2017

Little Rock Lake – Sartell Pool Drawdown Feasibility Study

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Little Rock Lake Morphology and Background Information:

Little Rock Lake is a 1,270 acre shallow lake located in the North Central Hardwood Forest (NCHF) Ecoregion in a transitional area between forested and agricultural areas. The lake has an average depth of eight feet and a maximum depth of 16 feet. Based on 1998 data, a detailed bathymetric map was created from sonar data collected by Dr. Charles Nelson at St Cloud State University (Figure 1). More recent depth data has been taken for the project area on Little Rock Lake and the Mississippi River (Figure 2 below and figures 33-58 in the appendix). The lake basin began as shallow wetland, and evolved into a vegetated marsh following the construction of a dam on the Mississippi River downstream of the Little Rock Creek outlet in 1907. Water levels were raised in 1934, further evolving the lake basin from a vegetated marsh into a turbid impoundment. As a result of the dam installation, waters levels increased over 15 feet in some places with Little Rock Lake water levels increasing over seven feet. It has been over 100 years since the initial impoundment, and water levels have not been allowed to fluctuate more than six inches above or below 1014 MSL. Without the natural drought cycle with rising and falling water levels, valuable plant growth expansion is not possible. “The progression from marsh to an open water lake, had profound impact on the lakes biota…” including the “deposition of organic matter in the sediments” (2009 Sediment Core Study of Little Rock Lake, Benton County, Minnesota). The lack of shoreline stability plant growth would provide along with the land use changes from scrub/shrub, wetland, and forested, to now largely agricultural has contributed to the significant increase in nutrients, sediment loading, and algal blooms currently effecting Little Rock Lake.

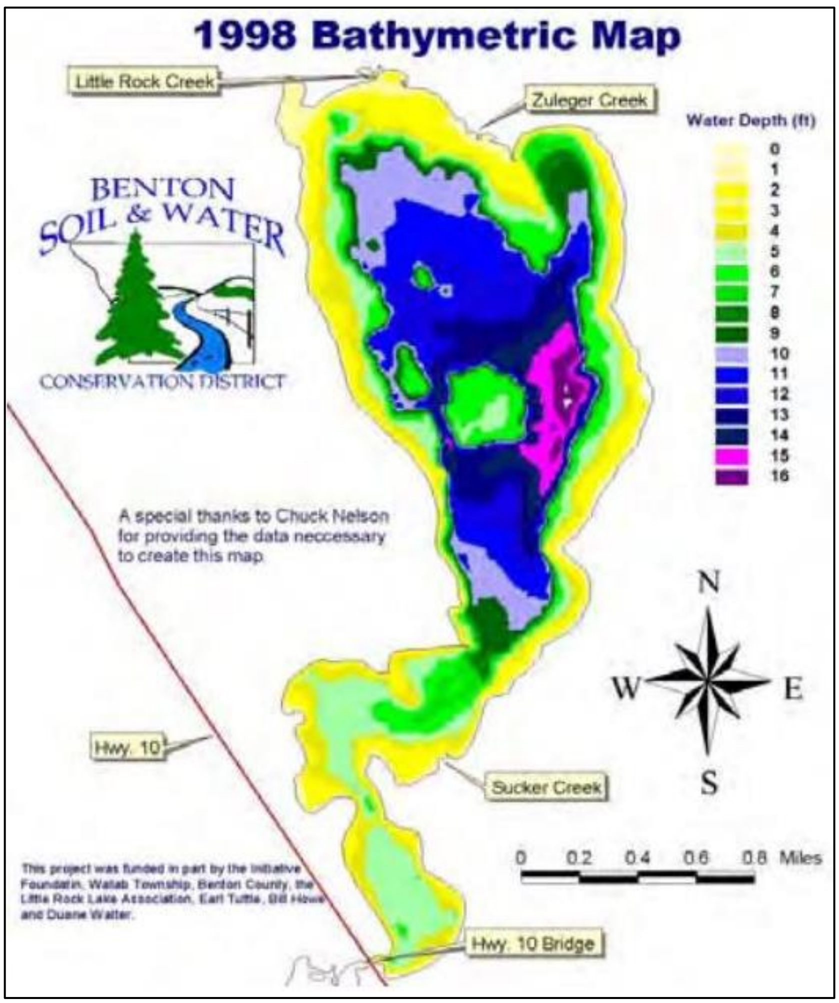

Figure 1: 1998 bathymetric map of Little Rock Lake. Image taken from the Little Rock Lake TMDL

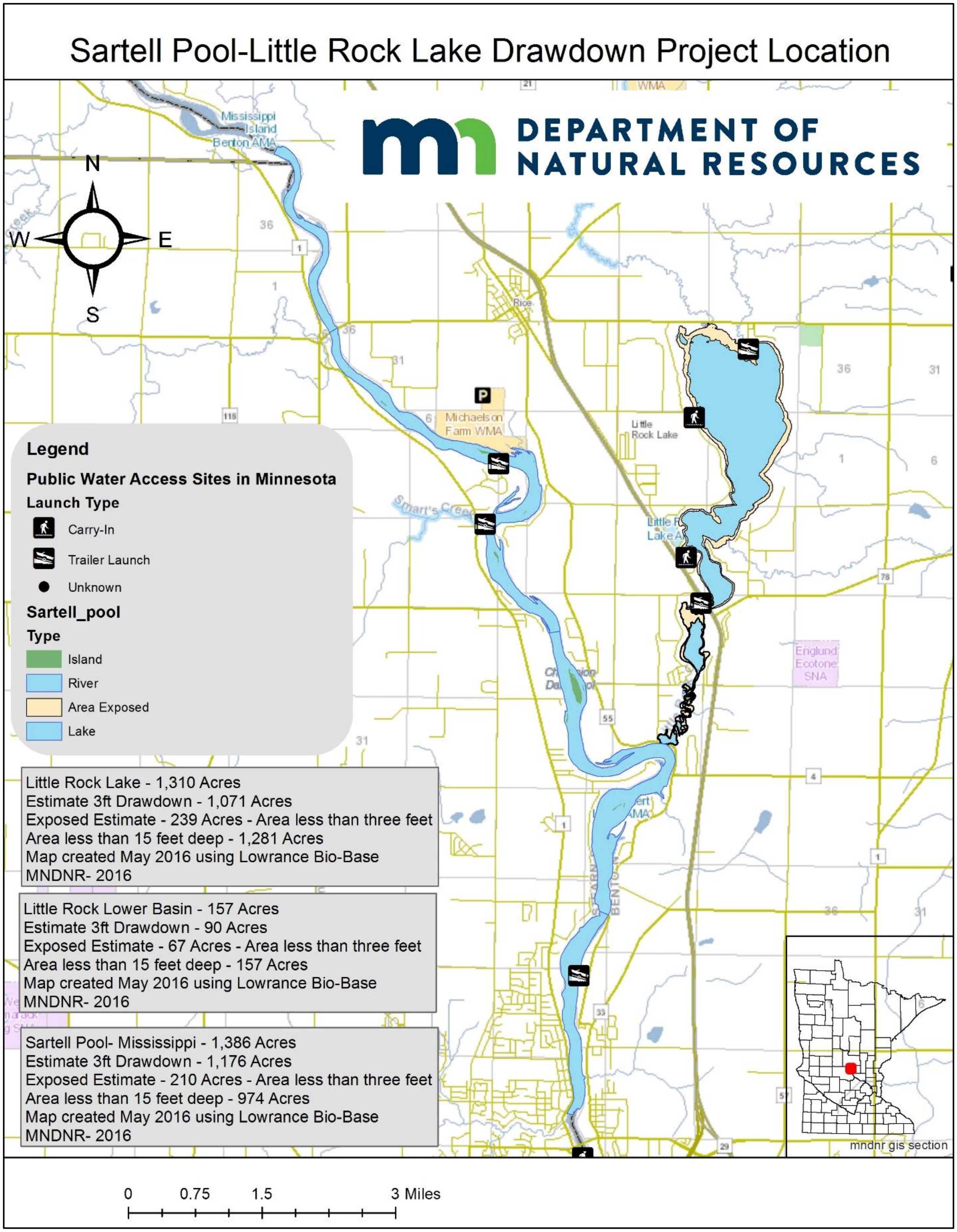

Figure 2: Drawdown project area

Sediment Core Studies:

Sediment Core Study of Little Rock Lake, Benton County, Minnesota 2009

A sediment core study of Little Rock Lake was completed in 2009. Sediment core layers were analyzed for lead-210 (^{210}Pb) to determine age of deposition. The study found that "the specific activity of ^{210}Pb in the surface sediments of the core was 5.88 pCi cm^{-2}, which is somewhat lower than the regional average" (Figure 4). The ^{210}Pb inventory was 22.73 cm^{-2} which is somewhat higher than the regional mean". Results of higher than normal ^{210}Pb inventory and lower than regional mean ^{210}Pb specific activity indicate a likely accelerated sediment input from the largely agricultural land use in the watershed.

Figure 3: Core sample location. Image taken from the "Sediment Core Study of Little Rock Lake, Benton County, Minnesota"

Organic matter content was higher at the bottom of the core, reflecting the marsh conditions that existed prior to the installation of the dam. Another high peak of organic matter between the depths of 40 cm and 55 cm is suspected to represent the time period following the installation of the dam when the lake changed from marsh conditions to open water (Figure 5). The higher water levels likely flooded a substantial amount of vegetation and therefore hindered the decomposition of that organic matter resulting in increased deposition which is reflected in the lower values seen in the upper 35 cm or the core. "The conversion from a marsh to a lake meant that fewer vascular plants were around in the lake and much of the primary production consisted of algae. Stephanodiscus niagarae is a diatom which is found in open water of lakes and rivers. Figure 5 shows a large increase of the diatom at 40 cm which also indicates the transition from marsh to open lake conditions.

Profiles of algal fossils also reflect the historic water level increases seen in Little Rock Lake (Figure 7). The bottom portion of the core is dominated by blue-green algae (Aphanizomenon, Anabaena, and Gloetrichia) and green alga (Pediastrum). The blue-green algae and green alga decline around the same time the stephanodiscus niagarae diatom begins to increase, signaling the rise of water levels in Little Rock Lake. While the rise in water levels are likely the reason for decline in pediastrum, the decline in blue green algae likely signals an increase in nutrients.

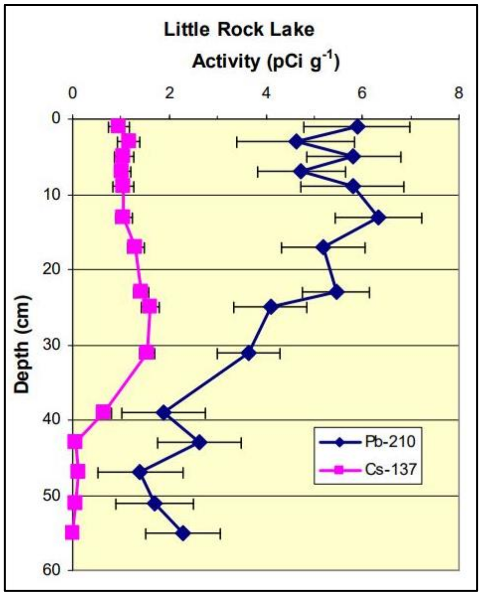

Figure 4: Radioisotope (^{210}Pb and ^{137}Cs) activities vs. sediment depth in the sediment core. Image taken from the "Sediment Core Study of Little Rock Lake, Benton County, Minnesota"

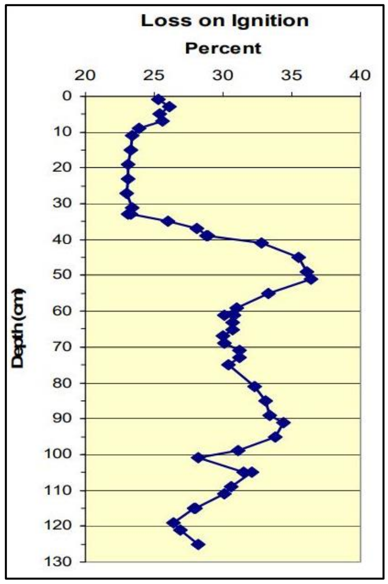

Figure 5: Loss of ignition (indicating organic matter content) vs depth in the sediment core. The peak between 40 cm and 55 cm may represent the time period soon after the installation of the dam. Image taken from the "Sediment Core Study of Little Rock Lake, Benton County, Minnesota"

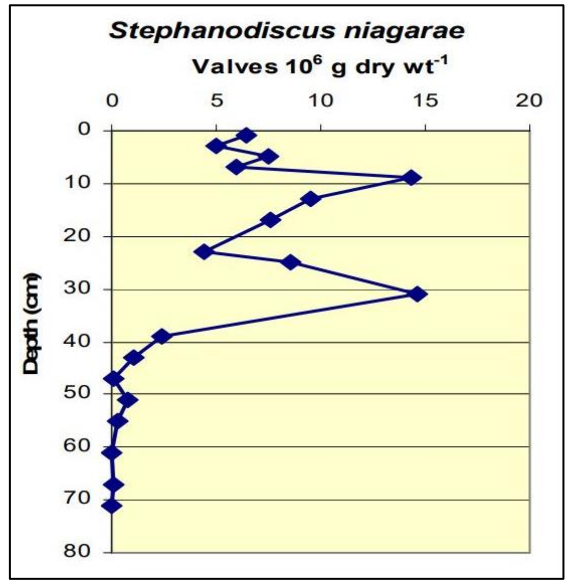

Figure 6: Diatom Stephanodiscus Niagarae vs. depth in the sediment core. Image taken from the "Sediment Core Study of Little Rock Lake, Benton County, Minnesota"

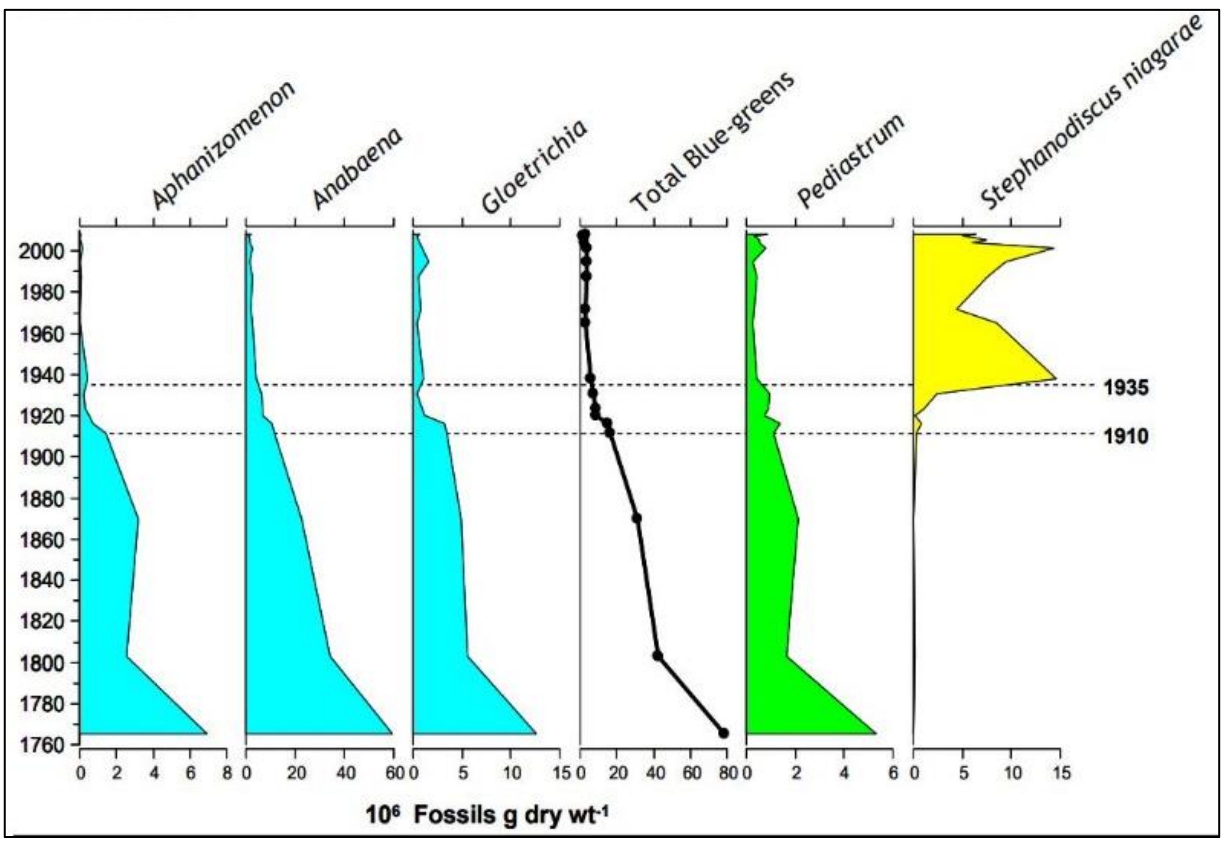

Figure 7: Profiles of selected algal fossils. Image taken from the "Sediment Core Study of Little Rock Lake, Benton County, Minnesota"

Water Quality Problems in Little Rock Lake:

Water clarity and algae blooms driven by exceptionally high phosphorus levels have been a concern for the lake since at least 1990. However, an extreme blue-green algae bloom in 2007 (Figures 9 and 10) produced toxin microcystin to the point that it became an acute public health risk around the lake and downstream to the residents of St. Cloud. St Cloud State professor Matt Julius has been testing microcystins in Little Rock Lake and notes "to put it in perspective 1 $\frac{ug}{L}$ is the UN safe level, Canada uses 2 $\frac{ug}{L}$. I routinely find 100+ $\frac{ug}{L}$ in the lake. I say plus because the ELISA only goes to 100 and we always hit the top. This is the worst known regionally." Phosphorus levels as high as five times greater than the standard acceptable amount, and chlorophyll-a levels 11 times greater than the standard have been recorded resulting in persistent water clarity depth readings of only a few inches. The insistent algal issues in Little Rock Lake is the worse known regionally, and is in the top 4% of the most polluted lakes in the state.

Figure 8: Algae bloom on Little Rock Lake

Figure 9: Blue-green algae bloom seen in Little Rock Lake in 2007

Figure 10: Blue-green algae blooms seen in Little Rock Lake in 2007

Little Rock Lake TMDL Results:

As a result of the extreme blue-green algae bloom in 2007, Little Rock Lake was listed as impaired in 2008 and subsequent plans including the nutrient TMDL and TMDL Implementation Plan were developed and completed in 2012 and 2013, respectively. The TMDL indicates that the highest concentration of phosphorus and other nutrients are seen during spring runoff with animal waste being a significant source, other sources include; internal loading, septic loads, greywater, and streambank/shoreline erosion. The TMDL sets an interim phosphorus reduction goal at 5,375 pounds (35%) and a final phosphorus reduction of 7,927 pounds (53%) is necessary to meet state water quality standards.

Internal Phosphorus Loading and Sediment Phosphorus Fractionation Analysis:

In 2008, Little Rock Lake was analyzed for internal phosphorus loading and sediment phosphorus fractionation to estimate rates of phosphorus release from sediments (Internal Phosphorus Loading and Sediment Phosphorus Fractionation Analysis for Little Rock Lake, Minnesota 2008). Concentration of total phosphorus in the sediment were divided into three main types; redox P, labile P, and refractory P. The labile P represents phosphorus which is either directly available for biological uptake and assimilation or can become available through recycling pathways. Refractory P represents phosphorus which is mostly inert and unavailable for biological uptake and is subject to burial. Redox P represents to sum of loosely bound and iron-bound P fractions which are correlated with sediment P release rates. The refractory P fraction accounted for 44% - 95% of the total sediment P concentration, while the labile P fraction accounted for 5% - 56% and the redox P accounted for 4% - 43%. Nearly all the sampled sites show a higher percentage of refractory P than labile P. The study concludes anoxic phosphorus release rate of 8 (mg $m^{-2}d^{-1}$) and 12.8 (mg $m^{-2}d^{-1}$) under oxic conditions. These rates are relatively high and fall within ranges observed for other eutrophic systems in western Wisconsin and eastern Minnesota. Wave action in near shore areas that are not protected by aquatic plants will accelerate the release of phosphorus under oxic conditions. Establishing a healthy aquatic plant community will reduce the release of this phosphorus.

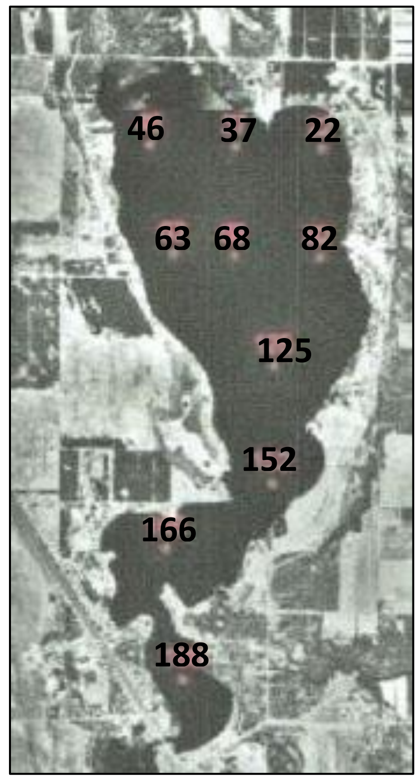

Figure 11: Sediment sample locations

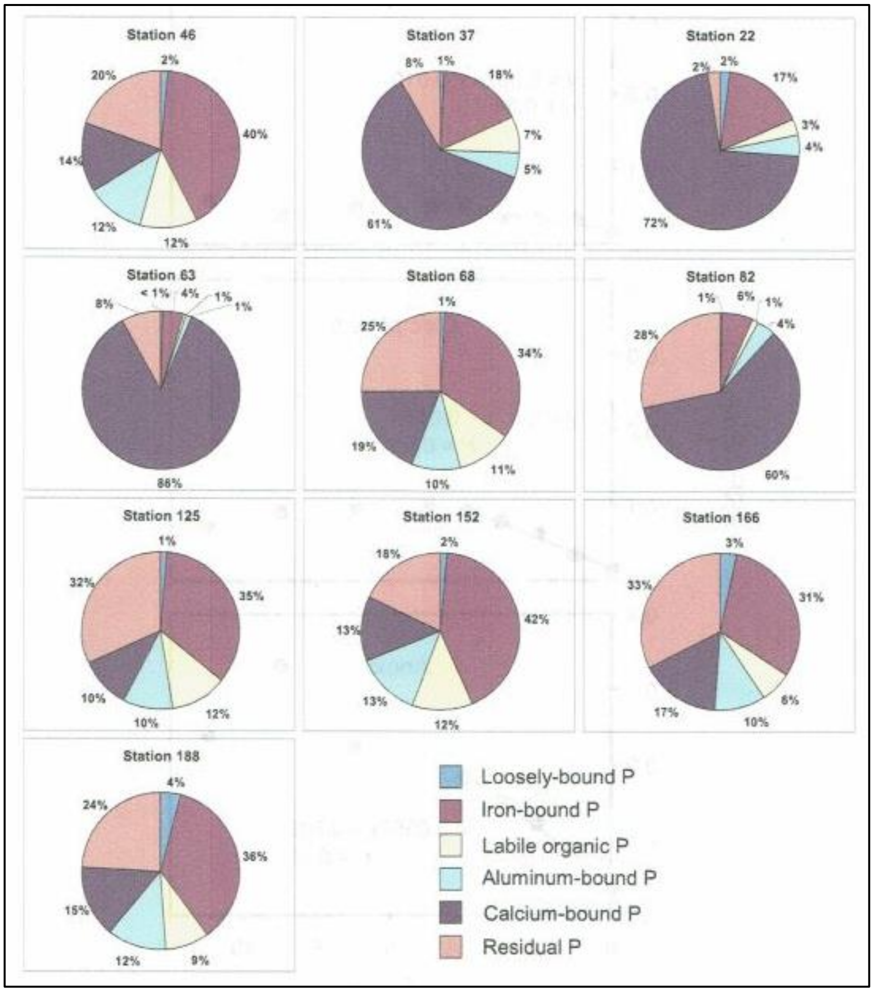

Figure 12: Sediment total phosphorus composition from sites shown in figure 8. The loosely-bound, iron-bound, and the labile organic represent the labile fractions while the aluminum-bound, calcium-bound, and residual are refractory.

