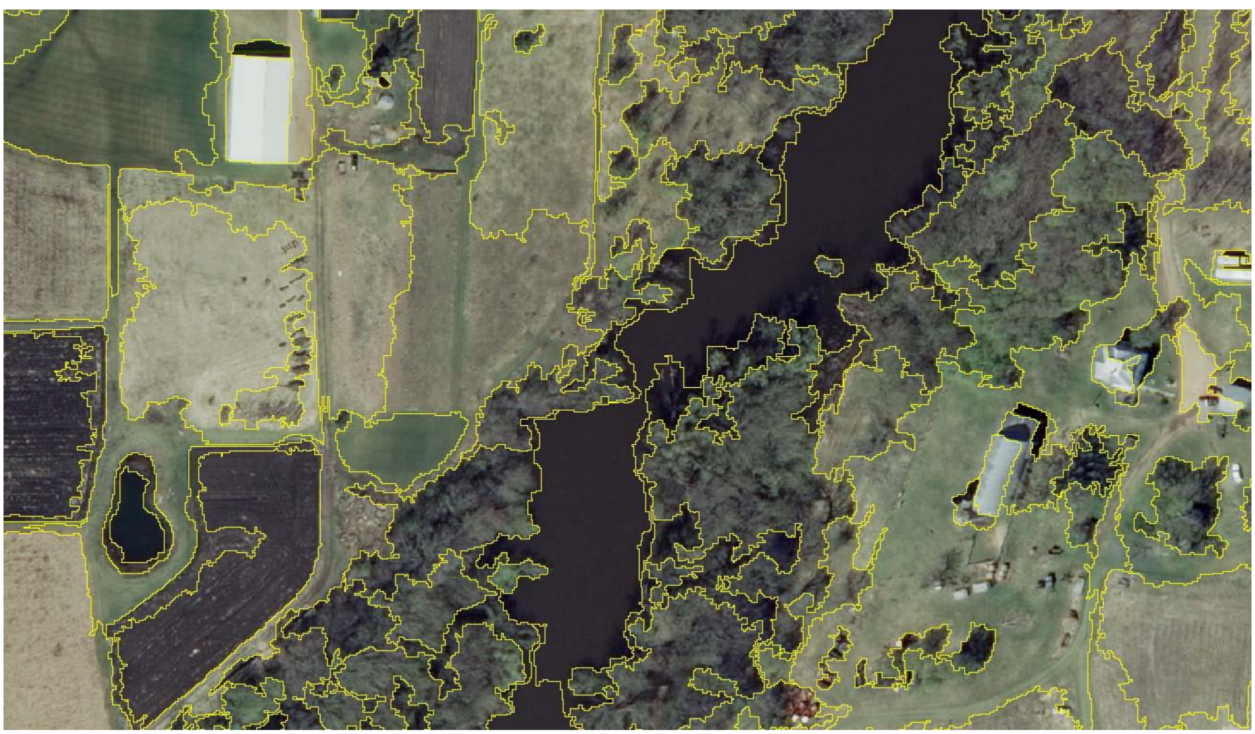


Figure 8. Segmentation based on data resampled to 50cm resolution displayed over the original unaltered 30cm imagery at a scale of 1:1000.

7.2 LiDAR/DEM processing

Several topographic metrics or indices were derived from the LiDAR/DEM data. These derived metrics and indices potentially provide a greater ability to discriminate wetland from upland than the DEMs alone. These derivatives are described in the following sections. Since the LiDAR DEMs have a resolution of 3m and the NED DEMs have a resolution of 10m, they were processed separately.

7.2.1 Curvature

The curvature of a surface at any given point helps to explain the speed and direction of the flow of water across the area in question. Each cell's curvature value is the second derivative of the surface based on its eight neighboring cells. This process can be completed using the Spatial Analyst extension in ArcGIS. A positive curvature value indicates the surface is upwardly convex at that point, while a negative value indicates the surface is upwardly concave (http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=curvature)

7.2.2 Planform Curvature

Planform curvature measures the curvature of a surface perpendicular to the direction of the maximum slope. A negative value indicates the surface is sidewardly concave, while a positive value indicates the surface is sidewardly convex. The curvature tool has an optional planform curvature output.
(http://blogs.esri.com/Support/blogs/mappingcenter/archive/2010/10/26/Understanding-Curvature-Rasters.aspx)

7.2.3 Profile Curvature

Profile curvature measures the curvature of a surface parallel to the direction of maximum slope. A negative value indicates the surface is upwardly convex, while a positive value indicates the surface us upwardly concave. The curvature tool has an optional profile curvature output.
(http://blogs.esri.com/Support/blogs/mappingcenter/archive/2010/10/26/Understanding-Curvature-Rasters.aspx)

7.2.4 Topographic Position Index (TPI)

TPI values provide a simple and powerful means to classify the landscape into morphological classes (Jenness 2005 and Tagil and Jenness 2008). TPI is a simplification of the Landscape Position Index described by Fels and Zobel (1995) and developed by Weiss (2001).

TPI for each cell is calculated by subtracting the mean elevation of its neighborhood from its own elevation value. A positive value indicates the pixel is higher than its neighbors, while a negative value indicates it is lower. This simple classification is a useful means of mapping topographic depressions. Groups of pixels with negative TPI scores represent such depressions, and are possible wetland locations.

A Digital Elevation Model (DEM) is the only data required to calculate TPI. An ArcGIS Model Builder was used to create the TPI (Fig. 9). Selecting appropriate neighborhood settings is an important part of the process. Selecting too small of a neighborhood will result in very fine resolution which is not adequate for detecting topographic depressions over large areas. Selecting too large of a neighborhood will result in depressions which may encompass upland areas as well. For the east-central project area, a circular neighborhood with radius of 15 and 20 cells (45 and 60 meter for the LiDAR DEMs) were selected.

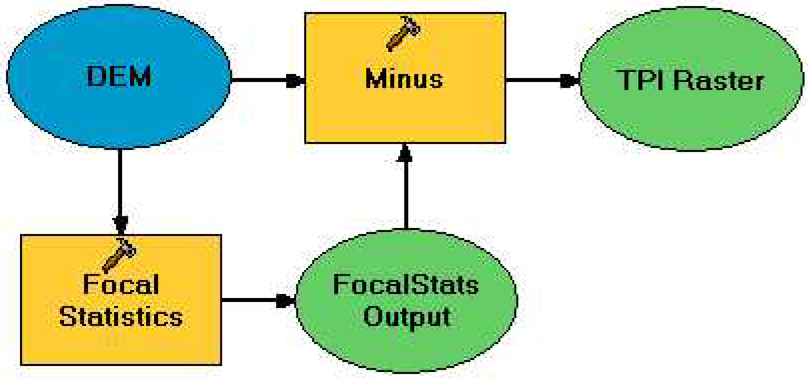


Figure 9. The ArcGIS Model Builder for calculating the TPI.

7.2.5 CTI

The Compound Topographic Index (CTI) is a function of both the slope and the upstream contributing area. CTI can be calculated as:

CTI = ln (A_s / (tan(β)),

where A_s = contributing area and β is the slope expressed in radians. Slope and flow direction were calculated using the TauDEM tool (Tarboton 2003). Flow direction was calculated using the D-Infinity (D-inf)algorithm. Flow direction was then used to derive the contributing drainage area, also using TauDEM. The slope grid and contributing area were then plugged in the equation for CTI.

Prior to calculating the CTI, 3m LiDAR DEMs were clipped to the quarter-quad boundaries. Topographic depressions (sinks) were then removed to generate a sinkless DEM. A python script was written to batch process the CTI. Testing was conducted to determine if it was necessary to modify the DEM to account for subsurface drainage connections such as road culverts in order to use the CTI for wetland mapping. The results of this testing indicate that the accuracy of the RandomForest ™ model were not improved by burning-in these subsurface features. Given the level of effort and expense involved in making these modifications, it was determined that future processing of CTI would not include these subsurface features.

7.3 Palsar

ASF MapReady Remote Sensing Tool Kit (MapReady, 2011) was used for terrain correction, geocoding, and exporting to geo-tiff file format. After terrain correction was applied the pre-processed PALSAR scenes still contained some distortion within in the project area so further geo-rectification was performed in ArcGIS using selected control points from the aerial imagery. The RADAR processing extension in Opticks (Opticks, 2011) was used to reduce speckle in the PALSAR data.

A 10 class maximum-likelihood clustering routine implemented in ERDAS Imagine software (ERDAS, 2008) was used to produce an unsupervised classification of the PALSAR data. Clusters visually identified as being associated with “wet forest" were assigned that classification value. Analysts noted some confusion between wet deciduous forest and pine plantations, some agricultural areas and urban areas. This confusion was remedied during subsequent image segmentation and classification steps. The final product from the PALSAR analysis was a binary 1/0 raster layer representing likely wet areas within deciduous forests. This layer was integrated into the overall wetland mapping process by incorporating it into the image segmentation process and as an additional ancillary data layer available to the photo-interpretation team.

7.4 SSURGO

Two soil map products were created as inputs in the NWI Update for Minnesota; (1) an oridinal map based on the predominant soil water regime, and (2) a continuous variable map based on the sum of component percentage that meets a specified hydric soil criterion. Both of these products rely on soils data from the NRCS (i.e. SSURGO). Soil variables are extracted from the NRCS database for the project area. The variables included in the analysis were the variables most likely to be related to wetland water regime (e.g. drainage class, flood frequency for April, pond frequency for April, and pond frequency for August).

Both data products can be created using the same MS Access query results from three basic queries.

Query 1

```
SELECT mapunit.mukey, mapunit.musym, mapunit.muname, component.compname, component.comppct_r,
component.drainagecl, component.geomdesc, component.cokey

FROM mapunit INNER JOIN component ON mapunit.[mukey] = component.[mukey];
```

Query 2

```
SELECT comonth.[cokey], comonth.[month], comonth.[flodfreqcl], comonth.[pondfreqcl]

FROM comonth

WHERE (((comonth.[month])="April"));
```

Query 3

```
SELECT comonth.[cokey], comonth.[month], comonth.[pondfreqcl]

FROM comonth

WHERE (((comonth.[month])="August"));
```

The first query is the related to the second and third queries using the [cokey] field toinclude all records from first query and only those records from the second and third query where the join fields are equal.

The complete query report is created by selecting all fields from first query and append the fields from the second and third queries. The result is exported to MS Excel.

Water Regime Product

The drainage class, April flood frequency, April pond frequency, and August pond frequency fields are contatenated and the results sorted on the concatenated field. The soil component data are then classified according the criteria in Table 11.

The resulting table includes water regime classes for all soil components. Map units may contain more than one component; therefore, the data must be summarized to the map unit level. This is done by concatenating the map unit symbol field with the water regime class. A pivot table is created to summarize component percentage (sum of comppct) by the new concatenated field of MUSYM-WR. For any map units that have more than one water regime, the predominant water regime is identified. Duplicate MUSYM values were eliminated so that the final table only includes distinct values.

For each map unit, select the component with the largest percentage contribution (max[comppct_r]). Join the tabular data from the MapUnit_WR worksheet to the SSURGO shapefile for a selected county. The water regime field is used as an indicator of wetness intensity from 0 to 8 with higher numbers indicate wetter, more permanent water regimes.

Table 11. SSURGO water regime values

Water Regime	Description	Values for Concatenated Field
0	All excessively drained, somewhat excessively drained, and well drained soils as well as udorthents, udipsamments, pits, and gravel. This water regime level also includes moderately well drained soils and somewhat poorly drained soils that do not flood.	Null-Null-Null-Null (Pits, Udipsamments); Excessively drained-None-None-None; Moderately well drained-None-None-None; Null-None-None-None; Somewhat excessively drained-None-None-None; Somewhat excessively drained-Rare-None-None; Somewhat poorly drained-None-None-None; Well drained-None-None-None
1	This water regime level includes moderately well drained soils and somewhat poorly drained soils that do flood at least rarely. (floodplain formations) This is similar to Cowardin's temporarily flooded "A" water regime.	Moderately well drained-Occasional-None-None; Moderately well drained-Rare-None-None; Somewhat poorly drained-Frequent-None-None; Somewhat poorly drained-Occasional-None-None
2	Poorly drained and very poorly drained soils that neither flood nor pond. This is similar to Cowardin's saturated "B" water regime.	Poorly drained-None-None-None; Very poorly drained-None-None-None
3	Poorly drained soils that occasionally flood during spring (almost all floodplain formations). Similar to Cowardin's "A" or "C" water regime depending on the length of flooding.	Poorly drained-Occasional-None-None
4	Very poorly drained soils with frequent spring flooding, but no ponding (almost all floodplain formations). Similar to Cowardin's seasonal "C" water regime.	Very poorly drained-Frequent-None-None
5	Very poorly drained soils with frequent spring flooding and spring ponding (almost all floodplain formations). Similar to Cowardin's seasonal "C" water regime.	Very poorly drained-Frequent-Frequent-None
6	Very poorly drained soils with no flooding, but that do have spring ponding (almost all depressional formations). Similar to Cowardin's seasonal "C" water regime.	Very poorly drained-None-Frequent-None
7	Very poorly drained soils with ponding throughout most, if not all the year (marsh). Similar to Cowardin's "F" or "G" water regime.	Very poorly drained-None-Frequent-Frequent
8	Map units designated as water (non-soil). Similar to "H" WR	Null-Null-Null-Null (Water)

Percent Hydric Soil Product

A new field called hydric percent (hydric_pct) was created in the MS Excel worksheet with all soil component data (obtained from query 4). The new field is set to zero for soil components that are not hydric (water regime = 0). For soil components that are hydric (water regime >0) the hydric percent value is equal to the component percent (comppct). The hydric percent data are summarized (sum of hydric_pct) by map unit symbol (the [musym] field) using the pivot table function.

The tabular data from this summary of the hydric soil percent (Sum_Hydric_Pct) worksheet are joined to the SSURGO shapefile for Wright County using the [musym] field. The hydric percent field is used as an indicator of the extent of hydric soils from 0% to 100% within each soil map unit.

