# Quality Assurance Plan for the National Wetland Inventory Update of Minnesota

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This document was prepared by the Minnesota Department of Natural Resources (MNDNR) with input and guidance from an interagency technical advisory committee. The agencies represented on the technical advisory committee include:

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# Table of Contents

## 1. Document Scope and Relationship to Other Documents

This document serves as the quality assurance project plan for the statewide update of the National Wetlands Inventory (NWI) for Minnesota. This plan is a supporting element of the Comprehensive Project Plan and is incorporated into this plan by reference.

## 2. Project Background

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 comprehensive wetland inventory for Minnesota. This projects aims to update and improve the NWI for Minnesota.

There are two main issues driving the need for an update of the NWI. First, the data are 25 to 30 years out of date. Many changes in wetland extent and type have occurred since the original delineation. Second, various limitations in the original methodology and source data resulted in an under representation of certain wetland classes. Without an up-to-date wetland inventory, it is difficult to meet wetland planning and management needs for the state.

Updating the NWI for Minnesota will involve acquisition of new remote sensing data (primarily spring, leaf-off, digital color-infrared imagery), compiling other available GIS data sets (e.g. soils, topography, other imagery), and incorporating these data in an efficient and accurate process to identify and classify wetlands. Wetlands will be classified using the system developed by Cowardin et al. (1979). The data will be captured electronically in GIS format and served to stakeholders and the public for free over the internet. Project management and quality control will be woven throughout this process.

## 3. Project Organization and Roles

The update of the National Wetland Inventory for Minnesota is a collaborative effort involving federal, state, and local agencies and organizations. The Ecological Resources Division of the Minnesota Department of Natural Resources (MNDNR) is responsible for coordinating this effort. Other key groups include: various end-users of these maps (stakeholders), the University of Minnesota Remote Sensing and Geospatial Analysis Laboratory (UM-RSGAL), a mapping contractor, the U.S. Fish and Wildlife Service, a technical advisory committee, and the MNDNR Enterprise Hydrography Team. The UM-RSGAL is responsible for evaluating methods and for acquiring field validation data. The mapping contractor is responsible for day-to-day wetland map production.

The organizational relationship of these groups is shown in Figure 3.1. The composition and roles of these various groups is discussed further in the Comprehensive Project Plan for the National Wetland Inventory Update of Minnesota.

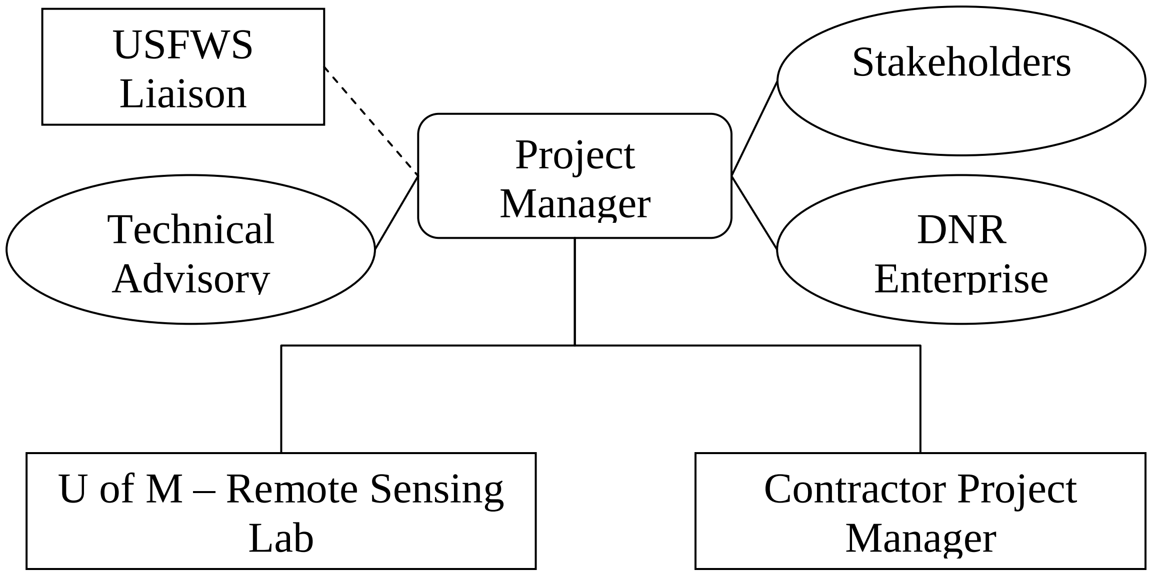


Figure 3.1: Organizational chart for the Minnesota NWI Update

# *4. Quality Assurance Objectives*

## 4.1. Accuracy

Map accuracy has two main components; positional accuracy and classification accuracy. These accuracy components and the quality assurance objectives for them are discussed below.

### *4.1.1. Positional Accuracy*

Positional accuracy is a measure of how close the mapped position of an object is to the real world position. Displacement of mapped objects can occur in three dimensions (x, y, and z), but the NWI does not have an elevation value. Therefore, positional accuracy is only measured in the horizontal plane (x and y directions).

Horizontal positional accuracy is difficult to test for wetland maps. Horizontal accuracy measures rely on comparing positions of well-defined points in the mapped data and the same points derived from a high-accuracy dataset such as survey grade global positioning system (GPS). Wetlands rarely have well-defined points. Apparent wetland boundaries can change seasonally or annually depending upon climate conditions and other factors.

The federal wetland mapping standard specifies that the primary control of horizontal accuracy will be the positional accuracy control of the base imagery, and that the goal is to have a horizontal (i.e. combined x and y error) root mean square error (RMSE) for base imagery of 5 meters or less. This project will adhere to a higher accuracy standard, the National Map Accuracy Standard for 1:6000 scale maps (FGDC 1998). Imagery acquired for this project will have a circular RMSE of 3.35 meters (11 feet) or less. This is equivalent to having 95% of well-defined points within 5.79 meters (19 feet). Detailed specifications for imagery acquisition are listed in Appendix A.

Accuracy testing methodology for imagery acquired for this project will follow the guidelines and specifications of National Standard for Spatial Data Accuracy (NSSDA) as described by the FGDC (1998). Twenty (20) to 40 high accuracy GPS points (sub-meter) will be collected for ground-control targets to test the positional accuracy of the base imagery for each image acquisition phase.

In addition, to ensure that wetland boundaries are reasonably coincident with the base imagery, we require that well-defined boundaries (e.g. water-land boundaries) should also fall within 5.79 meters (19 feet) of the boundary position as shown on the base imagery 95% of the time (root mean square error of 3.35 meters (11 feet)). This goal will be assessed by comparing randomly selected well defined wetland boundaries to their location on the imagery.

#### *4.1.2. Wetland/Upland Classification Accuracy*

Map classification accuracy is a measure of whether the objects or features of a map have been correctly identified. There are two types of errors that can occur. Errors of omission occur when an object that should be included in a mapped class is not included. Errors of commission occur when an object should not be included in a mapped class, but it is included. Map accuracy can be described relative to the omission error rate, the commission error rate, or a combination of these two. The producer's accuracy is equal to 100 percent minus the omission error rate in percent. The user's accuracy rate is equal to 100 percent minus the commission error rate in percent.

