Lake Wausau Bathymetric Mapping – UW-Stevens Point (Christine Koeller)

INTRODUCTION

Lake Wausau depths were surveyed in the summer and fall of 2012 and used to create a new bathymetric map that highlights features including relief, recreational amenities and public access, and sediment and aquatic vegetation distributions. Five-thousand copies of the map were printed for distribution through local municipalities, businesses, and the Lake Wausau Association. An additional 5000 copies will be printed when needed.

The previous public bathymetric map available through the Wisconsin Department of Natural Resources (WI DNR) for Lake Wausau dated back to 1973. The fluvial nature of Lake Wausau leads to morphological changes of the channel where scouring occurs in some areas and deposition and filling in other areas. Heavy flood events such as those experienced in fall 2010 and spring 2011 can create permanent and significant changes to the shoreline and depth distribution. The updated bathymetric map created in this study was a key component to the proposed hydrodynamic modeling performed by the US Army Corps of Engineers (US ACOE). Lake Wausau recreational lake users (including boaters, fishermen, paddle canoers, kayakers, birders, duck hunters, etc.) and land use planners will benefit from use of the updated map. Our primary objective in creating a new bathymetric map for Lake Wausau was to evaluate depth distribution, map accuracy, and compare to historic bathymetry.

Objective 1: Evaluate map accuracy through grid intersection depth comparisons.

Objective 2: Evaluate the depth distribution of Lake Wausau and compare to historic maps to identify areas of change.

METHODS

Bathymetry Data Acquisition

A global positioning system (GPS) receiver integrated with a sound navigation and ranging (Sonar) unit , or GPS/Sonar, survey was completed for Lake Wausau in 2012 using the University of Wisconsin-Stevens Point GIS Center's survey-grade Trimble equipment and a sonarmite echo sounder (R6 GPS receiver, TSC2 data collector). Instantaneous positional corrections were obtained from the Wisconsin Department of Transportation's Wisconsin Continuously Operating Reference Stations (WISCORS) which were accessed through a US-Cellular Blackberry phone modem. The WISCORS differential positioning corrected horizontal (lat/long) positions to sub-centimeter accuracy and vertical (elevation above sea level) positions to +/- 3cm. During the survey, transects spaced no more than 200 feet apart were run perpendicular to the direction of flow across Lake Wausau. Near-shore perimeter data was also acquired. Latitude, longitude, and depth (XYZ) positions were collected every second on the TSC2 data collector; positions with deviation >0.15 survey feet were not recorded to assure quality control of the vertical and horizontal data that were collected.

The XYZ data points were surveyed in May-October 2012 over an eleven day-period. The Trimble TSC2 data collector logged surface water elevation and depth for each XYZ data point with a one- second recording interval. Surface water elevations were collected using the WI-09 geoid model and NAVD 88 Datum. To calculate bottom elevation, depth was subtracted from surface water elevations. A full pool water elevation of 1160.7 feet above sea level (as maintained and reported by Domtar Paper Mill) was used to calculate adjusted depths from XYZ depth points (1160.7 – Bottom Elevation). All data points were collected on the Marathon County projected coordinate system in US survey feet (horizontally and vertically).

Surface Volume and Area Calculations

Total surface area and volume for Lake Wausau were calculated in ArcMap 10.0. Surface area (lake area with islands) was determined using the Calculate Geometry tool and the Lake Wausau polygon shapefile. Total volume was determined using a conical volume equation (1/3H(A1+A2+√(A1*A2))). Cumulative area (acres) and volume (acre-feet) for each contour interval were used to graph lake area vs. depth and lake volume vs. depth (Figure 2).

Additional lake morphology information was also printed on the map as requested by the WI DNR. Lake area without islands was determined by removing island areas from the Lake Wausau polygon shapefile. Shoreline mileage including islands was calculated by determining the perimeter of the Lake Wausau polygon shapefile. Finally, the surface area with depths less than 3 feet and greater than 20 feet were determined.

