

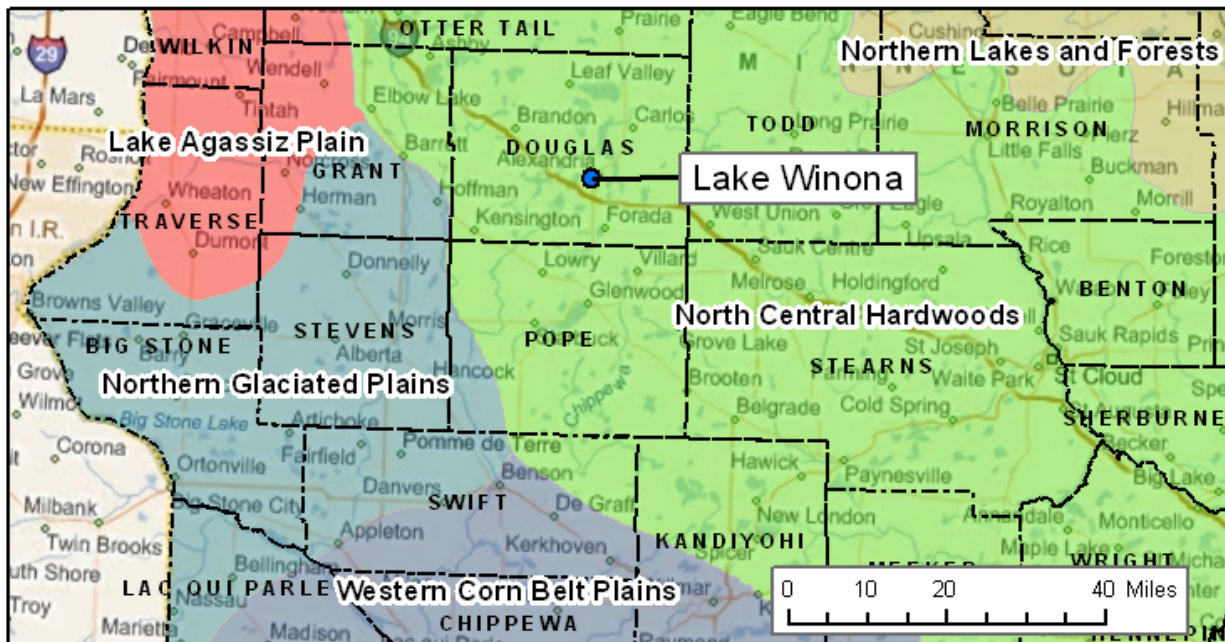
DRAFT 5.03.2011

Lake Winona site-specific nutrient criteria development



Lake Winona is located in the City of Alexandria, Minn., in Douglas County. Douglas County is located in the North Central Hardwoods Forests (NCHF) ecoregion. The Northern Glaciated Plains (NGP) ecoregion lies to the southwest. Lake Winona is located slightly southeast of the geographic center of Douglas County (Figure 1). Lake Winona was listed in 2002 as a nutrient-impaired water body (Section 303(d) of the federal Clean Water Act). That determination used ecoregion-based numeric translators to interpret the existing narrative standard (Table 1). Lake Winona’s total phosphorus (TP), chlorophyll-a (Chl-a) and Secchi values all exceeded the applicable translator values for the CHF ecoregion (Table 1) and as a result the lake was included on Minnesota’s 2002 impaired waters list.

Figure 1. Lake Winona location and ecoregions



Nutrients continue to exist at high concentrations in the lake. For example, from 2004 to 2009 summer total phosphorus concentrations in Lake Winona ranged over the summer months from 63 parts per billion (ppb or $\mu\text{g/l}$) to 298 ppb, compared to the ecoregion standard of 60 ppb or less that was adopted in 2008.

Table 1. Trophic Status Thresholds for Determination of Use Support for Lakes.

Thresholds used for 303(d) assessment prior to promulgation of numeric lake eutrophication standards.

