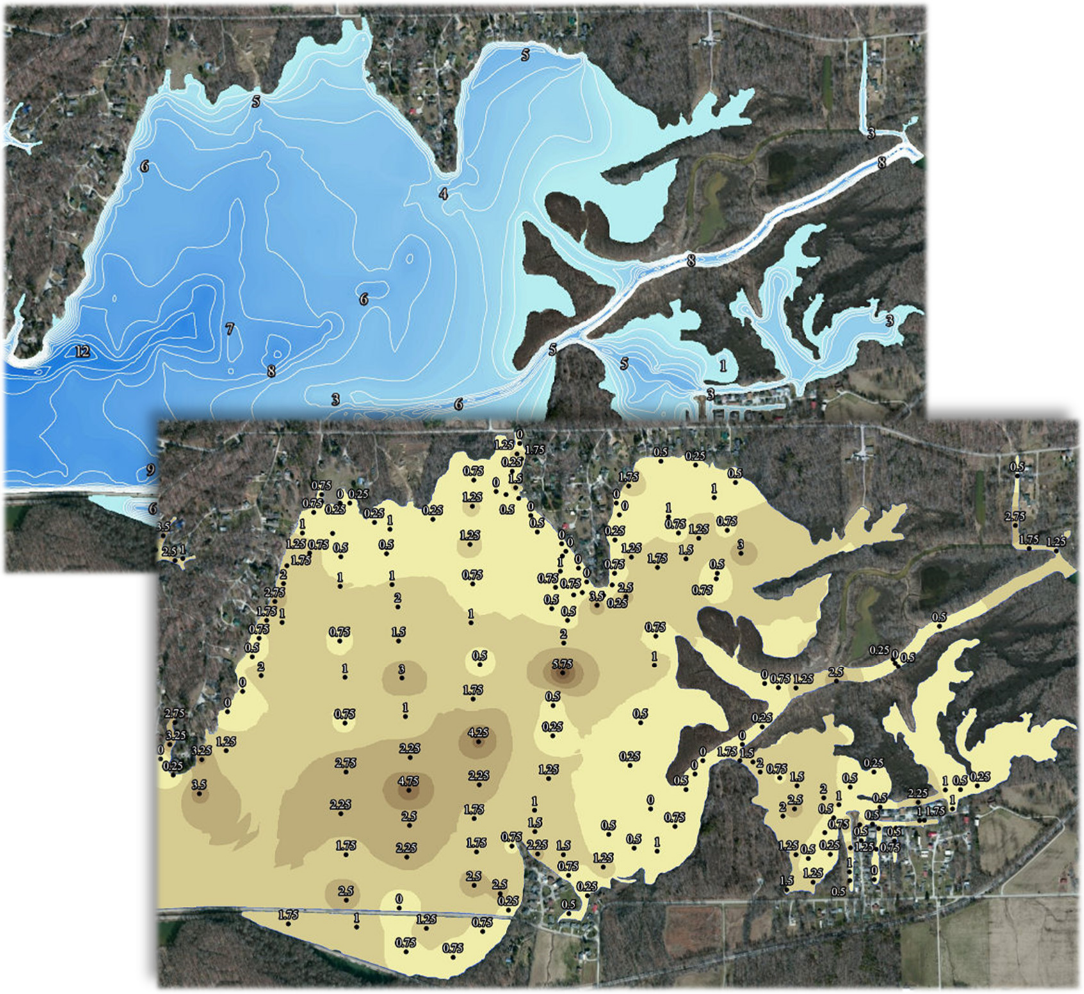

12/11/2014

Soft-Sediment Depths, Bathymetry, and Volumetric Updates of Lake Lemon, IN

ReMetrix LLC

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INTRODUCTION

Water volume and soft-sediment data for large lakes need periodic updating, as eroded soils are continuously transported and deposited within lake basins. Excessive amounts of aquatic vegetation can also contribute to the buildup of organic sediments on the lake bottom. Lake management assumptions made using incorrect bathymetric or soft-sediment information can significantly affect the results obtained.

In 2003 the Lake Lemon Conservancy District (LLCD) contracted ReMetrix to conduct a GIS-based mapping assessment of soft-sediment, bathymetry, and volumetric information for Lake Lemon. The Conservancy District uses the data from the assessment to help inform lake management decisions. In particular, soft-sediment thickness data within the littoral zone are important for planning sediment removal activities. Prior to 2003, the most recent full-lake assessment of Lake Lemon was a 1973 study performed by the USGS.

In 2014, LLCD recognized a need to update the soft-sediment, bathymetry, and volumetric data for the lake. Changes had been observed in the eleven years since the previous assessment, and updated data were needed to continue planning and refining lake management activities in the most accurate way possible. ReMetrix was again contracted to conduct an updated assessment using methodologies consistent with the 2003 survey, plus calculate the volumetric changes in soft-sediment and water since the previous assessment.

The maps and tables resulting from this updated assessment can be found in the Appendix.

Approach

Project activities involved two components: data acquisition and data assembly/interpretation. Two types of data were collected during data acquisition: bathymetric (water depth) data and soft-sediment thickness data. Bathymetric data were collected lake-wide. The contract required a maximum of 150-meters between hydroacoustic transects. Soft-sediment thickness points were typically collected in waters shallower than 8-feet, although some points were collected in waters up to 15-feet water depth in a few areas. The contract required collection of a minimum of 420 soft-sediment thickness measurements.

Data were collected using the technologies described below. The most recent aerial imagery was acquired from the Indiana Spatial Data Portal to cover the project area, both for planning and map display purposes. All data collection and analyses were performed by ReMetrix.

METHODOLOGY

Data Acquisition – General Information

The primary data collection tools used for this mission were a digital scientific echosounder linked to a sub-meter Differential Global Positioning System (DGPS) receiver, and a graduated sediment probe for collecting soft-sediment thickness data.

Fieldwork was conducted from June 2-12, 2014 with some breaks for scheduling and weather. Equipment was mounted on an 18-foot watercraft. Lake conditions were mostly calm during the days of fieldwork. Lake surface level readings were taken at the start of each day of fieldwork.

Field maps were used to increase efficiency and accuracy of the data collection. Field maps were prepared prior to data acquisition and underwent review and approval by representatives of LLCD. The hydroacoustic transect locations and spacing used in 2003 were used again to ensure comparable data. Once the transects were collected and a preliminary bathymetric analysis performed, the 2003 soft-sediment point sampling locations and spacing were again reviewed one final time against the preliminary 2014 bathymetric map to ensure they were still located within the current lake boundaries and areas of greatest sampling interest. During the initial planning meeting with LLCD, an additional 51 soft-sediment sampling locations were added to the 2003 sediment sampling total, most of which were added in the eastern end of the lake. These new sediment sampling points were also reviewed against the 2014 preliminary bathymetric map to ensure they were placed in appropriate areas for sampling.

The final hydroacoustic sampling transects and soft-sediment point sampling locations are shown on the maps in the Appendix.

Lake Water Level Elevation During the Project

The gauge used to establish the 629.7 ft lake level elevation for the 2003 survey has since disappeared. Pictures of the gauge, and the watermarks on the gauge, indicate that the gauge is well calibrated to the ~630 ft elevation of the spillway. Given that the lake was built in the 1950s, we assume that the geodetic datum to which the 630 ft elevation was referenced was NGVD 1929. This is supported by the 629.99 feet (mean, n=3) spillway elevation established by 2014 Bledsoe survey (see Appendix for information).

The 2014 Bledsoe survey establishes the NGVD29 to NAVD88 offset as -0.38 to -0.39 US Survey Feet (n=6). Thus, the gauge level in the 2003 survey, referenced to NAVD88, would have been 629.3 feet (respecting significant digits in the original number).

All elevations expressed for the bathymetry and lake level in this report, henceforth, reference the NAVD888 vertical datum.

The hydroacoustic data for the 2014 project were collected at a lake surface elevation of 629.61-ft, based on the on the Bledsoe survey. The lake level on the day of the day of the hydroacoustic survey was recorded with a white chisel mark on the boat ramp at Riddle Point (see Fig 1). The soft-sediment thickness data were collected approximately a week later when the water level was 1-inch higher than the hydroacoustic survey level (Fig 1). The soft-sediment data measurements were corrected back to the 629.61 water elevation prior to data analyses.

Figure 1. Water level mark for the 2014 hydroacoustic survey on the Riddle Point boat ramp (white chisel mark) which correlates to 629.61-feet of water elevation. The blue line mark on the PVC pole shows the +1-inch water level during soft-sediment sampling.

Hydroacoustic Data Acquisition

A BioSonics digital scientific echosounder was used to collect the data for water depth and lake morphology. The acoustic signal from the echosounder is reflected back to the boat when the signal encounters a material density change in the water column. As an example, the lake bottom is a substantial density change as compared to the water column, and thus the acoustic signal bounces strongly off the lake bottom.

Aquatic vegetation also represents a density change within the water column. Dense, submersed plant beds can return a strong echo, mimicking the bottom (a “false bottom” echo). A digital scientific echosounder enables proper adjustment of acoustic signals and receiver sensitivity to minimize plant detection, which results in a more accurate depiction of the actual lake bottom. Considering the presence of aquatic vegetation in Lake Lemon—especially in the lake’s east end—the ability to eliminate the possibility of false bottom interpretation is important for the overall accuracy of the final maps and calculations.

The acoustic signal response is digitally recorded along with a corresponding coordinate from the DGPS beacon. The echosounder was set to ping ten times per second, often resulting in thousands of data points along each transect. For this survey pre-planned transects were spaced at an average of 100 meters apart. Some canals and channels were also included in the eastern portion of the lake (see transect layout map in the Appendix).

Soft-Sediment Thickness Data Acquisition

Soft-sediment thickness survey information was acquired using a sediment probe and a GPS enabled computer with custom-programmed data collection software. The use of GPS facilitates accurate navigation to planned sampling locations. Soft-sediment thickness survey points were selected to correlate with the 2003 study. A total of 440 soft-sediment thickness points were surveyed throughout the lake, 20 more than initially planned in the project scope. While most of the sediment survey points were distributed within 50-feet of the shoreline, five crossing transects were also included in the eastern end of the lake in order to better assess sedimentation in that area.

Water depth and soft-sediment thickness were measured at each sediment probe sampling point. Soft-sediment thickness was measured in 0.25-foot increments. The sediment probe for this project is pictured in Figure 2. The probe was lowered in the water column until it encountered the top of the sediment surface, determining the water depth. The probe was then pushed into the soft-sediment layer until it met resistance. Resistance is defined as the sediment not yielding to moderate pressure applied by arm strength. No mechanical means were used to push the sediment probe into the sediment.

