Wetland Mapping and Protection for Tompkins County

PILOT PROJECT: Wetland Mapping for the Town of Dryden, New York

November 17, 2014

Nicholas Hollingshead
Independent Environmental GIS Consultant
152 Crescent Place
Ithaca, NY 14850

Funding and support provide by:
The Cayuga Lake Watershed Network
Tompkins County Soil and Water District

Contents

INTRODUCTION

The Tompkins County Water Quality Strategy focuses on the preservation and improvement of waters within the County. As transitional zones between the land and water, wetlands are critical for maintaining water quality, providing habitat for flora and fauna, and storing stormwater by moderating the impact of heavy rain events.

In 2008, a study titled *Wetland Protections in Tompkins County: Existing Status, Gaps, and Future Needs* found that up to 19% of the wetlands in Tompkins County have no protection under existing state and federal regulations. This study was funded by a Wetland Program Development Grant from the EPA, administered by the Tompkins County Soil and Water Conservation District, and overseen by the Tompkins County Water Resources Council (WRC) Wetlands Committee. In response to the findings of this study, the WRC Wetlands Committee has drafted a sample wetlands protection local law, which was approved by the WRC in 2012 and, has been presented to municipalities for adoption.

A complete and current wetland map is an important tool for municipalities seeking to protect wetlands with specific laws or through the review of site plans, such as stormwater plans. The New York State Department of Environmental Conservation (NYSDEC) and the U.S. Fish and Wildlife Service (USFWS) maintain their own wetland maps and associated geospatial datasets. However, these maps can be outdated, incomplete, and inaccurate.

The NYSDEC Freshwater Wetlands Maps, created to comply with the Freshwater Wetlands Act, show the approximate boundaries for only state jurisdictional wetlands. State jurisdictional wetlands include all wetlands greater than 12.4 acres in extent, and smaller wetlands only if they are determined to be of considerable local value. Therefore, the Freshwater Wetland Maps do not include most wetlands below 12.4 acres in size. Furthermore, according to a study on wetland trends in New York State completed for the NYSDEC, "the state regulatory maps are outdated and it is believed that many wetlands >12.4 acres are not depicted on the regulatory maps and therefore not subject to regulatory jurisdiction" (Huffman and Associates Inc., 2000).

The USFWS National Wetland Inventory (NWI) was created to map all wetlands, regardless of size or type, and has been a valuable tool for wetland conservation. However, numerous studies have shown that these maps tend to greatly underestimate the extent and number of wetlands (Morrissey & Sweeney, 2006; Nichols, 1994; Stolt & Baker, 1995; Werner, 2004). For example, a field study in Oswego and Onondaga Counties found that NWI maps underestimated wetland area by 61% and had significant spatial inaccuracies (McMullen & Meacham, 1996).

A longstanding action item of the Tompkins County Water Resources Council Work Plan has been to **"identify and map all wetlands that are not currently regulated by DEC or the federal government and are therefore vulnerable to disturbance and destruction from development."** The pilot project described in this report is the first step towards a new wetland map for Tompkins County. Using the latest geospatial mapping technologies and remote-sensing data resources, including recent high-resolution aerial imagery and LiDAR elevation data, wetlands were mapped for the Town of Dryden. The objectives of this study were to 1) develop an accurate and current map of all wetlands in the Town of Dryden; 2) assess the accuracy and viability of the mapping method prior to broader application to the entire county; and 3) assess the need for a revised Tompkins County wetland map by comparing the results of the pilot project to existing wetland data resources. The project was supported by the Cayuga Lake Watershed Network with funding from the Tompkins County Soil and Water Conservation District (TCSWCD) via the Finger Lakes – Lake Ontario Watershed Protection Alliance (FL-LOWPA), and in-kind match from several sources.

PROCESS

Wetlands in the Town of Dryden were mapped by visual interpretation of high-resolution aerial imagery available at no cost from the New York State Digital Orthoimagery Program (NYSDOP) and topographic analysis of high resolution LiDAR elevation data collected in 2008 by Pictometry (Rochester, NY) with funding from the Tompkins County Soil and Water Conservation District. All wetlands in the study area were delineated, with no minimum wetland size set, and described using the USFWS Cowardin classification for Wetlands and Deepwater Habitats (Cowardin, Carter, Golet, & LaRoe, 1979). Geospatial data processing and analysis were completed using Manifold 8.0 GIS System (Manifold Software Limited Wanchai, Hong Kong) and ArcGIS 10.1 (ESRI, Redlands, CA) as noted. The resulting geospatial dataset depicting wetlands in the Town of Dryden will be referred to as the Dryden 2012 Wetlands Map, in reference to the most recent NYSDOP aerial imagery which served as a primary data resource.