7.5 Layer stack

The input to the eCognition segmentation process is a tiff layer stack and the raw spring 2010 aerial imagery. The process for creating the tiff layer stack is summarized in Fig. 10. The NED 10 meter DEM was resampled to 3 meter resolution after the derived products were created. The SSURGO soils derived products were converted to raster format and added in the stack. All layers were clipped to the spring 2010 aerial image boundary. The final tiff layer stack consisted of the following layers:

1) Combined Curvature
2) Planimetric Curvature
3) Profile Curvature
4) TPI 15
5) TPI 20
6) CTI
7) Palsar
8) SSURGO Hydric Percentage
9) SSURGO Water Regime
10) DEM

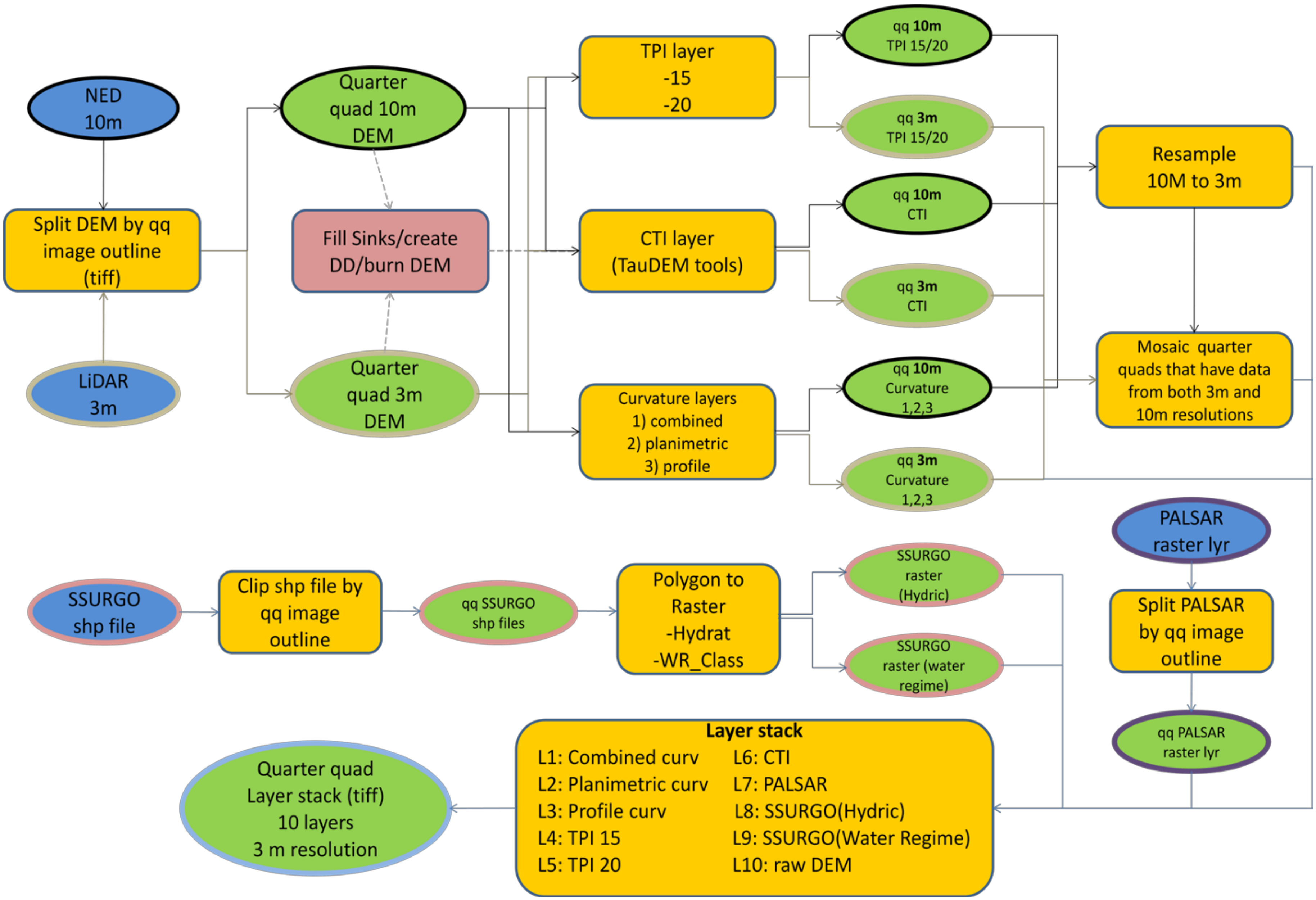


Figure 10. Process for creating the Layer stack for input into the segmentation and random forest classification.

8.0 NWI classification process

The NWI classification process for east-central Minnesota consists of three basic steps: 1) creation of image segments (polygons), 2) RandomForest™ classification of the segments, and 3) photo interpretation of the classified image segments. A detailed description of each of the steps is described in the sections below and outlined below and in Fig. 11.

The layer stack (described in previous section) and the 2010 spring 4-band imagery was input into eCognition software to create the image segments. The output of the segmentation process consists of two shapefiles; a polygon shapefile of the segments and a point shapefile of the centroids of the polygons. The polygons and points were related using a unique identification number (ID). The point file contains all of the descriptive information from the polygon segments and was used as the input into the random forest classification. Topology was built for the image segments and any issues are corrected. Additional fields (attribute, comments, field verified) were added to the image segments for the photo interpretation process.

A random forest classification was run using the point file and training data (described in section 6 above). The random forest classification classified each point based on the training data and assigned a confidence value to each classification. The resulting classification was then joined to the polygons using the unique ID. Once the photo interpretation process was completed for the quarter quads, those polygons become part of the training data used to train the random forest classification for subsequent quads.

The classified segments were then used to enhance a more traditional photo interpretation of the imagery. Each of the segments was viewed, edited (merged with neighboring segments of the same class or cut to exclude an area), and assigned a final NWI classification using a variety of imagery and data (see section 3). A custom object inspector was created to incorporate the information from the random forest classification as well as the soils and Radar classifications. Once a quarter quad was completed, the segments were dissolved based on NWI attribute and run through a quality control process that checks for overlaps, gaps and approved NWI codes.

The draft version of the NWI classification for the quarter quad was sent to the MN DNR for review. Once the review was completed, the quarter quad was merged into a seamless state-wide layer. The final NWI layer for the east-central project area was projected to Albers equal area projection for delivery to the U.S. Fish and Wildlife Service.

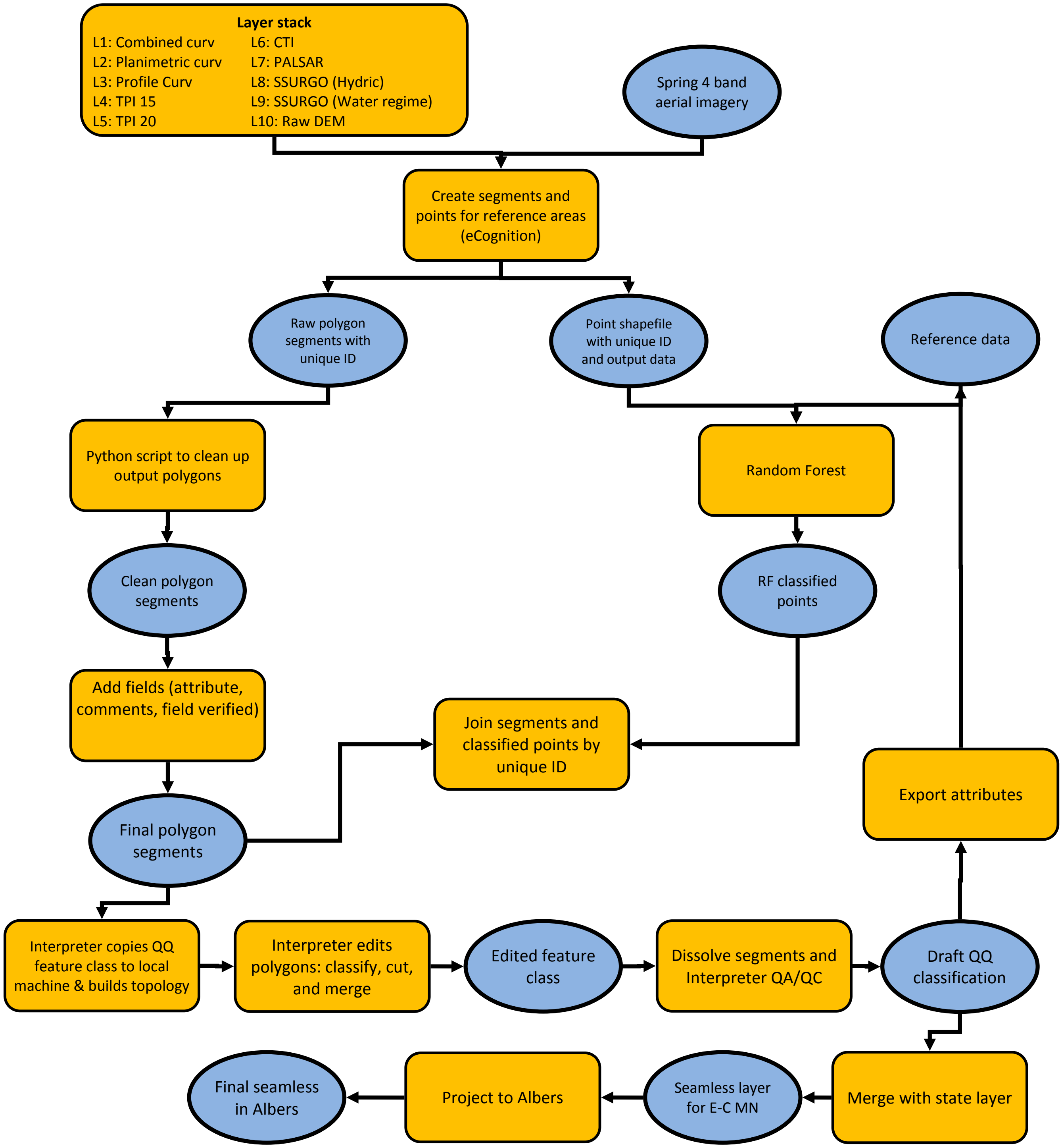


Figure 11. The NWI classification process for east-central Minnesota

8.1 MN DNR Field evaluation

An initial field assessment of the classified wetlands was completed by the MN DNR Division of Forestry Resource Assessment during the last week in October, 2011. The primary objective was to provide feedback to the Photo Interpreters on the initial wetland classification. The secondary objective was to identify classes which satisfy the peatland modifier in order to provide better examples to the Photo Interpreters. The results of the field assessment can be found in Appendix A.

8.2 Segmentation

The spring 4-band imagery and layer-stack files were imported into eCognition software (Trimble 2010) to create the image segmentation files. The eCognition processing rule-set developed for this project contains a sequence of over 250 separate operations. These operations include:

1. Initial quad-tree based image segmentation
2. Sub-processes to manage edge matching between adjacent quads
3. A multi-resolution image segmentation sequence
4. Hierarchical image object aggregation by spectral, topographic, and classification based characteristics
5. Segmentation based re-scaling of the 25m spatial resolution PALSAR layer to make it visually compatible when vectored and merged with vectors derived from the 0.5m base imagery
6. Derivation of contour lines within forested areas based on the DEM layer
7. Smoothing of all image object boundaries
8. Elimination of image objects smaller than the specified minimum mapping unit
9. Export of a final shape file for each quarter-quad

Improvements to the ruleset and process development were conducted by creating prototype segmentations for the photo-interpretation team to review. Suggestions and requests to improve the properties of the segmentation were made by the photo interpretation team and incorporated into subsequent versions of the segmentation process. The ultimate goal is to develop eCognition based segmentation and feature extraction processes (Figure 12) that support and complement the work done by the photo interpretation team rather than to try to replace human photo-interpretation entirely.

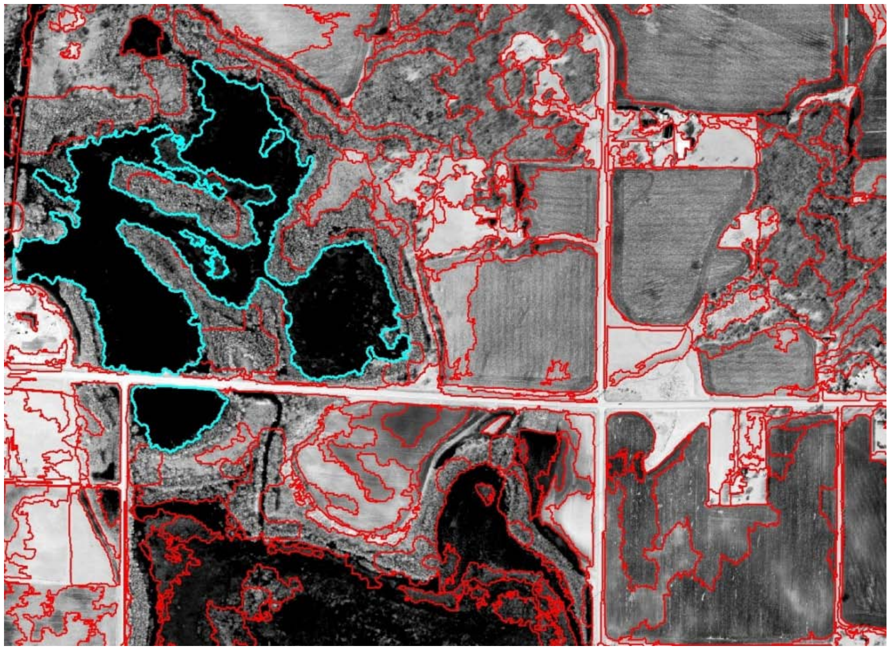


Figure 12. The unedited image segmentation results (red) with two wetland polygons selected (blue) displayed over the IR band of the primary 50cm resolution CIR imagery collected for this project

We considered the image segmentation effort to be successful when we reached a point it took less time for an interpreter to edit an eCognition derived segmentation shape file for a quarter-quad than it would have taken for that interpreter to manually digitize all of the features in that quarter-quad. The photo-interpretation team now spends the vast majority of its time interpreting wetland classes that are difficult to categorize when looking at the imagery. Most of the delineation is based on making minor edits to existing polygons rather than on manually creating new polygons for each feature. All subsequent segmentation process development efforts were directed toward improving the efficiency of the overall workflow in order to further reduce the amount of time required to complete the inventory within each quarter-quad.

An online tracking system was implemented where the photo-interpretation team could request processing of specific quarter-quads or suggest improvements to the segmentation process. Overall efficiency was also improved by optimizing the rule set for efficient batch processing using the production oriented functions provided by eCognition Server software. All image segmentation based polygons were assigned a unique identification number for tracking and to facilitate automated classification of the wetland characteristics with a RandomForest algorithm implemented in the R open-source statistical analysis environment (R Development Core Team 2011). Additional fields (attribute, comments, field verified) were added to the image segment attribute table to assist in the photo interpretation process.

8.3 Random forest

The Random Forest classification algorithm is described in detail in Brieman (2001). The random forest classification process requires training data as input for the classification process. The initial training data for the east-central project area was aggregated from on-the-ground field work and ancillary data. In total, 3350 points were used in the initial training data set. The breakdown by system and subsystem is shown in Table 12, with a breakdown by full code in 510 sites were visited during field work, 1967 were chosen from ancillary datasets, and an additional 873 were identified by DU staff from aerial imagery.

