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Lake Susan Use Attainability Assessment (UAA) Update

Prepared for:

RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

Riley
Purgatory
Bluff Creek
Watershed District

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1.0 Introduction

1.1 PURPOSE

Lake Susan was listed in 2010 as an impaired water body for nutrients by the Minnesota Pollution Control Agency (MPCA). As a result, the Riley Purgatory Bluff Creek Watershed District (RPBCWD) requested Wenck Associates, Inc. to:

1. Establish an appropriate water quality goal for the lake if different than the state standard
2. Provide components similar to a TMDL study (e.g., allocations to achieve water quality goals).
3. Articulate implementation elements to achieve recommended phosphorus reductions that facilitate “delisting” the lake as an impaired water body.

As part of the study, the District wanted to incorporate the recommendations and management activities recently completed on the lake to develop a current management strategy.

1.2 PAST STUDIES AND ACTIVITIES

Several studies and management activities have been completed on Lake Susan over the past 15 years. A list and description of the study or activity is provided below.

1.2.1 Susan and Rice Marsh Lake Use Attainability Analysis

In 1999 a Use Attainability Analysis (UAA) was completed for Lake Susan and Rice Lake Marsh (Barr, 1999). The study looked at establishing a water quality goal for the lake, along with identifying Best Management Practices (BMPs) to help meet the goal.

Watershed loading was analyzed using P8 and an internal load was calculated based on an empirical formula developed by Dillon and Rigler (1974). The watershed model evaluated existing and future conditions to determine ultimate loading conditions for the lake and evaluate the effectiveness of identified watershed BMPs. The analysis resulted in the following recommendations:

- Lake Susan should achieve a “Level II” water quality standard having a phosphorus concentration between 45 to 75 g/l range.
- Improve or add eight ponds to account for future urbanization.
- Upgrade one pond to address an under treated watershed.
- Add eight ponds in watersheds not currently treated.
- Treat Lake Susan with alum.

1.2.2 City of Chanhassen Non-Degradation Plan

In 2008 the City of Chanhassen completed a Non-Degradation Assessment (Wenck, 2008) as part of their National Pollutant Discharge Elimination System (NPDES) Phase II permit. The plan assessed changes in stormwater runoff volume, total phosphorus (TP) and total suspended sediment (TSS) loading in the City of Chanhassen since 1988 to predict how land use changes would impact loading in 2020. The assessment determined that based on current BMP practices, there isa net reduction in TP and TSS loading rates compared to 1988. There was an increase in stormwater runoff volume, however, so the City prescribed the following BMPs:

- New development or redevelopment abstraction requirement
- Implementation of a reforestation program
- Retrofitting volume management BMPs where opportunities arise
- Implementation of stream restoration, erosion control, and shoreline restoration projects to mitigate volume impacts.

1.2.3 University of Minnesota Carp Management and Native Submerged Aquatic Vegetation Establishment Study

The University of Minnesota (U of M) since 2007 has been conducting a study on carp management in Lake Susan (Sorenson, 2013 – Appendix A). The study is focused on identifying carp recruitment and management activities to bring carp biomass levels in line with lakes similar to Lake Susan. The goal of carp management was to limit nutrient reentrainment and improve water clarity associated with excessive carp populations. Activities completed as part of the study include:

- Tagging and tracking of carp
- Collecting water quality samples
- Removing carp in the winter of 2008-2009 Installing aeration in Rice Lake Marsh to limit winterkill of panfish

As a result of these activities, the carp population continues to be managed, lake water clarity has improved, and macrophyte density has increased. Curly-leaf pondweed and Eurasian watermilfoil, both invasive species, are present in the lake and there is a desire to preempt further establishment of the species in the lake (Knopik 2012 – Appendix B).

The U of M is currently evaluating transplanting native species to the lake to help their propagation and preempt further spreading of invasives. As of this report, they are continuing to implement and monitor the results of the transplanted native vegetation.

1.2.4 Carver County Soil and Water Conservation District Susan, Ann, Lucy Subwatershed: Stormwater Retrofit Assessment (SALSA)

In 2011 the Carver County Soil and Water Conservation District (SWCD) conducted a retrofit analysis for the Lake Susan (2011) watershed. The study focused on identifying cost-effective retrofit BMPs to reduce TP loads to the lake. A WINSLAMM model was developed to complete the watershed loading analysis and asses the effectiveness of the proposed BMPs.

The analysis identified installing iron enhanced sand filtration (Minnesota Filter) and increasing targeted pond volume as the two primary BMPs for implementation. In the study it identified 24 different sites where these could be implemented to supplement existing stormwater treatment systems. The cost effectiveness of these systems ranged from $71- $192/lb-TP/yr.

1.2.5 RPBCWD Water Quality Monitoring

The District has monitored the Lake Susan watershed for 15 years. During that time, they collected monitoring data in Lake Susan, Riley Creek, stormwater ponds, and wetlands. The data provided insight into which stormwater ponds were performing as designed and whether wetlands were serving as a source of TP to Lake Susan. These data were also used for calibrating watershed and lake loading models.

2.0 Water Quality Standards and Numeric Phosphorus Target

2.1 WATER QUALITY STANDARDS FOR LAKE SUSAN

Over the past 15 years, water quality goals established for Lake Susan have changed. A timeline and summary table of goals (Table 2-1) is provided below.

- The original UAA established that Lake Susan should achieve a “Level II” water quality standard, having a phosphorus concentration between 45 to 75 g/l range
- The District’s Overall Watershed Management plan (2008) designated Lake Susan as a deep lake and recommended the lake meet MPCA North Central Hardwood Forest (NCHF) ecoregion lake standards. Numeric TP, chlorophyll-*a*, and Secchi depth standards for lakes in the NCHF ecoregion are ≤40 µg/L, ≤14 µg/L, and ≥ 1.4 meter, respectively.
- In 2010 Lake Susan was impaired for nutrients by the MPCA based on NCHF ecoregion shallow lake standards. Numeric TP, chlorophyll-a, and Secchi depth standards for shallow lakes in the NCHF ecoregion are ≤60 µg/L, ≤20 µg/L, and ≥ 1.0 meter, respectively.

Table 2-1. Lake Susan Water Goals Summary.

	Average June-September Values		
	Total Phosphorus (µg/L)	**Chlorophyll-*a* (µg/L)**	**Secchi Depth (m)**
Lake Susan (UAA)	≤75	≤37[1]	≥0.7[1]
Overall Management Plan	≤40	≤14	≥1.4
MPCA NCHF Class 2B Shallow Lakes Standard	≤60	≤20	≥1.0

[1] Corresponding levels based on implied TP goal

To date, Lake Susan is designated as a shallow Class 2B water in the NCHF ecoregion by the MPCA. The MPCA defines a shallow lake as having either a maximum depth less than 15 feet or 80% or more of its surface area shallow enough to support submerged aquatic vegetation. Specific water quality standards for lakes are based on ecoregion and lake type (shallow or deep).

After review of the lake bathymetry (>85% less than 15ft) and the current goal established by the MPCA, it is recommended that Lake Susan be managed to Class 2B NCHF ecoregion shallow lake standards.

3.0 Watershed and Lake Characterization

3.1 OVERVIEW

Lake Susan (DNR # 1000-13) is located within the municipal boundary of Chanhassen in Carver County, Minnesota (Figure 3-1). Lake Susan has an area of 88 acres and a maximum depth of 17 feet. The lake is part of the Riley Creek watershed and is one of the many flow-through lakes along the creek's path to the Minnesota River. Lake Susan is a recreational lake used for fishing, boating and canoeing. It is readily accessible to the public through two parks featuring a public landing, fishing piers, observation decks, and walking/hiking trails.

Figure 3-1. Lake Susan in Carver County.

3.2 HISTORY OF THE LAKES AND THEIR WATERSHEDS

The predevelopment watershed of Lake Susan is believed to be similar to the current watershed area but dominated by open grassland and oak savannah canopy (Figure 3-2). In the late 1970s and early 1980s, commerical and residential developments increased in the watershed. Along with the development, the City's storm sewer system was installed, changing the efficiency of the runoff to the lake. Lake Susan now receives stormwater from over 2,553 acres, including Lake Ann and Lake Lucy watersheds. Implementation of stormwater management activities since the late 1980s has steadily improved the quality of stormwater runoff .At the same time, dense populations of carp and curly-leaf pondweed caused heavy algae blooms and poor water clarity. Monitoring data suggest conditions may have improved slightly in the early 1980s due to implementation of stormwater management activities and management of carp populations.

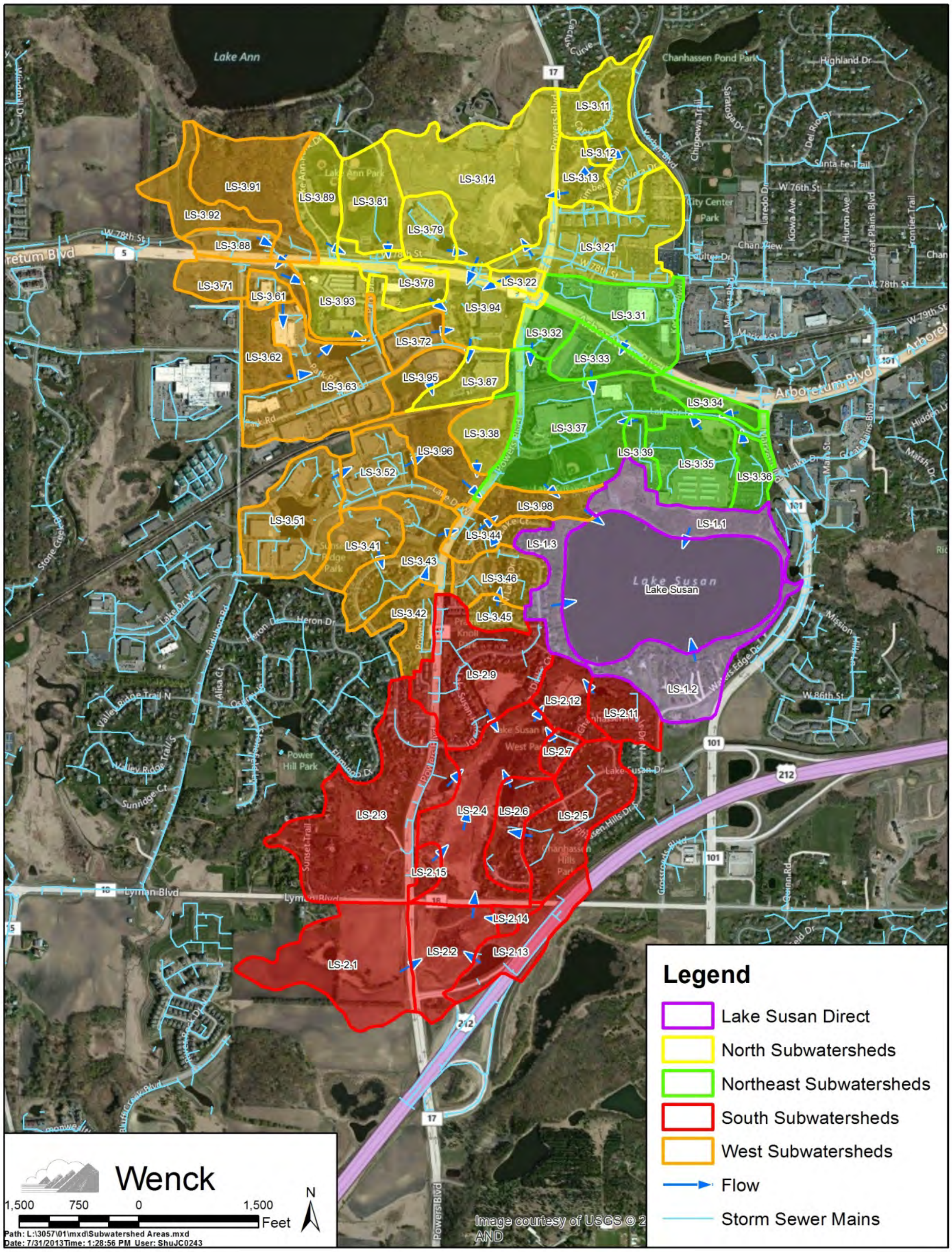

Figure 3-2. Lake Susan Watershed.

3.3 LAND USE

The Lake Susan watershed is characterized primarily by low-density residential, undeveloped, and industrial with stormwater basins throughout the watershed (Tables 3-1 and 3-2 and Figures 3-3 and 3-4).

Table 3-1. 2010 Land Use for the Lake Susan Watershed.

Land use [1]	Percent	Area (Acres)
Agricultural	5%	61
Farmstead	0%	2
Industrial and Utility	14%	178
Institutional	1%	18
Major Highway	6%	73
Mixed Use Commercial	0%	3
Mixed Use Industrial	0%	3
Multifamily	1%	14
Office	2%	22
Open Water	7%	95
Park, Recreational, or Preserve	16%	211
Retail and Other Commercial	4%	51
Single Family Attached	4%	47
Single Family Detached	20%	261
Undeveloped	19%	243
Total	100%	1281

[1] Source Metropolitan Council 2010.

Table 3-2. 2020 Land Use for the Lake Susan Watershed.

Land use [1]	Percent	Area (Acres)
Low Density Residential	21%	273
Medium Density Residential	8%	100.2
High Density Residential	6%	77.5
Industrial	24%	311.1
Institutional	8%	100.5
Commercial	4%	50.3
Mixed Use	0%	4.1
Railway	1%	11.8
Water	7%	86.2
Parks	18%	229.6
Right-of-Way	3%	36.6
Total	100%	1281

[1] Source Metropolitan Council 2020.

Categories used in the land used classification do not allow for a direct comparison between 2010 and 2020. However, a general evaluation of the categories and types of land uses demonstrate the remaining agricultural and undeveloped areas are planned to be converted to residential and commercial land uses. The change in land uses will further increase runoff volumes and TP loads going to Lake Susan.

