Lake Owasso Use Attainability Analysis

Diagnostic-Feasibility Study: Water Quality Issues and Potential Restorative Measures

Prepared for the
Grass Lake Watershed Management Organization

April 2009

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Executive Summary

Overview

This report describes the results of the Use Attainability Analysis (UAA) for Lake Owasso on the border of Roseville and Shoreview, MN. This study provides the scientific foundation for a lake-specific management plan that assesses the water body's physical, chemical, and biological condition and provides recommendations that would help improve the water quality of Lake Owasso. This study includes both a water quality assessment and prescription of protective and/or remedial measures for Lake Owasso and the tributary watershed. The conclusions and recommendations are based on the compilation of intensive lake water quality monitoring data for the summers of 2007 and 2008. This data was coupled with computer models, which were calibrated to the 2007 and 2008 datasets, to simulate the impact of the various phosphorus sources on the water quality in Lake Owasso.

A key result of these analyses and computations was the development of annual water and phosphorus budgets for Lake Owasso, identifying the relative percent contribution of each of the various sources to the annual water and phosphorus loads. In addition, best management practices (BMPs) were evaluated to compare their relative effect on the total phosphorus concentrations and Secchi disc transparencies (i.e., water clarity) in Lake Owasso. Management options were then assessed to determine attainment or non-attainment for the lake's water quality goals and recreational uses.

Water Quality Goals for Lake Owasso

The Grass Lake Watershed Management Organization (GLWMO) has established water quality goals for Lake Owasso as part of its 2001 *Watershed Management Plan*, based on the desired use of the lake and public perception.

Table EX-1 Lake Owasso Summary of Historical Water Quality Data, Goals, and Standards

Water Quality Parameter	Mean Summer-Average for Period of Record (1973-2008)	2008Summer Average	GLWMO Existing Goal	GLWMO Action Level	MPCA's Deep Lake Standard
Total Phosphorus	54 μg/L	32 μg/L	45 μg/L	--	40 μg/L
Secchi Disc	6.2 ft (1.9 m)	6.9 ft (2.1 m)	5.2 ft (1.6 m)	8.0 ft (2.45 m)	4.6 ft (1.4 m)
Chlorophyll *a*	15.7 μg/L	13 μg/L	20 μg/L	--	14 μg/L

The results of a lake user survey (conducted in the spring of 2007) as well as discussions at public meetings indicate that residents have concerns about macrophyte interference with recreational uses of the lake as well as decreasing lake clarity.

Total phosphorus, chlorophyll *a*, and Secchi disc transparency are key water quality indicators for the following reasons:

- Phosphorus generally controls the growth of algae in lake systems. Of all the substances needed for biological growth, phosphorus is typically the limiting nutrient, therefore higher phosphorus concentrations typically result in more algae and related problems.
- Chlorophyll *a* is the main photosynthetic pigment in algae. Therefore, the amount of chlorophyll *a* in the water indicates the abundance of algae present in the lake.
- Secchi disc transparency is a measure of water clarity, and is inversely related to the abundance of algae. Water clarity typically determines recreational-use impairment.

All three of these water quality indicators, either alone or in combination, can be used to determine a Trophic State Index (TSI). However, water transparency alone is typically used to develop the TSI_{SD} (Trophic State Index based on Secchi disc transparency) because people's perceptions of recreational-use impairment are often directly related to water clarity.. Water quality trophic status categories include oligotrophic (i.e., excellent water quality), mesotrophic (i.e., good water quality), eutrophic (i.e., poor water quality), and hypereutrophic (i.e., very poor water quality). Water quality characteristics of lakes in the various trophic status categories are listed below with their respective TSI ranges:

1. **Oligotrophic –** [$20 \leq TSI_{SD} \leq 38$] clear, low productive lakes, with total phosphorus concentrations less than or equal to 10 µg/L, chlorophyll *a* concentrations of less than or equal to 2 µg/L, and Secchi disc transparencies greater than or equal to 4.6 meters (15 feet).

2. **Mesotrophic –** [$38 \leq TSI_{SD} \leq 50$] intermediately productive lakes, with total phosphorus concentrations between 10 and 25 µg/L, chlorophyll *a* concentrations between 2 and 8 µg/L, and Secchi disc transparencies between 2 and 4.6 meters (6 to 15 feet).

3. **Eutrophic –** [$50 \leq TSI_{SD} \leq 62$] high productive lakes relative to a neutral level, with 25 to 57 µg/L total phosphorus, chlorophyll *a* concentrations between 8 and 26 µg/L, and Secchi disc measurements between 0.85 and 2 meters (2.7 to 6 feet).

4. **Hypereutrophic –** [$62 \leq TSI_{SD} \leq 80$] extremely productive lakes which are highly eutrophic and unstable (i.e., their water quality can fluctuate on daily and seasonal basis, experience periodic anoxia and fish kills, possibly produce toxic substances, etc.) with total phosphorus

concentrations greater than 57 μg/L, chlorophyll *a* concentrations of greater than 26 μg/L, and Secchi disc transparencies less than 0.85 meters (2.7 feet).

Lake Owasso Characteristics

Lake Basin Characteristics

Lake Owasso is a lake located on the border between the cities of Roseville and Shoreview. The normal water surface elevation is 886.6 feet MSL. At this elevation, the lake volume is approximately 4099 acre-feet. At the normal water surface elevation, the lake has a water surface area of approximately 375 acres and a mean depth of 10.9 feet. The maximum depth is 37 feet.

The outlet from Lake Owasso is located on the northwest side of the lake and flows under North Owasso Boulevard, discharging into a wetland area on the southwest side of Lake Wabasso. The outlet structure of Lake Owasso consists of a concrete box with three 8-foot plate weirs, followed by two reinforced concrete arched pipes. Discharge from Lake Owasso occurs when water levels are above 886.6 feet MSL; however, there is indication that ice build-up does limit the discharge from Lake Owasso during the winter months (Shoreview Public Works Director, personal communication, 1/18/2008).

Watershed Characteristics

Lake Owasso's 3060-acre watershed, including the surface area of the lake, is within the cities of Roseville and Shoreview. Runoff from the immediate watershed enters Lake Owasso through overland flow and at several sewer outfalls to the lake.

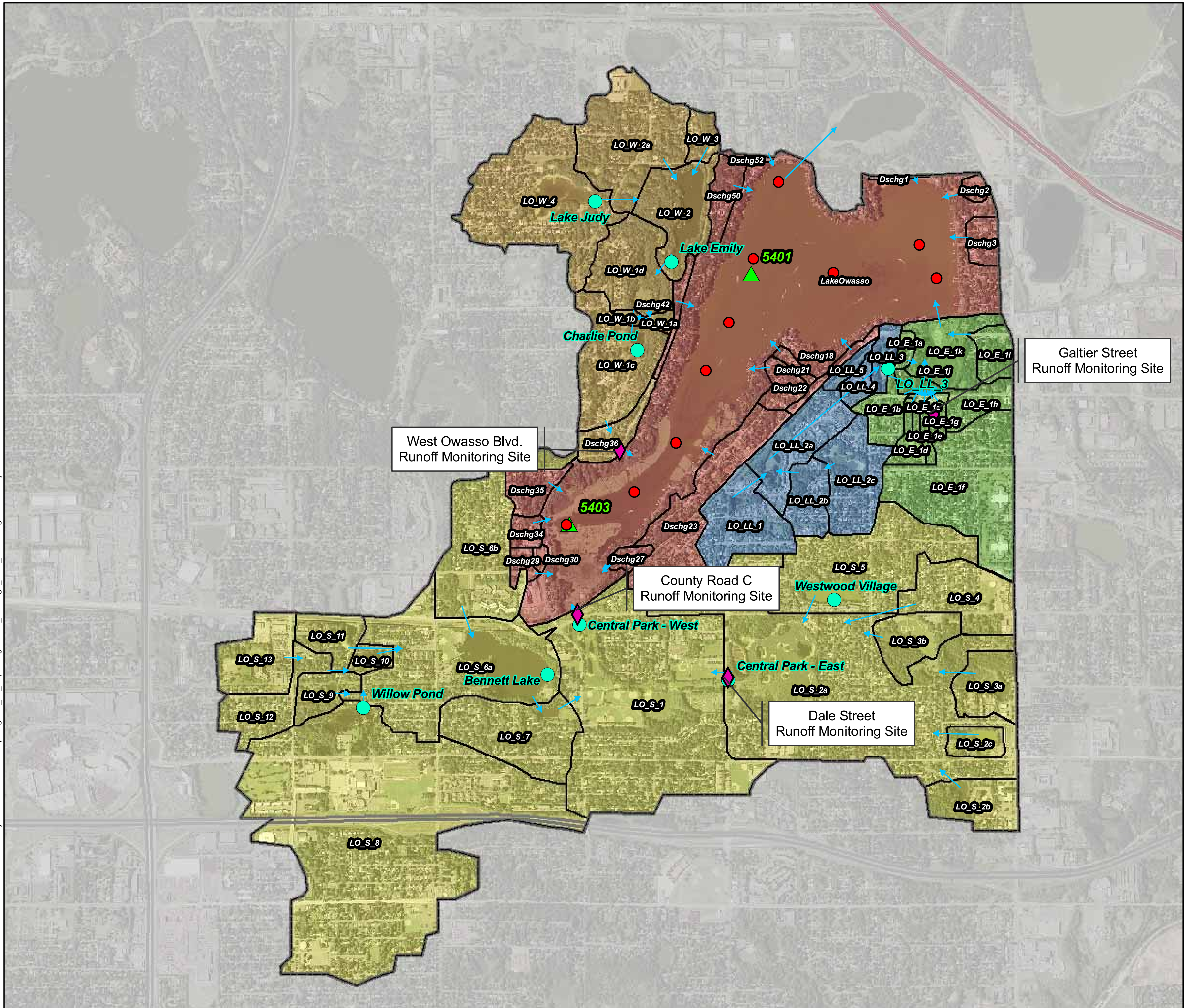
For this study, the Lake Owasso watershed was divided into five major "drainage districts" comprised of numerous smaller subwatershed area. Figure EX-1 shows the Lake Owasso drainage districts, subwatersheds, drainage patterns, and monitoring (in-lake water quality, sediment cores, watershed runoff monitoring stations, and pond discharge) locations. Each drainage district is briefly described below:

- **Direct Drainage District—** This drainage district is approximately 729.3 acres (including the surface area of Lake Owasso), which represents 23.8 percent of the Lake Owasso watershed. The drainage district consists primarily of low density residential land use. Work was started in the summer of 2007 to collect flows from subwatershed Dschg50 in an underground storage vault. Under normal conditions, these flows will be pumped to the West Drainage District and pass through the Charlie Pond system. Flood flows will be allowed to discharge from the existing outlet. For calibration, it was assumed that subwatershed Dschg50 discharged directly to Lake Owasso, as the new system was not functioning during the summer of 2007. Modeling of future conditions will reflect this change.

- **South Drainage District—**This 1581.3 acre drainage area represents approximately 51.6 percent of the Lake Owasso watershed. Runoff from this district is conveyed to the Central Park Ponds and discharges to Lake Owasso through the west Central Park Pond via a structure under County Road C. Other larger water bodies in the district include Willow Pond, Frog Pond, Bennett Lake, and Westwood Village Pond. Much of the drainage district consists of low-density residential and open space land uses as well as institutional, highway right-of-way, and several smaller areas of high- and medium-density residential and commercial land uses.
- **West Drainage District—**This drainage area covers approximately 360.1 acres, or 11.8 percent, of the Lake Owasso watershed. There is one land locked watershed (LO_W_3) in this district. Flows from this district pass through Charlie Pond before discharging to Lake Owasso. Other larger water bodies in this district include Lake Judy and Lake Emily. In the end of 2007, a CDS structure was installed on the northwest side of Lake Emily, treating discharges from watershed LO_S_2a before discharging into Lake Emily. The predominant land uses in this drainage district are low-density residential and open space.
- **East Drainage District—**This 213.3-acre drainage district represents about 7.0 percent of the Lake Owasso watershed. Runoff from this district is discharged to the bay south of Lake Owasso before discharging to the lake. This district is primarily composed of low density residential land use with some high density land use in the upper portions of the watershed.
- **Land Locked Drainage District—** This drainage district covers approximately 178 acres which represents about 5.8 percent of the Lake Owasso watershed. The drainage area was historically land locked although a pump has been installed in subwatershed LO_LL_2a that pumps high waters to subwatershed LO_LL_3, where it is discharged into the bay south of Lake Owasso. Subwatershed LO_LL_5 is still currently land locked and was assumed to contribute no flows to Lake Owasso. This drainage district consists primarily of low density residential land use, with wetland areas interspersed.

Current and future land uses for the watershed are shown in Figure EX-2. Low density residential land use has been identified as the major land use within the Lake Owasso watershed (55 percent) followed by open water and wetland (mostly Lake Owasso. Figure EX-3 summarizes the breakdown of land use categories in the Lake Owasso watershed, for both existing (2006) and future conditions. There are no significant changes expected in the Lake Owasso watershed land use.

The infiltration capacity of soils affects the amount of direct runoff resulting from rainfall. Soils with a higher infiltration rate have a lower runoff potential. Conversely, soils with low infiltration rates produce high runoff volumes and high peak runoff rates. According to the Ramsey County Digital Soils map, the underlying soils in the Lake Owasso watersheds are predominantly classified as hydrologic soil group (HSG) B, with moderate infiltration rates. The soils along the eastern side of the lake are classified as HSG A, characterized by high infiltration rates. Soils around wetland areas within the watershed typically have low to very low infiltration capacity. Figure EX-4 shows the distribution of the HSGs throughout the Lake Owasso watershed.



Sediment Core Locations (2007)

Runoff Monitoring (2007 & 2008)

In-Lake Water Quality Monitoring (2007 & 2008)

Pond Discharge Sites (2008)

Watershed Flow Direction

Subwatersheds

Drainage Districts

Direct

East

Land Locked

South

West

Feet

1,750 0 1,750

N

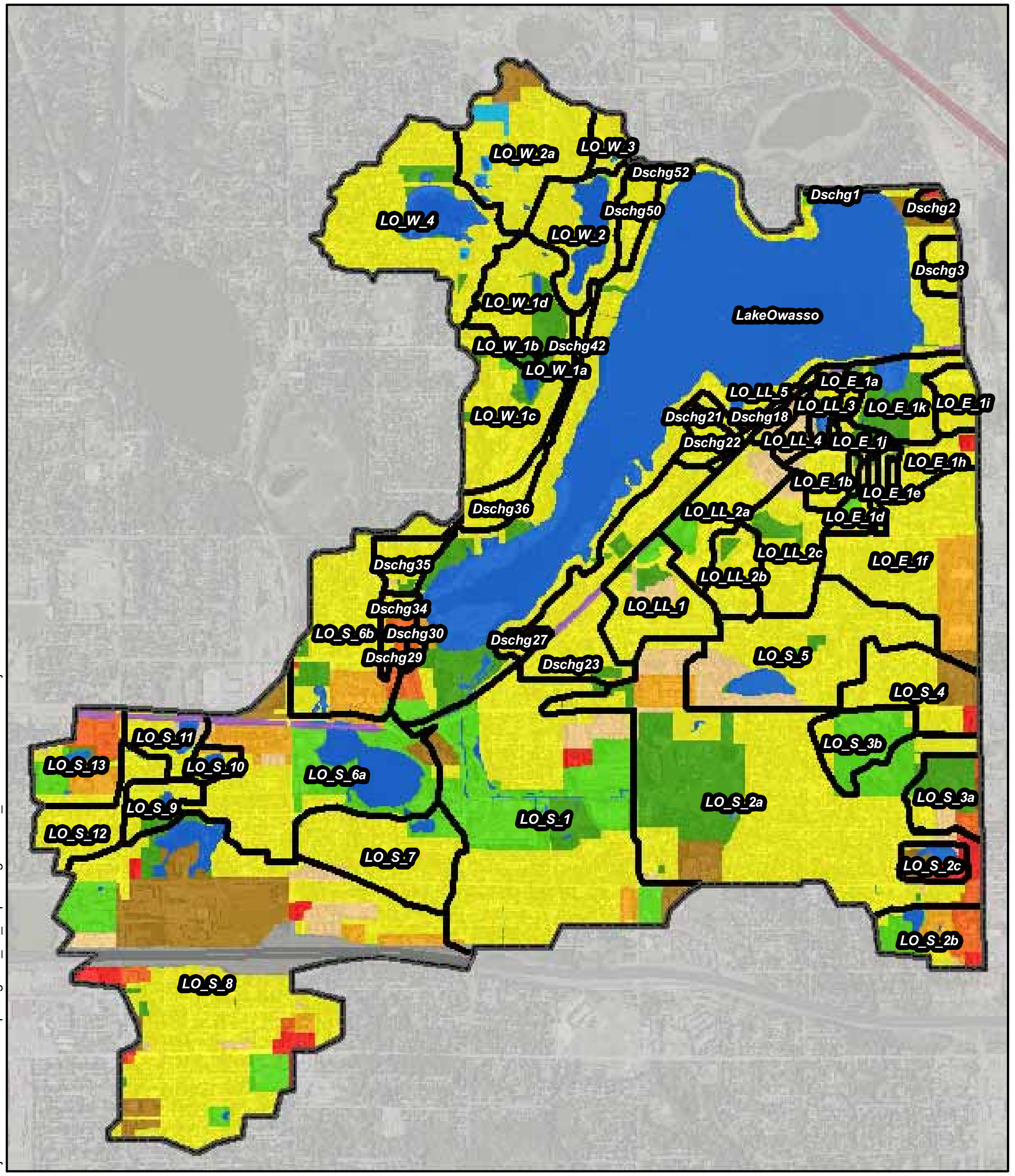
Figure EX-1

LAKE OWASSO DRAINAGE PATTERNS, SUBWATERSHEDS, & MONITORING LOCATIONS

Lake Owasso UAA

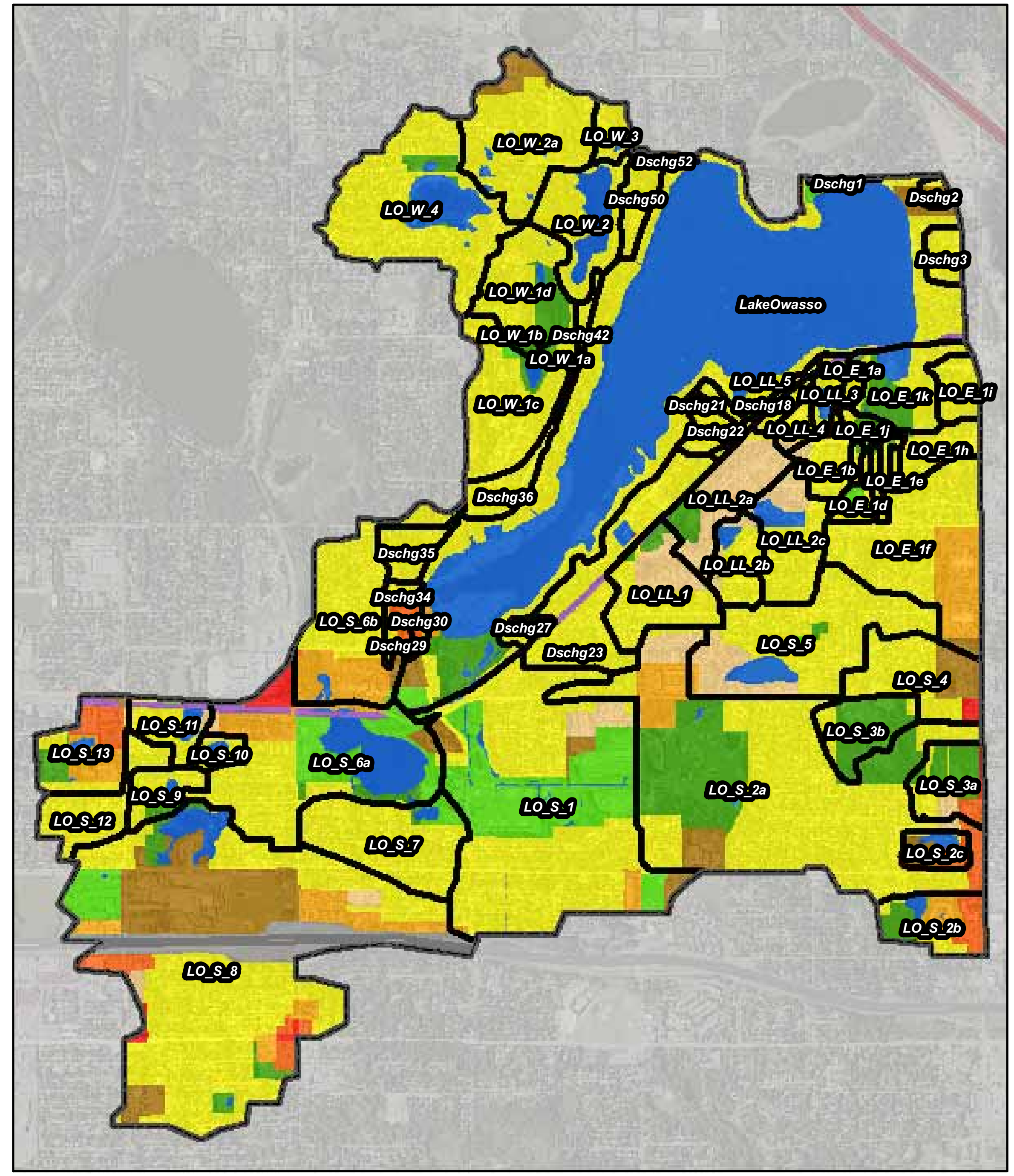
Grass Lake Watershed Management Organization

Existing (2006) Land Use



Source: 2001 GLWMO Watershed Management Plan, Modified to 2006 aerial photography

Full Development (Future) Land Use



Source: 2001 GLWMO Watershed Management Plan

Subwatershed

Land Use

- Commercial
- Developed Park
- Highway
- High-Density Residential
- Institutional
- Office/Industrial
- Low-Density Residential
- Medium-Density Residential
- Natural/Open Space
- Water
- Wetland
- Railroad

Feet

2,500 0 2,500

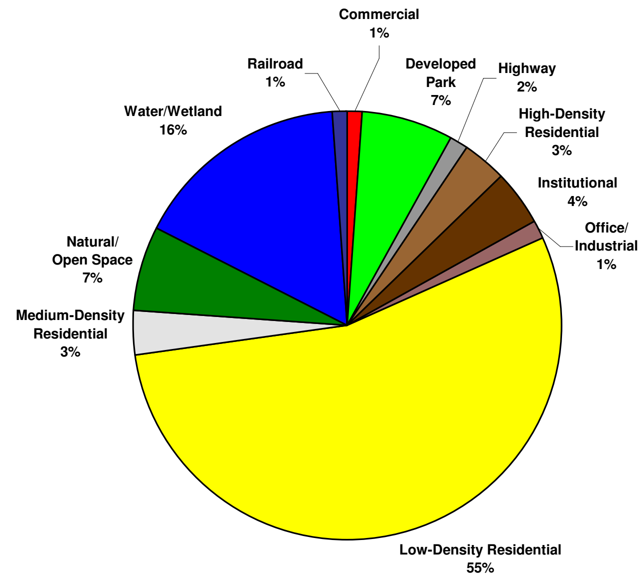
N

Figure EX-2

LAKE OWASSO WATERSHED
EXISTING AND FULL DEVELOPMENT
LAND USE

Lake Owasso UAA
Grass Lake Watershed Management Organization

Lake Owasso Watershed
Existing (2006) Land Use
Total Watershed Area = 3060 Acres



Lake Owasso Watershed
Full Development Land Use
Total Watershed Area = 3060 Acres

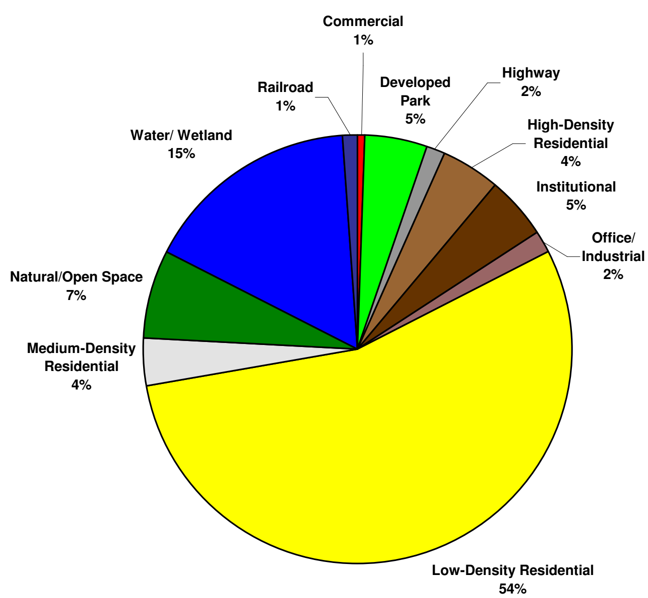


Figure EX-3
Lake Owasso Watershed
Existing (2006) and Full Development
Land Use Summary

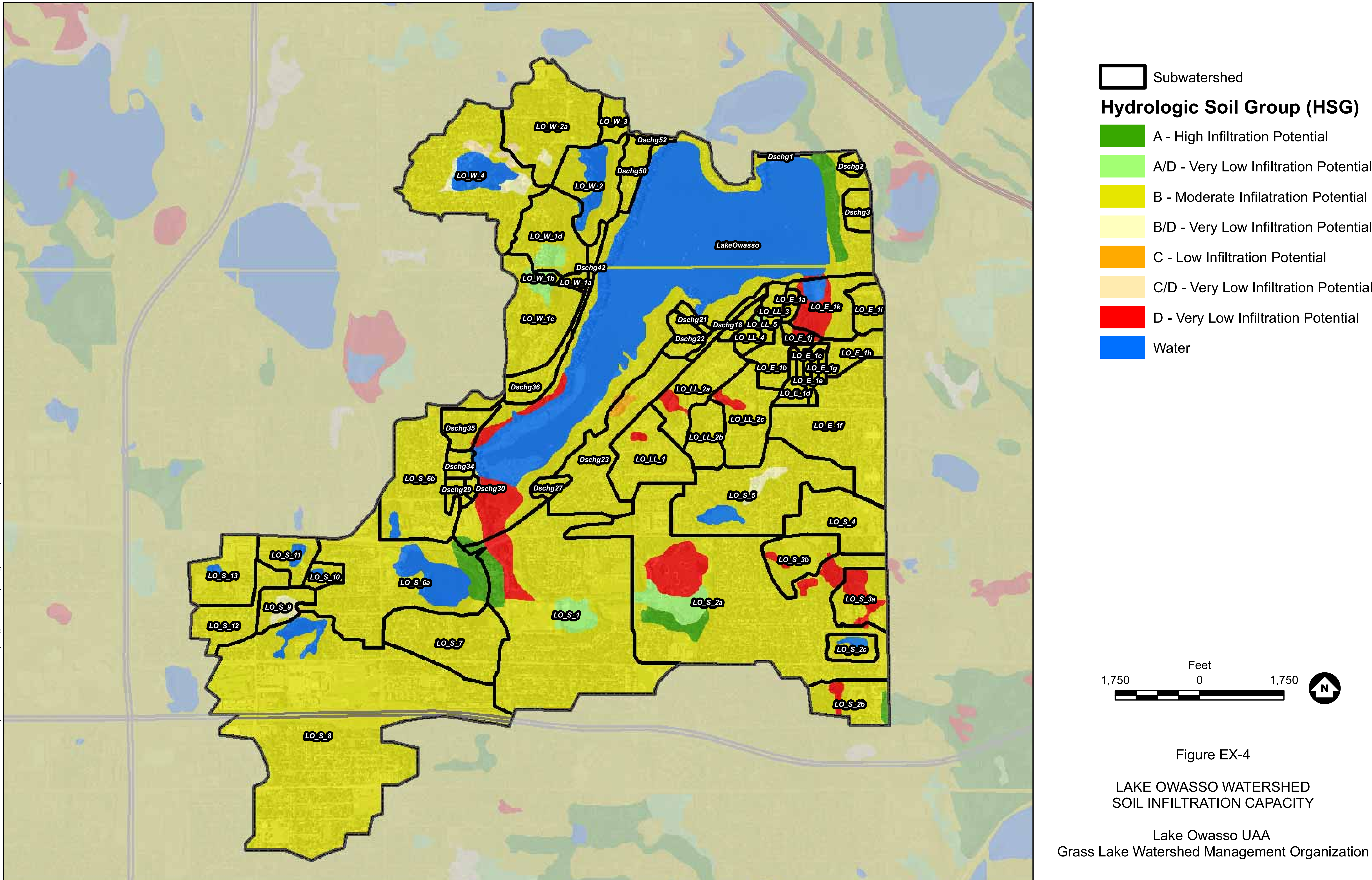


Figure EX-4

LAKE OWASSO WATERSHED
SOIL INFILTRATION CAPACITY

Lake Owasso UAA
Grass Lake Watershed Management Organization

Water Quality Problem Assessment

Lake Owasso Water Quality

Figure EX-5a shows the total phosphorus, Secchi disc, and chlorophyll *a* monitoring results for monitoring site 5401 in Lake Owasso for 2007 and 2008. Figure EX-5b shows the total phosphorus, Secchi disc, and chlorophyll *a* monitoring results for monitoring site 5403 in Lake Owasso for 2007 and 2008. Figure EX-6 shows the historical summer averages for the same three parameters.

Phosphorus

The summer average phosphorus concentrations at site 5401 for 2007 and 2008 were 30 µg/L and 32 µg/L, respectively. These values meet the GLWMO water quality goal of 45 µg/L as well as the MPCA deep lake criterion (40 µg/L). At site 5403, the summer-average total phosphorus concentrations for 2007 and 2008 (52 µg/L and 41 µg/L, respectively) do not meet the MPCA criterion, but the 2008 water quality meets the GLWMO water quality goal. The total phosphorus data collected from Lake Owasso during 2007 and 2008 were generally within the eutrophic (i.e., nutrient-rich) category during the summer.

Chlorophyll *a*

The 2007 and 2008 summer-average chlorophyll *a* concentrations at both sites 5401 (16 µg/L and 13 µg/L, respectively) and 5403 (12 µg/L and 9 µg/L) meet the GLWMO goal of 20 µg/L. However, the chlorophyll *a* concentration at site 5401 does not meet the MPCA deep lake criterion (14 µg/L) in 2007. The chlorophyll *a* data collected from Lake Owasso during 2007 and 2008 were generally within the eutrophic category throughout the summer, indicating that Lake Owasso may have experienced nuisance conditions of algal growth.

Secchi Disc

The 2007 summer-average Secchi disc transparency for both sites 5401 and 5403 (1.6 meters and 1.8 meters) just meet the GLWMO water quality goal (1.6 meters) and fall below the GLWMO established action level (2.45 meters), thereby causing this study to be conducted. The 2008 summer average transparency for sites 5401 and 5403 (2.1 meters and 2.0 meters) also met the GLWMO water quality goal. The summer averages at both monitoring sites meet the MPCA deep lake criterion (1.4 meters). The Secchi disc data collected from Lake Owasso during 2007 and 2008 were within the eutrophic category throughout the summer months.

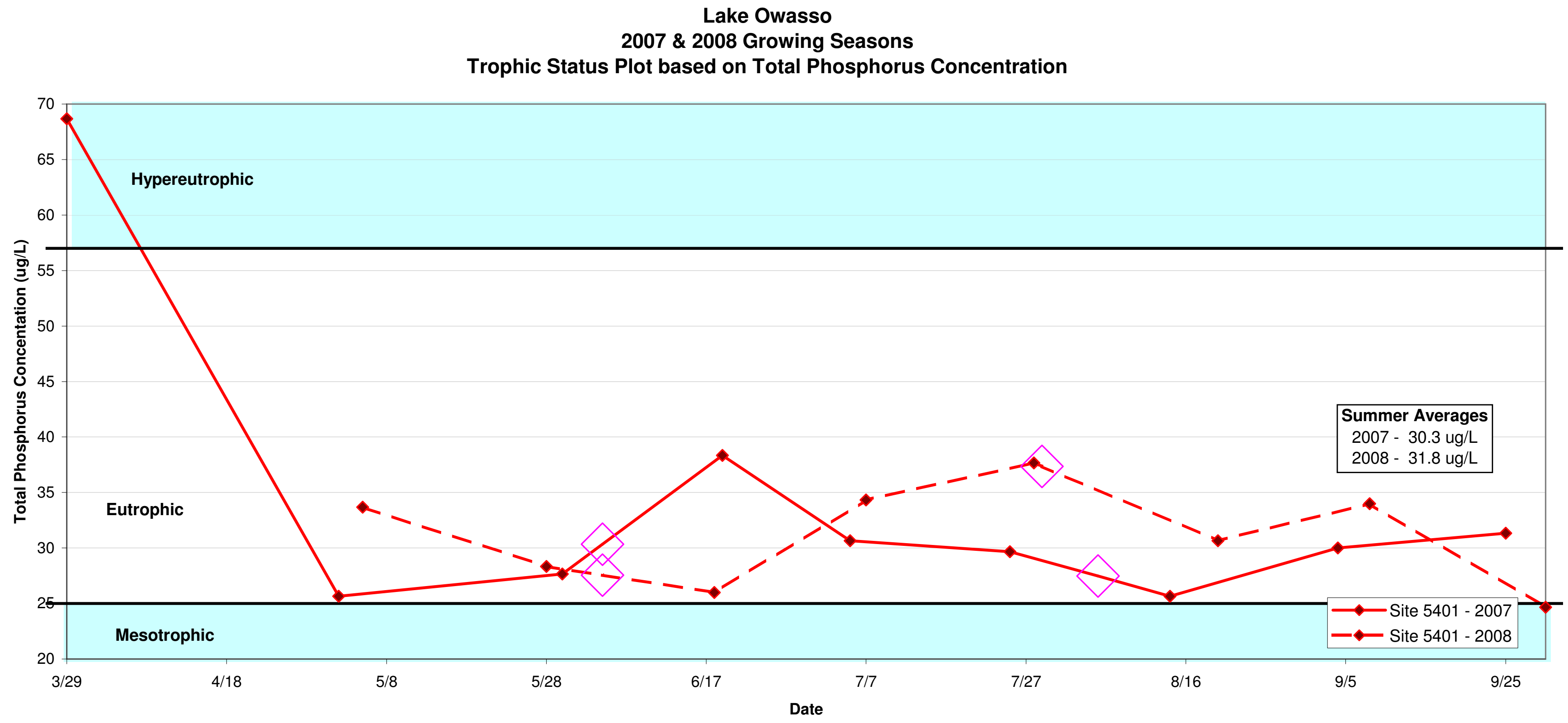
Temperature and Oxygen

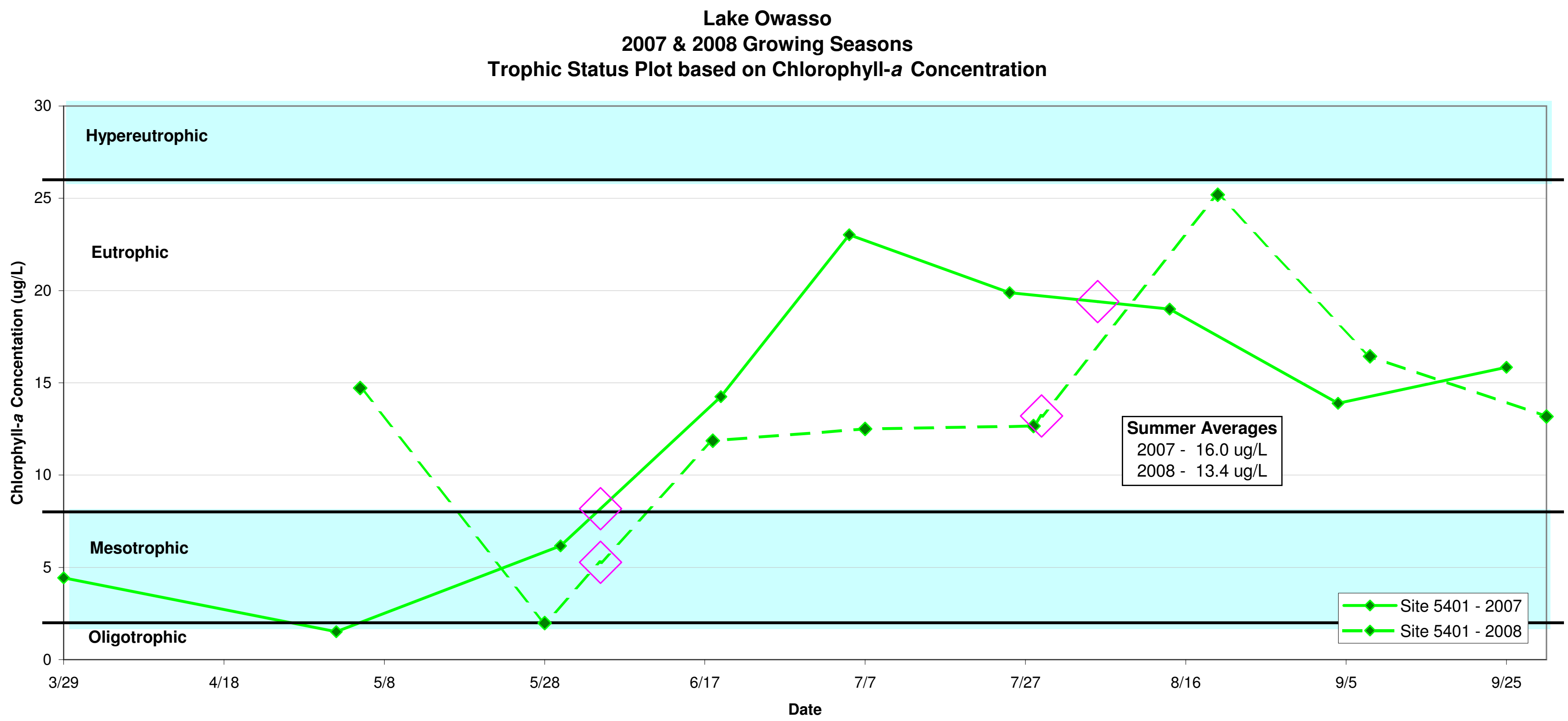
Temperature and dissolved oxygen measurements throughout the water column at both monitoring sites in Lake Owasso indicate that the entire lake does thermally stratify from May through early September, for both 2007 and 2008. At Site 5401, the depth to the thermocline was approximately 5 to 6 meters. At site 5403, the thermocline depth is about 2 to 3 meters. Because the thermocline persists throughout the summer, it can be inferred that Lake Owasso is a dimictic lake (completely mixes twice-annually).

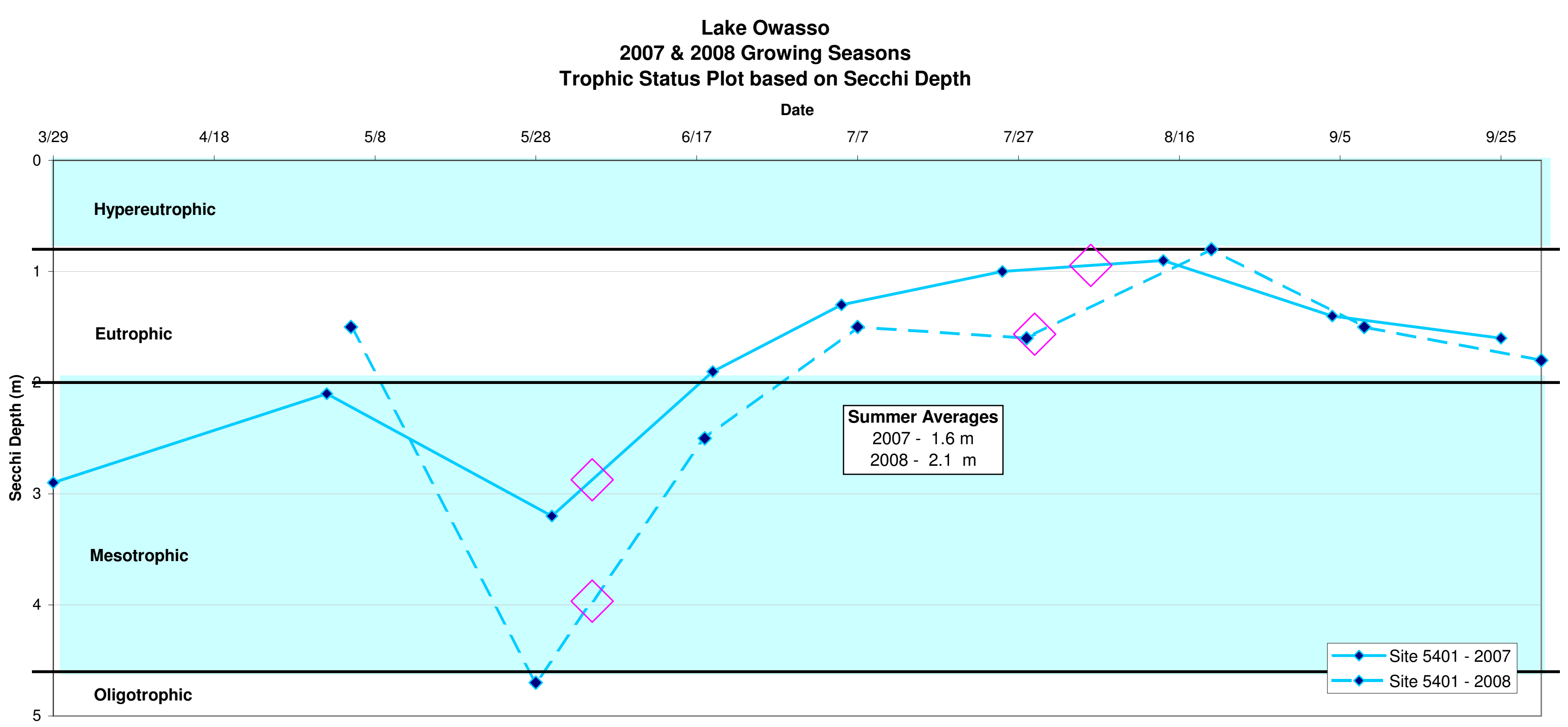
During both 2007 and 2008 in the summer months, dissolved oxygen levels varied greatly throughout the depth of the water column. Typically, dissolved oxygen levels ranged from 8 to 12 mg/L in the surface waters above the thermocline. However along and below the thermocline, dissolved oxygen levels continued to decline with concentrations less than 1 mg/L along the bottom of the lake. This indicates that Lake Owasso likely experiences sediment anoxia during the summer, resulting in internal phosphorus loading from the bottom sediments.

Chloride

Chloride measurements in Lake Owasso were relatively constant throughout the summer of 2007 with the average chloride concentration for the entire monitoring period measured at site 5401 being 55 mg/L, and at site 5403, 69 mg/L. In 2008, the average chloride level for the entire monitoring period at site 5401 was 57 mg/L and at site 5403, the concentration was 69 mg/L. The chloride concentrations for both years should not pose a threat to the biota of Lake Owasso.



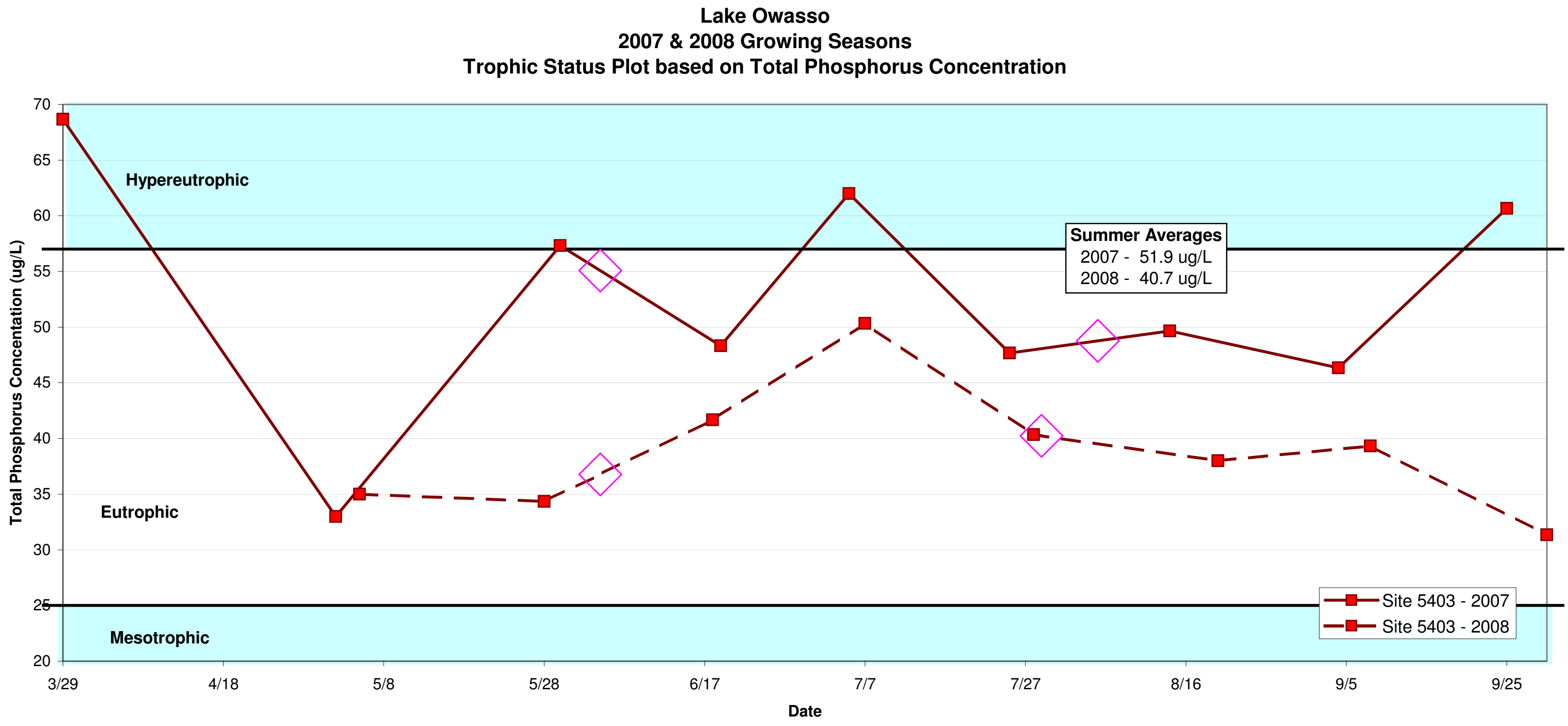


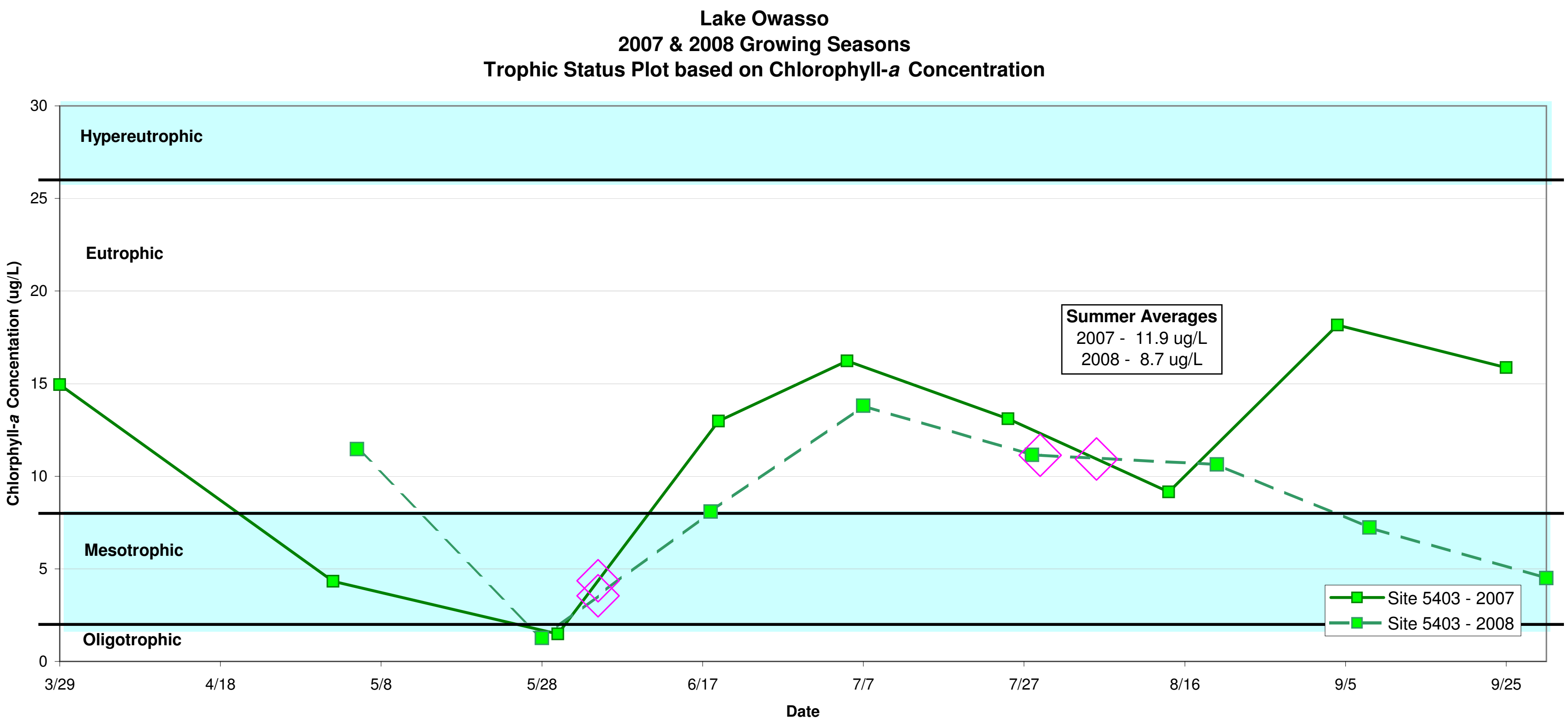


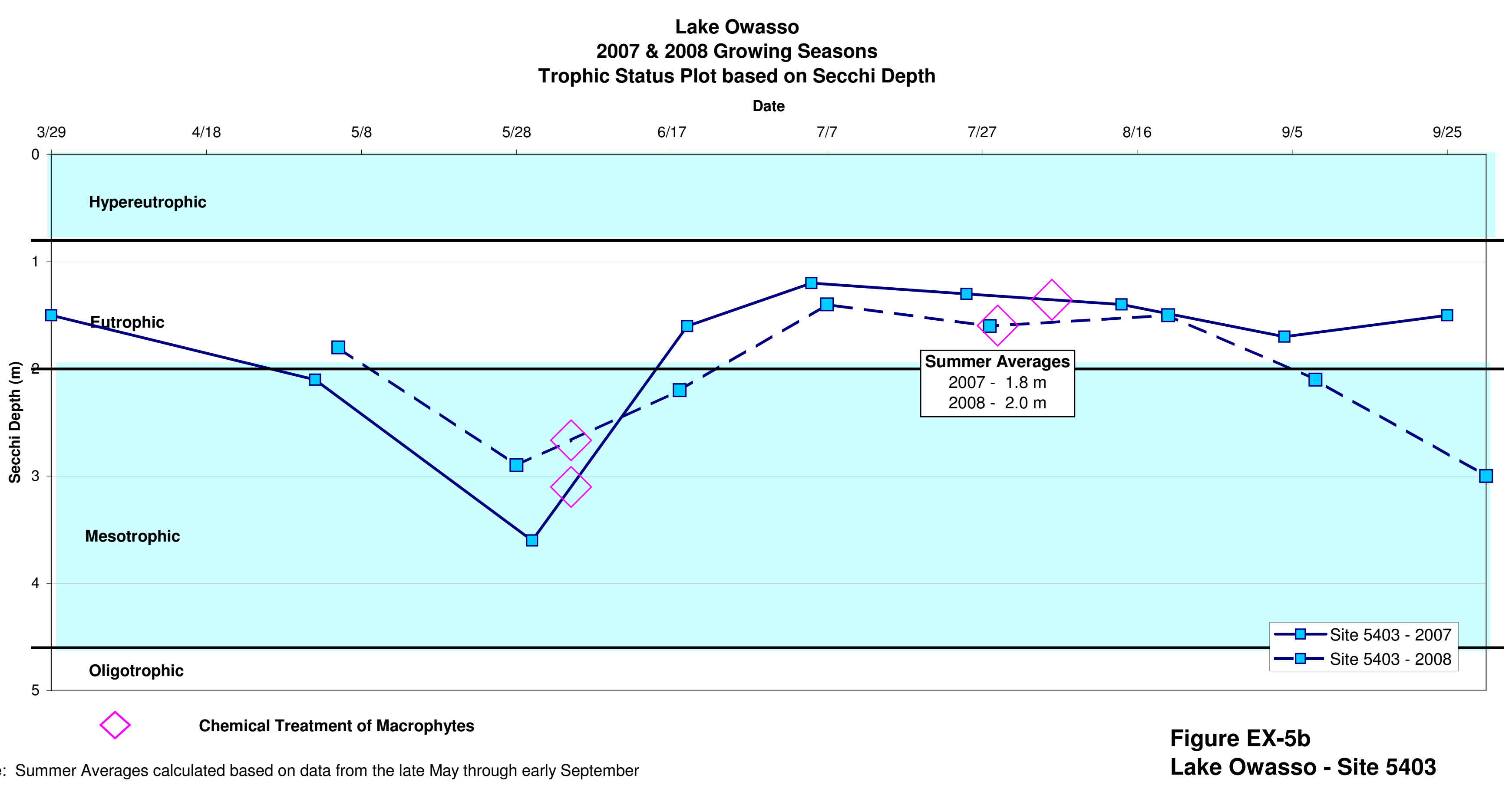
Chemical Treatment of Macrophytes

Note: Summer Averages calculated based on data from the late May through early September

Figure EX-5a
Lake Owasso - Site 5401
2007 & 2008 Water Quality

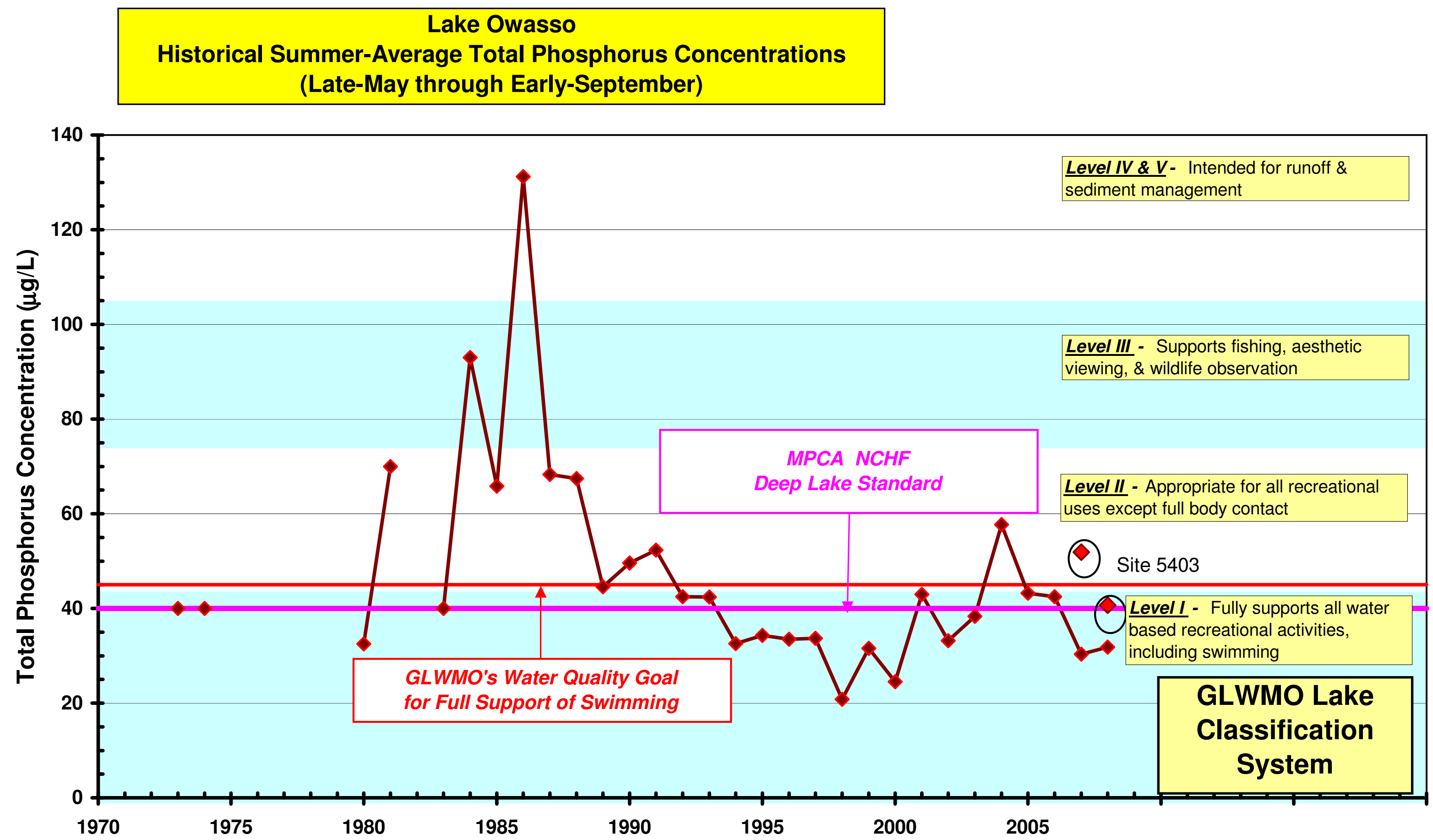


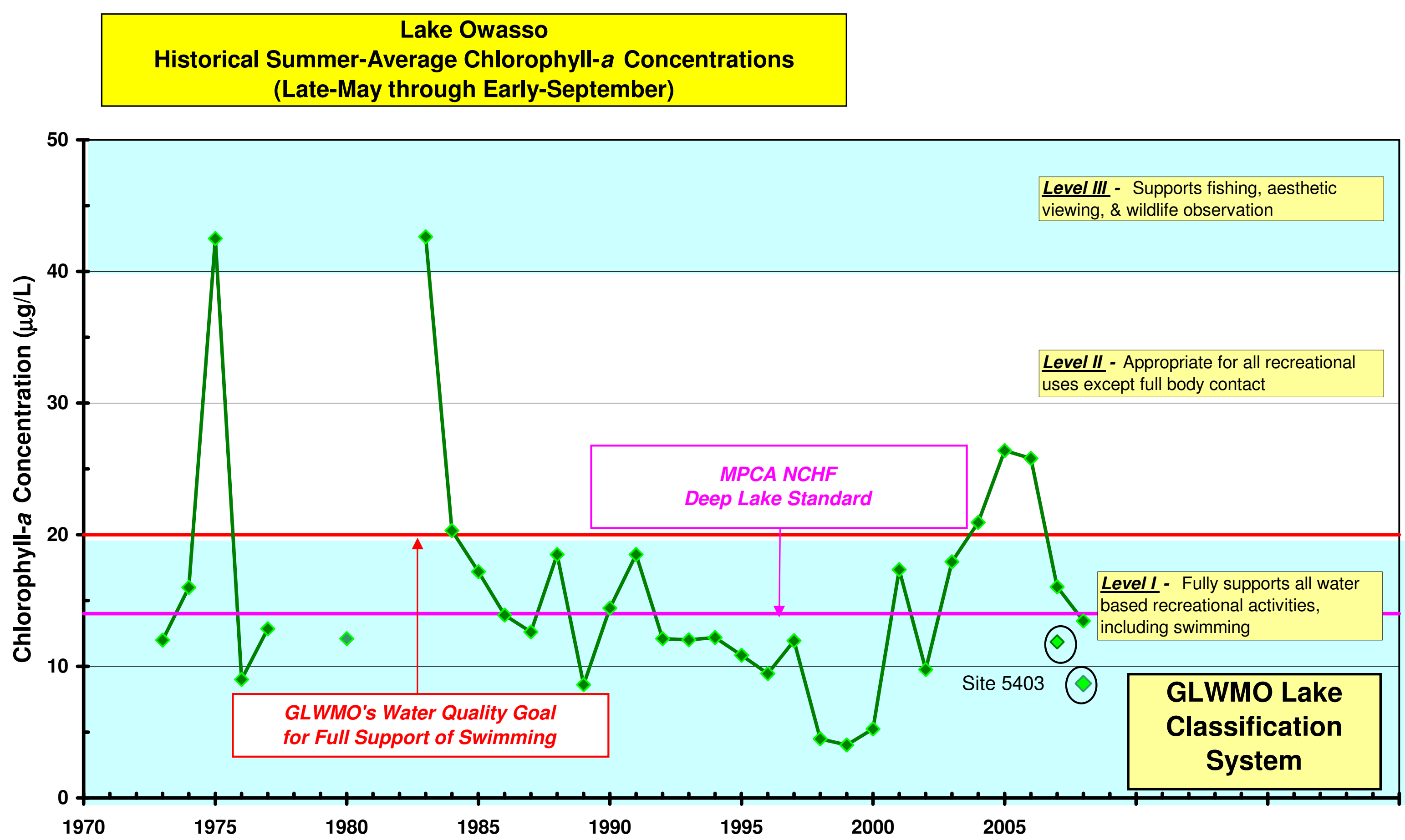




Note: Summer Averages calculated based on data from the late May through early September

Figure EX-5b
Lake Owasso - Site 5403
2007 & 2008 Water Quality





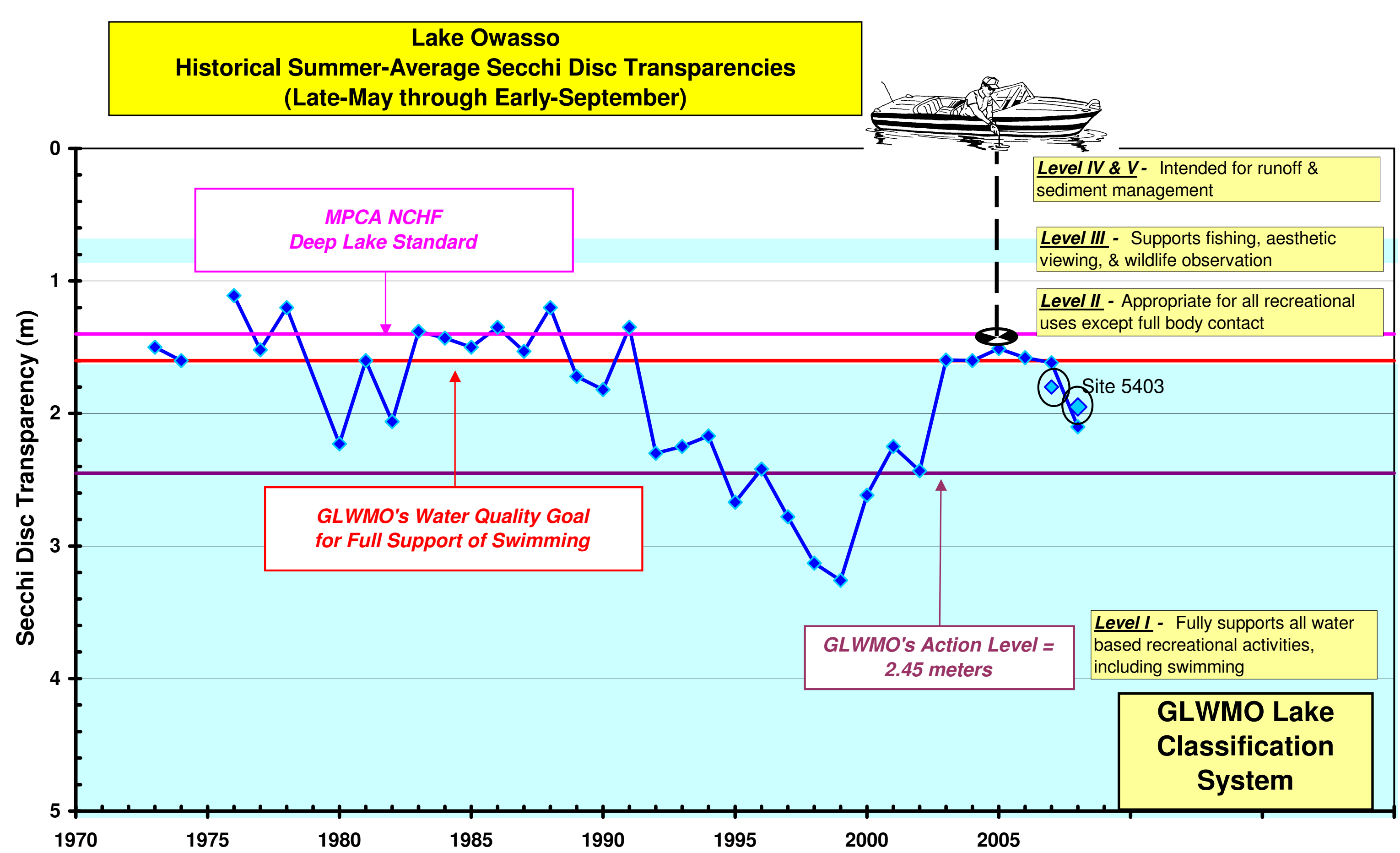


Figure EX-6
Lake Owasso Historical Summer Average (late May through early September) Total Phosphorus and Chlorphyll-*a* Concentrations and Secchi Depths

Trend Analysis

A trend analysis is often performed for lake studies when sufficient data is available. The analysis helps identifies if changes in measured water quality indices are statistically significant; it is a way to determine whether apparent trends constitute a real decline or improvement in lake water quality.

The trend analysis for Lake Owasso run using the past 10 years of water quality data (1998 through 2008) found that there has not been a significant change in total phosphorus concentrations over the past 10 years while there was a statistically significant increase in the Chlorophyll *a* concentration over the same time period. Additionally, there was a significant decrease in Secchi depth. Because all three parameters do not show a similar trend, no conclusions can be made about the significance of the changes in water quality over the past 10 years. However, both Chlorophyll *a* and Secchi depth indicate that there has been some degradation in Lake Owasso water quality.

The trend analysis for Lake Owasso for the period from 1983 through 2008 found that there has been a significant decrease in total phosphorus concentrations over the past several decades. There has not been a statistically significant change in the Chlorophyll *a* concentration over the same time period. Additionally, there was a significant increase in Secchi depth. Because all three parameters do not show a similar trend, no conclusions can be made about the significance of the changes in water quality over the past 3 decades. However, both total phosphorus and Secchi depth indicate that there has been some improvement in Lake Owasso water quality since the early 1980's. This is likely due to the implementation of water quality BMPs throughout the watershed..

Aquatic Communities

Phytoplankton

The phytoplankton communities, also called algae, in lakes form the base of the food web and affect recreational-use of the lake. An inadequate phytoplankton population limits the lake's zooplankton population and can, thereby, limit the fish production in a lake. Conversely, excess phytoplankton can alter the structure of the zooplankton community and interfere with sight-based fish predation, thereby also having an adverse effect on the lake's fishery. In addition, excess phytoplankton reduces water clarity; reduced water clarity can in itself make recreational-usage of a lake less desirable.

Ramsey County has been monitoring the various types and concentrations of phytoplankton communities in Lake Owasso throughout the summers for the past two decades. This data (through 2006) provides a look at historic trends in the phytoplankton levels throughout the summer as well as over the years. During 2006, the phytoplankton levels in Lake Owasso varied throughout the summer, with the peak phytoplankton concentration occurring in mid-August. Blue-green algae, which are typically nuisance species, were the dominant type of phytoplankton present in Lake Owasso for the entire season.

Zooplankton

Zooplankton—microscopic crustaceans—are vital to the health of a lake ecosystem because they feed upon the phytoplankton and are food themselves for many fish species. Protection of the lake's zooplankton community through proper water quality management practices protects the lake's fishery. Zooplankton is also important to lake water quality. Healthy zooplankton communities are characterized by balanced densities (numbers per square meter) of the three major groups: cladocera, copepoda, and rotifera. Cladocera have the largest impact on lake water clarity as they graze primarily on algae and can increase transparency if they are present in abundance. *Daphnia spp*. are among the larger cladocera species and are considered especially desirable in lakes because of their ability to consume large quantities of algae.

Ramsey County has been monitoring the various types and concentrations of zooplankton communities in Lake Owasso throughout the summers for the past two decades. In addition, the size distribution of *Daphnia spp.* were also monitored. These data provide a look at historic trends in the zooplankton levels throughout the summer as well as over the years.

The overall amount and distribution of the type of zooplankton in Lake Owasso varied throughout the 2007 season. Zooplankton concentrations were highest in early May. During June and July, the zooplankton concentrations declined and then increased again in September. The dominant groups in Lake Owasso in the early part of the season and throughout much of the summer were the copepods and rotifers. Later in the season, the numbers of the copepods declined while more cladocera species were present. In Lake Owasso, a very low numbers of the *Daphnia spp.* were observed in 2007, and those that were observed were relatively small.

Studies have been done that have analyzed zooplankton (cladocera) feeding patterns, relating body size to the maximum size of the particles ingested as well as establishing a relationship between the filtering rate of *Daphnia spp.*, temperature, and body size (Burns, 1968 and 1969). Data through the summer of 2007 was obtained from Ramsey County, processed to estimate zooplankton feeding rates, and the results have been preliminarily reviewed by Dr. Joseph Shapiro, University of Minnesota Emeritus Professor of Limnology. The general conclusion is that the *Daphinia spp* are present in low numbers and are small in size. As a result, filtering rates are relatively low and the impact on the reduction of phytoplankton is limited.

Planktivorous fish (such as sunfish and bluegills) eat zooplankton and will preferentially select the large Daphnia. Therefore, to thrive, the Daphnia require either a refuge from predators (i.e., deep, well-oxygenated water) or a smaller predator population. The MDNR fishery data shows that both smaller than average bluegills and other small panfish are present in Lake Owasso. The combination of these factors could likely contribute to the low Daphnia populations and decreased water clarity due to low phytoplankton filtering rates.

Macrophytes

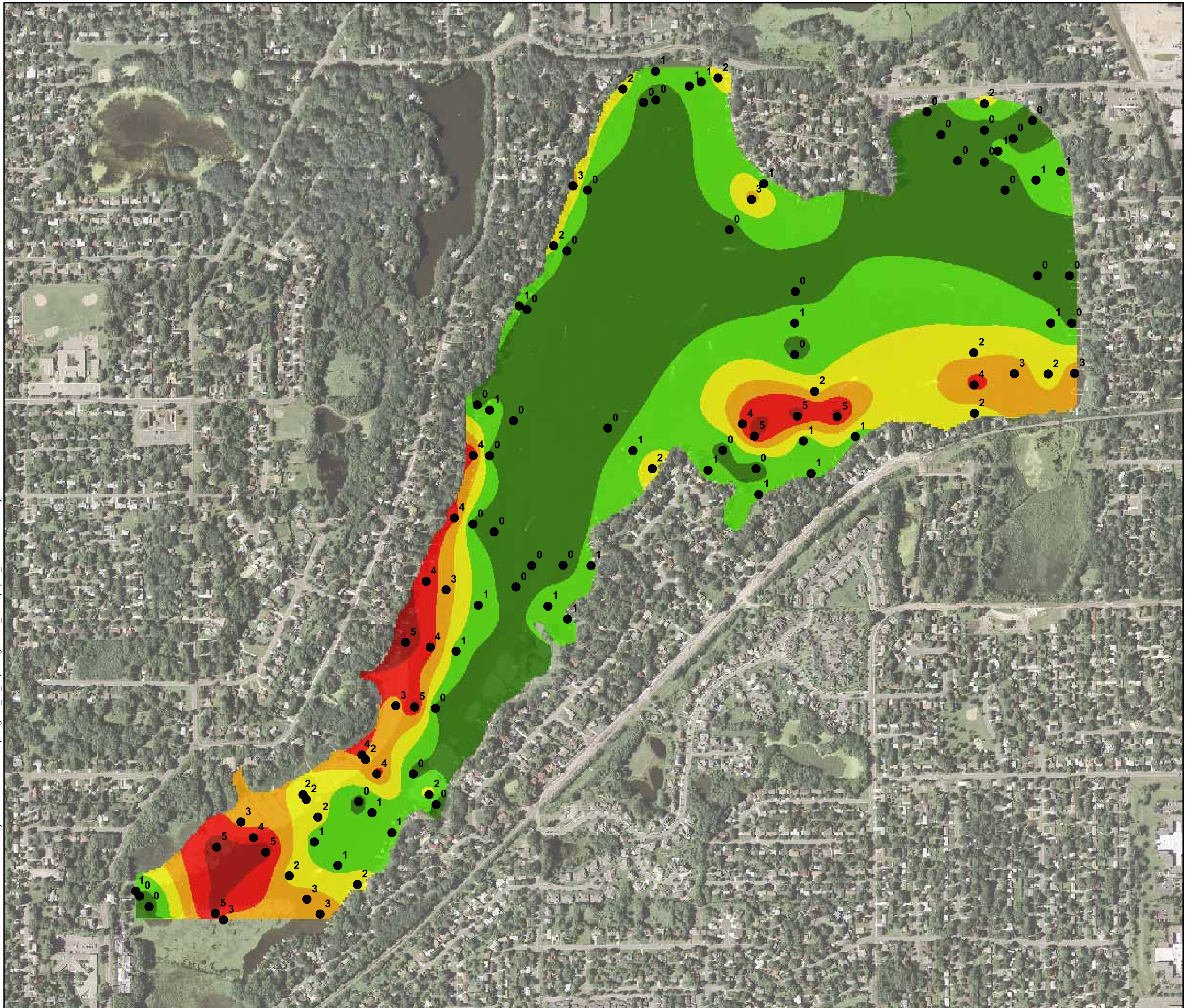
Aquatic plants (i.e., macrophytes and phytoplankton) are a natural part of most lake communities and provide many benefits to fish, wildlife, and people. They are among the primary producers in the aquatic food chain, providing food for other aquatic life.

Although macrophytes (i.e., lake weeds) play an important role in the lake ecosystem, the introduction of exotic (nonnative) aquatic plants into a lake may cause undesirable changes to the plant community and to the lake ecosystem. Two common non-native plants include Curlyleaf pondweed and Eurasian watermilfoil. Curlyleaf pondweed dies-off in early summer releases phosphorus to the lake, causing increased algal growth for the remainder of the summer. Eurasian watermilfoil is a nuisance, non-native species that can interfere with fishing and boating.

The most recent aquatic plant survey of Lake Owasso was conducted by Ramsey County in late May, 2007. Both Curlyleaf pondweed and Eurasian watermilfoil were present in the lake. The estimated coverage and density of Curlyleaf pondweed is summarized in Figure EX-7.

