# *Wirth Lake Excess Nutrients Total Maximum Daily Load Report*

***Prepared for Minnesota Pollution Control Agency***

***September 2010***

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# *Total Maximum Daily Load Report*

***Prepared for***
***Minnesota Pollution Control Agency***

***September 2010***

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# Wirth Lake
# Total Maximum Daily Load Report

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# Executive Summary

Wirth Lake is currently listed on the Minnesota Pollution Control Agency's (MPCA) 2008 303(d) Impaired Waters List due to excessive nutrients (phosphorus) and requires a Total Maximum Daily Load (TMDL) report. Wirth Lake (DNR ID 27-0037) has a surface area of 38 acres (15.4 hectares), a maximum depth of 26 feet (7.9 meters), and an estimated mean depth of 14 feet (4.3 meters). Wirth Lake is surrounded by significant wetland vegetation which provides excellent waterfowl habitat. The lake is bordered by parkland and open space areas, with Highway 55 to the north and Theodore Wirth Parkway to the west. The Wirth Lake watershed has a total area of 347 acres, largely consisting of low-density residential and park land uses. Stormwater from approximately 77 percent of the Wirth Lake watershed currently drains through some form of wet detention before it enters the lake.

Wirth Lake is an important recreational resource to residents of north Minneapolis and surrounding inner-ring suburbs and it is used extensively for swimming, fishing, non-motorized boating and aesthetic viewing. As noted in the Bassett Creek Watershed Management Commission (BCWMC) *Watershed Management Plan* (BCWMC WMP, 2004) the City of Golden Valley, the City of Minneapolis, the Minneapolis Park and Recreation Board (MPRB) and the BCWMC have been partners working to improve the water quality of Wirth Lake for several years. MPRB has worked on improving Wirth Lake for decades (MPRB, 2009). Wirth Lake is located within the North Central Hardwood Forest (NCHF) Ecoregion.

Table EX-1 summarizes the historical water quality information compared to the deep lake listing criteria. Because the causal water quality factor (TP) and one of the response factors (Chl *a*) exceed the Listing Criteria on average over the previous 10 years, Wirth Lake was listed as "Non-Supporting" on the 305(b) list and as "Impaired" on the 303(d) list (in 2002).

The TMDL report for the lake had a target start date of 2007 and a target completion date of 2012. The MPCA's projected schedule for TMDL completions, as indicated on Minnesota's 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the waterbody; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

**Table EX-1 Eutrophication Standards and Wirth Lake 10-Year Average Water Quality Parameters**

| Water Quality Parameter | MPCA Deep Lake Eutrophication Standards (NCHF Ecoregion) | Wirth Lake Historical (1992-2008) Growing Season Average | Wirth Lake 10-Year (1999-2008) Growing Season Average |
|---|---|---|---|
| Total Phosphorus (µg/L) | 40 | 55 | 41 |
| Chlorophyll *a* (µg/L) | 14 | 22 | 18 |
| Secchi disc (m) | 1.4 | 1.8 | 2.0 |

A significant source of background information for this TMDL report is contained in the BCWMC completed the *Wirth Lake Watershed and Lake Management Plan* (Barr Engineering Company, 1996).

The TMDL equation is defined as follows:

TMDL = Wasteload Allocation (WLA) + Load Allocation (LA) + Margin of Safety (MOS) + Reserve Capacity.

**For Wirth Lake, the Load Capacity using the NCHF standard as the endpoint is 99 pounds (lbs) of total phosphorus (TP) per year.**

The TMDL equation used to derive this Load Capacity for Wirth Lake is:

<u>Expressed as annual totals (based on 2005-06 water year):</u>

TMDL = 66 lbs. TP (WLA) + 26 lbs. TP (LA) + 7 lbs. TP (MOS) + 0 lbs. (Reserve Capacity) = 99 lbs per growing season

<u>Expressed in daily terms (based on 2005-06 water year):</u>

TMDL = 0.181 lbs/day (WLA) + 0.071 (LA) +0.019 (MOS) + 0 (Reserve Capacity) = 0.271 lbs per day, on average, over the water year

The wasteload allocation represents a 45% reduction in phosphorus load to Wirth Lake (Table EX-2). This will be achieved by eliminating Bassett Creek backflow from the upstream MS4s into Wirth Lake through the outlet under high creek flow events. The Load Allocation does not represent a change in the current total phosphorus load.

The reserve capacity for the lake is set at zero because the watershed is fully developed and no additional loading is expected from future redevelopment.

**Table EX-2 Wirth Lake Total Phosphorus Budgets and Wasteload and Load Allocations**

| Watershed TP Sources | Existing Annual TP Load (lbs/yr) | Annual TMDL Wasteload Allocation (WLA) (lbs/yr) | Daily TMDL Wasteload Allocation (WLA) (lbs/day) | Percent Reduction of Existing TP Load (Percent) |
|---|---|---|---|---|
| Direct Tributary Watershed MnDOT MS4 (#MS400170) | 28 | 28 | 0.077 | 0 |
| Direct Tributary Watershed Categorical MS4s (Hennepin County, Golden Valley and Minneapolis) | 38 | 38 | 0.104 | 0 |
| Bassett Creek Backflow MS4s (shown in Figure 6 & Table 4) | 55 | 0 | 0 | 100 |
| **Total Load Sources** | **121** | **66** | **0.181** | **45** |
| **Internal and Atmospheric Sources** | **Existing Annual TP Load (lbs/yr)** | **Annual TMDL Load Allocation (LA) (lbs/yr)** | **Daily TMDL Load Allocation (LA) (lbs/day)** | **Percent Reduction of Existing TP Load (Percent)** |
| Internal Sources | 20 | 20 | 0.055 | 0 |
| Atmospheric Sources | 6 | 6 | 0.016 | 0 |
| **Total Load Sources** | **26** | **26** | **0.071** | **0** |
| Margin of Safety (MOS) | NA | 7 | 0.019 | NA |
| **Overall Source Total** | **147** | **99** | **0.271** | **33** |

# 1.0 Introduction

Wirth Lake (DNR ID 27-0037) and most of its watershed is located in the City of Golden Valley (Figure 1), within the Upper Mississippi River Basin, Twin Cities Major Watershed HUC 07010206 and the North Central Hardwood Forest Ecoregion. The remaining portion of the watershed, south of the lake is in the City of Minneapolis and all of the shoreline around the lake is owned by the Minneapolis Park and Recreation Board (MPRB).

Wirth Lake is currently listed on the Minnesota Pollution Control Agency's (MPCA) 2008 303(d) Impaired Waters List due to excessive nutrients (phosphorus) and requires a Total Maximum Daily Load (TMDL) report. The lake was first listed on the MPCA's 303(d) list for aquatic recreation in 2002. The TMDL report for the lake had a target start date of 2007 and a target completion date of 2012. The MPCA's projected schedule for TMDL completions, as indicated on Minnesota's 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the waterbody; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

Wirth Lake is an important recreational resource to residents of north Minneapolis and surrounding inner-ring suburbs and it is used extensively for swimming, fishing, non-motorized boating and aesthetic viewing. As noted in the Bassett Creek Watershed Management Commission *Watershed Management Plan* (BCWMC WMP, 2004) the City of Golden Valley, the City of Minneapolis, the MPRB and the BCWMC have been partners working to improve the water quality of Wirth Lake for several years. MPRB has worked on improving Wirth Lake for decades (MPRB, 2009).

The BCWMC completed the *Wirth Lake Watershed and Lake Management Plan* (Barr Engineering Company, 1996) and the City of Minneapolis adopted a *Local Surface Water Management Plan* in 2006. The BCWMC and the City of Minneapolis entered into an agreement in 2005 to improve a stormwater quality treatment pond immediately west of the lake. That project was completed by the MPRB in the spring of 2006. In the mid 1990's the MPRB modified the outlet structure for the lake to minimize flood flows to the lake from

Bassett Creek, except for semi-rare backflow events. In 2002 the MPRB in cooperation with the Minnesota Department of Natural Resources installed an aeration system to prevent winter fish kills. As part of the 2006 renovation of the facilities at the swimming beach on the southeast corner of the lake, the MPRB constructed a stormwater treatment basin to treat stormwater runoff from the impervious surfaces at the beach. Current monitoring of Wirth Lake is being conducted by the MPRB.

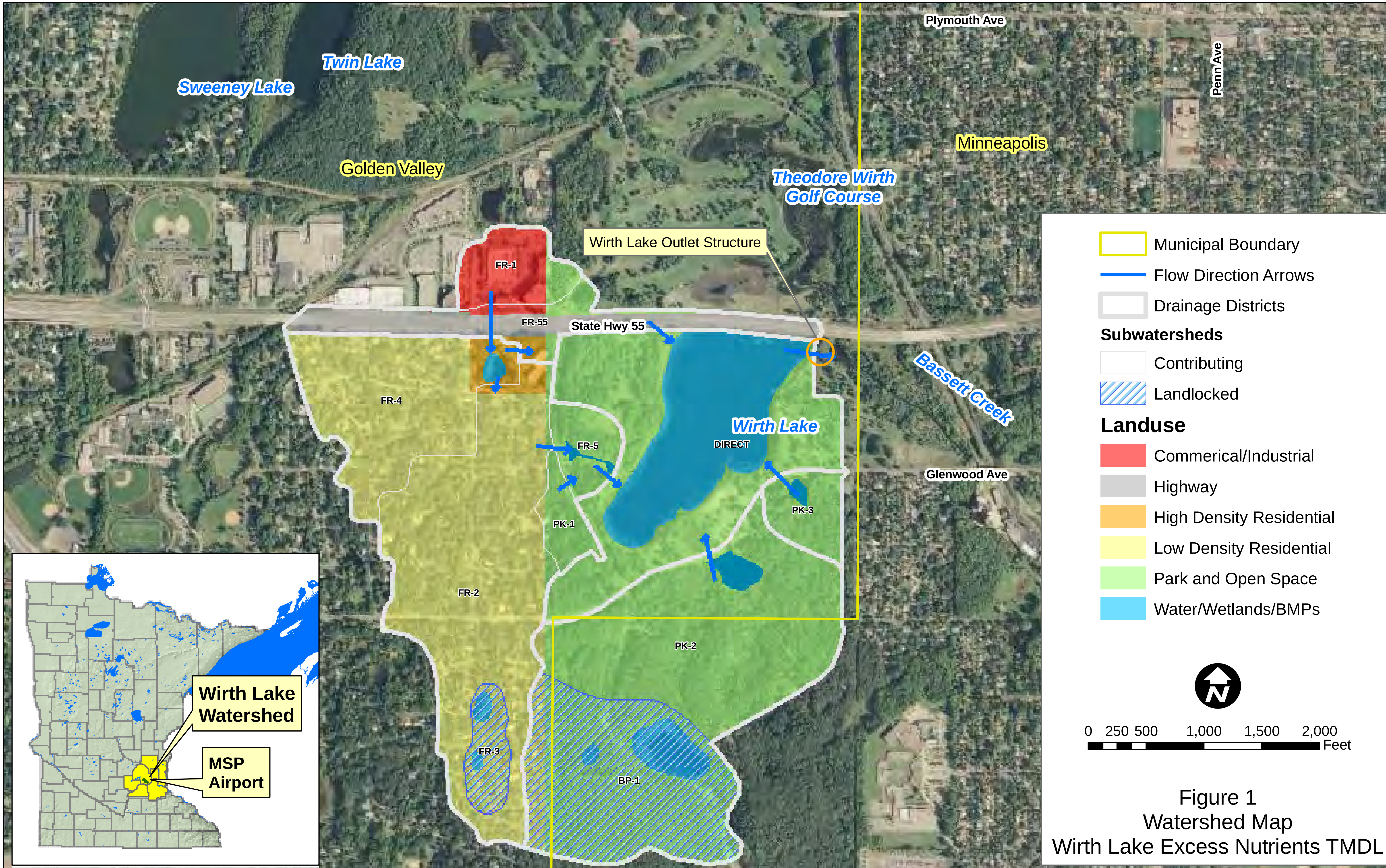


Figure 1
Watershed Map
Wirth Lake Excess Nutrients TMDL

# 2.0 Background Information

## 2.1 Applicable Water Quality Standards

Impaired waters are listed and reported to the citizens of Minnesota and to the EPA in the 305(b) report and the 303(d) list, named after relevant sections of the Clean Water Act. Assessment of waters for the 305(b) report identifies candidates for listing on the 303(d) list of impaired waters. The purpose of the 303(d) list is to identify impaired water bodies for which a plan will be developed to remedy the pollution problem(s) (the TMDL—this document).