The NWI uses a hierarchical map classification developed by Cowardin et al. (1979). Therefore, as it pertains to the NWI, classification accuracy can be calculated for different levels. At the highest level, it simply tests the accuracy of the discrimination between wetland and upland (non-wetland). The primary quality assurance goal for wetland/upland classification accuracy is dictated by the federal wetland mapping standard (FGDC 2009). This standard states:

> *"Ninety-eight percent of all wetlands visible on an image, at the size of the TMU or larger shall be mapped regardless of the origin (natural, farmed, or artificial)."*

The TMU is the targeted mapping unit, which is the smallest size wetland that can be consistently mapped and classified. For the Lower 48 States, the TMU must be 0.5 acres or smaller.

The federal standard recognizes the potential limitation of the available data by basing the goal on what is visible on an image. The goal of this project is to ensure that the NWI update meets this federal standard of a 98% producer's accuracy goal for wetland features. In addition, the wetland maps must also have a user's accuracy of no less than 92%. Evaluation of this goal will be conducted by comparing wetland maps to a set of validation points developed by independent image analysis by an experienced image analyst at the MNDNR.

For reporting purposes, wetland maps produced for this project will also be compared to an independently collected dataset of random field validation points. Data points will be collected by a third party and results from the error analysis will be included in the final metadata.

### 4.1.3. *Wetland Type Classification Accuracy*

In addition to assessing the classification accuracy at the highest hierarchical level (wetland/upland), this project will also assess the classification accuracy of wetland types. The accuracy goal for wetland types is also dictated by the federal standard, which reads:

> *". . .features that are at least 0.5 acres will be mapped with a demonstrated PA of 98% for feature accuracy and* ***85% for attribute accuracy****, or higher, across each DOQQ, as documented through external quality assessment of samples."*

Therefore, the accuracy goal for wetland types is to achieve an 85% overall classification accuracy (counting both errors of omission and commission) for wetlands at the Cowardin class level (Cowardin 1979). The same independent validation dataset developed from image analysis by the MNDNR for use in wetland/upland assessment will also be used for the wetland type classification assessment.

The same third-party, field validation effort conducted to determine the accuracy of wetland/upland classification accuracy will be used to assess the accuracy of wetland types.

## 4.2. Completeness

The completeness goal is to have 100% coverage of Minnesota with updated NWI data meeting the quality assurance goals described in this document. A few areas of the state have locally produced wetland maps that are more recent than the original NWI. These maps will be incorporated into this process as ancillary data, but may require additional effort to ensure that these locally produced maps meet the quality assurance objectives for the project.

## 4.3. Comparability

Data comparability is the degree to which one data set can be compared to another. The updated NWI data shall be internally comparable across Minnesota and externally comparable to data in the National Spatial Data Infrastructure (NSDI) database. However, because the methods, data, and mapping conventions have changed since the original NWI, the NWI update will not be entirely comparable with the original data. Assessment of wetland gains and losses over time is addressed through a separate program known as the wetland status and trends monitoring program.

This project strives for internally comparable data by using reasonably consistent methods for all regions throughout the State, and by maintaining consistent methods over the life time of this project, except where improvements are required for data quality. When method changes are proposed, these changes will be evaluated and documented before being implemented, thereby allowing adequate study to ensure data comparability. Methods employed for the NWI update will be aligned with the federal wetland mapping standard (FGDC 2009) and will be checked by the US Fish and Wildlife Service staff to ensure comparability and compatibility with data in the NSDI.

## 4.4. Reproducibility

A reproducible process is one that produces the same output given the same inputs. Reproducibility is important to ensuring that the data are comparable, but may, in some situations, have negative impact on accuracy. For example, a fully-automated process tends to be highly reproducible, but it may not fully capture the nuances in the source data that a well-trained photo-interpreter might catch. However, the use of human photo-interpreters introduces a degree of subjective judgment that may not be entirely consistent across all photo-interpreters.

It is anticipated that the final mapping method for the NWI update will be some type of semi-automated process. To the degree possible, elements of the mapping procedure will be automated to ensure reproducibility, but only if doing so does not have a significant negative impact on accuracy. For the elements of the procedure that rely on human photo-interpreters, reproducibility will be maintained by using well-documented standard operating procedures and training. A pilot study will be conducted to determine the feasibility of ensuring reproducibility. Photo-interpreters will be tested using a standard set of source data and results from different interpreters compared to determine the level of variability introduced by human interpreters. In addition, all wetland maps will undergo an internal review for consistency by a senior image analyst.

**Table 4.1: Data Quality Objectives for the NWI Update**

| Data Quality Measure | Basis | Goal |
|---|---|---|
| Horizontal Accuracy of Imagery | Comparison to survey grade GPS ground targets | Circular RMSE < 3.35 meters |
| Accuracy of wetland/upland determination | Comparison to validation points from independent image analysis | 98% producer's accuracy & 92% user's accuracy for wetland larger than the TMU and visible on the imagery |
| Accuracy of wetland/upland determination | Comparison to independent field points | Accuracy reported for producer's accuracy, user's accuracy, and overall accuracy |
| Accuracy of wetland classification (Cowardin class) | Comparison to validation points from independent image analysis | 85% overall accuracy |
| Accuracy of wetland classification (Cowardin class) | Comparison to field points | Accuracy reported for producer's accuracy, user's accuracy, and overall accuracy |
| Horizontal Accuracy of Wetland Boundaries | Comparison of well-defined wetland boundaries to imagery | Relative circular RMSE < 3.35 meters |
| Completeness | | Updated maps covering 100% of the state |
| Comparability | Qualitative | Consistent methods and data used across the state and meeting the federal wetland mapping standard |
| Reproducibility | Testing photo-interpreters | Maps produced by photo-interpreters for a standard set of data shall agree within +/-10% |

# 5. Data and Methods

## 5.1. Primary Data

Primary data used for the update of the NWI for Minnesota will be digital aerial imagery and high-resolution digital elevation models from light detecting and ranging (LiDAR). The minimum specifications for this imagery are as follows:

- Spring leaf-off conditions
- Multi-spectral (red, green, blue, and near-infrared)
- Georeferenced and ortho-rectified to remove terrain displacement
- Spatial resolution of 0.5-meter or finer
- No more than 5-years old at the time the wetland interpretation
- A horizontal accuracy with a circular RMSE of 3.35 meters (11.0 feet) or less

Whenever funding allows, imagery will be acquired with the following additional specifications:

- Overlap of 60% to allow full-stereo viewing

Leaf-off images are especially important in forested parts of the state where wetlands can be obscured due to canopy closure. Detailed specifications for imagery acquisition are listed in Appendix A.

In addition, the NWI Update Project will use high-resolution DEMs as a primary source of data for wetland mapping. The Minnesota Legislature recently appropriated $5.6 million to put toward completing LiDAR acquisition for the State. This acquisition is scheduled to be completed in 2012. The project schedule for the NWI update will be designed to take maximum advantage of the statewide LiDAR acquisition project.