Ecoregion	TP ppb	Chl ppb	Secchi m	TP Range ppb	TP ppb	Chl ppb	Secchi m
305(b):	Full Support			Partial Support to Potential Non-Support			
303(d):	Not Listed			Review	Listed		
NLF	< 30	<10	>=1.6	30 – 35	> 35	> 12	< 1.4
NCHF	< 40	< 15	>=1.2	40 - 45	> 45	> 18	< 1.1
WCBP & NGP	< 70	< 24	> 1.0	70 - 90	> 90	> 32	< 0.7
Winona 5-year Average (2000-2004)				150 - 313	227	102	0.45

Lake Winona morphometry and geology

Lake Winona is 185 acres in size and has a mean depth of 4.5 feet. The lake is widest at the southern end, and extends in a linear fashion 1.6 miles from southwest to northeast (Figure 2). It is narrowest and shallowest at its midpoint, where it is only 300 feet from shoreline to shoreline and approximately 3-feet deep. This constriction serves to divide the lake into two “basins,” referred to as North and South Winona. While it is a shallow lake, overall the lake bed along the shoreline has a moderate slope, so the lake depth reaches three plus feet a relatively short distance from the shoreline. Only 42 acres of the lake is three feet or less. The northern 80 percent of the lake basin lies in surficial outwash, while the southwestern 20 percent of the basin lies in undifferentiated glacial drift (Lindholm et al., 1972). Data from WSN (1994) indicate the lake to be a groundwater flow through lake, with the groundwater flow direction being from the southeast to northwest. Sediment core sampling during the MPCA-sponsored Phase 2 TMDL data collection program found sand under a 2- to 8-inch thick layer of fine, predominantly inorganic sediments at the southern and northern ends of the lake. However, a 1.9 meter long sediment core taken in the deepest part of the lake (near the north end of the mid lake narrows) for the purposes of identifying historical water quality and biological change in Lake Winona did not encounter sand but was rather organic material (Edlund et al., 2009).

Lake Winona is a No Wake lake, boating speeds being restricted to five miles per hour throughout the lake, with a public boat landing at the southern end. Local residents use the lake for pleasure boating. A retirement home on the lake maintains a pontoon and dock to take residents on pleasure cruises during summer months. Indications are that fishing activity is sporadic but does occur by lake residents. Jet Ski use has been observed on numerous occasions. Swimming is rare to nonexistent due to poor water quality.

The City of Alexandria (City) is present on the east and north sides of the lake, with the Alexandria airport and suburban lands in LaGrand Township on the south and west. Urban land uses dominate the watershed. The total watershed area of Lake Winona is 1,455 acres, resulting in a watershed to lake, basin ratio of approximately 8: 1 (Figure 2). The Alexandria Lakes Area Sanitary District (ALASD) wastewater treatment plant (WWTP) discharges into the south end of Lake Winona.

Water discharges northward from Lake Winona through culverts under Willow Drive, 3rd Avenue West, and Agnes Boulevard Northwest to Lake Agnes, which is interconnected with Lake Henry. From the Lake Henry outlet, water discharges through a series of wetlands, channels and pipes to Lake Le Homme Dieu, which connects to Lake Carlos and ultimately the Long Prairie River, a tributary of the Mississippi River.

Considerable effort has been expended to characterize Lake Winona and to identify means for improving the water quality of the lake. Important contributions to this body of work include the Clean Lakes Project, which culminated in the 1994 diagnostic study and implementation plan for Lake Winona (WSN, 1994), ongoing water quality sampling by ALASD, and the MPCA- sponsored water quality reviews and data collection program associated with the Lake Winona TMDL project (Earth Tech, 2008; AECOM, November 2009). More recently, the MPCA TMDL program provided water quality modeling of the hydrologic and nutrient budgets of Lake Winona (AECOM, November 2009). This section of the report summarizes the characteristics of Lake Winona and presents water and nutrient budget model results.

