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June 28, 2006

Reid Wronski, P.E.
City Engineer
City of River Falls
123 Elm Street
River Falls, WI 54022

Dear Reid:

Enclosed are electronic copies of the results of the bathymetric and sediment depth survey for Lake George as per the contract approved by the City in late April of this year. The pdf document on the disk summarizes the methods used to obtain the data, and the remainder of the letter report presents the map information on the bathymetry of the lake. All GIS layers to create the maps are also contained on the disk. Please review the information and contact me (phone: 651- 604-4783) if you have any questions. Thanks, Reid.

Sincerely,

Bonestroo Rosene Anderlik and Associates

Rich Brasch
Project Manager

cc.   Kristy Treichel

Background and purpose: The purpose of this work was to map the bottom contours of Lake George, River Falls, Wisconsin, and to map the thickness of flocculent sediments in this lake. This lake was created by a hydroelectric dam that backed up water over a set of old meanders in the Kinnickinnic River.

Methods

Bathymetric methods: Depth estimates were collected at >3,000 points by a combination of digital, bottom discriminating sonar and differential GPS. Sonar readings were corrected for offset and errors in angle using a calibration curve established at many points using a handline calibrated to the nearest centimeter. Depth soundings were further corrected to average lake level and elevation by reference to lake level at the top of the hydroelectric dam (865.5 feet above mean sea level) measured on 4 May 2006. Depth estimates were generally accurate to the nearest 1/10th foot. All areas in the project area were sounded in this manner to ensure complete coverage. Special attention was paid to sounding areas of the lake where depressions or high-bottoms occurred since these contribute disproportionately to basin morphometry.

Geographic Positioning: Horizontal positions were determined by differential GPS employing US Coast Guard low-frequency beacons for differential correction. Precision was sub-meter. Positions were collected in Universal Transverse Mercator format (meters UTM; NAD 1983). Data were displayed in relation to aerial photo coverages obtained from the Wisconsin DNR GIS Data Repository (http://www.dnr.state.wi.us/maps/gis/). Since these GIS data were found to be incorrectly georeferenced for this area, we georeferenced aerial photos by correction using three known ground points at determined by recording >100 ground truth position points.

Sediment sounding: Because depths were frequently shallower than can be accurately sounded using bottom discriminating sonar, we sound sediment surface and soft sediment depth using an extensible, calibrated, aluminum sounding rod. The rod was 0.6365 inches in diameter (5/8") and had a conical point of 0.6140 inches in height. The surface area of the sounding rod was therefore 0.6915 square inches. The sounding rod was used to find the sediment surface as the depth at which minimum detectable resistance was found. The hard bottom was located by penetrating the sediment with approximately 50 pounds of force which resulted in detection of a hard bottom that would resist penetration by 72 psi. This corresponds to the resistance of hard sand or gravel. Flocculent sediment thickness was found by difference between the depth of the soft sediment surface and the hard bottom. Sounding were performed at >100 separate points and the position of each was recorded using differential GPS as above.

Geostatistics: After data collection, data were filtered and maps created using standard geostatistical software. High- and low-pass filters were used in sonar depth data series to remove sonar readings that were unrealistically high or low. These were rare and can generally be recognized by estimating apparent bottom slope and removing data causing slopes to be physically unsupportable. Shore contours were set to a depth of "zero" in the lake depth maps or to the elevation of the lake level in the maps of site

elevation. Although high data-density required little interpolation, interpolation was accomplished by natural neighbor methods. Maps were created using geostatistical software and were concatenated with public GIS data. GIS coverages are supplied for all the maps discussed below.

Results

The Lake George environment presented several survey challenges owing to the very shallow depths across the lake, the large amount of soft sediment accumulated, the aquatic macrophytes in the eastern part of the basin, and the frequent occurrences of highly sonar reflective substrates (rock and other debris) buried beneath soft sediments. We therefore used both sonar and rod sounding to determine bottom contours since each are most accurate under differing conditions. Sonar readings are most accurate at bottom depth >3.5 feet (where multiple echos are infrequent and damped by software) and rod soundings are most accurate at bottom depths <7 feet (where bottom surface soundings are most repeatable). We therefore supply both map types for use in this work.