Figure 2. Sediment depth sampling probe (orange markings are 1-foot increments). Sediment from a sample point is visibly clinging to the probe in the photo at right.

DISCUSSION OF ANALYSES

Bathymetric Analysis

It was necessary to complete the bathymetric analysis prior to the soft-sediment volume analysis. The reason is that without the top of the sediment surface defined, the soft-sediment thickness contours are unable to be created.

The digital echosounder data were processed using commercial and proprietary software designed for hydroacoustic data analyses. The software algorithms are able to identify the bottom depth for each point collected along each transect. The software analysis process was supervised by an analyst to ensure that the analysis proceeded correctly. Also, depth readings from the echosounder were double-checked against physical water depth readings gathered during the sediment thickness probing.

The bathymetric data were plotted on a basemap of the lake using Geographic Information Systems (GIS) software. A bathymetric TIN model ("triangulated irregular network") was created using geostatistical software designed for surface modeling. Inverse distance weighting (IDW) was the statistical technique used to create the TIN model. The 1-foot bathymetric contour intervals used in this study were established in the project proposal. Again, as in all stages described in this report, the software analysis was supervised by an analyst to ensure that the analysis proceeded properly. Contours shallower than 10-feet of water depth were derived from the TIN. Contours deeper than 10-feet of water depth were derived from the TIN and occasionally experienced supplemental visual-editing to ensure that the contours properly followed the channel visible in the hydroacoustic data. The resulting bathymetric contours were smoothed and checked for positive correlation to the field data. The completed bathymetric map is shown in the Appendix.

Creation of the bathymetric contours in a true geographic framework is necessary for calculating water volumes on an entire lake basis and on an individual contour interval basis. Using a true geographic framework is also necessary in order to integrate the data with other lake and regional data sets.

Results of the bathymetric calculations indicate that 13,523 acre-feet (4,406,488,932 gallons) of water are in the lake (at a lake water-level of 629.61 feet).

Within the context of this project, the bathymetric data will be useful in interpreting which areas near shore currently have the least water depth. The data collected are not exhaustive, but should aid greatly in such determinations.

It should be noted that thermoclines can become established in Lake Lemon during summer months, and the exact depth of the thermocline can vary seasonally and from year to year. The table of water volume in one-foot depth increments, provided with this project, can also be used to calculate the water volume above a thermocline in any given season as needed.

Comparison to the 2003 Bathymetric Survey

As noted earlier, ReMetrix collected the same hydroacoustic transects and used the same analysis methods for the 2003 and 2014 hydroacoustic data. This enables an 'apples-to-apples' comparison between the two assessment years that is not complicated by differences in how the data were analyzed.

Between 2003 and 2014 the surface acres of the lake decreased. In order to make sure the numbers are comparable some changes needed to be made. There were two areas that were included in the 2003 study that were not included in the 2014 study. First is 10 acres of Bean Blossom Creek, and the second is the 21 acres of the cove leading into Shuffle Creek. The original acreage for 2003 is 1,513 acres. Removing these two areas from 2003 leaves 1,482 acres. Comparing this to 2014's 1,432 acres we see a -3.4% change. This 50-acre reduction in surface acres is due primarily to the expansion of the islands in the eastern section of the lake. The shoreline for 2014 was created using the most recent aerial imagery available for the area, as well as field data and field observations made during the project.

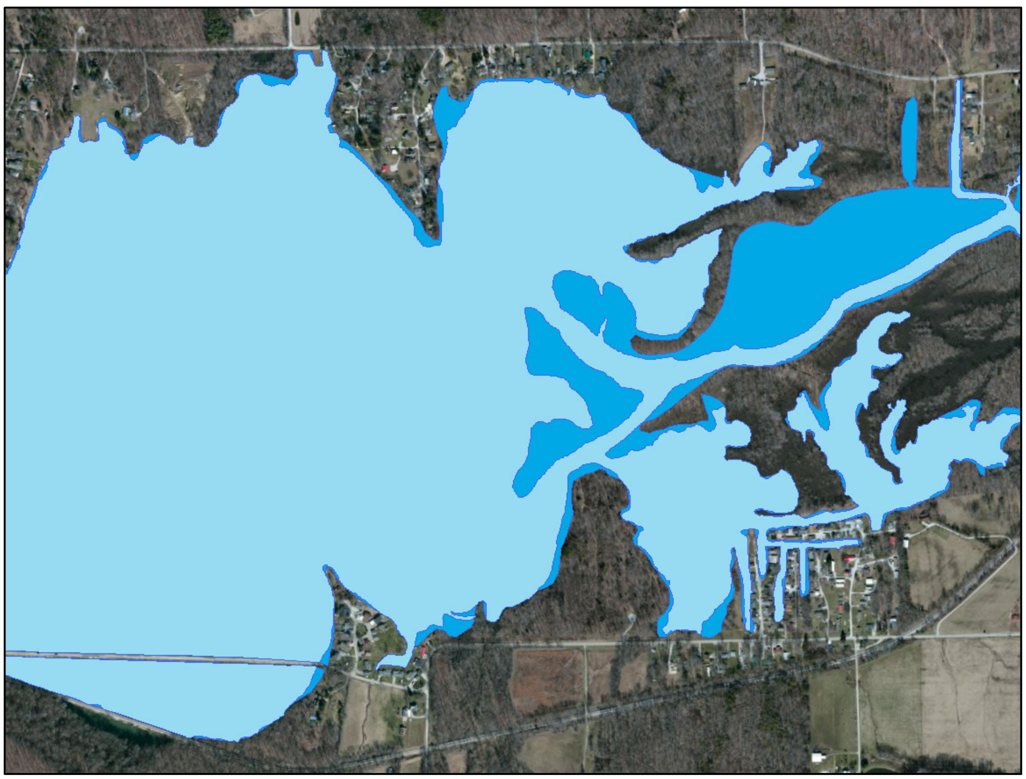

Figure 3. The differences in the shoreline of the eastern end of the lake can clearly be seen in this image. The dark blue represents the shoreline from 2003, the lighter blue is the 2014 shoreline.

The total water volume of the lake has also decreased from 2003 to 2014. In 2003, 14,420 acre-feet of water were in the lake as compared to 13,523 in 2014. This represents a loss of 897 acre-feet of water holding capacity, a -6.2% change. The increase in soft-sediment in the lake (see following sections), the reduction of surface acres, and a reduction in the maximum measured water depth from 30-feet in 2003 to 27-feet in 2014 are considered to be the major contributors to the decrease in total lake water volume.

While most of the bathymetric changes are subtle, there was one significant change on the western end of the lake near Cemetery Island. A portion of the channel that runs to the northwest of the island has almost completely filled in. This particular change is most likely the result of a significant hydrologic event (e.g., flood-level flow in the lake) as opposed to gradual sediment deposition.

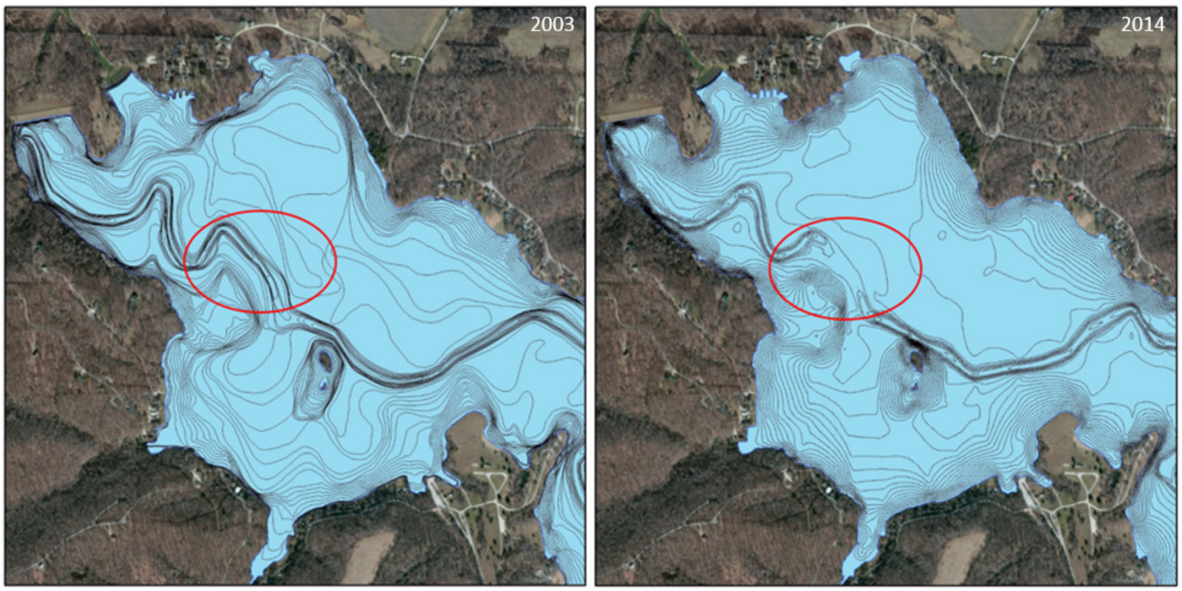

Figure 4. The images above highlight the change in the channel between 2003 (left) and 2014 (right).

One important part of this study was to produce comparable results. To that end, the same data processing methods and interpolation techniques were used for both the 2003 and 2014 studies. However some localized variations that are more pronounced than expected may still be evident. Localized variations are unavoidable due to the need to judiciously guide the data interpolation process in areas characterized by both sparse field data and known variability of lake bottom morphology.

An example is the degree of slope in the lake bottom from shallow water to deeper water. Field data from two adjacent hydroacoustic transects definitively indicate that the lake transitions from shallow to deep across a distance of 100 meters. However no field data exists between the transects to inform the interpolation process how steep the transition should be from shallow to deep. The transition could plausibly be a steep drop-off, a gradual slope, or even an undulating gradation. Sometimes in these localized situations the interpolation process will create a lake bottom model that is highly unlikely or clearly inconsistent with surrounding lake morphology. The ideal solution is to obtain more field data in the affected area, but that is not always possible or within the project scope and budget. The alternative solution is for the data analyst to supplement some localized, realistic 'guidance points' in the affected area to help the model produce a more realistic result. This situation is unavoidable because blindly accepting a clearly incorrect result of the model is imprudent. In fact this scenario illustrates the benefit of having a 'supervised' modeling process with a data analyst in comparison to an 'unsupervised,' fully automated process that does not include an experienced analyst to interpret and refine the model output when needed. So while the refined model may still be not an exact representation of the slope in the above example, and while some areas may be influenced to varying degrees by the judgment of the analyst, the supervised result is still much improved over the unsupervised result and is therefore a superior model to use.