The basis for assessing Minnesota lakes for impairment due to eutrophication includes the narrative water quality standard and assessment factors in Minnesota Rules 7050.0150. The MPCA has completed extensive planning and research efforts to develop quantitative lake eutrophication standards for lakes in different ecoregions of Minnesota that would result in achievement of the goals described by the narrative water quality standards. To be listed as impaired by the MPCA, the monitoring data must show that the standards for both total phosphorus (the causal factor) and either chlorophyll *a* or Secchi disc depth (the response factors) are not met (MPCA, 2007a). Wirth Lake was listed based on the deep lake eutrophication criteria for the NCHF ecoregion (Table 1).

**Table 1 MPCA Deep Lake Eutrophication Standards for Total Phosphorus, Chlorophyll *a* and Secchi Disc**

| 303(d) Classification | MPCA Deep Lake Eutrophication Standard |
|---|---|
| | North Central Hardwood Forest Ecoregion |
| Total Phosphorus (µg/L) | 40 |
| Chlorophyll-a (µg/L) | 14 |
| Secchi disc (m) | 1.4 |

Source: Minnesota Rule 7050.0222 Subp. 4. Class 2B Waters

## 2.2 General Lake Characteristics

Wirth Lake has a surface area of 38 acres (15.4 hectares), a maximum depth of 26 feet (7.9 meters), and an estimated mean depth of 14 feet (4.3 meters). Wirth Lake is surrounded by significant wetland vegetation which provides excellent waterfowl habitat. The lake is bordered by parkland and open space areas to the south and east, by Highway 55 to the north, and by Theodore Wirth Parkway to the west.

The Wirth Lake outlet is located in the northeast corner of the lake. A 8-foot wide by 4-foot high concrete box culvert, discharges water from Wirth Lake's main body directly into the main stem of Bassett Creek, separated by the 80-foot length of the culvert. Currently, there is 0.5 feet of sediment build-up inside the outlet culvert. The headwall of the culvert maintains the normal water elevation of Wirth Lake at approximately 818.0 feet. The water surface elevation of Bassett Creek under normal flow conditions is approximately one to two feet lower than the Wirth Lake outlet elevation. The 10- and 100-year Bassett Creek flood elevations are 820.4 and 821.5 feet, respectively, in the vicinity of the Wirth Lake outlet. Under existing conditions, bankfull flows (approximately 2-year frequency) in Bassett Creek would result in backflow from the creek into Wirth Lake. If the outlet structure were not in-place or was completely blocked, the low point for natural overflow between Wirth Lake and Bassett Creek would occur at a ground elevation of 824.2 feet.

## 2.3 General Watershed Characteristics

The Wirth Lake watershed has a total area of 347 acres (140 hectares) (excluding the landlocked areas). The watershed was separated into five "drainage districts" for this study—with four of the five districts representing distinct stormwater conveyances to the lake and the remaining district representing the direct subwatershed with diffuse runoff to the lake. Stormwater and phosphorus contributed to the lake from each drainage district was estimated with the P8 Urban Catchment Model. Stormwater from approximately 77 percent of the Wirth Lake watershed currently drains through some form of wet detention before it enters Wirth Lake. Figure 1 shows the subwatershed areas (where FR=France Avenue, PK=Park and BP=Birch Pond). Subwatersheds BP-1 and FR-3 are considered landlocked areas. Each of the five major drainage districts draining to the lake are described below:

**Highway 55 Drainage District**—This 25-acre drainage district is located north of the lake and contains a significant portion of the developed land within the Wirth Lake watershed (including subwatershed FR-55). The area is drained by four short storm sewers along the middle of the highway and a larger storm sewer which outlets to a drainage swale before discharging to Wirth Lake. Existing land use primarily consists of highway with some multi-family residential and parkland.

**France Avenue Drainage District**—This 159-acre drainage district is located west of the lake (including subwatersheds FR-1, FR-4, FR-2, PK-1 and FR-5). A storm sewer pipe conveys drainage from Subwatershed FR-1 under Highway 55 to a manhole adjacent to the pond in Subwatershed FR-4. Under high water level conditions in the Subwatershed FR-4 pond the manhole allows stormwater to be diverted into the Highway 55 (Subwatershed FR-55) drainage system. Existing land use consists primarily of single-family residential with some office space, undeveloped/parkland and multi-family residential. The Subwatershed FR-4 pond outlet, along with runoff from the remaining drainage district, is conveyed via the storm sewer network to a large, shallow wetland that discharges through a culvert to Wirth Lake. The France Avenue Drainage District includes approximately 51 percent of the total land area tributary to the lake. This contributes a significant portion of the stormwater runoff to Wirth Lake.

**Southeast Wirth Park Drainage District**—This 10-acre drainage district is located southeast of the lake (including subwatershed PK-3). Existing land use is entirely open space/parkland. Runoff from the area drains to a low area that, during larger storm events, would discharge to Wirth Lake through a culvert connected to an overflow catch basin structure.

**Wirth Lake Direct Drainage District**—This 83-acre drainage district consists of an area that drains directly to Wirth Lake without passing through a detention pond or conveyance system (including subwatershed DIRECT). Existing land use consists of open space/park development and water surface area. Presently, little opportunity for wet detention is available for stormwater runoff in this district.

**South Wirth Park Drainage District**—This 70-acre drainage district is located directly south of the lake (including subwatershed PK-2). Existing land use is almost entirely open space/park development. Runoff from the area drains to a large, shallow wetland that discharges through a culvert to Wirth Lake.

The Wirth Lake watershed is fully developed. Figure 1 shows the land use conditions within the watershed.

# 3.0 Wirth Lake Excess Nutrients Impairment

## 3.1 Surface Water Quality Conditions for Excess Nutrients

Historical (1992 to 2008) concentrations of total phosphorus (TP), chlorophyll *a* (Chl *a*) and Secchi disc depth (SD) for Wirth Lake were compiled for this analysis. For the purposes of this TMDL report, growing season mean (May through September) concentrations of TP, Chl *a* and SD were used to evaluate water quality. This growing season was chosen because it corresponds to the eutrophication criteria, it spans the months in which the lakes are most used by the public, and the months during which water quality is the most likely to suffer due to excessive nutrients leading to nuisance levels of algal growth (the critical condition).

Figure 2 shows the growing season means for TP, chl *a*, and SD measurements for Wirth Lake. The mean surface water concentrations of TP in Wirth Lake have ranged from 113 µg/L (1992) to 29 µg/L (2008) over the past 17 years, with a significantly improving trend in water quality. Table 2 shows that the mean growing season TP concentration over the last 10 years (1999 to 2008) is 41 µg/L and it is noted that the improving trend in water quality generally coincides with dryer than normal precipitation conditions, although the relationship between water year precipitation and growing season water quality in Wirth Lake has considerable variability relative to the TP standard.

The growing season average Chl *a* concentrations have ranged from 36 µg/L (1995) to 8 µg/L (2005) over the past 17 years, with a significantly improving trend in water quality. Table 2 shows that the mean growing season Chl *a* concentration over the last 10 years (1999-2008) is 18 µg/L.

**Table 2 Eutrophication Standards and Wirth Lake 10-Year Average Water Quality Parameters**

| Water Quality Parameter | MPCA Deep Lake Eutrophication Standards (NCHF Ecoregion) | Wirth Lake Historical (1992-2008) Growing Season Average | Wirth Lake 10-Year (1999-2008) Growing Season Average |
|---|---|---|---|
| Total Phosphorus (µg/L) | 40 | 55 | 41 |
| Chlorophyll *a* (µg/L) | 14 | 22 | 18 |
| Secchi disc (m) | 1.4 | 1.8 | 2.0 |

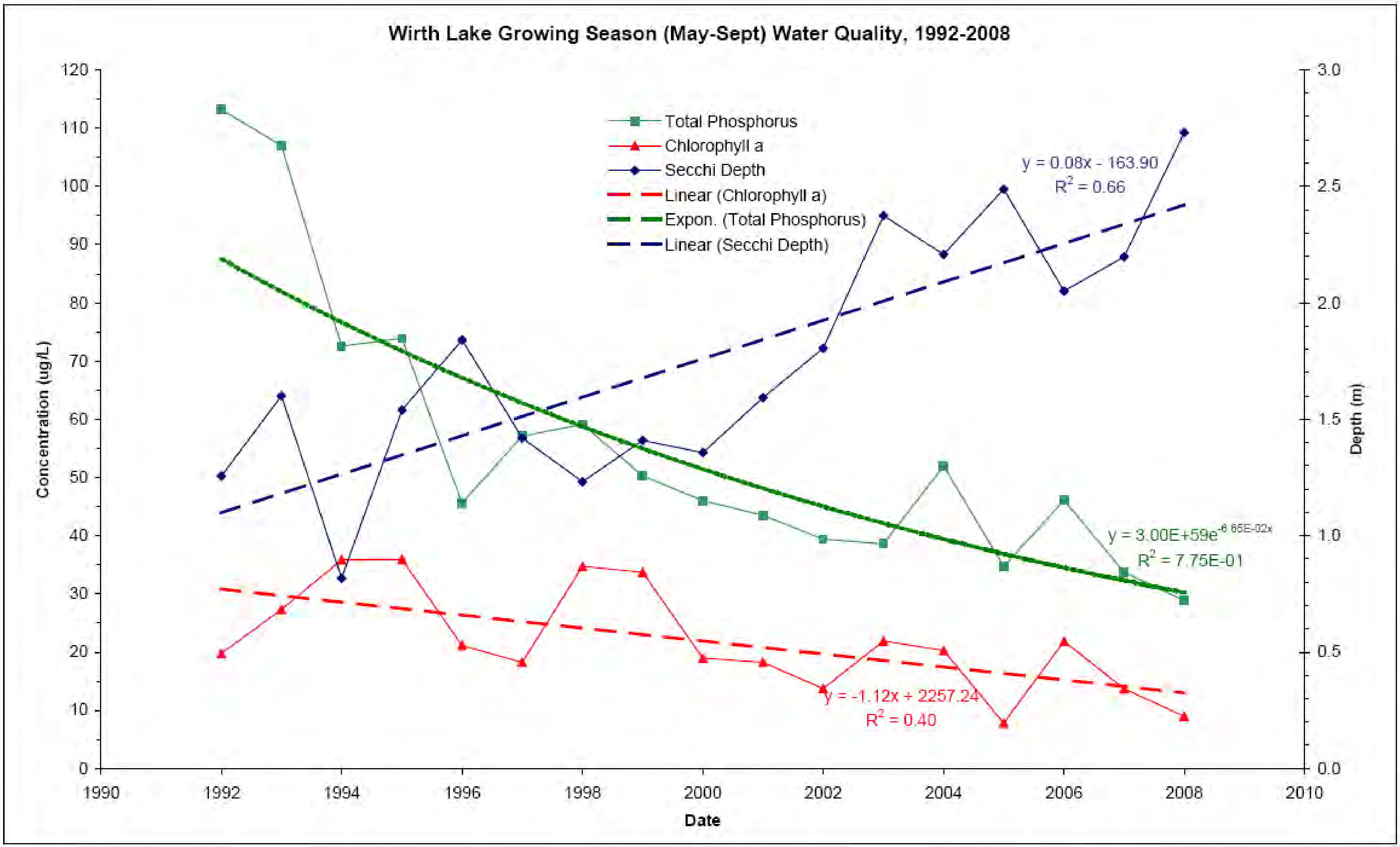


**Figure 2** **Wirth Lake Growing Season (May through September) Mean Secchi Depth, Total Phosphorus and Chlorophyll *a* Concentrations 1992-2008**

The growing season averages for SD have ranged from 0.8 meters (1994) to 2.7 meters (2008) over the past 17 years, with a significantly improving trend in water quality. Table 2 shows that the mean growing season SD transparency over the last 10 years (1999-2008) is 2.0 meters.

