

Swan Lake National Wildlife Refuge
Vegetation Cover (2000) Project Report¹

by

James A. Gonsoski, Thomas E. Burk, Paul V. Bolstad and Mary Balogh²

June 2004

Staff Paper Series No. 175

Department of Forest Resources

College of Natural Resources
and
Minnesota Agricultural Experiment Station
University of Minnesota
St. Paul, Minnesota

¹ Research supported by Cooperative Agreement USDI/1434-HQ-97-RU-01566 WO 49 between the University of Minnesota and the U.S. Fish and Wildlife Service.

² The authors are Graduate Research Assistant, Professor and Associate Professor, respectively, Department of Forest Resources, College of Natural Resources, University of Minnesota and GIS Coordinator, Region 3, U.S. Fish and Wildlife Service.

For more information about the Department of Forest Resources and its teaching, research, and outreach programs, contact the department at:

Department of Forest Resources

University of Minnesota

115 Green Hall

1530 Cleveland Avenue North

St. Paul, MN 55108-6112

Ph: 612-624-3400

Fax: 612-625-5212

Email: forest.resources@umn.edu

<http://www.cnr.umn.edu/FR/publications/staffpapers/>

The University of Minnesota is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, color, creed, religion, national origin, sex, age, marital status, disability, public assistance status, veteran status, or sexual orientation.

Table of Contents

SUMMARY	6
1. INTRODUCTION	7
1.1. BACKGROUND	7
1.2. REFUGE HISTORY.....	7
1.3. PRODUCTS.....	8
1.4. PROJECT MILESTONES.....	8
2. METHODS	9
2.1. GENERAL INFORMATION.....	9
2.2. IMAGE PREPARATION.....	9
2.3. POSITIONAL ACCURACY ASSESSMENT	9
2.4. CLASSIFICATION DEVELOPMENT	9
2.5. SPATIAL DATABASE DEVELOPMENT.....	10
2.6. THEMATIC ACCURACY ASSESSMENT	11
3. RESULTS	14
3.1. MAP CLASSES.....	14
3.2. THEMATIC ACCURACY ASSESSMENT	18
3.3. MAP CLASS AREAS.....	19
4. REFERENCES	22
APPENDIX A – DATA CD CONTENTS	23
APPENDIX B – DICHOTOMOUS KEY TO MAP CLASSES	24
APPENDIX C – POSITIONAL ACCURACY ASSESSMENT	26
APPENDIX D – THEMATIC ACCURACY ASSESSMENT	27
APPENDIX E – ATTRIBUTE TABLE FORMATS	28

List of Tables

Table 1. NVCS physiognomic-floristic levels	10
Table 2. Per-class accuracy summary	19
Table 3. Area statistics for the Swan Lake National Wildlife Refuge	20

List of Figures

Figure 1. Swan Lake Wildlife Refuge location, Chariton County, Missouri.....	8
Figure 2. Example of attribute items within vegetation cover shapefile.....	11
Figure 3. Accuracy assessment points visited at Swan Lake NWR.	12
Figure 4. Swan Lake National Wildlife Refuge vegetation cover map.	21

Contacts

Region 3 Great Lakes—Big River
BHW Federal Building
1 Federal Drive
Fort Snelling, Minnesota 55111-4056
Website: <http://midwest.fws.gov/>

Mary Balogh
Region 3 GIS Coordinator
Phone: (612) 713-5490
E-Mail: Mary_Balogh@fws.gov

Mary Mitchell
GIS Coordinator
Phone: (612) 713-5443
E-Mail: mary_s_mitchell@fws.gov

Acknowledgements

Several people offered their time and skills to complete this project. At the Fish and Wildlife Service Regional Office, Mary Balogh oversaw the project and quality-checked the data. My colleagues, Kari Geurts and Nicole Brown, at the University of Minnesota, provided keen eyes, technical expertise and kind words of support. Ryan Kirk, also of the University of Minnesota, provided background information and insights.

At Swan Lake Refuge, John Guthrie and Heather Lambert-Doherty contributed to the development of the vegetation classification and its field accuracy assessment. They provided detailed information about the refuge history and current management practices as well as acted as tour guides to some of the less traveled portions of the refuge. Swan Lake Refuge kindly provided housing, vehicles, and cookies as well as a chance to see one of the most beautiful old-growth forests in Missouri.

Summary

In the spring of 2004, the University of Minnesota Forest Resources Department in cooperation with Region 3 of the U.S. Fish and Wildlife Service (USFWS) created a high-resolution vegetation cover database for Swan Lake National Wildlife Refuge (NWR) in Chariton County, Missouri for use in resource planning. The area classified in this project includes the 11,000 acres within the primary boundary of the refuge as well as a surrounding area of 0.5 kilometers buffering the outside of that boundary.

A classification scheme was designed to attribute each homogenous area of vegetation greater than the minimum area of 0.5 hectare to a formation class of the National Vegetation Classification System (NVCS). In lieu of field reconnaissance, the initial classification was based on map layers created by the refuge staff for describing habitat on the refuge. From this, eleven map classes were derived. A high-resolution multi-spectral Ikonos (Space Imaging, LLC.) satellite image from August 7, 2000 was purchased and used as the reference for digitizing. Polygons representing each map class were created on-screen using ESRI ArcEdit (ArcInfo 8.3) and the satellite image at a scale of 1:12,000. Attributes were assigned to each polygon and all map products were created using ESRI ArcMap 8.3.

Thematic accuracy assessment was conducted using site visits to over 260 random points within the refuge during the spring of 2004. The overall thematic accuracy of individual polygons within the refuge boundaries to the formation class of the NVCS was 92%, significantly greater than the project goal of 80%.

Eleven map classes characterize the vegetation cover for Swan Lake with a total of 162 polygons subdividing the 11,020 acres (4,460 ha.) of the refuge. The majority of the refuge is herbaceous grasses, forbs and agricultural crops with 45% coverage or 4,929 acres (2015 hectares). Bottomland forest covers another 28.5% or 3138 ac. (1,270 ha.) of the refuge, much of this in the Yellow Creek Natural Area which defines the refuge's southern border. Another 20% of the refuge or about 2,100 ac. (860 ha.) is open water.

The vegetation cover database developed for Swan Lake is available in ArcInfo Export and shapefile formats.

1. Introduction

1.1. Background

The University of Minnesota Forest Resources Department in cooperation with Region 3 of the U.S. Fish and Wildlife Service (USFWS) created a high-resolution vegetation cover database of Swan Lake National Wildlife Refuge (NWR) in Chariton County, Missouri to assist in resource planning. This specific mapping project spanned the months of October 2003 through September 2004.

The classified area includes the 11,000 acres within the primary boundary of the refuge as well as a buffer area of 0.5 kilometers outside that boundary. It excludes the easements managed by refuge staff outside the primary refuge boundary.

Vegetation types were classified using the National Vegetation Classification System (NVCS). A set of map classes specific to the refuge were designed that crosswalk to the formation level of the NVCS and also include non-vegetated features such as roads, parking areas, and open water. A set of modifiers was used to clarify the map class.