For this project specifically, the difference between the 2003 and 2014 models is a factor of two different data analysts providing the guidance points in affected areas. The analyst who added the points in 2003 is no longer with the company, and the analyst in 2014 has significantly more lake mapping experience and created some different guidance points in some areas. The visual effect of these improvements in some areas can be significant although the overall statistical effect to the lake volume is relatively insignificant (likely <1%). The only way to obtain a more exact determination of the lake bottom morphology and volume is to conduct a more intensive field survey, use more advanced hydroacoustic equipment, and/or possibly attempt other data modeling techniques, none of which were scoped for this project since a key aim was to fairly closely replicate the project that was conducted in 2003.

Soft-Sediment Thickness Analysis

In 2003 two methods were attempted to model the soft-sediment thickness data: inverse distance weighting (IDW) and kriging. While both have strengths and weaknesses, the IDW model was chosen to be the more reliable of the two after comparisons to the raw data. Final maps were produced from the IDW model results. In order to make sure the 2014 results were comparable ReMetrix again used the IDW model to perform the analysis.

The final maps and table of soft-sediment thickness determinations from the IDW model are found in the Appendix. The relevant field data points are overlain as a reference layer on the maps.

The volume of the soft-sediment layer was calculated from the top of the sediment surface (the sediment-water interface) to the "hard pan" layer at the base of the soft-sediment layer. Using the IDW sediment-thickness model, this volume was calculated within a maximum of 8-foot water depth and shallower, but in some places the calculations extended deeper than 8-feet of water depth if the data permitted. The total soft-sediment volume within the modeled region is 1,548,372 yd^3 (960 acre-feet).

Using the data grid layer created from the soft-sediment data, the distribution and volume of soft-sediment can be calculated within different water-depth intervals or within specific sub-basins (such as coves).

Within the context of this project, the soft-sediment thickness data will be useful in interpreting the areas shallower than 8-feet of water depth that currently have the greatest accumulation of sediment. The data collected are not exhaustive but should aid greatly in such determinations throughout the lake.

Comparison to the 2003 Soft-Sediment Survey

In 2003 ReMetrix reported the lake had 1,398,618 yd^3 of soft-sediment within the regions of the lake that were sampled. In 2014 ReMetrix has calculated that there are now 1,548,372 yd^3 of soft-sediment in the same regions, a 9.7% increase (+149,754 yd^3).

There are a number of observations that highlight to this increase in soft-sediment volume. Since the 2003 survey the soft-sediments in the zone of analysis have shown a 12% increase in average bed thickness, from 0.88 ft (2003) to 0.99ft (2014). Second, the lake is slowly trending toward being shallower overall as sedimentation progresses, which translates into a greater area of the lake being included in the soft-sediment analysis zone. The soft-sediment analysis zone is within areas shallower than 15 ft of water depth, and increased 3.5% from 1,271.3 acres to 1,315.6 acres between 2003 to 2014 (Fig 5).

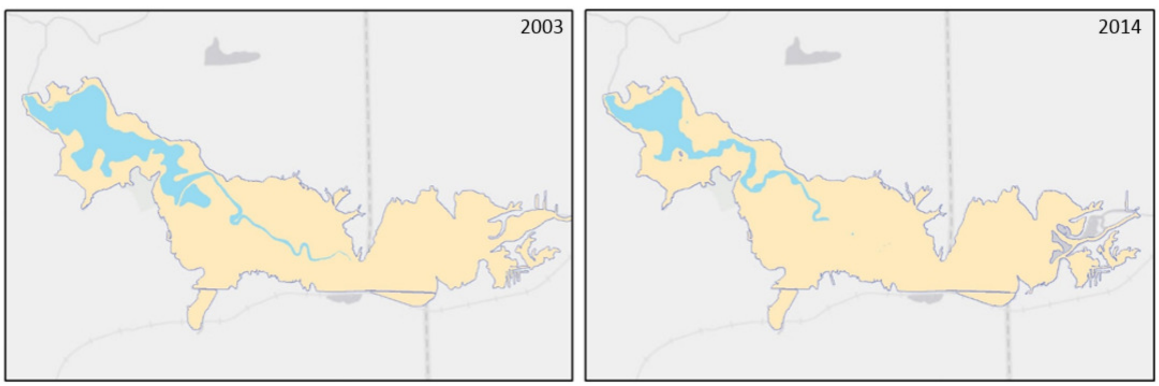

Figure 5. The differences between the 15ft water depth analysis zone can be easily seen between 2003 (left) and 2014 (right).

Data Delivery and Metadata

All final GIS data layers for this project are being provided to the Lake Lemon Conservancy District for use in their local GIS system. The data are provided as ESRI ArcGIS format in the following geographic coordinate system:

Projection: State Plane Indiana West
Datum: NAD83
Spheroid: GRS1980
Units: feet

Metadata are included with each of the digital GIS layers provided.

Other project-relevant metadata

- All project field data were collected June 2-12, 2014. The soft-sediment point sampling locations and hydroacoustic transects were planned in advance with LLCD.
- The hydroacoustic data were collected using a digital system integrating a BioSonics DT 420 kHz transducer and a sub-meter Trimble AG162 DGPS beacon.
- Water depth contours for the GIS layers were created by interpolating the values between the field data points into an inverse distance weighting (IDW) TIN using ESRI Geostatistical Analyst. Contours shallower than 10-feet of water depth were derived from the TIN. Contours deeper than 10-feet of water depth were derived from the TIN and occasionally underwent supplemental visual-editing to ensure that the contours properly followed the channel visible in the hydroacoustic data. The resulting bathymetric contours were smoothed and checked for positive correlation to the field data.
- Soft-sediment thickness results are an ESRI grid raster file. The grid displayed on the Soft-Sediment Thickness map in the Appendix was created using inverse distance weighting (IDW) of the field data points. No vector contours were derived from the grid because the raster grid values indicate the soft-sediment thickness, and can be queried using ArcGIS. The color-coded depths on the map depict where the vector contours would be located.
- Volume calculations were derived by using ESRI 3D Analyst to create a TIN surface followed by querying the statistics for each specified depth interval within the TIN.
- ReMetrix obtained the aerial imagery used in the project from a free web-site operated by Indiana University. However, ReMetrix does not own the imagery and is thus unable to redistribute it. For this reason, the background imagery was not delivered with the final project data.

The data and calculations delivered for this project are presented to the best of ReMetrix's knowledge. Interpolated and/or statistically modeled data are inherently estimates, by definition, so no warranty or guarantee is made concerning such information presented herein. ReMetrix makes every reasonable effort to provide the most accurate data within the scope of the project and the capabilities of the technology and associated equipment used to conduct the project. In effect, these data create a snapshot of project-area characteristics and conditions, but should at no time be interpreted as unequivocally accurate in every instance (particularly in regard to interpolated data).

Appendix

2014 Water Volume Calculations for Lake Lemon, IN

	Surface Sq. Meters	Surface Acres	Acre Feet	Cumulative Acre Feet	Cubic Meters	Cumulative Cubic Meters
***Surface - 1 Foot**	5,795,741.24	1,432.16	1,400.07	13,523.15	1,726,962.11	16,680,555.07
1 Foot-2 Foot	5537015.707	1,368.23	1,340.75	12,123.08	1,653,787.53	14,953,592.96
2 Foot-3 Foot	5315363.074	1,313.45	1,280.92	10,782.33	1,579,987.02	13,299,805.44
3 Foot-4 Foot	5053111.51	1,248.65	1,212.81	9,501.41	1,495,981.68	11,719,818.42
4 Foot-5 Foot	4764456.049	1,177.32	1,133.22	8,288.60	1,397,804.01	10,223,836.74
5 Foot-6 Foot	4409772.541	1,089.68	1,048.79	7,155.38	1,293,668.06	8,826,032.73
6 Foot-7 Foot	4080985.774	1,008.43	970.34	6,106.59	1,196,897.92	7,532,364.66
7 Foot-8 Foot	3774666.591	932.74	900.31	5,136.25	1,110,519.87	6,335,466.75
8 Foot-9 Foot	3,513,766.22	868.27	837.12	4,235.93	1,032,576.12	5,224,946.88
9 Foot-10 Foot	3,263,212.07	806.36	747.47	3,398.81	921,986.42	4,192,370.76
10 Foot-11 Foot	2,792,670.33	690.08	638.51	2,651.34	787,586.05	3,270,384.34
11 Foot-12 Foot	2,380,693.76	588.28	539.62	2,012.84	665,614.05	2,482,798.29
12 Foot-13 Foot	1,992,603.73	492.38	437.22	1,473.22	539,301.18	1,817,184.24
13 Foot-14 Foot	1,555,142.65	384.28	335.40	1,036.00	413,706.03	1,277,883.06
14 Foot-15 Foot	1,168,650.53	288.78	248.84	700.60	306,936.66	864,177.03
15 Foot-16 Foot	853,600.15	210.93	172.89	451.76	213,261.88	557,240.38
16 Foot-17 Foot	556,321.55	137.47	110.50	278.87	136,302.54	343,978.49
17 Foot-18 Foot	346,309.19	85.57	64.48	168.37	79,529.65	207,675.95
18 Foot -19 Foot	184,019.55	45.47	36.15	103.89	44,596.31	128,146.30
19 Foot -20 Foot	111,608.90	27.58	24.00	67.74	29,597.52	83,549.99
20 Foot -21 Foot	83,290.00	20.58	17.95	43.74	22,146.78	53,952.47
21 Foot -22 Foot	62,525.40	15.45	12.66	25.79	15,617.55	31,805.70
22 Foot -23 Foot	40,727.67	10.06	7.57	13.12	9,333.70	16,188.14
23 Foot -24 Foot	21,528.52	5.32	3.42	5.56	4,216.81	6,854.45
24 Foot -25 Foot	7,375.01	1.82	1.39	2.14	1,719.08	2,637.63
25 Foot -26 Foot	4,067.84	1.01	0.64	0.75	783.88	918.55
26 Foot -27 Foot	1,325.48	0.33	0.11	0.11	134.67	134.67

Mean Depth (Feet)
9.3

1 cubic meter = 35.3146666 cubic feet
1 cubic meter = 264.1720512 gallons
1 acre foot = 325,851.4318891 gallons

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2014 Sediment Volume Calculations for Lake Lemon, IN

