Wenck
Engineers • Scientists
Business Professionals

Wenck File 0147-243-2
March 2014

CLEAN WATER LAND & LEGACY AMENDMENT

Upper Minnehaha Creek Watershed Nutrient and Bacteria TMDL Study

Prepared for:

MINNESOTA POLLUTION CONTROL AGENCY
520 Lafayette Road
St. Paul, Minnesota 55155

Prepared by:

WENCK ASSOCIATES, INC.
1800 Pioneer Creek Center
P.O. Box 249
Maple Plain, Minnesota 55359-0249
(763) 479-4200

Table of Contents

Table of Contents (Cont.)

TABLES

FIGURES

APPENDICES

TMDL Summary Table

TMDL Summary Table				
EPA/MPCA Required Elements	**Summary**			**TMDL Page #**
Location	Located within the Minnehaha Creek Watershed District's upper watershed within the Mississippi River Basin. Located within Hennepin and Carver Counties west and southwest of the Twin Cities Metro Area.			P. 1-1, 1-2
303(d) Listing Information	**Water body**	**HUC/ Lake No.**	**Pollutant/ Stressor**	P. 1-3, 1-4
	Painter Creek	07010206-800	*E. coli*	
	Dutch Lake	27-0181-00	Nutrient/Eutrophication Biological Indicators	
	East Auburn Lake	10-0044-02	Nutrient/Eutrophication Biological Indicators	
	Forest Lake	27-0139-00	Nutrient/Eutrophication Biological Indicators	
	Gleason Lake	27-0095-00	Nutrient/Eutrophication Biological Indicators	
	Holy Name Lake	27-0158-00	Nutrient/Eutrophication Biological Indicators	
	Langdon Lake	27-0182-00	Nutrient/Eutrophication Biological Indicators	
	Long Lake	27-0160-00	Nutrient/Eutrophication Biological Indicators	
	Minnetonka (Halsted Bay)	27-0133-09	Nutrient/Eutrophication Biological Indicators	
	Minnetonka (Jennings Bay)	27-0133-15	Nutrient/Eutrophication Biological Indicators	
	Minnetonka (Stubbs Bay)	27-0133-12	Nutrient/Eutrophication Biological Indicators	
	Minnetonka (West Arm)	27-0133-14	Nutrient/Eutrophication Biological Indicators	
	Mooney Lake	27-0134-00	Nutrient/Eutrophication Biological Indicators	
	Stone Lake	10-0056-00	Nutrient/Eutrophication Biological Indicators	
	Tamarack Lake	10-0010-00	Nutrient/Eutrophication Biological Indicators	

TMDL Summary Table				
EPA/MPCA Required Elements	**Summary**			**TMDL Page #**
	Tanager Lake	27-0157-00	Nutrient/Eutrophication Biological Indicators	
	Wolsfeld Lake	27-0141-00	Nutrient/Eutrophication Biological Indicators	
	Snyder Lake	27-0108-00	Nutrient/Eutrophication Biological Indicators	
	School Lake	27-0151-00	These lakes are not yet included on the state's 303(d) list of impaired waters; however data indicate that these lakes qualify for inclusion on the list for nutrients due to impaired aquatic recreation.	
	Hadley Lake	27-0109-00		
	Turbid Lake	10-0051-00		
Applicable Water Quality Standards/ Numeric Targets	Criteria set forth in Minn. R. 7050.0150 (5) and 7050.0222 (total phosphorus and *E. coli.)*			Section 2.0
	Water body	**Numeric Target**		
	Painter Creek	No more than 126 organisms per 100 mL as a geometric mean of not less than five samples representative of conditions within any calendar month, nor more than 10% of all samples taken during any calendar month individually exceed 1,260 organisms per 100 mL		
	Dutch Lake	Total phosphorus concentration of 40 µg/L or less		
	East Auburn Lake	Total phosphorus concentration of 40 µg/L or less		
	Forest Lake	Total phosphorus concentration of 40 µg/L or less		
	Gleason Lake	Total phosphorus concentration of 60 µg/L or less		
	Holy Name Lake	Total phosphorus concentration of 60 µg/L or less		
	Langdon Lake	Total phosphorus concentration of 60 µg/L or less		
	Long Lake	Total phosphorus concentration of 40 µg/L or less		
	Minnetonka (Halsted Bay)	Total phosphorus concentration of 40 µg/L or less		
	Minnetonka (Jennings	Total phosphorus concentration of 40 µg/L or less		

TMDL Summary Table			
EPA/MPCA Required Elements	**Summary**		**TMDL Page #**
	Bay)		
	Minnetonka (Stubbs Bay)	Total phosphorus concentration of 40 µg/L or less	
	Minnetonka (West Arm)	Total phosphorus concentration of 40 µg/L or less	
	Mooney Lake	Total phosphorus concentration of 60 µg/L or less	
	Stone Lake	Total phosphorus concentration of 40 µg/L or less	
	Tamarack Lake	Total phosphorus concentration of 40 µg/L or less	
	Tanager Lake	Total phosphorus concentration of 40 µg/L or less	
	Wolsfeld Lake	Total phosphorus concentration of 40 µg/L or less	
	Snyder Lake	Total phosphorus concentration of 60 µg/L or less	
	School Lake	Total phosphorus concentration of 60 µg/L or less	
	Hadley Lake	Total phosphorus concentration of 40 µg/L or less	
	Turbid Lake	Total phosphorus concentration of 40 µg/L or less	
Loading Capacity (expressed as daily load)	Bacteria: *See Sections 4.2.1 and 4.2.7* Lake Nutrients: *See Sections 4.1.1 and 4.1.7*		Bacteria P. 4-22 to 4-26 Lake Nutrients P. 4-1 to 4-5 and 4-10 to 4-21
Wasteload Allocation	Bacteria: *See Section 4.2.3* Lake Nutrients: *See Section 4.1.3*		Bacteria P. 4-24 and 4-26 Lake Nutrients P. 4-7 to 4-21
Load Allocation	Bacteria: *See Section 4.2.2* Lake Nutrients: *See Section 4.1.2*		Bacteria P. 4-24 and 4-26 Lake Nutrients P. 4-6 to

TMDL Summary Table		
EPA/MPCA Required Elements	**Summary**	**TMDL Page #**
		4-21
Margin of Safety	Bacteria: An explicit 10% of the loading capacity for each flow zone was used to represent the MOS. *See Section 4.2.4* Lake Nutrients: Explicit MOSs of 5% were used for each of the Lakes, respectively, in addition to an implicit MOS. *See Section 4.1.4*	Bacteria P. 4-25 Lake Nutrients P. 4-9
Seasonal Variation	Bacteria: Load duration curve methodology accounts for seasonal variations. *See Section 4.2.5* Lake Nutrients: *See Section 4.1.5*	Bacteria P. 4-25 Lake Nutrients P. 4-9 to 4-10
Reasonable Assurance	TMDL implementation will be carried out on an iterative basis so that implementation course corrections based on periodic monitoring and reevaluation can adjust the strategy to meet the standard. *See Section 5.0*	Section 5.0
Monitoring	Progress of TMDL implementation will be measured through regular monitoring efforts of water quality and total BMPs completed. This will be accomplished through the efforts of several cooperating agencies and groups. *See Section 7.0*	Section 6.0
Implementation	This report sets forth an implementation framework to achieve the TMDL. (A separate more detailed implementation plan will be developed within one year after of EPA's approval of this TMDL report.) *See Section 6.0*	Section 7.0
Public Participation	*See Section 8.0* Public Comment Period: December 30, 2013 - January 30, 2014	Section 8.0

Acronyms

ac-ft	acre feet
ac-ft/yr	acre feet per year
AF	Anoxic factor
AUID	Assessment Unit ID
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
CAC	Citizens Advisory Committee
cfu	colony-forming unit
Chl-*a*	Chlorophyll-*a*
CN	Curve number
EPA	Environmental Protection Agency
EQuIS	Environmental Quality Information System
FWMC	Flow weighted mean concentration
GW	Groundwater
HHPLS	Hydrologic/Hydraulic and Pollutant Loading Study
in/yr	inches per year
km^2	square kilometer
LA	Load Allocation
lb	pound
lb/day	pounds per day
lb/yr	pounds per year
LGU	Local Government Unit
LMCD	Lake Minnetonka Conservation District
m	meter
MCES	Metropolitan Council Environmental Services
MCWD	Minnehaha Creek Watershed District
mg/L	milligrams per liter
mg/m^2-day	milligram per square meter per day
mL	milliliter
MLCCS	Minnesota Land Cover Classification System
MN DNR	Minnesota Department of Natural Resources
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
MPN	Most Probable Number
MPRB	Minneapolis Park and Recreation Board
MR	Minnesota Rules
MS4	Municipal Separate Storm Sewer Systems
NPDES	National Pollutant Discharge Elimination System
P8	Program for Predicting Polluting Particle Passage thru Pits, Puddles, & Ponds

RR	Release rate
SCS	Soil Conservation Service
SRO	Surface runoff
SONAR	Statement of Need and Reasonableness
SSTS	Subsurface Sewage Treatment Systems
SWPPP	Stormwater Pollution Prevention Plan
TDLC	Total Daily Loading Capacity
TMDL	Total Maximum Daily Load
TP	Total phosphorus
TRPD	Three Rivers Park District
UAL	Unit-area Load
µg/L	microgram per liter
WLA	Wasteload Allocation
WRAPP	Watershed Restoration and Protection Plan
XP-SWMM	XP Stormwater & Wastewater Management Model
yr	year

Executive Summary

This Total Maximum Daily Load (TMDL) study addresses nutrient impairments in twenty lakes and an *E. coli* impairment in Painter Creek within the Minnehaha Creek Watershed District (MCWD), which is located within the Upper Mississippi River Basin. The MCWD covers approximately 178 square miles in Hennepin and Carver Counties, including parts of Minneapolis, Minnesota and its western suburbs. The watershed drains to Minnehaha Creek and ultimately the Mississippi River. The water bodies addressed in this study are located within a distinct hydrologic basin within the MCWD referred to as the "Upper Watershed," which drains through agricultural land and suburbs west of Minneapolis to Lake Minnetonka, which outlets into Minnehaha Creek. The goal of this TMDL is to quantify the pollutant reductions needed to meet State water quality standards for nutrients in the lakes and *E*. *coli* standards in Painter Creek.

Fifteen of these lakes are defined as deep lakes for which the North Central Hardwood Forest ecoregion numeric water quality standards are a summer average total phosphorus concentration of 40 µg/L, 14 µg/L chlorophyll-*a*, and greater than 1.4 meter in Secchi depth. The other six lakes are shallow, for which the numeric water quality standards are a summer average total phosphorus concentration of 60 µg/L, 20 µg/L chlorophyll-*a*, and greater than one meter in Secchi depth.

Nutrient budgets were developed for all twenty lakes along with lake response models to set the TMDL and Load and Wasteload Allocations. A robust lake and stream monitoring dataset was available and was the basis of the nutrient budget calculations. Wasteload reductions ranging from no reduction to a 93 percent reduction and load reductions ranging from no reduction to 79 percent reduction will be necessary to meet water quality standards.

Flow and bacteria monitoring data recorded in Painter Creek were used to establish a load duration curve meeting the *E. coli* numeric standard of no more than 126 organisms per 100 mL as a geometric mean of not less than five samples representative of conditions within any calendar month, nor more than 10% of all samples taken during any calendar month individually exceed 1,260 organisms per 100 mL. A TMDL, Wasteload Allocations, and Load Allocations were established for five flow categories: high flow, wet, mid-range, dry, and low flow. No reductions are necessary for high flow, wet, and mid-range flows. A 31 percent reduction will be necessary during dry conditions and a 37 percent reduction under low flow conditions to meet *E. coli* concentration standards.

1.0 Project Overview

1.1 Purpose

This Total Maximum Daily Load (TMDL) study addresses nutrient impairments in twenty lakes in the Minnehaha Creek watershed, and an *E. coli* impairment in Painter Creek. The impaired water bodies are located in the Minnehaha Creek Upper Watershed in the Upper Mississippi River Basin, as shown on Figure 1.1. The Upper Watershed drains to Lake Minnetonka. Minnehaha Creek is formed as the outlet of the lake, which flows to the Mississippi River. The Upper Watershed is located in Hennepin and Carver Counties in the State of Minnesota.

The goal of this TMDL is to quantify the pollutant reductions needed to meet State water quality standards for nutrients in the lakes listed in Table 1.1 and bacteria standards in Painter Creek. This MCWD Upper Watershed Nutrient and Bacteria TMDL is established in accordance with Section 303(d) of the Clean Water Act and provides wasteload allocations (WLAs) and load allocations (LAs) for the watershed areas as appropriate.

A draft nutrient TMDL has been completed for Lake Hiawatha in the Minnehaha Creek Lower Watershed downstream of this project, near the mouth of Minnehaha Creek. That project assumes an upstream boundary load of no more than 1,279 lbs of phosphorus per growing season delivered at Gray's Bay Dam. Achievement of the goals outlined in this report for the Upper Minnehaha Watershed will help to assure that the boundary condition is maintained or improved.

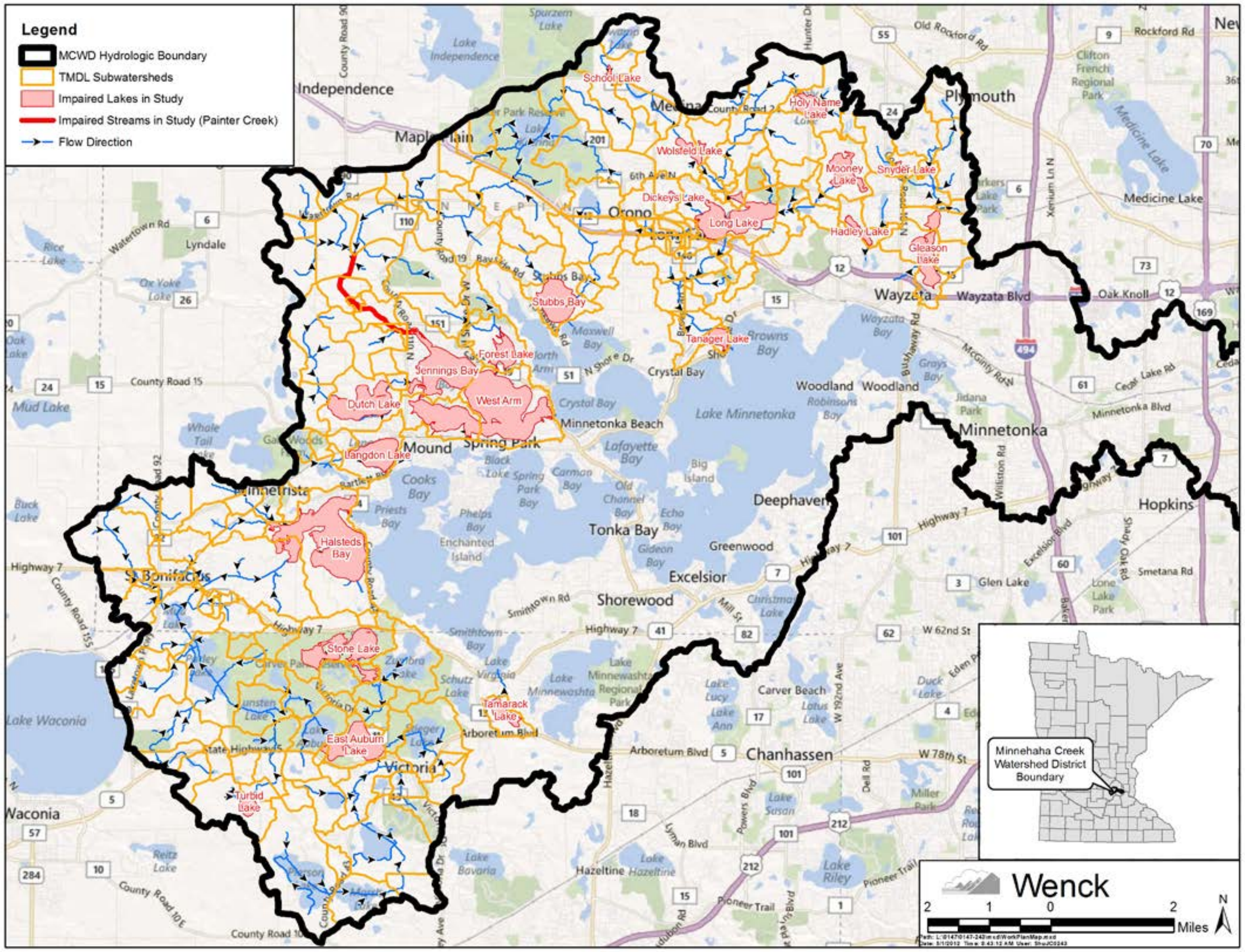


Figure 1.1. Minnehaha Creek Watershed District upper watershed impaired waters and drainage areas.

1.2 Problem Identification

The lakes addressed in this study were first placed by the Minnesota Pollution Control Agency (MPCA) on the State of Minnesota's 303(d) list of impaired waters for nutrient (total phosphorus) impairment in 2008 and 2010 as detailed in Table 1.1. In 2010, Painter Creek was placed on the 303(d) list for excess *E. coli* concentrations.

Table 1.1. Impairments addressed in this report.

Listed Water body Name	AUID#	Listed Pollutant	Impaired Use	Year Placed in Impairment Inventory	303(d) List Scheduled Start & Completion Dates
Painter Creek	07010206-700	*E. coli*	Aquatic recreation	2010	2011/2016
Dutch	27-0181-00	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2010	2011/2016
East Auburn	10-0044-02	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2010	2011/2016
Forest	27-0139-00	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2008	2012/2016
Gleason	27-0095-00	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2010	2011/2016
Holy Name	27-0158-00	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2010	2011/2016
Langdon	27-0182-00	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2010	2011/2016
Long (1)	27-0160-00	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2010	2011/2016
Minnetonka (Halsted Bay) (1)	27-0133-09	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2008	2009/2013
Minnetonka (Jennings Bay) (1)	27-0133-15	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2008	2009/2013
Minnetonka (Stubbs Bay)	27-0133-12	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2008	2009/2013
Minnetonka (West Arm)	27-0133-14	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2008	2009/2013
Mooney	27-0134-00	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2010	2011/2016
Stone	10-0056-00	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2008	2010/2013
Tamarack	10-0010-00	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2008	2012/2016
Tanager	27-0141-00	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2010	2011/2016

Listed Water body Name	AUID#	Listed Pollutant	Impaired Use	Year Placed in Impairment Inventory	303(d) List Scheduled Start & Completion Dates
Wolsfeld	27-0157-00	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2010	2011/2016
Snyder	27-0108-00	Nutrient/Eutrophication Biological Indicators	Aquatic recreation	2010	2011/2016
School	27-0151-00	(2)	(2)	(2)	NA
Hadley	27-0109-00	(2)	(2)	(2)	NA
Turbid	10-0051-00	(2)	(2)	(2)	NA

(1) These lakes were also listed for mercury in fish tissue (impaired aquatic consumption) in 1998. This impairment is not addressed herein.

(2) These lakes are on or expected to be on the draft 2014 303(d) list of impaired waters. Data indicate that these lakes qualify for inclusion on the list for nutrients.

1.3 Priority Ranking

The MPCA's projected schedule for TMDL completions on the 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 water body; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

1.4 Data Used in this Report

Considerable data is available to complete this TMDL and identify appropriate implementation strategies. The MCWD operates a robust annual monitoring program and conducts periodic detailed assessments of its resources. Sources used or consulted for this document include:

- Annual Hydrodata program data;
- Comprehensive Water Resources Management Plan;
- Hydraulic, Hydrologic, and Pollutant Loading Study;
- Functional Assessment of Wetlands;
- Upper Watershed Streams Assessment;
- Diatom-inferred TP in MCWD Lakes;
- Six Mile Creek Diagnostic Study; and
- LGU Annual Reports.

2.0 Impaired Waters and Minnesota Water Quality Standards

2.1 State of Minnesota Designated Uses

The impaired waters addressed in this TMDL are classified as Class 2B waters for which aquatic life and recreation are the protected beneficial uses.

2.2 State of Minnesota Standards and Criteria for Listing

***Nutrients*.** Under Minnesota Rules 7050.0150 and 7050.0222, Subp. 4, the lakes addressed in this study are located within the North Central Hardwood Forest ecoregion with a numeric target dependent on depth as listed in Table 2.1. Therefore, this TMDL presents load and wasteload allocations and estimated load reductions assuming an end point of ≤60 μg/L and ≤40 μg/L total phosphorus for shallow lakes and deep lakes, respectively.

In addition to meeting a phosphorus limit of 60 μg/L and 40 μg/L for shallow and deep lakes, chlorophyll-*a* and Secchi depth standards must also be met. In developing the lake nutrient standards for Minnesota lakes (Minn. Rule 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (Heiskary and Wilson, 2005). Clear relationships were established between the causal factor total phosphorus and the response variables chlorophyll-*a* and Secchi disk. Based on these relationships it is expected that by meeting the phosphorus targets of 60 μg/L and 40 μg/L for shallow and deep lakes, the chlorophyll-*a* and Secchi standards will likewise be met.

Table 2.1. Numeric standards for lakes in the North Central Hardwood Forest Ecoregion.

Parameters	Shallow[1] Lake Standard	Deep Lake Standard
Total Phosphorus (μg/L)	≤60	≤40
Chlorophyll-*a* (μg/L)	≤20	≤14
Secchi disk transparency (meters)	≥1.0	≥1.4

[1] Shallow lakes are defined as lakes with a maximum depth of 15 feet or less, or with 80% or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (littoral zone).

***E. coli*.** The Painter Creek bacterial impairment listing was based on *E. coli* measurements. Under Minnesota Rules 7050.0150 and 7050.0222 *E. coli* concentrations are:

"Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms/100 mL. The standard applies only between April 1 and October 31."

2.3 Analysis of Impairment

The criteria used for determining impairments are outlined in the MPCA document Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment – 305(b) Report and 303(d) List, January 2010. The applicable water body classifications and water quality standards are specified in MR Chapter 7050.0470 and MR 7050.0222, respectively.

3.0 Watershed and Water Body Characterization

The Minnehaha Creek Watershed District encompasses approximately 178 square miles in Hennepin and Carver Counties in the Upper Mississippi River Basin. The watershed includes eight major creeks (including Minnehaha Creek), 129 lakes (including Lake Minnetonka and the Minneapolis Chain of Lakes), and thousands of wetlands. The watershed consists of two distinct hydrologic basins. The “Upper Watershed” drains through 104 square miles of land and suburbs west of Minneapolis to Lake Minnetonka. The “Lower Watershed” consists of the area east of Lake Minnetonka that is drained by Minnehaha Creek and extends to the Mississippi River.

In 2001, the MCWD initiated a multi-year Hydrologic/Hydraulic and Pollutant Loading Study (HHPLS) of the watershed. The HHPLS Report (EOR 2003) presents a compilation of work by District staff, technical consultants, elected officials, and the public. The over-arching goal of the HHPLS was to improve and maintain the surface water, groundwater, and associated natural resources of the MCWD. The data collected during the study were used in various combinations to characterize subwatersheds and define both hydrologic and hydraulic parameters. Predictive quantity and quality computer models were developed. Portions of the HHPLS report and associated work products were used for development of this TMDL study.

In 2012, the MCWD retained Wenck Associates, Inc. to perform a diagnostic study of the Six Mile Creek subwatershed, located within the Upper Watershed of MCWD. The nutrient TMDLs for East Auburn, Stone, and Turbid lakes were developed concurrent to the TMDL study as part of this separate diagnostic and feasibility study of the Six Mile Creek subwatershed for MCWD.

3.1 Lakes

Lake morphometry for the impaired lakes is listed in Table 3.1.

Table 3.1. Lake morphometry for all impaired lakes in the study area.

Parameter	Surface Area	Average Depth	Maximum Depth	Lake Volume	Littoral Area	Depth Class	Drainage Area*
Water body	**acre**	**feet**	**feet**	**ac-ft**	**%**	**--**	**acre**
Dutch	176.0	14.0	42	2462	59	Deep	1567
E. Auburn	147.9	12.0	40	1781	28	Deep	7307
Forest	89.5	14.0	38	1227	59	Deep	855
Gleason	168.8	6.0	15	1009	100	Shallow	2437
Holy Name	70.0	5.0	8	340	100	Shallow	388
Langdon	142.4	8.0	32	1207	87	Shallow	913
Long	286.5	14.0	35	3982	54	Deep	5968
Halsted's Bay	561.1	13.2	32	7401	57	Deep	18760
Jennings Bay	305.6	12.0	22	3748	59	Deep	11121
Stubbs Bay	198.5	14.0	36	2777	56	Deep	1748
West Arm	822.3	13.0	29	10681	71	Deep	12967
Mooney	113.0	5.0	10	565	100	Shallow	486
Stone	99.3	10.2	30	1009	72	Deep	782
Tamarack	30.0	25.4	82	761	38	Deep	179
Tanager	53.7	10.0	18	512	80	Deep	7566
Wolsfeld	40.3	9.5	27	380	76	Deep	1553
Snyder	12.0	6.0	13	72	100	Shallow	362
School	11.1	8.1	15	90	81	Shallow	541
Hadley**	35.3	17.0	35	600	unknown	Deep	502
Turbid	39.9	10.4	35	417	65	Deep	493

*** Excludes Lake Surface**

**Bathymetry data was unavailable for Hadley Lake. The maximum depth was measured by MCWD staff in February 2012. The lake volume was estimated using the lake area and half of the measured maximum depth.

3.2 Streams

The impaired reach of Painter Creek extends from an unnamed creek within Painter Marsh to Lake Minnetonka (Jennings Bay). The Painter Creek subwatershed area is 8,669.5 acres in size.

3.3 Subwatersheds

Figures depicting the subwatersheds for each water body addressed in the TMDL study are included in Appendix A. Subwatersheds for each lake were delineated first by the HHPLS defined subwatersheds and further delineated to each lake outlet or monitoring station as relevant based on LiDAR data (flown in 2007 and distributed in 2008 for the areas within Hennepin County) and USGS Quadrangle Maps (within Carver County).

3.4 Land Use

Approximately 75 square miles of the MCWD Upper Watershed is included in the TMDL study area. A broad range of land use exists within the general TMDL study area and is shown in Table 3.2 below. Figures depicting land use for each impaired water body subwatershed are included in Appendix B.

Table 3.2. Land use in TMDL study area.

2010 METC Land Use	Area (acres)	Percent
Agricultural	7527	16%
Farmstead	344	1%
Golf Course	1005	2%
Industrial and Utility	240	1%
Institutional	799	2%
Major Highway	329	1%
Manufactured Housing Parks	4	< 1%
Mixed Use Commercial	13	< 1%
Mixed Use Industrial	10	< 1%
Mixed Use Residential	30	< 1%
Multifamily	133	< 1%
Office	23	< 1%
Open Water	6402	13%
Park, Recreational, or Preserve	6647	14%
Railway	8	< 1%
Retail and Other Commercial	315	1%
Seasonal/Vacation	18	< 1%
Single Family Attached	372	1%
Single Family Detached	10096	21%
Undeveloped	13444	28%
TOTAL	47760	100%

Source: 2010 Met Council

3.5 Historic Water Quality

3.5.1 Nutrients

Water quality sampling in the MCWD is conducted as part of the District's annual Hydrologic Data Monitoring Program, designed for the collection of background water quality and quantity data. The monitoring data set used for the purposes of this TMDL was obtained from the MCWD Water Quality Database and supplemented with data from the MPCA database as necessary. Sampling site locations are indicated on the maps included in Appendix A.

In general, historical in-lake water quality data collected from 2000 to 2012 was reviewed for use in the TMDL study. For the purposes of developing the majority of the nutrient TMDLs, only available data from 2005 to 2011 was used to establish the “average” condition. Data collected from 2005 to 2011 was chosen as the most representative data set due to the robust set of upper watershed wide stream monitoring data available during those years. The exception to this is East Auburn, Stone, and Turbid Lakes. As previously stated, the nutrient TMDLs for these lakes were developed concurrent to the TMDL study as part of the separate diagnostic and feasibility study of the Six Mile Creek Watershed conducted by MCWD. Available data from 2000 to 2012 was used to establish the “average” condition for those lakes. In some cases, in-lake data was not available for all years of the 2005 to 2011 or 2000 to 2012 data sets.

For Langdon Lake, there was available data excluded from the lake response modeling process. Langdon Lake was initially modeled using the available data from 2005-2011. However, the model did not calibrate well based on the monitored watershed data and the measured sediment release rate (72.4 µg/L modeled versus 103.7 µg/L observed for 2005-2011). The data shows a shift in water quality after 2008 (Figure 3.1 below). Due to the shift, Langdon was re-modeled using the 2009-2011 data. This model calibrated well for those data years (67.6 µg/L modeled and 64.7 µg/L observed). Therefore, the 2009-2011 model was used to set the TMDL.

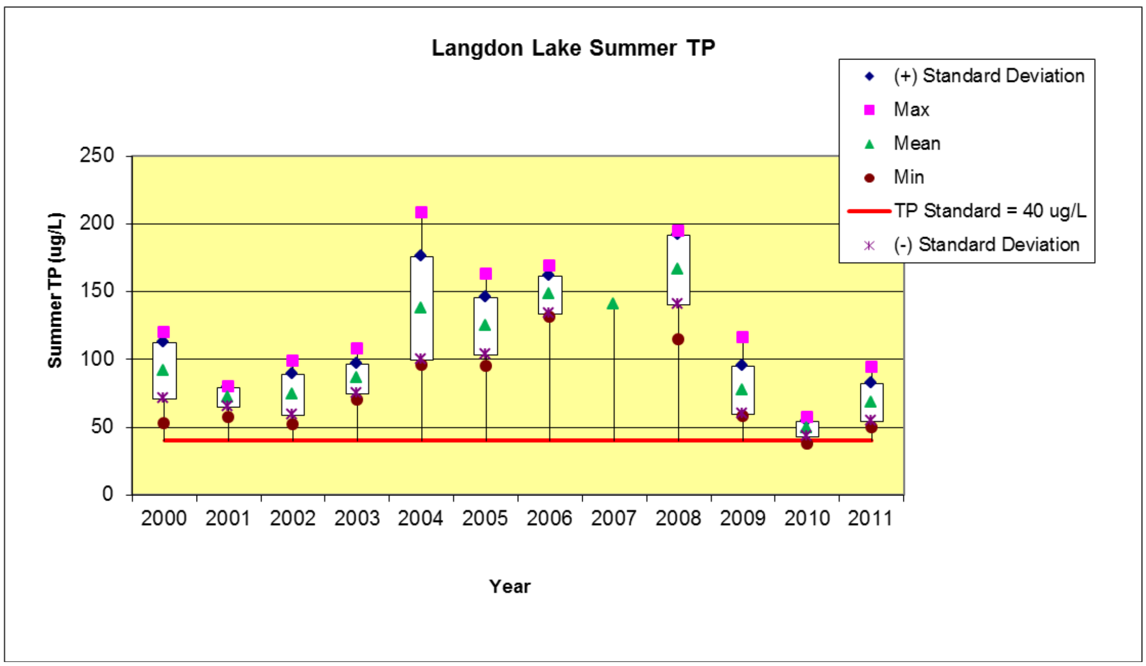


Figure 3.1. Langdon Lake summer TP concentrations.

Tables 3.3 and 3.4 list the June through September averages of total phosphorus (TP) concentration, chlorophyll-*a* (chl-*a*) concentration, and Secchi depth for each impaired lake. The table also lists the data years which were used to calculate the “average” condition for the TMDL study.

Table 3.3. Deep lake growing season averages for water quality parameters.

Lake Name	"Average" Condition Calculation Years	In-Lake "Average" Condition (Calculated June - September) TP Concentration (µg/L)	Chl-*a* Concentration (µg/L)	Secchi Depth (m)
Water Quality Standard for Deep Lakes		**40.0**	**14.0**	**1.4**
Dutch	2005-2011	54.8	35.5	1.1
E. Auburn	2008, 2010, 2012	49.4	40.5	1.3
Forest	2005-2011	58.7	55.1	0.8
Long	2005-2011	61.4	38.4	1.0
Halsted's Bay	2005-2011	88.5	60.0	0.8
Jennings Bay	2005-2011	97.4	66.5	0.8
Stubbs Bay	2005-2011	49.9	41.3	0.9
West Arm	2005-2011	59.8	47.4	1.1
Stone	2000, 2002, 2007-2008, 2010-2012	42.9	16.8	2.2
Tamarack	2005-2011	38.9	14.1	2.4
Tanager	2005-2011	92.0	74.3	0.9
Wolsfeld	2006-2008	80.1	56.8	0.8
Hadley	2006-2008	58.2	16.7	--
Turbid	2008, 2011, 2012	66.8	35.2	1.4

Table 3.4. Shallow lake growing season averages for water quality parameters.