The accuracy of the map attributes was determined through a detailed thematic assessment and analysis. Map attributes were required to meet an 80% accuracy standard. The quality of the spatial information was judged through positional accuracy testing. Spatial accuracy was required to meet the National Standard for Spatial Data Accuracy.

This report details the methods used to create the classification and assess its accuracy. It summarizes the resulting map classes and documents the crosswalk between the map classes and the NVCS formations.

1.2. Refuge History

Swan Lake NWR is located in the Grand River floodplain near its confluence with the Missouri River in Chariton County, Missouri approximately 30 miles southeast of Chillicothe, Missouri (Figure 1). Established in 1937, the refuge is about 11,000 acres in size. The majority of refuge land was once cleared and converted to agriculture.

Due to frequent flooding, the area was poor for farming and much of the land was sold to the USFWS. Swan Lake NWR provides resting and feeding habitat for waterfowl and other wildlife. The refuge acts as a wintering area for Canada geese with as many as 80,000 birds visiting annually. More than 100 bald eagles also spend winter at the refuge. The Yellow Creek Research Natural Area, within the refuge, is one of the largest remaining old growth bottomland hardwood forests in Missouri.

Public use of the refuge includes activities such as environmental education, wildlife observation, hiking, hunting and fishing. Current management practices include water regulation, moist soil management and prescribed burning (USFWS Fact Sheet, 2003).

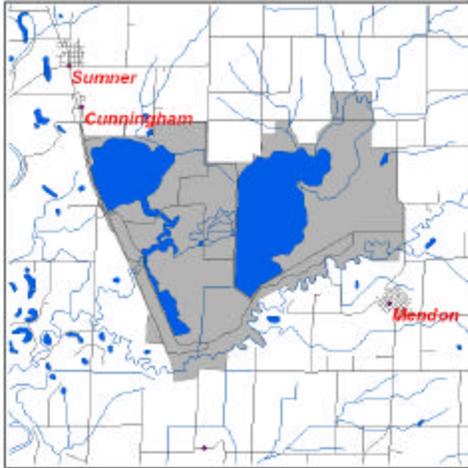


Figure 1. Swan Lake Wildlife Refuge location.



Chariton County, Missouri

1.3. Products

The products created for this project were:

- Vegetation cover database in ArcInfo Export and shapefile formats,
- Vegetation cover maps in 300 dpi Post Script (EPS) and 96 dpi TIF formats,
- Map class descriptions cross-walked to the NVCS with photo examples,
- Dichotomous key to derive the map classes used in mapping,
- Printed and digital copies of Ikonos high-resolution satellite image,
- Accuracy assessment points and field data in Arc/Info Export and shapefile formats,
- 200+ digital (JPG) photos taken during accuracy assessment,
- Appropriate metadata for each digital product,
- A CD-ROM of all digital products.

1.4. Project Milestones

A brief chronology of events for this mapping project was:

- October 2003 – Project initiated,
- October 2003 – High-resolution satellite image of area purchased,
- November 2003 – Initial vegetation classification list complete,
- December 2004 – Image interpretation and mapping,
- February 2004 – Preliminary vegetation cover layer complete,
- March 2004 – Site visit for accuracy assessment,
- May 2004 – Additional site visit for further accuracy assessment,
- August 2004 – Final edits,
- September 2004 – Completion and delivery of products.

2. Methods

2.1. General Information

The spatial database created for this project was projected in Universal Transverse Mercator (UTM), Zone 15, North American Datum of 1983 (NAD83). All units are in meters. The standard minimum mapping unit applied was 0.5 hectares, or roughly one acre. Features less than 0.5 hectares were not mapped.

2.2. Image Preparation

Parts of two high-resolution digital Ikonos (Space Imaging, LLC.) satellite images were purchased for this project. Each image was captured August 7, 2000 and had four 4-meter multi-spectral wavebands represented as blue (444-516 nm), green (506-595 nm), red (631-697 nm), and near-infrared (757-852 nm) as well as a 1-meter panchromatic band. The images were already geo-referenced by Space Imaging to a reported accuracy of 15 meters. The imagery was radiometrically-corrected and sharpened to 1 meter resolution using the panchromatic band. The images were not orthorectified. In general, elevation differences in the region are small. The two images were stitched together in a mosaic of the landscape using ERDAS Imagine 8.3 at the University of Minnesota Forest Resources Remote Sensing Lab. The final image was used as the background for digitizing polygons.

2.3. Positional Accuracy Assessment

Positional accuracy of the image was tested during field visits to Swan Lake in spring of 2004. Twenty points were collected at obvious locations such as road intersections and concrete pads using a Trimble GeoXT with WAAS real-time differential correction achieving better than 3 meter accuracy. Reference points on the image were determined at a scale of 1:1000. The data are provided in Appendix C. Using the National Standard for Spatial Data Accuracy (NSSDA) statistic, the Ikonos satellite image tested to 8 meter horizontal accuracy. Since the image was not orthorectified, no vertical accuracy tests were performed.

2.4. Classification Development

Time constraints and scheduling prevented a site reconnaissance visit to the refuge to determine the quality and types of the vegetation prior to mapping. Instead the initial classification scheme was developed using contributions by the resident biologist in the form of GIS shapefiles that defined habitat boundaries on the refuge. Throughout the mapping process, refuge staff were consulted to resolve questions of boundaries and species composition.

The classification scheme consists of map classes describing vegetation cover at the refuge. Each map class is assigned to one NVCS formation. A map class code is a 3-character code representing an acronym of the map class description. The basic NVCS hierarchical structure is shown in Table 1. Map classes are crosswalked to the NVCS at the Class, Group,

and Formation levels in the spatial database with short descriptions of each level provided as attributes. The two most detailed levels of the NVCS, Alliance and Association, were *not* requested for this project.

Table 1. NVCS physiognomic-floristic levels

Level	Primary Basis For Classification	Example
Class	Growth form and structure of vegetation	Woodland
Subclass	Growth form characteristics, e.g., leaf phenology	Deciduous Woodland
Group	Leaf types, corresponding to climate	Cold-deciduous Woodland
Subgroup	Relative human impact (natural/semi-natural or cultural)	Natural/Semi-natural
Formation	Additional physiognomic and environmental factors, including hydrology	Temporarily Flooded Cold-deciduous Woodland
Alliance	<i>Dominant/diagnostic species of uppermost or dominant stratum</i>	<i>Populus deltoides</i> Temporarily Flooded Woodland Alliance
Association	<i>Additional dominant/diagnostic species from any strata</i>	<i>Populus deltoides</i> – (<i>Salix amygdaloides</i>) / <i>Salix exigua</i> Woodland

An initial site visit to Swan Lake in March 2004 allowed for testing the classification scheme. Some questions arose as to the separation of the forest class into two different formations. Since vegetation was still dormant at that time, and large areas of the refuge were flooded, a return trip in May 2004 provided additional information to achieve the final set of map classes presented here.