Study area

The town of Dryden is 94 square miles, which is approximately 20% of Tompkins County (476 square miles). The Town of Dryden was chosen for the pilot study for the diversity of landscape conditions, land use activities, and wetland types that are present. In addition, data from a 2007 wetland field survey, which included portions of Dryden and Lansing, could provide the basis for an accuracy assessment (Schipanski, 2008). In the development of most geospatial data resources, particularly ones as complex as wetland data, a field-based accuracy assessment is important.

Figure 1. Tompkins County with the boundary of Dryden outlined in red.

Primary data resources

NYSDOP high resolution aerial imagery

High-resolution aerial imagery is available for the entire state of New York through the New York Statewide Digital Orthoimagery Program (NYSDOP). Imagery from 2002 through 2013 can be downloaded as image tile sets directly from the State's website (http://:gis.ny.gov). Imagery is available for Tompkins County for 2002, 2007, and 2012.

Year	Type	File format	Pixel resolution	Horizontal accuracy (95% conf. level)
2002	Color-Infrared	Compressed MrSID	0.5-ft City of Ithaca 1-ft Tompkins County	+/- 4.0 ft +/- 8.0 ft
2007	Natural color	Compressed JPEG2000	0.5-ft City of Ithaca 1-ft Tompkins County	+/- 2.0 ft +/- 8.0 ft
2012	4-band (natural color and near-infrared)	Compressed GeoTIFF	0.5-ft City of Ithaca 2-ft Tompkins County	+/- 4.0 ft +/- 8.0 ft

Table 1. High resolution aerial imagery available from NYSDOP for Tompkins County.

For most of the Town of Dryden, the coarser 1-ft and 2-ft pixel resolution datasets are available. The higher resolution imagery is only available for the southwest portion of the Town of Dryden which borders the City of Ithaca. All image tiles that covered the Town of Dryden were uncompressed and mosaicked to create a single contiguous image for each year, which was subsequently converted to Enhanced Compression Wavelet (ECW) format to improve image rendering speed.

Tompkins County LiDAR elevation data

In May 2008, LiDAR data were developed by Pictometry International Corp. (Rochester, NY) for Tompkins County for the purpose of supporting FEMA's Floodplain Map Modernization Program. Data were collected by Mapping Specialists, Inc. at a nominal post spacing of 1.4 meters. The LiDAR elevation point data were classified using TerraScan software (TerraSolid Limited, Helsinki, Finland) by an automatic classification algorithm. The data have expected horizontal and vertical positional accuracy in compliance with the National Standard for Spatial Data Accuracy (NSSDA) RMSE estimation of elevation data in support of 2 ft. contour mapping products.

The LiDAR elevation data were provided for the project by the Tompkins County GIS Division in LAS binary format v1.1. The data were processed using ESRI ArcGIS 10.1 LiDAR geoprocessing tools. A "bare earth" digital elevation model (DEM) was generated. LiDAR points classified as "ground" were loaded into a File Geodatabase and a Terrain dataset was created. A raster DEM was derived from the Terrain layer using a linear sampling method with a pixel resolution of 5 ft.

Several derivatives of the LiDAR DEM were also created to aid in identification of areas with hydrologic conditions suitable for wetlands, including a slope raster and 1-ft contour lines, using Manifold 8.0 Surface Tools. Streams were derived using the FlowStreams function with a threshold of 1000 cells (equivalent to 0.57 acres).

The compound topographic index (CTI) also known as a topographic wetness index (TWI), was applied to the LiDAR DEM for the purpose of identifying possible wet areas. First, depressions in the LiDAR-derived DEM were eliminated with a "sink-filling" function using the Manifold 8.0 Surface Tools. Then, the CTI was calculated for all LiDAR DEM raster cells using the CTI equation: $\ln\,(a/\tan B\,)$ where a equals the upstream contributing area; and B equals slope.

Another aspect of LiDAR data that has been shown to be useful for wetland identification under forest canopies is the intensity of the return signal (Lang & McCarty, 2009). The intensity of the return signal is primarily a function of the reflective properties of the materials that are hit by the laser. Water tends to absorb the infrared light used by most LiDAR systems, and therefore return intensity is lower in areas that are inundated or have saturated soils. The return intensity values of LiDAR points classified as "ground" were used to generate a raster surface using the same process as described above for derivation of the "bare earth" DEM. An iterative filtering process described by Land & McCarty (2009) using an enhanced Lee filter was applied to more clearly define possible wet areas.

Preliminary analysis of LiDAR-derivatives

The LiDAR derivatives were qualitatively analyzed to determine if they would be useful in the identification of wetlands and their boundaries. The data were examined across the landscape, particularly in areas known to have wetlands, and compared to the available NYSDOP high-resolution aerial imagery. The 5-ft LiDAR DEM raster, and its immediate derivatives (1-ft contours and streams) had a very high level of spatial accuracy and detail, and aligned accurately with the high-resolution aerial imagery. Subtle changes in elevation visible in the elevation data apparently corresponded closely with wetland boundaries apparent on the imagery.