Lake Name	"Average" Condition Calculation Years	In-Lake "Average" Condition (Calculated June - September) TP Concentration (µg/L)	Chl-*a* Concentration (µg/L)	Secchi Depth (m)
Water Quality Standard for Shallow Lakes		**60.0**	**20.0**	**1.0**
Mooney	2006-2008, 2011	78.2	50.8	1.0
Gleason	2005-2011	97.8	50.7	1.1
Holy Name	2006-2008	149.5	87.9	0.7
Snyder	2006-2008	71.6	44.1	1.0
Langdon	2009-2011	64.7	33.8	0.9
School	2009-2010	157.7	96.0	0.3

All lakes indicate an average summer TP concentration above the state standard with the exception of Tamarack Lake. The listed Tamarack Lake average TP concentration for 2005 to 2011 is below the state water quality standard concentration of 40 µg/L. However, the average TP concentration from 2001 to 2011 is 41.6 µg/L; above the standard. Figure 3.2 depicts the summer average TP concentrations in Tamarack Lake from 2001 to 2011. Even though the most recent period indicates the lake meets state standards, a TMDL was still completed for Tamarack Lake based on its official impaired status.

Allocations for the lake should serve to assure that loading will not increase and that it meets the standard over the long term.

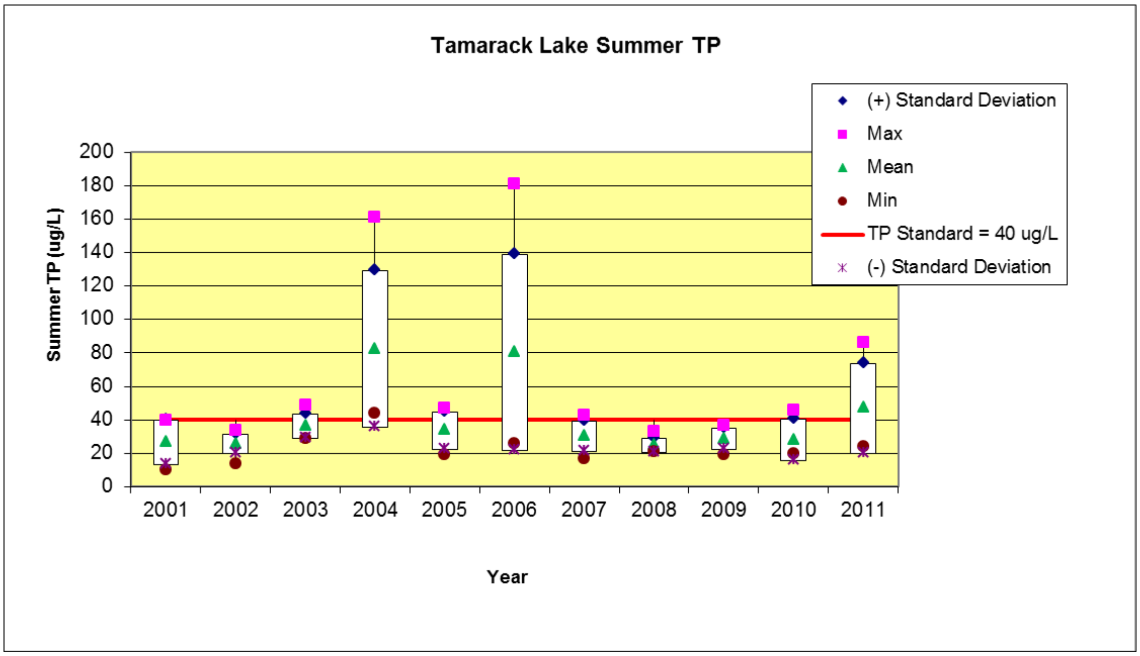


Figure 3.2. Tamarack Lake summer TP concentrations.

3.5.2 *E. coli*

A stream reach is placed on the 303(d) impaired waters list if the geometric mean (or "geomean") of the aggregated monthly *E. coli* concentrations for one or more months exceed 126 organisms per 100 mL. A water body is also considered impaired if more than 10% of the individual samples within a month exceed 1,260 organisms per 100 mL.

Table 3.5 shows the monthly geometric means for April to October for four sample stations located within the impaired reach of Painter Creek and two sample stations located upstream. The impaired reach of Painter Creek is approximately 2.37 miles long. Monthly geometric means, total number of samples, and the percentage of samples exceeding the acute standard are tabulated. Exceedances of the chronic and acute *E. coli* standard are shown in red. Geometric means are often used to describe bacteria data over arithmetic means as the geometric mean normalizes the ranges being averaged.

$$Geometric\ mean = \sqrt[n]{x_1 * \ x_2 * \ldots . x_n}$$

Available data from 2001 to 2011 was used for the purpose of the bacteria TMDL.

Wenck

Table 3.5. Monthly geometric mean of *E. coli* values for Painter Creek.

Sampling Point	Location	Data Years	April			May			June			July			August			September			October			All Months		
			n	Geo	%n > 1260	n	Geo	%n > 1260	n	Geo	%n > 1260	n	Geo	%n > 1260	n	Geo	%n > 1260	n	Geo	%n > 1260	n	Geo	%n > 1260	n	Geo	%n > 1260
CPA05 (Mile 0.39)	Within Impaired Reach	2001-2003	NA			6	72	0	14	88	0	9	178	0	8	197	0	12	427	25%	4	205	25%	53	167	8%
CPA01 (Mile 0.79)		2001-2003,2005-2006,2010-2011	7	5	0	18	23	6%	33	58	0	25	105	4%	22	137	9%	16	196	13%	11	85	9%	132	70	5%
CPA06 (Mile 1.3)		2010-2011	NA			7	31	0	9	80	0	9	186	0	7	148	0	10	157	0	2	27	0	44	100	0
CPA04 (Mile 2.0)		2002-2003, 2006, 2010-2011	2	4	0	15	30	0	20	87	0	18	187	0	14	132	0	14	150	0	9	24	0	92	81	0
CPA02 (Mile 4.16)	Upstream	2002-2003	NA			5	5	0	9	81	0	6	33	0	4	44	0	5	11	0	4	13	0	33	24	0
CPA03 (Mile 5.2)		2001-2003	3	3	0	11	13	0	15	49	0	12	48	0	11	35	0	6	59	0	6	13	0	64	29	0

Notes: n = number of samples
Geo = Geometric mean in MPN/100 mL

3.6 Pollutant Source Summary

3.6.1 Nutrients in Impaired Lakes

A key component to developing a nutrient TMDL is understanding the sources contributing to the impairment. This section provides a brief description of the potential sources in the watershed contributing to excess nutrients in the 20 lakes addressed in this TMDL. The latter sections of this report discuss the major pollutant sources that have been quantified using collected monitoring data and water quality modeling. The information presented here and in the upcoming sections together will provide information necessary to both assess the existing contributions of pollutant sources and target pollutant load reductions. MCWD has also completed a number of specialized studies that will inform implementation activities.

Both permitted and non-permitted sources are present within the watershed. There are a number of factors that can influence the nutrient levels in a lake. In the case of a number of the lakes addressed in this study, water quality in upstream lakes has a direct influence on the lakes located downstream in the watershed. Other factors influencing total phosphorus nutrient levels in these water bodies to consider are atmospheric nutrient loading, watershed nutrient loading, and internal phosphorus loading in each lake.

3.6.1.1 Permitted Sources

Phosphorus in lakes often originates on land. Phosphorus from sources such as phosphorus-containing fertilizer, manure, and the decay of organic matter can adsorb to soil particles. Wind and water action erode the soil, detaching particles and conveying them in stormwater runoff to nearby water bodies where the phosphorus becomes available for algal growth (Table 3.6.). Organic material such as leaves and grass clippings can leach dissolved phosphorus into standing water and runoff or be conveyed directly to water bodies where biological action breaks down the organic matter and releases phosphorus. Flow-through and ditched wetlands that have been disturbed and hydraulically altered can turn from a natural sink and become a source, exporting both particulate and dissolved phosphorus downstream. These wetlands typically fall under the “undeveloped” land use category.

Table 3.6. Potential permitted sources of phosphorus.

Permitted Source	Source Description	Phosphorus Loading Potential
Phase II Municipal Stormwater NPDES/SDS General Permit	Municipal Separate Storm Sewer Systems (MS4s)	Potential for runoff to transport sediment, grass clippings, leaves, car wash wastewater, and other phosphorus-containing materials to surface water through a regulated MS4 conveyance system.

Permitted Source	Source Description	Phosphorus Loading Potential
Construction Stormwater NPDES/SDS General Permit	Permits for any construction activities disturbing: 1) One acre or more of soil, 2) Less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than one acre or 3) Less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources.	The Environmental Protection Agency (EPA) estimates a soil loss of 20 to 150 tons per acre per year from stormwater runoff at construction sites. Such sites vary in the number of acres they disturb.
Multi-sector Industrial Stormwater NPDES/SDS General Permit	Applies to facilities with Standard Industrial Classification Codes in ten categories of industrial activity with significant materials and activities exposed to stormwater.	Significant materials include any material handled, used, processed, or generated that when exposed to stormwater may leak, leach, or decompose and be carried offsite.

3.6.1.2 Non-Permitted Sources

Table 3.7 describes several phosphorus sources that are not regulated by the NPDES program. For many lakes, especially shallow lakes, internal phosphorus sources can be a significant share of the total load to the lake. Under anoxic conditions at the lake bottom, weak iron-phosphorus adsorption bonds on sediment particles break, releasing phosphorus in a form highly available for algal uptake. In some cases such as Langdon Lake and Tanager Lake, a large pool of phosphorus is available in the sediments from decades of wastewater treatment plant effluent released into the lake. Carp and other rough fish uproot aquatic macrophytes during feeding and spawning and re-suspend bottom sediments, releasing phosphorus and increasing turbidity. Some aquatic vegetation species such as the invasive curly leaf pondweed die back in mid-summer, releasing phosphorus into the water column and often causing a late-summer algal bloom. (Eurasian watermilfoil, which is present in many of the lakes, is not a phosphorus source, but is an invasive that can negatively impact recreational use of lakes.)

Table 3.7. Potential non-permitted sources of phosphorus.

Non-Permitted Source	Source Description
Atmospheric Phosphorus Loading	Precipitation and dryfall (dust particles suspended by winds and later deposited).
Watershed Phosphorus Export	Variety in land use (see Table 3.2) creating both rural and urban stormwater runoff that does not pass through a regulated MS4 conveyance system.
Internal Phosphorus Release	Release from lake bottom sediments during periods of low dissolved oxygen; release from aquatic vegetation during senescence and breakdown.
Groundwater Contribution	Groundwater can be a source or sink for water in a lake and contains varying levels of phosphorus.
SSTS (Subsurface Sewage Treatment Systems)	SSTS failures on lakeshore homes can contribute to lake nutrient impairments. Contributions from SSTSs are estimated in Section 4 and are generally very small for the lakes in this study.

Table 3.8. Sources of phosphorus by lake.

Lake	Watershed Sources			Internal Sources				Upstream Lakes	Notes
	Agriculture	Urban	Other	Sediment Release	Historic Impacts (i.e. WWTP discharge)	Aquatic Vegetation (1)	Rough Fish (i.e. Carp) (2)		
Dutch	○	○	●	○			Δ		Phosphorus export from the extensive wetland system within the watershed is likely the predominant source. Eurasian watermilfoil is present. Carp and other rough fish present (2009).
E. Auburn			●			Δ	Δ	○	Eurasian watermilfoil and curly leaf pondweed present. Carp and other rough fish present (2012). Phosphorus export from the extensive wetland system within the watershed is likely the predominant source.
Forest		●	○	○			Δ		Eurasian watermilfoil present. Carp and other rough fish present (1992). Phosphorus export from upstream wetlands may be a contributing source.
Gleason		●		●		Δ	Δ	○	Eurasian watermilfoil and curly leaf pondweed present with the vegetation community dominated by coontail (Wenck 2007). Carp and other rough fish present (1996).
Holy Name	○	○	○	●					Source of excess watershed TP load likely from urban and agricultural areas.
Langdon		●	○	●	●				Rough fish present (1993). Historical wastewater effluent discharge load from the Mound Treatment Plant is thought to have impacted bottom sediment phosphorus concentrations and surface water concentrations in the lake. The plant operated from 1963 to 1974 (Wenck 2010). Phosphorus export from the upstream wetland system within the watershed may be a contributing source.
Long		●		●			Δ	●	Eurasian watermilfoil present. Carp and other rough fish present (2008).
Halsted Bay	○	○	●	●	○		Δ		Eurasian watermilfoil present. Carp and other rough fish present (2008). Halsted Bay was a secondary receiving water for the Victoria WWTP (Wenck 2007). Phosphorus export from the extensive wetland system within the watershed is likely a predominant source.
Jennings Bay	●	○	●	○	○		Δ	○	Eurasian watermilfoil present. Carp and other rough fish present (2008). Jennings Bay was a secondary receiving water for the Maple Plain WWTP (Wenck 2007). Phosphorus export from wetlands within the watershed is likely a source.
Stubbs Bay		●	○	○			Δ		Eurasian watermilfoil present. Carp and other rough fish present (2008). Phosphorus export from upstream wetlands may be a contributing source.
West Arm		○		●			Δ	●	Eurasian watermilfoil present. Carp and other rough fish present (2008).
Mooney	○	●	○	●		Δ	Δ		Curly leaf pondweed present (1995-2001, 2005, 2007-2011). A control program for curly leaf pondweed has been implemented by the Mooney Lake Association and herbicide treatment was performed in June 2011 (Blue Water Science 2011). Carp and other rough fish present (1992). Source of excess watershed TP load other than potential loading from urban and agricultural areas is unapparent.
Stone	○		○	●			Δ		Eurasian watermilfoil present. Rough fish present (2006). Upstream wetland may be a contributing phosphorus source.
Tamarack	○		○	●			Δ		Carp and other rough fish present (1994). Source of excess watershed TP load other than potential loading from agricultural areas is not apparent.
Tanager		○	○	○	○		Δ	●	Eurasian watermilfoil present. Rough fish present (1992). Tanager Lake was a primary receiving water for the Long Lake WWTP (Wenck 2007). Phosphorus export from upstream wetlands may be a contributing source.
Wolsfeld	●		●	○			Δ	○	Rough fish present (1993). Source of excess watershed TP load other than potential loading from agricultural areas is not apparent.
Snyder		○		○				●	
School	○		●	●					Source of excess watershed TP load likely from agricultural areas.
Hadley		●		●					
Turbid	●			●			Δ		Rough fish present (1992).

● Primary Source

○ Secondary Source

Δ Potential Source (Unknown Level of Impact)

Notes: (1) Very little aquatic vegetation information is available. A vegetation survey was performed in 2012 for East Auburn lake for the Six Mile Creek Diagnostic Study. Several lakes are included on the list of Minnesota's designated infested waters for Eurasian watermilfoil (an invasive plant species).

(2) Fish survey reports for the lakes addressed in this TMDL study were accessed from the Minnesota DNR LakeFinder website (http://www.dnr.state.mn.us/lakefind/index.html). Information was not available for all of the lakes. Fish survey data for Lake Minnetonka does not differentiate between bays.

3.6.2 *E. coli* Bacteria Sources

The lower portion of Painter Creek, which drains to Lake Minnetonka's Jennings Bay, is listed as impaired for *E. coli*. Bacteria loading can occur from both permitted and non-permitted sources. Permitted sources of bacteria can include industrial wastewater effluent, municipal wastewater treatment plant effluent, and municipal stormwater runoff.

Review of the Painter Creek watershed indicates that there are no current permitted wastewater discharges in the watershed. There are also no current Concentrated Animal Feeding Operations (CAFOs) within the watershed. However, there are NPDES/SDS Phase II permittees for municipal separate storm sewer systems (MS4s). Runoff from homes, pastures and other areas has the potential to transport waste from pets and other animals to surface water. Failing or nonconforming SSTS near waterways can also be a source of *E. coli* bacteria to streams, especially during dry periods when these sources continue to discharge and runoff driven sources are not active.

A roadside bacteria source assessment survey was performed in 2012 within the subwatersheds directly tributary to the impaired reach. The purpose of the assessment survey was to supplement wildlife and domestic animal estimates derived from literature values and census data by visually assessing potential bacteria sources in the Painter Creek subwatershed. The assessment survey area included both agricultural and urban areas. Appendix C includes a map of the surveyed areas and recorded observations. Based on the survey results, the primary source of bacteria loading is fecal matter from animals. Horses, cattle, chickens, turkeys, and ducks were all observed during the survey. In multiple cases, such livestock were observed directly adjacent to the creek on parcels in the riparian areas. Geese, deer, and other wildlife are also present in the Painter Creek subwatershed. Table 3.9 provides an estimate of the animals present and *E. coli* bacteria produced and available within the watershed.

Table 3.9. *E. coli b*acteria produced and available within the Painter Creek subwatershed.

Category	Source	Animal Units or Individuals in Subwatershed (8)	*E.coli* Organisms Produced Per Unit Per Month (Billions of Org.) (1)	Total *E. coli* Produced Per Month (Billions of Org.) (9)	Total *E. coli* Produced Per Month by Category (Billions of Org.) (9)	Total *E.coli* Available Per Month by Category (Billions of Org.) (7,9)	Percent by Category
Livestock (Surface Applied Manure) (6)	Horses (Animal Units)	170 - 200	8.0	1,400 - 1,600	110,000 - 150,000	110,000 - 150,000	75%
	Cattle (Animal Units)	60 - 80	1,900	110,000 - 150,000			
	Chickens/Turkeys (Animal Units)	0 - 0	650	0 - 0			
Wildlife	Deer (4)	40 - 120	10	400 - 1200	830 - 2400	830 - 2400	1%
	Waterfowl (5)	130 - 160	0.20	30			
	Other Wildlife	Equivalent of Deer	10	400 - 1200			
Human	Failing Septic Systems (3)	10	40	400	400	400	0%
Domestic Animals (2)	Improperly Managed Pet Waste	1030 - 1260	100	100,000 - 130,000	100,000 - 130,000	35,000 - 45,500	24%
					Total	150,000 - 200,000	100%

(1) Derived from literature values in Metcalf and Eddy (1991), Horsley and Witten (1996), Alderisio and DeLuca (1999), and ASAE Standards (1998). Values have been reported to two significant digits.
(2) 0.584 dogs/household and 0.638 cats/household (American Veterinary Medical Association, 2012)
(3) Based on map review, estimated 15 homes with septic systems adjacent to Painter Creek and a 25% failure rate (MPCA, 2012).
(4) Range based on 3 to 9 deer/sq mile (MNDNR 2011 Pre-Fawn Deer Density from Deer Population Model: Average of permit areas 229, 285, 338)
(5) Estimated from the MNDNR and US Fish & Wildlife Service 2011 Waterfowl Breeding Population Survey: Minnesota. The range of *E. coli* produced is very small and not apparent due to rounding.
(6) Based on data collected during the bacteria source assessment survey and and MPCA documented feedlots.
(7) Estimated that 35% of the E. Coli produced per month attributed to pet waste is improperly managed and available for runoff (CWP, 1999).
(8) Range provided is ±10% of the estimated number rounded to the nearest 10th.
(9) Rounded to two significant digits.

4.0 TMDL Development

4.1 Nutrients

4.1.1 Loading Capacity Methodology

The first step in developing an excess nutrient TMDL for lakes is to determine the total nutrient loading capacity or assimilative capacity for the lake. A key component for this determination is to estimate the current phosphorus loading by the sources for each lake. Following estimation of the current loading, lake response to phosphorus loading was modeled using the BATHTUB suite of models for the impaired lakes and the loading capacity was determined. The components of this process are described below.

4.1.1.1 Watershed Loading

Stream sampling data collected throughout the watershed from 2005-2011 was used to calculate watershed loading for the majority of the lakes addressed. 2005-2011 was used as the representative data period as it provided the most consistent data set. Discrete flow measurements and total phosphorus grab samples from 12 stream sampling sites were used to calculate Flow Weighted Mean Concentrations (FWMC) for total phosphorus. Figure 4.1 provides box plots of the FWMC data for each sample station examined. Sample station locations are indicated on the maps included in Appendix A.

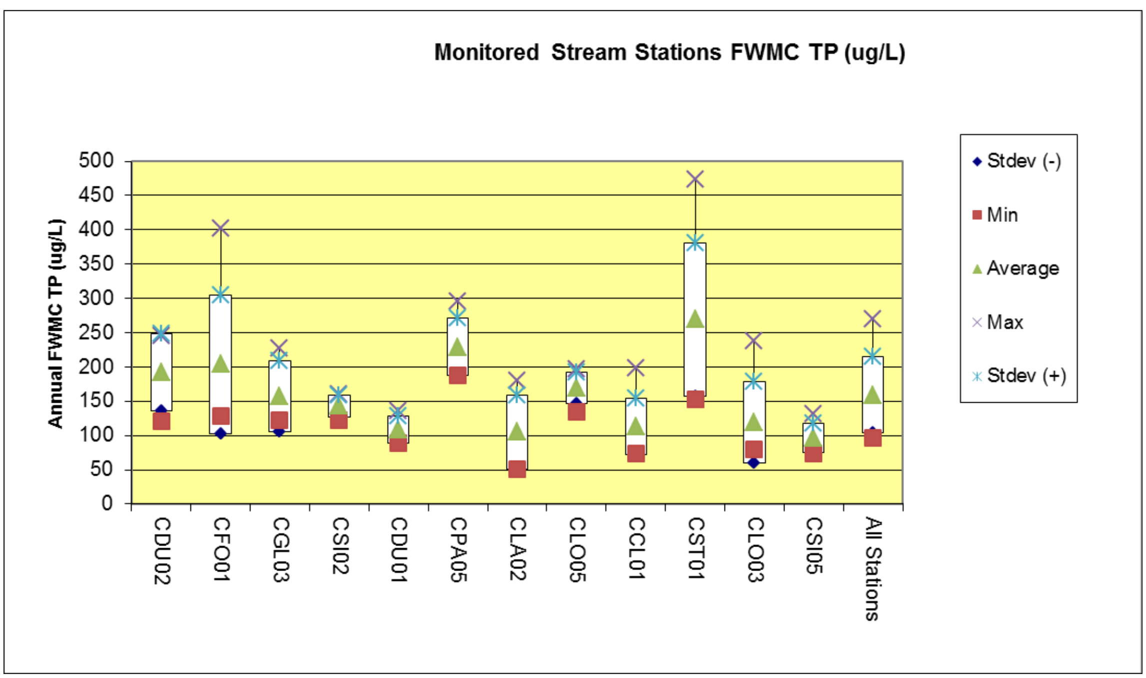


Figure 4.1. Total Phosphorus Flow Weighted Mean Concentration.

For unmonitored watersheds tributary to each lake, an average runoff volume and TP concentration applicable to the entire upper watershed area were used in the lake response models. The averages were calculated using the runoff volume and TP concentrations derived from the monitored subwatersheds tributary to each lake. The average watershed runoff depth was calculated as 5.12 inches/year. The average FWMC for the watershed was calculated as 159 µg/L. The range of values used to calibrate the models was 104 to 214µg/L (representing +/- the standard deviation from the average).

For East Auburn, Stone, and Turbid lakes, water volume and phosphorus loading to the lake were not monitored and therefore were derived from watershed modeling. An XP-SWMM model calibrated to annual runoff was developed to estimate runoff volumes. Once the volumes were estimated, a P8 model was developed to match the XP-SWMM runoff volumes on a monthly basis. Since water quality data were not available everywhere in the Six Mile Creek watershed, and the P8 model is of limited utility in agricultural parts of the watershed, a Unit Area Load (UAL) model was developed for the watershed. The UAL model was developed using the Minnesota Land Cover Classification System (MLCCS) and assigning categories a loading rate of lbs TP/acre (Table 4.1). The loading rates for each land use category were based on literature review values for land uses in Minnesota (Reckhow et al. 1980). The unmonitored watershed loads were then calculated by multiplying the percent of each land use category by its respective loading rate.

Table 4.1. Land Use Loading Rates Used to Estimate Runoff Concentrations.

MLCCS Land Use Category	Phosphorus Load (lbs/acre/year)
4% to 10% impervious cover	0.03
11% to 25% impervious cover	0.03
26% to 50% impervious cover	0.31
51% to 75% impervious cover	0.41
76% to 90% impervious cover	0.41
91% to 100% impervious cover	0.41
Agriculture	0.19
Emergent Marsh	0
Forest	0.03
Grassland	0.06
Open Water	0
Shrubland	0.06
Wetland	0

4.1.1.2 Septic System Loading

Septic information within the TMDL study area was collected by MCWD staff and provided by city, county, and Metropolitan Council Environmental Services (MCES) on septic systems in use. Based on the provided data, review of aerial photos, and a map review of the MCES facilities and infrastructure, the number of homes along the shore of each impaired lake using septic systems was estimated. Minimal information was available with regard to system failure rates, so a failure rate of 25% was applied to the estimated number of septic systems for use in the lake response models (MPCA, 2012). The annual load per septic system was calculated by assuming 2.8 people per system with a loading rate of 2.7 grams TP/person/day (USEPA Manual, 2002).

4.1.1.3 Upstream Lakes

Some of the lakes addressed in the TMDL have upstream lakes which are also addressed in the TMDL (Table 4.2). Meeting water quality standards in the downstream lakes is contingent on water quality improvements in the impaired upstream lakes. For example, improvements to Long Lake will be needed for Tanager Lake to meet state water quality standards. In turn, improvements to Wolsfeld, Holy Name, and School Lakes will be necessary to achieve water quality standards in Long Lake. Achieving water quality standards in Long Lake also assumes that ultimately the upstream Dickeys Lake, not addressed in this TMDL study, will meet the TP standard of 40 µg/L. (Note: Dickeys Lake is only slightly above the TP standard, and translates to only a three pound reduction from current estimated loading. This represents only about 0.4 percent of Long Lake's needed reduction. Dickeys Lake is not on the 303(d) list of impaired waters because it meets both chlorophyll-a and Secchi disk standards.)

Table 4.2. Upstream Lakes Addressed in this TMDL Study.

Lake	Upstream Lake
East Auburn	Stone
Gleason	Snyder
Long	Wolsfeld, Holy Name, School
Halsted Bay	E. Auburn, Stone, Turbid
Jennings Bay	Dutch
West Arm	Jennings Bay, Forest
Tanager	Long, Holy Name, Wolsfeld, School
Wolsfeld	School
Hadley	Mooney*

*Mooney is a landlocked lake. However, in emergency situations (high water/flood conditions) the capability exists to pump water from the lake to lower the water elevation. Water pumped from Mooney ultimately discharges to Hadley Lake. However, this system has never been operated and no pumping took place during the TMDL "average condition" period.

Kreatz Lake (lake number 27-0468-00), although not addressed in this TMDL study, is located directly upstream of Snyder Lake. Available data indicates that Kreatz Lake TP concentrations are exceeding state standards. Discharge from Kreatz Lake represents approximately 74% of the water load to Snyder. Improvements to Kreatz Lake are necessary in order to realize improvements in Snyder Lake. Kreatz Lake has been set as an upstream boundary condition of Snyder Lake and the load considered part of the load allocation (LA). Kreatz Lake is not addressed in this TMDL study because the lake is less than 10 acres in size and therefore was not assessed for listing. It is of note that the DNR and MPCA nomenclature for these lakes, which was used in this TMDL, is opposite of the local nomenclature. According to the DNR, the lake on the east side of County Road 101 in Plymouth, MN is Snyder Lake, and the lake on the west side of County Road 101 is Kreatz Lake. The City of Plymouth and local residents for many years have called the basin on the east side of County Road 101 Kreatz Lake, with Snyder Pond on the west side of the road.

Carl Krey Lake, Church Lake, Kelzer Pond, Stieger Lake, Wassermann Lake, and Sunny Lake are all located directly upstream of East Auburn Lake. These lakes represent approximately 85% of the water load to East Auburn and have been set as upstream boundary conditions with the load considered part of the LA. Available data indicates that Church and Wassermann Lakes are exceeding state standards and improvements are necessary to reach water quality goals in East Auburn Lake. It is of note that Wassermann Lake has a US EPA approved TMDL for nutrients and lake water quality is expected to improve.

There are other lakes upstream of those addressed in this TMDL that were not explicitly accounted for in each lake phosphorus and water budget. This is due to the lack of in-lake water quality data available for some upstream lakes as well as the data sets available for stream monitoring stations in close proximity to the downstream lake inlet (which include the phosphorus output from the upstream lake). The TP load from the upstream lakes not explicitly itemized is accounted for in the watershed load.

4.1.1.4 Atmospheric Deposition

A study conducted for the MPCA, "Detailed Assessment of Phosphorus Sources to Minnesota Watersheds" (Barr Engineering, 2004), estimated the atmospheric inputs of phosphorus from deposition for different regions of Minnesota. The rates vary based on the precipitation received in a given year. Precipitation received during 2005-2011 was within that study's average range (25" to 38"). That study's annual atmospheric deposition rate of 26.8 kg/km^2 for average precipitation years was used to calculate annual atmospheric deposition load for these lakes.

4.1.1.5 Groundwater

Groundwater (GW) can act as a source of water and phosphorus, a sink of water and phosphorus, or have no interaction with a lake. For the lakes addressed in this study, groundwater was determined to be either a net gain of water or a net loss. In some cases the source or sink of groundwater was calculated to have a negligible effect on the lake water budget. A description of the groundwater contribution calculation method can be found in Appendix D.

4.1.1.6 Internal Loading

Internal nutrient loading within a lake is typically the result of organic sediments releasing phosphorus into the water column. This often occurs when anoxic conditions are present, meaning that the lower portion of the water column is devoid of oxygen. Anoxic conditions occur when lakes stratify with warm, well oxygenated water near the surface and cold, oxygen depleted water at greater depths, down to the lake bottom. Temperature and dissolved oxygen profiles are used to determine the volume of lake water where anoxic conditions are occurring. The volume of the lake with anoxic conditions is used to calculate an anoxic factor (Nürnberg 2004), which is normalized over the entire lake basin and reported as a number of days. For example, if 25 percent of the volume of the lake experienced anoxic conditions for eight days, the anoxic factor would be two days. A description of the internal load calculation method and release rates can be found in Appendix E.

As discussed in Section 3.6, over-abundance of carp and some aquatic plants can also affect lake ecosystems by changing the dynamics of internal phosphorus loading. Minimal data is available to quantify carp and aquatic vegetation for the lakes addressed in this TMDL study (see Table 3.8).

4.1.1.7 BATHTUB Model (Lake Response)

Once the nutrient budget for a lake has been developed, the response of the lake to those nutrient loads must be established. Lake response to nutrient loading was modeled using the BATHTUB suite of models and the significant data set available for the impaired lakes. BATHTUB is a series of empirical eutrophication models that predict the response to phosphorus inputs for morphologically complex lakes and reservoirs (Walker 1999). Several models (subroutines) are available for use within the BATHTUB model, and the Canfield-Bachmann model was used to predict the lake response to total phosphorus loads. The Canfield-Bachmann model estimates the lake phosphorus sedimentation rate, which is needed to predict the relationship between in-lake phosphorus concentrations and phosphorus load inputs. The phosphorus sedimentation rate is an estimate of net phosphorus loss from the water column through sedimentation to the lake bottom, and is used in concert with lake-specific characteristics such as annual phosphorus loading, mean depth, and hydraulic flushing rate to predict in-lake phosphorus concentrations. These model predictions are compared to measured data to evaluate how well the model describes the lake system, and if necessary, the model parameters are adjusted appropriately to achieve an approximate match. Once a model is well calibrated, the resulting relationship between phosphorus load and in-lake water quality is used to determine the assimilative capacity.

To set the TMDL for each impaired lake in the study, the nutrient inputs partitioned between sources in the lake response model were then systematically reduced until the model predicted that each lake met the current total phosphorus standard of 60 μg/L as a growing season mean for shallow lakes and 40 μg/L for deep lakes. Lake response model results are included in Appendix F.

4.1.2 Load Allocation Methodology

The Load Allocation (LA) includes all non-permitted sources, including: atmospheric deposition, septic systems, discharge from upstream lakes, watershed loading from non-regulated areas, and internal loading. Some discharges from areas geographically located in a regulated MS4 that do not drain through a conveyance system (and therefore are not regulated sources) are also included in the LA (determined as described in the following section).