<u>Water Quality Monitoring:</u>

Benton Soil and Water Conservation District

Benton SWCD is currently in year two of a three year monitoring plan for Little Rock Creek and other tributaries to Little Rock Lake including; Bunker Hill Creek and Sucker Creek to evaluate our progress towards meeting watershed load reduction goals. This monitoring plan consists of bi-weekly chlorophyll-a, total phosphorus (TP), total suspended solids (TSS), BOD_5, and nitrate nitrogen, and total Kjeldahl nitrogen (TNK) samples as well as stream flow, pH, stream temperature, and dissolved oxygen measurements. A consultant was hired to evaluate the monitoring data each year to develop water quality progress reports. We will use these reports to evaluate the effects of watershed BMPs and other variables, and apply the adaptive management concepts in the implementation plan by adjusting implementation activities in future years.

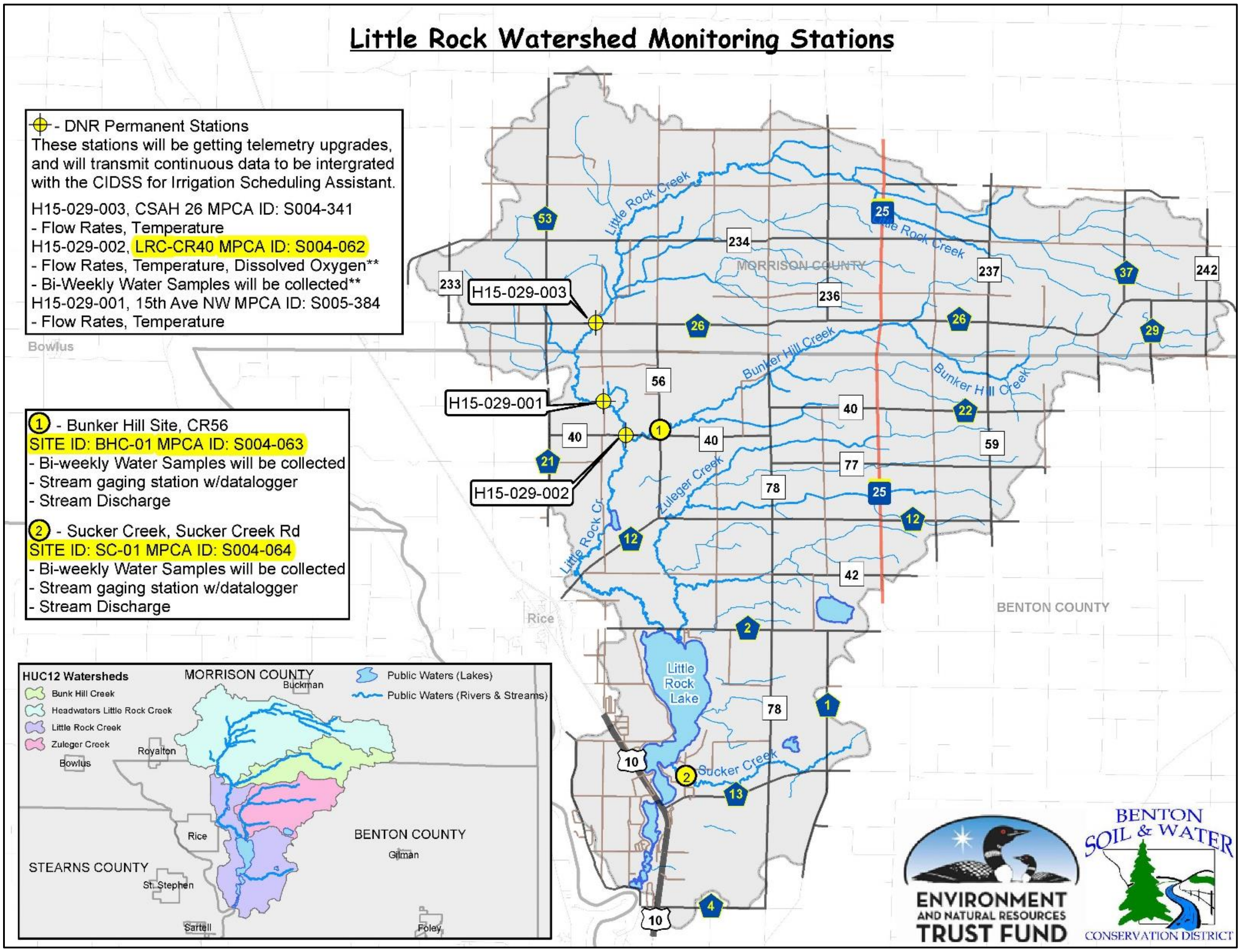

Figure 13: Little Rock Watershed monitoring stations Benton SWCD is currently taking water chemistry samples and flow data.

Little Rock Lake Association

Little Rock Lake Association has been monitoring the Lake since 2012. Water chemistry samples for total phosphorus, chlorophyll-a are taken monthly along with secchi depth water clarity measurements. The short period of record does not allow for statistically significant trend analysis at this time. While no statistically significant long term trend can be evaluated yet, 2017 data shows improvements over 2016 data for total phosphorus, chlorophyll-a, and secchi depth. When this data is visually compared with data from the TMDL study, it suggests that watershed BMPs are resulting in improvements in lake water quality. Consistent with the implementation plan, this signals the need to begin installing second priority implementation activities, including aquatic plant management.

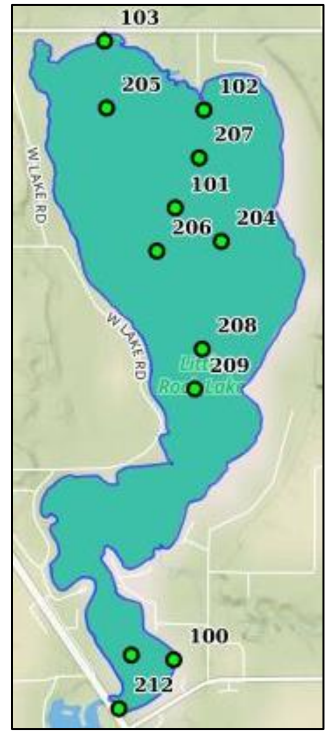

Figure 14: Sampling site locations on Little Rock Lake. Note: Site 204 is the primary site and values and graphs shown correspond with this site. http://app.mapfeeder.net/rmb.php/guest

Table 1: Water quality average values from 2012-2017 from site 204 (Figure 14)

2012-2017 Average Values	
Total Phosphorus (ug/L)	197.5
Chlorophyll-a (ug/L)	116.7
Secchi Depth (Ft)	2.1

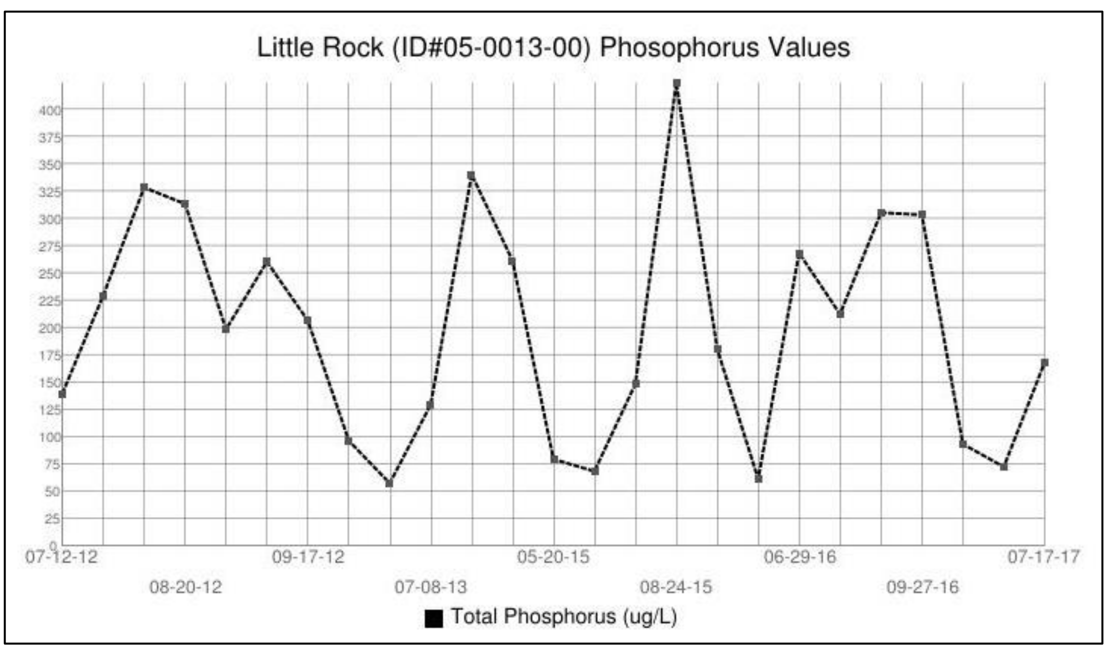

Figure 15: Little Rock Lake phosphorus values from 2012 – 2017 from site 204 (Figure 14)

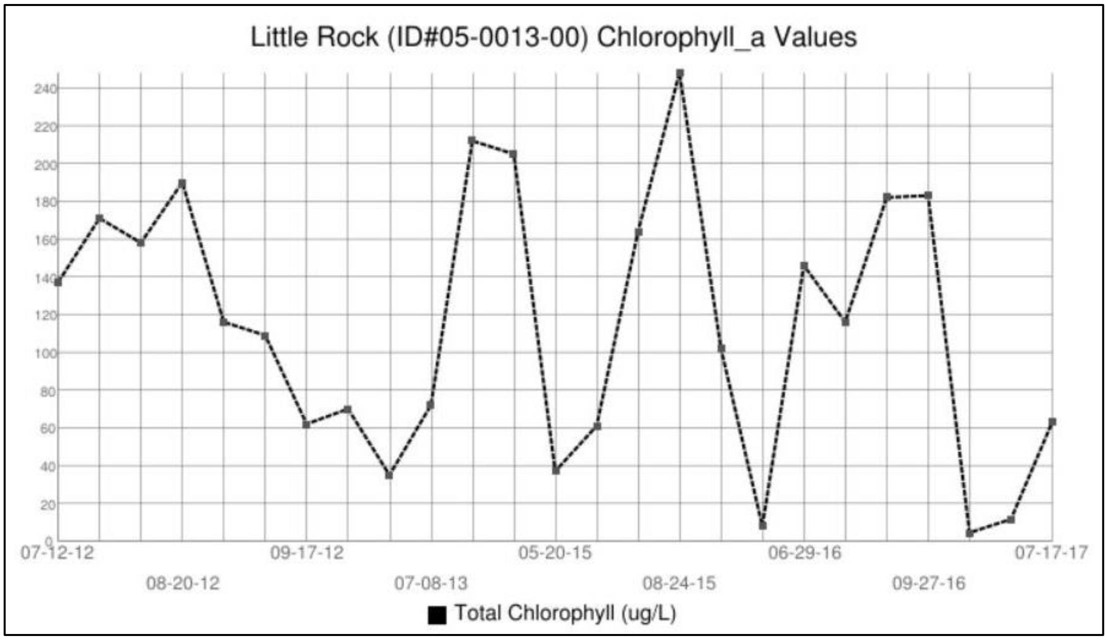

Figure 16: Chlorophyll-a values from 2012 – 2017 from site 204 (Figure 14)

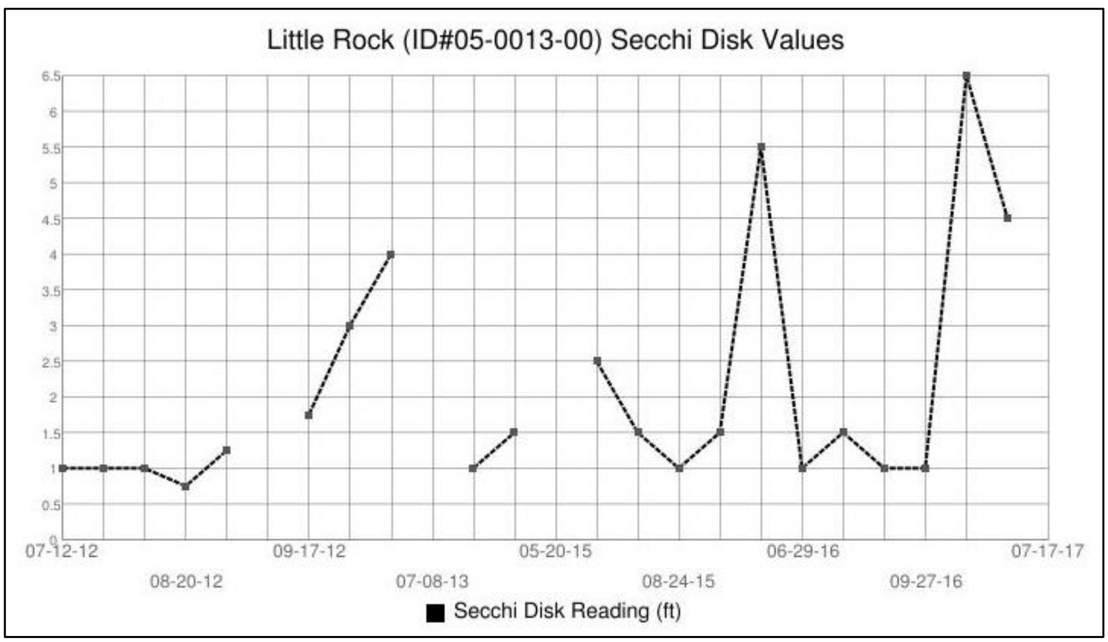

Figure 17: Secchi disk depth values from 2012 – 2017 from site 204 (Figure 14). Note: Data for 7-17-17 is not yet available

Minnesota Pollution Control Agency

The Minnesota Pollution Control Agency (MPCA) has initiated the Watershed Restoration and Protection Strategy (WRAPS) for the Mississippi River – Sartell watershed. This intensive watershed strategy will involve both monitoring and modeling. Numerous sites on Little Rock Creek and Bunker Hill Creek, and tributaries to Little Rock Lake, will be sampled during the WRAPS process (Figure 7). The WRAPS is anticipated to be completed in 2020. Sampling in the Little Rock Lake watershed will consist of biological (fish and invertebrates) and water chemistry, along with habitat assessments and flow monitoring.

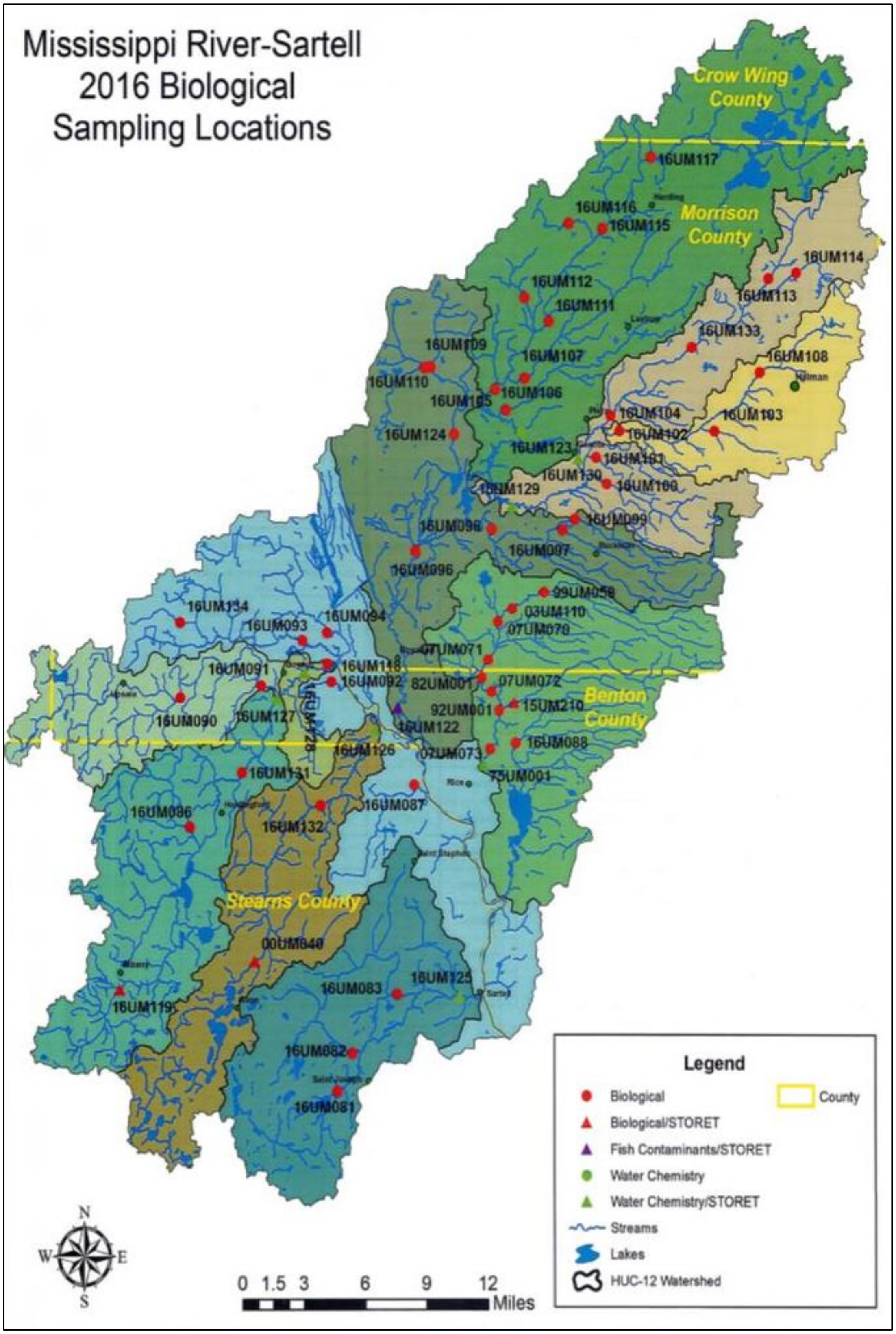

Figure 18: Sampling locations for the Mississippi River - Sartell Watershed WRAPS

Table 2: Sampling locations for the Mississippi River - Sartell Watershed WRAPS

Field Number	Stream Name	Location
00UM040	Spunk Creek	At Queens Rd, 2 mi. NE of Avon
03UM110	Little Rock Creek	US of Cty Rd 234, 5 mi. E of Royalton
07UM070	Little Rock Creek	Downstream of CR 36, 5 mi. NE of Royalton
07UM071	Little Rock Creek	DS of Nature Rd (CR 26)
07UM072	Little Rock Creek	Upstream of 15th Ave NW, 3 mi. NE of Rice
07UM073	Little Rock Creek	DS of 15th Ave NW, 2 mi NE of Rice
15UM210	Bunker Hill Creek	At CR 56, 3 mi. NE of Rice
16UM081	Watab River, South Fork	US of CR 51, 1.5 mi. SW of St Joseph
16UM082	Watab River, North Fork	At CR 3, 1.5 mi. NW of St Joseph
16UM083	County Ditch 12	At CR 2, 4 mi. W of Sartell
16UM086	Krain Creek	US of 190th Ave, 1 mi. W of Holdingford
16UM087	Stony Creek	DS of CR 17, 3 mi. W of Rice
16UM088	Zuleger Creek	DS of CR 12, 2 mi. NE of Rice.
16UM090	North Two River	US of CR 21, 2.5 mi W of Upsala
16UM091	North Two River	US of 110th Ave, 1 mi. SW of Bowlus
16UM092	Hazel Creek	At CR 25, 2 mi. SE of Bowlus
16UM093	Little Two River	US of 130th Ave, 1 mi. NE of Bowlus
16UM094	Hay Creek	US of CR 52, 2 mi. NE of Bowlus
16UM096	Platte River	US of CR 34, 4 mi. N of Royalton
16UM097	Buckman Creek	At 103rd St, 4 mi. S of Pierz
16UM098	Buckman Creek	At Kettl Rd, 5 mi. SW of Pierz
16UM099	Arramba Creek	At Hwy 25, 3.5 mi. S of Pierz
16UM100	Skunk Creek	DS of CR 241, 2 mi. SE of Pierz
16UM101	Trib. to Skunk River	DS of CR 239, 1 mi. S of Pierz
16UM102	Hillman Creek	US of 280th Ave, 1 mi. E of Pierz
16UM103	Trib. to Hillman Creek	US of 330th Ave, 6 mi. E of Pierz
16UM104	Skunk River	US of CR 39, 1 mi. NE of Pierz
16UM105	Little Mink Creek	Us of CR 255, 4 mi. W of Pierz
16UM106	Platte River	US of CR 43, 4.5 mi. NW of Pierz
16UM107	Big Mink Creek	DS of CR 279, 3.5 mi. NW of Pierz
16UM108	Hillman Creek	At Ranch Rd, 2 mi. NW of Hillman
16UM109	Trib. to Rice Creek	DS of 173rd St, 8 mi. NW of Pierz
16UM110	Trib. to Rice Creek	DS of CR 263, 8 mi. NW of Pierz
16UM111	Platte River	At CR 278, 4 mi. W of Lastrup
16UM112	Trib. to Platte River	US of CR 265, 5 mi. NW of Lastrup
16UM113	Skunk River	DS of CR 47, 4 mi. NW of Hillman
16UM114	Trib. to Skunk River	At CR 8, 5 mi. N of Hillman
16UM115	Platte River	US of CR 48, 3 mi. SW of Harding
16UM116	Wolf Creek	At Melody Rd, 4 mi. SW of Harding
16UM117	Platte River	At CR 275, 4 mi. NE of Platte
16UM118	Two River	at Great River Road, 2 mi. E of Bowlus
16UM119	South Two River	DS of CR 156, 1 mi. S of Albany
16UM122	Platte River	US of CR 40, 2 mi. S of Royalton
16UM123	Platte River	US of Hwy 27, 3 mi. SW of Pierz
16UM124	Rice Creek	US of Hwy 27, 5 mi. E of Little Falls
16UM125	Watab River	E side of 57th Ave. (Pinecone Rd), in park
16UM126	Spunk Creek	DS of Great River Road, 3.5 mi. SW of Royalton
16UM127	South Two River	Upstream of CR 21, 1 mi. SW of Bowlus
16UM128	Two River	At 40th St, 1 mi. E of Bowlus
16UM129	Skunk River	US of CR 36, 4 mi. SW of Pierz
16UM130	Skunk River	US of CR 38, 1 mi. S of Pierz
16UM131	South Two Ri ver	DS of 165th Ave, 2 mi NE of Holdingford
16UM132	Spunk Creek	US of 125 Ave., 4.5 miles E of Holdingford
16UM133	Skunk River	US of 320th Ave, just north of 183rd St., 6 mi NE of Pierz
16UM134	Little Two River	US of Dove Road, NW of Elmdale
75UM001	Little Rock Creek	US of CR 12, 1 mi. NE of Rice
82UM001	Little Rock Creek	Due west of 15th Ave, through corn field on field road.
92UM001	Little Rock Creek	Downstream of Cty Rd 40, DS of Bunker Hill Creek Confluence
99UM058	Little Rock Creek	~0.5 mi. W. of 250th Ave

Implementation Strategies:

Little Rock Lake Nutrient TMDL

The TMDL indicates that a combination of external and internal implementation strategies will be necessary with long term strategies involving "farm management to minimize excess phosphorus (fertilizer + animal feed – crop export – animal export)… coupled with traditional best management practices (BMPs) to reduce surface runoff and phosphorus transport from feedlots and cropland". Since the development of the TMDL, a significant effort has been put forth to address external phosphorus sources, and over 70 BMPs have been installed in the watershed (Figure 18). Not accounting for fate and transport estimates, or BMPs that are currently under construction and being planned, the phosphorus reduction estimate (using primarily BWSR calculators) is 2,340 pounds annually. While extensive work has been done to address the external sources, the internal loading has yet to be addressed. The TMDL indicates that the lake could potentially "keep itself healthy" for a longer period of time if the combination of reduced runoff from best management practices and increased plant growth in the lake can break the critical nutrient "balance point".