Bathymetric Elevation	Surface Sq. Meters	Surface Acres	Cubic Meters	Cubic Yards	Acre Feet	Mean Depth Within Interval
***Surface - 1 Foot**	156,635.3	38.7	52,959.8	69,269.2	42.9	1.1
1 Foot-2 Foot	179,343.8	44.3	46,562.9	60,902.3	37.7	0.9
2 Foot-3 Foot	151,387.3	37.4	51,939.4	67,934.5	42.1	1.1
3 Foot-4 Foot	197,391.0	48.8	66,745.2	87,300.0	54.1	1.1
4 Foot-5 Foot	225,087.2	55.6	77,997.3	102,017.2	63.2	1.1
5 Foot-6 Foot	289,058.7	71.4	94,143.0	123,135.1	76.3	1.1
6 Foot-7 Foot	328,311.7	81.1	104,839.5	137,125.6	85.0	1.0
7 Foot-8 Foot	352,222.5	87.0	101,936.0	133,328.0	82.6	0.9
8 Foot-9 Foot	313,493.2	77.5	92,873.0	121,474.0	75.3	1.0
9 Foot-10 Foot	306,893.9	75.8	118,675.0	155,221.9	96.2	1.3
10 Foot-11 Foot	505,449.4	124.9	141,818.4	185,492.5	115.0	0.9
11 Foot-12 Foot	369,580.0	91.3	82,699.5	108,167.5	67.0	0.7
12 Foot-13 Foot	200,516.3	49.5	59,355.8	77,634.9	48.1	1.0
13 Foot-14 Foot	228,186.9	56.4	55,627.0	72,757.8	45.1	0.8
14 Foot-15 Foot	136,061.4	33.6	35,637.0	46,611.7	28.9	0.9
TOTAL SUM	**3,939,618**	**974**	**1,183,809**	**1,548,372**	**960**	

Mean Depth of Sedimention (Feet)
0.99

1 square meter = 0.0002471 acres
1 cubic meter = 35.3146666 cubic feet
1 cubic meter = 1.3079506 cubic yards
1 cubic meter = 0.0008107 acre feet

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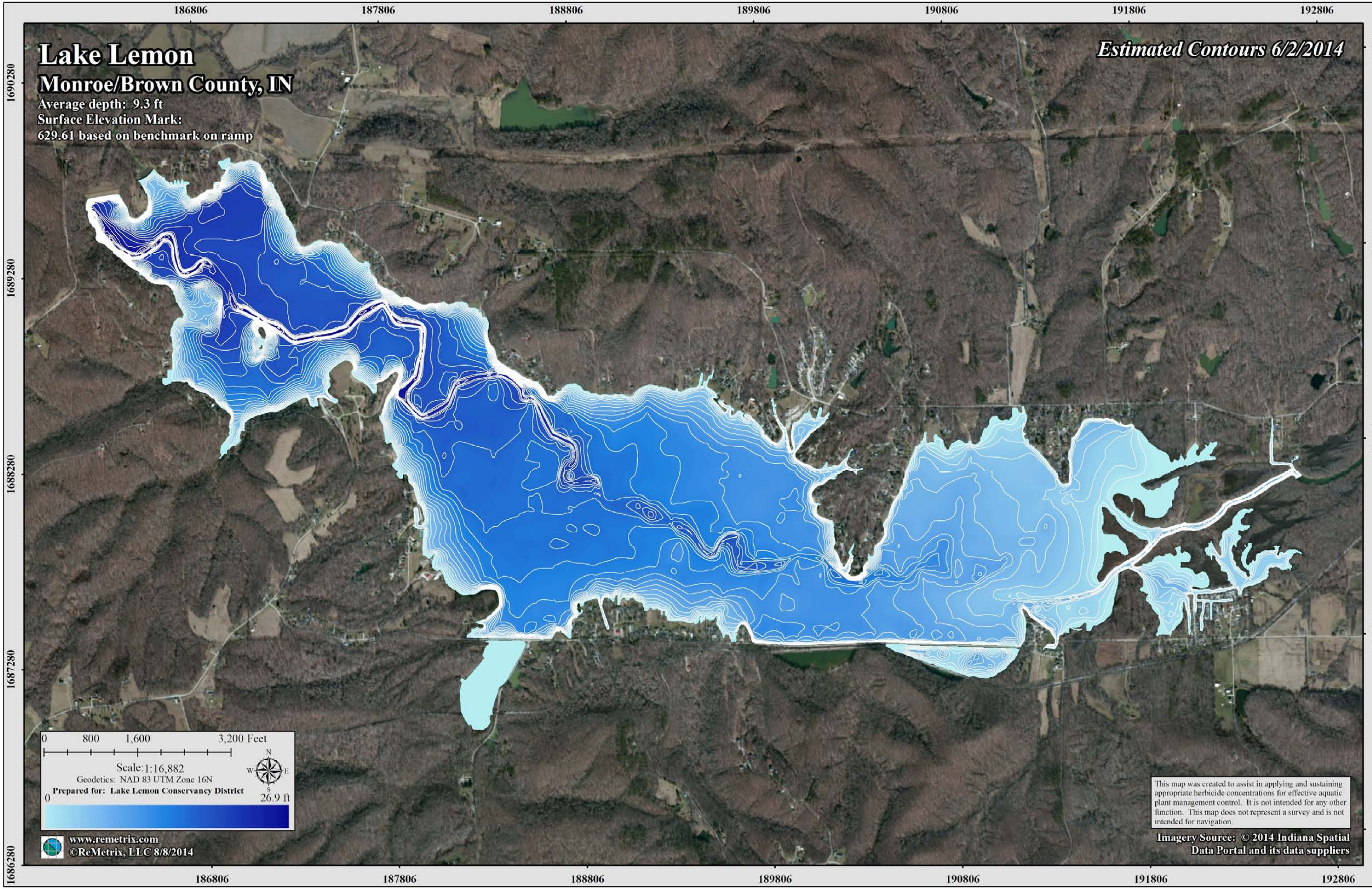
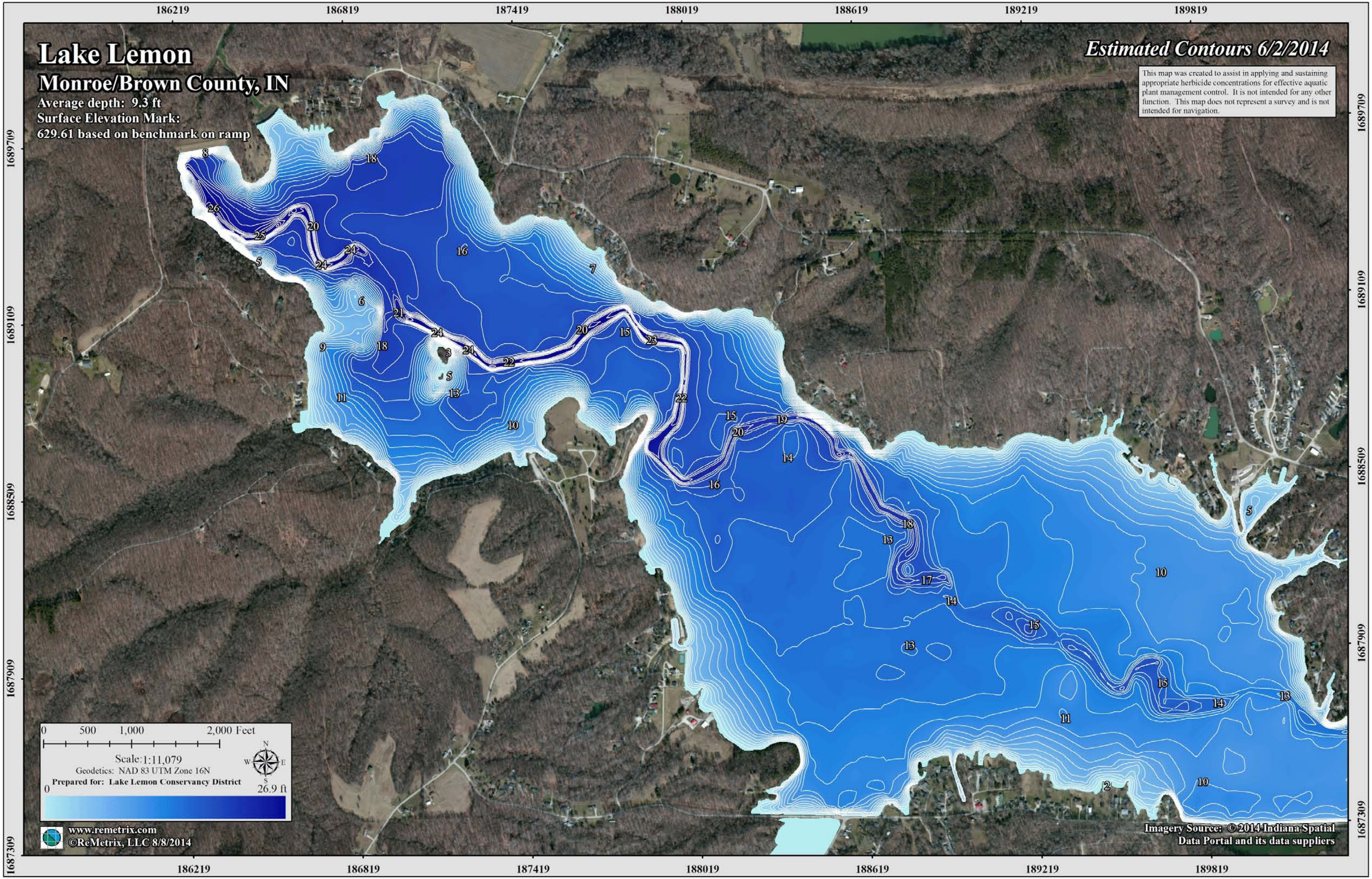


Lake Lemon
Monroe/Brown County, IN
Average depth: 9.3 ft
Surface Elevation Mark:
629.61 based on benchmark on ramp
Estimated Contours 6/2/2014
186806
187806
188806
189806
190806
191806
192806
1690280
1689280
1688280
1687280
1686280
0
800
1,600
3,200 Feet
Scale: 1:16,882
Geodetics: NAD 83 UTM Zone 16N
Prepared for: Lake Lemon Conservancy District
N
S
E
W
0
26.9 ft
www.remetrix.com
©ReMetrix, LLC 8/8/2014
This map was created to assist in applying and sustaining appropriate herbicide concentrations for effective aquatic plant management control. It is not intended for any other function. This map does not represent a survey and is not intended for navigation.
Imagery Source: © 2014 Indiana Spatial Data Portal and its data suppliers



