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For the Brown's Creek Watershed District

Benz Lake: Western Pasture Pond Subwatershed Study

3/1/2017

Cover Image

Western Pasture Pond 1, August 2016

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1. EXECUTIVE SUMMARY

The District developed a lake management plan for Benz Lake in 2009. The plan identified the pasture ponds to the west of Benz Lake as a potential large source of nutrient loading to the lake due to the land use and connectivity to the lake. The plan also identified internal loading within Benz Lake as another main component of the lakes phosphorus budget. The Lake Management Plan recommended further investigation into the western pasture pond subwatershed and its role in nutrient loading to the lake. The Plan also recommended addressing internal loading within Benz Lake.

The intent of this study is to investigate the western pasture pond subwatershed and to develop recommendations to reduce nutrient loading from the subwatershed AND from internal loading. A detailed assessment of the western pasture pond subwatershed was conducted and is presented in the Field Data Summary section. The assessment focused on three main elements; investigating the phosphorus dynamics within the two pasture ponds, conducting PTMApp analysis on the watershed to determine locations for watershed BMPs and determining dosage rates to address internal loading within Benz Lake.

Based on the findings of this study, internal load management using alum within Pond 2 has been determined to be the most effective way in which to manage nutrient loading from the subwatershed. In addition, the PTMApp analysis identified four sites within the Benz Lake watershed with high erosion rates. These are areas in which sediment and nutrient loading can be addressed via various types of BMP. These watershed improvements are recommended as a secondary priority. Finally, while internal loading within Benz Lake has been determined to be a significant component of the nutrient balance, we recommend holding off on doing an alum treatment on the lake until the effectiveness of the Pond 2 treatment can be evaluated.

2. FIELD DATA SUMMARY

In 2016, EOR collected additional field data to characterize and evaluate the western pasture ponds including the following: bathymetry of each of the ponds, survey of overflow points and connections, sediment cores within each of the ponds, plant survey of pond (Figure 1) and buffer zone characterization, and water quality sampling within the ponds. We also collected and analyzed additional sediment samples within Benz Lake and the ponds to determine if alum dosing of the sediment is feasible.

2.1. Pasture Ponds Aquatic Plant Assessment

An aquatic plant survey of each pond was conducted in August of 2016. The month of August represents a period of time in which most macrophytes (aquatic plants) are at or are near peak biomass. However, curly-leaf pondweed (*Potamogeton crispus*) has typically begun to senesce or is completely senesced in most Minnesota lakes by the 4th of July. Therefore, this survey may underestimate the abundance and/or presence of this species as this species was not observed during the August site visit.

A Floristic Quality Index was calculated based on aquatic plant species observed during the surveys to evaluate the health of the aquatic plant community in the Ponds relative to other lakes and ponds in Minnesota. Every macrophyte in the state of Minnesota has been assigned a coefficient of conservatism value (c-value) ranging from 0 to 10. The c-value of all macrophytes sampled from a lake is used to determine the FQI for a given lake. Species with a c-value of 0 include species like curly-leaf pondweed because this species is non-native and indicative of a highly disturbed environment. In comparison, a species like Oakes pondweed (*Potamogeton oakesainus*) has a c-value of 10 because this species is extremely rare and only found in undisturbed, pristine settings.

The average FQI score for Minnesota Lakes in the North Central Hardwood Forest ecoregion is 23.7±8 with a median of 22.5 for lakes (Radomski and Perleberg, 2012). Overall FQI scores in Pond 1 are representative of a moderately diverse plant community while observed FQI scores for Pond 2 are far below the ecoregion average (Table 1). Species with a c-value greater than 7 are considered to be intolerant to pollution while species with C-values less than 3 are considered to be tolerant to pollution. The presence of species with C-values greater than 7 (e.g., Three-way sedge, Yellow pond lily) identified during the survey suggests there is a viable seedbank of high quality species present in the ponds (Table 2).

Table 1. Aquatic plant survey dates by pond

Pond Name	Aquatic Plant Survey Date	Percent of sites with aquatic plants	FQI Score
Pond 1	8/10/2016	100%	19.1
Pond 2	8/10/2016	100%	13.8

Table 2. Aquatic plants surveyed

Scientific Name	Common Name	C-Value	Pond 1	Pond 2
Elodea canadensis	Canada waterweed	3		
Eleocharis palustris	Narrow-leaved spikerush	5	X	X
Ceratophyllum demersum	Coon's tail	3	X	
Dulichium arundinaceum	Three-way sedge	8		X
Iris versicolor	Blue Flag Iris	4	X	
Lemna Minor	Lesser Duckweed	5	X	X
Lemna trisulca	Star Duckweed	5	X	X
Nuphar lutea	Yellow pond lily	9	X	
Polygonum amphibium	Water smartweed	4	X	X
Potamogeton crispus	Curlyleaf pondweed	0		
Potamogeton pusillus	Small pondweed	7	X	
Potamogeton zosteriformis	Flatstem pondweed	6	X	
Sagittaria latifolia	Broad-leafed arrowhead	3	X	
Sagittaria rigida	Sessile-fruited arrowhead	7	X	X
Schoenoplectus acutus	Hardstem bulrush	6	X	
Sparganium eurycarpum	Giant Bur reed	5	X	
Typha spp.	Cattail	0		X
Wolffia borealis	Spotted Watermeal	5		X
		Average	5.31	4.87

2.2. Shoreline Buffer Assessment

An assessment of buffer width, quality, and type was performed concurrent with the aquatic plant survey. In general, there is an adequate buffer consisting of a transitional wetland fringe dominated largely by narrow-leaf cattails. The wetland fringe transitions fairly abruptly to vegetated uplands consisting of a mix of native grasses and pasture species including alsike clover and Kentucky bluegrass. The western most portion of Pond 2 has the highest quality buffer, consisting of a wetland to prairie to forest transition.

Noteworthy exceptions to the largely intact buffer include the area immediately east and adjacent to the southern 1/3rd of Pond 1 where an enclosed pasture and associated livestock are found less than 15 feet from the open water edge.