The Ramsey-Washington Metro Watershed District (RWMWD) also conducted a macrophyte survey of Lake Owasso in September 2005. During this survey, coontail was the most abundant macrophyte species, found in approximately 25% of the sites sampled in the littoral zone. Eurasian watermilfoil was the second most common macrophyte. According to the *Lake Owasso Management Plan* (Osgood, 2000) and information provided by Ramsey County, the MDNR and Ramsey County have conducted other aquatic plant surveys in Lake Owasso. The MDNR conducted surveys in 1948, 1955, 1981, and 1991. The other macrophyte surveys were conducted by Ramsey County in 1984, 1985, 1986, and again in 1990. The surveys indicate that Curlyleaf pondweed was present in Lake Owasso as far back as 1981.

Macrophytes in Lake Owasso have been both chemically controlled and mechanically harvested for several decades, although chemical treatment is the predominant control method. Although the MNDR currently limits chemical treatment to 15 percent of a lake's littoral (shallow) area, the aquatic plant control permit for Lake Owasso has existed longer than this restriction, and allows for the treatment of up to 21 percent of its littoral area, or about 62 acres. In recent years, the Lake Owasso Association has spent approximately $50,000 to $60,000 annually for macrophyte treatment. In both 2007 and 2008, the lake was chemically treated in June and July.



● Macrophyte Survey Points

Curlyleaf Pondweed

- Not Observed/Surveyed (0.0 - 0.5)
- Very Low Density (0.5 - 1.5)
- Low Density (1.5 - 2.5)
- Moderate Density (2.5 - 3.5)
- High Density (3.5 - 4.5)
- Very High Density (4.5 - 5+)

Area-Weighted Average for
Lake Owasso = 1.1

Feet
750 0 750

Figure EX-7

LAKE OWASSO MACROPHYTE SURVEY
CURLYLEAF PONDWEED
May 22-30, 2007

Lake Owasso UAA
Grass Lake Watershed Management Organization

Fish and Wildlife

According to the *Lake Owasso Management Plan* (Osgood, 2000), fishery surveys have been conducted for Lake Owasso in 1948, 1956-1959, 1961, 1971, 1976, 1981, 1991, 1992, 1994, and 1996. The most recent fishery survey was conducted by the MDNR in 2001 and a population assessment was conducted in 2006.

According to MDNR's most recent (2001) Lake Survey Report for Lake Owasso, bluegill is the most abundant species present in the Lake. Small pumpkinseed sunfish were also captured in record levels of abundance. Additionally, black crappie and yellow perch were sampled. Growth rates for the bluegill, pumpkinseed sunfish, and black crappie were found to be slow and yellow perch exhibited average growth rates. Muskellunge and walleye are the primary management species in Lake Owasso. These fish are stocked by the MDNR biennially. Northern pike were sampled above median levels for abundance. Growth rates for all the major predator species were found to be good. Other species sampled in Lake Owasso include black, brown, and yellow bullhead, green and hybrid sunfish, and largemouth bass.

A 2006 population assessment indicated that bluegill is still the most abundant fish species in the lake followed by black crappie. Northern pike and walleye were also sampled, as well as large mouth bass and muskellunge. The Lake Owasso fishery has been stocked almost annually with a variety of species since 1971 (Osgood, 2000).

Additionally, there have been several periods of low winter oxygen conditions in Lake Owasso that could have resulted in potential winterkill situations. There periods were noted in the winters of 1978/79, 1988/89, 1991/92, 1992/93, and 1996/97. The *Lake Owasso Management Plan* (Osgood, 2000) indicated that an aeration system would be installed in Lake Owasso in 2000.made available for use during these low oxygen conditions to help prevent the potential winterkill. This aeration system is operated by Ramsey County. Discussion with Ramsey County indicated that the system was most recently operated during the winter of 2007/2008 (Ramsey County Staff, personal communication, January 8, 2009).

In addition to supporting its fish populations, Lake Owasso provides habitat for seasonal waterfowl, such as ducks and geese, which find refuge and forage in the lake's diverse macrophyte communities in the lake's large littoral area.

Shoreland Habitat and Restoration Potential

Over the last decade, greater attention has been given to shoreland management and ecological restoration. Lake shore restoration programs encourage the establishment of natural buffer using native plants that are less prone to erosion and provide quality fish and wildlife habitat. In September 2005, the RWMWD conducted a visual survey (by boat) of the Lake Owasso shoreline. Various parameters, such as the shoreline material, shoreline slope, restoration potential, and ownership, were recorded. Restoration potential was a subjective assessment that considered the other three parameters as well as evidence of shoreland use.

Lake Owasso has approximately 5 miles of shoreland, with 2 miles having good restoration potential, just less than a mile having moderate restoration potential, and another 2 miles identified as having poor restoration potential. The northwest and west sides of the lake have 2 large sections that have poor restoration potential as the result of steep slopes and riprap (northwest side) and a large cattail fringe (west side).

Sediment Core Analysis

Ten sediment cores were collected from Lake Owasso in May, 2007 and were analyzed for mobile phosphorus (which may potentially be recycled back into the overlying water through a process termed internal phosphorus loading) and organic bound phosphorus. Figure EX-8 shows the Lake Owasso sediment core locations and the interpolated distribution of mobile phosphorus loading rates based on the sediment core results. The average whole-lake internal loading rates calculated for these ranges of mobile phosphorus concentrations were 0.5 mg/m^2/day for Lake Owasso, with the highest expected loading rate being 2.9 mg/m^2/d in the deepest portion of the lake. Table EX-2 shows how the internal loading rate (deep hole) in Lake Owasso compares to the rates calculated for other Metro Area lakes, using the same methodology. .

Table EX-2 Comparison of Lake Owasso Internal Phosphorus Loading Rates to Those of Other Metro Area Lakes

Lake	Internal P Load (mg/m^2/d)
Isles (pre-alum, deep hole)*	14.1
Harriett (pre-alum, deep hole)*	11.1
Calhoun (pre-alum, deep)*	10.8
Fish E**	10.5
Cedar (pre-alum)*	9.3
Fish W**	8.1
Como**	7.6
Harriet**	6.9
Como-littoral**	5.7
Calhoun (pre-alum, shallow)**	5.6
Parkers**	3.5
Lake Owasso (deep hole)	**2.9**
Phalen**	2.3
McCarrons**	2.0
Bryant**	1.5
Nokomis**	1.0
Minnewashta**	0.2
Christmas**	0.0

Sources:
*Huser et al. (2009)
**Pilgrim et al. (2007)

The average internal phosphorus loading rate calculated for all of the Metro Area Lakes in Table EX-2 is 6.3 mg/m^2/day. The internal phosphorus loading rate from the sediments calculated for Lake Owasso is below this average. It is important to note that these rates represent the maximum potential internal loading rate that the lakes could experience, given persistent thermal stratification of the water column and near-sediment dissolved oxygen depletion . Most of the time, the lakes experience less internal phosphorus loading than these rates would indicate (as they assume perfect internal loading conditions).

Additionally, the amount of organic bound phosphorus was consistently higher than the mobile phosphorus measured in the sediments, indicating that available mobile phosphorus exported from the sediments during anoxic periods is quickly used by algae or plants, especially in the shallower areas of the lake.

Review of the temperature and dissolved oxygen data for Lake Owasso indicates that the lake thermally stratifies during the summer and that dissolved oxygen levels are depleted along the sediments, suggesting that internal loading from the sediments is likely. Although Lake Owasso is considered a deep lake that does thermally stratify (dimictic), with minimal mixing due to wind action, the average depth of the lake is 10.9 feet. There are several deep holes in the lake but the majority of the lake is shallow. The alignment of the lake is from the southwest to the northeast and because the predominant winds during the summer months are from the south and southeast, some mixing of the shallow areas of the lake may be possible, potentially bringing phosphorus released from the sediments to the surface waters of the lake. Additionally, anecdotal evidence indicates that motorboat activity results in the resuspension of bottom sediments in shallow areas of the lake.

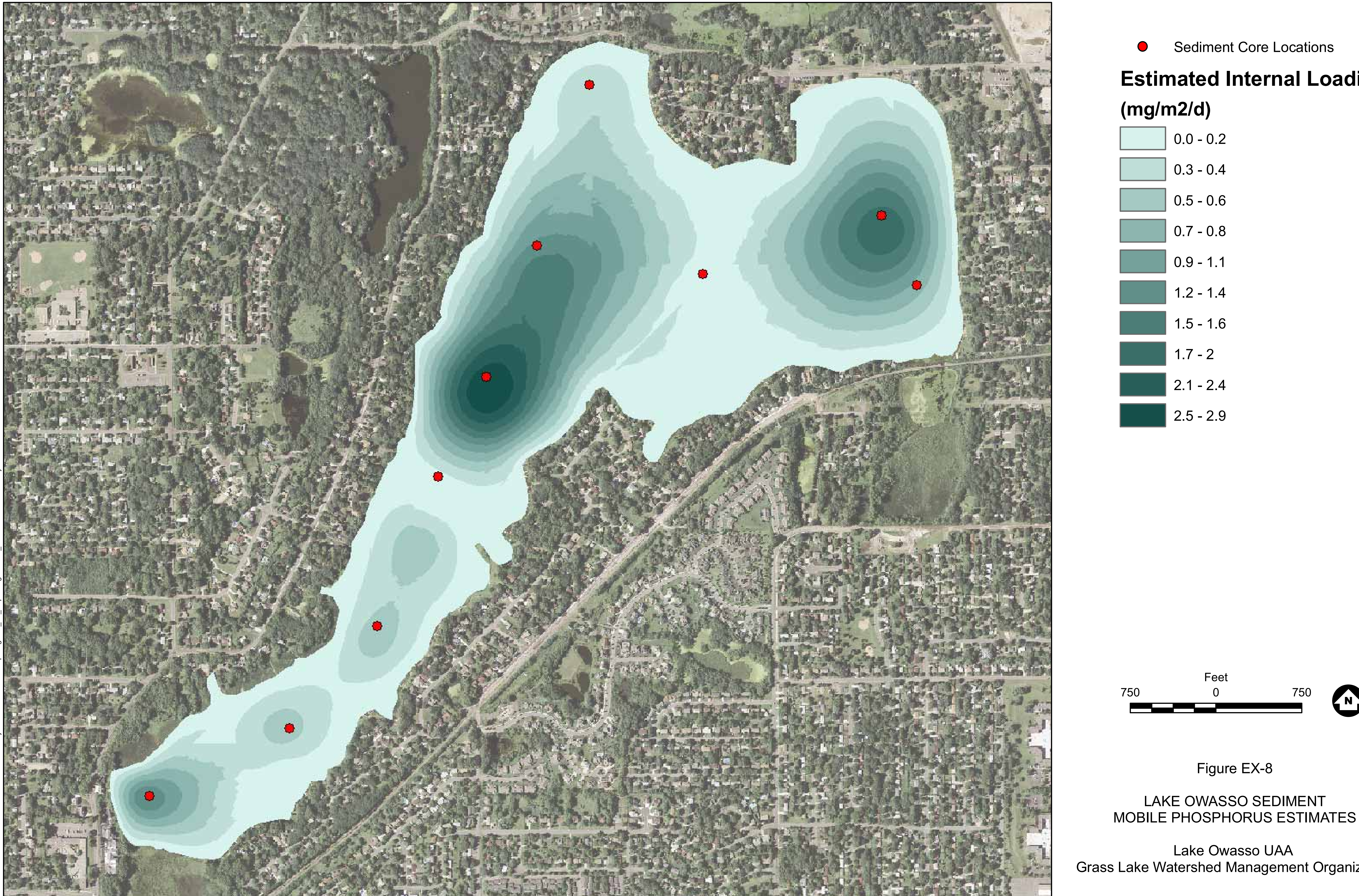


Figure EX-8

LAKE OWASSO SEDIMENT
MOBILE PHOSPHORUS ESTIMATES

Lake Owasso UAA
Grass Lake Watershed Management Organization

Baseline Lake Water Quality Status

There are several tools that can be used to evaluate the expected water quality in a lake. This study utilizes two different tools to estimate the expected water quality in Lake Owasso, including the relationship develop by Vighi and Chiaudani (1985) and the Minnesota Lake Eutrophication Analysis Program (MINLEAP) as developed by Heiskary and Wilson (1990) and programmed as part of the Wisconsin Department of Natural Resources Wisconsin Lake Modeling Suite (WiLMS, 2005). Additionally, Lake Owasso was part of a diatom reconstruction projects performed by the MPCA (Heiskary and Swain, 2002) that estimated historical phosphorus concentrations.

Vighi and Chiaudani

Vighi and Chiaudani (1985) developed a method to determine the phosphorus concentration in lakes that are not affected by anthropogenic (human) inputs. Using their method and information about the lake's mean depth and alkalinity or conductivity, the phosphorus concentration in a lake resulting from natural, background phosphorus loadings can be predicted. The Vighi and Chiaudani relationship was used to estimate the expected total phosphorus concentrations at each of the monitoring sites as well as across the lake as a whole.

The Vighi and Chiaudani relationship predicted phosphorus concentration from natural, background loadings to be 18.8 μg/L (ranging from 18.3 μg/L to 19.2 μg/L) based on specific conductivity. The expected total phosphorus concentration in Lake Owasso based upon the average alkalinity over the period of record was 22.4 μg/L. The predicted total phosphorus concentrations based upon the lake's specific conductivity and alkalinity are lower than the total phosphorus concentrations for monitoring sites 5401 and 5403 (30.3 μg/L and 51.9 μg/L, respectively), indicating that some improvement in lake water quality may be attainable.

Minnesota Lake Eutrophication Analysis Program (MINLEAP)

MINLEAP is intended to be used as a screening tool for estimating lake conditions and identifying "problem" lakes and has also been used to identify Minnesota lakes which may be in better or worse condition that they "should be" based upon their location, watershed area, and lake basin morphometry (Heiskary and Wilson, 1990).

Using the long-term summer average total phosphorus, chlorophyll *a*, and Secchi depth, MINLEAP estimated the expected concentration or depth of each of the above parameters as well as the standard error associated with the average values. For total phosphorus, the expected concentration was estimated to be 40 μg/L (with a range of 25 μg/L to 55 μg/L). The estimated chlorophyll *a* concentration was estimated to be 14.3 μg/L (with a range of 5 μg/L to 23.6 μg/L). The estimated Secchi depth for Lake Owasso was 1.6 meters (with a range of 0.9 meters to 2.3 meters). For all water quality parameters, the actual monitoring data falls within the range of a minimally-impacted lake with similar characteristics to Lake Owasso.

Water Quality Reconstruction from Fossil Diatoms

Diatom reconstructions of historical phosphorus concentrations can provide a opportunity to examine temporal and spatial trends in eutrophication, helping identify the timing and extent of cultural disturbances as well as identifying predisturbance conditions (Reavie et al., 1995). In 2002, the MPCA completed a study of diatoms in 55 lakes within Minnesota, including Lake Owasso.

The results of the diatom analysis for Lake Owasso indicate that, prior to European settlement, its water quality would have been categorized as mesotrophic (total phosphorus concentrations between 10 and 25 μg/L), with significant increases in total phosphorus and chloride occurring in the 1970s and 1990s, likely the result of development in the watershed and surrounding road network. Data from the mid- to late 1990s indicated declining total phosphorus levels, likely reflecting a period of less development and increased efforts to improve stormwater retention and treatment upstream of the lake. The sediment and diatom analysis also indicated that sediment accumulation rates increased steadily from 1900, with peaks in 1960 and 1980; some reductions in accumulation rates is evident since that time, again likely linked to decreasing development and use of stormwater treatment practices.

Lake Owasso Water and Pollutant Loads

Watershed Pollutant Load Modeling

Stormwater Volume Calibration

The stormwater runoff modeling calibration process involved two phases. First was the calibration of the predicted P8 runoff volume to actual stormwater monitoring data. The second phase included developing a water balance model calibrated to lake level data to verify runoff volumes and estimate the expected groundwater exchange.

Stormwater Monitoring Sites (2007 and 2008)

The P8 model runoff volumes were originally calibrated to the 2007 flow monitoring data at the Galtier Street, County Road C, and West Owasso Boulevard monitoring sites. The calibrated watershed runoff parameters were based on the Galtier Street monitoring station data, as this watershed did not contain any ponds or other water quality treatment devices. The watershed parameters were applied to all subwatersheds in the Lake Owasso watershed. For both the County Road C and West Owasso Blvd. sites, the initial 2007 P8 model runs over-predicted the runoff volumes at each site. To calibrate model predictions to the actual 2007 monitoring data, an “infiltration” rate was applied to the major natural ponds and wetlands located throughout the watersheds. . This “infiltration” rate is not solely a loss to infiltration but represents losses to infiltration as well as excessive evaporation. A limitation of the P8 pollutant loading model is that this rate is a constant loss that cannot vary throughout the year.

The calibration of the runoff predicted by the P8 model was further refined with the additional monitoring data collected in 2008. This included modifications to the estimated pond and wetland “infiltration” rates as well as developing modified discharge rating curves for both the Central Park Pond—East (Dale Street) and the Central Park Pond—West (County Road C) wetlands based on the 2008 flow monitoring data. Additionally, a baseflow parameter was incorporated into the West Owasso Boulevard system to account for continuous flows observed during 2008. Table EX-3 summarizes the results of the runoff volume calibration.

Table EX-3 Summary of Lake Owasso P8 Runoff Calibration

Parameter	Site 1: Galtier Street (LO_E_1f)	Site 2: County Road C (LO_S_1)	Site 3: West Owasso Blvd. (Dschg36)	Site 4: Dale Street (LO_S_2a)
2007 Individual Site Predicted/Observed Volume Ratios[1]	1.03	0.97	1.87[2]	N/A
2008 Individual Site Predicted/Observed Volume Ratios[1]	N/A	0.97	1.03	1.04

1. Based on Cumulative Runoff Volume over the monitoring period.
2. This discrepancy is due to variation of a single storm event across the Lake Owasso watershed, as reviewed on the Minnesota Climatology Working Group website (http://climate.umn.edu/hidradius/HIDENmapFile.asp)

Water Balance Model (2006 to 2008)

Daily precipitation, the total estimated daily watershed runoff to Lake Owasso from the calibrated P8 model, along with daily evaporation values (estimated by the Meyer Model for years prior to 2008 and daily values estimated from the St. Paul Campus Climatological Observatory for 2008) and the Lake Owasso discharge rating curve were used to develop a daily water balance model. WATBUD (developed by the MDNR) was used to estimate the groundwater exchange for Lake Owasso and to verify the watershed runoff volumes predicted by the P8 model for 2008 (the calibration period). The predicted lake levels were then compared to observed lake levels, and adjustments were made to the model input parameters to obtain an optimal match between predicted and observed conditions. The groundwater exchange values from the 2008 calibration were then applied to 2006 and 2007 for verification. The results of the water balance are shown on Figure EX-9.

Several key observations were made during the runoff calibration of the P8 model and development of the Lake Owasso water balance, including the following:

- Surveys of the inverts of the outlets of the Central Park wetlands (at Dale Street and at County Road C) and review of the flow monitoring data indicates that the water levels and discharges from these water bodies are, at times, significantly impacted by the water levels in Lake Owasso. This results in rating curves for the Central Park wetlands that vary with time, depending on the water levels of Lake Owasso.

- During both the summers of 2007 and 2008, there were several ponds and wetlands with water levels below their normal outlets during portions of the summer. This included the crossing at County Road C, whose contributing area is approximately half of the Lake Owasso watershed.

- Lake Owasso is a groundwater lake that experiences periods of seepage and recharge, throughout the year. The extent of groundwater exchange varies throughout the year (seasonally). Additionally, there is variability between years as well. This was confirmed by the use of winter lake level data to estimate groundwater exchange during periods of no discharge from the Lake.

- During the winter months, discharge from Lake Owasso is reduced due to the accumulation of ice around the outlet structure, as confirmed by the City of Shoreview (Maloney, personal communication, 1/18/2008). Therefore, the Lake Owasso rating curve is variable during the winter months and is dependent on the timing of the ice-on and ice-off conditions.

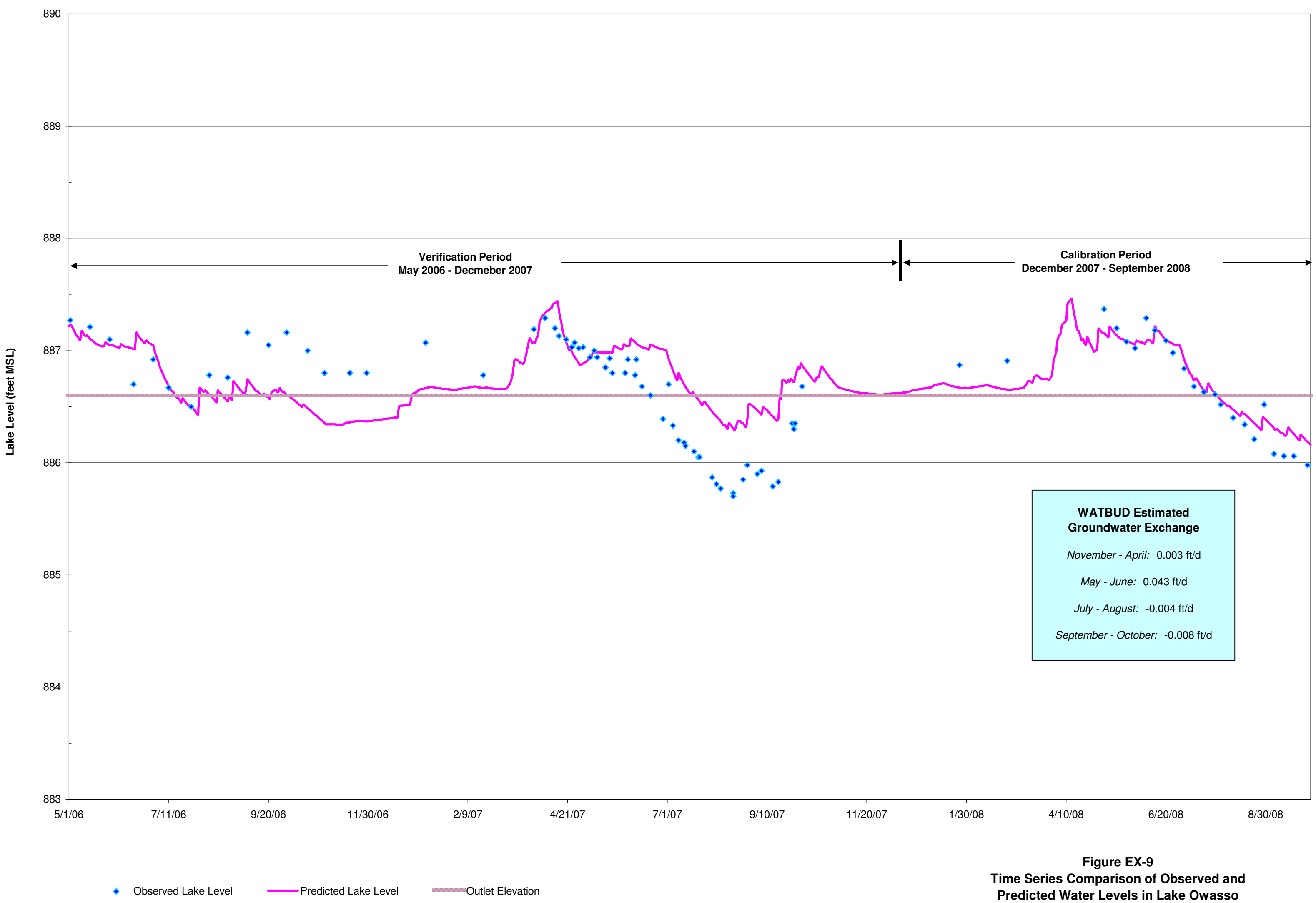


Figure EX-9
Time Series Comparison of Observed and Predicted Water Levels in Lake Owasso from the 2006 through 2008 Water Balance

Watershed Pollutant Loading Calibration

Because actual monitoring data related to the quantity and quality (total suspended solids (TSS) and total phosphorus (TP)) of stormwater runoff was available at monitoring locations around Lake Owasso in 2007, a detailed calibration of the particle and pollutant relationship in P8 was able to be performed so that model results would closely mimic the actual monitoring data from each of the sites. However, because total dissolved phosphorus was not measured, the model was not calibrated to the dissolved fraction.

Calibration was originally focused on data collected at the Galtier Street monitoring station, as this station reflected only watershed runoff (there was no treatment in the watershed upstream of the monitoring station). This would allow for the calibration of the P8 watershed pollutant loading parameters. Calibration at this site was for both TSS and TP event flow-weighted concentration, event loads, and cumulative loads. These watershed pollutant loading parameters were applied to all subwatersheds in the Lake Owasso watershed.

Similar to the runoff volume calibration method, the monitoring site at Galtier Street was used first to calibrate the pollutant parameters related to watershed build-up, wash-off, decay, and impervious and pervious runoff concentrations, as there are no treatment devices such as ponds or wetlands in the contributing watershed.

After the TSS parameter was calibrated, the TP parameters were calibrated. The 2007 water quality data was limited to total phosphorus data; therefore, it was not possible to calibrate the dissolved fraction of phosphorus (TP associated with P0). It was assumed that the P0 particle composition was equal to that used in the NURP50 particle file (99,000 mg/kg). The remaining TP particle compositions for the other particle fractions (P10% to P80%) were also maintained from the NURP50 particle file. However, the TP scale factor was adjusted to best match the Galtier Street monitoring data. Table EX-4 summarizes the results of the TSS and TP calibration procedure.

Table EX-4 TSS and TP Calibration Results (LkOwasso.par)

Parameter Adjusted	Calibrated Value
Accumulation Rate (lb/ac/day) (P10%-P50%/P80%)	1.6 / 2.8
Accumulation Decay Rate (1/day)	0.35
Impervious Runoff Coefficient	5
Impervious Runoff Exponent	3
Pervious Runoff Concentration (mg/L) (P10%-P50%/P80%)	50
Pervious Runoff Exponent	1
TP P0% Particle Composition (mg TP/kg TSS)	99000
TP P10%-P80% Particle Composition (mg TP/kg TSS)	3850
TSS Scale Factor	1
TP Scale Factor	0.7

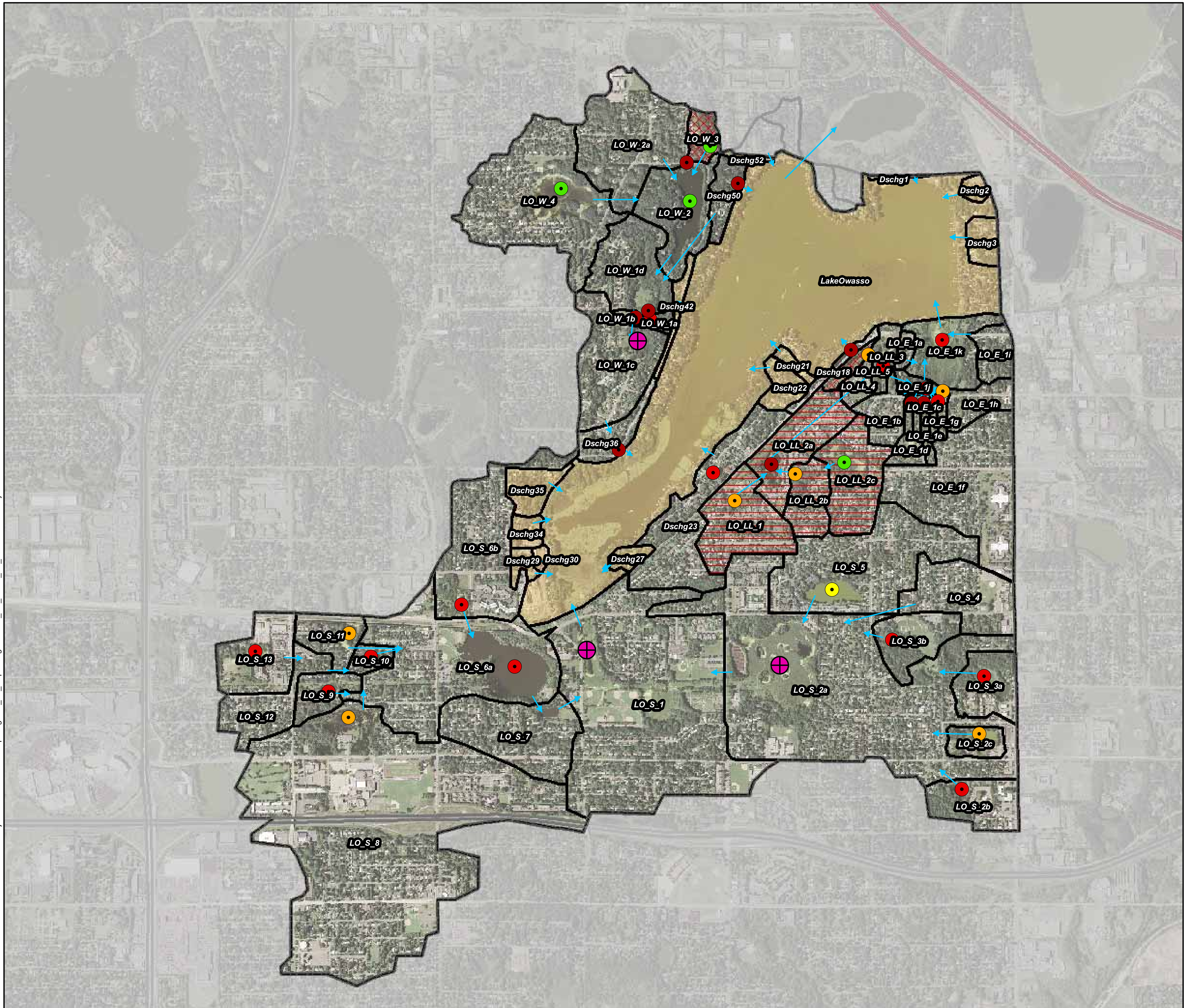
Grab samples collected in between storm events at County Road C (Central Park – West wetland) during the summer of 2008 indicated that the concentration of the wetland was significantly higher between storm events than the concentrations observed during actual storm events, indicating the potential "internal" loading of TP within the wetland. This internal loading may be the result of a variety of factors, such as the resuspension of sediments due to activity of carp (observed in the wetland during the summer of 2008), phosphorus release from sediments, and other biological activity in the wetland.

One of the limitations of the P8 model is that it does not account for particle resuspension or loading as the result of other chemical or biological activity. As a result, the FLUX model was used to help to estimate the rate of internal TP loading for each waterbody located immediately upstream of the County Road C (Central Park – West wetland), Dale Street (Central Park – East), and West Owasso Boulevard (Charlie Ponds) monitoring stations using both 2007 and 2008 data where applicable. The FLUX model (Walker 1986) uses continuous flow records and parameter concentrations from sampled events to develop flow weighted mean concentrations and loading (in kg/yr) for sites where both flow and sample analysis data are available.

The combination of the P8 predicted watershed loads and the estimated internal loading from watershed water bodies were used as inputs into the in-lake water quality models developed for Lake Owasso for the various climatic conditions.

The sediment and phosphorus removal efficiencies of the stormwater BMPs varies based on numerous factors, including the size of the pond or basin, the amount of stormwater treated, and design details such as the pond shape or outlet configuration. The P8 model developed for the 2008 watershed conditions was used to evaluate the performance of the BMPs within the Lake Owasso watershed.

The overall total phosphorus removal efficiency within the Lake Owasso watershed during the 2008 calibration year was approximately 64 percent. The predicted annual total phosphorus removal efficiencies for each pond, wetland or BMP modeled in P8 are shown in Figure EX-10, with the color of each treatment device representing the estimated annual total phosphorus removal as a percent. The BMP locations shown in orange, yellow, or green achieved predicted total phosphorus removal efficiencies greater than 40 percent (comply with NURP water quality standards). The BMP locations that shown in shades of red achieved predicted removal efficiencies less than 40 percent. Waterbodies that may act as a source of phosphorus to the system are shown with the pink cross-hair symbol.



TP Removal (%)

- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- Internal Phosphorus Loading
- Watershed Flow Direction
- Subwatersheds
- Land-Locked Watersheds
- Pumped Outlet Watersheds
- Watersheds without Treatment

Feet

1,750 0 1,750

N

Figure EX-10

LAKE OWASSO
TOTAL PHOSPHORUS REMOVAL EFFICIENCIES
EXISTING CONDITIONS - 2008

Lake Owasso UAA
Grass Lake Watershed Management Organization

In-Lake Water Quality Modeling

To evaluate the lake's response to watershed and internal loads of phosphorus under a range of precipitation conditions, in-lake water quality models were created to route the P8 generated watershed loads, along with the estimated internal load from the major waterbodies in the watershed, through the lake for the following time periods:

- "Dry" climatic conditions: May 2007 - September 2008
- "Average" climatic conditions: May 2004- September 2005
- "Wet" climatic conditions: May 2001- September 2002

Because the detailed in-lake water quality monitoring data in 2007 and 2008 was collected at two different locations within Lake Owasso (Site 5401 in the north and Site 5403 in the south), the in-lake water quality model was developed as a two-basin model. For the initial calibration of the Lake Owasso in-lake water quality model, the 2007 and 2008 water quality and the 2007 macrophyte survey data were used. However, because there was a significant amount of historic water quality data available at depth for Lake Owasso, in-lake modeling was performed for each climatic condition year to estimate the internal loading (from sediments and macrophyte senescence) within Lake Owasso. Parameters calibrated to the 2007 and 2008, such as the macrophyte coverage and estimated growth and die-back dates, were applied to all climatic condition models. Watershed runoff loads as predicted by P8, as well as the estimated watershed wetland "internal" loads, were developed specifically for each climatic condition.

The 2008 calibration year was selected to be representative of the dry climatic conditions for Lake Owasso, and was modeled as a two-basin in-lake model. For the wet (2002) and average (2005) climatic conditions, water quality data was only available at the northern sampling site (site 5401) and the in-lake water quality model was developed as a single basin.

The in-lake modeling methodology used for the Lake Owasso UAA is two-fold: First, the spring concentration is estimated with a steady-state, annual empirical lake model. Second, a spreadsheet mass balance model based on Dillon and Rigler (1974) is used that starts with the estimated spring concentration (from the empirical model) and routes external and internal phosphorous loads through the lake over many time steps throughout the summer season (May through September).

The method was used for existing land use conditions under a variety of climatic conditions. Once the internal loading rates have been calculated, the model could be used predictively, to evaluate lake phosphorus concentrations under a variety of BMP scenarios for each hydrologic condition. Impacts as the result of futures changes in land use were not evaluated as the Lake Owasso watershed is already fully-developed, the expected changes are minimal. As a result, future land use conditions were not evaluated.

Lake Owasso Water and Phosphorus Budgets

The main phosphorus sources to Lake Owasso include watershed runoff and internal loads from water bodies within the watershed, atmospheric deposition, groundwater inflows, as well as the estimated internal loads (due to things such as the die-back of Curlyleaf pondweed and release from sediments).

Using the mass balance equation, the net internal loading for each climatic condition was calculated. The internal loading sources of phosphorus quantified for Lake Owasso included both the release of phosphorus from the die-back of Curlyleaf pondweed as well as from anoxic sediment release. It is important to remember that the internal load is delivered over a concentrated period of time- the growing season- during which time it can efficiently contribute to nuisance algal growth in the lake. The annual phosphorus loads to Lake Owasso from the internal sources are summarized in Table EX-5, along with the sources of water loads to the lake as well as the external sources of phosphorus.

Figures EX-11, EX-12, and EX-13 show the annual water and phosphorus budgets for Lake Owasso for the wet, dry, and average climatic conditions, respectively. Because the dry climatic year (2008; also the calibration year) was modeled as a two-basin system, the water and phosphorus budgets are shown for both the south and north basins, as well as for the overall lake system. These water and phosphorus budget figures put the estimated internal phosphorus loads in perspective with the external watershed loads that Lake Owasso receives on an annual basis.

Table EX-5 Lake Owasso Water Loads and Phosphorus Loads for Wet, Dry, and Average Climatic Conditions

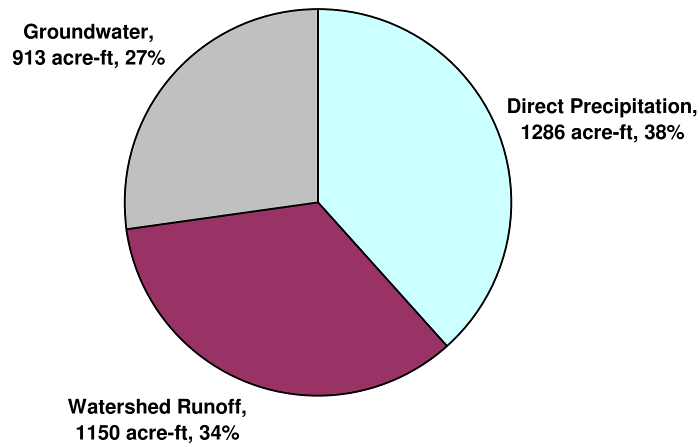
Climatic Condition		Wet	Dry[3]	Average
Water Year		2002	2008	2005
Water Budget				
Source		Volume (acre-ft)	Volume (acre-ft)	Volume (acre-ft)
Direct Precipitation		1286	644	987
Watershed Runoff		1150	509	401
Groundwater[1]		913	913	913
TOTAL WATER LOAD		***3348***	***2066***	***2300***
Phosphorus Budget				
Source		TP Load (lbs)	TP Load (lbs)	TP Load (lbs)
External Load Sources	Watershed Runoff	252	102	87
	Internal Loading from Watershed Water Bodies	89	29	60
	Atmospheric Deposition	90	88	91
	Groundwater	62	62	62
	TOTAL EXTERNAL LOAD	*493*	*281*	*300*
Internal Load Sources	Curlyleaf Pondweed[2]	184	184	184
	Internal Sediment Release	398	91	221
	TOTAL INTERNAL LOAD	*582*	*275*	*405*
TOTAL PHOSPHORUS LOAD		***1076***	***556***	***705***

1 - Groundwater exchange was estimated based on the 2008 Lake Owasso water balance modeling. It was assumed that the calibrated groundwater exchange would apply to all climatic conditions.

2 - Coverage & Density of Curlyleaf Pondweed assumed to be the same as estimated from the 2007 macrophyte survey conducted by Ramsey County Public Works for all climatic conditions.

3 - 2008 Calibration Year

Lake Owasso Annual Water Load (3,348 acre-ft)
2002 (Wet) Calibration Year



Lake Owasso Annual Phosphorus Load (1,076 lbs)
2002 (Wet) Calibration Year

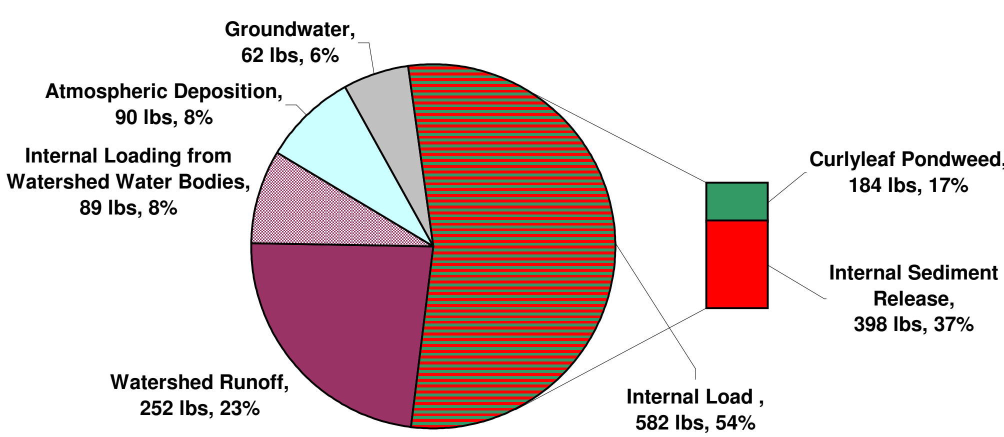


Figure EX-11
Lake Owasso
Water and Total Phosphorus Budget
Wet Climatic Conditions

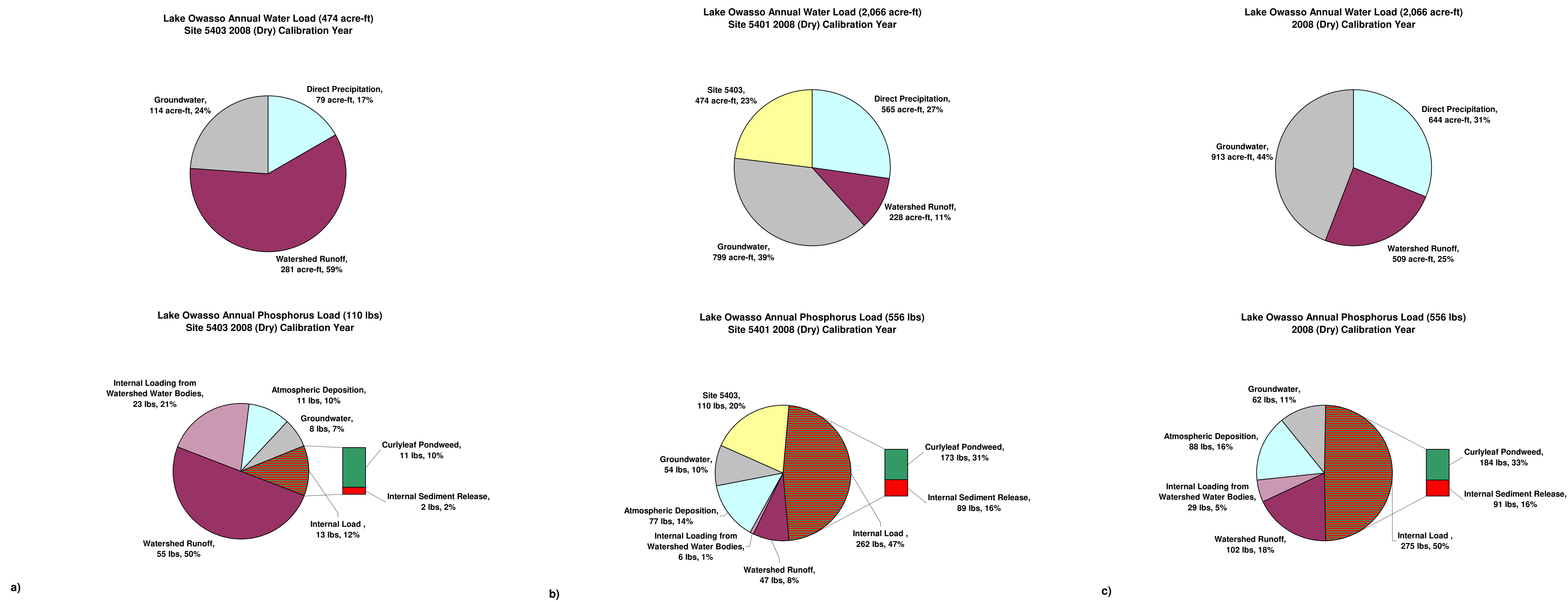


Figure EX-12
Lake Owasso
Water and Total Phosphorus Budget
Dry Climatic Conditions
a) Site 5403 (South Basin)
b) Site 5401 (North Basin)
c) Lake Owasso - Entire Basin

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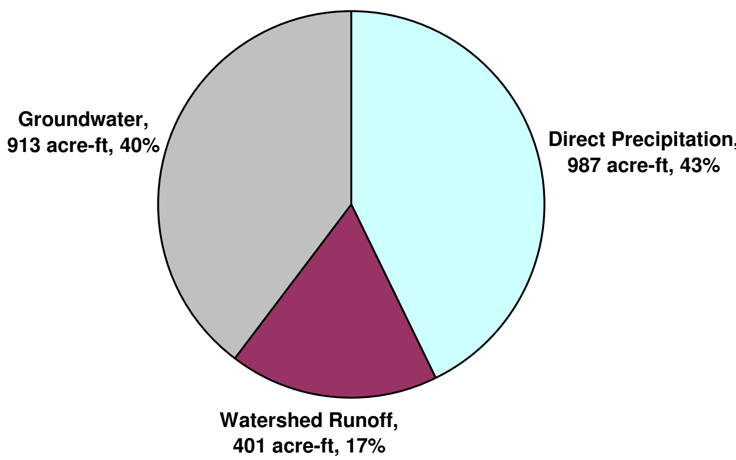
Lake Owasso Annual Water Load (2,300 acre-ft)
2005 (Avg) Calibration Year



Lake Owasso Annual Phosphorus Load (705 lbs)
2005 (Avg) Calibration Year

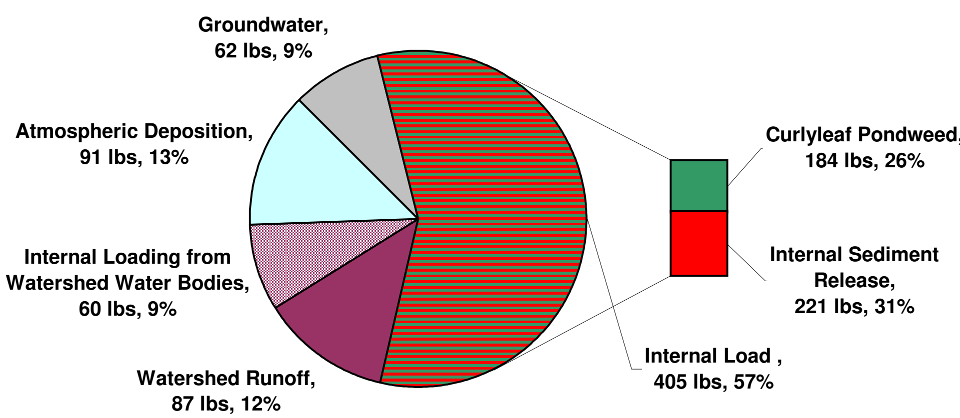


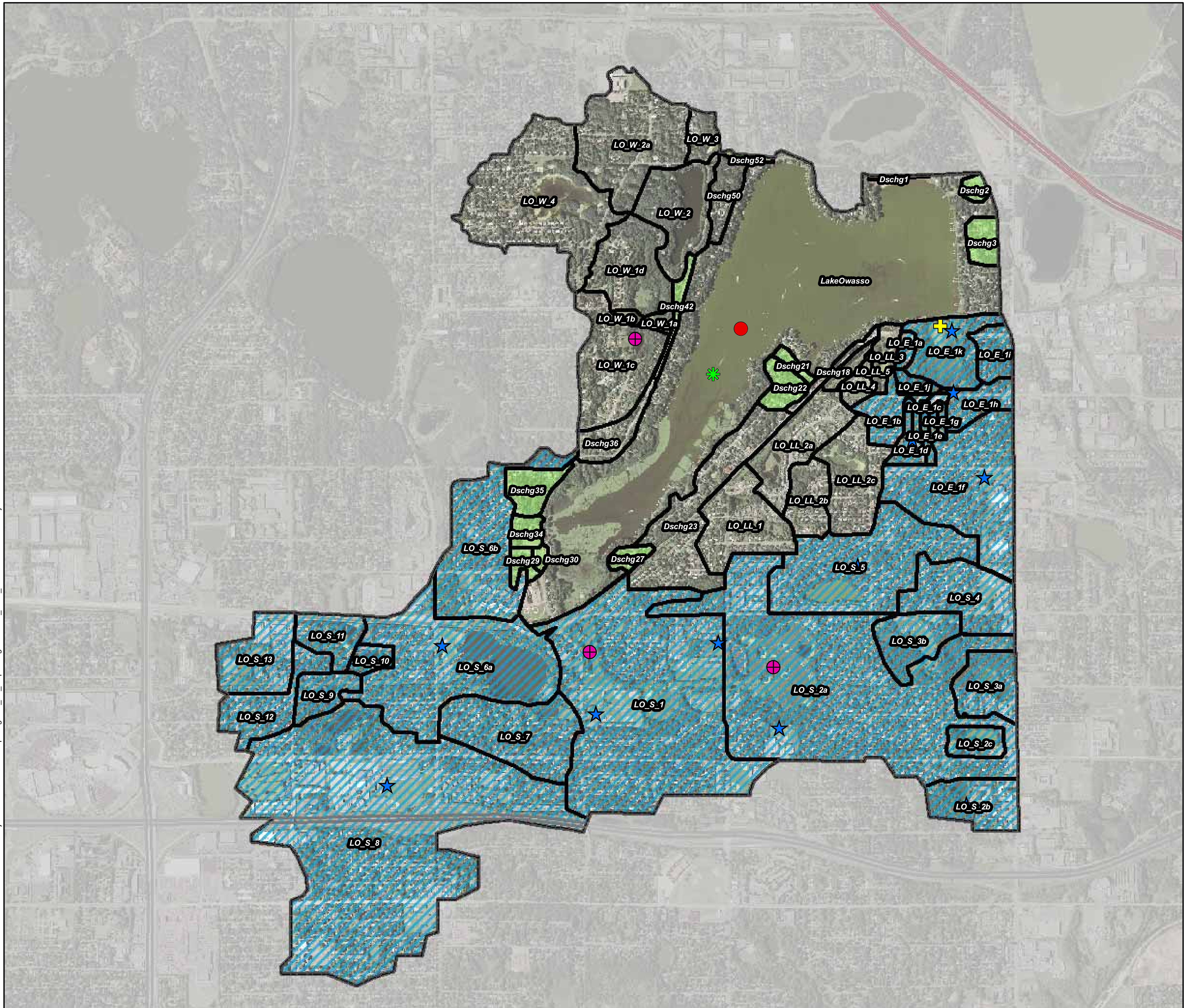
Figure EX-13
Lake Owasso
Water and Total Phosphorus Budget
Average Climatic Conditions

Feasibility Study

To maintain or improve the water quality in Lake Owasso, it will be necessary to implement BMPs in the lake as well as within the watershed. .A variety of treatment BMPs have been implemented in the Lake Owasso watershed in recent years as opportunities arose from road reconstruction or redevelopment. Additionally, several other types of BMPs were evaluated to estimate their potential impact on the overall water quality in Lake Owasso.

Three types of BMPs were considered for recommendation in this plan (structural, in-lake, and nonstructural), with each type being defined and discussed in Section 6.1 of this UAA. For watershed and in-lake water quality modeling, only structural and in-lake BMPs were evaluated for their potential impact on Lake Owasso's water quality, using the P8 and in-lake water quality models.

Specific BMP alternatives that were considered for Lake Owasso and its watershed are discussed in detail in Section 6.3 of the UAA. Selection of the BMP scenarios was primarily based upon the Lake Owasso phosphorus budgets developed for the various climatic conditions to target the major sources of phosphorus to the lake, and include: management of Curlyleaf pondweed, reductions in the estimated internal loading from water bodies within the watershed, treatment of all currently untreated watershed to NURP standards, development of extended detention in the bay in Ladyslipper Park, infiltration scenarios within the watersheds, alum treatment of sediments within the lake, as well as combinations of these BMP scenarios. Figure EX-14 shows the locations of the BMPs evaluated as part of the feasibility analysis and Table EX-6 summarizes the results of the various BMP scenarios evaluated as part of this UAA. Included in this summary table are the predicted in-lake water quality (TP and SD) for each climatic conditions as well as a planning level cost estimate for the BMPs evaluated. Figure EX-15 shows the estimated summer average total phosphorus concentration and Secchi depth in comparison with the MPCA and GLWMO goals for Lake Owasso. It is important to note that not all of the BMP alternatives evaluated are recommended for implementation.



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Scenario2:
Curlyleaf Pondweed Management

Scenarios 3 & 4:
Reduction in Internal Loading (10% & 50% Reduction)

Scenario 6:
Extended Detention in Bay (Ladyslipper Park)

Scenario 8:
Infiltration of 0.5" of Runoff from Contributing Impervious Area

Scenario 9:
Alum Treatment

Secnario 5:
Treatment to NURP Standards

Scenario 7:
Infiltration of 0.5" of Runoff from ALL Impervious Surfaces

Subwatershed

Feet
1,750 0 1,750

N

Figure EX-14

LAKE OWASSO
SUMMARY OF BMP SCENARIOS

Lake Owasso UAA
Grass Lake Watershed Management Organization

Table EX-6 Lake Owasso Summary of BMP Scenarios

Scenario		Summer Average Water Quality							Reduction in TP (%)	Estimated BMP Cost ($)
		Wet		Dry			Average			
		2001-2002		2007-2008			2004-2005			
		TP (µg/L)	SD (m)[10]	Site[1]	TP (µg/L)	SD (m)[10]	TP (µg/L)	SD (m)[10]		
1	Existing Conditions[2]	32	2.4	5403	41	2.0	45	1.5	--	--
				5401	32	2.1				
2	80% Reduction in Curlyleaf Pondweed[6]	21	3.7	5403	29	2.6	33	2.3	27 - 39%	$649,000
				5401	19	4.2				
3	10% Reduction in the Internal Loading from Watershed Waterbodies	31	2.4	5403	38	2.0	44	1.8	2 - 4%	N/A[12]
				5401	31	2.4				
4	50% Reduction in the Internal Loading from Watershed Waterbodies	28	2.6	5403	29	2.5	42	1.9	7 - 13%	N/A[12]
				5401	30	2.5				
5	Treatment of All "Untreated" Discharges to NURP Standards[5]	32	2.3	5403	40	2.0	45	1.8	0 - 3%	$350,000
				5401	31	2.4				
6	Extended Detention in Ladyslipper Park Pond (Replace outlet under the Railroad)[7]	32	2.3	5403	41	1.9	45	1.8	0 - 3%	$55,000
				5401	31	2.4				
7	Infiltration of 0.5 inches of Runoff from ALL Impervious Surfaces in the South and East Drainage Districts[3,8,11]	26	2.9	5403	32	2.3	37	2.1	4 - 20%	$4,770,000
				5401	30	2.4				
8	Infiltration of 0.5 inches of Runoff from Select Impervious Surfaces in the South and East Drainage Districts[3,9,11]	31	2.4	5403	37	2.1	44	1.8	2 - 3%	$389,000
				5401	31	2.4				
9	Alum Treatment (80% Reduction in Internal Load from Sediments)	28	2.6	5403	40	2.0	43	1.9	6 - 11%	$198,000
				5401	30	2.5				
10 (2 + 3)	80% Reduction in Curlyleaf Pondweed & 10% Reduction in the Internal Loading from Watershed Waterbodies[6]	20	3.9	5403	26	2.8	32	2.3	29 - 39%	N/A[12]
				5401	19	4.2				
11 (2 + 4)	80% Reduction in Curlyleaf Pondweed & 50% Reduction in the Internal Loading from Watershed Waterbodies[6]	17	5.4	5403	17	5.1	29	2.5	35 - 47%	N/A[12]
				5401	18	4.6				
12 (2 + 8)	80% Reduction in Curlyleaf Pondweed & Infiltration of 0.5 inches of Runoff from Select Impervious Surfaces in the South and East Drainage Districts[6,3,9]	20	3.9	5403	25	3.0	31	2.4	31 - 38%	$1,038,000
				5401	20	4.1				
13 (2 + 9)	80% Reduction in Curlyleaf Pondweed & Alum Treatment (80% Reduction in Internal Load from Sediments)[6]	17	5.1	5403	28	2.6	30	2.4	33 - 46%	$847,000
				5401	18	4.6				

TP: Total Phosphorus Chl*a*: Chlorophyll *a* SD: Secchi Depth

1 - For 2008 (Dry Climatic Conditions), Lake Owasso was modeled as 2 separate basins (5403 - Southern Basin, and 5401 - Northern Basin) as there was water quality data available for both areas of the lake. For 2002 (Wet Climatic Conditions) and 2005 (Average Climatic Conditions), the water quality data was only collected at basin 5401 and the lake was modeled as a single basin.

2 - Existing land use and 2008 watershed/BMP conditions. Very few changes are expected in land use as the Lake Owasso watershed is fully-developed. Therefore, it was assumed that existing land use is also reflective of future land use conditions.

3 - Internal loading from the watershed was modified for the infiltration scenario based on the reduction in water load to the wetlands.

4 - It is not feasible to treat all currently untreated direct discharges to Lake Owasso using a single NURP pond. This analysis was performed to demonstrate the impact that treating each discharge to NURP standards would have on overall lake water quality

5 - This scenario is not physically feasible as the currently "untreated" direct discharges are distributed around the entire shoreline of Lake Owasso. Additionally, there is not sufficient space to incorporate NURP ponds in each of the direct discharge watersheds. This scenario was evaluated to demonstrate the impact of treating all direct discharges on the overall water quality in Lake Owasso. This cost estimate is based on the construction of a single, hypothetical NURP pond sized to treat all "untreated" discharges to Lake Owasso.

6 - The estimated cost of the Curlyleaf Pondweed Treatment includes the MDNR variance to treat the entire littoral area of Lake Owasso, 4-years of herbicide application to the Lake, as well as 4-years of detailed macrophyte monitoring to track the herbicide treatment on the Curlyleaf pondweed coverage

7 - Development of an extended detention basin in Lady Slipper Park (in subwatershed LO_E_1k) along with the replacement of the outlet under the railroad embankment with a weir structure were evaluated as part of the 1991 *Report on the Diagnostic-Feasibility Study of Lake Owasso, Lake Wabasso, and Snail Lake.* Since 1991, the City of Roseville developed infiltration and sedimentation ponds in this area as part of the South Owasso Boulevard road reconstruction project in 2006. This study evaluates replacing the outlet under the railroad embankment only.

8 - Infiltration of 0.5" from all impervious surfaces in the South and East Drainage Districts is not feasible. This scenario was evaluated to estimate the maximum impact infiltration could potentially have on Lake Owasso's water quality.

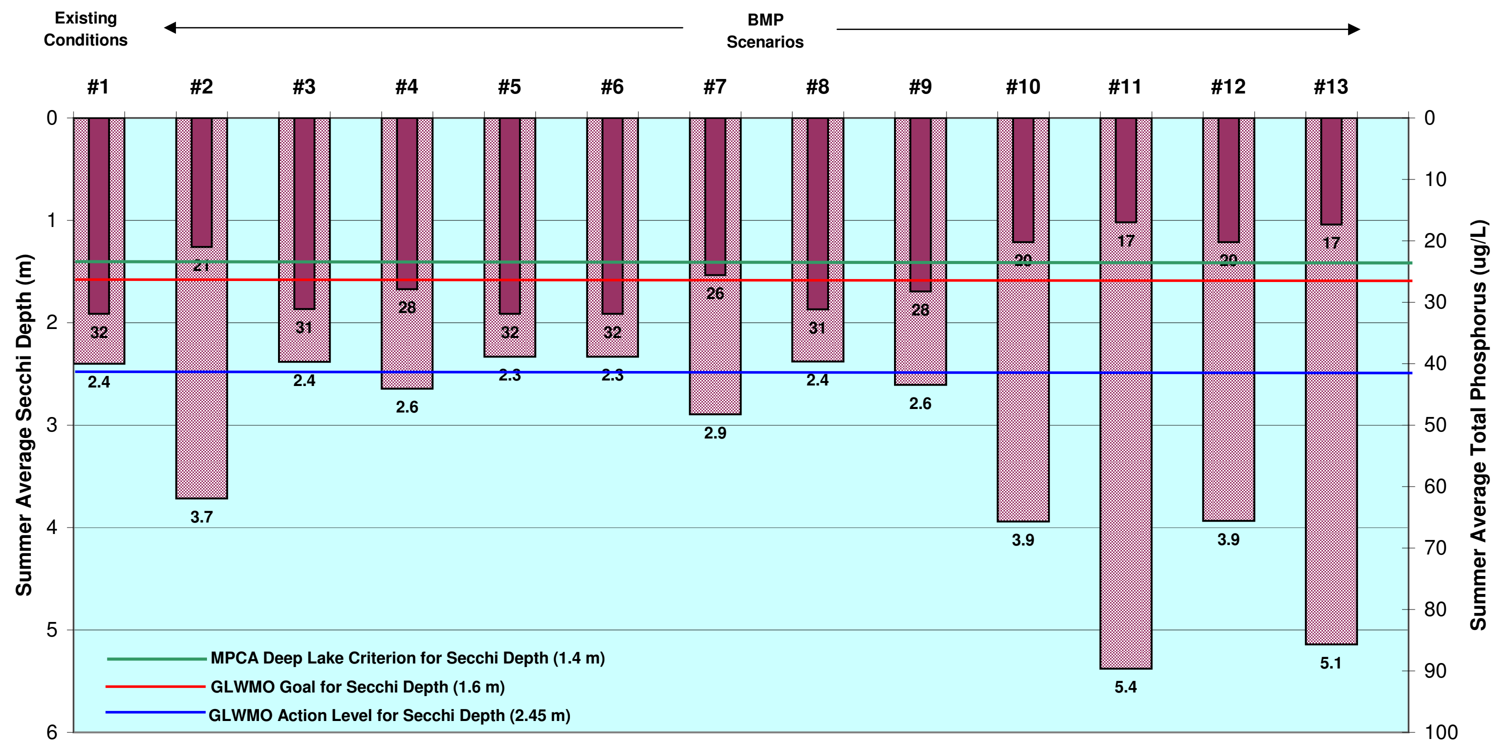
9 - Selected potential infiltration sites include 11 preliminary locations within the South and East Drainage Districts. Sites were selected based on the presence of open space, proximity to existing storm sewer (potential to reroute or divert flows), and topography. Available soils data were condsidered although much of the Lake Owasso is classified as undefined hydrologic soils group. These are planning level cost estimates and each site would require a more complete feasibility study before final design.

10 - Existing Condition summer average Secchi depth based on 2008 monitoring data; For all BMP scenarios, estimated based on the Secchi Depth versus Total Phosphorus Regression Relationship for Lake Owasso (See Figure

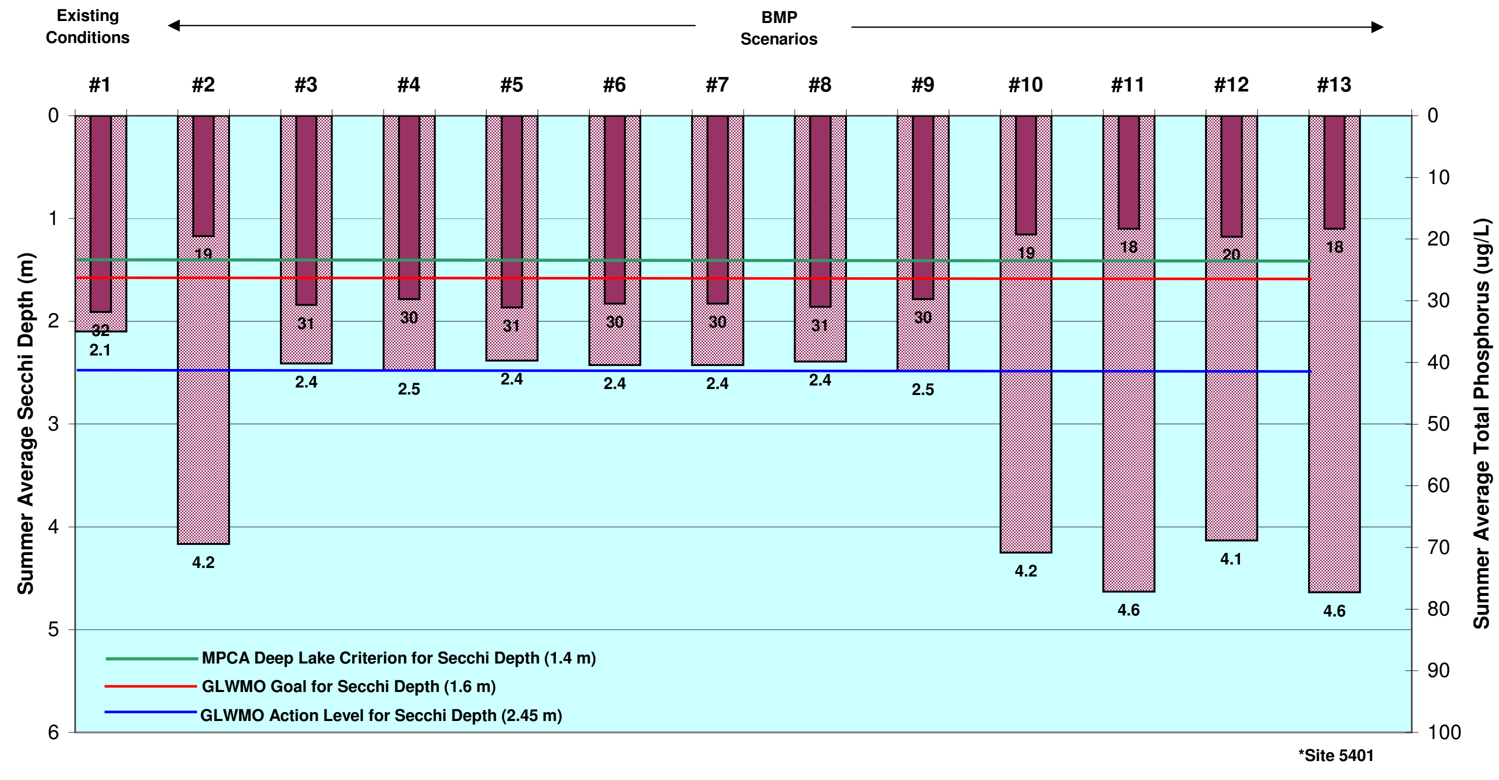
11 - The estimated cost of infiltration BMPs is based on typical unit costs ($13/sq.ft.) estimated for the construction of rain gardens plus 30 percent for engineering and design. Depression storage was assumed to be 18 inches. This cost does not include any potentially significant changes to the storm sewer system/additional piping that may be needed.

12 - Because specific BMPs to address the internal loading in the waterbodies within the watershed are not recommended until further studies of the internal loading can be completed, no costs have been estimated for these scenarios.

Lake Owasso Water Quality
Wet Year (2002) Climatic Conditions



Lake Owasso Water Quality
Dry Year (2008) Climatic Conditions*



Lake Owasso Water Quality
Average Year (2005) Climatic Conditions

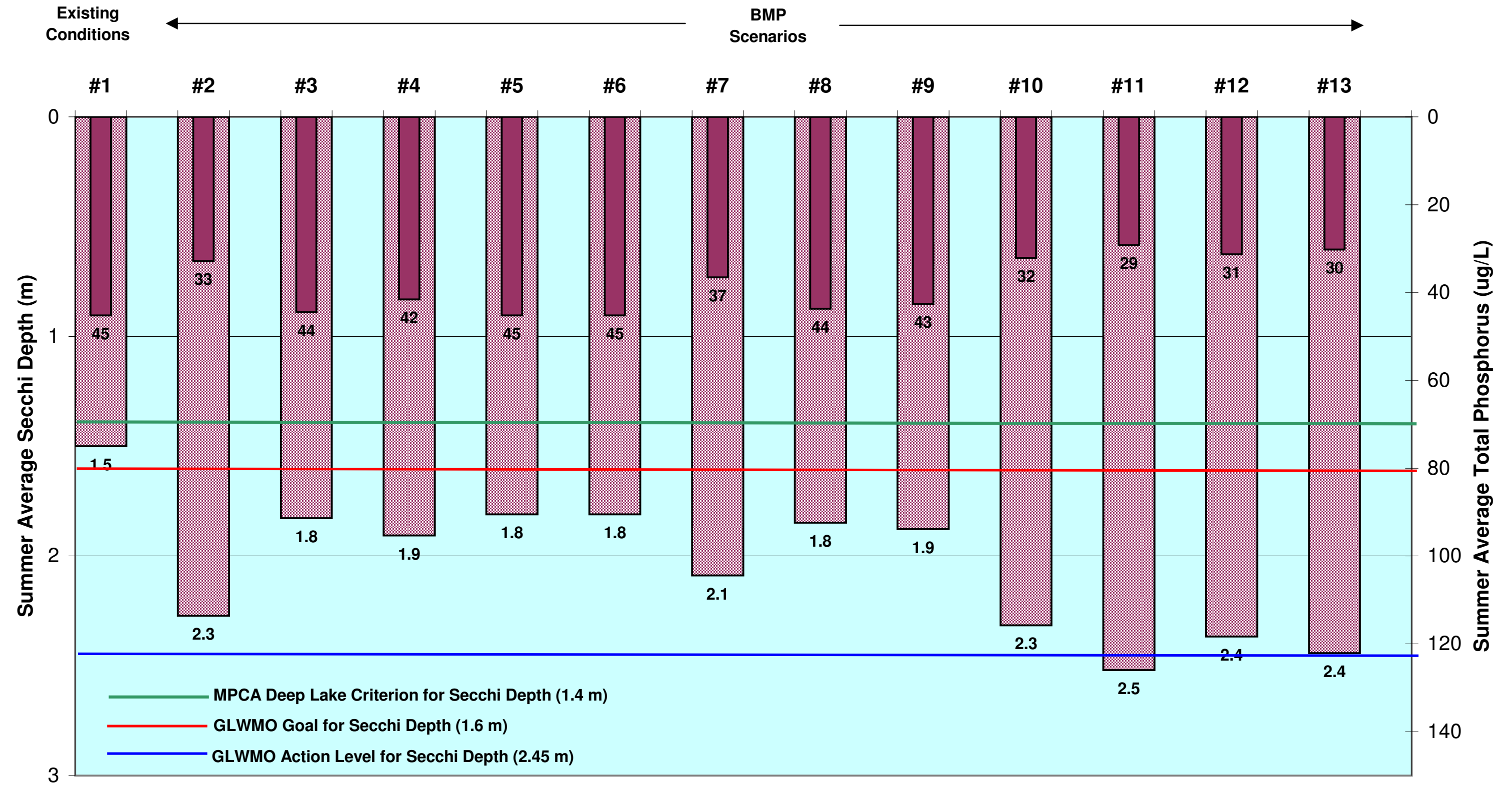


Figure EX-15
Lake Owasso Summary of BMP Scenario Results and Comparison with MPCA and GLWMO Goals

Conclusions

The following summary describes the main conclusions of this UAA that allowed for a diagnosis of the water quality issues in Lake Owasso and identification of the activities and projects that would help the lake continue to meet or improve its water quality goals in the future.

1. Water quality data collected in Lake Owasso for 2007 and 2008 would classify Lake Owasso as a eutrophic lake. Because data was collected in 2 sampling locations within the lake, the spatial variability of water quality in Lake Owasso was observed and water quality does vary through out the lake. The trend analysis for Lake Owasso using the past 10 years of water quality data (1998 through 2008) found that there has not been a significant change in total phosphorus concentrations over the past 10 years while there was a statistically significant increase in the Chlorophyll *a* concentration over the same time period. Additionally, there was a significant decrease in Secchi depth.

2. The MNLEAP model estimated the total phosphorus concentration in a minimally-impacted lake similar to Lake Owasso to be 40 μg/L (±15 μg/L), similar to the range of water quality observed in the lake. For the Vighi and Chiaudani model and the MPCA's diatom analysis, which are predictors of natural background phosphorus concentrations (no impact from anthropogenic sources), suggested that Lake Owasso's natural background phosphorus concentration would fall within the range of 18 to 22 μg/L. Comparison of these predicted values to observed water quality in the lake indicates that Lake Owasso's water quality falls within the expected range for a minimally-impacted lake with similar characteristic, but the background levels indicate that there is potential for water quality improvement.

3. Sediment cores collected and analyzed in 2007 indicated that the average intenal loading rate from sediment release for the whole lake was 0.5 mg/m^2/day with a maximum expected loading rate of 2.9 mg/m^2/d in the deepest sediment core collected. Although some internal loading from the sediments is likely, when compared to internal loading rates for lakes across the Twin Cities metro area, the maximum expected loading rate in Lake Owasso is significantly less than the average observed across the metro (6.3 mg/m^2/day).

4. A macrophyte survey completed in late-May 2007 quantified the distribution and density of Curlyleaf pondweed throughout Lake Owasso. This macrophyte, which dies-back in early summer, can act as a significant source of phosphorus in a lake system, as is the case with

Lake Owasso. In 2007, approximately 52% of the lake was covered by Curlyleaf pondweed. Review of historic macrophyte surveys and other reports about Lake Owasso indicate that Curlyleaf pondweed has been present in the lake as far back as 1981.

5. Relationships between the three key water quality parameters (total phosphorus, chlorophyll *a,* and Secchi depth) were evaluated. There is not a strong relationship observed between cholorphyll *a* and total phosphorus concentrations, showing a similar relationship to what was observed during earlier studies. The relationship in Lake Owasso suggests that the algae concentrations in Lake Owasso are not directly controlled by total phosphorus and are impacted by zooplankton grazing, to some extent. A direct relationship between Secchi depth and total phosphorus was developed to be used predictively. The variability in the data used to develop this relationship suggest that the Secchi depths predicted by this relationship should not be taken as absolute values but rather general indicators of the clarity that can be expected.

6. Review of temperature depth profiles in Lake Owasso at both monitoring sites (site 5401 in the north and site 5403 in the south), indicate that both basins thermally stratify during the summer months, with mixing occurring during spring and fall turnover (dimictic lake). Additionally, total phosphorus and dissolved oxygen data at depth, shows that along the bottom of the lake goes anoxic (devoid of oxygen) and phosphorus accumulates within the hypolimnion, being contained below the thermocline. Because water quality data was not collected in the third deep basin located on the east side of the lake, the Osgood Index was used to estimate the probability of mixing events to occur during summer stratification. This index indicated that this third basin would also be strongly stratified during the summer (dimictic).

   Although the deep areas of the lake strongly stratify, much of the lake is relatively shallow, with an average lake depth of less than 11-feet. It is possible for mixing to occur in these shallow areas of the lake as the result of wind and motor boat activity, although it is unclear what role mixing and resuspension in the shallow areas of the lake have on the overall water quality in Lake Owasso. Anecdotal information suggests that turbidity in the lake increases as the result of motor boats in shallow areas of the lake.

7. The 2001 MDNR fishery survey indicates that small numbers of carp are present in Lake Owasso. The activity of carp, and other benthivorous fish, can result in phosphorus loading

to the lake. Additionally, carp were observed in the Central Park – West (County Road C) wetland in the spring of 2008. In late summer, there was a fish-kill in the wetlands and dead carp were observed in the area.

8. The water and phosphorus budgets developed for Lake Owasso for the various climatic conditions indicates that the sources of the water and phosphorus loads to the lake are variable. Watershed runoff plays a variable role in total phosphorus loads to the lake depending on the climatic conditions, ranging from 12 to 23 percent of the total load. However, during dry conditions, there are periods where significant portions of the watershed do not discharge during storm events, as was observed in the summers of 2007 and 2008. There also appears to be internal loading from waterbodies and wetlands within the Lake Owasso watershed that contribute to the total phosphorus load to the lake (5 to 9 percent). These loads can possibly be attributed to carp activity or release of total phosphorus from sediments. Internal phosphorus loads from within Lake Owasso (the result of Curlyleaf pondweed die-back,release from lake sediments, wind mixing, roughfish activity) were estimated to range from 50 to 57 percent of the load to the lake. Other sources of total phosphorus to the lake include atmospheric deposition and groundwater.