Figure 3 shows the average seasonal variability in water quality parameters throughout the 2008 growing season in Wirth Lake. Lower TP and Chl *a* concentrations are typically seen in the late spring and early summer, while higher concentrations typically occur later in the summer months (generally an indication of internal phosphorus loading). The SD data indicate that algal productivity increases significantly in mid- to late-summer.

Table 2 summarizes the historical water quality information compared to the deep lake listing criteria. Because the causal water quality factor (TP) and one of the response factors (Chl *a*) exceed the Listing Criteria on average over the previous 10 years, Wirth Lake was listed as “Non-Supporting” on the 305(b) list and as “Impaired” on the 303(d) list (in 2002).

## 3.2 TMDL Modeling Methodology

Since water year precipitation alone did not adequately explain the exceedances of the water quality standards, and backflow from Bassett Creek into Wirth Lake can also occur during dryer years, a more-detailed approach to water balance and water quality modeling was used to evaluate the extent and cause of the problem on a longer-term basis. The more detailed modeling confirmed that backflow events are the primary contributor to the impaired condition and provided the means to estimate TP sources to Wirth Lake and the resultant water quality. Water balance and water quality modeling for this TMDL included:

- A P8 stormwater runoff model (P8 Urban Catchment Model; IEP, Inc., 1990) used to simulate the estimated water and TP loads on a daily basis from the watershed

- Incorporation of lake level data and monitoring data (flow and nutrients) for backflow from Bassett Creek to evaluate the Wirth Lake water and phosphorus balances during the calibration and validation time periods

- BATHTUB in-lake mass balance modeling that incorporated the water and TP loads from all potential sources and generated the resultant in-lake TP concentration.

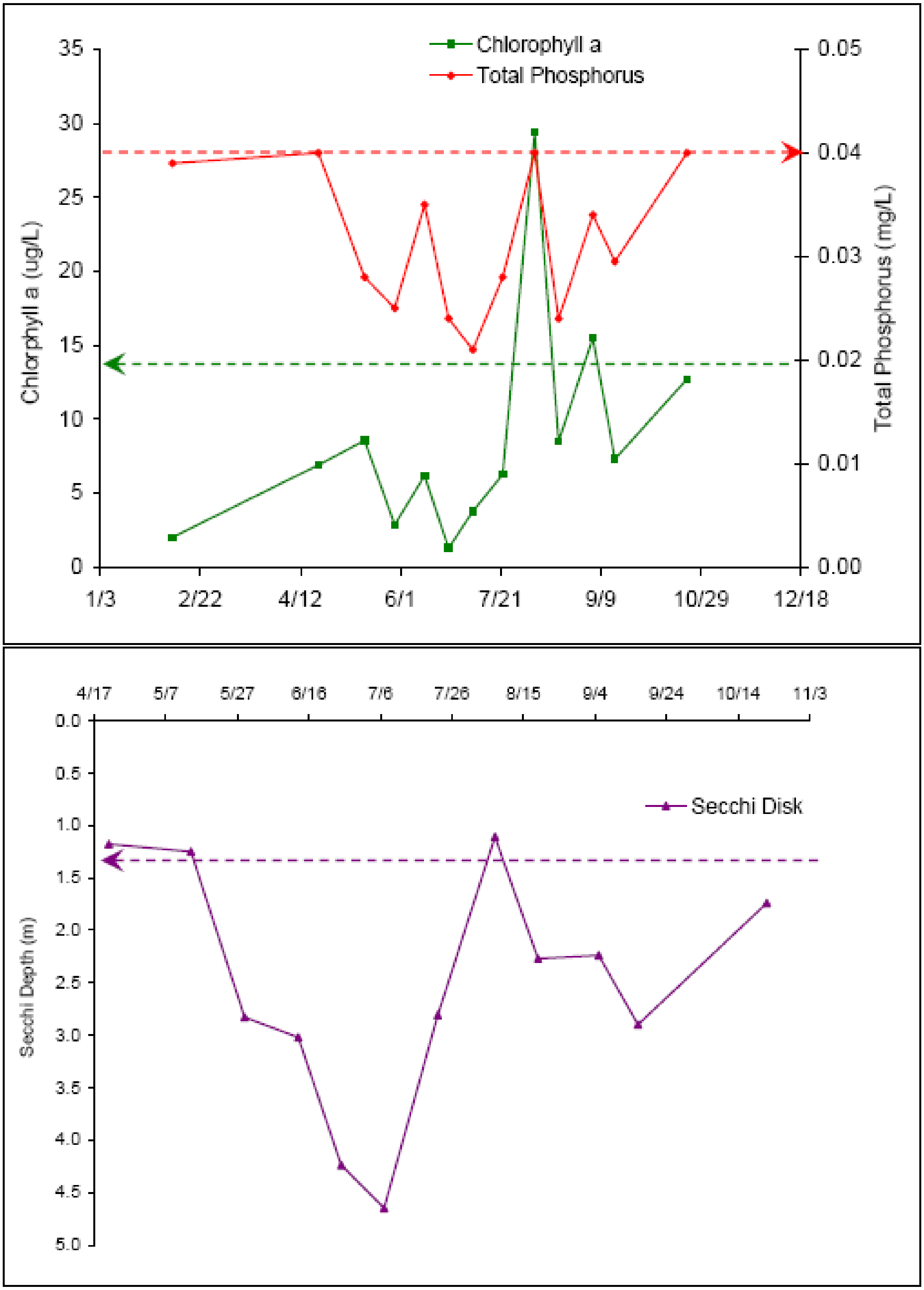


**Figure 3 Wirth Lake Seasonal Water Quality (2008)**

The P8 Urban Catchment Model, Bassett Creek monitoring data, and the in-lake water and phosphorus mass balance modeling are described in more detail in the following sections.

### 3.2.1 P8 Urban Catchment Model

P8 is a useful diagnostic tool for evaluating and designing watershed improvements and BMPs because it can estimate the treatment effect of several different kinds of potential BMPs. P8 tracks stormwater runoff as it carries phosphorus across watersheds and incorporates the treatment effect of detention ponds, infiltration basins, flow splitters, etc. on the TP loads that ultimately reach downstream water bodies. P8 accounts for phosphorus attached to a range of particulate sizes, each with their own settling velocity, tracking their removal accordingly. One limitation of using P8 for this study was that stormwater runoff monitoring data was not available for calibration of the modeling. As a result, the default inputs were maintained for the P8 modeling, with the remaining assumptions fully described in this section.

P8 also uses long-term climatic data so that watershed runoff and BMPs can be evaluated for varying hydrologic conditions. In this study, the P8 model (Version 3.4) was updated from the previous study (Barr Engineering Company, 1996) and used to generate runoff patterns resulting from storm events in the watershed for the 2005-06 (calibration) and 2006-07 (validation) water years (October 1st—September 30). Daily runoff volumes and phosphorus loads were estimated, based on the default watershed and BMP input parameters with directly and indirectly connected impervious percentage estimates for each watershed land use type. No watershed monitoring data was available to calibrate the P8 Model for this study, but the runoff volumes were checked by developing a water balance for Wirth Lake and comparing predicted and observed lake levels. Key input parameters used in the P8 model for the watershed included:

- Daily temperature and hourly precipitation, obtained from the Metropolitan Council's Bassett Creek Watershed Outlet Monitoring Program [WOMP] station for the 2005 through 2007 water years, wherever rainfall data were available; Minneapolis-St. Paul (MSP) airport data was used to supplement missing time periods as indicated in Appendix A

- Drainage area information: size, impervious (both directly and indirectly connected) area percentage estimates by land use type, as follows:

| Land Use | Directly Connected % | Indirectly Connected % |
|---|---|---|
| Open Space | 4 | 1 |
| Commercial/Industrial | 80 | 5 |
| Low Density Residential | 25 | 10 |
| High Density Residential | 20 | 20 |
| Highway | 80 | 0 |

- Existing BMP characteristics (normal and flood pool pond surface areas and volumes, outlet and flow splitter characteristics), with BMP pollutant removal only attributed to, and estimated for, practices that have permanent pool storage volumes

### 3.2.2 Water and Phosphorus Mass Balance Modeling

#### 3.2.2.1 Water Balance

Water enters Wirth Lake from watershed runoff, direct precipitation, groundwater and backflow from Bassett Creek during high discharge events. Evaporation, groundwater and outlet outflow represent potential components of lake discharge. Watershed inflow and evaporation estimates from the P8 modeling, along with daily direct precipitation inputs (included in Appendix A and discussed in Section 3.2.1), were combined in a spreadsheet with lake outflow and volume estimates to develop daily water balance calculations for Wirth Lake. The difference between the water balance predicted and actual lake levels (based on observations compiled by the MPRB for the calibration and validation time period) was optimized to determine the net groundwater flux for the lake.

Daily evaporation estimates from the P8 modeling were multiplied by a pan evaporation coefficient of 0.75 to determine the daily volume of water lost from the lake surface area. Lake water volume estimates at various stages were determined from the Minnesota Department of Natural Resources lake bathymetry data. Daily lake outflow rates and volumes were estimated using a weir equation (with a weir length of 8 feet and discharge coefficient of 3.3), based on the difference between the predicted lake level and the outlet elevation (818.0 feet).

#### 3.2.2.2 BATHTUB In-Lake Modeling

Phosphorus enters the lakes from watershed runoff, atmospheric deposition, and sediment release. The latter is referred to as "internal loading" and it may be a significant source of phosphorus in lakes that have a history of high phosphorus loads from their watershed. Phosphorus released or resuspended from the sediment, by macrophytes and/or benthic fish during the summer months builds up in the bottom water and can be entrained in the epilimnion whenever the thermocline drops and/or the lake mixes. This process can occur in both shallow and deep lakes.

Simple empirical eutrophication models, such as those available for use in BATHTUB (Walker, 2004), can be used to reconcile phosphorus loadings from a watershed with the phosphorus concentrations observed in the lake. Most of the empirical phosphorus models assume that the lake to be modeled is well-mixed, spatially, meaning that the phosphorus concentrations in the lake are uniform across the surface of the lake regardless of the locations of the major river and stream inlet locations. The primary strengths of using BATHTUB are that it can quickly be used to evaluate multiple empirical equations for their fit to the growing season observations, at a time scale that is consistent with the water quality standard, and the model complexity corresponds well with the available data and level of detail for Wirth Lake. A potential weakness is that it does not explicitly model lake hydrodynamics, including internal loading and entrainment of bottom waters, and this may represent a source of variability in comparing future monitoring and modeling data.

As previously described, watershed phosphorus loads were estimated with the P8 model, and were then used with the observed in-lake data in BATHTUB (Version 6.1) to determine which phosphorus sedimentation model provided the best fit to the average observed phosphorus concentration during the 2005-06 water year. The 2005-06 water year was chosen for this because it represented a current growing season that was likely impacted by a backflow event from Bassett Creek, and was intended to be the climate year used to evaluate the proposed lake improvement options for the lakes. The Wirth Lake BATHTUB model was calibrated using 2005-06 water year climatic and water quantity and quality data and validated with data from the 2006-07 water year. The 2006-07 water year was chosen for validation because it represented a year where backflow from Bassett Creek did not occur. Internal loading of phosphorus was adjusted such that the predicted total phosphorus concentrations matched the observed total phosphorus concentrations after accounting for the flow volume (determined from the water balance computations) and associated nutrient load for backflow from Bassett Creek. The Metropolitan Council's Bassett Creek WOMP station (located less than one mile downstream of the Wirth Lake outlet) monitoring data was used to determine the phosphorus concentration in the creek during backflow events. The phosphorus load from atmospheric deposition was calculated by multiplying the lake surface area by a loading rate of 0.15 lbs/acre/year, which is equivalent to the average year deposition rate for the Upper Mississippi River Basin reported by Barr (2004).

The 2006 observed average summer total phosphorus concentration was 46 µg/L. After calibration, the model was utilized to estimate the reduction in phosphorus loading necessary to achieve a mean growing season total phosphorus concentration of 38 µg/L and ensure compliance with the total phosphorus criteria for the NCHF Ecoregion.