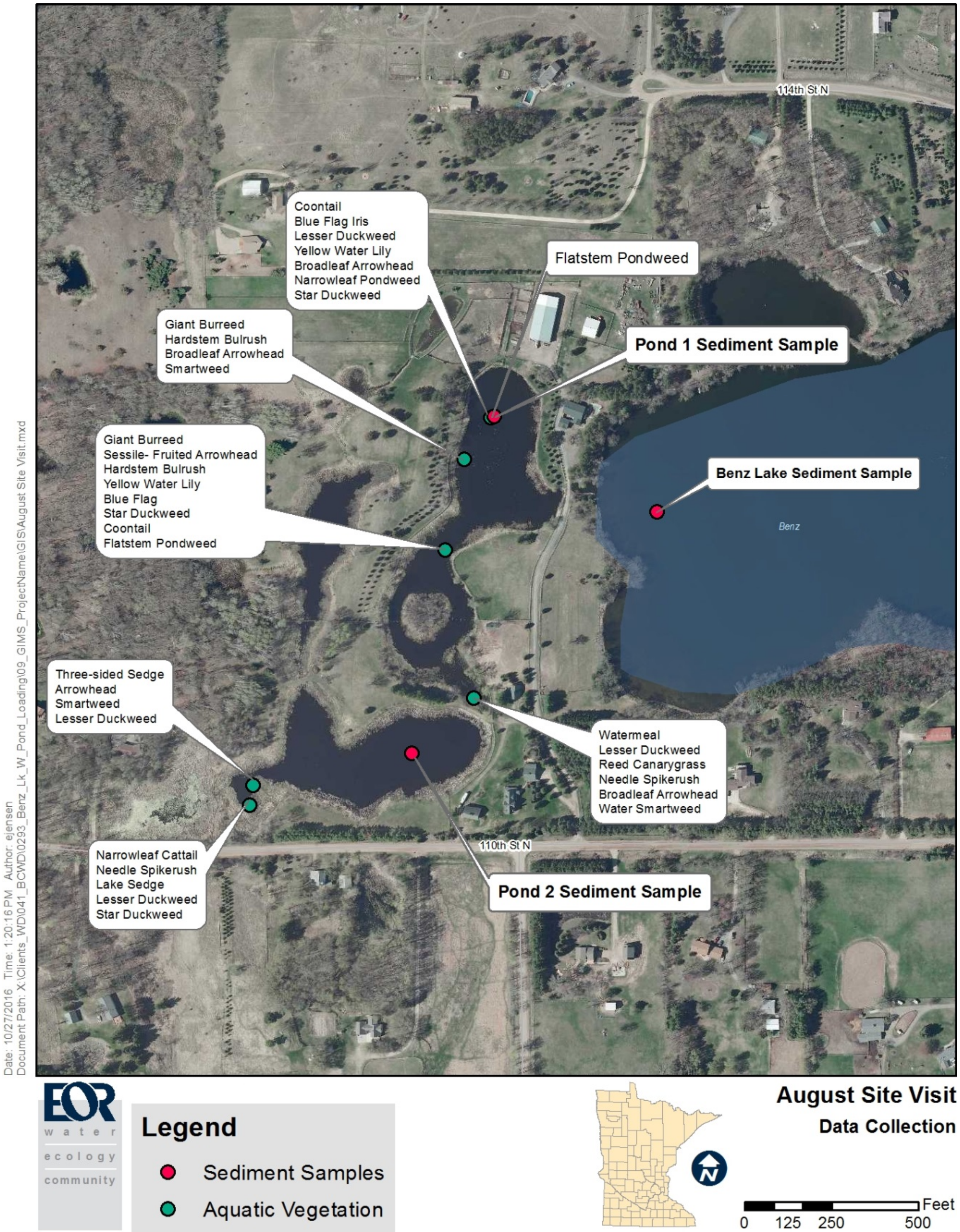

Figure 1. August 2016 Data Collection

2.3. Phosphorus Loading Characteristics

Based on the bathymetry data collected for the ponds, field review of overflow points and connections in the PCSWMM subwatersheds for this area, and other anecdotal information provided by conversations with nearby landowners, watershed flow and phosphorus loading dynamics were modeled in BATHTUB between the ponds and Benz Lake. A summary of the pond and lake physical characteristics are summarized in Table 1, and a summary of the subwatershed flow and loads are summarized in Table 2.

Most of the area west of Benz Lake flows to the southern pond (Pond 2) connects to Pond 1 via a 36" round metal culvert and into Benz Lake via a small channel (Figure 2). A review of historical aerial imagery suggests that water levels in both ponds were historically much lower than current conditions (Figure 3). Increased water levels have led to an extended hydroperiod (period of time in which soils/sediment are inundated) in areas that appear to have once been used for agriculture.

It is very likely that nutrient rich soils that were once under agricultural production are now part of the pond sediment as seen in the 1957 aerial photograph. The phosphorus load distribution to Pond 2 is approximately half from watershed runoff and half from sediment internal loading. Water quality improvements in Pond 2 will require a mix of watershed BMPs and internal load management strategies.

The phosphorus load distribution to Pond 1 is almost entirely from Pond 2. Water quality improvements in Pond 1 will likely be achieved through water quality improvements to Pond 2. The phosphorus load distribution to Benz Lake is about half from internal loading, one third from the direct drainage area, and one sixth from Pond 1. This suggests that Pond 1 is currently treating the phosphorus loads from Pond 2 and the western drainage area. Therefore, improvements to the western watershed and Pond 2 will be important for protecting the treatment capability of Pond 1. But watershed BMPs in the direct drainage area and internal load management are also needed to improve Benz Lake water quality.

Table 3. Lake and pond physical characteristics

Lake Basin	Surface Area (ac)	Average Depth (ft)	Volume (ac-ft)	2016 TP Conc. (µg/L)
Pond 1	4.7	1.2	5.6	180
Pond 2	3.7	1.1	4.2	487
Benz Lake	38.6	6.6	255	n/a*

* Summer average concentration from the 2009 Benz Lake Management Plan = 134 µg/L.