Management of Lake Winona at the local level involves Douglas County, the lead sponsor of the 1990 Agnes-Henry-Winona Clean Lakes Project (Clean Lakes Project). It has also involved the City of Alexandria, LaGrand Township, and ALASD. Lake associations provide oversight of management of several nearby lakes. While the Clean Lakes Project report had many good recommendations, it appears few were implemented, or that any one local agency had lead oversight authority for management of Lake Winona. ALASD, however, completed all the Clean Lake Project recommendations related to the Publicly Owned Treatment Works (POTW).

The Lake Winona TMDL Project includes public participation through a local stakeholder advisory committee established in 2006 by the MPCA, with 12 meetings held to date. Members of the committee are comprised of state and local agencies, ALASD representatives and local citizens interested in the project. The proposed site-specific standard was presented to the stakeholders and the majority of members agreed that it is appropriate for Lake Winona.

It is expected that the restoration of Lake Winona will be challenging and take a relatively long time. There are, however, examples of shallow lakes with rough fish populations that have been successfully restored (Helsel and Zagar, 2002). Restoration of several shallow lakes in the Twin Cities metropolitan area is underway now and will likely provide experience to guide efforts involving Lake Winona. One of these lakes, Kohlman Lake (Ramsey County), has many similarities to Lake Winona, including that it is an urban lake with a significant carp population. A flexible approach will be needed for Lake Winona to allow for changes in management strategies as new information is obtained.

Pollutant of concern

Total phosphorus has been identified as the nutrient that management practices will focus on for this TMDL. As phosphorus concentrations increase in a lake, so will primary production. Increases in primary production are indicated by increases in chlorophyll-a. If phosphorus concentrations increase enough, shallow lakes can change from being macrophyte dominated to algae dominated. Both an increase in chlorophyll-a concentration, and a switch to an algae-dominated lake will reduce the transparency of a lake, as measured by Secchi depth. Lake Winona has elevated phosphorus and chlorophyll-a concentrations, and very low Secchi transparency, with the lake now in an algae-dominated stable state. Phosphorus is often referred to as a causal factor, with chlorophyll-a and Secchi depth considered as the response factors. The Lake Winona TMDL establishes the reductions in TP needed in order for the response variables of chlorophyll-a and Secchi to meet the eutrophication standards for shallow lakes in the North Central Hardwoods Forest ecoregion, which provides the basis for developing the final TMDL allocations.

Point sources

Point sources are defined as discrete wastewater or stormwater discharge points that have a permit allowing the discharge through the NPDES permit program. Point sources in the Lake Winona watershed are the ALASD wastewater discharge, City of Alexandria stormwater outfalls, construction sites having one or more acres of disturbed land surface, and industries within 10 categories of Standard Industrial Codes.

Non-point sources

In the Lake Winona watershed the non-point sources of nutrients include LaGrand Township stormwater outfalls, atmospheric deposition and internal loading.

Applicable water quality standards and beneficial uses of Lake Winona

State of Minnesota law, under the jurisdiction of the MPCA, uses a classification system of beneficial uses of waters of the state, along with narrative and numeric water quality standards and non-degradation provisions to protect beneficial uses, including the physical, chemical, and biological integrity of waters of the state. Beneficial uses of Lake Winona are Class 2B, 3B, 4A, 4B, 5, and 6. Class 2B surface waters shall have water quality that permits the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life, and their habitats. In addition, Class 2B waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be used. It is the Class 2B beneficial uses of Lake Winona in particular that are not being met because of the nutrient impairment.

Minnesota water quality standards

Narrative and numeric water quality standards that protect specific beneficial uses of Lake Winona are as follows: Lake Winona is defined as a shallow lake (Minnesota Rules 7050.0150(Subp. 4.). "Shallow lake" means an enclosed basin filled or partially filled with standing fresh water with a maximum depth of 15 feet or less or with 80 percent or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (the littoral zone). Lake Winona meets both criteria of this definition, having a maximum depth of 9 feet and being greater than 80 percent littoral zone.