However, the CTI raster was not useful in identifying wetlands or their boundaries. Although the CTI raster identified areas which would have substantial accumulation of water, such as stream channels, CTI values for wetlands were not consistently higher or lower than neighboring upland areas. The CTI raster was not used to assist in wetland mapping.

LiDAR return intensity rasters, both the unfiltered and the enhanced Lee filtered, did not show a consistent pattern matching wetland occurrence or absence. In general, known wetland areas and upland areas could not be distinguished from one another using the return intensity data.

Although it was initially anticipated that the CTI and return intensity rasters might provide a means to classify the landscape into areas which were more likely or less likely to be wetlands using an automated process or by visual examination, none proved to be useful and there was no evidence that further processing would be productive. Therefore, neither the CTI nor the return intensity rasters were used in the wetland mapping process.

Mapping Method

Wetlands within the Town of Dryden and those intersecting the town boundary were mapped by image interpretation using the NYSDOP aerial imagery and visual analysis of the LiDAR DEM and its derivatives. Wetlands were delineated primarily using the NYSDOP 2012 imagery at a scale of at least 1:1,000. If wetland boundaries were not clearly identifiable on the NYSDOP 2012 imagery, the wetland boundaries were delineated using the LiDAR-derived slope raster and 1-ft contour lines if possible. The slope raster was themed or "symbolized" to highlight flatter areas, those between 0 and 5 degrees. This themed slope layer proved to be critical for identifying previously unmapped wetlands.

Oblique aerial imagery was also examined to aid in wetland identification. Oblique aerial imagery is captured at an angle and is particularly useful for determining vegetation structure and composition. For the Dryden study area, high resolution oblique aerial images were collected by Pictometry and available through the Microsoft Bing online map service.[1] Four oblique aerial images were available for most locations in the study area, excluding a small portion of southeast Dryden.

Other geospatial data resources that were referenced during the mapping process include the USGS National Hydrography Dataset (NHD)[2], the FEMA National Flood Hazard Layer (NFHL)[3], the 2007 Tompkins County Land Use and Land Cover layer[4], the NYSDEC Freshwater Wetland Maps, and the USFWS NWI.

All wetlands, regardless of size and origin, were mapped. Areas were determined to be wetland if hydrologic, topographic, and vegetative wetland indicators were all present. Hydrologic conditions supportive of wetland classification typically included visible surface water or saturated soils, which were generally more easily identified on CIR imagery. Vegetative indicators include specific vegetation types or growth forms, or specific species visible on the oblique imagery. Topographically, flatter areas, or areas at the bases of slopes were identified using the LiDAR DEM and its derivatives. Generally, areas were only classified as wetlands if there was sufficient evidence of wetland hydrology, wetland vegetation and appropriate topography, or, in the case of modified landscapes, that those conditions would exist if the area were allowed to revert to a natural state. Furthermore, evidence of wetland conditions on imagery from at least two of the three image years was generally required.

[1] http://www.bing.com/maps/
[2] http://nhd.usgs.gov/
[3] https://msc.fema.gov/portal
[4] http://cugir.mannlib.cornell.edu/bucketinfo.jsp?id=8010

Wetlands were classified according to the widely-accepted Cowardin classification system developed by the USFWS for the NWI (Cowardin et al., 1979). In this hierarchical classification scheme, wetlands are organized into five main systems (Marine, Estuarine, Riverine, Lacustrine, and Palustrine), which are divided into subsystems, classes, and subclasses based on hydrologic and vegetation characteristics. In Tompkins County, all wetlands fall within the Riverine, Lacustrine, and Palustrine systems. The USFWS formal definitions of these wetland systems are provided in Appendix A. Most wetlands in Tompkins County fall within the Palustrine category, which includes small non-vegetated waterbodies up to 8 ha (20 ac) in size. The Palustrine system divided into classes based on the dominant vegetation (such as trees, shrubs, emergents, or unconsolidated bottom if vegetation is absent) which are then divided into subclasses based on other vegetation characteristics (such as deciduous, evergreen, or dead vegetation).

Further description of wetlands is accomplished by adding special modifiers that indicate specific water regimes, water chemistry, soil attributes, or landscape alterations by humans or beavers. For all wetlands classified in the Cowardin scheme, a water regime modifier is assigned. For non-tidal wetlands, the water regime modifiers include: permanently flooded, intermittently exposed, semi-permanently flooded, seasonally flooded, saturate, temporarily flooded, intermittently flooded, and artificially flooded. Optionally, wetlands can be assigned modifiers that describe modifications to wetlands. These include: excavated, impounded, diked, partly drained, farmed, and artificial.

The Federal Geographic Data Committee (FGDC) Wetland Map Standards (2009), which has endorsed the Cowardin classification system, has defined a minimum standard for completeness of the wetland classification that includes: ecological system, subsystem, class and/or subclass, water regime, and special modifiers. The wetland mapping process completed for the Town of Dryden met those standards.