Table 4. Subwatershed areas and BATHTUB estimated load distribution

Lake Basin	Area (ac)				BATHTUB Estimated Load* (% total)		
	Lake Surface	Direct Drainage	Upstream Drainage	Total Watershed	Internal + Atm.	Direct Drainage	Upstream Lake
Pond 1	4.7	9.8	159.0	173.5	2%	9%	89%
Pond 2	3.7	155.3	0	159.0	53%	47%	0%
Benz Lake	38.6	115.7	173.5	327.8	49%	34%	17%

* Note that the BATHTUB estimated load distribution are for implementation planning purposes only due to a lack of long-term water quality data to calibrate the Pond 1 and Pond 2 models.

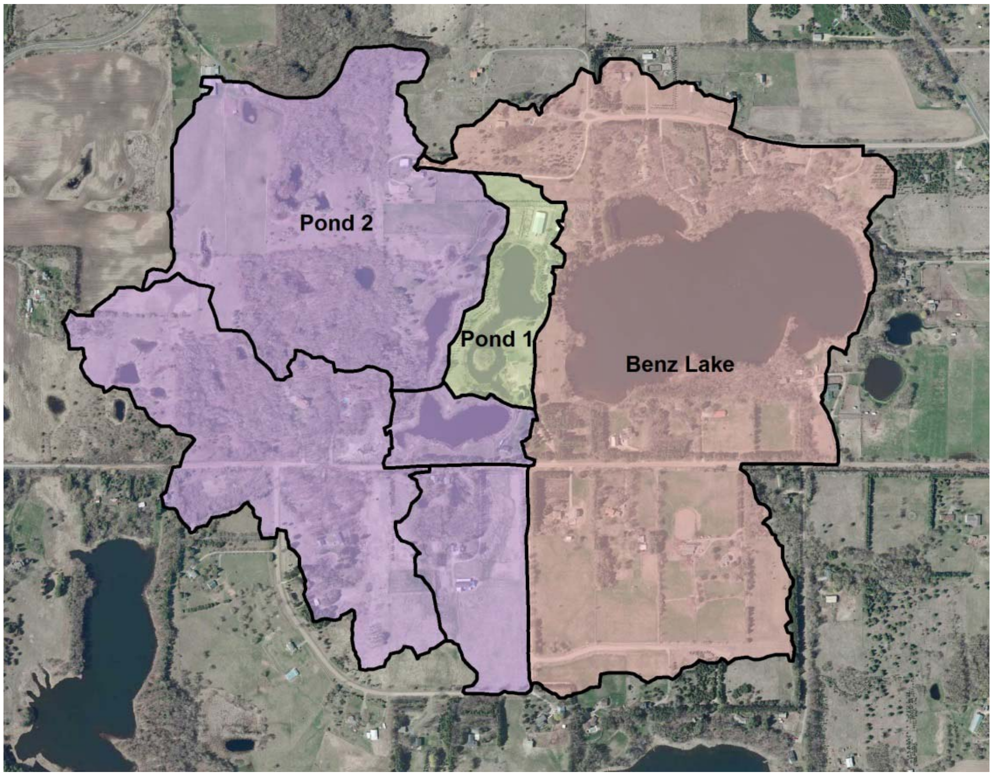

Figure 2. Benz Lake subwatersheds.

The Pond 2 drainage area is shaded in purple, the Pond 1 drainage area is shaded in green, and the Benz Lake drainage area is shaded in orange.

Figure 3. 1957 Aerial Photograph of Benz Lake

2.4. Sediment Sampling

A sediment sample was collected from Benz Lake and both of the western ponds on August 9, 2016, to estimate internal loading rates (Figure 4). The top 8 cm were composited and analyzed for total phosphorus, redox sensitive phosphorus (redox-p), biologically labile phosphorus, and the percent of organic matter. Biologically labile phosphorus is composed of labile organic phosphorus plus redox-P. Labile organic phosphorus consists of organic matter that is not strongly attached to sediment that will be broken down over time and eventually become bioavailable to algae. Redox-P consists of loosely bound and iron-bound P that can be released under the anoxic conditions that persist at the sediment/water interface in ponds and lakes during periods of thermal stratification. Internal loading due to anoxic release of phosphorus from sediments was calculated based on the expected release rate of phosphorus from the lakebed sediment using statistical regression equations developed from a large set of North American lakes (Nürnberg 1988) and the lake anoxic factor based on lake area, mean depth, and total phosphorus concentration (Nürnberg 1996). Internal loading due to anoxic release of phosphorus from sediments was estimated in this study based on the biologically labile phosphorus concentration (Table 5).

Pond 2 has a much larger pool of releasable phosphorus and a higher organic matter content in comparison with Pond 1, which is likely the result of a legacy of high nutrient inputs from the surrounding watershed to Pond 2. Higher rates of primary productivity associated with increased nutrients inputs from the watershed increases the rate of organic matter accumulation, thus explaining the higher percent organic matter observed in the Pond 2 sediment core (Reddy et al. 1996, Reddy and Delaune 2007). Accumulation of soil organic matter in ponds is not only a function of plant productivity but also depends on the rate of decomposition of dead and senescing plant material. Decomposition of organic matter is typically very slow in ponds with extended hydroperiods such as Pond 2. Therefore, Pond 2 will likely continue to accumulate organic matter unless watershed inputs to the pond are decreased. The continued accumulation of organic matter over time in Pond 2 will decrease the capacity for the pond to provide water quality treatment to Benz Lake.

Analysis of the Benz Lake sediment profile identified a very low percent organic matter and releasable phosphorus concentration which correlated with a low estimated phosphorus release rate. The sediment sample was collected in a portion of the lake that had a relatively hard bottom consisting largely of sand and gravel. Lakes that contain sediment with a low (i.e., less than 5%) percent organic matter are often associated with lower internal nutrient loads in comparison with lakes that have sediments containing a higher (more than 20%) percent organic matter.