Lake Lemon
Monroe/Brown County, IN
Average depth: 9.3 ft
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629.61 based on benchmark on ramp
Estimated Contours 6/2/2014
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186219
186819
187419
188019
188619
189219
189819
1689709
1689109
1688509
1687909
1687309
0 500 1,000 2,000 Feet
Scale: 1:11,079
Geodetics: NAD 83 UTM Zone 16N
Prepared for: Lake Lemon Conservancy District
0
26.9 ft
N
W
E
S
www.remetrix.com
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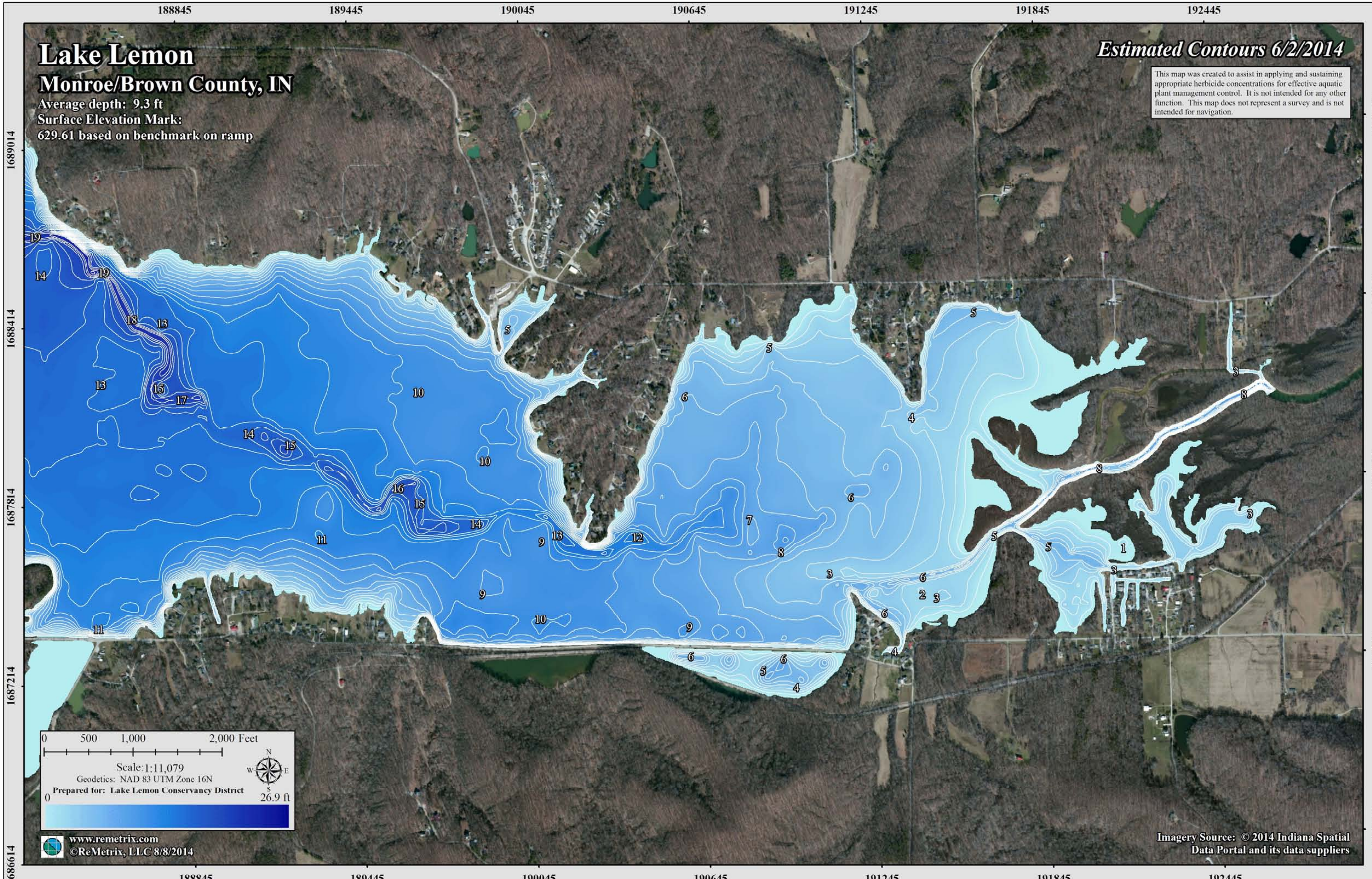
Imagery Source: © 2014 Indiana Spatial Data Portal and its data suppliers


Lake Lemon
Monroe/Brown County, IN
Average depth: 9.3 ft
Surface Elevation Mark:
629.61 based on benchmark on ramp
Estimated Contours 6/2/2014
This map was created to assist in applying and sustaining appropriate herbicide concentrations for effective aquatic plant management control. It is not intended for any other function. This map does not represent a survey and is not intended for navigation.
188845
189445
190045
190645
191245
191845
192445
1689014
1688414
1687814
1687214
1686614
0 500 1,000 2,000 Feet
Scale: 1:11,079
Geodetics: NAD 83 UTM Zone 16N
Prepared for: Lake Lemon Conservancy District
N
E
S
W
0
26.9 ft
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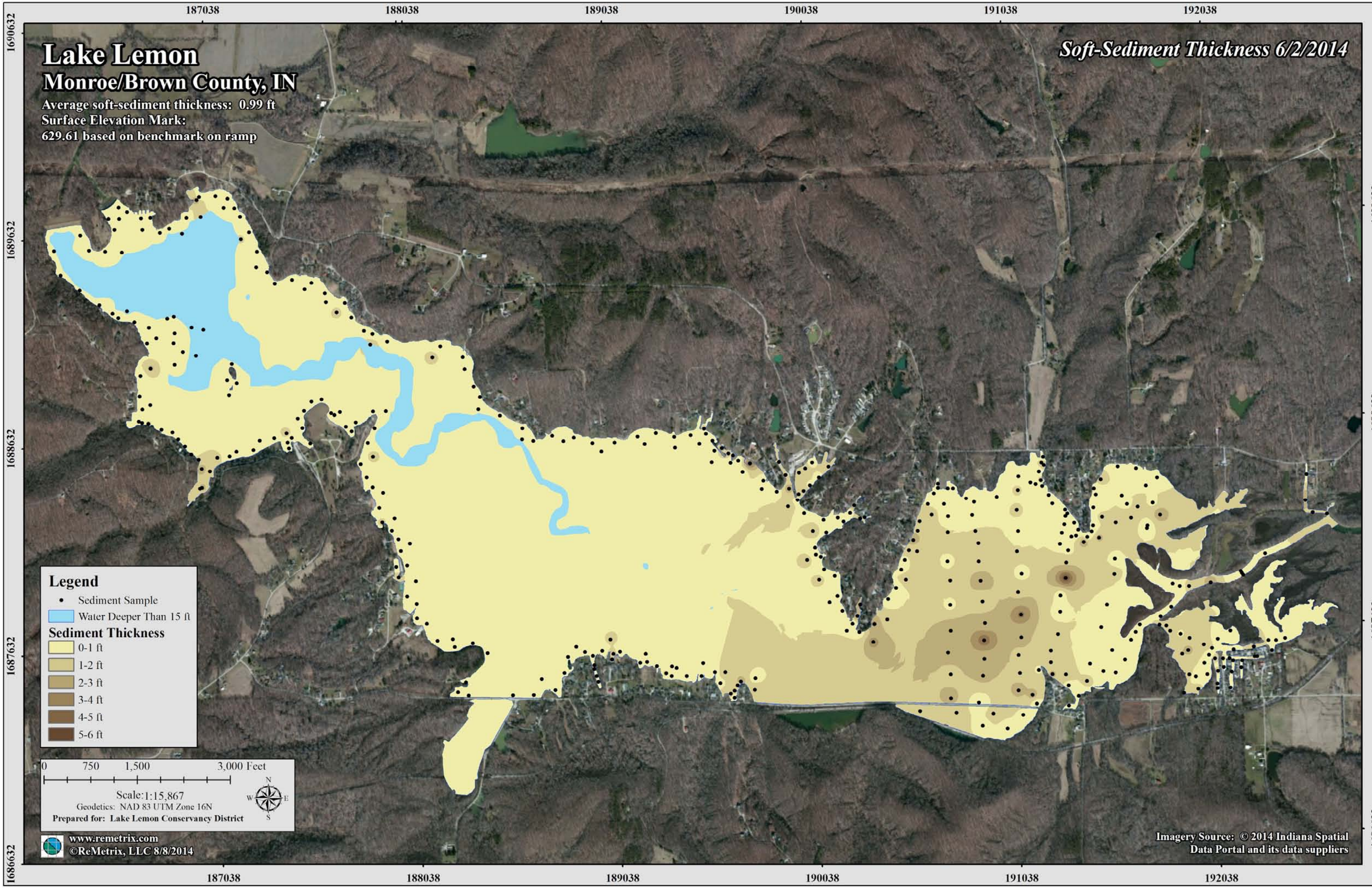