## 3.3 Modeling Results

Figure 4 shows the historical lake levels for Wirth Lake compiled by the MPRB along with the estimated Bassett Creek flood levels at the Wirth Lake outlet for various return periods. Comparing the Wirth Lake phosphorus concentrations shown in Figure 2 with the lake levels shown in Figure 4 indicates that the higher growing season mean phosphorus concentrations observed during the early to mid-1990s coincide with higher lake levels and high lake level fluctuations. Figure 4 shows that since 1997, the frequency and magnitude of the lake level fluctuations have diminished significantly, which coincides with the improving water quality trends shown in Figure 2. The recent lake level record indicates that one two-foot increase in lake level occurred at the end of 2005, while the lake level has since been maintained near the outlet level. As a result, data from 2005 through 2007 were used to calibrate and validate the modeling and determine phosphorus loads to the lake. The water year was used for each analysis running from October 1 through September 30, but only the growing season is used for comparing lake water quality to the standard.

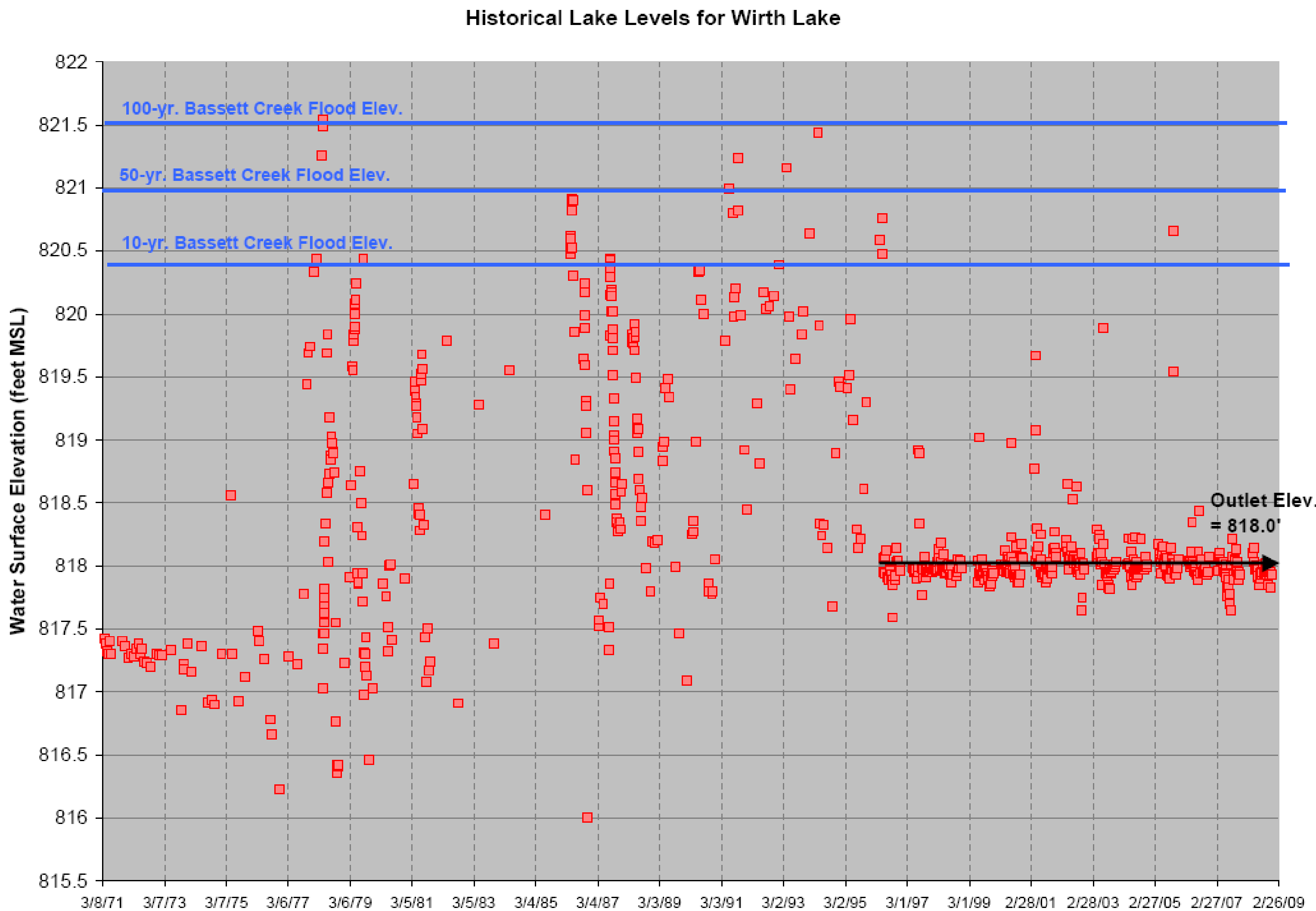


**Figure 4 Historical Lake Levels for Wirth Lake**

### 3.3.1 Lake Water Quantity/Quality Modeling

As previously discussed, watershed inflow estimates from P8 and direct precipitation were combined in a spreadsheet with lake outflow and volume estimates to develop daily water balance calculations for Wirth Lake. With the exception of a significant runoff event on October 5-6, 2005, Figure 5 shows good agreement between the predicted lake levels and the observations compiled by the MPRB for most of the calibration and validation time periods. A net groundwater flux of zero (groundwater inflow equals groundwater outflow) resulted in the best agreement between the predicted and observed lake levels in the water balance modeling. The observed lake levels on October 5-6, 2005 were at least one to two feet higher than the predicted water balance lake levels, indicating that it was not possible to generate enough runoff from the direct tributary watershed to Wirth Lake to account for the difference. The available monitoring data from the Bassett Creek WOMP station (location shown in Figure 6) indicated that the flow rate in the creek on October 5-6 ranged from approximately 400-450 cfs, which according to Figure 4, would coincide with the 10-year recurrence interval for flow in Bassett Creek and the creek stage would correspond well with the observed lake levels shown in Figure 5. Normally, Bassett Creek baseflow rates are approximately 10-20 cfs.

As a result, the water balance modeling was used to determine that a volume of 95.3 acre-feet of backflow from Bassett Creek had occurred on October 5-6, 2005, based on the difference between the predicted and observed Wirth Lake levels. The water balance modeling was then used to estimate that the subsequent outflow volume from Wirth Lake during Bassett Creek flow recession was 99.4 acre-feet. The Bassett Creek WOMP station monitoring data included a flow-weighted sample collected during October 5-6, 2005 that had a TP analysis result of 324 μg/L. Prior to this runoff event, the Wirth Lake surface water TP concentration was 35 μg/L on September 27, 2005. The net mass of phosphorus added to Wirth Lake from this Bassett Creek backflow event was estimated by initially estimating the fully mixed TP concentration in the lake immediately before the creek flow recession and then subtracting the direct watershed inflow and lake outflow mass associated with creek flow recession. This was done by combining the P8 model event loading with the respective starting lake and stream inflow volumes and their associated TP concentrations, and then subtracting the volume-weighted outflow phosphorus mass after the lake would have become fully mixed. The fully mixed Wirth Lake TP concentration resulting from the creek backflow was estimated to be 108 µg/L and the net mass of phosphorus added to Wirth Lake from the creek backflow, alone, was 55 lbs.

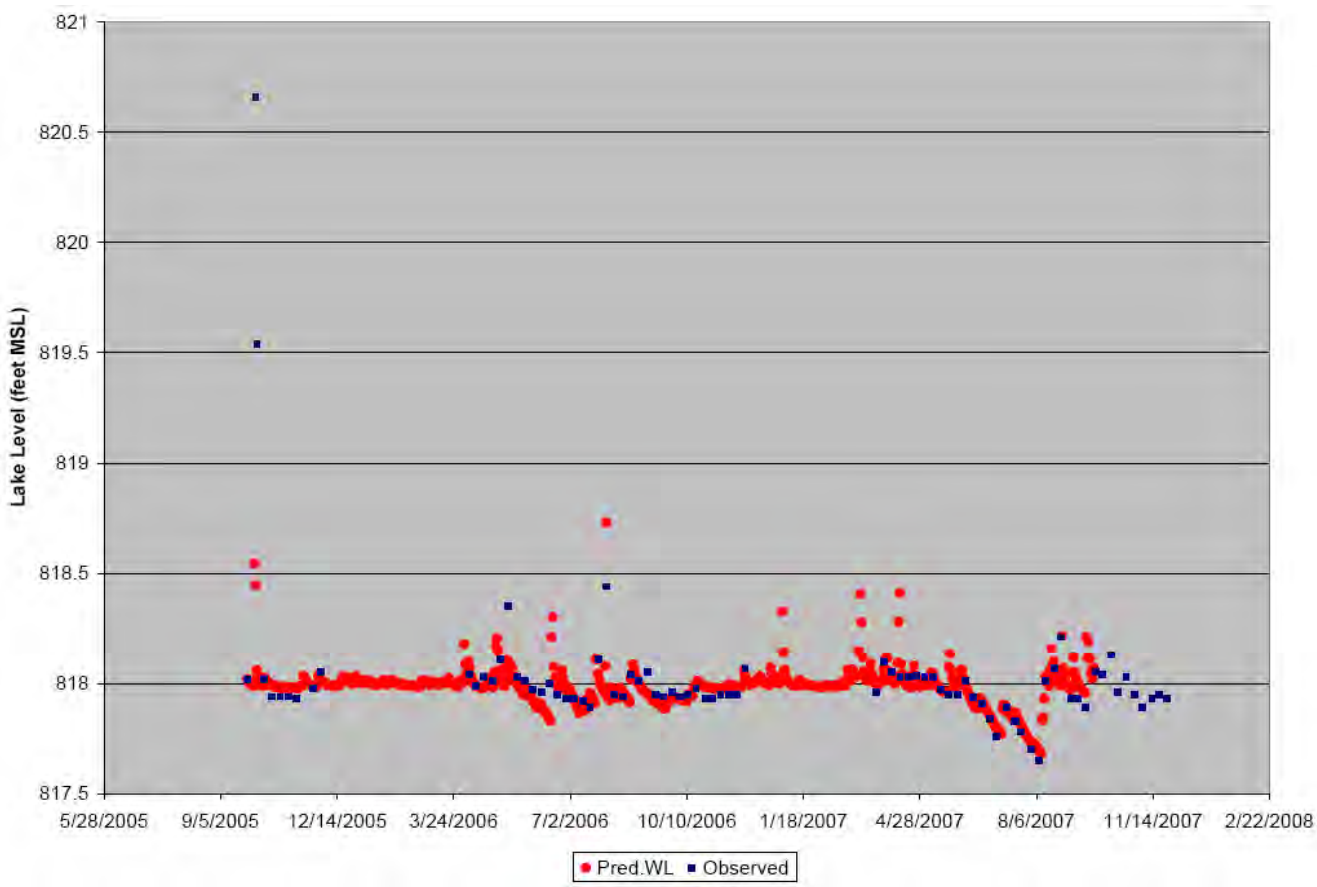


**Figure 5 Wirth Lake Water Balance Calibration**

As previously described, the P8 model watershed and creek backflow phosphorus loads were used with the observed in-lake data in BATHTUB to determine which phosphorus sedimentation model provided the best fit to the average observed phosphorus concentration during the 2005-06 water year. The phosphorus contribution from the net groundwater flux is accounted for in the internal loading estimates in BATHTUB. The BATHTUB model calibrated for phosphorus was used to determine the best models for predicting the observed chlorophyll-a concentration and Secchi disc transparency. The calibrated BATHTUB model was then validated by using it for the 2006-07 water year and comparing the result with the in-lake water quality observations.

Table 3 compares the in-lake water quality observations with the BATHTUB model results for the calibration and validation time periods. The calibrated version of the BATHTUB model was then used to predict how the lake water quality would change if the Wirth Lake outlet were configured in a way that would completely prevent backflow from Bassett Creek. Table 3 shows that the resulting in-lake TP concentration for this improvement option would drop from 46 to 38 µg/L and both TP and SD would meet the NCHF ecoregion eutrophication criteria for Wirth Lake.