Table 12: Breakdown of training points by system

Classification		Total
Palustrine:		
	Forested	359
	Scrub-Shrub	103
	Emergent	1029
	Aquatic Bed	311
	Unconsolidated Bed	547
Lacustrine:		
	Aquatic Bed	18
	Unconsolidated Bed	39
Riverine:		
	Unconsolidated Bed	22
Upland:		796

As each quarter quad was updated, additional training data was merged with the initial training data to create a more robust training data set. The predictor variable set included the spectral, DEM, PALSAR and soil map derived features that describe each image object polygon. Initial results indicate that the segmentation based Random Forest wetland classification separates wetlands from uplands with an overall (bootstrapped) accuracy rate of 92.2% and assigns wetland class with an overall (bootstrapped) accuracy rate of 66.87%. These accuracy values should be treated as an index only. Whenever the segmentation process is modified based on feedback from the photo-interpretation team the current Random Forest classification model becomes obsolete. The algorithm was automatically re-run whenever new segmentation files become available which means that classification accuracy values (including those reported here) are only useful as transient indices of the utility of the automated classification process. The formal accuracy assessment, designed to evaluate data that is ready to submit to the NWI, takes place only after the photo-interpretation and QA/QC processes are complete using a separate reference data set collected by the University of Minnesota. Initial results of the Random Forest classification are described in Appendix C.

8.3.1 Wetland Probability Layer

The WPL (Wetland Probability Layer) is a statistically derived index of the likelihood of wetland occurrence based on topographic inputs. All wetland polygons from the East Central NWI update were resampled into a 10m binary raster mask indicating wetland presence or absence. All 10m pixels in the mask (roughly 300,000,000) were included in the potential training population for a Random Forest ensemble classification algorithm. A series of 0.03% random sub-samples were drawn from the population to train the RandomForest classifier. Predictor variables were pixel-level derivatives of the USGS 10m resolution NED Digital Elevation Model; these were spatially cross-referenced to the training mask. The predictor variable set included: elevation, slope, catchment area and Compound Topographic Index (CTI= LN(([FlowAcc_Dem] + 0.001) / (([Slope_Dem] / 100) + 0.001))). CTI inputs were calculated with TauDEM using the D-infinity method. The result from the RandomForest classification was an index ranging from 0 to1 indicating the likelihood of any pixel in the population belonging to the class “wetland” based on solely on topographic predictors. The internal (OOB) estimate of error rate for the RandomForest classifier was 26.28% with an upland class error rate of 15.5% and a wetland class error of 49.68%.

Wetland Probability Layer Confusion matrix:

	Upland	Wetland	class.error
Upland	57919	10675	0.1556259
Wetland	15605	15801	0.4968796

8.4 Photo interpretation

A detailed list of steps for the photo interpretation process is listed in Appendix C.

8.4.1 Photo interpretation guide

A photo interpretation guide has been created to assist interpreters and help standardize NWI update methodology. This guide includes a brief description of the wetland class and is followed by a representative photo taken during the field training data process, as well as aerial imagery for spring and summer in CIR and natural color. These images will help the interpreter identify wetland types by viewing ground photos with paired aerial photos for the same wetland type.

8.4.2 Custom object inspector

A custom object inspector was created within ArcMap in order to make the photo interpretation process more efficient (Fig. 13). The custom object inspector allows the interpreter to view the attributes from the random forest classification, soils, and Radar classification as well as providing drop-down menus for the Attribute and field verification fields.

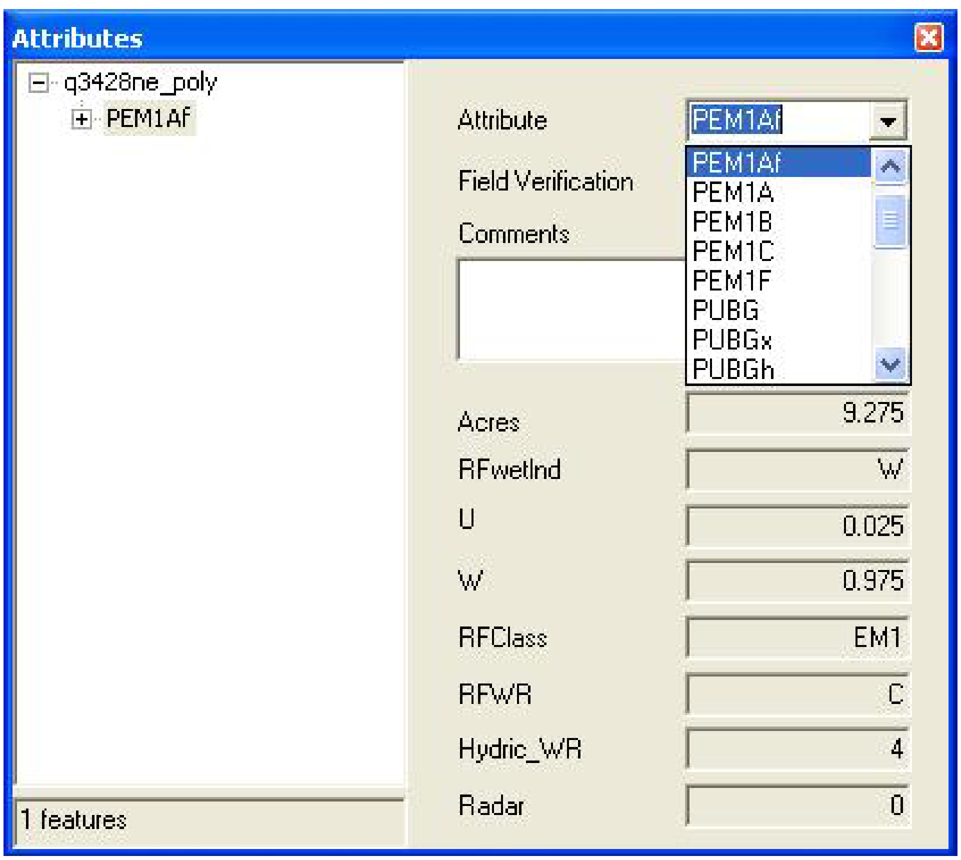


Figure 13. The custom object inspector for the east-central project area

8.4.3 Photo interpretation process

The photo interpreters viewed the segments over the spring 2010 imagery to identify wetland segments. The photo interpreters used the spring imagery, professional knowledge, photo interpretation guide, information provided by the object inspector, as well as the summer imagery to assign the NWI code. Additional data layers (USGS DRG, Radar classification, SSURGO soils, DEM) were also available to assist with the NWI classification. Adjacent segments of the same class were merged. Segments that have multiple wetland classes or combine wetland and upland classes were cut into separate polygons to conform to the NWI class boundary. Each quarter quad was interpreted systematically until the entire area had been completed. Additional details for the photo interpretation process are provided in Appendix A.

8.4.4 Quality assurance and quality control

Quality control and quality assurance (QA/QC) programs were written to automatically check for topological (gaps and overlaps) and attribute errors within the classification after the photo interpretation process was complete. Once a quarter-quad was completed, the interpreter executes the QA/QC program and corrects any identified errors before moving on to another quarter-quad. After successful execution of the QA/QC process by the interpreter, a second interpreter inspected 10% of the wetland classification to ensure consistency and accuracy of the wetland classification between individual interpreters. After the second review, the NWI QA/QC analyst reviewed the overall classification for that quarter-quad and executes a second series of automated QA/QC procedures provided by the USFWS.

The draft version of the NWI classification for the quarter quad was then sent to the Minnesota Department of Natural Resources for review. Errors found through the DNR review process were addressed prior to final production. Additional information on the DNR QA/QC review can be found in the Quality Assurance Project Plan for the National Wetland Inventory of Minnesota (DNR 2010).

Once the review was completed, the quarter quad was merged into a seamless state-wide layer. Final accuracy of the NWI update will be calculated by a third party organization (The University of Minnesota) not directly involved in the mapping process. The formal accuracy assessment was based on comparing updated NWI polygons to a field reference data source that was created and maintained separately from the reference data sources used in the production mapping process.

8.4.5 Merge with seamless layer

After completion of the QA/QC of the quarter quad, the data was merged into a seamless NWI layer for the east-central project area.

8.4.6 Final product generation

Before final product generation, the photo interpreted segments were generalized to “smooth” the polygons so they look more natural for the end user. This smoothing process also removes unnecessary vertices, thus reducing the storage requirements and improving the overall efficiency of the data. The final product was delivered in an Albers Equal Area projection for conformance to the FWS standard as well as the Universal Transverse Mercator projection to conform to the Minnesota standard for geospatial data.

9.0 Simplified Plant Community Classification system

In addition to the Cowardin classification system, the NWI update for Minnesota included the addition of a simplified plant community classification based on the classification of Eggers and Reed (1997). The 15 plant community classes from Eggers and Reed were re-grouped into nine simplified plant community classes with one additional class for non-vegetated aquatic communities (e.g. substrate types for certain systems/sub-systems including unconsolidated bottom, rock bottom, rocky shore, unconsolidated shore, and streambed). This simplification of the Eggers and Reed classification system was designed to provide information on wetland plant communities to the end users of the updated NWI within the bounds of what was currently possible to achieve with reasonable accuracy with remote sensing data. The simplified plant community classes are summarized in Table 13.

9.1 Combining Classes

1) Combine the Sedge Meadow, Fresh Wet Meadow, Wet to Wet-Mesic Prairie, and the herbaceous form of the Calcareous Fen into a single simplified Inland Wet Meadow class.
2) Combine the various bog types and subtypes of Eggers and Reed into a single simplified Peatland class.
3) Combine the Shrub-Carr, Alder Thicket, and the shrub form of the Calcareous Fen into a single simplified Shrub Wetland class.

Table 13: Simplified plant community classes

	Modified Plant Community Class	Eggers and Reed Plant Community Class
1	Seasonally Flooded Basin	Seasonally Flooded Basins - 16B
2	Wet Meadow	Sedge Meadow - 13A Fresh (Wet) Meadows - 15B Wet to Wet-Mesic Prairies - 15A Calcareous Fens (Herbaceous Type) - 14A
3	Shallow Marsh	Shallow Marshes - 13B
4	Deep Marsh	Deep Marshes - 12B
5	Shallow Open Water Community	Shallow Open Water Communities -16A
6	Peatland	Open Bog (Herbaceous Type) - 10A Open Bog (Shrub Type) - 7A Coniferous Bogs - 4A
7	Shrub Wetland	Shrub-Carrs - 8B Alder Thickets - 8A Calcareous Fens (Shrub Type) - 7B
8	Hardwood Wetland	Hardwood Swamps - 3B Floodplain Forests - 3A
9	Coniferous Swamps	Coniferous Swamps - 4B
10	Non-Vegetated Aquatic Community	NA

9.2 Classification cross-walk to Cowardin

Implementing this simplified plant community class was primarily a process of re-coding from the Cowardin classification system including wetland classes, subclasses, water regime modifiers, and special modifiers to the simplified plant community class. The applicability of the cross-walk between the Cowardin classification system and the simplified plant community classification system requires special attention to how the Cowardin codes were applied. This cross-walk is summarized in Table 14.

1) Split the Cowardin palustrine emergent class (PEM) across four simplified plant community classes based on water regime; Seasonally Flooded Basins (PEMA), Inland Wet Meadow (PEMB), Shallow Marshes (PEMC & PEMF), and Deep Marshes (PEMH).
2) There is some potential for class confusion between simplified Inland Wet Meadow class and the Seasonally Flooded Basin class. Particular attention is required during the photo-interpretation of the temporarily flooded (A) water regime for the PEM class to ensure proper class separation. The Eggers and Reed classification key states that Seasonally Flooded Basins are often cultivated or dominated by annuals such as smartweed and wild millet. Wetlands with photo-signatures indicating dominant plant communities are obligate wetland species (such as Typha) should not be classified as PEMA.
3) Split the Cowardin PAB class across Deep Marshes (PABF) and Shallow Open Water Communities (PABH) based on water regime.
4) Split the Cowardin forested wetland class (PFO) into Coniferous Wetland (PFO2 & PFO4) and Hardwood Wetland (PFO1) plant community classes based on sub-class with the exception of the coniferous wetlands that should be placed in the peatland class (see rule 5).
5) The peatland community class crosses the PEM, PSS, and PFO Cowardin classes. Additional interpretation beyond what is typically required for the NWI is needed to effectively separate the peatland community class. Wetlands that have photo-signatures that indicate closed canopy black spruce stands, sphagnum-moss/leather-leaf, sphagnum/sedge, sphagnum/tamarack, or possessing other peatland indicators such as the characteristic open water moat will be assigned a new special modifier (q) that will then be used to complete the cross-walk for the simplified peatland community class.

NOTE: This class is most closely related the Eggers and Reed bog classes, but the relationship is not expected to be perfect. According to Eggers and Reed, bogs have the following plant characteristics:

- *Tamarack (PFO2) and/or black spruce (PFO4) are dominant; growing on a continuous <u>sphagnum moss mat and acid, peat soils</u>*
- *Shrubs are ericaceous and evergreen (PSS3, PSS4) growing on a <u>sphagnum moss mat layer; peat soils are acidic</u>*
- *<u>Sphagnum moss mat on acid peat soils</u>; leatherleaf, pitcher plants, certain sedges, and other herbaceous species (PEM) tolerant of low nutrient conditions may be present*

The presence of a sphagnum moss mat and ericaceous shrubs can usually be photo-interpreted. In some cases, the tree canopy can be too dense to view the underlying layers. However, depending upon the characteristics of the tree canopy, the presence of a sphagnum mat can be inferred. The Native Plant Community Classification System refers to some wetlands with extensive sphagnum coverage as poor fens. Eggers and Reed does not make this distinction. These poor fens are difficult to separate from bogs without detailed field studies. In fact, fens and bogs may occur within the same wetland complex.