2.5. Spatial Database Development

Polygons representing discrete, homogenous areas of vegetation were digitized on-screen at a scale of 1:12,000 using ArcEdit and the August 2000 Ikonos image. In addition to the satellite image, ancillary GIS data layers provided additional information:

- Soil Types
- National Wetland Inventory
- Digital Orthophoto Quads (1 m resolution)
- Color infrared aerial photos (August 2001, 1:15,480)
- Digital Elevation Model for the local watershed (30m)

Areas having less than the minimum mapping unit (0.5 hectares) are regarded as insets into the largest adjacent map area and treated as that map class. Each polygon within the classified area has a unique map class assigned to it. Since the source image for the classification is from August 2000, map classes are assigned to the vegetation cover as of the ground date of the image.

The boundaries given to each polygon were determined by visually examining differences in texture, color, and shape of the objects in the satellite image. Arcs representing the boundary were then digitized using ESRI ArcEdit (ArcInfo 8.3). No arcs were duplicated or intersected. The coverage was verified to ensure that no polygon area was less than the minimum mapping unit of 0.5 hectares, that no sliver polygons were present, and that all polygons had appropriate label points.

Attribute fields were created and assigned using ESRI ArcMap (ArcView 8.3) editing the native coverage. The classified map class was assigned to an attribute field called MAP_CLASS. Based on field data from the accuracy assessment phase, any polygons having a different reference, or ground classification, were updated to show this correct value in the field MAP_ATT. The value in MAP_ATT therefore holds either the reference classification as found on the ground for polygons that were checked during accuracy assessment or it holds the original classification from the MAP_CLASS field. Modifiers which further clarify the map class were placed in separate attribute fields (Figure 2).

All map products were created using ESRI ArcMap (ArcView 8.3) and the original coverage in native format. As a final step, the native ArcInfo coverage was converted to both a shapefile format and a coverage export (E00) format using ESRI ArcToolbox 8.3 functions.

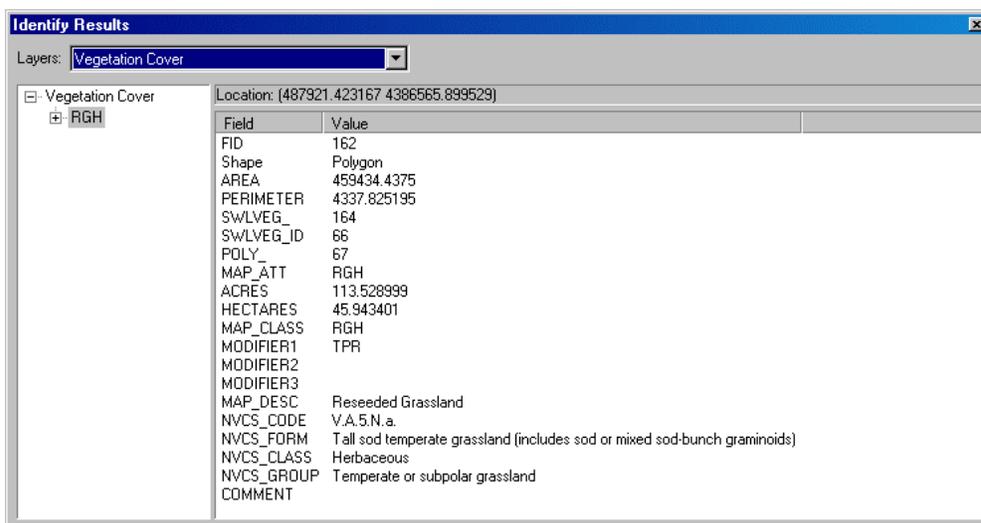


Figure 2. Example of attribute items within vegetation cover shapefile.

2.6. Thematic Accuracy Assessment

The thematic accuracy of the map classes was assessed by ground checking at random locations during two site visits to the refuge. Over 260 points within the boundary of the refuge were verified (Figure 3). The points were selected by defining a single polygon representing the refuge boundary and generating points within that polygon using an ArcView 3.3 extension, Random Points, version 1.1. The resulting point shapefile was used as input to an ArcInfo 8.3 IDENTITY (Point in polygon) function and the appropriate polygon number was assigned to each point. From the polygon number, the map class for that polygon was determined. The ArcInfo 8.3 ADDXY function generated the UTM coordinates for each of the points. Finally, all the information was exported to a spreadsheet format with additional columns added to record comments and the actual map class found at the point. This served as a master roster for points to verify during the assessment.

Maps at a scale of 1:1000 were prepared showing the polygon boundaries overlaid on the false-color satellite image with sample points and their ID numbers displayed. The same

dichotomous key used during the image interpretation phase to arrive at a map class for a polygon was also used to determine the ground reference class for the vegetation within a 40 meter radius of the sample point. Photographs of the vegetation cover at each point were taken and the photo number recorded on the data sheet. Information regarding dominant species, percent canopy and current site water levels was recorded in the comments.