Construction of 2012 Surface models and Contour Lines

The Lake Wausau polygon, shoreline points, and the XYZ survey data were used to construct the 2012 lake-bottom surface models in ArcMap 10.0. Lake shorelines were delineated from WROC 2012 aerial imagery at a scale of 1:1000, and then converted to a polygon in order to calculate surface area in acres. Data points (XYZ) were added along the shoreline (depth set to zero) and combined with the survey data points for interpolation purposes. All XYZ data were used to construct a 3D triangulated irregular network (TIN) model in ArcMap 10.0 (Figure 2) with constraints set to the Lake Wausau polygon boundaries which excluded island areas. Contours were derived from the 3D surface using the Surface Contour function in ArcMap 10.0, and corrected with manual interpretation using the XYZ data points. The reported contour intervals included a three-foot contour, five-foot contour, and every five feet thereafter up to the maximum depth (i.e. 3, 5, 10, 15, …, 35). Resulting contours were smoothed for final appearance on the map.

Comparison of Grid Intersects in Channel Areas

Intersecting grid transects were evaluated to determine spatial accuracy of the final map and lake model. Perpendicular transects that were parallel with the main channel areas were surveyed during the initial survey period. Depths at these intersections were compared between perpendicular tracts, and standard deviations were calculated to evaluate map accuracy. Grid transect locations were manually located using ArcMap 10.2 software and a comprehensive view of surveyed transects. A total of 338 grid intersections were manually identified that were relatively perpendicular and had adequate survey points near the intersection from both survey directions. A random number generator was used to select 60 intersections for statistical analysis. Survey depths nearest the intersection from the crossing survey tracts were manually documented.

Comparison of Depth Change from 1973 - 2012

The 2012 survey depths were compared to the historic 1973 depths to compare changes between the two survey periods. This historic Lake Wausau map was stitched together and georeferenced (as provided by the WI DNR in 2013) to the landscape in and around Lake Wausau. The historic contour lines were traced and depth information recorded. From the historic depth information, a 3D TIN model was constructed, and then converted to a 5m raster grid (depth grid). The 2012 3D TIN Model was also converted to a 5m raster grid. The 1973 depth grid was subtracted from the 2012 depth grid to show areas of depth change. Change less than four feet was ignored in the analysis and not spatially displayed.

RESULTS

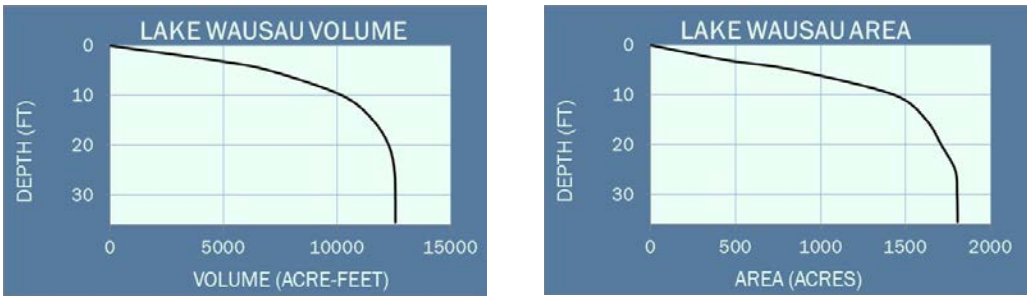

Figure 1: Cumulative volume curve vs. depth and cumulative area curve vs. depth in Lake Wausau, 2012.

Lake Wausau morphological characteristics were reported on the final lake map. Total area was 1814 acres with islands and 1971 without islands. Approximately 24 percent of the lake was less than 3 feet deep; 5.5 percent was greater than 20 feet deep (Figure 1). The total lake volume of 12,994 acre-feet is mostly concentrated in depth less than 10 feet (Figure 1). The maximum depth reached 35.4 feet while average depth totaled 6.7 feet. Almost 54 miles of shoreline were delineated and ### islands were identified.