Many larger wetlands are comprised of distinct areas that would be classified as different wetland types in the Cowardin system. Therefore, as is done for the NWI, wetlands were divided into multiple features with appropriate classifications. Each distinct wetland feature was given a unique identification number. Wetland features belonging to contiguous wetland areas were grouped using unique "wetland complex" identification numbers to support data management and analysis tasks.

Several additional attributes of wetland features were documented. Wetlands were classified by their likely origin, either "artificial" or "natural." Also, additional hydrologic descriptors were given for specific wetland types which are not identified in the Cowardin system. For instance, some wetlands were identified as vernal pools, agricultural ponds, or on a floodplain.

Although wetlands were mapped as carefully and accurately as possible, mapping was based solely on remote sensing data. It is important to acknowledge the limitation of this method. To document the uncertainty in the wetland classification process, some wetland features were attributed with a qualitative designation of "unlikely", possible, or "probable."

To ensure complete and thorough analysis of all parts of the study area, a 1-km by 2-km rectangular grid geospatial data layer was used to track and document progress. Each grid cell was marked as complete after thorough and systematic review.

Accuracy Assessment

A field-based accuracy assessment is an important component the geospatial data development process. However, field surveys can be time-consuming and expensive. A wetland field survey was completed in the summer of 2007 by GBH Environmental (Ithaca, NY) for the wetland gap analysis and it was assumed that this field survey would serve as the basis for the accuracy assessment (Schipanski, 2008). The field survey included 4 randomly selected north-south 100-ft wide transects, two in Lansing and two in Dryden. The total length of all transects combined was 33.4 miles and landowner access was granted for 17.4 miles of this length. A Garmin Geko 301 GPS unit was used to map wetland occurrences and the area of each wetland was estimated. The field survey data were not viewed and the transect locations were not known prior to the completion of the wetland mapping process to prevent bias. The objectives of the accuracy assessment were to assess the rate of omission error, the rate of commission error, and the accuracy of wetland boundaries.

RESULTS

Overview

All wetlands within the Town of Dryden or intersecting the town boundary were mapped. Therefore, portions of some mapped wetlands extended beyond the Dryden boundary. However, statistics given in this report include only wetlands or portions of wetlands within the boundary of the Town of Dryden. This provides a more clear definition of the area being described by the data and is important for comparisons to NWI and DEC Freshwater Map data. In addition, wetland areas given a probability of "unlikely", which indicates insufficient but suggestive evidence of a wetland occurring at a given location, are not included in the statistics.

In total, 5,641 acres of wetlands were mapped, which is approximately 9.4% of the total area of Dryden (Table 2). Natural Palustrine wetlands accounted for 91% of the total wetland area. Riverine and lacustrine wetlands were 0.6% and 2.4% of the total wetland extent, respectively. In total, 529 natural wetland complexes, contiguous wetland areas, were mapped. The median wetland complex size was 0.9 acres and the average was 10.0 acres. The distribution of wetland complexes sizes was skewed, with a large number of smaller wetlands and a small number of very large contiguous wetland areas. Fourteen wetland complexes were each over 100 acres, with the largest being 503 acres.

			Wetland area (acres)		
System	**Class**	**Subclass**	**Artificial**	**Natural**	**Total**
Lacustrine			19.1	118.8	137.8
Riverine	Unconsolidated shore			33.2	33.2
Palustrine	Emergent	Persistent	37.8	1,510.2	1,548.0
	Forested	Broad-leaved deciduous	0.7	1,316.1	1,316.7
		Dead		48.2	48.2
		Needle-leaved evergreen	0.1	736.0	736.1
	Scrub-shrub	Broad-leaved deciduous	8.6	1,450.0	1,458.6
		Dead		9.0	9.0
		Needle-leaved evergreen		9.4	9.4
	Unconsolidated bottom		280.4	63.7	344.1
Palustrine Total			*327.5*	*5,142.6*	*5,470.1*
TOTAL			**346.6**	**5,294.6**	**5,641.2**

Table 2. Summary of wetlands mapped in the Town of Dryden.

Artificial wetlands totaled 347 acres, of which 318 acres were farm ponds, residential ponds, and adjacent emergent vegetation areas caused by the artificial impoundment of water. In total, over 800 agricultural or residential ponds were mapped.

Comparison to USFWS NWI and NYSDEC Freshwater Wetland Maps

The USFWS NWI, the NYSDEC Freshwater Maps, and the Dryden 2012 Wetlands Map have been developed for different purposes using different data resources and geospatial technologies. It is important to keep these differences in mind when using or comparing wetland maps, as some quantitative differences may reflect differences in methods rather than differences in accuracy or actual changes in wetland extent over time.

NYSDEC Freshwater Wetland Maps

The NYSDEC created the Freshwater Wetland Maps to comply with the Freshwater Wetlands Act (Article 24 of the Environmental Conservation Law). The maps show the "approximate location of the actual wetland boundary" for all wetlands subject to the jurisdiction of the law (DEC, 1997). The law defines wetlands based on the presence of certain vegetation types or specific species, or as areas that are too wet to support that vegetation (DEC, 1997). Protection under the law is provided for wetlands greater than 12.4 acres in size, or smaller wetlands determined to be of considerable local value.