## 5.2. Ancillary Data

A variety of ancillary data may be used to compliment the primary data. Commonly used ancillary data for wetland mapping includes additional imagery from other seasons and years, elevation data, soils maps, hydrography, radar data, and other wetland maps (historic or local). Ancillary data will not be acquired with direct funding from the NWI update project. Therefore, the quality assurance standard for ancillary data is to use the best available data. More information on the available ancillary data can be found in the data availability assessment for the National Wetland Inventory update (MNDNR 2010).

## 5.3. Mapping Methods

The mapping methods will be developed and documented by the mapping contractor in consultation with the MNDNR project manager and the technical advisory committee for the NWI update. Method development will consider the methods assessment report produced by the University of Minnesota (Knight et al. 2010) and the data availability for Minnesota. Mapping methods will be incorporated into this plan by reference when available.

# 6. Quality Assurance Procedures

## 6.1. Documentation

Standard operating procedures for mapping, in-office review, and field validation will be developed and incorporated by reference into this quality assurance plan when available.

*Documents Pending*

- Quality Control Procedures for NWI Data Production (Appendix B)

*Documents Completed*

- Procedure for In-Office Review of NWI Data (Appendix C)
- Procedure for Field Validation of NWI Data (Appendix D)

## 6.2. Training

Two training programs will be developed for this project; 1) training for photo-interpreters and 2) training for field-data acquisition teams. Project staff engaged in these activities will be required to undergo the appropriate training program prior to starting work. All personnel involved in the project, regardless of their responsibilities will be made familiar with the general contents of the project control documents and where to access the current version of these documents for reference.

## 6.3. Contractor Review

All wetland map tiles (USGS 7.5 minute quadrangle tiles) will undergo an internal review by the mapping contractor's senior image analyst after the initial photo-interpretation, but before being submitted to the MNDNR as draft maps. Maps will be reviewed to ensure quality and completeness of the interpretation. Any map tiles not meeting the quality control objectives outlined in this document (such as capturing 98% of the wetlands visible on the image) will be returned to the primary photo-interpretation staff for revisions.

## 6.4. Stakeholder Review

Draft maps will be made available to all project stakeholders for review to help identify any inaccuracies. Stakeholder review will be coordinated by the MNDNR project manager. Draft data will be posted to the MNDNR ftp site. A limited number of GPS enabled mobile computing devices will be made available for loan to stakeholders wishing to conduct field reviews who do not otherwise have access to such equipment. A mark-up file will be created to indicate potential additions, deletions, and modifications to wetland boundaries as well as potential classification changes. These mark-up files will be reviewed by the MNDNR project manager and the mapping contractor for potential modifications to the wetland inventory maps.

## 6.5. MNDNR Review

The MNDNR will also review draft data to check for compliance with the data quality objectives outlined in section 4 of this document. The mapping contractor will address any issues identified in this review of the draft data.

After addressing comments on the draft data from the MNDNR and other project stakeholders, the mapping contractor will prepare and submit a final seamless NWI data set fpr the project area. The MNDNR will perform a final acceptance review on a random sample of the final data. This final data review will be used to calculate the accuracy statistics required by the federal wetland mapping standard (FGDC 2009) as summarized in sections 4.1.2 and 4.1.3 of this document.

## 6.6. Automated Data Quality Checks

Prior to submitting the final NWI data to the MNDNR, the vendor will use USFWS quality control tools or the equivalent to check the data for internal consistency. These checks are designed to ensure correct topology of the data (i.e. no gaps or overlaps) and that valid attributes have been assigned for all features (e.g. only valid Cowardin codes for Minnesota have been used).

## 6.7. Field Validation

After the data have been accepted, the UM-RSGAL will use the field observation data to calculate additional accuracy statistics including the user's accuracy, the producer's accuracy and the overall accuracy at both the feature level (wetland/upland) and at the wetland class level. The UM-RSGAL will develop a SOP for the acquisition of field validation data. This SOP will be incorporated in this QA plan by reference when it is available.

## 6.8. Audits and Reporting

The MNDNR project manager or designee shall periodically review the procedures used by the mapping contractor. This shall include a review to ensure that written procedures remain consistent, clear, and current. QA audits shall also include on-site assessments to ensure that photo-interpretation staff are following written procedures and that deviations from written SOPs are documented.

## 6.9. Corrective Action

The MNDNR project manager or designee shall keep a log of any issues identified through the QA audit reports described in Section 6.8, as well as the corrective action taken to address these issues. Possible problems requiring corrective action include:

Any non-conformance with the established quality control procedures outlined in the QAP shall be identified and corrected. The MNDNR project manager or designee shall issue a corrective action memorandum for each non-conformance condition and resolution.

## *7. References*

Cowardin L., V. Carter, F. Golet, and E. LaRoe. 1979. Classification of wetlands and Deepwater Habitats of the United States. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC, USA.

MNDNR (2010). Data Availability for the National Wetland Inventory Update of Minnesota. Minnesota Department of Natural Resources. St. Paul, MN. MNDNR website as accessed on April 20, 2010. http://files.dnr.state.mn.us/eco/wetlands/nwi_data_plan_v3.pdf

FGDC. 1998. Geospatial Positioning Accuracy Standards. Part 3: National Standards for Spatial Data Accuracy. Federal Geographic Data Commission. FGDC website as accessed on April 20, 2010. http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3

FGDC. 2009. FGDC Draft Wetland Mapping Standard. Federal Geographic Data Commission. FGDC website as accessed on April 20, 2010. http://www.fgdc.gov/standards/projects/FGDC-standards-projects/wetlands-mapping/

Knight, J.K, J. Corcoran, L. Rampi, B. Tolcser, and M. Voth. 2010. Wetland Mapping Methods for the Twin Cities Metropolitan Area. Remote Sensing and Geospatial Analysis Laboratory, Department of Forest Resources, University of Minnesota. St. Paul, MN. Project Report to the Minnesota Department of Natural Resources. pp. 57.

# Appendix A – Specifications for Imagery Acquisition
# Date: June 4, 2009

## Resolution

The imagery shall be collected at a ground sampling distance of 0.5-meter resolution or finer.

## Ground Condition

The imagery shall be collected under spring leaf-off conditions and shall be snow-free and cloud-free as well as free from flood water. Spring leaf-off is defined as the period in spring before leaves of any deciduous tree species have developed to the point where leaf shape can be observed. Snow-free means less than 5% of the ground surface is covered by snow. Minimal snow cover from residual stockpiles and along fence and windrows is acceptable. Cloud free means less than 5% of the image area is affected by clouds our cloud shadows.

## Spectral-Bands

The images shall be collected as 4-band multi-spectral digital imagery with spectral bands for red, green, blue, and near-infrared.

## Image Processing

At a minimum, the digital imagery will be georeferenced and ortho-rectified to remove topographical displacement and then mosaicked into a digital ortho quarter quad. Optionally, if funding allows, the imagery will also be acquired and delivered as full-stereo images.