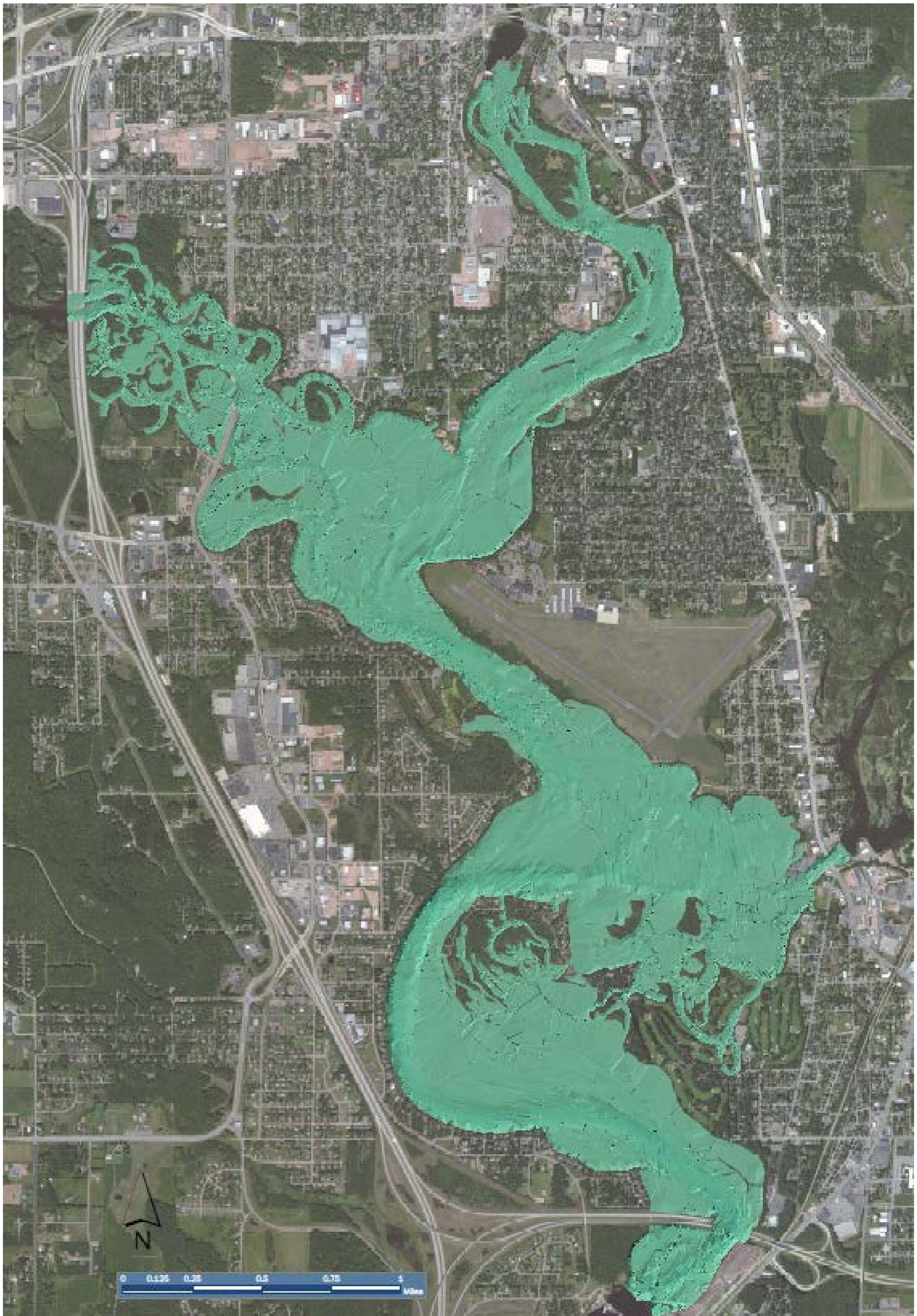

Figure 2: Lake Wausau 3D-TIN model derived from survey and shoreline XYZ data points (latitude, longitude, and depth) collected during the 2012 survey.