As atmospheric load is impossible to control on a local basis, no reduction in the source was assumed for the TMDLs. Also, septic systems when properly functioning do not discharge to surface water, so 100% reduction from failing systems is assumed. The general approach to internal load reductions was to evaluate the capacity for reducing the internal loading based on review of the existing sediment release rates and the lake morphometry. The capacity for watershed load reductions was also considered. For example, some watershed phosphorus export rates are already so low that large reductions would be infeasible. Therefore an internal load reduction is required to achieve water quality goals. However, in some cases, the situation was reversed and the internal load was already so low that watershed reductions were required. For example, the existing Stone Lake watershed load is 52 lbs/yr (approximately 0.07 lbs/acre/year) and the existing internal load is 130 lbs/yr (calculated using a sediment release rate of 3.5 mg/m^2-day). The watershed load is so low that a reduction would likely not be feasible. Therefore, the reduction was taken from the internal load (goal sediment release rate of 3.0 mg/ m^2-day) to achieve the in-lake water quality goal. As a converse example, the existing internal load for East Auburn Lake is 41 lbs/yr (calculated using a sediment release rate of 0.7 mg/ m^2-day) and the existing watershed load is 1,337 lbs/yr (approximately 1.5 lbs/acre/yr, in-line wetlands just upstream of the lake are a probable source of excess TP load). The reduction was taken from the watershed load because a reduction to the internal load would likely not be feasible due to the low existing sediment release rate. Table 4.3 presents the reductions required from the internal load and the watershed load to achieve water quality goals for each lake.

Table 4.3. Internal and watershed load reductions.

Lake Name	Depth Class	Internal Load Reduction(1)	Watershed Load Reduction(1)(2)
Dutch	Deep	10%	60%
E. Auburn	Deep	0%	31%
Forest	Deep	26%	60%
Gleason	Shallow	50%	64%
Holy Name	Shallow	79%	87%
Langdon	Shallow	21%	27%
Long	Deep	19%	62%
Halsted Bay	Deep	70%	72%
Jennings Bay	Deep	79%	72%
Stubbs Bay	Deep	0%	51%
West Arm	Deep	40%	93%
Mooney	Shallow	5%	89%
Stone	Deep	23%	0%
Tamarack	Deep	0%	0%
Tanager	Deep	70%	61%
Wolsfeld	Deep	34%	79%
Snyder	Shallow	0%	33%
School	Shallow	70%	75%
Hadley	Deep	54%	41%
Turbid	Deep	77%	20%

(1) considers MOS (5%)
(2) The total watershed load reduction is presented here and includes both WLA and LA. The tables in Section 4.1.7 split out the watershed load between WLA and LA (Non-MS4 runoff).

4.1.3 Wasteload Allocation Methodology

The WLA is required to include permitted discharges such as regulated stormwater. To address Construction and Industrial Stormwater NPDES/SDS General Permitting, one percent of the allowable watershed load has been assigned as a WLA for future permits. The remaining total wasteload has been distributed among regulated MS4s. Table 4.4 lists the regulated MS4s that will receive WLAs for each TMDL. Figures depicting the MS4 permittee jurisdictions for each lakeshed are included in Appendix G.

Table 4.4. Permitted MS4s in each Lakeshed.

ID Number	Name	Dutch	E. Auburn	Forest	Gleason	Holy Name	Langdon	Long	Halsted Bay	Jennings Bay	Stubbs Bay	West Arm	Mooney	Stone	Tamarack	Tanager	Wolsfeld	Snyder	School	Hadley	Turbid
MS400070	Carver County MS4	-	WLA	-	-	-	-	-	-	-	-	-	-	-	WLA	-	-	-	-	-	-
MS400079	Chanhassen City MS4	-	-	-	-	-	-	-	-	-	-	-	-	-	WLA	-	-	-	-	-	-
MS400138	Hennepin County MS4	WLA	-	WLA	WLA	WLA	WLA	WLA	WLA	WLA	WLA	WLA	WLA	WLA	-	WLA	WLA	WLA	-	WLA	-
MS400095	Independence City MS4	-	-	-	-	-	-	-	-	WLA	-	-	-	-	-	-	-	-	-	-	-
MS400142	Laketown Township MS4	-	WLA	-	-	-	-	-	WLA	-	-	-	-	WLA	-	-	-	-	-	-	WLA
MS400101	Long Lake City MS4	-	-	-	-	-	-	WLA	-	-	-	-	-	-	-	WLA	-	-	-	-	-
MS400103	Maple Plain City MS4	-	-	-	-	-	-		-	WLA	-	-	-	-	-	-	-	-	-	-	-
MS400105	Medina City MS4	-	-	-	-	WLA	-	WLA	-	WLA	-	-	WLA	-	-	-	WLA	-	WLA	-	-
MS400182	Minnehaha Creek WD MS4	-	-	-	WLA	-	-	-	WLA	-	-	-	-	-	-	-	-	-	-	-	-
MS400035	Minnetonka City MS4	-	-	-	WLA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS400106	Minnetrista City MS4	WLA	-	WLA	-	-	WLA		WLA	WLA	-	WLA	-	WLA	-	-	-	-	-	-	-
MS400170	MNDOT Metro District MS4	-	WLA	-	WLA	-		WLA	WLA	-	WLA	-	-	-	WLA	WLA	-	-	-	-	-
MS400108	Mound City MS4	WLA	-	-	-	-	WLA		WLA	WLA	-	WLA	-	-	-	-	-	-	-	-	-
MS400111	Orono City MS4	-	-	WLA	-	-	-	WLA	-	WLA	WLA	WLA	WLA	-	-	WLA	WLA	-	-	WLA	-
MS400112	Plymouth City MS4	-	-	-	WLA	WLA	-	WLA	-	-	-	-	WLA	-	-	-	-	WLA	-	WLA	-
MS400123	Spring Park City MS4	-	-	-	-	-	-	-	-	-	-	WLA	-	-	-	-	-	-	-	-	-
MS400124	St Bonifacius City MS4	-	-	-	-	-	-	-	WLA	-	-	-	-	-	-	-	-	-	-	-	-
MS400126	Victoria City MS4	-	WLA	-	-	-	-	-	WLA	-	-	-	-	WLA	WLA	-	-	-	-	-	-
MS400058	Wayzata City MS4	-	-	-	WLA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

The MS4 stakeholders reviewed three possible methods to assign each MS4 an individual WLA for each TMDL, and agreed the fairest approach is a “combination method” based half on the area of regulated land in the MS4’s jurisdiction in each lakeshed and half on land use and the percent impervious surface in the MS4 regulated area. The existing load was also partitioned between the MS4s based on runoff volume from a 1.3-inch event, calculated using composite curve numbers (CNs) and the SCS method, to determine required reductions.

The first step in partitioning the WLA and existing load among the MS4s was division of each lake watershed by MS4 permit holder. Next, the discharges to include in the WLA and those to include in the LA was determined. MS4s owned or operated within the entire jurisdiction of a city or township are subject to NPDES permit regulation. Counties, watershed districts, MnDOT, and other non-traditional MS4s are only subject to NPDES regulation for MS4s owned or operated within the U.S. Census Bureau-defined urban area. The 2010 U.S. Census Bureau-defined urban area was the dividing factor for the majority of the MS4 permitted areas. The percent impervious surface was also calculated for each MS4 regulated area using data from the HHPLS model, MLCCS land cover data, and Met Council land use data. For the MnDOT MS4 regulated area, MnDOT provided right of way data, impervious area and CN information for use in calculations. The impervious surface percentage for each MS4 regulated area was then used for the “combination method” calculation. These steps for partitioning the WLA and existing load are described in detail in Appendix H.

There is one non-stormwater NPDES –permitted point source in the Minnetonka (West Arm) watershed: Nilfisk-Advance Inc. (MN006648). Nilfisk-Advance, Inc. operates a groundwater remediation system located near the site of the former Advance Machine Company, 4080 Sunset Drive, Spring Park, and discharges groundwater treated with granulated activated carbon. The WLA for this facility is calculated below. This WLA may be expanded in the future if necessary, as long as the effluent concentration remains at levels that are less than or equal to the water quality standard.

- The maximum permitted flow rate is 0.144 MGD.
- The TP effluent concentration is 0.012 mg/L (based on a sample taken in June 2013); increased by 50 percent to account for uncertainty = 0.018 mg/L.
- Loading per day is: 0.144 x 0.018 x 8.34 conversion factor = 0.0216 lbs P/day. Loading per year is: 0.0216 x 365 days = 8 lbs P/year.

4.1.4 Margin of Safety

An explicit margin of safety (MOS) has been included in this TMDL. Five percent of the load has been set aside to account for any uncertainty in the lake response models. The 5% MOS was considered reasonable for all of the modeled lakes due to the quantity of watershed and in-lake monitoring data available. Watershed monitoring data collected over a 7 year period (2005 to 2011) was used for the majority of the lake modeling. In-lake monitoring data collected during the same 7 year period was also available for the majority of the lakes.

4.1.5 Seasonal Variation

Seasonal variation is accounted for through the use of annual loads and developing targets for the summer period, where the frequency and severity of nuisance algal growth will be the greatest.

Although the critical period is the summer, lakes are not sensitive to short term changes in water quality, rather lakes respond to long-term changes such as changes in the annual load. Therefore, seasonal variation is accounted for in the annual loads. Additionally, by setting the TMDL to meet targets established for the most critical period (summer), the TMDL will inherently be protective of water quality during the other seasons.

4.1.6 Future Growth Considerations/Reserve Capacity

The watersheds for these lakes are entirely within MS4 communities (and potentially subject to a WLA, determined as described in Section 4.1.3) with the exception of approximately 166 acres located in Watertown Township in the Halsted Bay subwatershed, areas of county and MnDOT right of way outside the U.S. Census Bureau-defined urban area, and agricultural and wetland drainage through unregulated conveyances. As such, urban stormwater is currently regulated under the NPDES Phase II stormwater permits and the reserve capacity is included in the WLA. The development projects that will occur will be covered under the member cities ordinances and the MCWD rules that are in place for development and redevelopment that are protective of water quality. Consequently, future development will have to meet watershed requirements that will account for pollution reductions in this TMDL.

Transfer of WLA to WLA will be required in the future for the East Auburn, Halsted Bay, Stone, and Turbid Lake TMDLs. Laketown Township has an orderly annexation agreement in place with the Cities of Victoria and Waconia. The Laketown Township WLA will be transferred to Victoria or Waconia as appropriate as land is annexed. Future transfer of loads will be based on methods consistent with those used in setting the allocations in this TMDL. Load transfers may also occur from LA to WLA or additional from WLA to WLA (e.g., due to expansion of the U.S. Census Bureau-defined urban area). In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified and will have an opportunity to comment on the reallocation.

4.1.7 TMDL Summary

The allowable TP load (TMDL) for each lake was divided among the WLA, LA, and the MOS as described in the preceding sections. Tables 4.5 through 4.24 below summarize the existing and allowable TP loads, the TMDL allocations, and required reductions for each lake. In these tables the total load reduction is the sum of the required WLA reductions plus the required LA reductions; this is not the same as the net difference between the existing and allowable total loads, however, because the WLA and LA reductions must accommodate the MOS (e.g. in Table 4.5 the difference between the total existing annual load, 591 lbs, and the total allowable load, 347 lbs, is 255 lbs; but the estimated load reduction is 262 lbs because it includes the MOS of 17 lbs).

The following rounding conventions were used in Tables 4.5 through 4.24:

- Values ≥1 reported in lbs/yr have been rounded to the nearest whole number.
- Values <1 reported in lbs/yr have been rounded to the nearest tenth of a pound.
- Values reported in lbs/day have been rounded to three significant digits.

Table 4.5. Dutch Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**591**	**1.62**	**347**	**0.950**	**262**	**44**
Wasteload	**Total WLA**	**319**	**0.874**	**126**	**0.346**	**193**	**60**
	Construction/Industrial SW	1	0.00406	1	0.00406	0.0	0
	Hennepin Co. (MS400138)	1	0.00354	0.5	0.00129	0.8	64
	Minnetrista (MS400106)	288	0.787	115	0.314	173	60
	Mound (MS400108)	29	0.0795	10	0.0268	19	66
Load	**Total LA**	**272**	**0.745**	**203**	**0.557**	**69**	**25**
	Non-MS4 runoff	10	0.0281	5	0.0127	6	55
	SSTS	46	0.125	0	0	46	100
	Upstream lakes	0	0	0	0	0	NA
	Atmospheric deposition	42	0.115	42	0.115	0	0
	Groundwater	0	0	0	0	0	NA
	Internal load	174	0.476	157	0.429	17	10
MOS				**17**	**0.0475**		

Table 4.6. East Auburn Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**2099**	**5.75**	**1551**	**4.25**	**626**	**30**
Wasteload	**Total WLA**	**1245**	**3.41**	**835**	**2.29**	**410**	**33**
	Construction/Industrial SW	10	0.0272	10	0.0272	0	0
	Carver County (MS400070)	1	0.00371	1	0.00371	0	0
	Laketown Township (MS400142)	2	0.00605	2	0.00605	0	0
	MNDOT (MS400170)	27	0.0752	11	0.0306	16	59
	Victoria City (MS400126)	1204	3.30	810	2.22	394	33
Load	**Total LA**	**854**	**2.34**	**639**	**1.75**	**215**	**25**
	Non-MS4 runoff	92	0.252	82	0.224	10	11
	SSTS	6	0.0167	0	0	6	100
	Upstream lakes	680	1.86	480	1.31	199	29
	Atmospheric deposition	35	0.0968	35	0.0968	0	0
	Groundwater	0	0	0	0	0	NA
	Internal load	41	0.112	41	0.112	0	0
MOS				**78**	**0.212**		

Table 4.7. Forest Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**327**	**0.896**	**189**	**0.518**	**147**	**45**
Wasteload	**Total WLA**	**194**	**0.530**	**78**	**0.213**	**116**	**60**
	Construction/Industrial SW	1	0.00248	1	0.00248	0	0
	Orono City MS4 (MS400111)	118	0.324	39	0.106	79	67
	Hennepin County (MS400138)	8	0.0228	3	0.00870	5	62
	Minnetrista City MS4 (MS400106)	66	0.181	35	0.0951	31	47
Load	**Total LA**	**134**	**0.366**	**102**	**0.280**	**31**	**24**
	Non-MS4 runoff	8	0.0219	4	0.00991	4	55
	SSTS	0	0	0	0	0	NA
	Upstream lakes	0	0	0	0	0	NA
	Atmospheric deposition	21	0.0586	21	0.0586	0	0
	Groundwater	0	0	0	0	0	NA
	Internal load	104	0.285	77	0.211	27	26
MOS				**9**	**0.0259**		

Table 4.8. Gleason Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**856**	**2.34**	**431**	**1.180**	**447**	**52**
Wasteload	**Total WLA**	**325**	**0.890**	**118**	**0.324**	**207**	**64**
	Construction/Industrial SW	1	0.00383	1	0.00383	0	0
	Hennepin County (MS400138)	10	0.0266	3	0.007	7	73
	MNDOT (MS400170)	5	0.0135	3	0.007	2	47
	Plymouth City MS4 (MS400112)	290	0.794	105	0.288	185	64
	Minnetonka City MS4 (MS400035)	2	0.00658	1	0.003	1	50
	Wayzata City MS4 (MS400058)	16	0.0437	5	0.014	11	69
	MCWD (MS400182)	0.5	0.00134	0.2	0.0006	0	57
Load	**Total LA**	**531**	**1.45**	**291**	**0.797**	**240**	**45**
	Non-MS4 runoff	0	0	0	0	0	NA
	SSTS	0	0	0	0	0	NA
	Upstream lakes	53	0.146	20	0	33	62
	Atmospheric deposition	40	0.111	40	0.111	0	0
	Groundwater	23	0.0642	23	0.0642	0	0
	Internal load	414	1.13	207	0.567	207	50
MOS				**22**	**0.0590**		

Table 4.9. Holy Name Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**450**	**1.23**	**106**	**0.290**	**350**	**78**
Wasteload	**Total WLA**	**32**	**0.088**	**1**	**0.0031**	**31**	**96**
	Construction/Industrial SW	0.1	0.000392	0.1	0.000392	0	0
	Medina City MS4 (MS400105)	27	0.0732	1	0.00233	26	97
	Hennepin County (MS400138)	0.1	0.000162	0.0	0.00000319	0	98
	Plymouth City MS4 (MS400112)	5	0.0144	0.1	0.000375	5	97
Load	**Total LA**	**418**	**1.14**	**99**	**0.272**	**319**	**76**
	Non-MS4 runoff	39	0.108	8	0.0216	32	80
	SSTS	0	0	0	0	0	NA
	Upstream lakes	0	0	0	0	0	NA
	Atmospheric deposition	17	0.0458	17	0.0458	0	0
	Groundwater	0	0	0	0	0	NA
	Internal load	362	0.991	75	0.205	287	79
MOS				**5**	**0.0145**		

Table 4.10. Langdon Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**393**	**1.08**	**325**	**0.891**	**84**	**21**
Wasteload	**Total WLA**	**166**	**0.454**	**121**	**0.332**	**44**	**27**
	Construction/Industrial SW	1	0.00383	1	0.00383	0	0
	Hennepin County (MS400138)	7	0.0195	4	0.0108	3	45
	Minnetrista City MS4 (MS400106)	65	0.178	58	0.159	7	11
	Mound (MS400108)	92	0.252	58	0.158	34	37
Load	**Total LA**	**228**	**0.623**	**188**	**0.514**	**40**	**17**
	Non-MS4 runoff	3	0.00716	2	0.00600	0.4	16
	SSTS	0	0	0	0	0	NA
	Upstream lakes	0	0	0	0	0	NA
	Atmospheric deposition	34	0.0932	34	0.0932	0	0
	Groundwater	0	0	0	0	0	NA
	Internal load	191	0.523	152	0.415	39	21
MOS				**16**	**0.0445**		

Table 4.11. Long Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**1465**	**4.01**	**761**	**2.08**	**742**	**51**
Wasteload	**Total WLA**	**665**	**1.82**	**255**	**0.697**	**411**	**62**
	Construction/Industrial SW	3	0.00812	3	0.00812	0	0
	Orono City MS4 (MS400111)	224	0.614	100	0.273	125	56
	Hennepin County (MS400138)	41	0.113	5	0.0150	36	87
	Plymouth City MS4 (MS400112)	0.0	0.000	0.0	0.000	0.0	0
	Long Lake City MS4 (MS400101)	164	0.449	29	0.0790	135	82
	Medina City MS4 (MS400105)	216	0.591	113	0.309	103	48
	MNDOT (MS400170)	17	0.0470	5	0.0132	12	72
Load	**Total LA**	**800**	**2.19**	**468**	**1.28**	**332**	**41**
	Non-MS4 runoff	8	0.0226	4	0.00999	5	56
	SSTS	0	0	0	0	0	NA
	Upstream lakes	363	0.994	97	0.265	266	73
	Atmospheric deposition	69	0.188	69	0.188	0	0
	Groundwater	39	0.106	39	0.106	0	0
	Internal load	322	0.881	261	0.713	61	19
MOS				**38**	**0.104**		

Table 4.12. Halsted Bay TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**6171**	**16.9**	**2064**	**5.65**	**4210**	**68**
Wasteload	**Total WLA**	**2858**	**7.82**	**771**	**2.11**	**2087**	**73**
	Construction/Industrial SW	10	0.0282	10	0.0282	0	0
	Hennepin County (MS400138)	15	0.0399	6	0.0160	9	60
	Minnetrista City MS4 (MS400106)	1289	3.53	382	1.04	907	70
	Mound (MS400108)	11	0.0310	5	0.0130	6.6	58
	MNDOT (MS400170)	16	0.0444	4	0.0104	12	76
	St Bonifacius City (MS400124)	183	0.502	77	0.211	106	58
	MCWD (MS400182)	9	0.0246	2	0.00583	7	76
	Victoria City (MS400126)	0.4	0.00117	0.0	0.000	0.4	93
	Laketown Township (MS400142)	1324	3.62	285	0.781	1038	78

Table 4.12, continued. Halsted Bay TMDL Summary.

Load	**Total LA**	**3314**	**9.07**	**1190**	**3.26**	**2123**	**64**
	Non-MS4 runoff	511	1.40	157	0.430	354	69
	SSTS	0	0.000	0	0	0	NA
	Upstream lakes	0	0.000	0	0.000	0	NA
	Atmospheric deposition	134	0.367	134	0.367	0	0
	Groundwater	141	0.386	141	0.386	0	0
	Internal load	2527	6.92	758	2.08	1769	70
MOS				**103**	**0.283**		

Table 4.13. Jennings Bay TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**3505**	**9.60**	**1039**	**2.84**	**2518**	**72**
Wasteload	**Total WLA**	**2159**	**5.91**	**596**	**1.63**	**1563**	**72**
	Construction/Industrial SW	7	0.0189	7	0.0189	0	0
	Medina City MS4 (MS400105)	538	1.47	140	0.383	398	74
	Orono City MS4 (MS400111)	244	0.669	92	0.251	153	62
	Hennepin County (MS400138)	7	0.0203	2	0.00589	5.3	71
	Minnetrista City MS4 (MS400106)	418	1.14	139	0.381	279	67
	Mound (MS400108)	31	0.0859	8	0.0232	23	73
	Independence City MS4 (MS400095)	806	2.21	189	0.517	617	77
	Maple Plain City MS4 (MS400103)	107	0.294	18	0.0506	88.8	83
Load	**Total LA**	**1346**	**3.69**	**391**	**1.07**	**955**	**71**
	Non-MS4 runoff	144	0.394	43	0.119	101	70
	SSTS	0	0.000	0	0	0	NA
	Upstream lakes	210	0.574	77	0.211	132	63
	Atmospheric deposition	73	0.200	73	0.200	0	0
	Groundwater	0	0.000	0	0.000	0	NA
	Internal load	920	2.52	198	0.541	722	79
MOS				**52**	**0.142**		

Table 4.14. Stubbs Bay TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**585**	**1.60**	**406**	**1.11**	**199**	**34**
Wasteload	**Total WLA**	**275**	**0.754**	**134**	**0.366**	**142**	**51**
	Construction/Industrial SW	2	0.00463	2	0.00463	0	0
	Orono City MS4 (MS400111)	269	0.735	129	0.354	139	52
	Hennepin County (MS400138)	5	0.0131	3	0.00719	2	45
	MNDOT (MS400170)	0.5	0.00129	0.1	0.000356	0.3	72
Load	**Total LA**	**309**	**0.847**	**252**	**0.690**	**57**	**19**
	Non-MS4 runoff	27	0.0734	15	0.0413	12	44
	SSTS	46	0.125	0	0.000	46	100
	Upstream lakes	0	0.000	0	0.000	0	NA
	Atmospheric deposition	47	0.130	47	0.130	0	0
	Groundwater	50	0.137	50	0.137	0	0
	Internal load	140	0.382	140	0.382	0	0
MOS				**20**	**0.0556**		

Table 4.15. West Arm TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**3421**	**9.37**	**1915**	**5.24**	**1602**	**47**
Wasteload	**Total WLA**	**156**	**0.427**	**19**	**0.0513**	**137**	**88**
	Construction/Industrial SW	1	0.00292	1	0.00292	0	0
	Orono City MS4 (MS400111)	31	0.0845	3	0.00849	28	90
	Hennepin County (MS400138)	19	0.0527	1	0.00265	18	95
	Minnetrista City MS4 (MS400106)	0.7	0.00179	0.0	0.0000411	0.6	98
	Mound (MS400108)	53	0.144	4	0.0099	49	93
	Spring Park City MS4 (MS400123)	43	0.118	2	0.00542	41	95
	Nilfisk-Advance Inc. (MN006648)	8	0.0219	8	0.0219	0	0
Load	**Total LA**	**3265**	**8.94**	**1800**	**4.93**	**1465**	**45**
	Non-MS4 runoff	0.2	0.000522	0.1	0.000378	0.1	27
	SSTS	0	0.000	0	0.000	0	NA
	Upstream lakes	1403	3.84	607	1.66	795	57
	Atmospheric deposition	197	0.538	197	0.538	0	0
	Groundwater	0	0.000	0	0.000	0	NA
	Internal load	1665	4.560	996	2.73	669	40
MOS				**96**	**0.262**		

Table 4.16. Mooney Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**209**	**0.572**	**134**	**0.368**	**81**	**39**
Wasteload	**Total WLA**	**65**	**0.178**	**7**	**0.0181**	**58**	**90**
	Construction/Industrial SW	0.2	0.000418	0.2	0.000418	0	0
	Medina City MS4 (MS400105)	8	0.0229	1	0.00355	7	84
	Orono City MS4 (MS400111)	1	0.00337	0.4	0.00109	1	68
	Hennepin County (MS400138)	0.7	0.00180	0.1	0.000200	0.6	89
	Plymouth City MS4 (MS400112)	55	0.150	5	0.0129	50	91
Load	**Total LA**	**144**	**0.394**	**121**	**0.331**	**23**	**16**
	Non-MS4 runoff	9	0.0258	2	0.00529	7.5	79
	SSTS	11	0.0292	0	0.000	11	100
	Upstream lakes	0	0.000	0	0.000	0	NA
	Atmospheric deposition	27	0.0740	27	0.0740	0	0
	Groundwater	0	0.000	0	0.000	0	NA
	Internal load	97	0.265	92	0.252	5	5
MOS				**7**	**0.0184**		

Table 4.17. Stone Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**206**	**0.563**	**186**	**0.508**	**29**	**14**
Wasteload	**Total WLA**	**34**	**0.0937**	**34**	**0.0937**	**0**	**0**
	Construction/Industrial SW	0.5	0.00142	0.5	0.00142	0	0
	Hennepin County (MS400138)	0.1	0.000276	0.1	0.000276	0	0
	Minnetrista City MS4 (MS400106)	9	0.0239	9	0.0239	0	0
	Victoria City (MS400126)	2	0.00479	2	0.00479	0	0
	Laketown Township (MS400142)	23	0.0633	23	0.0633	0	0
Load	**Total LA**	**171**	**0.469**	**142**	**0.389**	**29**	**17**
	Non-MS4 runoff	18	0.0484	18	0.0484	0	0
	SSTS	0	0.000	0	0.000	0	NA
	Upstream lakes	0	0.000	0	0.000	0	NA
	Atmospheric deposition	24	0.0650	24	0.0650	0	0
	Groundwater	0	0.000	0	0.000	0	NA
	Internal load	130	0.356	101	0.276	29	23
MOS				**9**	**0.0254**		

Table 4.18. Tamarack Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**73**	**0.201**	**73**	**0.201**	**0**	**0**
Wasteload	**Total WLA**	**6**	**0.0171**	**6**	**0.0171**	**0**	**0**
	Construction/Industrial SW	0.2	0.000591	0.2	0.000591	0	0
	Carver County (MS400070)	0.1	0.000312	0.1	0.000312	0	0
	Victoria City (MS400126)	4	0.01205	4	0.01205	0	0
	MNDOT (MS400170)	1	0.00325	1	0.00325	0	0
	Chanhassen City MS4 (MS400079)	0.3	0.000918	0.3	0.000918	0	0
Load	**Total LA**	**67**	**0.184**	**67**	**0.184**	**0**	**0**
	Non-MS4 runoff	15	0.0420	15	0.0420	0	0
	SSTS	0	0.000	0	0.000	0	NA
	Upstream lakes	0	0.000	0	0.000	0	NA
	Atmospheric deposition	7	0.0196	7	0.0196	0	0
	Groundwater	0	0.000	0	0.000	0	NA
	Internal load	45	0.122	45	0.122	0	0
MOS				**NA**	**NA**		

Table 4.19. Tanager Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**1178**	**3.22**	**447**	**1.22**	**753**	**64**
Wasteload	**Total WLA**	**174**	**0.477**	**68**	**0.187**	**106**	**61**
	Construction/Industrial SW	0.9	0.00249	0.9	0.00249	0	0
	Orono City MS4 (MS400111)	114	0.312	55	0.151	59	51
	Hennepin County (MS400138)	7	0.0180	2	0.00562	5	69
	MNDOT (MS400170)	7	0.0197	1	0.00333	6	83
	Long Lake City MS4 (MS400101)	46	0.125	9	0.0242	37	81
Load	**Total LA**	**1003**	**2.75**	**356**	**0.975**	**647**	**64**
	Non-MS4 runoff	0.2	0.000640	0.1	0.000335	0.1	48
	SSTS	0	0.000	0	0.000	0	NA
	Upstream lakes	737	2.02	258	0.705	480	65
	Atmospheric deposition	13	0.0352	13	0.0352	0	0
	Groundwater	14	0.0382	14	0.0382	0	0
	Internal load	239	0.654	72	0.196	167	70
MOS				**22**	**0.0612**		

Table 4.20. Wolsfeld Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**361**	**0.989**	**136**	**0.372**	**232**	**64**
Wasteload	**Total WLA**	**96**	**0.263**	**17**	**0.0470**	**79**	**82**
	Construction/Industrial SW	0.5	0.00126	0.5	0.00126	0	0
	Medina City MS4 (MS400105)	92	0.252	16	0.0440	76	83
	Orono City MS4 (MS400111)	3	0.00945	1	0.00180	3	81
	Hennepin County (MS400138)	0.0	0.000	0.0	0.000	0.0	80
Load	**Total LA**	**265**	**0.725**	**112**	**0.306**	**153**	**58**
	Non-MS4 runoff	88	0.242	22	0.0607	66	75
	SSTS	3	0.00833	0	0.000	3	100
	Upstream lakes	102	0.279	38	0.105	63	62
	Atmospheric deposition	10	0.0264	10	0.0264	0	0
	Groundwater	3	0.00687	3	0.00687	0	0
	Internal load	59	0.162	39	0.107	20	34
MOS				**7**	**0.0186**		

Table 4.21. Snyder Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**69**	**0.188**	**49**	**0.134**	**22**	**32**
Wasteload	**Total WLA**	**11**	**0.0313**	**8**	**0.0209**	**4**	**33**
	Construction/Industrial SW	0.1	0.000277	0.1	0.000277	0.0	0
	Hennepin County (MS400138)	0.9	0.00245	0.5	0.00146	0.4	40
	Plymouth City MS4 (MS400112)	10	0.0286	7	0.0191	3	33
Load	**Total LA**	**57**	**0.156**	**39**	**0.106**	**18**	**32**
	Non-MS4 runoff	0.0	0.000	0.0	0.000	0	11
	SSTS	0	0.000	0	0.000	0	NA
	Upstream lakes	37	0.100	18	0.0505	18	50
	Atmospheric deposition	3	0.00786	3	0.00786	0	0
	Groundwater	0	0.000	0	0.000	0	NA
	Internal load	18	0.0480	18	0.0480	0	0
MOS				**2**	**0.00670**		

Table 4.22. School Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**242**	**0.661**	**69**	**0.189**	**176**	**73**
Wasteload	**Total WLA**	**39**	**0.108**	**8**	**0.0207**	**32**	**81**
	Construction/Industrial SW	0.3	0.000766	0.3	0.000766	0	0
	Medina City MS4 (MS400105)	39	0.107	7	0.0199	32	81
Load	**Total LA**	**202**	**0.553**	**58**	**0.159**	**144**	**71**
	Non-MS4 runoff	60	0.165	17	0.0465	43	72
	SSTS	11	0.0291	0	0.000	11	100
	Upstream lakes	0	0.000	0	0.000	0	NA
	Atmospheric deposition	3	0.00727	3	0.00727	0	0
	Groundwater	0	0.000	0	0.000	0	NA
	Internal load	128	0.351	39	0.105	90	70
MOS				**3**	**0.00946**		

Table 4.23. Hadley Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD		**157**	**0.429**	**89**	**0.243**	**72**	**46**
Wasteload	**Total WLA**	**61**	**0.166**	**36**	**0.0973**	**25**	**41**
	Construction/Industrial SW	0.4	0.00109	0.4	0.00109	0	0
	Orono City MS4 (MS400111)	0.2	0.000445	0.1	0.000304	0	32
	Hennepin County (MS400138)	6	0.0168	2	0.00660	4	61
	Plymouth City MS4 (MS400112)	54	0.147	33	0.0893	21	39
Load	**Total LA**	**96**	**0.263**	**49**	**0.134**	**47**	**49**
	Non-MS4 runoff	0.0	0.000	0.0	0.000	0.0	34
	SSTS	0	0.000	0	0.000	0	NA
	Upstream lakes	0	0.000	0	0.000	0	NA
	Atmospheric deposition	8	0.0231	8	0.0231	0	0
	Groundwater	0	0.000	0	0.000	0	NA
	Internal load	88	0.240	40	0.110	47	54
MOS				**4**	**0.012**		

Table 4.24. Turbid Lake TMDL summary.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	**lbs/day**	**lbs/yr**	**lbs/day**	**lbs/yr**	**%**
TOTAL LOAD		**249**	**0.683**	**117**	**0.321**	**138**	**55**
Wasteload	**Total WLA**	**5**	**0.013**	**4**	**0.010**	**1**	**27**
	Construction/Industrial SW	0.8	0.00210	0.8	0.00210	0	0
	Laketown Township (MS400142)	4	0.011	3	0.008	1	32
Load	**Total LA**	**244**	**0.669**	**108**	**0.295**	**137**	**56**
	Non-MS4 runoff	84	0.2307	67	0.1845	17	20
	SSTS	15	0.0416	0	0.000	15	100
	Upstream lakes	0	0.000	0	0.000	0	NA
	Atmospheric deposition	10	0.0261	10	0.0261	0	0
	Groundwater	0	0.000	0	0.000	0	NA
	Internal load	135	0.371	31	0.0848	104	77
MOS				**6**	**0.0161**		

4.2 E. coli

The *E. coli* data used for the development of the Painter Creek TMDL are grab samples collected by MCWD between 2001 and 2011 that represent current conditions in the watershed. Samples were analyzed for fecal coliform prior to 2006 and more recently *E. coli*. All fecal coliform data was converted to *E. coli* "equivalents" using the following equation:

E. coli concentration (equivalents) = 0.63 x (Fecal Coliform Concentration)

The *E. coli* concentration standard of 126 cfu/100 mL was considered reasonably equivalent to the former fecal coliform standard of 200 cfu/100 mL from a public health protection standpoint. The SONAR (Statement of Need and Reasonableness) Book III Section VII.D.5 (MPCA 2007) supports this rationale using a log plot to show the relationship between these two parameters. The relationship has an R^2 value of 0.69. The above regression equation was deemed reasonable to convert fecal coliform data to *E. coli* equivalents. Appendix A includes a figure of the Painter Creek subwatershed which shows the location of the monitoring stations at which samples were collected to support this TMDL.