Lake Lemon
Monroe/Brown County, IN
Average soft-sediment thickness: 0.99 ft
Surface Elevation Mark:
629.61 based on benchmark on ramp
Soft-Sediment Thickness 6/2/2014
187038
188038
189038
190038
191038
192038
1690632
1689632
1688632
1687632
1686632
Legend
Sediment Sample
Water Deeper Than 15 ft
Sediment Thickness
0-1 ft
1-2 ft
2-3 ft
3-4 ft
4-5 ft
5-6 ft
0 750 1,500 3,000 Feet
Scale: 1:15,867
Geodetics: NAD 83 UTM Zone 16N
Prepared for: Lake Lemon Conservancy District
N
W
E
S
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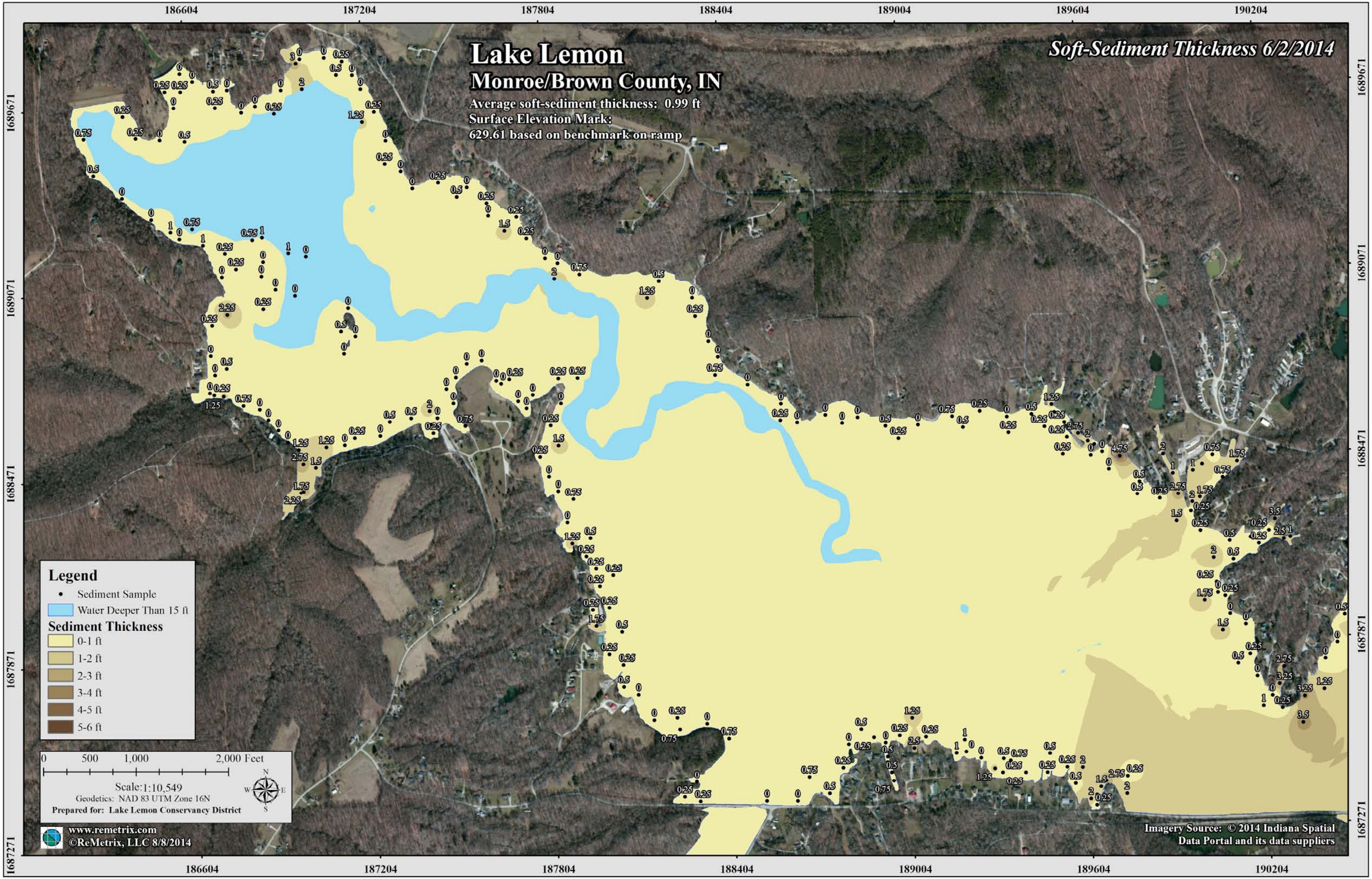
Imagery Source: © 2014 Indiana Spatial Data Portal and its data suppliers



Lake Lemon
Monroe/Brown County, IN
Average soft-sediment thickness: 0.99 ft
Surface Elevation Mark:
629.61 based on benchmark on ramp
Soft-Sediment Thickness 6/2/2014
Legend
Sediment Sample
Water Deeper Than 15 ft
Sediment Thickness
0-1 ft
1-2 ft
2-3 ft
3-4 ft
4-5 ft
5-6 ft
0 500 1,000 2,000 Feet
Scale: 1:10,549
Geodetics: NAD 83 UTM Zone 16N
Prepared for: Lake Lemon Conservancy District
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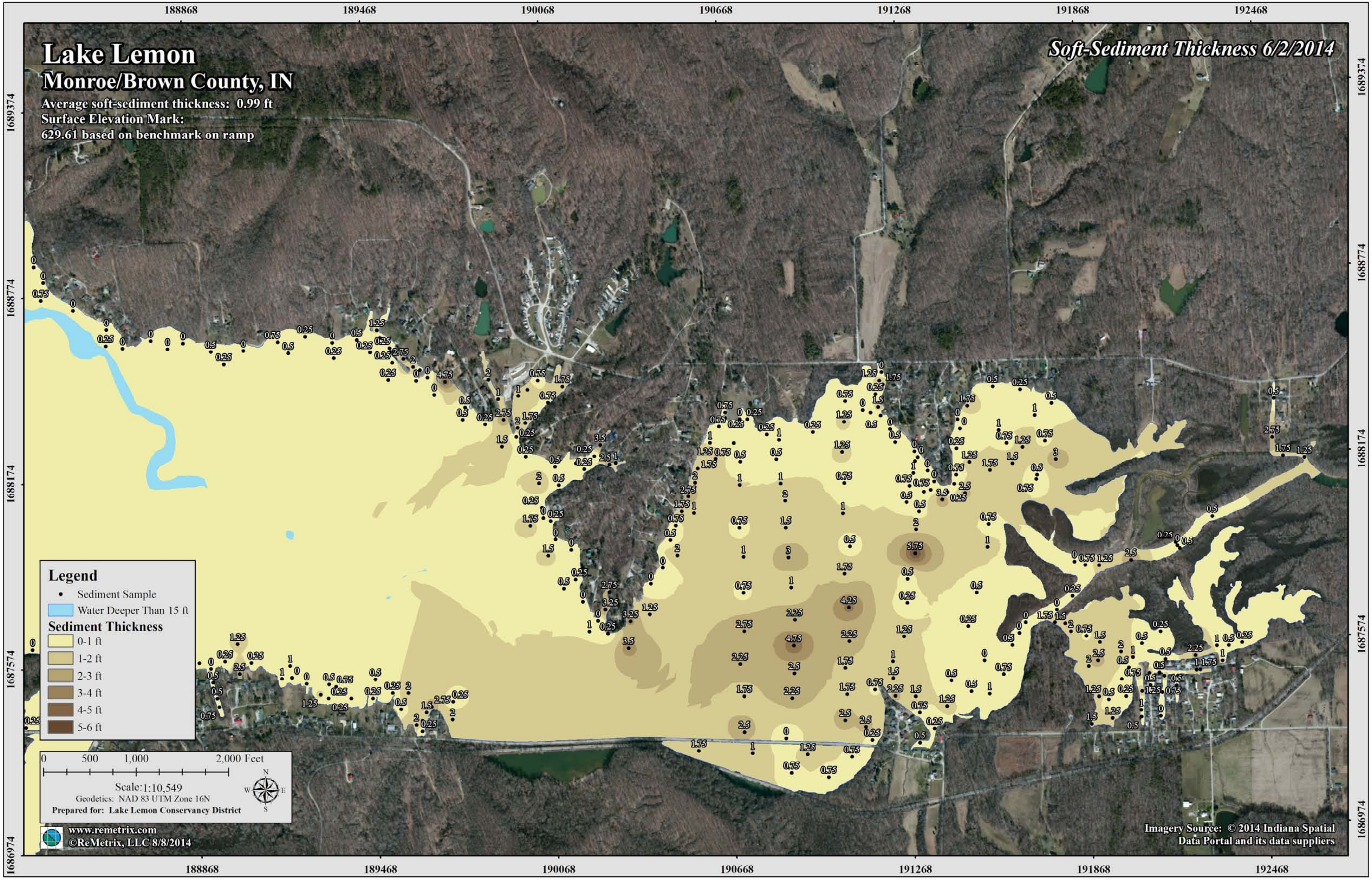
186604
187204
187804
188404
189004
189604
190204
1689671
1689071
1688471
1687871
1687271



Lake Lemon
Monroe/Brown County, IN
Average soft-sediment thickness: 0.99 ft
Surface Elevation Mark:
629.61 based on benchmark on ramp
Soft-Sediment Thickness 6/2/2014
Legend
Sediment Sample
Water Deeper Than 15 ft
Sediment Thickness
0-1 ft
1-2 ft
2-3 ft
3-4 ft
4-5 ft
5-6 ft
0 500 1,000 2,000 Feet
Scale: 1:10,549
Geodetics: NAD 83 UTM Zone 16N
Prepared for: Lake Lemon Conservancy District
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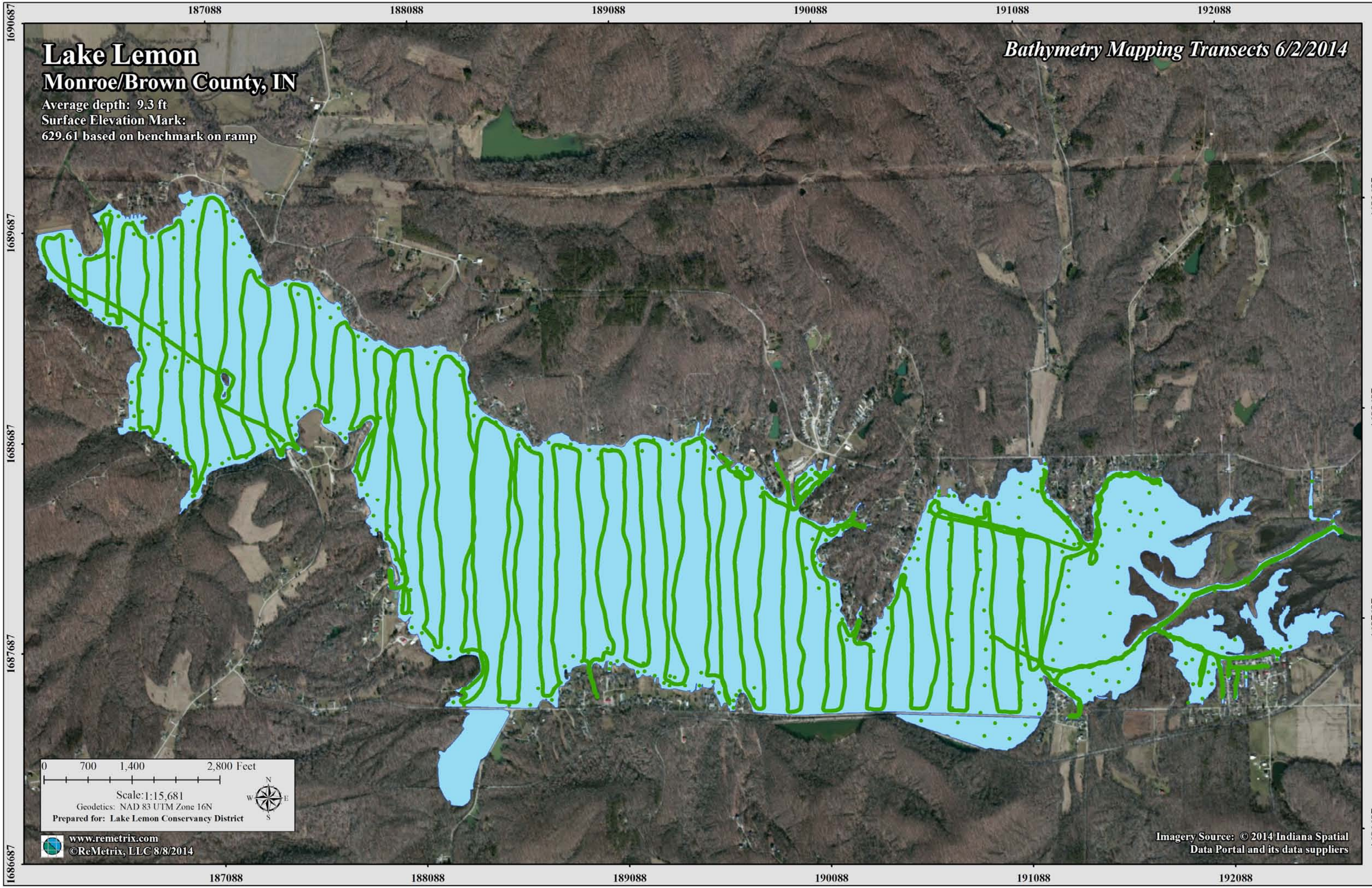
188868
189468
190068
190668
191268
191868
192468
1689374
1688774
1688174
1687574
1686974