## Overlap

The imagery shall be acquired with sufficient end lap and/or side lap to prevent any gaps in coverage and to provide all necessary coverage for accurate ortho-rectification and visual interpretation. For stereo coverage, end lap requirements increase to 60%.

## Control

Airborne GPS (Global Positioning Systems) and IMU (Inertial Measurement Unit) systems or equivalent technology/methodology will be used to meet these image specifications. The vendor will provide any ground control necessary to meet the specified horizontal accuracy requirements. The MNDNR will use ground control points established by MNDOT for the 2008 NAIP for verification.

## Elevation

The vendor will use the best available digital elevation model for the ortho-rectification process. Data resources include the MNDNR DEMs accessible through the MNDNR Data Deli (http://deli.dnr.state.mn.us) and the USGS National Elevation Dataset accessible through the Seamless Data Distribution System at EROS (http://seamless.usgs.gov/).

## Horizontal Accuracy

Horizontal accuracy should meet the National Map Accuracy Standard for 1:6,000 scale maps with a circular root mean square error of 3.35 meters. This is equivalent to having 95% of well-defined points within 5.79 meters. Accuracy testing methodology should follow the guidelines and specifications of NSSDA.

## Image Quality

Images shall be tonally balanced and image mosaics shall be uniform in contrast without abrupt variations between image tiles. Imagery shall be free of blemishes, scratches, and artifacts that obscure ground feature detail. Pixel resolution shall not be degraded by excessive image smear. DOQQs shall have a tonal range that prevents the clipping of highlight or shadow detail from the image. No more than 2% of the pixels may have a luminosity value in the first five or last five histogram bin values (0 to 4 or 251 to 255). If needed, contrast of the DOQQs should be stretched so that the difference between the 99th percentile of the luminosity histogram value and 1st percentile shall be greater than 120, with a preferred value of greater than 150. All DOQQs shall have a pixel count peak within ±15% of the middle digital value allowed for the bit depth. For an 8-bit depth image, the histogram peak must be between 108 and 148.

## Projection

The data shall be provided using the Universal Transverse Mercator, Zone 15 coordinate system using the 1983 North American Datum (UTM-15, NAD83, Meters).

## File Format

Digital orthophotos shall be delivered as GeoTIFF with world files delivered as uncompressed, georeferenced quarter quad tiles; and JPEG2000 delivered as compressed county mosaics. Stereo imagery shall be delivered as uncompressed tiff files along with exterior orientations and camera calibration data sufficient for establishing a digital stereo model. Images shall consist of 8 bits per band. Images may be collected at more than 8 bits per band, but shall be resampled to 8 bits per band for image delivery.

## Metadata Information

Metadata for this project shall meet the requirements of the Minnesota Geographic Metadata Guidelines (see http://www.mngeo.state.mn.us/chouse/meta.html) or the Federal metadata standard (see http://www.fgdc.gov/metadata/geospatial-metadata-standards). Supplemental metadata information includes the following:

1. Tested Horizontal Accuracy Statement
2. Lineage, including, but not limited to: flight height, photo acquisition dates (and reflights if any), overlap, sidelap, number of flight lines, number of exposures, direction of flight lines, control, resolution, tiling scheme, file sizes, description of the process used to create digital orthophotos, source of DEM, etc.
3. Spatial reference information: projection, ellipsoid, horizontal and vertical datum, horizontal and vertical units, UTM zone number.

# Appendix B – Quality Control Procedures for NWI Data Production

*This section is to be completed by the contractor or contractors selected for the NWI map production work.*

# Appendix C - Procedure for In-Office Review of NWI Data

This procedure is designed to validate the accuracy of the updated National Wetland Inventory maps for Minnesota through the comparison of updated NWI maps with independently photo-interpreted wetland data points. This allows for the creation and reporting of statistical accuracy estimates for the maps. A stratified random selection of sites is used for the validation sample set. All sites are assessed from aerial imagery and ancillary GIS data.

## Number of Photo-Interpreted Points

Minnesota has 20 wetland types based on an assessment of Cowardin classes from the original NWI. Statewide, this procedure aims to place at least 180 validation points for each of these 20 wetland types, 180 points in cultivated wetlands (which were not typically mapped in the original NWI) and 900 additional point observations for various upland land cover types. In situations where one or more of the 20 wetland types are not present in a region, points that would have been assigned to those types are distributed throughout the types that are present. This final sample of nearly 4500 validation points for the statewide NWI is sufficient to derive robust measures of the accuracy.

## Selection of Photo-Interpretation Sites

Validation sites are selected using a stratified-random design. Primary sampling units from Minnesota's wetland status and trends monitoring program (WSTMP) are used as the stratification layer. The stratified sampling scheme distributes points both spatially and between the wetland types. Existing wetland data from the WSTMP are used for an *a priori* stratification scheme. The purpose of this design is to 1) ensure that an adequate number of each wetland class and land cover class are represented, and 2) ensure that a reasonably random sample is selected so that valid statistical inferences can be made.

The sampling design tool for ArcGIS developed by the Biogeography Branch of NOAA was used to create a set of stratified random sampling points. The stratification data layer for this effort was interpreted wetland data from the combined 2006 - 2008 wetland status and trends monitoring program (WSTMP).

Some wetland classes in the WSTMP are aggregated from Cowardin classes. Samples were allocated between strata at the nominal rate of 180 sites per Cowardin wetland class (Table 1). Because some classes are aggregated in WSTMP, it cannot be guaranteed that 180 points will fall within each of the Cowardin classes. Rare wetland classes, with fewer than 20 observations in the validation data set, will be aggregated afterwards with a closely related wetland class for calculating accuracy statistics. In addition, there are 6 upland classes with 180 points allocated to each of these.

## Equipment

- WSTMP photo-interpreted wetlands GIS layer
- Recent high-resolution, spring leaf-off digital stereo imagery
- Stereo GIS workstation

- Ancillary GIS data including, but not limited to high resolution LiDAR digital elevation models, detailed soil survey data from USDA, and 2008 summer leaf-on imagery from USDA

## Procedure

The MNDNR image analyst will adhere to the following protocol when conducting this analysis.

1) Create a stratified random set of validation points using the sampling design tool for ArcGIS developed by the Biogeography Branch of NOAA and the 2006 – 2008 data from the Minnesota Wetland Status and Trends Program.
2) Using ArcGIS and StereoAnalyst, sequentially assess the correctness of the original WSTMP wetland class for each data point based on the NWI imagery and ancillary data.
3) Split the WSTMP classes, where needed, into the appropriate Cowardin classes (e.g. aquatic bed to PAB, L1AB, L2AB, R2AB, or R3AB) based on interpretation of the imagery.
4) Use the spatial join function of ArcGIS to relate the validation data to the updated NWI polygons (join points to polygons based on points falling within polygons).
5) Create a table with a record for each validation data point containing a field for the wetland class as determined by the QA analyst and a field for wetland class based on the updated NWI.
6) Aggregate rare wetland classes, those with fewer than 20 observations in the validation data set, with closely related wetland classes.
7) Summarize all records into an error matrix and report the errors of omission, errors of commission, and overall accuracy following the method described by Congalton and Green (1999).
8) Calculate the final accuracy metrics using class weights equal to the frequency of occurrence in the updated NWI.