Stream flow data was crucial to support development of the TMDL. Streamflow data paired with *E. coli* measurements allow exceedances to be evaluated by flow regime which, in turn, may provide insight into potential sources.

4.2.1 Loading Capacity Methodology

Loading capacity of the impaired stream was developed from a load duration curve. Load duration curves incorporate flow and *E. coli* data across stream flow regimes and provide loading capacities and a means of estimating load reductions necessary to meet water quality standards.

4.2.1.1 Flow Duration Curve Development

A flow duration curve (Figure 4.2) was developed using discrete 2000 to 2011 flow data collected seasonally at station CPA01, the furthermost downstream monitoring station within the impaired reach, located approximately 0.8 miles upstream from Jennings Bay. CPA01 was chosen for use due to the quantity of flow data available compared to the other three monitoring stations located within the impaired reach (CPA05, CPA06, and CPA04).

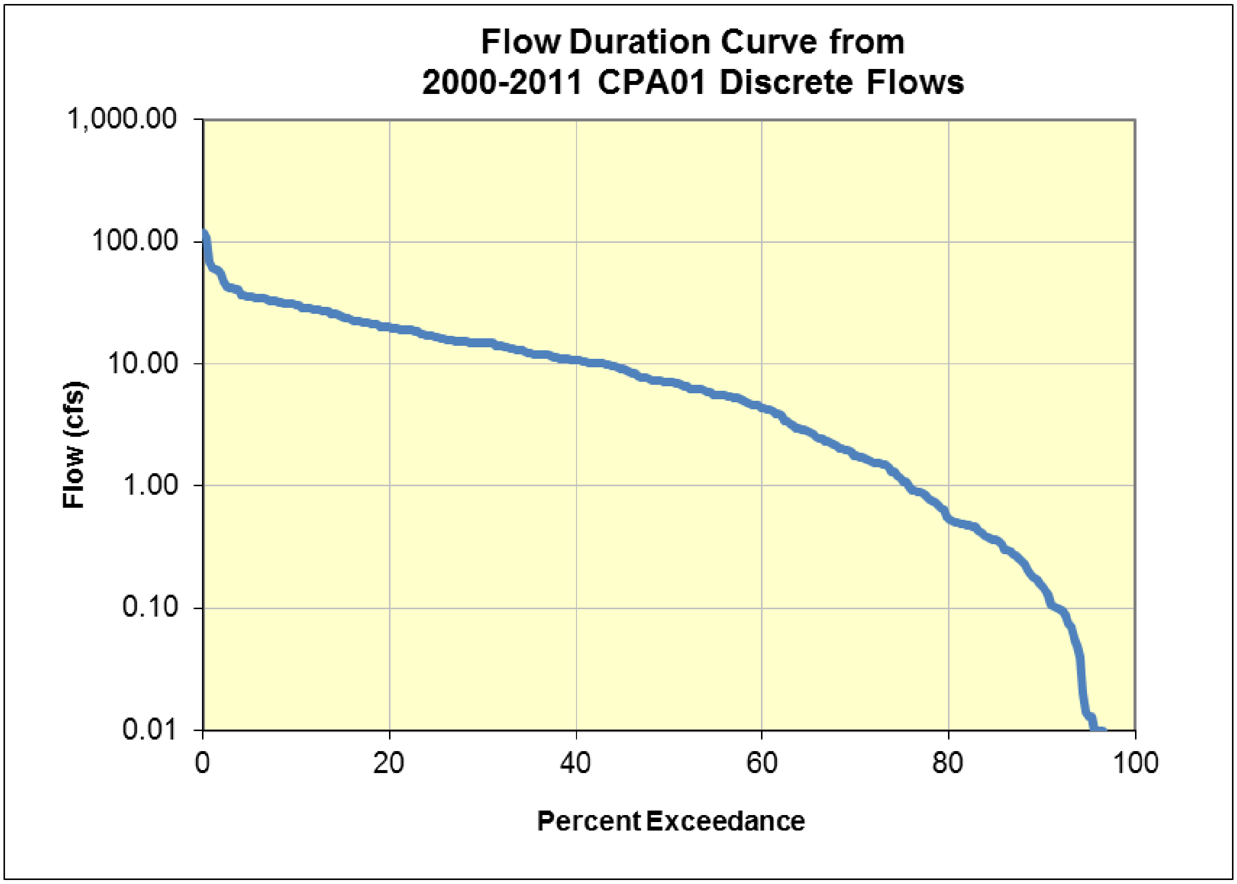


Figure 4.2. Painter Creek flow duration curve.

The curved line relates mean daily flow to the percent of time those values are exceeded. For example, at the 40% exceedance value, the streamflow was 10 cubic feet per second or greater 40% of the time.

4.2.1.2 Load Duration Curve Development

To develop a load duration curve, all average daily flow values were multiplied by the 126 cfu/100 mL standard and converted to a daily load to create a "continuous" load duration curve (Figure 4.3). On this figure the curve represents the loading capacity of the stream for each daily flow. The curve is divided into flow zones including High (0-10%), Wet (10-40%), Mid-range (40-60%), Dry (60-90%) and Low (90 to 100%) flow conditions. In the TMDL equation table (Table 4.28), for simplicity only the median (or midpoint) load of each flow zone is used to show the TMDL equation components. The loading capacity can also be compared to current conditions by plotting the measured load for each water quality sampling event. Each value that is above the curve represents an exceedance of the water quality standard while those below the line are below the water quality standard.

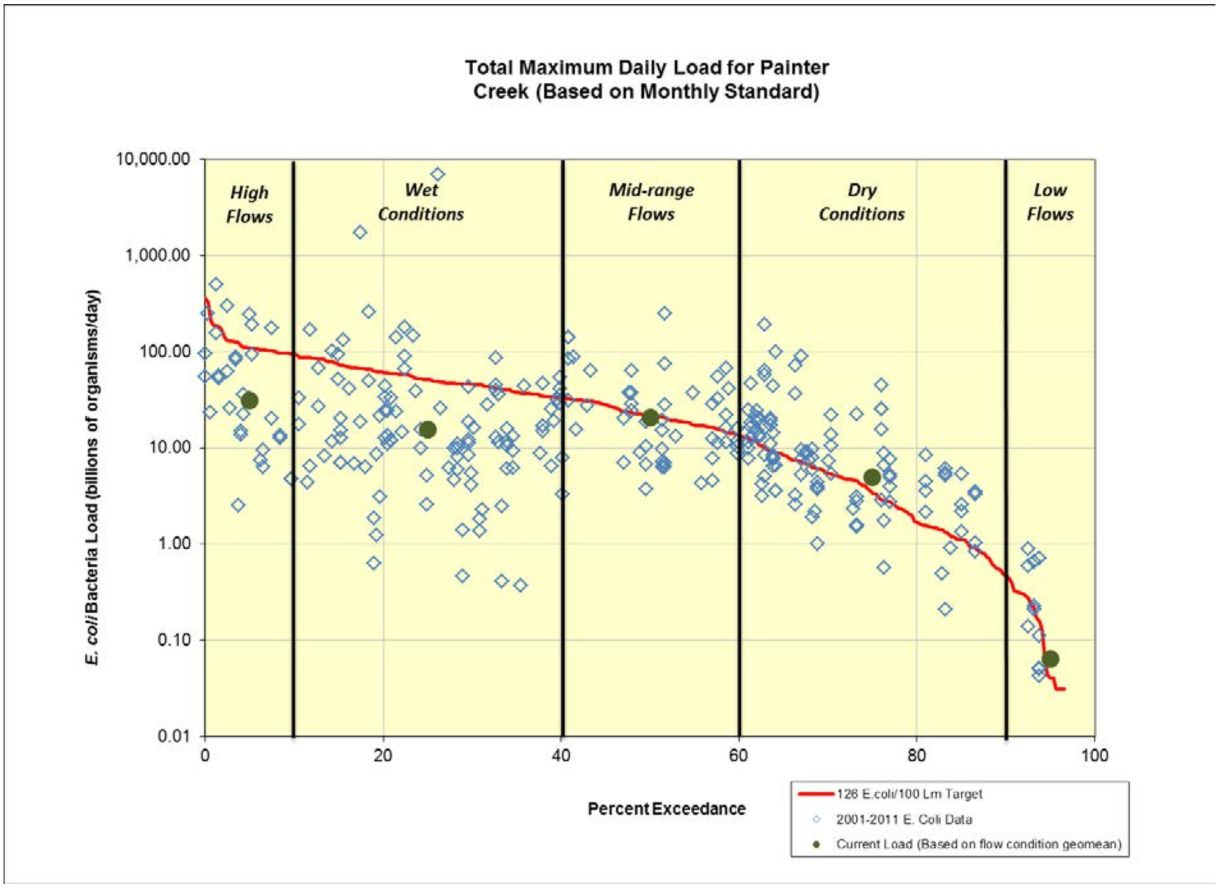


Figure 4.3. Painter Creek load duration curve (TMDL).

The calculated current load, based on the flow condition geomean and the median flow, indicates that load reductions are required in the impaired reach of Painter Creek for the Dry and Low Flow conditions. Although there are discrete data points where the measured load exceeds the TDLC for the High, Wet, and Mid-range flow conditions, reductions are not required based on the flow condition geomean.

4.2.2 Load Allocation Methodology

Non-point sources include all non-permitted sources in the watershed such as runoff from some agricultural land and non-regulated areas. This category also includes any *E. coli* considered "natural background." Natural background is that contribution that occurs outside of human influence. This would generally be wildlife contributions that are directly loaded to the water body (as opposed to loaded via a stormwater conveyance). Because the geomeans of the impaired reach of Painter Creek are below or meeting water quality standards for the High, Wet, and Mid-range conditions, the WLA and the LA were set equal to the calculated current load. Load remaining following subtraction of the MOS, WLA, and LA for each of these flow zones was identified as "Unallocated Load." The unallocated load is the difference between the allowed load and the total loading capacity of the impaired reach.

4.2.3 Wasteload Allocation Methodology

For bacteria TMDLs, sources of bacteria that require wasteload allocations may include wastewater dischargers, regulated MS4s, and sometimes others. There are currently no permitted wastewater dischargers in the Painter Creek impaired reach watershed. Table 4.26 lists the permitted MS4s receiving individual WLAs for the Painter Creek Bacteria TMDL. Appendix G includes a figure of the MS4 permit holder jurisdictions for the Painter Creek subwatershed.

Table 4.25 Painter Creek Permitted MS4s

ID Number	Name
MS400138	Hennepin County MS4
MS400095	Independence City MS4
MS400103	Maple Plain City MS4
MS400105	Medina City MS4
MS400106	Minnetrista City MS4
MS400111	Orono City MS4

The WLA was determined based on land area under the jurisdiction of MS4s determined by the same methods previously described in section 4.1.3 and detailed in Appendix H. The WLA is distributed amongst the MS4s based on the same methodology as well.

4.2.4 Margin of Safety

The MOS for the bacteria TMDL accounts for uncertainties in both characterizing current conditions and the relationship between the load, wasteload, monitored flows, and in-stream water quality so the TMDL allocations result in attainment of water quality standards. An explicit MOS equal to 10 percent of the total load was applied whereby 10 percent of the loading capacity for each flow regime was subtracted before allocations were made among wasteload and load. Ten percent was considered an appropriate MOS since the load duration curve approach minimizes a great deal of uncertainty associated with the development of TMDLs because the calculation of the loading capacity is very precise since it is the resulting product of flow multiplied by the target value. Most of the uncertainty with that calculation is therefore associated with the estimated flows in each assessed segment which were based on the discrete flow record at CPA01 and is considered fairly accurate.

4.2.5 Seasonal Variation

Geometric means for *E. coli* bacteria within the impaired reach of Painter Creek are above the state chronic standard in July through October. Exceedances of the acute standard also occur in September and October. Fecal bacteria are most productive at temperatures similar to their origination environment in animal digestive tracts. Thus, these organisms are expected to be at their highest concentrations during warmer summer months when stream flow is typically low and water temperatures are highest. High *E. coli* concentrations continue into the fall, which may be attributed to constant sources of *E. coli* (such as animal access to the stream) and less flow for dilution. However, this data may be skewed as more samples were collected in the summer months than in October. Seasonal and annual variations are accounted for by setting the TMDL across the entire observed flow record using the Load Duration Method.

4.2.6 Future Growth Considerations/Reserve Capacity

There are MS4 communities located within the Painter Creek Watershed potentially subject to a WLA (determined as described in Section 4.2.3). Urban stormwater is currently regulated under the NPDES Phase II stormwater permits except for areas of county and MnDOT right of way outside the U.S. Census Bureau-defined urban area and agricultural and wetland drainage through unregulated conveyances. The reserve capacity is included in the WLA. Development projects that will occur will be covered under the MCWD and member cities' rules in place for development and redevelopment that are protective of water quality. Consequently, future development will have to meet watershed requirements that will account for pollution reductions in this TMDL. Also, future development of agricultural land will result in alternate land uses, potentially reducing bacteria sources related to agriculture.

Future transfer of loads in this TMDL may be necessary. Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL. Load transfers may occur from LA to WLA or from WLA to WLA (e.g., due to expansion of the U.S. Census Bureau-defined urban area). In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified and will have an opportunity to comment on the reallocation.

4.2.7 TMDL Summary

Table 4.28 presents the current loading, the total loading capacity, margin of safety, wasteload allocations, and load allocations for the impaired reach of Painter Creek. Values reported in billions of organisms/day have been rounded to three significant digits. Due to rounding, the reported numbers may not sum exactly to the total values presented, and the required percent reductions may not exactly reflect the reported values.

Table 4.26. Painter Creek TMDL summary.

		Flow Regime				
		High	**Wet**	**Mid**	**Dry**	**Low**
		Billions of Organisms/day				
TOTAL LOAD		110	51.0	21.9	3.45	0.0401
Existing Load		30.8	15.5	20.5	4.99	0.0636
Wasteload	**Total WLA**	28.9	14.5	19.3	2.92	0.0339
	Medina City MS4 (MS400105)	7.85	3.94	5.22	0.778	0.00903
	Orono City MS4 (MS400111)	3.56	1.79	2.37	0.493	0.00572
	Hennepin County (MS400138)	0.0361	0.0181	0.0240	0.00318	0.0000369
	Minnetrista City MS4 (MS400106)	4.15	2.08	2.76	0.508	0.00590
	Independence City MS4 (MS400095)	11.8	5.92	7.85	1.04	0.0120
	Maple Plain City MS4 (MS400103)	1.56	0.783	1.04	0.103	0.00120
Load	**Total LA**	1.86	0.933	0.470	0.188	0.00218
Unallocated Load		67.9	30.5	0.000	0.000	0.000
MOS		11.0	5.10	2.19	0.345	0.00401
Estimated Load Reduction		**%**				
		0%	0%	0%	31%	37%

5.0 Reasonable Assurances

Reasonable assurance (RA) activities are programs that are in place to assist in attaining the Upper Watershed TMDL allocations and applicable water quality standards. The RA evaluation provides documentation that the TMDL's WLAs and LAs are properly calibrated and the TMDL loads will ultimately meet the applicable water quality targets. Without such calibration, a TMDL's ability to serve as an effective guidepost of water quality improvement is significantly diminished. The development of a rigorous RA demonstration includes both state and local regulatory oversight, funding, implementation strategies, follow-up monitoring, progress tracking and adaptive management. (Note: Some of these elements are described in sections 6.0 and 7.0.)

There are two separate but complimentary frameworks in place to ensure progress toward achieving the water quality targets identified in this TMDL. The first is between the MPCA and regulated MS4s through the MPCA's Stormwater Program. The second is between the Minnehaha Creek Watershed District (MCWD) and local government units (LGUs) in the TMDL study area through the MCWD's Water Resources Management Plan and the LGUs' local water management plans. Both of these frameworks are described in detail below.

5.1 MPCA Stormwater Program

The MPCA is responsible for applying federal and state regulations to protect and enhance water quality within the Upper Minnehaha Creek watershed. The MPCA oversees all regulated MS4 entities in stormwater management accounting activities. All regulated MS4s in the Upper Minnehaha Creek watershed fall under the category of Phase II. MS4 NPDES/SDS permits require regulated municipalities to implement BMPs to reduce pollutants in stormwater runoff to the Maximum Extent Practicable (MEP).

All owners or operators of regulated MS4s (also referred to as "permittees") are required to satisfy the requirements of the MS4 general permit. The MS4 general permit requires the permittee to develop a Stormwater Pollution Prevention Program (SWPPP) that addresses all permit requirements, including the following six minimum control measures:

- Public education and outreach
- Public participation
- Illicit Discharge Detection and Elimination (IDDE) Program
- Construction-site runoff controls;
- Post-construction runoff controls; and
- Pollution prevention and municipal good housekeeping measures

A SWPPP is a management plan that describes the MS4 permittee's activities for managing stormwater within their jurisdiction or regulated area. In the event a TMDL study has been completed, approved by U.S. EPA prior to the effective date of the general permit, and assigns a wasteload allocation to an MS4 permittee, that permittee must document the WLA in their application and provide an outline of the best management practices to be implemented in the current permit term to address any needed reduction in loading from the MS4.

MPCA requires applicants submit their application materials and SWPPP document to MPCA for review. Prior to extension of coverage under the general permit, all application materials are placed on 30-day public notice by the MPCA, to ensure adequate opportunity for the public to comment on each permittee's stormwater management program. Upon extension of coverage by the MPCA, the permittees are to implement the activities described within their SWPPP, and submit annual reports to MPCA by June 30 of each year. These reports document the implementation activities which have been completed within the previous year, analyze implementation activities already installed, and outline any changes within the SWPPP from the previous year.

The MPCA has assigned nutrient and bacteria loads for the Upper Watershed TMDLs to the regulated MS4s. The pollutant load allocations for each MS4 entity are outlined in section 4.0 of the TMDL. The MS4 General Permit, which became effective August 1, 2013, requires permittees to develop compliance schedules for any TMDL that received U.S. EPA-approval prior to the effective date of the General Permit. This schedule must identify BMPs that will be implemented over five-year permit term, timelines for their implementation, an assessment of progress, and a long term strategy for continued progress toward ultimately achieving those WLAs. Because this Upper Watershed TMDL will be approved after the effective date of the General Permit, MS4s will not be required to report on WLAs contained in this TMDL until the effective date of the next General Permit, expected in 2018.

Reasonable assurance that the WLAs calculated for the Upper Watershed TMDLs will be implemented is provided by regulatory actions. According to 40 CFR 122.44(d)(1)(vii)(B), NPDES permit effluent limits must be consistent with assumptions and requirements of all WLAs in an approved TMDL. MPCA's stormwater program and its NPDES permit program are the state programs responsible for ensuring that implementation activities are initiated and maintained, and effluent limits are consistent with the WLAs calculated from the TMDLs. The NPDES program requires construction and industrial sites to create SWPPPs which summarize how stormwater will be minimized from construction and industrial sites.

5.2 MCWD Water Resources Management Plan

The Minnehaha Creek Watershed District (MCWD) was created under the Minnesota Watershed District Act of 1955, which charged watershed districts with integrating water management efforts among city, county and state agencies. The overall goals of restoring impaired water resources and protecting water resources from further degradation require an active partnership between the MCWD and local government units (LGUs) which include all the cities and townships with the MCWD. MCWD has actively engaged in partnering efforts with LGUs whose jurisdiction areas are within the boundaries of the Upper Minnehaha Creek watershed. The MCWD's main effort at partnering with LGUs has been via implementation efforts devised from MCWD's Comprehensive Water Resources Management Plan of 2007 (referred to as the '2007 MCWD Plan').

Prior to the development of the Upper Watershed TMDLs, the MCWD sought to improve water quality within the TMDL study area boundaries. These efforts included various watershed studies and the crafting of nutrient loading reduction strategies. The MCWD completed a Hydrologic, Hydraulic, and Pollutant Loading Study (HHPLS) in 2003 to investigate water quantity and quality within the watershed. The HHPLS was intentionally designed to parallel the MPCA's TMDL program and incorporated an extensive public process to help identify water quality goals for all the major lakes and streams within the Minnehaha Creek watershed. Information from this effort was utilized as the foundation for MCWD developing initial nutrient load reduction targets.

The 2007 MCWD Plan includes phosphorus load reduction plans that were developed for each lake that did not meet the water quality goals identified through the HHPLS. These phosphorus load reduction plans consist of three main components: the MCWD regulatory program, MCWD capital improvement projects, and LGU requirements. The load reductions assigned to the LGUs were calculated based on existing land uses where a 15 percent reduction in loading was required from residential land use; 25 percent from agricultural land use; and 10 percent from other developed land use.

The District undertakes projects and programs each year as it implements its 2007 Plan. Some recent examples pertinent to this TMDL include:

- Partnered with the City of Plymouth to restore an eroding channel upstream of Gleason Lake (2012).
- Restored a partially drained wetland and expanded a City of Victoria pond that together will expand flood storage and water quality treatment for 250 acres tributary to Steiger Lake, which is upstream of East Auburn Lake (2013).
- Constructed four curb-cut rain gardens in a residential area tributary to Saunders Lake, which is upstream of Langdon Lake (2012).
- Installed an iron filing filter berm on a tributary just upstream of Dutch Lake to add particulate and dissolved phosphorus reduction (2012).
- Converted 20 acres of row crops in the Painter Creek subwatershed into upland prairie, three wetlands, a water control structure to control water level, and woodland plantings (2008)
- Converted 130 acres of cropland in the Six Mile Creek subwatershed just upstream of Halsted Bay to native prairie and created or expanded six wetlands through drain tile removal (2013).
- Operates a variety of grant programs to provide financial and technical assistance for residents, business owners, and local government units for water quality improvement projects such as: low impact development practices, stormwater BMPs, shoreline and streambank stabilization, replacement of failing septic systems, and environmental education/demonstration projects.
- Operates a Land Conservation Program to acquire fee title or conservation easements on key parcels to protect water resources, and develop and implement restoration projects and conservation management plans.
- Operates an active education and outreach program including information booths at numerous public events; maintaining an active traditional and social media presence; and an ongoing Citizen's Advisory Committee.

Under MN Statutes 103B.231, each LGU is required to prepare its own local water management plan, capital improvement program, and official controls as necessary to bring local water management into conformance with the watershed plan. These local water management plans are then reviewed and approved by the watershed district. Therefore, within the MCWD, the LGUs must identify in their local water management plans specific steps they will take to accomplish the phosphorus reductions that are assigned to them in the 2007 MCWD Plan. The MCWD provides the LGUs with the flexibility to determine the most efficient and cost-effective means of achieving the reductions. The LGUs must annually report to the MCWD their progress toward accomplishing their load reductions.

This existing framework for identifying reduction strategies and tracking progress toward achieving water quality goals closely parallels the framework for tracking progress toward TMDL goals through the MPCA's Stormwater Program. With the completion of the Upper Watershed TMDLs, the MCWD will serve to coordinate implementation efforts among LGUs and help ensure progress toward the TMDL targets.

In addition to the reductions that were assigned to the LGUs and reductions that were anticipated through implementation of the MCWD's regulatory program, the 2007 MCWD Plan identified capital improvement projects that the MCWD would undertake in order to achieve the remaining reductions that were needed to meet the water quality targets. Although the MCWD is a regulated MS4, its jurisdiction as a regulated MS4 entity is limited to the conveyances owned or operated by the District within the U.S. Census Bureau-defined urban area which is a fairly small area. Since the MCWD generally does not need the credit for the reductions it will achieve through its capital improvement program for the purposes of MS4 permit compliance, MCWD has adopted a policy that allows for the distribution of this credit among its member communities.

This policy ensures that credit for pollutant reductions achieved through MCWD projects is accounted for and is distributed in a fair and equitable way among its member communities in recognition that the funding for those projects comes from a watershed-wide ad valorem tax levy. The MCWD will track and report annually, by May 30th, to the MS4s and MPCA a summary of the reductions achieved through its projects in the previous calendar year and the breakdown of credit by MS4.

Reductions for the non-regulated (load allocation) portions of the TMDLs will also be needed. These loads include non-MS4 runoff, which includes some agricultural land as well as shoreline and streambank erosion, and internal loading, which is significant for some lakes. Both the Hennepin Conservation District and the Carver Soil & Water Conservation District provide technical and financial assistance to agricultural landowners to implement conservation efforts that reduce runoff and erosion and protect water quality. The MCWD's capital improvement program includes a number of internal load reduction projects and streambank stabilization projects, and the MCWD will continue to take the lead on efforts to reduce loading from these non-regulated sources.

5.3 Funding

LGU funding for water resource projects typically comes from some combination of the following sources: general tax revenue, special assessments, development fees, stormwater utility fees, and grants. The MCWD is funded through local property taxes. This annual tax base comprises one of the main funding mechanisms for MCWD sponsored implementation activities within the watershed. The MCWD utilizes this funding base to sponsor cost-share and grant programs to assist municipal partners with local water quality improvement projects. There are other funding mechanisms which the MCWD and LGUs may apply for in the State of Minnesota such as; grants under the Clean Water Legacy Act (CWLA) and funding through the Clean Water Partnership program. MCWD may also explore the funding mechanisms provided through the federal Section 319 grant program which provides cost share dollars to implement voluntary activities in the watershed.

The CWLA is a statute passed in Minnesota in 2006 for the purposes of protecting, restoring, and preserving Minnesota water and providing significant funding to do so. The Act discusses how MPCA and the involved public agencies and private entities will coordinate efforts regarding land use, land management, water management, etc. Cooperation is also expected between agencies and other entities regarding planning efforts, and various local authorities and responsibilities. This would also include informal and formal agreements to jointly use technical, educational, and financial resources.

The CWLA also provides details on the overall TMDL process and follow-up implementation strategy development, and how the funding will be used. The Minnesota Board of Soil and Water Resources administers the Clean Water Fund for restoration and protection grants, and has developed a detailed grants policy explaining what is required to be eligible to receive Clean Water Fund money (FY ’11 Clean Water Fund Competitive Grants Policy; Minnesota Board of Soil and Water Resources, 2011).

5.4 Schedule and Tracking

After the approval of the TMDL by EPA, the MCWD will work with LGUs to develop a general timeline and strategy for implementation activities to be conducted within each permit cycle and/or plan cycle. The reduction targets assigned to LGUs through the 2007 MCWD Plan were generally less stringent than those identified in the TMDL and can therefore serve as interim goals through the end of the current plan cycle in 2017. Progress toward the TMDL targets will be assessed as part of the decennial MCWD Plan revision and new targets will be set for that plan cycle. Progress will also be assessed through the reporting requirements of the MPCA’s stormwater program and NPDES permit requirements.

6.0 Monitoring Plan

Water quality sampling in MCWD is conducted as part of the annual Hydrologic Data Monitoring Program. MCWD has monitored lake water quality, stream flow and quality, precipitation and other hydrologic parameters annually beginning in 1968. Since 1997, the District has actively coordinated with other agencies to collect additional monitoring data. The ongoing program was expanded in 2002 and again in 2003 to include more monitoring locations and additional automatic monitoring equipment.

The District's monitoring program:

- Tracks long term lake and stream water quality trends,
- Quantifies nutrient and sediment export and watershed runoff
- Informs feasibility studies,
- Tracks efficacy of District Projects
- Provides model calibration datasets, and
- Provides the foundation for the District's Capital Improvement Program.

The program is a joint collaboration between MCWD, the Minneapolis Park and Recreation Board (MPRB), the Metropolitan Council Environmental Services (MCES), the Three Rivers Park District (TRPD), the Minnesota Pollution Control Agency (MPCA), the Lake Minnetonka Conservation District (LMCD), and the Minnesota Department of Natural Resources (MN DNR). In 2012 MCWD staff monitored 27 sites on Lake Minnetonka and 15 sites on other upper watershed lakes, and 17 additional upper watershed lakes were monitored by program partners. Streamflow and water quality were monitored at 31 stream sites in the upper watershed. Program data including a calculation of annual runoff, flow, pollutant loads, and precipitation is published annually in the Annual Hydrological Monitoring Report (posted on-line: http://www.minnehahacreek.org/data-center/monitoring-reports). Lake Report Cards summarizing data in a non-technical manner are published each year.

Progress toward meeting TMDL goals will be measured by regularly monitoring water quality and tracking total BMPs completed. Water quality monitoring will be accomplished through the Hydrologic Data Monitoring Program. It is anticipated that member cities and permitted MS4s will perform monitoring in the watershed or evaluation via other methods as applicable to the partitioned WLA and associated correlation to each NPDES permit.

7.0 Implementation Strategy Summary

7.1 Implementation Framework

The strategies described in this section are potential actions to reduce nutrient and bacterial loads in the Upper Watershed. These actions will be further developed in a separate, more detailed strategy development report. MCWD will coordinate implementation actions identified in this TMDL and the separate report.

NPDES permit requirements must be consistent with the assumptions and requirements of an approved TMDL and associated Wasteload Allocations. For the purposes of this TMDL, the baseline year for implementation will be the mid-range year of the data years used for the lake response modeling (Table 7.1) and development of the bacteria load duration curve. The rationale for this is that projects undertaken recently may take a few years to influence water quality. Any load-reducing BMP implemented since the baseline year will be eligible to “count” toward an MS4’s load reductions. If a BMP was implemented during or just prior to the baseline year, the MPCA is open to presentation of evidence by the MS4 permit holder to demonstrate that it should be considered as a credit.

Table 7.1. Implementation baseline years.

Water body	Baseline Year
Painter Creek	2006
Dutch	2008
East Auburn	2010
Forest	2008
Gleason	2008
Holy Name	2007
Langdon	2010
Long	2008
Halsted Bay	2008
Jennings Bay	2008
Stubbs Bay	2008
West Arm	2008
Mooney	2007
Stone	2006
Tamarack	2008
Tanager	2008
Wolsfeld	2007
Snyder	2007
School	2009
Hadley	2007
Turbid	2006

7.2 Potential Nutrient Reduction Implementation Strategies

Table 7.2 lists Best Management Practices (BMPs) that may be successful in reducing nutrient loads and managing lake water quality. Not all BMPs would be appropriate for every lake. These potential BMPs will be explored more thoroughly, including targeting the most appropriate BMPs for each water body, in the accompanying strategy report. Table 7.2 also shows typical cost ranges for each practice, and an estimated overall cost that will be refined in the strategy report. As noted in Section 5.2 above, the District and the MS4s have been and will continue to implement BMPs, and have already undertaken similar projects in the lakesheds since the TMDL baseline year.

Table 7.2. Potential nutrient reduction implementation strategies.