Lake Winona was listed as impaired in 2002 because it exceeded numeric translators (Table 1) used to interpret the narrative standard that refers to "excess algae." Since then, numeric eutrophication standards for lakes were adopted by the State of Minnesota in 2007 (Minnesota Rules 7050.0220.3) and approved by the U.S. EPA in 2008. These numeric standards have since become the basis for listing and de-listing nutrient-impaired lakes. The water quality of Lake Winona does not meet the 2008 eutrophication standards either for total phosphorus (the causal factor) or for chlorophyll-a and Secchi depth (the response factors). The eutrophication standards applicable to Lake Winona are provided in **bold** in Table 2.

Table 2. Minnesota lake eutrophication water quality standards

CHF ecoregion shallow lake standards are appropriate for evaluating Lake Winona

Ecoregion – lake type (use classification¹)	TP (ppb)	Chl-a (ppb)	Secchi (meters)
NLF – Designated Lake trout (Class 2A)	12	3	4.8
NLF – Designated Stream trout (Class 2B)	20	6	2.5
NLF – Aquatic Rec. Use (Class 2B)	30	9	2.0
CHF – Designated Stream trout (Class 2B)	20	6	2.5
CHF – Aquatic Rec. Use – Deep (Class 2B)	40	14	1.4
CHF – Aquatic Rec. Use – Shallow (Class 2B)	60	20	1.0
WCP & NGP – Aquatic Rec. Use – Deep (Class 2B)	65	22	0.9
WCP & NGP – Aquatic Rec. Use – Shallow (Class 2B)	90	30	0.7
Lake Winona (2000-2004 five-year average)	227	102	0.45

¹ Aquatic life and recreation use class as defined in Minn. R. 7050.0140, subp. 3 and Minn. R. 7050.0222 (Minnesota Rules Chapter 7050 2007). Class 2A is used for waters supporting a cold water fishery and refers specifically to lakes that support natural populations of lake trout. Stream trout refers to all other designated (managed) trout lakes. Class 2B is designation for waters supporting cool or warm water fishery and is the default classification for the majority of Minnesota’s lakes.

These criteria serve as a basis for delisting as well. Minnesota Rule Chapter 7050.0222 Subp. 4A. B. states eutrophication standards are compared to data averaged over the summer season (June through September). Exceedance of the total phosphorus and either the chlorophyll-a or Secchi disk standard is required to indicate a polluted condition (see Table 2 NCHF for applicable criteria). In turn, the TMDL uses these endpoints as a basis for developing allocations.

The focus of the eutrophication criteria is attaining the water quality standards for the response variables: Chl-a and Secchi. As written in the water quality standards, a lake would be deemed to meet standards if both response variables are met. This consideration may be most applicable in shallow lakes that can shift from an algal-dominated state (where Chl-a and Secchi criteria are exceeded) to a macrophyte-dominated state (where Chl-a and Secchi criteria are met). “Shifting” shallow lakes often requires reduction in P loading (external and internal) and addressing imbalances in the ecology of the lake that serve to keep the lake in an algal-dominated condition. The precise TP concentration where the lake “shifts” from one state to the other may or may not correspond to the TP criteria. As such, Chl-a and Secchi criteria are the primary emphasis for establishing a TMDL and modeling is used to determine a level of P that results in Chl-a and Secchi meeting these criteria. This level becomes a “site-specific” TP standard for the lake. As with any TMDL, the resulting TMDL would include defined wasteload and load allocations; however, the allocations would be based on what is needed to meet the Chl-a and Secchi criteria and the site-specific TP criteria.

Lake Winona phosphorus reconstruction

Down-core total phosphorus reconstructions conducted by Edlund et.al. (2009) show that Lake Winona is currently hypereutrophic (~120 ppb TP) with TP levels far in excess of pre-Euro-American TP concentrations. This increase in TP has come in steps, with the first increase occurring around WWII. The pre-war and pre-settlement TP reconstructions (1802-1933) ranged from 24-40 ppb TP. From 1947-1976, diatom-inferred TP in Lake Winona increased to 54-60 ppb before rapidly increasing in the last three decades to hypereutrophic levels of around 120 ppb in the two most recent (geologically) sediment core samples analyzed (1994, 2007). This implies that the NCHF shallow lakes eutrophication standard of 60 ppb is in the range of historically observed concentrations for Lake Winona.