The original wetland maps were completed in the 1980s using available high-resolution aerial imagery. The USGS National High Altitude Photography (NHAP) program color-infrared aerial photos were the most widely available at the time. The NYSDEC has defined a process for wetland map amendments. However, there have been no amendments submitted for Tompkins County, and the original maps were created between 1984 and 1986.[5]

USFWS NWI Program

The USFWS NWI program was established to document the distribution and occurrence of all wetlands and deepwater habitats in the United States. Wetlands are defined by the USFWS as

> *"…lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For the purposes of this classification wetlands must have one or more of the following three attributes: (I) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."* (Cowardin et al., 1979)

The USFWS definition of wetlands was not intended to be a regulatory definition, such as that used by the US Army Corps of Engineers to support enforcement of the Clean Water Act (Environmental Laboratory, 1987). The NWI wetland maps for the Tompkins County area were developed in the 1980s primarily by photointerpretation of USGS NHAP imagery.

Total wetland area

Considering the differences in the purpose, intended applications, and source data, significant differences between the NYSDEC Freshwater Wetland Maps, the USFWS NWI maps, and the new Dryden 2012 Wetlands Map were anticipated. As shown in Table 3, the NYSDEC Freshwater Wetland Maps include approximately 39% of the wetland area on the Dryden 2012 Wetlands Map. The NWI, which is similar to the Dryden 2012 Wetlands Map in terms of its purpose and methods, had 64% of the wetland area included in the Dryden 2012 Wetlands Map.

---

[5] http://www.dec.ny.gov/docs/wildlife_pdf/wtamdfildat4.pdf

	NYSDEC Freshwater Wetland Maps (ac)	NWI (ac)	Dryden 2012 Wetlands Map (ac)
Freshwater Emergent Wetland		678.8	1,548.0
Freshwater Forested/Shrub Wetland		2,558.9	3578.1
Freshwater Pond		176.6	344.1
Lake		131.3	137.8
Riverine		48.8	33.2
Total	**2,195.2**	**3,594.9**	**5,641.2**

Table 3. Total wetland area in the Town of Dryden as shown on NYSDEC Freshwater Wetland Maps, USFWS NWI maps, and the Dryden 2012 Wetlands Map.

Positional accuracy

Accurate wetland location data may be particularly important for regulatory purposes. Therefore, the degree of spatial overlap or agreement between the datasets is of interest. Due to significant advances in geospatial technologies, the recent aerial imagery and LiDAR elevation data have greatly improved positional accuracy over the imagery acquired and processed in the 1980s for the NYSDEC Freshwater Wetland Maps and the USFWS NWI. There is a high level of disagreement (a lack of overlap) between all three datasets (Table 4). Given that the Dryden 2012 Wetlands Map includes more wetland area, the large extent of wetland areas only in the Dryden 2012 Wetlands Map but not the other maps was expected.

However, the total wetland areas in the NWI and the NYSDEC Freshwater Wetland Maps that do not overlap with the Dryden 2012 Wetlands Map are also quite large. Although this may be due to actual differences in analyst interpretation or ecological changes, visual inspection of the data during the wetland mapping process revealed that positional inaccuracy accounts for a significant portion of these numbers. Further investigation of this issue was beyond the scope of this project, and would require substantial geospatial data processing and analysis.

Dryden 2012 Wetlands Map only	Overlap	USFWS NWI only	Agreement
2,704 ac	2,937 ac	653 ac	47%

Dryden 2012 Wetlands Map only	Overlap	NYSDEC Freshwater Wetland Maps only	Agreement
4,075 ac	1,566 ac	626 ac	26%

USFWS NWI only	Overlap	NYSDEC Freshwater Wetland Maps only	Agreement
2,339 ac	1,256 ac	940 ac	28%

Table 4. Spatial overlap of wetland maps. Natural and artificial wetlands are included. Agreement is calculated as the area of overlap divided by the total area of both wetland maps indicated.

Wetland occurrences

The NWI is known to be conservative in its identification of wetland occurrences, resulting in a low error of commission rate (Tiner, 1997). A comparison with the Dryden 2012 Wetlands Map confirms this. Of the 3,590 acres of wetlands identified by NWI, only 5.7 acres were not within or associated with wetland complexes included in the Dryden 2012 Wetlands Map. The 5.7 acres are divided among a total of 19 small wetlands, of which 16 (3.6 acres) appear to have been mostly small artificial ponds that either no longer exist or were errors in photointerpretation. The remaining three wetlands (2.0 acres total) appear to no longer be wet enough to be classified as wetlands.

Further comparison of the two datasets confirms that the NWI may have a high error of omission rate. This omission rate is highest for smaller wetlands as shown in Table 5, which shows the number of natural wetlands by size category in each dataset. In addition, 442 additional artificial ponds totaling 92 acres were included in the Dryden 2012 Wetlands Map, but were not previously mapped in the NWI.