Table 14: Cross-walk from Cowardin to simplified plant community type

System	Subsystem	Class	Subclass	Water Regime	Code	Modifier	Plant Community Class
Lacustrine	Limnetic	Rock Bottom		H	L1RBH		Non-Vegetated Aquatic Community
		Unconsolidated Bottom		H	L1UBH		Non-Vegetated Aquatic Community
		Aquatic Bed		H	L1ABH		Shallow Open Water Community
	Littoral	Rock Bottom		F	L2RBF		Non-Vegetated Wetland
				H	L2RBH		
		Unconsolidated Bottom		F	L2UBF		Shallow Open Water Community
				H	L2UBH		
		Aquatic Bed		F	L2ABF		Shallow Open Water Community
				H	L2ABH		
		Rocky Shore		A	L2RSA		Non-Vegetated Aquatic Community
				C	L2RSC		
		Unconsolidated Shore		A	L2USA		
				C	L2USC		
		Emergent	2-Nonpersistent	F	L2EM2F		Shallow Open Water Community
				H	L2EM2H		
Riverine	Lower Perennial	Rock Bottom		F	R2RBF		Non-Vegetated Aquatic Community
				H	R2RBH		
		Unconsolidated Bottom		F	R2UBF		Non-Vegetated Aquatic Community
				H	R2UBH		
		Aquatic Bed		F	R2ABF		Shallow Open Water Community
				H	R2ABH		
		Rocky Shore		A	R2RSA		Non-Vegetated Aquatic Community
				C	R2RSC		
		Unconsolidated Shore		A	R2USA		
				C	R2USC		
		Emergent	2-Nonpersistent	F	R2EM2F		Shallow Open Water Community
				H	R2EM2H		
	Upper Perennial	Rock Bottom		F	R3RBF		Non-Vegetated Aquatic Community
				H	R3RBH		
		Unconsolidated Bottom		F	R3UBF		Non-Vegetated Aquatic Community
				H	R3UBH		
		Aquatic Bed		F	R3ABF		Shallow Open Water Community
				H	R3ABH		
		Rocky Shore		A	R3RSA		Non-Vegetated Aquatic Community
				C	R3RSC		
		Unconsolidated Shore		A	R3USA		
				C	R3USC		
	Intermittent	Streambed		A	R4SBA		
				C	R4SBC		

Table 14– Cross-walk from Cowardin to simplified plant community type (continued)

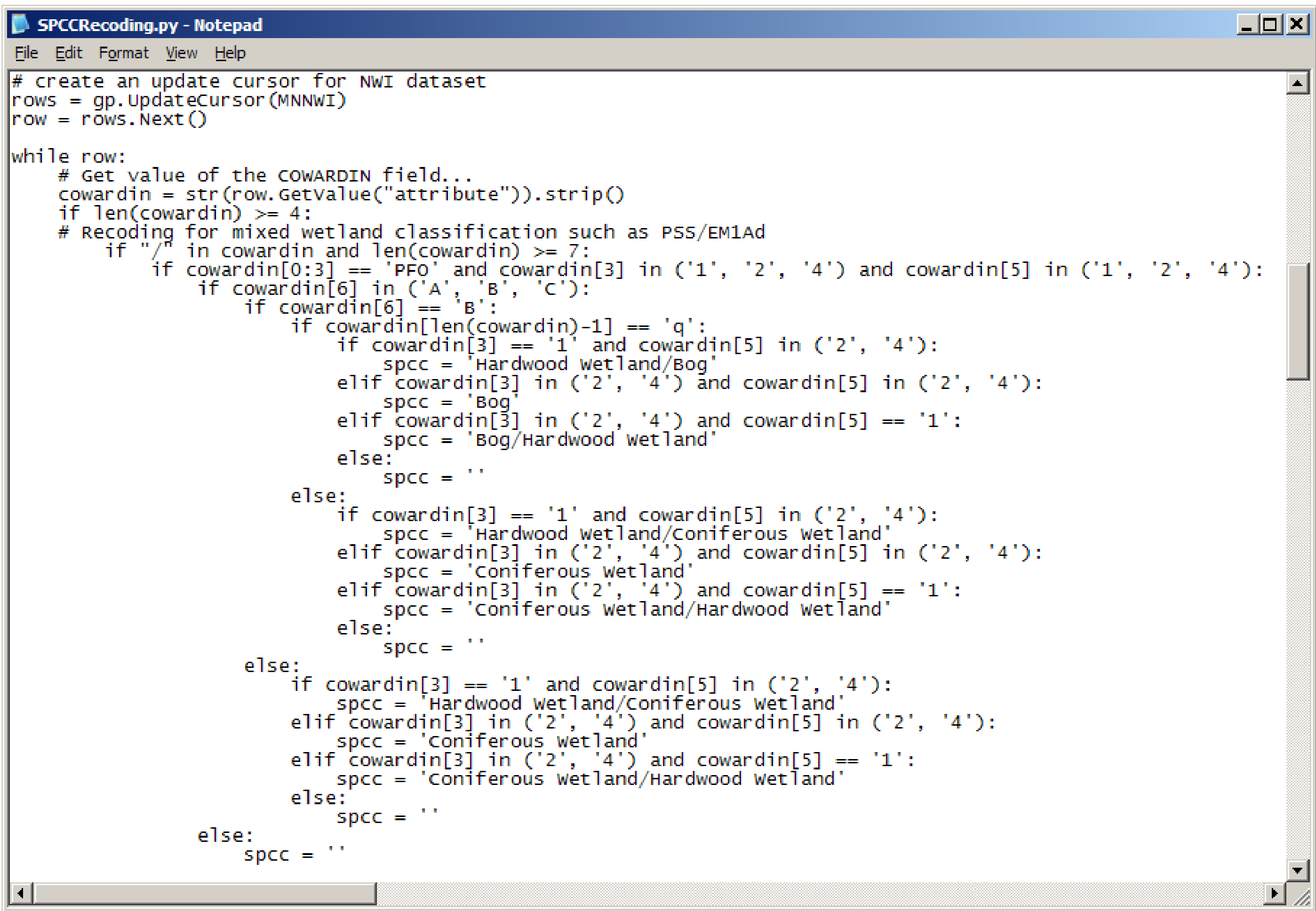
System	Subsystem	Class	Subclass	Water Regime	Code	Modifier	Plant Community Class
Palustrine	Palustrine	Rock Bottom		F	PRBF		Non-Vegetated Aquatic Community
				H	PRBH		
		Unconsolidated Bottom		F	PUBF		Shallow Open Water Community
				H	PUBH		
		Aquatic Bed		F	PABF		Deep Marsh
				H	PABH		Shallow Open Water Community
		Unconsolidated Shore		A	PUSA		Non-Vegetated Aquatic Community
				C	PUSC		
		Moss-Lichen		B	PMLB	q	Peatland
		Emergent	1-Persistent	A	PEM1A		Seasonally Flooded Basin
				B	PEM1B	not q	Wet Meadow
						q	Peatland
				C	PEM1C		Shallow Marsh
				F	PEM1F		
			2-Nonpersistent	F	PEM2F		Deep Marsh
				H	PEM2H		
		Scrub-Shrub	1-Broad-leaved deciduous	A	PSS1A		Shrub Wetland
				B	PSS1B		
				C	PSS1C		
			2-Needle-leaved deciduous	A	PSS2A		Shrub Wetland
				B	PSS2B	not q	Shrub Wetland
						q	Peatland
				C	PSS2C		Shrub Wetland
			3-Broad-leaved evergreen	B	PSS3B	q	Peatland
			4-Needle-leaved evergreen	A	PSS4A		Shrub Wetland
				B	PSS4B	not q	Shrub Wetland
					PSS4B	q	Peatland
				C	PSS4C		Shrub Wetland
		Forested	1-Broad-leaved deciduous	A	PFO1A		Hardwood Wetland
				B	PFO1B		
				C	PFO1C		
			2-Needle-leaved deciduous	A	PFO2A		Coniferous Wetland
				B	PFO2B	not q	Coniferous Wetland
						q	Peatland
				C	PFO2C		Coniferous Wetland
			4-Needle-leaved evergreen	A	PFO4A		Coniferous Wetland
				B	PFO4B	not q	Coniferous Wetland
						q	Peatland
				C	PFO4C		Coniferous Wetland

Water regimes shaded blue are the most likely regime for the associated Cowardin class

9.3 Data processing for SPCC

Geoprocessing functionalities within ArcGIS were utilized to generate a script to populate the SPCC based on the NWI code (Fig. 14). There were no additional input data, hardware and software required. The script can be run under any ArcGIS desktop environment. The following lists the detailed steps of developing, testing, deploying, and distributing the script.

(1) Write the python script in Notebook and saved it into a .py file.
(2) Test the script and check the field to see if it's correctly populated.
(3) Import into ArcToolbox as an arctool with a user-friendly interface.




```
# create an update cursor for NWI dataset
rows = gp.UpdateCursor(MNNWI)
row = rows.Next()

while row:
    # Get value of the COWARDIN field...
    cowardin = str(row.GetValue("attribute")).strip()
    if len(cowardin) >= 4:
    # Recoding for mixed wetland classification such as PSS/EM1Ad
        if "/" in cowardin and len(cowardin) >= 7:
            if cowardin[0:3] == 'PFO' and cowardin[3] in ('1', '2', '4') and cowardin[5] in ('1', '2', '4'):
                if cowardin[6] in ('A', 'B', 'C'):
                    if cowardin[6] == 'B':
                        if cowardin[len(cowardin)-1] == 'q':
                            if cowardin[3] == '1' and cowardin[5] in ('2', '4'):
                                spcc = 'Hardwood Wetland/Bog'
                            elif cowardin[3] in ('2', '4') and cowardin[5] in ('2', '4'):
                                spcc = 'Bog'
                            elif cowardin[3] in ('2', '4') and cowardin[5] == '1':
                                spcc = 'Bog/Hardwood Wetland'
                            else:
                                spcc = ''
                        else:
                            if cowardin[3] == '1' and cowardin[5] in ('2', '4'):
                                spcc = 'Hardwood Wetland/Coniferous Wetland'
                            elif cowardin[3] in ('2', '4') and cowardin[5] in ('2', '4'):
                                spcc = 'Coniferous Wetland'
                            elif cowardin[3] in ('2', '4') and cowardin[5] == '1':
                                spcc = 'Coniferous Wetland/Hardwood Wetland'
                            else:
                                spcc = ''
                    else:
                        if cowardin[3] == '1' and cowardin[5] in ('2', '4'):
                            spcc = 'Hardwood Wetland/Coniferous Wetland'
                        elif cowardin[3] in ('2', '4') and cowardin[5] in ('2', '4'):
                            spcc = 'Coniferous Wetland'
                        elif cowardin[3] in ('2', '4') and cowardin[5] == '1':
                            spcc = 'Coniferous Wetland/Hardwood Wetland'
                        else:
                            spcc = ''
                else:
                    spcc = ''
```

Figure 14. An example of part of the SPCC code.

10.0 Simplified key for hydro-geomorphic classification

10.1 HGM Classification Overview

A simplified Hydro-Geomorphic (HGM) Classification was created for the updated NWI for Minnesota based on the rules listed in this section (see Fig. 16-19). A geoprocessing script was created to automate the simplified HGM classification for the East-Central Project Area. The script was tested on one of the NWI quads in the East-Central Project Area and reviewed by DU and the MN DNR. The HGM script was refined based on the review comments from MN DNR until an acceptable solution was found. Every polygon in the NWI data layer has an HGM attribute for landscape position, landform/waterbody, and water flow path. The allowable classes are provided in Table 15.

Table 15– Allowable HGM classes for the East-Central Project Area

Landscape Position	Landform/Waterbody	Water Flow Path
Lentic Lotic River Lotic Stream Terrene	Island Fringe Floodplain Basin Flat Slope	Inflow Outflow Throughflow Bi-directional Non-tidal Isolated
	Lake River Pond	

10.2 Data Requirements and Layer Generation

The required data layers to perform the HGM classification on the updated NWI are:

(1) DEM
(2) Hydrology
(3) Public Water Inventory Basin Delineations

The DEM layer was a combination of the Lidar derived DEM (3 meter) and the National Elevation Dataset (10 meter) (see section 4.2.4). The hydrology layer was from the MN DNR hydrology layer (http://deli.dnr.state.mn.us/metadata.html?id=L260000072102) for the height above streams analysis and determining the water flow path. The Public Water Inventory Basin Delineations was downloaded from the MN DNR Data Deli (http://deli.dnr.state.mn.us/metadata.html?id=L390006600201).

Three derived layers from the DEM are also required to perform the HGM classification. A "height above streams" layer was derived from the DEM in order to determine the floodplain delineation. A "depressions" layer was derived from the DEM in order to identify the basin landform and a Slope (> 2%) layer was derived from the DEM in order to identify the slope landform.

10.2.1 Height Above Streams

There are many important ecological, environmental, and engineering issues of interest that occur within the riparian zone of rivers and streams. These areas can be important areas for biodiversity, sediment erosion and deposition, as well as flooding. Riparian ecosystems include the zone that occurs within the banks of a river or stream as well as the adjacent areas that are periodically influenced by flooding.

This section describes a GIS-based process for creating a modified digital elevation model (DEM) that depicts the height of land relative to the nearest stream or river course. The resulting modified DEM is referred to as height-above-stream (HAS) and it has potential value in helping to define the extent of the riparian zone adjacent to a defined set of streams or rivers. However, this analysis should not be confused in any way with floodplain maps derived from detailed engineering studies, on-site surveys, or hydrologic and hydraulic models. The steps to perform a HAS analysis are outlined in Table 16.

The data required to perform the HAS are a Digital elevation model, preferably be a high-resolution DEM derived from LiDAR and a river and stream centerline data. Careful consideration should be given to the features included in the rivers and stream data set. Existing data for river and streams typically also include other hydrologic features that may or may not be relevant to this analysis, such as storm sewers, aqueducts, and drainage ditches. Only the features that are relevant to the analysis should be extracted from the dataset prior to analysis (e.g. perennial rivers and streams). Also, errors in the linework may create errors in the output. For example, if the digitized stream line lies outside the bank of the stream as defined on a LiDAR-derived DEM, then the base elevation will be too high for that location.

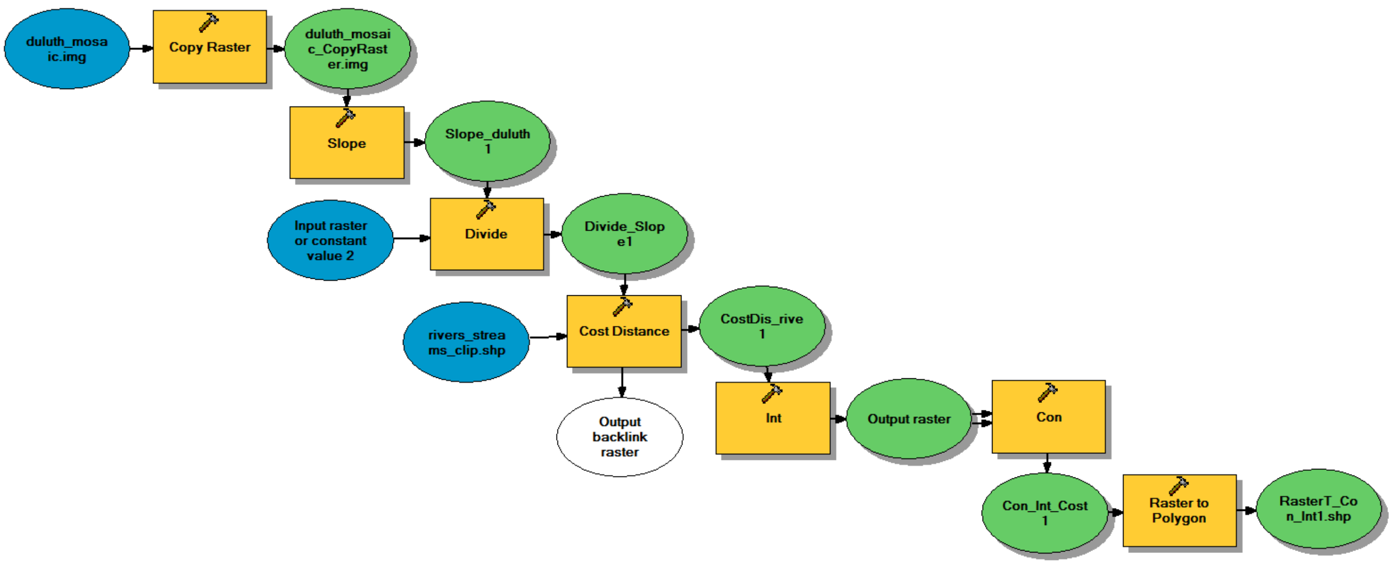


Figure 15. A ModelBuilder Model of the HAS Processing Steps.