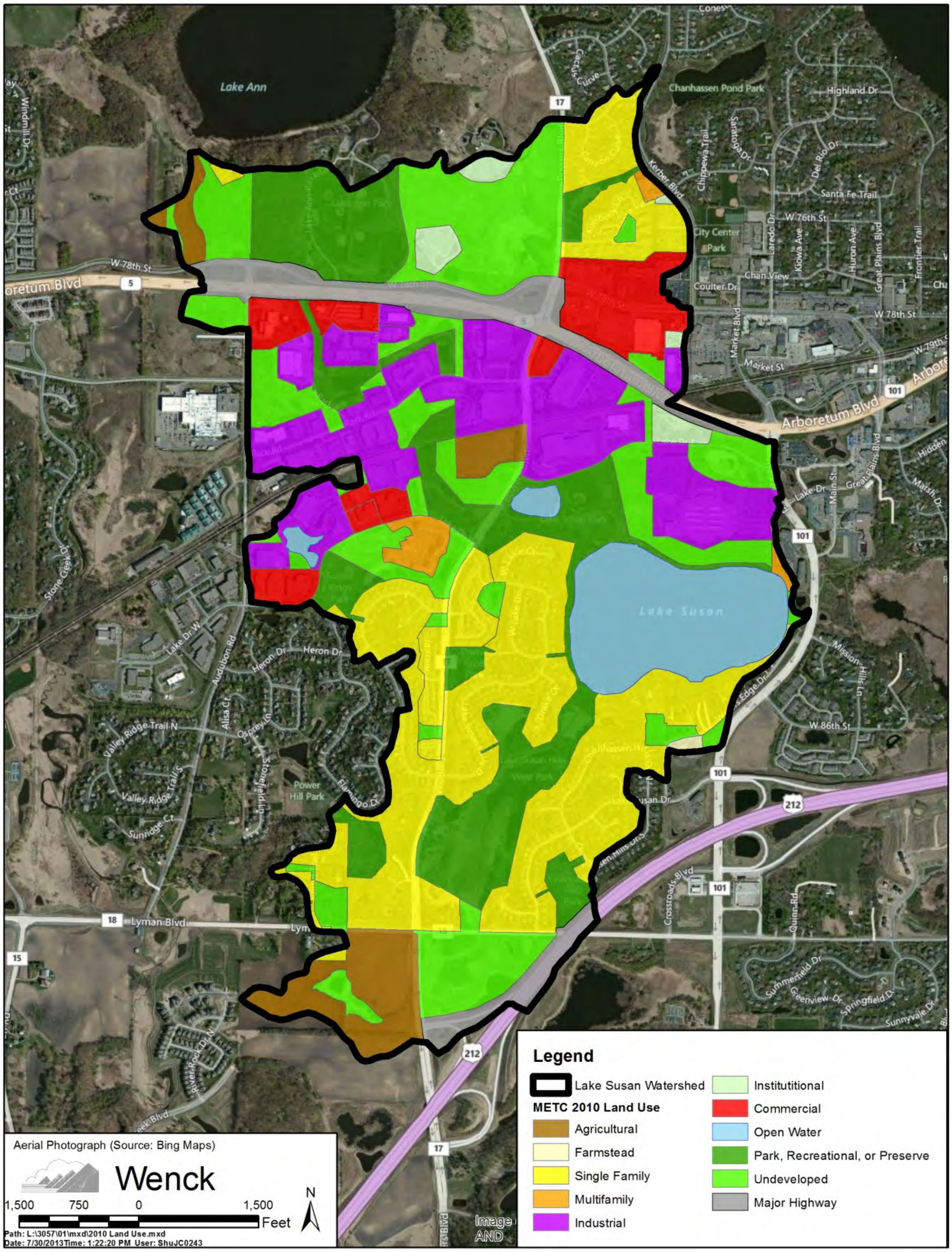

Figure 3-3. Lake Susan Watershed 2010 Land Use (Source: Metropolitan Council 2010).

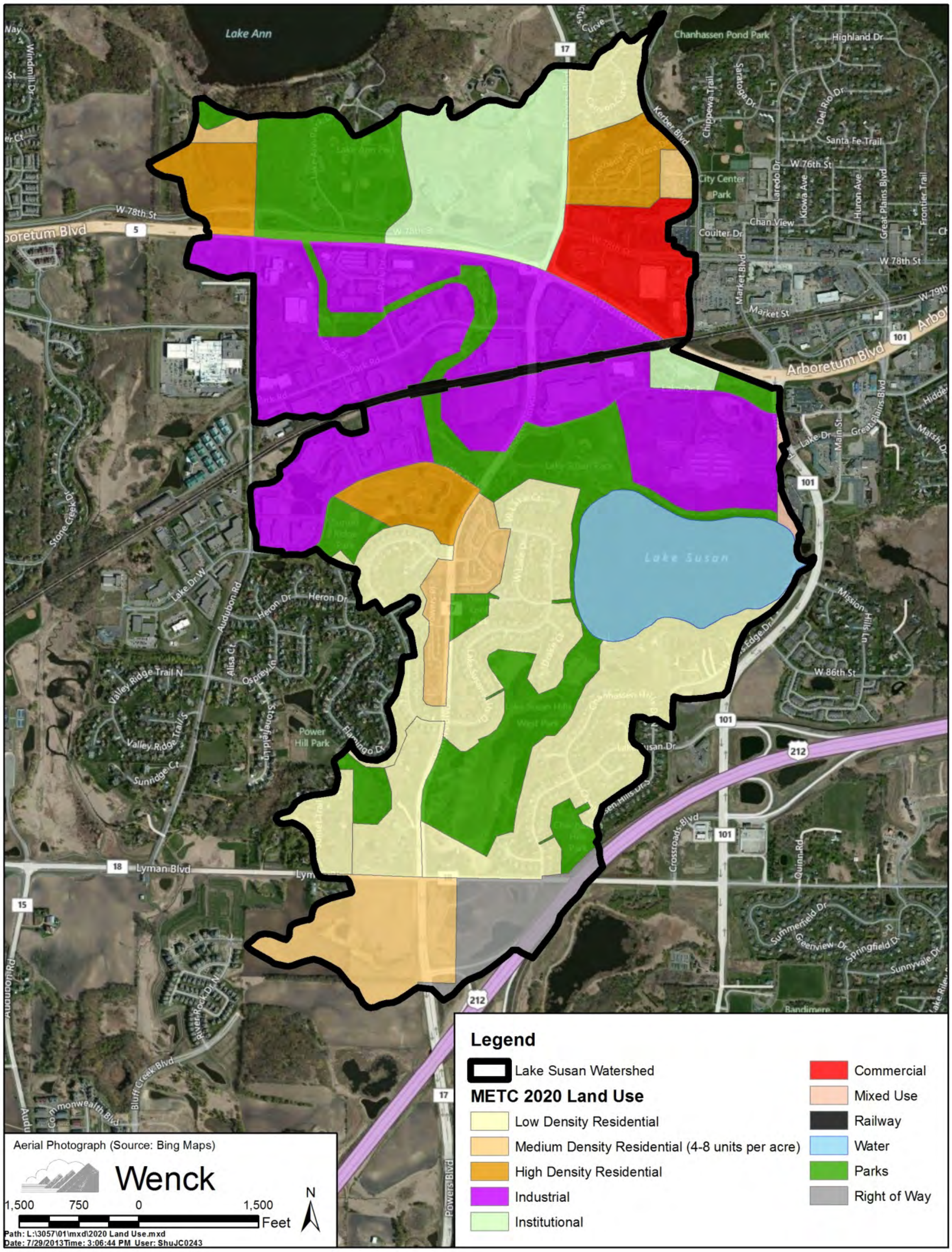

Figure 3-4. Lake Susan Watershed 2020 Land Use (Source: Metropolitan Council 2020).

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3.4 SOILS AND GEOLOGY

Topography in the Lake Susan watershed is dominated by rolling hills with depressions filled with ponds and wetlands. These features are composed of glacial till and outwash from the advance and retreat of glacial lobes during the most recent ice age.

The Lester-Kilkenny series (Figure 3-5) are the most common soil types in the lake watersheds. The series is characterized by a thin layer of loam above a thick layer of clay loam. The thick layer of clay loam limits the ability to implement infiltration practices in the watershed.

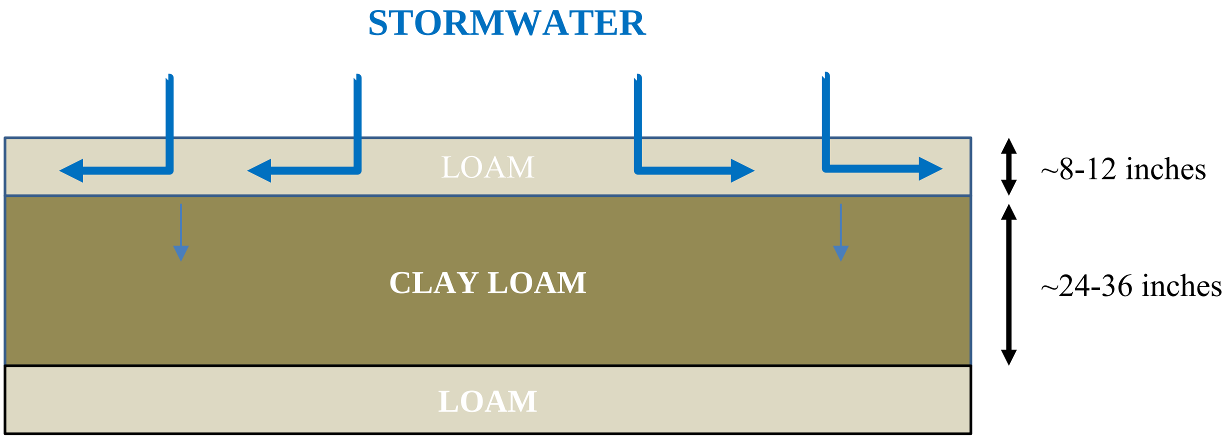


Figure 3-5. Typical Lester-Kilkenny Soil Profile in Lake Susan Watershed.

3.5 CLIMATOLOGICAL SUMMARY

Annual precipitation in the Twin Cities metro area has averaged about 30.3 inches from 1990 to 2012 (Figure 3-6). Average annual snowfall is approximately 50 inches, with the most severe melt runoff conditions usually occurring in March and early April. Lakes in the Minneapolis-St. Paul metropolitan area average approximately 132 days of ice cover per year, with average freeze and thaw dates occurring the last week of November and the first week of April, respectively. The average date of the last below-freezing temperature in the spring is April 27, and the average date of the first below-freezing temperature in the fall is October 2, yielding an average growing season of 157 days.

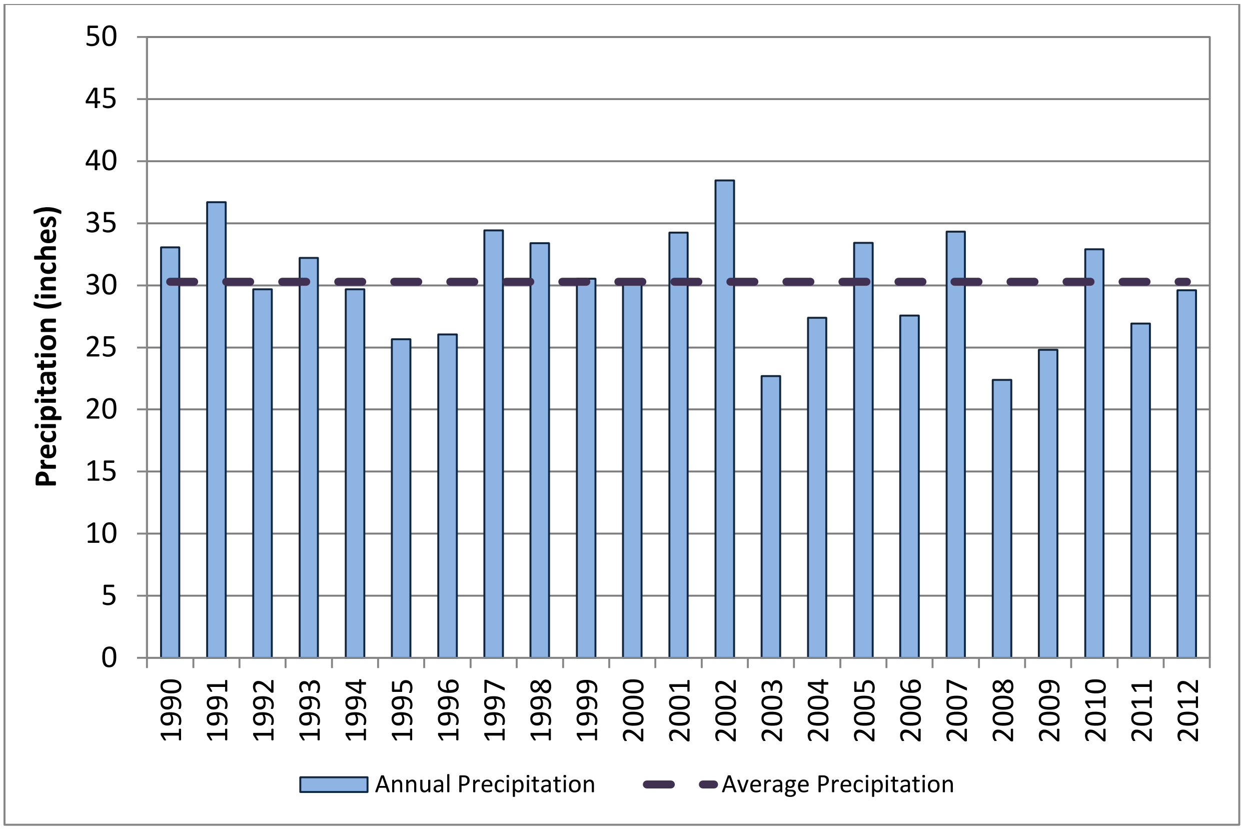


Figure 3-6. Annual and Average Precipitation Recorded at the Minneapolis/St. Paul International Airport.

It should be noted that although the data for the Minneapolis-St. Paul International Airport demonstrates a fairly consistent total average precipitation in a year, the intensity of the larger precipitation events has been changing over the last 20 years.

National Weather Service Hydrometeorological Design Studies Center recently released NOAA Atlas 14, Volume 8 (Atlas 14) which provides new precipitation frequency data for the Upper Midwest (NOAA Atlas 14, Volume 8, 2013). Atlas 14 was adopted and replaced the old Technical Paper-40 (TP-40) data. Atlas 14 is based on a longer period of record, an increased number and wider spatial distribution of rain gauges, and enhanced statistical techniques that greatly increases its accuracy. The report highlights that less frequent storm events have greater rainfall depths than what was previously estimated, resulting in greater strain on existing infrastructure that was designed to handle a lower rainfall depth.

3.6 LAKE MORPHOMETRY

The MPCA defines shallow lakes as enclosed basins with maximum depths less than 15 feet or systems where 80% or more of the surface area may support emerged or submerged aquatic vegetation (littoral zone). Lake Susan meets one of the two criteria for shallow lakes with a maximum depth of 17 ft. (slightly deeper than the shallow lake criteria) and a littoral area of 94% (Table 3-2 and Figure 3-7).

Lake Susan is characterized by very short residence times caused by a large direct watershed along with the upstream watersheds of lakes Ann and Lucy, for a total watershed area of 2,553 acres.

Table 3-2. Lake Susan Physical Parameters and Morphometry.

Parameter	Lake Susan
Area (acres)	88
Average Depth (feet)	10.3
Maximum Depth (feet)	17
Volume (acre-feet)	885
Residence Time (years)	0.96
Littoral Area (acres)	214
Littoral Area (percent)	94%
Total Watershed Area (acres)	2,553
Direct Drainage Area (acres) (Area below Ann & Lucy)	1,281
Watershed:Lake Area (ratio)	29:1
Lake Outflow (acre-ft/year)	926

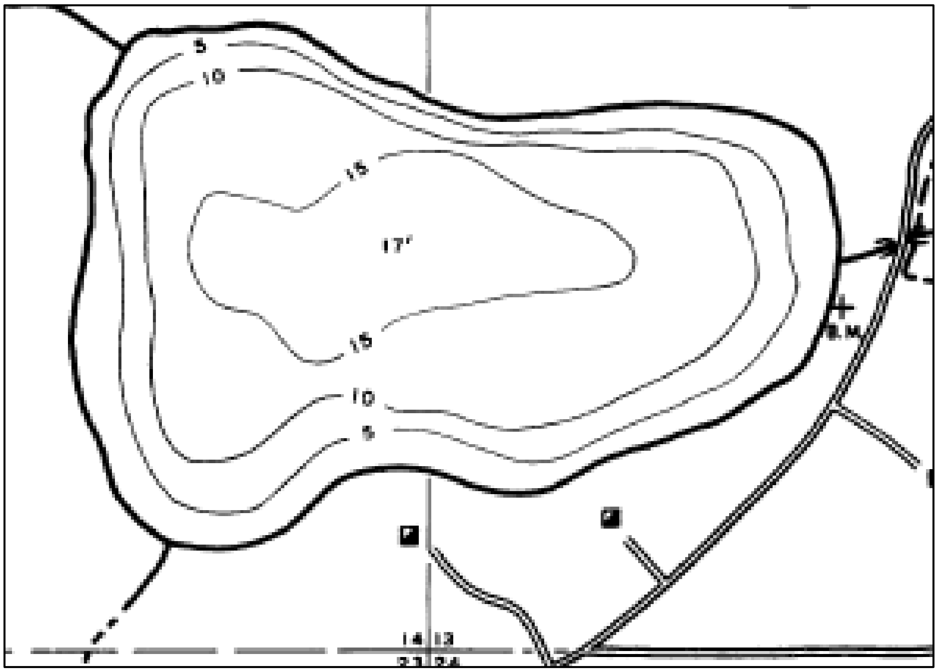


Figure 3-7. Lake Susan (Source: Minnesota DNR).