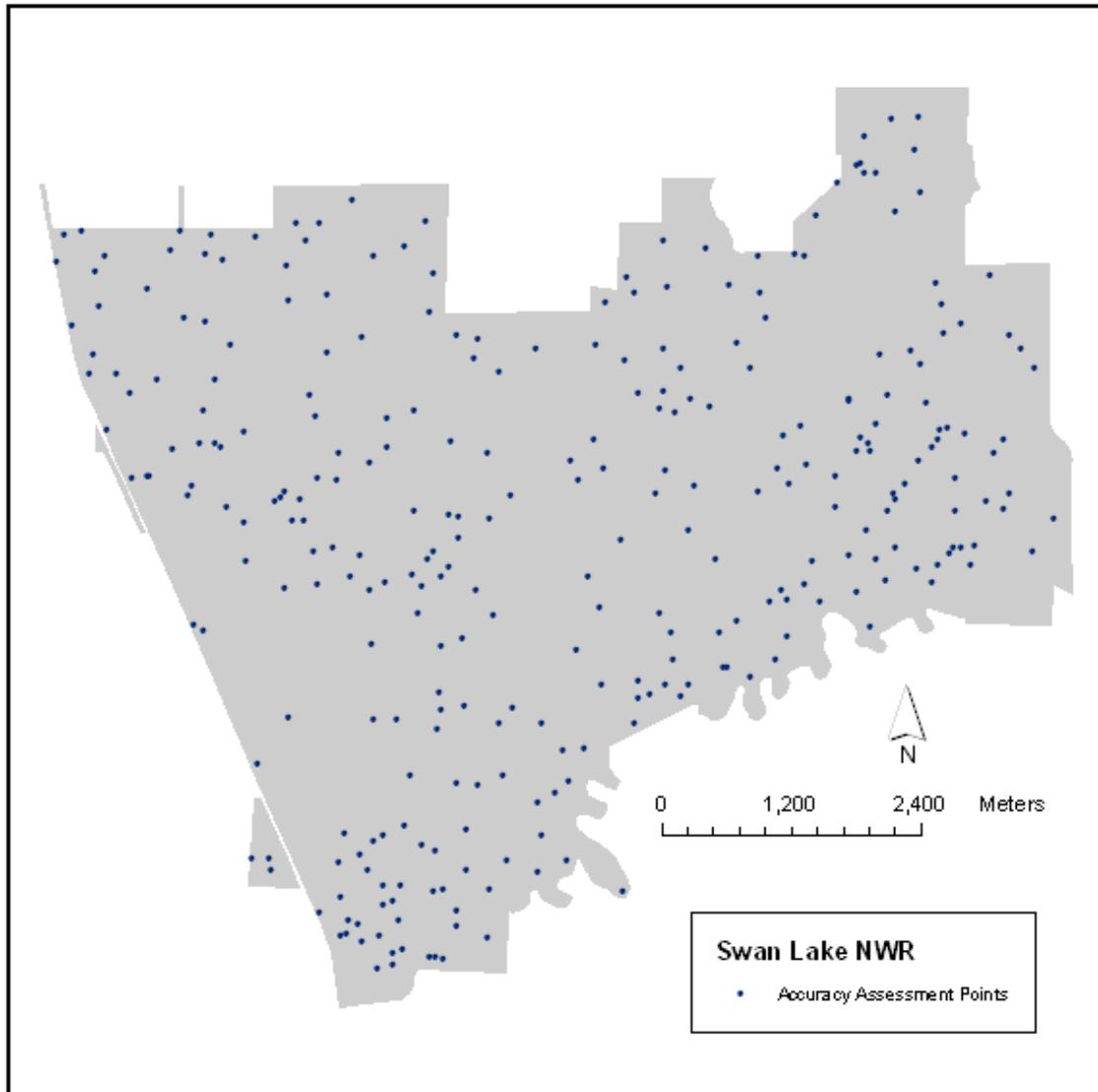


Figure 3. Accuracy assessment points visited at Swan Lake NWR.

The results of the thematic accuracy assessment were analyzed following procedures detailed in NBS/NPS Vegetation Mapping Program Accuracy Assessment Procedures (1994). Accuracy was calculated using an error matrix. The overall accuracy was computed as the ratio of the ground-check points having a correct classification to the total of all points. The overall accuracy of the map was then tested to see if it met or exceeded the 80% accuracy

standard using an hypothesis test. The null hypothesis – that the calculated accuracy is less than the claimed accuracy – was tested using a Student's-t statistic:

$$t = \frac{\hat{p} - p}{\sqrt{\frac{p(1-p)}{n}}}$$

where n is the actual number of assessment points, p is the required accuracy, and \hat{p} is the estimated accuracy. The calculated one-sided t value must exceed a critical value with $n-1$ degrees of freedom to reject the hypothesis and accept the alternative – that the estimated accuracy meets or exceeds the standard.

A 90% confidence interval was computed for the overall accuracy using the equation:

$$\hat{p} \pm \left\{ z_a \sqrt{\frac{\hat{p}(1-\hat{p})}{n}} + \frac{1}{2n} \right\}$$

where n is the actual number of assessment points, \hat{p} is the calculated accuracy and z_a is a constant of 1.645 for a two-sided limit at the 90% confidence interval.

The Kappa coefficient was computed as:

$$\hat{k} = \frac{P_{correct} - P_{chance}}{1 - P_{chance}}$$

where $P_{correct}$ is the proportion of correctly classified entries in the error matrix and P_{chance} is the proportion of points that could be expected to be classified correctly by chance.

$$P_{chance} \text{ was computed as: } P_{chance} = \sum_{i=1}^n P_{row(i)} P_{column(i)}$$

where $P_{row(i)}$ is the proportion of total entries that are in the row of the matrix for that map class, $P_{column(i)}$ is the proportion of all entries that are in the column of the matrix for that map class, and n is the total number of map classes.

Computing the errors of omission and commission in the error matrix determined the accuracy of the individual map classes. Omission errors are ground-check points that belonged to the class in question but are omitted from that class on the map. The producer's accuracy for the map class is computed as 100% minus the rate of omission error. Commission errors are map classifications that are found to be another class when ground-checked. The user's accuracy for the class is computed as 100% minus the rate of commission error.

For individual map classes, the accuracy requirement was considered met using a hypothesis test as well, though a less stringent one. The null hypothesis – that the calculated accuracy is the same as the threshold accuracy of 80% – was determined using a Student's-t statistic. Here, exceeding the threshold value would reject the null hypothesis and accept the alternative – that the calculated accuracy and the required accuracy were different and the required accuracy had not been met.

3. Results

3.1. Map Classes

Map class descriptions are derived using common terms for the vegetation types. For example, the map class Bottomland Hardwood Forest is represented by the map class code BHF, Freshwater Marsh by FWM.

Map classes may also have modifiers to indicate areas within the refuge that have a special designation. Each polygon within the coverage can have up to three additional modifiers. The modifiers are specific to an individual map class and indicate a subset of the map class.

- REF (Regenerating Forest) identifies areas of colonizing trees and shrubs invading grasslands within map class STH (Scattered Tree Grassland).
- TPR (Tallgrass Prairie) identifies areas reseeded with a prairie seed mix and is used within map class RGH (Reseeded Grassland Herbaceous).
- WDL (Woodlots) describes smaller areas of remnant forest within map class BHF (Bottomland Hardwood Forest).

Appendix B has a dichotomous key to derive the map classes. This key was developed to aid both in the image interpretation and in the accuracy assessment phases of the project. It uses specific criteria such as canopy density and species composition to arrive at the appropriate class.

The crosswalk from the map class to the NVCS formation uses the naming conventions defined in *Plant Communities of the Midwest* (Faber-Langendoen, 2001). Formation and alliance names follow standard conventions as defined by NatureServe using the Federal Geographic Data Committee standard (FGDC, 1997).

Crosswalk Legend

Map Class Code – Map Class Description

NVCS Class

NVCS Group

NVCS Formation

NVCS Class: FOREST

BHF -- Bottomland Hardwood Forest

Forest

Cold-Deciduous Forest

I.B.2.N.d. Temporarily flooded cold deciduous forest

This class consists of bottomland closed-canopy hardwood forest generally occurring on wet soil and in floodplains. It is dominated by pin oak, silver maple, swamp white oak, and shagbark hickory with green ash, elm, black willow, river birch, and honeylocust. The understory varies from open areas dominated with *Carex* spp. and woodland forbs to denser areas with a shrub layer composed of *Ribes missouriense*, *Symphoricarpos occidentalis*, and *Zanthoxylum americanum*. These areas are subject to seasonal flooding.

Modifier **WDL (Woodlot)** is used to indicate small patchy areas of less than 20 acres that are fragmented habitat and form fencerows or riparian strips.

NVCS Class: WOODLAND

STH – Scattered Tree Grassland

Woodland

Cold-deciduous woodland

II.B.2.N.b. Temporarily flooded cold-deciduous woodland

These are grassland areas where the tree canopy varies from 20% to 60% and is comprised mostly of early successional bottomland hardwood species. It is subject to occasional flooding.

Modifier **REF (Regenerating Forest)** is used to indicate areas where active management has been discontinued and that are now being colonized by bottomland tree species.

NVCS Class: SHRUB

SSW – Shrub Swamp

Shrubland

Cold-Deciduous Shrubland

III.B.2.N.f. Semipermanently flooded cold-deciduous shrubland

These are wetland communities dominated by deciduous woody vegetation less than 20 feet in height. Dominant species are mostly buttonbush *Cephalanthus occidentalis* and willow

Salix spp. with an underlying mix of sedges and grasses and/or emergent vegetation depending on water depth. The shrub layer varies from mostly open (25%) to closed (80%) and may contain scattered trees.