## Calculation of Accuracy Statistics

Upon completion of each project phase and subsequently for the state as a whole, classification accuracy estimates are produced by comparing updated NWI maps to the independent validation points developed through this procedure. These estimates describe overall and per class error rates in the NWI maps. Map accuracy is described relative to the omission error rate, the commission error rate, and the overall accuracy (Congalton and Green 1999). Given that validation sites were not distributed according to frequency, the results for each individual class will require a weighted adjustment based on the frequency of occurrence. In addition, the kappa coefficient of agreement, which is a measure of the accuracy of the accuracy of a classification that is adjusted for chance agreement, is computed. Finally, per class and overall accuracy estimator confidence intervals are provided.

Table 1: Sample stratification scheme. One-hundred eighty sites are allocated per Cowardin class.

| WSTMP Class | WSTMP Frequency | Cowardin Class Count | Cowardin Classes | NWI Frequency | Samples Sites |
|---|---|---|---|---|---|
| Aquatic Bed | 2.1% | 3 | L2AB, PAB, R2AB | 0.1% | 540 |
| Cultivated Wetland | 1.6% | 0 | f – modifier | 0.0% | 180 |
| Emergent | 23.7% | 3 | L2EM, PEM, R2EM | 43.4% | 540 |
| Forested | 36.8% | 1 | PFO | 21.8% | 180 |
| Scrub-Shrub | 19.1% | 1 | PSS | 24.5% | 180 |
| Unconsolidated Bottom | 2.2% | 7 | L2RS, L2US; PUB, PUS: R2US, R3US, R4SB | 7.9% | 1260 |
| Deepwater | 14.5% | 5 | L1UB, R2UB, R3RB, R3UB, L2UB | 2.3% | 900 |
| Agriculture | | 1 | U | | 180 |
| Natural Upland | | 1 | U | | 180 |
| Rural Development | | 1 | U | | 180 |
| Silviculture | | 1 | U | | 180 |
| Urban | | 1 | U | | 180 |

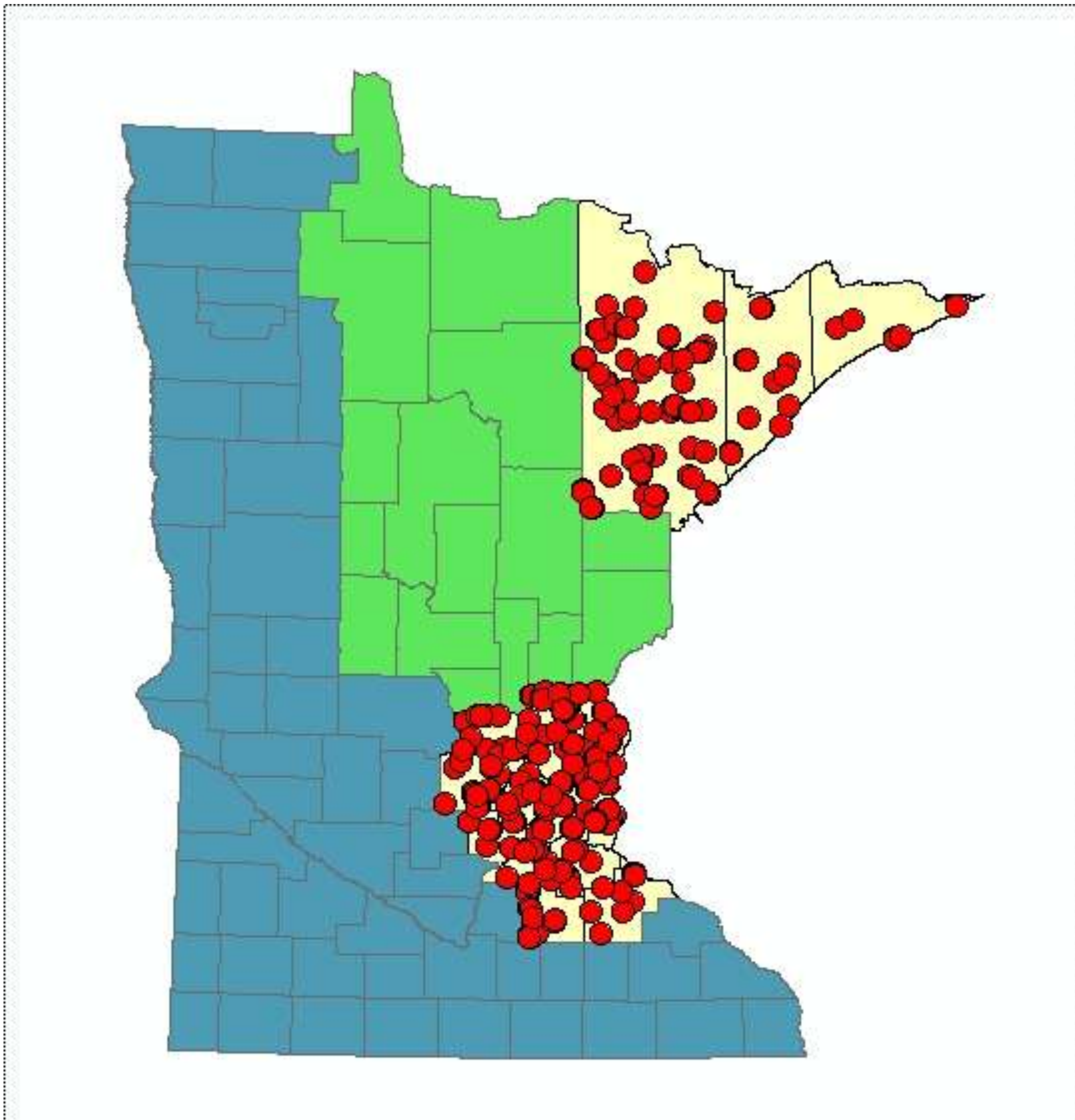

Figure 1: Example overview of the stratified random point distribution for a section of the NWI validation sites.