Table 16– Steps to Perform a Height Above Stream Analysis

1) Open ArcGIS and ensure that the Spatial Analyst extension is turned on (Customize>Extensions…)
2) Open the ArcToolbox window.
3) Extract the desired stream/river features for the project area from a stream GIS data layer such as DNR 24K Streams or the National Hydrography Dataset (NHD) for your desired project area (e.g. Analysis Tools>Extract>Clip).
4) Extract, clip, or mosaic the DEM as needed to match your project extent (e.g. Spatial Analyst Tools>Extraction>Extract by Rectangle).

5) Use the “Copy Raster” tool to set 0 values to Null (Data Management>Raster>Raster Dataset>Copy Raster).
6) Calculate the slope grid from the DEM selecting the output to be expressed as percent slope not degrees (Spatial Analyst>Surface>Slope). Make sure that the vertical and horizontal units are the same, or use a conversion factor to make the units the same.
7) Use raster calculator to convert the percent slope to fractional slope (rise/run) by dividing by 100 (Spatial Analyst Tools>Map Algebra>Raster Calculator).
8) Run a cost-distance analysis (Spatial Analyst Tools>Distance>Cost Distance). The source data is the selected stream/river features extracted in step three. The cost raster is the fractional slope grid created in step six.
9) In order to convert the raster to polygons and manipulate the features (dissolve, select, etc), first convert the raster values to integer (Spatial Analyst Tools>Math>Int).
10) To remove values more than a certain height above the stream, use a con statement (Spatial Analyst Tools>Conditional>Con). The input raster is the integer raster created in step 10, the expression is the SQL expression to select only the values you want in the output (e.g., VALUE <= 3), the input true raster is the same as the input raster, and the input false raster should be left blank. This means that if a pixel is less than or equal to 3 (meters above stream), the output includes that pixel, but if the value is 4 or greater the output does not include that pixel.
11) Convert the raster layer to polygon features (Conversion Tools>From Raster>Raster to Polygon).

The cost-distance tool calculates the least accumulative cost distance for each cell to the nearest source over a cost surface. In this instance the stream or river centerline feature is the source so the “cost” is set to zero for every grid cell that touches a river or stream feature. The algorithm first multiplies the distance across a cell from the source by the fractional slope (rise/run) to get the incremental height increase for each cell. As the algorithm progresses outward from the source, the value for each cell is determined by adding this incremental height to the lowest adjacent value. This is analogous to the way that water would spread out from the stream or river during a flood. This data can be combined with historic information on stream stage to estimate the extent of the riparian zone, if local stream gauging data are available and if vertical benchmarks exist to relate stream stage to local elevation.

10.2.2 Depressions

A depressions layer derived from a DEM will be created to represent depressions in the overall landscape. This layer will be used to identify basins in the landform part of the HGM classification. The only input required to create the depressions layer is a DEM (see section 4.2.4). Table 17 describes the process for creating the depressions layer.

Table 17– Steps to Create the Depressions Layer

1. *Convert raster from meters to feet:* using **Spatial Analyst > Math > Divide,** divide raster by the constant value 0.3048
    - Input raster or constant value 1: Original DEM
    - Input raster or constant value 2: 0.3048
    - Output raster: DEM_ft
2. *Preserve decimal points:* using **Spatial Analyst > Math > Times**, multiply raster by the constant value 1000
    - Input raster or constant value 1: DEM_ft
    - Input raster or constant value 2: 1000

- Output raster: DEM_ft_1000

3. *Convert raster value to a useable value:* using **Spatial Analyst > Math > Int**
    - Input raster or constant value: DEM_ft_1000
    - Output raster: Int_DEM
4. *Fill all depressions in the raster:* **Spatial Analyst > Hydrology > Fill**
    - Input surface raster: Int_DEM
    - Output surface raster: Fill_DEM
5. *Create a new raster layer whose values represent the distance between the original DEM and the Filled DEM:* **Spatial Analyst > Math > Minus**; input value 2 (original DEM) will be subtracted from input value 1 (filled DEM)
    - Input raster or constant value 1: Fill_DEM
    - Input rater or constant value 2: Int_DEM
    - Output raster: Dep_DEM
6. *Reclassify the raster:* **Spatial Analyst > Reclass > Reclassify**
    - Input raster: Dep_DEM
    - Reclass Field: Value
    - Reclassification: Select classify button, method: Standard Deviation (1)
    - Output raster: Dep_Reclass
7. *Convert the layer from Raster to Polygon:* **Conversion Tools > From Raster > Raster to Polygon**
    - Input raster: Dep_Reclass
    - Field: Value
    - Output Polygon features: Dep_poly
      *** Simplify polygons box should be checked.
8. *Add Field:* **Data Management Tools > Fields > Add Field**
    - Input table: Dep_poly
    - Field Name: Acres
    - Field Type: Double
9. *Calculate Acres:* **Data Management Tools > Fields > Calculate Field**
    - Input Table: Dep_poly
    - Field Name: Acres
    - Expression: !shape.area@acres!
    - Expression Type: Python_9.3

The resulting data will have roughly 3 classes, depending on the elevation variance within the landscape. GRIDCODE 3 will represent the lowest depressions; GRIDCODE 2 will represent shallow depressions and transitional areas, while GRIDCODE 1 will represent areas with the highest elevations. GRIDCODE values higher than 3 may be present depending on the elevation variance within the dataset. In cases such as this, the highest GRIDCODE value will represent the deepest depressions and as GRIDCODE values decrease so does the depth of the depression.

10.2.3 Slope

In order to determine if a wetland should be considered a slope landform, a slope layer was created from the DEM. A vector layer was then created from the slope layer that contains two classes (>2% slope and <=2% slope).

10.3 HGM Classification Process

The General steps for creating the script to create the HGM classification include:

(1) LANDSCAPE POSITION (Fig. 16): Make a feature layer of river/stream using the MN DNR hydro flow line data. Create a feature layer of lake/reservoir layer from all the Lacustrine wetlands of the NWI layer. Select the wetland polygons (all except for Lacustrine and Riverine wetlands) and make a feature layer of them. Loop through each wetland polygon to intersect the DNR river/stream, NWI Riverine wetlands and lake/reservoir layers. If there are no intersected water features for a wetland polygon, the Landscape field value becomes "Terrene". If the intersected water features are lakes or reservoirs only, update the Landscape field with the value "Lentic". If the intersected water features are NWI Riverine wetland polygons, further check to see if the intersected Riverine wetland flow through the wetland polygon. If the intersected Riverine wetland start or end at this wetland polygon, update the Landscape field with the value "Terrene". If the intersected Riverine wetland flow through or alongside the wetland and the wetland intersects a floodplain, update the Landscape field with the value "Lotic River". If the intersected water features are river/streams from the DNR layer, further check to see if the intersected river/streams flow through the wetland polygon. If the intersected river/stream start or end at this wetland polygon, update the Landscape field with the value "Terrene". If the intersected rivers or streams flow through or alongside the wetland and the wetland intersects a floodplain, update the Landscape field with the value "Lotic Stream". If the wetland doesn't intersect any floodplains, update the landscape field with the value "Terrene".

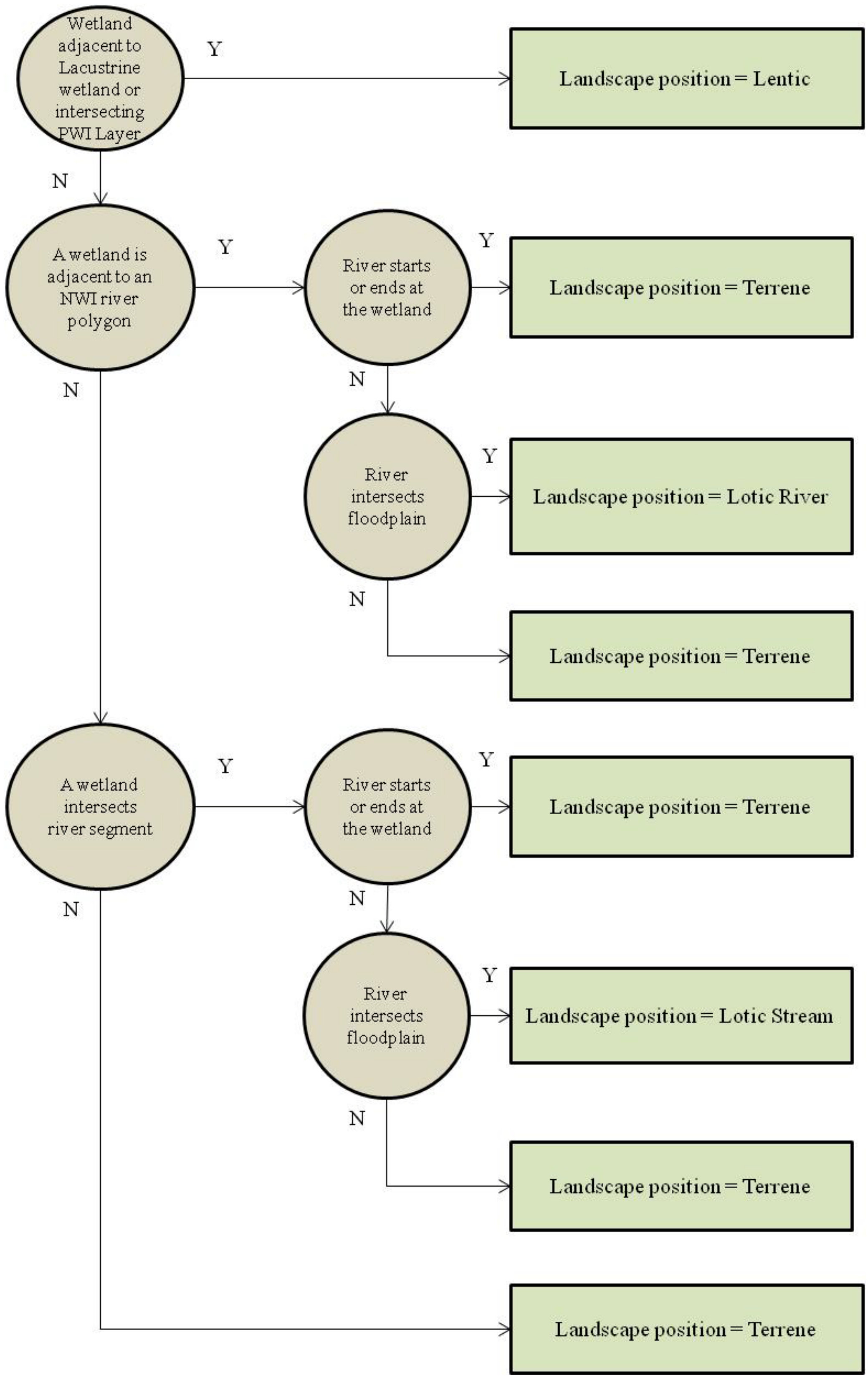


Figure 16. Landscape Position Decision Tree.

(2) LANDFORM (Fig. 17): Create a feature layer of water bodies from the unconsolidated bottom or aquatic bed wetlands of the NWI layer. Select the wetland polygons (all except for Lacustrine and Riverine wetlands) and make a feature layer of them. If the wetland polygon is completely contained by a water polygon, update the landform field with the value "Island". If the wetland polygon is not completely contained by a water polygon and it intersects permanent water bodies, update the landform field with the value "Fringe". If the Fringe wetlands have water regime classes of "A" then recode landform to "Flat". If the wetland polygon doesn't intersect any water bodies, but it is one of these types wetlands (R1US, R2US, R3US, R4US), update the landform field with the value "Fringe". If the wetland polygon doesn't intersect any water bodies and it is not one of these wetlands (R1US, R2US, R3US, R4US), further check to see if it intersects any floodplains. If it intersects a floodplain, update the landform field with the value "Floodplain". If it doesn't intersect any floodplains, but it intersects a depression, update the landform field with the value "Basin". Loop through each wetland polygon to intersect the slope layer. If at least half of the wetland occurs on a slope >2%, update the landform field with the value "Slope". Otherwise, update the landform field with the value "Flat".