3.7 WATERSHED HYDROLOGY

The Lake Susan drainage area spans approximately 1,281 acres and is divided into five subwatersheds for this study (Figure 3-8). General flow pattern in the north subwatershed is northeast to southwest, routing stormwater from commercial and residential areas through storm sewer and wetland areas to Riley Creek. The primarily residential and commercial land uses in the west portion of the drainage area route stormwater from west to east through storm sewer and stormwater ponds to Riley Creek. The northeast subwatershed consists primarily of commercial land use that routes water west to the stormwater pond located in Lake Susan Park, which outlets to Riley Creek upstream of Lake Susan. The south watershed collects runoff from residential and agricultural lands and routes water primarily northeast to the large wetland in Lake Susan Hills Park. The area of the Lake Susan direct watershed is approximately 65 acres.

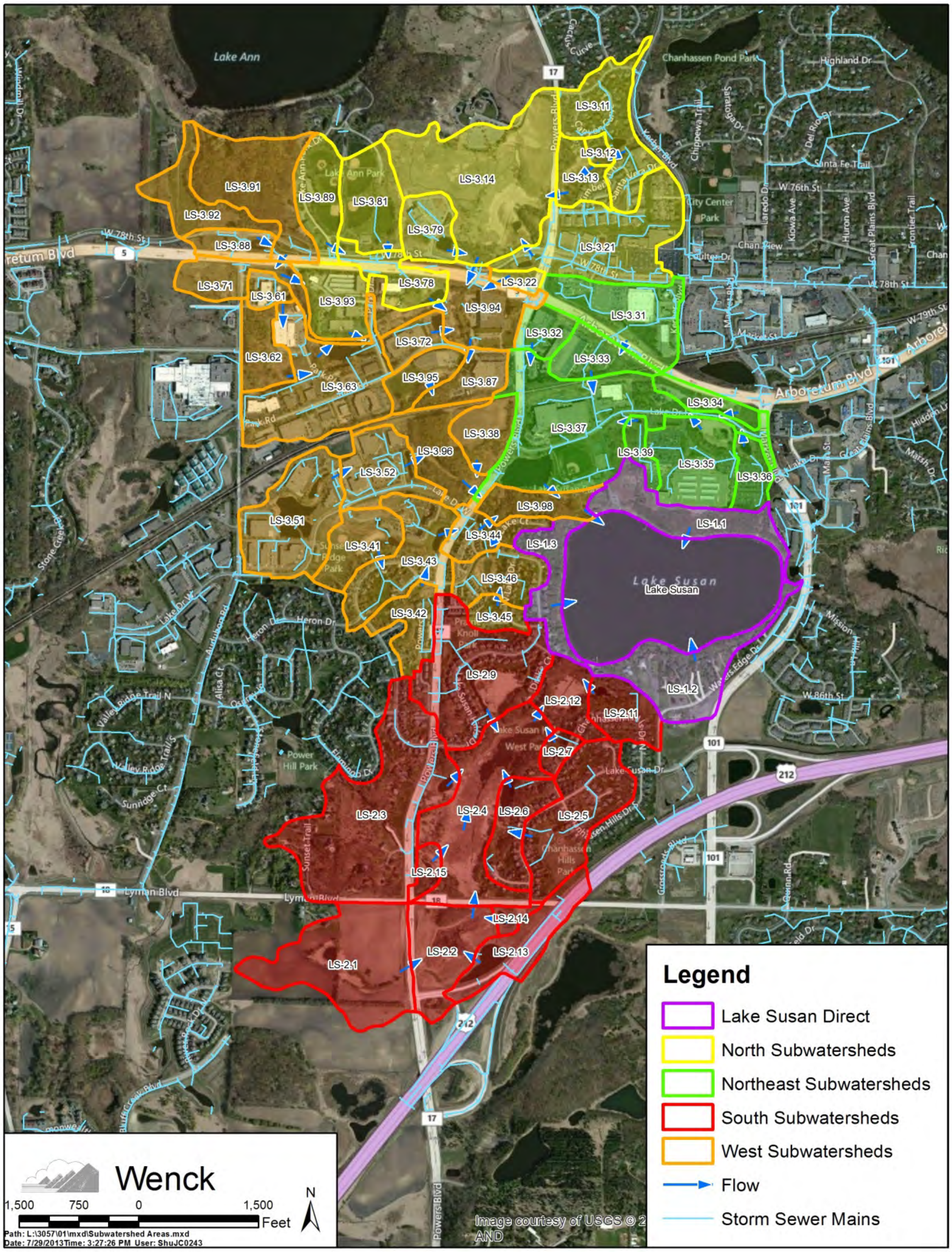


Figure 3-8. Lake Susan Watershed Flow Pattern.

Total water yield to Lake Susan from each of the major watersheds was estimated using a P8 model. A full description and overview of the model is provided in Section 4.1.1. The south subwatershed is the largest, but due to its limited impervious coverage it has the lowest runoff depth. The northeast subwatershed, which is dominated by commercial land use, has the highest runoff yield, whereas the north subwatershed has the second-highest yield along with the greatest runoff contribution to the Lake (Table 3-3 and Figure 3-9).

Table 3-3. Lake Susan Watershed Areas and Average Annual Water Yields.

Watershed	Contributing Area (acres)	Water Yield (acre-ft)	Runoff (inches)
North	317	203	7.7
Northeast	160	119	8.9
West	299	181	7.3
South	350	84	2.9
Direct	66	32	5.8
Total	1192	619	6.2

[1] 2004-2005 & 2008-2012 average annual subwatershed water yield modeled using P8

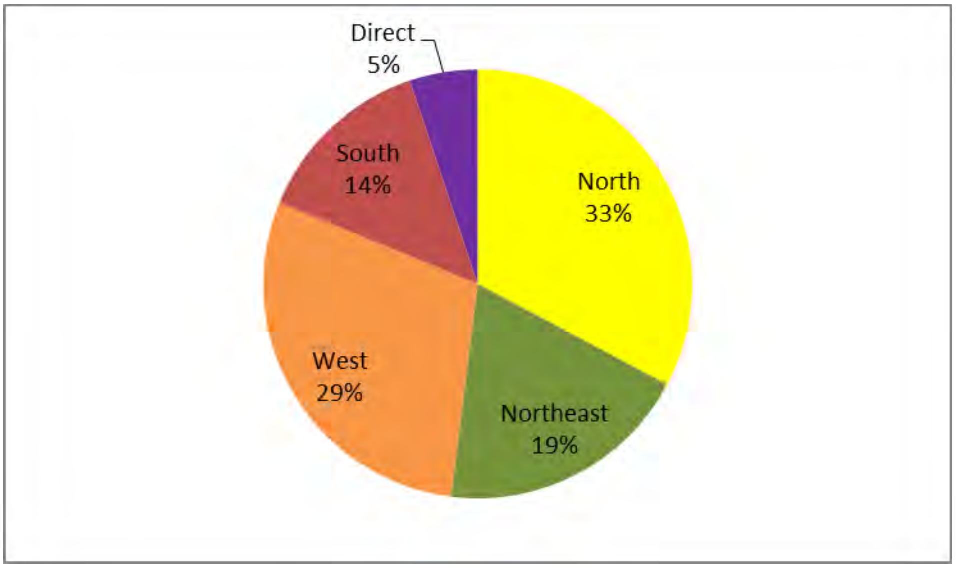


Figure 3-9. Lake Susan Average (2004-2005 & 2008-2012) Water Yield by Watershed.

3.8 WATER QUALITY

Lake water quality is typically measured by assessing the amount of algal growth and water clarity during the summer growing season. Excessive algal growth reduces water clarity and emits noxious odors. These are symptoms of lake eutrophication. When lakes become hypereutrophic, the entire food web is affected by changes in the algal community and water quality, including dissolved oxygen depletion and decreased water clarity. A healthy lake has a balanced growth of algae supporting the base of the food chain without degrading water quality or harming biological organisms. Algal growth (measured as total chlorophyll-*a*) is typically limited by the amount of phosphorus in the water column. Therefore, total phosphorus is considered a good companion measure of water quality along with algal growth and water clarity. Water clarity is affected by the amount of algae and suspended and dissolved particles in the water column.

3.8.1 Total Phosphorus

Lake Susan average summer TP is higher than the shallow lake standard of 60 µg/L in all seven seasons sampled (Figure 3-10). To be considered impaired, lake water quality must exceed the total phosphorus standard for the summer average over the past 10 years, plus exceed one of the response variables. In the seven recorded sampling seasons, there were 32 individual samples higher than the standard (56% of total).

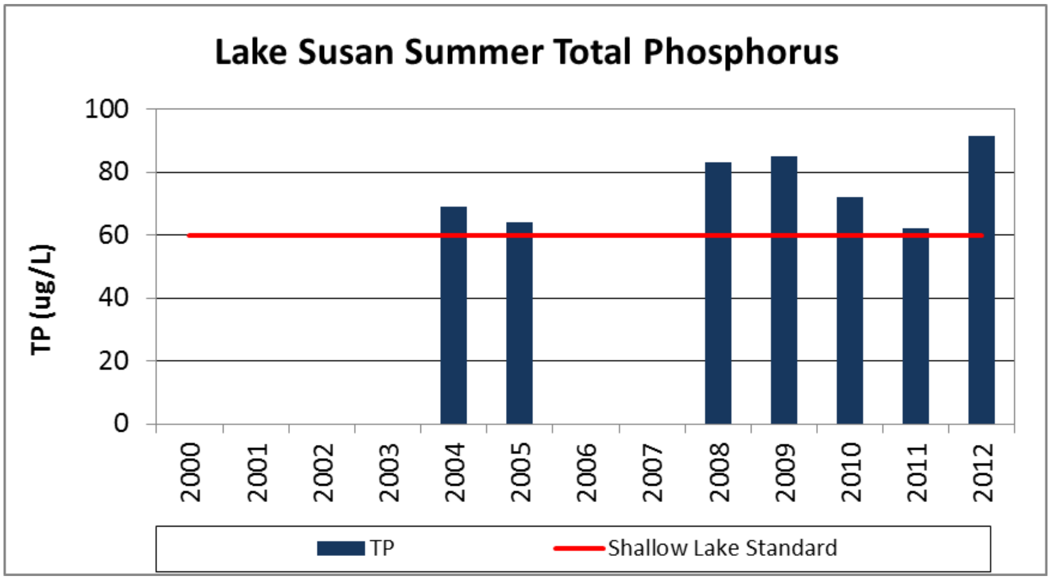


Figure 3-10. Summer (June 1 – September 30) Average Total Phosphorus in Lake Susan.
[1] 2008-2012 data sources are from the University of Minnesota and MPCA Environmental Data Access website
[2] 2004-2005 data was obtained solely from the MPCA Environmental Data Access website

3.8.2 Chlorophyll-*a*

Summer average chlorophyll-*a* was higher than the shallow lake standard of 20 µg/L six of the seven years since 2004 (Figure 3-11). Thirty-four summer chlorophyll-*a* values (June through September) were higher than the state standard (49% of total) since 2004. A majority of exceedances were recorded during the height of the growing season in July and August, when algae blooms are most prevalent.

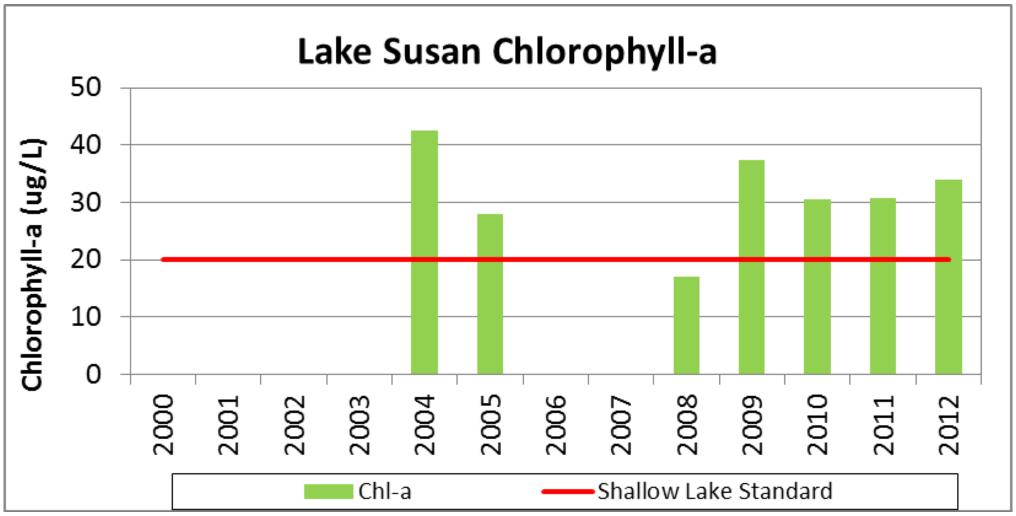


Figure 3-11. Summer (June 1 – September 30) Average Chlorophyll-a in Lake Susan.
[1] 2008-2012 data sources are from the University of Minnesota and MPCA Environmental Data Access website
[2] 2004-2005 data was obtained solely from the MPCA Environmental Data Access website

3.8.3 Transparency

Average summer Secchi depth is lower than the shallow lake standard in five of the seven sampling seasons since 2004 (Figure 3-12). There were 40 values lower than the state standard (58% of measurements from June to September) since 2004, and most were recorded in July and August during the peak of the growing season. Overall, summer Secchi depth from 2004-2012 has an average of 1.1 meters, suggesting water clarity summer averages are near the shallow lake standard.

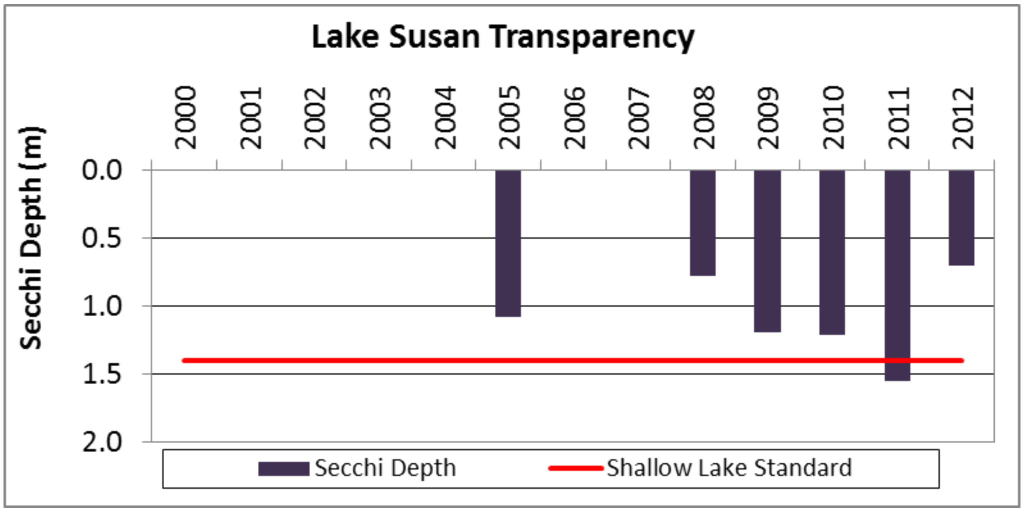


Figure 3-12. Summer (June 1 – September 30) Average Secchi Depth in Lake Susan.
[1] 2008-2012 data sources are from the University of Minnesota and MPCA Environmental Data Access website
[2] 2004-2005 data was obtained solely from the MPCA Environmental Data Access website

3.9 SHALLOW LAKE ECOLOGY

Shallow lakes are ecologically different from deep lakes. In shallow lakes, there is a greater proportion of sediment area to lake volume, allowing potentially larger sediment contributions to nutrient loads and higher potential sediment resuspension that can decrease water clarity. Biological organisms also play a greater role in maintaining water quality. Rough fish, especially carp, can uproot submerged aquatic vegetation and stir up sediment. Submerged aquatic vegetation stabilizes the sediment, reducing the amount that can be resuspended and cloud water clarity. Submerged aquatic vegetation also provides refuge for zooplankton, a group of small crustaceans that consumes algae.