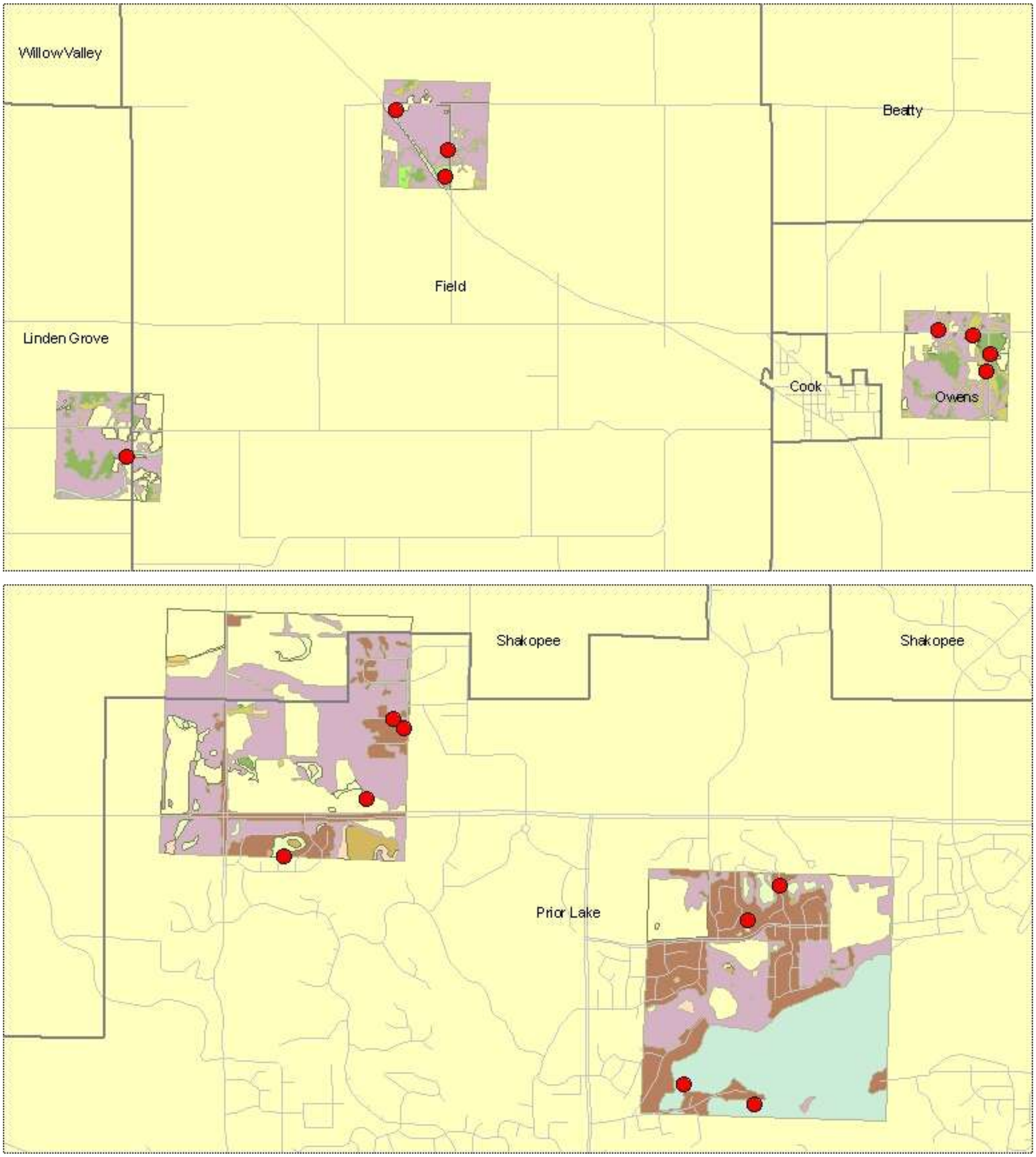


Figure 2: An example close-up of the stratified random point distribution for the NWI validation sites shown in relation to the WSTMP data near Cook, MN in St. Louis County (top) and in Prior Lake, MN in Scott County (bottom). Top and bottom figures are shown at different scales.

## References


Buja, K. and C. Menza. 2008. Manual for the Sampling Design Tool for ArcGIS. National Oceanic and Atmospheric Administration, Biogeography Branch, Silver Springs, MD. 17 p.

Congalton, R.G. and K. Green. 1999. Assessing the accuracy of remotely sensed data: principles and practices. CRC/Lewis Press, Boca Raton, FL. 137 p.

Cowardin L., V. Carter, F. Golet, and E. LaRoe. 1979. Classification of wetlands and Deepwater Habitats of the United States. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC. 79 p.

# Appendix D - Procedure for Field Validation of NWI Data
# Date: May 19, 2010

This procedure is designed to validate the accuracy of the updated National Wetland Inventory maps for Minnesota. This goal is accomplished through the comparison of independently sampled wetland data with the corresponding locations on the updated NWI maps, which allows for the creation and reporting of statistical accuracy estimates for the maps. A stratified random selection of sites within 200 feet of public roads is used for the validation sample set. All sites are assessed from ground level.

## Number of Field Observations

Minnesota has 20 wetland types based on an assessment of Cowardin classes from the original NWI (Table 1). Statewide, this procedure aims to place at least 60 validation sites for each of these 20 wetland types, 60 sites in cultivated wetlands (which were not typically mapped in the original NWI) and 300 additional point observations for various upland land cover types. In situations where one or more of the 20 wetland types are not present in a region, sites that would have been assigned to those types are distributed throughout the types that are present. The pool of validation points will be oversampled by several hundred sites to allow for discarding sites that cannot be safely or practically assessed from ground level. A final sample of 3,000 validation sites (including oversample) is sufficient to derive robust measures of the accuracy of the NWI product.

## Timing of Field Observations

Validation data is collected as contemporaneously as possible with the acquisition of the base imagery used for the NWI update to avoid potential problems with changes in wetland extent or type between the acquisition dates. For this procedure, the validation data should be collected within 1 year of the image acquisition, if possible, but no later than 2 years from the imagery acquisition. Field crews will note any signs of potential recent landscape change.

## Selection of Field Observation Sites

Validation sites are selected using a modified multi-layer stratified-random sampling design that was implemented using ArcGIS with the Geospatial Modeling Environment extension from Spatial Ecology, LLC (formerly known as Hawth's Tools). A flowchart describing the design is shown in Figure 3.The primary sampling unit is a random selection of 10% of the USGS quadrangles within each study area (Metro and Arrowhead). Secondary sampling units from Minnesota's wetland status and trends monitoring program (WSTMP) are intersected with a buffer (>50 ft, < 200 ft) of the Minnesota Department of Transportation GIS roads layer. The existing wetland data from the WSTMP are used for a tertiary stratification scheme. This stratified random sampling scheme is used to select field observation sites that fall within the range of wetland sizes and also within specified wetland classes and a general upland class. The stratified sampling scheme distributes sites both spatially and between the land cover types and wetland sizes. The purpose of this design is to 1) ensure that an adequate number of each class and wetland size are represented, 2) ensure that a reasonably random sample is selected so that valid statistical inferences can be made, 3) ensure that sites are likely to be accessible or at least viewable from the ground, and 4) to reduce travel time between sites.

Some wetland classes in the WSTMP are aggregated from Cowardin classes. Samples were allocated between strata at the nominal rate of 20 sites per Cowardin wetland class. Because some classes are aggregated in WSTMP, it cannot be guaranteed that 20 sites will fall within each of the Cowardin classes. Class frequencies will be monitored while sampling is ongoing. Rare classes will be oversampled to the extent possible. Classes that are extremely rare and lack sufficient field samples for statistical validity will be combined with other appropriate classes.