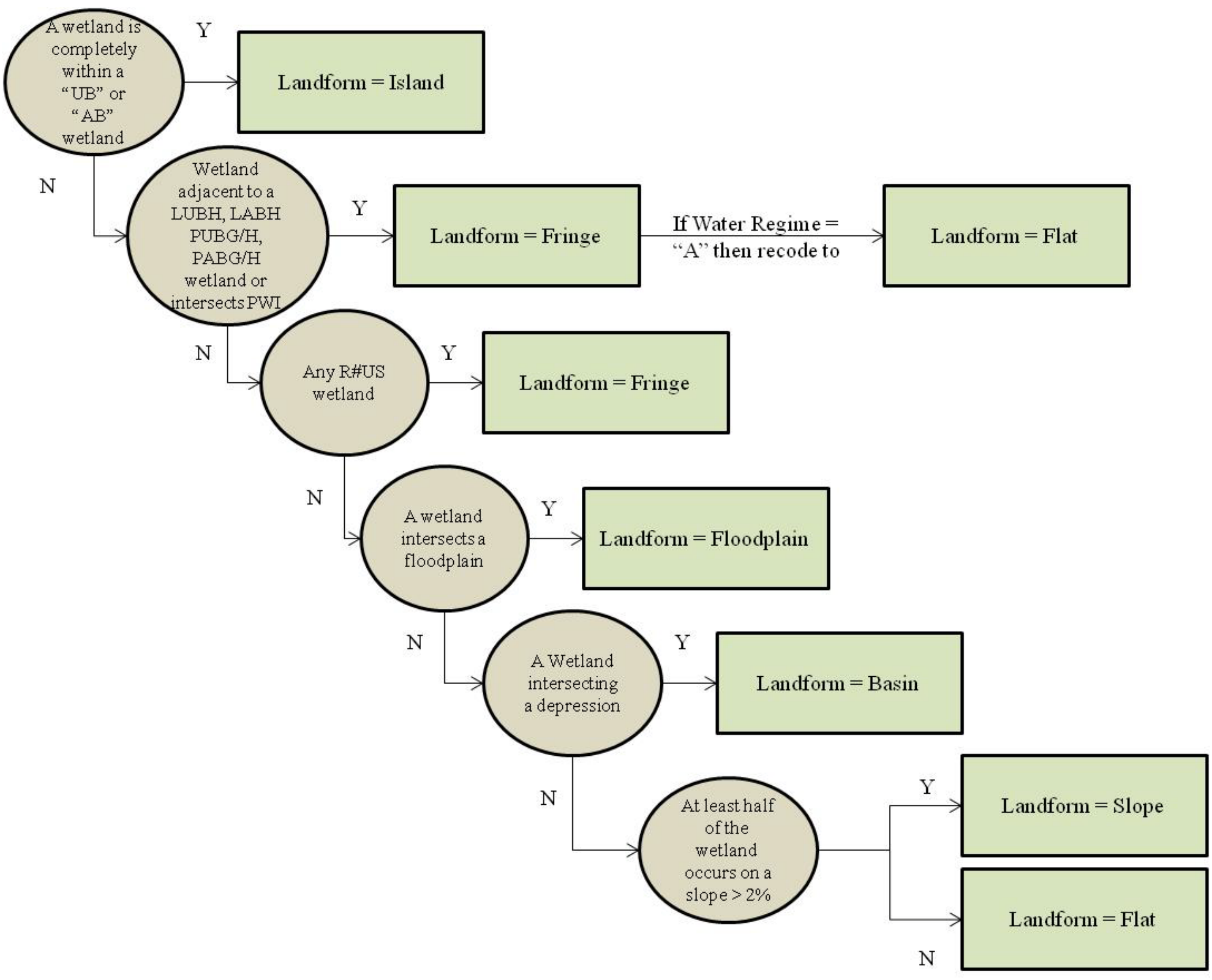


Figure 17. Landform Decision Tree.

(3) Water Flow Path (Fig. 18): Create a feature layer of lake/reservoir layer from all the Lacustrine wetlands of the NWI layer. Select the wetland polygons (all except for Lacustrine and Riverine wetlands) and make a feature layer of them. Loop through each wetland polygon to intersect the river/stream and lake/reservoir layers. If there are no intersected water features for a wetland polygon, the WaterFlowPath field value becomes “Isolated”. If the intersected water features are lakes/reservoirs only, update the WaterFlowPath field with the value “Bidirectional-Nontidal”. If the intersected water features are rivers or streams only and all of them end at the wetland polygon, update the WaterFlowPath field with the value “Inflow”. If all of the intersected rivers and streams start at and flow out of the wetland, update the WaterFlowPath field with the value “Outflow”. If the intersected rivers and streams flow through the wetland, update the WaterFlowPath field with the value “Throughflow”. Reclassify wetlands classified as “Isolated” above into “Bidirectional-Nontidal” if they intersect a “Bidirectional-Nontidal” wetland. Reclassify wetlands classified as “Isolated” above into “Inflow” if they intersect an “Inflow” wetland. Reclassify wetlands classified as “Isolated” above into “Outflow” if they intersect an “Outflow” wetland.

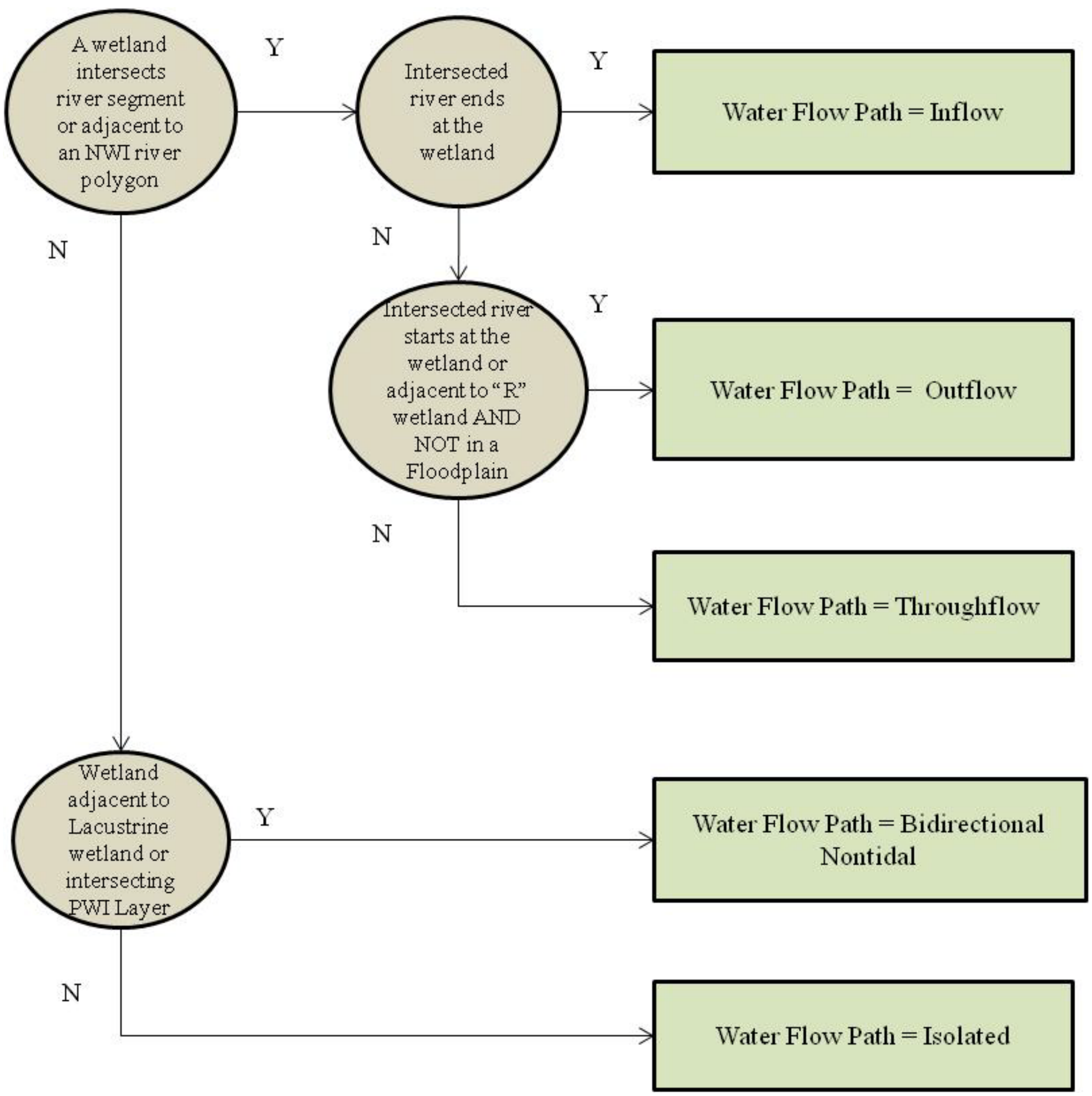


Figure 18. Water Flow Path Decision Tree.

(4) General Recodes (Fig. 19): The general recoding was done to directly assign HGM codes to specific NWI classes and to correct some HGM codes that were mislabeled in the scripting process. All lacustrine wetlands were selected and given a landscape position of "Lentic", landform of "Lake". In order to assign a Water Flow Path to the Lacustrine wetlands, the PWI layer was used to identify the Water Flow Path using a process similar to the Water Flow Path script. All Lacustrine wetlands were then assigned the Water Flow Path from the corresponding PWI layer. All riverine wetlands were given the following: "Lotic River, River, Throughflow". All palustrine unconsolidated bottom or aquatic bed wetlands were given a landform of "Pond". All "Fringe" wetlands were given a water flow path of "Bidirectional – Nontidal". All "Lotic River Outflow" wetlands were changed to "Terrine Outflow". All "Terrine Floodplain Isolated" wetlands were changed to "Lotic River Floodplain Isolated".

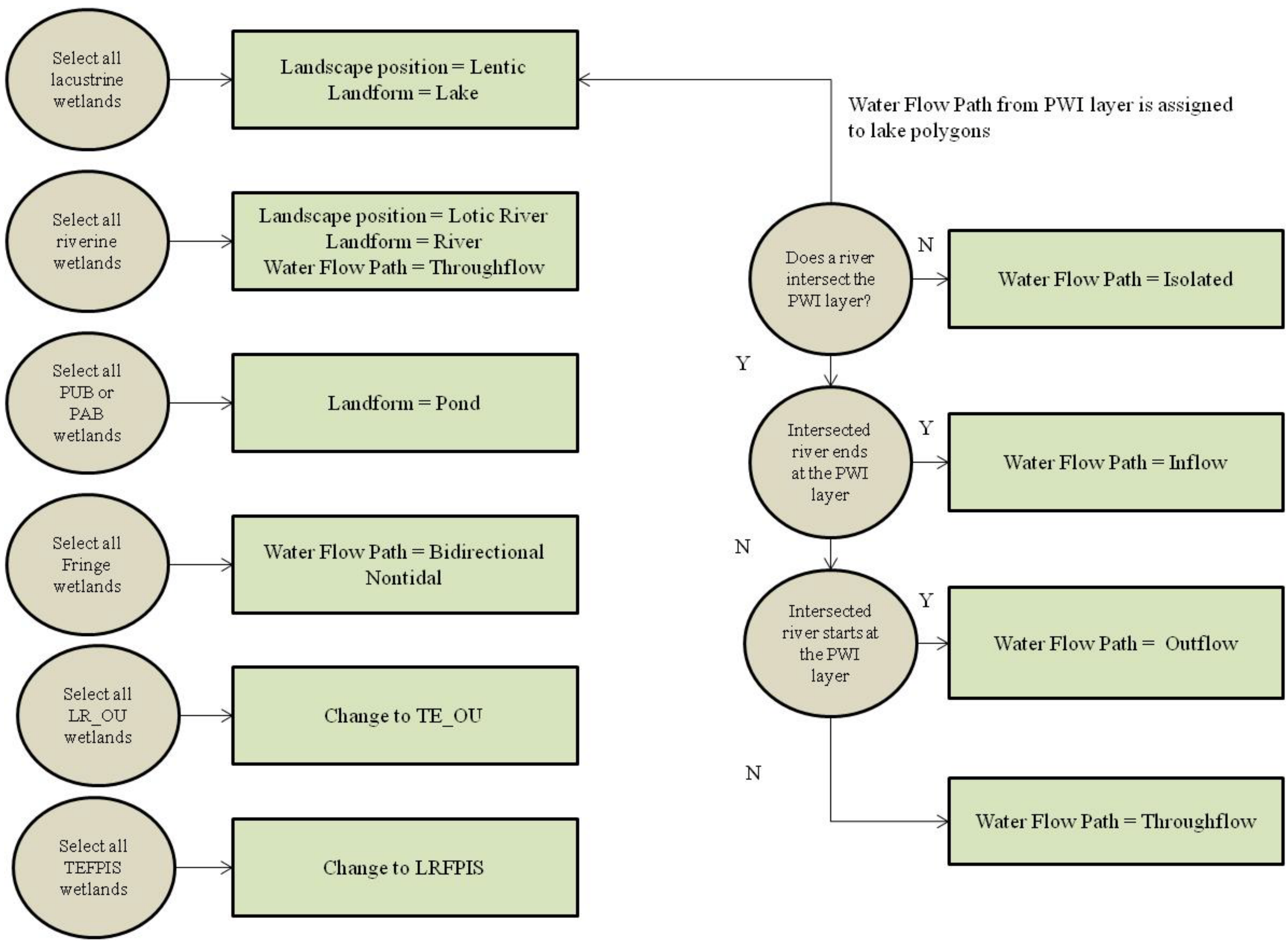


Figure 19. General Recodes.

(5) Combine the three fields (Landscape, Landform, and WaterFlowPath) into the simplified HGM classification and crosswalk to the HGM codes (Table 18).

Table 18– HGM description crosswalk to HGM codes

Landscape Position		Landform/Waterbody		Water Flow Path	
NAME	CODE	NAME	CODE	NAME	CODE
Lentic	LE	Island	IL	Inflow	IN
Lotic River	LR	Fringe	FR	Outflow	OU
Lotic Stream	LS	Floodplain	FP	Throughflow	TH
Terrene	TE	Basin	BA	Bi-directional Non-tidal	BI
		Flat	FL	Isolated	IS
		Slope	SL		
		Lake	LK		
		River	RV		
		Pond	PD		

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Appendix A: MN DNR NWI Field Verification Report

NWI Field Verification Report

MN DNR Division of Forestry Resource Assessment

November 15, 2011

Introduction

An initial field assessment of classified wetlands was completed during the last week in October, 2011. The primary objective of the field work was to verify the classification of wetland classes according to the Cowardin Classification System. The secondary objective was to identify classes which satisfy the peatland modifier. The field assessment started with 89 wetland polygons for class verification. In total, 45 wetland polygons were visited. Out of the remaining polygons; 12 were not visited due to time constraints and 32 were inaccessible.

Field Data

Prior to the field work, photo interpreters from Ducks Unlimited identified wetland polygons. The majority of wetland polygons were attributed with an appropriate Cowardin Classification which included [System - Class – Subclass - Water Regime - Special Modifiers] according to Figure 1b Wetlands and Deepwater Habitats Classification from the FGDC Wetlands Mapping Standard. The pre-field work classification was assigned under the field identified as 'PI_Class'. In the field, an assessment of the classification was made and noted in the 'Field_Clas'. The field observations can be re-visited in the office by looking at the associated photos taken in the field, as indicated by the 'Photo_num' field. Additionally, there is a point shapefile which illustrates the point at which each photo was taken. The wetland polygons where the class is different between the 'PI_Class' and the 'Field_Clas' are flagged by the 'Class_diff' field with a '1'.

Summary

Out of the total 45 polygons visited in the field, there were 16 polygons where the original and the field verified classification differed. The table below identifies the 16 polygons where the classification differed between the photo interpreted classes and the classes assigned in the field.

Wetland ID	PI Class	Field Class	Wetland ID	PI Class	Field Class
6	PFO4Bq	PFO2/4Bq	51	PFO2Bq	PFO1C
12	PUBGx	PUBFx	54	PFO4C	PFO1C
14	PEM1A	PEM1Ad	57	PEM1F	PFO1C
23	PEM1Af	PEM1A	61	PEM1C	PABF
41	PFO1A	PSS1B	64	PFO4C	PSS1C
42	PFO2Bq	PFO1/2B	72	PFO2/4q	PFO2Bq
43	PABG	PABF	73	PFO2/4Bq	PFO2Bq
47	PFO2Bq	PFO2B	84	PFO2/ML1Bq	PSS2/3Bq

Based on the field observations, the following are recommendations for continuing NWI classification via photo interpretation methodology.