NVCS Class: HERBACEOUS

AFH – Agricultural Fields

Herbaceous

Temperate or Subpolar Annual Grasslands or Forb

V.D.2.C.b Cultivated medium tall temperate or subpolar annual grassland (dominated by graminoids and/or forbs)

These are cultivated areas that are managed by and/or for humans and consist of a variety of grass and forb row crops such as wheat, corn or annual/perennial mixtures mowed for hay. These areas are subject to occasional flooding.

FWM – Freshwater Marsh

Herbaceous

Temperate or subpolar grassland

V.A.5.N.k. Seasonally flooded temperate or subpolar grassland

These are wetland plant communities flooded through most of the growing season though often drying in late summer. This class often occurs in creek channels and floodplains. Herbaceous emergent vegetation such as cattails, bulrushes, arrowheads, and sedges are present. This class also includes areas of wet meadow dominated by *Carex* spp.

MGH – Mesic Grassland

Herbaceous

Temperate or subpolar grassland

V.A.5.N.j. Temporarily flooded temperate or subpolar grassland

These are grassy fields dominated by reed canary grass, *Carex* spp. and native grasses with a small number of scattered shrubs and small trees. These areas were either rarely or never cultivated in the past. They are subject to flooding and surface water is often present during much of the year.

MSU – Moist Soil Unit

Herbaceous

Temperate or subpolar grassland

V.A.5.C.k. Cultivated seasonally flooded temperate or subpolar grassland

These are altered areas intentionally managed by flooding during the year and cultivated as needed to destroy the shrub layer and maximize plant growth. They are often seeded with

Polygonum species and/or millet. Water depths are typically shallow and the ground remains saturated year-round though late season drying can occur.

OLD – Oldfield

Herbaceous

Temperate or subpolar grassland

V.A.5.N.d. Medium-tall bunch temperate or subpolar grassland

These areas contain disturbed soils and are dominated by reed canary, smooth brome, quack grass and weedy herbaceous species. These areas are drier than those of mesic grassland and were once regularly cultivated for crops but now are left fallow. These areas are subject to occasional flooding.

RGH – Reseeded Grassland Herbaceous

Herbaceous

Temperate or subpolar grassland

V.A.5.N.a. Cultivated tall sod temperate grassland (includes sod or mixed sod-bunch graminoids)

Cultivated and restored native grassland due to seeding and subject to occasional flooding.

Modifier **TPR (Tallgrass Prairie)** is used for areas planted in a tall grass prairie seed mixture of big bluestem, Indian grass, cord grass, and/or fescues.

NVCS Class: None

DEV – Developed

These are areas developed for human use with more than 50% impervious surface.

OPW – Open Water

These areas of water have less than 4% visible vegetation, either floating or submerged.

3.2. Thematic Accuracy Assessment

The first site visit to the refuge occurred March 15, 2004 through March 21, 2004 during a period of high water levels. The trees had yet to leaf-out. Over 140 random sites distributed within the refuge boundaries were located using a Trimble GeoXT with an additional 41 points occurring on open water in Silver Lake. Since three and a half years had elapsed since the August 2000 satellite image was taken, several areas of the refuge had undergone radical change due to both extreme weather conditions (an extended drought followed by heavy rains) and management practices which included the cultivation of the marsh area for which the refuge is named: Swan Lake. Many of the errors (18 of 41) from the first accuracy assessment were due to these temporal differences. To correct for this in the assessment, 16 points that fell within Swan Lake (again, the lake, itself, not the entire refuge) were discarded since this area had its hydrology and species composition drastically changed. After discarding these points, the overall accuracy of the remaining sites visited during the first trip was 86.75% (Kappa 84.7%).

At the time of the first assessment there were two forest map classes defined: BHF (Bottomland Hardwood Forest) and MHF (Mesic Hardwood Forest), though only subtle distinctions based on elevation differences existed between them. After reviewing the assessment with the Region 3 GIS Coordinator, it was felt that several map classes including the forest classes were underrepresented in the point count. Further, the producer's accuracy for the forest classes was much too low due to ambiguities in the classification scheme.

To address the problems uncovered in the first field visit, a second visit took place May 15, 2004 through May 21, 2004 after leaf-out on the trees. During this visit, another random set of 200 points was generated; this point set was stratified primarily in the forest, marsh, and mesic grassland classes. From this set of possible points, more than 100 sites were actually visited. This time, though water levels were still high due to heavy rain, the characteristics of the tree and herbaceous layers were obvious. It was found that none of the areas designated initially as MHF could actually be considered such and were instead classified as BHF. Though these areas had a slightly dryer hydrology than other parts of the refuge, the species composition was essentially the same. Furthermore, no expected mesic hardwood tree species, such as red maples, sugar maples or white oaks could be found in these areas. Based on this, it was determined that there was only one forest NVCS formation in the refuge and only one map class was needed. The points originally assigned to the mesic forest class (MHF) but flagged in error because they were actually bottomland hardwood (BHF) were reassigned as correct BHF class points. The final assessment using the accuracy results from 268 points was then generated.

Results of the final accuracy assessment with an error matrix by map class are provided in Appendix D. In summary:

- Overall classification accuracy: 92.2%
- 90% Confidence Interval: 89.2% to 95.2%
- Overall Kappa statistic: 90.8%

Per-class producer and user accuracy is reported in Table 2. If the per-class accuracy fails to meet the 80% standard, a two-tailed Student's-t statistic tests whether the calculated accuracy is the same as the threshold accuracy of 80%. Here, the critical value must be exceeded in order to reject this. As shown in the table, all map classes met the minimum 80% accuracy standard.

Table 2. Per-class accuracy summary

Classification	Producer Accuracy	2T-stat*	Critical Value	User Accuracy	2T-stat*	Critical Value
Agricultural Fields	100%			84%		
Bottomland Hardwood	100%			100%		
Developed	100%			100%		
Freshwater Marsh	64%	1.47	1.77	82%		
Mesic Grassland	80%			80%		
Moist Soils	74%	0.77	1.71	100%		
Oldfield	88%			70%	0.79	1.83
Open Water	100%			100%		
Reseeded grassland	95%			90%		
Shrub Swamp	100%			67%	1.15	1.80
Sparse Tree Grassland	90%			95%		

* Two-tailed Student's-t statistic

3.3. Map Class Areas

The final vegetation map (Figure 4) is comprised of 162 polygons covering 11,020 acres within the boundaries of the refuge. An additional area of 0.5 kilometers surrounding the refuge was also included in the vegetation cover mapping. This area comprises an additional 70 polygons covering 4,942 acres for an overall total of over 15,962 acres mapped.

Complete area statistics for the vegetation map classes within the refuge are reported in Table 3. Herbaceous areas are the majority of the refuge landscape with 45% total coverage or over 4,929 acres (2,015 hectares). The herbaceous layer is a mix of managed areas including agricultural fields and moist soil units, semi-natural areas and natural grassland areas, some of which were reseeded to a prairie grass mix. The former marsh area called Swan Lake is now classified as a moist soil unit as a result of the cultivation and channel dredging that occurred during the summer of 2003.