9. Review of the 2008 runoff water quality monitoring data at the Dale Street monitoring station, just downstream from the City of Roseville Leaf Recycling Center, suggests that the compost area is not a significant source of phosphorus to Lake Owasso. Total phosphorus concentrations observed during storm events are similar to typical urban stormwater runoff concentrations. Good housekeeping practices at the Leaf Recycling Center site should continue to be promoted, including the maintenance of the vegetated buffers around the perimeter of the site as well as maintenance of a flat grade on the site to minimize stormwater runoff. Additionally, a small sedimentation pond site could be constructed on the site to collect and treat all surface runoff from the site, before discharging to the downstream wetland.

10. In-lake modeling indicates that the control of Curlyleaf pondweed will have the most significant impact on the total phosphorus concentrations and water clarity in Lake Owasso during the summer months, for all climatic conditions. The implementation of a Curlyleaf management plans is recommended to control the growth of this non-native, invasive species in order to limit its contribution to the internal total phosphorus load, and to allow native

macrophyte species to reestablish in Lake Owasso. See Section 8.3.1 for more details about the Curlyleaf management plan proposed for Lake Owasso.

11. Runoff from the majority of the Lake Owasso watershed is routed through stormwater pond or natural wetlands prior to discharging to the lake. Therefore the watershed runoff was identified being less important than other sourcse of phosphorus to Lake Owasso. As a result, a variety of structural BMPs in the watershed were shown to have limited impacts on the water clarity of Lake Owasso. However, watershed and in-lake water quality modeling was done evaluating the implementation of infiltration practices throughout the watershed, demonstrating that the BMPs can result in the improvement of water quality in Lake Owasso. Though no one specific project is currently recommended, it is recommended that the GLWMO and the Cities of Roseville and Shoreview continue to promote the implementation of infiltration BMPs throughout the Lake Owasso watershed as opportunities arise as the result of redevelopment and infrastructure improvement projects.

12. Evaluation of the runoff monitoring data, along with the water quality modeling results, indicate that internal loading occurs in several water bodies (Central Park-West wetland (County Road C), Central Park – East wetland (Dale Street), Charlie Ponds (West Owasso)) within the Lake Owasso watershed and contributes a significant portion of the annual phosphorus load to Lake Owasso (5 to 9 percent). Because the specific sources of these "internal" loads are not fully understood at this time, additional monitoring and studies are recommended for several of these water bodies to more completely understand the systems. The focus of these studies will be additional water quality monitoring, quantifying the potential impacts of the sediments on the phosphorus load, and the observations of carp activity in some of these water bodies. See Section 8.1 for more detailed discussion of the recommended monitoring and studies.

Recommendations

Many in-lake improvement options and site-specific structural BMPs were evaluated as to their feasibility and cost-effectiveness in the course of this UAA. Ultimately, the recommended approach for improving the Lake Owasso water quality involves adaptive management, or a management approach that involves monitoring the outcomes of implemented projects, and based on the results, modifies or improves on the way the system is managed. The following summarizes the recommended monitoring and studies for Lake Owasso and its watersheds, as well as the structural, in-lake, and nonstructural BMPs recommended for Lake Owasso.

Additional Monitoring & Study Recommendations

Water Quality Monitoring in Central Park – East and West Wetlands and Charlie Pond System

To better understand the water quality and potential internal phosphorus loading in the ponds and wetlands through the summer, water quality monitoring for an additional summer (early May through late September) is recommended in the deepest portions of the Central Park – East wetland, the Central Park – West wetland, and the Charlie Pond system. More details about this study can be found in Section 8.1.1 of this UAA.

The estimated cost for this additional monitoring is expected to range from $7,000 to $9,500 including field work, laboratory analysis, and a brief technical memorandum discussing the laboratory results.

Fisheries Impact Study on Water Quality

Carp, along with other benthivorous (bottom-feeding) fish, can have a direct influence on the phosphorus concentration in a lake or water body (LaMarra, 1975). They can also cause resuspension of sediments in shallow ponds and lakes, causing reduced water clarity and poor aquatic plant growth, as well as high phosphorus concentrations (Cooke et al., 1993).

MDNR fisheries surveys for Lake Owasso (2001) and Bennett Lake (2006) indicate that carp are present in low numbers in both lakes. A 2006 MDNR population assessment also supports that carp are present in Lake Owasso. From the 2007 Lake Owasso user survey, 42 percent of respondents indicated that the fishery in Lake Owasso includes a large rough fish population, including carp. Additionally, carp were observed in the Central Park – West (County Road C) wetland in both the spring and summer of 2008.

The results of this study should provide a better understanding of carp populations in the system, including Lake Owasso, Bennett Lake, and the Central Park – West (County Road C) and Central Park – East wetlands, as well as their impact on the phosphorus loads to Lake Owasso. Because these water bodies in this system are directly-connected to each other with very little change in elevation, carp populations likely move between the water bodies. Therefore, potential items to be considered when scoping this study should include:

- Quantifying carp population in all four water bodies
- Tracking carp movement between the water bodies in the system, throughout the course of a year)

- Identification of the key carp spawning locations within the system
- Collection of water quality grab samples in the Central Park – West wetland during the study period to estimate potential impacts of carp activity on water quality (total phosphorus and total suspended solids)

Because of the need for more detailed investigation into the scope of this project as well as the potential variability in the scope, estimated costs for this study have not been developed. However, potential partnerships with the University of Minnesota and the MDNR may be possible as there is significant interest in carp management in lakes, and there is currently research being conducted to better understand this invasive fish. More details about this study can be found in Section 8.1.2 of this UAA.

Sediment Core Collection and Analysis

Release of phosphorus from sediments within water bodies within the Lake Owasso watershed may contribute to the estimated internal phosphorus load from the watershed (Central Park – East wetland, Central Park – West wetland, Bennett Lake, and Charlie Ponds). Collection and analysis of sediment cores will help better understand the mobile phosphorus associated with the sediments in these waterbodies and their potential contribution to the phosphorus loads to Lake Owasso. Along with mobile phosphorus, the sediment cores will be analyzed for organic phosphorus and total iron. More details about this study can be found in Section 8.1.3 of this UAA.

The estimated cost for the sediment cores collection and analysis is $7,900.

Water Quality Monitoring in Lake Owasso – Shallow Area

Although the deep areas of the lake strongly stratify, mixing and sediment resuspension are likely occurring in the shallow areas as the result of wind and motorboat activity. It is unclear what the potential mixing in the shallow areas of the lake has on the overall water quality observed in Lake Owasso. Therefore, additional water quality monitoring in the shallow area of the lake is recommended to help understand the water quality and mixing dynamics in the shallow areas of Lake Owasso. Sampling should begin in May and continue through the end of September, and should include the collection of samples at 1 meter depth increments, from the surface to the sediments. More details about this study can be found in Section 8.1.4 of this UAA.

This recommendation assumes that Ramsey County will collect the water quality samples at the shallow monitoring site, and that monitoring at Site 5401 (the north, deep basin) will be performed as part of Ramsey County's regular lake monitoring program. The estimated cost for water quality monitoring at a second site in Lake Owasso for one year, including field collection, laboratory analysis, and a brief technical memorandum discussing the laboratory results is expected to range from $1,800 to $2,800.

Structural BMP Recommendations

Incorporation of Infiltration BMPs throughout the Watershed

The watershed and in-lake water quality modeling of Lake Owasso has demonstrated that infiltration of stormwater runoff throughout the watershed can reduce the total phosphorus load to the lake and improve the overall water quality in Lake Owasso. Several potential sites for more regional infiltration BMPs were evaluated as part of the feasibility study. Though no single project would result in a dramatic improvement in water quality in Lake Owasso, the cumulative impact of infiltration BMPs distributed throughout the watershed can improve the overall lake water quality.

No specific infiltration projects are recommended at this time; however, we recommend that the GLWMO and the Cities of Roseville and Shoreview continue to promote the use of infiltration BMPs as opportunities associated with redevelopment and road reconstruction arise and where site conditions are conducive to infiltration.

In-Lake BMP Recommendations

Several in-lake BMPs were evaluated as part of the feasibility study including the management of Curlyleaf pondweed in Lake Owasso as well as a whole-lake alum treatment to minimize release of phosphorus from the lake's bottom sediments. Because the treatment of Curlyleaf pondweed is estimated to have the most significant impact on Lake Owasso's water quality, it is the primary recommended in-lake water quality BMP.

Curlyleaf Pondweed Management

- Curlyleaf pondweed can be managed by treatment with herbicide. Because Curlyleaf pondweed is such a significant portion of the phosphorus budget, it is the recommended in-lake management approach for Lake Owasso. This management plan would include several treatment and monitoring activities over the course of the recommended four year management plan. Activities would include:

- Herbicide (Endothall) treatment of Curlyleaf pondweed in spring (requiring an aquatic plant management permit and letter of variance from the MDNR, as well as permission from lake homeowners)

- Aquatic plant monitoring (surveys required by the MDNR both pre-treatment and post-treatment).

- Biomass monitoring (required by the MDNR to determine treatment effectiveness and effect on native plant communities)

- Turion monitoring (required by the MDNR to determine the potential for Curlyleaf growth in following years)

- Herbicide residue monitoring (to determine herbicide concentration in the water column during the 21-day period after treatment)

- Analysis and annual reporting (to the MDNR to summarize the impact of Curlyleaf pondweed treatment on Lake Owasso and to confirm compliance with permit requirements).

The estimated total cost of the four-year Curlyleaf pondweed management plan including all treatment, monitoring, and reporting is $649,000.

Nonstructural BMP Recommendations

It is quite difficult to effectively model the effects of nonstructural BMPs on lake water quality, but studies have shown that they are effective at reducing phosphorus loads. Examples of effective nonstructural BMPs that would be appropriate for the Lake Owasso watersheds include:

1. An evaluation of road salting practices in the Lake Owasso watershed is recommended. Also, storage of road salt in this area should be evaluated to determine whether unintended runoff from storage areas is occurring.
2. Continue the existing street sweeping program, including an early spring sweeping, a late fall sweeping, and additional sweepings as needed.
3. Continue public education programs to inform the residents of the Lake Owasso watershed of ways to reduce phosphorus loading through proper handling of yard fertilizers and wastes, pet wastes, soaps and detergents.
4. Encourage industrial/commercial areas to institute good housekeeping practices, including appropriate disposal of yard wastes, appropriate disposal of trash and debris, appropriate storage and handling of soil and gravel stockpiles.
5. Discourage the feeding of waterfowl at shoreline areas around Lake Owasso and upstream ponding areas.
6. Encourage vegetated buffers between yards and the shore of Lake Owasso and upstream ponding areas.

Lake Owasso Use Attainability Analyses

Diagnostic-Feasibility Study: Water Quality Issues and Potential Restorative Measures

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1.0 Introduction

1.1 GLWMO Water Quality Policies and Goals

The Grass Lake Watershed Management Organization (GLWMO) water quality goals as stated in the 2001 GLWMO *Watershed Management Plan* (WMP) are to:

- Manage the GLWMO's water resources on a regional basis to meet the goals established for each lake

- Maintain or restore the water quality of the GLWMO lakes to allow for the continuation or enhancement of existing recreation activities and habitat.

To accomplish its goals, the GLWMO established a water body classification system and determined the respective roles of the GLWMO and the cities in water quality management.

1.1.1 Policies for Lake Owasso Water Quality

1. All water bodies in the GLWMO will be classified according to either the GLWMO lake and pond classification system or the GLWMO wetland classification system. The GLWMO lake and pond classification system contains five categories that will be used by the GLWMO and member cities to classify lakes and ponds, defined as follows (see Table 5-1 of the *2001 WMP* for detailed descriptions of the categories and water quality parameters associated with each category):

   Category I. Water bodies in this category are typically used for swimming and other direct contact recreational activities. These water bodies have the highest/best water quality and are usually the most popular water bodies with the public. Category I lakes are managed to provide water quality capable of supporting direct contact activities, such as swimming, scuba diving, snorkeling, and waterskiing. A reasonable water quality goal for Category I lakes is a minimum Secchi disc transparency of 1.0 meters, and a summer average transparency of at least 1.6 meters. Transparencies in this range are considered characteristic of moderately eutrophic (i.e., nutrient rich) lakes.

   Category II. Water bodies in this category are typically used for incidental contact recreational activities such as boating and fishing that involve indirect contact with lake water. These water bodies have poorer water quality than Category I water bodies, but are still popular with the public.

Category III. Water bodies in this category serve important functions for wildlife habitat and aesthetic enjoyment, and may also provide opportunities for warm-water fishing, provided winter kill does not occur. These water bodies may have poorer water quality than Category I and II water bodies and typically are not viewed as swimmable.

Category IV—Nutrient Traps. Water bodies in this category are intended to reduce downstream loading of phosphorus and other nutrients that contribute to water pollution. These ponds are designed to have phosphorus removal efficiencies of at least 50 percent.

Category V—Sediment Traps. These water bodies are similar to Category IV water bodies, but are too small to effectively remove a significant fraction of nutrients. These basins will generally have phosphorus removal efficiencies of less than 50 percent.

2. Category I-III water bodies will be managed for non-degradation of water quality, with allowance for natural variability. This means that developments and city projects should be designed to preserve existing water quality so far as reasonably possible, even when existing water quality is better than the water body classification might otherwise infer. To conform to this policy, implementation of best management practices will be required during development and other types of construction.

3. Category I-III water bodies will also be managed to preserve and promote bio-diversity and improve aesthetics.

4. The GLWMO labeled water bodies as either WMO-managed, cooperatively managed, or city managed. "WMO-managed" means the WMO is responsible for all water quality management activities, including classification, setting numeric goals, monitoring, tracking data, etc. "Cooperatively managed" means the cities are responsible for all water quality management activities, except for classification, which is the WMO's responsibility. "City managed" means the cities are responsible for all water quality management activities.

   The GLWMO considers Lake Owasso, Lake Wabasso, Snail Lake, and grass Lake to be WMO-managed resources. Therefore the GLWMO established the following water quality policies for Lake Owasso:

   1. Lake Owasso will be managed for non-degradation of water quality.
   2. Lake Owasso will be managed to preserve and promote bio-diversity and improve aesthetics.

3. The GLWMO is responsible for all water quality management activities in and around Lake Owasso.
4. The action level for Lake Owasso is a minimum Secchi Disc transparency of 2.45 meters.
5. The GLWMO will monitor Lake Owasso using survey level water quality monitoring, and aesthetic and habitat monitoring, as a minimum. If the water quality action level is reached, Management Level and Intensive water quality monitoring will be performed.
6. Improve communications between the GLWMO and Ramsey County by coordinating with Ramsey County regarding proposed lake management actions and to seek information annually from Ramsey County regarding future lake management actions.
7. Manage Lake Owasso such that its water quality matches its intended use.

1.1.2 Lake Owasso Water Quality Goals

Based on its existing and desired use, the GLWMO classified Lake Owasso as a Category I water body.

1.1.2.1 Total Phosphorus

Phosphorus generally controls the growth of algae in lake systems and it is a useful measure to evaluate the lake's overall water quality. A summer-average total phosphorus goal of 45 µg/L was established by the GLWMO for Lake Owasso, based on the desired use of the lake and public perception. A total phosphorus goal of 45 µg/L is less stringent than the MPCA total phosphorus water quality criterion of 40 µg/L for deep lakes in the North Central Hardwood Forests ecoregion (Table 1-1).

The mean summer-average total phosphorus concentration for Lake Owasso is 54 µg/L for the period of record (1973 to 2008). This mean long term summer-average indicates that Lake Owasso currently does not meet the GLWMO's goal for in-lake phosphorus concentration. However the 2008 summer average does meets the GLWMO's goal for in-lake phosphorus concentration and the MPCA's total phosphorus concentration criterion for deep lakes (Table 1-1).

Table 1-1 Lake Owasso Summary of Historical Water Quality Data

Water Quality Parameter	Mean Summer-Average for Period of Record (1973-2008)	2008Summer Average	GLWMO Existing Goal	GLWMO Action Level	MPCA's Deep Lake Standard
Total Phosphorus	54 μg/L	32 μg/L	45 μg/L	--	40 μg/L
Secchi Disc	6.2 ft (1.9 m)	6.9 ft (2.1 m)	5.2 ft (1.6 m)	8.0 ft (2.45 m)	4.6 ft (1.4 m)
Chlorophyll *a*	15.7 μg/L	13 μg/L	20 μg/L	--	14 μg/L

1.1.2.2 Water Clarity (Secchi Disc)

Transparency is measured by submerging a black and white patterned disc (a Secchi disc) into the lake. The depth at which the Secchi disc disappears determines the lake's transparency. A summer-average water clarity goal of 1.6 meters (5.2 feet) Secchi disc transparency was established by the GLWMO for Lake Owasso. The GLWMO's current water clarity goal is more stringent than the MPCA's water quality criterion for water clarity of 1.4 meters (4.6 feet) for deep lakes in the North Central Hardwood Forests ecoregion.

The mean summer-average water transparency for Lake Owasso is 1.9 meters (6.2 feet) for the period of record (1973 to 2008) and 2.1 meters (6.9 feet) 2008. The mean summer-average for the period of record and specifically for 2008 indicates that Lake Owasso currently meets the GLWMO's water clarity goal as well as the MPCA clarity criterion (Table 1-1). However, the recent summer average clarity is less than the GLWMO's "action level" for Lake Owasso. Additionally, over the past 6 years (2003-2008), there has been a decrease in the water clarity in Lake Owasso, with an average summer transparency of 1.7 meters, just meeting the existing GLWMO goal and not meeting the "action level" established for Lake Owasso. Because the summer average transparency has fallen below the GLWMO "action level", the GLWMO is responsible for conducting management level and intensive water quality monitoring, as established in the 2001 *WMP*. These actions also include the completion of this study to evaluate the water quality in Lake Owasso and develop management options that will help improve the lake's water quality.

1.1.2.3 Chlorophyll *a*

Chlorophyll *a* is the main photosynthetic pigment in algae. Therefore, the amount of chlorophyll *a* in the water indicates the abundance of algae present in the lake. GLWMO's chlorophyll *a* goal of 20 μg/L for category I water bodies is less stringent than the MPCA chlorophyll *a* water quality criterion of 14 μg/L for deep lakes in the North Central Hardwood Forests ecoregion (Table 1-1).

The mean summer-average chlorophyll *a* concentration for Lake Owasso is 15.7 µg/L for the period of record (1973-2008) and 13 µg/L in 2008. As a result the 2008 summer average chlorophyll *a* concentration in Lake Owasso currently meets the goal established by the GLWMO and the MPCA's deep lake chlorophyll *a* criterion (Table 1-1).

1.2 Lake Owasso and the Impaired Waters List

The MPCA 303(d) Impaired Waters list results from the federal Clean Water Act, which requires states to define water quality standards, to identify waters that are impaired or are not meeting these standards, and to develop plans to improve the water quality in these impaired waters such that the standards are met. These standards vary depending on the designated use of the water body, such as for drinking water, fishing, swimming, irrigation, or industrial purposes. In Minnesota, the MPCA is responsible for the enforcement of the Clean Water Act in Minnesota. Every 2 years, the MPCA is required to publish an updated list of impaired waters that do not meet the state's water quality standards.

For all water bodies listed on the 303(d) Impaired Waters list, the MPCA requires that a strategy is developed to improve the quality of impaired waters by conducting a Total Daily Maximum Load (TMDL) study for each pollutant that causes a water body to fail to meet state water quality standards. TMDLs are often described as the maximum amount of a pollutant that can enter a surface and/or groundwater such that water quality standards are met. A TMDL study identifies point and nonpoint sources of each pollutant for which the water body fails to meet water quality standards. Water quality sampling and computer modeling are generally used to determine how much each pollutant source must reduce its contribution to assure the water quality standard is met.

Lake Owasso was listed on the MPCA's 2008 303(d) Impaired Waters List for mercury in fish tissues, impacting aquatic consumption. The lake was included as part of the statewide mercury TMDL which was approved by the EPA in 2008. Lake Owasso is not currently listed on the MPCA's 2008 303(d) Impaired Waters List for any other water quality impairments.

In the context of the 303(d) Impaired Waters list, Lake Owasso is considered a deep lake by the MPCA. The current phosphorus criterion is 40 µg/L for deep lakes in the Central Hardwood Forest ecoregion of Minnesota. The MPCA outlines the water quality criteria in the Minnesota Rules, Chapter 7050—Water Quality Standards for Protection of Waters of the State (amended in 2008).

Although Lake Owasso is not currently listed on the MPCA 303(d) Impaired Waters list, the average summer water quality in Lake Owasso for the past decade suggests that the lake could be listed on the MPCA 303(d) Impaired Waters list in the future. The water quality monitoring, computer modeling, and remedial measures recommended as a part of this UAA would be useful in keeping Lake Owasso off the MPCA's 303(d) Impaired Waters list or during the completion of a future TMDL study for Lake Owasso, should this be required.

1.3 Overview of Lake Use

Lake Owasso is considered one of the GLWMO's most significant lakes. As a Category 1 lake, the lake is typically used for swimming and other direct contact activities as well as other recreational activities such as boating, fishing, wildlife habitat, and aesthetic viewing. Lake Owasso is a popular public resource, and there has been considerable public interest in the quality of Lake Owasso, as is evidenced by an active lake association.

There are currently two public access points on the lake, both located on the north side of the lake along North Owasso Boulevard. The first access point is the boat launch on the northeast corner of the lake. The second access point is the public swimming beach located just to the west of the boat launch.

Historically, extreme lake levels have been a concern in Lake Owasso. Ramsey County operated a series of groundwater pumping stations to augment low water levels until a state rules prohibited the use of groundwater to control lake levels. High water levels in the lake have been addressed with the construction of a controlled outlet.

1.4 Public Perception of Lake Water Quality

In March 2007, a survey was sent to 580 homeowners, deeded-access residents, and those living nearby (non-resident) to Lake Owasso. A total of 188 responses were received (141 responses were residents/deeded-access while 47 were non-resident responses). The purpose of the survey was to gauge how people living around Lake Owasso use the lake, what they value about it, and what they would like to improve in the lake.

This section summarizes some of the key conclusions of this survey as they pertain to the current and desired uses of Lake Owasso, and homeowners' perceptions of the current water quality of their lakes. The complete version of the surveys and homeowners' responses can be found in Appendix A of this report.

1.4.1 Pubic Use of Lake Owasso and Perception of Water Quality

Some of the most notable questions and answers from the Lake Owasso Homeowners' Survey are included below.

1. In the past 12, months, how have you used Lake Owasso?

Most of the survey respondents indicated that the most common uses of Lake Owasso are observation of nature (both scenery and wildlife) and activities such as swimming, fishing, boating, and water skiing. Lakeshore and deeded-access residents more commonly used the lake for the various water sports where as those residents living near the lake, but who do not have direct access to the lake, predominantly enjoy the scenery and wildlife viewing the lake provides. In addition, many residents use the lake in the winter when it is ice-covered.

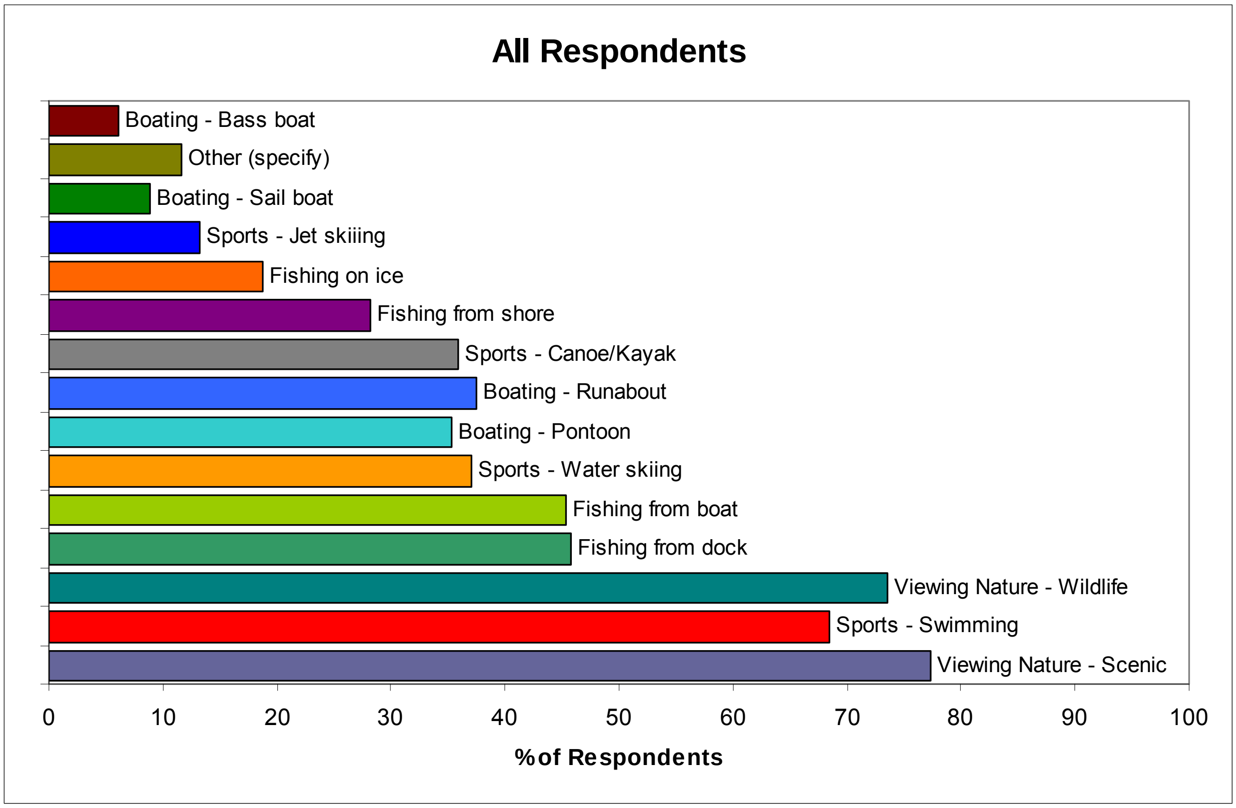


Figure 1-1 Recreational Uses of Lake Owasso

2. **How often in the past 12 months have you used Lake Owasso for recreation?**

Most survey respondents indicate that they have used Lake Owasso for recreation in the past year, although there were some respondents who do not use the lake at all. Typically, lakeshore and deeded-access residents used the lake more frequently than those who do not have direct access to the lake.

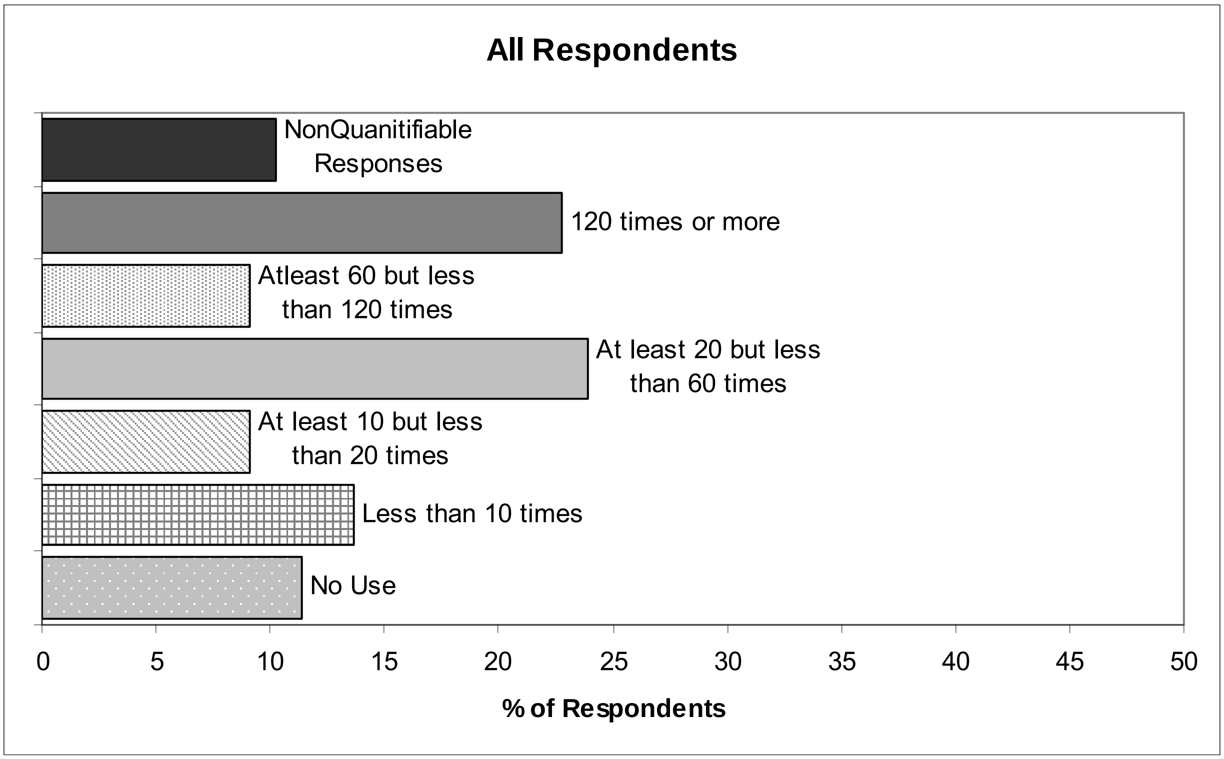


Figure 1-2 Frequency of Recreational Uses of Lake Owasso

3. Do aquatic plants interfere with your enjoyment of Lake Owasso?

More than half of the survey respondents indicated that aquatics plants do interfere with their enjoyment of Lake Owasso (those responding "Yes" and "Sometimes"). This percentage is greater for lakeshore and deeded-access residents, than those who do not have direct access to the lake.

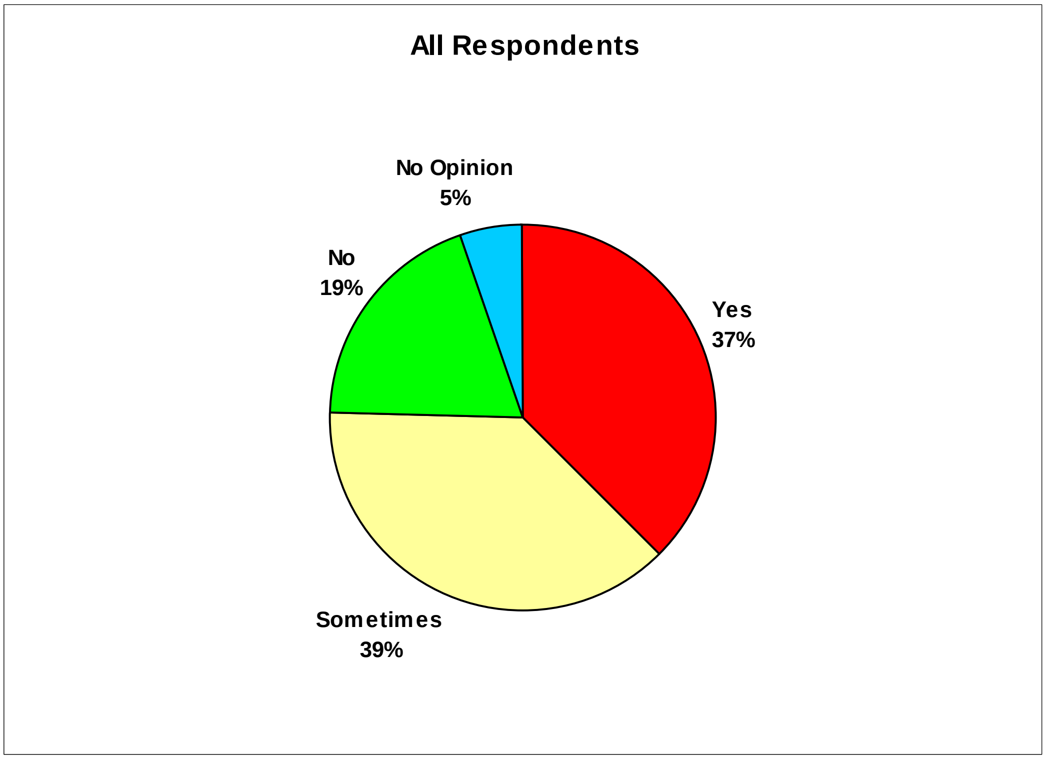


Figure 1-3 Interference of Aquatic Plants on Recreational Uses of Lake Owasso

4. How has aquatic plant interference changed over the past years?

The majority of survey respondents indicated that the interference by aquatic plants has gotten worse over the past few years.

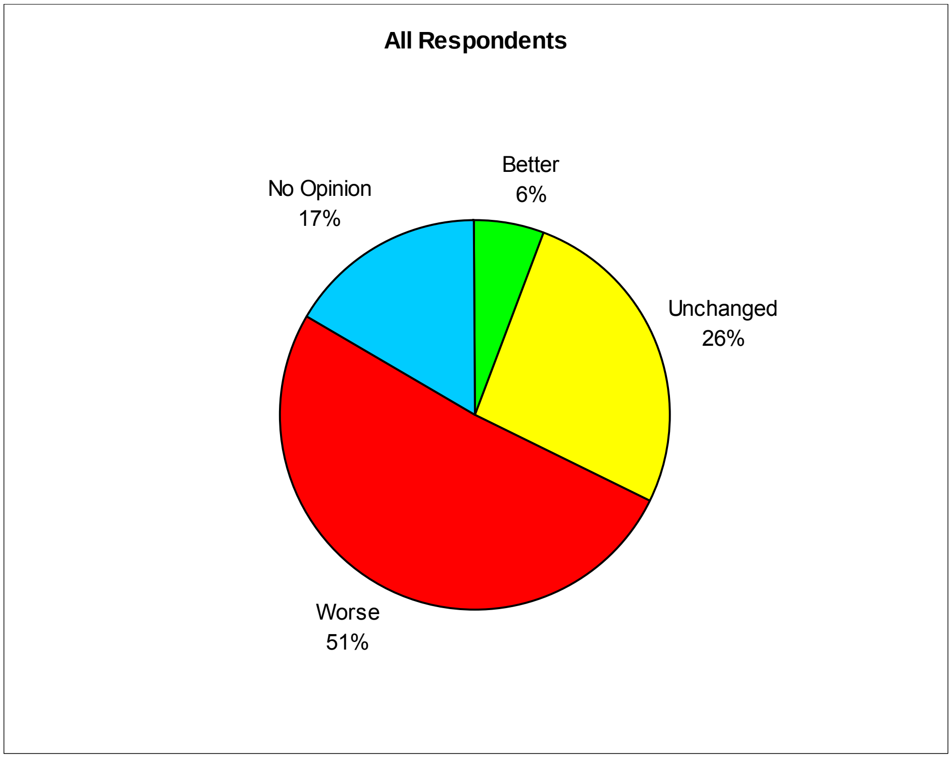


Figure 1-4 Change in Interference of Aquatic Plants on Recreational Uses of Lake Owasso

5. Which plants are the most problematic to your personal use of Lake Owasso?

The most problematic plants in Lake Owasso, as identified by the survey respondents, included filamentous green algae, Eurasian watermilfoil, northern watermilfoil, and Curlyleaf pondweed.

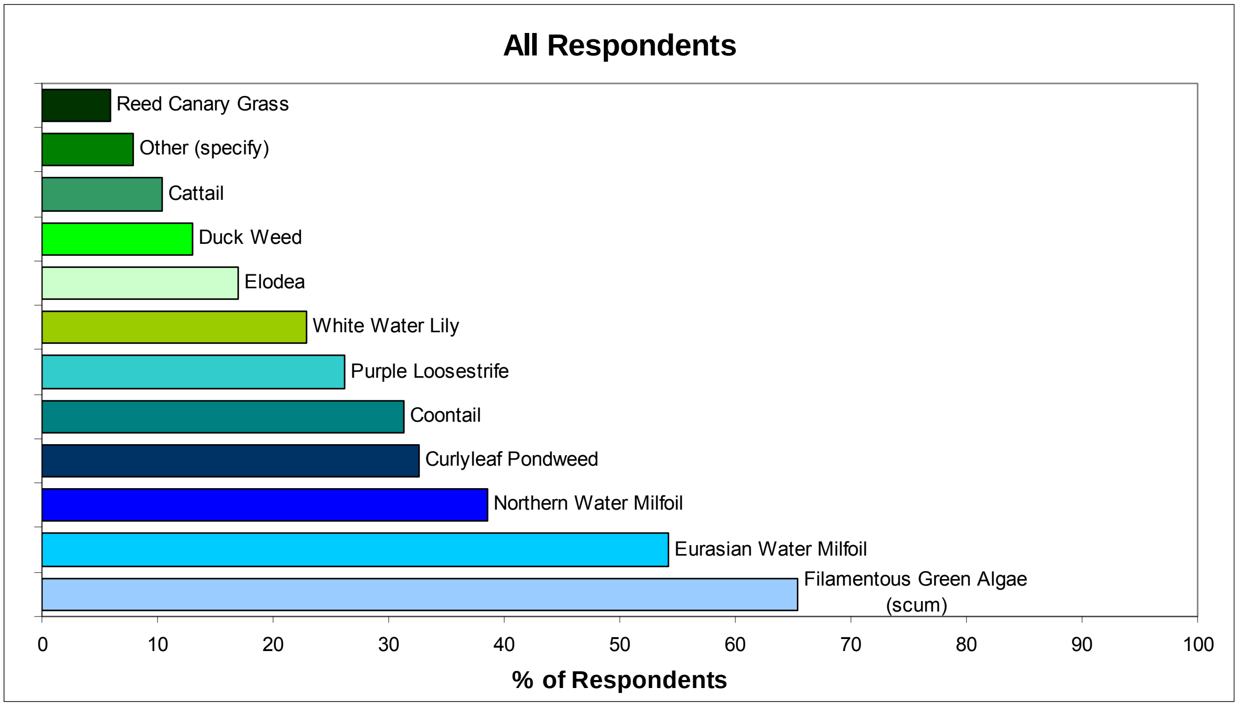


Figure 1-5 Problematic Aquatic Plants in Lake Owasso

6. How would you describe the clarity of Lake Owasso over the past 2 years?

Half of all survey respondents indicated that the water clarity has gotten worse in the past two years. A third of all respondents thought that water clarity was about the same in the past two years.

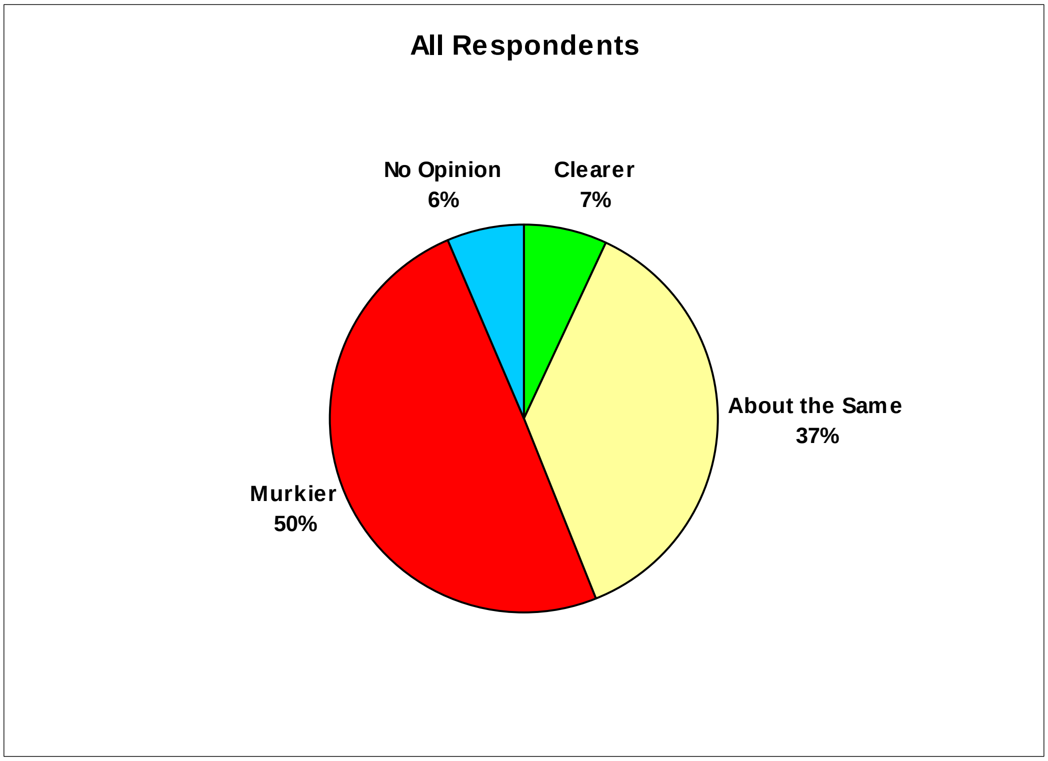


Figure 1-6 Change in Clarity in Lake Owasso

7. Which month does Lake Owasso have the worst water clarity?

August was identified as the month during the growing season with the worst water clarity.

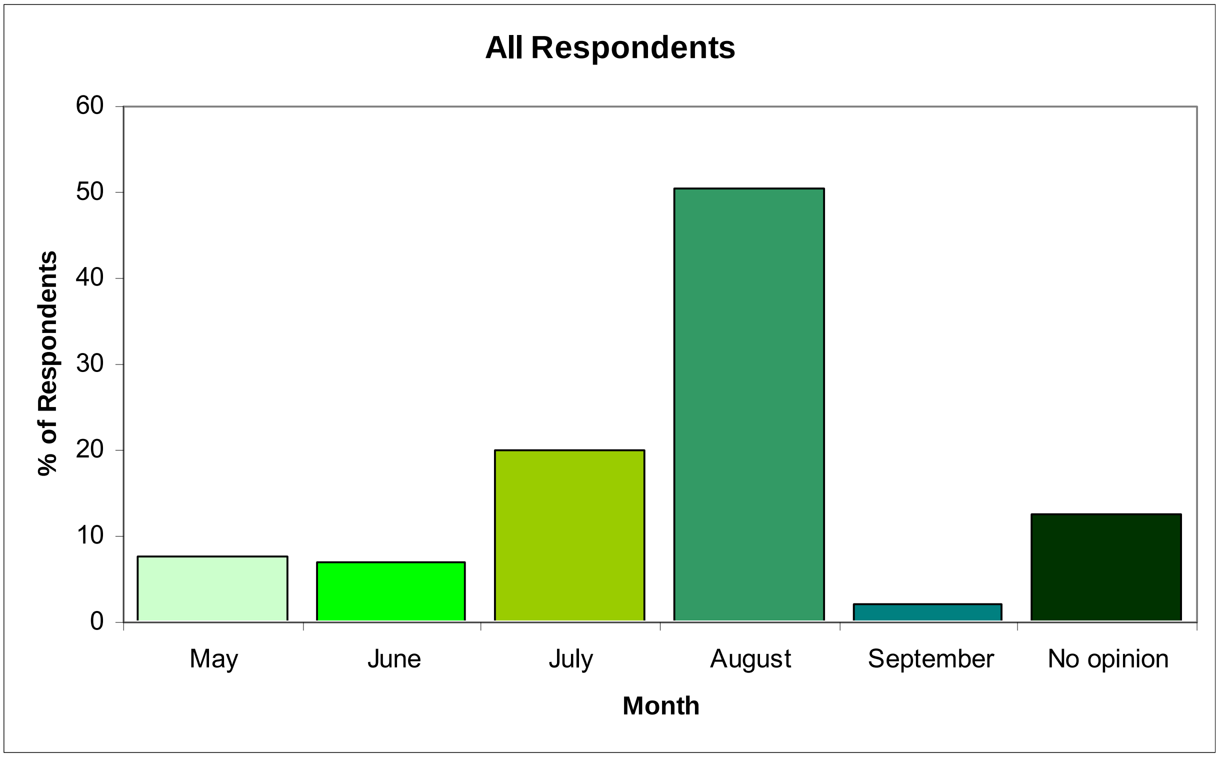


Figure 1-7 Month of Worst Water Clarity in Lake Owasso

8. What are the most important criteria for the quality of the lake?

Survey respondents indicated that the top 3 criteria impacting the quality of Lake Owasso were water clarity, having no invasive/non-native aquatic plants, and stable water levels. Stable water levels were identified as being much more important to lakeshore and deeded-access residents than to those living near the lake with no direct access.

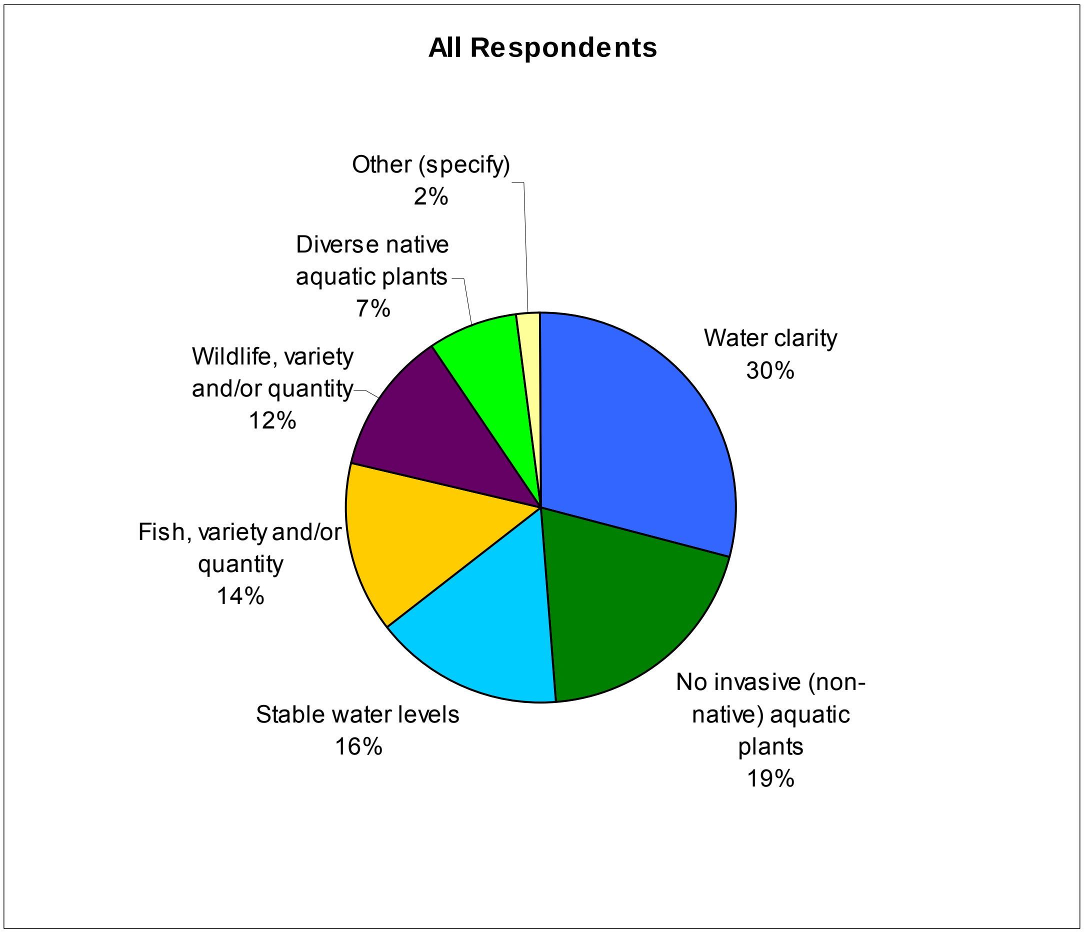


Figure 1-8 Important Criteria for the Quality of Lake Owasso

9. Have you noticed any of the following relative to the fish population in Lake Owasso? Those survey respondents that fish on Lake Owasso indicated the following about the fish populations within the lake. However, many respondents indicated that they did not fish in Lake Owasso and could not answer questions about the fish population.

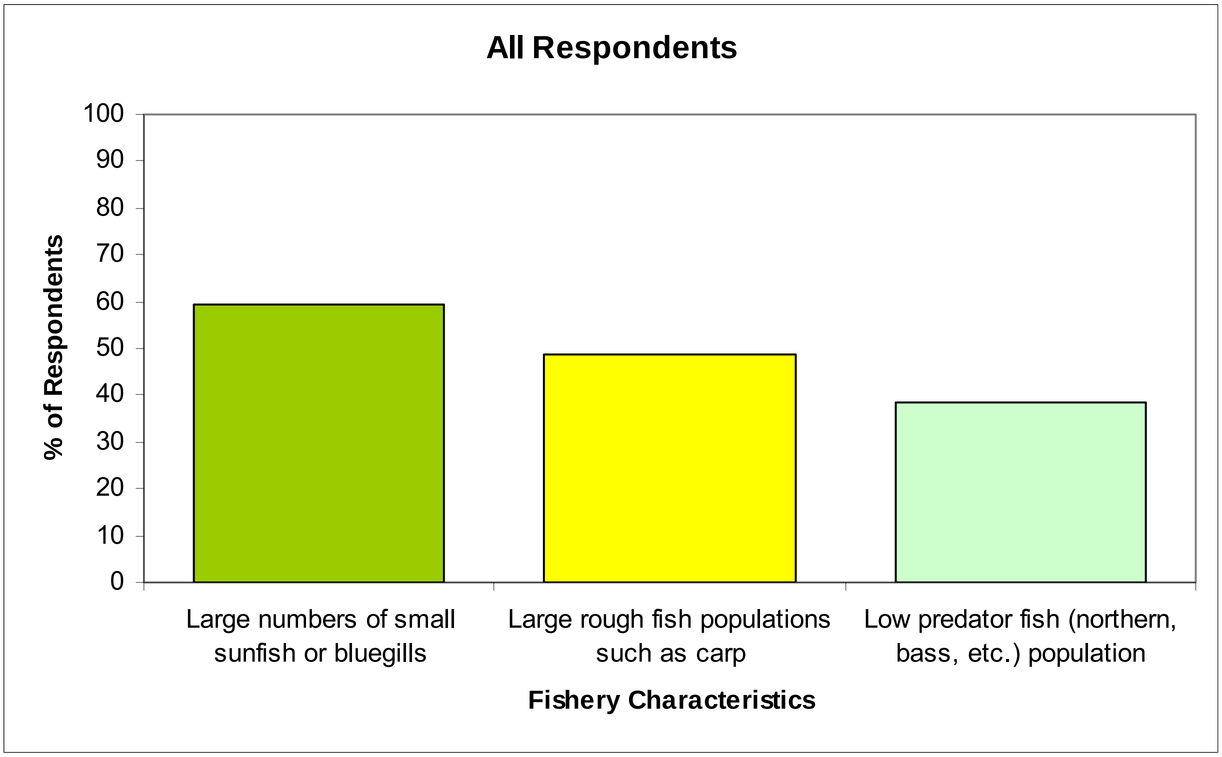


Figure 1-9 Characteristics of Fish Populations in Lake Owasso

10. What aquatic plant control method do you support for Lake Owasso?

Only those respondents who are lakeshore or deeded-access residents were asked which methods of aquatic plant control they supported. More than half of all respondents supported chemical treatments or mechanical harvesting. Some survey respondents supported both methods of aquatic plant management.

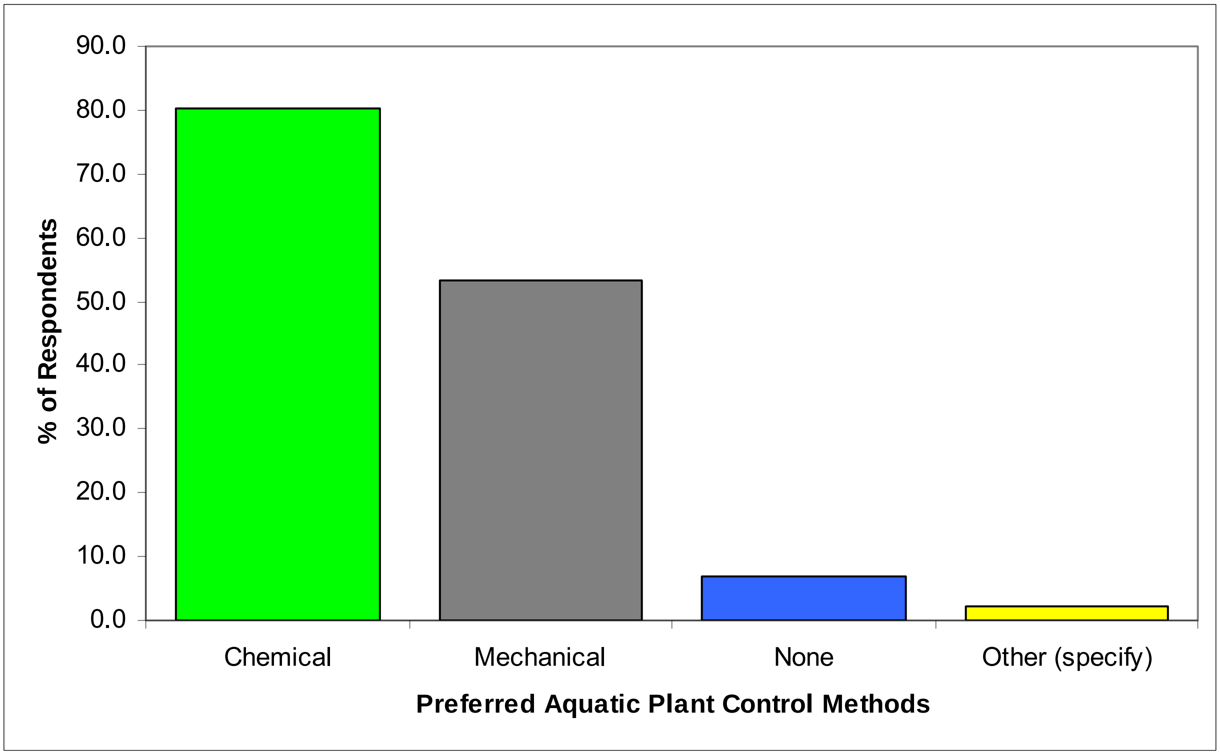


Figure 1-10 Supported Aquatic Plant Management Methods in Lake Owasso

11. What do you do to help decrease phosphorus and sediments to the lakes?

Most survey respondents indicated that they kept lawn and grass clippling off the streets, driveways, and sidewalks, they used phosphorus-free or no fertilizer, and they also directed downspouts onto their lawns and gardens.

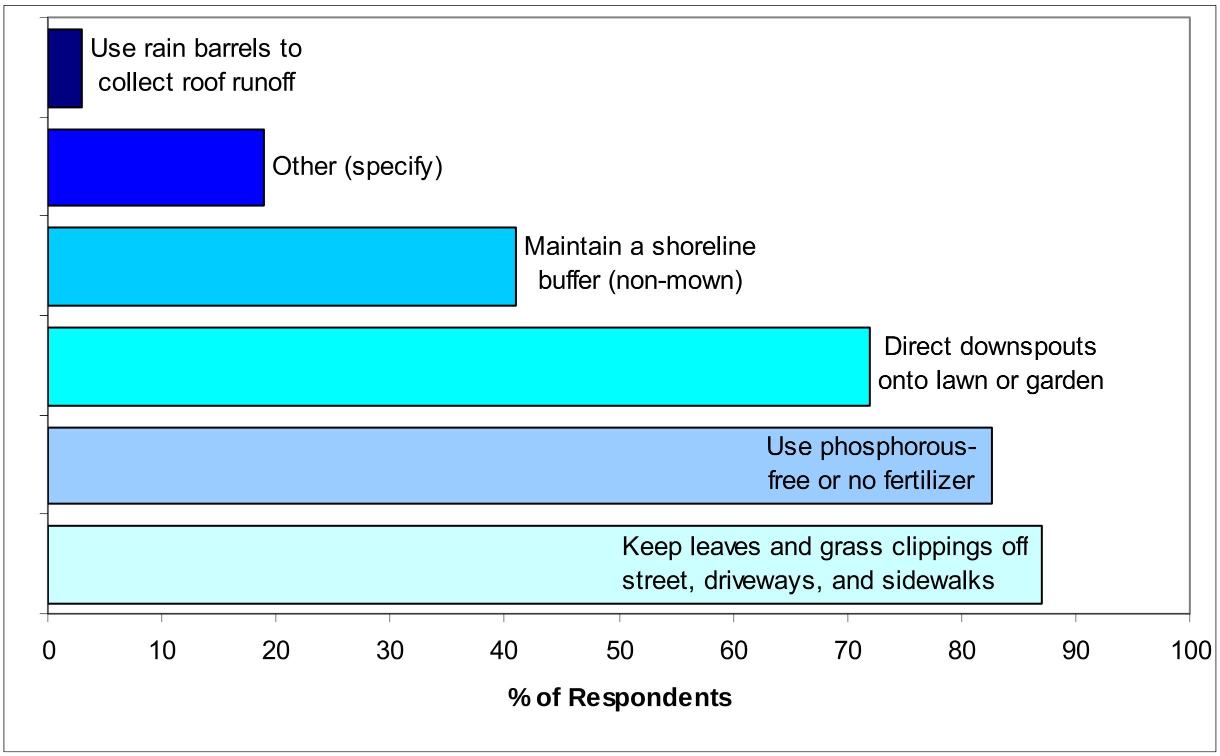


Figure 1-11 Actions by Residents to Decrease Phosphorus and Sediment Loads to Lake Owasso

1.5 Past Studies

There have been several studies of Lake Owasso in the past. These studies include:

- *Water Quality Management Alternatives: A Report on the Diagnostic Feasibility Study of Lake Owasso, Lake Wabasso, and Snail Lake*, 1991
- *Lake Owasso Management Plan*, 2000

1.6 Report Coverage

This report on Lake Owasso's water quality will answer the following four questions that apply to properly managing lakes:

1. What is the general condition of the lake?
2. Are there problems or trends evident in the lake's water quality?
3. What is a reasonably achievable goal for water transparency and phosphorus?
4. If there are water quality problems, what would be the most effective solutions?

To answer the first question, this report begins with description of the lake, the watershed, methods of data collection, and analysis. The results of water quality monitoring are then summarized in tables, figures, and accompanying descriptions.

To answer the second question, water quality data are analyzed for trends and compared to established water quality standards for the lake.

To answer the third and final questions, a water quality model, developed specifically for the lake's watershed, is described. The model incorporates the water quality data, land use characteristics, and Best Management Practices (BMPs). The model is then used to evaluate the impact of changing land use patterns and BMPs on the water quality of Lake Owasso. This includes the relative contributions of runoff and pollutants from each subwatershed. Based on these analyses, the cost and effectiveness of alternative management solutions are discussed. The final step is a set of recommendations for improving and protecting the water quality of Lake Owasso.

Background information sections are also included in the report. Section 2.0 covers general concepts in lake water quality, and the first part of the discussion section (Section 6.0) gives an overview of BMPs for controlling the quality of urban watershed runoff.

2.0 General Concepts in Lake Water Quality

There are a number of concepts and terminology that are necessary to describe and evaluate a lake's water quality. This section is a brief discussion of those concepts, divided into the following topics:

- Eutrophication
- Trophic status
- Limiting nutrients
- Stratification
- Nutrient recycling and internal loading

To learn more about these five topics, one can refer to any text on limnology (the science of lakes and streams).

2.1 Eutrophication

Eutrophication, or lake degradation, is the accumulation of sediments and nutrients in lakes. As a lake naturally becomes more fertile, algae and weed growth increases. The increasing biological production and sediment inflow from the lake's watershed eventually fill the lake's basin. Over a period of many years, the lake successively becomes a pond, a marsh and, ultimately, a terrestrial site. This process of eutrophication is natural and results from the normal environmental forces that influence a lake. Cultural eutrophication, however, is an acceleration of the natural process caused by human activities. Nutrient and sediment inputs (i.e., loadings) from wastewater treatment plants, septic tanks, and stormwater runoff can far exceed the natural inputs to the lake. The accelerated rate of water quality degradation caused by these pollutants results in unpleasant consequences. These include profuse and unsightly growths of algae (algal blooms) and/or the proliferation of rooted aquatic weeds (macrophytes).

2.2 Trophic Status

Not all lakes are at the same stage of eutrophication; therefore, criteria have been established to evaluate the nutrient status of lakes. Trophic state indices (TSIs) are calculated for lakes on the basis of total phosphorus, chlorophyll *a* concentrations, and Secchi disc transparencies, and. TSI values describe the condition of a lake in terms of its trophic status (i.e., its degree of fertility), with higher TSI values indicative of higher fertility and generally poorer water quality. All three of the parameters can be used to determine a TSI. However, water transparency is typically used to develop the TSI_{SD} (trophic state index based on Secchi disc transparency) because public perceptions of recreational use impairment are most often directly related to water clarity. The TSI rating system places Lake Owasso in the mesotrophic (i.e., medium fertility) trophic status category. Trophic status categories include oligotrophic (i.e., excellent water quality), mesotrophic (i.e., good water quality), eutrophic (i.e., poor water quality), and hypereutrophic (i.e., very poor water quality). Water quality characteristics of lakes in the various trophic status categories are listed below with their respective TSI ranges:

1. **Oligotrophic** – [$20 \leq TSI_{SD} \leq 38$] clear, low productive lakes, with total phosphorus concentrations less than or equal to 10 µg/L, chlorophyll *a* concentrations of less than or equal to 2 µg/L, and Secchi disc transparencies greater than or equal to 4.6 meters (15 feet).
2. **Mesotrophic** – [$38 \leq TSI_{SD} \leq 50$] intermediately productive lakes, with total phosphorus concentrations between 10 and 25 µg/L, chlorophyll *a* concentrations between 2 and 8 µg/L, and Secchi disc transparencies between 2 and 4.6 meters (6 to 15 feet).
3. **Eutrophic** – [$50 \leq TSI_{SD} \leq 62$] high productive lakes relative to a neutral level, with 25 to 57 µg/L total phosphorus, chlorophyll *a* concentrations between 8 and 26 µg/L, and Secchi disc measurements between 0.85 and 2 meters (2.7 to 6 feet).
4. **Hypereutrophic** – [$62 \leq TSI_{SD} \leq 80$] extremely productive lakes which are highly eutrophic and unstable (i.e., their water quality can fluctuate on daily and seasonal basis, experience periodic anoxia and fish kills, possibly produce toxic substances, etc.) with total phosphorus concentrations greater than 57 µg/L, chlorophyll *a* concentrations of greater than 26 µg/L, and Secchi disc transparencies less than 0.85 meters (2.7 feet).

Determining the trophic status of a lake is an important step in diagnosing water quality problems. Trophic status indicates the severity of a lake's algal growth problems and the degree of change needed to meet its recreational goals. Additional information, however, is needed to determine the cause of algal growth and a means of reducing it.

2.3 Limiting Nutrients

The quantity or biomass of algae in a lake is usually limited by the water's concentration of an essential element or nutrient "the limiting nutrient". (For rooted aquatic plants, the nutrients are derived primarily from the sediments.) The limiting nutrient concept is a widely applied principle in ecology and in the study of eutrophication. It is based on the idea that plants require many nutrients to grow, but the nutrient with the lowest availability, relative to the amount needed by the plant, will limit plant growth. It follows then, that identifying the limiting nutrient will point the way to controlling algal growth.

Nitrogen (N) and phosphorus (P) are generally the two growth-limiting nutrients for algae in most natural waters. Analysis of the nutrient content of lake water and algae provides ratios of N:P. By comparing the ratio in water to the ratio in the algae, one can estimate whether a particular nutrient may be limiting. Algal growth is generally phosphorus-limited in waters with N:P ratios greater than 12. Laboratory experiments (bioassays) can demonstrate which nutrient is limiting by growing the algae in lake water with various concentrations of nutrients added. Bioassays, as well as fertilization of in-situ enclosures and whole-lake experiments, have repeatedly demonstrated that phosphorus is usually the nutrient that limits algal growth in freshwaters. Reducing phosphorus in a lake, therefore, is required to reduce algal abundance and improve water transparency. Failure to reduce phosphorus concentrations will allow the process of eutrophication to continue at an accelerated rate.

2.4 Stratification

The process of internal loading is dependent on the amount of organic material in the sediments and the depth-temperature pattern, or “thermal stratification,” of a lake. Thermal stratification profoundly influences a lake’s chemistry and biology. When the ice melts and air temperature warms in spring, lakes generally progress from being completely mixed to stratified with an upper layer or warm well-mixed water (epilimnion), cold temperatures in a bottom layer (hypolimnion), and a layer of varying depth that will have a sharp temperature gradient (thermocline). Because of the density differences between the lighter warm water and the heavier cold water, stratification in a lake can become very resistant to mixing. When this occurs, generally in mid-summer, oxygen from the air cannot reach the bottom lake water and, if the lake sediments have sufficient organic matter, biological activity can deplete the remaining oxygen in the hypolimnion. The epilimnion can remain well-oxygenated, while the water above the sediments in the hypolimnion becomes completely devoid of dissolved oxygen (anoxic). Complete loss of oxygen changes the chemical conditions in the water and sediment, allowing phosphorus that had remained bound to the sediments to reenter the lake water.

As the summer progresses, phosphorus concentrations in the hypolimnion can continue to rise until oxygen is again introduced (recycled). Dissolved oxygen concentration will increase if the lake sufficiently mixes to disrupt the thermal stratification. Phosphorus in the hypolimnion is generally not available for plant uptake because there is not sufficient light penetration to the hypolimnion to allow for growth of algae. The phosphorus, therefore, remains trapped and unavailable to the plants until the lake is completely mixed. In shallow lakes this can occur throughout the summer, with sufficient wind energy (polymixis). In deeper lakes, however, only extremely high wind energy is sufficient to destratify a lake during the summer and complete mixing only occurs in the spring and fall (dimixis). Cooling air temperature in the fall reduces the epilimnion water temperature, and consequently increases the density of water in the epilimnion. As the epilimnion water density approaches the density of the hypolimnion water very little energy is needed to cause complete mixing of the lake. When this fall mixing occurs, phosphorus that has built up in the hypolimnion is mixed with the epilimnion water and becomes available for plant and algal growth.

2.5 Nutrient Recycling and Internal Loading

The significance of thermal stratification in lakes is that the density change in the metalimnion provides a physical barrier to mixing between the epilimnion and the hypolimnion. While water above the metalimnion may circulate as a result of wind action, hypolimnetic waters at the bottom generally remain isolated. Consequently, very little transfer of oxygen occurs from the atmosphere to the hypolimnion during the summer.

Shallow water bodies may circulate many times during the summer as a result of wind mixing. Lakes possessing these wind mixing characteristics are referred to as **polymictic** lakes. In contrast, deeper lakes generally become well-mixed only twice each year. This usually occurs in the spring and fall. Lakes possessing these mixing characteristics are referred to as **dimictic** lakes. During these periods, the lack of strong temperature/density differences allow wind-driven circulation to mix the water column throughout. During these mixing events, oxygen may be transported to the deeper portions of the lake, while dissolved phosphorus is brought up to the surface.

Phosphorus enters a lake from either watershed runoff or direct atmospheric deposition. It would, therefore, seem reasonable that phosphorus in a lake can decrease by reducing these external loads of phosphorus to the lake. All lakes, however, accumulate phosphorus (and other nutrients) in the sediments from the settling of particles and dead organisms. In some lakes this reservoir of phosphorus can be reintroduced in the lake water and become available again for plant uptake. This resuspension or dissolution of nutrients from the sediments to the lake water is known as “internal loading”. As long as the lake’s sediment surface remains sufficiently oxidized (i.e., dissolved oxygen remains present in the water above the sediment), its phosphorus will remain bound to sediment particles as a ferric-hydroxy-phosphate complex. When dissolved oxygen levels become extremely low at the water-sediment interface (as a result of microbial activity using the oxygen), the chemical reduction of ferric iron to its ferrous form causes the release of dissolved phosphorus, which is readily available for algal growth, into the water column. The amount of phosphorus released from internal loading can be estimated from depth profiles (measurements from surface to bottom) of dissolved oxygen and phosphorus concentrations. Even if the water samples indicate the water column is well oxidized, the oxygen consumption by the sediment during decomposition can restrict the thickness of the oxic sediment layer to only a few millimeters. Therefore the sediment cannot retain the phosphorus released from decomposition or deeper sediments which result in an internal phosphorus release to the water column. Low-oxygen conditions at the sediments, with resulting phosphorus release, are to be expected in eutrophic lakes where relatively large quantities of organic material (decaying algae and macrophytes) are deposited on the lake bottom.

If the low-lying phosphorus-rich waters near the sediments remain isolated from the upper portions of the lake, algal growth at the lake's surface will not be stimulated. Shallow lakes and ponds can be expected to periodically stratify during calm summer periods, so that the upper warmer portion of the water body is effectively isolated from the cooler, deeper (and potentially phosphorus-rich) portions. Deep lakes typically retain their stratification until cooler fall air temperatures allow the water layers to become isothermal and mix again. However, relatively shallow lakes are less thermally stable and may mix frequently during the summer periods. Shallow lakes are therefore frequently polymictic, experiencing alternating periods of stratification and destratification. It is the destratification, brought about by wind-induced mixing of the water column, that re-introduces phosphorus to the upper (epilimnetic) portion of the lake.

The pH of the water column can also play a vital role in affecting the phosphorus release rated under oxic conditions. Photosynthesis by macrophytes and algae during the day tend to raise the pH in the water column, which can enhance the phosphorus release rate from the oxic sediment. Enhancement of the phosphorus release at elevated pH (pH > 7.5) is thought to occur through replacement of the phosphate ion (PO_4^{-3}) with the excess hydroxyl ion (OH^-) on the oxidized iron compound (James et. al., 2001).

Another potential source of internal phosphorus loading is the die-off and subsequent decay of Curlyleaf pondweed, an exotic (i.e., non-native) lake weed prevalent in Lake Owasso. Curlyleaf pondweed grows tenaciously during early spring, crowding out native species. It releases a small reproductive pod that resembles a small pinecone during late June. After Curlyleaf pondweed dies out in early July, it may sink to the lake bottom and decay, causing oxygen depletion and exacerbating internal sediment release of phosphorus. This potential increase in phosphorus concentration during early July can result in algal blooms during the peak of the recreational season (the fourth of July).

3.0 Basin and Watershed Characteristics

3.1 Basin Characteristics

3.1.1 Lake Owasso

Lake Owasso covers an area of approximately 375 acres (MDNR) (Figure 3-1). The lake, which is located in the Cities of Roseville and Shoreview (Ramsey County), receives stormwater runoff from a watershed of approximately 3060 acres (including the lake surface area). The lake is located in the southwest quarter of Section 36, Township 30 N, Range 22 W.

Lake Owasso is located just upstream of Lake Wabasso, a 46.4-acre (MDNR) basin located northeast of Lake Owasso. The discharge from Lake Owasso is located on the northwest side of the lake and flows under North Owasso Boulevard, discharging into a wetland area on the southwest side of Lake Wabasso. The outlet structure of Lake Owasso consists of a concrete box with three 8-foot plate weirs, followed by two reinforced concrete arched pipe (See Appendix B). Discharge from Lake Owasso occurs when water levels are above 886.6 feet MSL; however, there is indication that ice build-up does limit the discharge from Lake Owasso during the winter months (Shoreview Public Works Director, personal communication, 1/18/2008). The location of the discharge from Lake Owasso is shown Figure 3-1.

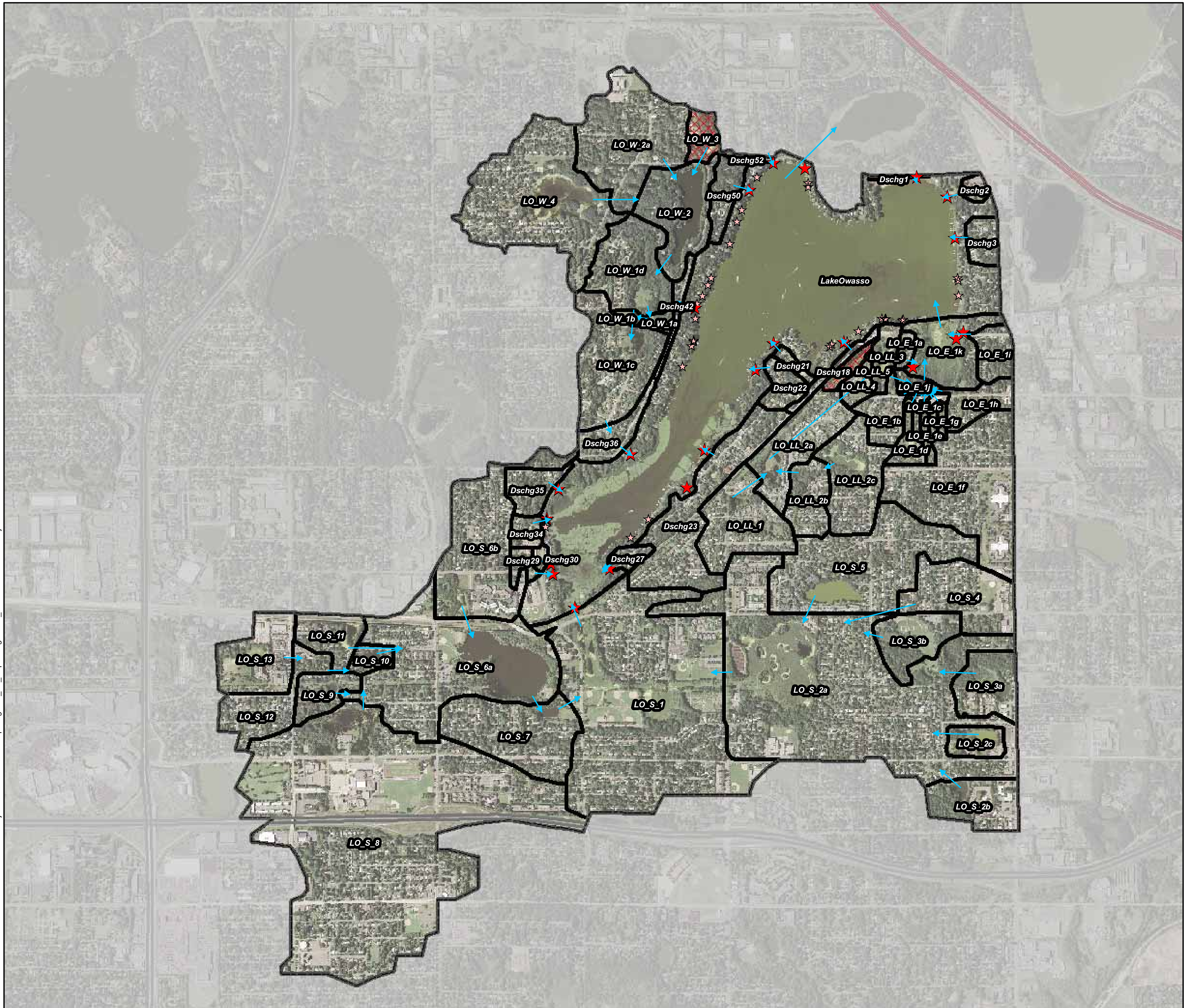
Lake Owasso is a deep lake with a maximum depth of 37.0 feet and a mean depth of 10.9 feet (Figure 3-2). The littoral zone (shallow area– generally less than 15-feet deep -- where light can penetrate and promote the growth of macrophytes) is estimated to be about 293 acres (or about 78 percent of the lake). Although much of the lake ranges from 5 to 10 feet in depth, there are three deep areas within the lake. There is a small deep pool, with a maximum depth of about 20 feet, located in the southwest corner of the lake. There is another larger pool about 27 feet deep in northeast corner of the lake. Finally, the largest deep pool is located in the northwest part of the lake and has a maximum depth of about 37 feet. Additional information on the morphometry of Lake Owasso is presented in Table 3-1.