Rod soundings: Figures 1-3 and Figures 6 and 7. Show map coverages created from rod soundings. The salient features are a large shallow submerged point projecting in a southwesterly then southerly direction projecting from the point of land at the eastern shore of the entry point of the Kinnickinnic River, a meandering streambed near the western shore and a depression near the eastern shore of the lake (Figure 1). The origin of this depression can be seen in Figure 2 because the hard bottom bathymetry shows a drowned, meandered stream channel along the east bank of the lake. At some point in the past, the Kinnickinnic River meandered to the east of its current bed and carved a deep channel near the east shore of Lake George.

Due to damming, sediment accumulation has been quite substantial in Lake George (Figure 3) with soft sediment depths of 6-8 feet quite common. Sediments have substantially filled both the current river channel near the western shore and the drowned river channel near the eastern shore (Figure 3).

Sonar soundings: Sonar readings indicate a similar bottom form but are less accurate than the rod soundings in the eastern part of the lake basin due to shallow depths and interference from macrophytes. Sonar soundings show the current river channel distinctly but lose resolution in the shallow parts of the lake basin (Figure 4). Contours of the sonar coverage are found in Figure 5.

Elevation coverages: Figures 6 and 7 show the rod sounding coverages (Figures 1 and 2) calculated in elevation above mean sea level. These data were corrected using the lake level referenced to the top of the hydroelectric dam (865.5 feet above MSL). These coverages are identical to those in Figures 1 and 2 except for their units and differences in contour lines because they are drawn offset by 0.5 feet in depth (i.e., the first contour is drawn at the 0.5 foot level shown in Figures 1 and 2).

Figure 1. Bathymetric map showing depth in feet to the sediment surface of Lake George, Wisconsin. Depths were determined by sediment penetration measurements. Coverages were created using natural neighbor methods.

N
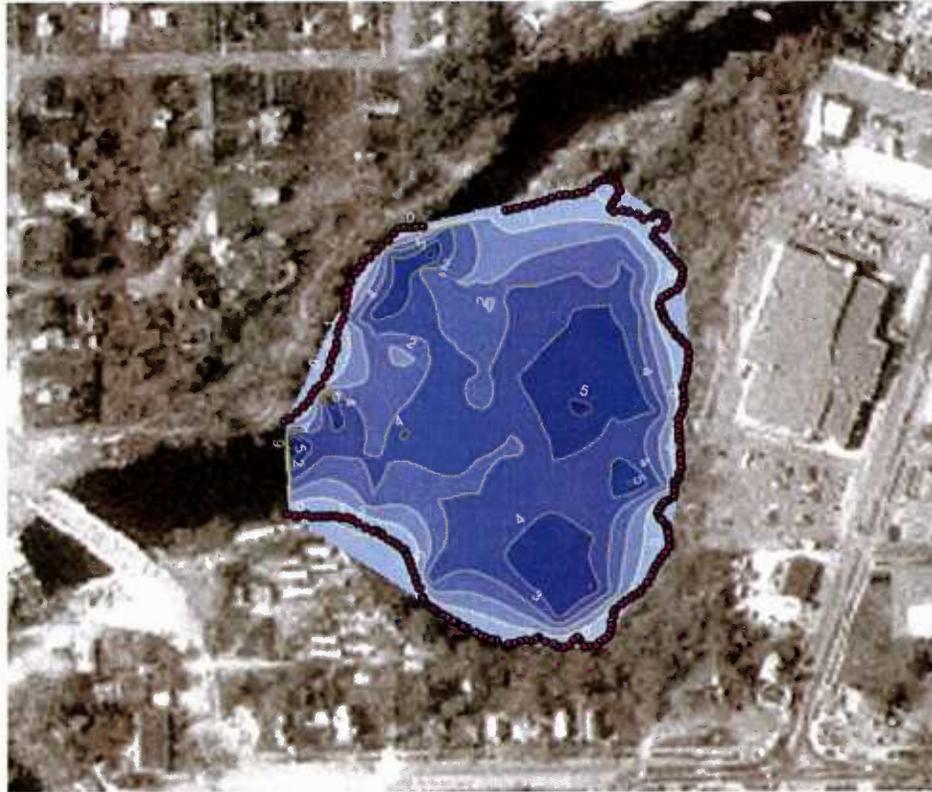
Bathymetry (feet)
z_surf_mm
z_surf_nn_cont