Water balance

Hydrologic modifications

One of the impacts of both historical and recent development in the watershed is the natural hydrology of Lake Winona has been significantly altered by a variety of human actions. Construction of the local road network disconnected several areas from discharging into the lake. For instance, Winona Drive West prevents a 366-acre area west of Lake Winona from discharging to the lake. Another hydrologic alteration to the lake has occurred via the construction of storm sewers by the City to provide drainage into the lake. Storm sewered watersheds include areas that naturally are not in the Lake Winona watershed, such as some areas of the City east of State Highway 29. Runoff entering Lake Winona from storm sewered areas will exhibit stormwater discharge characteristics typical of urbanization. For instance, there will be peak flow rates and pollutant concentrations greater than during pre-development conditions. Furthermore, impervious areas and the hydraulically efficient storm sewer system reduce the percentage of rainfall recharging groundwater, resulting in an increase in runoff volume. A final hydrologic modification to Lake Winona, the addition of the ALASD wastewater discharge to the lake, has significantly increased the volume of water entering and flowing through the lake versus natural conditions.

Water balance results

The water balance for Lake Winona was tabulated using the computer model BATHTUB (Walker, 2004) for each year from 2000 to 2008. Runoff volumes were computed with the computer model WinSLAMM and input into BATHTUB. ALASD annual discharge volumes were obtained from NPDES permit discharge monitoring reports and input to BATHTUB. Precipitation and evaporation data used for the water balance for direct precipitation into and evaporation out of Lake Winona were obtained from the climate station at the Alexandria Airport. An important feature regarding the watershed is the dominance of urban land uses (near 100 percent). Soils throughout the Lake Winona watershed are sandy, which naturally infiltrate more rain and produce less runoff than silt or clay dominated soils.

Five subwatersheds (Figure 2) were used for the runoff modeling, with three of the subwatersheds being within City boundaries, and two representing areas within LaGrand

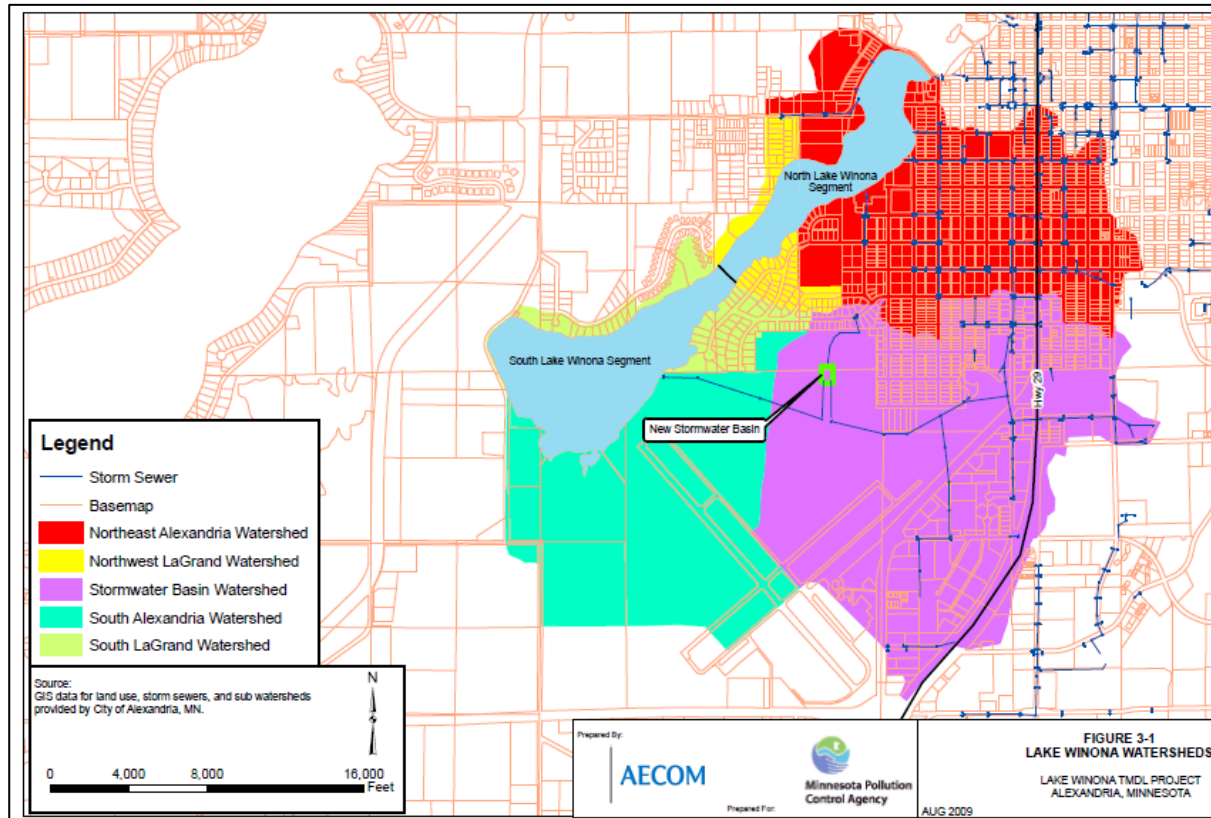
Township. Information on City storm sewer systems and a field reconnaissance of the watershed were used to identify and characterize existing stormwater best management practices. The WinSLAMM input files were implemented using a continuous simulation approach to obtain annual runoff volumes for the 2000-2009 period. Water balance results are provided in Table 3. The magnitude of runoff and direct precipitation entering the lake is near equal, as is the balance between precipitation and evaporation.