Table 3: Reduction estimates for implemented BMPs

Total Reduction Estimates	
Total Suspended Solids (tons)	1814
Soil (tons)	1825
Phosphorus (lbs.)	2340
Nitrogen (lbs.)	4553
Fecal Coliform (CFU)	7.7E+14

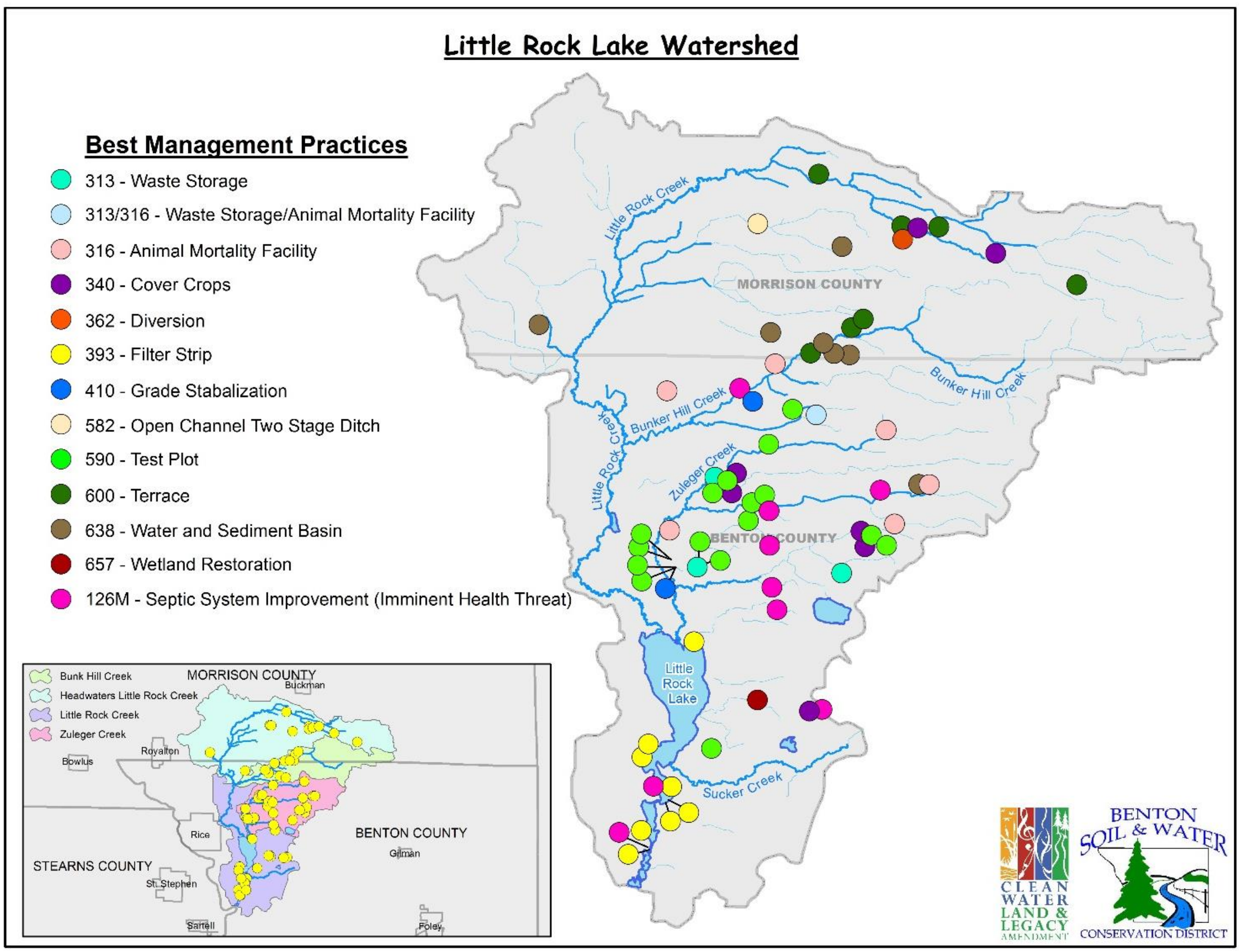

Figure 18: BMPs installed in the Little Rock Lake Watershed since 2012

Little Rock Lake and Creek Watershed Protection and Improvement Plan (TMDL Implementation Plan)

A group of stakeholders (exclusively watershed residents, mostly farmers) were assembled to develop an implementation plan. The criteria for choosing BMPs included the need and effectiveness of the BMP as well as the likelihood that the land owners would install the BMP. The implementation plan will address the root cause of the phosphorus problem and has a high likelihood of being embraced by the individuals that will need to install the BMPs. First priority implementation practices include; nutrient management, cover crops, feedlot projects, residue and tillage management, filter strips, irrigation management, stream crossings, contour buffer strips, prescribed grazing, lakeshore native buffers, rain gardens, water and sediment control basin, wetland restoration, and education outreach. Implementation of first priority practices has been ongoing since the plan development. Anecdotal reports by lake users suggest we are starting to see improvements and recent water quality data collected by the lake association supports these reports. Recent discussions have concluded it is time to start in lake and second priority practices.

The plan lists few in lake management options, but includes aluminum sulfate treatment, aquatic plant management, and carp control as second priority practices. The TMDL states that "if significant improvements in lake water quality are not achieved within a few years after significant reductions in P load are accomplished, application of alum or other chemicals would help to accelerate recovery by trapping historical P loads in the lake sediments". Lake residents have since been hoping for the water clarity benefits the ALUM treatment or other practices could provide.

Alternative Options:

About four years ago the DNR began exploring the option of performing a drawdown on Little Rock Lake – Sartell Pool with the purpose of improving water quality, shoreland stability, and fish and wildlife habitat. Since then, the Little Rock Lake Association has been working closely with the DNR to determine feasibility of this project and other in lake management practices. A total of six options have been examined including; the complete system drawdown, a temporary drawdown with a coffer dam, creek inlet filtration, dredging, vegetative mats, barley/straw, and ALUM.

The following is information assembled by the Little Rock Lake Association FAQ document.

Option A: Complete System Drawdown

The lake level would be drawn down over a period of six weeks by about three feet. This would expose several feet of shoreline in many areas of the lake and channel. The existing exposed sediment and much would settle into solid soil. There is a seed bank of native seeds in this soil. The time-line for the drawdown would allow these valuable native aquatic plants to establish on the shoreline. As they grow, they will take up and filter many of the nutrients in the soil, including phosphorus. This would enable shore soil to remain soil, even after a drawdown. The most serious pollutant in Little Rock Lake is phosphorus. Phosphorus can be reduced by air, solar exposure, compaction and plant growth that uses nutrient rich soil.

The drawdown would allow the DNR and SWCD to complete some badly needed projects along the shoreline of the lake and river to stop erosion and runoff. Some of these projects cannot be completed without the drawdown as the shore line needs to be exposed to use equipment to help.

- ***How long will the drawdown effects last?***
  The established plants will provide fish and wildlife habitat and shoreline stability due to increased root density on an ongoing basis. It would have an immediate effect on our water quality. The estimated improvement in water quality could last 7-10 years and maybe longer if some of the runoff issues in the watershed are addressed and we all employ good stewardship or our shoreline.
- ***What can I do as a lake property owner to ensure the impact of the drawdown is successful?***
  LRLA will be putting together a post drawdown maintenance and education plan to ensure we all are aware and help to ensure the positive effects of the drawdown are maintained for as long as possible.
- ***Where has this been done before?***
  In Minnesota, this has been done in several shallow basins, the Mississippi River Pool 8 & 9 and various places around the country.
- ***What would the costs to be for a complete system drawdown?***
  There is an economic impact for Eagle Creek Energy to shut down the dam for six weeks in terms of lost production capacity. The estimated cost for the six weeks of lost energy production is around $235,000. There will be additional costs to install erosion control projects and plantings.
- ***What is the downside to conducting a complete drawdown?***
  During the six weeks when the lake will be drawn down three feet, there will be difficulty navigating the lake, river, and channel. There will most likely be foul odors as the shoreline dries out and there is a potential fish kill during drawdown. Lastly we anticipate as the lake cleans itself up there will be more plant growth (weeds) within the lake itself. While this is a downside to some, it is good for the lake and a natural way to utilize the phosphorus that remains in the lake.

Option B: Drawdown with Coffer Dam

Eagle Creek would open up the dam in order to draw the lake/river down three feet for about a one week period. This would allow enough time to install a large, water filled tube (Dam it dam, tube dam, among others) at a narrow and shallow area of the Harris Channel. Once installed, the river levels would be allowed to refill, while on the lake side of this coffer dam pumps would be installed to remove the incoming water. The drawdown would be six weeks long, however a longer or shorter duration could be negotiated. This would expose several feet of shoreline in many areas of the lake and channel. The existing exposed sediment and much would settle into solid soil. There is a seed bank of native seeds in this soil. The time-line for the drawdown would allow these valuable aquatic plants to establish themselves. As they grow, they will take up and filter many of the nutrients in the soil, including phosphorus. The shore soil will remain solid, even after the drawdown

- ***What would the costs be?***
  - Purchase of custom fit, temporary coffer dam: $27,000 - $35,000
  - Training: $6,000
  - Installation/Removal: $10,000
  - Pump rental: $49,450 (for 8 weeks)
  - Operation of pumps with use of diesel generator estimated 540 gallons diesel/day * $2.40/gallon (5/1/17): $1296/day
    - Total operation of pump for 60 days: $77,760

- Total for six week drawdown period: $170,260 - $220,000
    - Ongoing storage and maintenance of coffer dam: Estimated $1,500/year
    - Cost/Charge from Eagle Creek for one week of drawdown for installation and one week removal: Unknown at this time
- ***Why not use this method?***
  This method will only treat the lake habitat and water quality issue. Mississippi River would not get the benefit of valuable plant growth for shoreline stability and fish habitat, or erosion control projects. Similar concerns as the complete drawdown; difficulty navigating the lake and channel during the drawdown, foul odor as the shoreline dries out and potential fish kill. Additional drawbacks are; constant noise from generators and pumps running. A drawdown (likely one week each) would need to be completed on the entire system both at the installation and removal of the dam. There are also additional risks associated with this option; potential liability issue if a large rain even hits either the Mississippi River of Little Rock Lake watershed, potential flooding until dam would be deflated/removed. The main reason for looking into this method is to avoid impacting the river residents and six weeks of recreation.

Option C: Creek Input (inlet) Filtration

A potential filtration system would consist of a large retention screen with a filter media (carbon or resin) to filter or trap the pollutants that are coming into the lake on each of the three inlet creeks.

- ***How long would the filtration results last?***
  Eventually the filters would become saturated and need to be washed or replaced. The length of time to replacement would depend on intensity and type of pollutants being filtered. This system would also require an enclosure that filtration devices would be mounted on.
- ***Where has this been done before?***
  This type of system has been used in sewage plants and industrial sites for waste/pollutant control with great results using proper maintenance techniques. There is no known lake system of our size that has used filtration.
- ***What would the costs be?***
  It is difficult to determine since there are no known lake filtration system. We believe it would be expensive. The cost would depend on number of filtration devices needed, the amount of water input, and the required on-going maintenance.
- ***Why not use this method?***
  It would not solve the underlying pollutant problems coming from the watershed to the lake. It is unknown if the lake would have the capacity to turn over and improve if the inlets were filtered. This method could also impair movement of fish and wildlife around the filtration systems.

Option D: Dredging

Hydraulic dredging uses suction pumps and piping to move degraded material and water from the lake bottom directly to a storage or disposal site. The dredge material is typically disposed of at a permitted solid waste facility or off-site location. It can also be reused as fill, road sub-base, or in land applications. The removal of sediments from the lake bottom using equipment to pump the silt out of the lake. The sediment is then disposed of on land. This option does not address quality directly.

- ***How long will the dredging results last?***

This would remove existing material in select locations which can be a major source of phosphorus. If the source of the phosphorus is not taken care of, this may not lower the phosphorus levels in the lake. The results may vary as the dredging would stir up layers of sediment in the lake bottom. The lake would still have to process or flush these nutrients out. In reviewing other lake dredging projects, the dredging appears to be a fairly on-going process. Storm Lake, Iowa operates the dredging equipment all season.

- ***Where has this been done before?***
  Storm Lake Iowa has an ongoing project. It appears they operate dredging equipment all summer, each year.
  Fountain Lake, Albert Lea starting in 2017. Fountain Lake has an area of 550 acres, less than half the size of Little Rock Lake.
- ***What would the costs be?***
  The estimated cost for Fountain Lake dredging is $12 - $18 per cubic foot of sludge including the cost to store the sludge.
- ***Why not use this method?***
  Storm Lake, Iowa has recognized only a tiny improvement in water clarity. Dredging would not solve the underlying pollutants coming from the watershed into the lake. It is unknown if the lake would have the capacity to turn over and improve. This method may only stir up more phosphorus in the sediment. The potential damage to fish, wildlife or habitat is unknown

Option E: Vegetative Mats

May also be referred to as Becmats, tussocks, flotations or suds. These are natural floating islands, composed of vegetation growing on a buoyant mat which floats on the lake. The growing plants process nutrients as they grow. The effect is similar to having aquatic vegetation and shoreline vegetation to filter the nutrients and sediment.

- ***How long would the mats last?***
  It would vary depending on the size of the mat and the growing season. There would be ongoing maintenance of the mats
- ***Where has this been done before?***
  To our knowledge, it has been used in small golf course ponds and treatment lagoons. We have no information where it has been used on a lake.
- ***What would the costs be?***
  The costs are unknown at this time. Grant funding would be unlikely since the method has not been proven to be effective on a large scale.
- ***Why not use this method?***
  The mats might be a navigation hazard on the lake. It is unknown what the size of the mat would need to be to have an effect on improving the water quality
  Shoreline buffers of aquatic and shoreline plants would have the same or better effect on the water quality.
  In some applications effective removal of phosphorus occurred at 50% or more of lake area coverage. It is unlikely that is reasonable or practical for Little Rock Lake.

Option F: Barley/Straw

An amount of barley straw is placed in the lake. Decomposition of barely creates hydrogen peroxide which prevents algae growth

- ***How long would the effects last?***
  It would vary depending on the amount of barley input and the location on the lake. The rate of decay of the barley is typically 2-6 weeks to start forming hydrogen peroxide which inhibits the algae growth. The barely would need to be replaced every 4-6 months.
- ***Where has it been done before?***
  We have no knowledge of this method being used on a large scale, such as a lake
- ***What would the costs be?***
  Again, it would depend on the amount of barely straw to use, the availability, and the ongoing maintenance.
- ***Why not use this method?***
  We don't know what effect a large amount of decomposing barely straw would have on the rest of the lake. It still only treats a symptom and not the cause. It would reduce the algal growth but has not been effective in a large setting. This would not have a positive effect on the water quality. The barely may also be a navigation hazard.

Option G: Aluminum Sulfate (Alum)

Alum treatment binds up phosphorus in water and settles to the bottom – puts a cop on the bottom of the lake. It would involve applying the chemical to portions of the lake and channel over three feet deep.

- ***How long would the effects last?***
  It binds phosphorus in a matter of weeks, likely to improve water quality. For eight years or more, 85% effective when used properly. It is best suited in deeper lakes that don't experience as much wind mixing as Little Rock Lake. We would have an initial improvement in water clarity. This would also depend on the amount of phosphorus coming into the lake via the creeks after the chemical application
- ***Where has it been done before?***
  Spring Lake in 2012, among others.
- ***What would the costs be?***
  $450 per acres where the water is greater than three feet deep. This would be 1159 multiplied by $450/acre = $521,550. We are not sure if this would include the application of the chemical.
- ***Why not use this method?***
  Potential chemical reaction to lake water. No swimming or pets allowed in the water during application. It does not address the source of the problem. It merely puts a blanket over it for a while. It does not establish submerged vegetation that continuously process nutrients. This does not enhance fish and wildlife habitat.

Cost Effectiveness

Of the options listed above, the only other feasible option would be the coffer dam. However, this option would provide benefits to Little Rock Lake only, will cost more than twice what the proposed drawdown will, and will expose significantly less shoreline, thereby decreasing the amount of plant growth and their associated benefits. The proposed drawdown will expose 704 acres of soil and would equate to $\frac{\$333}{acre}$ while the coffer would only expose 306 acres at $\frac{\$816}{acre}$.

Preliminary Research

Erosion Maps

In 2016 Stearns SWCD and DNR staff completed a shoreland erosion survey of the entire project area of the Mississippi River. The process included 18 sites where erosion rates were estimated using the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) method (Rosgen 2006). Individual and cumulative annual erosion estimates can be found in table 4. At many of the sites, installing BMPs will be most cost effectively installed if work can be completed from the water side, as opposed to from the top of the bank. Some sites do not appear to be feasible from the top of bank. During the drawdown we will install erosion control measures at the top priority sites that are amenable to construction from the water side. We expect to complete construction at the top three sites. The DNR has created maps showing sites with the highest erosion rates (tons/year/foot) for the project area on the Mississippi River.

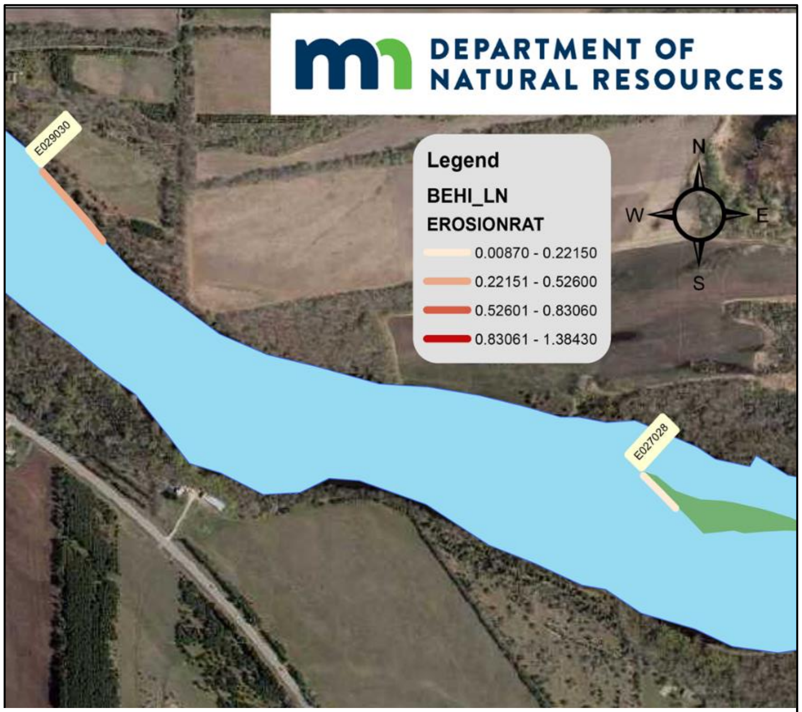

Figure 19: Mississippi River – Sartell Pool sites with high erosion rates

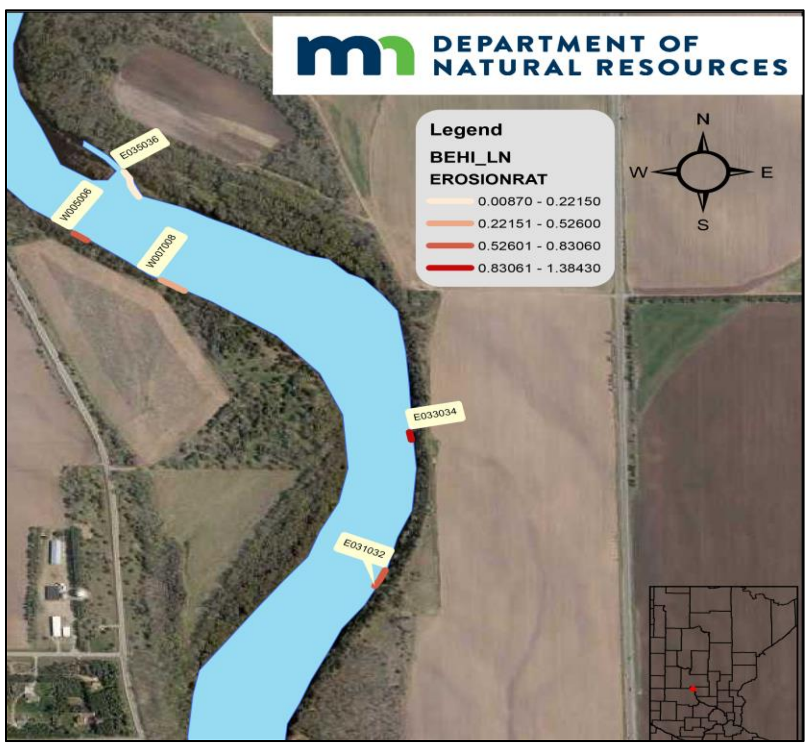

Figure 20: Mississippi River – Sartell Pool sites with defined~~high~~ erosion rates. Note: site E033034 has the highest erosion rate followed by site E031032 (Table 4)

Figure 21: Mississippi River – Sartell Pool sites with defined erosion rates. Note: site E023024 has the third highest erosion rate (Table 4)

Figure 22: Mississippi River – Sartell Pool sites with high erosion rates.

Table 4: Erosion rates for sites within the project area on the Mississippi River

Station	BEHI rating (Worksheet 3-11) (adjective)	NBS rating (Worksheet 3-12) (adjective)	Bank erosion rate (Figure 3-9 or 3-10) (ft/yr)	Length of bank (ft)	Study bank height (ft)	Erosion subtotal [(4)×(5)×(6)] (ft^3/yr)	Erosion Rate (tons/yr/ft) {[(7)/27] × 1.3 / (5)}
E033034	Very High	High	0.575	70.0	50.0	2012.50	1.38430
E031032	Very High	High	0.575	150.0	30.0	2587.50	0.83060
E023024	High	Very High	0.872	205.0	17.0	3038.92	0.71370
W005006	High	High	0.575	100.0	25.0	1437.50	0.69210
E025026	High	High	0.575	96.0	19.0	1048.80	0.52600
W009010	High	Moderate	0.380	270.0	25.0	2565.00	0.45740
W007008	Very High	High	0.575	75.0	16.0	690.00	0.44300
E029030	Very High	High	0.575	500.0	15.0	4312.50	0.41530
E021022	High	High	0.575	150.0	11.0	948.75	0.30450
W011012	High	High	0.575	1000.0	10.0	5750.00	0.27690
W003004	Very High	Moderate	0.380	100.0	15.0	570.00	0.27440
E019020	Very High	High	0.575	300.0	8.0	1380.00	0.22150
E017018	High	Moderate	0.380	1372.0	10.0	5213.60	0.18300
E015016	High	Moderate	0.380	350.0	8.0	1064.00	0.14640
W013014	High	Low	0.250	121.0	12.0	363.00	0.14440
E035036	High	High	0.575	150.0	4.0	345.00	0.11070
E027028	High	Moderate	0.380	240.0	5.0	456.00	0.09150
W001002	Low	Moderate	0.073	200.0	2.5	36.25	0.00870

Exposed Shoreline Maps

The entire lake and river project area was mapped using a GPS depth finder to determine how many acres of shoreline will be exposed during the drawdown. In total, the three foot drawdown would expose an estimated 704 acres of soil along the Mississippi River and Little Rock Lake. Maps are shown in the appendix.

Table 5: Amount of shoreline that will be exposed during the drawdown

Location	Area Exposed (acres)
Little Rock Lake	239
South Basin/Channel	67
Mississippi River	398
Total Area Exposed	704

Analogous Drawdowns Done in Minnesota

In recent years, drawdowns have become a more commonly used lake management method throughout Minnesota. Results from nearly all previously measured drawdowns on wetland basins have shown favorable results (Figures 23, 24, and 25), including increased water clarity and decreased phosphorus levels. Based on these results, the proposed drawdown project will provide a phosphorus reduction between 30% - 40% and a 50% - 75% water clarity increase. However, it must be noted that while general lake morphology is similar between Little Rock Lake and the lakes shown in figures 23 and 24, various aspects of the drawdown itself will vary. Many of these projects were complete drawdowns which were performed for an entire season or more. For this reason it is likely that the phosphorus reductions and water clarity improvements that will be seen for this project will be on the lower end of the ranges stated above. However, a drawdown performed on a wildlife management area just upstream of Little Rock Lake (Sartell WMA, 2003), did achieve significant emergent plant growth in a similar time frame.