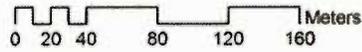| <VALUE>	z_surf_nn_cont
0 - 1	CONTOUR
1.000000001 - 2	—— 0 - 1
2.000000001 - 3	—— 2
3.000000001 - 4	—— 3
4.000000001 - 5	—— 4
5.000000001 - 6	—— 5
6.000000001 - 7	—— 6

Meters
0 20 40   80   120   160

Figure 2. Bathymetric map showing depth of hard bottom in Lake George, Wisconsin. Depths were determined by sediment penetration measurements. Coverages were created using natural neighbor methods.

Bathymetry (feet)
z_hard_nn_cont
hard_bot_nn_z

z_hard_nn_cont hard_bot_nn_z

CONTOUR	<VALUE>
0 - 1	0 - 1
2	1.000000001 - 2
3	2.000000001 - 3
4	3.000000001 - 4
5	4.000000001 - 5
6	5.000000001 - 6
7	6.000000001 - 7
8	7.000000001 - 8
9	8.000000001 - 9
10	9.000000001 - 10
11	10.00000001 - 11
	11.00000001 - 12

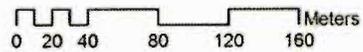N

Meters
0 20 40 80 120 160

Table 3. Bathymetric map showing sediment thickness in Lake George, Wisconsin. Thicknesses were determined by difference between sediment surface measurements and depths to hard bottom using sediment penetration measurements (Figures 1 and 2). Coverages were created using natural neighbor methods.

Bathymetry (feet)
thickness_ft
thickness_ft_cont

thickness_ft	thickness_ft_cont
<VALUE>	CONTOUR
0 - 1	—— 0 - 1
1.000000001 - 2	—— 2
2.000000001 - 3	—— 3
3.000000001 - 4	—— 4
4.000000001 - 5	—— 5
5.000000001 - 6	—— 6
6.000000001 - 7	—— 7
7.000000001 - 8	

N

Meters
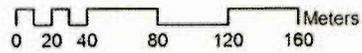0 20 40   80   120   160

Figure 4. Bathymetric map showing depth in feet to the sediment surface of Lake George, Wisconsin, determined by bottom discriminating sonar. Coverage was created using natural neighbor methods.

Bathymetry (feet)
sonar_depth_cl

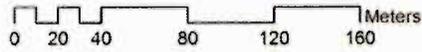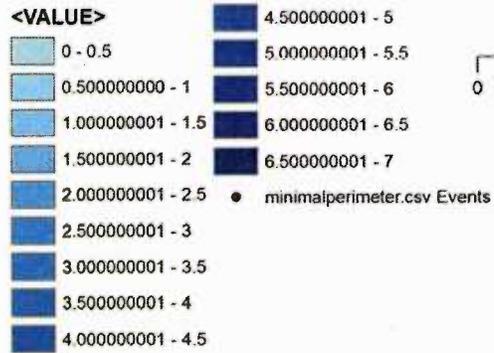| `<VALUE>`	
0 - 0.5	4.500000001 - 5
0.500000000 - 1	5.000000001 - 5.5
1.000000001 - 1.5	5.500000001 - 6
1.500000001 - 2	6.000000001 - 6.5
2.000000001 - 2.5	6.500000001 - 7
2.500000001 - 3	● minimalperimeter.csv Events
3.000000001 - 3.5	
3.500000001 - 4	
4.000000001 - 4.5	

0 20 40 80 120 160 Meters

Figure 5. Bathymetric map showing contours of depth in feet to the sediment surface of Lake George, Wisconsin. Depths were determined by sonar. Coverage was created using natural neighbor methods. Sonar measurements were most accurate above 3.5 feet of depth.