Table 3-1 Lake Owasso Morphometry

Lake Characteristic	Lake Owasso
Lake MDNR ID	62-0056
Normal Water Level (NWL)	886.6
Surface Area (acres)	375
Mean Depth (feet)	10.9
Maximum Depth (feet)	37
Volume (below the NWL) (acre-feet)	4098.7
Thermal Stratification Pattern	Dimicitic
Watershed Area (acres)*	3060

*Includes surface area of lake

Lake Owasso was formed in glacial till when the most recent glaciers receded approximately 10,000 years ago. The area surrounding the lake is composed of different types of glacial deposits. Lake Owasso is considered a groundwater lake, meaning that the lake level represents the approximate groundwater table and it undergoes periods of recharge and seepage. The potentiometric gradient of the underlying aquifers is towards the southwest (Barr, 1991).



Watershed Flow Direction

Watersheds

Subwatershed

Land Locked Subwatershed

Direct Discharges

City or County

Residental

Feet

1,750 0 1,750

N

Figure 3-1

LAKE OWASSO WATERSHED

Lake Owasso UAA
Grass Lake Watershed Management Organization

Barr Footer: Date: 12/15/2008 12:07:56 PM File: I:\Projects\23\62\946\GIS\Maps\Figures_for_Report\Figure3-1_Watershed.mxd User: jak2

Bathymetry

Elevation (Depth)

- 851.6 MSL (35 feet)
- 856.6 MSL (30 feet)
- 861.6 MSL (25 feet)
- 866.6 MSL (20 feet)
- 871.6 MSL (15 feet)
- 876.6 MSL (10 feet)
- 881.6 MSL (5 feet)
- 886.6 MSL (0 feet)

Feet

750 0 750

N

Figure 3-2

LAKE OWASSO BATHYMETRY

Lake Owasso UAA
Grass Lake Watershed Management Organization

3.2 Watershed Characteristics

3.2.1 Land Use

There have been several studies of Lake Owasso completed in the past, and the watershed has been previously subdivided. For this study, the subwatersheds, as delineated in the *GLWMO Watershed Management Plan* (Barr, 2001), were used as a starting point. These subwatersheds were further refined, including delineation of the drainage areas contributing to each of the major discharge points into Lake Owasso, as identified by the discharge location surveys completed by the Cities of Shoreview and Roseville and digital storm sewer information provided by each of the cities(Figure 3-1).

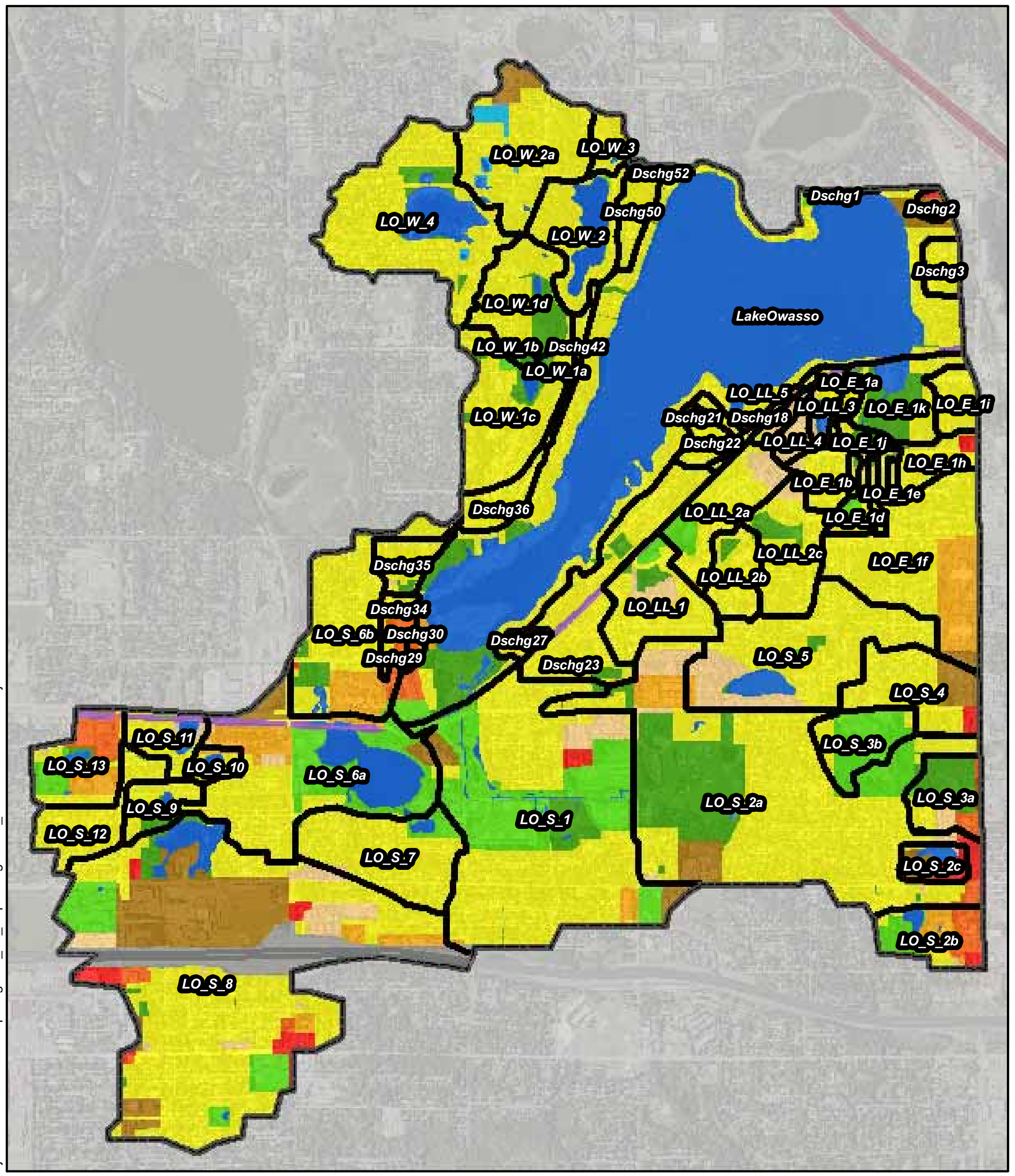
Existing (2006) and full-development (2020) land use patterns within the watersheds were identified for the purpose of predicting changes in runoff volumes and annual phosphorus loads before and after development (Figure 3-3). Existing land use conditions were determined using GIS land use information from the *GLWMO Watershed Management Plan* (Barr, 2001) and verified (and adjusted as necessary) using 2006 aerial photography. Full-development land use information from the *GLWMO Watershed Management Plan* was also used for the year 2020. The Lake Owasso watershed is fully-developed and land use is not expected to change significantly. The existing and future land use conditions for the Lake Owasso subwatersheds are summarized in Tables 3-2 and 3-3, respectively.

The Lake Owasso watershed covers approximately 3060 acres, including the surface area of the lake. The land use is predominantly residential. There is also a significant amount of water and wetland as well as developed park and open space. There is some commercial and office/industrial land use in the eastern portion of the watershed along Rice Street, as well as a small area in the far western portion of the watershed. Highway 36 runs east to west in the southern part of the watershed. Figure 3-4 summarizes the land use composition of the Lake Owasso watershed.

3.2.2 Soils

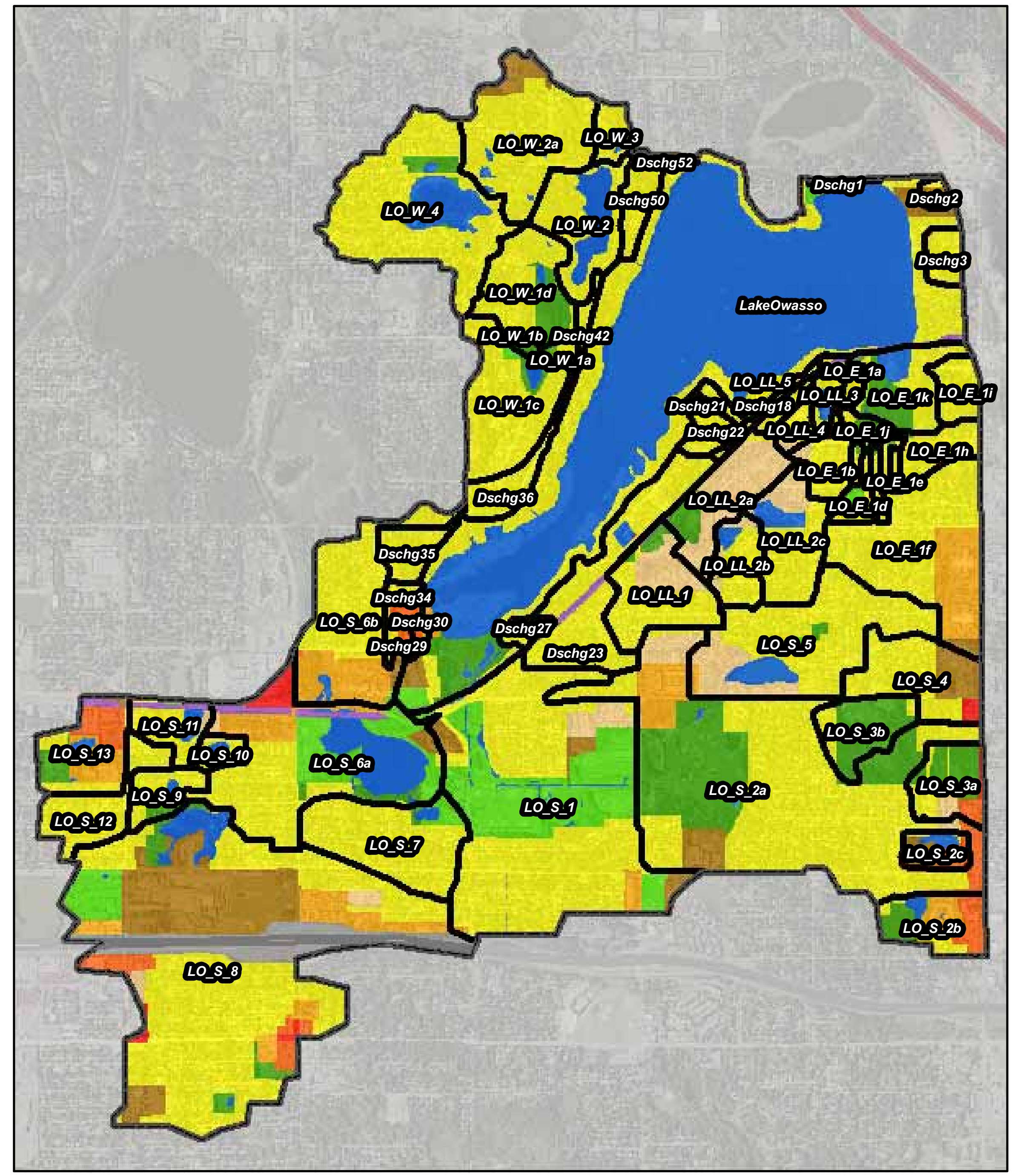
The infiltration capacity of soils affects the amount of direct runoff resulting from rainfall. Soils with a higher infiltration rate have a lower runoff potential. Conversely, soils with low infiltration rates produce high runoff volumes and high peak runoff rates. According to the Ramsey County Digital Soils map based on the Natural Resource Conservation Service (NRCS) Soil Survey, the underlying soils in the Lake Owasso watersheds are predominantly classified as hydrologic soil group (HSG) B, with moderate infiltration rates. The soils along the eastern side of the lake are classified as HSG A, characterized by high infiltration rates. Soils around wetland areas within the watershed typically have low to very low infiltration capacity. Figure 3-5 depicts the hydrologic soils group classification for soils within the Lake Owasso watersheds.

Existing (2006) Land Use



Source: 2001 GLWMO Watershed Management Plan, Modified to 2006 aerial photography

Full Development (Future) Land Use



Source: 2001 GLWMO Watershed Management Plan

Subwatershed

Land Use

- Commercial
- Developed Park
- Highway
- High-Density Residential
- Institutional
- Office/Industrial
- Low-Density Residential
- Medium-Density Residential
- Natural/Open Space
- Water
- Wetland
- Railroad

Feet

2,500 0 2,500

N

Figure 3-3

LAKE OWASSO WATERSHED
EXISTING AND FULL DEVELOPMENT
LAND USE

Lake Owasso UAA
Grass Lake Watershed Management Organization

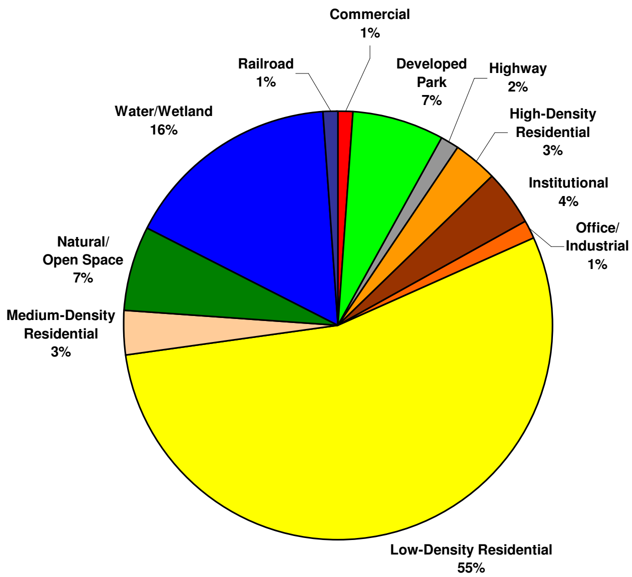
Table 3-2 Lake Owasso Watershed—Existing (2006) Land Use

Subwatershed	Commercial	Developed Park	Highway	High-Density Residential	Institutional	Office/ Industrial	Low-Density Residential	Medium-Density Residential	Natural/Open Space	Water/ Wetland	Railroad	TOTAL Acres
Dschg1	0.0	0.8	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	**1.1**
Dschg18	0.0	0.0	0.0	0.0	0.0	0.0	3.9	0.0	0.0	0.0	2.4	**6.4**
Dschg2	0.8	0.0	0.0	0.0	3.2	0.0	0.2	0.0	0.0	0.0	0.2	**4.4**
Dschg21	0.0	0.0	0.1	0.0	0.0	0.0	3.9	0.0	0.0	0.0	0.0	**3.9**
Dschg22	0.0	0.0	0.0	0.0	0.0	0.0	12.1	0.0	0.0	0.0	0.0	**12.1**
Dschg23	0.0	0.0	0.0	0.4	0.0	0.0	57.0	0.1	4.1	0.0	5.3	**66.9**
Dschg27	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.1	0.0	0.8	**5.9**
Dschg29	0.0	0.0	0.0	0.2	0.0	3.5	1.5	0.2	0.0	0.0	0.0	**5.5**
Dschg3	0.0	0.0	0.0	0.0	0.0	0.0	10.8	0.0	0.0	0.0	0.0	**10.8**
Dschg30	0.0	0.0	0.0	0.6	0.0	1.7	0.0	0.0	0.2	0.0	0.0	**2.6**
Dschg34	0.0	0.0	0.0	0.0	0.0	2.6	4.9	0.0	0.0	0.0	0.0	**7.5**
Dschg35	0.0	0.0	0.0	0.0	0.0	0.0	13.4	0.4	1.6	0.0	0.0	**15.4**
Dschg36	0.0	0.0	0.0	0.0	0.0	0.0	16.8	0.0	0.1	0.0	0.0	**16.8**
Dschg42	0.0	0.0	0.0	0.0	0.0	0.0	6.6	0.0	0.2	0.0	0.0	**6.7**
Dschg50	0.0	0.0	0.0	0.0	0.0	0.0	14.0	0.1	0.5	0.0	0.0	**14.6**
Dschg52	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	**2.5**
LakeOwasso	0.1	5.3	0.8	2.1	4.8	4.3	113.9	0.0	26.1	383.8	4.7	**545.9**
LO_E_1a	0.0	0.0	0.0	0.0	0.0	0.0	3.9	0.0	0.5	0.0	0.0	**4.3**
LO_E_1b	0.0	0.0	0.0	0.0	0.0	0.0	15.2	1.9	0.0	0.0	0.0	**17.1**
LO_E_1c	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.5	0.0	0.0	**2.4**
LO_E_1d	0.0	3.2	0.0	0.0	0.0	0.0	6.2	0.0	0.4	0.0	0.0	**9.8**
LO_E_1e	0.0	0.0	0.0	0.0	0.0	0.0	3.9	0.0	0.5	0.0	0.0	**4.4**
LO_E_1f	0.0	0.0	0.0	25.5	2.6	0.0	70.1	0.0	0.8	0.0	0.0	**99.1**
LO_E_1g	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.3	0.0	0.0	**2.5**
LO_E_1h	1.7	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.8	0.1	0.0	**17.5**
LO_E_1i	0.0	0.0	0.0	0.0	0.0	0.0	14.6	0.0	0.0	0.0	0.0	**14.6**
LO_E_1j	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	3.6	0.5	0.0	**5.9**
LO_E_1k	0.0	0.0	0.0	0.0	0.0	0.0	12.9	0.0	15.4	5.0	2.2	**35.5**
LO_LL_1	0.0	2.5	0.0	0.0	0.0	0.0	34.3	5.4	3.4	0.0	1.4	**47.0**
LO_LL_2a	0.0	6.0	0.0	0.0	0.0	0.0	27.0	6.4	0.1	0.0	2.1	**41.5**
LO_LL_2b	0.0	0.0	0.0	0.0	0.0	0.0	20.6	0.0	1.6	0.0	0.0	**22.2**
LO_LL_2c	0.0	0.0	0.0	0.0	0.0	0.0	34.1	2.9	5.7	0.0	0.0	**42.7**
LO_LL_3	0.0	0.0	0.0	0.0	0.0	0.0	4.0	3.1	0.7	1.7	1.1	**10.5**
LO_LL_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.2	0.0	0.0	0.0	**8.2**
LO_LL_5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	3.5	0.0	0.2	1.5	**5.8**
LO_S_1	2.6	74.6	0.6	3.9	6.7	0.0	141.0	10.0	13.0	3.9	1.8	**258.3**
LO_S_10	0.0	0.0	0.0	1.0	0.0	0.0	5.1	0.2	0.0	1.8	0.0	**8.1**
LO_S_11	0.0	1.0	0.0	0.0	0.1	0.0	12.6	1.7	0.0	2.9	2.7	**21.0**
LO_S_12	0.0	0.0	0.0	0.1	0.0	0.0	31.5	0.1	0.3	0.0	0.0	**32.0**
LO_S_13	0.0	6.5	0.0	8.4	0.5	9.4	9.3	0.3	1.0	1.5	1.6	**38.6**
LO_S_2a	4.2	15.2	0.0	9.8	10.6	3.5	170.7	13.6	63.7	0.7	0.0	**291.9**
LO_S_2b	1.7	7.6	0.1	7.2	0.0	7.6	4.3	0.3	0.0	2.0	0.0	**30.8**
LO_S_2c	3.7	0.0	0.0	0.0	4.2	0.0	1.8	0.7	0.0	2.5	0.0	**12.9**
LO_S_3a	0.9	0.6	0.1	0.0	0.0	3.9	5.4	3.8	14.0	0.0	0.0	**28.6**
LO_S_3b	0.0	21.7	0.0	0.0	0.0	0.0	7.4	0.0	0.0	0.0	0.0	**29.1**
LO_S_4	2.6	0.0	0.0	0.0	9.6	0.0	34.7	0.0	0.0	0.0	0.0	**46.8**
LO_S_5	0.0	1.3	0.0	1.5	0.0	0.0	73.5	16.4	1.6	7.3	0.0	**101.5**
LO_S_6a	0.0	31.6	0.0	14.4	8.9	0.0	45.7	2.4	0.1	26.3	5.7	**135.2**
LO_S_6b	0.3	0.5	0.0	12.9	0.0	2.3	57.4	0.4	5.9	1.6	0.0	**81.4**
LO_S_7	0.0	5.4	0.0	0.0	0.0	0.0	55.6	0.7	0.2	1.4	0.0	**63.2**
LO_S_8	12.6	25.1	48.2	8.3	71.9	3.8	176.2	19.3	7.0	11.2	0.0	**383.8**
LO_S_9	0.0	0.0	0.0	0.0	0.0	0.0	13.7	0.0	2.5	1.1	0.0	**17.3**
LO_W_1a	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.0	1.3	0.0	0.0	**4.0**
LO_W_1b	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	**2.3**
LO_W_1c	0.0	1.5	0.0	0.0	0.0	0.0	51.2	0.0	5.2	1.9	0.0	**59.8**
LO_W_1d	0.0	0.0	0.0	0.0	0.0	0.0	34.2	0.0	10.7	1.2	0.0	**46.2**
LO_W_2	0.0	0.4	0.0	0.0	0.0	0.0	31.9	0.0	0.0	14.1	0.0	**46.4**
LO_W_2a	0.0	0.0	0.2	0.0	7.1	0.0	63.4	0.0	0.0	7.1	0.0	**77.9**
LO_W_3	0.0	0.0	0.0	0.0	0.0	0.0	10.4	0.0	0.0	0.4	0.0	**10.8**
LO_W_4	0.0	0.0	0.0	0.0	0.0	0.0	87.6	0.0	5.9	19.0	0.0	**112.5**
TOTAL Acres	**31.2**	**211.8**	**50.0**	**96.4**	**130.3**	**42.6**	**1662.4**	**102.1**	**200.9**	**499.1**	**33.4**	**3060**
%	**1.0**	**6.9**	**1.6**	**3.2**	**4.3**	**1.4**	**54.3**	**3.3**	**6.6**	**16.3**	**1.1**	**100.0**

Table 3-3 Lake Owasso Watershed—Future Land Use

Subwatershed	Commercial	Developed Park	Highway	High-Density Residential	Institutional	Office/ Industrial	Low-Density Residential	Medium-Density Residential	Natural/Open Space	Water/ Wetland	Railroad	TOTAL Acres
Dschg1	0.0	0.7	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.0	1.1
Dschg18	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	2.4	6.4
Dschg2	0.0	0.0	0.0	0.0	3.2	0.0	1.2	0.0	0.0	0.0	0.0	4.4
Dschg21	0.0	0.0	0.0	0.0	0.0	0.0	3.9	0.0	0.0	0.0	0.0	3.9
Dschg22	0.0	0.0	0.0	0.0	0.0	0.0	12.1	0.0	0.0	0.0	0.0	12.1
Dschg23	0.1	0.0	0.0	0.0	0.0	0.0	59.5	0.1	0.0	1.9	5.3	66.9
Dschg27	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.1	0.0	0.8	5.9
Dschg29	0.0	0.0	0.0	0.2	1.1	2.2	1.9	0.0	0.0	0.0	0.0	5.5
Dschg3	0.0	0.0	0.0	0.0	0.0	0.0	10.8	0.0	0.0	0.0	0.0	10.8
Dschg30	0.0	0.0	0.0	0.6	0.0	1.7	0.0	0.0	0.2	0.0	0.0	2.6
Dschg34	0.0	0.0	0.0	0.0	0.0	2.6	4.9	0.0	0.0	0.0	0.0	7.5
Dschg35	0.0	0.0	0.0	0.0	0.0	0.0	15.4	0.0	0.0	0.0	0.0	15.4
Dschg36	0.0	0.0	0.0	0.0	0.0	0.0	16.8	0.0	0.0	0.0	0.0	16.8
Dschg42	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.0	0.0	0.0	0.0	6.7
Dschg50	0.0	0.0	0.0	0.0	0.0	0.0	14.6	0.0	0.0	0.0	0.0	14.6
Dschg52	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	2.5
LakeOwasso	0.0	5.3	0.0	2.1	9.1	0.0	128.0	0.0	15.3	381.5	4.5	545.8
LO_E_1a	0.0	0.0	0.0	0.0	0.0	0.0	3.9	0.0	0.5	0.0	0.0	4.3
LO_E_1b	0.0	0.0	0.0	0.0	0.0	0.0	14.7	2.4	0.0	0.0	0.0	17.1
LO_E_1c	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.5	0.0	0.0	2.4
LO_E_1d	0.0	3.2	0.0	0.0	0.0	0.0	6.2	0.0	0.4	0.0	0.0	9.8
LO_E_1e	0.0	0.0	0.0	0.0	0.0	0.0	3.9	0.0	0.5	0.0	0.0	4.4
LO_E_1f	0.0	0.0	0.0	26.8	2.7	0.0	69.0	0.0	0.6	0.0	0.0	99.1
LO_E_1g	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.3	0.0	0.0	2.5
LO_E_1h	0.0	0.0	0.0	0.0	0.0	0.0	16.8	0.0	0.6	0.1	0.0	17.5
LO_E_1i	0.0	0.0	0.0	0.0	0.0	0.0	14.6	0.0	0.0	0.0	0.0	14.6
LO_E_1j	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	3.6	0.5	0.0	5.9
LO_E_1k	0.0	0.0	0.0	0.0	0.0	0.0	16.1	0.0	12.2	5.0	2.2	35.5
LO_LL_1	0.0	0.0	0.0	0.0	0.0	0.0	28.1	14.6	2.9	0.0	1.4	47.0
LO_LL_2a	0.0	0.0	0.0	0.0	0.0	0.0	1.4	31.9	6.0	0.0	2.1	41.5
LO_LL_2b	0.0	0.0	0.0	0.0	0.0	0.0	15.2	4.7	0.1	2.3	0.0	22.2
LO_LL_2c	0.0	0.0	0.0	0.0	0.0	0.0	27.9	9.5	0.0	5.3	0.0	42.7
LO_LL_3	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.0	0.2	1.7	1.1	10.5
LO_LL_4	0.0	0.0	0.0	0.0	0.0	0.0	7.0	1.2	0.0	0.0	0.0	8.2
LO_LL_5	0.0	0.0	0.0	0.0	0.0	0.0	4.1	0.0	0.0	0.2	1.5	5.8
LO_S_1	0.0	79.9	0.4	4.6	9.9	0.0	148.5	8.8	0.2	3.9	1.8	258.0
LO_S_10	0.0	0.0	0.0	0.6	0.0	0.0	5.2	0.5	0.0	1.8	0.0	8.1
LO_S_11	0.0	0.9	0.0	0.0	0.0	0.0	13.3	1.2	0.0	2.9	2.7	21.0
LO_S_12	0.0	0.0	0.0	0.1	0.0	0.0	31.9	0.0	0.0	0.0	0.0	32.0
LO_S_13	0.0	0.0	0.0	10.6	0.7	9.4	9.2	0.0	5.7	1.5	1.6	38.6
LO_S_2a	0.0	1.9	0.0	17.0	10.7	7.5	169.1	12.2	72.9	0.7	0.0	291.9
LO_S_2b	0.0	0.0	0.0	7.5	0.0	8.6	5.7	0.0	7.0	2.0	0.0	30.8
LO_S_2c	0.0	0.0	0.0	0.0	4.2	4.0	2.2	0.0	0.0	2.5	0.0	12.9
LO_S_3a	1.4	0.0	0.0	0.0	0.0	3.3	6.8	3.8	13.3	0.0	0.0	28.6
LO_S_3b	0.0	0.0	0.0	0.0	0.0	0.0	7.4	0.0	21.7	0.0	0.0	29.1
LO_S_4	2.6	0.0	0.0	0.0	11.8	0.0	32.5	0.0	0.0	0.0	0.0	46.8
LO_S_5	0.0	1.3	0.0	2.1	0.0	0.0	71.9	17.3	1.3	7.5	0.0	101.5
LO_S_6a	7.1	27.2	0.0	14.2	3.2	0.0	46.0	1.3	4.2	26.3	5.7	135.2
LO_S_6b	0.3	0.5	0.0	22.1	2.1	0.3	54.2	0.0	0.3	1.6	0.0	81.4
LO_S_7	0.0	4.4	0.0	0.0	0.0	0.0	56.4	0.0	1.0	1.4	0.0	63.2
LO_S_8	4.1	15.0	46.3	25.5	75.0	12.4	179.0	5.3	9.9	11.2	0.0	383.7
LO_S_9	0.0	0.0	0.0	0.0	0.0	0.0	14.1	0.0	2.1	1.1	0.0	17.3
LO_W_1a	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.0	1.3	0.0	0.0	4.0
LO_W_1b	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	2.3
LO_W_1c	0.0	1.4	0.0	0.0	0.0	0.0	53.7	0.0	2.8	1.9	0.0	59.8
LO_W_1d	0.0	0.0	0.0	0.0	0.0	0.0	34.3	0.0	10.6	1.2	0.0	46.2
LO_W_2	0.0	0.0	0.0	0.0	0.0	0.0	32.3	0.0	0.0	14.1	0.0	46.4
LO_W_2a	0.0	0.0	0.0	0.0	9.0	0.0	67.0	0.0	0.0	1.9	0.0	77.9
LO_W_3	0.0	0.0	0.0	0.0	0.0	0.0	10.4	0.0	0.0	0.4	0.0	10.8
LO_W_4	0.0	0.0	0.0	0.0	0.0	0.0	88.8	0.0	5.1	18.6	0.0	112.5
TOTAL Acres	**15.5**	**142.4**	**46.8**	**134.1**	**142.7**	**52.0**	**1672.5**	**114.5**	**205.2**	**501.0**	**33.1**	**3060**
%	**0.5**	**4.7**	**1.5**	**4.4**	**4.7**	**1.7**	**54.7**	**3.7**	**6.7**	**16.4**	**1.1**	**100.0**

Lake Owasso Watershed
Existing (2006) Land Use
Total Watershed Area = 3060 Acres



Lake Owasso Watershed
Full Development Land Use
Total Watershed Area = 3060 Acres

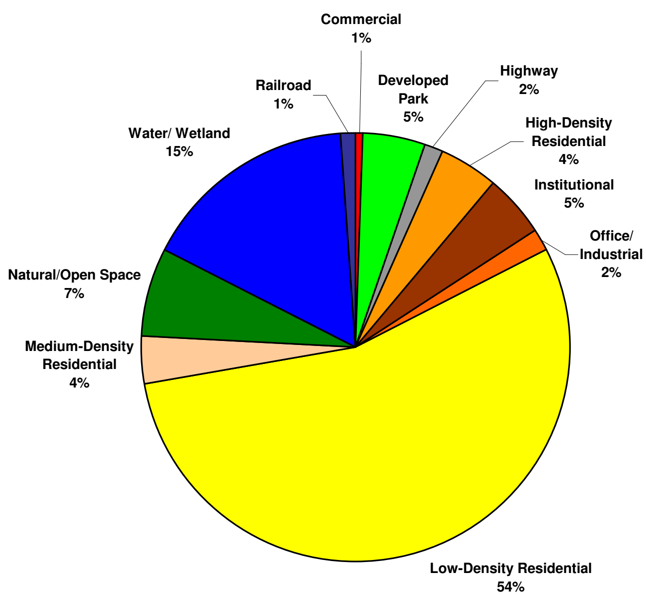
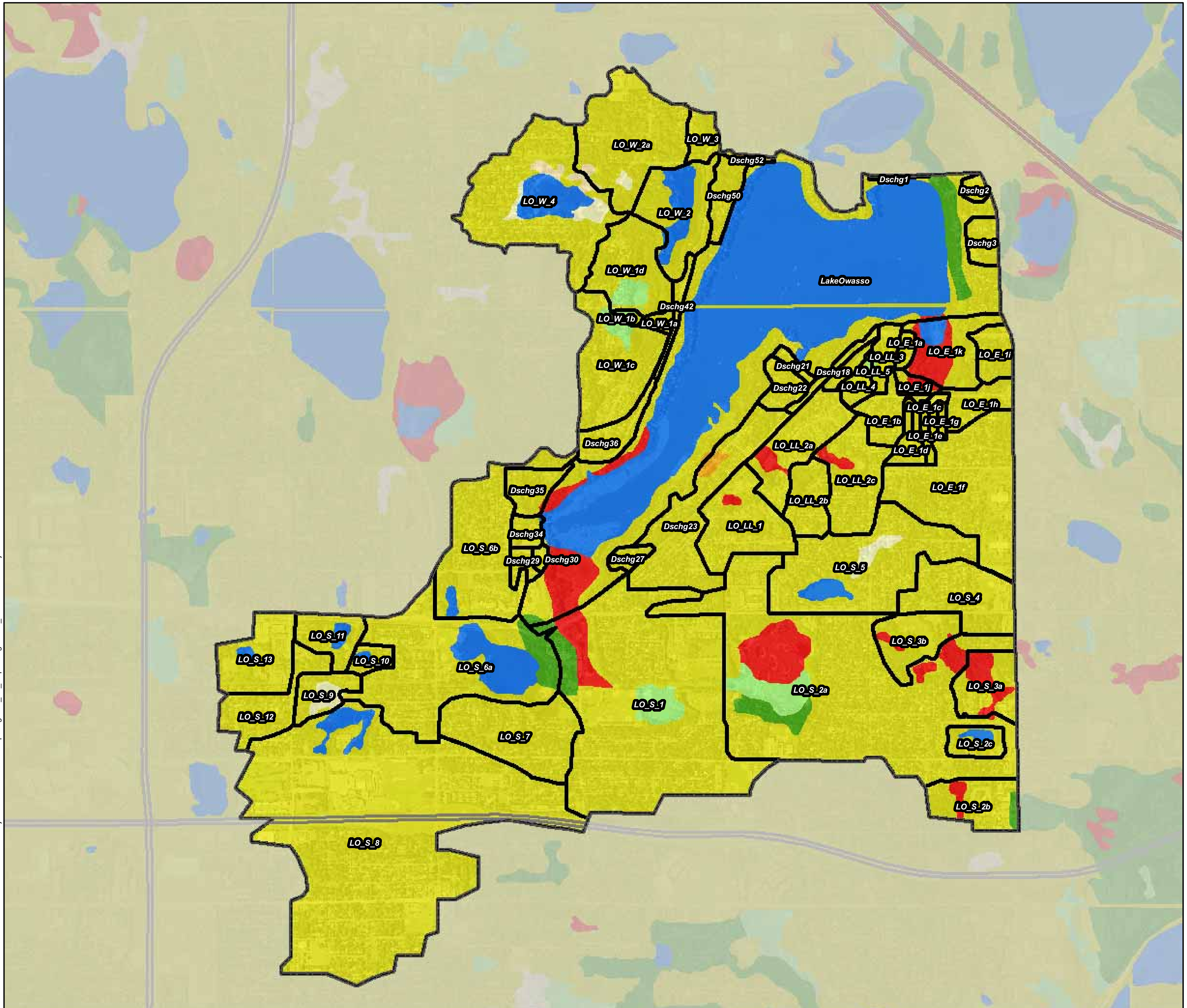


Figure 3-4
Lake Owasso Watershed
Existing (2006) and Full Development
Land Use Summary



Subwatershed

Hydrologic Soil Group (HSG)

- A - High Infiltration Potential
- A/D - Very Low Infiltration Potential
- B - Moderate Infilatration Potential
- B/D - Very Low Infiltration Potential
- C - Low Infiltration Potential
- C/D - Very Low Infiltration Potential
- D - Very Low Infiltration Potential
- Water

Feet

1,750 0 1,750

N

Figure 3-5

LAKE OWASSO WATERSHED
SOIL INFILTRATION CAPACITY

Lake Owasso UAA
Grass Lake Watershed Management Organization

4.0 Methods

4.1 Data Collection

4.1.1 Lake Water Quality Data

Lake Owasso has historical water quality data for basic parameters from 1973 to 2008. This data has been collected by a variety of agencies and monitoring programs. The MDNR collected water quality data in the early 1970s and the Metropolitan Council (MetCouncil) collected data in the later 1970s through the early 1980s. Data collected in 1980 and 1984 were collected as part of the MetCouncil's Citizen-Assisted Monitoring Program (CAMP). Secchi depth data for Lake Owasso has been collected as part of the MPCA's Citizen Lake Monitoring Program (CLMP) from 1976 through the present. However, the majority of the water quality data for Lake Owasso (from 1984 through the present) has been collected by Ramsey County, including the more detailed sampling efforts in 2007 and 2008.

In 2007, and again in 2008, an intensive water quality sampling program was implemented for Lake Owasso during the open-water season. Because the recent summer average transparencies in Lake Owasso fell below the GLWMO "action level", the intensive data collection program was completed to evaluate current water quality conditions in the lakes. This data was used to calibrate the water quality models developed as part of the UAA. There were two monitoring sites on Lake Owasso (Figure 4-1). The first site (5401) was located in the deep area in the northwest corner of the lake. This site is also the location where sampling has historically occurred in Lake Owasso. The second site (5403) was located in the deeper area located in the southwest corner of the lake. There were nine sampling events from the end of March through late September in 2007. There were eight sampling events from early May through late September in 2008.

Table 4-1 lists the water quality parameters, and specifies when and at what depths samples or measurements were collected. Dissolved oxygen, temperature, specific conductance, and Secchi disc transparency were measured in the field; whereas, water samples were analyzed in the laboratory for total phosphorus, pH, chlorophyll *a*, chloride, hardness, and alkalinity. The procedures for chemical analyses of the water samples are shown in Table 4-2. Generally, the methods can be found in *Standard Methods for Water and Wastewater Analysis.*

Table 4-1 Water Quality Sampling Parameters

Parameters	Depth (Meters)	Sampled or Measured During Each Sample Event
Dissolved Oxygen	Surface to bottom profile	X
Temperature	Surface to bottom profile	X
Specific Conductance	Surface to bottom profile	X
Secchi Disc	—	X
Total Phosphorus	0-2 Meter Composite Sample	X
Total Phosphorus	Profile at 1.0 meter intervals from 3 meters to 0.5 meters above lake bottom	X
Soluble Reactive Phosphorus	Profile at 1.0 meter intervals from 3 meters to 0.5 meters above lake bottom	X
Total Dissolved Phosphorus	Profile at 1.0 meter intervals from 3 meters to 0.5 meters above lake bottom	X
pH	0-2 Meter Composite Sample	X
pH	Profile at 1.0 meter intervals from 3 meters to 0.5 meters above lake bottom	X
Chlorophyll *a*	0-2 Meter Composite Sample	X
Turbidity	0-2 Meter Composite Sample	X
Chloride	0.5 meters above lake bottom	X
Hardness	Surface to Bottom Profile	X
Alkalinity	Surface to Bottom Profile	X

Table 4-2 Procedures for Chemical Analyses Performed on Water Samples

Analysis	Procedure	Reference
Total Phosphorus	Persulfate digestion, manual ascorbic acid	Standard Methods, 18th Edition (1992) modified per Eisenreich, et al., Environmental Letters 9(1), 43-53 (1975)
Chlorophyll *a*	Spectrophotometric	Standard Methods, 18th Edition, 1992, 10200 H
pH	Potentiometric measurement, glass electrode	Standard Methods, 16th Edition, 1985, 423
Specific Conductance	Wheatstone bridge	Standard Methods, 16th Edition, 1985, 205
Temperature	Thermometric	Standard Methods, 16th Edition, 1985, 212
Dissolved Oxygen	Electrode	Standard Methods, 16th Edition, 1985, 421F
Transparency	Secchi disc	
Chloride	Automated colorimetric with ferricyanide	EPA 325.1
Hardness		EPA 130.2
Alkalinity		SM2320 B-97

To define a “summer-average” for each water quality parameter, the typical averaging period was late May through early September to be consistent with the MPCA’s method for evaluating lake water quality. For some years, the averaging period was June through early September if data for late May was not available.

4.1.2 Sediment Core Samples

All lakes accumulate phosphorus (and other nutrients) in the lake sediments from the settling of particles and dead organisms. In some lakes this reservoir of phosphorus can be reintroduced in the lake water and become available again for plant uptake. This resuspension or dissolution of nutrients from the sediments to the lake water is known as “internal loading”. Sediment cores were collected from Lake Owasso in May of 2007 to determine sediment phosphorus concentrations that can lead to internal phosphorus loading.

Multiple sediment cores were taken from Lake Owasso (Figure 4-1) and were analyzed for mobile phosphorus (which potentially can contribute directly to internal phosphorus loading) and organic bound phosphorus. Phosphorus fractions were determined according to a modified version of Psenner et al. (1988) and internal loading estimates were calculated according to the method developed by Pilgrim et al. (2007). After laboratory analysis, sediment phosphorus concentrations were modeled to determine lake wide potential internal phosphorus loading rates using Geostatistical Analysis within the ArcMap GIS program.

4.1.3 Macrophyte Monitoring

Macrophyte (aquatic plant) monitoring for Lake Owasso has been completed for several years. Most recently, macrophytes in Lake Owasso were monitored in 2007 at the end of May by Ramsey County. A detailed map of the 2007 macrophyte monitoring results, specifically focusing on Curlyleaf pondweed coverage, is presented and discussed in this report. A brief summary of past monitoring results for the lake is also presented in this report.

4.1.4 Stormwater Runoff Monitoring

In 2007 and 2008, the Ramsey Washington Metro Watershed District (RWMWD) installed three watershed runoff monitoring stations around Lake Owasso (Figure 4-1). These stations monitored both flow and water quality. These stations collected flow data (area-velocity) every 10 minutes during operation. The water quality sampling was a composite sampling system triggered by changes in the observed water level during storm events.

In 2007, the first monitoring site was located on the south side of Owasso Bay, in the storm sewer running along Galtier Street. This site monitored runoff from subwatershed LO_E_1f. This watershed does not have any ponds or other treatment devices. The second monitoring station was located on the southside of Lake Owasso at downstream of the County Road C crossing at the outlet of Central Park Pond west. This station corresponds with the outlet of subwatershed LO_S_1. There are many stormwater ponds, wetlands, and lakes within this watershed including Westwood Village Pond, Bennett Lake, and the Central Park Ponds (east and west). The third site was located on the west side of Lake Owasso, just downstream of the CDS treatment structure at West Owasso Boulevard. This monitoring site corresponds to the combined outlet of subwatershed Dschg36 and LO_W_1c (Charlie Pond) . Runoff through this watershed passes through numerous lakes and ponds, including Lake Judy, Lake Emily, and the Charlie Pond system.

Because additional data was needed to verify the P8 model runoff predictions, watershed runoff flow and water quality modeling was continued in the summer of 2008. In 2008, the monitoring station from Galtier Street was moved to Dale Street where the Central Park - East wetland discharges into the Central Park – West wetland (at the outlet of subwatershed LO_S_2a). This site was selected to help monitor the potential water quality impacts of the City of Roseville Leaf Recycling Center. The other two monitoring stations installed in 2008 were located at the County Road C crossing at the outlet of Central Park Pond - West and just downstream of the CDS treatment structure at West Owasso Boulevard. These sites were the same as those monitored in 2007, although at County Road C, the 2008 monitoring station was located at the upstream end of the County Road C crossing while in 2007, it was located at the downstream end of the pipe. This station was moved to reduce the influence of Lake Owasso water level fluctuations on the flow monitoring data, as both the Central Park – East and Central Park – West wetlands can be impacted by Lake Owasso water levels.

In addition to the installation of the automatic flow and water quality sampling stations in 2008, RWMWD staff collected water quality grab samples at the Dale Street and County Road C stations to establish an understanding of the baseline (non-storm event) water quality in these two wetlands. These grab samples were typically collected between storm events by the RWMWD staff.

4.1.5 Discharge Location Survey (2007)

The *Water Quality Management Alternatives* study (Barr, 1991) considered 12 major inlet locations to Lake Owasso. These locations were typically larger inflow locations under the jurisdiction of the City or the County.

Concerns expressed by lake residents about untreated direct discharges to Lake Owasso were addressed by conducting a survey of all pipes, regardless of jurisdiction or size, discharging to the lake. The Cities of Shoreview and Roseville staff conducted these surveys in the early summer of 2007, recording the size and type of pipe, as well as using GPS and/or parcel address to locate the discharge to the lake. There are also photographs of each discharge to Lake Owasso in the City of Shoreview. The approximate location of each discharge as well as the party responsible for maintenance is included in Figure 3-1. This survey identified 23 discharges to Lake Owasso under public jurisdiction (City or County). However, a few of these pipes have been bulkheaded and no longer discharge to the lake. There were 32 discharges to the lake coming from residential properties to the lake. Appendix C includes additional information about the 2007 discharge survey.

4.1.6 Pond Discharge Survey (2008)

The summer of 2007 experienced below average precipitation for much of the summer, making calibration of P8 model runoff difficult (see Section 4.2.2 for a more complete discussion). In 2007, there were several ponds within the Lake Owasso watershed whose water levels had dropped below the normal outlet and were not discharging (as observed on a single field visit in August). More detailed information about the discharges from some of the key lakes, ponds, and wetlands throughout the summer would aid in the model calibration and validation process. Therefore, in 2008, nine of the major ponds and wetlands in the Lake Owasso watershed were monitored approximately every two weeks during June and July. Monitoring was limited to observations of whether the water levels in the ponds were above or below the invert of the normal outlet structure. Ponds monitored included: Lake Judy (LO_W_4), Lake Emily (LO_W_2), Charlie Pond (LO_W_1c), Willow Pond (LO_S_8), Bennett Lake (LO_S_6a), Central Park Pond – East (LO_S_2a), Central Park Pond – West (LO_S_1), Westwood Village Pond (LO_S_5), and the wetland located in subwatershed LO_LL_3. Results of the pond discharge surveys can be found in Appendix D.

4.2 Watershed Stormwater and Total Phosphorus Loadings

The computer model P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds, IEP, Inc., 1990) was used to estimate both the stormwater runoff and phosphorus loads introduced from the entire Lake Owasso watersheds. P8 is a useful diagnostic tool for evaluating and designing watershed improvements and Best Management Practices (BMPs).

When evaluating the results of the modeling, it is important to consider that the results provided are more accurate in terms of relative differences than in absolute results. The model will predict the percent difference in phosphorus reduction between various BMP options in the watershed fairly accurately. It also provides a realistic estimate of the relative differences in phosphorus and water loadings from the various subwatersheds and major inflow points to the lake. However, since runoff quality is highly variable with time and location, the phosphorus loadings estimated by the model for a specific watershed may not necessarily reflect the actual loadings, in absolute terms. Various site-specific factors, such as lawn care practices, illicit point discharges, and erosion due to construction are not accounted for in the model. The model provides values that are considered to be typical of the region, given the watershed's respective land uses.

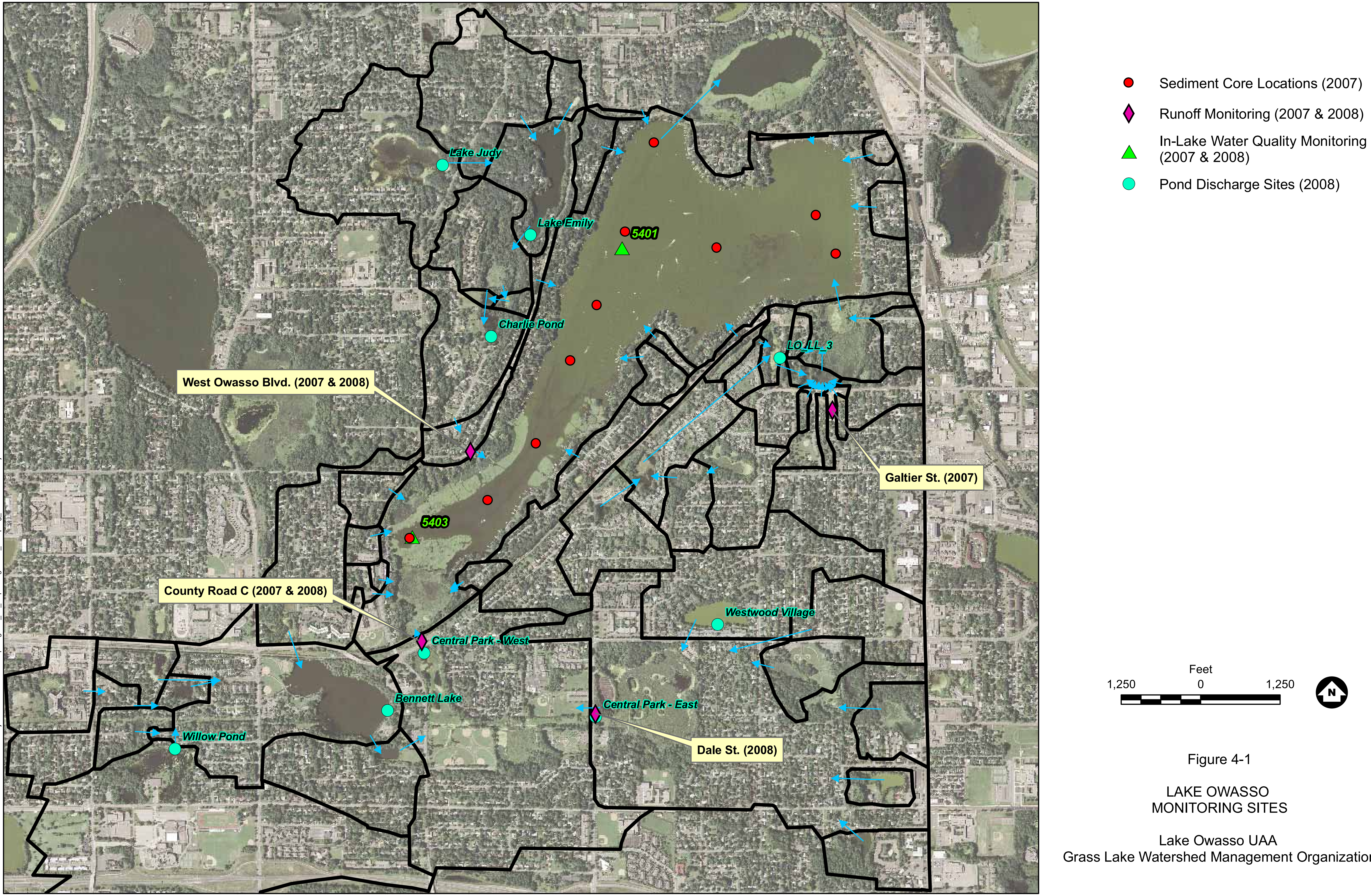


Figure 4-1

LAKE OWASSO
MONITORING SITES

Lake Owasso UAA
Grass Lake Watershed Management Organization

Barr Footer: Date: 11/8/2007 1:19:03 PM File: I:\Projects\23\62\946\GIS\Maps\Figures_for_Report\Figure4-1_Sampling_Sites.mxd User: jak2

4.2.1 Water Quality Modeling (P8) of Varying Hydrologic Conditions

The amount of stormwater runoff and associated pollutant loading from a watershed is dependent upon hydrologic conditions such as precipitation patterns and soil saturation conditions. To evaluate the watershed loading under differing hydrologic conditions, the P8 model was run for three time periods that represent average, wet, and dry climatic conditions.

- “Average” climatic conditions: May 2004- September 2005
- “Wet” climatic conditions: May 2001- September 2002
- “Dry” climatic conditions: May 2007 - September 2008

The P8 model requires hourly precipitation and daily temperature data for each of the modeled time periods. For model calibration, a continuous hourly precipitation file was developed based on data from the National Weather Service (NWS) Downtown Saint Paul Airport station for 2006 through 2008 and from the NWS Minneapolis-St. Paul International Airport station for years prior to 2006. The Downtown Saint Paul monitoring station is located approximately 7.5 miles from Lake Owasso while the Minneapolis-St. Paul Airport station is located approximately 10.5 miles from Lake Owasso. Local daily precipitation data from the Minnesota High Density Network of rain gages (Vadnais) were used to augment the observed hourly data from the Downtown Saint Paul Airport and Minneapolis-St. Paul International Airport NWS stations. Daily temperature data was obtained from the NWS station at the Minneapolis-St. Paul International Airport station. To model the various climatic conditions, the same hourly precipitation and temperature data were used. See Figure 4-2 for the location of the precipitation gages.

See Appendix E for additional information on the P8 model input files.

4.2.2 Water Quality Model (P8) Calibration

4.2.2.1 Stormwater Volume Calibration

The stormwater runoff model calibration process involved two phases. First was the calibration of the predicted P8 runoff volume to actual stormwater monitoring data. The second phase included developing a water balance model calibrated to lake level data to verify runoff volumes and estimate the expected groundwater exchange.

4.2.2.1.1 Stormwater Monitoring Sites (2007 and 2008)

Initially, the P8 model runoff volumes were calibrated to the 2007 observed flows at each of the runoff monitoring stations. Because there were no ponds or treatment devices within the watershed contributing runoff to the monitoring station on Galtier Street (outfall of subwatershed LO_E_1f), this station was used to estimate the watershed runoff parameters to be applied to all subwatersheds across the entire Lake Owasso watershed. It is important to note that there were few storm events during the summer of 2007 that contributed flows from the pervious surfaces in the watershed contributing to the monitoring station on Galtier Street. Figure 4-3a shows the results of the 2007 runoff volume calibration for the monitoring site at Galtier Street. The calibrated watershed parameters based on the 2007 Galtier Street site were applied to all watersheds contributing runoff to Lake Owasso.

The contributing watersheds to the County Road C (2007 and 2008 monitoring), the West Owasso Boulevard (2007 and 2008 monitoring), and the Dale Street (2008 monitoring) sites have several lakes and wetlands within them. Under default conditions in P8, treatment devices such as ponds do not lose water through infiltration (or excessive evaporation) and will remain at their normal water level, even during extended periods of little or no rainfall.

The summer of 2007 was very hot and dry during June July, and the first half of August, and a field inspection of ponds and wetlands in August 2007 indicated that many of these water bodies were below their normal water level and were not discharging downstream. Therefore, for all devices that were natural water bodies (ponds or wetlands), an “infiltration” rate was applied to calibrate the cumulative runoff volume predicted by P8 to the monitoring data from the County Road C and West Owasso Boulevard monitoring sites, respectively. This “infiltration” rate is not solely a loss to infiltration but represents losses to infiltration as well as excessive evaporation.

The summer of 2008 was also a very dry summer. The runoff monitoring data, in conjunction with the pond discharge survey data, indicated that similar to the summer of 2007, there were periods during which many of the major ponds within the watershed were not discharging runoff downstream. With this additional monitoring data, the P8 model runoff calibration was further refined. This included modifications to the estimated pond and wetland “infiltration” rates as well as developing modified discharge rating curves for both the Central Park Pond – East (Dale Street) and the Central Park Pond – West (County Road C) wetlands based on the 2008 flow monitoring data. Surveys of the inverts of the Central Park pond’s outlet (conducted in May 2008 by the City of Roseville) and review of the flow monitoring data indicates that the water levels and discharges from these water bodies are, at times, significantly impacted by the water levels in Lake Owasso. This results in rating curves for each of these ponds that vary with time, depending on the level of Lake Owasso. The outlet rating curves used in P8 were selected based on the conveyance system characteristic and best fit to the cumulative runoff volumes in 2007 and 2008 for the stations at Dale St. and County Road C.

Figures 4-3b, 4-3c, and 4-3d show the results of the P8 runoff volume calibration to the West Owasso Boulevard (2007 and 2008), County Road C (2007 and 2008), and Dale Street (2008) monitoring data, respectively. Table 4-3 summarizes the results of the runoff calibrated volume calibration. Appendix E includes more detailed information about the selection of the parameters used in P8.

Table 4-3 Summary of Lake Owasso P8 Runoff Calibration

Parameter	Site 1: Galtier Street (LO_E_1f)	Site 2: County Road C (LO_S_1)	Site 3: West Owasso Blvd. (Dschg36)	Site 4: Dale Street (LO_S_2a)
2007 Individual Site Predicted/Observed Volume Ratios[1]	1.03	0.97	1.87[2]	N/A
2008 Individual Site Predicted/Observed Volume Ratios[1]	N/A	0.97	1.03	1.04

1. Based on Cumulative Runoff Volume over the monitoring period.
2. This discrepancy is due to variation of a single storm event across the Lake Owasso watershed, as reviewed on the Minnesota Climatology Working Group website (http://climate.umn.edu/hidradius/HIDENmapFile.asp)

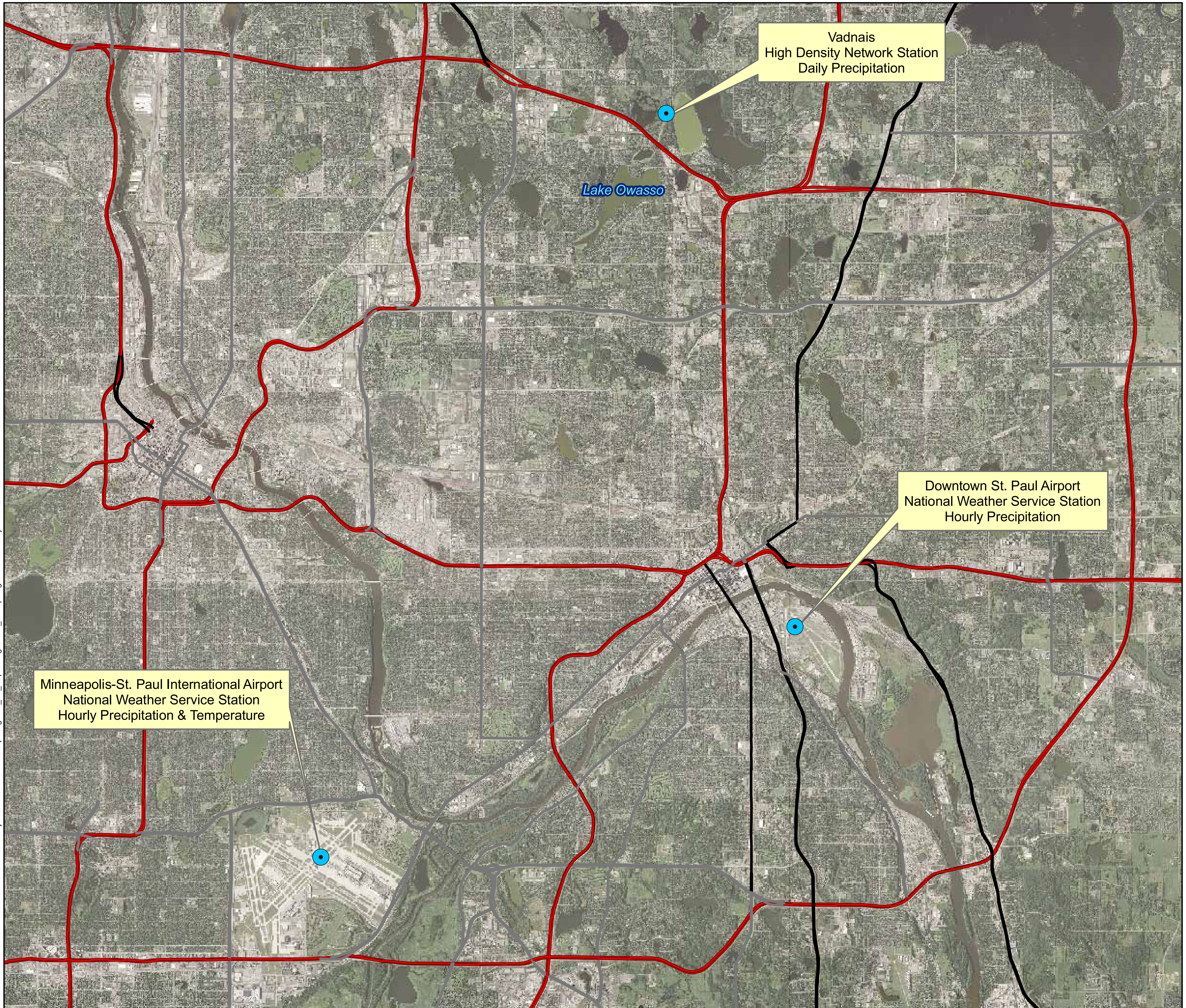


Figure 4-2

PRECIPITATION GAGE LOCATIONS

Lake Owasso UAA
Grass Lake Watershed Management Organization

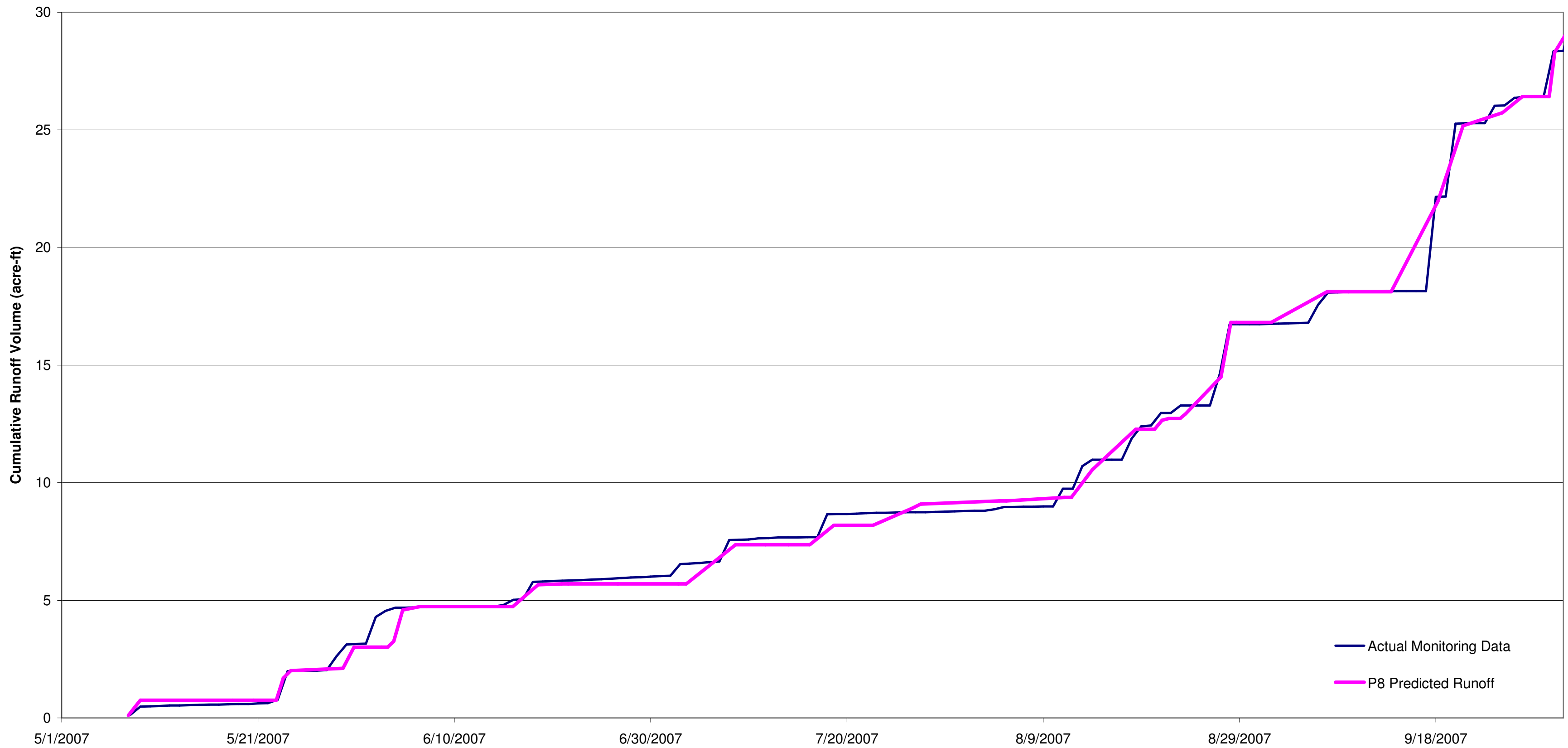
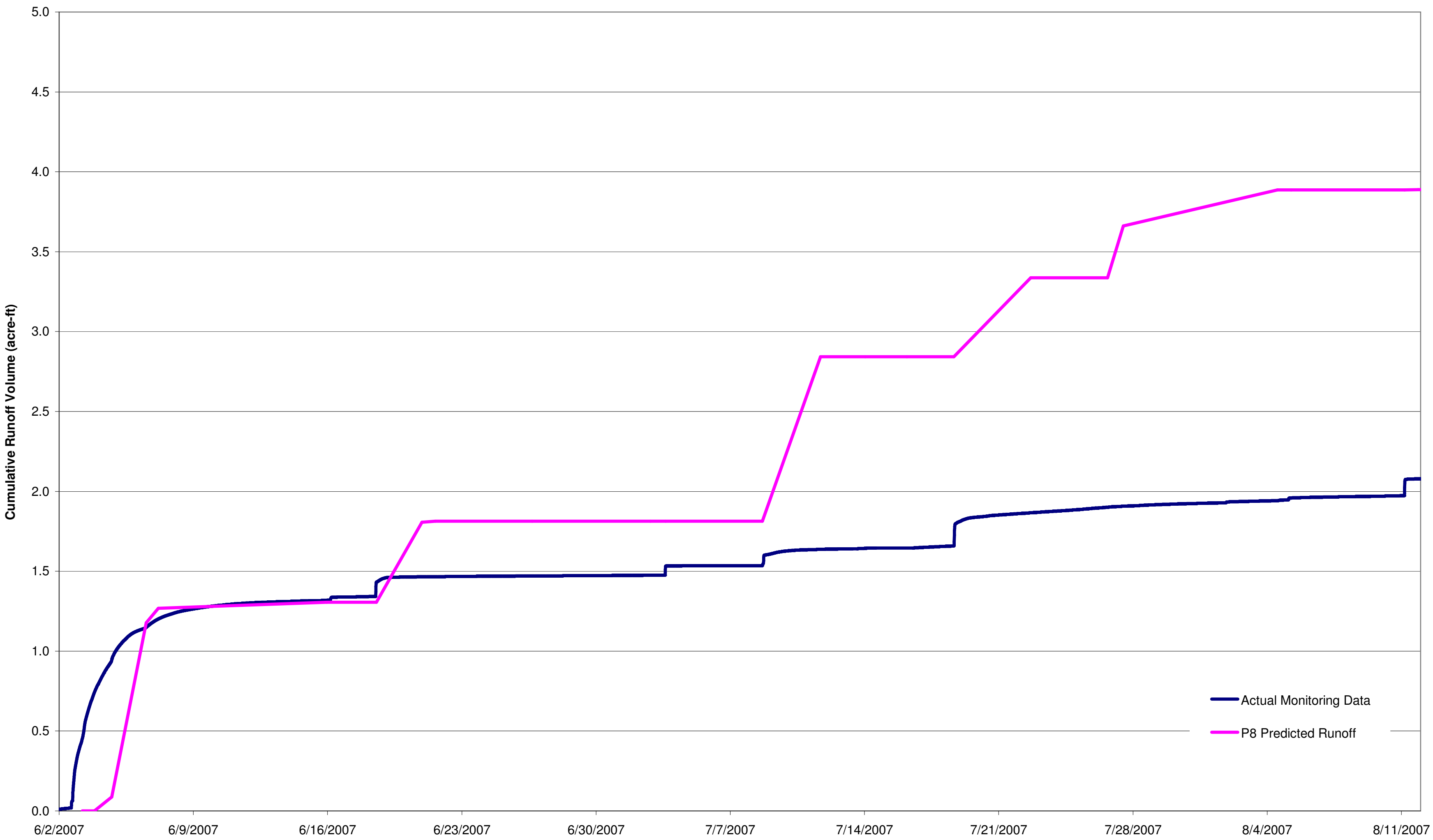
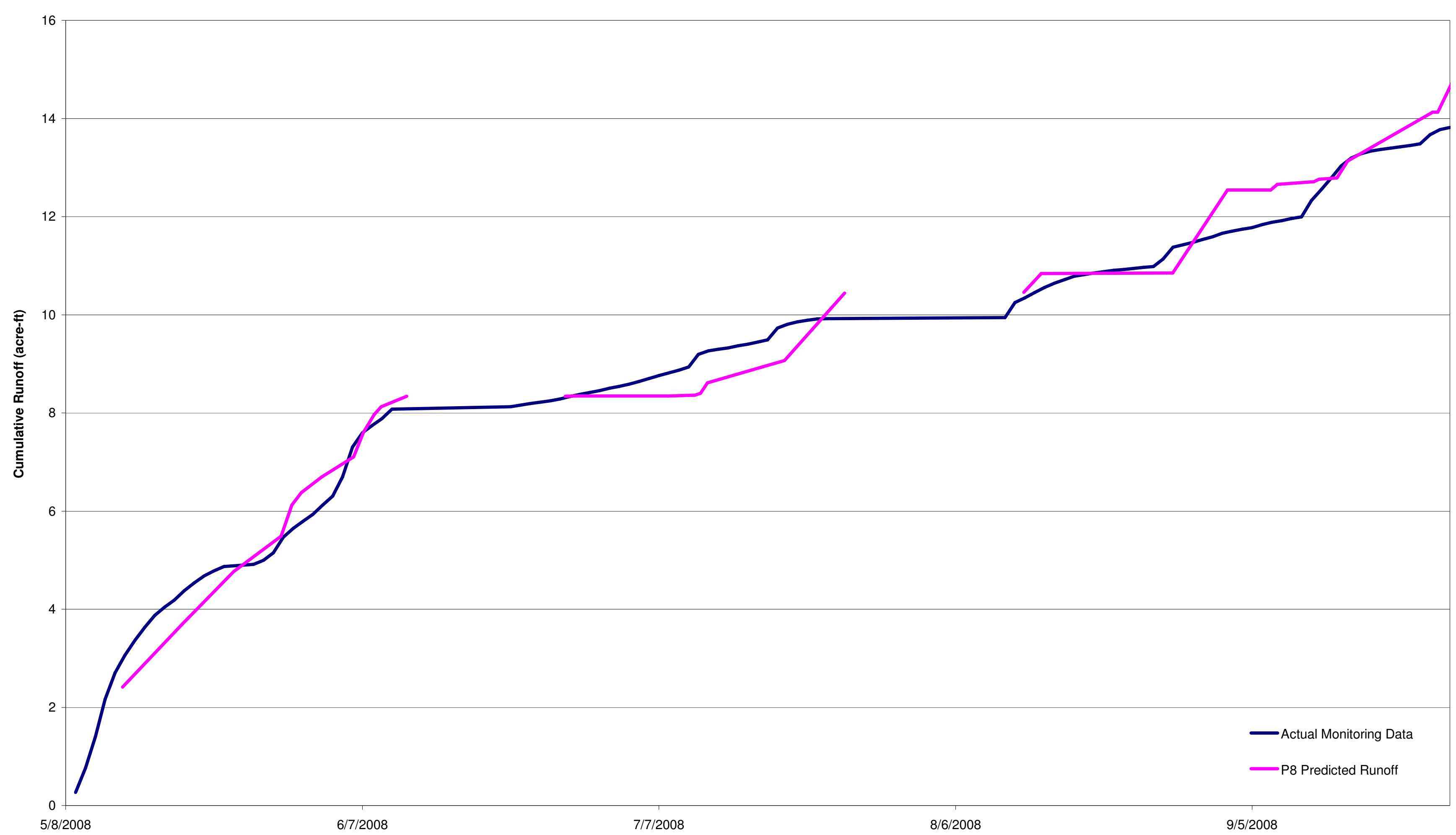


Figure 4-3a
Cumulative Runoff Volume for Monitoring Period
(5/8/2007 - 10/1/2007)
Station at Galtier St.