- All of the peatlands (without trees) that were visited had low growing ericaceous shrub layer (mostly leather leaf). As such, it would be more appropriate to use the PSS3 class rather than the PML1 class. It is assumed that this is fairly typical for open peatlands in this region.
- A couple of the wetlands visited where given a mixed class assignment of PFO2/4 assuming that there was a mixture of Tamarack and Black Spruce when in fact there was very little Black Spruce. Some additional effort is probably warranted to separate the signatures of Tamarack and Black Spruce. Fall peak-color imagery may be available and useful.
- Avoid using the 'G' water regime and instead use 'F' or 'H' – according to the 4th bullet under general guidance for water regime on p. 17 of NWI Technical Documentation.
- PFO4 – several of these were actually PFO1 – can be easily mistaken in spring imagery where the deciduous has leafed out. Carefully distinguish deciduous from conifer foliage.
- PSS vs. PFO – difficult to differentiate in some cases without stereo – particularly for wetlands with young or stunted trees.

Follow-up

The Resource Assessment staff will continue to collaborate with Ducks Unlimited to verify NWI classification. The second field assessment of NWI classification in the metro study area will occur in Spring 2012 after more wetlands have been identified and classified.

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Appendix B: Initial Random Forest Results

A series of RandomForest™ models were developed to classify polygons generated via image segmentation into Wetland/Upland, NWI class, and water regime categories. Seven hundred twenty-seven training points were used as the response values required to build each model.   The Predictor variable set includes the DEM, spectral, PALSAR and soil map derived features that describe each polygon (insert table reference).

The following tables and plots are generated by the RandomForest Algorithm using internal error estimation techniques (bootstrapping) this information does not represent external validation using independent data.

Both the contingency tables and plots report the error rate. The classification accuracy is one minus the error rate. Variable importance plots express the decrease in accuracy associated with withholding a particular variable from a subset of trees in the forest. When a particular variable is withheld and the trees without it register a lower accuracy rate than trees that include it, its importance is understood to be high. To interpret the plots, it is only necessary to note that the variables on the top of the plot are most important in terms of forest level classification accuracy and those on the bottom are least important.

A second set of RF models were generated with the CTI variables entirely removed from the predictor set in order to compare the overall forest level accuracy estimates.

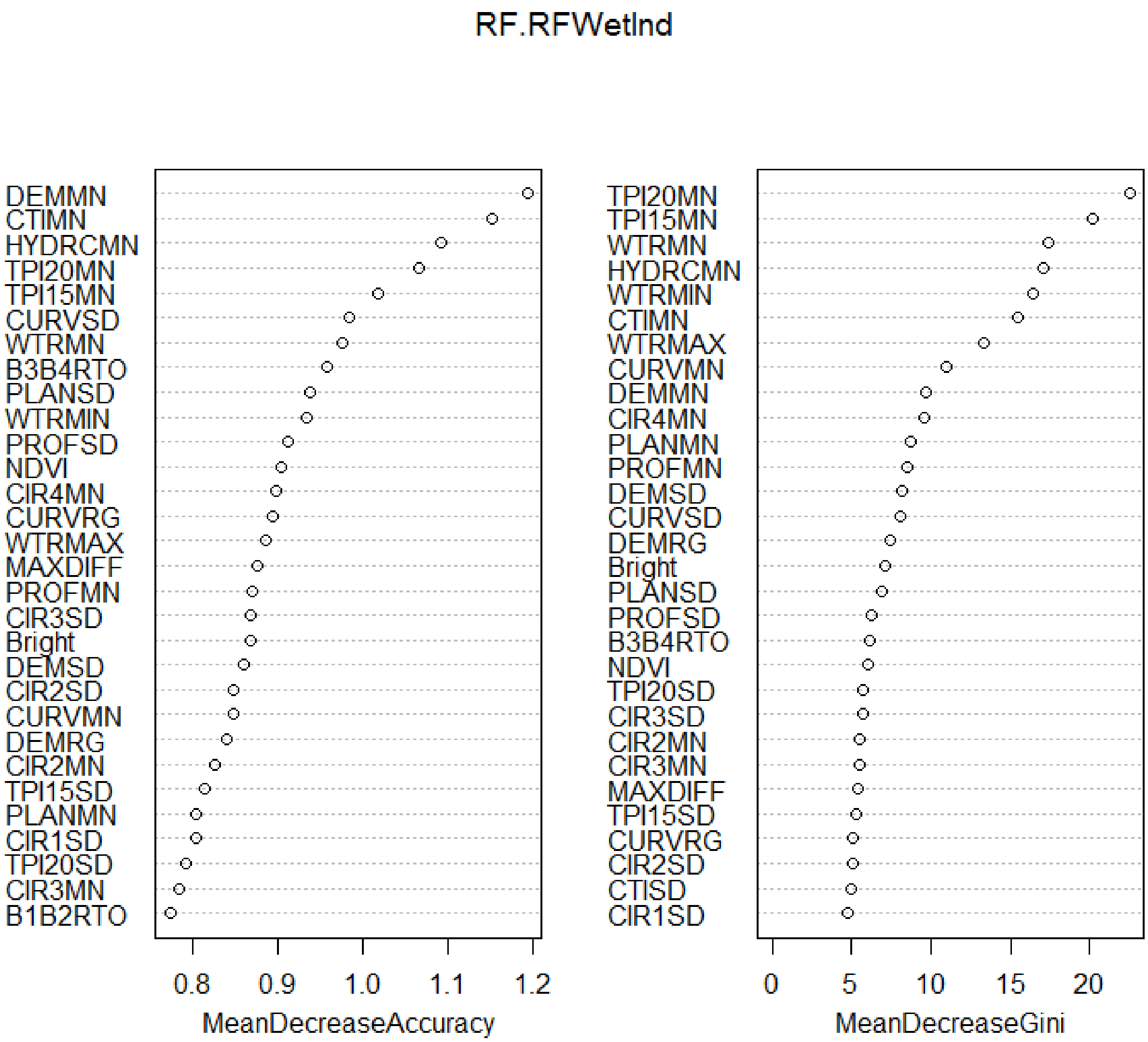
Overall OOB error rate	With CTI	W/O CTI
Wetland/Upland	7.8%	6.96%
Class	34.09%	33.13%
Water Regime	36.61%	37.45%

Given the marginal effect of adding the CTI variables and the additional time required to generate the hydrologically conditioned DEM, using CTI from the hydorlogically conditioned DEM is not warranted.

Key to the Variable Importance Plot Abbreviation System

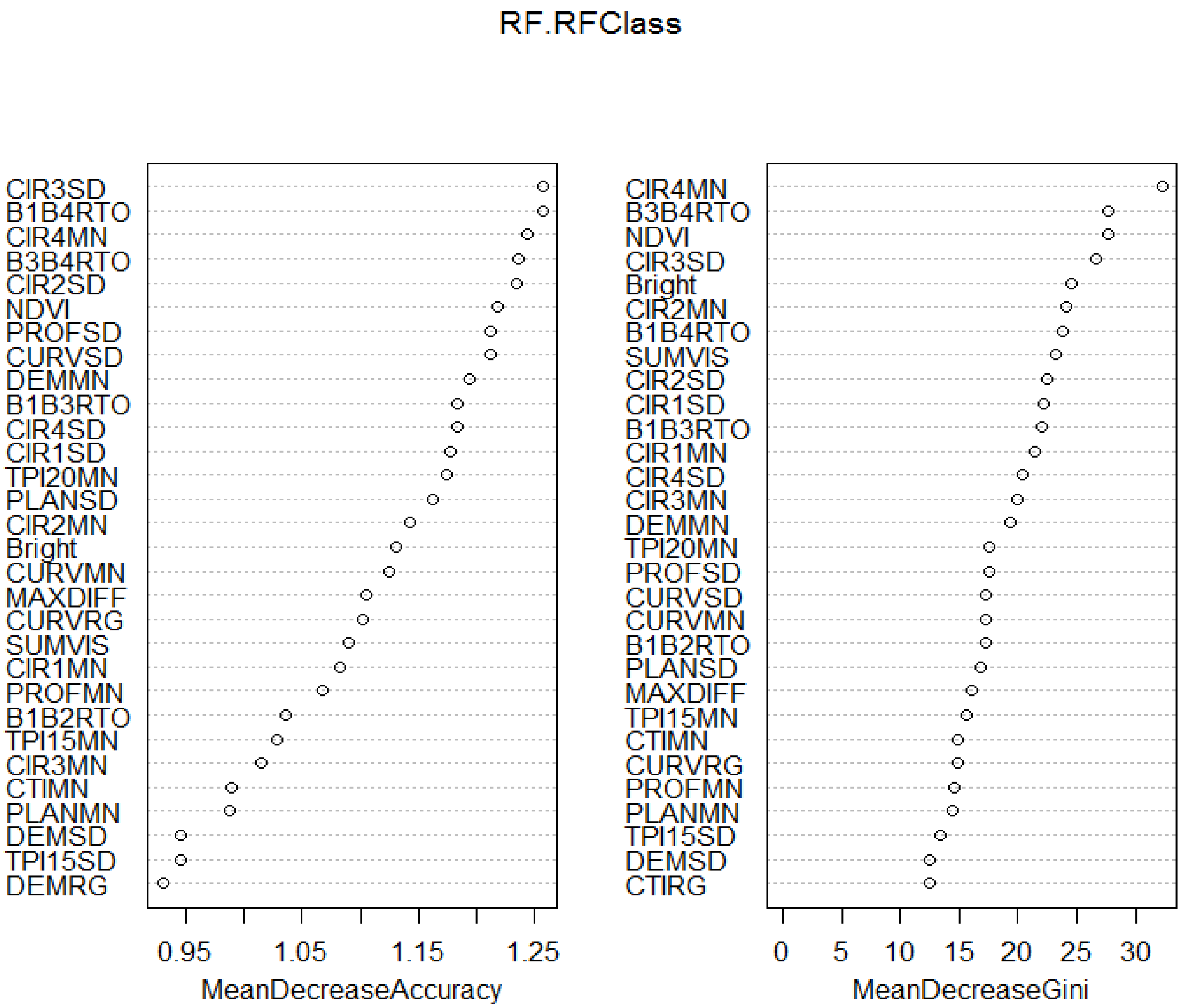
Features		Calculations	
CIR4	Color IR (Band 4)	*MN*	*Object level Mean value of feature pixels*
PROF	Profile Curvature	*SD*	*Object level Range (Max -Min) of feature pixel values*
CURV	Curvature	*RG*	*Object level Standard Deviation of feature pixel values*
PLAN	Plan Curvature	*RTO*	*Band Ratio*
DEM	Raw Elevation Values	*SUM*	*Object level mean of Sum of multiple features*
TPI15	Topographic Position Index (15 pixel window)		
CTI	Compound Topographic Index		
PLSR	PALSAR Binary Value		
Bright	Overall Brightness (sum of spectral values)		
MAXDIF	Maximum Difference in spectral values		

```
Call:
 randomForest(x = Predictors, y = Response.RFWetInd, ntree = 1000,      importance = TRUE)
               Type of random forest: classification
                     Number of trees: 1000
No. of variables tried at each split: 5

        OOB estimate of  error rate: 6.96%
Confusion matrix:
    U   W class.error
U 171  36  0.17391304
W  22 604  0.03514377
```

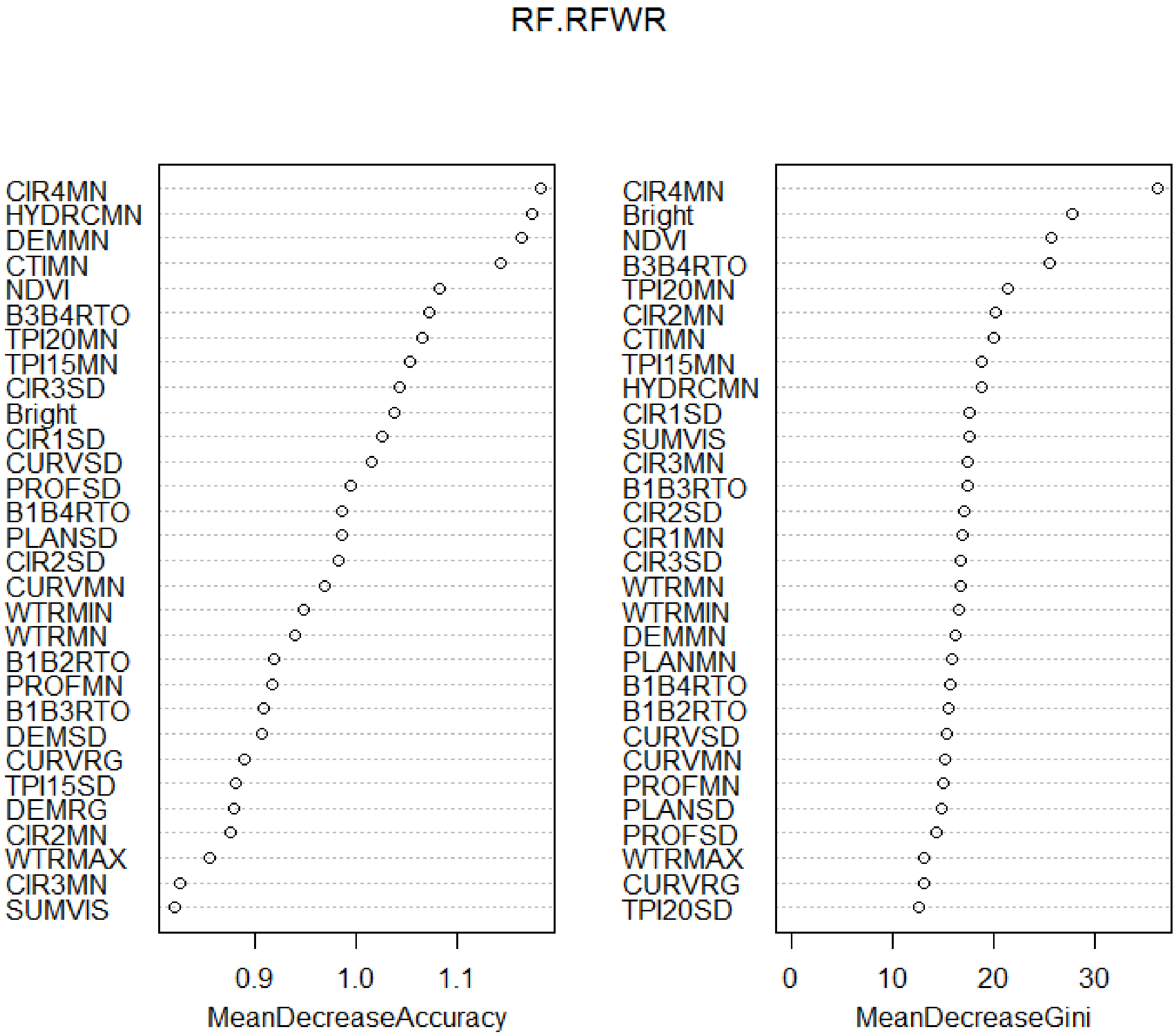


```
Call:
 randomForest(x = Predictors, y = Response.RFClass, ntree = 1000,      importance = TRUE)
               Type of random forest: classification
                     Number of trees: 1000
No. of variables tried at each split: 5

        OOB estimate of  error rate: 33.13%
Confusion matrix:
```