Reduction Target	Potential BMP/Reduction Strategy	Range of BMP/ Reduction Strategy Costs	Total Estimated Associated Cost
Watershed Load	**Education Programs –** *Provide education and outreach on grazing management, low-impact lawn care practices, and other topics to increase awareness of sources of pollutants.*	$2,000 - $10,000	$42,000 - $210,000
	Shoreline Restoration – *Encourage property owners to restore their shoreline with native plants and install/enhance shoreline buffers.*	$15,000 - $22,500	$315,000 - $472,500
	Raingarden/Bio-filtration Basins – *Encourage the use of rain gardens and similar features as a means of increasing infiltration and evapotranspiration. Opportunities may range from a single property owner to parks and open spaces.*	$500 - $10,000	$105,000 – $2,100,000
	Stormwater Pond Retrofits/Installation - *As opportunities arise, retrofit stormwater treatment through a variety of BMPS. Pond expansion and pre-treatment of water before it reaches the ponds may be beneficial dependent on drainage area. Also, identify target areas for new stormwater pond installation.*	$30,000 - $100,000	$1,890,000 - $6,300,000
	Street Sweeping Program Review/Implementation – *Identify target areas for increased frequency of street sweeping and consider upgrades to traditional street sweeping equipment.*	$100,000 - $200,000	$1,500,000 - $3,000,000

Reduction Target	Potential BMP/Reduction Strategy	Range of BMP/ Reduction Strategy Costs	Total Estimated Associated Cost
	Agricultural BMP Implementation – *Encourage property owners to implement agricultural BMPs for nutrient load reduction. The Agricultural BMP Handbook for Minnesota (MDA 2012) provides an inventory of agricultural BMPs that address water quality in Minnesota. Several examples include conservation cover, buffer strips, grade stabilization, controlled drainage, rotational grazing, and irrigation management, among many other practices.*	\$15,000 - \$20,000	\$315,000 - \$420,000
Internal Load	**Technical Review –** *Prior to internal load reduction strategy implementation, a technical review is recommended to evaluate the cost and feasibility of lake management techniques such as hypolimnetic withdrawal, alum treatment, and hypolimnetic aeration to manage internal nutrient sources.*	\$25,000 - \$50,000	\$325,000 - \$650,000
	Alum Dosing – *If determined feasible based on technical review, chemically treat with alum to remove phosphorus from the water column as well as bind it in sediments.*	\$155,000 - \$465,000	\$2,015,000 - \$6,045,000
	Hypolimnetic Withdrawal or Aeration – *If determined feasible based on technical review, pump nutrient-rich water from the hypolimnion to an external location for phosphorus treatment and discharge treated water back into the lake. Or as an alternate option, aerate the hypolimnetic waters to maintain oxic condition (the anoxic condition of the hypolimnetic sediments is the contributor to the internal phosphorus load).*	\$150,000 - \$1,000,000	\$1,950,000 - \$13,000,000
	Aquatic Plant Surveys/Vegetation Management – *Conduct periodic aquatic plant surveys and prepare and implement vegetation management plans.*	\$10,000 - \$15,000	\$130,000 - \$195,000
	Rough Fish Surveys/Management – *Consider partnership with the DNR to monitor and manage the fish population. Evaluate options to reduce rough fish populations such as installation of fish barriers to reduce rough fish access and migration.*	\$10,000 - \$15,000	\$130,000 - \$195,000

Reduction Target	Potential BMP/Reduction Strategy	Range of BMP/ Reduction Strategy Costs	Total Estimated Associated Cost
SSTS Load	**Septic System Inspection Program –** *Although not a significant source of nutrients, Hennepin and Carver Counties should continue to inspect and order upgrades of existing septic systems; prioritizing properties near surface waters.*	$25,000 - $30,000	$50,000 - $60,000
Total Estimated Nutrient TMDL Implementation Cost			$8,452,000 - $32,228,000
Total Estimated Nutrient TMDL WLA Reduction Implementation Cost			$2,958,000 - $11,280,000
Total Estimated Nutrient TMDL LA Reduction Implementation Cost			$5,494,000 - $20,948,000

Construction Stormwater: The wasteload allocation for stormwater discharges from sites where there is construction activities reflects the number of construction sites of one or more acres expected to be active in the watershed at any one time, and the Best Management Practices (BMPs) and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in the State's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local construction stormwater requirements must also be met.

Industrial Stormwater: The wasteload allocation for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES industrial stormwater permit coverage is required, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at the industrial sites are defined in the State's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying, and Hot Mix Asphalt Production facilities (MNG490000). If a facility owner/operator obtains coverage under the appropriate NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local stormwater management requirements must also be met.

7.3 Potential E. coli Reduction Implementation Strategies

Table 7.3 lists Best Management Practices (BMPs) that may be successful in reducing bacteria loads. These potential BMPs will be explored more thoroughly, including targeting the most appropriate BMPs by location, in the accompanying strategy report. Table 7.3 also shows typical cost ranges for each practice, and an estimated overall cost that will be refined in the strategy report.

Table 7.3. Potential *E. coli* reduction implementation strategies.

Potential BMP/Reduction Strategy	Total Estimated Associated Cost
Streambank Stabilization/Buffer Enhancement – *Stabilize native vegetation to filter runoff from pastures adjacent to the stream. A recommended goal is at least 50 feet of buffer on 100% of both sides of the stream.*	$200,000 - $250,000
Education – *Provide educational and outreach opportunities about proper fertilizer use, manure management, grazing management, and other topics to encourage good individual property management practices.*	$2,000 - $10,000
Pasture Management – *Livestock exclusion from public waters, creating alternate livestock watering systems, rotational grazing, and vegetated buffer strips between grazing land and surface* water bodies.	$5,000 - $25,000
Manure Management – *Reduction of winter spreading, eliminate spreading near open inlets, apply at agronomic rates, erosion control practices, and manure stockpile runoff controls.*	$5,000 - $25,000
Septic System Inspection Program Review *Although not a significant source of bacteria, Hennepin County should continue to inspect and order upgrades of existing septic systems; prioritizing properties near Painter Creek and its tributaries.*	$25,000 - $30,000
Limit Animal Access to the Stream – *Limit animal access to the stream by installing fencing in pastures where access is unimpeded and installing buffer vegetation where existing fencing is directly adjacent to the stream bank.*	$50,000 - $75,000
Pet Waste Management – *Review member cities local ordinances and associated enforcement and fines for residents who do not clean up pet waste. Increase enforcement and education about compliance with such an ordinance.*	$5,000 - $15,000
Total Estimated Bacteria TMDL Implementation Cost	$292,000 - $430,000
Total Estimated Bacteria TMDL WLA Reduction Implementation Cost	$272,000 - $400,000
Total Estimated Bacteria TMDL LA Reduction Implementation Cost	$20,000 - $30,000

7.4 Adaptive Management

This list of implementation elements and the more detailed implementation strategy report that will be prepared following this TMDL assessment focuses on adaptive management (Figure 7.1). Continued monitoring and “course corrections” responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL. Management activities will be changed or refined to efficiently meet the TMDL and lay the groundwork for de-listing the impaired water bodies.

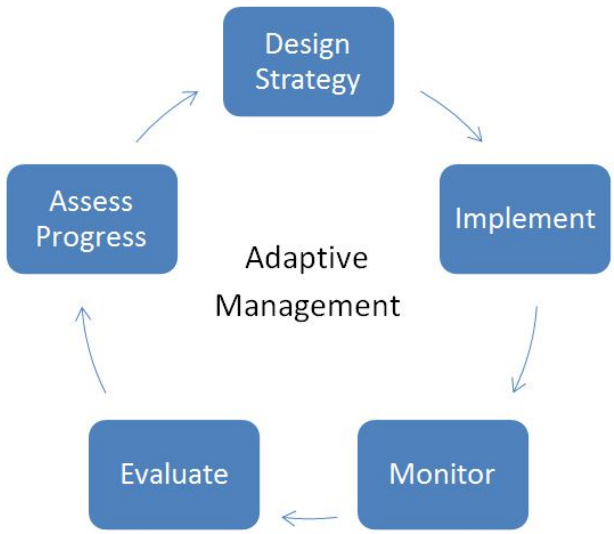


Figure 7.1. Adaptive Management.

8.0 Public Participation

A stakeholder participation process was undertaken for this TMDL to obtain input from, review results with, and take comments from the public and interested and affected agencies regarding the development of and conclusions of the TMDL.

The stakeholder process involved meetings and other communications as tabulated below.

Table 8.1 Stakeholder communications.

Date	Communication Method	Content
February 9, 2012	Mailing	Introductory letter, fact sheet, map, and meeting invitation
March 7 and 8, 2012	Meeting	Project kickoff
April 16, 2012	E-mail	Revised water body list and meeting invitation
May 8, 2012	Meeting	Preliminary modeling results and discussion of allocation approaches
September 5, 2012	E-mail	Memo on allocation approaches and sample calculations
December 13, 2012	E-mail	Revised memo on allocation approaches and sample calculations
February 28, 2013	Meeting	WLA and existing load partitioning, Painter Creek Source assessment, and implementation
July 18, 2013	E-mail	Pre-public notice review and comment opportunity on draft TMDL report
August 27, 2013	Meeting	Discuss comments and draft implementation strategy table

The following cities/agencies/interested parties were invited to project meetings and received email communications regarding the project:

- Deephaven
- Excelsior
- Greenwood
- Independence
- Long Lake
- Maple Plain
- Medina
- Minnetonka
- Minnetonka Beach
- Plymouth
- Shorewood
- Spring Park
- St. Bonifacius
- Tonka Bay
- Victoria
- Wayzata
- Woodland
- Laketown Township
- BWSR
- Met Council Environmental Services
- MN Department of Agriculture
- DNR
- MN Department of Health
- MnDOT
- Three Rivers Park District
- MN Agricultural Water Resource Center
- MN Milk Producers Association

- Minnetrista
- Mound
- Orono
- Watertown Township
- Carver County
- Hennepin County
- Mooney Lake Association President
- Freshwater Society

It is of note that a lengthy public participation process was previously completed in 2003 as part of the HHPLS. Background information on water resources management, lakes, modeling, water quality, and water quantity was provided to participants at a series of meeting held throughout the MCWD. In turn, participants provided input on the water resources issues in their areas and management strategies were presented and discussed. More information regarding this stakeholder process can be found in the HHPLS report (EOR 2003).

Also of note, development of the MCWD Comprehensive Water Resources Management Plan 2007-2017 incorporated an extensive public and technical planning process. The MCWD Board of Managers convened a Technical Advisory Committee (TAC) of City representatives and state and other agency staff as well as a Citizens Advisory Committee (CAC) of interested citizens. The development process is detailed in Appendix B of the plan (Wenck 2007).

The official TMDL public comment period was held from December 30, 2013 through January 30, 2014.

9.0 Literature Cited

American Society of Agricultural Engineers (ASAE). 1998. Standards Engineering Practices Data.

American Veterinary Medical Association (AVMA). 2012. U.S. Pet Ownership & Demographics Sourcebook. << https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx >>

Alderisio, K.A, and DeLuca, H. 1999. Seasonal Enumeration of Fecal Coliform Bacteria from the Feces of Ring-Billed Gulls (Larus delawarensis) and Canada Geese (Branta canadensis). Applied and Environmental Microbiology p. 5628-5630.

Barr Engineering Company. 2004 (updated 2007). Phosphorus Sources to Minnesota Watersheds. Prepared for Minnesota Pollution Control Agency.

Blue Water Science. 2011. Aquatic Plant Surveys for Mooney Lake, Hennepin Co, Minnesota, 2011. Prepared for Mooney Lake Association and City of Plymouth.

Center for Watershed Protection (CWP). 1999. A Survey of Residential Nutrient Behavior in the Chesapeake Bay. <<http://www.myxyz.org/phmurphy/dog/DogWasteSurveyChesapeakeBay2.pdf>>

Emmons and Olivier Resources, Inc. 2003. Minnehaha Creek Watershed District Hydrologic/Hydraulic and Pollutant Loading Study (HHPLS) Report.

Heiskary, S.A. and C.B. Wilson. 2005. Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria, 3rd Edition.

Horsley and Witten, Inc. 1996. Identification and evaluation of nutrient and bacterial loadings to Maquoit Bay, New Brunswick and Freeport, Maine. Final Report.

Metcalf and Eddy. 1991. Wastewater Engineering: Treatment, Disposal, Reuse. 3rd Edition. McGraw-Hill, Inc., New York.

Minnesota Department of Agriculture (MDA). 2012. The Agricultural BMP Handbook for Minnesota. September 2012.

Minnesota Department of Natural Resources and U.S. Fish and Wildlife Service. 2011. Waterfowl Breeding Population Survey for Minnesota. <<http://files.dnr.state.mn.us/recreation/hunting/waterfowl/waterfowl_survey2011.pdf>>

Minnesota Department of Natural Resources (MNDNR). 2011. Pre-Fawn Deer Density from Deer Population Model.

Minnesota Geological Survey. 1989. Hennepin County, MN Geologic Atlas.

Minnesota Geological Survey. 2009. Carver County, MN Geologic Atlas.

Minnesota Pollution Control Agency (MPCA). 1999. Baseline Water Quality of Minnesota's Principal Aquifers: Twin Cities Metropolitan Region. January 1999. <<http://www.pca.state.mn.us/index.php/water/water-types-and-programs/groundwater/groundwater-monitoring-and-assessment/statewide-baseline-study.html>>

Minnesota Pollution Control Agency (MPCA). 2007. Statement of Need and Reasonableness (SONAR) in the Matter of Proposed Revisions of Minnesota Rules Chapter 7050, Relating to the Classification and Standards for Waters of the State. Book III of III. July 2007.

Minnesota Pollution Control Agency (MPCA). 2009. Bacteria TMDL Protocols and Submittal Requirements.

Minnesota Pollution Control Agency (MPCA). 2010. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List. 2010 Assessment Cycle. <<http://www.pca.state.mn.us/publications/wq-iw1-04.pdf>>

Minnesota Pollution Control Agency (MPCA). 2012. 2011 Annual Report Summary: Minnesota Subsurface Sewage Treatment Systems. June 2012.

Nürnberg, G.K. 1997. Coping With Water Quality Problems Due to Hypolimnetic Anoxia in Central Ontario Lakes. Water Quality Research Journal of Canada 32 (2): 391-405.

Nürnberg, G. K. 2004. Quantified Hypoxia and Anoxia in Lakes and Reservoirs. The Scientific World Journal 4: 42-54.

Nürnberg, G. 2005. Quantification of Internal Phosphorus Loading in Polymictic Lakes. Verhanlungen Interationalen Vereinigung Limnologie (SIL). Vol. 29.

Pitt, R. 1999. Small Storm Hydrology and Why it is Important for the Design of Stormwater Control Practices. Advances in Modeling the Management of Stormwater Impacts, Volume 7.

Reckhow, K.H., M.N. Beaulac, and J.T. Simpson. 1980. Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients. Report No. EPA/440/5-80-011. US EPA, Office of Water Regulations and Standards, Washington, D.C.

Sharpley, A.N., T. Daniel, G. Gibson, L. Bundy., M. Cabrera, T. Sims, R. Stevens, J. Lemunyon, P. Kleinman, and R. Parry. 2006. Best Management Practices to Minimize Agricultural Phosphorus Impacts on

Water Quality. United States Department of Agriculture, Agricultural Research Service, Publication ARS-163. <<http://www.ars.usda.gov/is/np/BestMgmtPractices/Best%20Management%20Practices.pdf>>

U. S. Environmental Protection Agency. 2002. Onsite Wastewater Treatment Systems Manual.

U.S. Department of Agriculture (USDA). 1986. Urban Hydrology for Small Watersheds (TR-55). <<http://www.cpesc.org/reference/tr55.pdf>>

Walker, W.W. 1985. Empirical Methods for Predicting Eutrophication in Impoundments, Report 3. Prepared for office, Chief of Engineers, U.S. Army, Washington, D.C., Technical Report E-81-9, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, draft 1983, published 1985.

Walker, W. W. 1999. Simplified Procedures for Eutrophication Assessment and Prediction: User Manual. USACE Report w-96-2.

Walker, W. W. 2003. Consideration of Variability and Uncertainty in Phosphorus Total Maximum Daily Loads for Lakes. J. Water Resour. Plng. and Mgmt. 129 (4): 337-344.

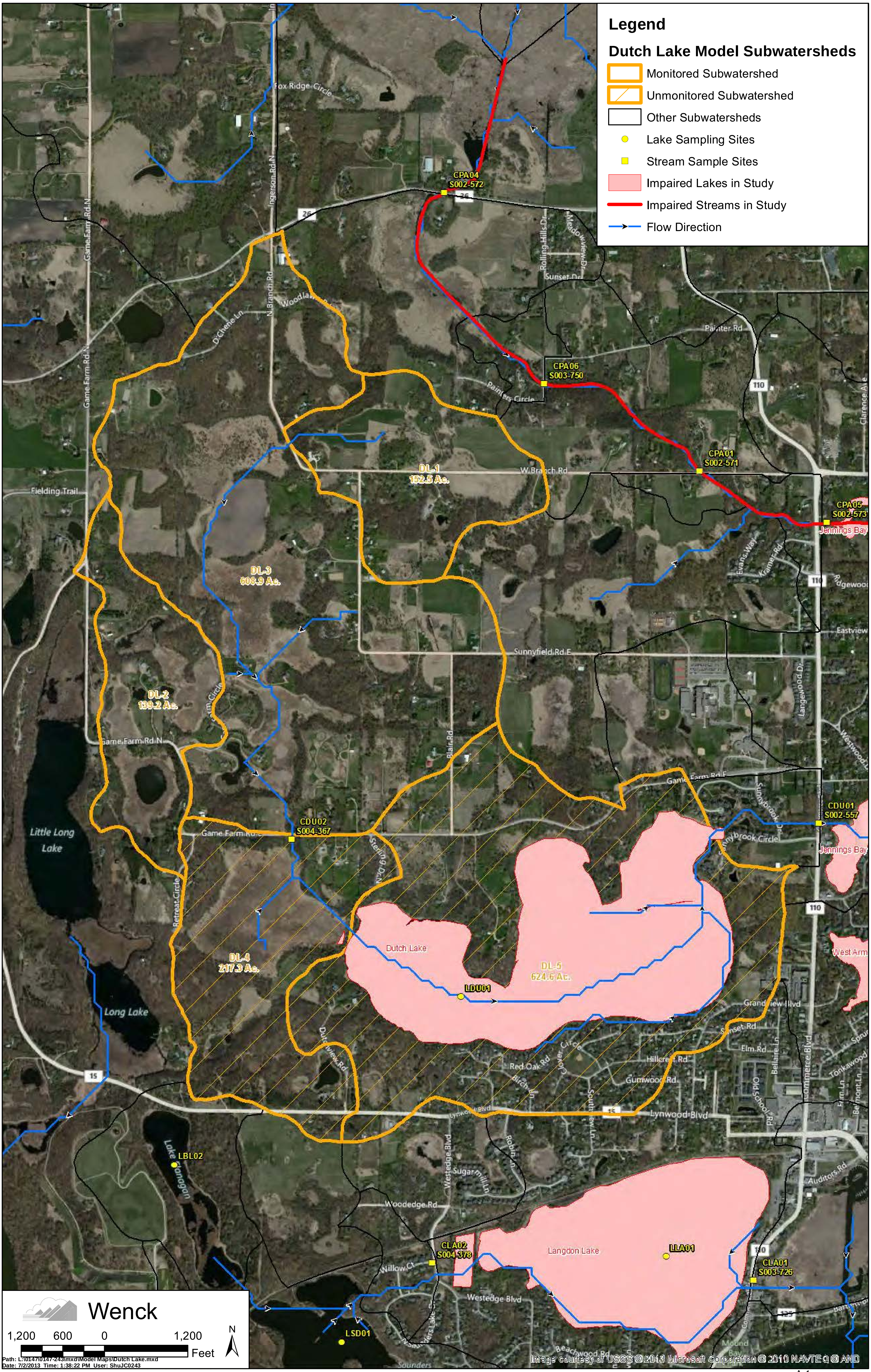
Wenck Associates, Inc. 2013. Minnehaha Creek Watershed District Six Mile Creek Diagnostic Study. Wenck File 0185-5050.

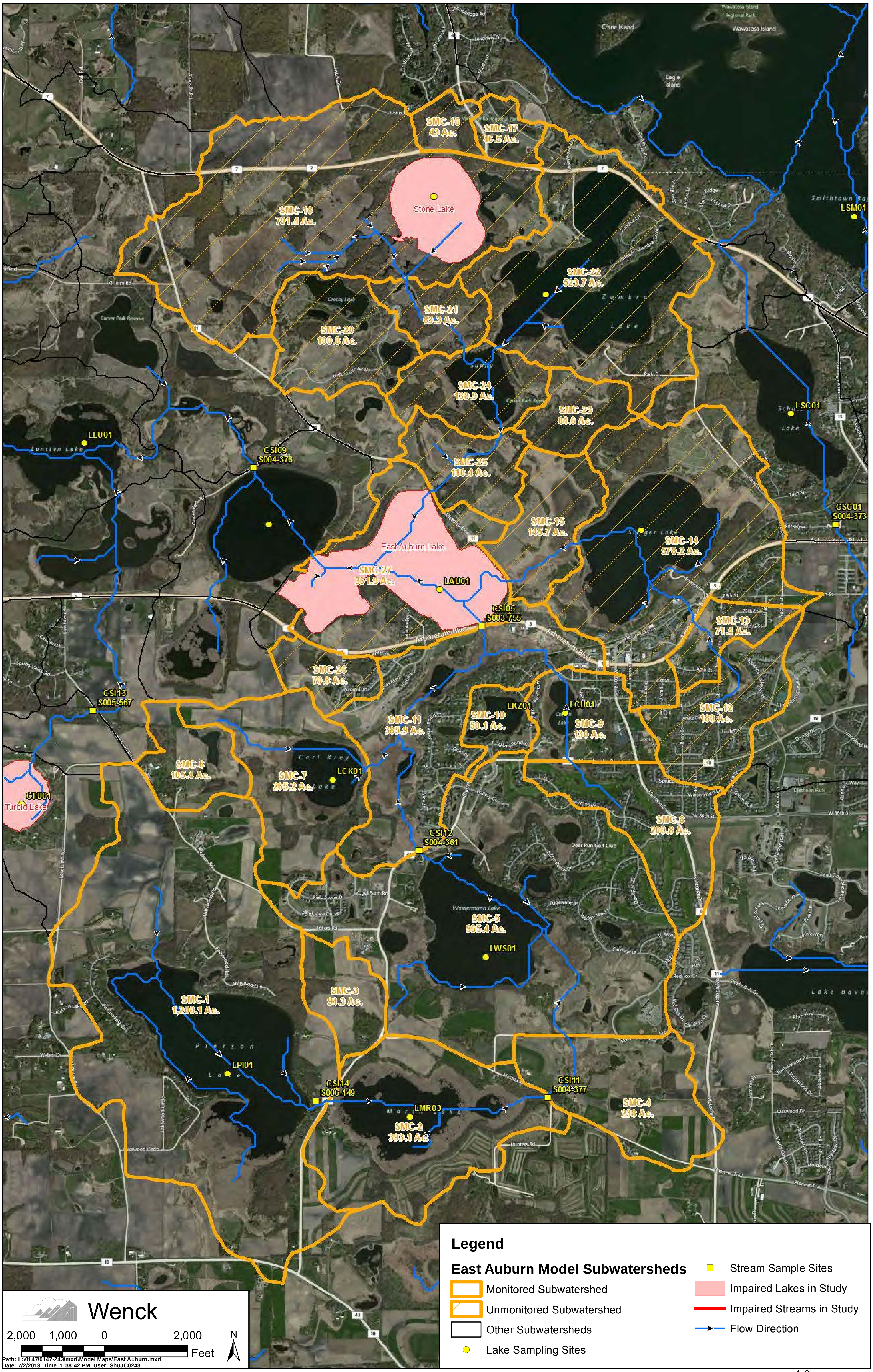
Wenck Associates, Inc. 2010. Preliminary Langdon Lake Water Quality Improvement Project Feasibility Study. Wenck File 0185-4568

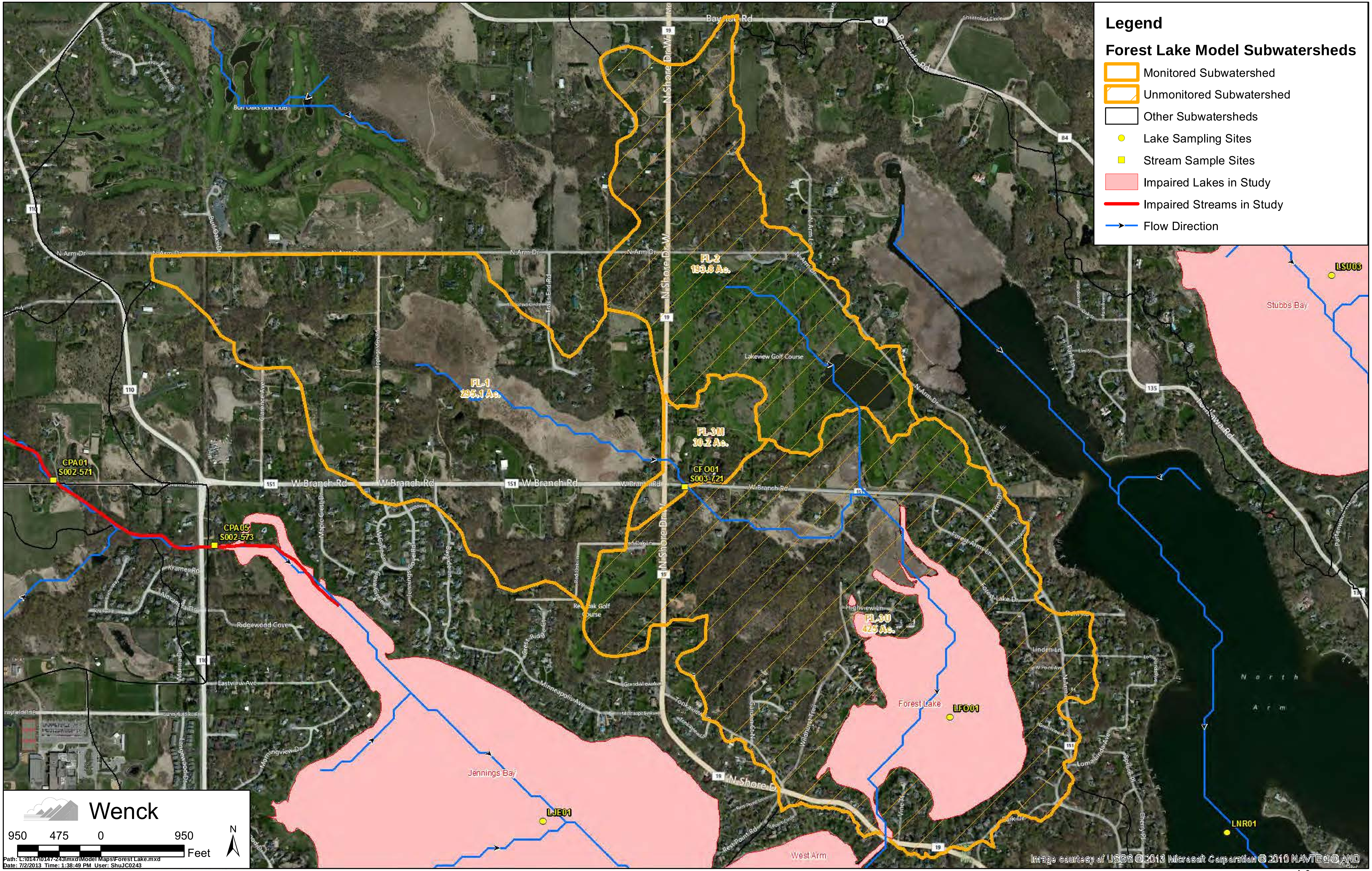
Wenck Associates, Inc. 2007. Minnehaha Creek Watershed District Comprehensive Water Resources Management Plan. Wenck File 0185-4315

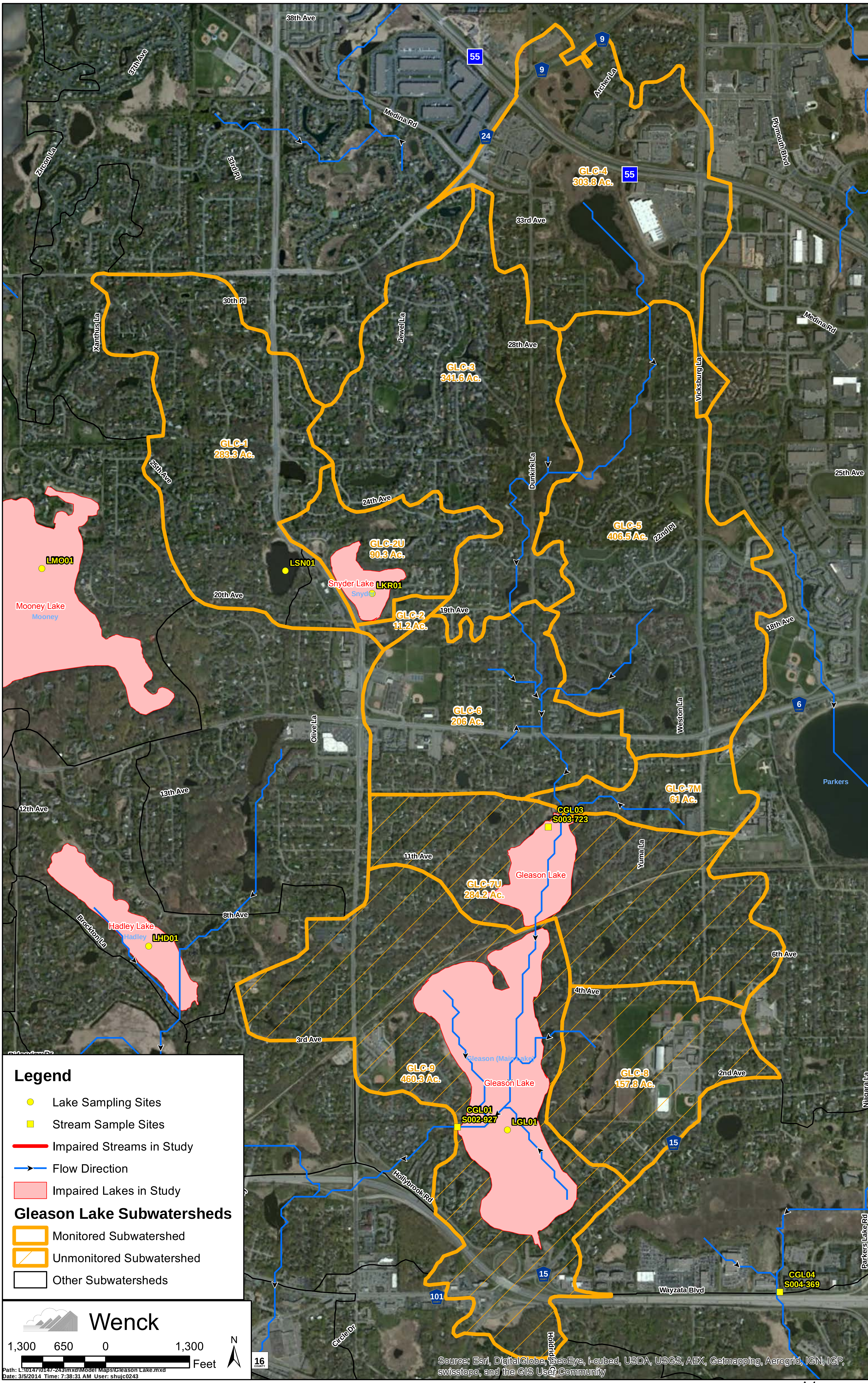
Appendix A

Subwatershed Figures

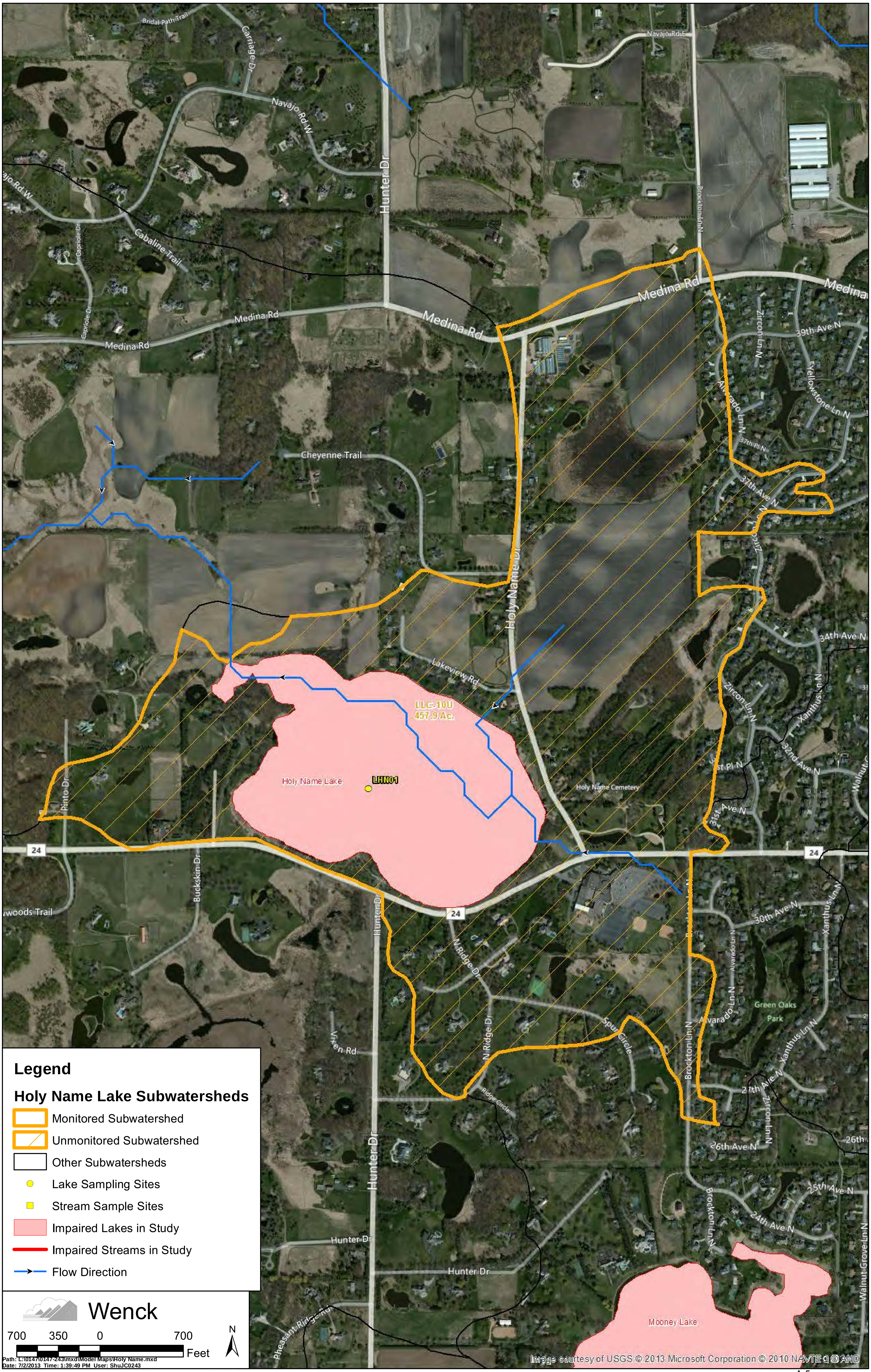

Legend
Dutch Lake Model Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
Lake Sampling Sites
Stream Sample Sites
Impaired Lakes in Study
Impaired Streams in Study
Flow Direction
CPA04
S002-572
CPA06
S003-750
CPA01
S002-571
CPA05
S002-573
CDU01
S002-557
CDU02
S004-367
DL-1
152.5 Ac.
DL-2
139.2 Ac.
DL-3
608.9 Ac.
DL-4
217.3 Ac.
DL-5
624.6 Ac.
Dutch Lake
LDU01
Little Long Lake
Long Lake
Lake Langdon
LBL02
Langdon Lake
LLA01
CLA02
S004-378
CLA01
S003-726
LSD01
Fox Ridge Circle
Ingerson Rd N
Game Farm Rd N
N Branch Rd
Woodland Rd
D'Chene Ln
Fielding Trail
W Branch Rd
Painter Rd
Painters Circle
Rolling Hills Dr
Meadowview Dr
Sunset Dr
Jennings Bay
Sunnyfield Rd E
Eastview
Blair Rd
Game Farm Rd E
Game Farm Rd
Sterling Dr
Retreat Circle
Sunnybrook Circle
West Arm
Red Oak Rd
Clover Circle
Hillcrest Rd
Gumwood Rd
Elm Rd
Grandview Blvd
Lynwood Blvd
Commerce Blvd
Westedge Blvd
Sugarmill Ln
Woodedge Rd
Willow Ct
Robin Ln
Auditors Rd
Clarence Ave
Ridgewood
Westwood Ln
Evans Way
Kramer Rd
Wenck
1,200 600 0 1,200
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Dutch Lake.mxd
Date: 7/2/2013 Time: 1:38:22 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