Wetland boundaries on the NYSDEC Freshwater Wetland Maps are more generalized and less precisely defined than the wetlands depicted in either the NWI or Dryden 2012 Wetlands Map, making detailed comparisons based on corresponding wetland areas more challenging or not possible. Therefore, only a general, study area-wide comparison was made (Table 6). The DEC Freshwater Wetland Maps include 30 wetlands fully within Dryden and 7 which are partially within Dryden. The smallest wetland is 8.3 acres. The NYSDEC Freshwater Wetland Maps generally do not include wetlands below 12.4 ac. However, it appears that the NYSDEC Freshwater Wetlands Map do not include a large number of the wetlands that are over 12.4 ac.

Dryden 2012 Wetlands Map	NWI					Dryden 2012 Total *n*	Not in NWI	NWI Omission Rate
	<0.5 ac	0.5-1.0 ac	1.0-2.0 ac	2.0-12.4 ac	>12.4 ac			
< 0.5 ac	24		1			205	180	88%
0.5 - 1.0 ac	8	6				80	66	83%
1.0 - 2.0 ac	8	13	4	1		74	48	65%
2.0 - 12.4 ac	7	5	12	28		101	49	49%
> 12.4 ac			1	19	47	70	3	4%
NWI Totals	47	24	18	48	47	530	345	65%

Table 5. Wetlands by size category: Natural wetlands in the NWI and Dryden 2012 Wetlands Map.

Size	Dryden 2012 Wetlands Map (*n*)	NYSDEC Freshwater Wetland Maps
< 0.5 ac	205	
0.5 - 1.0 ac	80	
1.0 - 2.0 ac	74	
2.0 - 12.4 ac	101	5
> 12.4 ac	70	32
Totals	**530**	**37**

Table 6. Wetlands by size category: Natural wetlands on the Dryden 2012 Wetlands Map and the NYSDEC Freshwater Wetland Map.

Differences in the extent and abundance of wetlands described by the NWI, the NYSDEC Freshwater Wetlands, and the Dryden 2012 Wetlands Map may be attributed to a number of factors. Wetlands are not static landscape elements and changes in climate (rainfall and temperature) or hydrology (increased beaver activity, for example), may lead to actual increases in wetland extent. Furthermore, as mentioned previously, the wetland maps differ in their mapping methods and program objectives. Also, the NWI and the NYSDEC Freshwater Wetland Maps were created using imagery that is approximately 30 years old. The Dryden 2012 Wetlands Map was created using imagery collected as recently as 2012. Despite these factors, however, it appears that a significant portion of the difference is also due to improvements in the detection of wetlands and their boundaries associated with advancements in geospatial and remote sensing technologies.

Accuracy Assessment

Following the completion of the mapping process, an accuracy assessment using the wetland field survey data collected by GBH Environmental was attempted. As the field survey data were prepared for analysis, the limitations of the field survey data became apparent. Although the initial goals of the accuracy assessment were to quantify the error of omission rate, the error of commission rate, and the wetland boundary accuracy, the assessment was limited to an estimate of the error of commission rate only.

Field survey data limitation

Data describing the location of the field survey and the wetland sites were limited. The field survey included two transects in the Town of Dryden. Data that could be used to determine the transect locations, such as the geographic coordinates of the start and end points or GPS track logs, were not available. The transect locations were estimated based on the locations of the wetland survey points.

To determine an error of commission rate for the Dryden 2012 Wetlands Map, data describing the survey area where wetlands were not found are necessary. The field survey transects totaled 33.4 miles, of which only 17.4 were surveyed due to access limitations. However, data that could be used to determine which transect portions were visited, such as a GPS track log or landowner and parcel access information, were not archived. Therefore, an error of commission rate could not be determined.

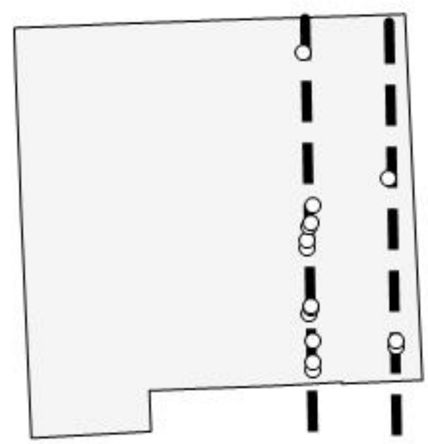

Figure 2. Approximate location of field survey transects and wetland sites in Dryden.

Estimating an error of omission rate was also problematic. For each wetland, only a single latitude/longitude location was collected in the field using a recreational grade GPS unit. When GPS data could not be acquired, geographic coordinates were approximated on a hardcopy map. Both methods may lead to inaccurate location data. Geographic coordinates were not provided for some wetlands, and for the current project were estimated from a survey map provided in the final study report.