**Table 3 Results of Wirth Lake Water Quality Modeling**

| Water Quality Parameter | 2005-06 Water Year | | | 2006-07 Water Year | |
|---|---|---|---|---|---|
| | Observed | Calibrated | Calibrated w/o Creek Backflow | Observed | Validated |
| Total Phosphorus (µg/L) | 46 | 46 | 38 | 34 | 36 |
| Chlorophyll *a* (µg/L) | 22 | 21 | 17 | 14 | 15 |
| Secchi disc (m) | 2.1 | 1.6 | 2.0 | 2.2 | 2.2 |

### 3.3.2 Phosphorus Sources and Contributions

Table 4 shows the relative contributions of phosphorus to Wirth Lake, during 2005-06, from different sources based on the modeling detailed in Section 3.3.1. During the 2006 growing season, internal sources of phosphorus contributed 14% of the total phosphorus load to Wirth Lake. Bassett Creek backflow from the upstream MS4s (see Figure 6) represented 37% of the annual total phosphorus load. Watershed runoff loading from the direct tributary watershed contributed 45% of the total phosphorus load to the lake. Atmospheric deposition contributed 4% of the phosphorus load to the lake.

**Table 4 Existing Wirth Lake Phosphorus Budget**

| Source | Total Phosphorus Load, 2005-06 Water Year (lbs) |
|---|---|
| Direct Tributary Watershed (MS4s include MNDOT, Hennepin County, and the Cities of Golden Valley and Minneapolis [see Figure 6]) | 66 |
| Bassett Creek Backflow (upstream MS4s include MNDOT, Hennepin County, and the Cities of Plymouth, Medina, Minnetonka, Medicine Lake, New Hope, Crystal, Robbinsdale, St. Louis Park, Golden Valley and Minneapolis [shown in Figure 6]) | 55 |
| Atmospheric Deposition | 6 |
| Internal Load | 20 |
| Total Load | 147 |

## 3.4 Methodology for Load Allocations, Wasteload Allocations and Margin of Safety

A TMDL is defined as follows (EPA 1999):

$$\text{TMDL} = \text{WLA} + \text{LA} + \text{MOS} + \text{Reserve Capacity}$$

Where:

| | | |
|---|---|---|
| WLA | = | Wasteload Allocation to Point Sources |
| LA | = | Load Allocation to NonPoint Sources |
| MOS | = | Margin of Safety |
| Reserve Capacity | = | Load set aside for future allocations from growth or changes |

This section will define each of the terms in this equation for Wirth Lake and will discuss seasonal variation and reasonable assurances for the TMDL.

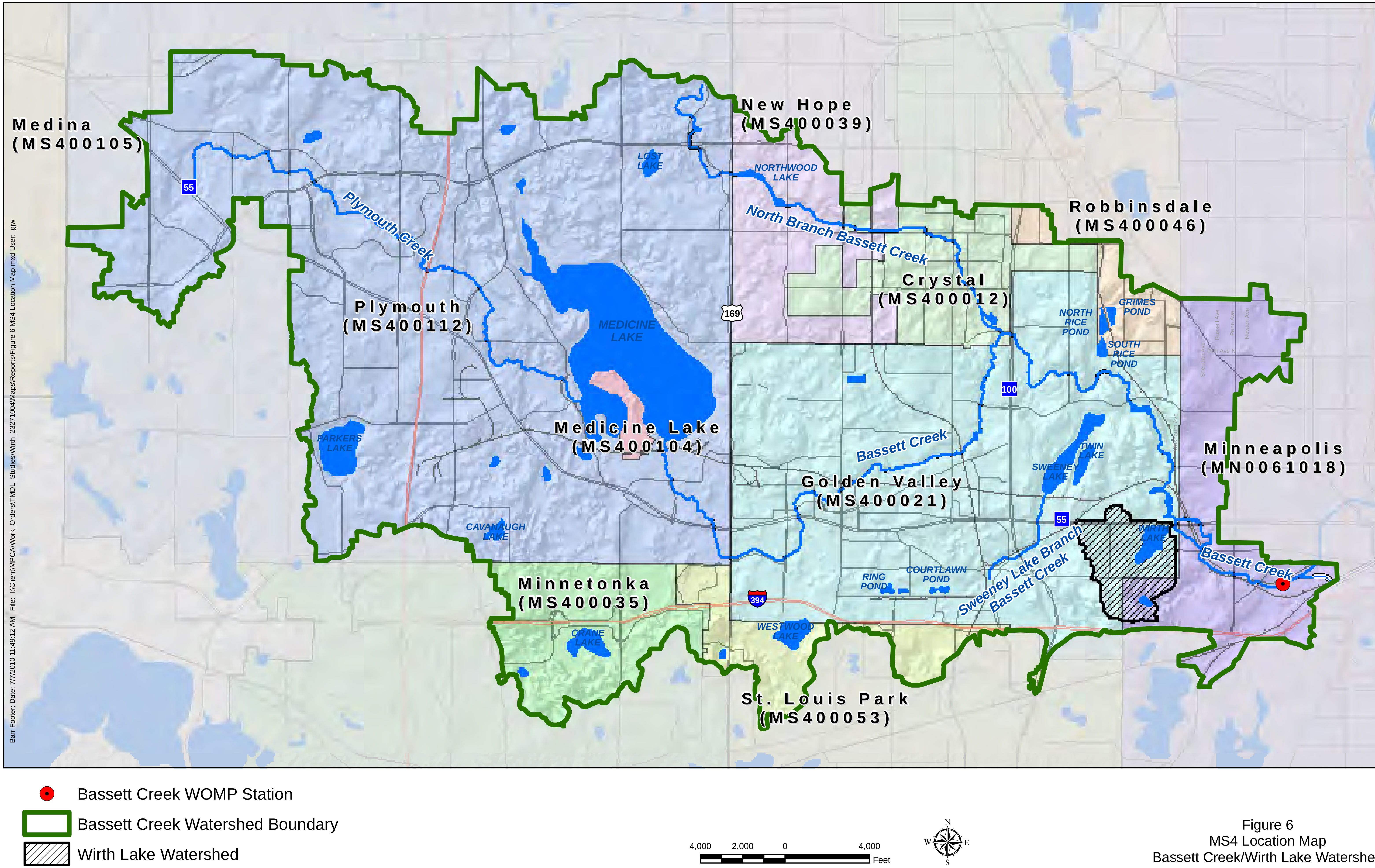


Figure 6
MS4 Location Map
Bassett Creek/Wirth Lake Watershed

Of the two years modeled in this study, the one resulting in the critical condition for water quality in the lake was the 2005-06 water year (the growing season of 2006). During the 2005-06 water year, the watershed phosphorus load, internal load and Bassett Creek backflow phosphorus combined to produce higher growing season, in-lake phosphorus concentrations in the lake compared with 2007 (when creek backflow would not have occurred). The allocations presented in this TMDL are based on the management scenarios required to bring the growing season average TP concentration to 40 μg/L (NCHF ecoregion criteria) during the climactic conditions observed during the 2005-06 water year. Also, because it is a year of average precipitation, it serves as a fair baseline to set allocations. It is reasonable to expect that, on average, phosphorus sources in the watershed will have existing watershed TP loads consistent with those modeled during the growing season of 2006.

### 3.4.1 Wasteload Allocations

Wirth Lake and its direct tributary watershed are entirely located within MS4 regulated communities or regulated conveyance systems. Permitted industrial and construction stormwater sources do not appear to represent a phosphorus loading concern in this watershed because of the relatively small drainage areas that they represent, and are expected to represent in the future, in the fully developed watershed.

For the purpose of the TMDL allocations, industrial and construction stormwater have been combined with a categorical WLA for the cities of Golden Valley and Minneapolis and Hennepin County in the direct tributary watershed. A categorical WLA for these sources of runoff is justified because the drainage includes a similar mix of land use and/or municipal operations. The remainder of the TMDL WLA was assigned to MNDOT in the direct tributary watershed. As shown in Table 4, existing backflow from Bassett Creek includes upstream MS4 areas that includes drainage from MNDOT, Hennepin County, and the Cities of Plymouth, Medina, Minnetonka, Medicine Lake, New Hope, Crystal, Robbinsdale, St. Louis Park, Golden Valley and Minneapolis. No allocation has been included in the TMDL for this Bassett Creek drainage, as allowable backflow into Wirth Lake under any circumstance. Appendix B provides documentation that modifying the Wirth Lake outlet to prevent backflow from Bassett Creek would not adversely impact the upstream or downstream flood levels in the creek in the vicinity of the lake during various flood events.

### 3.4.2 Load Allocations to Nonpoint Sources

The load allocation for Wirth Lake is attributable to the internal and atmospheric loads of phosphorus to the lake. Atmospheric phosphorus loads were estimated assuming a 0.15 lbs/acre/year loading rate. The amount of internal phosphorus loading was a calibration parameter used in the BATHTUB modeling described in Section 3.3.

As shown in Table 4, the atmospheric and internal loading combined for 26 lbs. of the total phosphorus loading during the 2005-06 water year. No reduction in atmospheric or internal loading was assumed in setting the load allocations to ensure that the NCHF criteria will be met for the TMDL.

### 3.4.3 Margin of Safety

Under Section 303(d) of the Clean Water Act, a margin of safety is required as part of a TMDL. The MOS accounts for the uncertainty that the allocations set in the TMDL will result in the water body meeting the water quality standard. As shown in Table 3, eliminating the Bassett Creek backflow is expected to reduce the in-lake phosphorus concentration to 38 µg/L, which is 5 percent lower than the 40 µg/L TP criteria applicable to Wirth Lake. Thus, an explicit MOS of 5 percent of the total loading capacity was used to account for uncertainty in the TMDL allocation process. There is a low level of uncertainty expected in setting the TMDL allocations for this watershed due to the extensive long-term monitoring that has been completed. In addition, the calibration/validation process used in this study also minimized the errors associated with erroneous assumptions or model error, and a recent year with high overall loading and in-lake phosphorus levels was used for setting the allocations (2005-06 water year).

### 3.4.4 Reserve Capacity

Because significant development is not expected in the watershed areas in this study into the future, existing conditions represents ultimate land use conditions for setting the allocations for Wirth Lake and no reserve capacity has been applied to the TMDL.

## 3.5 Phosphorus TMDL Allocations for Wirth Lake

The phosphorus TMDL allocations for Wirth Lake were developed to the meet the applicable deep lake eutrophication criteria. Allocations were set so that the lake met the total phosphorus criterion for the NCHF ecoregion. In addition, the Secchi disc transparency criterion of 1.4 meters will be met with the TMDL allocations. For Wirth Lake, the 2005-06 water year represented the critical condition with respect to phosphorus loading and resulting growing season mean total phosphorus concentration in the water column. The annual duration of 365 days was used to determine the daily load and wasteload allocations of phosphorus for the lake (Table 5).

## 3.6 Seasonal Variation

Phosphorus concentrations in the lake vary significantly during the growing season, generally peaking in August. The TMDL guideline for total phosphorus is defined as the growing season (May or June through September) mean concentration (MPCA, 2007b). Accordingly, water quality scenarios (under different management options) were evaluated in terms of the mean growing season total phosphorus (mid-May through September), when the critical condition for the lake occurs.