Evaluation of Bathymetric Model Accuracy

The standard deviation (±1 SD) between perpendicular transect lines at random grid intersections was evaluated using Microsoft Office Excel 2010. There was little difference between standard deviations in the two data sets ($depth_1$ = 6.8; $depth_2$ = 6.72). There was also little difference between the mean depths between the two data sets (x_1=10.69, x_2=10.64) and standard deviation error bars shows the depths are not different (Figure 3). This confirms depths acquired with the Ohmex Sonarmite depth sounder were calibrated well and the model is representative of Lake Wausau's morphology.

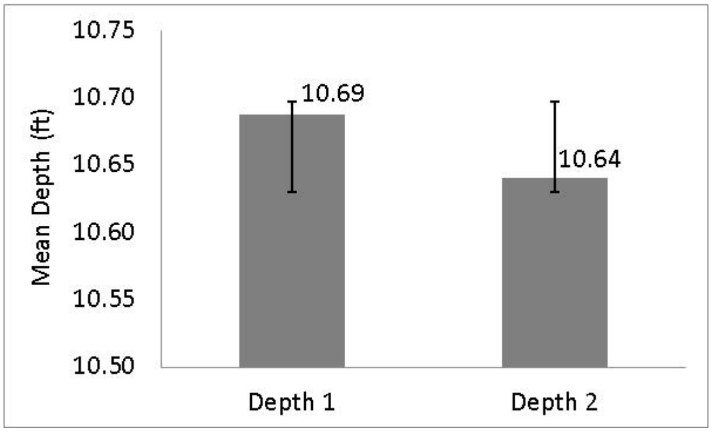

Figure 3: Standard deviation error bars (± 1SD) for mean depths between $depth_1$ and $depth_2$ data sets at random grid intersections across Lake Wausau (2012).

Depth Change from 1973 - 2012

Changes in depth from 1973 to 2012 were displayed spatially to show areas that were deeper and shallower in 2012 than in the 1973 map (Figure 4). Areas with less than four feet of change were ignored for the following reasons:

- Potential error during georeferencing of the historic map.
- Potential drawing errors during the original survey.
- Model construction errors across shallow reaches of the Lake Wausau.
- Fluctuations in water elevation between the survey periods.

Areas appearing shallower in 2012 are prominent to the east of Rib Mountain Drive (Figure 4) and in the bay north of the Central Islands area (Figure 5). Areas that appeared deeper in 2012 are scattered across the surface. Depth change through the main channel should be interpreted with caution as there may drawing errors in the original survey and also in the georeferencing of the historic map.