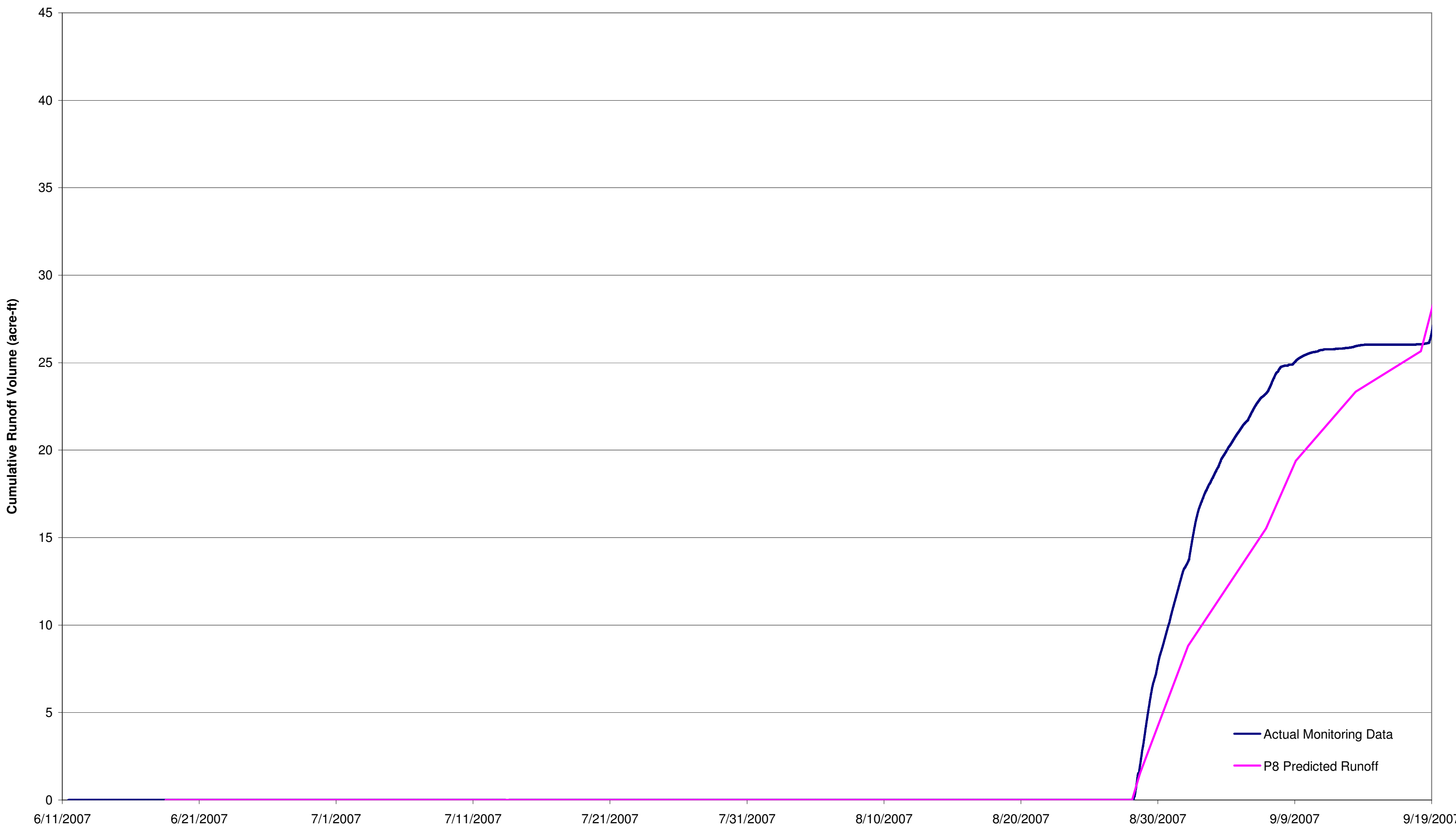


Cumulative Runoff Volume for Monitoring Period (6/2/2007 - 8/14/2007)

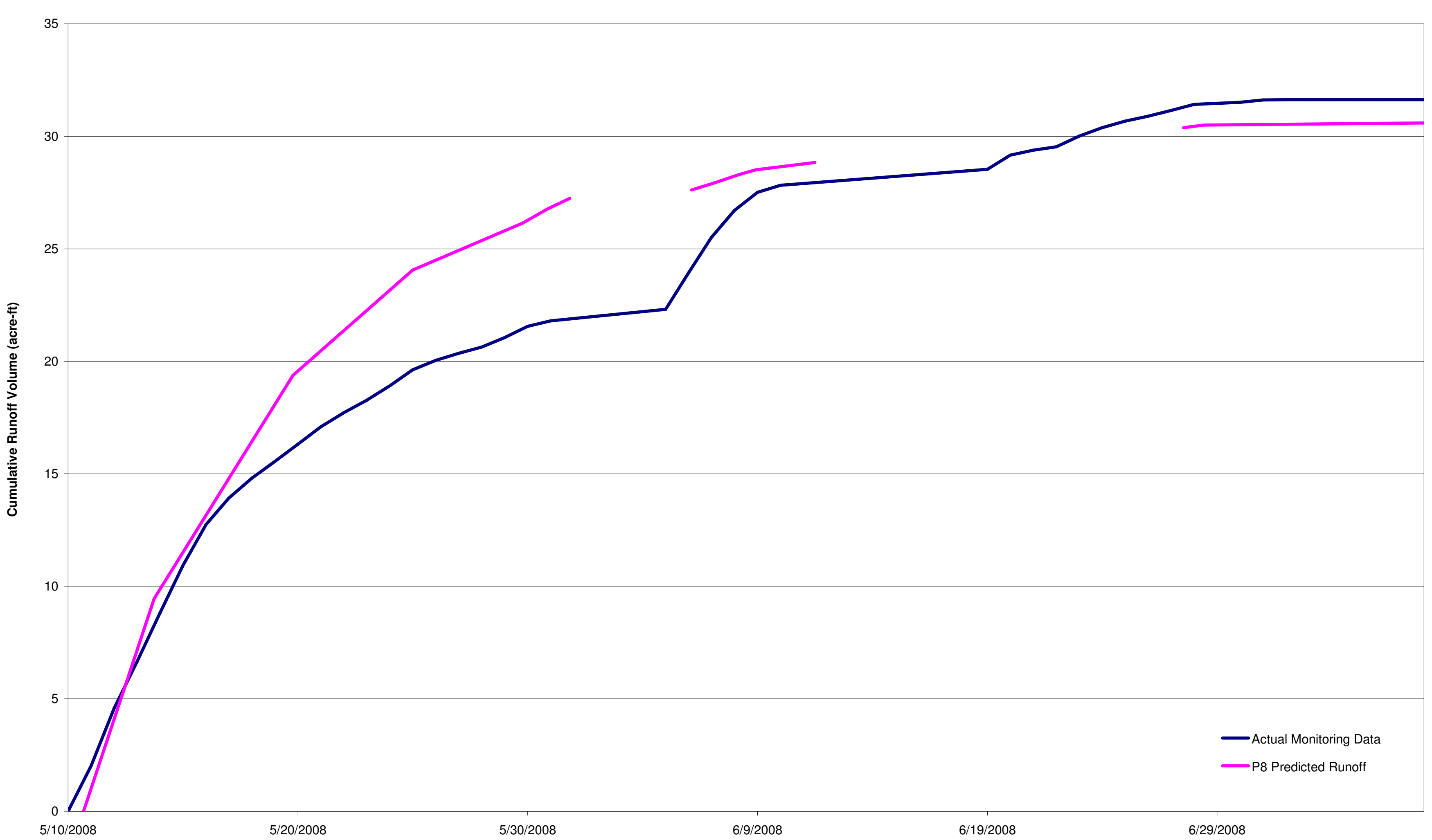


Cumulative Runoff Volume for Monitoring Period (5/9-6/11/2008, 6/23-7/28/2008, 8/11-9/25/2008)

Figure 4-3b
Cumulative Runoff Volume for 2007 & 2008
Station at West Owasso Boulevard



Cumulative Runoff Volume for Monitoring Period
(6/11/2007 - 9/18/2007)



Cumulative Runoff Volume for Monitoring Period
(5/10/2008 - 5/31/2008, 6/5/2008 - 6/10/2008, 6/19/2008 - 7/8/2008)

Figure 4-3c
Cumulative Runoff Volume for 2007 & 2008
Station at County Road C

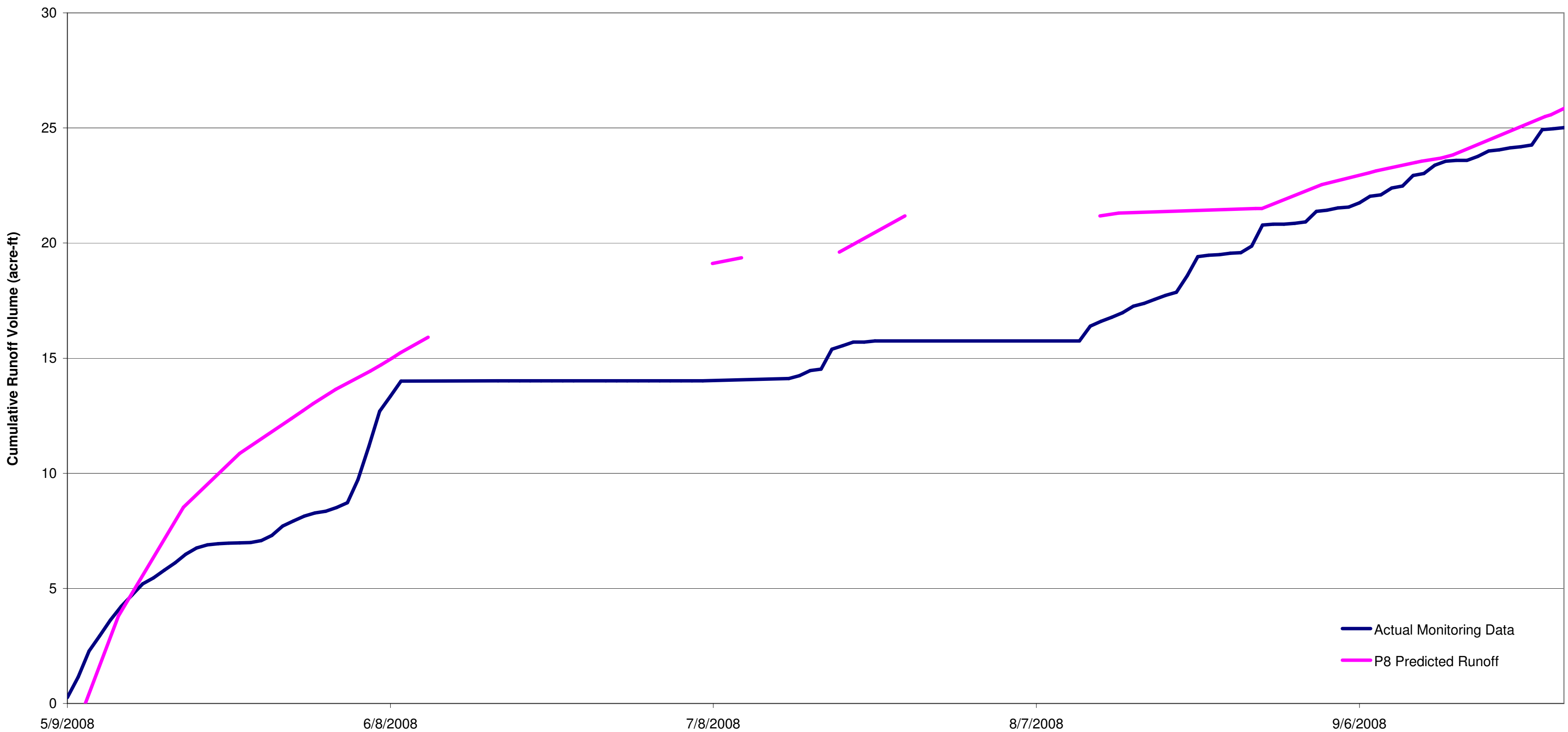


Figure 4-3d
Cumulative Runoff Volume for Monitoring Period
(5/9-6/8/2008, 6/22-6/27/2008, 6/28-7/10/2008, 7/17-7/25/2008, 8/12-9/25/2008)
Station at Dale Street

4.2.2.1.2 Water Balance Model

The daily precipitation. the total estimated daily watershed runoff to Lake Owasso from the calibrated P8 model, along with daily evaporation values (estimated by the Meyer Model for years prior to 2008 and daily values estimated from the St. Paul Campus Climatological Observatory for 2008) and the Lake Owasso discharge rating curve were used as inputs to the daily water balance model, WATBUD (developed by the MDNR), for 2008 (the calibration period). WATBUD was used to estimate the groundwater exchange for Lake Owasso, verify the runoff volumes predicted by P8, and simulate lake levels during this time period. The predicted lake levels were then compared to observed lake levels, and adjustments were made to the P8 and water balance model input parameters to obtain an optimal match between predicted and observed conditions.

Table 4-4 summarizes the stage-storage-discharge relationship developed for Lake Owasso based on basin bathymetry data (see Figure 3-2) and outlet characteristics: As previously mentioned, Lake Owasso is a groundwater lake that experiences periods of seepage and recharge, throughout the year. Also, during the winter months, discharge from Lake Owasso is reduced due to the accumulation of ice around the outlet structure, as confirmed by the City of Shoreview (Shoreview Public Works Director, personal communication, 1/18/2008).

Table 4-4 Stage-Storage-Discharge for Lake Owasso

Elevation	Water Surface Area	Cumulative Storage Volume (acre-feet)	Discharge (cfs)
851.6	13.1	0.0	0
861.6	52.2	326.2	0
866.6	68.8	628.5	0
871.6	86.3	1016.2	0
876.6	115.8	1521.6	0
881.6	270.3	2486.9	0
886.6	374.4	4098.7	0
886.7	376.2	4120.4	0.7
886.8	379.5	4162.4	2.1
886.9	382.5	4200.1	3.4
887.0	386.5	4250.8	5
888.0	416.8	4652.6	35
890.0	440.8	5510.2	60

Use of the WATBUD model indicates that the expected groundwater exchange in Lake Owasso typically varies throughout the year and also varies from year to year, especially during the winter months. To account for the variability of the groundwater exchange throughout the year as well as the change in the lake's rating curve during the winter months, the WATBUD modeling was separated into several periods throughout 2008 to account for groundwater and discharge variability. For calibration of the groundwater exchange to the 2008 lake level data, the WATBUD model was separated into the following groundwater exchange periods:

- Winter (December 2007 through March 2008) – this assumes there was no discharge from Lake Owasso during this period.
- May 2008 through June 2008
- July 2008 through August 2008
- September 2008

April 2008 was not evaluated as part of the WATBUD analysis as the ice out dates for other lakes in the region occurred in mid- to late April, resulting in an expected change in the Lake Owasso rating curve sometime during this month (Minnesota Climatology Working Group website, accessed 1/5/2009). It was assumed that the groundwater exchange predicted from the winter months (December 2007 through March 2008) would also be applicable during April.2008. October and November, in both 2007 and 2008, could not be evaluated due to limited lake level data during these months. It was assumed that groundwater exchange during October would be similar to that during September, while in November, groundwater would be similar to the expected groundwater exchange during the winter months.

Review of lake level data during the winter months (January and February during periods without thaw events) for the past decade (1998 through 2008), indicates that during some years, there is groundwater inflow into Lake Owasso while other years, there is seepage from the lake during the winter. This seepage analysis assumes that during the months of January and February, there is no discharge from Lake Owasso as the result of ice build-up around the outlet structure, and that the changes in water levels during these months are the results of groundwater exchange only. Table 4-5 summarizes the estimated daily winter groundwater exchange for 1998 through 2008.

Table 4-5 Estimated Winter Groundwater Exchange in Lake Owasso based on Lake Level Data (1998 to 2008)

Year	Winter Groundwater Exchange[1] (ft/d)
1998	-0.001
1999	0.002
2000	-0.003
2001[2]	-0.009
2002	N/A[3]
2003	N/A[3]
2004	0.001
2005	N/A[3]
2006	No Data
2007	-0.007
2008	0.001

1 – Winter is defined as January and February, assuming that there is no discharge from Lake Owasso due to accumulation of ice around the outlet. Groundwater exchange estimates do not include thawing events during these periods.

2 – Seepage estimate is based on lake level data for February and March.

3 – Groundwater exchange not able to be calculated due to thawing events during this period.

Figure 4-4a illustrates the results of the water balance modeling results for Lake Owasso, including the groundwater exchange estimated by WATBUD as well as the assumption that there is no discharge from Lake Owasso from December 15 through April 15 (based on average ice on and ice off conditions for the region). Additionally, the estimated groundwater exchanges for the periods evaluated are summarized on the figure. According to the 2008 WATBUD calibration, during the winter and spring, Lake Owasso received groundwater inflow at a rate ranging from 0.003 feet/day to 0.043 feet/day. During the summer and fall, Lake Owasso lost water to seepage at a rate ranging from 0.004 feet/ day to 0.008 feet/day. The estimated 2008 groundwater exchange rates were assumed to apply to the same periods in 2006 and 2007 to verify the groundwater exchange.

The predicted water levels for the calibration period closely match the actual lake level data. Applying the same groundwater exchange to 2006 and 2007 conditions yields a predicted lake level pattern similar to the observed pattern but with a slightly different magnitude. This is likely the result of the combination of several factors. The first factor is related to the variability in the Lake Owasso discharge rating curve as the result of ice accumulation around the outlet structure. The water balance model results (as shown on Figure 4-4a) are based on the assumption that discharge from Lake Owasso is zero from December 15 through April 15 (based on regional average ice on and ice off conditions). However, historical records show that there can be a significant amount of variability (on the order of several weeks in either direction) for the timing of the ice on and ice off conditions, impacting the predicted lake levels.

The second factor is the variability in the groundwater exchange throughout the year as well as from year to year. Previous studies of Lake Owasso suggest that the lake experiences periods of recharge as well as discharge. This was also seen during the WATBUD modeling. The variability of the groundwater exchange between years was also demonstrated by the estimation of groundwater exchange during the winter months, as summarized in Table 4-5.

Figure 4-4b shows the comparison of the predicted to the actual lake levels for the 2008 calibration period, including the regression equation and coefficient for these data. The regression indicates a close relationship between actual lake levels and the model results.

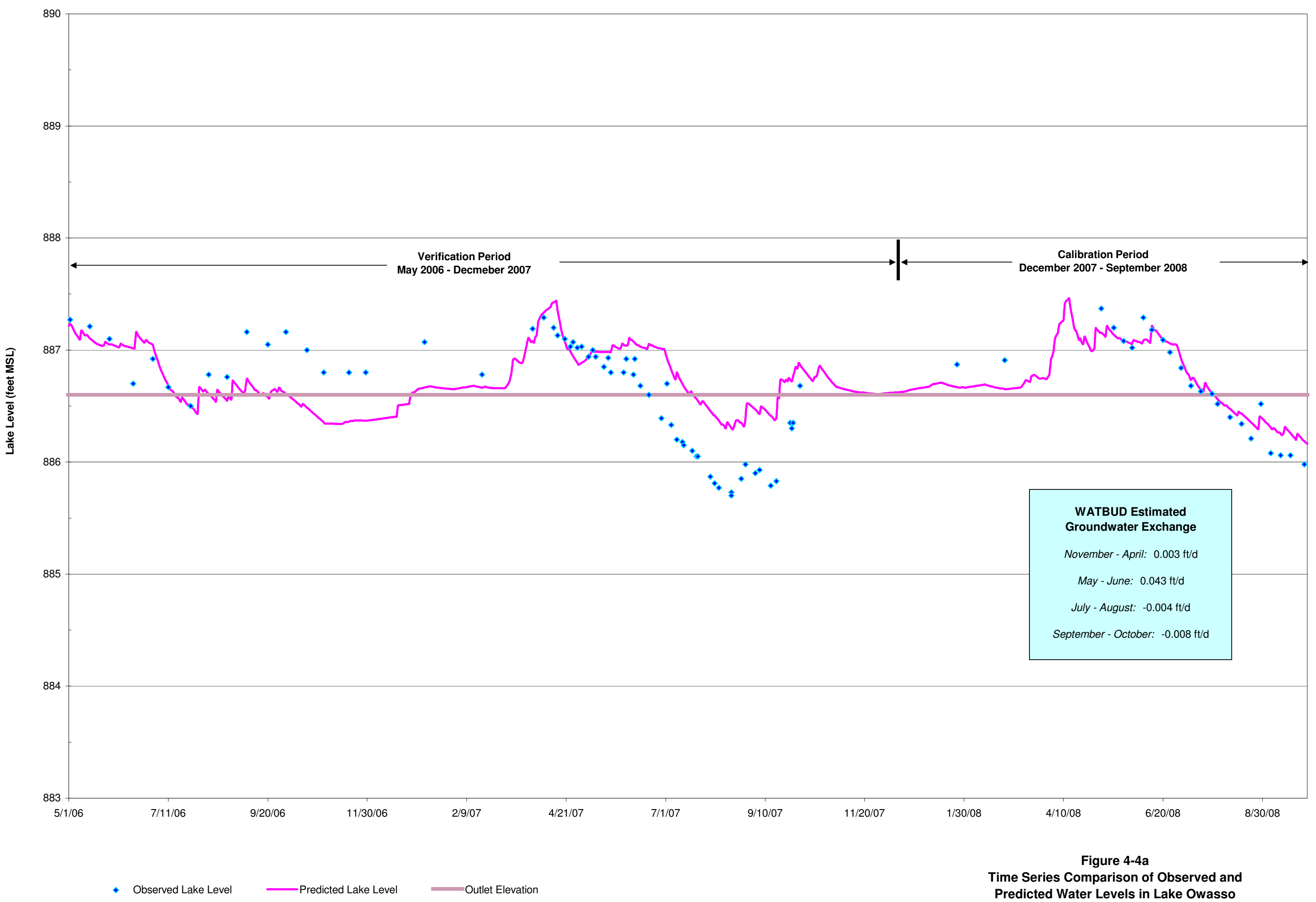
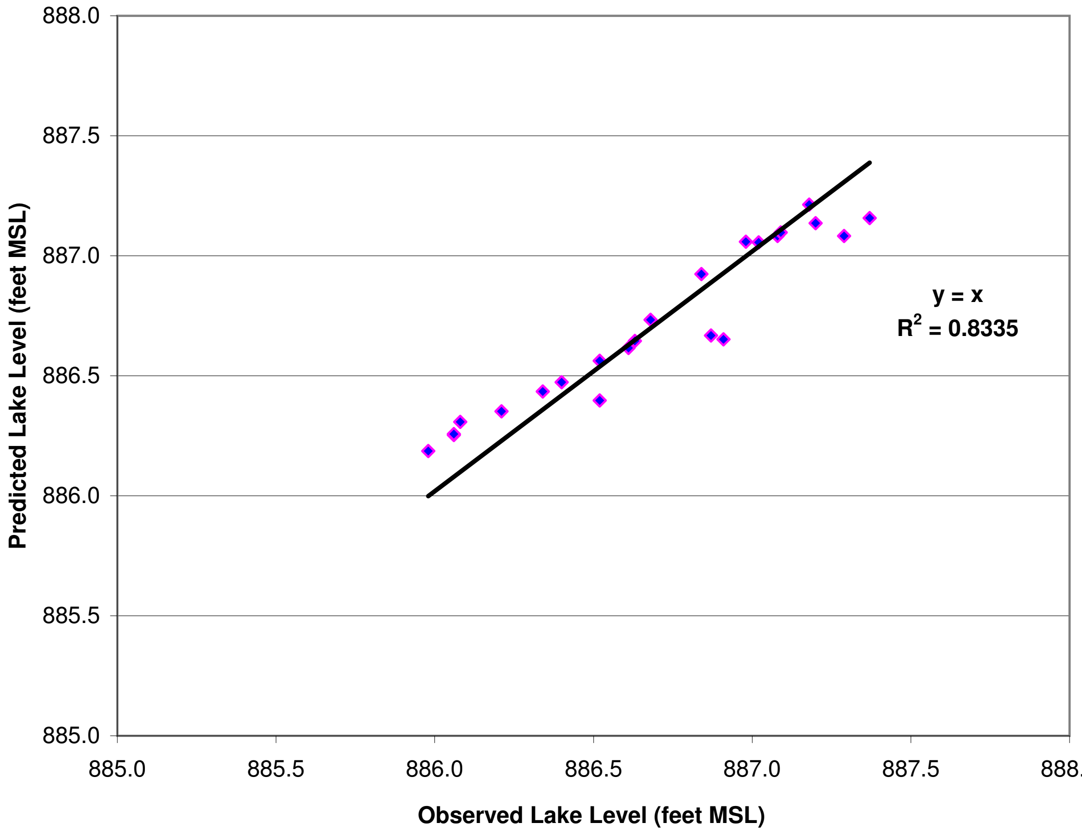


Figure 4-4a
Time Series Comparison of Observed and Predicted Water Levels in Lake Owasso from the 2006 through 2008 Water Balance



2007 - 2008 Calibration Period

Figure 4-4b
Regression Analysis of the Observed and Predicted Water Levels

4.2.2.2 Pollutant Loading Calibration

Because actual monitoring data related to the quantity and quality (total suspended solids (TSS) and total phosphorus (TP)) of stormwater runoff was available at monitoring locations around Lake Owasso in 2007, a detailed calibration of the particle and pollutant relationship in P8 was performed so that model results would closely mimic the actual monitoring data from each of the sites. However, because total dissolved phosphorus was not measured, the model was not calibrated to the dissolved fraction.

The report "P8 Enhancements and Calibration to Wisconsin Sites", Walker (1997) was used as a guide for the steps used to calibrate the Lake Owasso P8 model. The calibration steps outlined by Walker were followed with a few exceptions.

Calibration was originally focused on data collected at the Galtier Street monitoring station, as this station reflected only watershed runoff (there was no treatment in the watershed upstream of the monitoring station). This would allow for the calibration of the watershed pollutant loading parameters. Calibration at this site was for both TSS and TP event flow-weighted concentration, event loads, and cumulative loads. These watershed pollutant loading parameters were applied to all subwatersheds in the Lake Owasso watershed. Because there was no data related to the dissolved phosphorus concentration collected in 2007, the dissolved fraction was not calibrated.

The P8 model was calibrated to the average event flow-weighted concentration for total suspended solids (TSS) and total phosphorus (TP), as well as total event loads and cumulative loads (for the storm events selected for calibration). The pollutant calibration process began with the NURP50% particle file as developed by Walker for the median NURP monitoring site.

4.2.2.2.1 Total Suspended Solids Calibration

Following Walker's calibration steps, suspected monitored outliers were eliminated from the calibration process (Step 5). After completing the water volume calibration, Walker recommends calibrating the TSS (Step 14). Because all other pollutant concentrations are dependent on the amount of solids, TSS calibration is a critical step.

Similar to the runoff volume calibration method, the monitoring site at Galtier Street was used to first calibrate the pollutant parameters related to watershed build-up, wash-off, decay, and impervious and pervious runoff concentrations, as there are no treatment devices such as ponds or wetlands in the contributing watershed.

Five storm events were used for the TSS calibration at Galtier Street. Initial P8 runs applied the NURP50% particle file. Results indicated that P8 both over- and under-predicted TSS concentrations for the various calibration storm events. Based on the cumulative TSS load for the calibration events, P8 resulted in an overall under-prediction of the TSS loads.

P8 predicts TSS loads based on both pervious and impervious surfaces. To address the runoff TSS concentration from the pervious areas, the pervious runoff concentration and the pervious runoff exponent were adjusted for the various particle classes. According to *P8 Urban Catchment Model Program Documentation, Version 2.4* (Walker, 2000) based on typical sediment rating curves the pervious runoff exponent ranges between 0.1 and 1.6 for rivers. Other particle files supplied with the P8 model (NURP90.par, Monroe.par, and Lincoln.par) were reviewed to determine a range for the pervious runoff concentration since no pervious area monitoring data were available. Based on this review the P10% to P50% concentrations were found to range between 100 and 400 mg/L while the P80% concentration ranged between 200 and 800 mg/L. Numerous combinations of the pervious runoff concentration and exponent were examined. A pervious runoff concentration for the P10%-P50% of 100 mg/L and 200 mg/L for the P80% with a runoff exponent of 0.1 produced the best results for pervious runoff concentrations. (50 ppm/1).

According to *P8 Urban Catchment Model Program Documentation, Version 1.1* (Walker, 1990) any of the buildup/washoff parameters can be adjusted for calibration. Rescaling the impervious area particle loading for the different particle classes (P10% - P80%) as recommended in Step 14 of Walker's report was done to reduce the impervious runoff concentration. The NURP50 accumulation rates (1.75 and 3.5 lb/ac/day for P10%-P50% and P80% respectively) were reduced to 1.6 lb/ac/day for the P10%-P50% particle classes and 2.8 lb/ac/day for the P80% particle class. These adjustments alone did not sufficiently reduce the impervious runoff concentration.

The P8 documentation states that the exponential washoff relationship used by the model is similar to that employed by the EPA's Stormwater Management Model (SWMM). Therefore, documentation for SWMM (Huber et al., 1988) was reviewed to determine acceptable values for the washoff parameters. The documentation revealed that the impervious washoff coefficient could range between 1 and 10. It also mentions that this coefficient can vary by almost five orders of magnitude. The SWMM documentation also indicates that the impervious washoff exponent typically ranges between 1.1 and 2.6, with most values near 2.0. The SWMM documentation states that both of the parameters can be varied to calibrate the model to observed data. In addition to the ranges supplied by the SWMM documentation, the other particle files supplied with P8 were reviewed for typical ranges in the buildup/washoff parameters.

Again various combinations for the buildup/washoff parameters were simulated with the best results produced from the following parameters:

- Accumulation rates: 1.6 lb/ac/day (P10%-P50%) and 2.8 lb/ac/day (P80%)
- Accumulation Decay Rate : 0.35 day^{-1}
- Impervious Washoff Coefficient : 5
- Impervious Washoff Exponent : 3.0

Using the buildup/washoff and pervious runoff parameters listed above resulted in the overall arithmetic mean predicted to observed ratio of the flow weighted mean TSS concentration to equal 100 percent based on the representative monitoring site data. Table 4-6 summarizes the results of the TSS (and TP) calibration procedure.

Table 4-6 TSS & TP Calibration Results (LkOwasso.par)

Parameter Adjusted	Calibrated Value
Accumulation Rate (lb/ac/day) (P10%-P50%/P80%)	1.6 / 2.8
Accumulation Decay Rate (1/day)	0.35
Impervious Runoff Coefficient	5
Impervious Runoff Exponent	3
Pervious Runoff Concentration (mg/L) (P10%-P50%/P80%)	50
Pervious Runoff Exponent	1
TP P0% Particle Composition (mg TP/kg TSS)	99000
TP P10%-P80% Particle Composition (mg TP/kg TSS)	3850
TSS Scale Factor	1
TP Scale Factor	0.7

Figure 4-5 shows the TSS (and TP) pollutant loading results for the Galtier Street monitoring station when calibrated to 2007 data.

4.2.2.2.2 Total Phosphorus Calibration

The water quality data at the monitoring sites was limited to total phosphorus data, therefore it was not possible to calibrate the dissolved fraction of phosphorus (TP associated with P0%). It was assumed that the P0 particle composition was equal to that used in the NURP50 particle file (99,000 mg/kg). The remaining TP particle compositions for the other particle fractions (P10%-P80%) were also maintained from the NURP50 particle file. However, the TP scale factor was adjusted to best match the 2007 Galtier Street monitoring data. The TP scale factor was set to 0.7. Table 4-6 summarizes the pollutant loading and water quality component information for the Lake Owasso particle file. Figure 4-5 also shows the pollutant loading calibration results at the Galtier Street monitoring station, which reflects the calibration of the watershed runoff pollutant load (with no water quality improvement practices in place in the watershed).

The next step in the calibration of the P8 model was to calibrate the predicted TP load to the actual monitored loads at the County Road C and West Owasso Boulevard (2007 & 2008) monitoring stations as well as the Dale Street (2008) monitoring stations. The watersheds contributing to these sites have many natural and constructed ponds and wetlands that provide some pollutant removal as water passes through them. See Appendix E for more discussion about the selection of the P8 parameters as well as a summary of the P8 devices.

Grab samples collected in between storm events at County Road C (Central Park – West wetland) during the summer of 2008 indicated that the concentration of the wetland was significantly higher between storm events than the concentrations observed during actual storm events, indicating the potential "internal" loading of TP within the wetland. This internal loading may be the result of a variety of factors, such as the resuspension of sediments due to activity of carp (observed in the wetland during the summer of 2008), phosphorus release from sediments, and other biological activity in the wetland.

Grab samples were also collected at the Dale Street monitoring station (Central Park – East wetland) in 2008, just upstream from the County Road C wetland. However, unlike the grab samples collected at the County Road C wetland, the TP concentrations of the grab samples from the Dale Street site were lower than the TP concentrations observed during storm events. Also, the Dale Street monitoring site was located just downstream from the City of Roseville Leaf Recycling Center. However, the observed TP concentrations at the Dale Street site were similar to typical urban stormwater runoff TP concentrations, indicating that the City of Roseville Leaf Recycling Center may not be a significant source of TP to Lake Owasso.

One of the limitations of the P8 model is that it does not account for particle resuspension or loading as the result of other chemical or biological activity. As a result, a modeling method was developed to estimate a rate of internal TP loading for each waterbody located immediately upstream of the County Road C (Central Park – West wetland), Dale Street (Central Park – East), and West Owasso Boulevard (Charlie Ponds) monitoring stations.

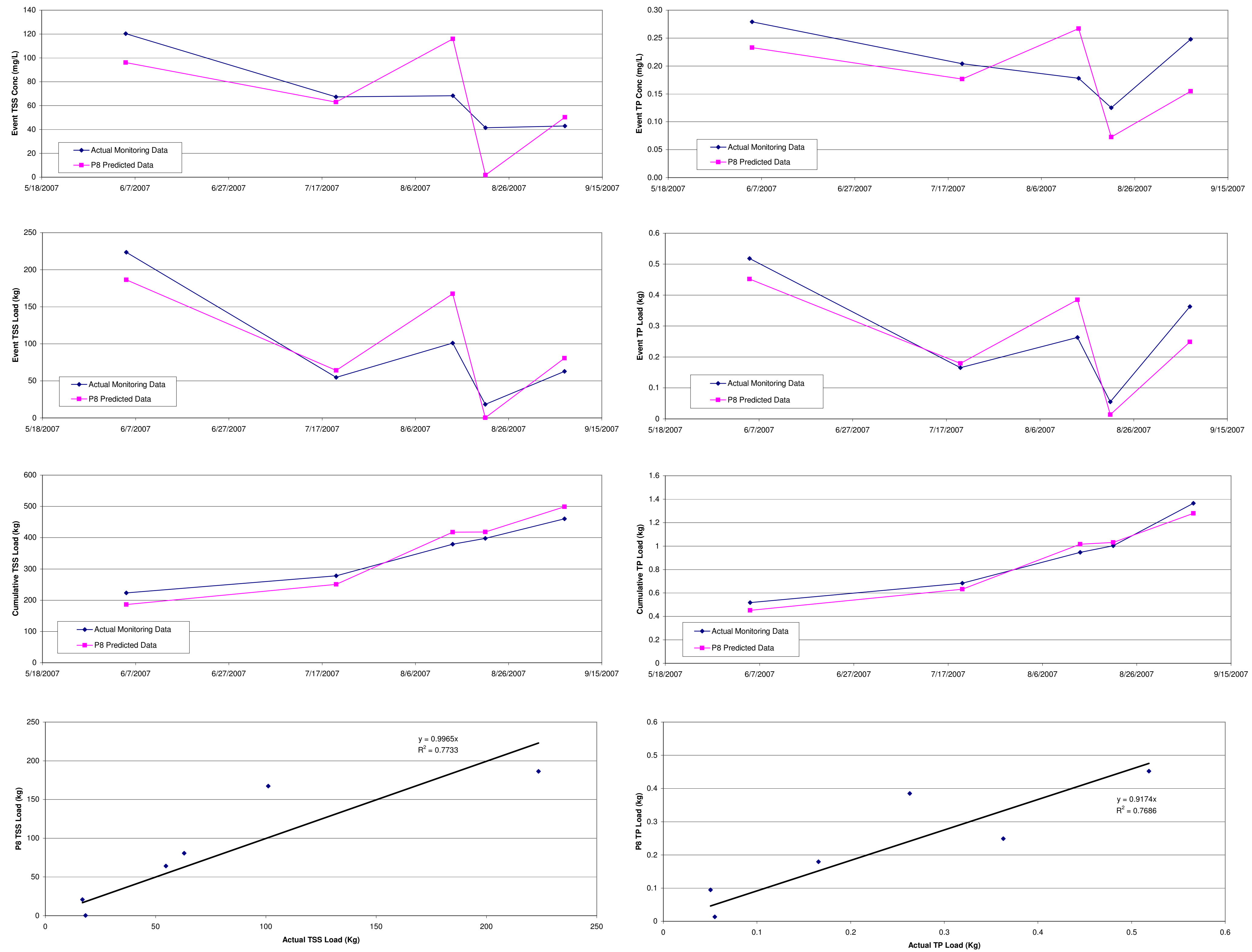


Figure 4-5
2007 Pollutant Calibration at Galtier Street

4.2.2.2.2.1 FLUX Modeling

To help estimate the internal TP loading rate in the water bodies immediately upstream of the County Road C (Central Park – West wetland), Dale Street (Central Park – East wetland), and West Owasso Boulevard (Charlie Pond system) monitoring stations, the FLUX model was used to estimate the actual TP load at each of the runoff water quality monitoring stations.

FLUX is an interactive computer program designed for use in estimating the loadings of water quality components from tributary sampling. FLUX (Walker 1986) uses continuous flow records and parameter concentrations from sampled events to develop flow weighted mean concentrations and loading (in kg/yr) for sites where both flow and sample analysis data are available. For more information about the FLUX model, see Appendix E.

FLUX was used at all the runoff monitoring stations including the County Road C (2008), Dale Street (2008), and West Owasso Boulevard (2007 & 2008) monitoring stations as well as the Galtier Street (2007) monitoring station which was originally used to calibrate the P8 watershed runoff volume and water quality parameters.

TP loads were estimated for the period of record (both flow and water quality) available for each of the sites. Table 4-7 summarizes the estimated TP loads estimated by FLUX at each of the monitoring sites. Also summarized in the table is the P8-predicted TP load for the same period of time as well as the estimated daily “internal” TP loading rate (the difference between the FLUX load and the P8 load divided by the days in the period used for the FLUX modeling). It was assumed the internal loading only occurred during the months of May through September (the growing season).

Table 4-7 FLUX Results and Estimated Internal TP Loading in the Central Park Wetlands (County Road C and Dale St.) and the Charlie Pond System (West Owasso Blvd.)

Monitoring Station	Period	FLUX TP Load (lbs)	P8 TP Load (lbs)[1]	Pond Area @ NWL (acres)	Internal TP Loading Rate ($mg/m^2/d$)
Galtier St	5/7/2007 – 10/3/2007	14.3	12.3	N/A	N/A
Dale Street (Central Park – East)	5/10/2008 – 9/29/2008	31.2	6.6	20.3	1.0
County Road C (Central Park – West)	5/10/2008 – 7/3/2008	40.3	9.0	11.6	5.1
West Owasso Blvd. (Charlie Ponds)[2]	5/10/2007 – 10/3/2007	21.3	4.7	3.5	2.9
	5/10/2008 – 9/29/2008	12.1	2.5	3.5	

1 – P8 loads based on existing land use conditions

2 – Internal TP loading rate in the Charlie Pond System was based on the average of the rates estimated for 2007 and 2008.

4.2.2.2.2.2 Total Phosphorus Mass Balance Model of the Central Park – West Wetland (County Road C)

The internal TP load in each wetland was originally estimated based on the application of the daily internal loading rate (as estimated by the comparison of the FLUX and P8 modeling results) and the period of each P8 storm event. However, applying the daily internal TP loading rate alone makes the assumption that the internal TP load from each water body reaches the lake during each storm event.

Actual flow monitoring data for the County Road C and Dale Street monitoring stations indicate that there are periods during both the summers of 2007 and 2008 where the water levels in the wetlands are below the normal water levels and were not discharging downstream into Lake Owasso. During these periods with low water levels (water levels below the normal water level),, any internal phosphorus load would accumulate in the wetlands until the water levels rise and the water body begins to discharges downstream (to Lake Owasso).

In order to account for the accumulation of the internal phosphorus load in the wetland during low water levels and the discharge from the wetland when water levels rose above the outlet elevation, a phosphorus mass balance model was developed for the Central Park – West wetland (County Road C). This model considers both the water and phosphorus loads and losses as predicted by the P8 model, the available storage available in the wetland, and the daily internal TP load (the sum of the load from the Central Park – East and Central Park – West wetlands).

The mass balance model calculated the TP mass (and concentration) in the Central Park – West wetland for each storm event period through the summer of 2008, using the following equation:

Wetland P = Observed P + Runoff P + Upstream Device P + Internal P – Infiltration P – Discharge P

For the first iteration of this TP mass balance, the internal TP load in each wetland was estimated based on the application of the daily internal loading rate (as estimated by the comparison of the FLUX and P8 modeling results) and the period of each P8 storm event. The estimated daily internal phosphorus load from the Central Park - East wetland (Dale St) was also adjusted to reflect periods when the wetland was not discharging downstream to the Central Park – West (County Road C) wetland.

Grab samples collected from the Central Park – West wetland between storm events during the summer of 2008 indicated a maximum observed TP concentration of 580 µg/L. In the mass balance model, it was assumed that the maximum wetland TP concentration (as the result of accumulating phosphorus loads) could not exceed 600 µg/L. Using the original internal TP load numbers resulted in wetland TP concentrations greater than 600 µg/L. Therefore, the threshold TP concentration of 600 µg/L and the phosphorus loads and losses predicted by P8 were used to back-calculate the maximum internal TP load within the wetland. If the back-calculated internal TP load was less than the load originally predicted based on the daily internal loading rate predicted by the FLUX modeling, the back-calculated load was used; otherwise, the original internal TP load was used in the mass balance. The mass balance was then used to estimate the TP concentration within the Central Park – West wetland.

The estimated wetland TP concentration (as predicted from the mass balance) and discharge volume (as predicted by the calibrated P8 model) were used to calculate the actual TP load reaching Lake Owasso as the result of the internal loading in the Central Park – East and West wetlands.

For the Charlie Pond system (West Owasso Blvd), a TP mass balance was not used to estimate the internal TP load to Lake Owasso from this system as was done for the Central Park – West Wetland. Unlike the Central Park – West wetland, continuous flow was observed at the West Owasso Blvd. monitoring station for the majority of both the summers of 2007 and 2008. As a result, only the estimated daily internal loading rate from the P8/FLUX comparison was applied for each storm event.

The internal TP loads estimated for waterbodies upstream of both the County Road C and West Owasso Blvd. discharges were then used inputs into the in-lake water quality model. The TP loads input into the in-lake water quality model were adjusted to differentiate between the dissolved phosphorus and the phosphorus associated with particulates (that would settle out more quickly and have less impact on the overall water quality in Lake Owasso). The TP load was adjusted by a factor of 0.44 (the ratio of dissolved phosphorus to total phosphorus based on the 2008 grab samples collected the County Road C site). See Section 4.3 for a more complete discussion of the Lake Owasso in-lake water quality modeling.

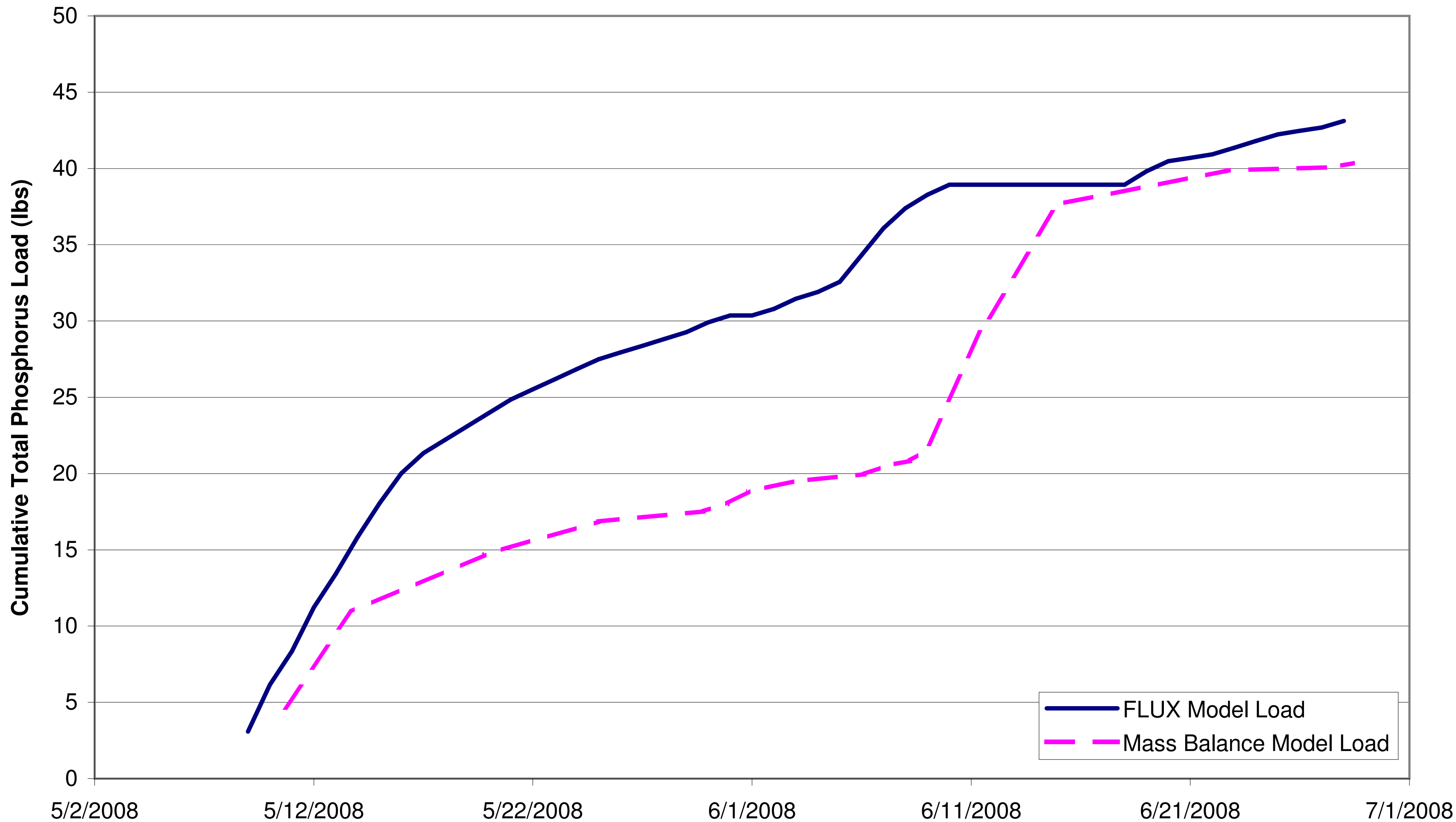


Figure 4-6
Total Phosphorus
Mass Balance Loads vs. FLUX Loads
for Central Park - West (County Road C) Wetland - 2008

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4.3 In-Lake Water Quality Model

4.3.1 In-lake Water Quality Modeling Methodology

While the P8 and FLUX models are useful tools for evaluating runoff volumes and pollutant concentrations from a watershed, another method is needed to predict the in-lake phosphorus concentrations that are likely to result from the various phosphorus loads.

To evaluate the lake's response to watershed and internal loads of phosphorus under a range of precipitation conditions, in-lake water quality models were created to route the P8 generated watershed loads, along with the estimated internal load from the major waterbodies in the watershed, through the lake for the following time periods:

- "Dry" climatic conditions: May 2007 - September 2008
- "Average" climatic conditions: May 2004- September 2005
- "Wet" climatic conditions: May 2001- September 2002

Water quality data has been collected in Lake Owasso since the early 1970's. The monitoring location was in the northern portion of the lake (site 5401). However, in 2007 and 2008, the detailed in-lake water quality monitoring data was collected at two different locations within Lake Owasso (Site 5401 in the north and Site 5403 in the south). For the initial calibration of the Lake Owasso in-lake water quality model, the 2007 and 2008 water quality and the 2007 macrophyte survey data were used. The in-lake model was developed as a two basin model. Figure 4-7 shows the division of Lake Owasso as modeled in the two-basin in-lake model for 2007 and 2008.

Because there was a significant amount of historic water quality data available at depth for Lake Owasso, in-lake modeling was performed for each climatic condition to estimate the internal loading (from sediments and macrophyte senescence) within Lake Owasso. Parameters calibrated to the 2007 and 2008, such as the macrophyte coverage and estimated growth and die-back dates, were applied to all climatic condition models. Watershed runoff loads as predicted by P8, as well as the estimated watershed wetland "internal" loads, were developed specifically for each climatic condition.

The 2008 calibration year was selected to be representative of the dry climatic conditions for Lake Owasso, and was modeled as a two-basin in-lake model. For the wet (2002) and average (2005) climatic conditions, water quality data was only available at the northern sampling site (site 5401) and the in-lake water quality model was developed as a single basin.

The in-lake modeling methodology used for the Lake Owasso UAA is two-fold: First, the spring concentration is estimated with a steady-state, annual empirical lake model. Second, a spreadsheet mass balance model based on Dillon and Rigler (1974) is used that starts with the estimated spring concentration (from the empirical model) and routes external and internal phosphorous loads through the lake over many time steps throughout the summer season (May through September).

The method described in the following sections was used for existing land use conditions under a variety of climatic conditions. Once the internal loading rates have been calculated, the model could be used predictively, to evaluate lake phosphorus concentrations under a variety of BMP scenarios for each hydrologic condition. Impacts as the result of futures changes in land use were not evaluated as the Lake Owasso watershed is already fully-developed, the expected changes are minimal. As a result, the changes in the pollutant loads to the lake will not have a significant impact on the overall lake water quality.

4.3.1.1 Predicting Springtime Concentration in Lake Owasso

4.3.1.1.1 Predicting Springtime Concentration in Lake Owasso – Dry Conditions (2008) – Two Basin Model

Water quality monitoring data from Lake Owasso was used to determine the empirical model that could best predict the spring concentration in the lake. For the southern portion of Lake Owasso (Station 5403), the Dillon and Rigler model with a phosphorus retention term from Nurnberg (1984) was used to predict the spring total phosphorus concentration.

$$P_{SPRING} = \frac{L(1-R)}{z\rho}$$

where:

P_{SPRING} = spring total phosphorus concentration (µg/L)
L = areal total phosphorus loading rate (mg/m²/yr)
R = retention coefficient as defined by Nurnberg (1984)
= $15/(18+ q_s)$
q_s = annual areal water outflow load (m/yr)
= Q/A
z = lake mean depth (m)
ρ = hydraulic flushing rate (1/yr)
= 1/(hydraulic residence time) = 1/(V/Q)
Q = annual outflow (m³/yr)
V = lake volume (m³)
A = lake surface area (m²)

For the northern portion of Lake Owasso (Station 5401), the Dillon and Rigler model with a phosphorus retention term from Larsen and Mercier (1976) was used to predict the spring total phosphorus concentration.

$$P_{SPRING} = \frac{L(1-R)}{z\rho}$$

where:

P_{SPRING} = spring total phosphorus concentration (µg/L)
L = areal total phosphorus loading rate ($mg/m^2/yr$)
R = retention coefficient as defined by Larsen and Mercier (1976)
= $1/(1+\rho^{(1/2)})$
q_s = annual areal water outflow load (m/yr)
= Q/A
z = lake mean depth (m)
ρ = hydraulic flushing rate (1/yr)
= 1/(hydraulic residence time) = 1/(V/Q)
Q = annual outflow (m^3/yr)
V = lake volume (m^3)
A = lake surface area (m^2)

4.3.1.1.2 Predicting Springtime Concentration in Lake Owasso – Wet and Average Conditions (2002 & 2005) – One Basin Model

For the wet (2002) and average (2005) climatic scenarios where Lake Owasso is modeled as a single basin, the Dillon and Rigler empirical model with a phosphorus retention from Larsen and Mercier (1976) was used to predict the spring total phosphorus concentration.

$$P_{SPRING} = \frac{L(1-R)}{z\rho}$$

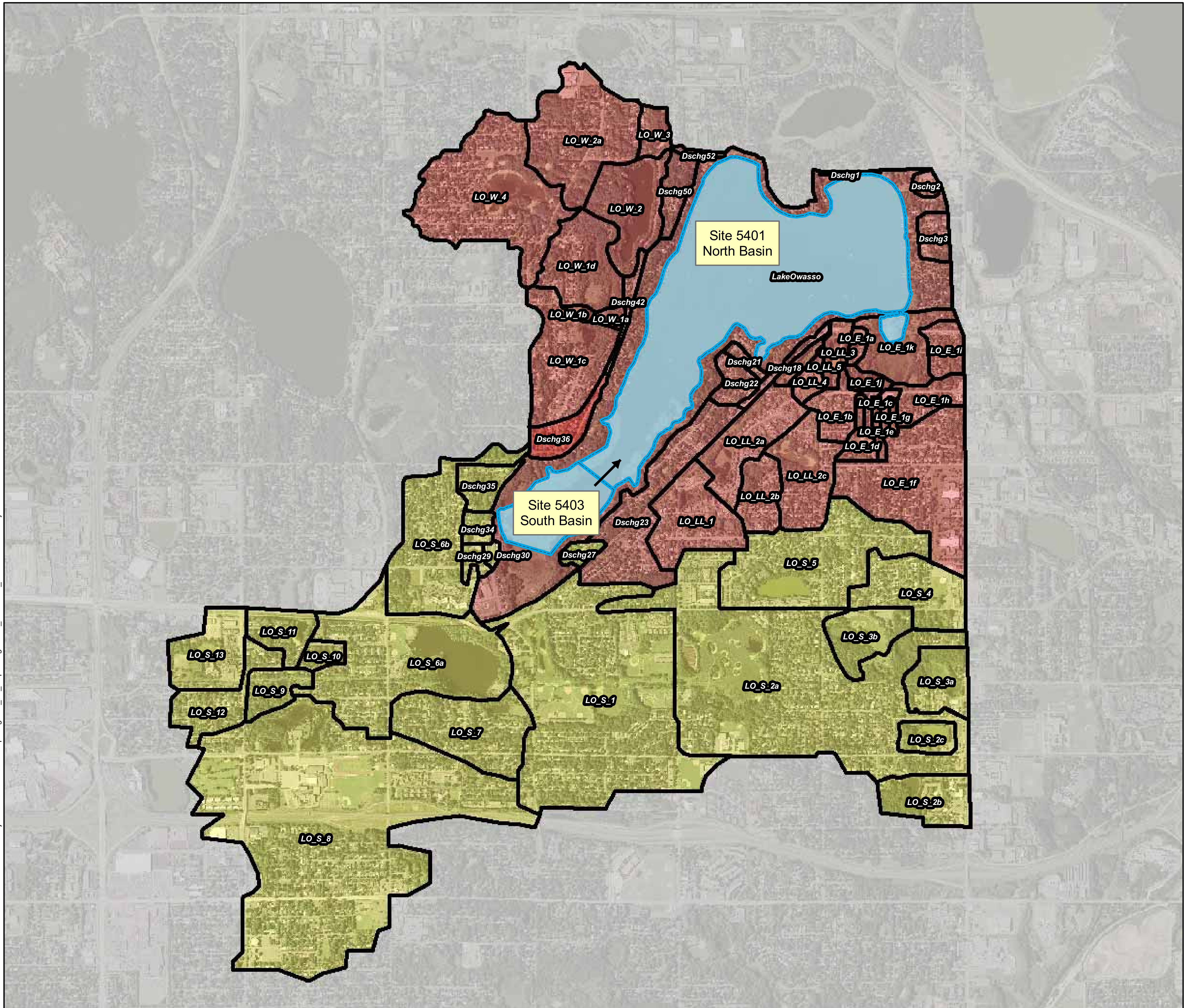
where:

P_{SPRING} = spring total phosphorus concentration (μg/L)
L = areal total phosphorus loading rate (mg/m²/yr)
R = retention coefficient as defined by Larsen and Mercier (1976)
= $1/(1+\rho^{(1/2)})$
q_s = annual areal water outflow load (m/yr)
= Q/A
z = lake mean depth (m)
ρ = hydraulic flushing rate (1/yr)
= 1/(hydraulic residence time) = 1/(V/Q)
Q = annual outflow (m³/yr)
V = lake volume (m³)
A = lake surface area (m²)

For all the in-lake water quality models (both the single-basin and two-basin models), the areal loading rate to Lake Owasso was based on the watershed loads (as predicted by the P8 model) as well as the internal loads from the Central Park wetlands (County Road C) and Charlie Pond system (predicted by the TP mass balance on the Central Park – West wetland and by the TP loading rate estimated by the FLUX modeling, respectively), For the two basin in-lake model, the watershed loads to the southern basin (5403) included the P8 watershed loads as well as the internal loads from the Central Park – East and Central Park – West wetlands. The loading rate to the northern basin (5401) was based on the P8 predicted watershed loads, the internal loads from the Charlie Pond system, as well as loads from the southern basin (5403). Additionally, in all cases, the in-lake water quality model also included the load associated with groundwater inflows (predicted by the water loads from the WATBUD model and the Lake Owasso water balance along with an assumed TP concentration of 25 μg/L, a value typical in groundwater in the Twin Cities metropolitan area (USGS, 2005)).

Early summer, summer-average and fall overturn concentrations, however, are often not well represented in steady state empirical models such as Dillon and Rigler. Most empirical phosphorus models assume that the lake to be modeled is well-mixed, meaning that the phosphorus concentrations within the lake are uniform. This assumption is useful in providing a general prediction of lake conditions (especially for springtime concentrations), but it accounts for neither the seasonal changes in phosphorus concentrations nor the effect of internal phosphorus load that can occur in a lake throughout the summer and fall. Therefore, mass balance models are needed that look at the effect of the total phosphorus loads at different timesteps throughout the year to provide reasonable predictions of summer-average epilimnetic lake phosphorus concentrations.

Historical water quality data for Lake Owasso shows that the phosphorus concentrations vary significantly during the summer as a result of additional watershed runoff and internal loading of phosphorus. For this reason, the Dillon and Rigler equation was used to calculate a spring concentration in the lake, but a mass balance model that builds off of this predicted spring concentration was used to calculate the in-lake phosphorus concentrations at various times throughout the growing season.



Division of Lake Owasso into Two-Basins for In-Lake Water Quality Modeling

To Site 5401 (North Basin)

To Site 5403 (South Basin)

Subwatersheds

Note: The area directly tributary to Lake Owasso (subwatershed "Lake Owasso") was routed directly to the north basin for in-lake water quality modeling purposes.

Feet
1,750 0 1,750

N

Figure 4-7

LAKE OWASSO
TWO-BASIN IN-LAKE
WATER QUAILTY MODEL (2008)

Lake Owasso UAA
Grass Lake Watershed Management Organization

Barr Footer: Date: 3/22/2009 5:35:47 PM File: I:\Projects\23\62\946\GIS\Maps\Figures_for_Report\Figure4-7_TwoBasin_Model.mxd User: jak2

4.3.1.2 Accounting for Seasonal Variation of Watershed Loads and Internal Loading in the In-Lake Water Quality Models

As previously mentioned, a spreadsheet mass balance model based on Dillon and Rigler (1974) was used to reconcile phosphorus loadings from the watershed with phosphorus concentrations observed in the lake. The in-lake mass balance model routes external and internal phosphorous loads through the lake over the summer season (May through September).

In the mass balance model, internal load from the lake sediments was calculated by deduction, using the following equation, calculated at time intervals varying from a few days to two weeks:

Internal P = Observed P + Outflow P + Coontail Uptake P – Watershed Runoff P – P from Curlyleaf Pondweed - Atmospheric P ± Groundwater P

In the above mass balance model, the watershed runoff P term includes both the watersheds runoff (as predicted by the P8 model) as well as the estimated internal TP load from wetlands and waterbodies within the Lake Owasso watershed.

In addition, sediment cores from Lake Owasso were collected and analyzed for mobile phosphorus (mobile P) in order to measure the maximum potential for internal loading rate of phosphorus from the lake sediments. These data were helpful in verifying the amount of internal load deduced by the mass balance model.

Internal load from Curlyleaf pondweed was calculated within the mass balance model, using an estimated stem density (based on visual observation during macrophyt+e monitoring events), an estimated grams dry weight per stem and an estimated phosphorus content per dry weight (these values were measured as a part of a study of Big Lake in Wisconsin (Barr, 2001).

Uptake of phosphorus by coontail was also estimated in the model, using the following equation from Lombardo and Cooke (2003):

$$\mu g\ TP/g\ (plant\ ww)/d=1/(.0927\cdot(weeks)-.0097)$$

Where

ww = Plant wet weight per m^2, estimated based on a qualitative density measurement (range of 1 to 3, based on macrophyte monitoring on the lakes). The qualitative density measurements were related to wet weight based on data by Vidakoviae et al. 2002, and Newman, 2004.

5.0 Results

5.1 Compiled Data

Water quality and limnological data acquired during the preparation of this management plan are compiled in the Appendices. Appendix A summarizes the results of the survey sent to the lakeshore owners/residents that live along, have deeded access to, or live nearby Lake Owasso. Appendix B includes the drawing of the outlet of Lake Owasso. Appendix C summarizes the results of the discharge surveys conducted by the Cities of Roseville and Shoreview during the summer of 2007. Appendix D summarizes the pond discharge surveys as conducted in late May through late July 2008. Appendix E summarizes the P8 parameter selection process during calibration and pond data used for development of the P8 model. The pond data is based on pond field surveys, data taken from development plans or using ArcView and estimated average depths. Appendix F is the tabulated 2007 and 2008 in-lake water quality data for Lake Owasso collected as a part of this UAA. Selected water quality parameters from Appendix F are analyzed and summarized in the discussion below. Appendix G contains the results of a trend analysis performed on the historical water quality data available for Lake Owasso. Appendix H summarizes the historic zooplankton and phytoplankton data for Lake Owasso as collected by Ramsey County. Appendix H also includes the preliminary memo related to the zooplankton filtering rates from Dr. Joseph Shapiro, University of Minnesota Emeritus Professor of Limnology.

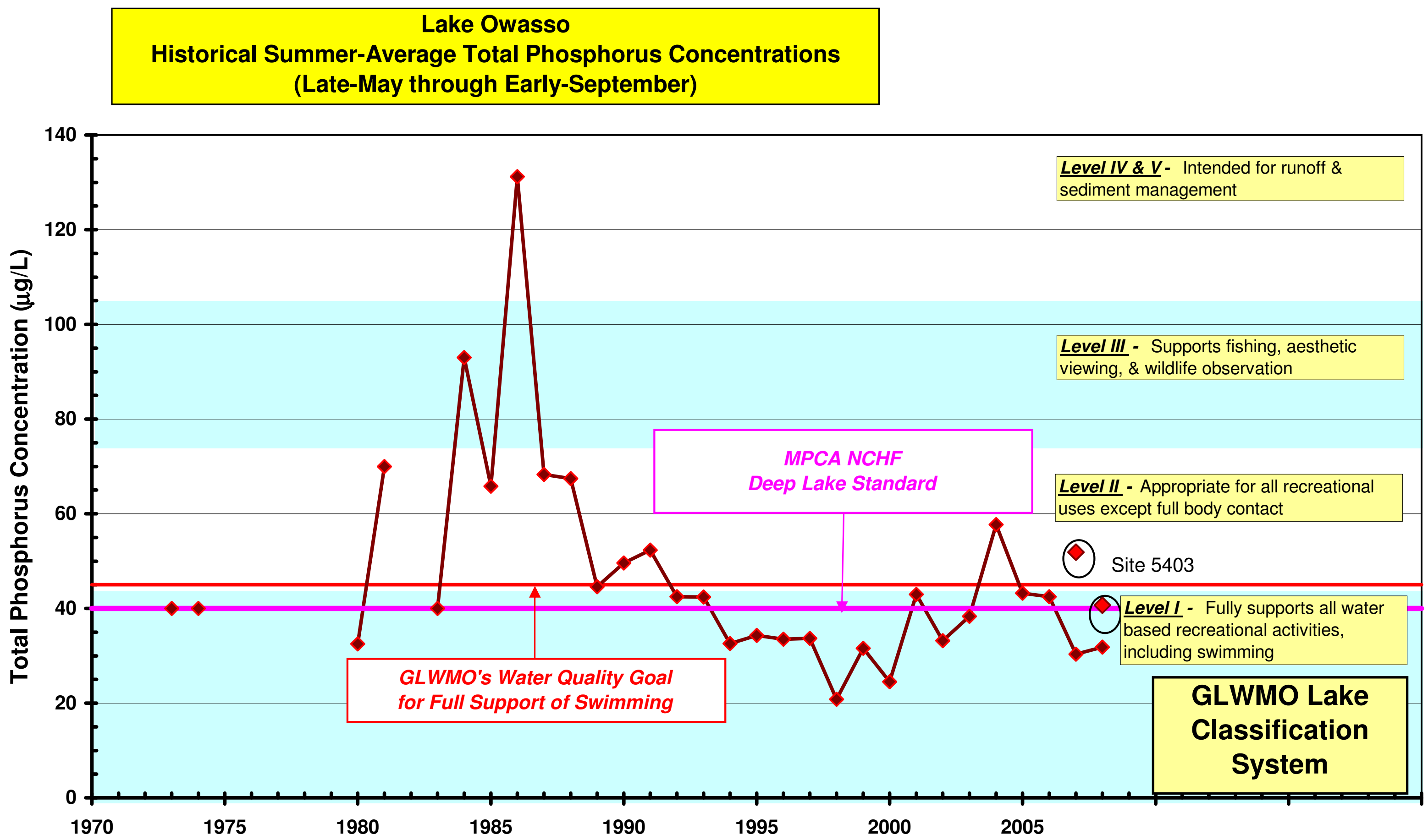
Appendix I summarizes any fishery and stocking data for the Lake as obtained from the MDNR. Appendix J includes macrophyte survey data. Appendix K includes the Lake Owasso Shoreline Survey results, as conducted by RWMWD staff. Appendix L includes the results of the in-lake water quality modeling for each of the climatic conditions. Appendix M contains the results of the 2007 sediment core analysis. Appendix N shows the detailed cost estimates for the BMPs analyzed in this study. The significance of all of these data and how they were used in this study are described below.

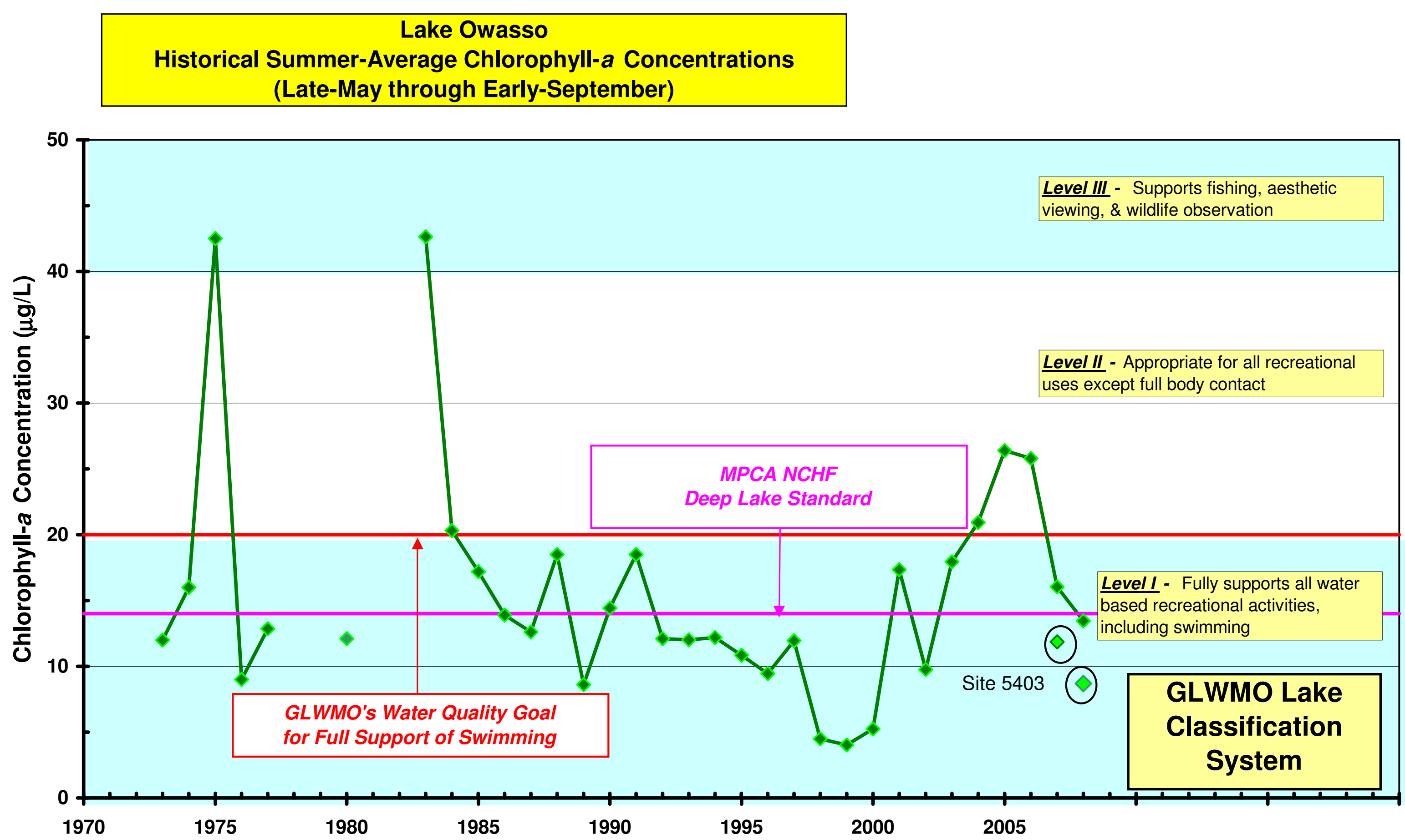
5.2 Trend Analyses of Total Phosphorus, Secchi Disc Transparency, and Chlorophyll *a* Data

5.2.1 Historical Water Quality-Lake Owasso

Historical water quality data, in terms of summer-average total phosphorus, Secchi disc and chlorophyll *a*, for Lake Owasso are presented in Figure 5-1. To define a “summer-average” for each water quality parameter, the typical averaging period was the end of May through early September to be consistent with the MPCA's method for evaluating lake water quality. For some years, the averaging period was June through early September if data for late May was not available.

In addition to the average over the period of record, two other values are noted on each chart: the GLWMO water quality goal as stated in the GLWMO *Watershed Management Plan* (Barr, 2001) and the MPCA's deep lake standard for each water quality parameter. The plot of the historical Secchi depths includes a third value, the GLWMO action level (as defined by the GLWMO *Watershed Management Plan* (Barr, 2001)).





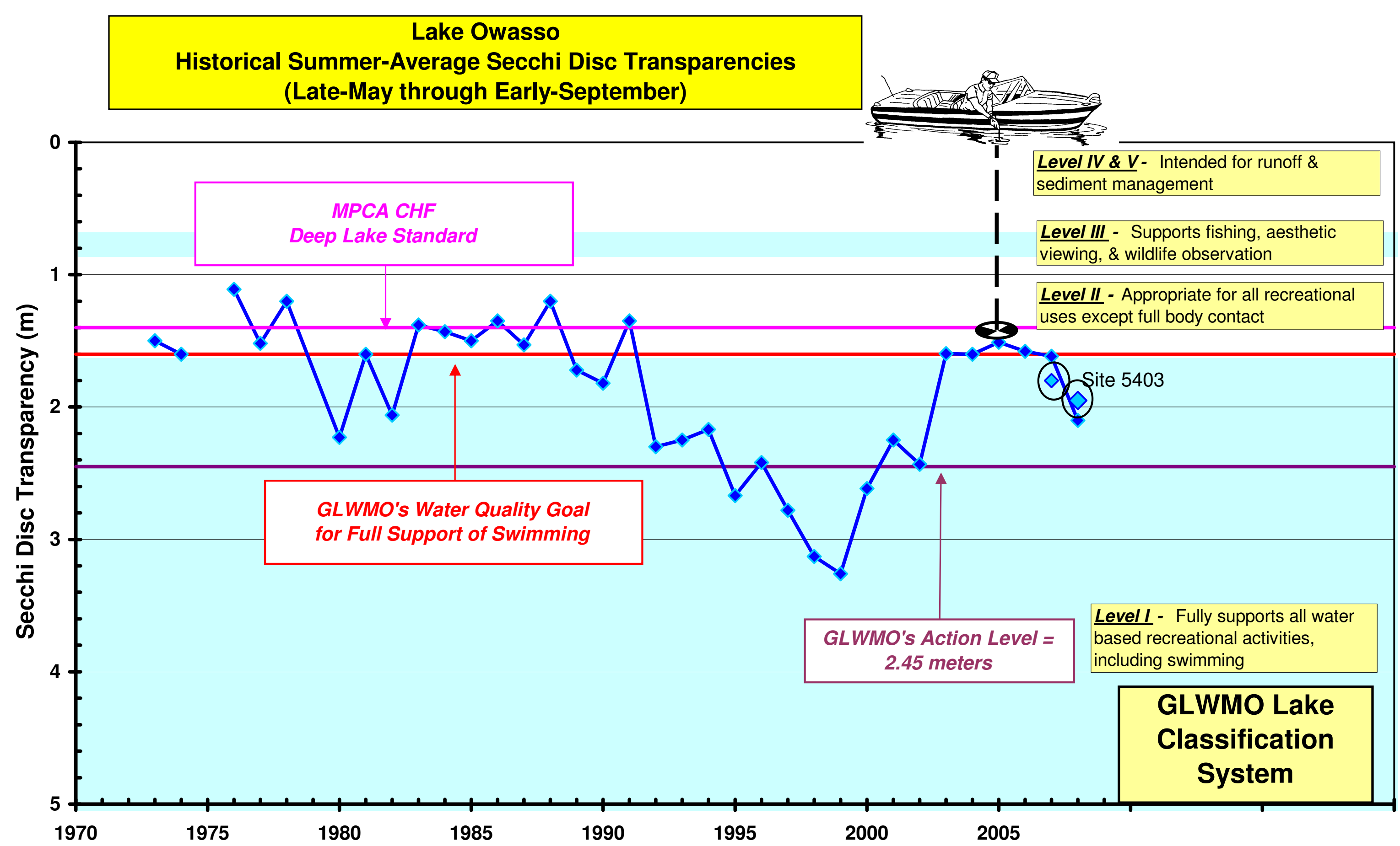


Figure 5-1
Lake Owasso Historical Summer Average (late May through early September) Total Phosphorus and Chlorphyll-*a* Concentrations and Secchi Depths

The compiled data for summer-average water quality variables from Lake Owasso were analyzed to develop relationships between the water quality parameters: total phosphorus, chlorophyll *a*, and Secchi depth.

It was shown in the *Water Quality Management Alternatives* study (Barr, 1991) that the changes in chlorophyll *a* concentrations are unrelated to changes in phosphorus levels in Lake Owasso. Although phosphorus concentrations in lakes place limits on the overall abundance of algae, other features of lakes frequently modify the actual amounts of algae that are present. This can be especially true when zooplankton, which feed upon algae are of sufficient abundance and size allow, reduce the amount of algae to well below the limit allowed by the phosphorus levels.

Lake Owasso continues to show a similar relationship between total phosphorus and chlorophyll *a* concentrations through the present, as shown in Figure 5-2. Also plotted in Figure 5-2, is the total phosphorus and chlorophyll *a* regression equation developed by the MPCA based on a statewide lake database (MPCA, 2005). The slope of the relationship for Lake Owasso is much lower than the slope of the MPCA relationship, suggesting that the algae concentrations in Lake Owasso are likely more impacted by zooplankton grazing than in the lakes used by the MPCA to develop the statewide total phosphorus and chlorophyll *a* regression equations.

Because of the poor correlation (r^2=0.18) between the total phosphorus and chlorophyll *a* concentrations in Lake Owasso and because total phosphorus and Secchi depth are the major management parameters, a direct relationship between total phosphorus and Secchi depth was developed for Lake Owasso. Figure 5-3 shows the relationship between total phosphorus concentrations and Secchi depths in the lake. The regression equation relating total phosphorus to Secchi depth is:

$$[SD] = 4.0 - [\ 3.03 * (\ ([TP] - 20) / (\ ([TP] - 20) + 9.67\ )\ ); (r^2=0.60)$$

Where:

[TP]	=	measured or estimated epilimnetic (mixed surface layer) mean summer total phosphorus concentration (µg/L)
SD	=	estimated mean summer Secchi disc transparency (m)

This equation was used to relate predicted in-lake total phosphorus concentrations to Secchi disc transparency, allowing for the comparison to the GLWMO's water quality goals as well as the MPCA's Deep Lake water quality standards (Table 1-1).

It is important to note there is a significant amount of scatter in the total phosphorus and Secchi depth data used to develop this predictive equation. Variance bands around this regression equation were developed to demonstrate that when interpreting the results of this equation, it should be understood that there is some variance associated with the predicted value, and it cannot be considered as absolute.