**Table 5 Wirth Lake Total Phosphorus Budgets and Wasteload and Load Allocations**

| Watershed TP Sources | Existing Annual TP Load (lbs/yr) | Annual TMDL Wasteload Allocation (WLA) (lbs/yr) | Daily TMDL Wasteload Allocation (WLA) (lbs/day) | Percent Reduction of Existing TP Load (Percent) |
|---|---|---|---|---|
| Direct Tributary Watershed MnDOT MS4 (#MS400170) | 28 | 28 | 0.077 | 0 |
| Direct Tributary Watershed Categorical MS4s (Hennepin County, Golden Valley and Minneapolis) | 38 | 38 | 0.104 | 0 |
| Bassett Creek Backflow MS4s (shown in Figure 6 & Table 4) | 55 | 0 | 0 | 100 |
| **Total Load Sources** | **121** | **66** | **0.181** | **45** |
| **Internal and Atmospheric Sources** | **Existing Annual TP Load (lbs/yr)** | **Annual TMDL Load Allocation (LA) (lbs/yr)** | **Daily TMDL Load Allocation (LA) (lbs/day)** | **Percent Reduction of Existing TP Load (Percent)** |
| Internal Sources | 20 | 20 | 0.055 | 0 |
| Atmospheric Sources | 6 | 6 | 0.016 | 0 |
| **Total Load Sources** | **26** | **26** | **0.071** | **0** |
| Margin of Safety (MOS) | NA | 7 | 0.019 | NA |
| **Overall Source Total** | **147** | **99** | **0.271** | **33** |

# 4.0 Monitoring Plan to Track TMDL Effectiveness

The water quality in Wirth Lake has been monitored for over 30 years, and will continue to be monitored for the foreseeable future. The MPRB will continue to monitor the water quality on an annual basis. The typical lake sampling protocol is to visit the lakes 8 to 10 times between April and September. The following water quality parameters are measured at each visit. All parameters except Secchi disc and chlorophyll *a* are measured at various depths in the water column (every 1 to 2 meters.)

- Secchi disc
- Dissolved Oxygen
- Temperature
- Total Phosphorus
- Chlorophyll *a*

Though not a requirement of what is called for in the TMDL monitoring plan, it is recommended that stakeholders monitor the long-term effectiveness of the water quality improvement project(s) proposed for Wirth Lake and its watershed. The primary TMDL monitoring activity will be evaluating the backflow prevention structure to ensure that it is functioning properly and minimizing phosphorus loading. Documentation of installed BMPs and testing of removal efficiencies of representative phosphorus reduction BMPs should be conducted, where possible.

Comprehensive phytoplankton, zooplankton, macrophyte and fisheries surveys should be considered for the lake during at least one of the years that surface water quality monitoring is being accomplished. As part of this survey, carp populations would be enumerated by size class using a catch-tag-release-recapture method or similar approach for producing reliable estimates of fish populations.

The comparison between future monitoring data and the modeling results in this study can be conducted as follows:

1. Using monitoring results (flow and water quality sampling data), calculate the annual load (or the load over some other time period) of phosphorus leaving the basins.
2. Run the in-lake models for same time period and calculate the load that the model predicts for pre-project conditions.

3. Compare the two loads, and calculate the percent reduction that was achieved over the time period of interest.

# 5.0 TMDL Implementation Strategies

## 5.1 Annual Load Reductions

To begin with, TMDL implementation will focus on continuing nonstructural practices in the watershed, maintain existing structural BMPs and eliminating Bassett Creek backflow as a source of phosphorus to Wirth Lake. To meet the standards under the NCHF ecoregion, the overall phosphorus load to Wirth Lake will need to be reduced by 48 pounds per year (33%) in order to achieve the TMDL allocation of 99 pounds per year.

Load reductions for construction stormwater activities are not specifically targeted in this TMDL. It should be noted that construction stormwater activities are considered in compliance with provisions of this TMDL if they obtain a Construction General Permit under the NPDES program and properly select, install and maintain all BMPs required under the permit, including any applicable additional BMPs required in of the Construction General Permit for discharges to impaired waters, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

## 5.2 Specific Projects/Practices

Phosphorus load reduction project(s) will be implemented in a stepwise manner, with implementation of structural backflow prevention as the main objective to go along with nonstructural practices that are either ongoing or have already occurred prior to this report. It is anticipated that it will take up to 5 years to implement the project involving structural modifications to the Wirth Lake outlet, which will be required to achieve the annual load reductions prescribed in the allocations. The estimated capital construction cost to complete the Wirth Lake outlet modifications is $200,000.

Maintenance of existing structural practices in the watershed has been ongoing and will continue to be documented in the MS4 SWPPPs. Implementation and maintenance of structural and nonstructural practices in the watershed will be performed to maintain existing loads.

Completed and future implementation practices designed to further reduce phosphorus loading in Wirth Lake are detailed in Table 6. These elements are based on the BCWMCs watershed planning efforts and may be modified and/or further evaluated as needed.

**Table 6 Wirth Lake TMDL Implementation Strategies**

| Management Practice | Timeline/ Frequency |
|---|---|
| **The top priority practice required to ensure compliance with the TMDL is construction of a lake outlet structure to prevent backflow from Bassett Creek and minimize additional phosphorus loading to Wirth Lake.** | **Implement within 5 years of TMDL approval** |
| Best Management Practices (BMPs) that achieve a level of removal of phosphorus and suspended solids that would be equal or greater than the level of removal that would be achieved by a permanent pool that provides for storage of 2.5 inches of runoff volume from the entire development site is required for all new development and redevelopment. This requirement, and the requirement that the quality of stormwater runoff cannot be degraded, has been in effect for all new development and redevelopment in the watershed since 1994. | Apply to new development and redevelopment projects |
| Consider a policy that would require that all new development and redevelopment infiltrate the first one inch of rainfall from all impervious, surfaces where feasible. Opportunities to implement extended detention basins, infiltration basins, biofiltration basins, grit chambers, and other BMPs will continue to be identified as part of new development, redevelopment, and maintenance projects where they will provide a water quality benefit to the Lake. | Apply to new development and redevelopment projects |
| As new BMPs and water quality improvement technologies are developed they will be evaluated to determine if they can provide a water quality benefit to the Lake and they will be implemented if determined to be reasonable and practicable. | As needed/ identified |
| The existing program to promote the development of shoreline buffers will be continued. | Ongoing |
| Existing BMPs will be monitored and maintained to insure that they continue to provide the water quality benefits that they were intended to provide. | Ongoing |
| The city street sweeping program will continue and as new technology and new techniques are developed they will be evaluated to determine if they would provide a water quality benefit to the Lake and implemented if found to be reasonable and practicable. | Ongoing |
| The Bassett Creek Watershed Management Commission will work with roadway authorities to initiate a roadway load reduction program which will consist of the construction of permanent BMPs and roadway sweeping. Mn/DOT currently sweeps curbed highways once per year in the spring. | Ongoing as roadway drainage system improvement project(s) are completed |
| The water quality education program will continue to work with watershed residents to increase their understanding of practices that would reduce the amount of pollutants entering the Lake. | Ongoing |

## 5.3 Responsible Parties

The BCWMC will initially take the lead role in implementing the Wirth Lake Outlet project to achieve the WLA defined in this TMDL. However, other entities are expected to continue to fulfill their existing responsibilities in stormwater management to help meet the goals of this TMDL. Particularly, because these are "waters of the state", the project partners and other local units of government will pursue state and federal assistance, wherever possible.

Specifically, work in the Wirth Lake watershed will:

- Continue to implement volume and runoff rate reduction BMPs on all development and redevelopment projects to comply with BCWMC standards.
- Look for opportunities to implement projects through the Capital Improvements Programs to reduce runoff and nutrient export wherever possible, taking advantage of (cost-share or land acquisition) programs for water quality improvements.
- Continue to implement Storm Water Pollution Prevention Plans (SWPPPs) and to improve public works maintenance practices wherever possible.

# 6.0 Reasonable Assurances

The following should be considered as reasonable assurance that implementation will occur and result in the necessary nutrient load reductions in Wirth Lake toward meeting its designated uses.

- The key implementation activity to achieve the load reduction is the installation of the backflow prevention outlet structure. This installation will be accomplished because the BCWMC has identified a funding source and the project will be considered for inclusion in the 2012 Capital Improvement Plan.
- The implementation strategies section identifies specific BMP opportunities sufficient to maintain current load levels and help achieve the necessary load reduction and associated adoption schedule.
- The BMPs and other actions outlined in Section 5.0 have all been demonstrated to be effective in reducing transport of pollutants to surface water. Also, local resource managers are currently implementing many of these BMPs and actions.
- The stakeholder group convened to provide feedback, and input into the project had broad representation from government, citizens, and technical experts.
- Monitoring will be conducted to track progress and guide adjustments in the implementation approach.
- The MS4, Construction and Industrial Activities NPDES Permits requires permittees to provide reasonable assurances that if an EPA-approved TMDL has been developed, they must review the adequacy of their stormwater pollution prevention plans (SWPPP) to meet the TMDL's WLA set for stormwater sources. If the SWPPP is not meeting the applicable requirements, schedules and objectives of the TMDL, they must modify their SWPPP, as appropriate, within 18 months after the TMDL is approved.
- All significant development, redevelopment, industrial, and construction projects need to be designed to maintain or improve existing developed hydrology and pollutant loadings to fully comply with the local watershed and government authorities, NPDES, and anti-degradation requirements.

# 7.0 Public Participation

Public participation for the Wirth Lake TMDL has occurred through meetings and updates on the TMDL project, including:

- On February 17 and June 22, 2009 TMDL meetings were conducted between watershed representatives, the MPCA and staff from the following stakeholders that have responsibility for the watershed phosphorus loadings:

| Name | Stakeholder Organization |
|---|---|
| Ginny Black | Bassett Creek Watershed Management Commission |
| Tim Brown | Minneapolis Park and Recreation Board |
| Pat Byrne | City of Minneapolis |
| Lois Eberhart | City of Minneapolis |
| Barb Lioda | MnDOT |
| Linda Loomis | City of Golden Valley |
| Jeff Oliver | City of Golden Valley |
| Dan Stauner | Bassett Creek Watershed Management Commission |
| Marcey Westrick | Board of Water and Soil Resources |
| Nick Proulx | MN DNR |
| Joel Settles | Hennepin County Environmental Service |

- Several email communications occurred throughout the project between the MPCA project manager and those listed above. The stakeholders reviewed and commented on the draft TMDL in May 2010.

- A project website was maintained and updated throughout the course of the project: www.pca.state.mn.us/water/tmdl/project-wirthlake.html

- The BCWMC has also been periodically briefed on the study through the duration.

- A public information meeting regarding the TMDL was held on June 24, 2010.

# References


Bassett Creek Watershed Management Commission (BCWMC). 2004. *Watershed Management Plan.*

Barr Engineering Company. 1996. *Wirth Lake Watershed and Lake Management Plan*. Prepared for the Bassett Creek Watershed Management Commission.

Barr Engineering Company. 2004. Detailed Assessment of Phosphorus Sources to Minnesota Watersheds. Prepared for the Minnesota Pollution Control Agency.

IEP, Inc. 1990. P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds; Urban Catchment (computer) Model (Version 3.4).

Minneapolis Park and Recreation Board (MPRB). 2009. Water Resources Report.

Minnesota Pollution Control Agency (MPCA). 2007a. *Guidance Manual for Assessing the Quality of Minnesota Surface Waters For The Determination of Impairment 305(b) Report and 303(d) List.* http://www.pca.state.mn.us/publications/wq-iw1-04.pdf

Minnesota Pollution Control Agency (MPCA). 2007b. Lake Nutrient TMDL Protocols and Submittal Requirements. http://www.pca.state.mn.us/publications/wq-iw1-10.pdf

U.S. Environmental Protection Agency (EPA). 1999. *Protocol for Developing Nutrient TMDLs.* First Edition.

Walker, W.W., Jr. 2004. Bathtub – Version 6.1 Simplified Techniques for Eutrophication Assessment & Prediction. USAE Waterways Experiment Station.