Estimates of the locations of wetland survey points appeared to be very imprecise. Wetland field survey points were up to 300 feet from any approximated transect line, which exceeded the described transect width of 100 feet. Determining which wetland field survey points corresponded to which Dryden 2012 Wetlands Map wetland or other locations on the landscape was difficult or, in some cases, not possible. Furthermore, it appeared that, due to the challenges associated with fieldwork, several locations described in the field survey as distinct wetlands were likely parts of the same larger wetland. Finally, because each wetland location identified in the field survey was described by a single geographic coordinate, the data could not be used to assess wetland boundary accuracy.

Accuracy assessment results

Due to the data limitations described, strong conclusions about the accuracy of the Dryden 2012 Wetlands Map should not be drawn from this accuracy assessment. In the field survey, a total of 42 wetlands were found, of which 29 were located in Dryden. Of the 29 wetland sites, three appeared to be referring to a single contiguous wetland. Therefore, of 27 unique wetlands surveyed, fifteen points matched wetland features on the Dryden 2012 Wetlands Map.

Of the twelve wetlands in the field survey that were missed in the Dryden 2012 Wetlands Map, six appeared to be natural wetlands, each estimated to be 0.4 acres or less. A review of the imagery and topographic data revealed that these locations showed no significant vegetative, hydrologic, or topographic indications of wetland occurrence. One of the missed wetlands was described as a seep, which would have been extremely difficult to identify from aerial imagery.

Three of the twelve survey points were for wetlands along small stream channels. Stream channels were not mapped for the Dryden 2012 Wetlands mapped because reliable surface hydrology data was already available. If the wetlands along the stream channels were very narrow, it is likely that that would not have been considered for mapping. One of the twelve survey points indicating the presence of a wetland referred to a farm swale. Due to the significant hydrologic and vegetation modifications, accurate classification of such a wetland can be difficult or impossible from aerial imagery. Finally, determination of wetland occurrence or absence could not be made for the remaining two points due to imprecise location data, which indicated that the survey points might or might not refer to nearby wetlands.

Using the 25 survey points that could be located with sufficient accuracy and confidence, the error of omission rate for wetland occurrence on the Dryden 2012 Wetlands Map was 40%. Although the field survey did not provide sufficient data for a more comprehensive accuracy assessment, it did suggest that the smallest wetlands would still likely be underrepresented in a new wetland map for Tompkins County, though significantly less underrepresented than on NWI and NYSDEC Freshwater Wetland Maps.

In general, there are numerous factors that may affect mapping accuracy. Wetlands that are larger, more saturated, and more clearly defined topographically are likely to be mapped with much higher accuracy. Wetlands that are saturated for shorter time periods may not show sufficient hydrologic or vegetation indicators to be mapped as wetlands.

CONCLUDING REMARKS

The purpose of the pilot project was to map all wetlands in the Town of Dryden, with an emphasis on capturing wetland types that were not as accurately represented by existing wetland maps. Wetlands that were smaller in size or relatively drier, which are more difficult to interpret on aerial imagery, were considered particularly important to capture. Therefore, the current study tended towards a less conservative approach than the NWI. As Tiner (1997) indicates, NWI maps are conservative in their classification of areas as wetlands. Errors of commission are extremely rare, but errors of omission appear to be common for the NWI. This was supported by the findings of the current study.

An adequate accuracy assessment could not be completed using the available wetland field survey data. Although the data may have been sufficient for the 2008 wetland gap analysis, data critical for an assessment of the Dryden 2012 Wetlands Map were missing. A complete accuracy assessment of the Dryden 2012 Wetlands Map should be completed and would provide essential information for end users of the data, such as planners and local government agencies. However, it is expected that even without the accuracy assessment, the new wetland map will be a valuable planning tool.

The visual analysis of high-resolution aerial imagery remains the most viable method for efficiently mapping wetlands across large areas. Today, the availability of better aerial imagery, high resolution elevation data (LiDAR) and georeferenced oblique aerial imagery make it possible to achieve much higher levels of accuracy, completeness, and detail in much less time than in the past. The LiDAR data and its derivatives were particularly important for making improvements in accuracy. LIDAR data are available for the remaining area of Tompkins County, as well as for many other counties in New York, and could be used to improve wetland mapping across the State.

PROJECT DELIVERABLES

The products of this mapping project are available to all government agencies and other interested parties. Contact the Cayuga Lake Watershed Network to obtain copies. The products available include:

1. the Dryden 2012 Wetlands Map geospatial dataset in ESRI Shapefile and Personal Geodatabase formats;
2. metadata describing the methods and geospatial analyses used to create the wetland geospatial dataset;
3. a set of digital maps in PDF file format; and
4. the final report summarizing the results of the mapping process including a description of the methods, accuracy assessment, and a comparison to previous wetland datasets.