To develop these variance bands, the dataset was divided into two groups based on the variance observed in the Secchi depth data. In the lower total phosphorus concentrations (concentration less than 60 μg/L), the variance in the Secchi depth data was about 3 times greater than it was for the higher total phosphorus concentrations (greater than 60 μg/L). It was assumed that the data in the two groups were normally distributed. Using the calculated variance for each data group, the upper and lower 95th percentiles around the regression equation were estimated.

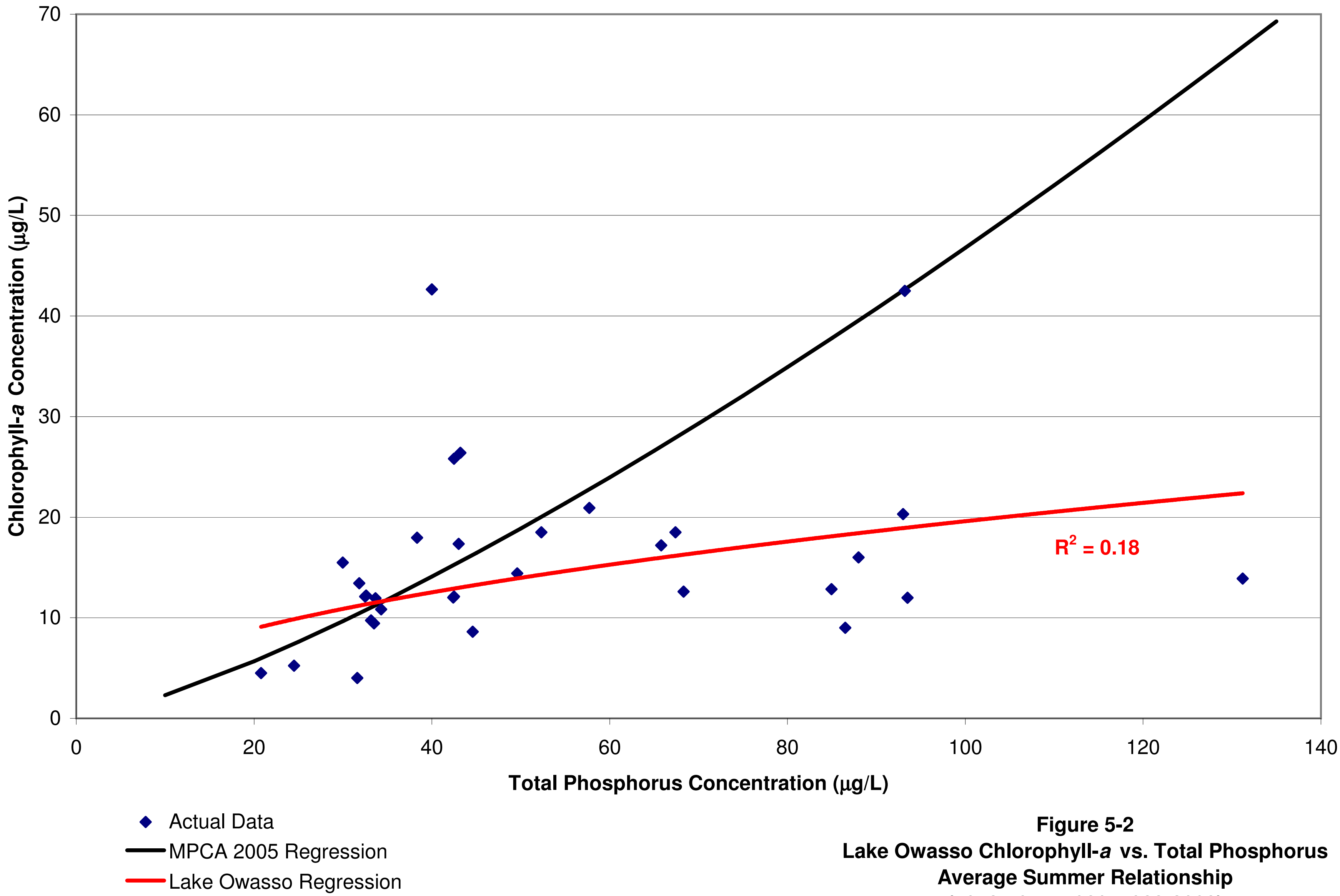


Figure 5-2
Lake Owasso Chlorophyll-*a* vs. Total Phosphorus
Average Summer Relationship
(1973-1977, 1980, 1983-2008)

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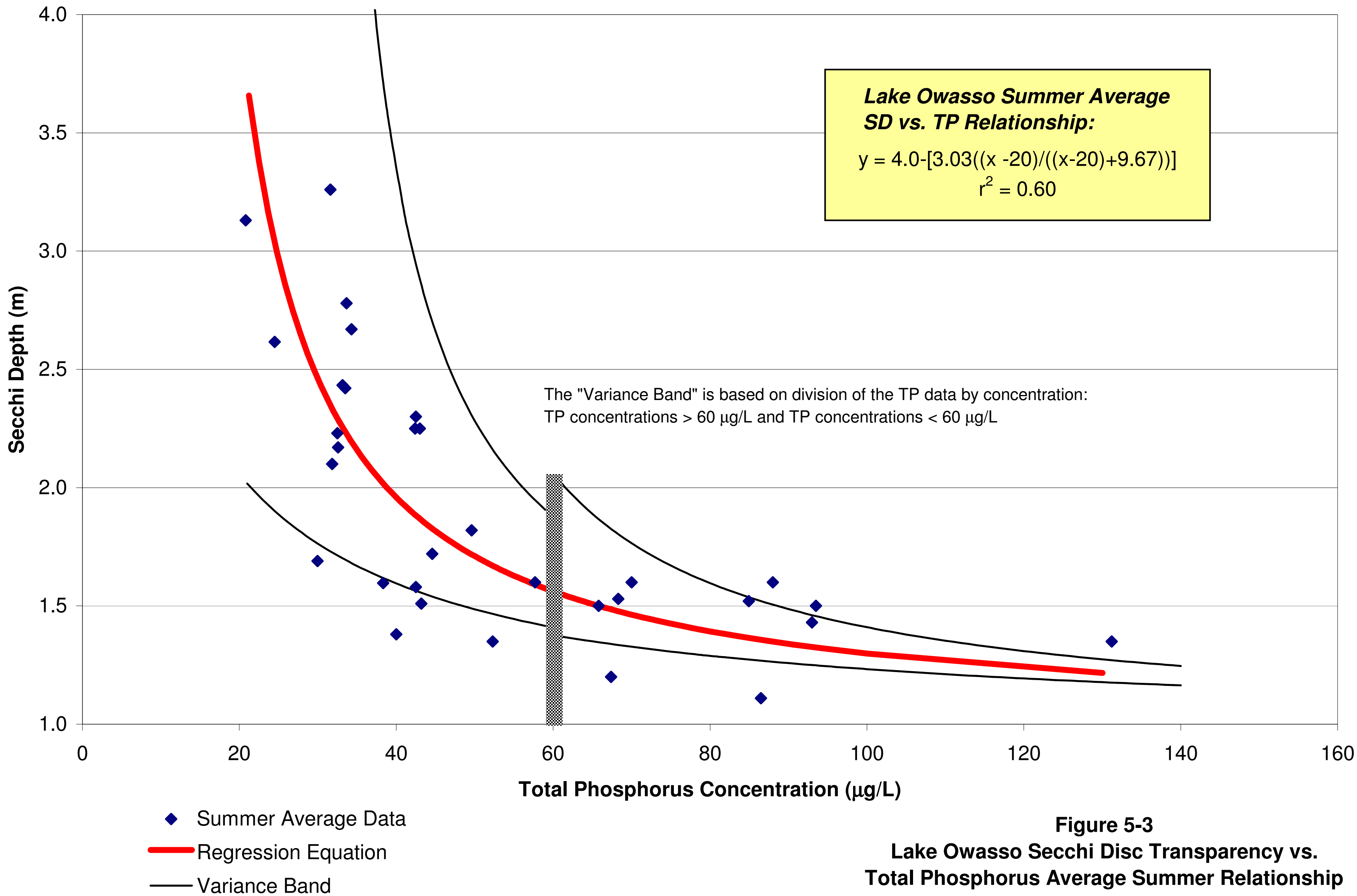


Figure 5-3
Lake Owasso Secchi Disc Transparency vs.
Total Phosphorus Average Summer Relationship
(1973-1974, 1976-1977, 1980-1981, 1983-2008)

5.2.2 Lake Owasso Water Quality Trend Analysis

A trend analysis of Lake Owasso's historical water quality data was completed to determine if the lake had experienced significant degradation or improvement during all (or a portion of) the years for which water quality data are available. Summer-average values (the typical averaging period was late-May through early-September to be consistent with the MPCA's method for evaluating lake water quality) were calculated and analyzed were used to determine water quality trends. Long-term trends are typically determined using standard statistical methods (i.e., linear regression and analysis of variance). Trend analyses were run for two different time periods. The first period was for the most recent 10 years of water quality data, evaluating the same time period that the MPCA typically considers when looking at listing surface waters for water quality impairment on the 303(d) Impaired Waters List. The second considered a period with complete water quality data for all three water quality parameters (from 1983 through 2008).

For this report, the Mann-Kendall/Sen's Slope Trend Test was used to determine water quality trends and their significance. To complete the trend test, the calculated summer average must be based on at least 4 measured values during the sampling season and at least 5 years of data are required. The trend was considered significant if the slope of the regression was statistically significant at the 95 percent confidence interval. Also, to conclude an improvement requires concurrent decreases in TP and Chlorophyll *a* concentrations, as well as increases in Secchi disc transparences; a conclusion of degradation requires the inverse of the relationship above.

The trend analysis for Lake Owasso run using the past 10 years of water quality data (1998 through 2008) found that there has not been a significant change in total phosphorus concentrations over the past 10 years while there was a statistically significant increase in the Chlorophyll *a* concentration over the same time period. Additionally, there was a significant decrease in Secchi depth. Because all three parameters do not show a similar trend, no conclusions can be made about the significance of the changes in water quality over the past 10 years. However, both Chlorophyll *a* and Secchi depth indicate that there has been some degradation in Lake Owasso water quality.

The trend analysis for Lake Owasso for the period from 1983 through 2008 found that there has been a significant decrease in total phosphorus concentrations over the past several decades. There has not been a statistically significant change in the Chlorophyll *a* concentration over the same time period. Additionally, there was a significant increase in Secchi depth. Because all three parameters do not show a similar trend, no conclusions can be made about the significance of the changes in water quality over the past 3 decades. However, both total phosphorus and Secchi depth indicate that there has been some improvement in Lake Owasso water quality since the early 1980's. This is likely due to the implementation of water quality BMPs throughout the watershed..

Results of the trend analysis can be found in Appendix G.

5.3 Seasonal Patterns in 2007 & 2008 Water Quality Conditions

Total phosphorus, Secchi disc, and chlorophyll *a* were measured for Lake Owasso in 2007 and 2008 by Ramsey County.

Phosphorus is the plant nutrient that most often limits the growth of algae. Phosphorus-rich lake water indicates a lake has the potential for abundant algal growth, which can lead to lower water transparency and a decline in hypolimnetic oxygen levels in a lake. According to previous studies (Heiskary and Wilson, 1990) summer-average phosphorus concentrations of 40 µg/L typically result in algal scums being evident (greater than 10 µg/L chlorophyll *a*) for about 65 percent of the summer and nuisance algal bloom conditions (greater than 20 µg/L chlorophyll *a*) for approximately 25 percent of the summer.

Chlorophyll *a* is a measure of algal abundance within a lake. High chlorophyll concentrations indicate excessive algal abundance (i.e., algal blooms), which can lead to recreational use impairment. As stated above, chlorophyll *a* measurements greater than 20 µg/L indicate "nuisance conditions."

Secchi disc transparency is a measure of water clarity. Perceptions and expectations of people using a lake are generally correlated with water clarity. Results of a survey completed by the Metropolitan Council (Osgood, 1989) revealed the following relationship between a lake's recreational use impairment and Secchi disc transparencies:

- Moderate to severe use-impairment occurs at Secchi disc transparencies less than 1 meter (3.3 feet).
- Moderate impairment occurs at Secchi disc transparencies of 1 to 2 meters.
- Minimal impairment occurs at Secchi disc transparencies of 2 to 4 meters.
- No impairment occurs at Secchi disc transparencies greater than 4 meters

Other notable water quality parameters that were measured in 2007 and 2008 in the lakes are temperature and dissolved oxygen, (which indicate the level of stratification in the lakes as well as measure the habitat environment for aquatic species) and chloride (which indicates the degree to which road salts have run off into the lakes from surrounding streets and parking lots, potentially adversely affecting lake biota).

Based on protection of the aquatic community from adverse toxic effects, the standard for chloride in Class 2B waters is as follows (Minnesota Rules 7050):

Chronic standard = 230 mg/L

Acute standard = 860 mg/L (MS), 1720 mg/L (FAV)

Where:

FAV = stands for "Final acute value" and means an estimate of the concentration of a pollutant corresponding to the cumulative probability of 0.05 in the distribution of all the acute toxicity values for the genera or species from the acceptable acute toxicity tests conducted on a pollutant.

MS = stands for "Maximum Standard" and means the highest concentration of a toxicant in water to which aquatic organisms can be exposed for a brief time with zero to slight mortality. The MS equals the FAV divided by two.

This section provides a brief discussion of these parameters as they were measured in Lake Owasso during 2007 and 2008 monitoring seasons.

5.3.1 Water Quality Parameters

Figure 5-4a shows the total phosphorus, Secchi disc, and chlorophyll *a* monitoring results for monitoring site 5401 in Lake Owasso for 2007 and 2008. Figure 5-4b shows the total phosphorus, Secchi disc, and chlorophyll *a* monitoring results for monitoring site 5403 in Lake Owasso for 2007 and 2008. Temperature, oxygen, and chloride data are tabulated in Appendix F.

Phosphorus

The 2007 spring total phosphorus concentration was 26 µg/L at monitoring site 5401 while in the southwest corner of the lake, at site 5403, the total phosphorus concentration was 33 µg/L. This places the lake at the low end of the eutrophic status category. The 2007 peak phosphorus concentration at site 5401 during the summer was 38 µg/L by mid-June. The peak summer phosphorus concentration at site 5403 was 62 µg/L by the beginning of July.

The 2008 spring total phosphorus concentration was 34 µg/L at monitoring site 5401 while in the southwest corner of the lake, at site 5403, the total phosphorus concentration was 35 µg/L. This places the lake at the low to mid range of the eutrophic status category. The peak phosphorus concentration at site 5401 during the summer was 38 µg/L at the end of July. The peak summer phosphorus concentration at site 5403 was 50 µg/L by the beginning of July.

The summer average phosphorus concentrations at site 5401 for 2007 and 2008 were 30 µg/L and 32 µg/L, respectively. These values meet the GLWMO water quality goal of 45 µg/L as well as the MPCA deep lake criterion (40 µg/L). At site 5403, the summer-average total phosphorus concentrations for 2007 and 2008 (52 µg/L and 41 µg/L, respectively) do not meet the MPCA criterion, but the 2008 water quality meets the GLWMO water quality goal. The total phosphorus data collected from Lake Owasso during 2007 and 2008 were generally within the eutrophic (i.e., nutrient-rich) category during the summer.

Isopleths of total phosphorus concentrations at depth through the summers of 2007 and 2008 for both Sites 5401 and 5403 in Lake Owasso can be found in Appendix F.

Chlorophyll *a*

The 2007 and 2008 spring chlorophyll *a* concentrations at monitoring site 5401 were 2 µg/L and 15 µg/L, respectively, while site 5403, chlorophyll *a* concentrations were 4 µg/L and 12 µg/L. These concentrations classify Lake Owasso as mesotrophic in 2007 and eutrophic in 2008. In 2007, as phosphorus concentrations increase over the course of the summer, chlorophyll *a* concentrations rose sharply in June to peak in the beginning of July for both sites 5401 and 5403 (peak concentrations of 23 µg/L and 16 µg/L, respectively), placing Lake Owasso in the eutropic category. There was a second peak in chlorophyll *a* concentration (18 µg/L) at monitoring site 5403 in the beginning of September that was higher than the peak in early July. In 2008, the peak chlorophyll *a* concentration at site 5401 (25 µg/L) occurred in mid-August, after the total phosphorus peak that occurred in the end of July. At site 5403, the 2008 peak chlorophyll *a* concentration (14 µg/L) occurred in early July, similar to the pattern seen in total phosphorus.

The 2007 and 2008 summer-average chlorophyll *a* concentrations at both sites 5401 (16 µg/L and 13 µg/L, respectively) and 5403 (12 µg/L and 9 µg/L) meet the GLWMO goal of 20 µg/L. However, the chlorophyll *a* concentration at site 5401 did not meet the MPCA deep lake criterion (14 µg/L) in 2007. The chlorophyll *a* data collected from Lake Owasso during 2007 and 2008 were generally within the eutrophic category throughout the summer, indicating that Lake Owasso may have experienced nuisance conditions of algal growth.

Secchi Disc

The 2007 spring Secchi disc transparency was 2.1 meters for the both monitoring sites on Lake Owasso, placing lake on the border of the mesotrophic-eutrophic status category. In 2008, the spring Secchi disc transparency at site 5401 was 1.5 meters and at site 5403 was 1.8 meters. For both years, as summer progressed, Secchi disc transparency gradually decreased. At site 5401, transparency reached a minimums of 0.9 meters in early August 2007 and 0.8 meters in early August 2008 . At site 5403, transparency was at its minimum in early July 2007 with a Secchi depth of 1.2 meters. In early July 2008, the minimum transparency at site 5403 was 1.4 meters.

The 2007 summer-average Secchi depth for both sites 5401 and 5403 (1.6 meters and 1.8 meters) just meet the GLWMO water quality goal (1.6 meters) but both are less than the GLWMO established action level (2.45 meters) for Lake Owasso. The 2008 summer average transparency for sites 5401 and 5403 (2.1 meters and 2.0 meters) also meet the GLWMO water quality goal. The summer averages at both monitoring sites meet the MPCA deep lake criterion (1.4 meters). The Secchi disc data collected from Lake Owasso during 2007 and 2008 were within the eutrophic category throughout the summer months.

Temperature and Oxygen

Temperature and oxygen measurements throughout the water column at both monitoring sites in Lake Owasso indicate that the entire lake does thermally stratify from May through early September, for both 2007 and 2008. At Site 5401, the depth to the thermocline was approximately 5 to 6 meters. At site 5403, the thermocline depth is about 2 to 3 meters.

By late Sept, temperature profiles indicate that the lake mixed at both monitoring locations, with the higher temperatures extending into the bottom waters of the lake. This is consistent with the presumption that Lake Owasso is a dimictic lake (completely mixes twice-annually).

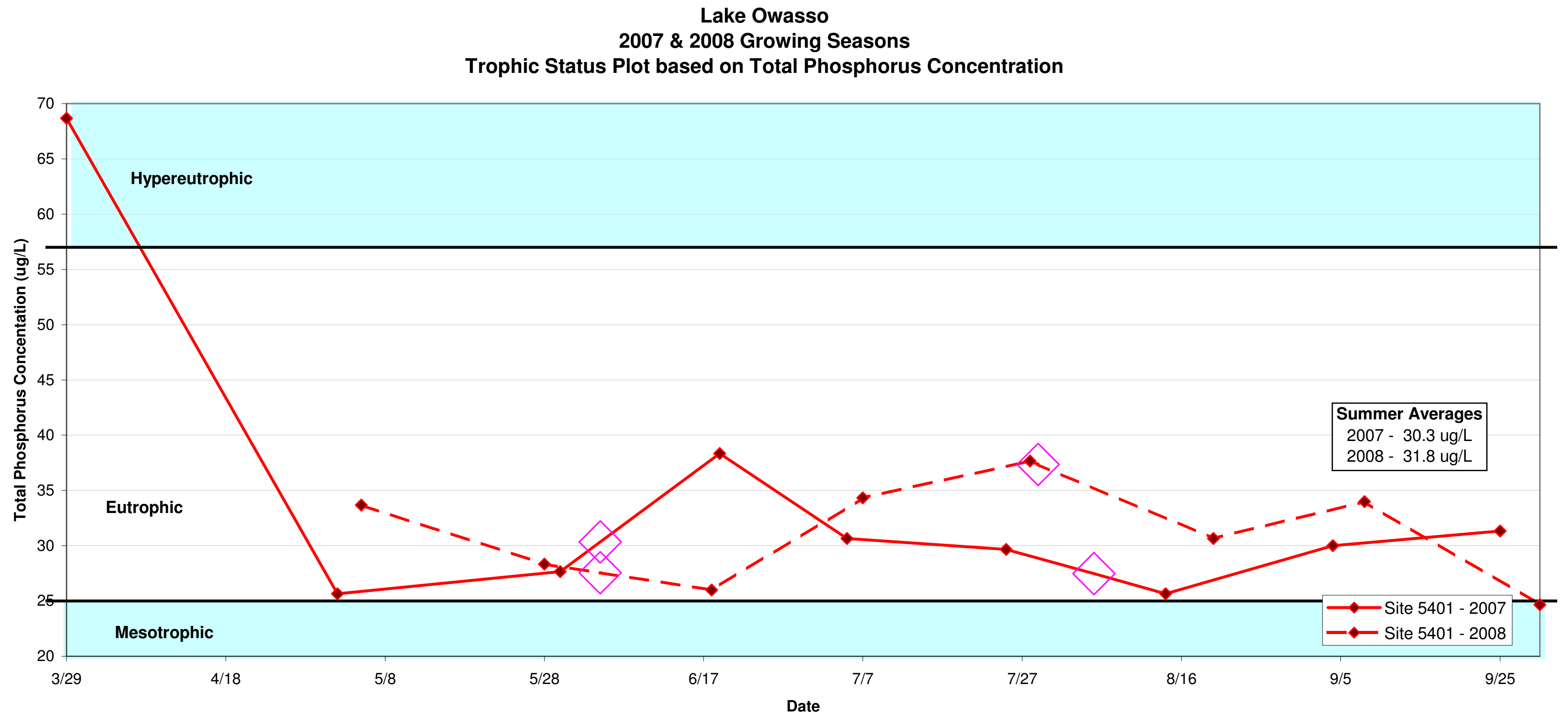
During the summer months, dissolved oxygen levels varied greatly throughout the depth of the water column. Typically, dissolved oxygen levels ranged from 8 to 12 mg/L in the surface waters above the thermocline. However along and below the thermocline, dissolved oxygen levels continued to decline with concentrations less than 1 mg/L along the bottom of the lake. This trend is seen at both monitoring sites in 2007 and 2008. This indicates that Lake Owasso likely experiences sediment anoxia during the summer, resulting in internal phosphorus loading. Phosphorus released from the sediments during these periods of oxygen depletion, accumulated in the hypolimnion, and eventually making its way to the surface waters, increasing the lake’s surface phosphorus concentration.

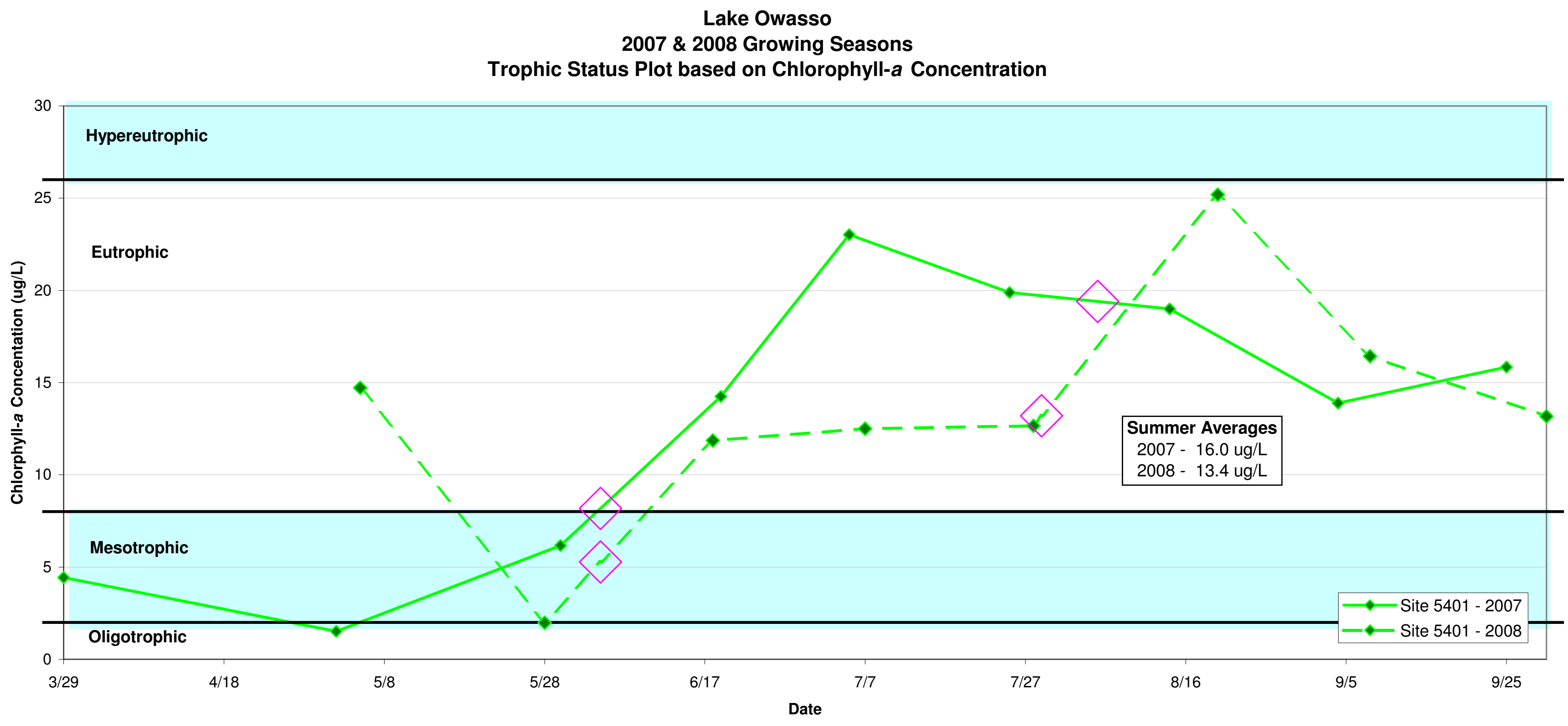
Chloride

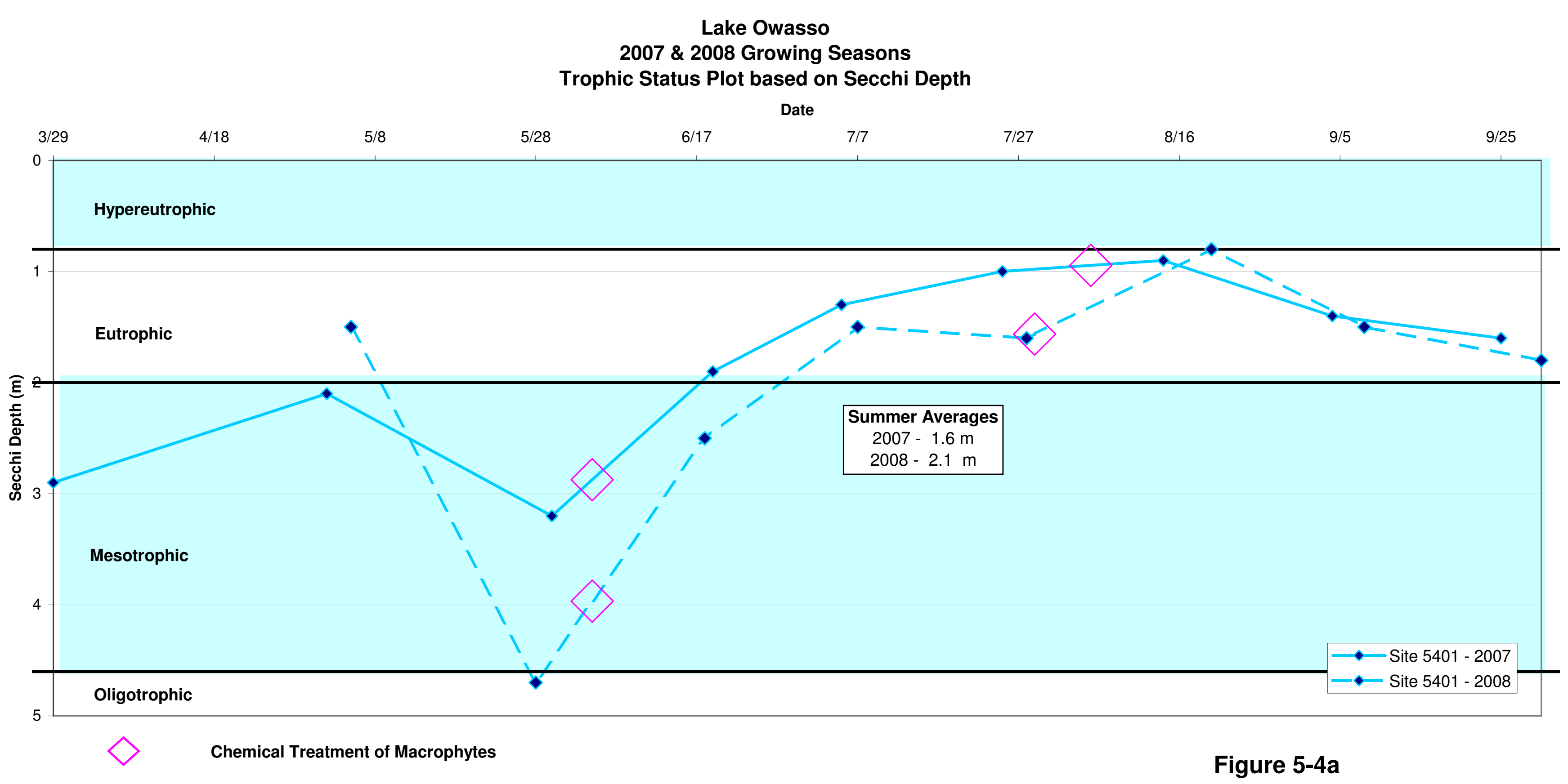
Chloride measurements in Lake Owasso were relatively constant throughout the summer of 2007 at both monitoring locations, ranging from 50 to 60 mg/L. The exception was on June 19 at site 5403 when chloride concentrations at the surface were 200 mg/L. The average chloride concentration for the entire monitoring period measured at site 5401 was 55 mg/L, and at site 5403, it was 69 mg/L.

In 2008, the surface chloride levels at both sites 5401 and 5403 typically ranged from 50 to 70 mg/L. The average chloride level for the entire monitoring period at site 5401 was 57 mg/L and at site 5403, the concentration was 69 mg/L.

The chloride concentrations for both years should not pose a threat to the biota of Lake Owasso.

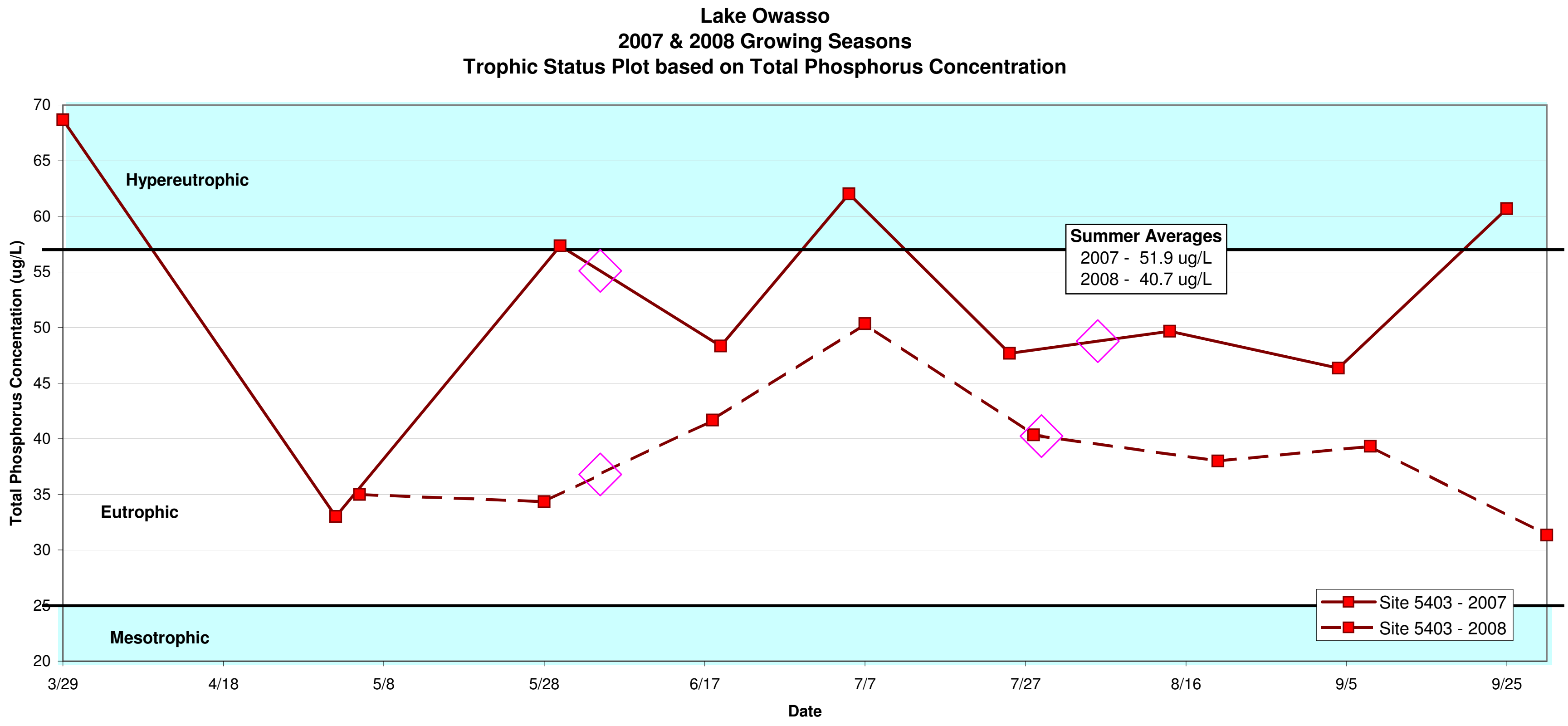


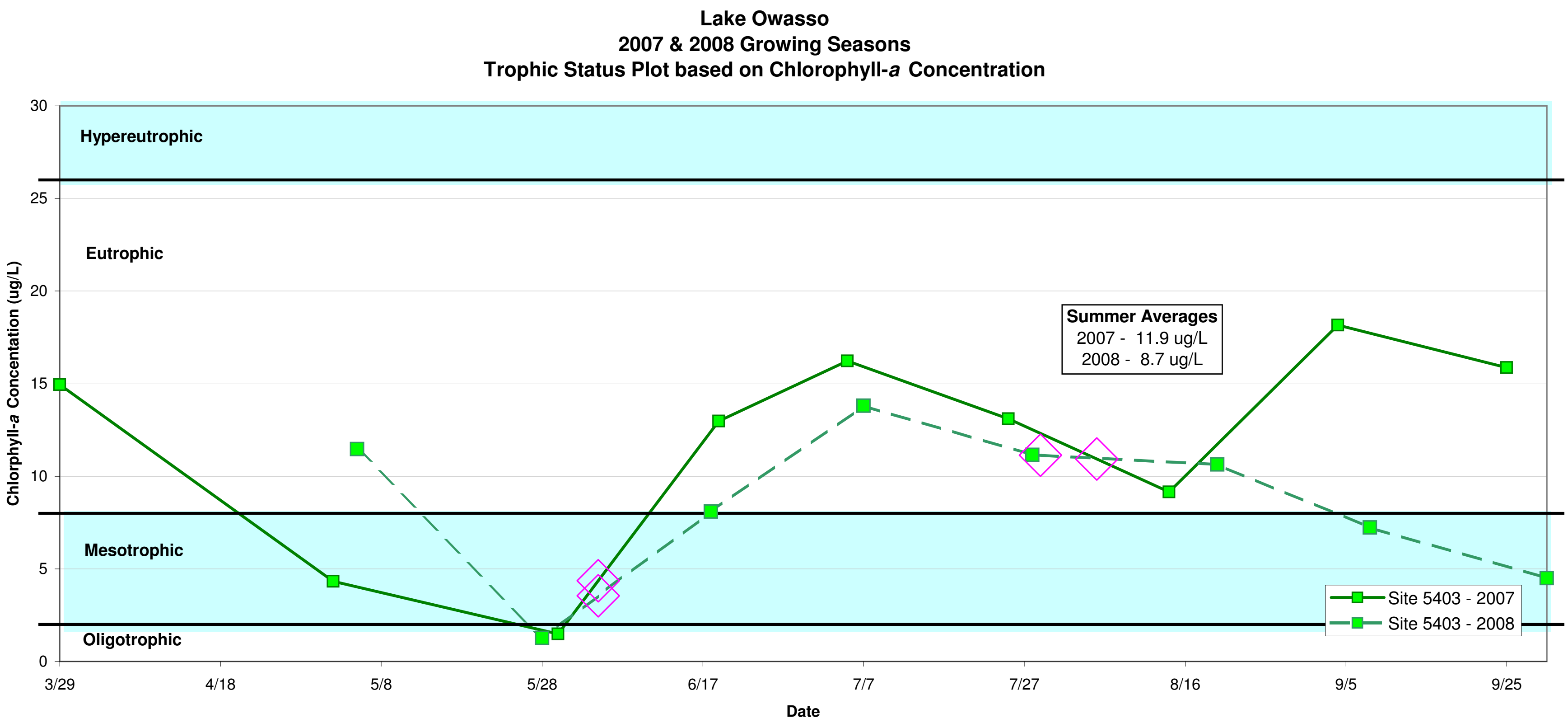


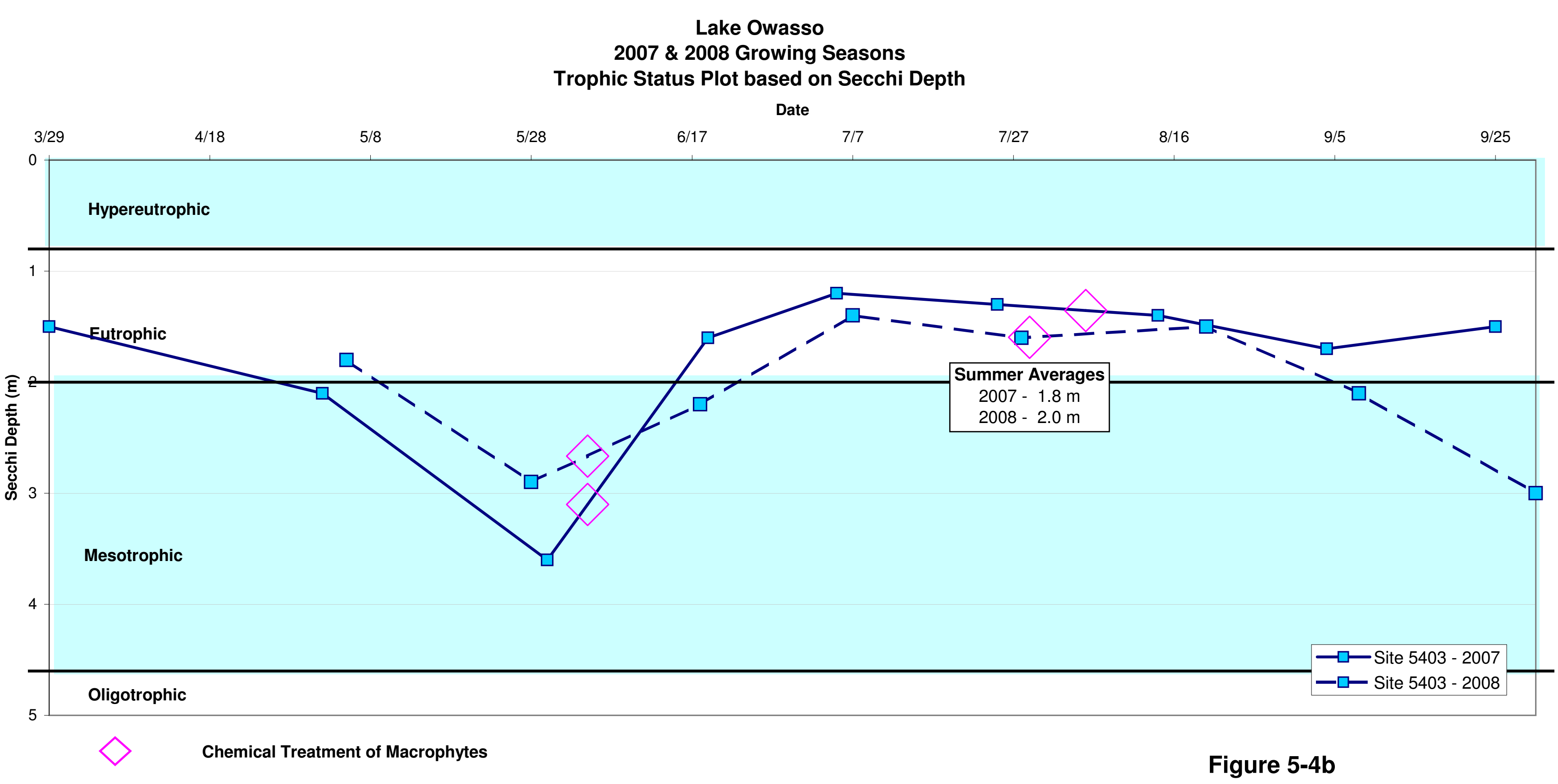


Note: Summer Averages calculated based on data from the late May through early September

Figure 5-4a
Lake Owasso - Site 5401
2007 & 2008 Water Quality







Note: Summer Averages calculated based on data from the late May through early September

Figure 5-4b
Lake Owasso - Site 5403
2007 & 2008 Water Quality

5.3.2 Sediment Core Results

Ten sediment cores were collected from Lake Owasso in May, 2007 and were analyzed for mobile phosphorus (which contributes directly to internal phosphorus loading) and organic bound phosphorus. Figure 5-5 shows the Lake Owasso sediment core locations and the interpolated distribution of mobile phosphorus loading rates based on the sediment core results. The average whole-lake internal loading rates calculated for these ranges of mobile phosphorus concentrations were 0.5 mg/m^2/day for Lake Owasso, with the highest expected loading rate being 2.9 mg/m^2/d in the deepest portion of the lake. Table 5-1 shows how the internal loading rate (deep hole) in Lake Owasso compares to the rates calculated for other Metro Area lakes, using the same methodology. None of the lakes shown in Table 5-1 had alum treatments at the time of the sediment core sampling.

Table 5-1 Comparison of Lake Owasso Internal Phosphorus Loading Rates to Those of Other Metro Area Lakes

Lake	Internal P Load (mg/m^2/d)
Isles (pre-alum, deep hole)*	14.1
Harriett (pre-alum, deep hole)*	11.1
Calhoun (pre-alum, deep)*	10.8
Fish E**	10.5
Cedar (pre-alum)*	9.3
Fish W**	8.1
Como**	7.6
Harriet**	6.9
Como-litoral**	5.7
Calhoun (pre-alum, shallow)**	5.6
Parkers**	3.5
Lake Owasso (deep hole)	**2.9**
Phalen**	2.3
McCarrons**	2.0
Bryant**	1.5
Nokomis**	1.0
Minnewashta**	0.2
Christmas**	0.0

Sources:
*Huser et al. (2009)
**Pilgrim et al. (2007)

The average internal phosphorus loading rate calculated for all of the Metro Area Lakes in Table 5-1 is 6.3 mg/m^2/day. The internal phosphorus loading rate from the sediments calculated for Lake Owasso is below this average. It is important to note that these rates represent the maximum potential internal loading rate that the lakes could experience, given the ideal dissolved oxygen concentrations and mixing conditions. Therefore, Lake Owasso will likely experience less internal phosphorus loadings than these rates would indicate (as they assume perfect internal loading conditions).

Additionally, the amount of organic bound phosphorus was consistently higher than the mobile phosphorus measured in the sediments, indicating that available mobile phosphorus exported from the sediments during anoxic periods is quickly used by algae or plants, especially in the shallower areas of the lake.

Review of the temperature and dissolved oxygen data for Lake Owasso indicates that the lake thermally stratifies during the summer and that dissolved oxygen levels are depleted along the sediments, suggesting that internal loading from the sediments is likely. Although Lake Owasso is considered a deep lake that does thermally stratify (dimictic), with minimal mixing due to wind action, the average depth of the lake is 10.9 feet. There are several deep holes in the lake but the majority of the lake is relatively shallow. The alignment of the lake is from the southwest to the northeast and because the predominant winds during the summer months are from the south and southeast, some mixing of the shallow areas of the lake may be possible, potentially bringing phosphorus released from the sediments to the surface waters of the lake. Additionally, anecdotal information from Lake Owasso residents suggests that mixing in the shallow areas of the lake does occur as the result of motorboat activity, especially in the southern end of the lake.

More information about the sediment core testing from Lake Owasso can be found in Appendix M.

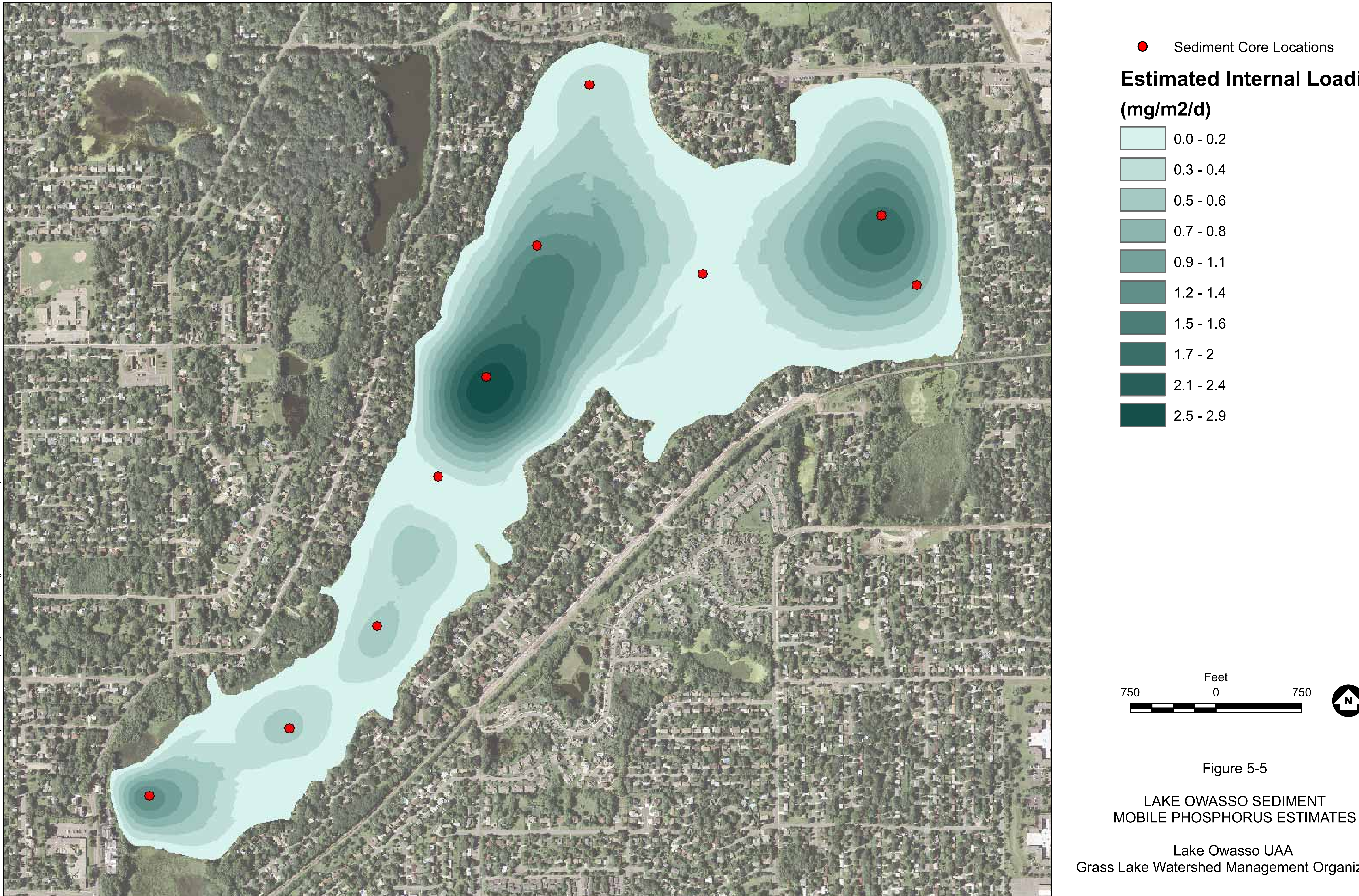


Figure 5-5

LAKE OWASSO SEDIMENT
MOBILE PHOSPHORUS ESTIMATES

Lake Owasso UAA
Grass Lake Watershed Management Organization

5.3.3 Aquatic Communities

In addition to physical and chemical indices of lake water quality, an evaluation of the plant and animal species that inhabit the water provide valuable information about the health of the lake. An assessment of the current situation with respect to the aquatic communities in the lake is provided in the following sections.

5.3.3.1 Phytoplankton

The phytoplankton communities in lakes form the base of the food web and affect recreational-use of the lake. Phytoplankton, also called algae, is small aquatic plants naturally present in all lakes. They derive energy from sunlight (through photosynthesis) and from dissolved nutrients found in lake water. They provide food for several types of animals, including zooplankton, which are in turn eaten by fish.

An inadequate phytoplankton population limits the lake's zooplankton population and can, thereby, limit the fish production in a lake. Conversely, excess phytoplankton can alter the structure of the zooplankton community and interfere with sight-based fish predation, thereby also having an adverse effect on the lake's fishery. In addition, excess phytoplankton reduces water clarity; reduced water clarity can in itself make recreational-usage of a lake less desirable.

Green algae are considered beneficial as they are edible to zooplankton and serve as a valuable food source.

Blue-green algae are considered nuisance algae because they:

- are generally inedible for fish, waterfowl, and most zooplankton,
- float at the lake surface in expansive algal blooms,
- may be toxic to animals when occurring in large blooms, and
- can interfere with recreational uses of the lake

Ramsey County has been monitoring the various types and concentrations of phytoplankton communities in Lake Owasso throughout the summers for the past two decades. This data (through 2006) provides a look at historic trends in the phytoplankton levels throughout the summer as well as over the years. Figure 5-6 shows that the overall phytoplankton levels in Lake Owasso varies during throughout the summer of 2006, with the peak phytoplankton concentration occurring in mid-August. Blue-green algae, which are typically nuisance species, were the dominant type of phytoplankton present in Lake Owasso for the entire season.

Historic phytoplankton data can be found in Appendix H.

5.3.3.2 Zooplankton

Zooplankton—microscopic crustaceans—are vital to the health of a lake ecosystem because they feed upon the phytoplankton and are food themselves for many fish species. Protection of the lake's zooplankton community through proper water quality management practices protects the lake's fishery. Zooplankton is also important to lake water quality. Healthy zooplankton communities are characterized by balanced densities (numbers per meter squared) of the three major groups: cladocera, copepoda, and rotifera.

The rotifers and copepods in lakes graze primarily on extremely small particles of plant matter and, therefore, do not significantly affect lake water transparency by removing algae. By contrast, cladocera graze primarily on algae and can increase transparency if they are present in abundance. *Daphnia spp*. is among the larger cladocera species and is considered especially desirable in lakes because of their ability to consume large quantities of algae. Fish predation, however, may alter the community structure by reducing the numbers of larger-bodied zooplankton (i.e., cladocerans and copepods).

There is not a surrogate measurement of zooplankton biomass similar to Chl *a* concentration for phytoplankton biomass. Therefore, zooplankton must be identified and counted to get an estimate of zooplankton biomass.

Ramsey County has been monitoring the various types and concentrations of zooplankton communities in Lake Owasso throughout the summers for the past two decades. In addition, the size distribution of *Daphnia spp.* were also monitored. These data provide a look at historic trends in the zooplankton levels throughout the summer as well as over the years.

Figure 5-7 shows the zooplankton concentrations (expressed as the number of organisms per cubic meter of lake) for Lake Owasso on each of the sampling dates throughout the summer of 2007. The historic zooplankton data are present in Appendix H.

The overall amount and distribution of the type of zooplankton in Lake Owasso varied throughout the 2007 season. Zooplankton concentrations were highest in early May. During June and July, the zooplankton concentrations declined and then increased again in September. The dominant groups in Lake Owasso in the early part of the season and throughout much of the summer were the copepods and rotifers. Later in the season, the numbers of the copepods declined while more cladocera species were present. In Lake Owasso, a very low numbers of the *Daphnia spp.* were observed in 2007, and those that were observed were relatively small.

Studies have been done that have analyzed zooplankton (cladocera) feeding patterns, relating body size to the maximum size of the particles ingested as well as establishing a relationship between the filtering rate of *Daphnia spp.*, temperature, and body size (Burns, 1968 & 1969).   Data through the summer of 2007 was obtained from Ramsey County, processed to estimate zooplankton feeding rates, and the results have been reviewed by Dr. Joseph Shapiro, University of Minnesota Emeritus Professor of Limnology. A memo summarizing the preliminary results can be found in Appendix H. The general conclusion is that the *Daphinia spp* are present in low numbers and are small in size. As a result, filtering rates are relatively low and the impact on the reduction of phytoplankton is limited.

Planktivorous fish (such as sunfish and bluegills) eat zooplankton and will preferentially select the large Daphnia. Therefore, to thrive, the Daphnia require either a refuge from predators (i.e., deep, well-oxygenated water) or a smaller predator population. The MDNR fishery data shows that both smaller than average bluegills and other small panfish are present in Lake Owasso (see Section 5.3.4.4). The combination of these factors could likely contribute to the low Daphnia populations and decreased water clarity due to low phytoplankton filtering rates.

5.3.3.3 Macrophytes

Aquatic plants (i.e., macrophytes and phytoplankton) are a natural part of most lake communities and provide many benefits to fish, wildlife, and people. They are among the primary producers in the aquatic food chain, providing food for other aquatic life. Macrophytes (aquatic plants growing in the shallow, or littoral, area of the lake) perform a number of valuable functions in Lake Owasso. Specifically, macrophyte communities:

- Provide habitat for fish, insects, small aquatic invertebrates, and zooplankton
- Provide food for waterfowl, fish, and wildlife
- Oxygen production
- Provide spawning areas for fish in early spring
- Help stabilize marshy borders of the lake; which help protect shorelines from wave erosion
- Provide nesting sites for waterfowl and marsh birds

Macrophytes are an important component of the lake ecosystem (Ozimek, Gulati, and Van Donk 1990). However, the introduction of exotic (nonnative) aquatic plants into a lake may cause undesirable changes to the plant community and to the lake ecosystem. Dense stands of some mat-forming plant species reduce oxygen exchange, deplete available dissolved oxygen, increase water temperatures, and increase internal loading rates of nutrients (Frodge, Thomas, and Pauley 1991; Frodge et al. 1995; Seki, Takahashi, and Ichimura 1979). Dense canopies formed by some nonnative species (e.g., Curlyleaf pondweed and Eurasian watermilfoil) reduce native plant diversity and abundance, thereby reducing habitat complexity. This reduction in habitat complexity results in reduced macroinvertebrate diversity and abundance (Krull 1970, Keast 1984) and also reduces growth of fishes (Lillie and Budd 1992). The introduction of a nonnative plant species to a lake is not only deleterious to human use of aquatic systems, but is also detrimental to the native ecosystem.

Once a lake becomes infested with Curlyleaf pondweed, this plant typically replaces native vegetation, thereby increasing its coverage and density. Curlyleaf pondweed begins growing in late August, grows throughout the winter at a slow rate, grows rapidly in the spring, and dies in early summer (Madsen et al. 2002). Native plants that grow from seed in the spring are unable to grow in areas already occupied by Curlyleaf pondweed, and are displaced by this plant. Curlyleaf pondweed die-off in early summer releases phosphorus to the lake, causing increased algal growth for the remainder of the summer.

Eurasian watermilfoil is a nuisance, non-native species that typically replaces native vegetation. It has a canopy style growth pattern that causes heavy growth near the surface, making it more visible and a greater nuisance for boating and fishing.

An aquatic plant survey of Lake Owasso was conducted by Ramsey County in late May, 2007. Table 5-2 summarizes the macrophyte species observed in Lake Owasso.

Table 5-2 Lake Owasso Summary of Observed Macrophyte Species (May 2007)

Potomogeton crispus	Curlyleaf pondweed
Potomogeton amplifolius	Large-leaf pondweed
Potomogeton pectinatus	Fine-leaf (Sago) pondweed
Potomogeton natans	Floating-leaf pondweed
Myriophyllum exalbescens	Northern watermilfoil
Myriophyllum spicatum	Eurasian watermilfoil
Ceratophyllum demersum	Coontail
Nuphar Variegata	Yellow water lily
Nymphaea odorata	White water lily
Chara vulgaris	Muskgrass
Zanichellia palustris	Horned pondweed
Najas flexilis	Bushy pondweed
--	Unidentified filamentous algae

As mentioned above, the die-off of Curlyleaf pondweed (*Potomogeton crispus*) can significantly contribute to the phosphorus load within a lake. Curlyleaf pondweed was present in Lake Owasso during the spring of 2007. The estimated coverage and density of Curlyleaf pondweed is summarized in Figure 5-8. The non-native species Eurasian watermilfoil (*Myriophyllum spicatum*) is also present in Lake Owasso. According to the MDNR, Eurasian watermilfoil was first identified in Lake Owasso in 2000.

The Ramsey-Washington Metro Watershed District (RWMWD) also conducted a macrophyte survey of Lake Owasso in September 2005. During this survey, coontail was the most abundant macrophyte species, found in approximately 25% of the sites sampled in the littoral zone. Eurasian watermilfoil was the second most common macrophyte. Other common sampled species were Nitella and white and yellow waterlilies. Many of the macrophyte species observed in the May 2007 survey were also observed in the September 2005 survey.

According to the *Lake Owasso Management Plan* (Osgood, 2000) and information provided by Ramsey County, the MDNR and Ramsey County have conducted other aquatic plant surveys in Lake Owasso. The MDNR conducted surveys in 1948, 1955, 1981, and 1991. The other macrophyte surveys were conducted by Ramsey County in 1984, 1985, 1986, and again in 1990. The surveys indicate that Curlyleaf pondweed was present in Lake Owasso as far back as 1981.

Macrophytes in Lake Owasso have been both chemically and mechanically controlled for several decades, although chemical treatment is the predominant control method. Treatments typically occur in late May or early June and treat all macrophyte species, not just specific non-native species such as Curlyleaf pondweed or Eurasian watermilfoil. Although the MNDR currently limits treatment to 15 percent of a lake's littoral (shallow) area, the aquatic plant control permit for Lake Owasso has existed longer than this restriction, and allows for the treatment of up to 21 percent of its littoral area, or about 62 acres.

In recent years, the Lake Owasso Association has spent approximately $50,000 to $60,000 annually for macrophyte treatment. In both 2007 and 2008, the lake was chemically treated in June and July.

Macrophyte survey data can be found in Appendix J.

5.3.3.4 Fish and Wildlife

According to the *Lake Owasso Management Plan* (Osgood, 2000), fishery surveys have been conducted for Lake Owasso in 1948, 1956-1959, 1961, 1971, 1976, 1981, 1991, 1992, 1994, and 1996. The most recent fishery survey was conducted by the MDNR in 2001 and a population assessment was conducted in 2006.

According to MDNR's most recent (2001) Lake Survey Report for Lake Owasso, bluegill is the most abundant species present in the Lake. Small pumpkinseed sunfish were also captured in record levels of abundance. Additionally, black crappie and yellow perch were sampled. Growth rates for the bluegill, pumpkinseed sunfish, and black crappie were found to be slow and yellow perch exhibited average growth rates. Muskellunge and walleye are the primary management species in Lake Owasso. These fish are stocked by the MDNR biennially. Northern pike were sampled above median levels for abundance. Growth rates for all the major predator species were found to be good. Other species sampled in Lake Owasso include black, brown, and yellow bullhead, green and hybrid sunfish, and largemouth bass.

A 2006 population assessment indicated that bluegill is still the most abundant fish species in the lake followed by black crappie. Northern pike and walleye were also sampled, as well as large mouth bass and muskellunge.

The Lake Owasso fishery has been stocked almost annually with a variety of species since 1971 (Osgood, 2000). See Appendix I for more detailed information about the Lake Owasso fishery and stocking programs.

Additionally, there have been several periods of low winter oxygen conditions in Lake Owasso that could have resulted in potential winterkill situations. There periods were noted in the winters of

1978/79, 1988/89, 1991/92, 1992/93, and 1996/97. The Lake Owasso Management Plan (Osgood, 2000) indicated that an aeration system would be installed in Lake Owasso in 2000 and used during these low oxygen conditions to help prevent the potential winterkill. This aeration system is operated by Ramsey County. Discussion with Ramsey County indicated that the system was most recently operated during the winter of 2007/2008 (Ramsey County Staff, personal communication, January 8, 2009).

In addition to supporting its fish populations, Lake Owasso provides habitat for seasonal waterfowl, such as ducks and geese, which find refuge and forage in the lake's diverse macrophyte communities in the lake's large littoral area.

Information related to the Lake Owasso fishery and stocking information can be found in Appendix I.

5.3.3.5 Shoreland Habitat and Restoration Potential

Over the last decade, greater attention has been given to shoreland management and ecological restoration. Lake shore restoration programs encourage the establishment of natural buffer using native plants that are less prone to erosion and provide quality fish and wildlife habitat. In September 2005, the RWMWD conducted a visual survey (by boat) of the Lake Owasso shoreline. Various parameters, such as the shoreline material, shoreline slope, restoration potential, and ownership, were recorded. Restoration potential was a subjective assessment that considered the other three parameters as well as evidence of shoreland use.

Lake Owasso has approximately 5 miles of shoreland, with 2 miles having good restoration potential, just less than a mile having moderate restoration potential, and another 2 miles identified as having poor restoration potential. The northwest and west sides of the lake have 2 large sections that have poor restoration potential as the result of steep slopes and riprap (northwest side) and a large cattail fringe (west side).

More detailed information about this shoreland assessment can be found in Appendix K, including a summary of the various parameters for Lake Owasso and a figure showing the restoration potential of each of the lakeshore parcels.

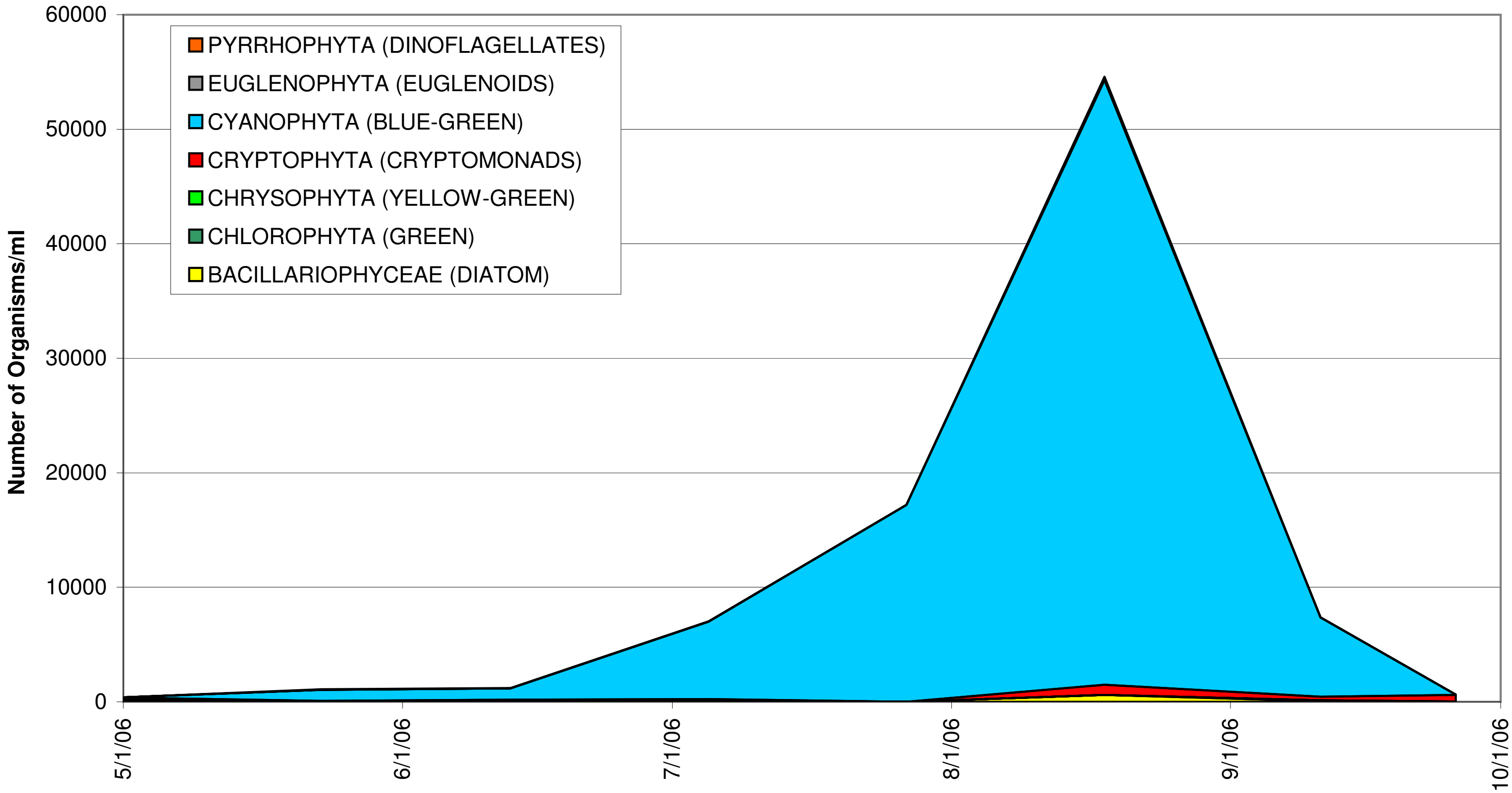
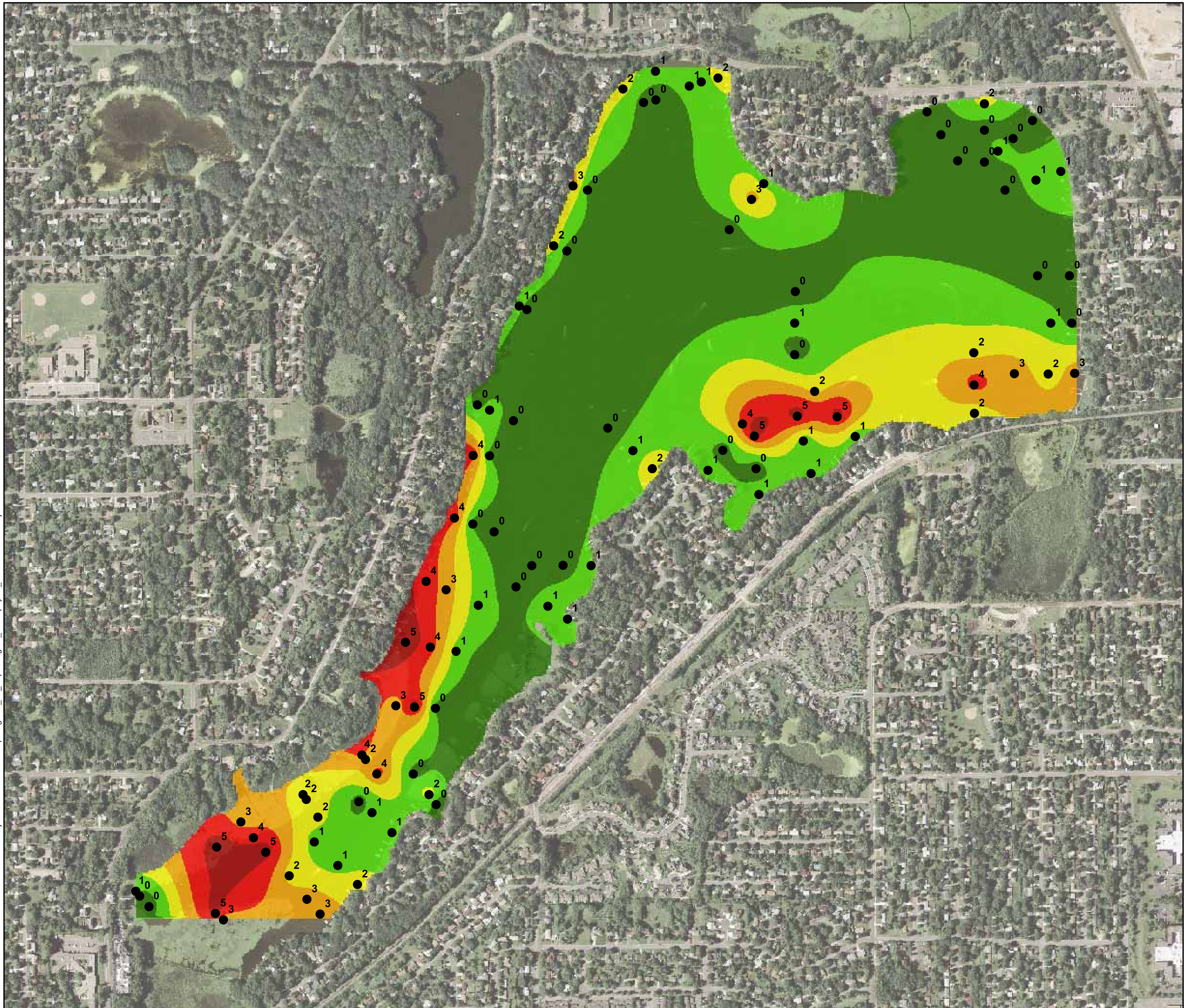


Figure 5-6
2006 Phytoplankton Concentrations



● Macrophyte Survey Points

Curlyleaf Pondweed

- Not Observed/Surveyed (0.0 - 0.5)
- Very Low Density (0.5 - 1.5)
- Low Density (1.5 - 2.5)
- Moderate Density (2.5 - 3.5)
- High Density (3.5 - 4.5)
- Very High Density (4.5 - 5+)

Area-Weighted Average for
Lake Owasso = 1.1

Feet
750 0 750

N

Figure 5-8

LAKE OWASSO MACROPHYTE SURVEY
CURLYLEAF PONDWEED
May 22-30, 2007

Lake Owasso UAA
Grass Lake Watershed Management Organization

5.4 Water Quality Modeling Results

5.4.1 Baseline Lake Water Quality Status

There are several tools that can be used to evaluate the expected water quality in a lake. This study utilizes two different tools to estimate the expected water quality in Lake Owasso, including the relationship develop by Vighi and Chiaudani (1985) and the Minnesota Lake Eutrophication Analysis Program (MINLEAP) as developed by Heiskary and Wilson (1990) and programmed as part of the Wisconsin Department of Natural Resources Wisconsin Lake Modeling Suite (WiLMS, 2005). Additionally, Lake Owasso was part of a diatom reconstruction projects performed by the MPCA (Heiskary and Swain, 2002) that estimated historical phosphorus concentrations.

5.4.1.1 Vighi and Chiaudani

Vighi and Chiaudani (1985) developed a method to determine the phosphorus concentration in lakes that are not affected by anthropogenic (human) inputs. Using their method and information about the lake's mean depth and alkalinity or conductivity, the phosphorus concentration in a lake resulting from natural, background phosphorus loadings can be predicted. Alkalinity is considered more useful for this analysis because it is less influenced by the modifying effect of anthropogenic inputs. Alkalinity was measured in Lake Owasso in 2007 along with conductivity measurements, so the expected phosphorus concentration was calculated using both parameters.

Vighi and Chiaudani relationship was used to estimate the expected total phosphorus concentrations at each of the monitoring sites as well as across the lake as a whole. Specific conductivity was relatively constant at both monitoring sites throughout the summer, and the estimated ranges were very similar. Therefore, the following is a discussion of the results using the average conductivity values from Lake Owasso. The Vighi and Chiaudani relationship predicted phosphorus concentration from natural, background loadings to be 18.8 μg/L (ranging from 18.3 μg/L to 19.2 μg/L).

Alkalinity was also used to estimate the expected total phosphorus concentration in Lake Owasso. Like specific conductivity, the alkalinity was fairly constant throughout the lake and as a result, the following only discusses the results of the Vighi and Chiaudani equation based on the average alkalinity for Lake Owasso for the entire 2007 monitoring period. The expected total phosphorus concentration in Lake Owasso based upon the average alkalinity over the period of record was 22.4 μg/L

The predicted total phosphorus concentrations based upon the lake's specific conductivity and alkalinity are lower than the 2007/2008 total phosphorus concentrations for monitoring sites 5401 and 5403 (30.3 µg/L and 51.9 µg/L, respectively), indicating that some improvement in lake water quality may be attainable.

5.4.1.2 Minnesota Lake Eutrophication Analysis Program (MINLEAP)

MINLEAP is intended to be used as a screening tool for estimating lake conditions and identifying "problem" lakes. MINLEAP is particularly useful for identifying lakes requiring "protection" versus those requiring "restoration" (Heiskary and Wilson, 1990). In addition, MINLEAP modeling has been done in the past to identify Minnesota lakes which may be in better or worse condition that they "should be" based upon their location, watershed area, and lake basin morphometry (Heiskary and Wilson, 1990).

Using the long-term summer average total phosphorus, chlorophyll *a*, and Secchi depth, MINLEAP estimated the expected concentration or depth of each of the above parameters as well as the standard error associated with the average values. For total phosphorus, the expected concentration was estimated to be 40 µg/L (with a range of 25 µg/L to 55 µg/L). The estimated chlorophyll *a* concentration was estimated to be 14.3 µg/L (with a range of 5 µg/L to 23.6 µg/L). The estimated Secchi depth for Lake Owasso was 1.6 meters (with a range of 0.9 meters to 2.3 meters). For all water quality parameters, the actual water quality data falls within the range of a minimally-impacted lake with similar characteristics to Lake Owasso.

5.4.1.3 Water Quality Reconstruction from Fossil Diatoms

Diatom reconstructions of historical phosphorus concentrations can provide a opportunity to examine temporal and spatial trends in eutrophication, helping identify the timing and extent of cultural disturbances as well as identifying predisturbance conditions (Reavie et al., 1995). In 2002, the MPCA completed a study of diatoms in 55 lakes within Minnesota, including Lake Owasso.