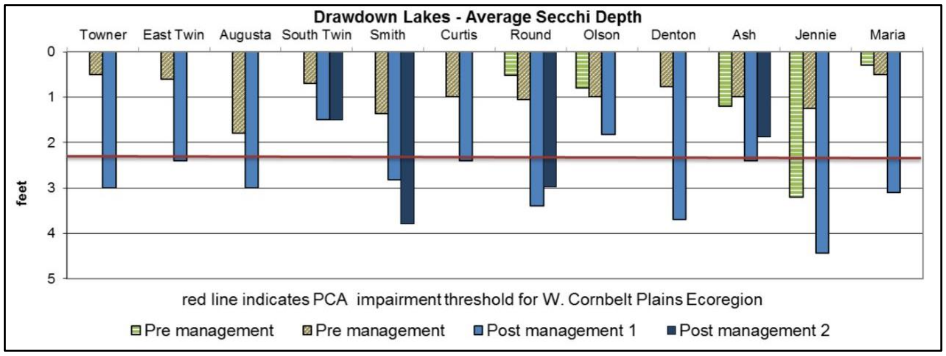

Figure 23: Secchi transparency readings on drawdown lakes pre and post projects in Minnesota

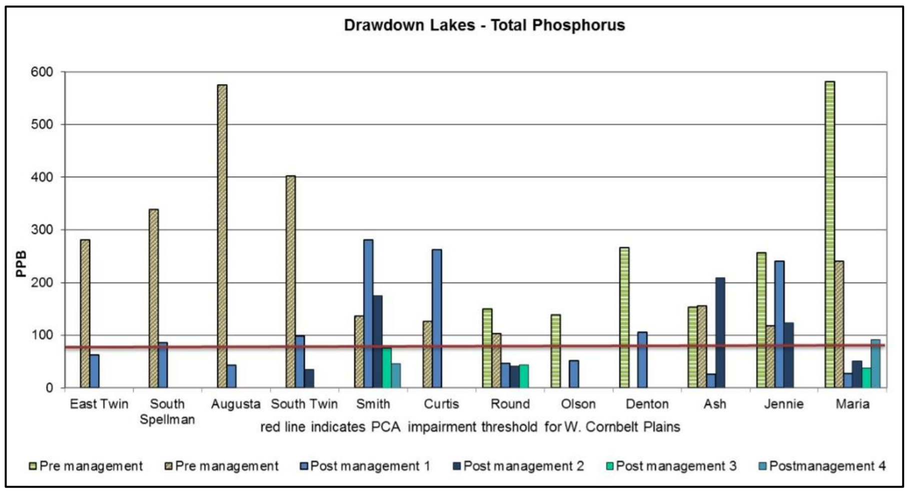

Figure 24: Total phosphorus concentration on drawdown lakes pre and post project in Minnesota

We have kept in contact with the TMDL modeler Bill Walker regarding the potential water quality effects of this drawdown. He states that "Another mechanism that would provide water quality benefits would be that drawdown during August would help to flush nutrients out of the Lake during the season when the water column concentrations are highest. This would have a cumulative effect of reducing the nutrients that have accumulated in the water and sediments over the years." He has also stated in phone calls that perpetuating plant growth in the near shore areas will help reduce recycling and re-suspension of nutrients, which is important for the lake because of its size, shape and long fetch (which causes extensive wave action).

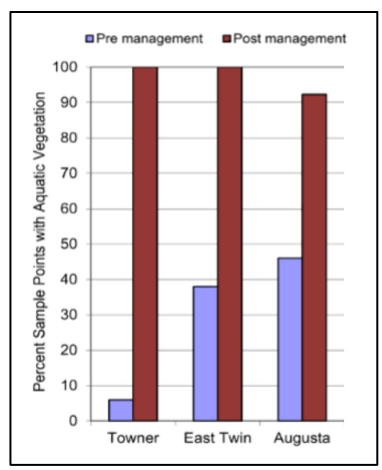

Figure 25: Percent sample points with aquatic vegetation on drawdown lakes pre and post projects in Minnesota.
http://files.dnr.state.mn.us/aboutdnr/reports/legislative/2012-shallow-lk-mgmt.pdf

Drawdowns have been routinely used for wetland restoration in waterfowl basins and on navigable channels of the Mississippi River. In 2003, a drawdown was performed on the Sartell Wildlife Management Area (WMA). This drawdown is perhaps to most comparable to the proposed drawdown on Little Rock Lake because the Sartell WMA is in the same watershed. The Sartell WMA drawdown showed very promising results for the establishment of aquatic plants. This drawdown was performed for a longer period of time, significant plant growth was seen in a short time frame. The drawdown began in mid-summer, however due to flooding from large rain events, no vegetation had germinated prior to the flood. Water levels did not decrease until late-July and early-August. The lake basin would likely see similar vegetation growth results due to a remnant extensive seed bed.

Figure 26: Vegetation growth on August 15th after the drawdown on Sartell WMA

Figure 27: Vegetation growth on August 29th after the drawdown on Sartell WMA. Note: This photo was taken just 14 days after the photo shown in Figure 26, and significant plant growth has already established.

Figure 28: Another photo of the vegetation growth on August 29th after the drawdown on Sartell WMA. Note: This photo was taken just 14 days after the photo shown in Figure 26, and significant plant growth has already established.

Figure 29: Height of vegetation growth on August 29th after the drawdown on Sartell WMA. Note: This photo was taken just 14 days after the photo shown in Figure 26, and significant plant growth has already established.

Little Rock Lake Current Model

During a 2001 data gathering project for Little Rock Lake, a lake current model was developed by Charles Nelson. The model shows the predicted water movement within the lake under varying wind directions. As shown in figures 30 and 31, predicted water movements at many near shore and shallow locations are accelerated in areas that currently have little if any aquatic vegetation.

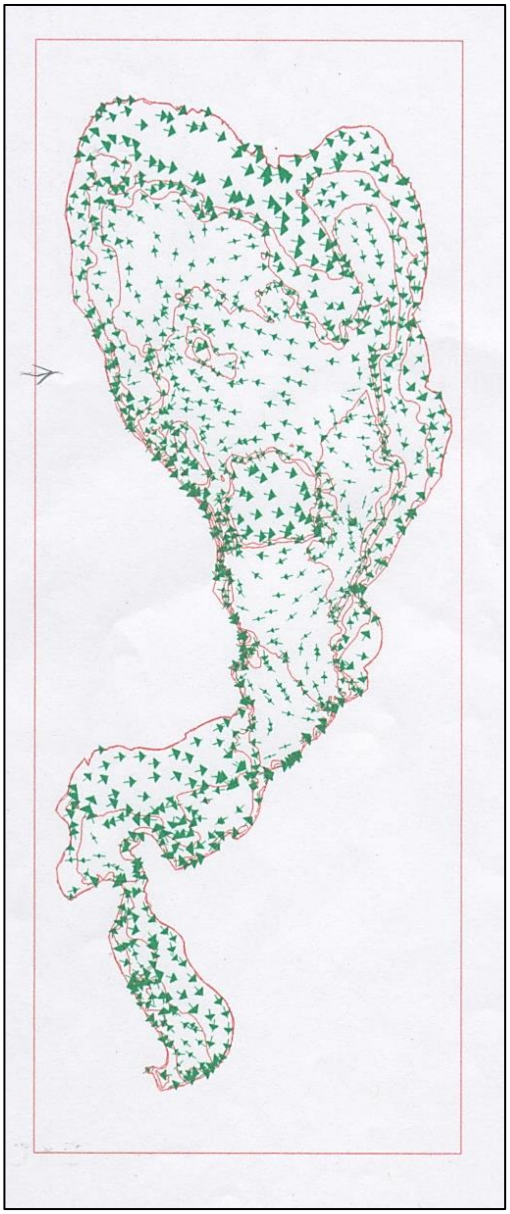

Figure 30: This map is representing a model, generated by Dr. Charles Nelson, for the speed of currents. Specifically, it shows how the wind will affect currents in Little Rock Lake under wind conditions of five (5) meters per second with the wind blowing at a bearing of 270 degrees. The larger the arrow size, the greater the current speed.

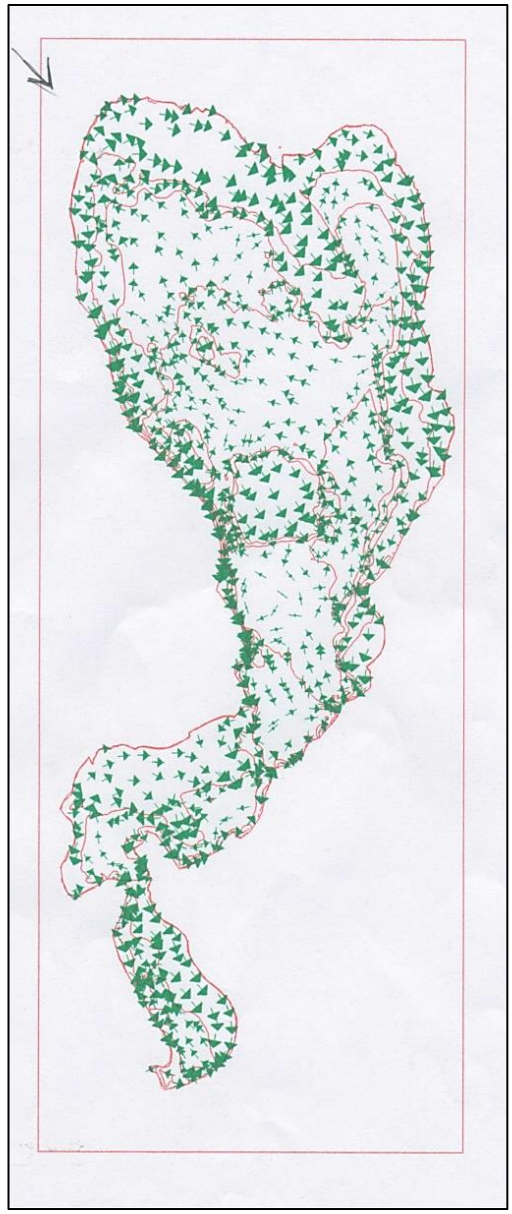

Figure 31: This map represents the same model, but the data used to generate this map includes a wind at five (5) meters per second blowing at a bearing of 315 degrees. The larger the arrow, the greater the current speed.

Aquatic Invasive Species Assessment

Little Rock Lake is currently known to contain three invasive species; common carp, zebra mussels (lower basin) and curly-leaf pondweed. Carp and other bottom feeding fish contribute to water quality issues because they increase nutrient levels in the lake through their foraging. Curly-leaf pond weed also has negative effects on water quality as these plants affect internal nutrient cycling which can result in algal blooms. While significant amounts of curly-leaf pond weed have been present on Little Rock Lake in the past, the very low water clarity depth has likely prevented all plant growth in the lake, including curly-leaf pond weed. It is likely that the drawdown will allow significant populations to return due to the increased water clarity. With increases in water clarity, many species of plants will likely proliferate. Currently, species such as flatstem pondweed, Sago pondweed and bushy pondweed have been observed with moderate increases in water clarity.

To date, no in-lake management practices have been initiated regarding aquatic invasive species (AIS) management. As TMDL Implementation has begun focusing on secondary practices, AIS management efforts will increase as carp management and AIS plant management are both listed as secondary implementation focuses. This switch to focusing on secondary practices has come at a great time as Benton County is currently in the process of developing a county wide AIS management plan. The plan will assess the presence and severity of AIS and focus management and restoration strategies, with some focus on carp control.

As a means of carp management, the Little Rock Lake Association began their first annual Carp Fishing Contest in 2017. This event has a significant turnout of 106 participants. This contest not only promoted AIS awareness but also removed nearly 3,000 pounds of carp from the lake. Carp control and removal alone is not likely to have a high percentage impact on phosphorus reduction. It will however help extend the timeline of benefits of the drawdown by reducing the degradation of the aquatic plant community.

Complete System Drawdown Project Details

Cost Calculation of the Project

Eagle Creek Renewable Energy (Eagle Creek) has investigated the feasibility of a controlled three-foot drawdown over a six week period at its federally licensed Sartell Hydroelectric Project. In order to accomplish the planned drawdown of the project impoundment, Eagle Creek will need to shut down the generating equipment to avoid hydraulic operating issues with the station turbines, and provide controlled flow releases through spillway gates at the dam to gradually lower the project impoundment to the targeted elevation. The drawdown effort will result in an extended period of non-generation at the project and associated loss of energy production revenue and capacity value. Several meetings have been held with EC to determine the feasibility of the drawdown and the cost associated with the activity. The costs associated with investigating the technical feasibility of an impoundment drawdown, including the planning, permitting and labor associated with the manipulation of the spillway gates, and monitoring the project during the drawdown and refill, are not being sought for this project. Costs are based solely on the lost energy and capacity revenue as a result of an extended station outage. Costs were calculated based on historic energy production records calculated on a weekly basis for the proposed drawdown timeframe of August 1 – September 15, 2018. The calculations are shown below in Table 6.

Table 6: Weekly average cost calculations for Eagle Creek Energy

Month	Weekly Average Costs
August	$44,556 per week * 4 weeks = $178,224
September	$28,154 per week * 2 weeks = $56,308
Total for 6 Weeks	**$234,532**

Table 7: Breakdown of drawdown project expenses and sources

Activity	Total Cost	Source of Funding				
		State Grant	EC/LRLA	DNR		Landowner
				Cash	In-Kind	Match
Drawdown the water at Sartell dam by three feet	$235,000	$166,250	$68,750	-	-	-
Education outreach	$5,000	-	$3,000	-	$2,000	-
Engineering and technical assistance	$20,000	$20,000	-	-	TBD	-
Erosion control project installation	$134,000	-	-	$134,000	-	25%
Plantings, clean up, post drawdown education and maintenance activities	$55,000	-	20,000 *includes volunteer boyscouts	$20,000	$15,000	-
Post drawdown activites	$5,000	-	$5,000	-	-	-
Administration and coordination	$12,000	$12,000	-	-	-	-
Total Cost	**$466,000**	**$198,250**	**$96,750**	**$154,000**	**$17,000+**	

Public Acceptance of the Project

The DNR conducted a survey in 2016 to evaluate public acceptance of the project. Post-card and online surveys were mailed and made available to all potentially affected area shoreline residents (907), nearly 54% of all postcards were returned and numerous online responses were also received from non-residents alike. Results show that this project is widely accepted (65% overall) approval, either in favor or impartial. However, acceptance rates from the lake residents were significantly higher than the river residents (95%). The limited navigation on the river, channel, and lake along with recreational impacts were the main reasons for public disapproval. The survey indicated the drawdown would occur July – August, however, due to the higher revenue loss during these months the project was pushed back to August – September. As a result, acceptance of this project from river residents improved as recreation and navigation will not be hindered on July 4th. As this project has progressed, public acceptance of this project has significantly increased with almost 100% approval from lake residents.

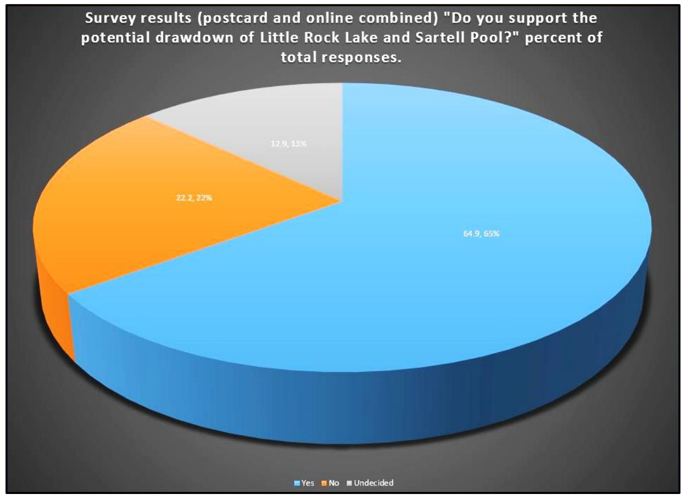

Figure 32: Results from 2016 survey conducted to evaluate public support for the drawdown

Social Implications of the Drawdown

The newly exposed soil during the drawdown will allow native plant species to flourish. Current conditions in the lake have allowed for very minimal plant growth. The drawdown will allow these native plants to establish and will likely be quite abundant along shoreline. Lake and River residents were informed they will likely see a significant change in abundance of aquatic plants "weeds," and were informed that while the presence of aquatic plants can be less than aesthetically pleasing to some, there are water quality benefits of this plant growth.

Percentage of Phosphorus Treated

The drawdown will aerate, compact and achieve solar exposure for the soil, facilitating plant growth and nutrient uptake to reduce phosphorus levels and increase water clarity. Based on results from other drawdowns performed in Minnesota, the proposed drawdown project will provide a phosphorus reduction between 30% - 40% and a 50% - 75% water clarity increase.

Table 7: Estimated reductions for 3 erosion control projects

Soil (estimated savings)	368 (T/yr)
Phosphorus	356 (lbs/yr)

The three erosion control projects which will be completed during the drawdown will provide an additional phosphorus reduction. Based on DNR erosion rate calculations, the top three sites were chosen to install erosion control BMPs. The top erosion site has already been surveyed and designed. The installation of these projects will significantly reduce total suspended solids, soil, and phosphorus (Table 9).

For the purposes of estimating the phosphorus reduction that will result from the drawdown, we have taken a conservative approach. Little Rock Lake has several unique characteristics that make predicting the impacts using TMDL calculations very difficult and perhaps unreliable without in-depth study. Based on other drawdowns, we know the impact will be significant.

We feel the phosphorus reduction values from other drawdowns will be more closely related to the Little Rock Lake system than the increase in water clarity from other drawdowns. Therefore, we chose to perform our calculations on the phosphorus reductions followed by a comparison to water clarity expectations for validation. One aspect of Little Rock Lake that complicates estimating is the complex phosphorus feedback loops that occur, primarily during the summer months when precipitation is low. We did not add anything to our estimates to account for these complex feedback loops. Additionally, internal loading was not explicit in the TMDL allocation because it is implicit in the calibration. We chose to look at release rates from the sediment study.

The following states how the phosphorus reduction values were calculated

<u>Assumptions:</u>

- Lake phosphorus reduction data from other drawdown projects are typically between 30% and 40%. **We used 30% in our calculations.**
- Phosphorus release rates from the sediment studies were 8-12 mg/square meter/day. **We used 8 in our calculations.**
- The surface area exposed in Little Rock Lake during the drawdown, including the lower parts, is 306 acres (1,238,338 square meters). **We limited our calculations to the exposed areas of the lake exclusively.**
- **Phosphorus release reductions were limited to a 90 day** period (approximately June to August), which coincides the closest to the typical low flow time period when in-lake sources are the greatest.

<u>Calculation:</u>

1. $8\, mg \frac{\frac{phosphorus}{square\ meter}}{Day} \div 453{,}592 \frac{mg}{pound} = 0.0000176369\, pounds \frac{\frac{phosphorus}{square\ meter}}{Day}$

2. $0.0000176369\, pounds \frac{\frac{phosphorus}{square\ meter}}{Day} \times 1{,}238{,}338\ square\ meters = 21.84 \frac{pounds\ of\ phosphorus}{day}$

3. $21.84 \frac{pounds\ of\ phosphorus}{day} \times 30\% = 6.5 \frac{pounds\ of\ phosphorus\ reduction}{day}$

4. $6.5 \frac{pounds\ of\ phosphorus\ reduction}{day} \times 90\ days = 598\ pounds\ of\ phosphorus\ reduced\ (annually)$

<u>Validation:</u>

$589\ pounds\ of\ phosphorus\ reduced\ (annually) \times 0.45359237 = 267\ kilograms\ annually$

- Local phosphorus reduction goal set during the TMDL study is 907 kilograms (2,000 pounds). This would avoid the most serious algae blooms.
- Interim TMDL phosphorus reduction goal is 2,450 kilograms (5,401 pounds)

- Final TMDL phosphorus reduction goal is 3,685 kilograms (8,124 pounds)

A 589 pound phosphorus reduction is very reasonable and would be expected to produce visually measurable (secchi disk) improvements to water clarity, and a noticeable reduction in the severity of algae blooms. However, given the conservative assumptions in our calculations, we expect the reductions to be at least double the calculations, or at least 1,000 pounds. Other drawdowns produced a 50% - 75% water clarity improvement, which would equate to several inches to perhaps a foot in Little Rock Lake, and as much as a 2,000 phosphorus reduction. This further validates the conservative estimate of 589 pounds. For the purposes of this feasibility study and grant application we will use 589 pounds.

Effective Life of the Drawdown / Future Maintenance

Work Done Pre-Drawdown to Extend Effected Life

In the years following the development of the Little Rock Lake TMDL and Implementation Plan there have been significant efforts to address external sources of phosphorus with the installation of over 70 BMPs in the watershed. Additional BMPs are being installed and others are being planned. While the drawdown itself will address internal phosphorus loading, this project gives the opportunity to address additional external sources of phosphorus loading as well. Based on figures 19-22 and table 4, the top three erosion sites were chosen to implement erosion control BMPs. Additionally, the DNR and LRLA along with numerous volunteers will work to plant native plant species to increase shoreline stability and decrease runoff. These projects will assist in extending the effective life of the drawdown as the TMDL states that the lake could potentially "keep itself healthy" for a longer period of time if the combination of reduced runoff from best management practices and increased plant growth in the lake can break the critical nutrient "balance point". It is believed that the drawdown will bring the lake to this critical nutrient balance point.

Effective Life of the Drawdown

Previous drawdowns have shown to be effective in the short term (7 – 10 years) and somewhat effective in the years that follow. In many cases, a drawdown will need to be periodically repeated over time, to maintain benefits. Watershed nutrient loading reductions and sedimentation reductions are necessary to favor long term improvements. It is felt that with combining several projects (within the watershed, in the lake and on the river) that increased clarity and decreased algal growth can be achieved. A stakeholder committee will be organized with representatives from the lake, river, general public, agencies and Eagle Creek Energy to evaluate the effectiveness of the drawdown. The intent is for the public to generate criteria in which subsequent drawdowns may be considered. There is potential for an area Lake Improvement District (LID) that may be able to collect funding for future projects involving water quality improvements such as drawdowns.

Plant Growth during the Drawdown

Resident seedbed within the lake basin is likely rich, however, seed examinations have not been performed. Drawdowns in similar basins typically yield quick results from plant growth if the time frame is in peak summer temperatures (June-August). Several wetland management guidelines suggest that later and quicker drawdown cycles typically result in increased cattail production in managed basins. We expect to see significant colonization of wetland favored grasses and forbs during the drawdown. Initial lake survey reports from DNR (1945) suggest that species such as prairie cord grass, bulrush, cattail, cane grass and giant burred were "common or abundant". In addition, "submerged vegetation was present in great variety and abundance. Much of it usually is present in lakes of cool temperatures and clear water". Species such as leafy pondweed, coontail and bushy pondweed were considered abundant. While species such as floatingleaf pondweed, claspingleaf pondweed and flatstem pondweed were considered common in the 1945 survey. There are some sites where public funding may allow the opportunity to insure that some emergent plant growth does occur. By using volunteer labor and native plant plugs in public areas (Benton Beach, Benton County Park carry in access, Little Rock Lake Public access) to re-establish some areas with known plant growth, we will be able to measure the success of planting during the drawdown.

Future Maintenance

As of now, only one drawdown is scheduled for this lake. The TMDL states the lake could potentially "keep itself healthy" for a longer period of time if the combination of reduced runoff from best management practices and increased plant growth in the lake can break the critical nutrient "balance point". The drawdown is anticipated to provide sufficient benefits, and therefore additional projects have not been scheduled. As the LRLA and DNR are the primary leads for this project and therefore they will be responsible for any future maintenance and planning.

The LRLA is in the process of developing a post drawdown education and maintenance plan. This plan will work to keep the public educated on the drawdown and outline the necessary steps to maintain project quality over time such as; posting signage, suggesting no wake zones, restricting four-wheeler navigation on newly exposed soil, and plant management.