Table 3. Lake Winona annual water balance: 2000-2008

Year	Inflow from Source (hm ³ /yr) ¹			Evaporation (hm ³ /yr)	Total (hm ³ /yr)
	ALASD ²	Runoff	Precipitation		
2000	3.0	0.7	1.1	-1.1	3.7
2001	3.5	1.1	1.0	-1.1	4.5
2002	3.4	1.4	1.0	-1.1	4.7
2003	3.7	0.8	1.2	-1.2	4.5
2004	3.5	0.8	1.0	-1.0	4.3
2005	3.8	1.5	1.7	-1.0	6.0
2006	3.6	0.7	0.9	-1.2	4.0
2007	3.6	1.1	0.9	-1.2	4.4
2008	3.5	0.9	1.2	-1.1	4.5
Average	3.5	1.0	1.1	-1.1	4.5

¹ 1 hm³/yr = 0.724 million gallons per day
² ALASD wastewater discharge to Lake Winona (Source: NPDES wastewater permit Discharge Monitoring Reports)
Source: AECOM, October 2010, "Revised Lake Winona TMDL"

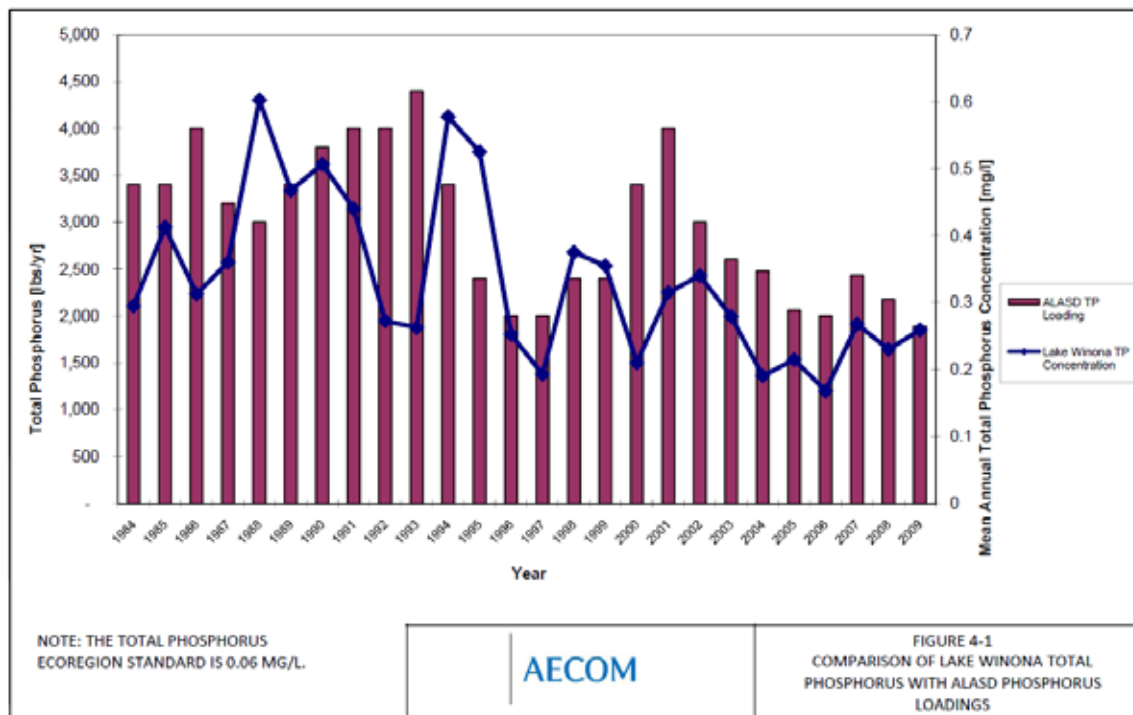
Figure 2. Lake Winona watershed



Existing loads

Existing phosphorus loads, both external and internal, were examined to determine the feasibility of potential restoration efforts needed to meet water quality goals. The data indicate that existing phosphorus loads fluctuate from year to year and were almost five times higher than what Lake Winona can assimilate and still meet eutrophication standards (Figure 3). The analysis showed that Lake Winona presently exists in an algal-dominated turbid steady-state condition, and that a reverse switch to a macrophyte-dominated clear water condition is needed for the eutrophication standards to be met. Given the magnitude of reductions needed and the uncertainty associated with modeling responses to ecological changes in the lake, an adaptive management approach is likely needed to meet TMDL goals. This will require continued data collection and periodic evaluation to assess progress and determine next steps in the process.

Figure 3. ALASD TP loading rates and corresponding Lake Winona in-lake TP



Load reductions needed

The primary sources of phosphorus to Lake Winona are phosphorus in lake- bottom sediments, stormwater runoff from the city and other surrounding areas, and the local wastewater treatment facility, Alexandria Lakes Area Sanitary District (ALASD).

Extensive TMDL modeling for Lake Winona indicates that both chlorophyll-a and Secchi depth will be met at an in-lake TP level of approximately 75 ppb (Table 4). The modeling assumes that in-lake management options such as carp removal and possibly consolidation of sediment and/or phosphorus precipitation will be part of an adaptive management approach. The TMDL uses the response variables chlorophyll-a and Secchi depth to determine TMDL allocations. Ecoregion-based standards for chlorophyll-a and Secchi depth were used to determine predicted total phosphorus load reduction ranges needed to restore the lake and remove it from the 303(d) list.

Through the stakeholders process, it was decided the TMDL would follow an adaptive management process to reduce total phosphorus loading from ALASD and the city stormwater discharge to a level where chlorophyll-a and Secchi depth standards are met. Point source TP reduction could then be maintained at the level that keeps chlorophyll-a and Secchi in compliance with standards.