Table 5. Releasable phosphorus concentration, predicted anoxic factor, and anoxic release rate (Nürnberg 1988, 1996)

Lake Basin	Organic Matter (%)	Bio-labile P (mg/kg dry)	Total Phosphorus (mg/kg dry)	Anoxic Factor (days/yr)	Est. Release Rate (mg/m2-anoxic day)	Est. Release Rate (lb/ac/yr)
Pond 1	9.2%	484	580	79	1.31	4.25
Pond 2	20.8%	607	1,013	101	2.14	6.98
Benz Lake	2.4%	118	173	71	0.20	0.65

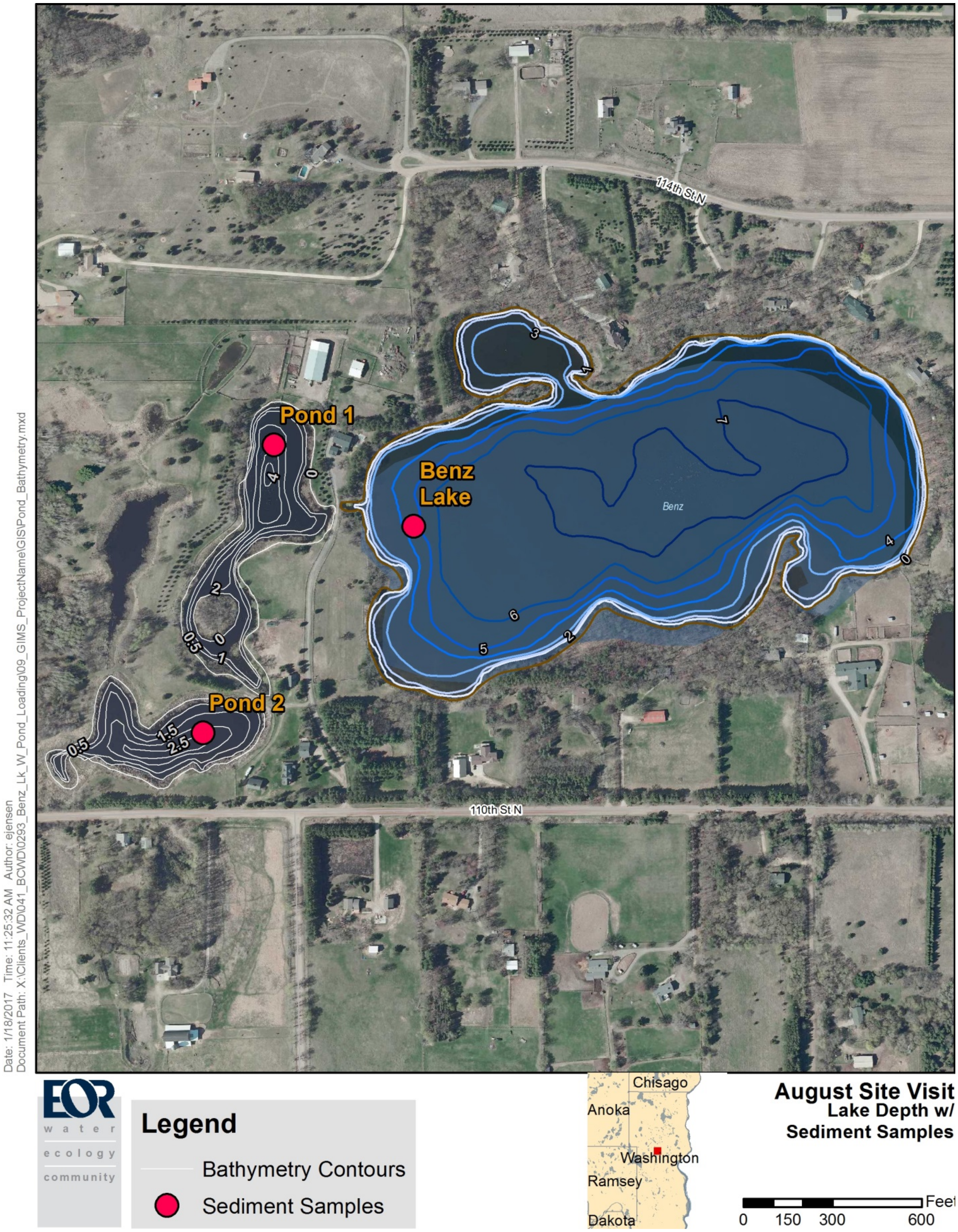

Figure 4. Sediment Core Sampling Location.

3. ALTERNATIVES ANALYSIS

Based on field data collected in 2016, we investigated various management options for reducing nutrient loading from the western pasture ponds and for reducing the internal loading that occurs within the lake. The alternatives analysis includes the costs and benefits of each approach as well as any potential drawbacks.

3.1. Pasture Pond and Benz Lake Internal Load Management: Alum Treatment

A sediment alum treatment is the application of aluminum sulfate as a floc layer at the pond sediment/water interface that can bind with phosphorus released from the sediments for an extended period of time. When applied at an appropriate dose, alum will prevent internal recycling of phosphorus over 5-10 years. However, there are a finite number of alum binding sites in each alum treatment that are used over time as phosphorus is slowly released by the lake sediments. Therefore, additional alum treatments are needed every 5-10 years, depending on the initial dose and on contributions of phosphorus from the watershed.

A preliminary alum dose was estimated for Pond 1 and Pond 2 based on observed releasable phosphorus sediment concentrations. An alum treatment requires a buffer to maintain pH levels and minimize impacts to aquatic organisms. Projected costs designed to treat the top 4 centimeters of the sediment column profile in Pond 1 and 2 are provided in Table 4 and are dependent on costs of the compound, mobilization of the equipment and personnel required to conduct the treatment. Costs for an alum treatment requiring a sodium aluminate buffer are reflected in the maximum costs provided in Table 4.

3.1.1. Benefits and considerations

Inactivation of sediment phosphorus release via application of alum should be explored in Pond 2 given the observed high phosphorus release rate. Alum treatment of Pond 1 should only be considered in the event that alum treatment of Pond 2 does not sufficiently reduce the concentration of phosphorus reaching Benz Lake. Alum treatment of the pond sediment will limit the release of phosphorus from the sediment in Pond 2 and will strip phosphorus from the water column in Pond 2. This will result in immediate improvements to water clarity and reduced phosphorus export to Benz Lake that should continue for 5-10 years.

Table 6. Water column stripping and sediment inactivation costs for alum treatment of Pond 1 and Pond 2.