Appendix

Exposed Project Area on the Mississippi River

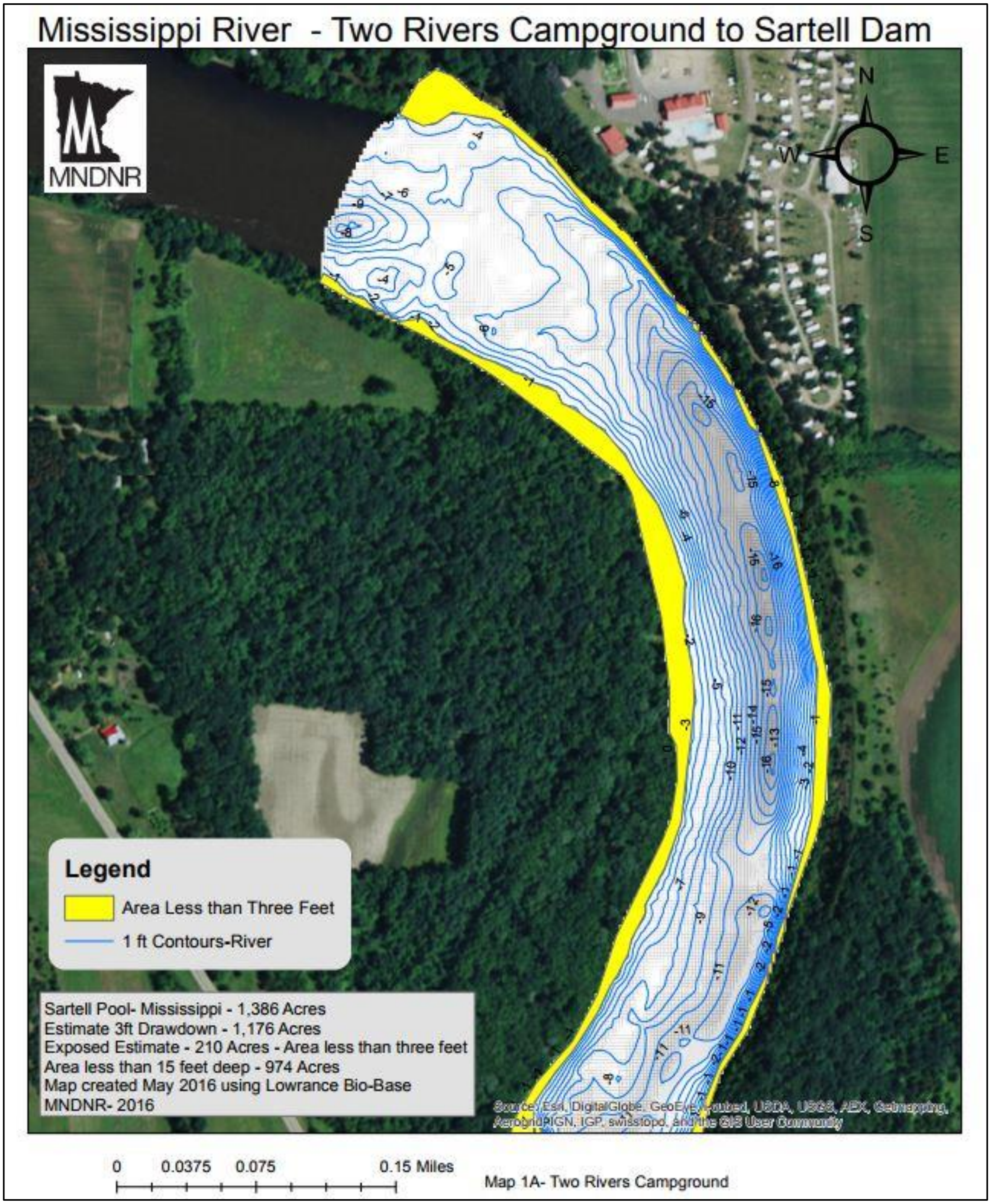

Figure 33: Exposed project area on the Mississippi River

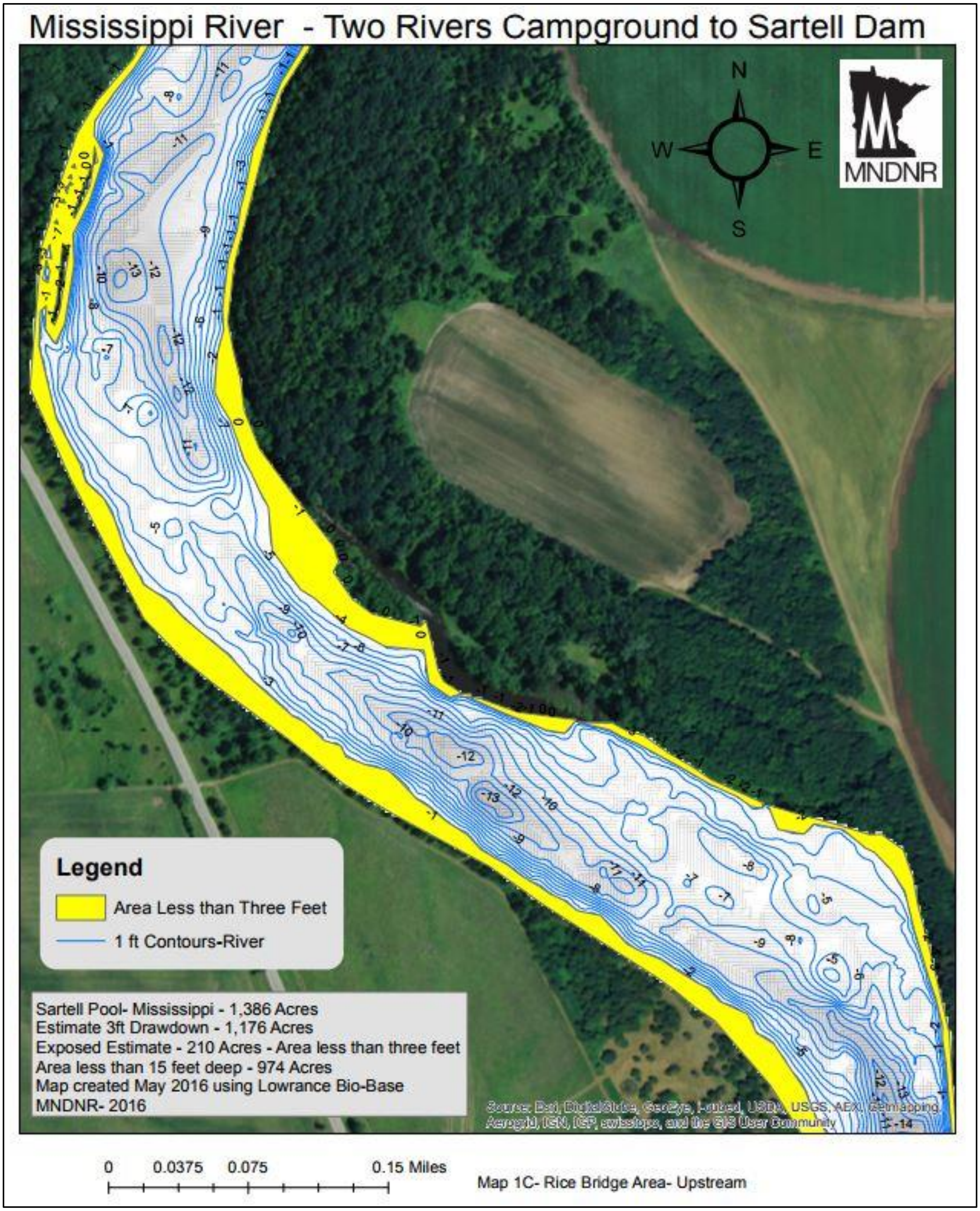

Figure 34: Exposed project area on the Mississippi River

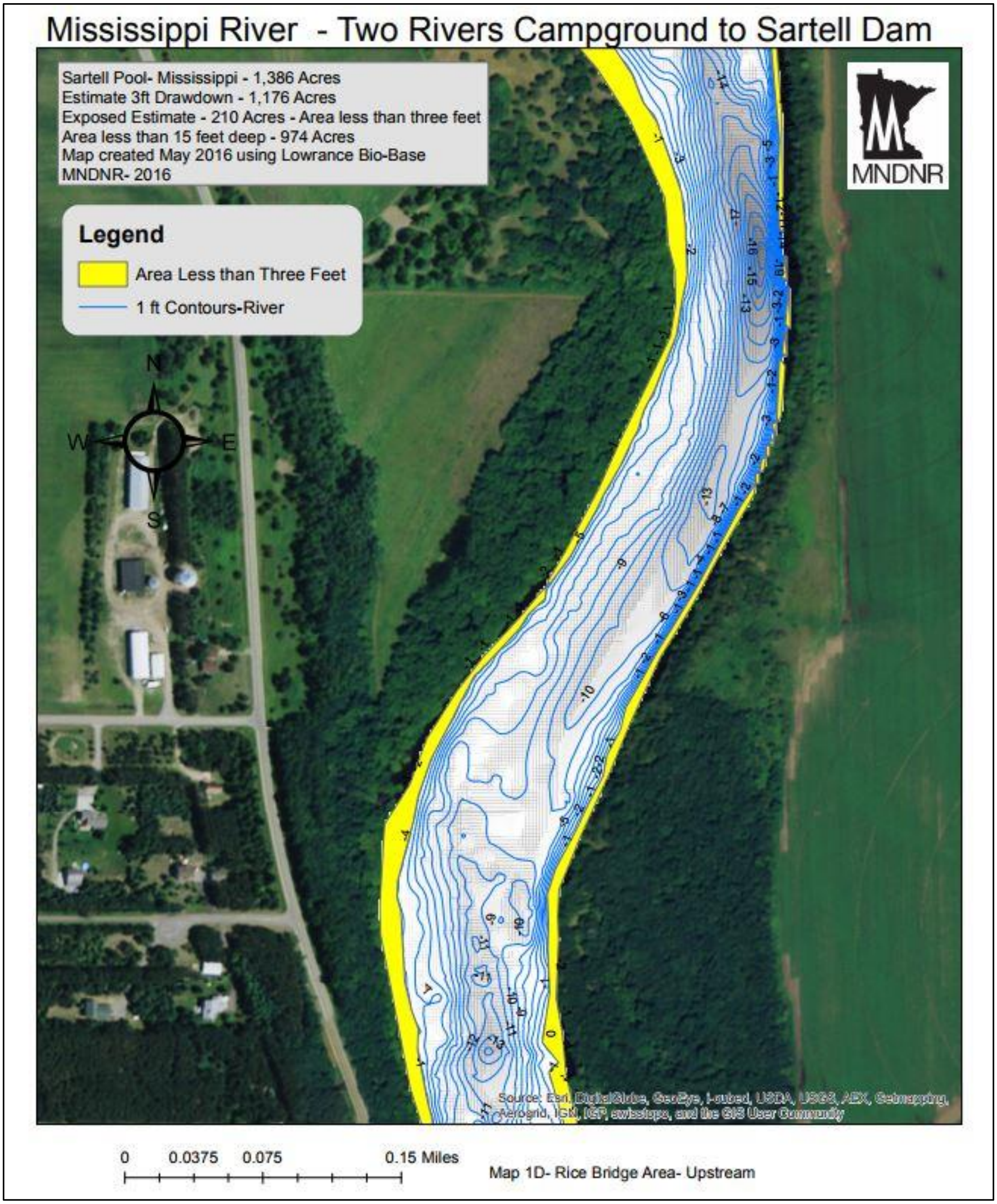

Figure 35: Exposed project area on the Mississippi River

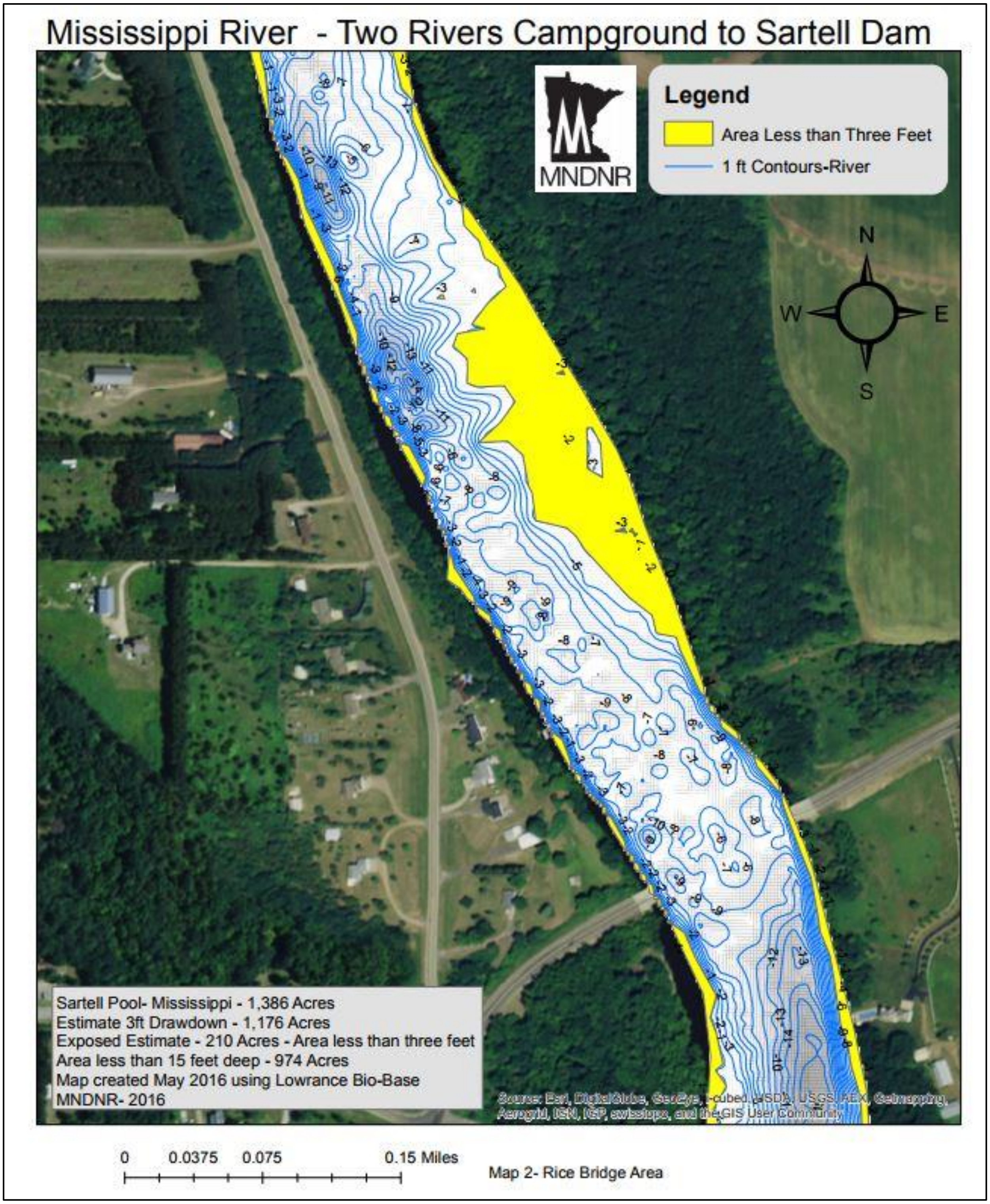

Figure 36: Exposed project area on the Mississippi River

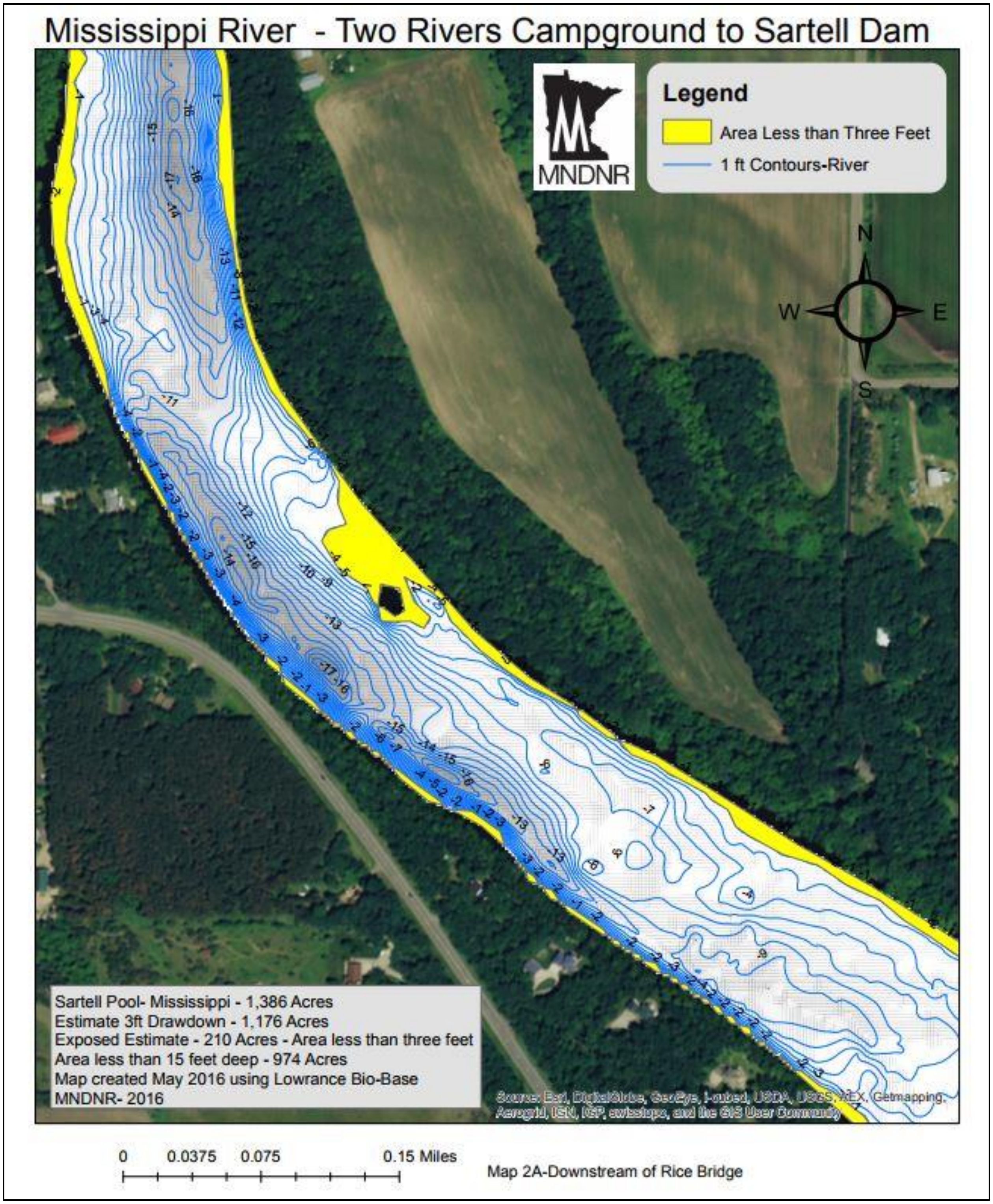

Figure 37: Exposed project area on the Mississippi River

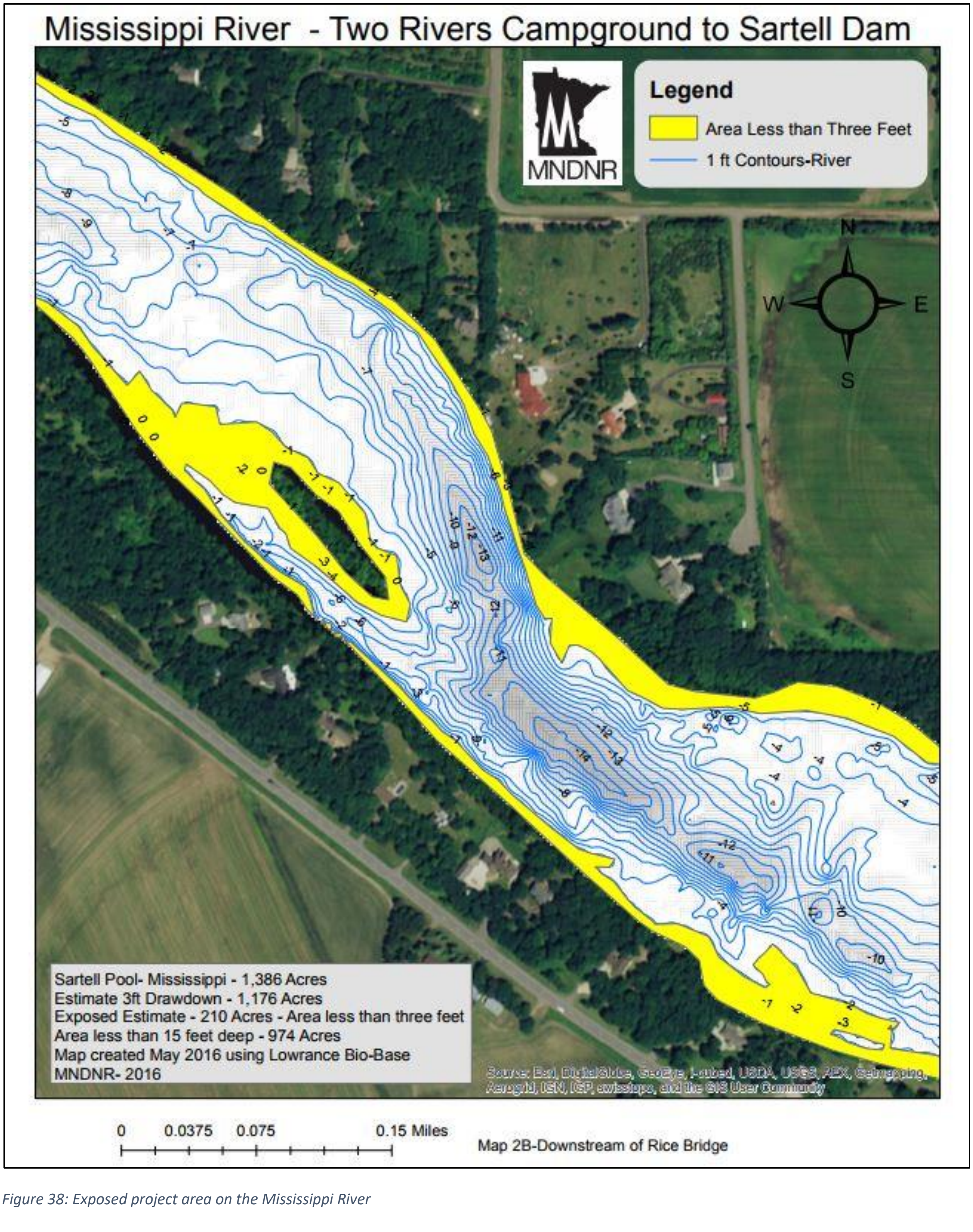

Figure 38: Exposed project area on the Mississippi River

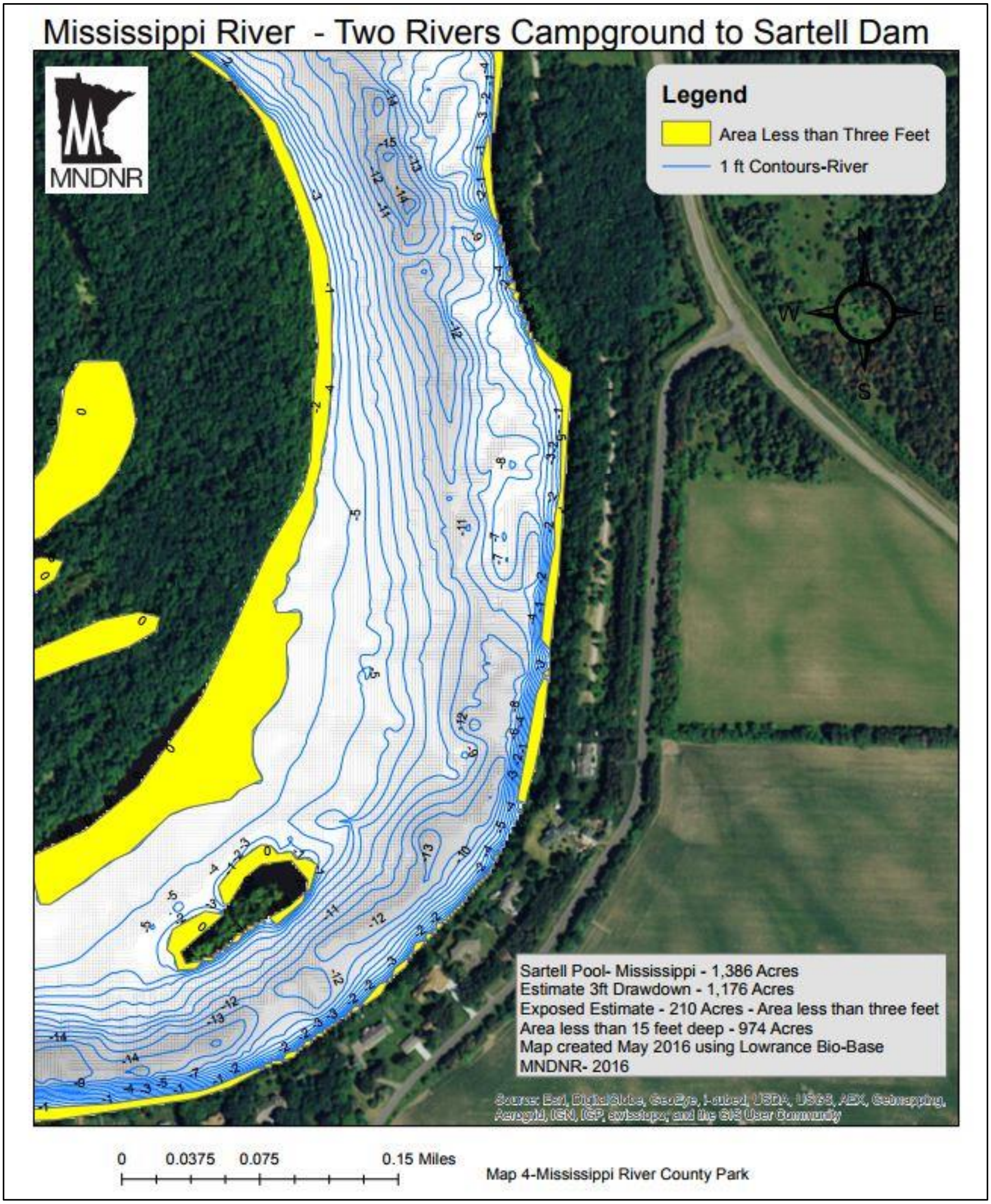