Lake Lemon
Monroe/Brown County, IN
Average depth: 9.3 ft
Surface Elevation Mark:
629.61 based on benchmark on ramp
Bathymetry Mapping Transects 6/2/2014
187088
188088
189088
190088
191088
192088
1690687
1689687
1688687
1687687
1686687
0 700 1,400 2,800 Feet
Scale: 1:15,681
Geodetics: NAD 83 UTM Zone 16N
Prepared for: Lake Lemon Conservancy District
N
S
E
W
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Imagery Source: © 2014 Indiana Spatial Data Portal and its data suppliers

Bledsoe Riggert Guerrettaz
LAND SURVEYING · CIVIL ENGINEERING

LAKE LEMON BENCHMARK ELEVATION
SECTION 34, T10N, R1E, MONROE CO., INDIANA
JOB No. 8325
Client Name: LAKE LEMON CONSERVANCY DISTRICT

N

0 25 50 100
SCALE 1"=100'

NOTES:
1. FIELD WORK PERFORMED JUNE 4, 2014.

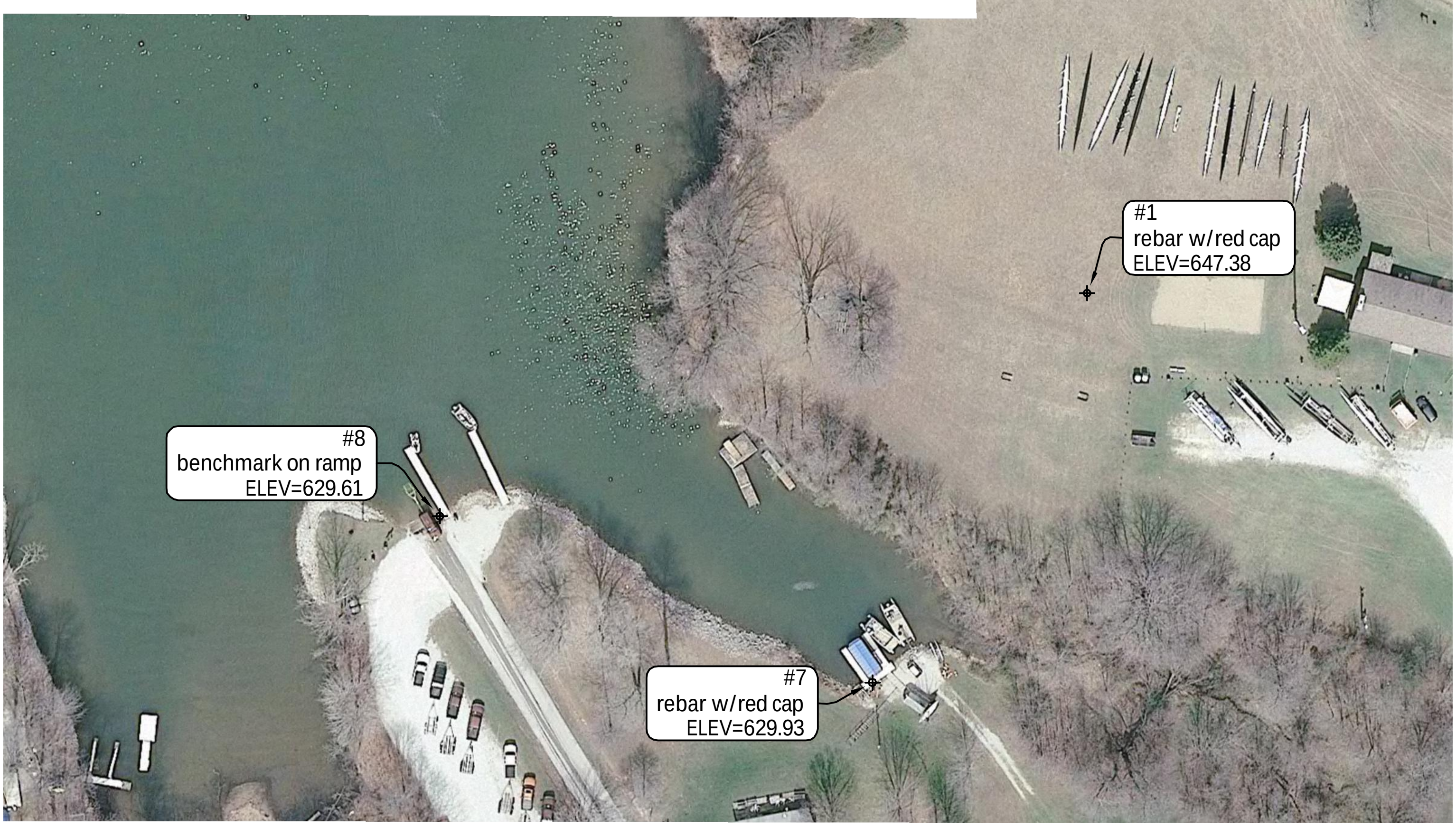
2. COORDINATES SHOWN HEREON ARE BASED UPON GRID NORTH ESTABLISHED FROM STATIC GPS OBSERVATIONS DATED JUNE 4, 2014 AND POST-PROCESSED USING OPUS (NGS ONLINE POSITIONING USER SERVICE). REFERENCE FRAME NAD83(2011) EPOCH 2010.0000, INDIANA STATE PLANE COORDINATES ZONE 1302 WEST, U.S. SURVEY FEET.

3. ELEVATIONS SHOWN HEREON ARE BASED UPON STATIC GPS OBSERVATIONS DATED JUNE 4, 2014. ELEVATIONS ARE TO NAVD88 (COMPUTED USING GEOID 12A), U.S. SURVEY FEET.

4. CONVERTED ELEVATIONS ARE ALSO SHOWN HEREON. ELEVATIONS WERE CONVERTED FROM NAVD 88 TO NGVD 29 WITH THE ORTHOMETRIC HEIGHT CONVERSION TOOL (VERTCON) AVAILABLE ON THE NGS WEBSITE.

CONTROL POINTS

#	NORTHING	EASTING	ELEV. (NAVD88)	ELEV. (NGVD29)	DESCRIPTION
1	1462992.0773	3142790.3942	647.38	647.76	rebar w/red cap
2	1463460.0727	3142784.6588	633.83	634.21	rebar w/red cap
7	1462778.5819	3142672.6307	629.93	630.31	rebar w/red cap
8	1462869.7760	3142435.3909	629.61	629.99	benchmark on ramp



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LAKE LEMON SPILLWAY BENCHMARKS
SECTION 28, T10N, R1E, MONROE CO., INDIANA
JOB No. 8325
Client Name: LAKE LEMON CONSERVANCY DISTRICT

N

0 25 50
SCALE 1"=50'

NOTES:
1. FIELD WORK PERFORMED JUNE 4, 2014.

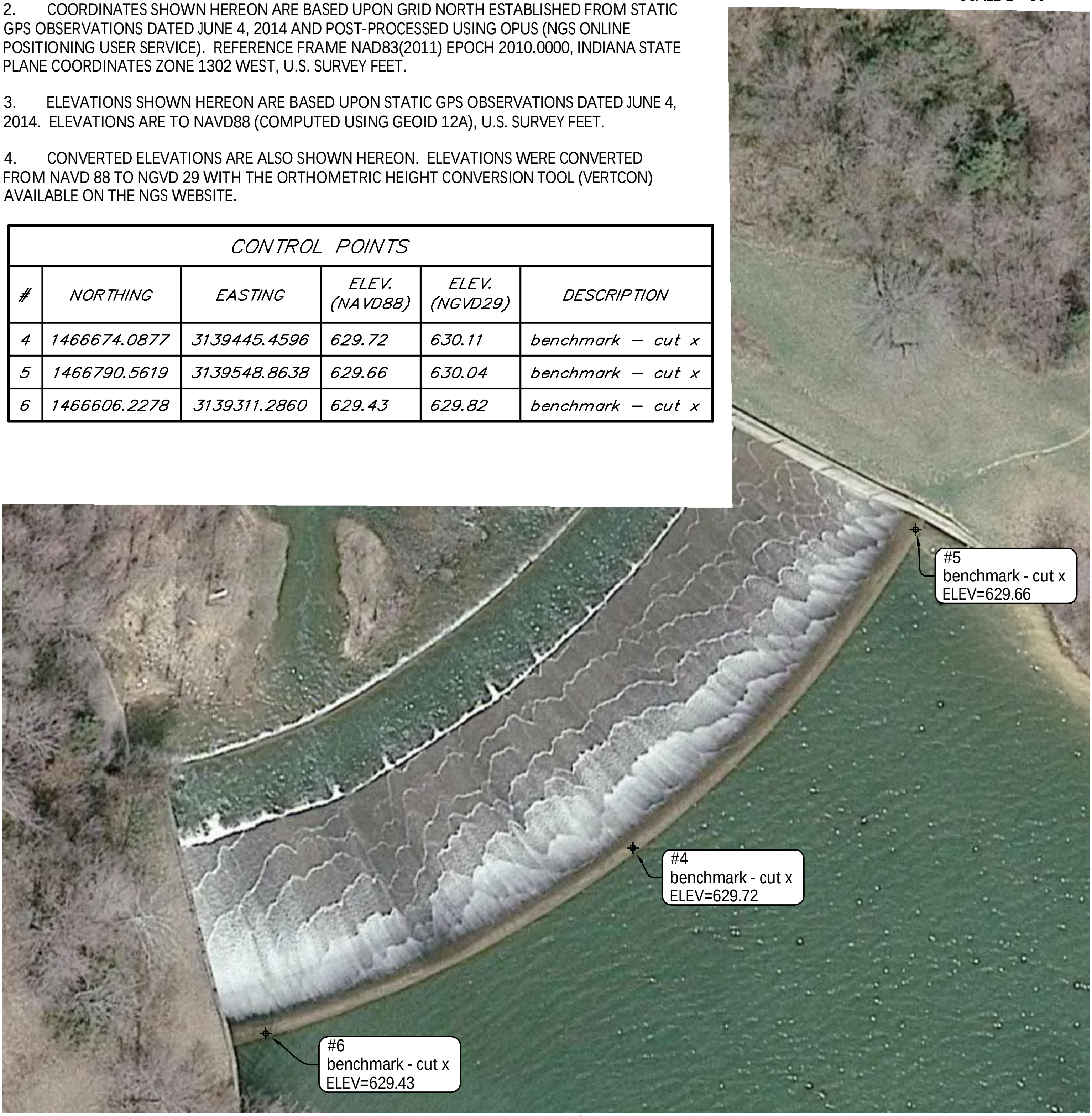
2. COORDINATES SHOWN HEREON ARE BASED UPON GRID NORTH ESTABLISHED FROM STATIC GPS OBSERVATIONS DATED JUNE 4, 2014 AND POST-PROCESSED USING OPUS (NGS ONLINE POSITIONING USER SERVICE). REFERENCE FRAME NAD83(2011) EPOCH 2010.0000, INDIANA STATE PLANE COORDINATES ZONE 1302 WEST, U.S. SURVEY FEET.