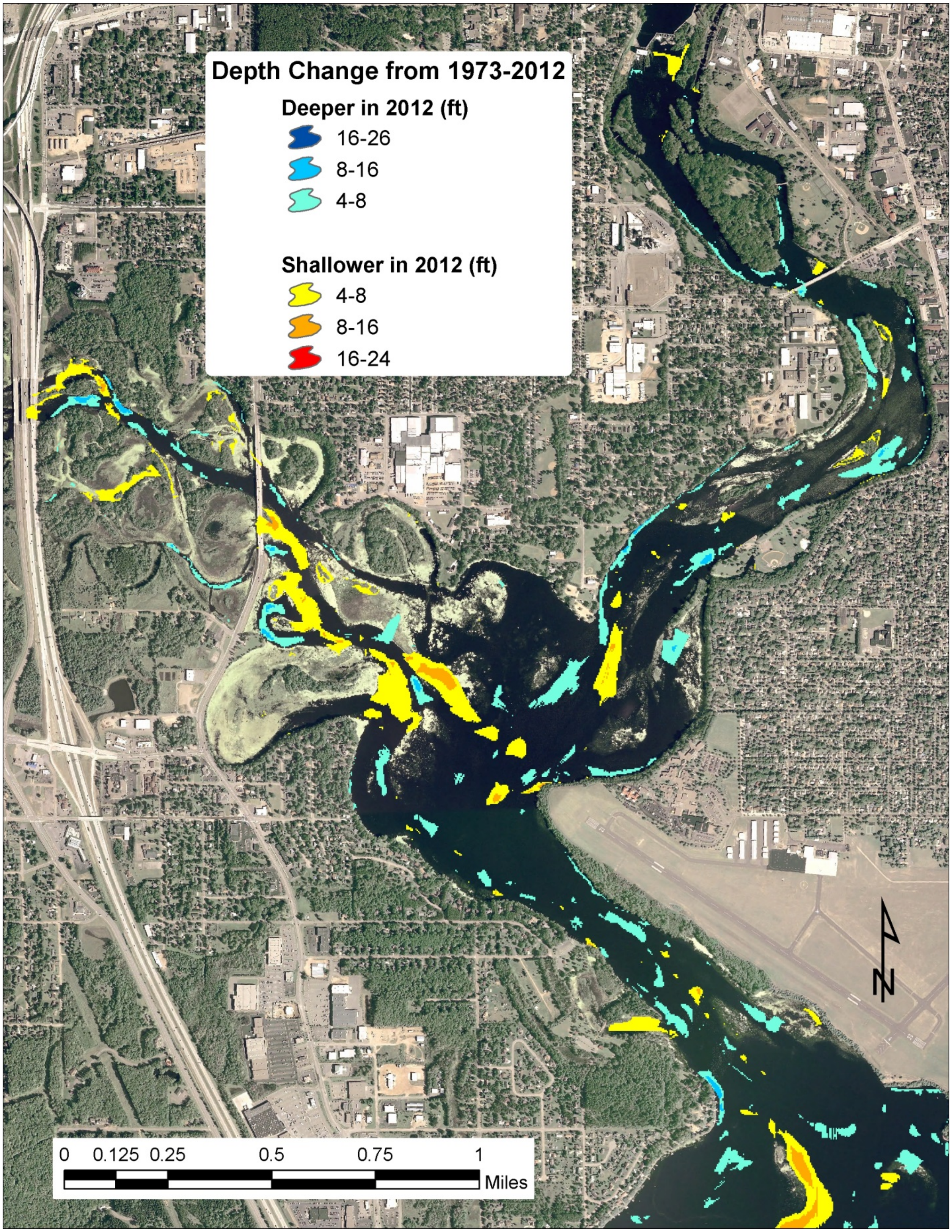

Figure 4: Depth change across northern Lake Wausau from 1973-2012 survey periods. Depth change less than 4 feet is not reported.