The results of the diatom analysis for Lake Owasso (Table 5 3) indicates that Pre-European settlement, the lake's total phosphorus and chloride levels suggested mesotrophic conditions. The analysis indicated that significant increases in total phosphorus and chloride occurred in the 1970s and 1990s, likely the result of development in the watershed and surrounding road network. Data from the mid- to late 1990s indicated declining total phosphorus levels, likely reflecting a period of less development and increased efforts to improve stormwater retention and treatment upstream of the lake.

The sediment and diatom analysis also indicated that sediment accumulation rates increased steadily from 1900, with peaks in 1960 and 1980; some reductions in accumulation rates is evident since that time, again likely linked to decreasing development and use of stormwater treatment practices.

Table 5-3 Diatom-Inferred Total Phosphorus and Chloride Concentrations in Lake Owasso

Lake	Parameter	Units	1750	1800	1970	1990
Lake Owasso	TP	µg/L	22	21	38	32
	Chloride	mg/L	2	1	27	27

5.4.2 Watershed Load Modeling Results

Using the calibration discussed in Section 4.2.2, the P8 model was used to simulate the flow and treatment of stormwater throughout the Lake Owasso watersheds for each of the modeled climatic conditions. Additionally, comparison of monitoring data to the P8 modeling results indicated that some of the wetlands and water bodies within the watershed can actually act as sources of phosphorus to Lake Owasso during certain times of the year. As a result, the P8 loads were augmented with estimated "internal" loads from select watershed waterbodies (based on FLUX and mass balance model). See Section 4.2 for a more detailed discussion of the watershed and in-lake water quality modeling methodology.

The following general scenarios were modeled:

- Existing Watershed Conditions for 2007 & 2008
- Wet, Dry, and Average Climatic Conditions for Existing Watershed Conditions

For each scenario, the stormwater runoff volume and phosphorus mass load to each of the lakes was predicted using the P8 model along with the results of the FLUX and mass balance modeling to estimate the watershed "internal" loading. The predicted runoff and loadings were then used as input into the in-lake model to predict in-lake phosphorus concentrations.

5.4.2.1 Watershed Loading for Existing Conditions for 2007 & 2008

The Lake Owasso watershed (3062 acres including the surface of Lake Owasso) was divided into five "drainage districts" comprised of numerous smaller subwatershed areas to facilitate the pollutant load modeling. Existing conditions for 2007 and 2008 were based on current land use data along with in-place watershed BMPs. Because the Lake Owasso watershed is fully developed and no significant changes in land use are expected, it is assumed that the evaluation of the existing land use data will also be reflective of future land use conditions. Two BMPs were implemented in the City of Shoreview between the summer of 2007 to the summer of 2008, and as a result, separate existing conditions watershed models were developed for each year to account for the change in the in-place watershed BMPs. Figure 5-9 shows the drainage districts. Each district is described below including a discussion of the watershed changes implemented in the watershed between 2007 and 2008:

- **Direct Drainage District—** This drainage district is approximately 729.3 acres (including the surface area of Lake Owasso), which represents 23.8 percent of the Lake Owasso watershed. The drainage district consists primarily of low density residential land use. Work was started in the summer of 2007 to collect flows from subwatershed Dschg50 in an underground storage vault. Under normal conditions, these flows will be pumped to the West Drainage District and pass through the Charlie Pond system. Flood flows will be allowed to discharge from the existing outlet. For calibration, it was assumed that subwatershed Dschg50 discharged directly to Lake Owasso, as the new system was not functioning during the summer of 2007. Modeling of future conditions will reflect this change.
- **South Drainage District—**This 1581.3 acre drainage area represents approximately 51.6 percent of the Lake Owasso watershed. Runoff from this district is conveyed to the Central Park Ponds and discharges to Lake Owasso through the west Central Park Pond via a structure under County Road C. Other larger water bodies in the district include Willow Pond, Frog Pond, Bennett Lake, and Westwood Village Pond. Much of the drainage district consists of low-density residential and open space land uses as well as institutional, highway right-of-way, and several smaller areas of high- and medium-density residential and commercial land uses.
- **West Drainage District—**This drainage area covers approximately 360.1 acres, or 11.8 percent, of the Lake Owasso watershed. There is one land locked watershed (LO_W_3) in this district. Flows from this district pass through Charlie Pond before discharging to Lake Owasso. Other larger water bodies in this district include Lake Judy and Lake Emily. In the end of 2007, a CDS structure was installed on the northwest side of Lake Emily, treating discharges from watershed LO_S_2a before discharging into Lake Emily. The predominant land uses in this drainage district are low-density residential and open space.
- **East Drainage District—**This 213.3-acre drainage district represents about 7.0 percent of the Lake Owasso watershed. Runoff from this district is discharged to the bay south of Lake Owasso before discharging to the lake. This district is primarily composed of low density residential land use with some high density land use in the upper portions of the watershed.
- **Land Locked Drainage District—** This drainage district covers approximately 178 acres which represents about 5.8 percent of the Lake Owasso watershed. The drainage area was historically land locked although a pump has been installed in subwatershed LO_LL_2a that

pumps high waters to subwatershed LO_LL_3, where it is discharged into the bay south of Lake Owasso. Subwatershed LO_LL_5 is still currently land locked and was assumed to contribute no flows to Lake Owasso. This drainage district consists primarily of low density residential land use, with wetland areas interspersed.

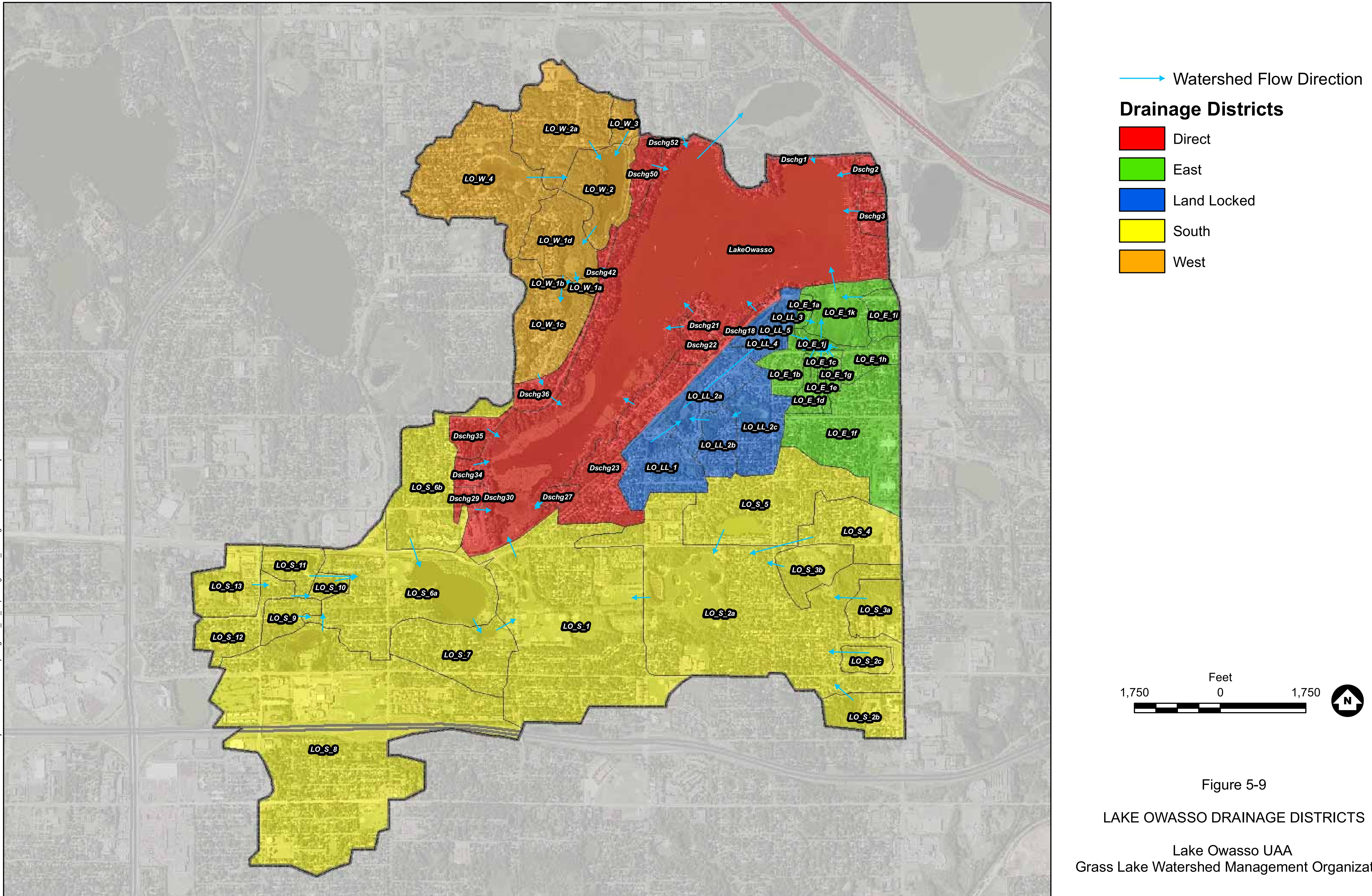


Figure 5-9

LAKE OWASSO DRAINAGE DISTRICTS

Lake Owasso UAA
Grass Lake Watershed Management Organization

Annual stormwater and phosphorus contributions to Lake Owasso were estimated for each drainage district using the P8 and FLUX models. These loadings were used to determine the total Lake Owasso external stormwater and phosphorus budgets under existing land use and the 2007 and 2008 hydrologic conditions. Table 5-4 summarizes the 2007 and 2008 total watershed runoff volumes and total phosphorus loads as predicted by the calibrated P8 model (for both the 2007 and 2008 watershed BMP scenarios). Additionally, the estimated "internal" phosphorus load from watershed water bodies is also summarized.

Table 5-4 2007 and 2008 Watershed Runoff and Total Phosphorus Loads to Lake Owasso

Parameter	2007 Water Year (10/1/2006 – 9/30/2007)	2008 Water Year (10/1/2007 – 9/30/2008)
Watershed Runoff Water Load (acre-ft)	563	509
Watershed Runoff Total Phosphorus Load (lbs)	124	102
Estimated Internal Phosphorus Load from Watershed Water Bodies (lbs)	45	29

The 1991 *Water Quality Management Alternatives* study estimated the hydrologic and phosphorus budgets for Lake Owasso for 1985 to 1987. This study predicted annual watershed water loads to Lake Owasso ranging from 1,598 acre-feet to 2,814 acre-feet. This is approximately 3 to 5 times more volume than the annual water loads predicted for both 2007 and 2008. Both 2007 and 2008 were relatively dry summers as were the summers of 1985, 1986, ad 1987, which were the years used for the 1991 study. The difference in the estimated water loads is that the results of the SWMM model developed for the Lake Owasso watershed for the 1991 study were not calibrated to actual monitoring data. Runoff estimates from the P8 model for this UAA were calibrated to actual runoff monitoring data. It was also observed during both the summer of 2007 as well as the summer of 2008 that there were significant periods of time where water levels in many of the major water bodies within the watershed were below their normal outlet and were not discharging downstream. In both the summer of 2007 as well as 2008, there were periods where more than half of the watershed did not contribute watershed runoff to Lake Owasso during several consecutive storm events.

5.4.2.1.1 Existing Conditions BMP Performance

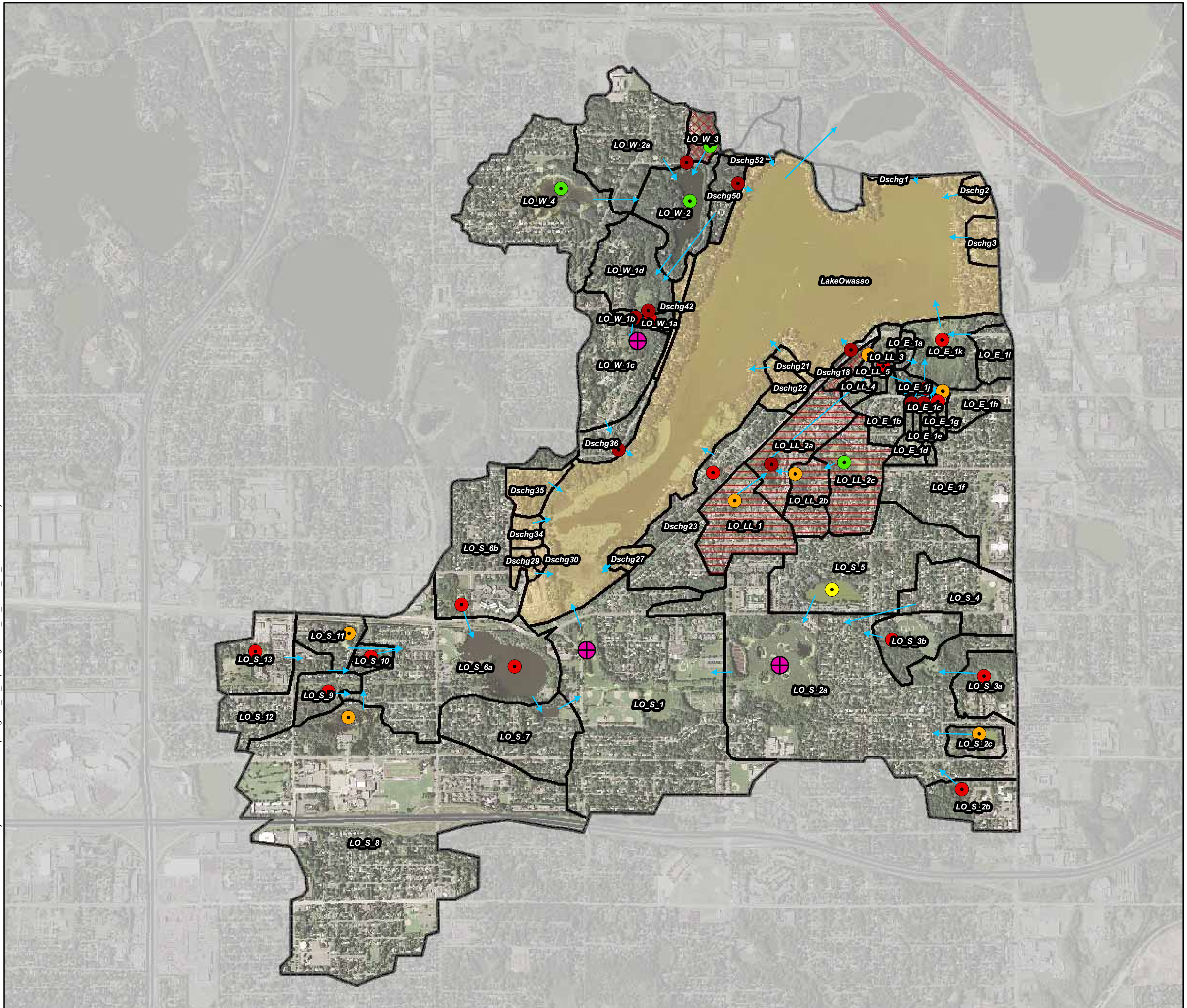
Throughout the Lake Owasso watershed, stormwater runoff flows sequentially through a number of ponds or infiltration basins before discharging to the lakes. The sediment and phosphorus removal efficiencies of the stormwater BMPs varies based on numerous factors, including the size of the pond or basin, the amount of stormwater treated, and design details such as the pond shape or outlet configuration. The existing stormwater BMPs throughout the Lake Owasso watershed were modeled in P8 based on information obtained from as-built construction plans, previous modeling, topographic data, and field survey. The P8 model developed for the 2008 watershed conditions was used to evaluate the performance of the BMPs within the Lake Owasso watershed.

The overall total phosphorus removal efficiency within the Lake Owasso watershed during the 2008 calibration year was about 64 percent. The predicted annual total phosphorus removal efficiencies for each pond, wetland or BMP modeled in P8 are shown in Figure 5 10, with the color of each treatment device representing the estimated annual total phosphorus removal as a percent. The BMP locations shown in orange, yellow, or green achieved predicted total phosphorus removal efficiencies greater than 40 percent (comply with NURP water quality standards). The BMP locations that shown in shades of red achieved predicted removal efficiencies less than 40 percent.

Review of water quality monitoring data collected in 2008 along with calibration of the P8 model suggests that the Central Park – East and West wetlands and the ponds in the Charlie Pond system can act as sources of phosphorus to Lake Owasso. For that reason, these locations are shown on Figure 5-10 as a pink, cross-haired symbol. Also shown are the subwatersheds that currently do not have any water quality treatment before discharging into Lake Owasso.

The range of phosphorus removal efficiencies is the result of a variety of factors. Some of the modeled ponds are natural ponds and wetlands that were not designed as NURP water quality treatment ponds and do not have sufficient dead storage volume to increase phosphorus removals. Some of the BMPs were constructed prior to the onset of the water quality treatment requirements, and were designed only primarily for rate control purposes. Other BMPs with predicted removal efficiencies below NURP standards may not be sized adequately for the amount of runoff and pollutant loading received under existing conditions.

The phosphorus removal efficiency of a pond or other BMP can also depend upon the sediment particle distribution of the inflowing stormwater. Stormwater that has been treated in upstream water quality ponds tends to have a higher fraction of soluble phosphorus, as much of the particulate phosphorus has already been settled out. Soluble phosphorus can be extremely difficult to remove through conventional BMPs, and therefore in some cases, the predicted removal efficiency of a pond can be negatively impacted by inflows from upstream BMPs with high fractions of soluble phosphorus. This effect can be especially pronounced with water quality treatment ponds located at the downstream end of a series of treatment ponds.



TP Removal (%)

- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- Internal Phosphorus Loading
- Watershed Flow Direction
- Subwatersheds
- Land-Locked Watersheds
- Pumped Outlet Watersheds
- Watersheds without Treatment

Feet

1,750 0 1,750

N

Figure 5-10

LAKE OWASSO
TOTAL PHOSPHORUS REMOVAL EFFICIENCIES
EXISTING CONDITIONS - 2008

Lake Owasso UAA
Grass Lake Watershed Management Organization

5.4.2.2 Watershed Loading for Wet, Dry, and Average Climatic Conditions

The amount of stormwater runoff and associated pollutant loading from a watershed is dependent upon hydrologic conditions such as precipitation patterns and soil saturation conditions. To evaluate the watershed loading under differing hydrologic conditions, the P8 model was run for three time periods that represent average, wet, and dry climatic conditions. Additionally, the watershed "internal" loads, based upon the FLUX modeling and the phosphorus mass balance model for Central Park – West wetland, were updated for each climatic conditions.

- "Average" climatic conditions: May 2004- September 2005
- "Wet" climatic conditions: May 2001- September 2002
- "Dry" climatic conditions: May 2007 - September 2008

Table 5-5 summarizes the precipitation depths associated with the water years (October 1 through September 30) as well as the growing season (May through September) for each of the specific climatic periods.

Table 5-5 Water Year and Growing Season Precipitation Depths for Wet, Dry and Average Climatic Conditions

Climatic Condition	Year	Precipitation Depth (in)[1]	
		Water Year	Growing Season
Wet	2002	41.2	28.4
Dry	2008	24.5	13.0
Average	2005	31.6	20.2

1 – Precipitation depths based on hourly data from the Downtown St. Paul Airport and the Minneapolis-St. Paul International Airport adjusted using the daily High Density Network data near Lake Owasso (see Section 4.2.1)

Table 5-6 summarizes the estimated external water loads, including the modeled watershed runoff volume, and external phosphorus loads to Lake Owasso for the three climatic conditions. This table also summarizes the estimated internal phosphorus loads to the lake, as will be discussed in Section 5.4.3.

Table 5-6 Lake Owasso Water Loads and Phosphorus Loads for Wet, Dry, and Average Climatic Conditions

Climatic Condition		Wet	Dry[3]	Average
Water Year		2002	2008	2005
Water Budget				
Source		Volume (acre-ft)	Volume (acre-ft)	Volume (acre-ft)
Direct Precipitation		1286	644	987
Watershed Runoff		1150	509	401
Groundwater[1]		913	913	913
TOTAL WATER LOAD		***3348***	***2066***	***2300***
Phosphorus Budget				
Source		TP Load (lbs)	TP Load (lbs)	TP Load (lbs)
External Load Sources	Watershed Runoff	252	102	87
	Internal Loading from Watershed Water Bodies	89	29	60
	Atmospheric Deposition	90	88	91
	Groundwater	62	62	62
	TOTAL EXTERNAL LOAD	*493*	*281*	*300*
Internal Load Sources	Curlyleaf Pondweed[2]	184	184	184
	Internal Sediment Release	398	91	221
	TOTAL INTERNAL LOAD	*582*	*275*	*405*
TOTAL PHOSPHORUS LOAD		***1076***	***556***	***705***

1 - Groundwater exchange was estimated based on the 2008 Lake Owasso water balance modeling. It was assumed that the calibrated groundwater exchange would apply to all climatic conditions.

2 - Coverage & Density of Curlyleaf Pondweed assumed to be the same as estimated from the 2007 macrophyte survey conducted by Ramsey County Public Works for all climatic conditions.

3 - 2008 Calibration Year

5.4.3 Internal Phosphorus Load Estimates

Phosphorus enters Lake Owasso from watershed runoff, atmospheric deposition, groundwater inflow, macrophyte senescence, and sediment release. The last two sources of phosphorus in the list are often referred to as the “internal load.”

Curlyleaf pondweed is an invasive macrophyte that can be an important source of phosphorus in a lake system. This macrophyte begins its lifecycle in the fall of the year and its senescense (die-off) begins in early summer. Once the plants die, the biomass begins to decompose and releasing soluble phosphorus to the water column. In this form, the phosphorus can quickly be utilized by algae, leading to intense algal blooms for the remainder of the summer. Additionally, the decay of the organic material can also result in oxygen depletion which in turn can cause the release of phosphorus for the lake bottom sediments.

Loading from the lake bottom sediments can also be a significant source of phosphorus in lakes that have a history of high phosphorus loads from their watershed. Like with Curlyleaf pondweed, phosphorus released from the sediments, either as the result of anoxic (void of oxygen) or high pH conditions, is typically in a dissolved form, causing algal blooms and decreases in water quality. Internal loading from the sediments is influenced by the lake’s mixing and stratification patterns.

The monitoring data for Lake Owasso supports that it is a dimictic lake, meaning the lake thermally stratifies during the summer months and completely mixes only twice per year, during the spring and fall turnover events. Temperature and water quality monitoring data at depth shows that Lake Owasso experienced strong thermal stratification in both the northern and southern basins in the lake. Dissolved oxygen data indicates that the bottom waters become anoxic (devoid of oxygen) during the summer months. Elevated phosphorus measurements below the depth of the thermocline also show that phosphorus accumulates in the hypolimnion along the sediments as well. However, in the deep areas of the lake where strong thermal stratification occurs, the phosphorus from anoxic sediment release will likely remain in the hypoliminion until the lake complete mixes during a turnover event.

Although Lake Owasso is considered a deep lake with three basins that thermally stratify during the summer months, much of the lake is relatively shallow with the average depth of 10.9 feet for the entire lake. Because there are shallow areas of the lake, mixing and sediment resuspension as the result of wind, motorboating, and carpactivity, may also be a source of phosphorus to the lake. Observations of carp activity in the Central Park – West wetland (which is directly connected to Lake Owasso) suggest that carp are likely active in Lake Owasso as well. Additionally, observations by lake residents indicated that motor boating activity results in increased turbidity in the south end of the lake. However, there have been no data collected in these shallow areas of the lake to quantify the associated phosphorus loads with these sources, and they have not been incorporated into the in-lake water quality modeling.

5.4.3.1 In-Lake Modeling Results

The phosphorus mass balance for Lake Owasso, as described in Section 4.3, was calculated based on existing land use conditions for each of the climatic scenarios. Measured in-lake water quality data collected from May to September for 2002 (Wet), 2005 (Average), and 2008 (Dry) were also used in the in-lake models. Using the mass balance equation, the net internal loading for each climatic condition was calculated. The internal loading sources of phosphorus quantified for Lake Owasso included both the release of phosphorus from the die-back of Curlyleaf pondweed as well as from anoxic sediment release. It is important to remember that the internal load is delivered over a concentrated period of time- the growing season- during which time it can efficiently contribute to nuisance algal growth in the lake. The annual phosphorus loads to Lake Owasso from the internal sources are summarized in Table 5-6, along with the sources of water loads to the lake as well as the external sources of phosphorus.

Figures 5-11, 5-12, and 5-13 show the annual water and phosphorus budgets for Lake Owasso for the wet, dry, and average climatic conditions, respectively. Because the dry climatic year (2008; also the calibration year) was modeled as a two-basin system, the water and phosphorus budgets are shown for both the south and north basins, as well as for the overall lake system. These water and phosphorus budget figures put the estimated internal phosphorus loads in perspective with the external watershed loads that Lake Owasso receives on an annual basis. Actual results of the 2008 (dry) in-lake water quality model calibration are shown in Figure 5-14a and Figure 5-14b. In-lake modeling calibration results for all other years (2007, 2002 (wet), and 2005 (average)) can be found in Appendix L of this UAA.

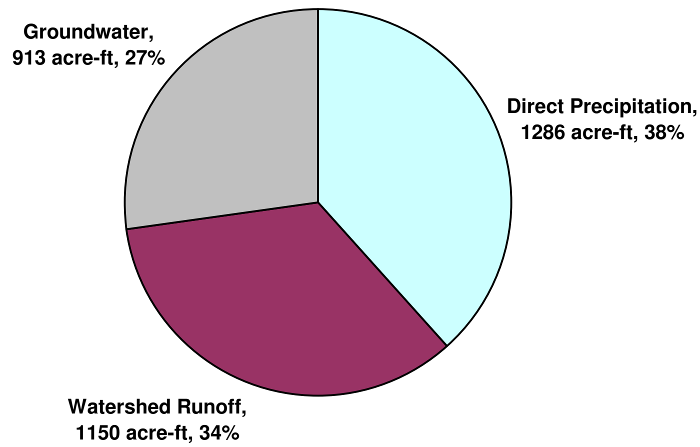
Figure 5-11 shows the breakdown of the Lake Owasso water load as well as the relative contribution of the external (watershed) and internal phosphorus loads for wet climatic conditions (water year 2002). During wet climatic conditions, direct precipitation on the lake was the most significant source of water to Lake Owasso (38 percent), closely followed by watershed runoff (34 percent). With regards to phosphorus loading to the lake, internal loads contribute ~54 percent of the total annual load of phosphorus (13 percent from Curlyleaf pondweed and 37 percent from release from sediments).

Figure 5-12 (a), 5-12 (b), and 5-12 (c) shows the breakdown of the Lake Owasso water load as well as the relative contribution of the external (watershed) and internal phosphorus loads for dry climatic conditions (water year 2008). During dry climatic conditions, groundwater inflow was the most significant source of water to Lake Owasso (44 percent), followed by direct precipitation to the lake (31 percent). With regards to phosphorus loading to the lake as a whole (Figure 5-12 (c)), internal loads contribute ~49 percent of the total annual load of phosphorus to the lake (33 percent from Curlyleaf pondweed and 16 percent from release from sediments).

Because water quality monitoring data for 2008 (the dry/calibration year) is available in both the north and south basins of Lake Owasso and the in-lake model was developed as a two basin model, the variations in phosphorus loading across the lake area could be evaluated. More than half of the watershed runoff passes through the south end of Lake Owasso (site 5403) before flows move north to the outlet on the northeast side of the lake. Figure 5-12 (a) shows the water and phosphorus budgets for the south basin of Lake Owasso. Watershed runoff has the most significant impact on this basin in the lake, accounting for 59 percent of the water load and nearly 71 percent of the phosphorus load. Internal phosphorus loading accounts for 12 percent of the phosphorus load in the south basin, the majority of it associated with the die-back of Curlyleaf pondweed. Figure 5-12 (b) shows the water and phosphorus budget for the north basin of Lake Owasso. In the north basin, groundwater was the most significant source of water (39 percent). Internal phosphorus loading is the most significant contributor to the phosphorus load in the north basin, accounting for 47 percent of the total phosphorus budget.

Figure 5-13 shows the breakdown of the Lake Owasso water load as well as the relative contribution of the external (watershed) and internal phosphorus loads for average climatic conditions (water year 2005). During average climatic conditions, direct precipitation on the lake was the most significant source of water to Lake Owasso (43 percent), closely followed by groundwater (40 percent). With regards to phosphorus loading to the lake, internal loads contribute ~57 percent of the total annual load of phosphorus (26 percent from Curlyleaf pondweed and 31 percent from release from sediments).

Lake Owasso Annual Water Load (3,348 acre-ft)
2002 (Wet) Calibration Year



Lake Owasso Annual Phosphorus Load (1,076 lbs)
2002 (Wet) Calibration Year

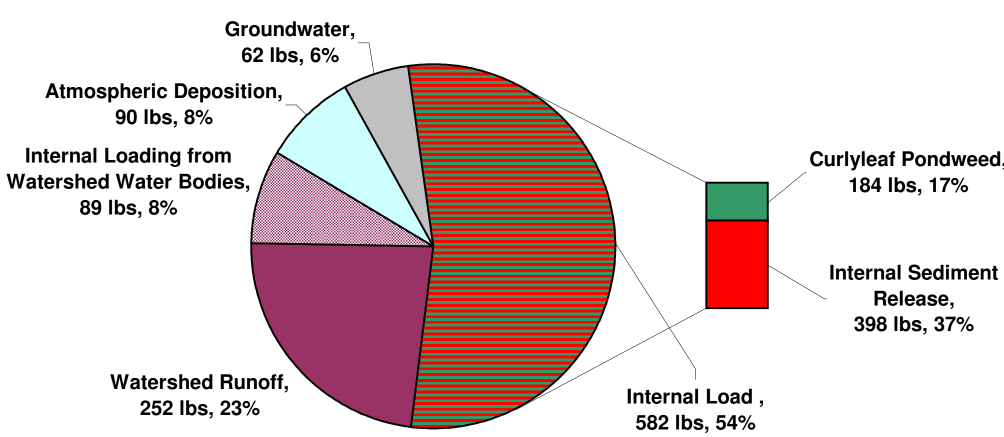


Figure 5-11
Lake Owasso
Water and Total Phosphorus Budget
Wet Climatic Conditions

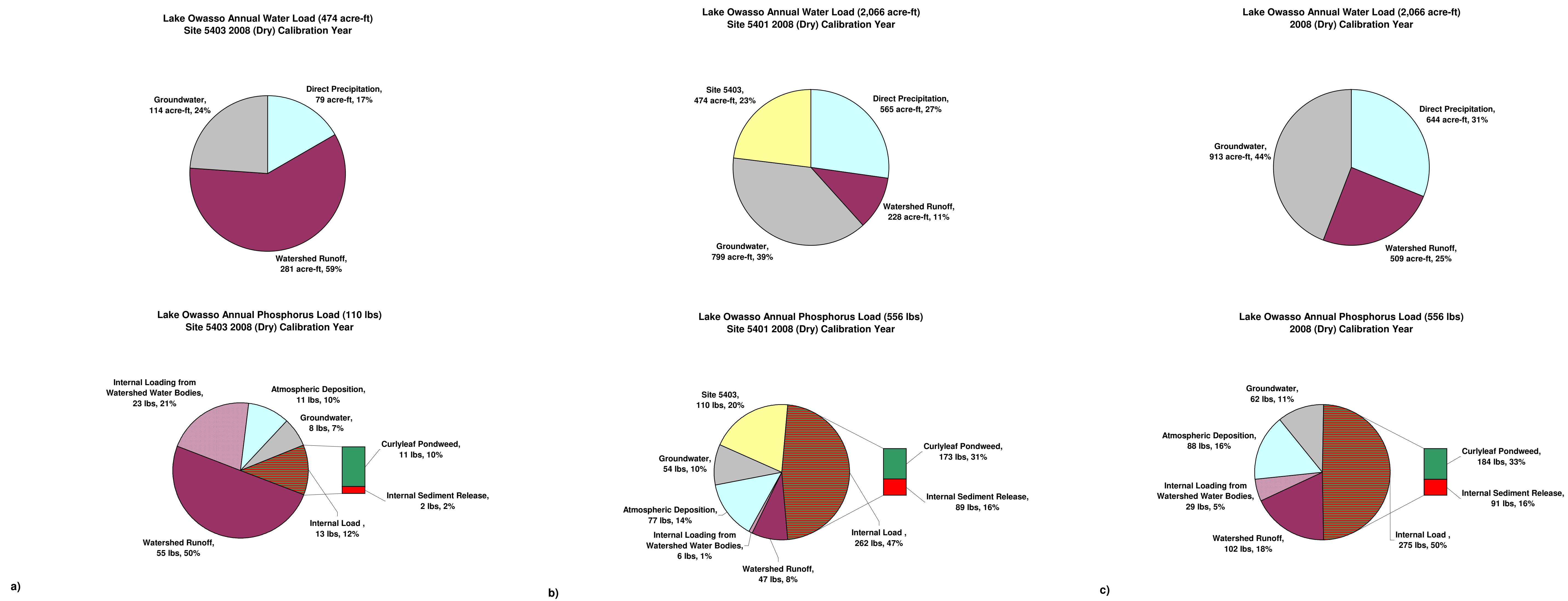
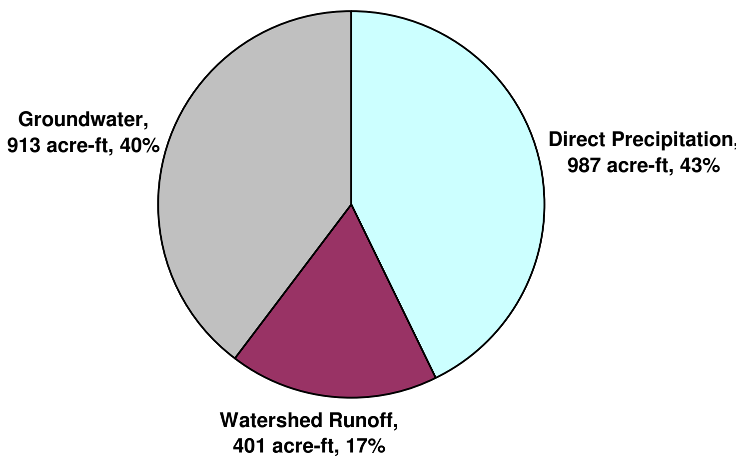


Figure 5-12
Lake Owasso
Water and Total Phosphorus Budget
Dry Climatic Conditions
a) Site 5403 (South Basin)
b) Site 5401 (North Basin)
c) Lake Owasso - Entire Basin

Lake Owasso Annual Water Load (2,300 acre-ft)
2005 (Avg) Calibration Year



Lake Owasso Annual Phosphorus Load (705 lbs)
2005 (Avg) Calibration Year

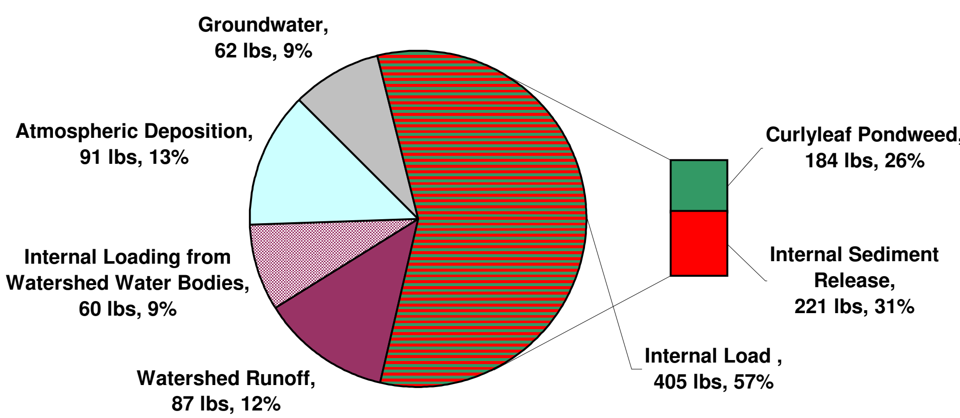


Figure 5-13
Lake Owasso
Water and Total Phosphorus Budget
Average Climatic Conditions

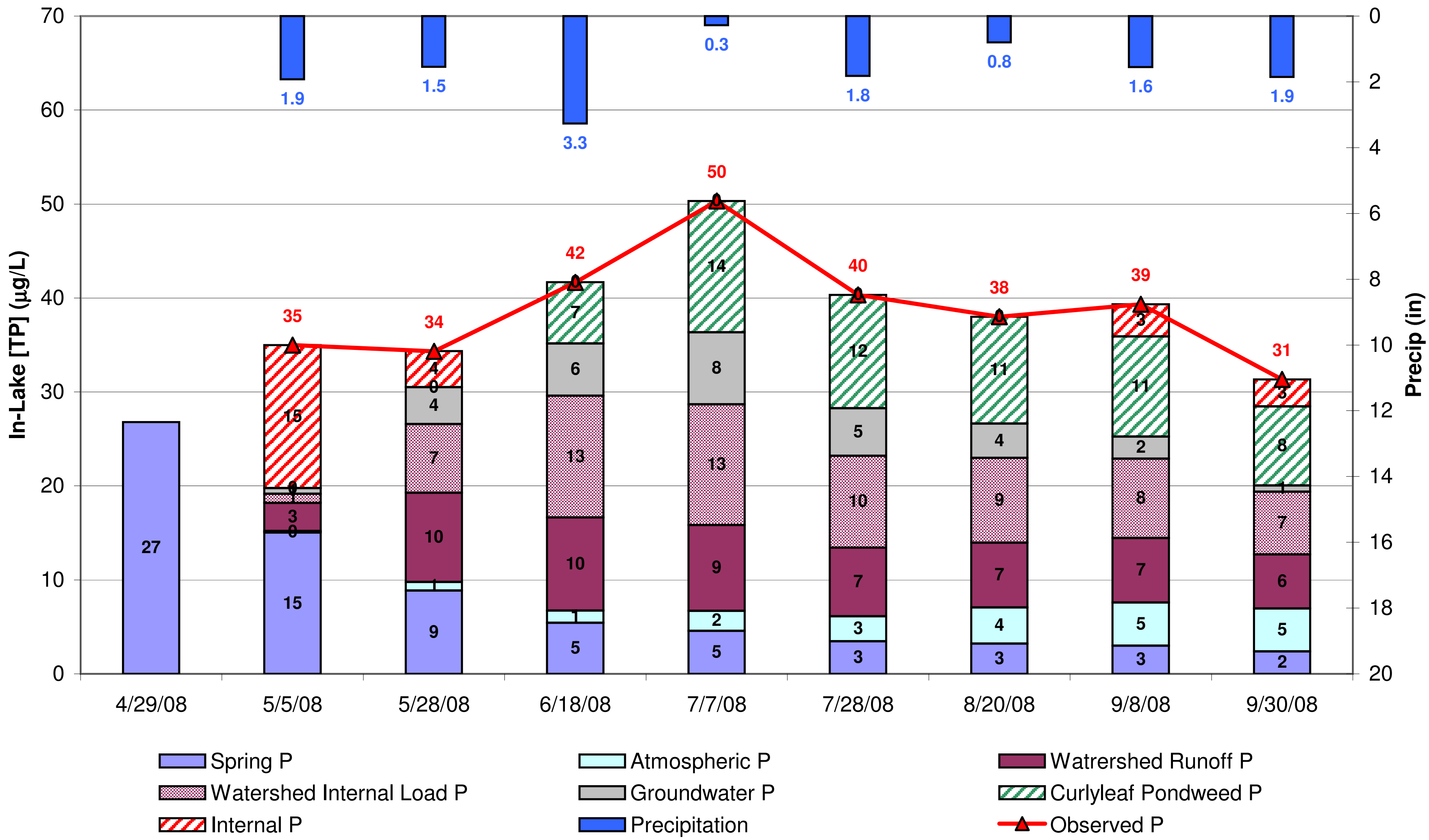


Figure 5-14a
Lake Owasso Site 5403
2008 (Dry) In-Lake Water Quality Model Calibration

P:\Mpls\23 MN\62\2362946\WorkFiles\Modeling\InLake\Calibration20072008\LakeOwasso_2008_5403_Loads4_Test3.xls: Figure5-14a

6.0 Discussion

6.1 General Discussion of Improvement Options

This section discusses improvement options and general Best Management Practices (BMPs) to remove phosphorus and/or reduce sediment and litter entering a lake. Three types of BMPs were considered during the preparation of this report: structural, in-lake, and nonstructural.

1. Structural BMPs remove a fraction of the pollutants and sediment loads contained in stormwater runoff prior to discharge into receiving waters.
2. In-Lake BMPs reduce phosphorus already present in a lake, and/or prevent the release of phosphorus from anoxic lake sediments.
3. Nonstructural BMPs (source control) eliminate pollutants at the source and prevent pollutants from entering stormwater flows.

6.1.1 Structural BMPs

Structural BMPs temporarily store and treat urban stormwater runoff to reduce flooding, remove pollutants, and provide other amenities (Schueler, 1987). Water quality BMPs are specifically designed for pollutant removal. Their effectiveness is summarized in Table 6-1. Structural BMPs control total suspended solids and total phosphorus loadings by slowing stormwater and allowing particles to settle in areas before they reach the receiving waters. Settling areas can be ponds, storm sewer sediment traps, or vegetative buffer strips. Settling can be enhanced by treatment with flocculating chemicals prior to entering the settling basin (see alum treatment plants below).

When choosing a structural BMP, the ultimate objective must be well understood. The BMP should accomplish the following (Schueler 1987):

1. Reproduce, as nearly as possible, the stream flow before development
2. Remove at least a moderate amount of most urban pollutants
3. Require reasonable maintenance
4. Have a neutral impact on the natural and human environments
5. Be reasonably cost effective compared with other BMPs

Table 6-1 General Effectiveness of Stormwater BMPs at Removing Common Pollutants from Runoff

Best Management Practice (BMP)	Suspended Sediment	Total Phosphorus	Total Nitrogen	Oxygen Demand	Trace Metals	Bacteria	Overall Removal
Wet Pond	5	3	2	3	4	?	4
Infiltration Trench or Basin	5	3	3	4	5	4	4
Porous Pavement	4	4	4	4	4	5	4
Water Quality Inlet (Grit Chamber)	1	?	?	?	?	?	?
Filter Strip	2	1	1	1	1	?	1

Percent Removal	Score
80 to 100	5
60 to 80	4
40 to 60	3
20 to 40	2
0 to 20	1
Insufficient Knowledge	?

Source: Schueler 1987

Examples of structural BMPs commonly installed to improve water quality include:

- Wet detention ponds
- Vegetative buffer strips
- Oil and grit separators
- Alum treatment plants

Each of the BMPs is described below and their general effectiveness is summarized in Table 6-1.

6.1.1.1 Wet Detention Ponds

Wet detention ponds (sometimes called “NURP” ponds after the Nationwide Urban Runoff Program) are impoundments that have a permanent pool of water and also have the capacity to hold runoff and release it at slower rates than incoming flows. Wet detention ponds are one of the most effective methods available for treatment of stormwater runoff. Wet detention ponds are used to interrupt the transport phase of sediment and pollutants associated with it, such as trace metals, hydrocarbons, nutrients, and pesticides. When designed properly, wet detention ponds can also provide some removal of dissolved nutrients. Detention ponds have also been credited with reducing the amount of bacteria and oxygen-demanding substances as runoff flows through the pond.

During a storm, polluted runoff enters the detention basin and displaces "clean" water until the plume of polluted runoff reaches the basin's outlet structure. When the polluted runoff does reach the outlet, it has been diluted by the water previously held in the basin. This dilution further reduces the pollutant concentration of the outflow. In addition, much of the total suspended solids and total phosphorus being transported by the polluted runoff and the pollutants associated with these sediments are trapped in the detention basin. A well-designed wet detention pond could remove approximately 80 to 95 percent of total suspended solids and 40 to 60 percent of total phosphorus entering the pond (MPCA, 1989).

As storm flows subside, finer sediments suspended in the pond's pool will have a relatively longer period of time to settle out of suspension during the intervals between storm events. These finer sediments eventually trapped in the pond's permanent pool will continue to settle until the next storm flow occurs. In addition to efficient settling, this long detention time allows some removal of dissolved nutrients through biological activity (Walker, 1987). These dissolved nutrients are mainly removed by algae and aquatic plants. After the algae die, the dead algae can settle to the bottom of the pond, carrying with them the dissolved nutrients that were consumed, to become part of the bottom sediments.

The wet detention process results in good pollutant removal from small storm events. Runoff from larger storms will experience pollutant removal, but not with the same high efficiency levels as the runoff from smaller storms. Studies have shown that because of the frequency distribution of storm events, good control for more frequent small storms (wet detention's strength) is very important to long-term pollutant removal.

6.1.1.2 Infiltration

Infiltration is the movement of water into the soil surface. For a given storm event, the infiltration rate will tend to vary with time. At the beginning of the storm, the initial infiltration rate represents the maximum infiltration that can occur because the soil surface is typically dry and full of air spaces. The infiltration rate will tend to gradually decrease as the storm event continues because the soil air spaces fill with water. For long duration storms the infiltration rate will eventually reach a constant value, the minimum infiltration rate (the design infiltration rate). The infiltrated runoff helps recharge the groundwater and mitigate the impacts of development. Stormwater flows into an infiltration basin, pools on the ground surface, and gradually infiltrates into the soil bed. Pollutants are removed by adsorption, filtration, volatilization, ion exchange, and decomposition. Therefore, infiltration is one of a few BMPs that can reduce the amount of dissolved pollutant in stormwater. Infiltration BMP devices, such as porous pavements, infiltration trenches and basins, and rainwater gardens, can be utilized to promote a variety of water management objectives, including:

- Reduced downstream flooding
- Increased groundwater recharge
- Reduced peak stormwater discharges and volumes
- Improved stormwater quality

An infiltration basin collects and stores stormwater until it infiltrates to the surrounding soil and evaporates to the atmosphere. Infiltration basins remove fine sediment, nutrients (including dissolved nutrients), trace metals, and organics through filtration by surface vegetation, and through infiltration through the subsurface soil. Deep-rooted vegetation can increase infiltration capacity by creating small conduits for water flow. Infiltration basins are designed as a grass-covered depression underlain with geotextile fabric and coarse gravel. A layer of topsoil is usually placed between the gravel layer and the grassed surface. Pretreatment is often required to remove any coarse particulates (leaves and debris), oil and grease, and soluble organics to reduce the potential of groundwater contamination and the likelihood of the soil pores being plugged. Infiltration can also be promoted in existing detention ponds by excavating excess sediments (typically the fines that have seal the bottom of the pond) and exposing a granular sub-base (assuming one was present prior to the original construction of the detention pond).

Rainwater gardens (a form of bio-retention) are shallow, landscaped depressions that channel and collect runoff. To increase infiltration, the soil bed is sometimes amended with mulch or soils with greater infiltration capacity. Vegetation in the rainwater gardens take up nutrients and stored runoff is reduced through evapotranspiration. Bio-retention is commonly located in parking lot islands, or within small pockets in residential areas. Bio-retention is primarily designed to remove sediment, nutrients, metals, and oil and grease. Secondary benefits include flow attenuation, volume reduction, and removal of floatables, fecal coliform, and BOD.

6.1.1.3 Vegetated Buffer Strips

Vegetative buffer strips are low sloping areas that are designed to accommodate stormwater runoff traveling by overland sheet flow. Vegetated buffer strips perform several pollutant attenuation functions, mitigating the impact of development. Urban watershed development often involves disturbing natural vegetated buffers for the construction of homes, parking lots, and lawns. When natural vegetation is removed, pollutants are given a direct path to the lake—sediments cannot settle out; nutrients and other pollutants cannot be removed. Additional problems resulting from removal of natural vegetation include streambank erosion and loss of valuable wildlife habitat (Rhode Island Department of Environmental Management, 1990).

The effectiveness of buffer strips is dependent on the width of the buffer, the slope of the site, and the type of vegetation present. Buffer strips should be 20-feet wide at a minimum, however 50 to 75 feet is recommended. Many attractive native plant species can be planted in buffer strips to create aesthetically pleasing landscapes, as well as havens for wildlife and birds. When properly designed, buffer strips can remove 30 to 50 percent of total suspended solids from lawn runoff. In addition, well-designed buffer strips will discourage waterfowl from nesting and feeding on shoreland lawns. Such waterfowl can be a significant source of phosphorus to ponds, by grazing turfed areas adjacent to the water and defecating in or near the water's edge where washoff into the pond is probable.

6.1.1.4 Oil and Grit Separators

Oil-grit separators (e.g., StormCeptors) are concrete chambers designed to remove oil, sediments, and floatable debris from runoff, and are typically used in areas with heavy traffic or high potential for petroleum spills such as parking lots, gas stations, roads, and holding areas. A three-chamber design is common; the first chamber traps sediment, the second chamber separates oil, and a third chamber holds the overflow pipe. The three-chambered unit is enclosed in reinforced concrete. They are good at removing coarse particulates, but soluble pollutants tend to pass through. In order to operate properly, the devices must be cleaned out regularly (at least twice a year). Oil-grit separators can be especially beneficial when used as pre-treatment for an infiltration basin or pond. They can also be incorporated into existing stormwater system or included in an underground vault detention system when no available land exists for a surface detention basin. Only moderate removals of total suspended solids can be expected; however, oil and floatable debris are effectively removed from properly designed oil and grit separators.

6.1.1.5 Alum Treatment Plants

In addition to the commonly installed structural BMPs discussed above, alum treatment plants are becoming an option for efficiently removing phosphorus from tributaries, rather than directly treating the lake with alum to remove phosphorus. Alum (aluminum sulfate) is commonly used as a flocculent in water treatment plants and as an in-lake treatment for phosphorus removal. To treat inflows in streams or storm sewers, part of the flow is diverted (e.g., 5 cfs) from the main flow and treated with alum. After the alum is injected in the diverted flow it passes to a detention pond to allow the flocculent to settle out before the water enters the lake. Alum treatment has been shown to remove up to 90 percent of the soluble and particulate phosphorus from the inflows.

6.1.2 In-Lake BMPs

In-lake BMPs reduce phosphorus already present in a lake or prevent the release of phosphorus from the lake sediments. Several in-lake BMPs are discussed below.

6.1.2.1 Removal of Benthivorous (Bottom-Feeding) Fish

Benthivorous fish, such as carp and bullhead, can have a direct influence on the phosphorus concentration in a lake (LaMarra, 1975). These fish typically feed on decaying plant and animal matter and other organic particulates found at the sediment surface. The fish digest the organic matter, and excrete soluble nutrients, thereby transforming sediment phosphorus into soluble phosphorus available for uptake by algae at the lake surface. Depending on the number of benthivorous fish present, this process can occur at rates similar to watershed phosphorus loads.

Benthivorous fish can also cause resuspension of sediments in shallow ponds and lakes, causing reduced water clarity and poor aquatic plant growth, as well as high phosphorus concentrations (Cooke et al., 1993). In some cases, the water quality impairment caused by benthivorous fish can negate the positive effects of BMPs and lake restoration. Depending on the numbers of fish present, the removal of benthivorous fish may cause an immediate improvement in lake water quality. The predicted water quality improvement following removal of the bottom-feeding fish is difficult to estimate, and will require permitting and guidance from the MDNR. In addition, using fish barriers to prevent benthivorous fish from spawning may adversely affect the spawning of game fish, such as northern pike.

6.1.2.2 Application of Alum (Aluminum Sulfate)

Internal loading due to release from the sediment can be a significant source of phosphorus loading to a lake. Sediment release of phosphorus to the lake occurs during the summer months, when the water overlying the sediments is depleted of oxygen. This internal load of phosphorus is transported to the entire lake during late summer or early fall, when the surface waters cool sufficiently for wind-mixing to mix the entire lake (often referred to as "fall turnover"). Phosphorus released from the sediments is typically in a dissolved form, which can be quickly utilized by algae, leading to intense algae blooms. Areal application of alum has proven to be a highly effective and long-lasting control of phosphorus release from the sediments, especially where an adequate dose has been delivered to the sediments and where watershed sediment and phosphorus loads have been minimized (Moore and Thorton, 1988). Alum will remove phosphorus from the water column as it settles and then forms a layer on the lake bottom that covers the sediments and prevents phosphorus from entering the lake as internal load. An application of alum to the lake sediments can decrease the internal phosphorus load by 80 percent (*Effectiveness and Longevity of Phosphorus Inactivation with Alum*, Welch and Cook, 1999) and will likely be effective for approximately 7 to 10 years, depending on the control of watershed nutrient loads.

6.1.2.3 Application of Herbicides

Controlling Curlyleaf pondweed can be done by herbicide treatments applied from a barge or boat or by mechanical harvesting, or by a combination of these methods. Herbicide treatments are more effective at eradicating the plant but MDNR regulations limit the extent of the lake that can be treated in any year. Aquatic herbicides are among the most closely scrutinized compounds known, and must be registered for use by both the U.S. EPA and the State of Minnesota. Registration of an aquatic herbicide requires extensive testing. Consequently, all of the aquatic herbicides currently registered for use are characterized by excellent toxicology packages, are only bio-active for short periods of time, have relatively short-lived residuals, and are not bioconcentrated (*The Lake Association Leader's Aquatic Vegetation Management Guidance Manual*, Pullmann, 1992). Examples of two aquatic herbicides appropriate for use in controlling the Curlyleaf pondweed growth in lakes are Reward (active ingredient = Diquat) and Aquathol-K (active ingredient = Endothall).

The use of low-level Sonar application has recently been found to selectively control exotic weed species such as Eurasian watermilfoil and Curlyleaf pondweed (*Whole-Lake Applications of Sonar for Selective Control of Eurasian Watermilfoil*, Getsinger *et al*, 2001). Due to past history of Sonar applications and the limited research on the new low level applications the use of Sonar is not feasibly at this time.

Both chemical and mechanical harvesting of macrophytes has been occurring in Lake Owasso for several decades. Until 2009, the MDNR permit for macrophyte management in Lake Owasso allowed for treatment of approximately 62 acres annually (up to 28 percent of the littoral area), which is greater than what the MDNR typically permits for herbicide treatment of macrophytes. Unless otherwise approved, the MDNR will currently only permit 15 percent of the littoral zone of a given lake be treated with herbicides.

6.1.2.4 Application of Copper Sulfate

Copper sulfate applications can be a highly effective algaecides in some cases, but these efforts are always temporary (days) and can have high annual costs. In addition, care must be taken to limit the impacts on none target organisms, such as invertebrates, and possible sediment contamination with copper. The primary effects on algae include inhibition of photosynthesis and cell division as a result of the additional cupric ion, the form of copper toxic to algae, present in the water column (Cooke *et al*, 1993). Blue-green algae are particularly sensitive to copper sulfate treatments. As a result, after a copper sulfate treatment is made the blue-green algae concentration is knocked back. However, after a few days the green algae (fast growers) take control and within a few weeks the chlorophyll *a* concentration can be back to pretreatment levels (Ed Swain, MPCA). As the algae die and settle out of the water column they take with them the nutrients they used for growth. Therefore, copper sulfate application may temporarily reduce the total phosphorus concentration in a water body by removing the phosphorus that is associated with algal biomass. Once the algae have settled out of the water column and start to decompose, soluble phosphorus is released back into the water column that can be used for future algal growth. As a result, copper sulfate treatments are typically not considered a long-term solution to nutrient loading problems.

6.1.2.5 Mechanical Harvesting

Harvesting of lake macrophytes is typically used to remove plants that are interfering with uses such as boating, fishing, swimming, or aesthetic viewing. Mechanical control involves macrophyte removal via harvesting, hand pulling, hand digging, rotovation/cultivation, or diver-operated suction dredging. Small-scale harvesting may involve the use of the hand or hand-operated equipment such as rakes, cutting blades, or motorized trimmers. Individual residents frequently clear swimming areas via small-scale harvesting or hand pulling or hand digging.

Large-scale mechanical control often uses floating, motorized harvesting machines that cut the plants and remove them from the water onto land, where they can be disposed. Mechanical harvesters consist of a barge, a reciprocating mower in front of the barge that can cut up to a depth of roughly 8 feet, and an inclined porous conveyer system to collect the cuttings and bring them to the surface. Typically a lake association or homeowner would contract a large scale harvesting operation at an estimated cost of $500/acre (McComas, 2007).

Removal of aquatic vegetation through mechanical harvesting has been shown to not be an effective nutrient control method (Cooke et al, 1993). However, none of this research was focused on the internal phosphorus load reduction due to mechanical harvesting of Curlyleaf pondweed. Blue Water

Science's 2000 *Orchard Lake Management Plan* suggests that there is up to 5.5 pounds of phosphorus per acre of Curlyleaf pondweed. Additional research mentions that harvesting can reduce the extent of nuisance Curlyleaf pondweed growth if harvesting occurs for several years and reduce stem densities by up to 80 percent (McComas and Stuckert, 2000). Therefore, harvesting of Curlyleaf pondweed may significantly reduce the phosphorus in the water column of a lake assuming enough biomass can be removed from the lake. This assumes that enough time and equipment would be available to harvest the Curlyleaf pondweed prior to die-back in early July.

While mechanical harvesting is more acceptable to the MDNR than chemical methods, it would still require an MDNR permit and provide only temporary benefits and must be repeated annually. The MDNR regulations state that the maximum area that can be harvested is 50 percent of the littoral zone.

6.1.2.6 Hypolimnetic Withdrawal

Hypolimnetic withdrawal involves discharging the nutrient-rich waters from hypolimnion instead of surface waters. This typically results in a reduced hypolimnetic detention time, decreased chance for anaerobic conditions to develop, and reduced phosphorus availability for epilimnetic entrainment. The withdrawal is accomplished by extending a pipe from the lakes outlet along the lake bottom to the deepest part of the lake. This pipe can act as either a siphon or water can be pumped at a predetermined rate. By discharging nutrient-rich water from the hypolimnion the internal phosphorus load available when stratification breaks down can be reduced.

6.1.2.7 Hypolimnetic Aeration

Hypolimnetic aeration involves the oxygenation in the hypolimnion of a thermally-stratified lake to raise the dissolved oxygen content within this layer of the lake without disrupting the stratification or temperature. By aerating the hypoliminion, the anoxic conditions that often develop along the sediment-water interface during the summer months in many thermally-stratified lakes can be minimized, reducing the internal phosphorus loading from the lake sediments into the water column. Hypolimnetic aeration can achieved through a variety of designs and set-ups, which can include mechanical agitation, injection of pure oxygen, and injection of air.

6.1.2.8 Iron Salt Applications

The application of iron salts (such as ferric chloride or ferric sulfate) can be used to reduce TP concentrations within a lake. In aerobic conditions, the iron salts can be used to precipitate and/or inactivate the TP associated with lake sediments. Application of iron salts alone has not been shown to be effective in the long term. However, when used in combination with hypolimentic aeration, the results of the treatment have been more effective.

6.1.3 Nonstructural BMPs

Nonstructural ("Good Housekeeping") BMPs discussed below include:

1. Public Education
2. City Ordinances
3. Street Sweeping
4. Deterrence of waterfowl

Good housekeeping practices reduce the pollutant at its source.

6.1.3.1 Public Education

Public education regarding proper lawn care practices, such as fertilizer use and disposal of lawn debris, can result in reduced organic matter and phosphorus loadings to the lake. A public information and education program may be implemented to teach residents within the Lake Owasso watersheds how to protect and improve the quality of the lake. The program would include distribution of fliers to all residents in the watershed and placement of advertisements and articles in the city's newsletters and the local newspapers. Information could also be distributed through organizations such as lake associations, local schools, Girl Scouts and Boy Scouts, and other local service clubs.

Initiation of a stenciling program to educate the public about stormwater could help reduce loadings to the storm sewer system. Volunteers could place stenciled messages (i.e., "Dump No Waste, Drains to Lake Owasso") on all storm sewer catch basins within the Lake Owasso watershed.

6.1.3.2 City Ordinances

Fortunately, Minnesota already has a statewide phosphorus fertilizer ban already in place that restricts the residential use of phosphorus fertilizer.

6.1.3.3 Street Sweeping

Most often, street sweeping is performed only in the spring, after the snow has melted and in the fall, after the leaves have fallen, to reduce this potential source of phosphorus from entering the storm sewer. For most urban areas, street sweeping has relatively low effectiveness from late spring (after the streets are cleaned of accumulated loads) until early fall (prior to the onset of leaf fall) (Bannerman, 1983). The use of vacuum sweepers is preferred over the use of mechanical, brush sweepers. The vacuum sweepers are more efficient at removing small phosphorus-bearing particles from impervious surfaces within the watershed. Fall street sweeping is particularly important in the watersheds directly tributary to the lakes, where treatment of stormwater is not available.

6.1.3.4 Deterrence of Waterfowl

The role of waterfowl in the transport of phosphorus to lakes is often not considered. However, when the waterfowl population of a lake is large relative to the lake size, a substantial portion of the total phosphorus load to the lake may be caused by the waterfowl. Waterfowl tend to feed primarily on plant material in or near a lake; the digestive processes alters the form of phosphorus in the food from particulate to dissolved. Waterfowl feces deposited in or near a lake may result in an elevated load of dissolved phosphorus to the lake. One recent study estimated that one Canada goose might produce 82 grams of feces per day (dry weight) while a mallard may produce 27 grams of feces per day (dry weight) (Scherer et al., 2002). Waterfowl prefer to feed and rest on areas of short grass adjacent to a lake or pond. Therefore, shoreline lawns that extend to the water's edge will attract waterfowl. The practice of feeding bread and scraps to waterfowl at the lakeshore not only adds nutrients to the lake, but attracts more waterfowl to the lake and encourages migratory waterfowl to remain at the lake longer in the fall.

Two practices often recommended to deter waterfowl are construction of vegetated buffer strips, and prohibiting the feeding of waterfowl on public shoreline property. As stated above, vegetated strips along a shoreline will discourage geese and ducks from feeding and nesting on lawns adjacent to the lake, and may decrease the waterfowl population.

6.2 Previous Water Quality Improvement Recommendations

Several studies have been completed for Lake Owasso. This section summarizes the key recommendations, as discussed in the previous studies. Additionally, a brief discussion of any work aligning with the study recommendations that has been performed since the completion of these studies is also discussed.

6.2.1 *Water Quality Management Alternatives* Report (1991)

The *Water Quality Management Alternatives: A Report on the Diagnostic-Feasibility Study of Lake Owasso, Lake Wabasso, and Snail Lake* (Barr, 1991) made a variety of BMP recommendations for the Lake Owasso watershed to improved water quality in the lake. BMP recommendations were limited to projects within the watershed, and do not focus on addressing internal loading in Lake Owasso.

Some of the key BMP recommendations included:

- Development of extended detention in the Central Park – West wetland (LO_S_1),, in Charlie Pond (LO_W_1c), and in Ladyslipper Park ((LO_E_1j and LO_E_1k) near the bay on the southeast side of Lake Owasso) – either through the increase in storage or modification of outlet structure

- Increase wetland treatment in the Central Park – West wetland and in Ladyslipper Park
- Implementation of proprietary devices (oil/grit separators) throughout the watershed, including the area directly tributary to the lake
- Implementation of "Good Housekeeping Practices" throughout the watershed (fertilizer management, litter control, catch basin cleaning, and street sweeping).

Since the completion of the *Water Quality Management Alternatives* study, several BMPs based on the projects recommended in the 1991 report have been implemented throughout the watershed. These BMPs include:

- Additional storage and water quality treatment developed in the Central Park –West wetland in 1995.
- Rain gardens and a series of sedimentation ponds were constructed in Ladyslipper Park during the reconstruction of South Owasso Boulevard in 2006.
- Several proprietary structures have been implemented throughout the watershed including oil/grit separators in subwatersheds Dschg36 (2001), Dschg18 (2006), and LO_W_2a (2007). Additionally, and underground storage and treatment system was constructed along Owasso Heights Road in 2007, collecting runoff from subwatershed Dschg50, redirecting normal flows to the Charlie Pond system for treatment rather than discharging directly to the lake.

6.2.2 *Lake Owasso Management Plan* (2000)

The Lake Owasso Management Plan was developed as a response to concerns raised by residents to changes to the management of Lake Owasso. This study discussed the following management options:

- Maintain high water clarity as the result of continued protection of the lake's native macrophytes while controlling Eurasian watermilfoil and other nonnative species through continued monitoring of water quality, aquatic plant surveys, and regular milfoil inspections.
- Prevention of Eurasian watermilfoil from becoming problematic – this item was not longer valid as Eurasian watermilfoil was discovered in the lake in 2000.
- Provide safe and pleasant recreational uses by continuing their aquatic nuisance control plan and conducting a scientifically-based lake use study of Lake Owasso.
- Finding a solution to low lake levels by exploring feasible options for lake level augmentation

- Coordinate lake management by:
    - Continued work with the MDNR for aquatic plant management activities
    - Increased control and enforcement of recreational uses of the lake
    - Management of the fisheries by the MDNR
    - Management of lake levels
    - Dredging of Lake Owasso to remove materials that have been artificially or excessively deposited in the lake
    - Control of geese by encouraging lake shore restoration
    - Continued monitoring and evaluation of lake water quality
    - Continued implementation of watershed and stormwater management

The *Lake Owasso Management Plan* as included a discussion about the "Shallow Lake Bonus," related to the balanced management of aquatic plants. The idea of the shallow lake bonus suggests that when a lake supports healthy and diverse aquatic plants, water clarity increases. There are typically two types of stable lake systems that have very different characteristics and management methods: plant-dominated systems as well as algae dominated systems.

6.3 Feasibility Analysis

A trend analysis of the past 10 years of water quality data indicates that there has been a significant decrease in the water clarity in Lake Owasso, with an average summer transparency of 1.7 meters, just meeting the existing GLWMO goal. This value, however, does not meet the "action level" established by the GLWMO for Lake Owasso, and as a result, this UAA was required to evaluate Lake Owasso's current water quality conditions as well as evaluate management options that will help improve water quality in the lake.

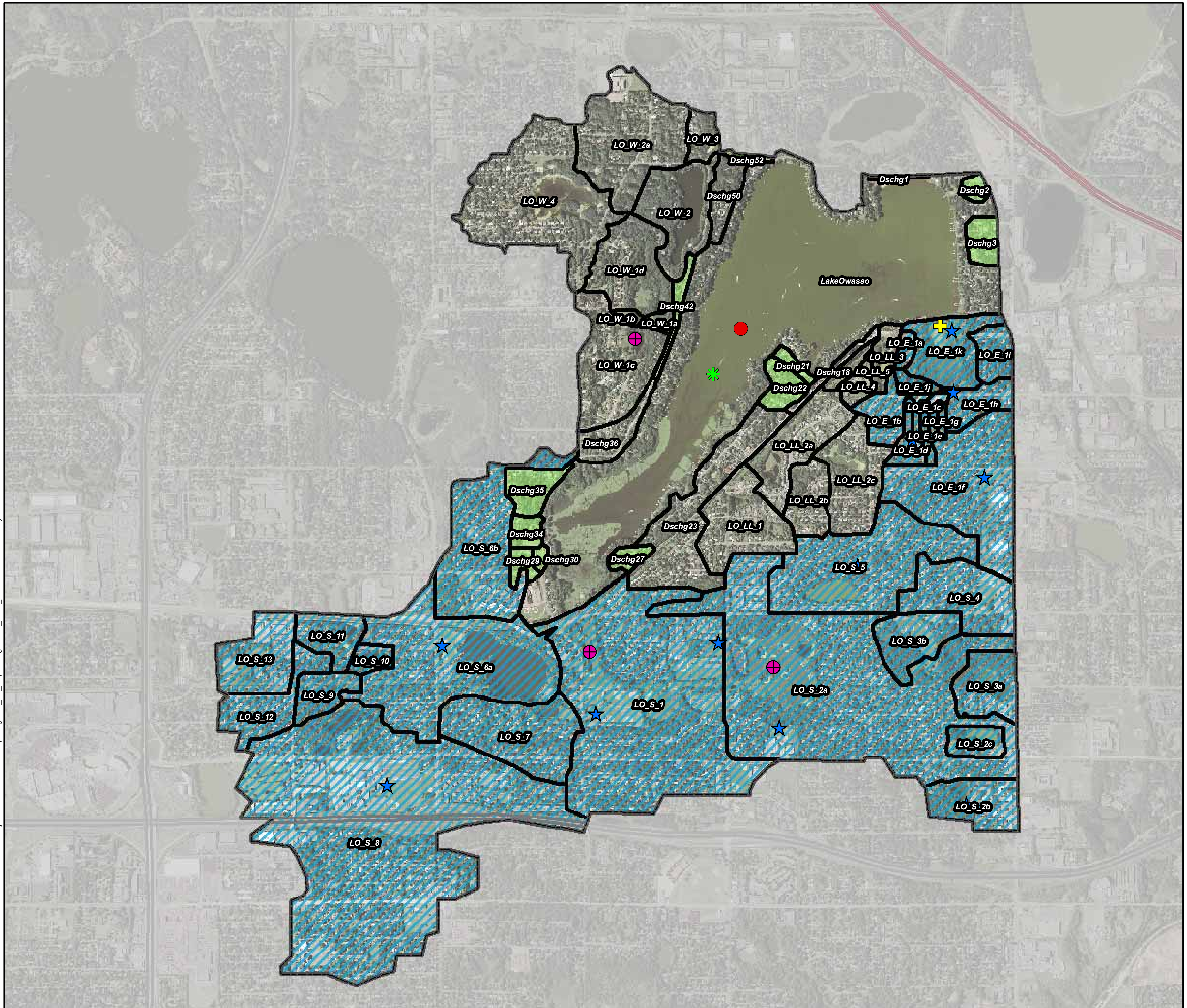
To maintain or improve the water quality in Lake Owasso, it will be necessary to implement BMPs in the lake as well as in the watershed. .A handful of treatment BMPs have been implemented in the Lake Owasso watershed in recent years as opportunities arose from road reconstruction or redevelopment. Some of these projects are summarized in Section 6.2.

Three types of BMPs were considered for recommendation in this plan:

1. Structural
2. In-lake
3. Nonstructural

Each of these types of BMPs are defined and discussed in Section 6.1. For watershed and in-lake water quality modeling, only structural and in-lake BMPs were evaluated for their potential impact on Lake Owasso's water quality. Section 6.3.14 includes a discussion of nonstructural BMPs as they apply to the Lake Owasso watershed.

Specific BMP alternatives that were considered for Lake Owasso and its watershed are discussed below and shown in Figure 6-1. Selection of the BMP scenarios was primarily based upon the Lake Owasso phosphorus budgets developed for the various climatic conditions to target the major sources of phosphorus to the lake. Table 6-2 summarizes the results of the various BMP scenarios evaluated as part of this UAA. Included in this summary is the predicted in-lake water quality (TP and SD) for each climatic conditions as well as a planning level cost estimate for the BMPs evaluated. A more detailed breakdown of estimated costs is available in Appendix N. Figure 6-2 shows the estimated summer average total phosphorus concentration and Secchi depth in comparison with the MPCA and GLWMO goals for Lake Owasso. It is important to note that not all of the BMP alternatives discussed below are recommended for implementation.



Scenario2:
Curlyleaf Pondweed Management

Scenarios 3 & 4:
Reduction in Internal Loading (10% & 50% Reduction)

Scenario 6:
Extended Detention in Bay (Ladyslipper Park)

Scenario 8:
Infiltration of 0.5" of Runoff from Contributing Impervious Area

Scenario 9:
Alum Treatment

Secnario 5:
Treatment to NURP Standards

Scenario 7:
Infiltration of 0.5" of Runoff from ALL Impervious Surfaces

Subwatershed

Feet
1,750 0 1,750

N

Figure 6-1

LAKE OWASSO
SUMMARY OF BMP SCENARIOS

Lake Owasso UAA
Grass Lake Watershed Management Organization

Barr Footer: Date: 3/22/2009 8:23:27 PM File: I:\Projects\23\62\946\GIS\Maps\Figures_for_Report\Figure6-1_BMP_Scenarios.mxd User: jak2

Table 6-2 Lake Owasso Summary of BMP Scenarios

Scenario		Summer Average Water Quality								Reduction in TP (%)	Estimated BMP Cost ($)
		Wet		Dry			Average				
		2001-2002		2007-2008			2004-2005				
		TP (µg/L)	SD (m)[10]	Site[1]	TP (µg/L)	SD (m)[10]	TP (µg/L)	SD (m)[10]			
1	Existing Conditions[2]	32	2.4	5403	41	2.0	45	1.5		--	--
				5401	32	2.1					
2	80% Reduction in Curlyleaf Pondweed[6]	21	3.7	5403	29	2.6	33	2.3		27 - 39%	$649,000
				5401	19	4.2					
3	10% Reduction in the Internal Loading from Watershed Waterbodies	31	2.4	5403	38	2.0	44	1.8		2 - 4%	N/A[12]
				5401	31	2.4					
4	50% Reduction in the Internal Loading from Watershed Waterbodies	28	2.6	5403	29	2.5	42	1.9		7 - 13%	N/A[12]
				5401	30	2.5					
5	Treatment of All "Untreated" Discharges to NURP Standards[5]	32	2.3	5403	40	2.0	45	1.8		0 - 3%	$350,000
				5401	31	2.4					
6	Extended Detention in Ladyslipper Park Pond (Replace outlet under the Railroad)[7]	32	2.3	5403	41	1.9	45	1.8		0 - 3%	$55,000
				5401	31	2.4					
7	Infiltration of 0.5 inches of Runoff from ALL Impervious Surfaces in the South and East Drainage Districts[3,8,11]	26	2.9	5403	32	2.3	37	2.1		4 - 20%	$4,770,000
				5401	30	2.4					
8	Infiltration of 0.5 inches of Runoff from Select Impervious Surfaces in the South and East Drainage Districts[3,9,11]	31	2.4	5403	37	2.1	44	1.8		2 - 3%	$389,000
				5401	31	2.4					
9	Alum Treatment (80% Reduction in Internal Load from Sediments)	28	2.6	5403	40	2.0	43	1.9		6 - 11%	$198,000
				5401	30	2.5					
10 (2 + 3)	80% Reduction in Curlyleaf Pondweed & 10% Reduction in the Internal Loading from Watershed Waterbodies[6]	20	3.9	5403	26	2.8	32	2.3		29 - 39%	N/A[12]
				5401	19	4.2					
11 (2 + 4)	80% Reduction in Curlyleaf Pondweed & 50% Reduction in the Internal Loading from Watershed Waterbodies[6]	17	5.4	5403	17	5.1	29	2.5		35 - 47%	N/A[12]
				5401	18	4.6					
12 (2 + 8)	80% Reduction in Curlyleaf Pondweed & Infiltration of 0.5 inches of Runoff from Select Impervious Surfaces in the South and East Drainage Districts[6,3,9]	20	3.9	5403	25	3.0	31	2.4		31 - 38%	$1,038,000
				5401	20	4.1					
13 (2 + 9)	80% Reduction in Curlyleaf Pondweed & Alum Treatment (80% Reduction in Internal Load from Sediments)[6]	17	5.1	5403	28	2.6	30	2.4		33 - 46%	$847,000
				5401	18	4.6					

TP: Total Phosphorus Chl*a*: Chlorophyll *a* SD: Secchi Depth

1 - For 2008 (Dry Climatic Conditions), Lake Owasso was modeled as 2 separate basins (5403 - Southern Basin, and 5401 - Northern Basin) as there was water quality data available for both areas of the lake. For 2002 (Wet Climatic Conditions) and 2005 (Average Climatic Conditions), the water quality data was only collected at basin 5401 and the lake was modeled as a single basin.