3. ELEVATIONS SHOWN HEREON ARE BASED UPON STATIC GPS OBSERVATIONS DATED JUNE 4, 2014. ELEVATIONS ARE TO NAVD88 (COMPUTED USING GEOID 12A), U.S. SURVEY FEET.

4. CONVERTED ELEVATIONS ARE ALSO SHOWN HEREON. ELEVATIONS WERE CONVERTED FROM NAVD 88 TO NGVD 29 WITH THE ORTHOMETRIC HEIGHT CONVERSION TOOL (VERTCON) AVAILABLE ON THE NGS WEBSITE.

CONTROL POINTS

#	NORTHING	EASTING	ELEV. (NAVD88)	ELEV. (NGVD29)	DESCRIPTION
4	1466674.0877	3139445.4596	629.72	630.11	benchmark – cut x
5	1466790.5619	3139548.8638	629.66	630.04	benchmark – cut x
6	1466606.2278	3139311.2860	629.43	629.82	benchmark – cut x



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Orthometric Height Conversion per National Geodetic Service VERTCON tool

Orthometric height conversion is performed by calculating the datum shift based from modeled values. The VERTCON tool can be found at the following web address: https://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl

Control Point #1 (Rebar with red cap)
Latitude: 39 15 47.22
Longitude: 086 24 43.75
NAVD 88 height: 197.321818644 meters = 647.38 feet
Datum shift(NAVD 88 minus NGVD 29): -0.117 meter
Converted to NGVD 29 height: 197.439 meters = 647.76 feet

Control Point #2 (Rebar with red cap)
Latitude: 39 15 51.85
Longitude: 086 24 43.78
NAVD 88 height: 193.191770384 meters = 633.83 feet
Datum shift(NAVD 88 minus NGVD 29): -0.117 meter
Converted to NGVD 29 height: 193.309 meters = 634.21 feet

Control Point #4 (Benchmark- Cut X on Spillway)
Latitude: 39 16 23.86
Longitude: 086 25 25.93
NAVD 88 height: 191.940563881 meters = 629.72 feet
Datum shift(NAVD 88 minus NGVD 29): -0.117 meter
Converted to NGVD 29 height: 192.058 meters = 630.11 feet

Control Point #5 (Benchmark- Cut X on Spillway)
Latitude: 39 16 25.00
Longitude: 086 25 24.61
NAVD 88 height: 191.92014224 meters = 629.66 feet
Datum shift(NAVD 88 minus NGVD 29): -0.117 meter
Converted to NGVD 29 height: 192.037 meters = 630.04 feet

Control Point #6 (Benchmark - Cut X on Spillway)
Latitude: 39 16 23.2
Longitude: 086 25 27.64
NAVD 88 height: 191.851866904
Datum shift(NAVD 88 minus NGVD 29): -0.117 meter
Converted to NGVD 29 height: 191.969 meters

Control Point #7 (Rebar with red cap)
Latitude: 39 15 45.12
Longitude: 086 24 45.26
NAVD 88 height: 192.003048006 meters = 629.93 feet
Datum shift(NAVD 88 minus NGVD 29): -0.117 meter
Converted to NGVD 29 height: 192.120 meters = 630.31 feet

Control Point #8 (Benchmark- Notch on Boat Ramp)
Latitude: 39 15 46.04
Longitude: 086 24 48.27
NAVD 88 height: 191.90520701 meters = 629.61 feet
Datum shift(NAVD 88 minus NGVD 29): -0.117 meter
Converted to NGVD 29 height: 192.022 meters = 629.99 feet

GPS Static Data Post Processing Report Generated by OPUS

Control Point #1

FILE: log0604r.tps OP1402415132992

NGS OPUS SOLUTION REPORT
========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

USER: roser@brgcivil.com DATE: June 10, 2014
RINEX FILE: log0155r.14o TIME: 15:46:54 UTC

SOFTWARE: page5 1209.04 master93.pl 022814 START: 2014/06/04 17:13:00
EPHEMERIS: igr17953.eph [rapid] STOP: 2014/06/04 21:20:30
NAV FILE: brdc1550.14n OBS USED: 11884 / 13082 : 91%
ANT NAME: TPSHIPER_II NONE # FIXED AMB: 86 / 96 : 90%
ARP HEIGHT: 2.000 OVERALL RMS: 0.017(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) IGS08 (EPOCH:2014.4241)

	NAD_83(2011)		IGS08	
X:	309453.621(m)	0.003(m)	309452.805(m)	0.003(m)
Y:	-4935327.307(m)	0.010(m)	-4935325.901(m)	0.010(m)
Z:	4015079.728(m)	0.014(m)	4015079.633(m)	0.014(m)
LAT:	39 15 47.22482	0.008(m)	39 15 47.25228	0.008(m)
E LON:	273 35 16.25365	0.004(m)	273 35 16.22335	0.004(m)
W LON:	86 24 43.74635	0.004(m)	86 24 43.77665	0.004(m)
EL HGT:	164.192(m)	0.017(m)	163.006(m)	0.017(m)
ORTHO HGT:	197.322(m)	0.031(m) [NAVD88 (Computed using GEOID12A)]		

	UTM COORDINATES UTM (Zone 16)	STATE PLANE COORDINATES SPC (1302 IN W)
Northing (Y) [meters]	4346140.385	445920.877
Easting (X) [meters]	550713.923	957924.428
Convergence [degrees]	0.37204685	0.42479093
Point Scale	0.99963167	1.00000796
Combined Factor	0.99960592	0.99998220

US NATIONAL GRID DESIGNATOR: 16SEJ5071346140(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DM4640	INCB INDOT COLUMBUS CORS ARP	N391150.495	W0855742.931	39555.2
DM5389	INPL PLAINFIELD CORS ARP	N394130.686	W0862339.850	47626.4
AI5432	IUCO INDIANA UNIVERSIT CORS ARP	N391026.605	W0863023.182	12809.4

NEAREST NGS PUBLISHED CONTROL POINT

KA0322	B 53	N390947.	W0862454.	11141.6

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

Control Point #2
FILE: log0604u.tps OP1402415215932

NGS OPUS-RS SOLUTION REPORT
========================

All computed coordinate accuracies are listed as 1-sigma RMS values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

USER: roser@brgcivil.com DATE: June 10, 2014
RINEX FILE: log0155u.14o TIME: 15:56:38 UTC

SOFTWARE: rsgps 1.37 RS91.prl 1.99.2 START: 2014/06/04 20:04:21
EPHEMERIS: igr17953.eph [rapid] STOP: 2014/06/04 21:22:36
NAV FILE: brdc1550.14n OBS USED: 10008 / 12267 : 82%
ANT NAME: TPSHIPER_II NONE QUALITY IND. 13.39/ 37.78
ARP HEIGHT: 2.000 NORMALIZED RMS: 0.478

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) IGS08 (EPOCH:2014.42428)

X:	309447.083(m)	0.003(m)	309446.267(m)	0.003(m)
Y:	-4935234.058(m)	0.009(m)	-4935232.652(m)	0.009(m)
Z:	4015187.557(m)	0.011(m)	4015187.462(m)	0.011(m)
LAT:	39 15 51.85018	0.007(m)	39 15 51.87764	0.007(m)
E LON:	273 35 16.22488	0.004(m)	273 35 16.19458	0.004(m)
W LON:	86 24 43.77512	0.004(m)	86 24 43.80542	0.004(m)
EL HGT:	160.064(m)	0.013(m)	158.878(m)	0.013(m)
ORTHO HGT:	193.194(m)	0.018(m) [NAVD88 (Computed using GEOID12A)]		

	UTM COORDINATES UTM (Zone 16)	STATE PLANE COORDINATES SPC (1302 IN W)
Northing (Y) [meters]	4346282.967	446063.510
Easting (X) [meters]	550712.308	957922.680
Convergence [degrees]	0.37205199	0.42479753
Point Scale	0.99963166	1.00000796
Combined Factor	0.99960656	0.99998285

US NATIONAL GRID DESIGNATOR: 16SEJ5071246282(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DL2760	INHC HENDRICKS COUNTY CORS ARP	N394524.651	W0863123.535	55503.3
DM4658	INSY SEYMOUR CORS ARP	N385736.280	W0855142.432	58373.6
DM4634	INAS ASHBORO CORS ARP	N392322.229	W0870639.629	61840.2
DM4652	INLN LINTON CORS ARP	N390146.987	W0870912.114	69170.4
DL5983	INSI SEILER INDY CORS ARP	N395109.598	W0860026.356	74003.4
DM4648	INGG INDOT GREENSBURG CORS ARP	N392135.415	W0853053.737	78105.2
DM4654	INPA PAOLI CORS ARP	N383357.706	W0862930.634	77838.3
DM4656	INSG SCOTTSBURG CORS ARP	N384103.137	W0854743.301	83700.8
DM5387	INPD PENDLETON CORS ARP	N395823.493	W0854610.772	96108.6

NEAREST NGS PUBLISHED CONTROL POINT Information on nearest mark is not available due to database connectivity issues or has restrictions on when or how it can be published.

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.