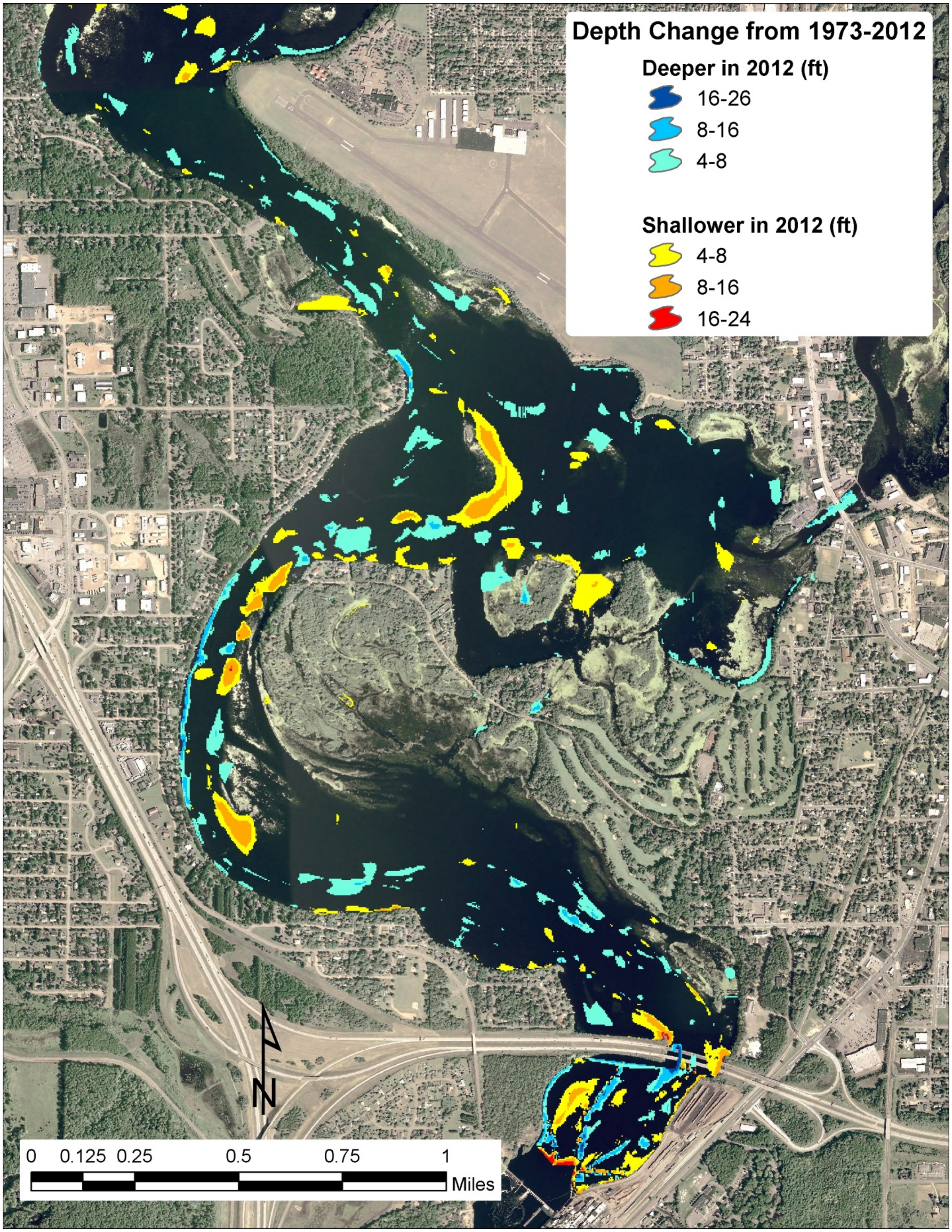

Figure 5: Depth change across southern Lake Wausau from 1973-2012 survey periods. Depth change less than 4 feet is not reported.

DISCUSSION

Fluvial systems such as Lake Wausau can experience remarkable depth change over time and evaluation of depth is important for lake management and future planning. The depths collected in 2012 showed substantial change from those reported in 1973, giving us a better picture of how water is moving through Lake Wausau, and what areas may be accumulating materials from modes including transported sediments and aquatic plant debris. Although sediments can transported from upstream environments and trapped in downstream impoundments, they are also carried off the landscape during rainfall and snowmelt. Sediments can also be picked up from erosional sites adjacent to the shoreline, particularly during fast flow and high water events. Sedimentation rates can be slowed down when healthy rooted vegetation is maintained in the near-shore environment (<35 feet from the shoreline), particularly in steep shoreline areas.

Aquatic plant management requires a good understanding of depth distribution in a lake. Plants need light penetration to establish, and knowing the depth plants are likely to root gives managers a place to start when searching for plants including invasives and/or rare/endangered species.

The depth data collected in this study will serve as baseline information for tracking changes in the future. Depths were collected with high-accuracy survey equipment (Trimble) with sub-centimeter capability (<1cm horizontal; ±3cm vertical). Bottom elevation information was derived from the results, and can be used in the future to see how the lake changes over time by revisiting surveyed locations and recording new depth information.