Waterbody	Dosing Method	Minimum Total Cost	Maximum Total Cost	Internal Load (lb/yr)	Cost/Pound TP Removed
Pond 1	Water column stripping and sediment treatment	$27,374	$45,105	0.0	NA
Pond 2		$29,358	$47,924	52.25	$560-$920
Benz		$49,281	$76,222	66.7	$740-$1,140

3.2. Watershed BMPs

The PTMapp ("Prioritize, Target and Measure" application) GIS toolset was used to better understand sediment sources in the Brown's Creek watershed originating from upland, *landscape* sources. *Landscape* sediment sources are those eroded by sheet or rill flow (i.e., very small channels), the type of erosion often associated with agricultural row-cropped fields but which can apply to any landcover type. PTMapp also has the capacity to predict total phosphorus loads derived from landscape sources. Sediment and phosphorus GIS layers derived from PTMapp were symbolized to reveal the portions of the Benz Lake watershed where the highest sediment and phosphorus loading rates are being derived. Once these nutrient and sediment loading hotspots were identified, PTMapp was used to identify specific spots at the field scale that may potentially be contributing a disproportionate amount of the total sediment/phosphorus load by calculating stream power index (SPI). Stream power index signatures are indicative of potentially erosive overland flow paths such as steeply sloped gullies and ravines. These gullies and ravines have the potential to convey landscape sediment and nutrient sources to downstream water bodies. Four separate areas were identified in the Brown's Creek watershed based on this analysis (Figure 5). Upstream drainage areas were delineated for each high SPI location and a PTMapp estimated sediment and phosphorus load was calculated for each, providing an assessment of each potential best management practice (BMP) site's current landscape sediment and phosphorus loading to Benz Lake (Table 5).

Table 7. PTMapp estimated sediment, phosphorus load, and upstream drainage area for identified BMPs.

BMP	Watershed Area (Acres)	TP Load (lb/year)	TSS Load (kg/year)
1	11.36	5.00	11,341
2	24.29	0.82	1,861
3	5.10	0.25	560
4	57.81	7.82	17,738

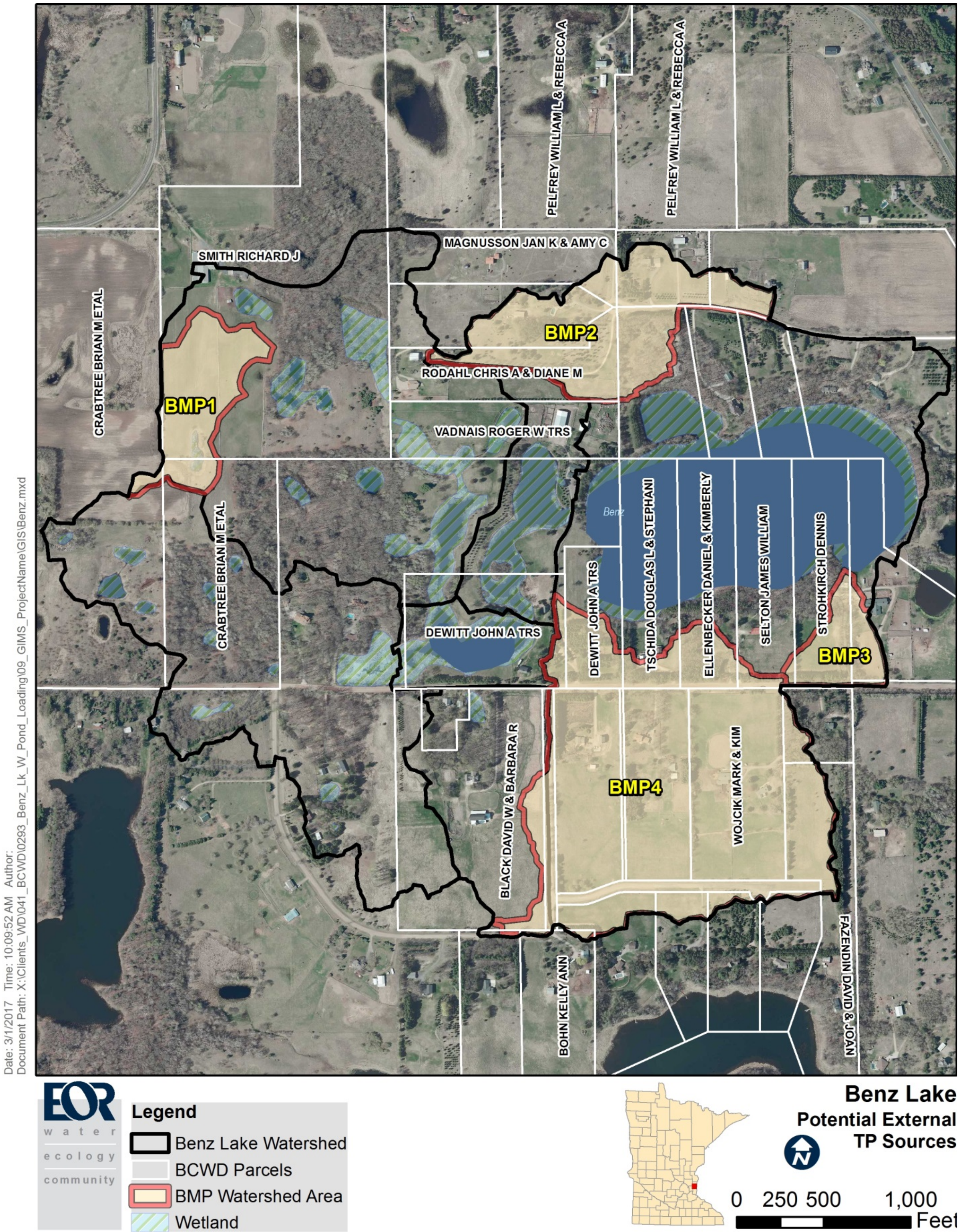

Figure 5. Potential External Total Phosphorus Sources Identified by PTMapp.