## Equipment

- Handheld GPS device (e.g. Trimble Juno SB loaded with Terrasync, sample site database, roads layer, property ownership, recent aerial imagery, and digital camera)
- Binoculars and/or laser range finder (for off-site assessment)
- Waterproof boots or waders, hip boots, or knee boots (as required)
- Personal safety/comfort gear (insect repellent, sunscreen, water, cell phone)

## Procedure

Field crews will adhere to the following protocol when navigating to and sampling the field observation sites.

1. Navigate to the roadway nearest to the field site.
2. Use caution and common sense in locating a safe parking site (make sure you can pull far enough off the road).
3. Place sign identifying purpose of work in car window (e.g. "University of Minnesota field work team")
4. Record coordinates of parked vehicle to enable easy return.
5. Attempt to identify the property owner where the site is located and request entry permission.
6. If permission is given, provide letter describing purpose of work to land owner and navigate using GPS to the sample site. If permission cannot be obtained, determine if the site can be viewed from the road and make assessment from the public right-of-way. Sites that cannot be visited or viewed from the road will be noted, skipped, and another site will be selected at random from the oversample pool.
7. Use the digital field forms to record the following information at the field site:
    a. Date and time of observation
    b. Initials of field crew
    c. Location of observation in GPS coordinates (post-processed for differential correction). Be sure to record the location from which the observation is made even if the site cannot be directly accessed.

d. Ensure that the GPS provides a minimum of 50 continuous position fixes at each site to reduce the PDOP.
e. Determination of wetland or upland
f. For uplands, classification of upland type
g. For wetlands, classification of wetland type (Cowardin class-level)
h. Narrative comments including primary land cover, dominant plant species, land use activities, and any potentially unusual field condition (e.g. flooding, recent landscape change, etc.)
i. Digital photographs of the site at cardinal directions and canopy, if the site can be accessed; otherwise a photo of the site from the roadway

## Calculation of Accuracy Statistics

Upon completion of field sampling for each project phase and subsequently for the state as a whole, classification accuracy estimates are produced. These estimates describe overall and per class error rates in the NWI maps. Map accuracy is described relative to the omission error rate, the commission error rate, and the overall accuracy (Congalton and Green 1999). Given that validation sites were not distributed according to frequency, the results for each individual class will require a weighted adjustment based on the frequency of occurrence. In addition, the kappa coefficient of agreement, which is a measure of the accuracy of the accuracy of a classification that is adjusted for chance agreement, is computed. Finally, per class and overall accuracy estimator confidence intervals are provided.

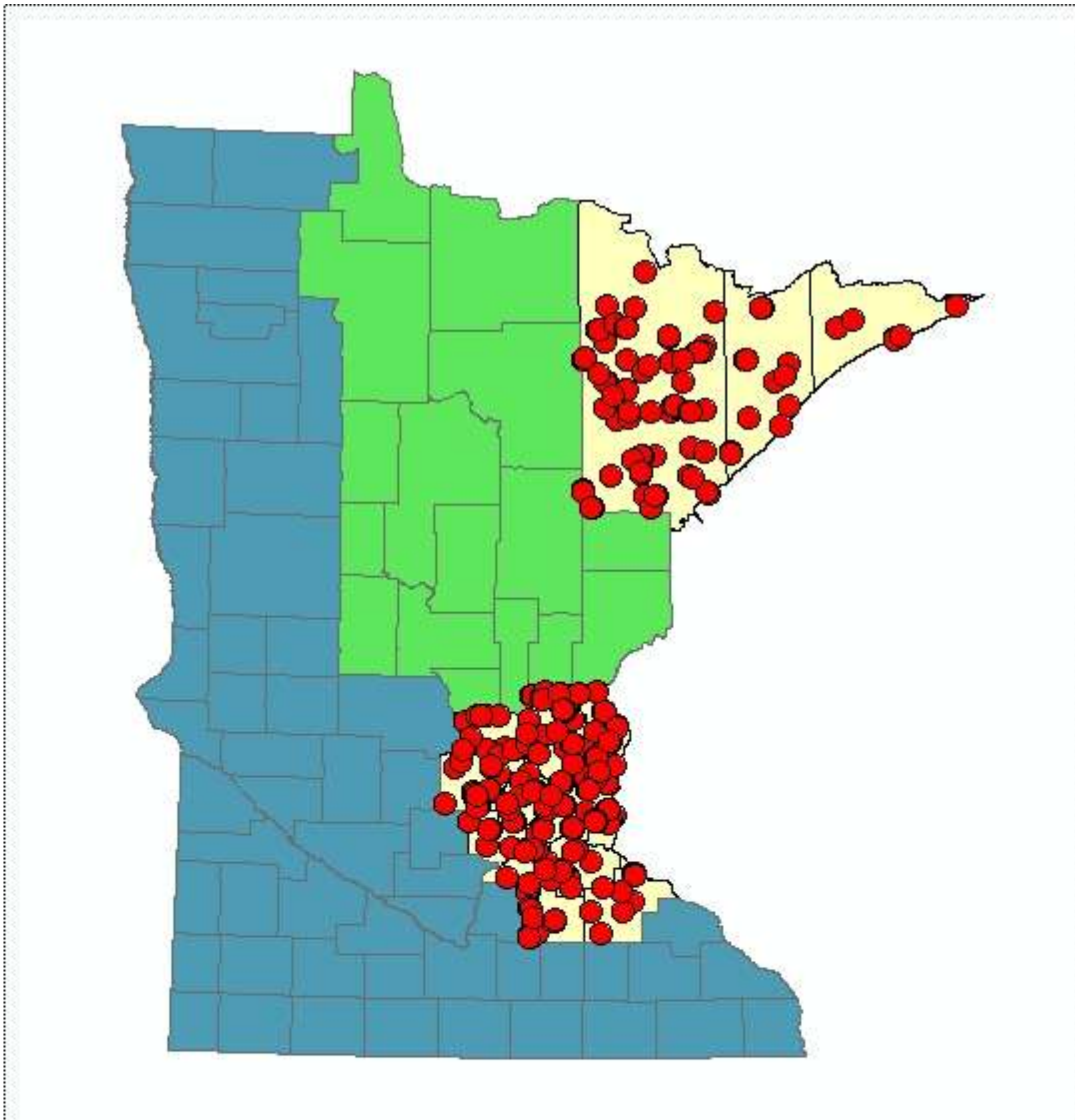

Figure 1: Overview of a sample stratified random point distribution for the NWI validation sites.