All of these interactions reflect a lake being in two alternative stable states: a clear water state and a turbid water state. The clear water state is characterized by a robust and diverse submerged aquatic vegetation community, balanced fish community, and large daphnia (zooplankton that are very effective at consuming algae). Alternatively, the turbid water state typically lacks submerged aquatic vegetation, is dominated by rough fish, and is characterized by both sediment resuspension and algal productivity. The state in which the lake persists depends on the biological community as well as the nutrient conditions in the lake. Therefore, lake management must focus on the biological community as well as the water quality of the lake.

The following five-step process for restoring shallow lakes was developed in Europe and is also applicable here in the United States:

- Forward “switch” detection and removal
- External and internal nutrient control
- Biomanipulation (reverse “switch”)
- Plant establishment
- Stabilization and management of the restored system

The first step refers to identifying and eliminating those factors, also known as “switches,” that are driving the lake into a turbid water state. These can include high nutrient loads, invasive species such as carp and curly-leaf pondweed, altered hydrology, and direct physical impacts such as plant removal. Once the switches have been eliminated, an acceptable nutrient load must be established. After the first two steps, the lake is likely to remain in the turbid water state even though conditions have improved, and it must be forced back into the clear lake state by manipulating its biology (also known as biomanipulation). Biomanipulation typically includes whole lake drawdown and fish removal. Once the submerged aquatic vegetation has been established, management will focus on stabilizing the lake in the clear lake state (steps 4 and 5).

3.10 FISHERIES

The U of M is actively managing the rough fish population in lake to improve water clarity and facilitate reestablishment of native macrophyte populations (Sorenson 2013-Appendix A). The U of M is continuing to monitor fish species biomass abundance in the lake to ensure management of carp while also trying to establish a similar specie biomass distribution as seen in Metro lakes similar to Lake Susan.

3.11 AQUATIC VEGETATION

For the past 15 years, aquatic vegetation has been a major issue in Lake Susan. Curly-leaf pondweed and Eurasian watermilfoil are invasive species that present the greatest threat to the lake. In addition to managing carp, the U of M is continuing to establish native species in the lake by transplanting species from lakes Lucy and Ann (Knopik 2012, - Appendix B). As of this report, bushy pondweed, northern watermilfoil, and water star grass have been the most successful in the lake. The U of M intends to continue to evaluate the success of transplanting going forward. Aquatic plant monitoring and management will continue to be an ongoing activity on the lake.

4.0 Phosphorus Source Assessment and Lake Response

4.1 MODELING APPROACH

The following is a general description of the modeling approach and results used to assess water and nutrient loads to Lake Susan as well as the lake response to those loads.

4.1.1 Watershed P8 Model

Watershed nutrient loading was estimated using a P8 model developed for the Lake Susan watershed. P8 is a water quality model based on routing of flow, TP and TSS through networks of water quality treatment devises. TP removal is predicted using an empirical TP retention function. RPBCWD originally developed a P8 model as a part of the original UAA study. The model was updated with most current land use and watershed data and used to predict water yields and TP loading to each lake. The model operates on an hourly time-step and was used to predict watershed yields/loads annually for a seven-year period (2004-05 & 2008-2012).

The watershed model was validated using data from stormwater pond and wetland water quality monitoring data where available. Model runoff coefficients were systematically reduced to provide the best fit possible for runoff volumes. Average modeled runoff volumes over the modeled period agreed with 95% of monitored values and were determined to be reasonable.

4.1.2 Lake Response Model

A BATHTUB lake response model was developed for Lake Susan to assess the impacts of various improvement projects on in-lake water quality. The purpose of the model was to develop a phosphorus budget for the lake, identify the major factors influencing current and future water quality, and provide an understanding of the level and magnitude of project implementation required to meet identified water quality goals. A publicly available model, BATHTUB was developed by William W. Walker for the U.S. Army Corps of Engineers (Walker 1999). BATHTUB has been used successfully in many lake studies in Minnesota and throughout the United States. It is a steady-state annual or seasonal model that predicts a lake's summer (June – September) mean surface water quality. Its time-scales are appropriate because watershed P loads are determined on an annual or seasonal basis, and the summer season is critical for lake use and ecological health. BATHTUB has built-in statistical calculations that account for data variability and provide a means for estimating confidence in model predictions. It accounts for water and P inputs from tributaries, watershed runoff, the atmosphere, sources internal to the lake, and (if appropriate) groundwater; and accounts for outputs through the lake outlet, groundwater (if appropriate), water loss via evaporation, and P sedimentation and retention in the lake sediments. Through BATHTUB, several different mass-balance P models can be evaluated.

For most lakes in Minnesota, the Canfield-Bachmann lake formulation (Canfield and Bachmann 1981) is typically the appropriate model. BATHTUB's in-lake water quality predictions include two response variables, chlorophyll-*a* concentration and Secchi depth, in addition to TP concentration. Empirical relationships between in-lake TP, chlorophyll-*a*, and Secchi depth form the basis for predicting the two response variables.

4.2 NUTRIENT SOURCE LOADS

The following is a description of the major phosphorus sources to Lake Susan, including a summary of the sources.

4.2.1 Atmospheric Phosphorus Load

Atmospheric load refers to phosphorus precipitating from the air to the surface of the lake. Atmospheric inputs from wet and dry deposition are estimated using the rates in the MPCA report "Detailed Assessment of Phosphorus Sources to Minnesota Watersheds" (Barr Engineering, 2004), and are based on annual figures. The values used for dry, average, and wet precipitation are 24.9, 26.8, and 29.0 kg/km^2-year, respectively. These are equivalent to 0.22, 0.24, and 0.26 pounds/acre-year for dry, average, and wet years, respectively.

The atmospheric load (pounds/year) for Lake Susan was calculated by multiplying the lake area (acres) by the atmospheric deposition rate (pounds/acre-year). For example, in an average precipitation year, the atmospheric load to Lake Susan would be 0.239 pounds/acre-year times the lake surface area (88 acres), which is 21.1 pounds/year. The watershed is small enough that it is unlikely that there are significant geographic differences in rainfall intensity and amounts across the watershed.

4.2.2 Watershed Phosphorus Load

Watershed loading to Lake Susan was estimated using the P8 model discussed in Section 4.1.1. A summary table of the P8 output is provided in Appendix C. The following is a description of the model results for each watershed.

4.2.2.1 Lake Susan Watershed

The Lake Susan watershed loading analysis was broken into five subwatersheds (North, Northeast, South, West, and Direct) (Table 4-1). The largest phosphorus load comes from the north subwatershed where there are several developed subwatersheds with no treatment of stormwater prior to discharging into Riley Creek. The south and west subwatersheds are the next highest loading watersheds. The south subwatershed is partially developed, but through monitoring has shown high concentrations of phosphorus in the wetland prior to discharging into Lake Susan, indicating there is a potential it is a source of phosphorus.

Table 4-1. Modeled Stormwater TP Concentration and Load for the Lake Susan Watershed.

Year	North Subwatershed		Northeast Subwatershed		South Subwatershed		West Subwatershed		Direct Subwatershed	
	Outflow TP		Outflow TP		Outflow TP		Outflow TP		Outflow TP	
	(µg/L)	(lbs./yr)	(µg/L)	(lbs./yr)	(µg/L)	(lbs./yr)	(µg/L)	(lbs./yr)	(µg/L)	(lbs./yr)
2004	213	168	141	73	425	165	179	134	245	29
2005	240	154	145	59	528	140	189	114	299	29
2008	265	100	143	28	625	47	198	59	358	21
2009	269	100	150	31	585	59	207	63	354	20
2010	240	149	142	49	485	141	188	101	305	31
2011	215	145	142	55	407	152	172	108	259	29
2012	229	136	136	47	454	115	177	94	287	27
Avg.	**200**	**136**	**142**	**49**	**469**	**117**	**184**	**96**	**291**	**26**

4.2.3 Internal Phosphorus Load

Internal TP loading from lake sediments is an important aspect of phosphorus budgets. Lake sediments release phosphorus when dissolved oxygen levels drop below 2 mg/L. Lake sediments also release phosphorus under oxygenated (oxic) conditions but typically at a much lower rate. However, because shallow lakes have a large sediment-water interaction, oxic release of phosphorus can also be important.

To estimate internal loading in Lake Susan, an anoxic factor (Nürnberg 2004), which summarizes the period where anoxic conditions exist over the sediments, is estimated from the dissolved oxygen profile data. The anoxic factor is expressed in days but is normalized over the area of the lake. The anoxic factor is then used along with a sediment release rate to estimate the TP load from the sediments. Phosphorus release rates were estimated by collecting cores from Lake Susan and incubating them in the lab under oxic and anoxic conditions (ACOE-ERD 2011; Appendix B).

The measured rate of TP release from anoxic sediments in Lake Susan was 9.8 mg/m^2/day (Figure 4-1), which is typical of release rates in eutrophic lakes (productive) The release rates were combined with calculated anoxic factors to estimate the total annual phosphorus mass contributed by sediments (Table 4-2; Nürnburg 2004).

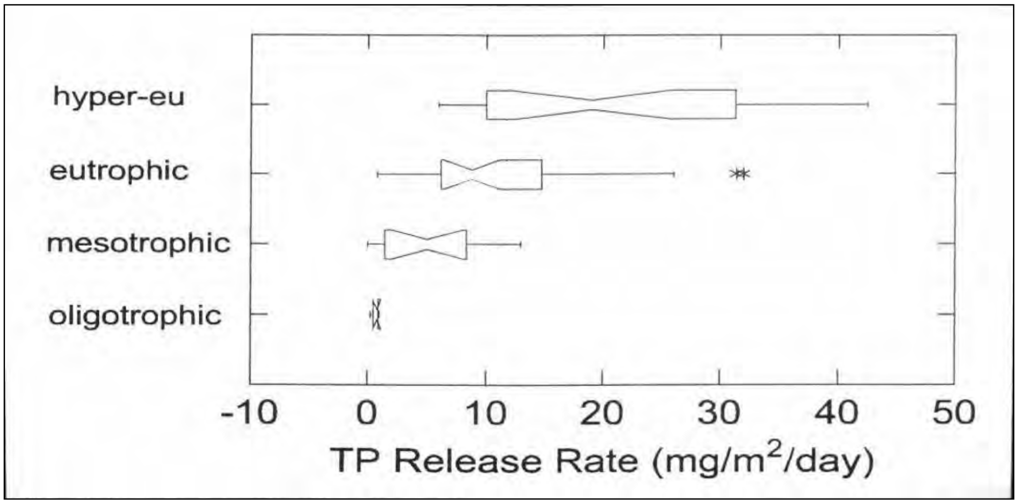


Figure 4-1. Sediment TP Release Rates by Eutrophic Condition. (Nürnberg 1997).

Lake Susan's anoxic factors ranged from 21.2 to 53.1 days (Table 4-2). These constantly long anoxic periods combined with relatively high sediment phosphorus release rates result in substantial internal loading. Calculations show that sediment internal loading can be up to 410 lbs/year, which is similar in magnitude to total watershed loading (Table 4-2).

Table 4-2. Estimated Internal TP Loading Summary for Lake Susan Lake.

Year	Release Rate ($mg/m^2/day$)	Anoxic Factor (days)	Gross Load ($mg/m^2/summer$)	Total Load (kg)	Total Load (pounds)
2004	9.8	21.2	208	74	164
2005	9.8	36.4	357	127	281
2008	9.8	24.5	240	86	189
2009	9.8	46.8	459	163	361
2010	9.8	53.1	520	186	410
2011	9.8	36.4	357	127	281
2012	9.8	36.4	357	127	281
Estimated Modeled Maximum[1]	9.8	36.4	357	127	281

[1] This represents the highest potential internal load based on the maximum measured anoxia. The value is based on a shallow lake equation developed to estimate anoxic factors in polymictic lakes (Nurnberg 2005-6).

4.3 SOURCE SUMMARY AND CURRENT PHOSPHORUS BUDGET

Once all of the TP sources have been estimated, the loads from each source are included in a lake response model to evaluate the link between TP loading and lake water quality. The following is a summary of the BATHUB lake response model and the nutrient budgets developed for Lake Susan.

4.3.1 BATHTUB Model Fit

To develop the average TP budget for Lake Susan, a model period of 2004 through 2012 (excluding 2006 and 2007 due to limited data) was selected based on data availability. This recent period had the most complete data set including lake water quality data, hydrologic monitoring in the watershed, and pond water quality data. The average of this seven-year period was used as the baseline for the TP budget development. The Canfield-Bachmann natural lakes model was used for this lake. Appendix C contains a complete summary of the inputs, outputs, and assumptions used in the BATHTUB model for Lake Susan.

The Lake Susan model performed reasonably well with the exception of 2008 and 2012 (Figure 4-2). A possible explanation for low modeled TP concentrations could be due to a relatively low TP load.

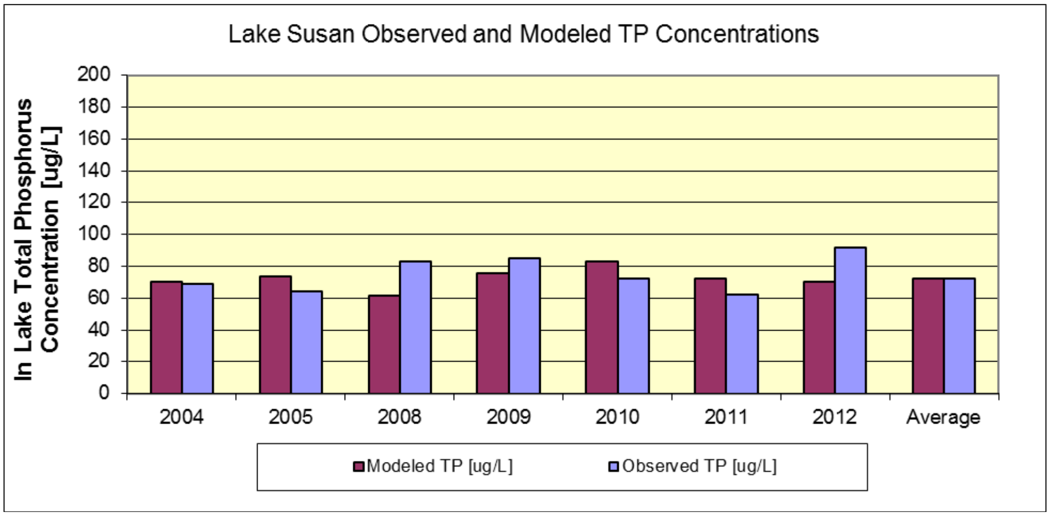


Figure 4-2. Modeled and Observed Summer TP in Lake Susan

4.3.2 Lake Phosphorus Budgets

An average TP budget was developed for Lake Susan (Figure 4-3). Lake Susan water quality is impacted by both stormwater TP loading (57%) and internal loading (38%) of the TP budget for Lake Susan. Developing BMPs which target these two sources will be key to long-term management of TP to Lake Susan.

The upstream watershed (Lake Ann and Lucy) only contribute 2% of the load to the lake indicating preservation of these lakes will also be a key factor in the long-term success of Lake Susan.