2 - Existing land use and 2008 watershed/BMP conditions. Very few changes are expected in land use as the Lake Owasso watershed is fully-developed. Therefore, it was assumed that existing land use is also reflective of future land use conditions.

3 - Internal loading from the watershed was modified for the infiltration scenario based on the reduction in water load to the wetlands.

4 - It is not feasible to treat all currently untreated direct discharges to Lake Owasso using a single NURP pond. This analysis was performed to demonstrate the impact that treating each discharge to NURP standards would have on overall lake water quality

5 - This scenario is not physically feasible as the currently "untreated" direct discharges are distributed around the entire shoreline of Lake Owasso. Additionally, there is not sufficient space to incorporate NURP ponds in each of the direct discharge watersheds. This scenario was evaluated to demonstrate the impact of treating all direct discharges on the overall water quality in Lake Owasso. This cost estimate is based on the construction of a single, hypothetical NURP pond sized to treat all "untreated" discharges to Lake Owasso.

6 - The estimated cost of the Curlyleaf Pondweed Treatment includes the MDNR variance to treat the entire littoral area of Lake Owasso, 4-years of herbicide application to the Lake, as well as 4-years of detailed macrophyte monitoring to track the herbicide treatment on the Curlyleaf pondweed coverage

7 - Development of an extended detention basin in Lady Slipper Park (in subwatershed LO_E_1k) along with the replacement of the outlet under the railroad embankment with a weir structure were evaluated as part of the 1991 *Report on the Diagnostic-Feasibility Study of Lake Owasso, Lake Wabasso, and Snail Lake.* Since 1991, the City of Roseville developed infiltration and sedimentation ponds in this area as part of the South Owasso Boulevard road reconstruction project in 2006. This study evaluates replacing the outlet under the railroad embankment only.

8 - Infiltration of 0.5" from all impervious surfaces in the South and East Drainage Districts is not feasible. This scenario was evaluated to estimate the maximum impact infiltration could potentially have on Lake Owasso's water quality.

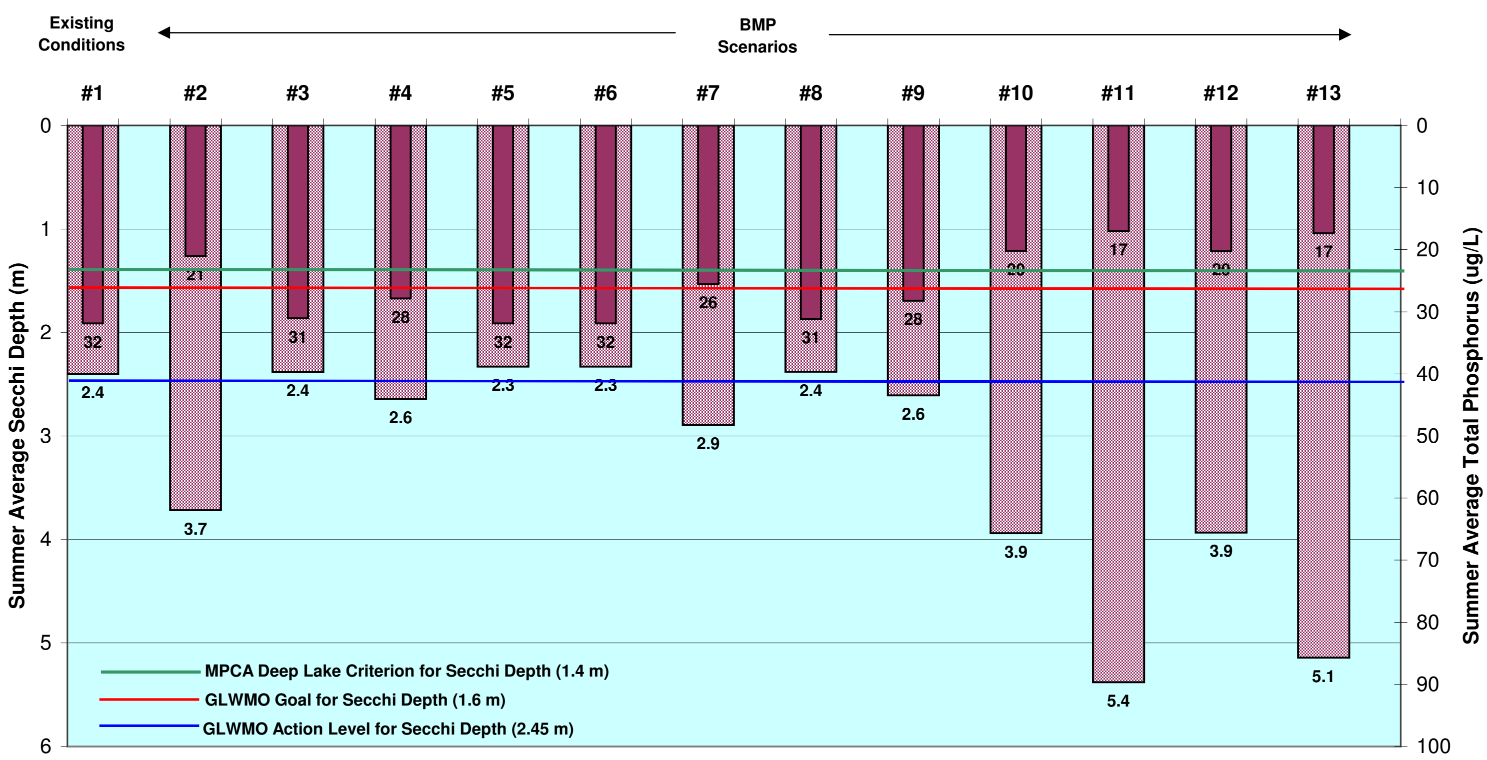
9 - Selected potential infiltration sites include 11 preliminary locations within the South and East Drainage Districts. Sites were selected based on the presence of open space, proximity to existing storm sewer (potential to reroute or divert flows), and topography. Available soils data were condsidered although much of the Lake Owasso is classified as undefined hydrologic soils group. These are planning level cost estimates and each site would require a more complete feasibility study before final design.

10 - Existing Condition summer average Secchi depth based on 2008 monitoring data; For all BMP scenarios, estimated based on the Secchi Depth versus Total Phosphorus Regression Relationship for Lake Owasso (See Figure

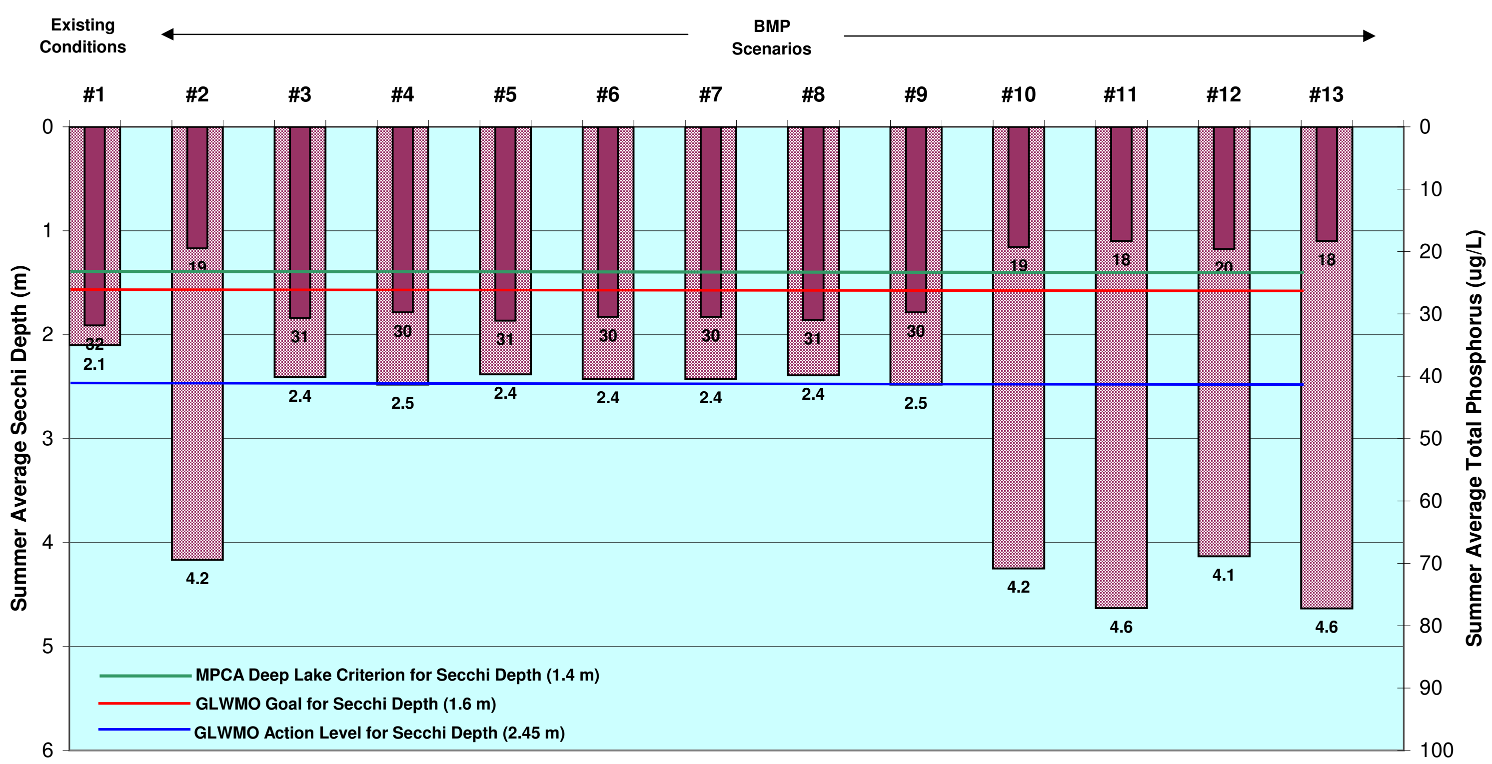
11 - The estimated cost of infiltration BMPs is based on typical unit costs ($13/sq.ft.) estimated for the construction of rain gardens plus 30 percent for engineering and design. Depression storage was assumed to be 18 inches. This cost does not include any potentially significant changes to the storm sewer system/additional piping that may be needed.

12 - Because specific BMPs to address the internal loading in the waterbodies within the watershed are not recommended until further studies of the internal loading can be completed, no costs have been estimated for these scenarios.

Lake Owasso Water Quality
Wet Year (2002) Climatic Conditions



Lake Owasso Water Quality
Dry Year (2008) Climatic Conditions*



*Site 5401

Lake Owasso Water Quality
Average Year (2005) Climatic Conditions

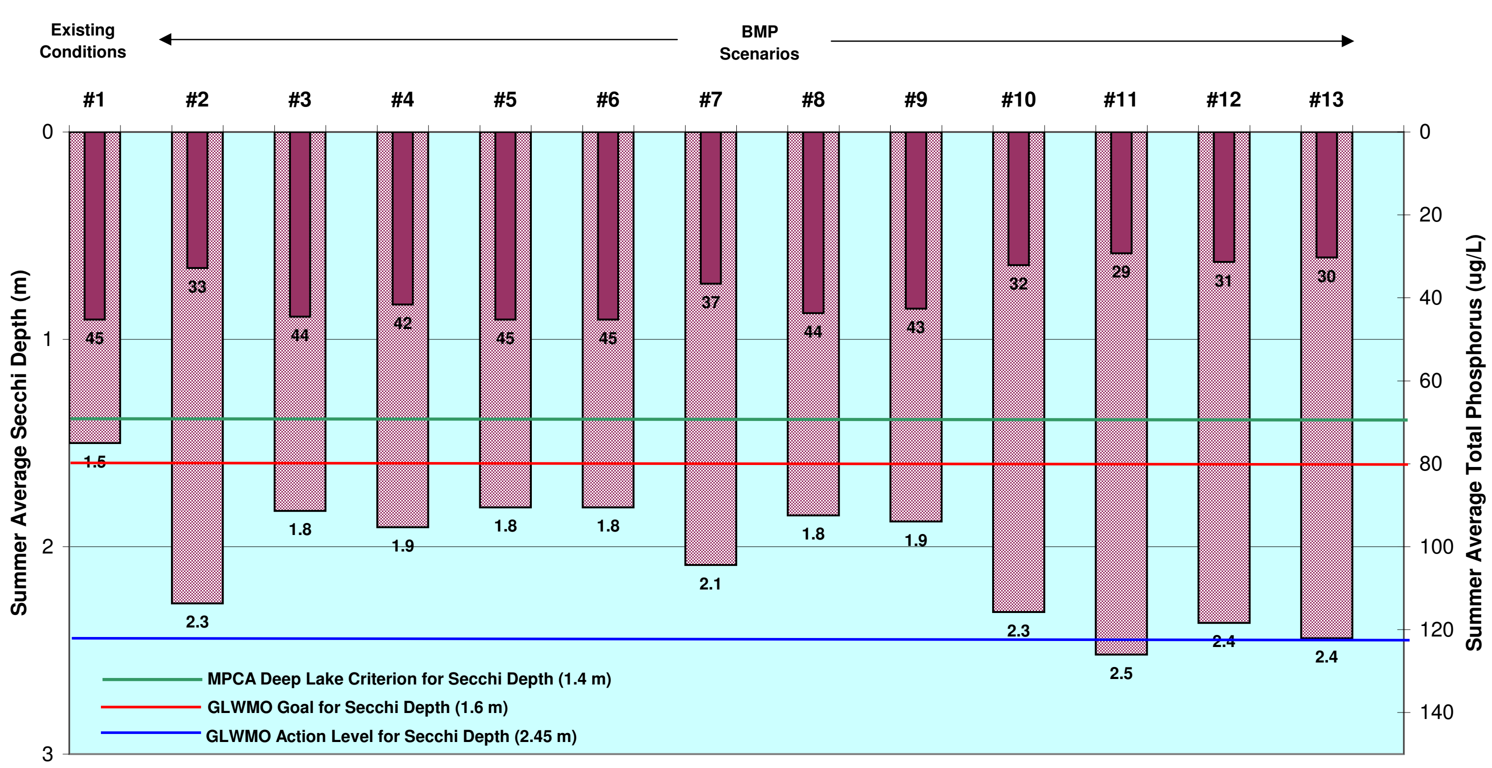


Figure 6-2
Lake Owasso Summary of BMP Scenario Results and Comparison with MPCA and GLWMO Goals

6.3.1 Scenario 1: Existing Conditions

The existing conditions scenario is reflective of existing land use and the 2008 watershed and BMP conditions for the wet, dry, and average climatic scenarios. These values (based on the monitoring data for each year reflective of the climatic conditions) are used as a baseline for comparison when evaluating the impact of potential BMPs on the overall water quality of Lake Owasso.

6.3.2 Scenario 2: Curlyleaf Pondweed Treatment

Both historic and current macrophyte surveys of Lake Owasso indicate the widespread presence of problematic non-native species in Lake Owasso: Curlyleaf pondweed. Survey results from May 2007 indicate that Curlyleaf pondweed was found at moderate densities in several areas of the lake. Curlyleaf pondweed was especially focused in the southern “arm” of the lake as well as along the shoreline north of the railroad tracks. Historic surveys, as far back as 1981, indicate that Curlyleaf pondweed has been present in Lake Owasso.

Management of Curlyleaf pondweed is recommended to protect the lake’s native plant community and prevent dense plant growths that create recreational nuisance conditions. Management of Curlyleaf pondweed may also minimize the impact of die-off that typically occurs in early to mid-summer, which can cause increased phosphorus levels in the lake resulting in algal growth and decreased water quality and clarity.

Water quality modeling indicates that phosphorus released from the die-back of Curlyleaf pondweed can significantly affect Lake Owasso’s water quality during the summer months, accounting for about 17 to 33 percent of the phosphorus load to the lake on an annual basis. Following treatment of Curlyleaf pondweed in Lake Owasso, modeling simulations indicate the summer-average total phosphorus concentration would be reduced by 27 to 39 percent based on the various climatic conditions (See Table 6-2). This translates to a reduction in the summer average total phosphorus concentrations by 11 to 13 μg/L. The estimated total phosphorus concentrations would result in a summer-average Secchi disc transparency of 2.3 to 4.2 meters (increased from 1.5 to 2.4 meters for existing conditions), depending on the climatic condition .

The model assumes that the treatment of Curlyleaf pondweed will decrease the internal phosphorus load from the die-back of the macrophyte by 80 percent.

The estimated capital cost of the Curlyleaf pondweed treatment is $649,000 (or approximately $162,000 annually). This estimate includes a variety of components including:

- Obtaining the MDNR treatment permit and letter of variance
- Obtaining letters of permission to treat within 150 feet of shoreline property boundaries
- 4-years of Endothall treatments of Lake Owasso (this assumes treatment of the entire littoral area, approximately 293 acres)
- 4-years of Monitoring, Analysis, and Reporting

Currently, the Lake Owasso homeowners association spends $50,000 – 60,000 per year on macrophyte management. See Section 8.3.1 for a more detailed discussion of the proposed Curlyleaf pondweed management plan for Lake Owasso and Appendix N for a more detailed breakdown of the estimated costs.

Because the management of Curlyleaf pondweed can have a significant impact on the Lake Owasso summer water quality, is one of the recommended in-lake BMPs.

6.3.3 Scenario 3: 10% Reduction in the Internal Loading from Watershed Waterbodies

Evaluation of the runoff monitoring data along with modeling results indicated that internal loading occurs in several water bodies within the watershed and contributes a significant portion of the annual phosphorus load to Lake Owasso (5 to 9 percent). Because additional monitoring and studies are recommended to better understand these sources of phosphorus to Lake Owasso, the impact of specific BMPs could not be evaluated. However, modeling scenario assuming a 10 percent reduction in this internal load was evaluated to estimate the impact on the overall water quality in Lake Owasso.

Modeling simulations indicate that by reducing the internal load from waterbodies in the watershed, the summer-average total phosphorus concentration would be reduced by 2 to 4 percent based on the various climatic conditions (See Table 6-2). This translates to a reduction in the summer average total phosphorus concentration by 1 to 3 μg/L. The estimated total phosphorus concentrations would result in a summer-average Secchi disc transparency of 1.8 to 2.4 meters (increased from 1.5 to 2.4 meters for existing conditions), depending on the climatic condition.

Specific BMPs to address the internal loading from waterbodies in the watershed are not recommended at this time. Current information suggests that the loading is the result of carp activity in the wetlands or potentially the release of phosphorus from the sediments in the wetland. Further investigations and monitoring are recommended to develop appropriate management plans for the waterbodies (see Section 8.1 for a more complete discussion of the recommended monitoring and studies). Therefore, costs have not been estimated at this time.

6.3.4 Scenario 4: 50% Reduction in the Internal Loading from Watershed Waterbodies

Similar to BMP Scenario 3, this modeling scenario assumes a 50 percent reduction in the internal load. Modeling simulations indicate that by reducing the internal load from waterbodies in the watershed, the summer-average total phosphorus concentration would be reduced by 7 to 13 percent based on the various climatic conditions (See Table 6-2). This translates to a reduction in the summer average total phosphorus concentrations by 2 to 4 μg/L. The estimated total phosphorus concentrations would result in a summer-average Secchi disc transparency of 1.9 to 2.6 meters (increased from 1.5 to 2.4 meters for existing conditions), depending on the climatic condition.

Like Scenario 3, specific BMPs to address the internal loading from waterbodies in the watershed are not recommended at this time. However, further investigations and monitoring are recommended to develop appropriate management plans for the waterbodies (see Section 8.1 for a more complete discussion of the recommended monitoring and studies). Therefore, costs have not been estimated at this time.

6.3.5 Scenario 5: Treatment of All Currently "Untreated" Direct Discharges to NURP Standards

Appoximately 55 direct discharges to Lake Owasso, under both public (23) and private (32) jurisdiction, have been identified and inventoried, as a response to address concerns of lake residents. About half of the public discharges have water quality treatment upstream of Lake Owasso. There are, however, about 45 (13 public and 32 private) of these discharges that currently receive no water quality treatment before discharging to the lake.

To better understand the impact of these currently untreated watershed discharges on the overall water quality of Lake Owasso, a hypothetical scenario was developed, evaluating the treatment of all direct discharges to Lake Owasso to NURP water quality removal standards. Only those discharges that are under public jurisdiction were evaluated (see Figure 6-1 for the 10 subwatersheds) and were routed to a water quality treatment pond designed to NURP standards. It is important to note that this BMP scenario is not feasible due to space limitations within the currently untreated watersheds and was only performed to demonstrate the impact of water quality treatment in these watersheds on Lake Owasso's water quality.

Water quality modeling indicates that treating the currently untreated direct discharges will have little impact on Lake Owasso's water quality during the summer months. Treatment to NURP water quality standards would only result in a 0 to 3 percent reduction in the total phosphorus concentration in the lake for the three climatic conditions (See Table 6-2). This translates to a reduction in the summer average total phosphorus concentrations by 0 to 1 μg/L. The estimated total phosphorus concentrations would result in a summer-average Secchi disc transparencies similar to what is observed during existing conditions.

As a result of this analysis, the construction of NURP water quality treatment ponds in the currently untreated watersheds is not recommended as a structural BMP for implementation It should also be noted that NURP ponds area typically designed for the removal of particulates (and phosphorus bound to the particulates), and have very little impact on dissolved phosphorus. However, as opportunities arise to retrofit stormwater BMPs in these specific subwatersheds, as well as throughout the Lake Owasso watershed, .the Cities of Roseville and Shoreview, along with the GLWMO, should continue to consider the implementation of infiltrations practices, such as the 2009 pervious pavement project planned in the Woodridge area of Shoreview, which address both particulate and dissolved phosphorus fractions, where feasible.

6.3.6 Scenario 6: Extended Detention in Ladyslipper Park Pond

As part of *Water Quality Management Alternatives* study (Barr, 1991), extended detention in Ladyslipper Park (subwatershed LO_E_1k) was one of the recommended BMPs within the Lake Owasso watershed, either through the creation of a extended detention basin within the park or through the installation of a weir structure at the outlet from the bay under the Northern Pacific Railroad.

In 2006, as part of the South Owasso Boulevard road reconstruction project, several sedimentation ponds were constructed on the south end of the park, although these are not extended detention basins, as recommended in the *Water Quality Management Alternatives* study (Barr, 1991).

Extended detention through the installation of a weir-structure was reevaluated as part of this study. Flows could be detained within the bay for a longer period through the use of a restricted outlet structure, such as a notched-weir. The current outlet is an open channel flowing from the bay to Lake Owasso. Installation of this structure would need approval from the from the Northern Pacific Railroad for work to be completed within the railroad right-of-way as well as from the MDNR for work to be completed within a public wetland and proposed modifications to a wetland elevation.

Water quality modeling indicates that extended detention within the bay in Ladyslipper Park will have little impact on Lake Owasso's water quality during the summer months. The extended detention would only result in a 0 to 3 percent reduction in the total phosphorus concentration in the lake for the three climatic conditions (See Table 6-2). This translates to a reduction in the summer average total phosphorus concentrations by 0 to 1 μg/L. The estimated total phosphorus concentrations would result in a summer-average Secchi disc transparencies similar to what is observed during existing conditions.

The estimated capital cost of the installation of weir structure at the outlet of the bay for extended detention is approximately $55,000. However, because of the limited impact of extended detention on the overall water quality of Lake Owasso for all climatic conditions, it is not a recommended BMP for implementation.

6.3.7 Scenario 7: Infiltration of 0.5 Inches of Runoff from all Impervious Surfaces in the South and East Drainage Districts

Implementation of infiltration BMPs in the Lake Owasso watershed was evaluated to determine the potential reduction in watershed runoff and nutrient loading to Lake Owasso and the associated impacts on in-lake water quality.

The first step was to identify the feasibility of infiltration in the watershed based on soil conditions, topography, and land use. Based on information from the Ramsey County soil survey, the soils in much of the Lake Owasso watershed are primarily undefined or urban soil types. This is because much of the Lake Owasso watershed was already developed at the time the soils surveys were originally completed. Soils that are classified are typically Hydrologic Soil Group B (moderate infiltration potential) with some areas of Hydrologic Soils Group A (high infiltration potential) in the far eastern parts of the watershed. Most wetland areas have soils classified as Type D soils, or soils not good for the infiltration of stormwater. Conversations with the City of Shoreview also indicated that soils in the western part of the Lake Owasso watershed are not conducive to infiltration. Additionally, the western part of the watershed has a much steeper terrain than in the south and east, which is not ideal for infiltration BMPs. Therefore, as the result of the general soils conditions and the topography in the western watersheds, implementation of infiltration BMPs was only considered in the South and East drainage districts.

The first scenario evaluated served as an extreme case for the implementation of infiltration throughout the Lake Owasso watershed. This scenario assumed that the first 0.5 inches of runoff from ALL impervious surfaces in both the South and East drainage districts would be able to be infiltrated, regardless of the actual opportunities (available open space, topography, soil type, proximity to existing storm sewer, etc.) to retrofit infiltration BMPs throughout the watershed. Under this scenario, approximately 300 acres of impervious surface would be treated by infiltration.

Water quality modeling indicates that implementation of infiltration practices throughout the Lake Owasso watershed can significantly affect Lake Owasso's water quality during the summer months. Currently, watershed runoff accounts for about 22 to 31 percent of the phosphorus load to the lake on an annual basis. Modeling simulations indicate that with the implementation of infiltration throughout the watershed, the summer-average total phosphorus concentrations in the lake would be reduced by 4 to 20 percent based on the various climatic conditions (See Table 6-2). This translates to a reduction in the summer average total phosphorus concentrations by 2 to 8 μg/L. The estimated total phosphorus concentrations would result in a summer-average Secchi disc transparency of 2.1 to 2.9 meters (increased from 1.5 to 2.4 meters for existing conditions), depending on the climatic condition.

It is important to note that infiltration not only reduces the volume of watershed runoff but can also result in the reduction of the estimated internal load from upstream waterbodies in the watershed to Lake Owasso. This is related to a reduction in the overall phosphorus and water loads to the waterbodies that potentially act a source of phosphorus to Lake Owasso. Reducing the water load to these water bodies also reduces the discharge volume, and thus the phosphorus load, to Lake Owasso.

Again, this scenario represents an extreme condition that is not likely feasible in the Lake Owasso watershed. However, a planning level cost estimate was developed for implementation of infiltration at this scale. This cost estimate for this scenario assumes that the infiltration practices will be designed with 18 inches of depression storage. Assuming a typical unit cost for the design and construction of rain garden infiltration systems, the estimated cost for infiltration of runoff from all impervious surfaces in the South and East drainage districts is $4,770,000.

The next scenario looks at select sites for the implementation of potential infiltration BMPs within the South and East drainage districts.

6.3.8 Scenario 8: Infiltration of 0.5 Inches of Runoff from Select Impervious Surfaces in the South and East Drainage Districts

This scenario further refines the previous scenario (Scenario 7) that considered infiltration of 0.5 inches of runoff from all impervious surfaces in the South and East drainage districts. This scenario considered available open space. In some cases, the open space includes developed park areas (such as ballfields and other playing fields) and the selection of sites did not distinguish between public and private land. Topography and the proximity to existing storm sewer where also used to identify sites that could provide more regional infiltration opportunities by diverting and treating a portion of the runoff from the existing storm sewer system.

Eleven potential infiltration sites were selected throughout the South and East drainage districts, to infiltrate runoff from approximately 25 acres of impervious surface within this area (See Figure 6-3 and Table 6-3 for locations and location descriptions). Because of the limited area available in some locations for the development of infiltration areas, as well as the generally large size of the expected contributing areas, it was assumed that only a fraction of the flows from the contributing area would be diverted to the proposed regional infiltration basins. On average, it was assumed that about 50 percent of the flows from the first 0.5 inches of runoff from the impervious surfaces within the entire contributing area would be treated by infiltration.

Water quality modeling indicates that implementation of select regional infiltration practices throughout the Lake Owasso watershed can impact Lake Owasso's water quality during the summer months. Modeling simulations indicate that with the implementation of select regional infiltration throughout the watershed, the summer-average total phosphorus concentrations in the lake would be reduced by 2 to 3 percent based on the various climatic conditions (See Table 6-2). This translates to a reduction in the summer average total phosphorus concentrations by 1 to 4 μg/L. The estimated total phosphorus concentrations would result in a summer-average Secchi disc transparency of 1.8 to 2.4 meters (increased from 1.5 to 2.4 meters for existing conditions), depending on the climatic condition.

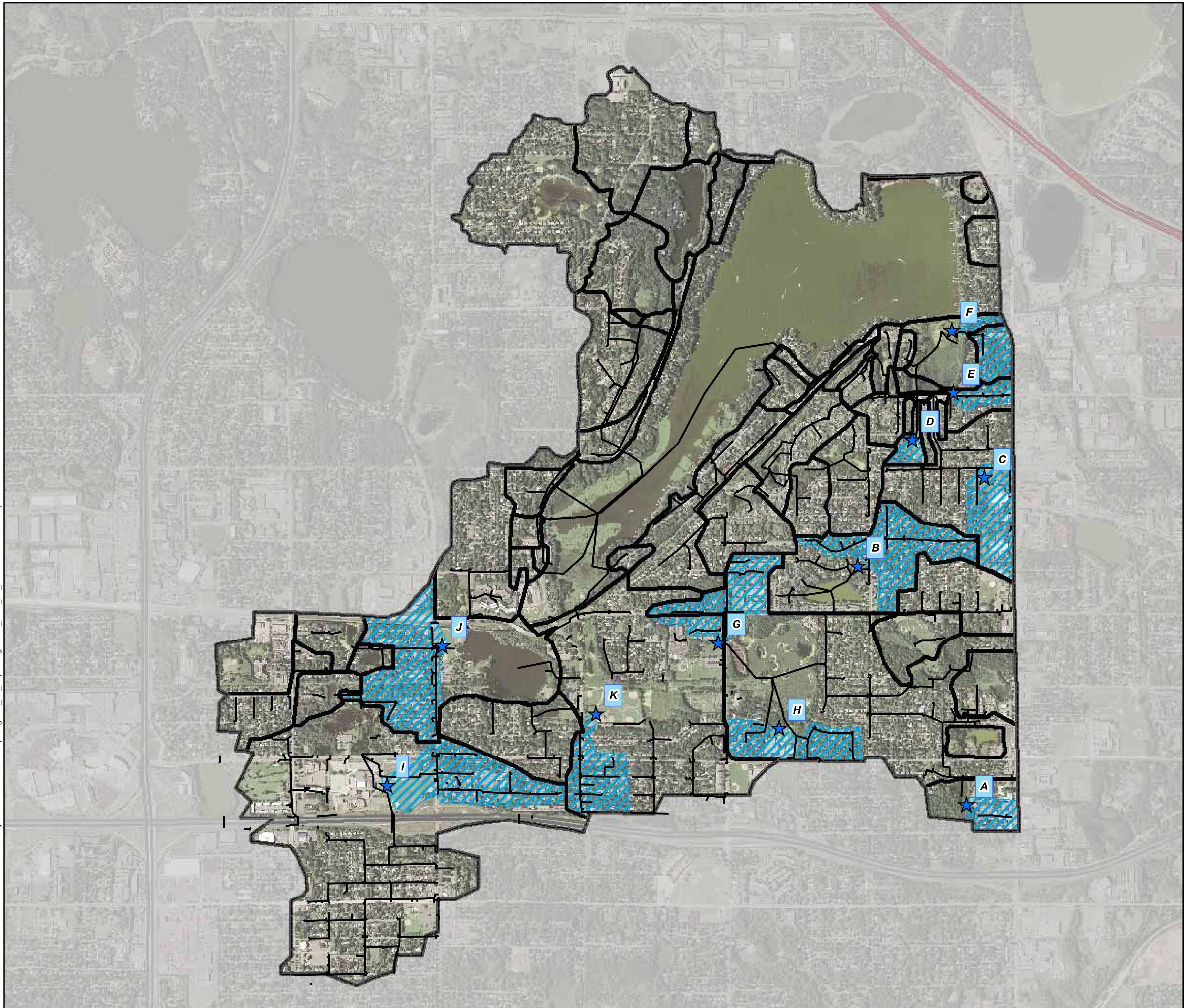
Table 6-3 Location Description of Select Infiltration BMPs

Infiltration Area ID	Location Description
A	Materion Park - On Southside of Pond
B	Open space in the Southwest Corner of Woodhill Drive and Western Ave N
C	Northwest Corner of Rosedale Estates
D	Mapleview Park
E	Private Parcel Along Southeast Corner of Ladyslipper Park
F	Private Parcel Along Northeast Corner of Ladyslipper Park
G	Central Park - North of Soccer Field
H	Central Park Elementary School Ballfields
I	Roseville High School - Playing Fields
J	Central Park - Ballfields West of Bennett Lake
K	Central Park - Ballfields South of Central Park - West Wetland

Implementation of infiltration practices throughout the Lake Owasso watershed is recommended. As previously mentioned, unlike NURP treatment (wet detention), infiltration can reduce both dissolved and particulate fractions of phosphorus in stormwater runoff as well as runoff volumes. As opportunities arise to retrofit stormwater BMPs the Lake Owasso watershed, the Cities of Roseville and Shoreview, along with the GLWMO, should continue to consider the implementation of infiltrations practices where feasible.

The planning level cost estimates for the select infiltration projects is $389,000. This estimate is based on the same assumptions for infiltration as outlined for Scenario 7. Potential additional costs for each specific project shown in Figure 6-3 may include the following:

- Complete feasibility studies that would verify local site conditions are conducive for infiltration and to identify specific needs for each project
- Costs associated with the purchase of private land or obtaining easements
- Complexity of the project to preserve existing uses of the area (e.g. infiltration in areas that are currently ball/playing fields)
- Costs associated with the rerouting of existing storm sewer and the construction of flow diversion structures.



★ Infiltration of 0.5" of Runoff from Contributing Impervious Area

Infiltration BMPs Subwatersheds

Storm Sewer

Subwatershed

Note: For watersheds and in-lake modeling, it was assumed that only a fraction of watershed runoff would be diverted to the proposed infiltration BMPs.

Feet

1,750 0 1,750

N

Figure 6-3

SCENARIO 7: LOCATION & APPROXIMATE WATERSHEDS OF SELECT INFILTRATION BMPs

Lake Owasso UAA
Grass Lake Watershed Management Organization

6.3.9 Scenario 9: Alum Treatment

In-lake application of alum (aluminum sulfate) to prevent sediment phosphorus release in Lake Owasso during the summer months was also evaluated. Water quality modeling indicates that sediment-released phosphorus can affect the lake's water quality during the summer months, accounting for about 16 to 37 percent of the phosphorus load to the lake on an annual basis.

Following an alum treatment of Lake Owasso, which based on literature was assumed to decrease the internal phosphorus load by 80 percent, modeling simulations indicate the summer-average total phosphorus concentration would be reduced by 6 to 11 percent based on the various climatic conditions (See Table 6-2). This translates to a reduction in the summer average total phosphorus concentrations by 2 to 4 µg/L. This would result in summer-average Secchi disc transparencies ranging from 1.9 to 2.6 meters (increased from 1.5 to 2.4 meters for existing conditions), depending on the climatic condition.

The estimated capital cost of an in-lake alum application in Lake Owasso is $198,000, based on dosing information that pertains to the internal loading rate calculated for the lake's sediments using the results from the 2007 sediment core analysis (see Section 5.3.2 for more discussion about the sediment core analysis).

The longevity of an alum treatment is difficult to estimate, as it depends on many factors including the degree to which watershed sediment and phosphorus loads are controlled, flow regimes (especially in shallow lakes) and the accuracy with which the alum treatment was dosed. Because sediment core analyses allow for a more accurate dosing calculation, it is reasonable to expect that an alum treatment of Lake Owasso would be correctly dosed. For this reason, it is estimated that an alum treatment of Lake Owasso could last as long as 10 years, especially in the deeper areas of the lake. This assumption is consistent with observations of other alum-treated lakes (Welch and Cooke, 1999).

An alum treatment of Lake Owasso is currently not recommended at this time. This may be an option for future consideration, after the Curlyleaf pondweed management plan has been implemented and the impacts of that management effort have been evaluated.

6.3.10 Scenario 10: Curlyleaf Pondweed Treatment + 10% Reduction in the Internal Loading from Watershed Waterbodies

Scenario 10 evaluated the implementation of the treatment of Curlyleaf pondweed to address internal phosphorus loads as well as reducing the internal phosphorus loads from the upstream waterbodies within the watershed by 10 percent. Modeling simulations indicate this combination of BMPs would reduce the summer-average total phosphorus concentrations by 29 to 30 percent depending on the various climatic conditions (See Table 6-2). This translates to a reduction in the summer average total phosphorus concentration of 12 to 13 μg/L. The estimated total phosphorus concentrations would result in a summer-average Secchi disc transparency of 2.3 to 4.2 meters (increased from 1.5 to 2.4 meters for existing conditions), depending on the climatic condition.

Because specific BMPs to reduce the internal loading from the watershed waterbodies have not been recommended until further studies can be completed in these waterbodies. As a result, the costs for the internal load reductions have not been estimated. The expected costs for Curlyleaf pondweed are discussed in Section 6.3.2. More details about Curlyleaf pondweed management area discussed in Section 8.3.1.

6.3.11 Scenario 11: Curlyleaf pondweed treatment + 50% Reduction in the Internal Loading from Watershed Waterbodies

Scenario 11 evaluated the implementation of the treatment of Curlyleaf pondweed to address internal phosphorus loads as well as reducing the internal phosphorus loads from the waterbodies within the watershed by 50 percent. Modeling simulations indicate this combination of BMPs would reduce, the summer-average total phosphorus concentrations by 35 to 47 percent based on the various climatic conditions (See Table 6-2). This translates to a reduction in the summer average total phosphorus concentration of 14 to 16 μg/L. The estimated total phosphorus concentrations would result in a summer-average Secchi disc transparency of 2.5 to 5.4 meters (increased from 1.5 to 2.4 meters for existing conditions), depending on the climatic condition.

Because specific BMPs to reduce the internal loading from the watershed waterbodies have not been recommended until further studies can be completed in these waterbodies. As a result, the costs for the internal load reductions have not been estimated. The expected costs for Curlyleaf pondweed are discussed in Section 6.3.2. More details about Curlyleaf pondweed management area discussed in Section 8.3.1.

6.3.12 Scenario 12: Curlyleaf pondweed treatment + Infiltration of 0. 5 Inches of Runoff from Select Impervious Surfaces in the South and East Drainage Districts

Scenario 12 evaluated the implementation of the treatment of Curlyleaf pondweed to address internal phosphorus loads as well as distributed infiltration BMPs throughout the Lake Owasso watershed. Water quality modeling indicates that implementation this combination of BMPs can significantly improve Lake Owasso's water quality during the summer months, indicating that the summer-average total phosphorus concentrations in the lake would be reduced by 31 to 38 percent depending on the various climatic conditions (See Table 6-2). This translates to a reduction in the summer average total phosphorus concentrations of 12 to 14 μg/L. The estimated total phosphorus concentrations would result in a summer-average Secchi disc transparency of 2.4 to 4.1 meters (increased from 1.5 to 2.4 meters for existing conditions), depending on the climatic condition.

The estimated cost of the combined treatments, including the Curlyleaf pondweed management and the implementation of infiltrations BMPs throughout the watershed was $1,038,000.

6.3.13 Scenario 13: Curlyleaf Pondweed Treatment + Alum Treatment

Scenario 13 evaluated the implementation of two different in-lake treatments to address the major sources of internal phosphorus loading: management of Curlyleaf pondweed and an alum treatment to reduce loading from the sediments. Water quality modeling indicates that implementation this combination of BMPs can significantly improve Lake Owasso's water quality during the summer months, indicating that the summer-average total phosphorus concentrations in the lake would be reduced by 33 to 46 percent depending on the various climatic conditions (See Table 6-2). This translates to a reduction in the summer average total phosphorus concentrations of 14 to 15 μg/L. The estimated total phosphorus concentrations would result in a summer-average Secchi disc transparency of 2.4 to 5.1 meters (increased from 1.5 to 2.4 meters for existing conditions), depending on the climatic condition.

The estimated cost of the combined treatments, including the Curlyleaf pondweed management and the alum treatment was $847,000.

6.3.14 Nonstructural BMP Alternatives for Lake Owasso

Water quality treatment ponds and other traditional BMPs are effective at removing most coarse particulates and phosphorus associated with coarse particles. However, these BMPs may not be highly effective at removing soluble phosphorus, or phosphorus associated with extremely small particles. Therefore, source control becomes extremely important in reducing the amount of phosphorus contained in stormwater runoff. Nonstructural BMPs are effective at reducing the amount of phosphorus on-site, prior to transport by stormwater runoff. Examples of effective nonstructural BMPs that would be appropriate for the Lake Owasso watershed include:

1. Provide public education programs to inform the residents of the Lake Owasso watershed of ways to reduce phosphorus loading through proper handling of yard wastes, fertilizers, pet wastes, soaps, and detergents.
2. Encourage industrial/commercial area owners to institute good housekeeping practices, including appropriate disposal of yard wastes, appropriate disposal of trash and debris, appropriate storage and handling of soil and gravel stockpiles.
3. Discourage the feeding of waterfowl at shoreline areas around Lake Owasso.
4. Encourage vegetated buffers between yards and wetlands and ponds.
5. Require vegetated buffers between yards and the shore of Lake Owasso.
6. Perform regular street sweeping, especially in high-density residential areas, industrial/commercial areas, and any other areas containing large areas of impervious (paved surfaces), such as school and church parking lots. Spring and fall street sweeping will provide the most benefits for phosphorus source reduction.

It is not possible to model the effects of all nonstructural BMPs accurately, but studies have shown that they are moderately effective at reducing phosphorus loads.

7.0 Conclusions

Examination of the most recent 10 years of summer average water quality data for Lake Owasso indicates that the summer average total phosphorus, chlorophyll *a*, and Secchi depth were 38 μg/L, 15.6 μg/L, and 2.1 m, respectively. Typically, the summer averages of the most recent 10 years of water quality data are used by the MPCA for considering listing of impaired waters on the 303(d) Impaired Waters list. Although most parameters, with the exception of chlorophyll *a* concentrations, meet the MPCA deep lake standards, the average total phosphorus concentration for the past 10 years is very close to the MPCA criterion. If lake water quality would decline even slightly, it is possible that Lake Owasso could be listed on the MPCA's 303(d) Impaired Waters list and a Total Maximum Daily Load (TMDL) study would be required to address the sources of impairment. This can be a costly and time-consuming process. Therefore, the conclusions and recommendations of this UAA will be extremely useful in aiding the GLWMO, City of Shoreview, and City of Roseville with the implementation of watershed and lake BMPs that improve lake water quality and reduce the likelihood of Lake Owasso being listed on the 303(d) Impaired Waters list.

The following summary describes the main conclusions of this UAA that allowed for a diagnosis of the water quality issues in Lake Owasso and identification of the activities and projects that would help the lake continue to meet or improve its water quality goals in the future.

1. Water quality data collected in Lake Owasso for 2007 and 2008 would classify Lake Owasso as a eutrophic lake. Because data was collected in 2 sampling locations within the lake, the spatial variability of water quality in Lake Owasso was observed and water quality does vary through out the lake. The trend analysis for Lake Owasso using the past 10 years of water quality data (1998 through 2008) found that there has not been a significant change in total phosphorus concentrations over the past 10 years while there was a statistically significant increase in the Chlorophyll *a* concentration over the same time period. Additionally, there was a significant decrease in Secchi depth.

2. The MNLEAP model estimated the total phosphorus concentration in a minimally-impacted lake similar to Lake Owasso to be 40 μg/L (±15 μg/L), similar to the range of water quality observed in the lake. For the Vighi and Chiaudani model and the MPCA's diatom analysis, which are predictors of natural background phosphorus concentrations (no impact from anthropogenic sources), suggested that Lake Owasso's natural background phosphorus concentration would fall

within the range of 18 to 22 μg/L. Comparison of these predicted values to observed water quality in the lake indicates that Lake Owasso's water quality falls within the expected range for a minimally-impacted lake with similar characteristic, but the background levels indicate that there is potential for water quality improvement.

3. Sediment cores collected and analyzed in 2007 indicated that the average intenal loading rate from sediment release for the whole lake was 0.5 mg/m^2/day with a maximum expected loading rate of 2.9 mg/m^2/d in the deepest sediment core collected. Although some internal loading from the sediments is likely, when compared to internal loading rates for lakes across the Twin Cities metro area, the maximum expected loading rate in Lake Owasso is significantly less than the average observed across the metro (6.3 mg/m^2/day).

4. A macrophyte survey completed in late-May 2007 quantified the distribution and density of Curlyleaf pondweed throughout Lake Owasso. This macrophyte, which dies-back in early summer, can act as a significant source of phosphorus in a lake system, as is the case with Lake Owasso. In 2007, approximately 52% of the lake was covered by Curlyleaf pondweed. Review of historic macrophyte surveys and other reports about Lake Owasso indicate that Curlyleaf pondweed has been present in the lake as far back as 1981.

5. Relationships between the three key water quality parameters (total phosphorus, chlorophyll *a,* and Secchi depth) were evaluated. There is not a strong relationship observed between cholorphyll *a* and total phosphorus concentrations, showing a similar relationship to what was observed during earlier studies. The relationship in Lake Owasso suggests that the algae concentrations in Lake Owasso are not directly controlled by total phosphorus and are impacted by zooplankton grazing, to some extent. A direct relationship between Secchi depth and total phosphorus was developed to be used predictively. The variability in the data used to develop this relationship suggest that the Secchi depths predicted by this relationship should not be taken as absolute values but rather general indicators of the clarity that can be expected.

6. Review of temperature depth profiles in Lake Owasso at both monitoring sites (site 5401 in the north and site 5403 in the south), indicate that both basins thermally stratify during the summer months, with mixing occurring during spring and fall turnover (dimictic lake). Additionally, total phosphorus and dissolved oxygen data at depth, shows that along the bottom of the lake goes anoxic (devoid of oxygen) and phosphorus accumulates within the hypolimnion, being contained below the thermocline. Because water quality data was not collected in the third deep basin

located on the east side of the lake, the Osgood Index was used to estimate the probability of mixing events to occur during summer stratification. This index indicated that this third basin would also be strongly stratified during the summer (dimictic).

Although the deep areas of the lake strongly stratify, much of the lake is relatively shallow, with an average lake depth of less than 11-feet. It is possible for mixing to occur in these shallow areas of the lake as the result of wind and motor boat activity, although it is unclear what role mixing and resuspension in the shallow areas of the lake have on the overall water quality in Lake Owasso. Anecdotal information suggests that turbidity in the lake increases as the result of motor boats in shallow areas of the lake.

7. The 2001 MDNR fishery survey indicates that small numbers of carp are present in Lake Owasso. The activity of carp, and other benthivorous fish, can result in phosphorus loading to the lake. Additionally, carp were observed in the Central Park – West (County Road C) wetland in the spring of 2008. In late summer, there was a fish-kill in the wetlands and dead carp were observed in the area.

8. The water and phosphorus budgets developed for Lake Owasso for the various climatic conditions indicates that the sources of the water and phosphorus loads to the lake are variable. Watershed runoff plays a variable role in total phosphorus loads to the lake depending on the climatic conditions, ranging from 12 to 23 percent of the total load. However, during dry conditions, there are periods where significant portions of the watershed do not discharge during storm events, as was observed in the summers of 2007 and 2008. There also appears to be internal loading from waterbodies and wetlands within the Lake Owasso watershed that contribute to the total phosphorus load to the lake (5 to 9 percent). These loads can possibly be attributed to carp activity or release of total phosphorus from sediments. Internal phosphorus loads from within Lake Owasso (the result of Curlyleaf pondweed die-back,release from lake sediments, wind mixing, roughfish activity) were estimated to range from 50 to 57 percent of the load to the lake. Other sources of total phosphorus to the lake include atmospheric deposition and groundwater.

9. Review of the 2008 runoff water quality monitoring data at the Dale Street monitoring station, just downstream from the City of Roseville Leaf Recycling Center, suggests that the compost area is not a significant source of phosphorus to Lake Owasso. Total phosphorus concentrations observed during storm events are similar to typical urban stormwater runoff concentrations.

Good housekeeping practices at the Leaf Recycling Center site should continue to be promoted, including the maintenance of the vegetated buffers around the perimeter of the site as well as maintenance of a flat grade on the site to minimize stormwater runoff. Additionally, a small sedimentation pond site could be constructed on the site to collect and treat all surface runoff from the site, before discharging to the downstream wetland.

10. In-lake modeling indicates that the control of Curlyleaf pondweed will have the most significant impact on the total phosphorus concentrations and water clarity in Lake Owasso during the summer months, for all climatic conditions. The implementation of a Curlyleaf management plans is recommended to control the growth of this non-native, invasive species in order to limit its contribution to the internal total phosphorus load, and to allow native macrophyte species to reestablish in Lake Owasso. See Section 8.3.1 for more details about the Curlyleaf management plan proposed for Lake Owasso.

11. Runoff from the majority of the Lake Owasso watershed is routed through stormwater pond or natural wetlands prior to discharging to the lake. Therefore the watershed runoff was identified being less important than other sourcse of phosphorus to Lake Owasso. As a result, a variety of structural BMPs in the watershed were shown to have limited impacts on the water clarity of Lake Owasso. However, watershed and in-lake water quality modeling was done evaluating the implementation of infiltration practices throughout the watershed, demonstrating that the BMPs can result in the improvement of water quality in Lake Owasso. Though no one specific project is currently recommended, it is recommended that the GLWMO and the Cities of Roseville and Shoreview continue to promote the implementation of infiltration BMPs throughout the Lake Owasso watershed as opportunities arise as the result of redevelopment and infrastructure improvement projects.

12. Evaluation of the runoff monitoring data, along with the water quality modeling results, indicate that internal loading occurs in several water bodies (Central Park-West wetland (County Road C), Central Park – East wetland (Dale Street), Charlie Ponds (West Owasso)) within the Lake Owasso watershed and contributes a significant portion of the annual phosphorus load to Lake Owasso (5 to 9 percent). Because the specific sources of these “internal” loads are not fully understood at this time, additional monitoring and studies are recommended for several of these water bodies to more completely understand the systems. The focus of these studies will be additional water quality monitoring, quantifying the potential impacts of the sediments on the

phosphorus load, and the observations of carp activity in some of these water bodies. See Section 8.1 for more detailed discussion of the recommended monitoring and studies.

8.0 Recommendations

Many in-lake improvement options and site-specific structural BMPs were evaluated as to their feasibility and cost-effectiveness in the course of this UAA. Ultimately, the recommended approach for improving the Lake Owasso water quality involves adaptive management, or a management approach that involves monitoring the outcomes of implemented projects, and based on the results, modifies or improves on the way the system is managed. Several BMPs were evaluated that may significantly improve the water quality in Lake Owasso. While the main goals of the recommended BMPs are to reduce phosphorus concentrations and increase water clarity, an added benefit of the increases in water clarity may be the enhancement of native macrophyte community. The recommended BMPs include those that should be implemented first, either in the lake or within the watershed, to begin addressing the loads to Lake Owasso. A second tier of “Future BMPs” are identified as possible projects to be implemented once the impact of the first BMPs implemented can be evaluated.

In addition to the implementation of BMPs to improve water quality in Lake Owasso, there were potential sources of phosphorus to the lake identified that are not fully understood at this time, such as the internal loading in the Central Park – East and West wetlands and the Charlie Pond system. Modeling has demonstrated that reductions in these loads can result in a significant improvement in Lake Owasso’s water quality. To better understand these systems, and to help develop appropriate management plans to reduce loading to Lake Owasso, additional monitoring and studies are recommended before any specific BMPs are implemented.

The following sections summarize the recommended monitoring and studies for Lake Owasso and its watersheds, as well as the structural, in-lake, and nonstructural BMPs recommended for Lake Owasso.

8.1 Additional Monitoring & Study Recommendations

8.1.1 Water Quality Monitoring in Central Park – East and West Wetlands and Charlie Pond System

It was determined from the 2007 and 2008 runoff monitoring efforts and the Lake Owasso watershed water quality modeling that some of the wetlands within the Lake Owasso watershed experience some internal phosphorus loading that contributes to the overall total phosphorus loading to Lake Owasso.

To better understand the water quality in these ponds, and wetlands through the summer, water quality monitoring for an additional summer is recommended. This water quality monitoring should occur in the deepest portions of the Central Park – East wetland, the Central Park – West wetland, and the Charlie Pond system. Sampling should begin in early-May and continue through the end of September. Samples should be collected every two weeks

The water quality monitoring should focus on collecting grab samples (to be analyzed for total phosphorus, dissolved phosphorus, chlorophyll *a,* and total suspended solids). Additionally, dissolved oxygen, temperature, and pH profiles in the deepest locations in each of these wetlands should also be collected.

The estimated cost for this additional monitoring is expected to range from $7,000 to $9,500 including field work, laboratory analysis, and a brief technical memorandum discussing the laboratory results. See Appendix N for a more detailed breakdown of the cost estimates.

8.1.2 Fisheries Impact Study on Water Quality

Carp, along with other benthivorous (bottom-feeding) fish, can have a direct influence on the phosphorus concentration in a lake or water body (LaMarra, 1975). They can also cause resuspension of sediments in shallow ponds and lakes, causing reduced water clarity and poor aquatic plant growth, as well as high phosphorus concentrations (Cooke et al., 1993).

MDNR fisheries surveys for Lake Owasso (2001) and Bennett Lake (2006) indicate that carp are present in low numbers in both lakes. A 2006 MDNR population assessment also supports that carp are present in Lake Owasso. From the 2007 Lake Owasso user survey, 42 percent of respondents indicated that the fishery in Lake Owasso includes a large rough fish population, including carp. Additionally, carp were observed in the Central Park – West (County Road C) wetland in both the spring and summer of 2008.

Carp activity may contribute to the estimated internal phosphorus load within the Central Park – West (County Road C) wetland. Additionally, carp activity within Lake Owasso may also be source of phosphorus to the lake. To better understand the carp activity in the system and the potential contribution of carp to the phosphorus loads to Lake Owasso, a study is recommended to better understand the fishery, focusing mainly on carp and other benthivorous fish.

The results of this study should provide a better understanding of carp populations in the system, including Lake Owasso, Bennett Lake, and the Central Park – West (County Road C) and Central

Park – East wetlands. Because these water bodies are directly-connected to each other with very little change in elevation between the water bodies, carp populations likely move between the water bodies. Therefore, potential items to be considered when scoping this study should include:

- Quantifying carp population in all four water bodies
  - Typically, netting significantly underestimates carp populations in MDNR fishery surveys (e.g. Lake Owasso and Bennett Lake fishery surveys).
  - Netting is typically difficult in shallow areas and may not be able to be done in the Central Park – West and Central Park – East wetlands.
  - Electrofishing may be an option in the wetlands although backpack electrofishing may be limited by depth of wetland and by substrate on the bottom of the wetland. However, access with a boat equipped with electrofishing equipment may also be limited.
- Tracking carp movement between the water bodies in the system, throughout the course of a year (Dr. Peter Sorenson from the University of Minnesota has done similar tracking of carp in several west metro area lakes)
- Identification of the key carp spawning locations within the system
  - Understanding of how other Lake Owasso fish populations may use the Central Park – West wetland (spawning, feeding, etc.)
- Collection of water quality grab samples in the Central Park – West wetland during the study period to estimate potential impacts of carp activity on water quality (total phosphorus and total suspended solids) (See discussion Section 8.1.1)

Because of the need for more detailed investigation into the scope of this project as well as the potential variability in the scope, estimated costs for this study have not been developed. However, potential partnerships with the University of Minnesota and the MDNR may be possible as there is significant interest in carp management in lakes, and there is currently research being conducted to better understand this invasive fish.

If the study of the fishery concludes that the activity of carp in the system is having a significant impact on the water quality of Lake Owasso and the Lake Owasso-Central Park West wetland – Bennett Lake system indicates that carp management may be an option, a typical management strategy would include the combination of the following key steps: elimination of reinfestation, suppressment of recruitment, and removal of adult carp (Sorenson, 2009). Removal and management of carp would require permitting and guidance from the MDNR.

Supressment of recruitment involves preventing the eggs from hatching or preventing the young from surviving. This can be achieved by preventing adult carp from spawning in nursery areas along with removal of adult carp. A single female carp can lay up to 2 million eggs during spawning (Sorensen, 2009). Elimination of reinfestation means "blocking" the movement of carp between waterbodies. Both the suppressment of recruitment and the elimination of reinfestation can be achieved through the use of fish barriers. Physical barriers and electric barriers have been used to control the movement of carp between water bodies. More recently, sonic barriers (using bubble curtains) are being studied and implemented to control carp movement.

Many electric fish barriers have been installed to control the movement of carp between water bodies. Although these barriers can be fully effective at preventing the movement of carp, their success is linked to the maintenance of the electrical current. As a result, automatic back-up generators are required to maintain the electric field during power outages. Also, a dropping fine screen is recommended should there be complete power failure. Electric barriers require a budget for monthly operation and maintenance costs, as they need to be constantly supplied with electricity. Current cost estimates for installations of electric fish barriers on two lakes in southern Minnesota ranged from $250,000 to $300,000. This cost includes equipment and installation but does not include the estimated monthly operation and maintenance costs.

The final step in carp management includes the harvesting of adult carp in the lakes. Carp harvesting has been performed on many lakes in the Twin Cities metropolitan area. It is important to note that carp harvesting, and its potential impact on the long term management of carp populations, may not always be an option for a lake (Sorensen, 2009). A study of the carp within the Lake Owasso system should provide a better understanding of the carp population as well as the potential to manage this species.

8.1.3 Sediment Core Collection and Analysis

Release of phosphorus from sediments within water bodies within the Lake Owasso watershed may contribute to the estimated internal phosphorus load from the watershed. Collection and analysis of sediment cores will help better understand the mobile phosphorus associated with the sediments in these waterbodies and their potential contribution to the phosphorus loads to Lake Owasso. Along with mobile phosphorus, the sediment cores will be analyzed for organic phosphorus and total iron. Additionally, the water quality monitoring proposed for these water bodies (see Section 8.1.1) will help determine reasons for the phosphorus release from sediment (e.g., Is the release the result of anoxic conditions along the sediments? Is the release of phosphorus as the result of pH conditions?).

The collection of 10 sediment cores is proposed for anytime after ice out (April). Cores would be collected in the following water bodies (# of cores proposed):

- Central Park – East (Dale Street) wetland (1)
- Central Park – West (County Road C) wetland (4)
- Bennett Lake (2)
- Charlie Pond System (3)

The estimated cost for the sediment cores collection and analysis is $7,900. See Appendix N for a more detailed breakdown of the cost estimate.

8.1.4 Water Quality Monitoring in Lake Owasso – Shallow Area

Although the deep areas of the lake strongly stratify, mixing and sediment resuspension are likely occurring in the shallow areas as the result of wind and motorboat activity. It is unclear what the potential mixing in the shallow areas of the lake has on the overall water quality observed in Lake Owasso. Therefore, additional monitoring in the shallow area of the lake is recommended to help understand the water quality and mixing dynamics in the shallow areas of Lake Owasso, Sampling should begin in May and continue through the end of September. Sampling should occur monthly (a minimum of 5 samples collected through the summer) should include the collection of samples at 1 meter depth increments, at a minimum sampling at the surface and along the bottom sediments. Monitoring should include analysis of the following parameters: total phosphorus, total dissolved phosphorus, Secchi depth, chlorophyll *a*, dissolved oxygen, temperature, pH, and specific conductivity.

This recommendation assumes that Ramsey County will collect the water quality samples at the shallow monitoring site, and that monitoring at Site 5401 (the north, deep basin) will be performed as part of Ramsey County's regular lake monitoring program. The estimated cost for water quality monitoring at a second site in Lake Owasso for one year, including field collection, laboratory analysis, and a brief technical memorandum discussing the laboratory results is expected to range from $1,800 to $2,800. See Appendix N for a more detailed breakdown of the cost estimate.

8.2 Structural BMP Recommendations

Several structural BMPs were evaluated as part of the feasibility analysis, including the implementation of NURP water quality treatment ponds, the implementation of regional infiltration BMPs as well as the development of extended detention in the bay on the southside of Lake Owasso. However, of the structural BMPs evaluated, the implementation of infiltration BMPs throughout the watershed appears to provide the most benefit to Lake Owasso water quality, as discussed in the following section.

8.2.1 Infiltration BMPs Incorporated in the Watershed

The watershed and in-lake water quality modeling of Lake Owasso has demonstrated that infiltration of stormwater runoff throughout the watershed can reduce the total phosphorus load to the lake and improve the overall water quality in Lake Owasso. Several potential sites for more regional infiltration BMPs were evaluated as part of the feasibility study. Though no single project would result in a dramatic improvement in water quality in Lake Owasso, the cumulative impact of infiltration BMPs distributed throughout the watershed can improve the overall lake water quality.

No specific infiltration projects are recommended at this time; however, we recommend that the GLWMO and the Cities of Roseville and Shoreview continue to promote the use of infiltration BMPs as opportunities associated with redevelopment and road reconstruction arise and where site conditions are conducive to infiltration.An excellent example of incorporating infiltration BMPs along with road reconstruction and other infrastructure improvements projects is the *Woodbridge Street Neighborhood Road Reconstruction Project* in the City of Shoreview. This project, to be completed during the summer of 2009, incorporates the use of pervious pavement on several streets in the Lake Owasso watershed on the eastside of the lake, including Woodbridge Street, Owasso Lane East, Jerrold Avenue, Edgewater Avenue, and Soo Street. As designed, the proposed stormwater management for the project will infiltrate stormwater runoff for storms up to the 10-year event and will eliminate a direct stormwater discharge to Lake Owasso. This project will provide runoff volume reduction and phosphorus load reduction in a portion of the watershed where runoff is currently untreated.

8.3 In-Lake BMP Recommendations

Several in-lake BMPs were evaluated as part of the feasibility study including the management of Curlyleaf pondweed in Lake Owasso as well as a whole-lake alum treatment to minimize release of phosphorus from the lake's bottom sediments. Because the treatment of Curlyleaf pondweed is estimated to have the most significant impact on Lake Owasso's water quality, it is the primary recommended in-lake water quality BMP.

8.3.1 Herbicide Treatment of Curlyleaf Pondweed

Curlyleaf pondweed can be managed by treatment with herbicide. Because Curlyleaf pondweed is such a significant portion of the phosphorus budget, it is the recommended management approach for

Lake Owasso. Herbicide treatment of Curlyleaf pondweed consists of annual spring herbicide treatment until this species is removed from Lake Owasso. Treatment would occur in late-April or early-May when the water temperature is approximately 55 to 60º F. Assuming normal plant growth conditions, treatment would be completed by the second week of May. Curlyleaf pondweed would be treated with the herbicide Endothall at a dose of approximately 1 mg/L. To remove this species from the lake, treatment would need to continue annually until Curlyleaf pondweed and viable turions are eliminated. Treatment would be expected to continue for four years, although some spot treatments could occur after this period to attain the project goal. The estimated total cost of the 4-year Curlyleaf pondweed management program is $649,000, including obtaining the treatment permit from the MDNR, treatment of the lake, as well as the monitoring and reporting that is required by the MDNR. Detailed cost estimates for the Curlyleaf pondweed treatment in Lake Owasso can be found in Appendix N.

It is also important to note that the management of Curlyleaf pondweed as described in this section is different than the macrophyte management that currently happens in Lake Owasso. Since this BMPs would reduce the amount of Curlyleaf pondweed in the spring and result in increased clarity, it is possible that native macrophytes will expand their range. Also, since the MDNR permit would be specifically for the management of Curlyleaf pondweed, it may not be possible to manage for other macrophytes later in the summer as is currently done.

8.3.1.1 Treatment Permit

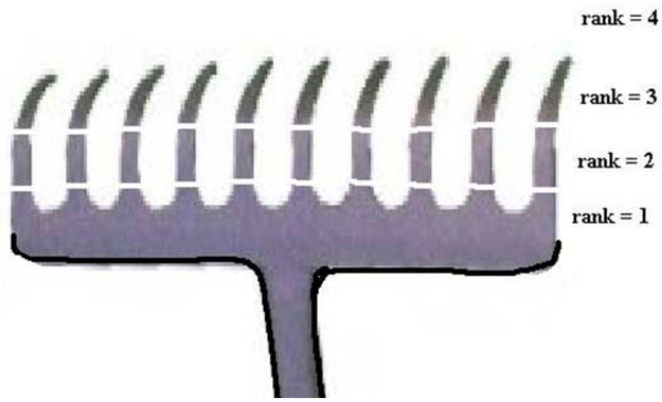
An aquatic plant management control permit must be obtained from the Minnesota Department of Natural Resources (MDNR) prior to herbicide treatment of Lake Owasso. In addition, since more than 15 percent of the lake would be treated with herbicide, a letter of variance must be obtained from the MDNR. To maximize the effectiveness of the treatment, lake home owners would be asked to sign a permission form granting GLWMO permission to treat the area from the property boundary to 150 feet out. Should any residents not choose to sign the permission form, the area from property boundary to 150 feet out would not be treated for these residents, but the rest of the lake would receive treatment.

The estimated cost to attain a letter of variance, treatment permit, and letters of permission to treat within 150 feet of riparian property boundaries is $6,500. The treatment permit would require monitoring to determine treatment effectiveness. Monitoring details are discussed in the following sections.

8.3.1.2 Aquatic Plant Monitoring

The MDNR requires a pretreatment aquatic plant survey be conducted after the water temperature reaches 48 degrees Fahrenheit. The primary purpose of the pre-treatment survey would be to determine Curlyleaf pondweed coverage prior to treatment. The survey would also determine native species present at the time of treatment. Two post treatment surveys would also be required to determine treatment effectiveness and treatment effects on the native plant community. Post treatment surveys would occur during June and August.

Point- intercept sampling methodology would be used for the pre-treatment and post treatment surveys. This method requires the creation of a regular grid of sample points over an orthorectified map or aerial photo of the lake. Each sample point would be numbered and downloaded into a GPS unit to allow for navigation to each sample point in the field. The MDNR would create the sample grid to use for the survey and provide it as an electronic file to the GLWMO. These sample points would be used for each sample date. The number of sample points and sampling grid spacing varies depending upon the size of the lake. In general, a minimum 125 sample points would be located in the littoral zone of the lake (i.e., shallow area of the lake where plants grow) and the maximum distance between adjacent points in the sample grid would be 300 feet. At each of these points, water depth would be measured with an electronic depth finder for depths greater than 8 feet, or depth stick for depths less than 8 feet. All plant taxa retrieved on a plant rake sampler or observed within one square meter of sample site would be recorded. The plant rake sampler would be constructed from a double-headed garden rake tied onto the end of a rope at least 25 feet long or attached to a 16-foot pole. Taxa of samples recovered on the rake or observed in the water would be identified to species level if possible. At each sample point the sample point number, the sample depth, the plant taxa observed, and the estimated abundance of each taxon would be recorded. The abundance of each species would be estimated using the following ranking system (See Figure 8-1):



- Rank 1 = < 1/3 of the rake head,
- Rank 2 = > 1/3 and < 2/3 of the rake head,
- Rank 3 = Plants filling >2/3 of the rake head,
- Rank 4 = Plants over the top of the rake

Figure 8-1 Macrophyte Monitoring Abundance Ranking

Surveyors would not have to sample in depths that are more than one inter-point distance deeper than the deepest vegetation, but they would sample at least one interval deeper than where vegetation was found.

A voucher specimen of each taxon identified would be collected, pressed and labeled with a standard herbarium label.

The following data would be reported to the MDNR:

- Frequency of occurrence of each species found in the survey and the combined frequency of: native submersed aquatic plants, all submersed aquatic plants, and all species found. Frequency of occurrence is calculated as the number of points in which a taxon (or combined taxa) occurred divided by the total number of points sampled (sample points that were deeper than the maximum depth where plants were found are excluded).

- Average number of submersed native species at each sample point and the standard error

- Average number of all submersed species at each sample point and the standard error

- Observed maximum depth of vegetation growth.

8.3.1.3 Biomass Monitoring

The MDNR requires, collection of biomass samples from 35 sample locations, during each sample event, to determine treatment effectiveness and the effect of treatment on the native plant community. Sample locations in the pre-treatment survey would be limited to locations containing Curlyleaf pondweed. The purpose of limiting pre-treatment sample locations to locations containing Curlyleaf pondweed would be to insure that the data adequately show treatment effectiveness. Biomass samples collected during the two post-treatment surveys would be collected from the same sample locations sampled during the pre-treatment survey. The pre-treatment and post treatment data would be compared to determine the reduction in Curlyleaf pondweed biomass and the increase in native plant biomass following treatment.

Samples would be collected using a rake attached to a pole. At each sample point, the rake would be lowered from the boat perpendicular to the bottom and then raised up to the water surface while slowly being twisted in a clockwise direction. Plant species from each sample would be separated into species and oven-dried to a constant weight.

8.3.1.4 Turion Monitoring

The MDNR also requires collection of turion samples from 35 sample locations in October to determine the potential for new Curlyleaf pondweed growth during the subsequent year. Sample stations would be the 35 biomass sample stations. Samples would be processed and the number of turions at each sample location would be determined.

8.3.1.5 Herbicide Residue Monitoring

Herbicide residue monitoring would determine herbicide concentration in the water column during a 21 day period after treatment. For management of Curlyleaf pondweed, a 48 hour contact time of Endothall at a concentration of 1.0 mg/L would be required for effective treatment. Herbicide residue monitoring at one and two days after treatment would measure herbicide concentration in the water column and determine whether the required contact time had been attained. Herbicide residue monitoring would also show the degradation rate of the herbicide. Knowing the degradation rate of the herbicide would be necessary to verify that the herbicide degraded prior to the growth of native vegetation and, hence, did not adversely impact the lake’s native community. Endothall is expected to degrade into carbon dioxide and water within 21 days after treatment.

Herbicide residue samples would be collected from 2 locations within Lake Owasso. The stations would be located at the south end of the lake as well as in the northern portion of the lake near the outflow. Samples would be collected at 1, 2, 7, 14, and 21 days after treatment. Sample collection would be at mid-depth.

8.3.1.6 Analysis and Reporting

Monitoring data would be analyzed and reported annually to the MDNR. The analysis and report would determine the degree of Curlyleaf pondweed control attained and confirm the positive or neutral effect of the herbicide treatment on the native plant community. The analysis would include the preparation of maps showing Curlyleaf pondweed coverage prior to and following each herbicide treatment. Analysis of the native plant community would include both an analysis of individual species and a community wide analysis. Specific analyses to be performed include frequency of occurrence and density (low, average, high) of individual species, diversity of the plant community, floristic quality index of the plant community (would determine the average quality of the plants comprising the community), percent open area, and percent similarity of the plant communities between sample events within each year and between years. Plant biomass would be compared between sample events to evaluate the decline in Curlyleaf pondweed and to evaluate the response of the native plant community to the treatment. Turion numbers would be evaluated to confirm an anticipated decrease in turions from the treatments. Herbicide residual monitoring data would be analyzed to confirm the correct application of the herbicide and to evaluate the herbicide degradation rate to confirm that the herbicide caused no harm to the native plant community. The data analysis and report would be submitted to the Minnesota DNR annually to confirm compliance with permit requirements.

8.3.1.7 Monitoring Cost Estimate

The estimated cost to complete the monitoring program, including aquatic plant, biomass, turion, and herbicide residue, is $183,700. The aquatic plant monitoring cost assumes the MDNR would require an aquatic plant survey of 150 sample points and biomass and turion sampling at 35 sample points. If the MDNR would require either more or fewer sample points, the cost would change accordingly.

8.3.2 Future In-Lake BMP: Alum Treatment

The recommended BMP to address internal loads in Lake Owasso is the management of Curlyleaf pondweed. The Curlyleaf pondweed management plan, if implemented, will occur over a four-year period. However, if water quality in Lake Owasso has not improved after the management of Curlyleaf pondweed to the desired levels (or does not meet the GLWMO goals and the MPCA deep lake criteria), an alum treatment of the lake should be reevaluated and considered. Modeling indicates that an alum treatment in Lake Owasso would improve the overall water quality in the lake, although not to the levels expected by the Curlyleaf pondweed management.

The estimated cost of a whole-lake alum treatment based on an alum dosing rate estimated by the results of the sediment core analysis is $198,000.

8.4 Nonstructural BMP Recommendations

It is quite difficult to effectively model the effects of nonstructural BMPs on lake water quality, but studies have shown that they are effective at reducing phosphorus loads. The results of this study have shown that existing wetlands and ponds will be effective at removing large diameter particles and the associated phosphorus from stormwater runoff after completion of proposed development. However, dissolved phosphorus and phosphorus associated with extremely small particles may not be effectively removed. Therefore, source control (reduction of particles and phosphorus deposited on site) will be important in the lakes watersheds in the future as development continues.

Examples of effective nonstructural BMPs that would be appropriate for the Lake Owasso watersheds include:

1. An evaluation of road salting practices in the Lake Owasso watershed is recommended. Also, storage of road salt in this area should be evaluated to determine whether unintended runoff from storage areas is occurring.
2. Continue the existing street sweeping program, including an early spring sweeping, a late fall sweeping, and additional sweepings as needed.
3. Continue public education programs to inform the residents of the Lake Owasso watershed of ways to reduce phosphorus loading through proper handling of yard fertilizers and wastes, pet wastes, soaps and detergents.
4. Encourage industrial/commercial areas to institute good housekeeping practices, including appropriate disposal of yard wastes, appropriate disposal of trash and debris, appropriate storage and handling of soil and gravel stockpiles.
5. Discourage the feeding of waterfowl at shoreline areas around Lake Owasso and upstream ponding areas. Waterfowl feces can add a significant amount of dissolved phosphorus to a lake or pond. Lake shorelines provide essential nesting and feeding habitat for some waterfowl. However, the habit of leaving bread scraps and other food for waterfowl encourages a large number to congregate and nest.
6. Encourage vegetated buffers between yards and the shore of Lake Owasso and upstream ponding areas. Vegetated buffers are effective at trapping suspended solids and nutrients

from runoff. Requiring/encouraging vegetated buffers between yards and the lake will reduce the amount of phosphorus from yard runoff, and will prevent shoreline erosion. Vegetated buffers also discourage waterfowl from nesting and feeding on yards adjacent to the lake.

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