Figure 39: Exposed project area on the Mississippi River

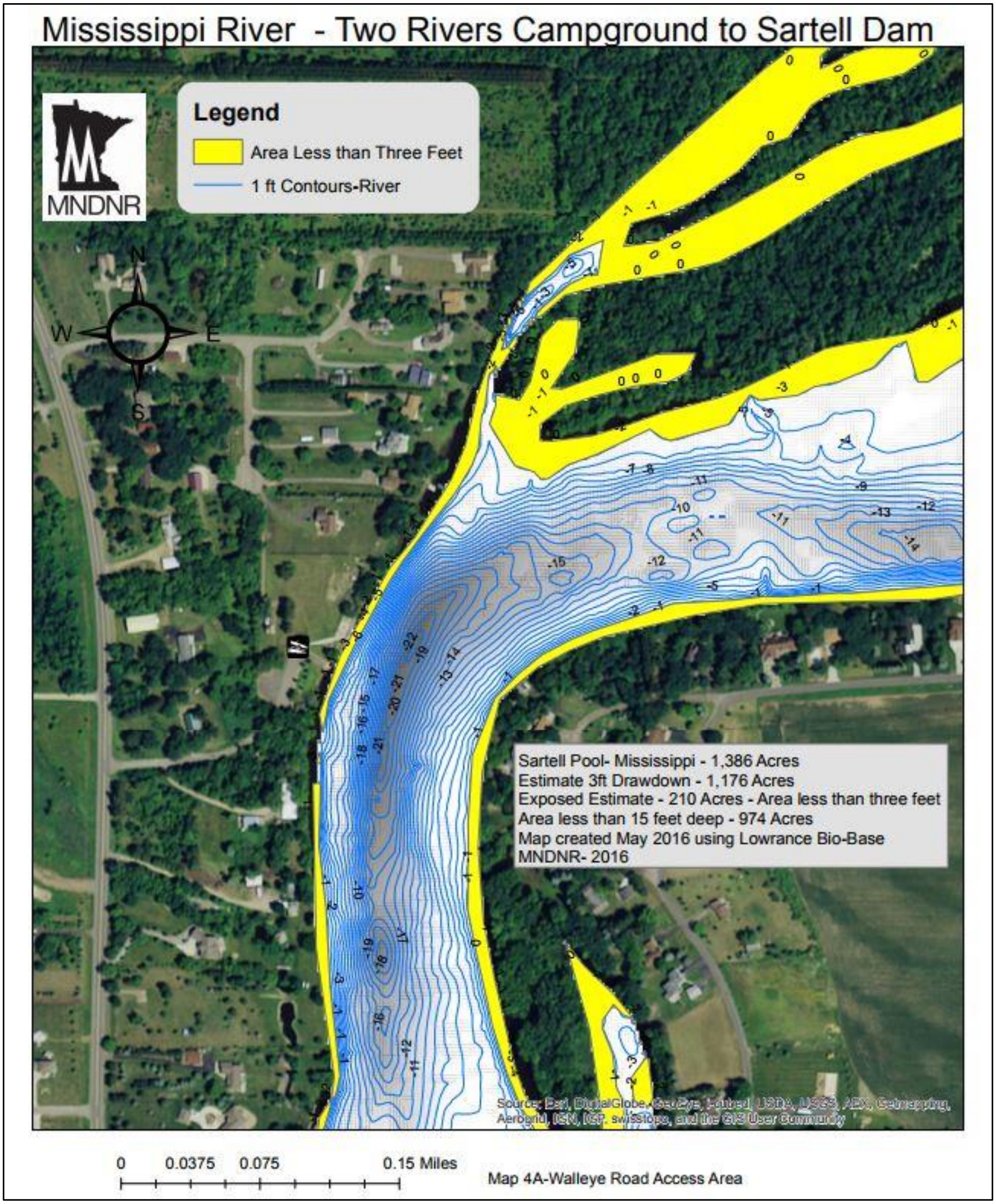

Figure 40: Exposed project area on the Mississippi River

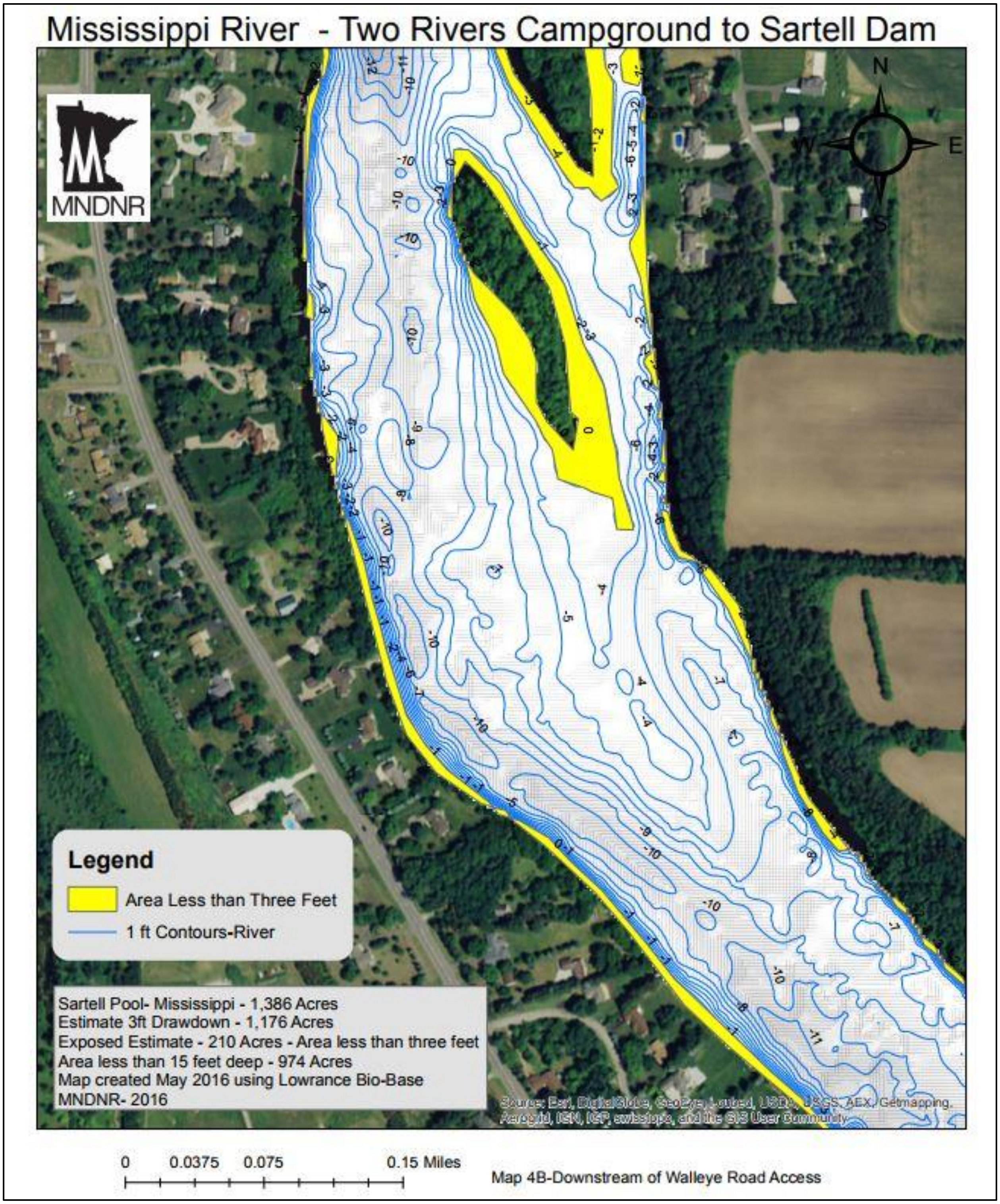

Figure 41: Exposed project area on the Mississippi River

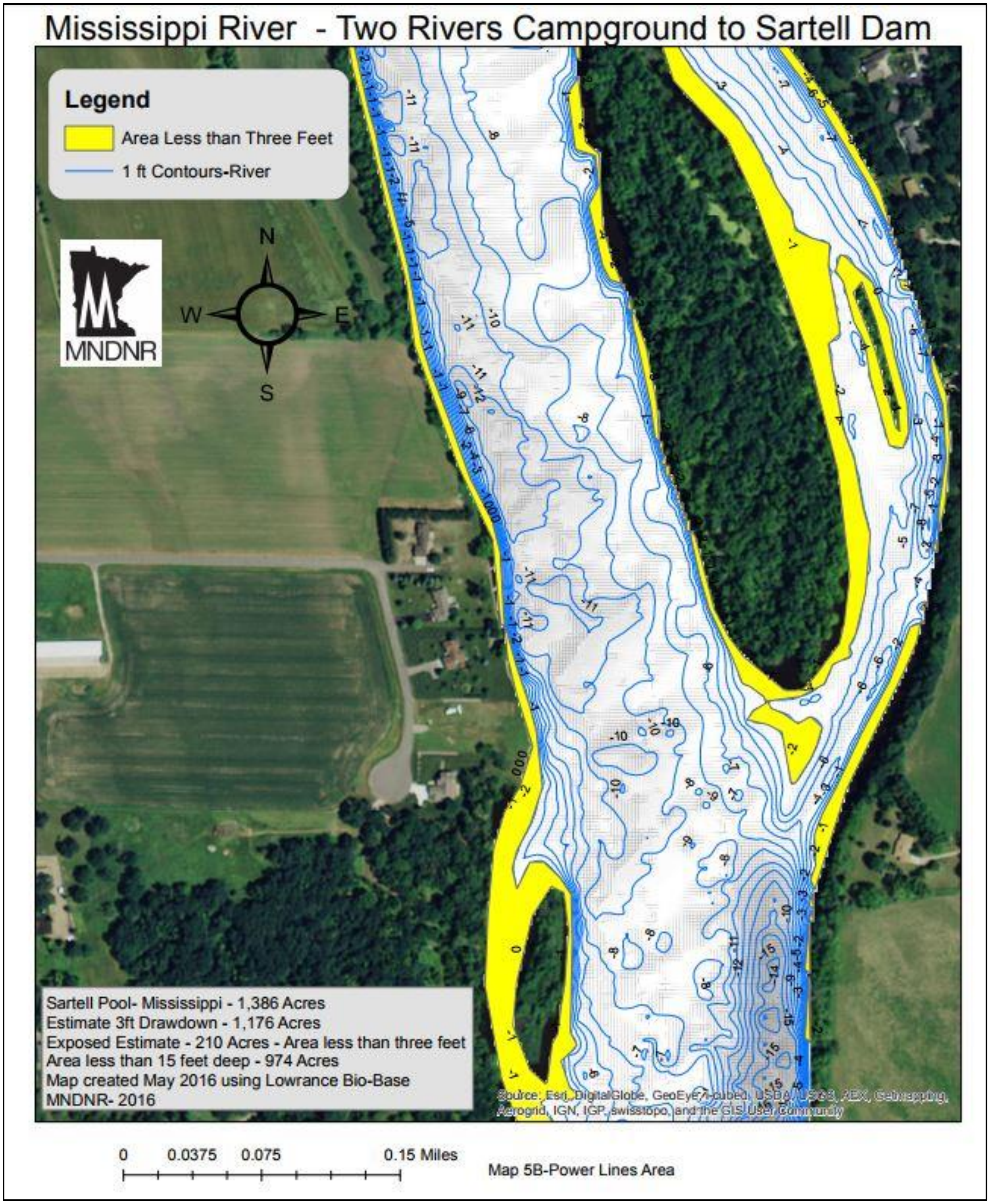

Figure 42: Exposed project area on the Mississippi River

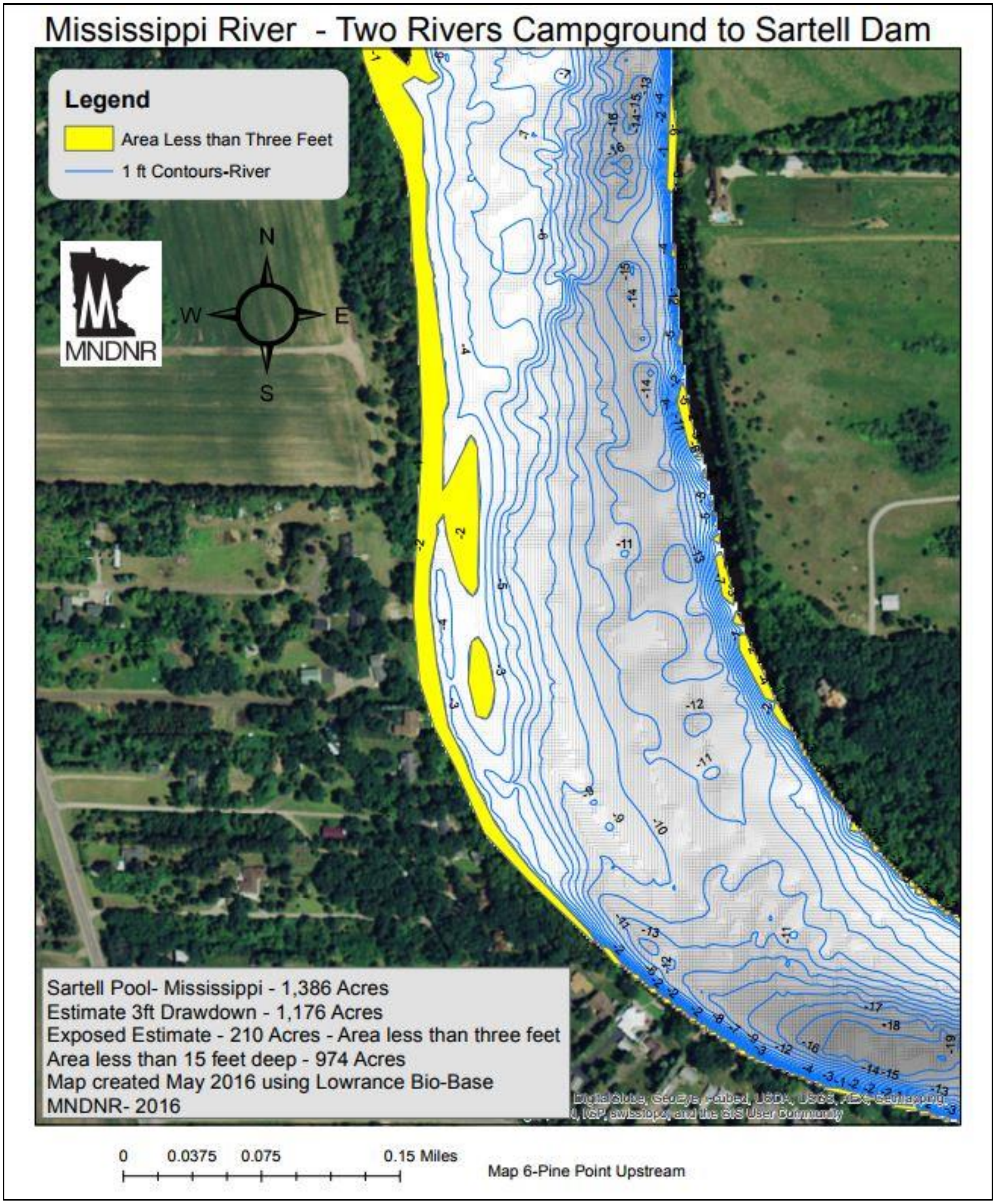

Figure 43: Exposed project area on the Mississippi River

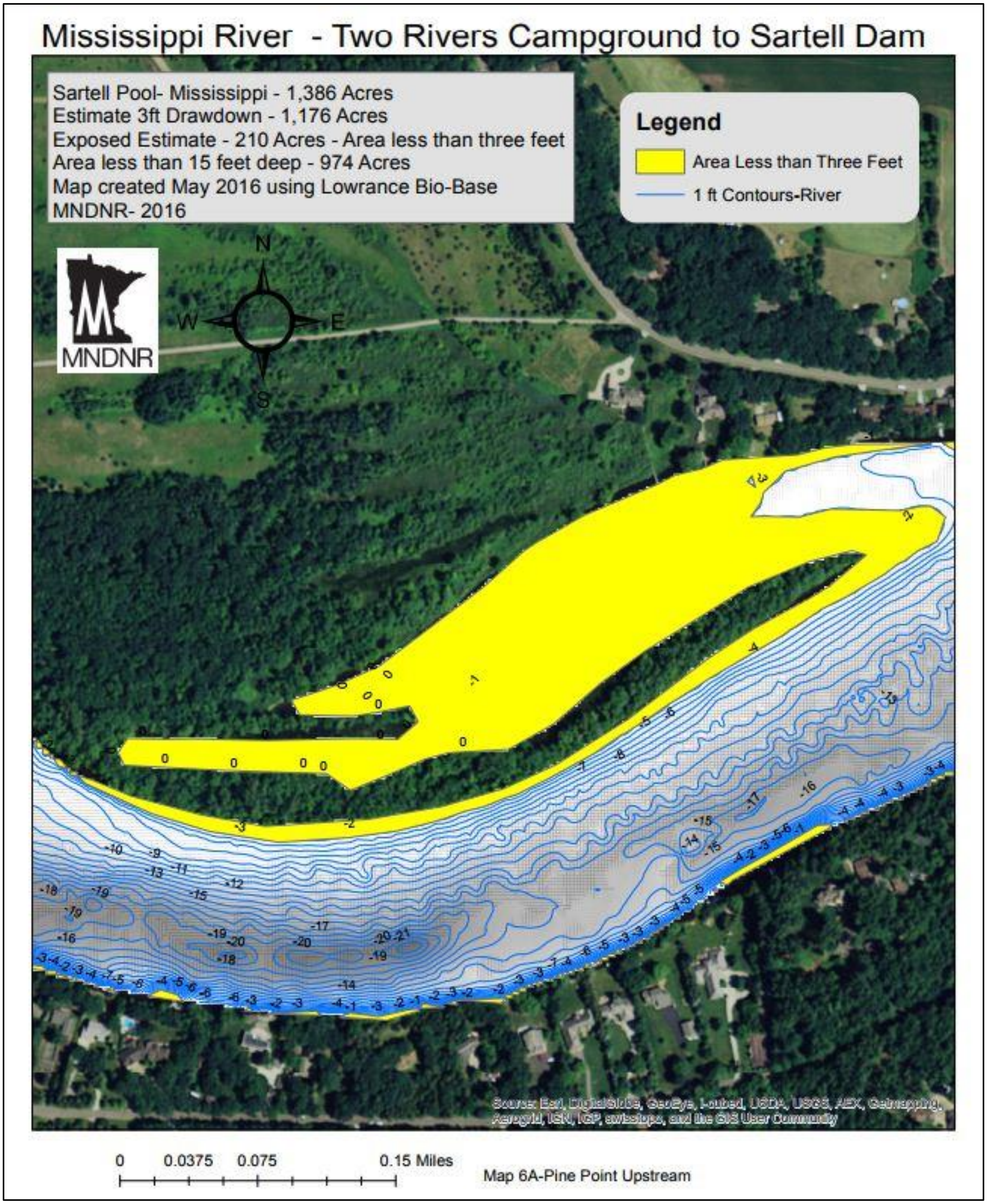

Figure 44: Exposed project area on the Mississippi River

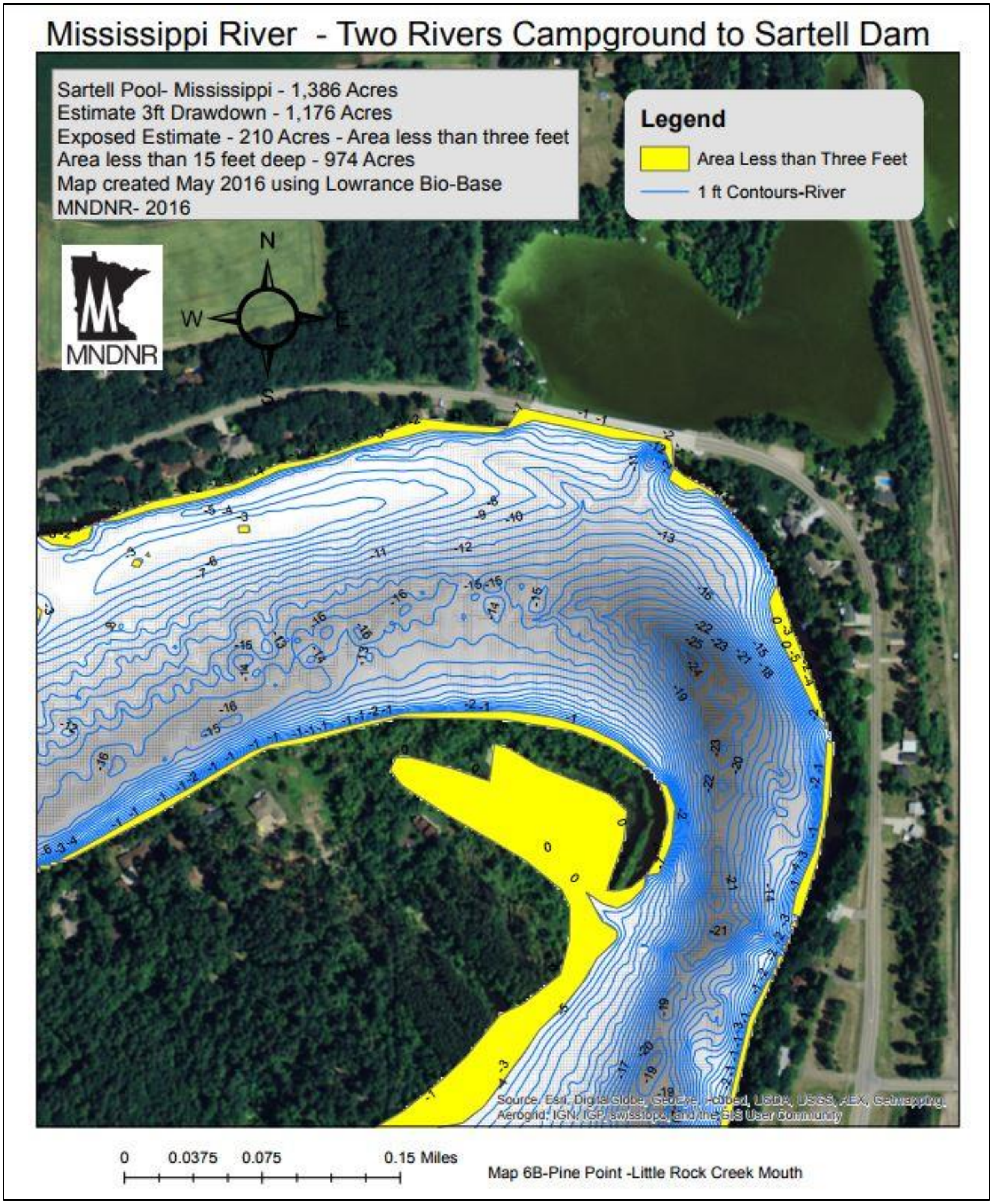

Figure 45: Exposed project area on the Mississippi River