PTMapp BMP Option 1

- Grassed waterway with a small sediment basin to capture runoff leaving agricultural field
- Visible on aerial imagery, possible near-channel source
- Downstream wetland treatment

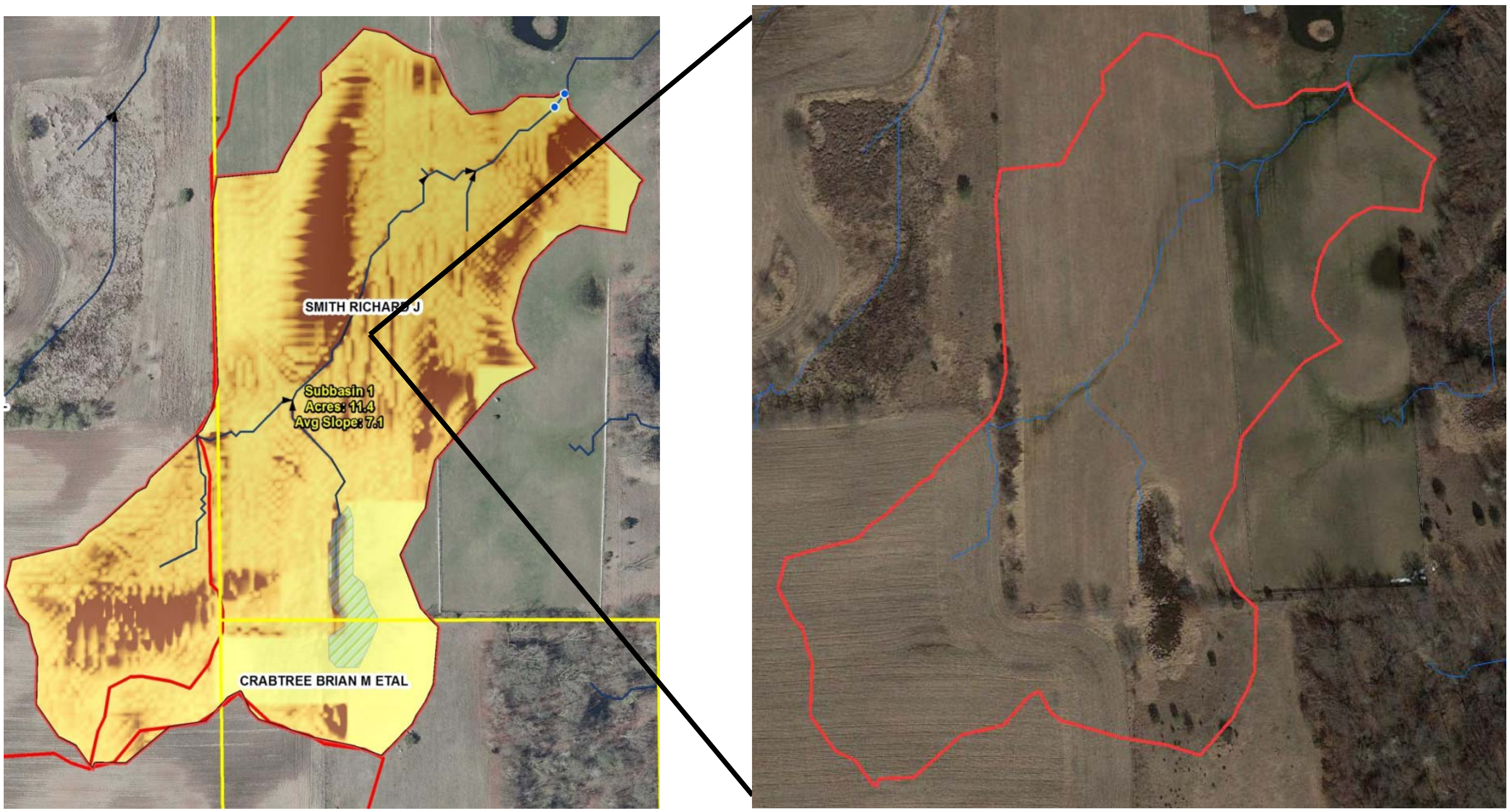

Figure 6. PTMApp Watershed BMP 1

PTMapp BMP Option 2

- Rain garden/ bioretention basin to capture runoff from two overland flow paths draining rural residential areas
- Direct to Benz Lake with no downstream wetland treatment, no erosion visible on aerial photography
- Confluence of two Stream Power Index (SPI) signatures