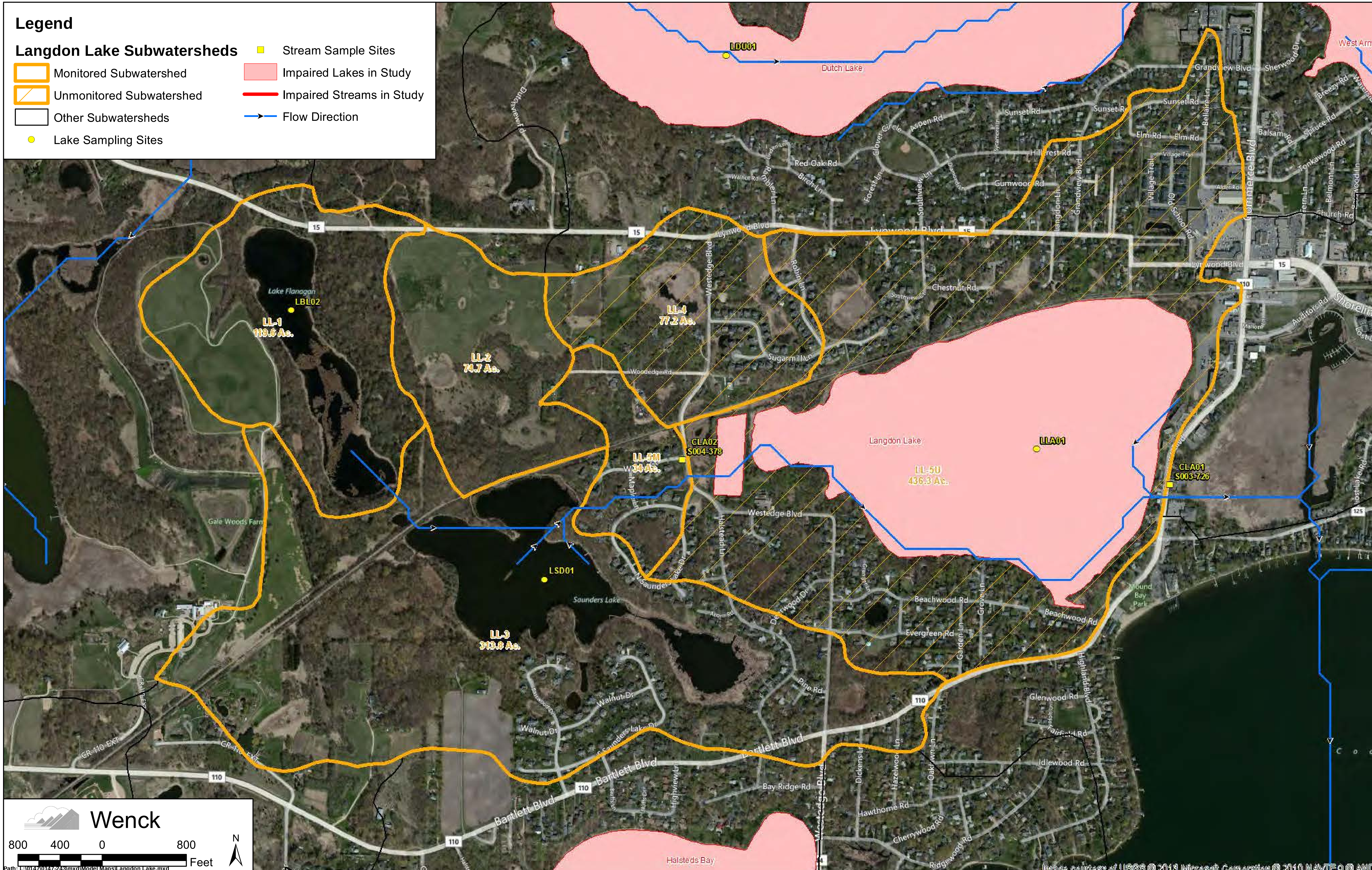

Legend
East Auburn Model Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
Lake Sampling Sites
Stream Sample Sites
Impaired Lakes in Study
Impaired Streams in Study
Flow Direction
Wenck
2,000 1,000 0 2,000
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\East Auburn.mxd
Date: 7/2/2013 Time: 1:38:42 PM User: ShuJC0243
Stone Lake
East Auburn Lake
Turbid Lake
SMC-16
43 Ac.
SMC-17
46.5 Ac.
SMC-18
791.4 Ac.
SMC-22
523.7 Ac.
SMC-21
63.3 Ac.
SMC-20
180.8 Ac.
SMC-24
138.9 Ac.
SMC-23
84.6 Ac.
SMC-25
118.4 Ac.
SMC-15
145.7 Ac.
SMC-14
370.2 Ac.
SMC-27
361.9 Ac.
SMC-13
71.4 Ac.
SMC-26
70.8 Ac.
SMC-11
385.9 Ac.
SMC-10
50.1 Ac.
SMC-9
130 Ac.
SMC-12
180 Ac.
SMC-6
105.4 Ac.
SMC-7
265.2 Ac.
SMC-8
200.8 Ac.
SMC-5
805.4 Ac.
SMC-3
94.3 Ac.
SMC-1
1,200.1 Ac.
SMC-2
393.1 Ac.
SMC-4
238 Ac.
LSM01
LSC01
LLU01
CSI09
S004-376
CSC01
S004-373
LAU01
CSI05
S003-755
CSI13
S005-567
LKZ01
LCU01
LCK01
CTU01
CSI12
S004-361
LWS01
LPI01
CSI14
S006-149
LMR03
CSI11
S004-377

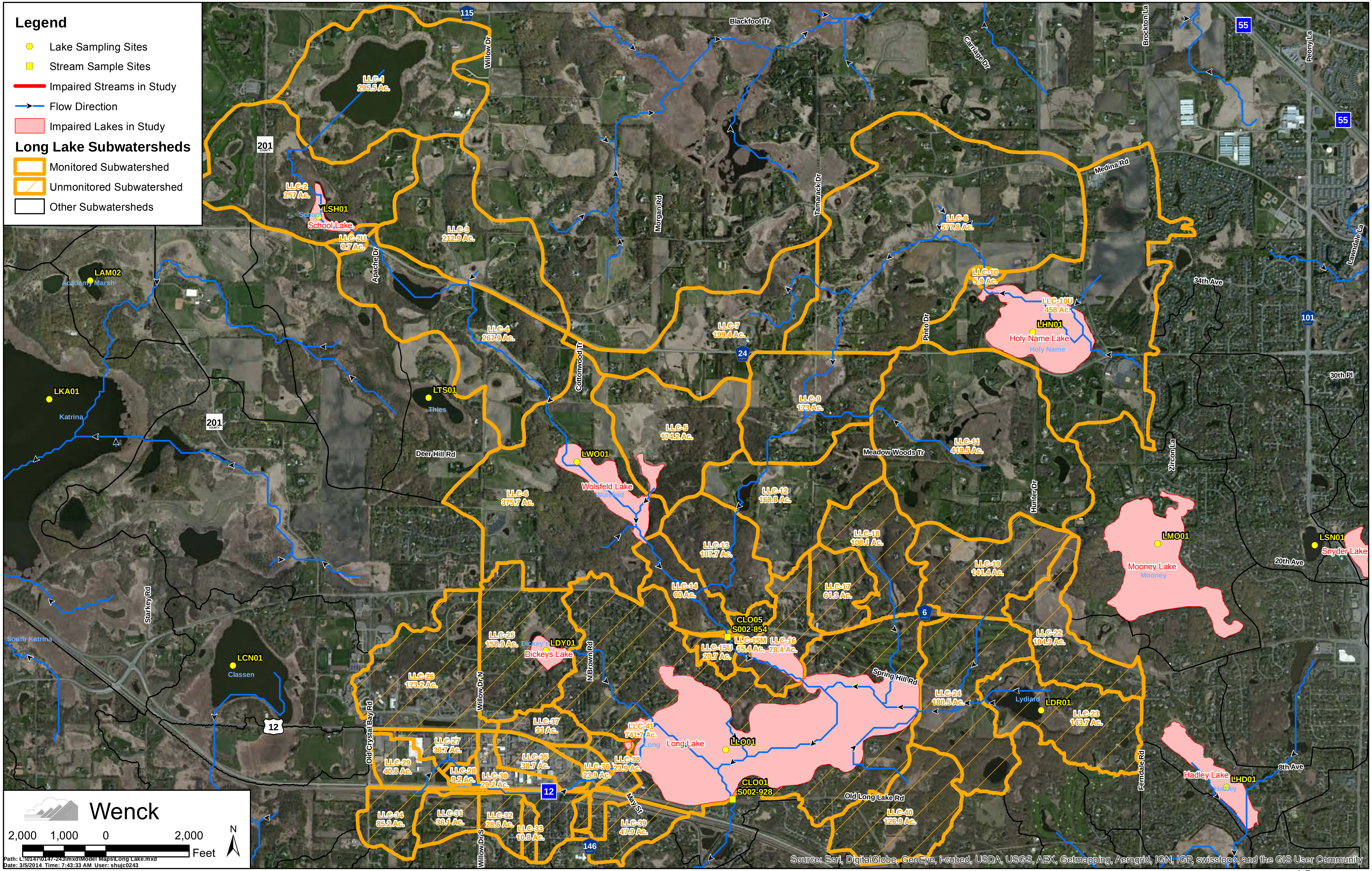

Legend
Forest Lake Model Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
Lake Sampling Sites
Stream Sample Sites
Impaired Lakes in Study
Impaired Streams in Study
Flow Direction
FL-2
FL-1
FL-3M
FL-3U
CF001
S003-721
CPA01
S002-571
CPA05
S002-573
LSU03
LFO01
LJE01
LNR01
Stubbs Bay
Forest Lake
Jennings Bay
West Arm
North Arm
Lakeview Golf Course
Red Oak Golf Course
Burl Oaks Golf Club
N Arm Dr
W Branch Rd
N Shore Dr W
Bayside Rd
Wenck
950 475 0 950
Feet
N
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

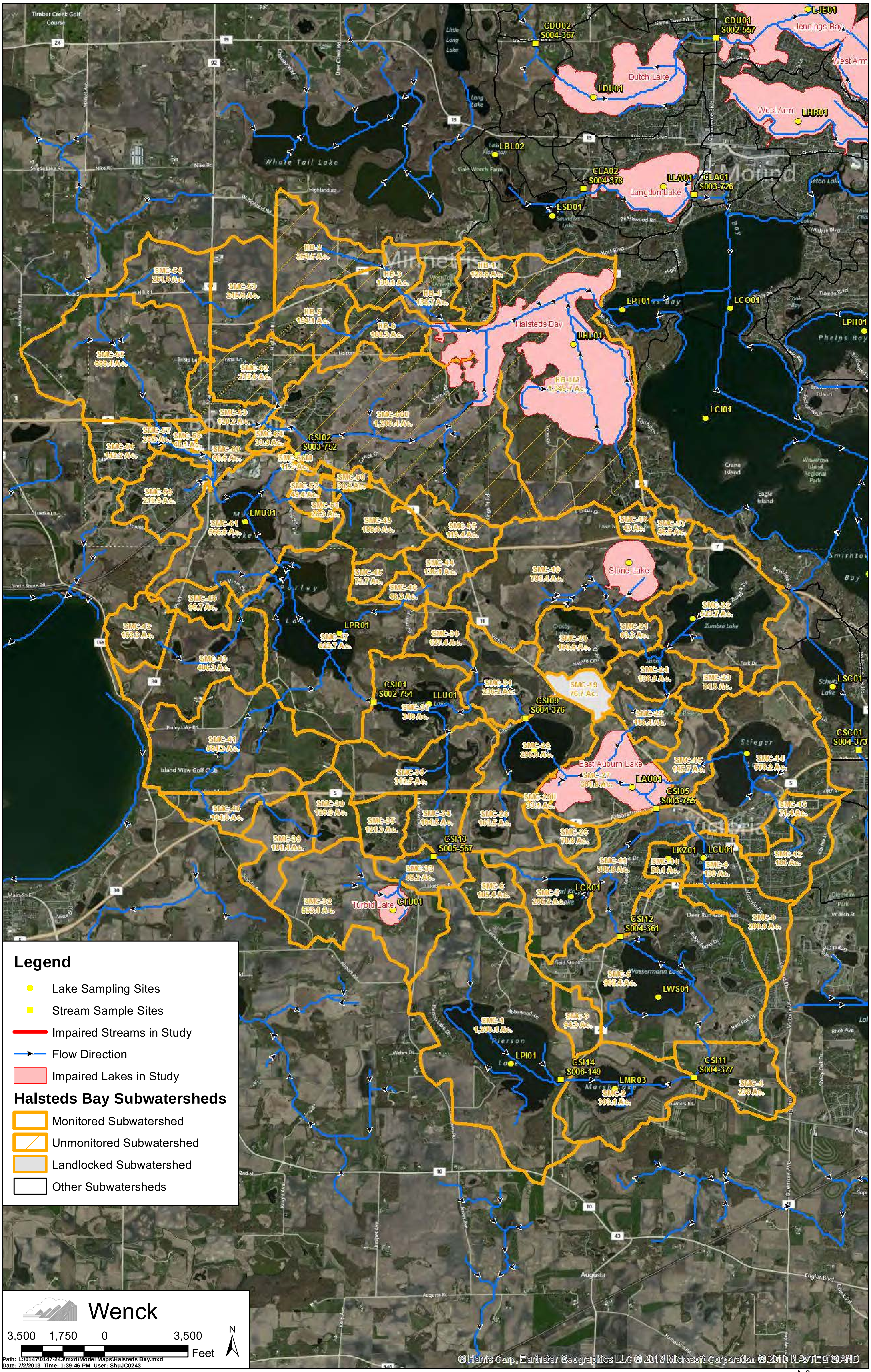


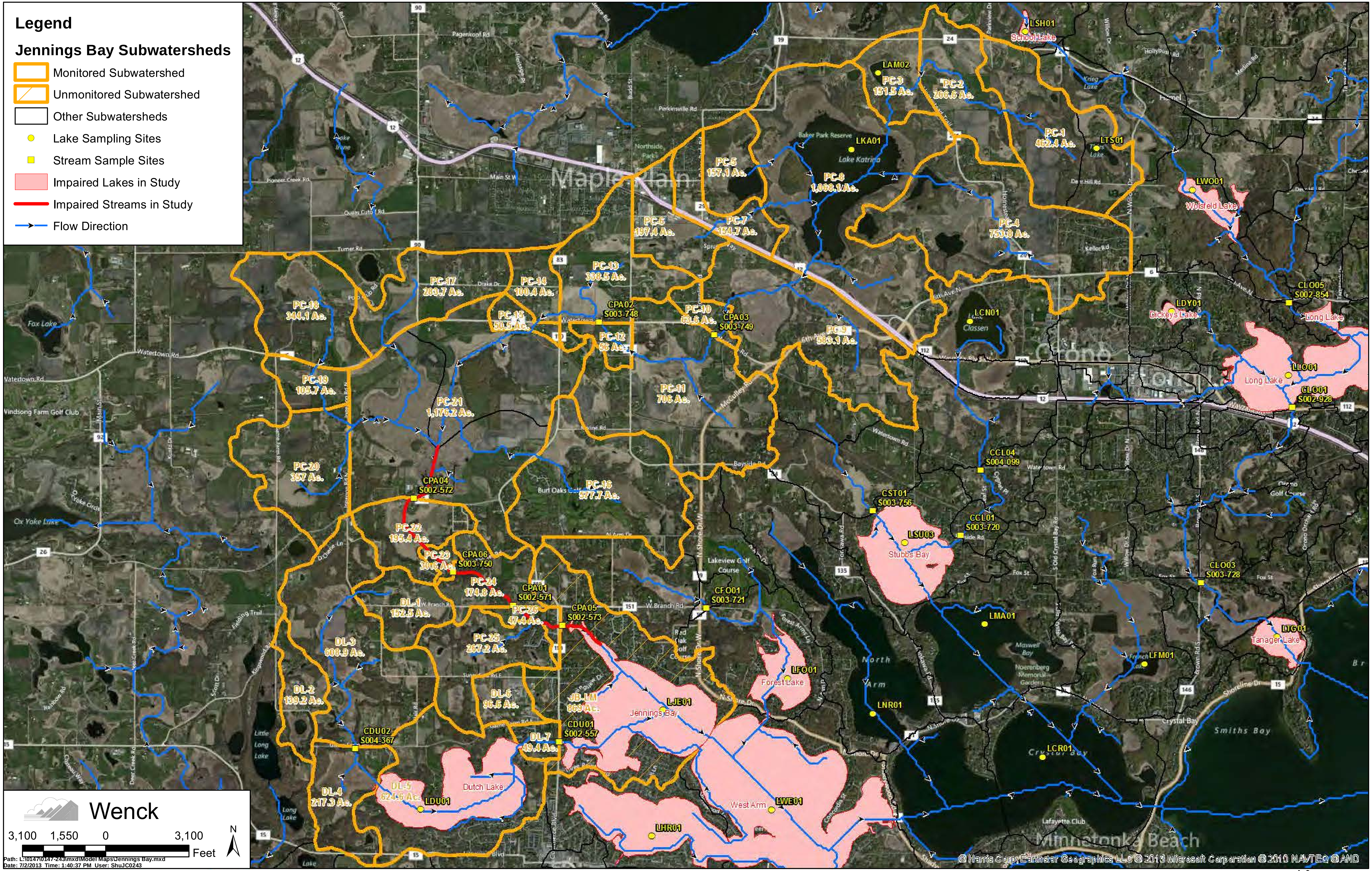
GLC-1
283.3 Ac.
GLC-2U
90.3 Ac.
GLC-2
11.2 Ac.
GLC-3
341.6 Ac.
GLC-4
303.8 Ac.
GLC-5
406.5 Ac.
GLC-6
206 Ac.
GLC-7M
61 Ac.
GLC-7U
284.2 Ac.
GLC-8
157.8 Ac.
GLC-9
460.3 Ac.
LMO01
LSN01
LKR01
LHD01
LGL01
CGL03
S003-723
CGL01
S002-927
CGL04
S004-369
Mooney Lake
Mooney
Snyder Lake
Snyder
Hadley Lake
Hadley
Gleason Lake
Gleason (Main Lake)
Parkers
38th Ave
37th Ave
33rd Pl
33rd Ave
30th Pl
28th Ave
25th Ave
24th Ave
22nd Pl
20th Ave
19th Ave
18th Ave
13th Ave
12th Ave
11th Ave
8th Ave
6th Ave
4th Ave
3rd Ave
2nd Ave
Medina Rd
Zircon La
Xanthus La
Jewel La
Dunkirk La
Vicksburg La
Plymouth Blvd
Archer La
Weston La
Olive La
Yuma La
Brockton La
Hollybrook Rd
Holdridge
Circle Dr
Wayzata Blvd
Niagara La
Parkers Lake Rd
55
9
24
6
15
16
101
Legend
Lake Sampling Sites
Stream Sample Sites
Impaired Streams in Study
Flow Direction
Impaired Lakes in Study
Gleason Lake Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
Wenck
1,300 650 0 1,300
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Gleason Lake.mxd
Date: 3/5/2014 Time: 7:38:31 AM User: shujc0243
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community


Legend
Holy Name Lake Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
Lake Sampling Sites
Stream Sample Sites
Impaired Lakes in Study
Impaired Streams in Study
Flow Direction
Wenck
700 350 0 700
Feet
N
LLC-10U
457.9 Ac.
Holy Name Lake
LHN01
Mooney Lake
Holy Name Cemetery
Green Oaks Park
Medina Rd
Hunter Dr
Holy Name Dr
Brockton Ln N
Cheyenne Trail
Lakeview Rd
Navajo Rd W
Cabaline Trail
Carriage Dr
Bridal Path Trail
Pinto Dr
Buckskin Dr
N Ridge Dr
Spur Circle
Ridge Circle
Vixen Rd
Pheasant Ridge Rd
Zircon Ln N
Alvarado Ln N
Xanthus Ln N
Yellowstone Ln N
39th Ave N
37th Ave N
34th Ave N
32nd Ave N
31st Ave N
30th Ave N
27th Ave N
26th Ave N
25th Ave N
24th Ave N
Walnut Grove Ln N
24
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND
Path: L:\0147\0147-243\mxd\Model Maps\Holy Name.mxd
Date: 7/2/2013 Time: 1:39:49 PM User: ShuJC0243

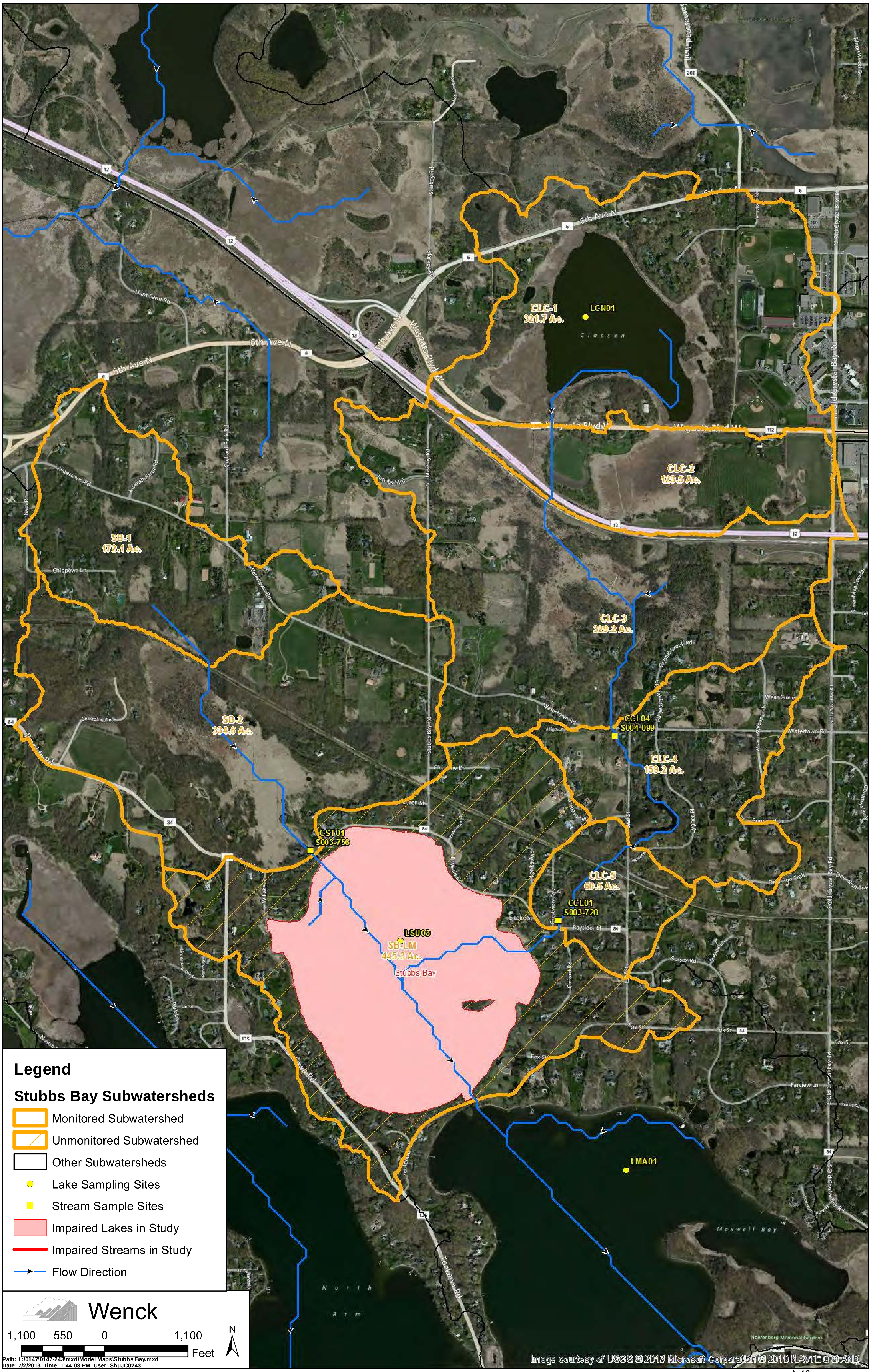

Legend
Langdon Lake Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
Lake Sampling Sites
Stream Sample Sites
Impaired Lakes in Study
Impaired Streams in Study
Flow Direction
Dutch Lake
LDU01
Lake Flanagan
LBL02
LL-1
119.6 Ac.
LL-2
74.7 Ac.
LL-4
77.2 Ac.
LL-5M
34 Ac.
LL-5U
436.3 Ac.
LL-3
313.8 Ac.
Langdon Lake
LLA01
CLA02
S004-378
CLA01
S003-726
LSD01
Saunders Lake
Halsteds Bay
West Arm
Gale Woods Farm
Lynwood Blvd
Bartlett Blvd
Westedge Blvd
Commerce Blvd
Shoreline
Wenck
800 400 0 800
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Langdon Lake.mxd
Date: 7/2/2013 Time: 1:41:13 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