Bottomland forest, concentrated in the Yellow Creek Natural Area and Elk Creek, make up another 28.5% or 3,138 ac. (1,270 ha.). Much of Yellow Creek forest is in a single contiguous area stretching along the southern boundary of the refuge. Additional areas (~3%) of remnant forest left as fencerows and riparian strips along channels and small creeks are given the special modifier of 'woodlot'.

Approximately 20% of the refuge is open water during a normal year with about 2,100 ac. (860 ha.) being Silver Lake. Shrubland in the form of buttonbush swamp covers another 3.7% of the area or 411 ac. (166 ha.). The shrubland intergrades between freshwater marshes in the deeper, muckier water to the drier woodland area that buffers the forest. Shrubland is

generally in shallow water. The woodland areas, with 20 – 60% tree coverage, are spread over 10 polygons but total just 296 ac. or 2.7%. Developed land takes up the least area with just less than one-half percent.

Table 3. Area statistics for the Swan Lake National Wildlife Refuge

Class Description	Class	Polygons	Acres	%	Formation	Description
Forest		40	3138	28.5%		
Bottomland Forest	BHF	40	3138	28.5%	I.B.2.N.d.	Temporarily flooded cold-deciduous forest
Woodland		10	296	2.7%		
Scattered Tree Grassland	STH	10	296	2.7%	II.B.2.N.b.	Temporarily flooded cold-deciduous woodland
Shrubland		8	411	3.7%		
Shrub Swamp	SSW	8	411	3.7%	III.B.2.N.f.	Semipermanently flooded cold-deciduous shrubland
Herbaceous		95	5979	45.2%		
Agricultural Fields	AFH	26	1361	12.3%	V.D.2.C.b.	Cultivated medium tall temperate or subpolar annual grassland
Freshwater Marsh	FWM	9	366	3.3%	V.A.5.N.k.	Seasonally flooded temperate or subpolar grassland
Mesic Grassland	MGH	20	508	4.6%	V.A.5.N.j.	Temporarily flooded temperate or subpolar grassland
Moist Soils	MSU	14	2166	19.7%	V.A.5.C.k.	Cultivated seasonally flooded temperate or subpolar grassland
Oldfield	OLD	10	238	2.2%	V.A.5.N.d.	Medium-tall bunch temperate or subpolar grassland
Reseeded Grassland	RGH	16	340	3.1%	V.A.5.N.a.	Tall sod temperate grassland
Other		9	2197	19.9%		
Open Water	OPW	4	2142	19.4%	None	
Developed Areas	DEV	5	55	0.5%	None	
Refuge Totals		162	11020	100%		

Swan Lake National Wildlife Refuge

Chariton County, Missouri

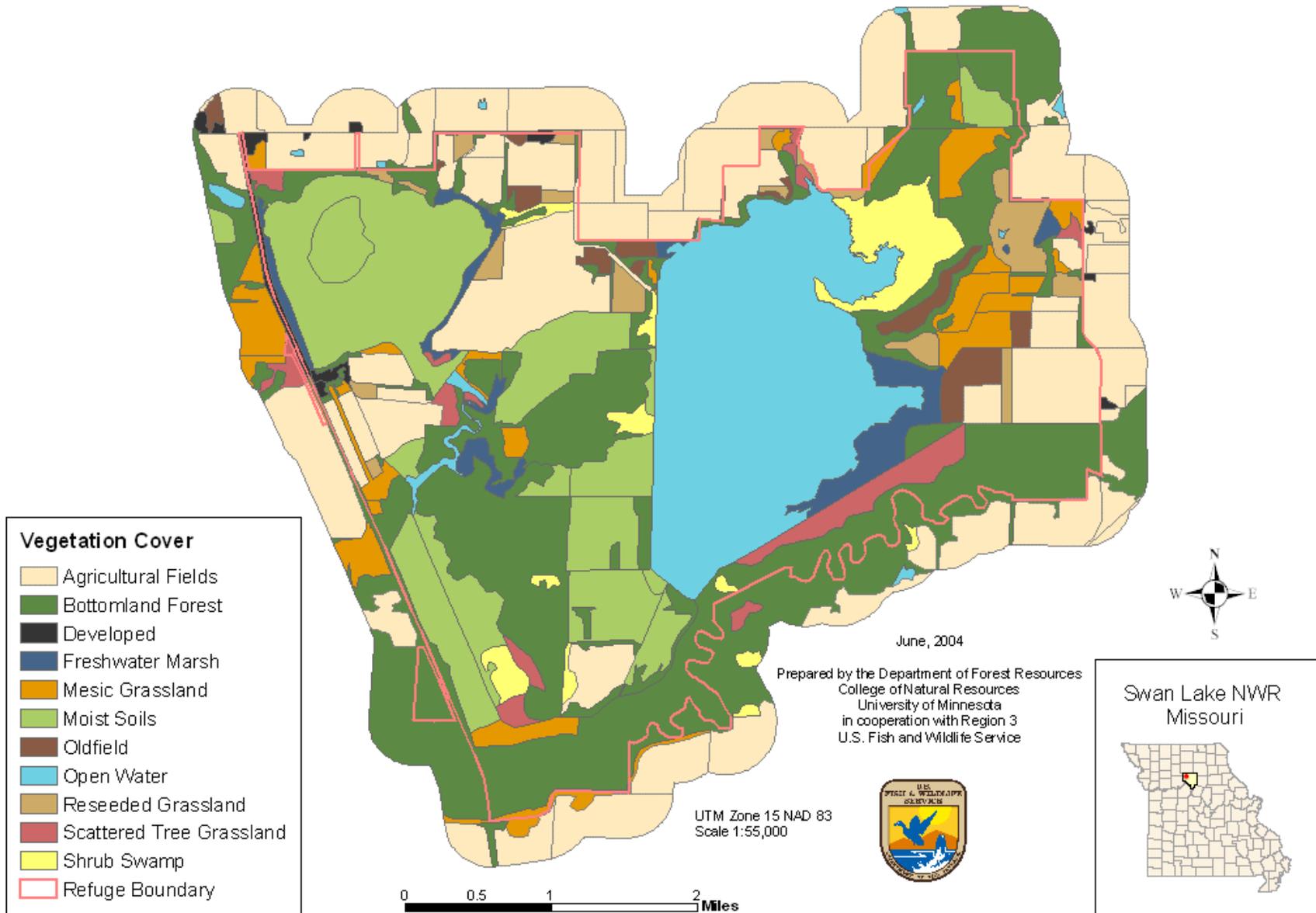


Figure 4. Swan Lake National Wildlife Refuge vegetation cover map.

4. References

Congalton, Russell G., Kass Green. 1999. *Assessing the Accuracy of Remotely Sensed Data: Principles and Practices*. Boca Raton : Lewis Publications.

Environmental Systems Research Institute. 1994. *Accuracy Assessment Procedures. NBS/NPS Vegetation Mapping Program. Final Draft*. Prepared for the U. S. Department of Interior National Biological Survey and National Park Service.

Faber-Langendoen, D., editor. 2001. *Plant Communities of the Midwest: Classification in an Ecological Context*. Association for Biodiversity Information, Arlington, VA. 61 pp. + appendix (705 pp.).