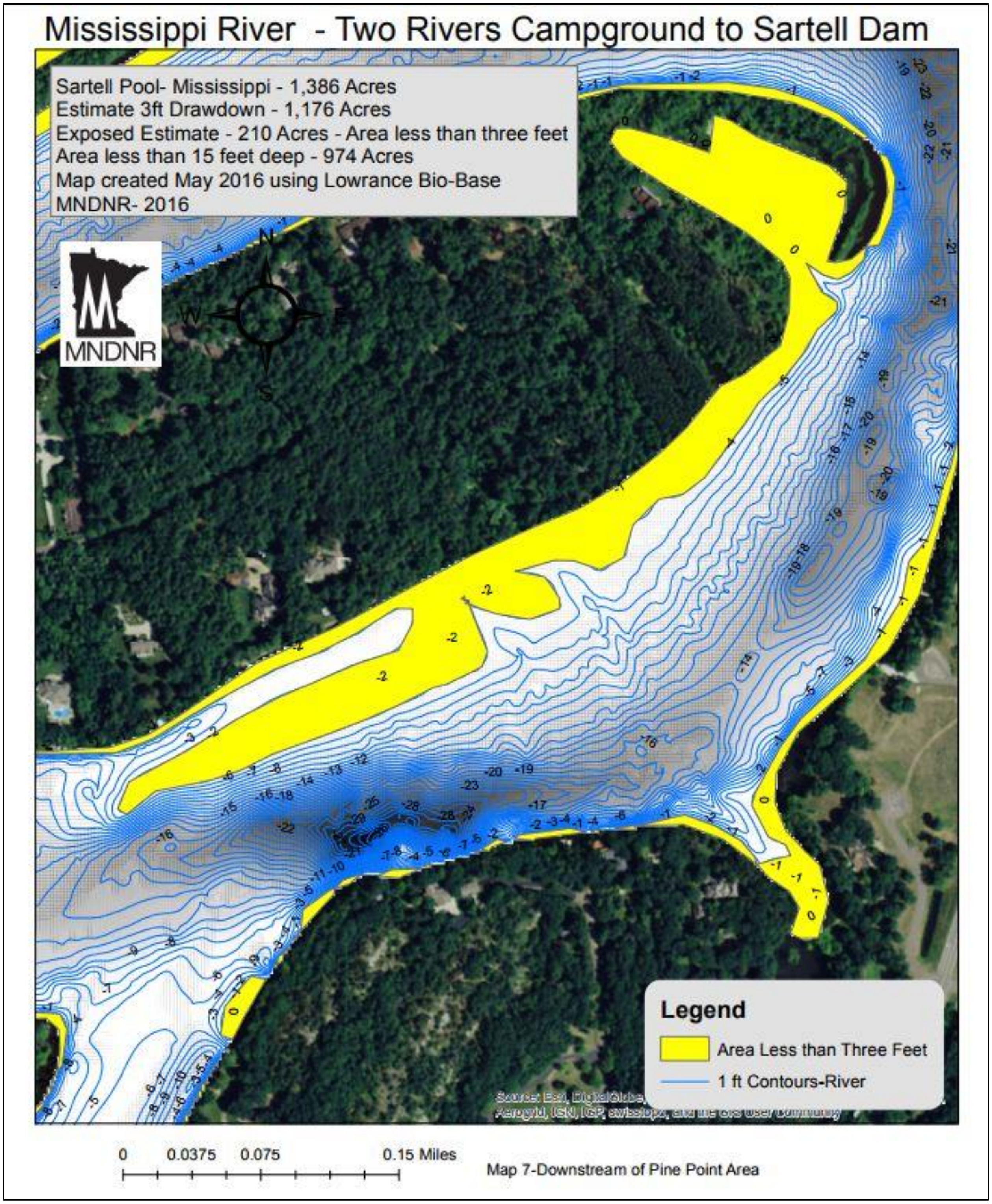

Figure 46: Exposed project area on the Mississippi River

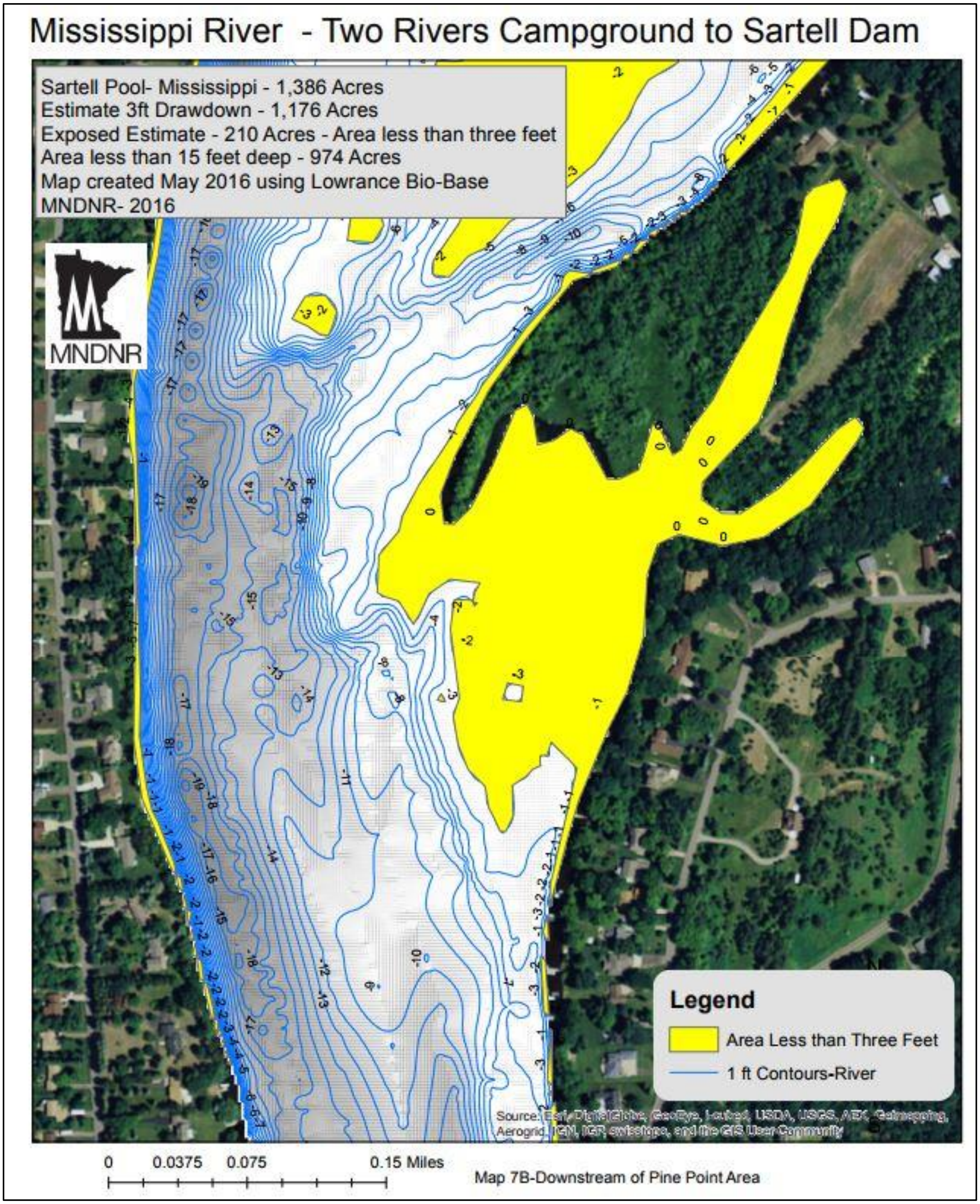

Figure 47: Exposed project area on the Mississippi River

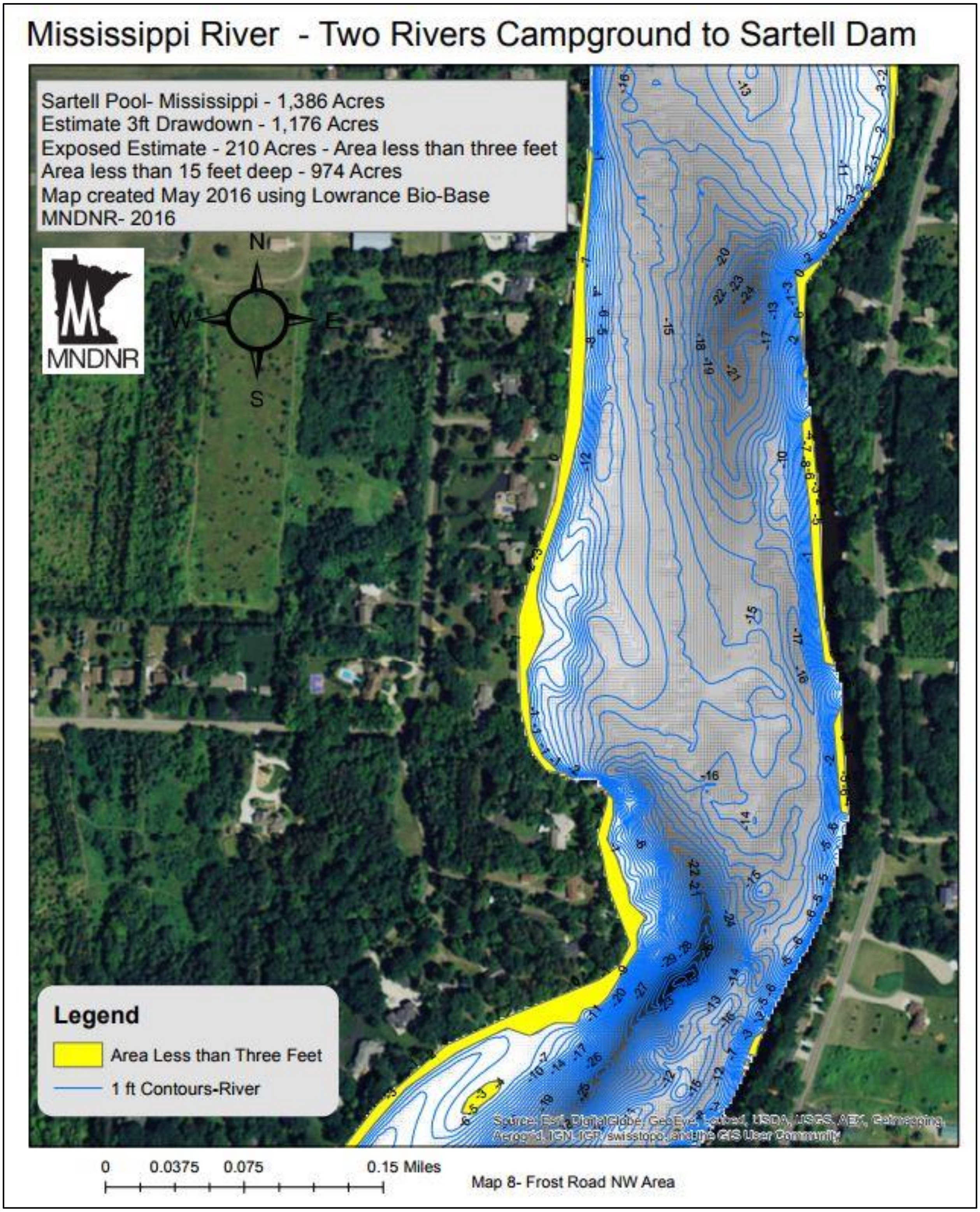

Figure 48: Exposed project area on the Mississippi River

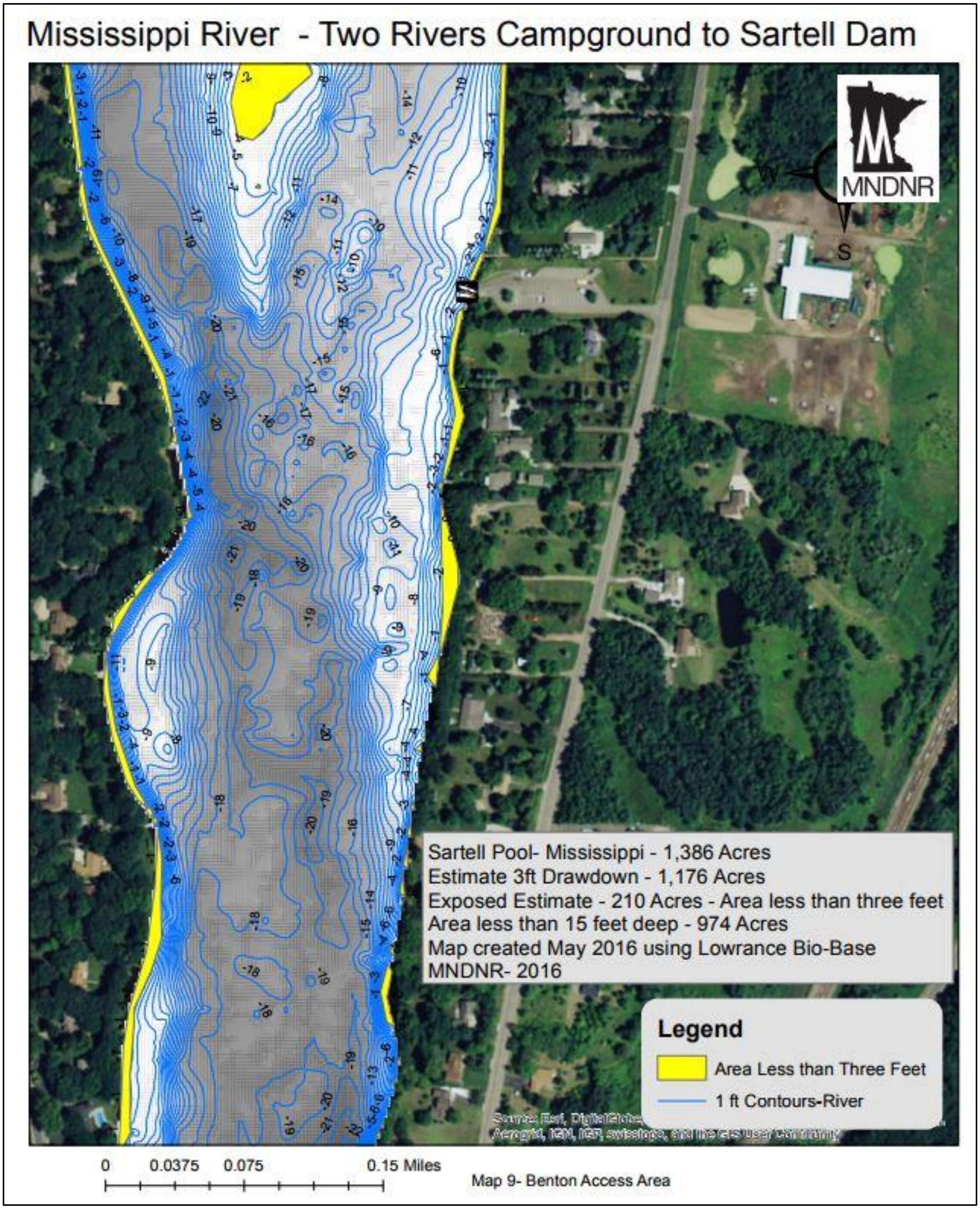

Figure 49: Exposed project area on the Mississippi River

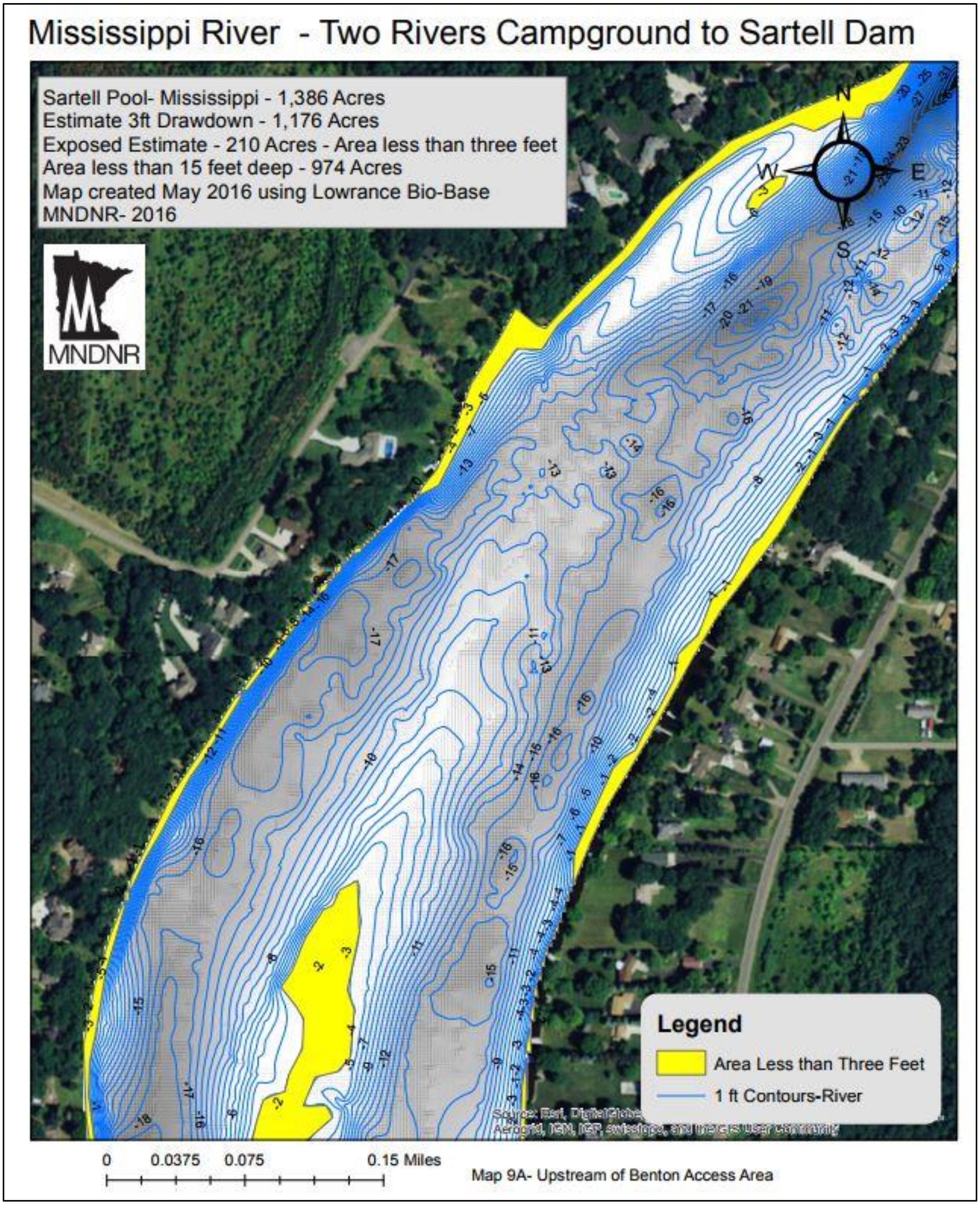

Figure 50: Exposed project area on the Mississippi River

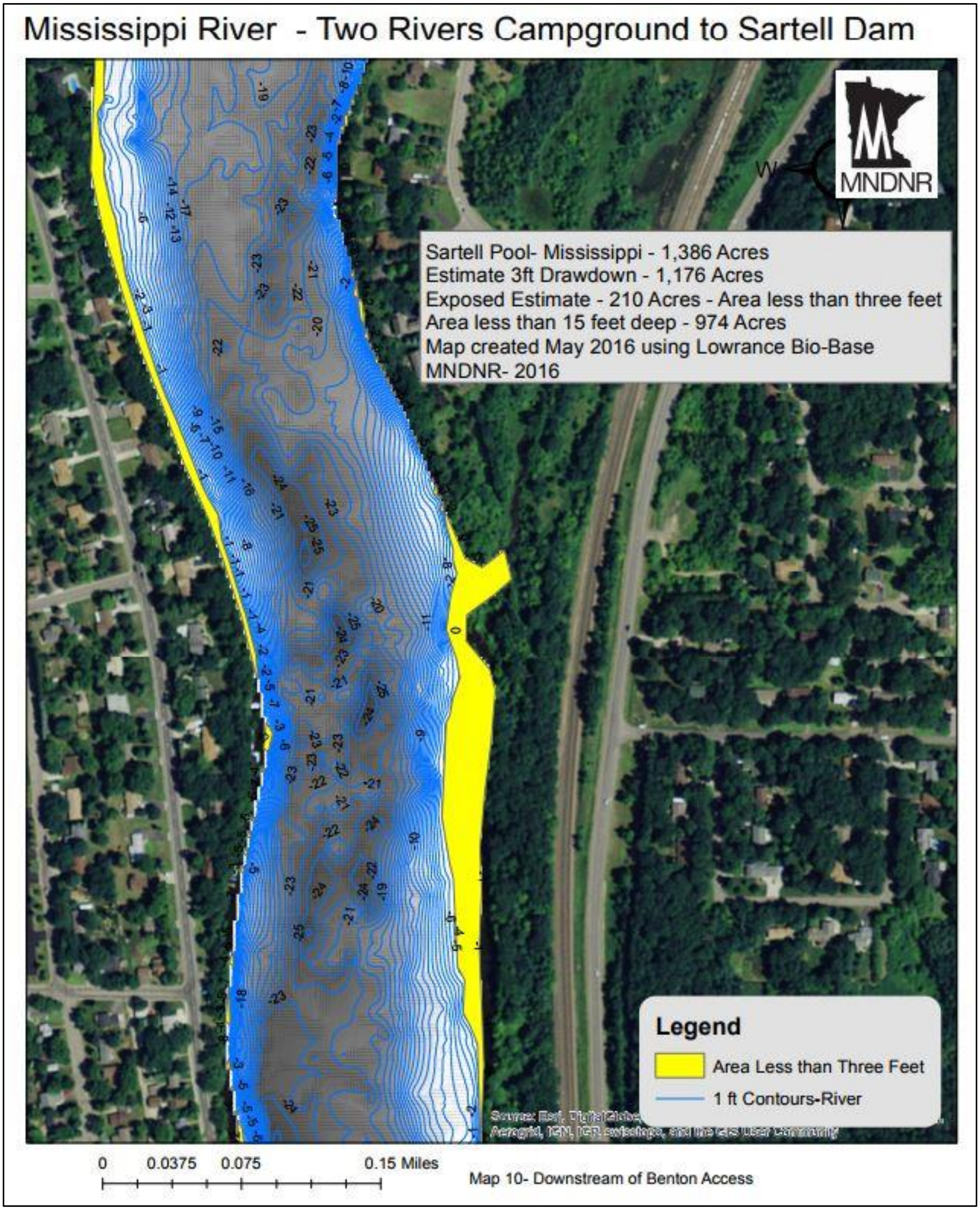

Figure 51: Exposed project area on the Mississippi River

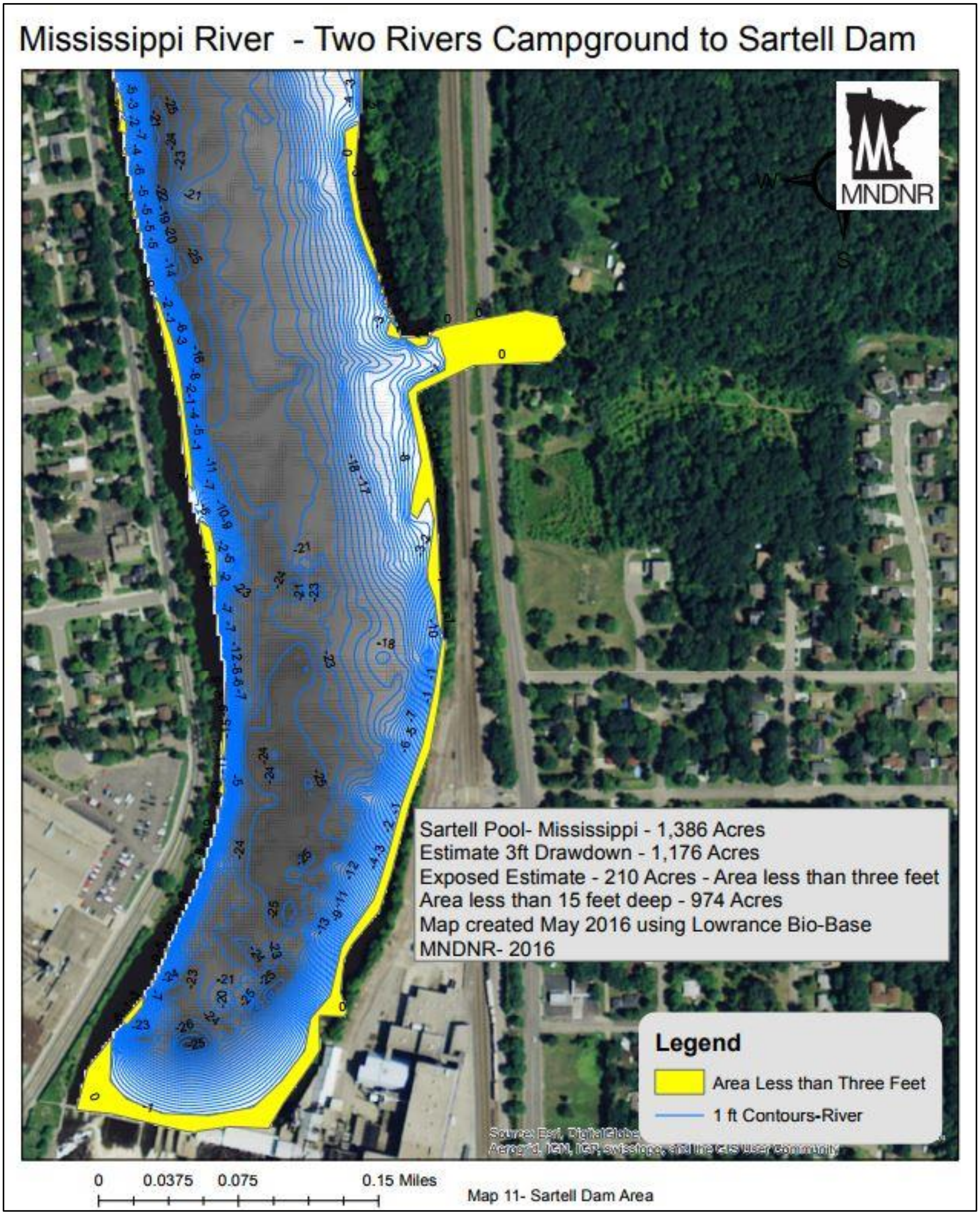

Figure 52: Exposed project area on the Mississippi River