Figure 6. Bathymetric map showing elevation in feet above MSL of the sediment surface of Lake George, Wisconsin. Depths were determined by sediment penetration measurements. Coverages were created using natural neighbor methods.

Bathymetry (feet)
elev_sed_top
sed_top_elev

elev_sed_top sed_top_elev

CONTOUR	<VALUE>
859 - 860	858.6879883 - 859
861	859.0000001 - 860
862	860.0000001 - 861
863	861.0000001 - 862
864	862.0000001 - 863
865	863.0000001 - 864
	864.0000001 - 865
	865.0000001 - 866

N

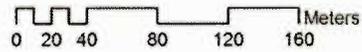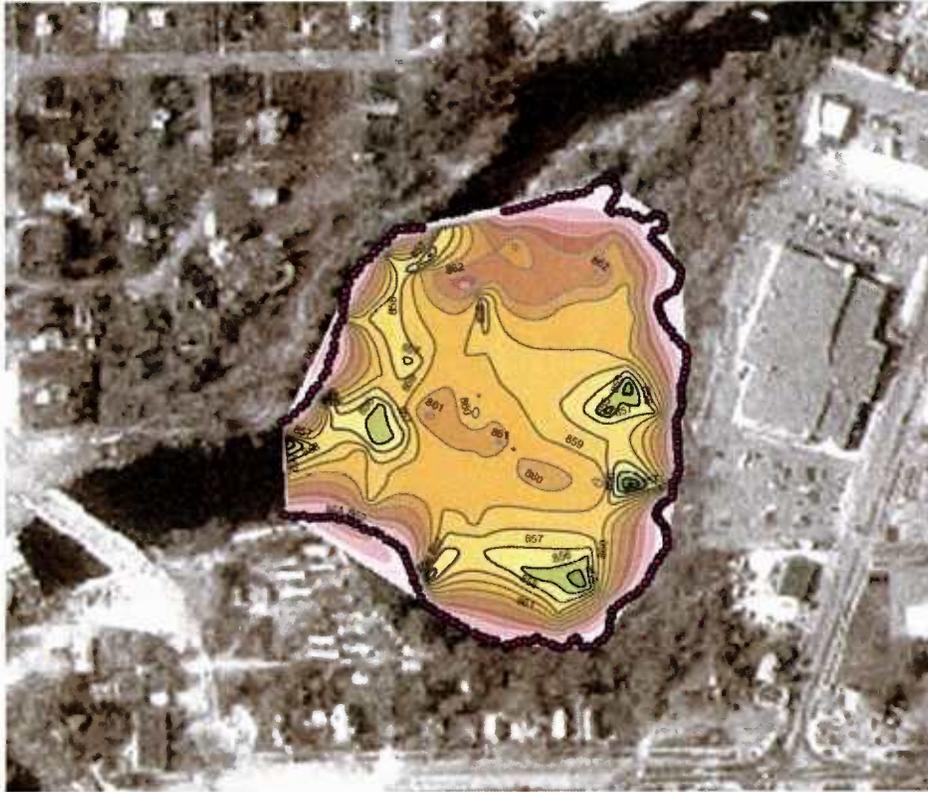Meters
0 20 40   80   120   160

Figure 7. Bathymetric map showing elevation in feet above MSL of the hard bottom surface of Lake George, Wisconsin. Depths were determined by sediment penetration measurements. Coverages were created using natural neighbor methods.

Bathymetry (feet)
elev_hard_bot_cont
hard_bot_elev

elev_hard_bot_cont hard_bot_elev

CONTOUR	<VALUE>
854 - 855	853.6386108 - 854
856	854.0000001 - 855
857	855.0000001 - 856
858	856.0000001 - 857
859	857.0000001 - 858
860	858.0000001 - 859
861	859.0000001 - 860
862	860.0000001 - 861
863	861.0000001 - 862
864	862.0000001 - 863
865	863.0000001 - 864
	864.0000001 - 865
	865.0000001 - 866

N

0 20 40   80   120   160 Meters