Federal Geographic Data Committee. 1997. *Geospatial Positioning Accuracy Standards. Part 3: National Standard for Spatial Data Accuracy*, FGDC-STD-007.3-1998: Washington, D.C., Federal Geographic Data Committee.

Federal Geographic Data Committee. 1998. *Vegetation classification standard*, FGDC-STD-005: Washington, D.C., Federal Geographic Data Committee.

Grossman, D. H., D. Faber-Langendoen, A. S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. D. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. *International Classification of Ecological Communities: Terrestrial Vegetation of the United States. Volume I. The National Vegetation Classification System: development, status, and applications*. The Nature Conservancy, Arlington, Virginia, USA.

Kirk, Ryan W., Thomas E. Burk, Paul V. Bolstad, and John H. Schomaker. 1999. *Construction of a Geographic Information System for Wildlife Refuge Planning: Swan Lake National Wildlife Refuge. Staff Paper Series No. 137*. Department of Forest Resources, College of Natural Resources, University of Minnesota. St. Paul, Minnesota, USA.

NatureServe. 2003. *NatureServe Explorer: An online encyclopedia of life* [web application]. Version 1.8. NatureServe, Arlington, Virginia. Retrieved January 22, 2004 from <http://www.natureserve.org/explorer>.

U.S. Fish and Wildlife Service – Swan Lake National Wildlife Refuge. 2003. *Fact sheet*. As retrieved on 10 December, 2003 from <http://midwest.fws.gov/SwanLake/factsheet.html>.

Appendix A – Data CD Contents

assessment – data related to the accuracy assessment phase of the project

[photos]: all digital photos for the project in JPG format
swl_photo_index.xls: a spreadsheet cross-referencing photos to data points
AssessmentPoints.eps: Map of data points visited in Postscript format
AssessmentPoints.tif: Map of data points visited in TIF format
swl_AccPos.xls: A spreadsheet of positional accuracy analysis data
swl_AccThm.xls: A spreadsheet of thematic assessment data, i.e. the error matrix
swl_field_points: Shapefile point database of site visit points at Swan Lake with attributes
swl_field_points_metadata: Text and XML versions of metadata

document – reports and documents describing the project

[class_examples]: Digital photos demonstrating each map classification
swl_classification.xls: a spreadsheet showing classification linked to photos examples
swl_vegreport: Word document and PDF of the final project report

graphics – illustrations used in the report, CD, or map products

case layout.ai: Adobe Illustrator artwork for the CD jewel-case back and side
cd layout.ai: Adobe Illustrator artwork for the CD itself
cover layout.ai: Adobe Illustrator artwork for the CD jewel-case front
fwslogoc.tif: Wildlife Service Logo in TIF format

maps – finished map products

SwanLakeArea.tif: Refuge Area map
SwanLake1.tif: 96 dpi Vegetation Cover Map in portrait orientation.
SwanLake1.eps: 300 dpi Postscript Vegetation Cover Map, portrait.
SwanLake2.tif: 96 dpi Vegetation Cover Map, landscape, labeled with class.
SwanLake2.eps: 300 dpi Postscript Vegetation Cover Map, landscape, labeled with class.
SwanLake3.tif: 96 dpi Vegetation Cover Map cropped to refuge boundary, portrait.
SwanLake3.eps: 300 dpi Postscript Vegetation Cover Map cropped to refuge boundary.

veg2004 – the vegetation cover spatial database

[habitat_shapefiles]: a set of refuge provided shapefiles used to make initial map classification
swlveg.shp: the vegetation cover database in shapefile format
swlveg.e00: the vegetation cover database in ArcInfo Export format
swlveg.lyr: an ArcGIS 8.3 layer file defining a display symbology for swlveg.shp
swl_class.dbf: Dbase4 format table with map classes, NVCS codes and descriptions
swlveg_metadata.txt: Text format of metadata
swlveg_metadata.xml: XML format of metadata

Appendix B – Dichotomous Key to Map Classes

Instructions: If you answer YES for the question, follow the directions for YES. Otherwise, follow the directions for NO. This key is useful only for the specific purpose of assigning map classes to vegetation cover types found within the boundaries of the Swan Lake NWR.

1. Is vegetation cover > 1% overall?
YES, go to 2.
NO, not classed
2. Does open water (including non-rooted vegetation) cover > 96% of the area?
YES, map class **OPW – Open Water**.
NO, go to 3.
3. Is the area comprised of more than 50% impervious surface?
YES, map class **DEV – Developed**.
NO, go to 4.
4. Was the area actively managed on an annual basis and planted with vegetation by or for humans?
YES, go to 8 → Altered.
NO, go to 5.
5. Is the cover of herbaceous vegetation greater than the cover of trees, shrubs (More than 25% herbaceous)?
YES, go to 10 → Herbaceous.
NO, go to 6.
6. Is the cover of trees greater than the cover of shrubs, herbs (More than 25% trees)?
YES, go to 7.
NO, map class **SSW – Shrub Swamp**.
7. Do tree crowns overlap, generally forming 60% - 100% cover?
YES, go to 16 → Forest.
NO, go to 17 → Woodland.
8. Altered – Is the area actively managed on an annual basis through cultivation and planting of row crops?
YES, map class **AFH – Agricultural Fields**.
NO, go to 9.
9. Altered – Is the water level and land surface of the area actively managed (completely flooded at least once a year then allowed to dry)?
YES, map class **MSU – Moist Soil Unit**.
NO, not classed.

10. Herbaceous – Is the tree cover > 20%?
YES, go to 17 → Woodland.
NO, go to 11.
11. Herbaceous – Is the area flooded or submerged (visible standing water) most of the year most years?
YES, go to 12.
NO, go to 13.
12. Herbaceous – Is the area dominated by rooted floating and/or submerged vegetation?
YES, not classed.
NO, map class **FWM – Freshwater Marsh**
13. Herbaceous – Was the area plowed and permanently reseeded at one time?
YES, go to 15.
NO, go to 14.
14. Herbaceous – Is the area disturbed fallow crop land dominated by oldfield grasses such as smooth brome and quack grass?
YES, map class **OLD – Oldfield**.
NO, map class **MGH – Mesic Grassland**.
15. Herbaceous – Was the area reseeded to a perennial prairie with Indian Grass, Big Bluestem and fescues?
YES, map class **RGH – Reseeded Grassland – Modifier TPR – Tallgrass Prairie**.
NO, map class **RGH – Reseeded Grassland**.
16. Forest – Is the forested area smaller than 20 contiguous acres, for example, fencerows?
YES, map class **BHF – Bottomland Hardwood Forest – Modifier WDL – Woodlot**
NO, map class **BHF – Bottomland Hardwood Forest**
17. Woodland – Is the area generally herbaceous and being colonized with a tree/shrub layer with canopy between 25% and 60%?
YES, map class **STH – Scattered Tree Grassland – Modifier REF – Regenerating Forest**.
NO, map class **STH – Scattered Tree Grassland**.