Contact information:

Cayuga Lake Watershed Network
170 Main Street P.O. Box 348
Aurora, NY 13026
607-319-0475
steward@cayugalake.org
http://www.cayugalake.org/

REFERENCES

Cowardin, L., Carter, V., Golet, F., & LaRoe, E. (1979). *Classification of Wetlands and Deepwater Habitats of the United States. FWS/OBS-79/31* (p. 131). Retrieved from http://www.fws.gov/wetlands/Documents/Classification-of-Wetlands-and-Deepwater-Habitats-of-the-United-States.pdf

DEC. (1997). Environmental Conservation Law: Article 24 Freshwater Wetlands. Retrieved from http://www.dec.ny.gov/docs/wildlife_pdf/wetart24a.pdf

Environmental Laboratory. (1987). *Corps of Engineers Wetlands Delineation Manual* (Vol. 1). Vicksburg, MS.

Huffman and Associates Inc. (2000). *Wetlands Status and Trend Analysis of New York State - Mid-1980's to Mid-1990's. Prepared for the New York State Department of Environmental Conservation* (p. 17). Larkspur, California.

Lang, M. W., & McCarty, G. W. (2009). Lidar intensity for improved detection of inundation below the forest canopy. *Wetlands*, *29*(4), 1166–1178. doi:10.1672/08-197.1

McMullen, J. M., & Meacham, P. A. (1996). A comparison of wetland boundaries delineated in the field to those boundaries on existing state and federal wetland maps in central New York State. In G. Mulamoottil, B. G. Warner, & E. A. McBean (Eds.), *Wetlands: Environmental Gradients, Boundaries, and Buffers* (pp. 193–205). Boca Raton, Florida: CRC Press LLC, Lewis Publishers.

Morrissey, L. A., & Sweeney, W. R. (2006). Assessment of the National Wetlands Inventory: Implications for wetlands protection. *Geographic Information Systems and Water Resources IV AWRA Spring Specialty Conference, Houston, TX. May 8-10, 2006*, 1–6.

Nichols, C. (1994). *Map Accuracy of National Wetlands Inventory Maps for Areas Subject to Maine Land Use Regulation Commission Jurisdiction* (pp. Ecological Services report R5–94/6, 14pp.). Hadley, MA.

Schipanski, N. (2008). *Wetland Protections in Tompkins County: Existing Status, Gaps, and Future Needs* (p. 75). Ithaca, NY.

Stolt, M. H., & Baker, J. C. (1995). Evaluation of National Wetland Inventory Maps to inventory wetlands in the Southern Blue Ridge of Virginia. *Wetlands*, *15*(4), 346–353.

Tiner, R. W. (1997). NWI Maps: What They Tell Us. *National Wetlands Newsletter*, *19*(2), 7–12. Retrieved from http://www.fws.gov/wetlands/Documents/NWI-Maps-What-They-Tell-Us.pdf

Werner, H. W. (2004). Accuracy assessment of National Wetland Inventory maps at Sequoia and Kings Canyon National Parks. *Park Science*, *23*(1), 19–23.

APPENDIX A. PALUSTRINE, LACUSTRINE, AND RIVERINE SYSTEMS IN THE USFWS COWARDIN CLASSIFICATION

Wetlands mapped in the study area were classified as Palustrine, Lacustrine, and Riverine systems in the USFWS Cowardin classification scheme for wetlands and deepwater habitats as described in this USFWS publication:

Cowardin, L., Carter, V., Golet, F., & LaRoe, E. (1979). *Classificatino of Wetlands and Deepwater Habitats of the United States. FWS/OBS-79/31* (p. 131). Retrieved from http://www.fws.gov/wetlands/Documents/Classification-of-Wetlands-and-Deepwater-Habitats-of-the-United-States.pdf

The basic definitions of these systems from this report are given below.

"The Palustrine System includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ‰. It also includes wetlands lacking such vegetation, but with all of the following four characteristics: (1) area less than 8 ha (20 acres); (2) active wave-formed or bedrock shoreline features lacking; (3) water depth in the deepest part of basin less than 2 m at low water; and (4) salinity due to ocean-derived salts less than 0.5 ‰." (*p. 10*)

"The Lacustrine System includes wetlands and deepwater habitats with all of the following characteristics: (1) situated in a topographic depression or a dammed river channel; (2) lacking trees, shrubs, persistent emergents, emergent mosses or lichens with greater than 30% areal coverage; and (3) total area exceeds 8 ha (20 acres). Similar wetland and deepwater habitats totaling less than 8 ha are also included in the Lacustrine System if an active wave-formed or bedrock shoreline feature makes up all or part of the boundary, or if the water depth in the deepest part of the basin exceeds 2 m (6.6 feet) at low water. Lacustrine waters may be tidal or nontidal, but ocean derived salinity is always less than 0.5 ‰." (p. 9)

"The Riverine System includes all wetlands and deepwater habitats contained within a channel, with two exceptions: (1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) habitats with water containing ocean-derived salts in excess of 0.5 ‰. A channel is “an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of standing water” (Langbein and Iseri 1960:5)." (*p. 7*)