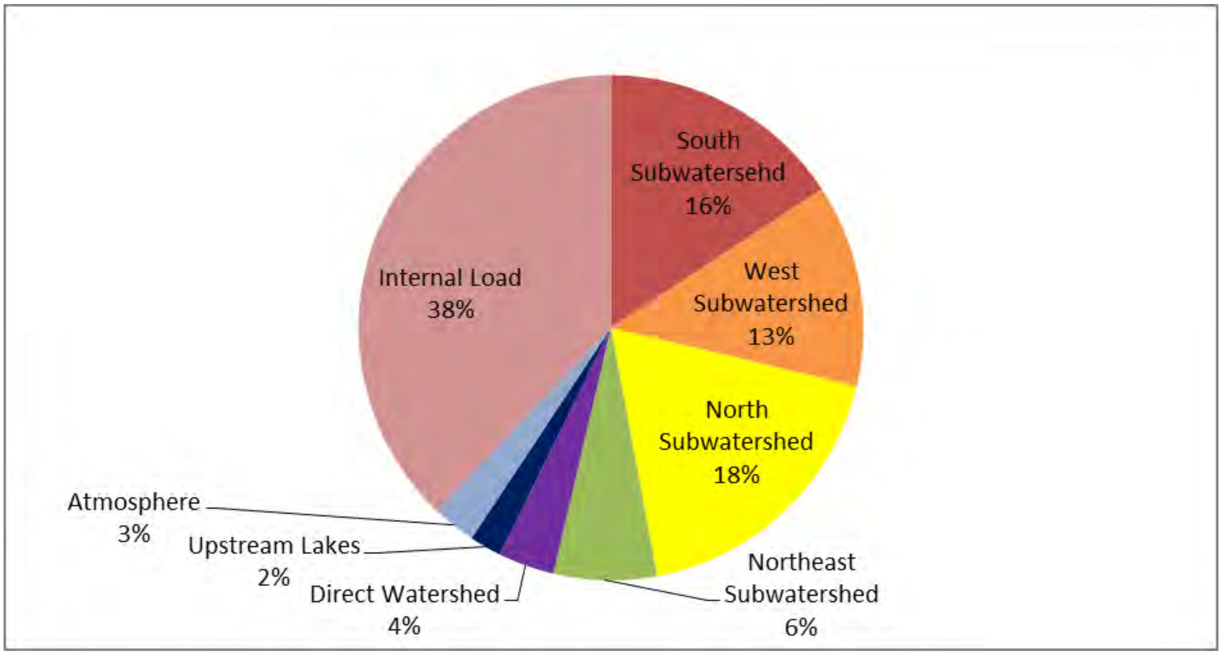


Figure 4-3. Average TP Loading by Source for Lake Susan.

4.4 PHOSPHORUS LOAD ALLOCATIONS

The numerical load reduction calculated for Lake Susan was derived to solve for a numeric target of 60 µg/L of TP as a summer average.

4.4.1 Total Loading Capacity

The first step in developing a nutrient budget for lakes is to estimate the total nutrient loading capacity. For this estimate, the current nutrient budgets and the lake response modeling (average of 2004-2005 and 2008-2012) presented in Section 4.3 were used as the starting point. The nutrient inputs were systematically reduced until the model predicted at what amounts Lake Susan met the current TP standard of 60 µg/L. The model-predicted nutrient loads for this model scenario represent the total loading capacity for each lake. Total loading capacity for Lake Susan is 557 pounds per year. Further details of how this was applied are included in the following sections.

4.4.2 Load Allocations

The Load Allocation includes watershed runoff, upstream lakes contribution, atmospheric deposition, and internal loading. No changes are prescribed for atmospheric deposition because this source is impossible to control. Internal loading in Lake Susan is about 38% of the phosphorus budget and presents a significant opportunity for load reduction. The remainder of the reduction was targeted in the watershed as there are multiple opportunities to implement water quality projects in the upstream watershed. Upstream lakes were held at current conditions assuming they will be protected under stormwater nondegradation rules.

4.4.3 Load Reduction

Table 4-3 presents the results of the load reduction calculation for Lake Susan. Lake Susan requires a 25% reduction in TP loading to meet the shallow lake goal. A 25% reduction equates to an annual TP load reduction of 185 pounds. To achieve this reduction, the internal load needs to be lowered 127 pounds, with the remaining 58 pounds coming from watershed reductions.

Table 4-3. Load Allocation Summary for Lake Susan.

Source	Existing TP Load [1]	Target TP Loading	Recommended Load Reduction	
	(lbs/year)	**(lbs/year)**	**(lbs/year)**	**%**
Watershed	424	366	58	14%
Upstream Lakes	16	16	0	0%
Atmosphere	21	21	0	0%
Internal Load	281	154	127	45%
TOTAL	**742**	**557**	**185**	**25%**

[1] Existing load is the average for the years 2004-2005 and 2008-2012.

5.0 Implementation Plan

5.1 MANAGEMENT ACTIVITY SELECTION

The purpose of this plan is to identify water quality goals for the management of Lake Susan and to identify projects necessary to reach those goals. Potential projects to reduce nutrient loading were selected using the P-8 model, BATHTUB Lake model, and sediment cores collected on the lake. General feasibility of the projects was evaluated to determine if appropriate improvements are possible at the selected sites. Projects deemed feasible were carried forward to effectiveness evaluations and planning-level cost estimates.

5.2 ADAPTIVE MANAGEMENT

Implementation will be conducted using adaptive management principles (Figure 5-1). Adaptive management is essentially a phased approach where a strategy is identified and implemented in the first cycle. After implementation of that phase has been completed, progress toward meeting the goals is assessed. A new strategy is then formed to continue making progress toward meeting the goals. These steps are continually repeated until established goals are met. This process allows for future technological advances that may alter the course of actions. Continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategies for attaining the water quality goals of this management plan.

Adaptive management will be applied using the five-year planning cycle used by MS4s. The first five years will be used to implement projects that are ready to go, develop feasibility studies and designs for other projects, and continue monitoring and outreach activities. The second five years will be used to continue implementing projects on the ground as well as monitoring to assess effectiveness of the selected practices.

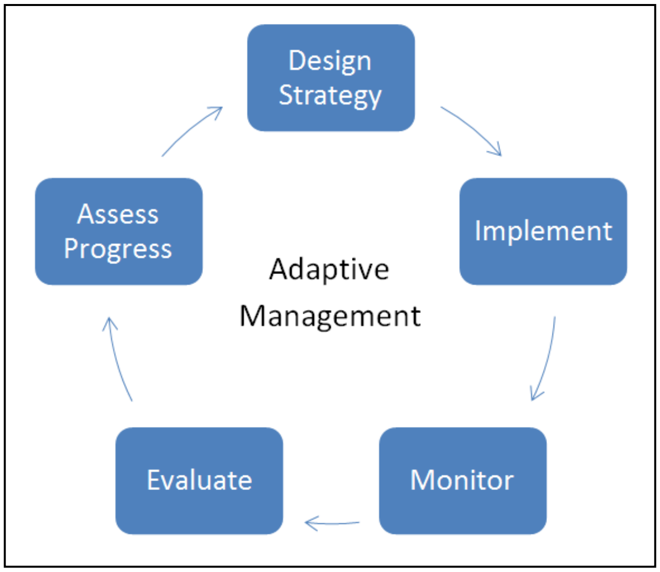


Figure 5-1. Adaptive Management.

5.3 LAKE SUSAN WATERSHED NUTRIENT MANAGEMENT

Prioritization of projects/activities was broken down into three categories:

- **Near-term Projects** – Projects that can leverage existing public properties to facilitate quicker implementation
- **Collaboration Projects** – Projects that require collaboration with multiple partners or are tied to redevelopment/retrofitting a site
- **Management Strategies** – Strategies/Policies to be implemented to assist with maintaining load reductions achieved.

Within each category, several projects were identified to reduce stormwater nutrient loading to Lake Susan. Brief descriptions of projects or activities are provided in this section.

In addition to project descriptions, conceptual cost estimates were developed for all of the near-term projects. Cost estimates assumed a 30-year life expectancy. Cost estimates include design, construction, operation, and maintenance costs associated with effective implementation of the project. This method also was consistent with the approach taken by the SALSA report.

5.3.1 Near-Term Projects

Near-Term projects were identified based on their cost effectiveness and ease of implementation by working with one or two land owners (Table 5-1, Figure 5-2). A conceptual cost estimate and potential effectiveness were completed for each of the near-term projects.

Table 5-1.Near-Term Projects.

Project	Name	Description
1	Alum Treatment - Lake Susan	• Complete Alum treatment on Lake Susan in areas >10ft
2	Lake Susan Park Pond Enhancement	• Increase the pond dead pool storage by 1ft • Install a Minnesota Filter to treat TP
3	Lake Susan Hills West Park – Wetland Restoration	• Install a Minnesota Filter in a modified weir system at the outlet of the wetland to treat TP
4	Lake Drive West Pond Enhancement	• Increase the pond dead pool storage by 1ft • Install a Minnesota Filter to treat TP
5	Target Pond Upgrade	• Expand the footprint of the existing pond to create greater live storage • Increase dead pool storage by 1ft • Install a Minnesota Filter to treat TP

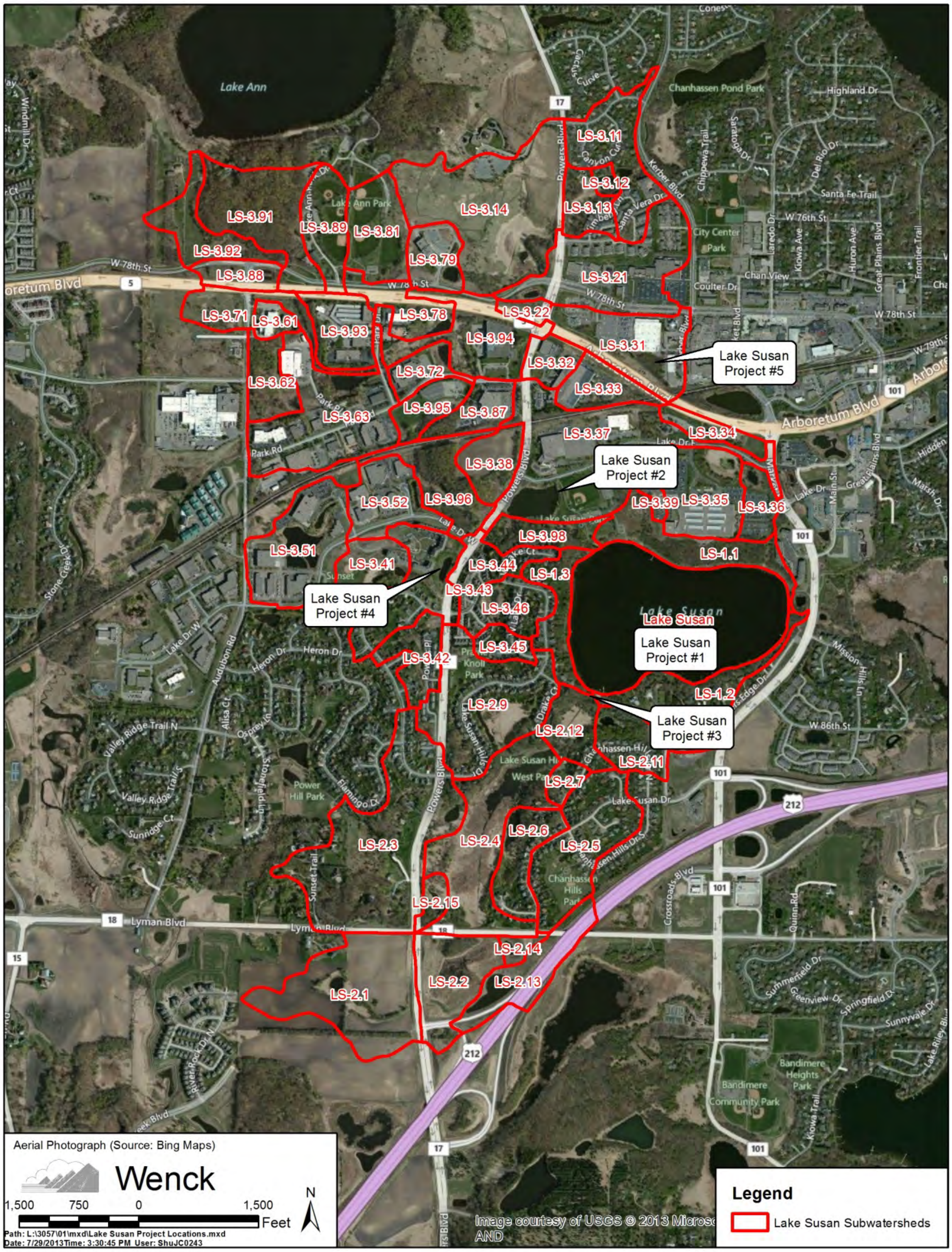


Figure 5-2. Near-Term Projects for Lake Susan.

5.3.2 Project #1 - Alum Treatment – Lake Susan

Internal loading in Lake Susan is 38% of the TP budget. Sediment release rates are relatively high and represent a good opportunity to reduce loading to Lake Susan. Reducing internal phosphorus loading in Lake Susan to similar rates observed in typical metro lakes (1.5 mg/m^2/day) translates to 250 pounds less TP annually.

Sediment phosphorus inactivation is one of the more effective tools to control internal loading in the sediment. Alum is the most common chemical used to permanently bind TP. The aluminum-phosphorus bond is very stable under typical environmental conditions and provides a long-term "depository" for phosphorus in the lake. Coupled with identified near-term watershed improvements, alum treatment could occur now and maintain a long life span, possibly 20 to 30 years (Figure 5-3).

The estimated project life cycle cost for an alum treatment of Lake Susan is $280,071 including the dose calculations, application, and materials (Table 5-2). The estimate efficiency of the project is $37/lb of TP/yr.

Table 5-2. Cost Estimate for Project #1 - Lake Susan Alum Dosing.

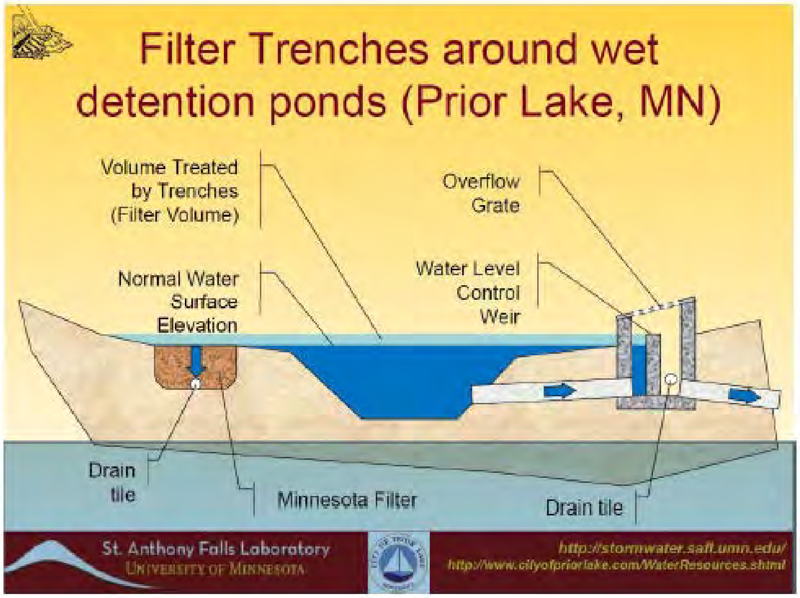
Item	Description	Qty	Unit	Unit Price	Item Total
1	Mobilization and Demobilization [1]	1	L.S.	$ 12,500.00	$ 12,500.00
2	Alum Dosing - 100 mg Al/m^{2} [1]	52	AC	$ 2,750.00	$ 143,000.00
3	Alum Dosing - 175 mg Al/m^{2}	15	AC	$ 4,800.00	$ 71,040.00
4	Monitoring of Dosing [1]	1	L.S.	$ 5,000.00	$ 5,000.00
5	Dosing Documentation [1]	1	L.S.	$ 6,000.00	$ 6,000.00
6	Plans/Specs/Bidding Assistance [1]	1	L.S.	$ 6,000.00	$ 6,000.00
				Treatment Total =	$ 243,540.00
				15% Contingency =	$ 36,531.00
				Total Implementation Cost =	$ 280,071.00
				30 yrs Operation and Maintenance ($0/yr) =	$ -
				Project Life Cycle Total Cost =	**$ 280,071.00**
				Project TP Removal (lb TP/Yr) =	**250**
				Project Efficiency ($/lb TP removed) =	**$ 37.34**

[1] Includes follow-up spot treatment in 15 years of 14 acres

Figure 5-3. Project #1 – Alum Treatment Location – Lake Susan.