Appendix C – Positional Accuracy Assessment

Point	GPS X	Image X	Diff X	(Diff X) ²	GPS Y	Image Y	Diff Y	(Diff Y) ²	(Diff X) ² + (Diff Y) ²			
1	480064.06	480065.56	-1.50	2.25	4387037.00	4387037.50	-0.50	0.25	2.5			
2	479460.06	479466.43	-6.37	40.5769	4387039.50	4387038.00	1.50	2.25	42.8269			
4	482630.56	482636.37	-5.81	33.7561	4387538.00	4387535.50	2.50	6.25	40.0061			
6	483027.21	483031.03	-3.82	14.5924	4386784.50	4386784.00	0.50	0.25	14.8424			
7	483052.00	483057.09	-5.09	25.9081	4386364.50	4386362.00	2.50	6.25	32.1581			
8	484310.28	484308.53	1.75	3.0625	4386373.00	4386374.00	-1.00	1	4.0625			
9	483953.81	483958.09	-4.28	18.3184	4385985.50	4385986.00	-0.50	0.25	18.5684			
10	483919.18	483923.37	-4.19	17.5561	4385186.50	4385185.00	1.50	2.25	19.8061			
11	483879.50	483883.62	-4.12	16.9744	4383556.50	4383555.00	1.50	2.25	19.2244			
12	483862.25	483865.60	-3.35	11.2225	4382747.00	4382747.88	-0.88	0.7744	11.9969			
13	484346.21	484351.31	-5.10	26.01	4382371.50	4382373.00	-1.50	2.25	28.26			
14	484873.03	484875.46	-2.43	5.9049	4382895.00	4382898.00	-3.00	9	14.9049			
15	487369.18	487372.75	-3.57	12.7449	4384346.00	4384343.00	3.00	9	21.7449			
16	488842.96	488847.50	-4.54	20.6116	4384352.50	4384352.50	0.00	0	20.6116			
17	488616.31	488621.59	-5.28	27.8784	4386512.00	4386511.00	1.00	1	28.8784			
18	488618.59	488624.00	-5.41	29.2681	4387617.50	4387614.00	3.50	12.25	41.5181			
19	486240.46	486245.09	-4.63	21.4369	4386940.00	4386940.50	-0.50	0.25	21.6869			
20	482238.43	482240.93	-2.50	6.25	4385969.50	4385967.50	2.00	4	10.25			
21	481645.28	481650.46	-5.18	26.8324	4384855.00	4384855.00	0.00	0	26.8324			
22	481218.59	481221.71	-3.12	9.7344	4383401.50	4383404.00	-2.50	6.25	15.9844			
				370.889				65.7744	436.6634	Sum		
				18.5444				3.2887	21.8332	Avg		
				4.3063				1.8135	4.6726	RMSE		
									8.0873	NSSDA		
									10.0274	CMAS		

Actual points: Ground control points collected on March 15-16, 2004 at Swan Lake Refuge using a Trimble GeoXT with WAAS differential correction (under 3 meter accuracy).

Reference points: Determined by positioning points at a scale of 1:1000 and capturing UTM coordinates.
 Ikonos image captured 7 August, 2000. Image is a combination of 4 spectral bands at 4 meters pan-sharpened to 1 meter resolution. Image rectified by Space Imaging as 15-meter CE90 not including effects of terrain and resampled for UTM 15 NAD 83.

NSSDA computed at the 95% confidence level assuming RMSE(X) = RMSE(Y) using 1.7308 * RMSE.
 FGDC-STD-007.3-1998

Appendix D – Thematic Accuracy Assessment

Classification	Reference											User			
	AGH	BHF	DEV	FWM	MGH	MSU	OLD	OPW	RGH	SSW	STH	TOTAL	Accuracy	2T-stat	Critical
Agricultural Fields	21				1	3						25	84%		
Bottomland Hardwood		78										78	100%		
Developed			6									6	100%		
Freshwater Marsh				9		2						11	82%		
Mesic Grassland				2	20	1					2	25	80%		
Moist Soils						20						20	100%		
Oldfield					2		7		1			10	70%	0.79	1.83
Open Water								41				41	100%		
Reseeded grassland					1		1		18			20	90%		
Shrub Swamp				3		1				8		12	67%	1.15	1.80
Sparse Tree Grassland					1						19	20	95%		
Producer TOTAL	21	78	6	14	25	27	8	41	19	8	21	268			
Accuracy	100%	100%	100%	64%	80%	74%	88%	100%	95%	100%	90%				
2T-stat				1.47		0.77									
Critical				1.77		1.71									
Overall Classification Accuracy:			92.2%												
90% Confidence Interval:			89.2%	95.2%											
1T-Stat:			4.98												
Critical:			1.28												
Overall Kappa Coefficient:			90.8%												
<p>The sum of the off-diagonal cells in each row of the error matrix indicates the commission error for that particular class. Commission error means that map polygons were committed to the class in question, but in the field turned out to belong to a different class. The User Accuracy is computed as 100% - the commission error.</p> <p>The sum of the off-diagonal cells in each column indicates the omission error for that particular class. Omission error pertains to areas that actually (i.e., in the field) belonged to the class in question, but were omitted from that class on the map. The Producer Accuracy is computed as 100% - the omission error.</p>															

Appendix E – Attribute Table Formats

Attribute Table for the Vegetation Cover database – swlveg

Field	Type	Width	Decimal	Description
Shape	POLYGON	8	0	ESRI shapefile type
Area	Float	19	11	Area of polygon in meters squared
Perimeter	Float	19	11	Perimeter of polygon in meters
Swlveg_	Number	9	0	Internal feature number
Swlveg_id	Number	9	0	Internal ID number
Poly_	Number	9	0	Primary polygon ID
MAP_ATT	String	16	0	Polygon's map class currently 2004
Acres	Number	13	11	Computed as AREA / 4046.85
Hectares	Number	13	11	Computed as AREA / 10000
Map_class	String	16	0	Polygon's map class as of image date 2000
Modifier1	String	16	0	Refuge defined modifier to further define class
Modifier2	String	16	0	Not used
Modifier3	String	16	0	Not used
Map_desc	String	128	0	Short description of MAP_ATT
Nvcs_code	String	50	0	NVCS formation code – June 1997 FGDC-STD-005
Nvcs_form	String	254	0	NVCS formation description
Nvcs_class	String	254	0	NVCS class designator
Nvcs_group	String	254	0	NVCS group designator
Comment	String	254	0	Notes

Attribute Table for the Field Point database – swl_field_points

Field	Type	Width	Decimal	Description
Shape	POINT	6	0	ESRI shapefile type
ID	Number	9	0	Unique number per point
OID_	Number	9	0	Internal point identifier
Point	String	13	0	Text ID value for point, i.e. equals ID value
UTM_east	String	16	0	Point's UTM Easting value Zone 15 NAD83
UTM_north	String	17	0	Point's UTM Northing value Zone 15 NAD83
Current	String	13	0	Polygon's map class currently in 2004
Reference	String	17	0	Point map class as ground-truthed
Class	String	17	0	Polygon's map class as classified from image
Comments	String	60	0	Field notes, i.e. species mix, canopy
Photo_	String	22	0	ID number of photo taken at point
Polygon	String	13	0	POLY_ value in swlveg shapefile
Fielddate	String	19	0	Date of field visit to point