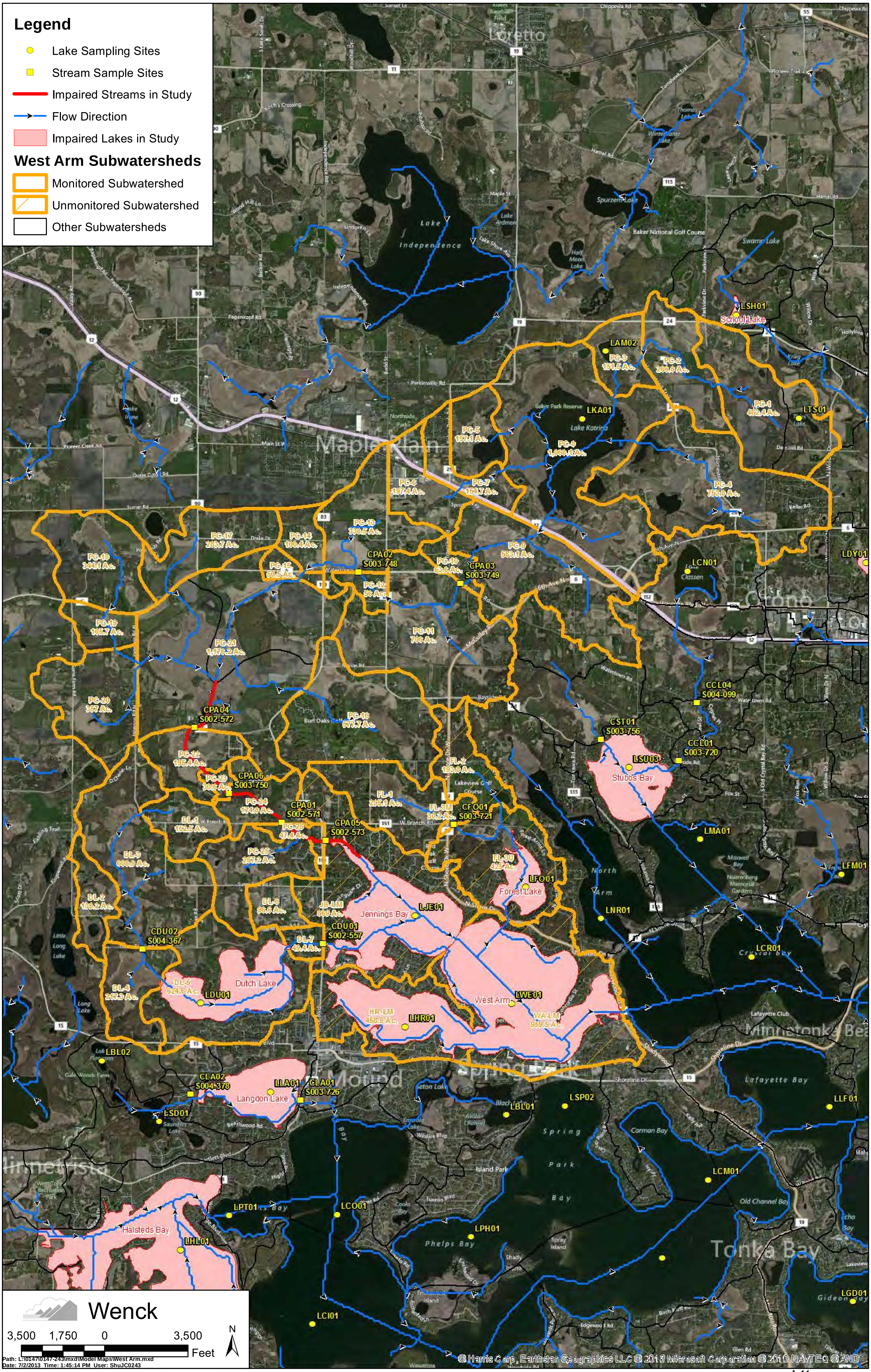

Legend
Lake Sampling Sites
Stream Sample Sites
Impaired Streams in Study
Flow Direction
Impaired Lakes in Study
Long Lake Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
LLC-1 295.5 Ac.
LLC-2 257 Ac.
LSH01
School Lake
LLC-2U 9.7 Ac.
LLC-3 212.9 Ac.
LLC-4 267.9 Ac.
LLC-5 174.2 Ac.
LLC-6 375.7 Ac.
LLC-7 199.4 Ac.
LLC-8 577.8 Ac.
LLC-9 173 Ac.
LLC-10 5.9 Ac.
LLC-10U 458 Ac.
LHN01
Holy Name Lake
LLC-11 419.5 Ac.
LLC-12 169.8 Ac.
LLC-13 107.7 Ac.
LLC-14 60 Ac.
LLC-15U 20.7 Ac.
LLC-15M 15.4 Ac.
LLC-16 78.4 Ac.
LLC-17 61.3 Ac.
LLC-18 108.1 Ac.
LLC-19 141.4 Ac.
LLC-22 104.3 Ac.
LLC-23 143.7 Ac.
LLC-24 180.5 Ac.
LLC-25 158.9 Ac.
LLC-26 173.2 Ac.
LLC-27 30.7 Ac.
LLC-28 9.2 Ac.
LLC-29 40.8 Ac.
LLC-30 29.2 Ac.
LLC-31 36.1 Ac.
LLC-32 28.6 Ac.
LLC-33 10.8 Ac.
LLC-34 85.2 Ac.
LLC-35 38.7 Ac.
LLC-36 23.9 Ac.
LLC-37 31 Ac.
LLC-38 23.9 Ac.
LLC-39 47.9 Ac.
LLC-40 126.9 Ac.
LLC-41 7417 Ac.
LWO01
Wolsfeld Lake
LTS01
Thies
LAM02
Academy Marsh
LKA01
Katrina
South Katrina
LCN01
Classen
LDY01
Dickeys Lake
CLO05 S002-854
CLO01 S002-928
LLO01
Long Lake
LDR01
Lydiard
LMO01
Mooney Lake
LSN01
Snyder Lake
LHD01
Hadley Lake
Blackfoot Tr
Willow Dr
Morgan Rd
Tamarack Dr
Carriage Dr
Brockton Ln
Peony Ln
Medina Rd
Lawndale Ln
34th Ave
30th Pl
20th Ave
8th Ave
Apache Dr
Cottonwood Tr
Pinto Dr
Deer Hill Rd
Meadow Woods Tr
Hunter Dr
Zircon Ln
Starkey Rd
Old Crystal Bay Rd
Willow Dr N
N Brown Rd
Spring Hill Rd
Old Long Lake Rd
Fernbrook Ln
May St
Willow Dr S
115
201
55
24
101
6
12
146
Wenck
2,000 1,000 0 2,000
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Long Lake.mxd
Date: 3/5/2014 Time: 7:43:33 AM User: shujc0243
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

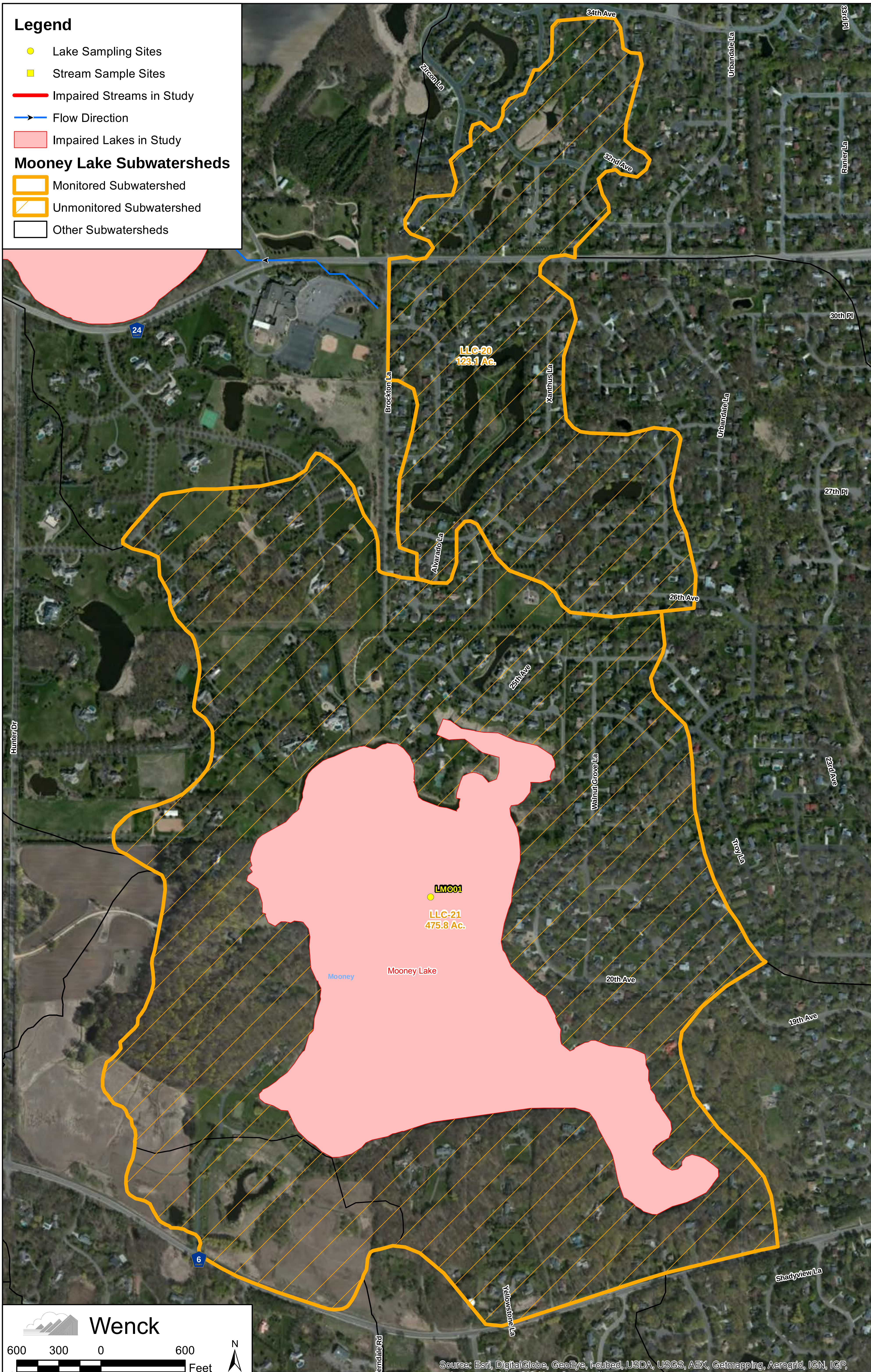

Legend
Lake Sampling Sites
Stream Sample Sites
Impaired Streams in Study
Flow Direction
Impaired Lakes in Study
Halsteds Bay Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Landlocked Subwatershed
Other Subwatersheds
Wenck
3,500 1,750 0 3,500
Feet
N
Halsteds Bay
Stone Lake
East Auburn Lake
Turbid Lake
Langdon Lake
Dutch Lake
Jennings Bay
West Arm
Whale Tail Lake
CDU02 S004-367
CDU01 S002-557
LJE01
LDU01
LHR01
LBL02
CLA02 S004-378
LLA01
CLA01 S003-726
LSD01
LPT01
LCO01
LPH01
LHL01
LCI01
CSI02 S003-752
LMU01
LPR01
CSI01 S002-754
LLU01
CSI09 S004-376
LSC01
CSC01 S004-373
LAU01
CSI05 S003-755
LKZ01
LCU01
LCK01
CSI13 S005-567
CTU01
CSI12 S004-361
LWS01
LPI01
CSI14 S006-149
LMR03
CSI11 S004-377
Path: L:\0147\0147-243\mxd\Model Maps\Halsteds Bay.mxd
Date: 7/2/2013 Time: 1:39:46 PM User: ShuJC0243
© Harris Corp, Earthstar Geographics LLC © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

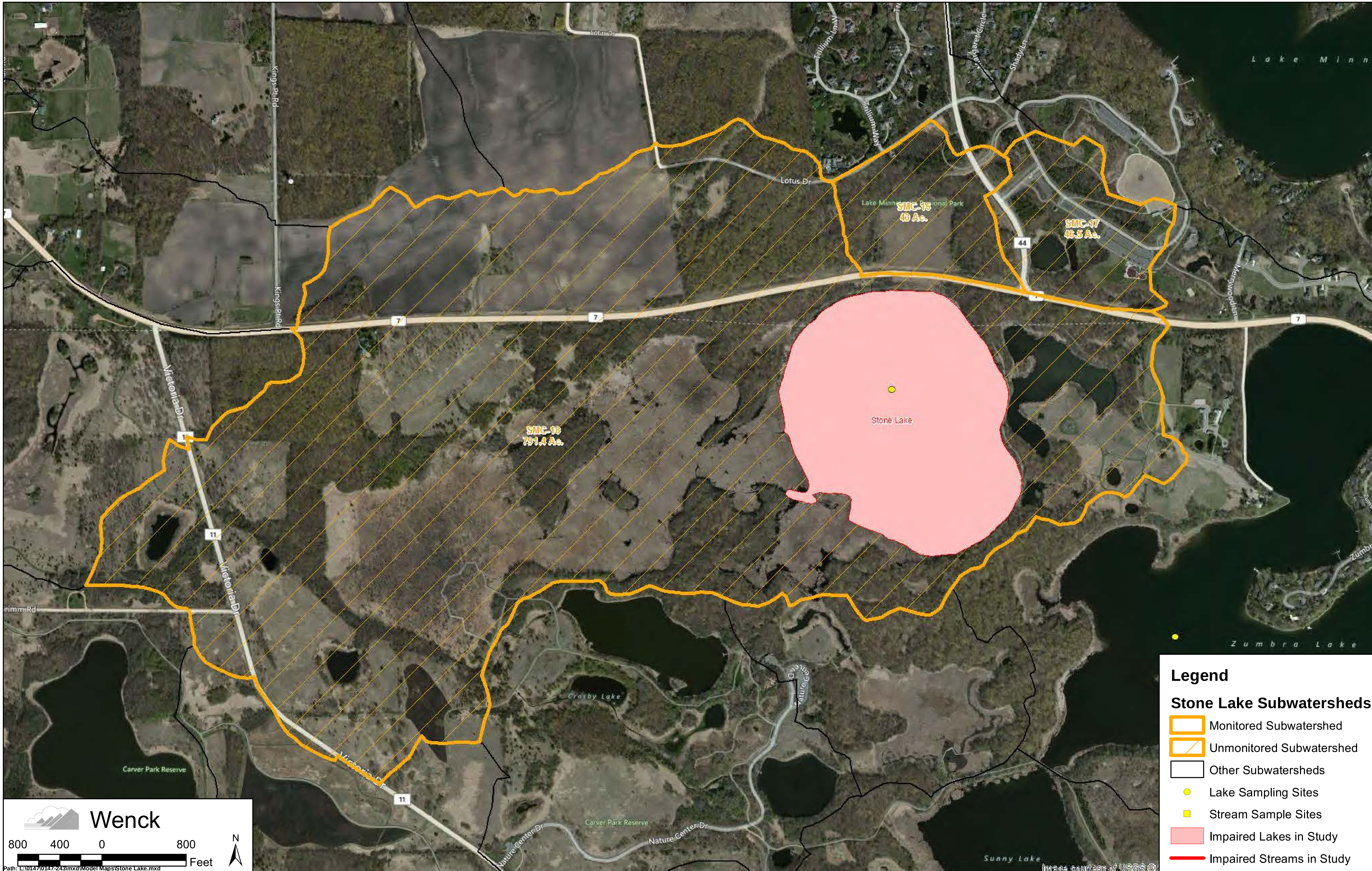


Legend
Jennings Bay Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
Lake Sampling Sites
Stream Sample Sites
Impaired Lakes in Study
Impaired Streams in Study
Flow Direction
Wenck
3,100 1,550 0 3,100
Feet
N
Maple Plain
Minnetonka Beach
LSH01
School Lake
LAM02
PC-3 151.5 Ac.
PC-2 206.6 Ac.
PC-1 462.4 Ac.
LTS01
LKA01
Lake Katrina
PC-5 157.1 Ac.
PC-8 1,008.1 Ac.
LWO01
Wolsfeld Lake
PC-6 197.4 Ac.
PC-7 154.7 Ac.
PC-4
PC-13 338.5 Ac.
PC-17 289.7 Ac.
PC-14 100.4 Ac.
PC-18 344.1 Ac.
PC-15
CPA02 S003-748
PC-12
PC-10
CPA03 S003-749
PC-9
LCN01
Classen
LDY01
Dickeys Lake
CLO05 S002-854
Long Lake
LLO01
CLO01 S002-928
PC-19 105.7 Ac.
PC-21 1,176.2 Ac.
PC-11 706 Ac.
PC-20 357 Ac.
CPA04 S002-572
PC-16 577.7 Ac.
CCL04 S004-099
CST01 S003-756
LSU03
Stubbs Bay
CCL01 S003-720
PC-22 195.4 Ac.
PC-23
CPA06 S003-750
PC-24 174.8 Ac.
CPA01 S002-571
CPA05 S002-573
PC-26
CFO01 S003-721
CLO03 S003-728
DL-1 152.5 Ac.
DL-3 606.9 Ac.
PC-25 267.2 Ac.
LMA01
LFM01
LTG01
Tanager Lake
LFO01
Forest Lake
DL-2 139.2 Ac.
DL-6 96.6 Ac.
JB-LM
LJE01
Jennings Bay
LNR01
North Arm
CDU02 S004-367
CDU01 S002-557
DL-7 49.4 Ac.
LCR01
Crystal Bay
Smiths Bay
DL-4 217.9 Ac.
DL-5
LDU01
Dutch Lake
West Arm
LWE01
LHR01
Fox Lake
Ox Yoke Lake
Lakeview Golf Course
Path: L:\0147\0147-243\mxd\Model Maps\Jennings Bay.mxd
Date: 7/2/2013 Time: 1:40:37 PM User: ShuJC0243

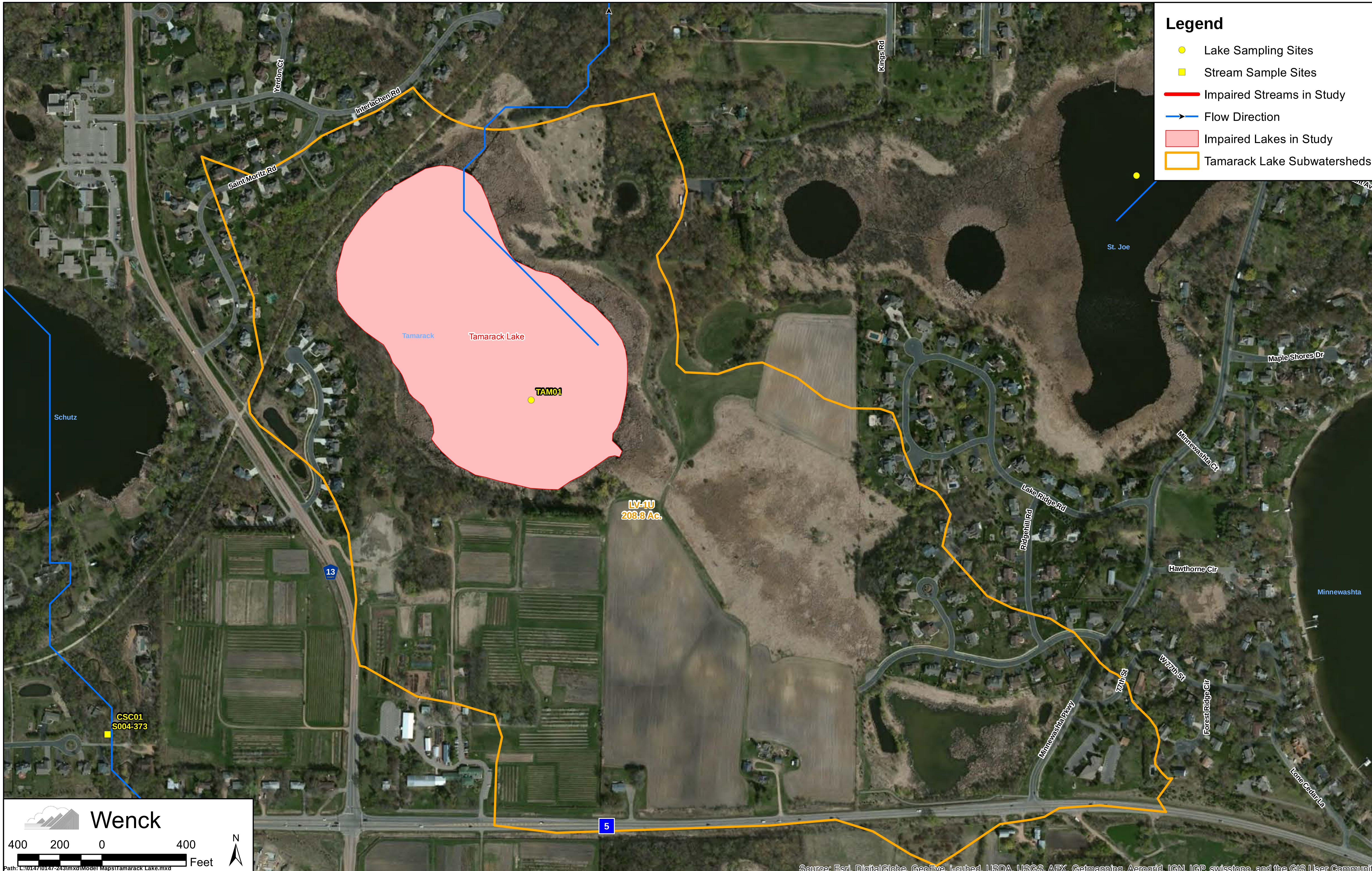

Legend
Stubbs Bay Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
Lake Sampling Sites
Stream Sample Sites
Impaired Lakes in Study
Impaired Streams in Study
Flow Direction
Wenck
1,100 550 0 1,100
Feet
N
CLC-1
321.7 Ac.
LCN01
CLC-2
123.5 Ac.
CLC-3
329.2 Ac.
CLC-4
159.2 Ac.
CLC-5
60.5 Ac.
SB-1
172.1 Ac.
SB-2
334.6 Ac.
SB-LM
445.3 Ac.
LSU03
CST01
S003-756
CCL04
S004-099
CCL01
S003-720
LMA01
Stubbs Bay
Maxwell Bay
North Arm
6th Ave N
Wayzata Blvd W
Watertown Rd
Path: L:\0147\0147-243\mxd\Model Maps\Stubbs Bay.mxd
Date: 7/2/2013 Time: 1:44:03 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

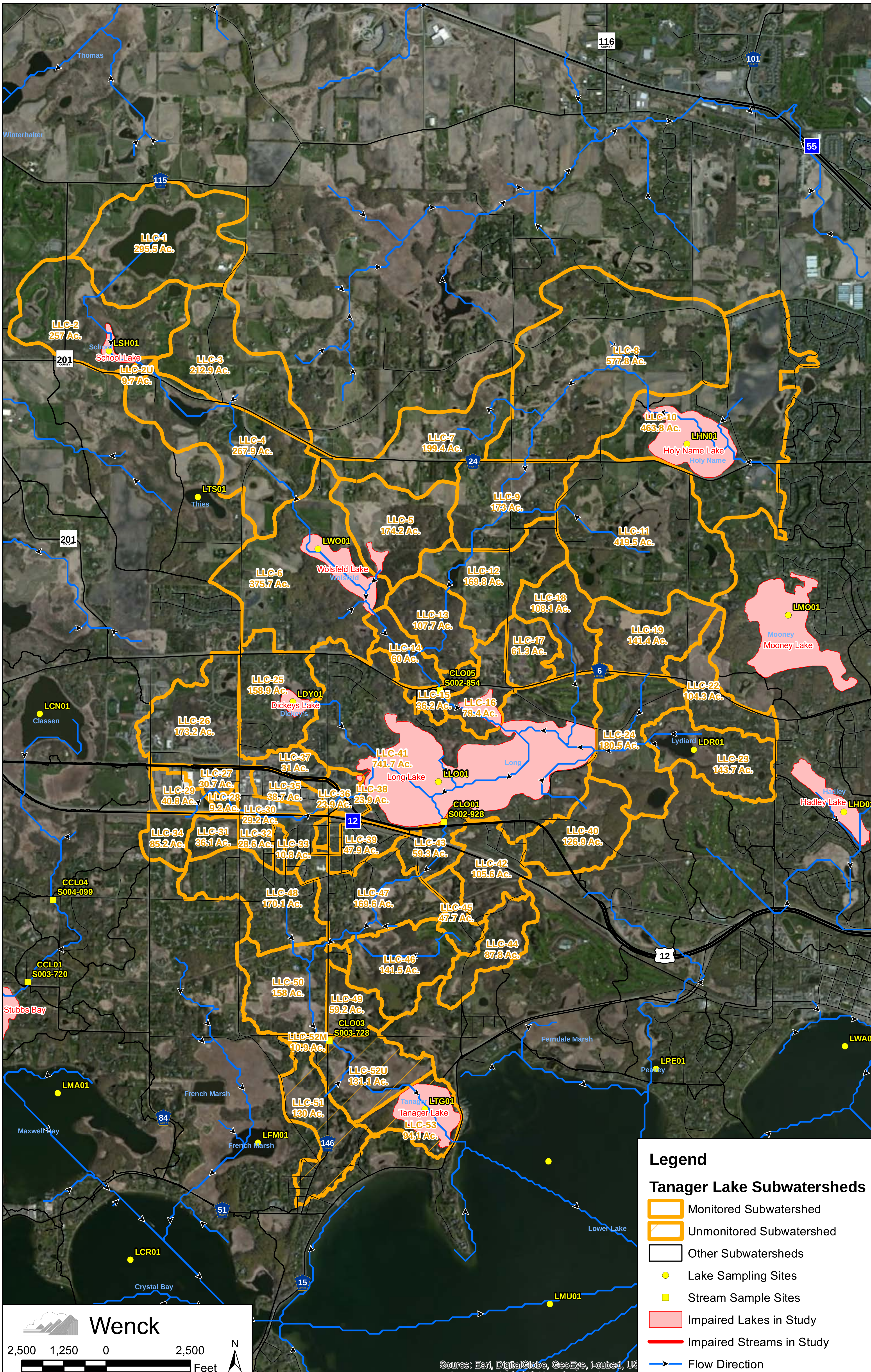

Legend
Lake Sampling Sites
Stream Sample Sites
Impaired Streams in Study
Flow Direction
Impaired Lakes in Study
West Arm Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
Wenck
3,500 1,750 0 3,500
Feet
N
Path: L:\0147\0147-2493\mxd\Model Maps\West Arm.mxd
Date: 7/2/2013 Time: 1:45:14 PM User: ShuJC0243
© Harris Corp, Earthstar Geographics LLC © 2013 Microsoft Corporation © 2010 NAVTEQ © AND
Lake Independence
Maple Plain
Loretto
Mound
Spring Park
Minnetrista
Crono
Tonka Bay
School Lake
Lake Katrina
Stubbs Bay
Forest Lake
Jennings Bay
Dutch Lake
West Arm
Langdon Lake
Halsteds Bay
LSH01
LAM02
LKA01
LTS01
LCN01
LDY01
CCL04 S004-099
CST01 S003-756
CCL01 S003-720
LSU03
LMA01
LFM01
LFO01
LJE01
LNR01
LCR01
LWE01
LHR01
LDU01
LBL02
CLA02 S004-378
LLA01
CLA01 S003-726
LSD01
LBL01
LSP02
LLF01
LCM01
LPT01
LCO01
LPH01
LHL01
LCI01
LGD01
CPA02 S003-748
CPA03 S003-749
CPA04 S002-572
CPA06 S003-750
CPA01 S002-571
CPA05 S002-573
CFO01 S003-721
CDU02 S004-367
CDU01 S002-557
WA-LM 959.5 Ac.
HR-LM 458.9 Ac.
North Arm
Lafayette Bay
Crystal Bay
Phelps Bay
Spring Park Bay

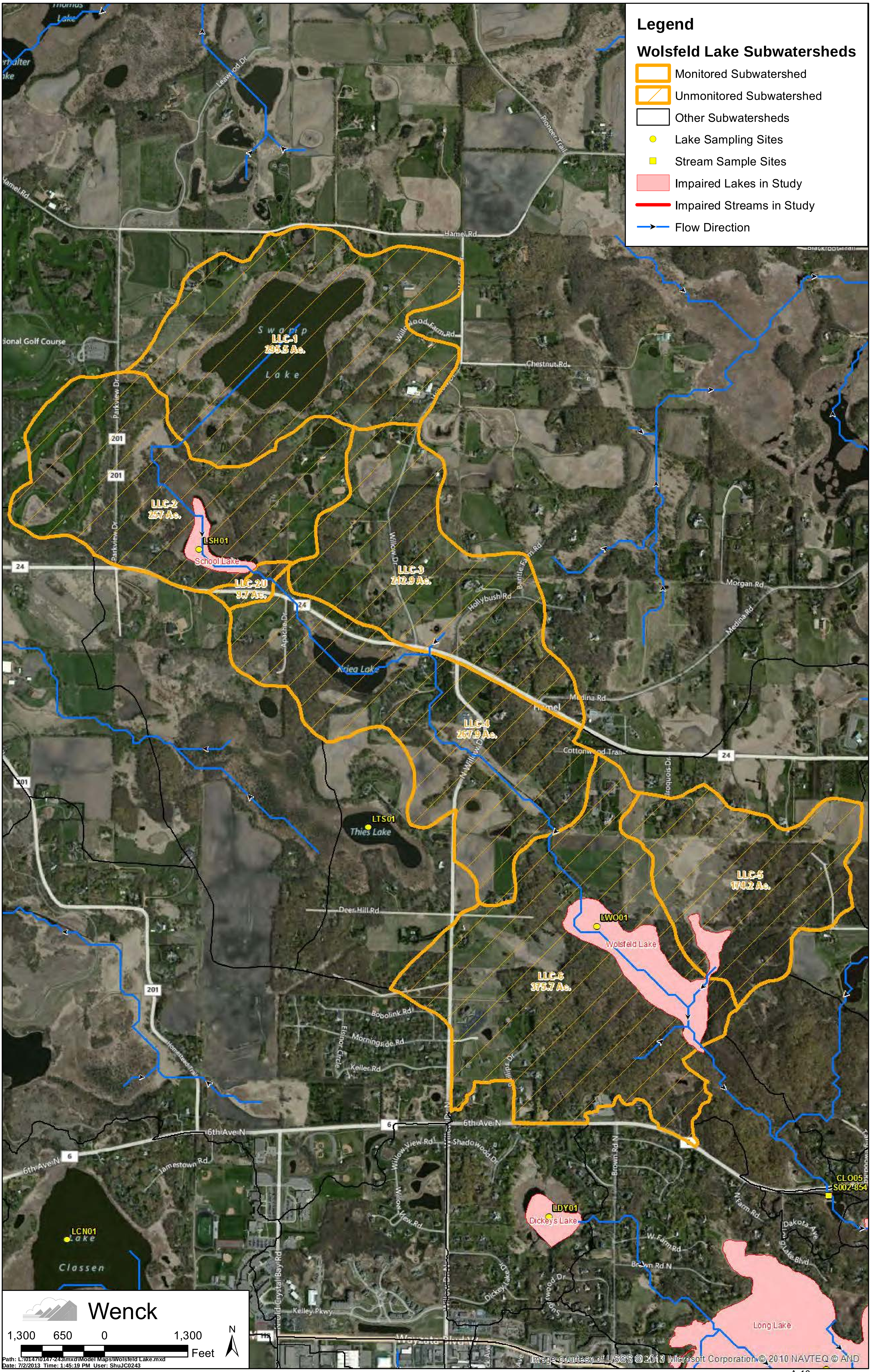

Legend
Lake Sampling Sites
Stream Sample Sites
Impaired Streams in Study
Flow Direction
Impaired Lakes in Study
Mooney Lake Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
LLC-20
123.1 Ac.
LMO01
LLC-21
475.8 Ac.
Mooney
Mooney Lake
34th Ave
Zircon La
Urbandale La
33rd Pl
Ranier La
32nd Ave
30th Pl
Brockton La
Xanthus La
27th Pl
Alvarado La
26th Ave
25th Ave
Hunter Dr
Walnut Grove La
23rd Ave
Troy La
20th Ave
19th Ave
Shadyview La
Yellowstone La
Ferndale Rd
24
6
Wenck
600 300 0 600
Feet
N
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

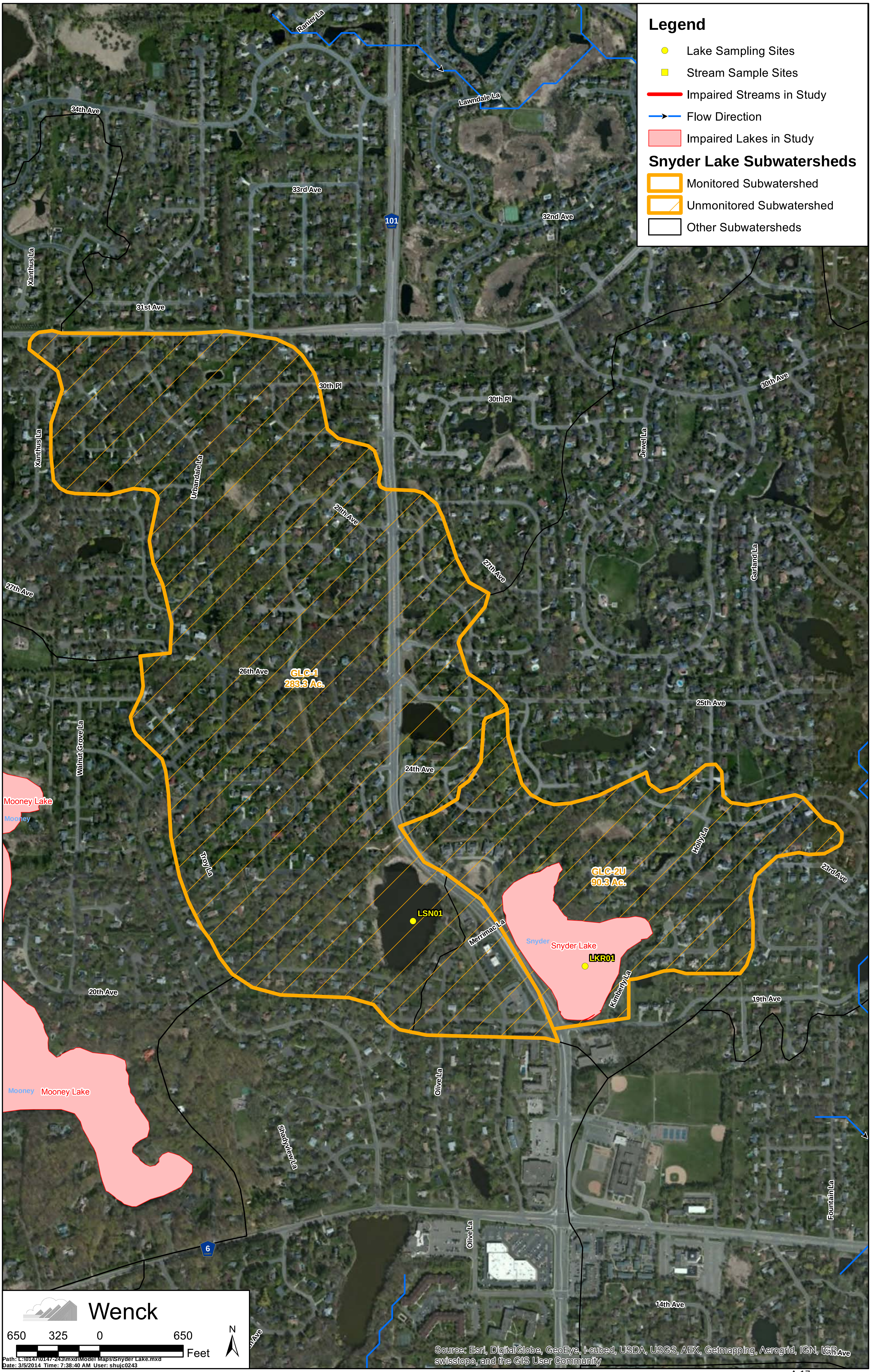


Lotus Dr
Kings Pt Rd
Lotus Dr
Lake Minnetonka Regional Park
SMC-16
43 Ac.
SMC-17
46.5 Ac.
L a k e   M i n n e
Stone Lake
SMC-18
791.4 Ac.
Victoria Dr
Crosby Lake
Carver Park Reserve
Nature Center Dr
Sunny Lake
Z u m b r a   L a k e
Zumbra Dr
Image courtesy of USGS
Legend
Stone Lake Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
Lake Sampling Sites
Stream Sample Sites
Impaired Lakes in Study
Impaired Streams in Study
Wenck
800 400 0 800
Feet
N