	AB	EM1	FO1	FO1/2	FO1/EM1	FO1/SS1	FO2	SS1	SS1/EM1	SS3	U_Ag	U_FO1	U_FO4	U_Open	U_Rec	U_Res	U_Urban	UB	class.error
AB	16	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0.6923077
EM1	11	243	12	0	0	1	0	2	0	0	9	1	0	0	1	0	0	10	0.1620690
FO1	2	29	40	0	1	0	0	2	0	0	2	3	0	2	0	1	0	0	0.5121951
FO1/2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0000000
FO1/EM1	0	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0000000
FO1/SS1	0	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0000000
FO2	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0000000
SS1	0	18	5	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0.6969697
SS1/EM1	0	18	2	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	1.0000000
SS3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0000000
U_Ag	0	20	1	0	0	0	0	0	0	0	84	0	1	0	0	0	0	0	0.2075472
U_FO1	0	2	6	0	0	0	0	0	0	0	2	15	0	0	0	0	0	0	0.4000000
U_FO4	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0.0000000
U_Open	0	3	2	0	0	0	0	0	0	0	2	0	0	2	2	0	1	0	0.8333333
U_Rec	0	3	0	0	0	0	0	0	0	0	1	0	0	1	8	0	0	0	0.3846154
U_Res	0	5	1	0	0	0	0	0	0	0	2	0	0	0	0	12	1	0	0.4285714
U_Urban	0	1	0	0	0	0	0	0	0	0	3	0	0	0	0	1	7	0	0.4166667
UB	11	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	102	0.1774194



```
Call:
 randomForest(x = Predictors, y = Response.RFWR, ntree = 1000,      importance = TRUE) 
               Type of random forest: classification
                     Number of trees: 1000
No. of variables tried at each split: 5

        OOB estimate of  error rate: 37.45%
Confusion matrix:
   A B   C  F G   H K   X class.error
A 63 2  83  4 0   5 0  31   0.6648936
B  8 0  12  0 0   0 0   1   1.0000000
C 63 1 138  3 0   8 0  10   0.3811659
F  5 0  11 10 0  18 0   2   0.7826087
G  0 0   0  0 0   2 0   0   1.0000000
H  4 0   5  8 2 126 0   0   0.1310345
K  0 0   0  0 0   1 0   0   1.0000000
X 17 0   6  0 0   0 0 184   0.1111111
```



Appendix C: Photo Interpretation Process

1. Data layers are feed into eCognition segmentation software at GPRO(Great Plains Regional Office)
    a. Combined Curvature
    b. Planimetric Curvature
    c. Profile Curvature
    d. TPI 15
    e. TPI 20
    f. CTI
    g. Palsar
    h. SSURGO Hydric %
    i. SSURGO Water Regime
    j. DEM
    k. Spring 2010 aerial imagery
2. eCognition exports to GLARO
    a. segment polygon shapefile
        i. named *quadname*_polys (q3131ne_polys)
            a. W:\GreatLakes_NWI_Update\MN\EcognitionOutput\polys
            b. Fields
                i. COORID (double)
                ii. ACRES
            c. To be loaded into MN_NWI Feature Dataset
    b. Point shapefile
        i. named *quadname*_points (q3131ne_points)
            a. W:\GreatLakes_NWI_Update\MN\EcognitionOutput\points
            b. Fields
                i. COORID (double)
                ii. All the export fields from eCognition
            c. To be used in Random Forest

3. Import Script
    a. Input – all polygon shapefiles in W:\GreatLakes_NWI_Update\MN\EcognitionOutput\polys
    b. Backs up shapefiles to external hard drive (\\GLARO_SDE\Backup\NWI_Backup\ MN\ RawSegmentShapefiles)
    c. Repair Geometry
    d. Add fields
        i. ATTRIBUTE (text 20)
        ii. COMMENTS (TEXT 255)
        iii. FIELD_VER (Text 1)
    e. Loads polygon shapefiles into File Geodatabase
        i. W:\GreatLakes_NWI_Update\MN\ActiveDatabase\MN_NWI_2010.gdb
        ii. MN_NWI feature dataset
        iii. Individual Feature Classes named named *quadname*_polys (q3131ne_polys)
    f. Delete shapefiles from W:\GreatLakes_NWI_Update\MN\EcognitionOutput\polys once they have been backed up to external hard drive and added to file geodatabase.
    g. Copies feature classes from W:\GreatLakes_NWI_Update\MN\ActiveDatabase\MN_NWI_2010.gdb to \\GLARO_SDE\backup\Nwi_backup \MN\ActiveDatabase\MN_NWI_2010.gdb

4. Editor Tool - V:\Installs\GIS Misc\NWI\Object Inspector\Minnesota Object Inspector
    a. Interpreter can manually fill in the ATTRIBUTE field, or add codes to a list to select from the drop down.
    b. Joins quad with Random Forest .dbf (W:\GreatLakes_NWI_Update\MN\RandomForest\RF Results)based on COORID
    c. Only certain fields appear
        i. ATTRIBUTE
        ii. ACRES –
        iii. FIELD_VER
        iv. COMMENTS
        v. RFwetlnd – from random forest table
        vi. U– from random forest table
        vii. W– from random forest table
        viii. RFSubsys– from random forest table
        ix. RFSubcl– from random forest table
        x. Hydric WR_CLASS– from random forest table
        xi. Radar– from random forest table

5. Before starting the 1st quad
    a. Use ArcCatalog to copy W:\GreatLakes_NWI_Update\MN\ActiveDatabase\MN_NWI_2010.gdb to local machine (D:\Working\NWI)
    b. Copy W:\GreatLakes_NWI_Update\MN\ActiveDatabase\MN_NWI.mxd to local machine (D:\Working\NWI)
    c. Install Object Inspector - Run Minnesota Object Inspector.msi under V:\Installs\GIS Misc\NWI\Object Inspector\Minnesota Object Inspector (install for everyone, not just me)
    d. Install MN NWI QA/QC toolbox: V:\Installs\GIS Misc\NWI\QAQC Toolbox\MN_WI
    e. Load Find Multipart Polygon script to ArcMap button - V:\Installs\GIS Misc\ArcMap_Scripts_Tools\Find_Multipart_Polygons
    f. Map B:\GLARO_SDE\Backup\Nwi_Backup\MN\PostPhotoInterpSegments – select reconnect at logon

6. Pre-Photo Interpretation

    a. Using ArcCatalog, copy the quad for editing from W:\GreatLakes_NWI_Update\MN\ActiveDatabase\MN_NWI_2010.gdb and paste it into D:\Working\NWI \MN \MN_NWI_2010.gdb in the MN_NWI feature dataset
    b. Mark on map which quad you checked out. This is very important to make sure two people are not working on the same quads.
    c. Still in Catalog, right-click on the MN_NWI feature dataset on your computer and go to New and then Topology
        i. The default name and cluster tolerance are fine
        ii. Select the newly added feature dataset
        iii. The default rank is fine
        iv. Click Add Rule
            a. Add Must Not Overlap
            b. Add Must Not Have Gaps
        v. Finish
        vi. Topology does not need to be validated at this time

7. The Map Document

a. Add feature dataset to D:\Working\NWI \MN\ MN_NWI.mxd
    a. Or change the data source to save the symbology from a previous quad
b. Image Boundary – the actual extent of the eCognition segmentation data for each quarter quad
c. Reference grid – a simple polygon fishnet to help keep track of what has/has not been done
d. Original NWI – this layer can be used for reference, but many of the codes are suspect.
e. SSURGO Soils – another reference layer displayed by suggested water regime
f. Topo – USGS 1:24k topographic map.
g. Bing Maps – Aerial
h. CIR_2010 – 2010 Raster\MN_1FT_2010 and/or MN_HALFMETER_2010 displayed 4,2,3)
i. TrueColor_2010 Raster\MN_1FT_2010 and/or MN_HALFMETER_2010 displayed 1,2,3)
j. 2009 NAIP
    a. A group of county level .sid images. Can be expanded to turn different counties on/off or to move them up/down in drawing order
k. MN_NAIP_2008

8. Photo Interpretation

a. Start editing nwi quad segment layer
b. Open Attribute editor
c. Merge/cut/classify polygons
    i. Make sure to look at all imagery and the topo
    ii. Check auxiliary data if unsure
    iii. Fill in attribute for all wetland polygons
    iv. If unsure, mark field verified field as “N”
    v. Leave comments if there are questions
    vi. We need to classify upland examples, but do not spent a lot of time on this step
    vii. Save edits often
    viii. Keep track of your progress on the map with graphics
    ix. Save the map document on occasion
    x. At least 1/day backup the feature dataset to W:\GreatLakes_NWI_Update\Data Backup

9. QA/QC own quarter quad
    a. When photo interpretation on a quad is complete, attribute and dissolve upland polygons.
        i. Select all unattributed polygons
        ii. Calculate ATTRIBUTE field with "U"
        iii. Select by attribute all "U" codes
        iv. Merge all "U" segments
        v. Select **ALL** segments and explode multipart features
        vi. Calculate acreage and visually check all polygons under .05 acres
    b. Run the MN NWI QAQC toolbox tools from ArcToolbox or the Command Prompt
        i. All Attributes must be valid
        ii. Double-check questionable attributes
            1. Usually mixed classes like AB/UB or EM/UB
        iii. No sliver polygons (under 0.01 acres)
            1. Merge these with neighboring polygon
        iv. No PUBs over 20 acres
            1. Open water over 20 acres should be a Lake (L1 or L2)
    c. Add the Topology (say no to adding layers involved in the topology since it Is already added)
        i. Start editing segment polygon layer
        ii. Run the validate topology for entire layer
        iii. Open the error inspector and search on all rules, for entire extent.
        iv. The Must Not have Gaps rule will flag all of the outside polygons – they are ok and can be ignored or marked as exceptions.
        v. All overlaps and gaps on the inside of the quad need to be corrected
            1. For gaps, use the create to make a new polygon
                i. Check to see if it should be merged with a neighbor
            2. For overlaps, use the merge to merge to the overlap to one of the neighboring polygons.
            3. Save edits
    d. Re-run the sliver test from the QA/QC toolbox
    e. Save edits/stop editing
    f. Copy with ArcCatalog into W:\GreatLakes_NWI_Update\ReadyforQAQC_MN_NWI_2010
    g. Copy quad segment layer into B:\GLARO_SDE\Backup\Nwi_Backup\MN\PostPhotoInterpSegements
    h. Fill out QAQC Status.xls on W:\GreatLakes_NWI_Update\Finished Geodatabases
        1. Quarter Quad Name (or number)
        2. State abbreviation
        3. Interpreter name
        4. Date in MM/DD/YYYY format that quad was completed
        5. Copied to backup – put Y to indicate the edited segment quad layer was copied from local hard drive to B:\GLARO_SDE\Backup\Nwi_Backup\MN\PostPhotoInterpSegements
        6. Save and close .xls
    i. Use ArcCatalog to delete segment quad feature class from D:\Working\NWI \MN \MN_NWI_2010.gdb\MN_NWI

10. QA/QC another interpreter's quarter quad
    a. Copy segment data from W:\GreatLakes_NWI_Update\ReadyforQAQC_MN_NWI_2010 to local machine.
    b. Perform visual inspection
    c. Rerun steps 9a through 9e
    d. Copy with ArcCatalog into W:\GreatLakes_NWI_Update\Finished_MN_NWI_2010
    e. Fill out QAQC Status.xls on W:\GreatLakes_NWI_Update\Finished Geodatabases
    f. Copy quad segment layer into B:\GLARO_SDE\Backup\Nwi_Backup\MN\PostPhotoInterpSegements rename with "postqaqc" at end.

11. Analyst QA/QC
    a. Fill out QAQC Status.xls on W:\GreatLakes_NWI_Update\Finished Geodatabases
    b. Copy and delete from W:\ GreatLakes_NWI_Update\MN\ Finished_MN_NWI_2010.gdb
    c. Check attributes and investigate any uncommon codes
    d. Perform visual inspection on quad
    e. Select all “U” codes and merge
        i. Select all unattributed polygons
        ii. Calculate ATTRIBUTE field with “U”
        iii. Select by attribute all “U” codes
        iv. Merge all “U” segments
        v. Select **ALL** segments and explode multipart features
        vi. Calculate acreage and visually check all polygons under .05 acres
    f. Run tool to check for adjacent features with the same attribute
    g. Validate and run topology (gaps and overlaps) and fix any errors
    h. Append classified segment data to Reference Data
        i. Select quad segments by attribute
            “ATTRIBUTE” <> “U”
        ii. Join selected table with W:\GreatLakes_NWI_Update\Codes\NWI_Code_LookupTable .dbf and export attributed records to .dbf
            a. FULL_CODE (All Valid codes)
            b. Class
            c. Subclass
            d. WATER_REG
            e. Modifier
            f. Wetland
        iii. Append exported .dbf to W:\GreatLakes_NWI_Update\MN\RandomForest\Reference_Data\Reference_Data.dbf
    i. Export all wetland segments to database to be sent to MNDNR for review
    j. Export all segments to B:\GLARO_SDE\Backup\Nwi_Backup\MN\Finished
    k. Append individual quarter quad segment feature class into seamless dataset for entire project area: vector.glarogis. MN_NWI_2010
    l. Runs QA/QC tool box tools for MN
        i. All Attributes must be valid
        ii. No sliver polygons under 0.01 acres
        iii. No PUBs over 20 acres
        iv. No L1UBs under 20 acres
    m. Validate and run topology (gaps and overlaps) and fix any errors
    n. When complete
        i. Dissolve W:\GreatLakes_NWI_Update\MN\State_Level_NWI\ MN_State_NWI_2010.gdb
            1. Dissolve Field: ATTRIBUTE
            2. Uncheck Create multipart features
        ii. Convert result to coverage
        iii. Run GENERATE <in cov> <out cov> 4 BendSimplify errorcheck
        iv. Delete uplands and non-attributed polygons