5.3.3 Project #2 - Lake Susan Park Pond Enhancement

The stormwater pond located in the eastern portion of Lake Susan Park receives stormwater from a mainly industrial and commercial area north and east of the park. It currently provides some TP removal prior to discharging to Riley Creek just upstream of Lake Susan. Improvement of the TP removal could be achieved by increasing the storage of the basin and installing a Minnesota Filter around the perimeter of the basin (Figures 5-4, 5-5, 5-6).



Filter Trenches around wet detention ponds (Prior Lake, MN)

St. Anthony Falls Laboratory
UNIVERSITY OF MINNESOTA

http://stormwater.safl.umn.edu/
http://www.cityofpriorlake.com/WaterResources.shtml

Figure 5-4. Profile overview of Minnesota Filter Installation (Erickson. A and Gulliver J., 2010).

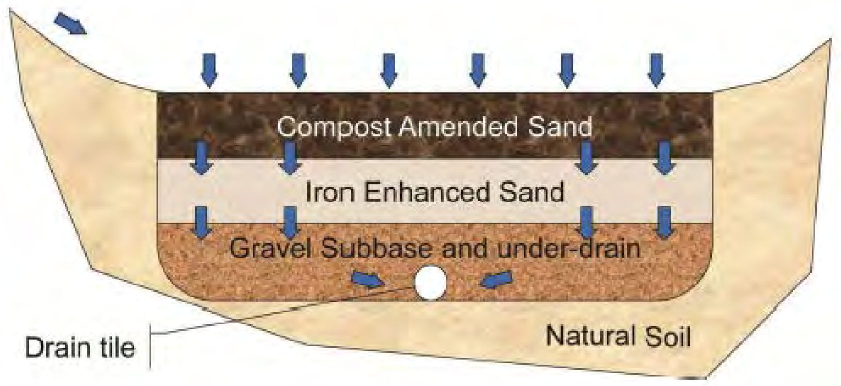


Figure 5-5. Profile view of Minnesota Filter Installation (Erickson. A and Gulliver J., 2010).

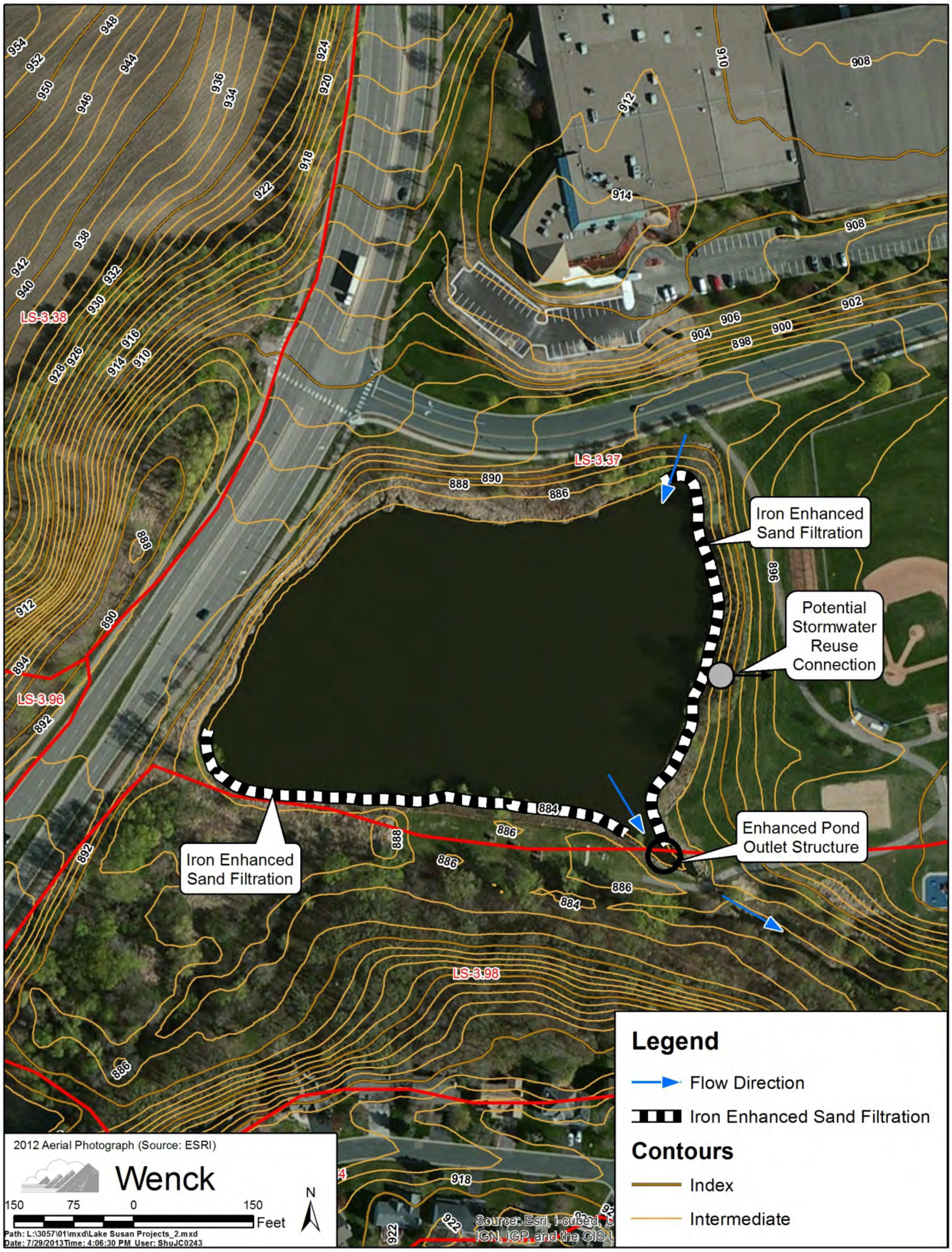


Figure 5-6. Project #2 – Lake Susan Park Pond Enhancement.

Based on an initial review, an additional 6 acre-feet of dead storage could be added to the pond by increasing the outlet elevation by 1.5 feet. The increase in dead storage along with the installation of the Minnesota Filter would result in an additional 31 pounds of TP removal. The project life cycle cost is approximately $89,500, not accounting for any easement or land acquisition costs (Table 5-3). The estimate efficiency of the project is $98/lb of TP/yr.

Table 5-3. Cost Estimate for Project #2 - Lake Susan Park Stormwater Pond Enhancement.

Item	Description	Qty	Unit	Unit Price	Item Total
1	Iron Enhanced Sand Filtration [1, 2]	2,600	S.F.	$ 21.57	$ 56,082.00
2	Outlet Structure	1	L.S.	$ 7,000.00	$ 7,000.00
	Construction Total =				$ 63,082.00
	15% Legal/Design and Administration =				$ 9,462.30
	15% Contingency =				$ 9,462.30
	Total Construction Cost =				$ 82,006.60
	30 yrs Operation and Maintenance ($250/yr) [3] =				$ 7,500.00
	Project Life Cycle Total Cost =				**$ 89,506.60**
	Project TP Removal (lb TP/Yr) =				**30.6**
	Project Efficiency ($/lb TP removed) =				**$ 97.50**

[1] Unit Price from Carver County SWCD Salsa Report - Structural Sand Filter (including peat, compost, iron amendments,

[2] Unit Price from Carver County SWCD Salsa Report - Assumes filter to be 15 feet in width

[3] Carver County SWCD Salsa Report

In addition to the water quality improvements proposed for the pond, stormwater in the pond could be used to irrigate the adjacent parkland. Installing the irrigation system could remove additional phosphorus while saving money by limiting irrigation of parkland.

5.3.4 Project #3 - Lake Susan Hills West Park – Wetland Restoration

The wetland discharging into the southwest portion of the Lake Susan receives runoff from a combination of residential, highway and agricultural land uses (Figure 5-7). As a result of monitoring conducted by the District, this wetland (subwatershed 2.4 and 2.12) has been shown to be a significant source of phosphorus for Lake Susan. Treatment of the wetland is proposed through the installation of a weir that forces water through an iron sand filtration system before entering Lake Susan. This location for treatment was chosen after District monitoring in the wetland showed that phosphorus concentrations increased with distance downstream in the wetland, indicating treatment prior to discharge to the lake as the optimal location for treatment.

The proposed project would install two rows of sheet pile with a layer of iron sand filings located between the two rows of sheet piles. The layout is similar to that used for the Minnesota Filter except that the outflow through the weir would occur through underdrains installed through the weir. The project would aim to establish a permanent pool elevation of 882.5ft in the wetland basin prior to discharging to Lake Susan. This would be an increase in the permanent pool and would provide additional settling prior to discharging to Lake Susan. The increase in elevation would also assure the layer of iron enhanced sand would be above the OHW of Lake Susan, limiting the potential for the iron layer to become anoxic and potentially release phosphorus. A high flow bypass would be installed to allow overflow during high precipitation events.

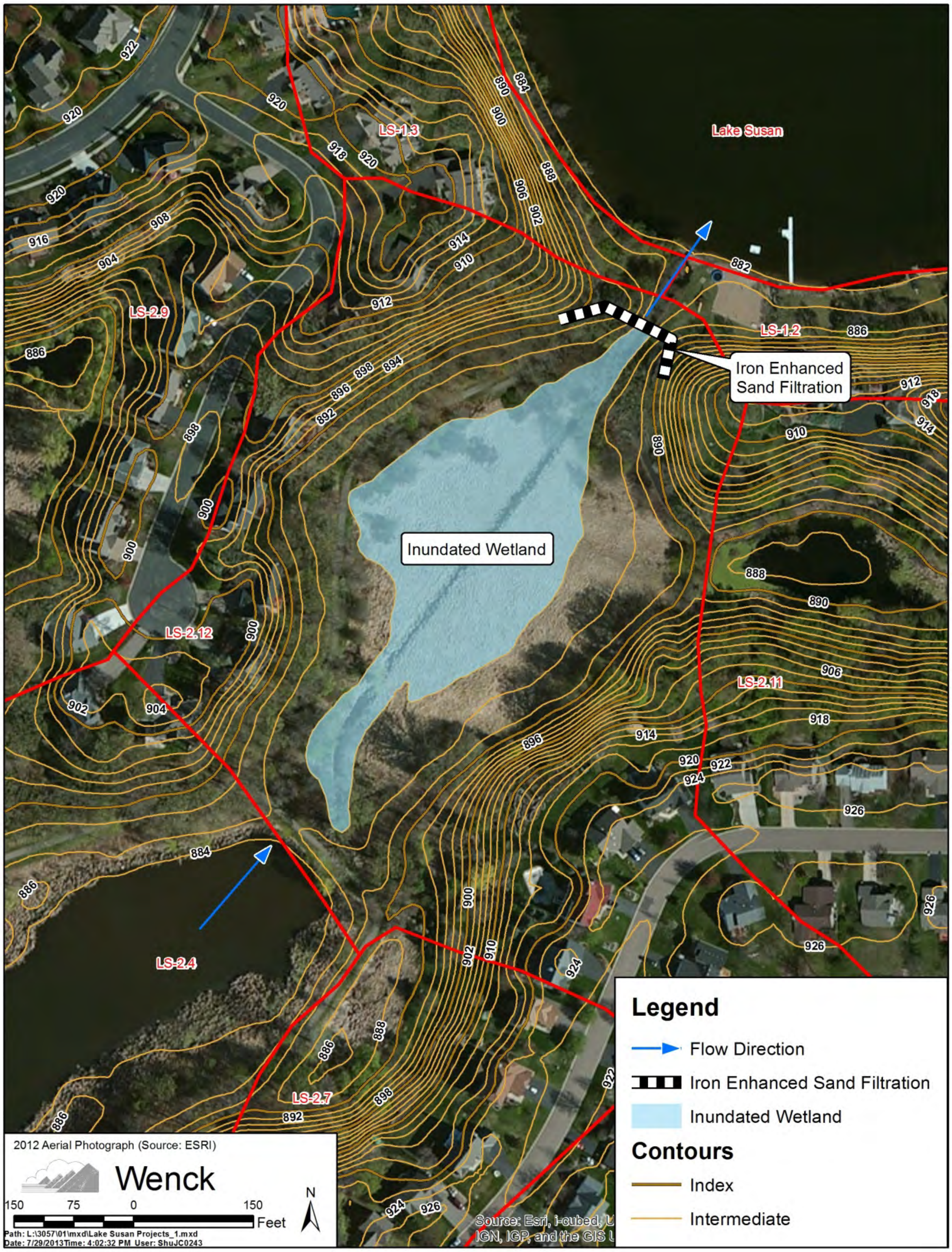


Figure 5-7. Project #3 – Lake Susan Hills Park – Wetland Enhancement.

Additional agency coordination would need to be completed as the project moves closer to a 100% design to ensure any agency concerns are addressed prior to permitting. Based on an initial review, an additional 2.0 acre-feet of dead storage could be added to the pond. The increase in dead storage along with the installation of the Minnesota Filter would result in an additional 67 pounds of TP removal.

The project life cycle cost is approximately $251,500, not accounting for any easement or land acquisition costs (Table 5-4). The estimated efficiency of the project is $126/lb of TP/yr.

Table 5-4. Cost Estimate for Project #3 - Lake Susan Hills Park Wetland Enhancement.

Item	Description	Qty	Unit	Unit Price	Item Total
1	Mobilization and Demobilization	1	L.S.	$ 10,000.00	$ 10,000.00
2	Dewatering	1	L.S.	$ 10,000.00	$ 10,000.00
2	Site Clearing	1	L.S.	$ 5,000.00	$ 5,000.00
3	Iron Enhanced Sand Filtration [1, 2]	2,500	S.F.	$ 21.57	$ 53,925.00
4	Sheetpile	1,750	S.F.	$ 50.00	$ 87,500.00
5	Site Restoration	1	L.S.	$ 4,000.00	$ 4,000.00
Construction Total =					$ 170,425.00
15% Legal/Design and Administration =					$ 25,563.75
15% Contingency =					$ 25,563.75
Total Construction Cost =					$ 221,552.50
30 yrs Operation and Maintenance ($1,000/yr) =					$ 30,000.00
Project Life Cycle Total Cost =					**$ 251,552.50**
Project TP Removal (lb TP/Yr) =					**66.6**
Project Efficiency ($/lb TP removed) =					**$ 125.90**

[1] Unit Price from Carver County SWCD Salsa Report - Structural Sand Filter (including peat, compost, iron amendments,

[2] Unit Price from Carver County SWCD Salsa Report - Assumes filter to be 15 feet in width

5.3.5 Project #4 - Lake Drive West Pond Enhancement

The stormwater pond located in the southwest quadrant of Lake Drive West and Powers Boulevard could have its removal efficiency improved by installing a Minnesota Filter (Figure 5-8). It currently treats runoff from a primarily residential area. The City is also evaluating improving this pond based on regular maintenance of existing stormwater ponds in the City. Based on an initial review, an additional 0.75 acre-feet of dead storage could be added to the pond. The increase in dead storage along with installing the Minnesota Filter would result in an additional 5 pounds of TP removal.