Table 1: WSTMP classes in Minnesota and corresponding Cowardin Classes.

| WSTMP Class | WSTMP Frequency | Cowardin Class Count | Cowardin Classes | NWI Frequency |
|---|---|---|---|---|
| Aquatic Bed | 2.1% | 3 | L2AB, PAB, R2AB | 0.1% |
| Cultivated Wetland | 1.6% | 0 | f - modifier | 0.0% |
| Emergent | 23.7% | 3 | L2EM, PEM, R2EM | 43.4% |
| Forested | 36.8% | 1 | PFO | 21.8% |
| Scrub-Shrub | 19.1% | 1 | PSS | 24.5% |
| Unconsolidated Bottom | 2.2% | 7 | L2RS, L2US, PUB, PUS, R2US, R3US, R4SB | 7.9% |
| Deepwater | 14.5% | 5 | L1UB, R2UB, R3UB, R3RB, L2UB | 2.3% |
| Agriculture | | 1 | U | |
| Natural Upland | | 1 | U | |
| Rural Development | | 1 | U | |
| Silviculture | | 1 | U | |
| Urban | | 1 | U | |
| ~~Other~~ | - | ~~1~~ | ~~U~~ | - |

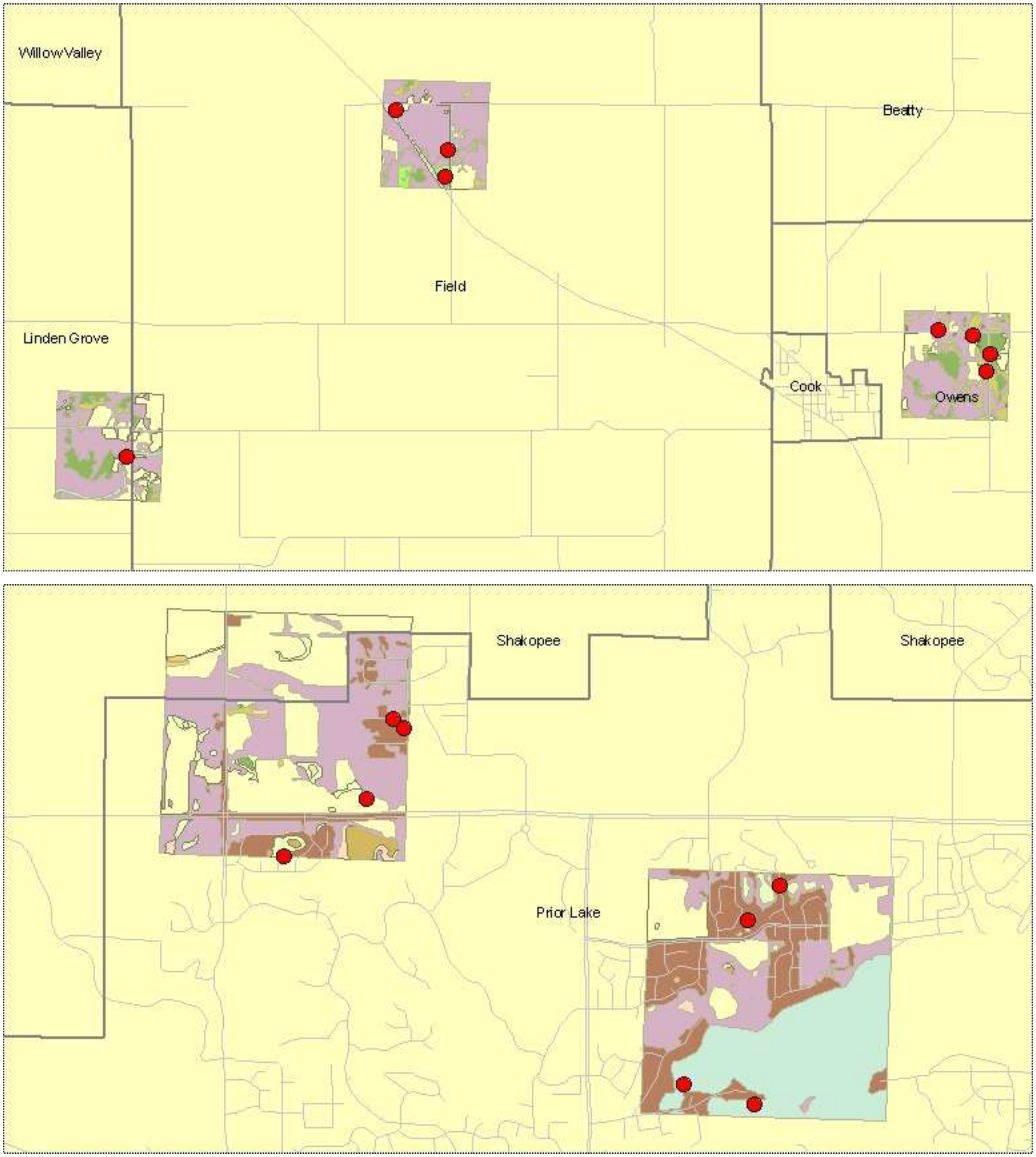


Figure 2: A sample close-up of the stratified random point distribution for the NWI validation sites shown in relation to the 2006 WSTMP data near Cook, MN in St. Louis County (top) and in Prior Lake, MN in Scott County (bottom). Top and bottom figures are shown at different scales.

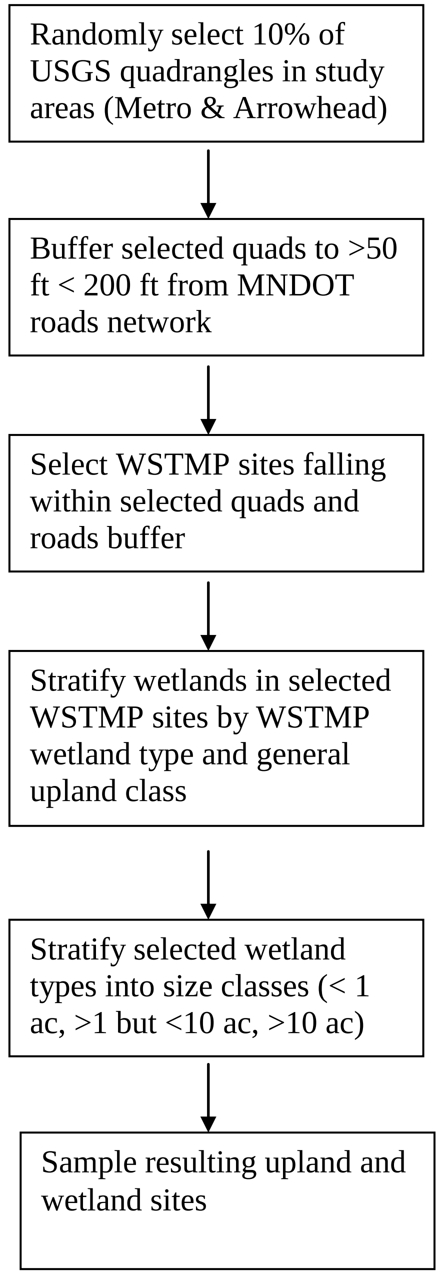


Figure 3: Process diagram for sample site selection

## References

Congalton, R.G. and K. Green. 1999. Assessing the accuracy of remotely sensed data: principles and practices. CRC/Lewis Press, Boca Raton, FL. 137 p.

Cowardin L., V. Carter, F. Golet, and E. LaRoe. 1979. Classification of wetlands and Deepwater Habitats of the United States. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC. 79 p.

Spatial Ecology, LLC, 2010. Introducing the Geospatial Modeling Environment. http://www.spatialecology.com/gme/.  Retrieved 4/19/2010.