# Appendices

# Appendix A

## P8 Model Precipitation Data

Minneapolis / St. Paul Airport (MSP) & Bassett Creek WOMP gage hourly precipitation (expressed in hundredths of an inch) data (10/1/2005-9/30/07)

| Year | Month | Day | Hourly precipitation (hundredths of an inch) | | | | | | | | | | | | | | | | | | | | | | | | Daily Total (in.) | Precipitation Station |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | 10 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 36 | 22 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 5 | 198 | 68 | 38 | 15 | 3 | 3.89 | WOMP |
| 2005 | 10 | 5 | 5 | 13 | 27 | 0 | 0 | 1 | 0 | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.51 | WOMP |
| 2005 | 10 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 1 | 0 | 0 | 1 | 6 | 7 | 4 | 0.24 | WOMP |
| 2005 | 10 | 13 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | WOMP |
| 2005 | 10 | 17 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.07 | WOMP |
| 2005 | 10 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2005 | 10 | 23 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.06 | WOMP |
| 2005 | 10 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.07 | WOMP |
| 2005 | 11 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 0 | 0.05 | WOMP |
| 2005 | 11 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 1 | 0.04 | WOMP |
| 2005 | 11 | 13 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | WOMP |
| 2005 | 11 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.02 | WOMP |
| 2005 | 11 | 15 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 3 | 2 | 3 | 2 | 1 | 4 | 4 | 2 | 1 | 0 | 0 | 0 | 0.29 | WOMP |
| 2005 | 11 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2005 | 11 | 27 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.08 | WOMP |
| 2005 | 11 | 28 | 0 | 5 | 3 | 0 | 0 | 2 | 1 | 0 | 0 | 7 | 12 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 2 | 4 | 4 | 4 | 0.51 | WOMP |
| 2005 | 11 | 29 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.17 | WOMP |
| 2005 | 11 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2005 | 12 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | MSP |
| 2005 | 12 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.07 | MSP |
| 2005 | 12 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | MSP |
| 2005 | 12 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.01 | MSP |
| 2005 | 12 | 14 | 1 | 1 | 2 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0.12 | MSP |
| 2005 | 12 | 15 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0.04 | MSP |
| 2005 | 12 | 21 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | MSP |
| 2005 | 12 | 23 | 0 | 3 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.10 | MSP |
| 2005 | 12 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 3 | 0.06 | MSP |
| 2005 | 12 | 30 | 2 | 4 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 2 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.22 | MSP |
| 2006 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.16 | MSP |
| 2006 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.01 | MSP |
| 2006 | 1 | 4 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.05 | MSP |
| 2006 | 1 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0.03 | MSP |
| 2006 | 1 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 2 | 1 | 0 | 0 | 0 | 0.08 | MSP |
| 2006 | 1 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | MSP |
| 2006 | 1 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0.01 | MSP |
| 2006 | 1 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | MSP |
| 2006 | 1 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0.02 | MSP |
| 2006 | 1 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 2 | 1 | 1 | 1 | 0 | 0 | 1 | 0.11 | MSP |
| 2006 | 1 | 29 | 2 | 1 | 3 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0.13 | MSP |
| 2006 | 1 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 6 | 0 | 0 | 0.08 | MSP |
| 2006 | 2 | 1 | 4 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.09 | MSP |
| 2006 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | MSP |
| 2006 | 2 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.12 | MSP |
| 2006 | 2 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | MSP |
| 2006 | 2 | 14 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.05 | MSP |
| 2006 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | WOMP |
| 2006 | 3 | 5 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 3 | 2 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0.13 | WOMP |
| 2006 | 3 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | WOMP |
| 2006 | 3 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 | 1 | 0 | 5 | 5 | 0.16 | WOMP |
| 2006 | 3 | 13 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | WOMP |
| 2006 | 3 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.11 | WOMP |
| 2006 | 3 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.11 | WOMP |
| 2006 | 3 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 3 | 0.07 | WOMP |
| 2006 | 3 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 2 | 0 | 0 | 1 | 0 | 0 | 0.14 | WOMP |
| 2006 | 3 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | WOMP |
| 2006 | 4 | 2 | 0 | 1 | 4 | 5 | 8 | 11 | 11 | 3 | 7 | 14 | 1 | 0 | 0 | 6 | 6 | 8 | 7 | 8 | 2 | 1 | 0 | 0 | 0 | 0 | 1.03 | WOMP |
| 2006 | 4 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 6 | 32 | 10 | 3 | 0 | 0 | 0 | 0 | 0 | 0.62 | WOMP |
| 2006 | 4 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0.04 | WOMP |
| 2006 | 4 | 19 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2006 | 4 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 0.06 | WOMP |
| 2006 | 4 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.26 | WOMP |
| 2006 | 4 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 9 | 14 | 8 | 3 | 2 | 3 | 2 | 0 | 0 | 1 | 1 | 1 | 1 | 0.46 | WOMP |
| 2006 | 4 | 29 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 4 | 7 | 5 | 6 | 8 | 7 | 7 | 12 | 7 | 2 | 3 | 3 | 4 | 0 | 0 | 0.79 | WOMP |
| 2006 | 4 | 30 | 0 | 1 | 4 | 3 | 6 | 5 | 1 | 2 | 5 | 7 | 7 | 6 | 3 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 4 | 3 | 4 | 0.63 | WOMP |
| 2006 | 5 | 1 | 9 | 7 | 6 | 5 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0.31 | WOMP |
| 2006 | 5 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 26 | 37 | 7 | 0 | 0.84 | WOMP |
| 2006 | 5 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0.08 | WOMP |
| 2006 | 5 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 | WOMP |
| 2006 | 5 | 12 | 0 | 0 | 0 | 0 | 1 | 3 | 5 | 3 | 5 | 4 | 3 | 3 | 4 | 0 | 2 | 1 | 2 | 3 | 5 | 2 | 2 | 1 | 0 | 0 | 0.49 | WOMP |
| 2006 | 5 | 13 | 2 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0.11 | WOMP |
| 2006 | 5 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2006 | 5 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.09 | WOMP |
| 2006 | 5 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.01 | WOMP |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 5 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2006 | 5 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 1 | 0 | 0 | 0 | 0 | 0 | 0.16 | WOMP |
| 2006 | 5 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 2 | 0 | 0 | 0.12 | WOMP |
| 2006 | 6 | 1 | 0 | 0 | 0 | 0 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.07 | WOMP |
| 2006 | 6 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 6 | 0.19 | WOMP |
| 2006 | 6 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2006 | 6 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.09 | WOMP |
| 2006 | 6 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 87 | 4 | 1 | 135 | 68 | 3 | 0 | 2.98 | WOMP |
| 2006 | 6 | 17 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 11 | 0 | 0 | 0 | 0 | 0.15 | WOMP |
| 2006 | 6 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0.01 | WOMP |
| 2006 | 6 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 7 | 1 | 0 | 0 | 7 | 1 | 0 | 0.26 | WOMP |
| 2006 | 6 | 25 | 0 | 0 | 0 | 0 | 0 | 7 | 24 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.33 | WOMP |
| 2006 | 6 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2006 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.16 | WOMP |
| 2006 | 7 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.27 | WOMP |
| 2006 | 7 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0.04 | WOMP |
| 2006 | 7 | 14 | 0 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.09 | WOMP |
| 2006 | 7 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 10 | 13 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.33 | WOMP |
| 2006 | 7 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 5 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.37 | WOMP |
| 2006 | 7 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0.02 | WOMP |
| 2006 | 7 | 22 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2006 | 7 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 43 | 3 | 83 | 11 | 0 | 0 | 0 | 0 | 0 | 1.40 | WOMP |
| 2006 | 7 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0.12 | WOMP |
| 2006 | 8 | 1 | 6 | 20 | 2 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 4 | 1 | 0 | 5 | 0 | 6 | 23 | 0 | 0 | 4 | 4 | 0.82 | WOMP |
| 2006 | 8 | 2 | 22 | 8 | 142 | 62 | 52 | 14 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.03 | WOMP |
| 2006 | 8 | 6 | 0 | 1 | 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.37 | WOMP |
| 2006 | 8 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 2 | 1 | 3 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 0.26 | WOMP |
| 2006 | 8 | 14 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.08 | WOMP |
| 2006 | 8 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2006 | 8 | 23 | 0 | 0 | 0 | 0 | 6 | 5 | 6 | 5 | 4 | 4 | 5 | 6 | 6 | 5 | 6 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.64 | WOMP |
| 2006 | 8 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 2 | 0 | 1 | 2 | 2 | 3 | 3 | 3 | 3 | 2 | 0.26 | WOMP |
| 2006 | 8 | 25 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0.31 | WOMP |
| 2006 | 8 | 26 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0.12 | WOMP |
| 2006 | 8 | 27 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0.06 | WOMP |
| 2006 | 8 | 28 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | WOMP |
| 2006 | 8 | 29 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | WOMP |
| 2006 | 8 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2006 | 9 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0.01 | WOMP |
| 2006 | 9 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.06 | WOMP |
| 2006 | 9 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 10 | 5 | 3 | 1 | 0 | 0 | 0 | 0 | 0.21 | WOMP |
| 2006 | 9 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2006 | 9 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 0.07 | WOMP |
| 2006 | 9 | 27 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.06 | WOMP |
| 2006 | 9 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | WOMP |
| 2006 | 9 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2006 | 9 | 30 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2006 | 10 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0.02 | WOMP |
| 2006 | 10 | 11 | 0 | 0 | 1 | 3 | 7 | 5 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.19 | WOMP |
| 2006 | 10 | 16 | 0 | 0 | 0 | 0 | 0 | 11 | 7 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.22 | WOMP |
| 2006 | 10 | 17 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2006 | 10 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.05 | WOMP |
| 2006 | 10 | 19 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.13 | MSP |
| 2006 | 11 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | MSP |
| 2006 | 11 | 13 | 0 | 5 | 5 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.14 | MSP |
| 2006 | 11 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0.03 | MSP |
| 2006 | 11 | 27 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.12 | MSP |
| 2006 | 11 | 28 | 0 | 0 | 2 | 4 | 1 | 0 | 4 | 1 | 26 | 24 | 10 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.77 | MSP |
| 2006 | 12 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.01 | MSP |
| 2006 | 12 | 12 | 4 | 0 | 0 | 0 | 0 | 7 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.15 | MSP |
| 2006 | 12 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 24 | 12 | 24 | 26 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.99 | MSP |
| 2006 | 12 | 22 | 4 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.08 | MSP |
| 2006 | 12 | 28 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.06 | MSP |
| 2006 | 12 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0.01 | MSP |
| 2006 | 12 | 30 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 6 | 1 | 2 | 2 | 1 | 0 | 0 | 0 | 0.17 | MSP |
| 2006 | 12 | 31 | 4 | 4 | 2 | 6 | 6 | 17 | 11 | 5 | 6 | 6 | 2 | 6 | 0 | 0 | 1 | 4 | 7 | 6 | 7 | 5 | 2 | 0 | 0 | 0 | 1.07 | MSP |
| 2007 | 1 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 0 | 0.06 | MSP |
| 2007 | 1 | 15 | 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.32 | MSP |
| 2007 | 1 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | MSP |
| 2007 | 1 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.07 | MSP |
| 2007 | 1 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | MSP |
| 2007 | 2 | 6 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.11 | MSP |
| 2007 | 2 | 24 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 4 | 2 | 2 | 4 | 4 | 2 | 2 | 1 | 1 | 1 | 2 | 4 | 0.36 | MSP |
| 2007 | 2 | 25 | 10 | 14 | 10 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0.64 | MSP |
| 2007 | 2 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 1 | 1 | 0.07 | MSP |
| 2007 | 3 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 4 | 4 | 7 | 7 | 12 | 4 | 0 | 5 | 7 | 7 | 4 | 4 | 1 | 0 | 0 | 1 | 1 | 0.70 | MSP |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 3 | 2 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.24 | MSP |
| 2007 | 3 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0.02 | WOMP |
| 2007 | 3 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 2 | 0.06 | WOMP |
| 2007 | 3 | 25 | 1 | 0 | 4 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.10 | WOMP |
| 2007 | 3 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 5 | 0 | 0 | 0 | 0 | 0.09 | WOMP |
| 2007 | 3 | 28 | 0 | 4 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 2 | 2 | 4 | 5 | 8 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.32 | WOMP |
| 2007 | 3 | 30 | 0 | 3 | 23 | 20 | 4 | 4 | 0 | 1 | 11 | 13 | 8 | 10 | 8 | 3 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1.12 | WOMP |
| 2007 | 3 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 7 | 2 | 1 | 0 | 0 | 3 | 2 | 6 | 8 | 27 | 3 | 3 | 2 | 4 | 0 | 0 | 0.76 | WOMP |
| 2007 | 4 | 1 | 1 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0.09 | WOMP |
| 2007 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0.02 | WOMP |
| 2007 | 4 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | WOMP |
| 2007 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2007 | 4 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 2 | 3 | 2 | 0.11 | WOMP |
| 2007 | 4 | 11 | 1 | 1 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 2 | 4 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.17 | WOMP |
| 2007 | 4 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | WOMP |
| 2007 | 4 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 15 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 16 | 0.48 | WOMP |
| 2007 | 4 | 23 | 16 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.17 | WOMP |
| 2007 | 4 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 14 | 1 | 10 | 0 | 0 | 0.26 | WOMP |
| 2007 | 5 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0.07 | WOMP |
| 2007 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.07 | WOMP |
| 2007 | 5 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 0 | 0 | 0 | 0 | 0.31 | WOMP |
| 2007 | 5 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 1 | 0.26 | WOMP |
| 2007 | 5 | 9 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | WOMP |
| 2007 | 5 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | WOMP |
| 2007 | 5 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.07 | WOMP |
| 2007 | 5 | 23 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.75 | WOMP |
| 2007 | 5 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 6 | 8 | 14 | 3 | 3 | 4 | 2 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.47 | WOMP |
| 2007 | 5 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 18 | 3 | 0 | 4 | 0 | 0 | 0.26 | WOMP |
| 2007 | 5 | 31 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2007 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0.02 | WOMP |
| 2007 | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 16 | 3 | 0 | 0 | 1 | 0 | 0.36 | WOMP |
| 2007 | 6 | 3 | 0 | 0 | 1 | 4 | 3 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.17 | WOMP |
| 2007 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | WOMP |
| 2007 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2007 | 6 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 0.05 | WOMP |
| 2007 | 6 | 16 | 0 | 0 | 2 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.07 | WOMP |
| 2007 | 6 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 30 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.33 | WOMP |
| 2007 | 6 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0.02 | WOMP |
| 2007 | 6 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2007 | 7 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0.03 | WOMP |
| 2007 | 7 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.09 | WOMP |
| 2007 | 7 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | 5 | 36 | 3 | 0 | 0 | 0 | 0 | 0 | 0.78 | WOMP |
| 2007 | 7 | 14 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | WOMP |
| 2007 | 7 | 16 | 0 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.06 | WOMP |
| 2007 | 7 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 21 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0.26 | WOMP |
| 2007 | 7 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0.02 | WOMP |
| 2007 | 8 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 8 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0.15 | WOMP |
| 2007 | 8 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2007 | 8 | 11 | 0 | 0 | 0 | 60 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22 | 2 | 1 | 0 | 0 | 0.94 | WOMP |
| 2007 | 8 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 | WOMP |
| 2007 | 8 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 1.00 | WOMP |
| 2007 | 8 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2007 | 8 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 7 | 3 | 7 | 3 | 0 | 7 | 7 | 3 | 1 | 5 | 4 | 0 | 0 | 0 | 0.51 | WOMP |
| 2007 | 8 | 19 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 1 | 0 | 0 | 50 | 9 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0.67 | WOMP |
| 2007 | 8 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | WOMP |
| 2007 | 8 | 21 | 0 | 0 | 10 | 24 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0.38 | WOMP |
| 2007 | 8 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 2 | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.15 | WOMP |
| 2007 | 8 | 27 | 0 | 19 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.30 | WOMP |
| 2007 | 8 | 28 | 0 | 0 | 67 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.05 | WOMP |
| 2007 | 9 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 61 | 4 | 1 | 9 | 0.75 | WOMP |
| 2007 | 9 | 7 | 15 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.18 | WOMP |
| 2007 | 9 | 9 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2007 | 9 | 18 | 0 | 0 | 0 | 0 | 7 | 1 | 35 | 5 | 3 | 0 | 3 | 14 | 8 | 0 | 0 | 1 | 14 | 43 | 0 | 15 | 6 | 1 | 0 | 0 | 1.56 | WOMP |
| 2007 | 9 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 55 | 42 | 0 | 0 | 0 | 0 | 0 | 0.97 | WOMP |
| 2007 | 9 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 43 | 4 | 0 | 0 | 0 | 0 | 0 | 0.47 | WOMP |
| 2007 | 9 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 0 | 0 | 0 | 0.31 | WOMP |
| 2007 | 9 | 27 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | WOMP |
| 2007 | 9 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | WOMP |
| 2007 | 9 | 30 | 0 | 0 | 0 | 0 | 13 | 5 | 1 | 0 | 0 | 0 | 4 | 11 | 1 | 0 | 4 | 16 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0.56 | WOMP |