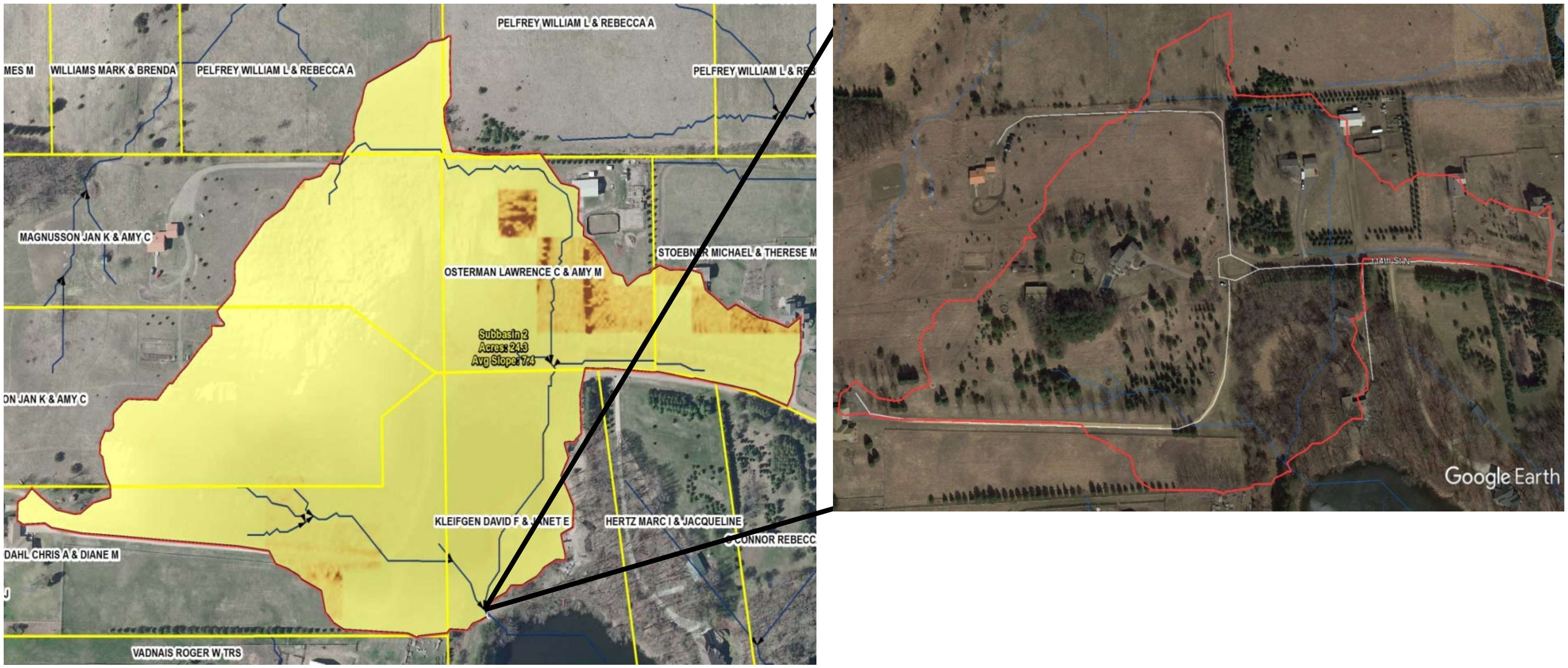

Figure 7. PTMApp Watershed BMP 2

PTMapp BMP Option 3

- Shoreline restoration/ buffer strip implementation with livestock exclusion
- Direct to Benz Lake with no downstream wetland treatment
- Overland flow path through pastured area with livestock

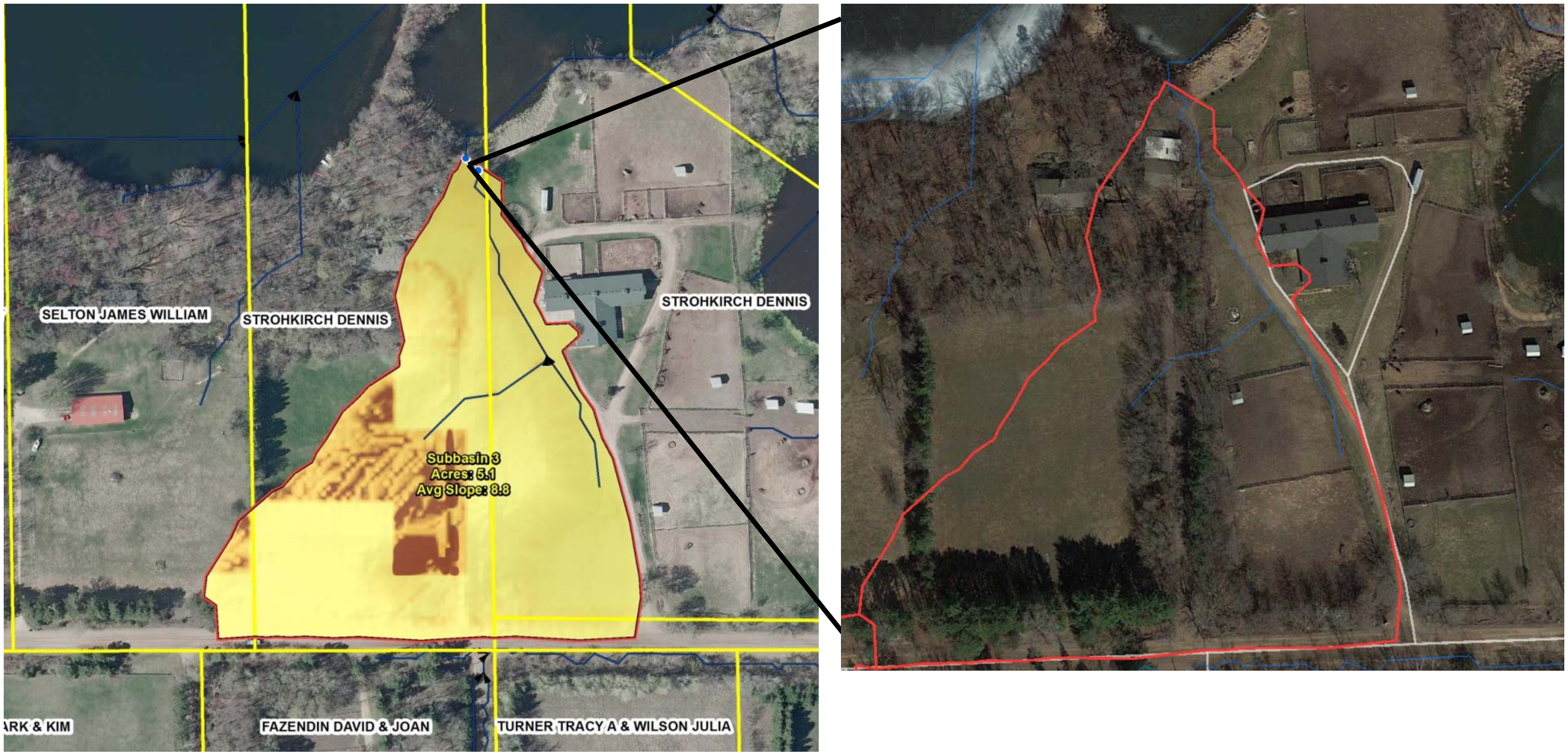

Figure 8. PTMApp Watershed BMP 3

PTMapp BMP Option 4

- Iron-enhanced sand filter to capture runoff from two overland flow paths draining rural residential areas
- Direct to Benz Lake with no downstream wetland treatment
- Confluence of two Stream Power Index (SPI) signatures, possible near channel source