Exposed Area on Little Rock Lake

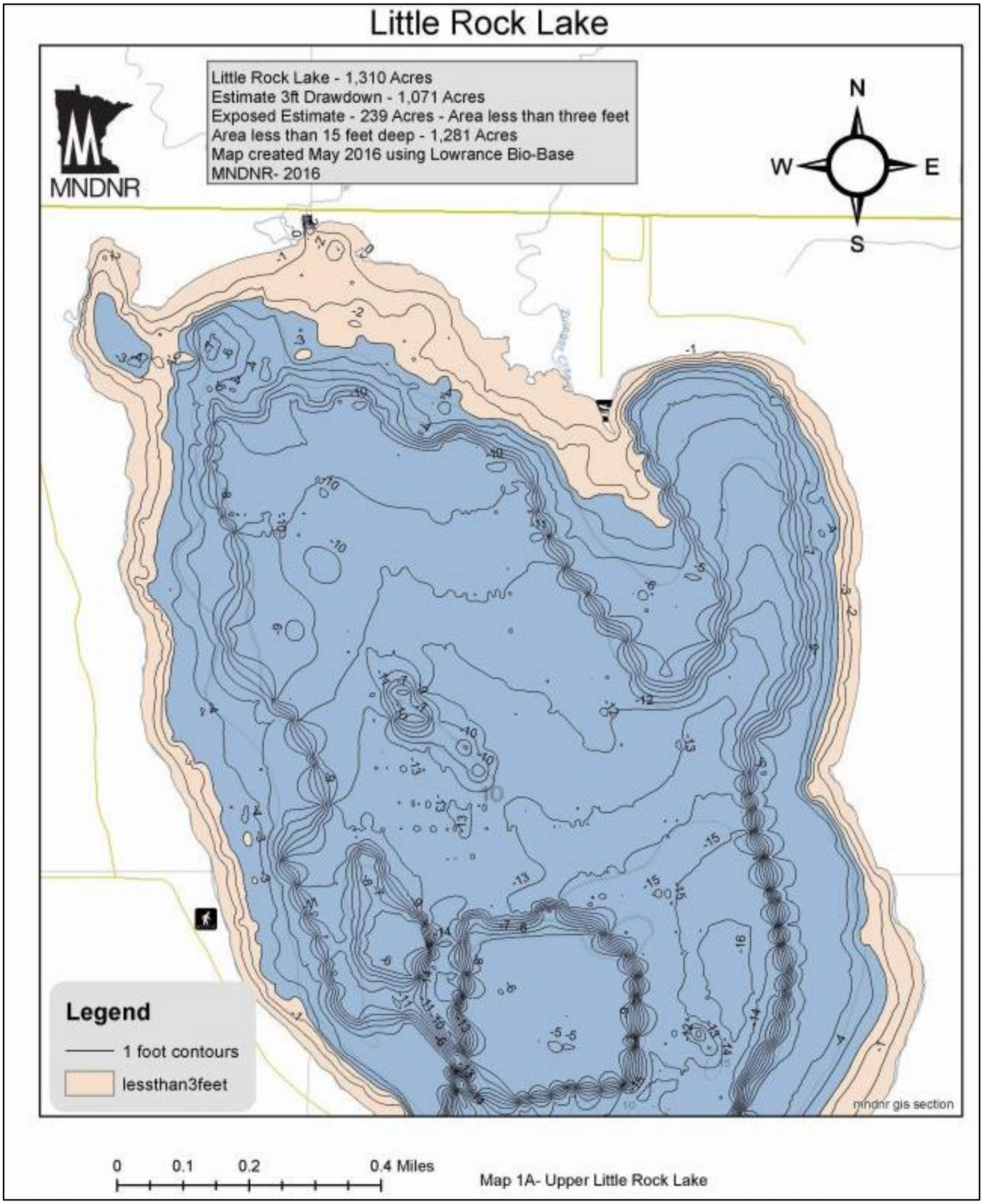

Figure 53: Exposed project area on Little Rock Lake

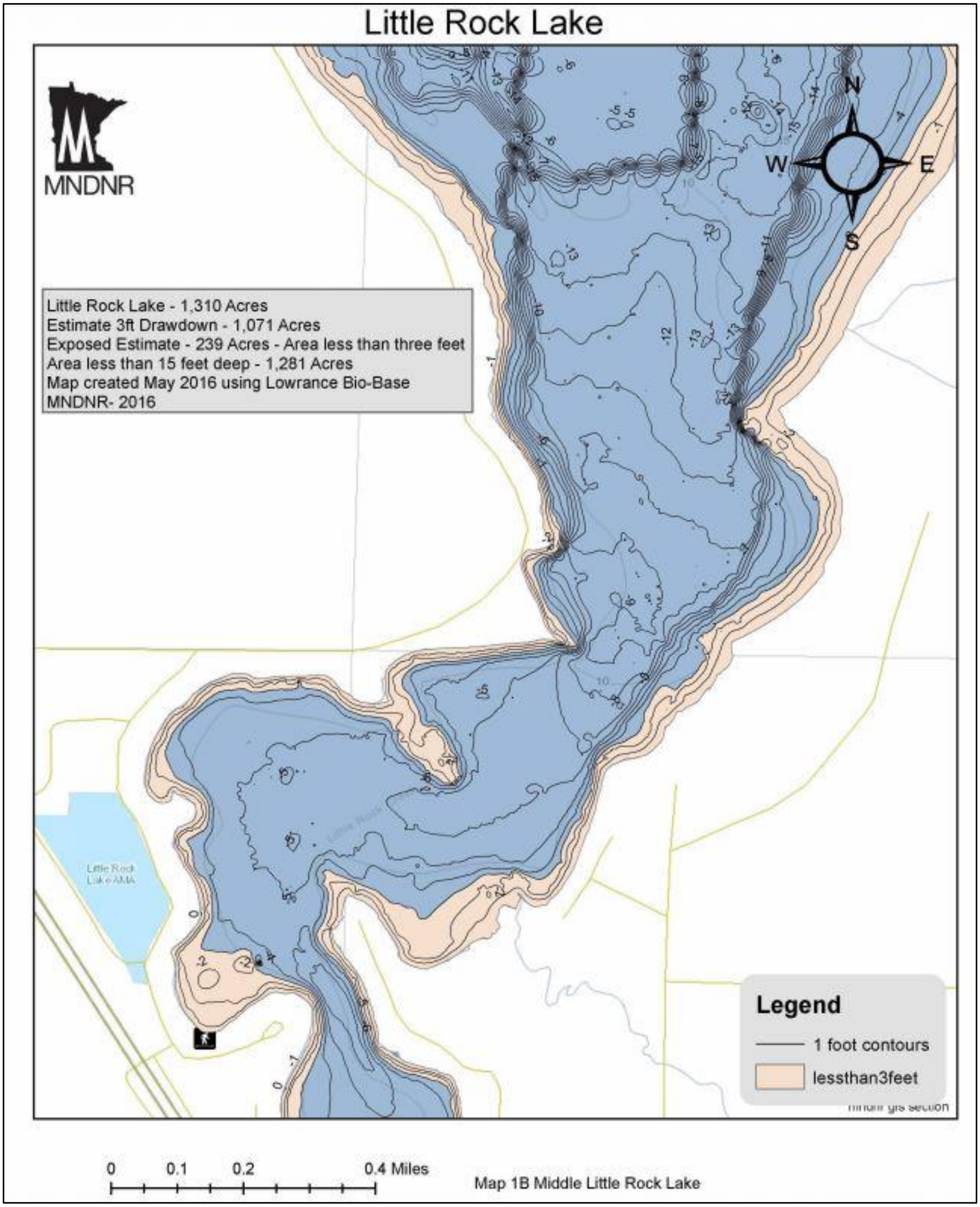

Figure 54: Exposed project area on Little Rock Lake

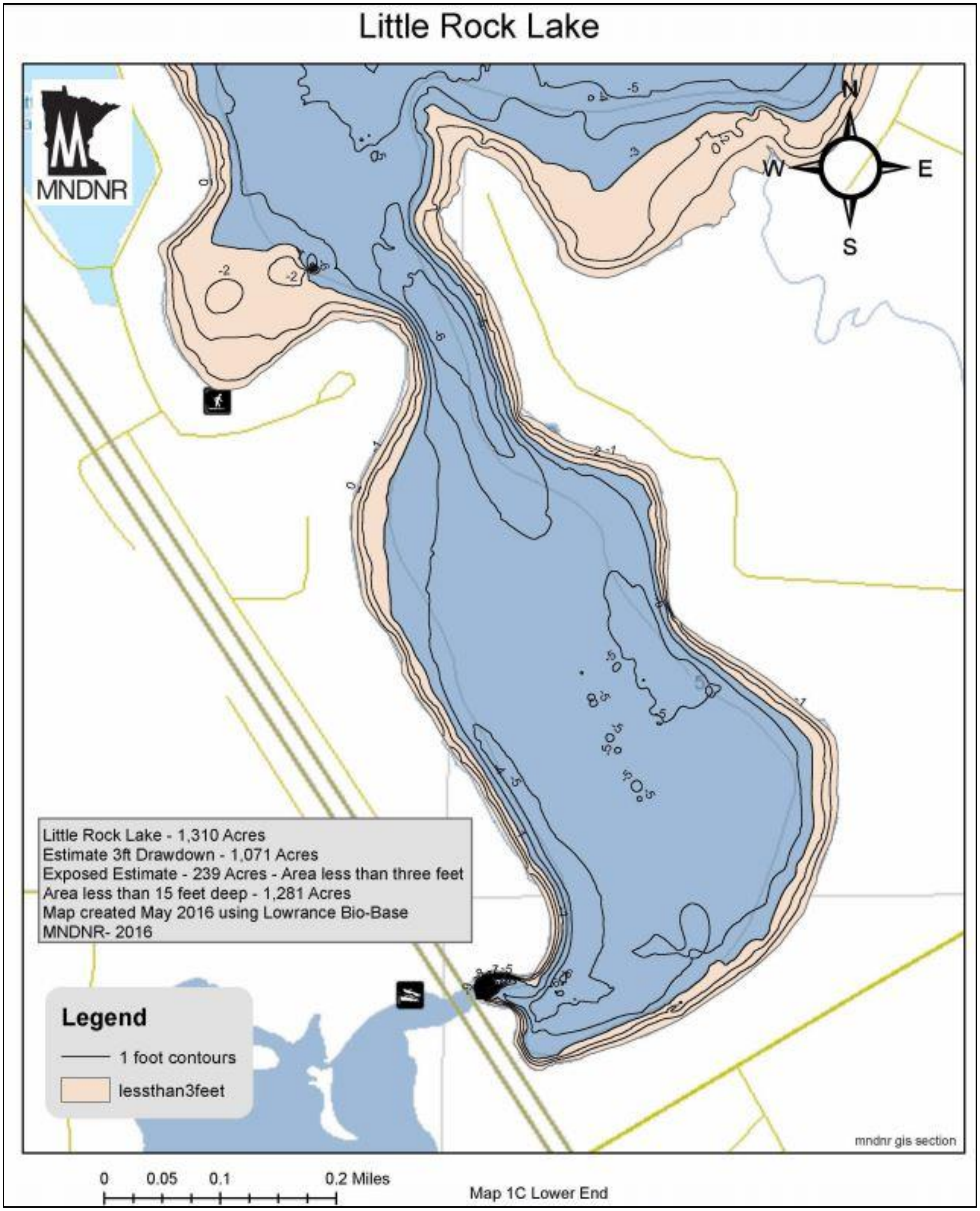

Figure 55: Exposed project area on Little Rock Lake

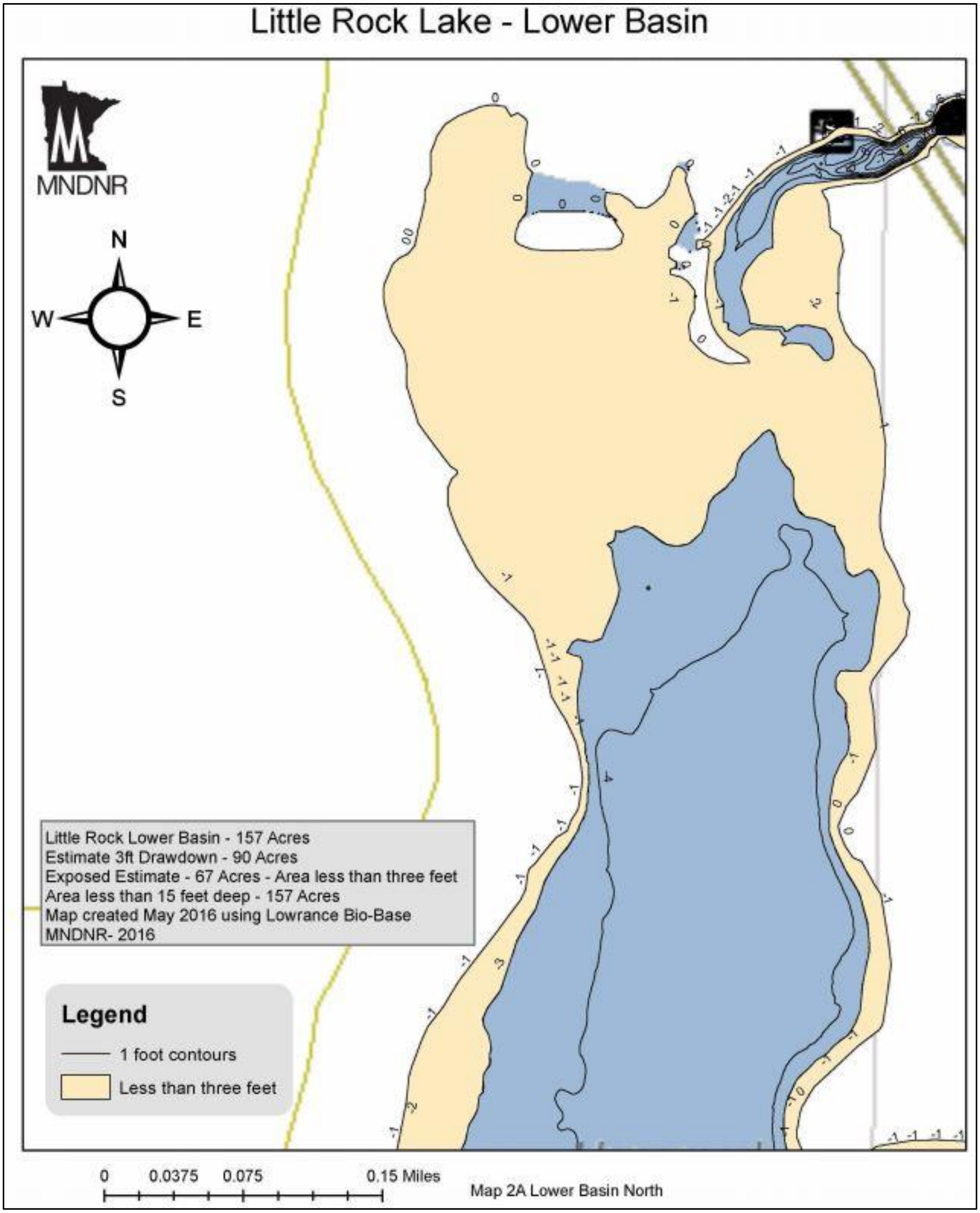

Figure 56: Exposed project area on Little Rock Lake

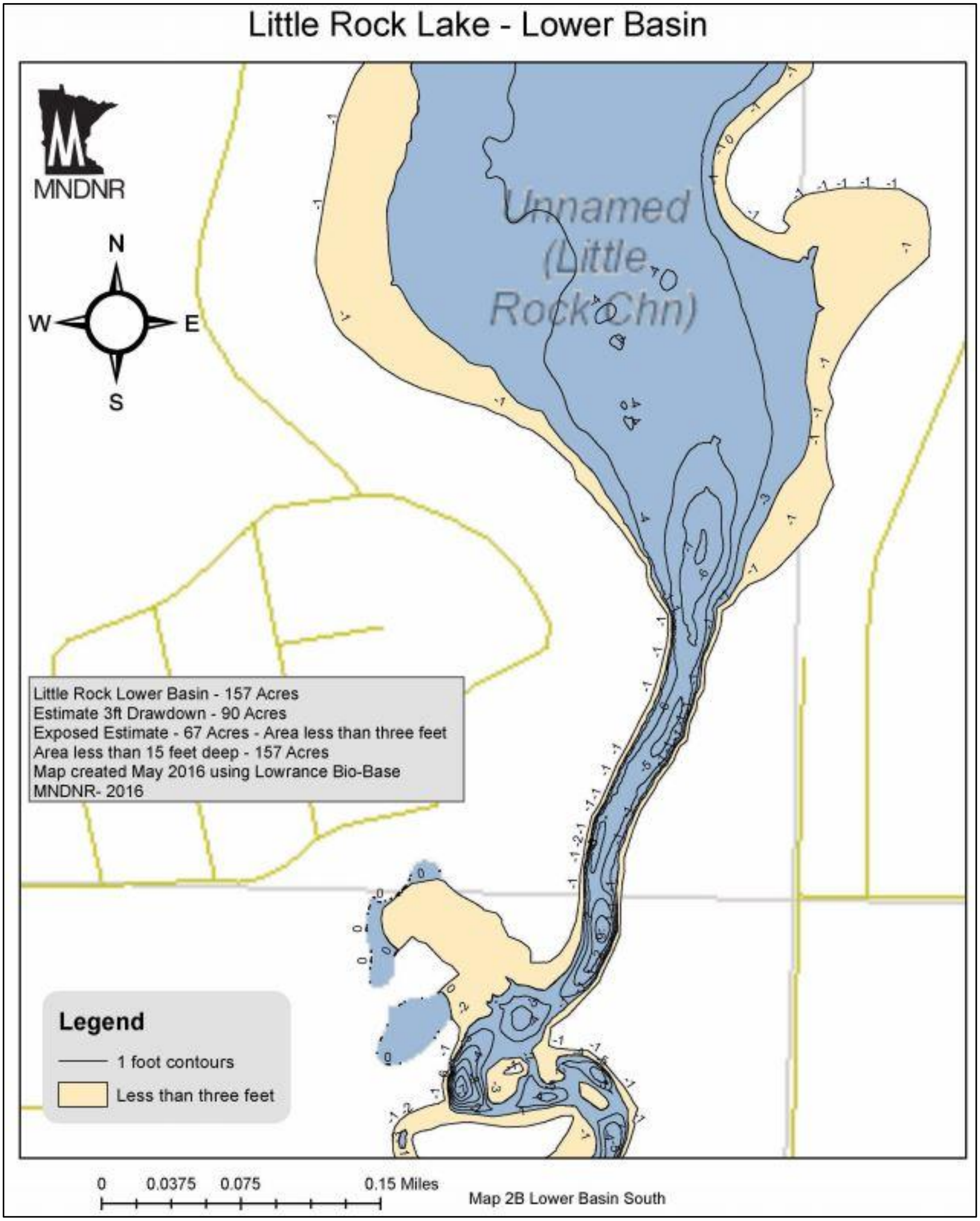

Figure 57: Exposed project area on Little Rock Lake

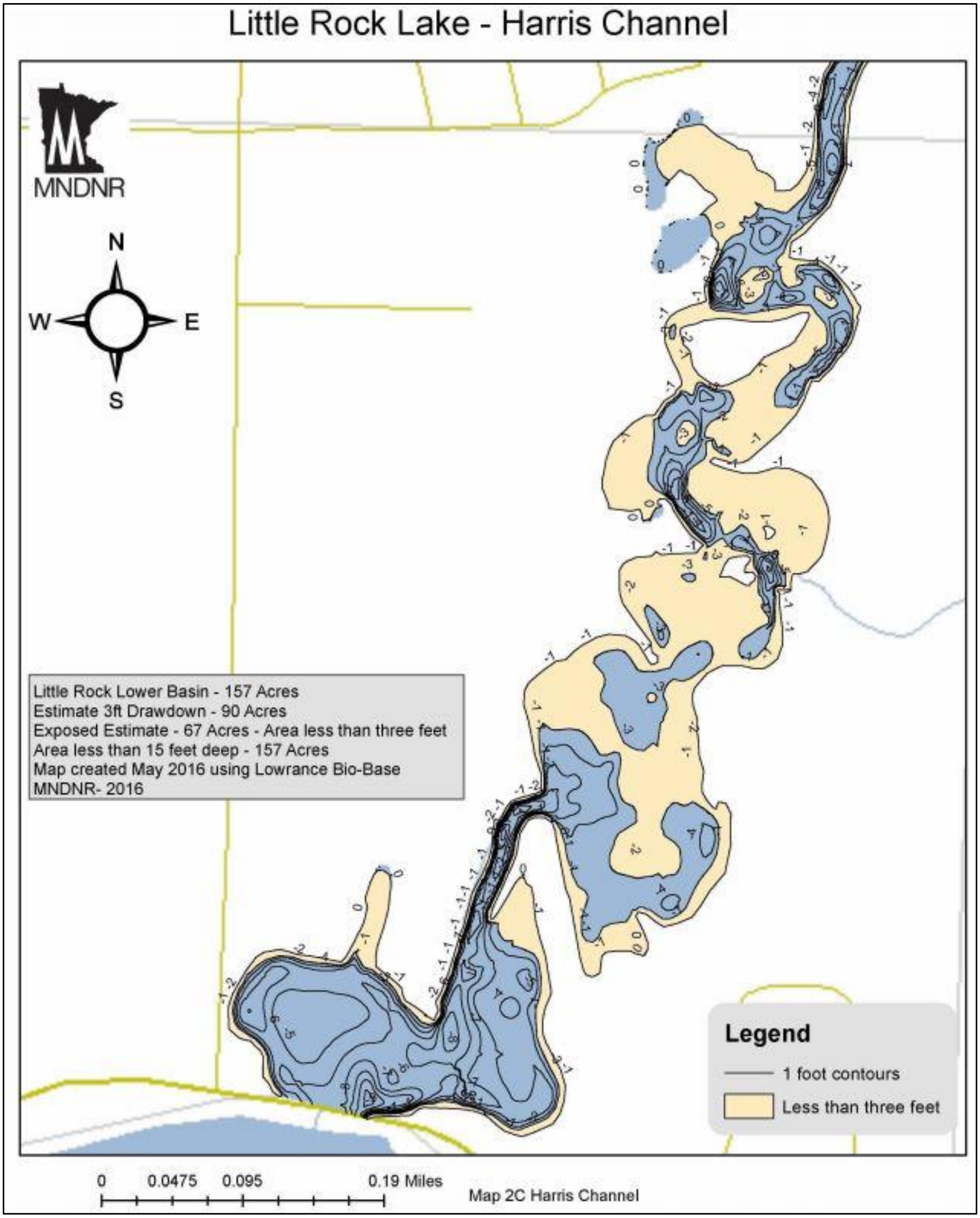

Figure 58: Exposed project area on Little Rock Lake

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