Table 4. Lake Winona BATHUB model results

Predicts in-lake TP, Chl-a and Secchi response to reductions in P loading from ALASD given a range of discharge rates. Reductions based on 2000-2004 5-year average model, 90% internal load reduction

Percent Reduction ¹	ALASD Flow [MGD]	ALASD Inflow Phosphorus Conc. [ppb]	South Winona			North Winona		
			Total P [ppb]	Chl-a [ppb]	Secchi Depth[m]	Total P [ppb]	Chl-a [ppb]	Secchi Depth[m]
Target TP = 60 ppb								
80	2.5	82.8	60.3	14.1	1.23	57.7	11.7	1.39
81		78.7	58.3	13.4	1.27	55.8	11.2	1.43
80.2		81.0	59.9	14.0	1.23	57.3	11.6	1.40
75	3.4	103.5	71.5	18.0	1.04	68.1	14.9	1.18
80		82.8	60.7	14.3	1.22	58.2	11.9	1.37
80.5		80.7	59.6	13.9	1.24	57.2	11.6	1.40
80.4		81.1	59.9	14.0	1.23	57.4	11.6	1.40
80.4	4.7	81.1	60.5	14.2	1.22	58.2	11.9	1.37
80.6		80.3	60.0	14.0	1.23	57.8	11.8	1.38
Target Secchi = 1.0; Chlorophyll-a <=20 ppb								
75	2.5	103.5	70.5	17.7	1.06	67.0	14.6	1.20
70		124.2	80.1	21.3	0.93	75.7	17.4	1.07
72.8		112.6	74.6	19.2	1.00	70.8	15.8	1.14
72.8	3.4	112.6	75.9	19.7	0.98	72.2	16.2	1.12
73		111.8	75.4	19.5	0.99	71.8	16.1	1.12
73.2		111.0	75.0	19.4	0.99	71.8	16.1	1.13
73.3		110.5	74.8	19.3	1.00	71.3	15.9	1.13
73.6	4.7	109.3	75.7	19.6	0.99	72.4	16.3	1.11
74		107.6	74.8	19.3	1.00	71.6	16.0	1.13

Source: AECOM, 2011

Proposed site-specific standard

Minnesota lake eutrophication standards allow for establishment of site-specific criteria. An approach for site-specific criteria development for Lake Winona has been presented. Given its very small watershed, relative shallowness, short water residence time, predominance of point source inputs and proximity within the City of Alexandria, the focus for site-specific criteria for Winona should be on reducing the frequency and severity of nuisance algal blooms and improving transparency such that rooted macrophytes can become established. Details on the approach are included in the draft TMDL. Following is a summary of pertinent criteria setting considerations and draft site-specific criteria:

- TP = 75 ppb as a summer-mean as measured at the established South Winona sampling site.
- Viable chlorophyll-a < 20 ppb as a summer-mean as measured in South Winona. This should keep maximum chlorophyll-a below 60 ppb and reduce frequency of 30 ppb (severe nuisance blooms) from about 55-60 percent of the summer to about 30 percent of the summer. This value is also equivalent to the current chlorophyll-a criterion for shallow NCHF lakes.
- Secchi as a summer-mean of 1.0 m or greater as measured in South Winona. This value is equivalent to current Secchi criterion for shallow NCHF lakes. It also corresponds with the proposed TP and chlorophyll-a criteria based on extensive Lake Winona TMDL modeling.
- Meeting these criteria in South Winona will be fully protective of North Winona as well since it (North) exhibits slightly lower TP and Chlorophyll-a as compared to South Winona as a result of in-lake “processing” as water moves from south to north in the lake. These criteria will also be protective of the downstream lakes, Agnes, Henry and LeHomme Dieu, which are currently not impaired.
- Annual Loading from POTW – Apply average annual loading as NPDES permit limit to achieve in lake phosphorus concentration of 75 ppb.

To assess compliance with the TMDL water quality will be monitored at consistent sites within North and South Winona. Data from South Winona will be used to assess compliance with the TMDL. This approach provides a margin of safety as the lake was originally listed based on a whole-lake average from both basins.

Table 5. Comparison of ecoregion-based standards to proposed site-specific standards

Parameter	NCHF	NGP	Winona (proposed)
Total Phosphorus µg/l	≤ 60	90	75
Chlorophyll-a µg/l	≤ 20	30	≤ 20
Secchi Transparency (m) “not less than”	1.0	0.7	1.0

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