# Appendix B

## Wirth Lake/Bassett Creek Floodplain Analysis Memorandum

BARR

# External Memorandum


**To:** Chris Zadak

**From:** Sarah Stratton and Katie Wenigmann, Barr Engineering


**Subject:** Wirth Lake BMP

**Date:** May 11, 2009

**Project:** 23271004 Wirth Lake TMDL

**c:** Len Kremer and Greg Wilson

This memo describes the results of the floodplain analysis completed for Wirth Lake and adjacent portions of Bassett Creek from Plymouth Avenue in Golden Valley to Penn Avenue in Minneapolis (Figure 1). The purpose of this floodplain analysis was to determine how Wirth Lake's flood storage affects the floodplain elevations along Bassett Creek. This memo is intended to outline the modeling methodology and assumptions made for completing the floodplain modeling, as well as summarizing the results of the analysis.

## XPSWMM Model

The US E.P.A.'s Storm Water Management Model (SWMM), with a computerized graphical interface provided by XP Software (XP-SWMM), was chosen as the computer modeling package for this study. The XP-SWMM model is able to use rainfall and watershed information to generate runoff hydrographs or utilize user input hydrographs that are routed simultaneously through complicated pipe and natural channel flow networks. The model can account for detention in ponding areas, backwater conditions, weirs, orifices, and backflow through culverts, all of which do occur in this study area. Version 10.6 of the XP-SWMM model was used to model Wirth Lake and Bassett Creek from the flood storage area between Plymouth Ave and Highway 55 (Golf Course Pond) to Penn Avenue.

Bassett Creek was previously modeled using the U.S. Army Corps of Engineers HEC-1 (hydrologic model) and HEC-2 (hydraulic model) models for the effective FEMA Flood Insurance Rate Maps dated September 2004. For this study, Barr chose the XP-SWMM model due to its more robust modeling capabilities, especially with regards unsteady flow, flood storage areas and complicated outlet structures.

## XPSWMM Modeling Assumptions and Methodologies

The contributing watershed area to Wirth Lake, not including the surface area of Wirth Lake, is 307.7 acres. Watershed input parameters for the Wirth Lake watershed were calculated using geographic information systems (GIS) along with typical published values for infiltration parameters. As mentioned previously, the Bassett Creek watershed area was previously modeled using the HEC-1 hydrologic model. Therefore, the inflow hydrographs for Bassett Creek at Plymouth Avenue for the 100-year (6 inches), 50-year (5.3-inches), and 10-year (4.2-inches) 24-hour design storms were taken from the HEC-1 model and entered into XP-SWMM.

In the XP-SWMM model, water can be stored in manmade basins or natural ponding areas until it reaches a certain elevation corresponding to an outlet, such as overflow via a weir, orifice and/or overland flow. Elevation-storage curves were obtained for Wirth Lake and for the Theodore Wirth Golf Course flood storage area north of Highway 55 on Bassett Creek using a digital elevation model (DEM) developed from 2007 Light Detection and Ranging (LIDAR) data acquired by Science Applications International Corporation (SAIC) for the US Army Corps of Engineers St. Paul District.

The normal water surface elevation of the Theodore Wirth Golf Course flood storage area was assumed to be the same as the control structure (modified weir) elevation of 815.5. The normal water surface elevation of Wirth Lake was surveyed by Barr Engineering as 818, the same invert elevation as the Wirth Lake outlet structure. The Wirth Lake outlet structure was modeled as an orifice that flows into an 8-ft wide by 3.5-ft high box culvert which discharges water to Bassett Creek.

According to the Hennepin County FEMA Flood Insurance Rate Map (September 2004), the 100-year, 50-year, and 10-year flood elevations at Penn Avenue are approximately 815 feet, 814 feet, and 813 feet, respectively. These elevations were used as the starting water surface elevations (i.e. backwater elevations) at the downstream end of the model (Penn Avenue). Backwater can be defined as a rise in water surface elevation caused by some obstruction such as a narrow bridge or culvert opening that limits the area through which water can flow.

Floodplain cross sections for Bassett Creek were obtained from the HEC-2 model, a survey completed by Barr Engineering on May 5, 2009 and/or the DEM from the LiDAR data. More specifically, cross sections for the two railroad bridges located upstream of Penn Avenue, the box culvert connecting Wirth Lake and Bassett Creek, the dual box culverts under Highway 55, and the culvert under the Old Penn Avenue bridge crossing were also surveyed on May 5, 2009. All other cross sections were obtained from the HEC-2 model, with some supplemental data obtained from the DEM.

## Modeling Results

Two floodplain scenarios for each design storm (10-yr, 50-yr, and 100-yr) were modeled in the XP-SWMM model:

- Existing Conditions: allows Wirth Lake to overflow into Bassett Creek *and* allows Bassett Creek to overflow into Wirth Lake.
- Proposed Condition: only allows Wirth Lake to overflow into Bassett Creek once it reaches an elevation of 824.2 (the low point of the saddle between Wirth Lake and Bassett Creek). This option is being investigated as it would reduce nutrient loading into Wirth Lake.

Table 1 presents the comparison of the peak flood elevations for the three design storms at different locations along the study area between Highway 55 and Penn Avenue for the two floodplain scenarios.

**Table 1: Comparison of peak flood elevations for the three design storms at different locations for the existing and proposed condition scenarios.**

| Location | Peak Flood Elevation (ft) | | | | | |
|---|---|---|---|---|---|---|
| | 100-Year 24-Hour Existing Conditions | 100-Year 24-Hour Proposed Conditions | 50-Year 24-Hour Existing Conditions | 50-Year 24-Hour Proposed Conditions | 10-Year 24-Hour Existing Conditions | 10-Year 24-Hour Proposed Conditions |
| Theodore Wirth Golf Course Flood Storage Area[1] | 824.8 | 824.8 | 824.2 | 824.2 | 822.9 | 822.9 |
| Wirth Lake | 820.9 | 821.0 | 820.4 | 820.6 | 819.7 | 820.1 |
| Bassett Creek where Wirth Lake inflows | 820.9 | 821.0 | 820.4 | 820.4 | 819.4 | 819.4 |
| Bassett Creek at Glenwood Avenue | 819.9 | 820.0 | 819.4 | 819.5 | 818.6 | 818.5 |
| Bassett Creek at U/S face Fruen Mill Dam | 817.5 | 817.6 | 817.0 | 817.1 | 816.5 | 816.5 |
| Bassett Creek at M.N. & S. Railroad Bridge | 816.6 | 816.6 | 815.7 | 815.7 | 814.4 | 814.4 |
| Bassett Creek at B.N. Railroad Bridge | 815.5 | 815.5 | 814.4 | 814.4 | 813.3 | 813.3 |
| Bassett Creek at Penn Avenue | 815.0 | 815.0 | 814.0 | 814.0 | 813.0 | 813.0 |

[1] Directly upstream of the Highway 55 control structure

It should be noted that for the proposed conditions scenario, it was assumed that the normal water surface elevation of Wirth Lake would remain at 818 feet, even though the outlet structure would be blocked. It is possible that the natural hydrology of the lake would change to maintain a different normal water surface elevation. However, a flap gate could be installed that would allow Wirth Lake to overflow at an elevation of 818 but would prevent Bassett Creek from flowing into Wirth Lake.

## Conclusion

If the Wirth Lake outlet was modified to prohibit Bassett Creek from flowing into Wirth Lake there would be no significant changes to the peak flood elevations of Bassett Creek and no increases in flood damage.


Figure 1
Study Area
Wirth Lake and Bassett Creek
Floodplain Modeling Study
N
0 250 500 1,000 1,500 2,000
Feet
Municipal Boundary
Wirth Lake Watershed
Sweeney Lake
Twin Lake
Theodore Wirth
Golf Course Pond
Plymouth Ave
Highway 55
Control Structure
Wirth Lake Outlet Structure
State Hwy 55
Bassett Creek
Golden Valley
Wirth Lake
Glenwood Ave
Minneapolis
Penn Ave
Fruen Mill Dam
M.N. & S. Railroad Bridge
B.N. Railroad Bridge