The project life cycle cost is approximately $25,400, not accounting for any easement or land acquisition costs (Table 5-5). The estimated efficiency of the project is $177/lb of TP/yr.

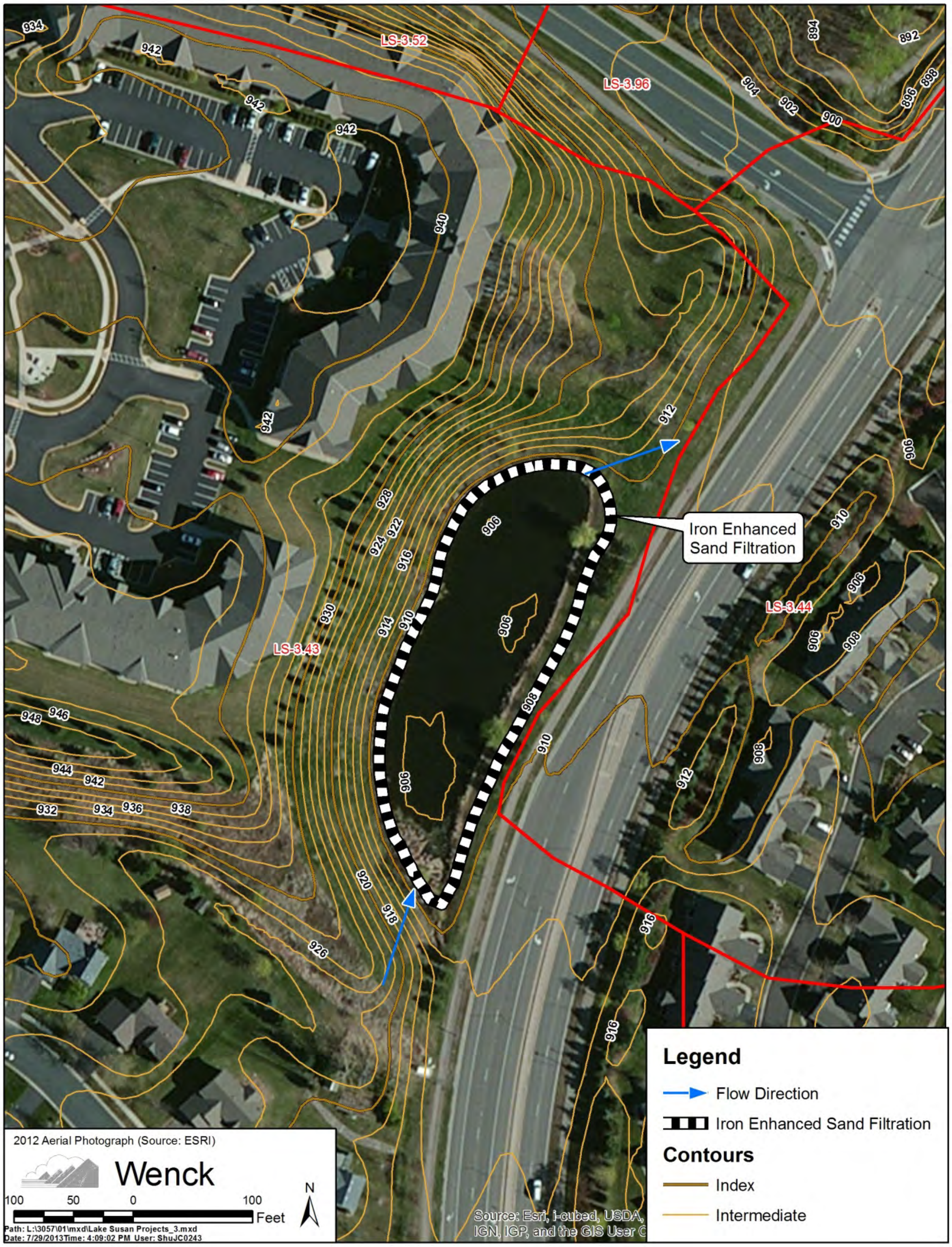


Figure 5-8. Project #4 – Lake Drive West Pond Enhancement.

Table 5-5. Cost Estimate for Project #4 - Lake Drive West Pond Enhancement.

Item	Description	Qty	Unit	Unit Price	Item Total
1	Iron Enhanced Sand Filtration [1, 2]	500	S.F.	$ 21.57	$ 10,785.00
2	Outlet Structure	1	L.S.	$ 3,000.00	$ 3,000.00
				Construction Total =	$ 13,785.00
				15% Legal/Design and Administration =	$ 2,067.75
				15% Contingency =	$ 2,067.75
				Total Construction Cost =	$ 17,920.50
				30 yrs Operation and Maintenance ($250/yr) [3] =	$ 7,500.00
				Project Life Cycle Total Cost =	**$ 25,420.50**
				Project TP Removal (lb TP/Yr) =	**4.8**
				Project Efficiency ($/lb TP removed) =	**$ 176.53**

[1] Unit Price from Carver County SWCD Salsa Report - Structural Sand Filter (including peat, compost, iron amendments,

[2] Unit Price from Carver County SWCD Salsa Report - Assumes filter to be 15 feet in width

[3] Carver County SWCD Salsa Report

5.3.6 Project #5 - Target Pond Upgrade

The Target Pond adjacent to TH 5 includes drainage from primarily commercial development (Figure 5-9). The pond is undersized for its drainage area, leading to frequent overtopping and inadequate water quality treatment. Possible expansion was assessed by evaluating current site constraints, current easements, and load reduction potential. In addition to expansion, installation of a Minnesota Filter Bench was evaluated for reduction of TP to Lake Susan. Based on an initial review, an additional 1.2 acre-feet of dead storage could be added to the pond. The increase in dead storage along with the installation of the Minnesota Filter would result in an additional 19 pounds of TP removal.

The project life cycle cost is approximately $81,200, not accounting for any easement or land acquisition costs (Table 5-6). The estimated efficiency of the project is $142/lb of TP/yr.

Table 5-6. Cost Estimate for Project #5 - Target Pond Upgrade.

Item	Description	Qty	Unit	Unit Price	Item Total
1	Iron Enhanced Sand Filtration [1, 2]	750	S.F.	$ 21.57	$ 16,177.50
2	Outlet Structure	1	L.S.	$ 5,000.00	$ 5,000.00
3	Pond Excavation	2,500	C.Y.	$ 13.00	$ 32,500.00
4	Site Restoration	1	L.S.	$ 3,000.00	$ 3,000.00
				Construction Total =	$ 56,677.50
				15% Legal/Design and Administration =	$ 8,501.63
				15% Contingency =	$ 8,501.63
				Total Construction Cost =	$ 73,680.75
				30 yrs Operation and Maintenance ($250/yr) [3] =	$ 7,500.00
				Project Life Cycle Total Cost =	**$ 81,180.75**
				Project TP Removal (lb TP/Yr) =	**19.0**
				Project Efficiency ($/lb TP removed) =	**$ 142.42**

[1] Unit Price from Carver County SWCD Salsa Report - Structural Sand Filter (including peat, compost, iron amendments, or similar)

[2] Unit Price from Carver County SWCD Salsa Report - Assumes filter to be 15 feet in width

[3] Carver County SWCD Salsa Report

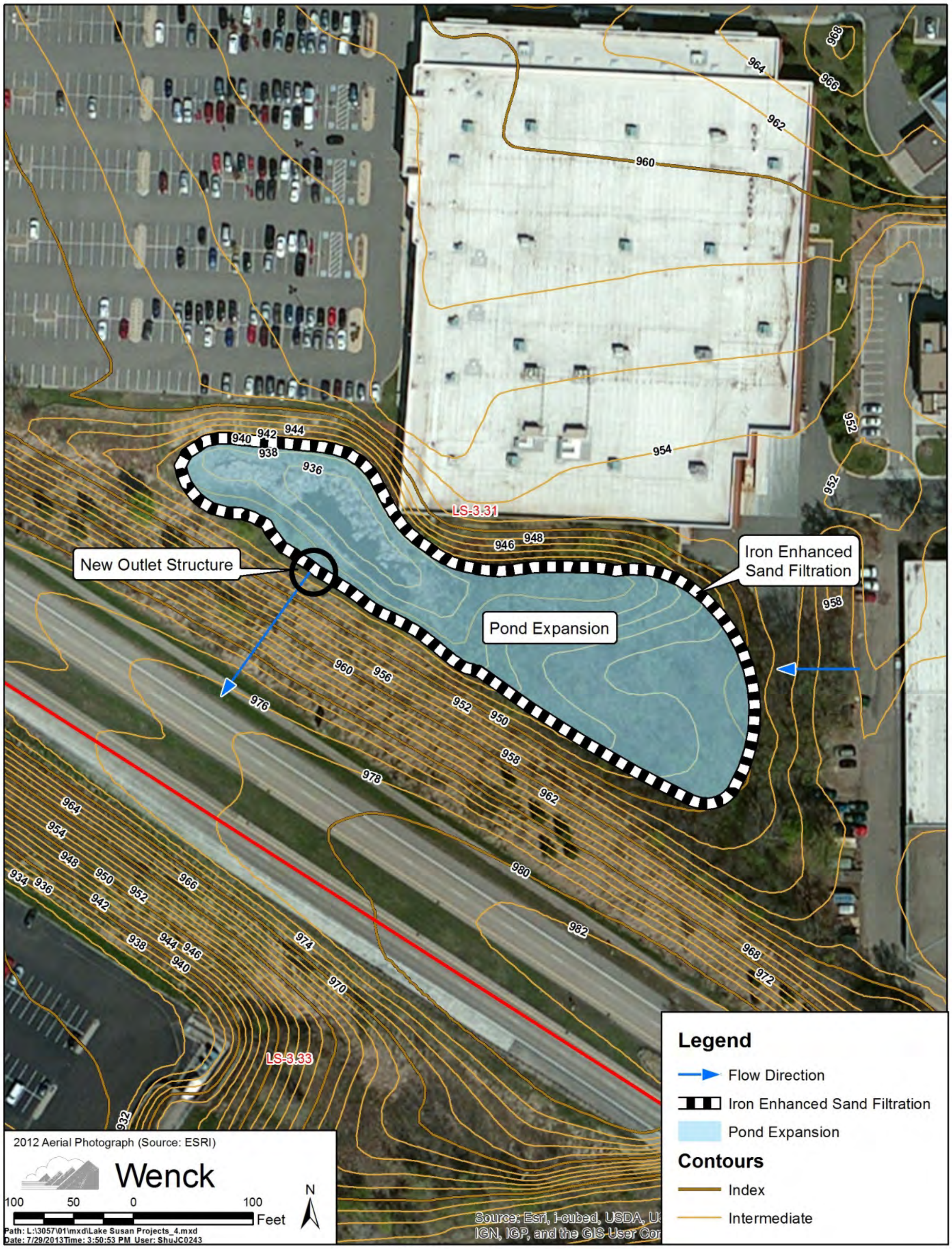


Figure 5-9. Project #5 – Target Pond Upgrade.

5.3.7 Summary

Projects identified for the near-term consist of both in-lake and watershed projects. Targeting of both of these large sources of TP to Lake Susan is critical for the long-term management of the lake. Projects were numbered based on an understanding of ease of implementation and efficiency of the projects. Table 5-7 presents a summary of the costs, TP reduction, and efficiency of each of the five near-term projects.

Table 5-7. Lake Susan Near-Term Project Summary.

Project	Name	Project Life Cycle Cost ($)	TP Reduction (lb/yr)	Efficiency ($/lb TP)
1	Alum Treatment - Lake Susan	$280,071	250	$37
2	Lake Susan Park Pond Enhancement	$89,507	31	$98
3	Lake Susan Hills West Park – Wetland Restoration	$251,553	67	$126
4	Lake Drive West Pond Enhancement	$25,421	5	$177
5	Target Pond Upgrade	$81,181	19	$142
TOTAL		**$727,733**	**372**	**$65**

5.4 COLLABORATION PROJECTS

Collaboration projects (Figure 5-10) were identified based on three criteria:

1. Existing Infrastructure Enhancements – which would provide additional benefit but do not have as high cost/benefit ratio
2. Site Retrofit – sites which require retrofitting on fully developed sites and would require private landowner coordination if/when the site would redevelop
3. Wetland Enhancement – potential locations which require further monitoring to confirm potential load reduction

Collaboration projects could progress faster if sites redevelop, funds become available to target certain areas in the watershed, or land use changes.

Figure 5-10. Collaborative Projects for Lake Susan.

5.4.1 Existing Infrastructure Enhancements

Several pond locations were identified as part of this study that were also identified as part of the SALSA Report (Table 5-8). These ponds were identified to have Minnesota Filters installed to improve their TP removal efficiency. A list of the ponds and proposed removal and costs are provided in the table below:

Table 5-8. Lake Susan – Collaboration Projects – Existing Infrastructure Enhancements.

Project	Pond	Location
E-1	3.63	NE of Park Place Rd - Adjacent to Riley Creek
E-2	3.72	N of Park Road Rd - Adjacent to Riley Creek
E-3	3.78	SE of Park Dr. and TH 5 – adjacent to Riley Creek
E-4	3.79	NE of 78th and Private drive
E-5	3.21	NW of Co. Rd 17 and TH 5
E-6	3.12	N of Kimberly Lane
E-7	2.9	W of Lake Susan Hills Dr.
E-8	2.3	SE of Lake Susan Hills Dr. and Powers Blvd.
E-9	3.44	N of Essex Rd.

5.4.2 Site Retrofits

Three subwatersheds were identified that are adjacent to Riley Creek which through retrofitting could limit potential delivery of TP to Lake Susan. Specific BMPs are not prescribed as it will be at the discretion of the landowner to decide on their preferred alternative. Table 5-9) of the potential stormwater BMP improvements that could be implemented are provided in the table below:

Table 5-9. Lake Susan – Collaboration Projects – Site Retrofits.

Project	Sub.	Description	Site BMPs	Typical Installation Cost[1]
S-1	3.93	Commercial Development adjacent to Park Ct.	Bioretention	$13.87/sq ft.
			Permeable Asphalt	$14.00/sq ft.
			Impervious Conversion	$20.04/sq ft.
			Wet Pond	$5.09/sq ft.
S-2	3.94	Teleplan Site – SE quadrant of Powers Blvd. and TH 5	Wet Pond	$5.09/sq ft.
			Permeable Asphalt	$14.00/sq ft.
			Impervious Conversion	$20.04/sq ft.
			Bioretention	$13.87/sq ft.
S-3	3.87 & 3.95	IWCO Site – SW quadrant of Park Rd and Powers Blvd.	Bioretention	$13.87/sq ft.
			Wet Pond	$5.09/sq ft.
			Permeable Asphalt	$14.00/sq ft.

[1] Carver County Soil and Water Conservation District Susan, Ann, Lucy Subwatershed: Stormwater Retrofit Assessment (SALSA), 2010

5.4.3 Wetland Restoration

Additional investigation should be done on the wetland located in subwatershed 3.14. The wetland appears to have been ditched and may be a source of phosphorus as was determined in Lake Susan Hills Park (Subwatershed 2.4 & 2.12). Monitoring in the future should be done to determine if this is a source of TP. If found as a source, implementation activities should be done to either treat water discharging from the wetland or look to have stormwater routed around the wetland.