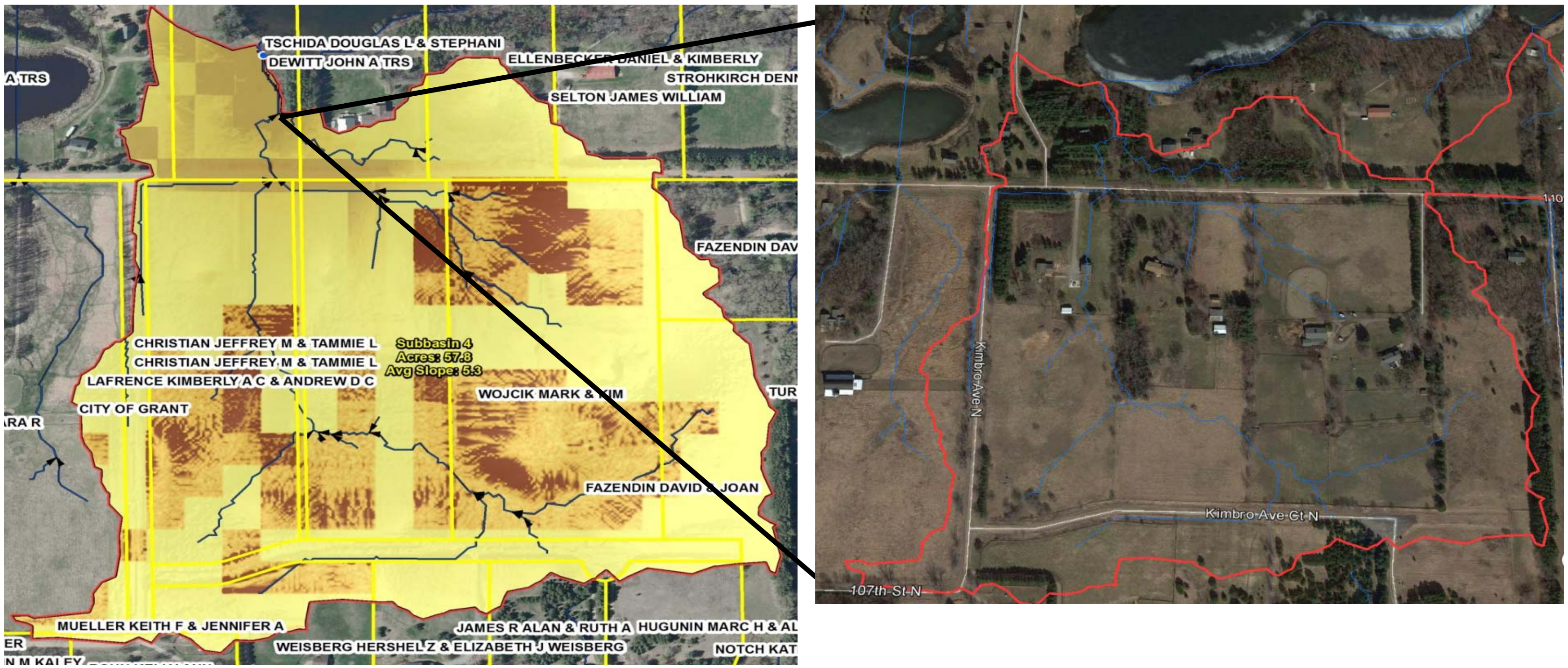

Figure 9. PTMApp Watershed BMP 4

3.2.1. Benefits and considerations:

Four potential BMPs were identified as high priority for field verification based on a review of PTMapp landscape sediment/phosphorus loads, SPI signatures, and cost estimates per pound of phosphorus removed (Table 6). Load reduction estimates and subsequently cost estimates represent the portion of the phosphorus load that is derived from field sources that actually is transported to downstream surface waters (Benz Lake); therefore, practices that appear to result in seemingly small phosphorus reductions should not be disregarded. Additionally, PTMApp does not measure phosphorus loading resulting from gully/ravine formation or from sources such as excess fertilizer applied on residential lawns or contributions from feedlots (i.e., only landscape sediment is estimated). Therefore, PTMApp estimates of phosphorus load reductions are likely conservative estimates of the potential reduction that would be achieved through implementation of the BMP (because of the unknown but potentially significant amount of phosphorus generated from gully erosion or other sources (livestock) associated with these potential sites. Results reported here are based on PTMapp GIS analysis. As such, the next step needs to be a field-verification of each potential BMP site to confirm each as a significant sediment/phosphorus source and a suitable site for the appropriate BMP. This is particularly important in cases where near-channel sources or contributions from other unaccounted (livestock) are suspected to be occurring.

Table 8. Potential Watershed BMPs within the Benz Lake watershed.

BMP ID	BMP Description	Estimated Total Cost	Existing TP Load	TP Load Reduction	Cost/ Pound TP Removed
1	Grassed waterway with small sediment basin	$27,500	5.00	4.50*	$6,000
2	Large rain garden/ bioretention basin	$3,500	0.82	0.5*	$7,000
3	Shoreline restoration/ buffer strip with livestock exclusion	$2,500	0.25	0.25*	$10,000
4	Iron-enhanced sand filter to capture runoff from two overland flow paths draining rural residential areas	$52,000	7.82	7.00*	$7,500

* Nutrient loads derived from near channel sources as well as from livestock/horses are not accounted for in PTMapp, there is a potential for additional load reduction.

4. MANAGEMENT RECOMMENDATIONS

Improvements to the western watershed and Pond 2 will be important for protecting the treatment capability of Pond 1 which currently treats Pond 2. While the alum treatment of Pond 2 represents a significant source of phosphorus reduction for Pond 1 and Pond 2, this practice alone will not necessarily achieve the reduction needed for Benz Lake given that only one sixth of the load to Benz Lake is derived from Pond 1. A review of watershed practices using the PTMapp toolset identified four potential watershed BMP options; these sites need to be field verified to confirm each as a significant sediment/phosphorus source and a suitable site for the appropriate BMP. While internal load management will be required to improve Benz Lake water quality, sediment cores taken from Benz Lake identified relatively low sediment TP concentrations which suggest that reducing contributions from external sources should be the first step before attempts to control internal sources are made.

Implementation Activities in Priority Order

Pond 2 Alum Treatment		$48,000
BMP 1	Grassed waterway & small sediment basin	$27,500
BMP2	Large bioretention basin	$3,500
BMP3	Shoreline restoration & livestock exclusion	$2,500
BMP4	Iron-enhanced sand filter	$52,000
Benz Lake Alum Treatment		$76,000

5. REFERENCES

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Radomski, P., and D. Perleberg. 2012. Application of a versatile aquatic macrophyte integrity index for Minnesota lakes. Ecological Indicators 20:252-268.