5.5 MANAGEMENT STRATEGIES

5.5.1 Management Strategy #1 - Rules Implementation

The RPBCWD is currently undergoing the reinstatement of their rules. As part of the rule development the District should implement water quality goals that at a minimum have post project TP levels that meeting pre-project. Implementation of this strategy will ensure gains captured through other activities/projects in the watershed are maintained.

5.5.2 Management Strategy #2 - Stabilize Stream Corridors

Urban stream corridors experience degradation due to increased volumes and velocities associated with development. Limiting erosion/degradation of stream corridors reduces potential transport of TP to Lake Susan. Improvement of these corridors will also improve biotic integrity and further improves biological uptake of TP.

5.5.3 Management Strategy #3 - Shoreline Restoration

An evaluation of shoreline conditions will identify impacts from trail runoff, invasive vegetation, and other impacts that may reduce habitat quality. Impacted areas may be restored using bioengineering and native vegetation. Lake Susan has minimally developed and impacted shorelines, with only a few areas that appear to be impacted. While shoreline restoration provides minimal TP load reductions, it provides habitat, aesthetic, and shoreline stabilization benefits. A full shoreline restoration with native plantings can cost $30-50 per linear foot, depending on the width of the buffer.

5.5.4 Management Strategy #4 - Coordination with Public Entities

RPBCWD coordination with partner public agencies (City of Chanhassen, Carver County SWCD, Minnesota Department of Natural Resources, etc.) on ongoing activities within the watershed will allow for easier project implementation by leveraging partner resources along with ensure goals are aligned between the different agencies to protect Lake Susan.

An example is coordinating between the District and the City of Chanhassen on BMP implementation associated with road reconstruction projects. Coordination between the entities will help identify opportunities to identify BMPs along create opportunities for cost-sharing

5.5.5 Management Strategy #5 - Education and Outreach

Public information and education is a top priority of RPBCWD. It plays an essential role in protecting aquatic habitat and recreational values by increasing awareness about reducing pollutants at their sources through changes in behavior. Through the District's education and outreach program it can inform stakeholders of how they can make a difference improving the water quality of Lake Susan along with make cost share dollars available to implement projects.

An example project could be community rain gardens. Rain gardens help reduce stormwater phosphorus loading especially in undertreated neighborhoods. The cost of individual, residential rain gardens can range from $4,000 to $7,000, depending on size and whether labor is by the property owner or contractor. Based on soils, it was assumed each rain garden would need an under drain and that 10% of the residential runoff could be treated.

5.5.6 Management Strategy #6 - Aquatic Vegetation Management

The District has actively managed submerged aquatic vegetation in Lake Susan since the late 1980s. Active management has included contracted harvesting and chemical treatment both to prevent the overgrowth of aquatic weeds and to control curly-leaf pondweed control. Active management of submerged aquatic vegetation improves habitat and lake aesthetics.

Currently the District is working with the U of M to monitor the success of establishing native species in the lake (Knopik 2012, Appendix B). The continued effort to establish natives will create a healthier ecosystem for the lake.

Vegetation surveys could be included with aquatic vegetation management activities to track the long term effects of the management activities on the plant community. These data will also help identify key management species to refine management practices. A simple point intercept method every five years provides a long term record for vegetation diversity and abundance.

5.5.7 Management Strategy #7 - Fisheries Management

The University of Minnesota has been actively involved in management of the fisheries on Lake Susan (Sorenson 2013-Appendix A). Through the removal of carp and aeration of Rice Lake Marsh panfish populations have begun to rebound effectively manage carp populations on the lake. However if the District desires it may partner with the Minnesota DNR to develop stocking plans to improve the balance in the fisheries.

5.5.8 Management Strategy #8 – Monitoring

5.5.8.1 Water Quality Monitoring

RPBCWD monitors Lake Susan for water quality, including TP, chlorophyll-*a* and Secchi depth, as well as field parameters such as dissolved oxygen and temperature. This monitoring will continue in the future.

5.5.8.2 Aquatic Vegetation Monitoring

RPBCWD should continue to coordinate with the U of M and DNR to address aquatic vegetation species diversity and abundance to ensure efforts to establish native species is successful.

5.5.8.3 Fish Monitoring

Regular monitoring of the fish community by the University of Minnesota and/or Minnesota DNR will continue to provide information to evaluate any changes that may need to be addressed. Changes that need to be monitored include fishery balance, rough fish, especially common carp, and maintaining their low biomass numbers.

5.6 IMPLEMENTATION PLAN SUMMARY AND COSTS

5.6.1 Implementation Projects

A number of capital projects were identified to reduce TP loading to Lake Susan (Table 5-10). Projects also were assessed by estimating costs per pound TP removal over a 30-year period. These cost estimates provide comparisons among projects; however, there are other factors that may make a project attractive beyond just TP removal.

If all of the projects for Lake Susan were implemented, the total life cycle cost would be about $727,700, with a potential TP load reduction of 372 pounds annually. In total, these projects would exceed the identified reduction goal of 185 pounds annually. The most cost effective projects for Lake Susan are identified as “Near-Term” projects and include the expansion and installation of a Minnesota Filter on the Lake Susan Park Pond, Lake Drive West Pond, and Target Pond. Additionally alum treatments of Lake Susan along with an enhancement of the Lake Susan Hills Park wetland were identified as the most cost effective solutions.

Table 5-10. Lake Susan Near-Term Project Summary.

Project	Name	Project Life Cycle Cost ($)	TP Reduction (lb/yr)	Efficiency ($/lb TP)
1	Alum Treatment - Lake Susan	$280,071	250	$37
2	Lake Susan Park Pond Enhancement	$89,507	31	$98
3	Lake Susan Hills West Park – Wetland Restoration	$251,553	67	$126
4	Lake Drive West Pond Enhancement	$25,421	5	$177
5	Target Pond Upgrade	$81,181	19	$142
TOTAL		**$727,733**	**372**	**$65**

Further, sites identified as "Collaboration Projects" could potentially be designed for additional removals. The projects were identified as pond enhancements, site retrofits and wetland enhancements (Table 5-11).

Table 5-11. Collaboration Projects for Lake Susan.

Existing Infrastructure Enhancements		
Project	**Pond**	**Location**
E-1	3.63	NE of Park Place Rd - Adjacent to Riley Creek
E-2	3.72	N of Park Road Rd - Adjacent to Riley Creek
E-3	3.78	SE of Park Dr. and TH 5 – adjacent to Riley Creek
E-4	3.79	NE of 78th and Private drive
E-5	3.21	NW of Co. Rd 17 and TH 5
E-6	3.12	N of Kimberly Lane
E-7	2.9	W of Lake Susan Hills Dr.
E-8	2.3	SE of Lake Susan Hills Dr. and Powers Blvd.
E-9	3.44	N of Essex Rd.
Site Retrofits		
Project	**Sub.**	**Description**
S-1	3.93	Commercial Development adjacent to Park Ct.
S-2	3.94	Teleplan Site – SE quadrant of Powers Blvd. and TH 5
S-3	3.87 & 3.95	IWCO Site – SW quadrant of Park Rd and Powers Blvd.
Wetland Enhancements		
Project	**Sub.**	**Description**
W-1	3.14	Wetland located in NW quadrant of TH 5 and Powers Blvd.

5.6.2 Management Strategies

Management strategies identified should also be implemented to preserve gains achieved with the implementation of the identified projects.

1. Rules Implementation
2. Stabilize Stream Corridors
3. Shoreline Restoration
4. Coordination with Public Entities
5. Education and Outreach
6. Aquatic Vegetation Management
7. Fisheries Management
8. Monitoring
    a. Water Quality
    b. Aquatic Vegetation
    c. Fisheries

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7.0 Glossary

Aeration Any active or passive process by which intimate contact between air and liquid is assured, generally by spraying liquid in the air, bubbling air through water, or mechanical agitation of the liquid to promote surface absorption of air.

Algae Microscopic organisms/aquatic plants that use sunlight as an energy source (e.g., diatoms, kelp, seaweed). One-celled (phytoplankton) or multicellular plants either suspended in water (plankton) or attached to rocks and other substrates (periphyton). Their abundance, as measured by the amount of chlorophyll-*a* (green pigment) in an open water sample, is commonly used to classify the trophic status of a lake.

Algal Bloom Population explosion of algae in surface waters due to an increase in plant nutrients such as nitrates and phosphates.

Alum Common name for commercial-grade Aluminum Sulfate. Its chemical formula is generally denoted by $Al_2(SO^4)_3$ X $12H_2O$. Most often used in lakes as a way to precipitate a floc that settles through the water column, removing fine particles to the sediment and building up a barrier layer to contain soluble phosphorus in the bottom sediments.

Anoxic Without oxygen.

Aquatic Organisms that live in or frequent water.

Aquifer A saturated permeable geologic unit that can transmit significant quantities of water.

Biomass The total quantity of plants and animals in a lake. Measured as organisms or dry matter per cubic meter, biomass indicates the degree of a lake system's eutrophication or productivity.

Chlorophyll-*a* Green pigment present in all plant life and necessary for photosynthesis. The amount present in lake water depends on the amount of algae and is therefore used as a common indicator of water quality.

Clarity The transparency of a water column. Measured with a Secchi disc.

Concentration Expresses the amount of a chemical dissolved in water. The most common units are milligrams per liter (mg/L) and micrograms per liter (µg/L). One milligram per liter is equal to one part per million (ppm). To convert micrograms per liter (µg/1) to milligrams per liter (mg/1), divide by 1000 (e.g. 30 µg/l = 0.03 mg/1). To convert milligrams per liter (mg/1) to micrograms per liter (µg/1), multiply by 1000 (e.g. 0.5 mg/l = 500 µg/1).

Daphnia Small crustacean (zooplankton) found in lakes. Prey for many fish species.

Dissolved Oxygen (DO) The amount of free oxygen absorbed by the water and available to aquatic organisms for respiration; amount of oxygen dissolved in a certain amount of water at a particular temperature and pressure, often expressed as a concentration in parts of oxygen per million parts of water.

Ecosystem A system formed by the interaction of a community of organisms with each other and with the chemical and physical factors making up their environment.

Erosion The wearing away and removal of materials of the earth's crust by natural means.

Eutrophic Pertaining to a lake or other body of water characterized by large nutrient concentrations such as nitrogen and phosphorous and resulting high productivity. Such waters are often shallow, with algal blooms and periods of oxygen deficiency. Lakes can be classified as *oligotrophic* (nutrient poor), *mesotrophic* (moderately productive), *eutrophic* (very productive and fertile), or *hypereutrophic* (extremely productive and fertile).

Eutrophication The process by which lakes and streams are enriched by nutrients, and the resulting increase in plant and algae growth. This process includes physical, chemical, and biological changes that take place after a lake receives inputs for plant nutrients – mostly nitrates and phosphates – from natural erosion and runoff from the surrounding land basin. *Cultural eutrophication* is the accelerated eutrophication that occurs as a result of human activities in the watershed that increase nutrient loads in runoff water that drains into lakes

Filamentous Algae Algae that forms filaments or mats attached to sediment, weeds, piers, etc.

Food Chain The transfer of food energy from plants through herbivores to carnivores. An example: insect-fish-bear or the sequence of algae being eaten by small aquatic animals (zooplankton) which in turn are eaten by small fish which are then eaten by larger fish and eventually by people or predators.

Groundwater Water contained in or flowing through the ground. Amounts and flows of groundwater depend on the permeability, size, and hydraulic gradient of the aquifer.

Habitat The place where an organism lives that provides an organism's needs for water, food, and shelter. It includes all living and non-living components with which the organism interacts.

Hydrologic Referring to or involving the distribution, uses, or conservation of water on the Earth's surface and in the atmosphere. The hydrologic cycle is the process by which the Earth's water is recycled. Atmospheric water vapor condenses into the liquid or solid form and falls as precipitation to the ground surface. This water moves along or into the ground surface and finally returns to the atmosphere through transpiration and evaporation.

Hydrology The study of water, especially its natural occurrence, characteristics, control and conservation.

Impervious A term denoting the resistance to penetration by water or plant roots; incapable of being penetrated by water; non-porous.

Invertebrates Animals without an internal skeletal structure such as insects, mollusks, and crayfish.

Limiting Nutrient or Factor The nutrient or condition in shortest supply relative to plant growth requirements. Plants will grow until stopped by this limitation; for example, phosphorus in summer, temperature or light in fall or winter.

Littoral The near-shore shallow water zone of a lake, where aquatic plants grow.

Nitrate (NO3-) An inorganic form of nitrogen important for plant growth. Nitrogen is in this stable form when oxygen is present. Nitrate often contaminates groundwater when water originates from manure pits, fertilized fields, lawns or septic systems.

Non-native A species of plant or animal that has been introduced.

Nutrients Elements or substances such as nitrogen and phosphorus that are necessary for plant growth. Large amounts of these substances can become a nuisance by promoting excessive aquatic plant growth.

Organic Matter Elements or material containing carbon, a basic component of all living matter.

Permeability The ability of a substance, such as rock or soil, to allow a liquid to pass or soak through it.

Phosphorus Key nutrient influencing plant growth in freshwater lakes. Soluble reactive phosphorus is the amount of phosphorus in solution that is available to plants. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particulate form.

Photosynthesis The process by which green plants convert carbon dioxide (CO2) dissolved in water to sugar and oxygen using sunlight for energy. Photosynthesis is essential in producing a lake's food base, and is an important source of oxygen for many lakes.

Phytoplankton Microscopic floating plants, mainly algae, that live suspended in bodies of water and that drift about because they cannot move by themselves or because they are too small or too weak to swim effectively against a current.

Plankton Small plant organisms (phytoplankton and nanoplankton) and animal organisms (zooplankton) that float or swim weakly though the water.

Precipitation Rain, snow, hail, or sleet falling to the ground.

Predator An animal that hunts and kills other animals for food.

Prey An animal that is hunted or killed by another for food.

Runoff Water that flows over the surface of the land because the ground surface is impermeable or unable to absorb the water.

Secchi Disc An 8-inch diameter plate with alternating quadrants painted black and white that is used to measure water clarity (light penetration). The disc is lowered into water until it disappears from view. It is then raised until just visible. An average of the two depths, taken from the shaded side of the boat, is recorded as the Secchi disc reading.

Sedimentation The removal, transport, and deposition of detached soil particles by flowing water or wind. Accumulated organic and inorganic matter on the lake bottom. Sediment includes decaying algae and weeds, marl, and soil and organic matter eroded from the lake's watershed. The sedimentation rate of lakes or impoundments can be estimated by measuring the amount of suspended solids (particulate matter) of inflowing streams.

Shorelines With banks, those areas along streams, lakes, ponds, rivers, wetlands, and estuaries where water meets land. The topography of shorelines and banks can range from very steep to very gradual.

Soluble Capable of being dissolved.

Species A group of animals or plants that share similar characteristics such as can reproduce.

Stormwater Runoff Water falling as rain during a storm and entering a surface water body like a stream by flowing over the land. Stormwater runoff picks up heat and pollutants from developed surfaces such as parking lots.

Submerged Aquatic Vegetation (SAV) Aquatic plants larger than algae with all photosynthetic parts below the surface of the water. Many are rooted, but some are free-floating.

Subwatershed A smaller geographic section of a larger watershed unit with a drainage area of between 2 and 15 square miles and whose boundaries include all the land area draining to a point where two second order streams combine to form a third order stream.

Water Table The top or “surface” of groundwater. The water table level changes in response to amounts of groundwater recharge flowing in, and amounts of water leaving the ground through seeps, springs, and wells.

Watershed The geographic region within which water drains into a particular river, stream, or body of water.

Wetland Transitional between terrestrial and aquatic ecosystems, wetlands are places where the water table is at or near the surface and where hydric soils and hydrophytic (water-loving) vegetation predominate.

Zooplankton Microscopic or barely visible animals that eat algae. These suspended plankton are an important component of the lake food chain and ecosystem. For many fish, they are the primary source of food.