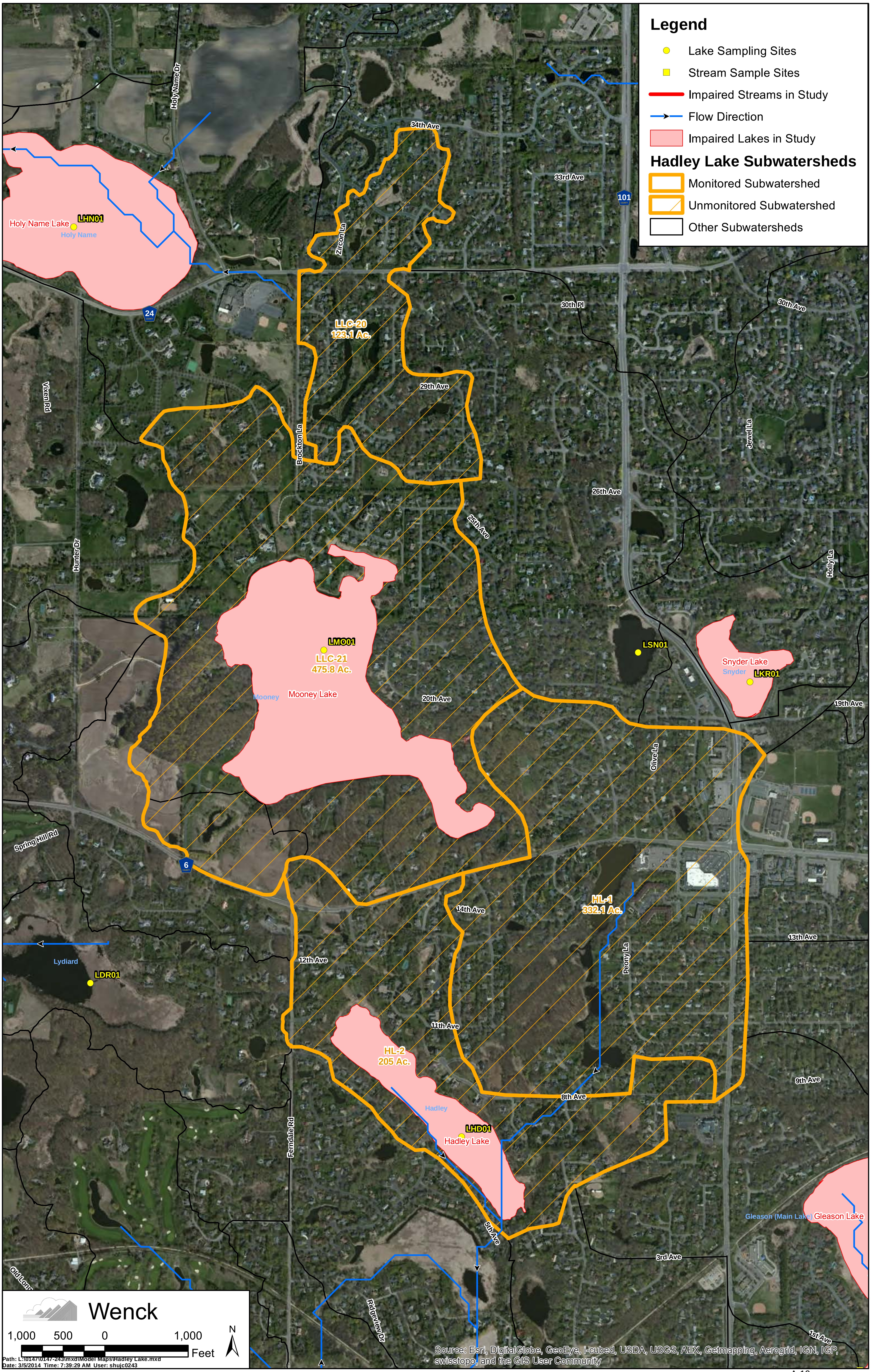

Legend
Lake Sampling Sites
Stream Sample Sites
Impaired Streams in Study
Flow Direction
Impaired Lakes in Study
Tamarack Lake Subwatersheds
Tamarack
Tamarack Lake
TAM01
LV-1U
208.8 Ac.
Schutz
St. Joe
Minnewashta
CSC01
S004-373
Interlachen Rd
Yardon Ct
Saint Moritz Rd
Kings Rd
Maple Shores Dr
Minnewashta Ct
Lake Ridge Rd
Ridgehill Rd
Hawthorne Cir
W 77th St
77th St
Forest Ridge Cir
Minnewashta Pkwy
Lone Cedar La
13
5
Wenck
400 200 0 400
Feet
N
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community


Legend
Tanager Lake Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
Lake Sampling Sites
Stream Sample Sites
Impaired Lakes in Study
Impaired Streams in Study
Flow Direction
Wenck
2,500 1,250 0 2,500
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Tanager Lake.mxd
Date: 3/5/2014 Time: 7:44:05 AM User: shujc0243
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
LLC-1 295.5 Ac.
LLC-2 257 Ac.
LLC-2U 9.7 Ac.
LLC-3 212.9 Ac.
LLC-4 267.9 Ac.
LLC-5 174.2 Ac.
LLC-6 375.7 Ac.
LLC-7 199.4 Ac.
LLC-8 577.8 Ac.
LLC-9 173 Ac.
LLC-10 463.8 Ac.
LLC-11 419.5 Ac.
LLC-12 169.8 Ac.
LLC-13 107.7 Ac.
LLC-14 60 Ac.
LLC-15 36.2 Ac.
LLC-16 78.4 Ac.
LLC-17 61.3 Ac.
LLC-18 108.1 Ac.
LLC-19 141.4 Ac.
LLC-22 104.3 Ac.
LLC-23 143.7 Ac.
LLC-24 180.5 Ac.
LLC-25 158.9 Ac.
LLC-26 173.2 Ac.
LLC-27 30.7 Ac.
LLC-28 9.2 Ac.
LLC-29 40.8 Ac.
LLC-30 29.2 Ac.
LLC-31 36.1 Ac.
LLC-32 28.6 Ac.
LLC-33 10.8 Ac.
LLC-34 85.2 Ac.
LLC-35 38.7 Ac.
LLC-36 23.9 Ac.
LLC-37 31 Ac.
LLC-38 23.9 Ac.
LLC-39 47.9 Ac.
LLC-40 126.9 Ac.
LLC-41 741.7 Ac.
LLC-42 105.6 Ac.
LLC-43 59.3 Ac.
LLC-44 87.8 Ac.
LLC-45 47.7 Ac.
LLC-46 141.5 Ac.
LLC-47 169.6 Ac.
LLC-48 170.1 Ac.
LLC-49 59.2 Ac.
LLC-50 158 Ac.
LLC-51 130 Ac.
LLC-52M 10.9 Ac.
LLC-52U 131.1 Ac.
LLC-53 94.1 Ac.
LSH01
School Lake
LTS01
Thies
LWO01
Wolsfeld Lake
LHN01
Holy Name Lake
LMO01
Mooney Lake
LDY01
Dickeys Lake
LCN01
Classen
CLO05 S002-854
LLO01
Long Lake
CLO01 S002-928
Lydiard
LDR01
Hadley Lake
LHD01
CCL04 S004-099
CCL01 S003-720
Stubbs Bay
CLO03 S003-728
Tanager Lake
LTG01
LMA01
Maxwell Bay
French Marsh
LFM01
Ferndale Marsh
LPE01
Peavey
LWA01
Lower Lake
LMU01
LCR01
Crystal Bay
Thomas
Winterhalter
116
101
55
115
201
24
6
12
84
146
51
15


Legend
Wolsfeld Lake Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
Lake Sampling Sites
Stream Sample Sites
Impaired Lakes in Study
Impaired Streams in Study
Flow Direction
LLC-1
205.5 Ac.
Swamp Lake
LLC-2
257 Ac.
LSH01
School Lake
LLC-2D
3.7 Ac.
LLC-3
212.9 Ac.
LLC-4
267.9 Ac.
LTS01
Thies Lake
LLC-5
174.2 Ac.
LWO01
Wolsfeld Lake
LLC-6
375.7 Ac.
LDY01
Dickeys Lake
LCN01
Lake Classen
CLO05
S002-854
Long Lake
Hamel Rd
Chestnut Rd
Morgan Rd
Medina Rd
Cottonwood Trail
Willow Dr
Parkview Dr
6th Ave N
Deer Hill Rd
Bobolink Rd
Morningside Rd
Keller Rd
Kelley Pkwy
Wayzata Blvd W
Hamel
Wenck
1,300 650 0 1,300
Feet
N
Path: L:\0147\0147-24\mxd\Model Maps\Wolsfeld Lake.mxd
Date: 7/2/2013 Time: 1:45:19 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

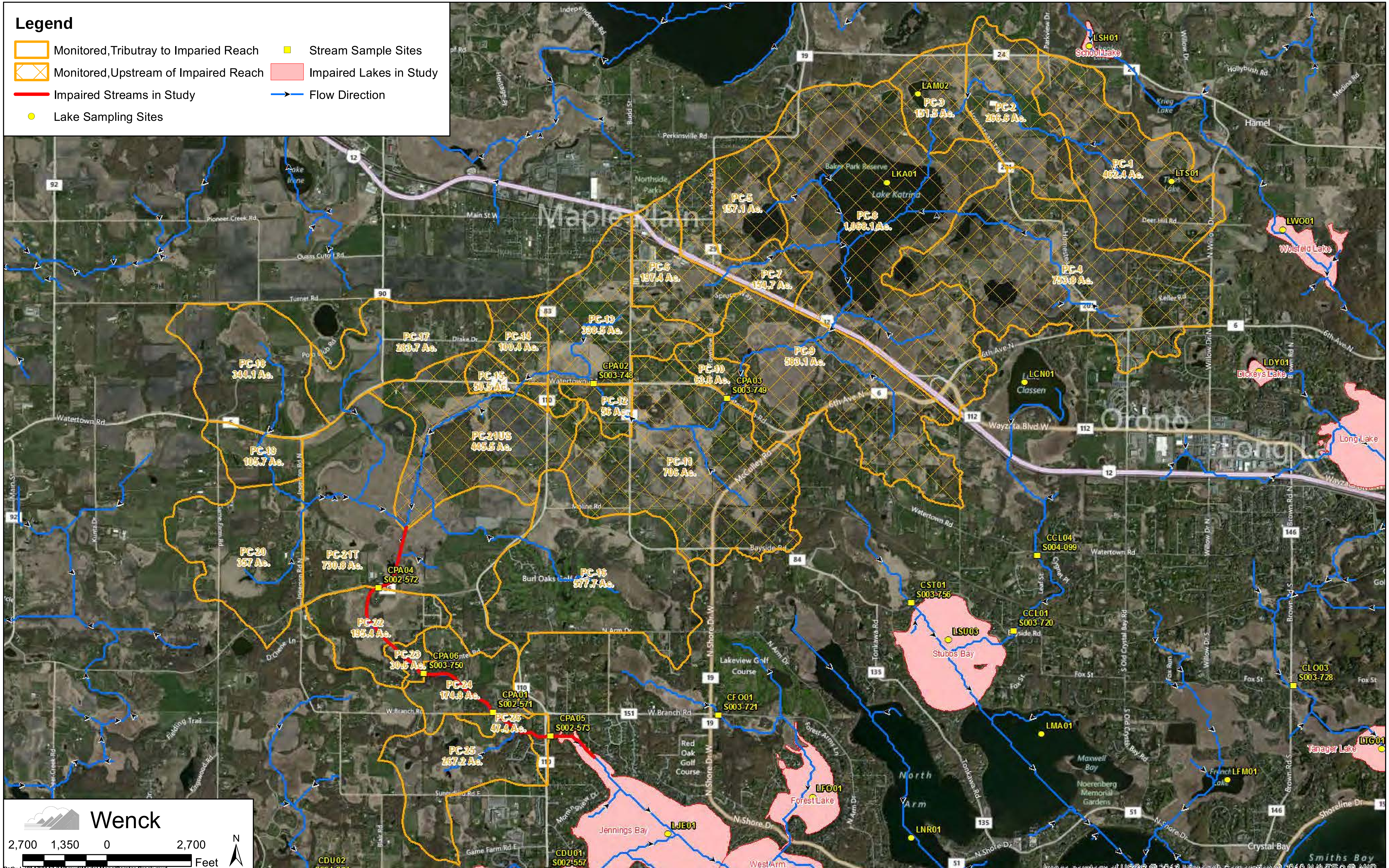

Legend
Lake Sampling Sites
Stream Sample Sites
Impaired Streams in Study
Flow Direction
Impaired Lakes in Study
Snyder Lake Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
GLC-1
283.3 Ac.
GLC-2U
90.3 Ac.
LSN01
Snyder Lake
LKR01
Mooney Lake
Mooney Lake
Ranier La
Lawndale La
34th Ave
33rd Ave
32nd Ave
31st Ave
30th Pl
30th Pl
30th Ave
Xanthus La
Xanthus La
Urbandale La
28th Ave
27th Ave
27th Ave
Jewel La
Garland La
26th Ave
25th Ave
24th Ave
Walnut Grove La
Troy La
Holly La
23rd Ave
Merrimac La
Kimberly La
19th Ave
20th Ave
Olive La
Olive La
Shadyview La
Fountain La
14th Ave
101
6
Wenck
650 325 0 650
Feet
N
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Date: 3/5/2014 Time: 7:38:40 AM User: shujc0243


Leawood Dr
Hamel Rd
Parkview Dr
201
National Golf Course
Willowood Farm Rd
Willow Dr
LLC-1
295.5 Ac.
LLC-2
257 Ac.
LSH01
School Lake
24
Apache Dr
Legend
School Lake Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
Lake Sampling Sites
Stream Sample Sites
Impaired Lakes in Study
Impaired Streams in Study
Flow Direction
Wenck
700 350 0 700
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\School Lake.mxd
Date: 7/2/2013 Time: 1:42:38 PM User: ShuJC0243
Image courtesy of USGS



Legend
Lake Sampling Sites
Stream Sample Sites
Impaired Streams in Study
Flow Direction
Impaired Lakes in Study
Hadley Lake Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
Holy Name Lake
LHN01
Holy Name
Holy Name Dr
34th Ave
33rd Ave
Zircon La
30th Pl
30th Ave
LLC-20
123.1 Ac.
29th Ave
Vixen Rd
Brockton La
Jewel La
26th Ave
25th Ave
Hunter Dr
Holly La
LMO01
LLC-21
475.8 Ac.
Mooney
Mooney Lake
LSN01
Snyder Lake
Snyder
LKR01
20th Ave
19th Ave
Olive La
Spring Hill Rd
14th Ave
HL-1
332.1 Ac.
13th Ave
12th Ave
Peony La
Lydiard
LDR01
11th Ave
HL-2
205 Ac.
9th Ave
8th Ave
Hadley
LHD01
Hadley Lake
Fernbrook Rd
5th Ave
3rd Ave
Gleason (Main Lake)
Gleason Lake
Ridgeview Dr
1st Ave
101
24
6
Wenck
1,000 500 0 1,000
Feet
N
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Date: 3/5/2014 Time: 7:39:29 AM User: shujc0243

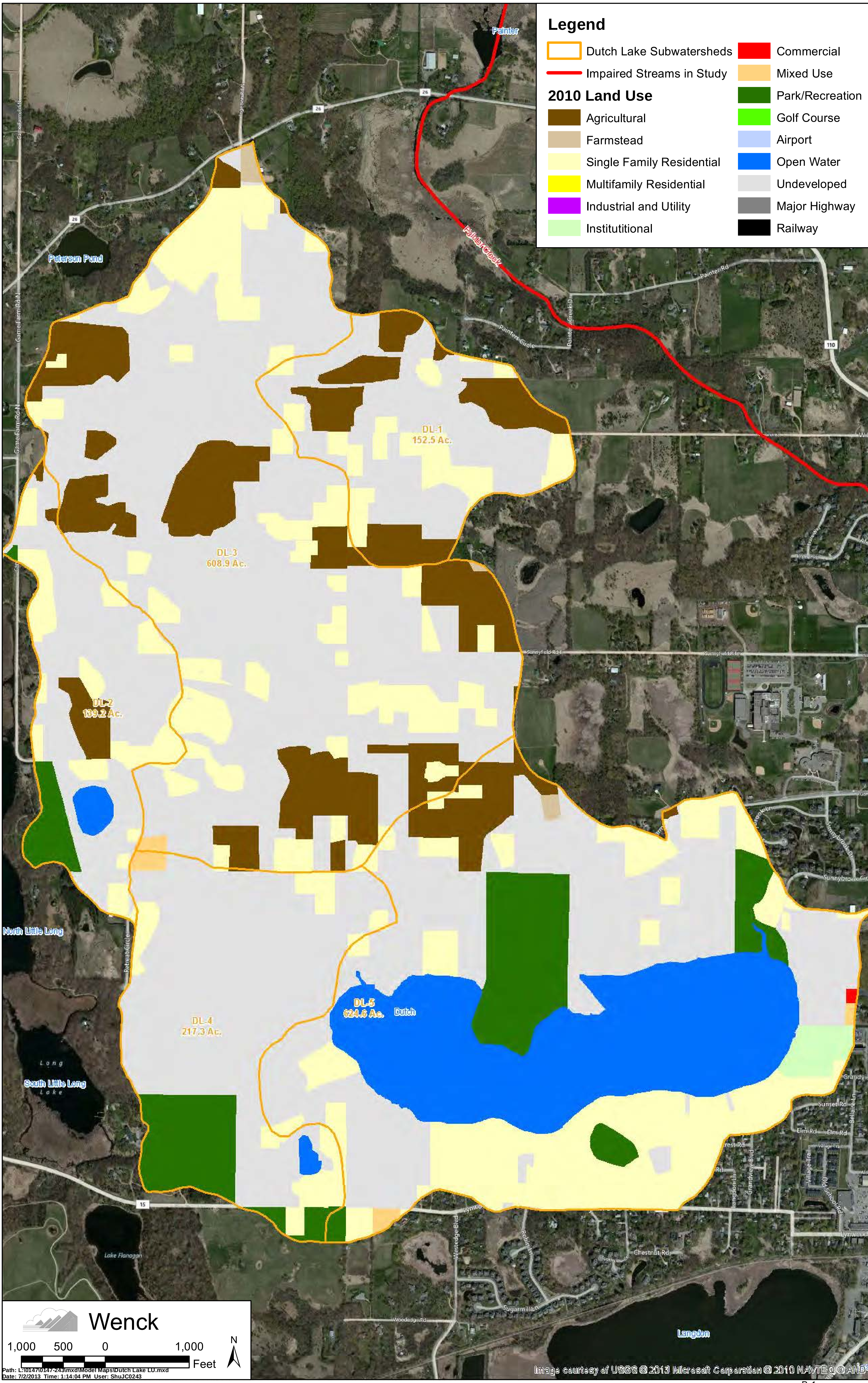
Legend
Turbid Lake Subwatersheds
Monitored Subwatershed
Unmonitored Subwatershed
Other Subwatersheds
Lake Sampling Sites
Stream Sample Sites
Impaired Lakes in Study
Impaired Streams in Study
Flow Direction
CSI13
S005-567
SMC-32
539.1 Ac.
Turbid Lake
CTU01
Spring Valley Rd
Cardinal Ln
Wildwood Rd
Airport Rd
Laketown Rd
Scandia Rd
Reitz Lake Rd
Wenck
700 350 0 700
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Turbid Lake.mxd
Date: 7/2/2013 Time: 1:44:45 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND



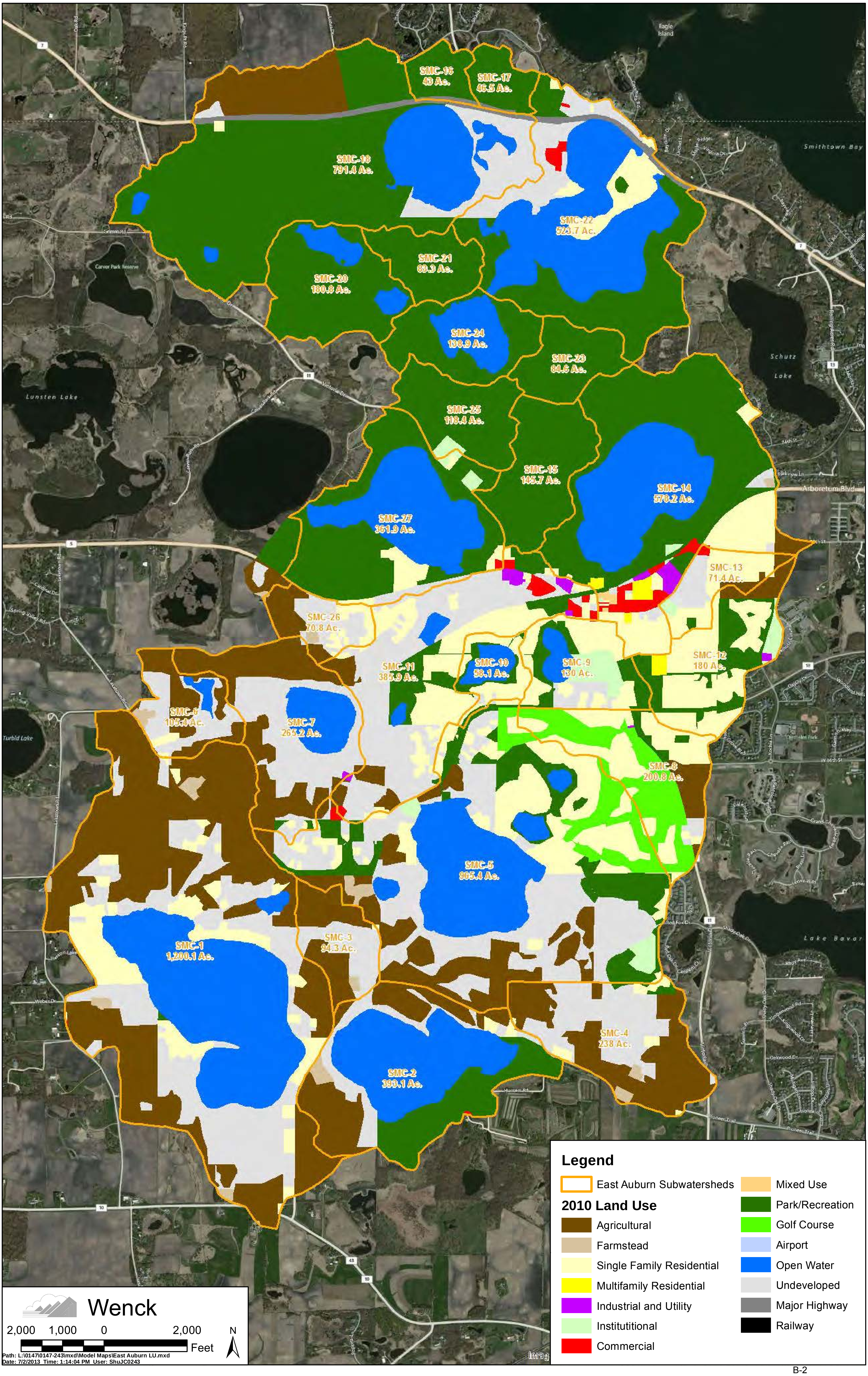
Path: L:\0147\0147-243\mxd\Model Maps\Painter Creek.mxd
Date: 7/2/2013 Time: 1:42:33 PM User: ShuJC0243

Appendix B

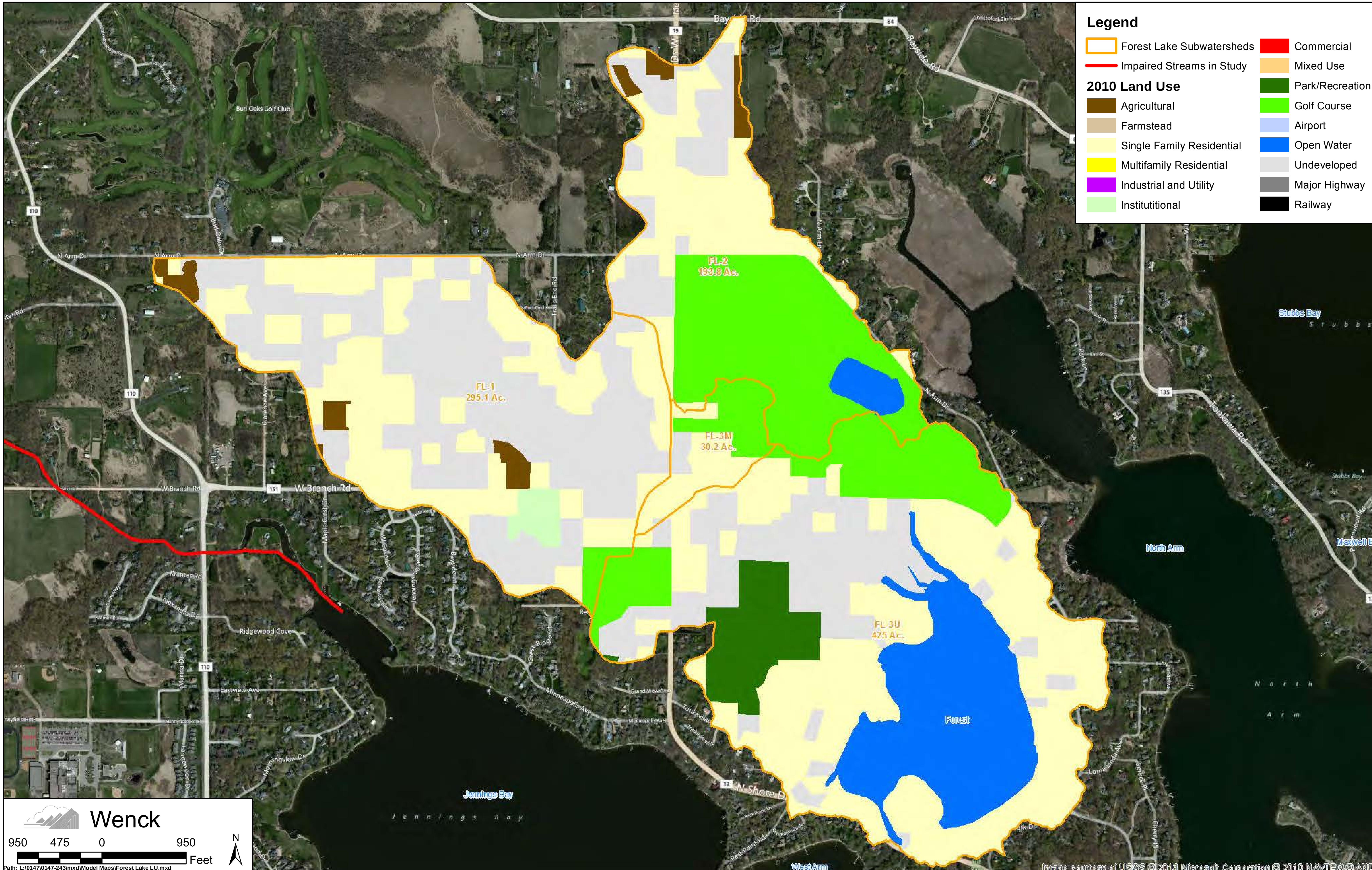
Landuse Figures



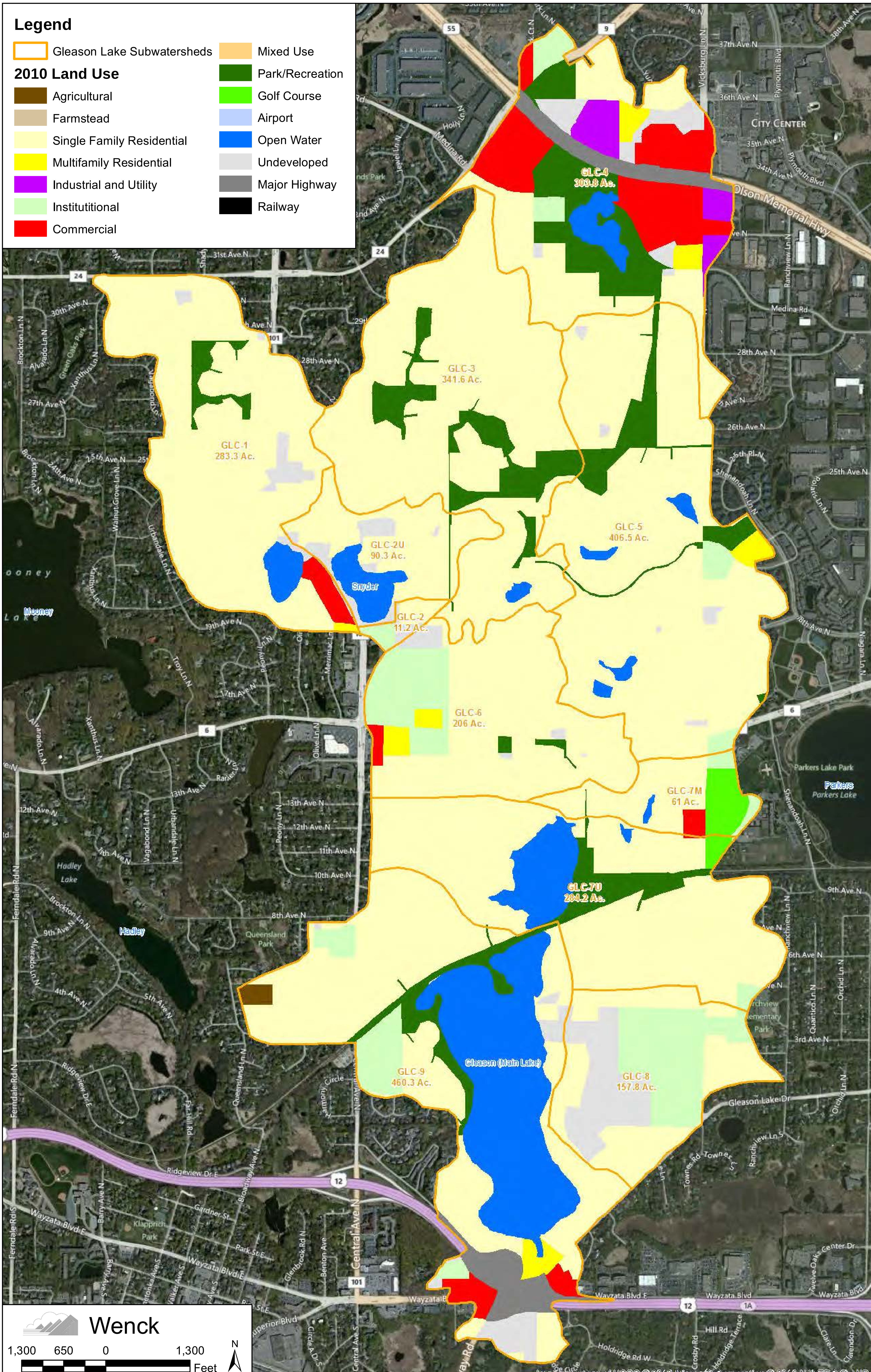
Legend
Dutch Lake Subwatersheds
Impaired Streams in Study
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
DL-1
152.5 Ac.
DL-2
139.2 Ac.
DL-3
608.9 Ac.
DL-4
217.3 Ac.
DL-5
624.6 Ac.
Dutch
Peterson Pond
North Little Long
South Little Long
Langdon
Painter
Painter Creek
Wenck
1,000 500 0 1,000
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Dutch Lake LU.mxd
Date: 7/2/2013 Time: 1:14:04 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

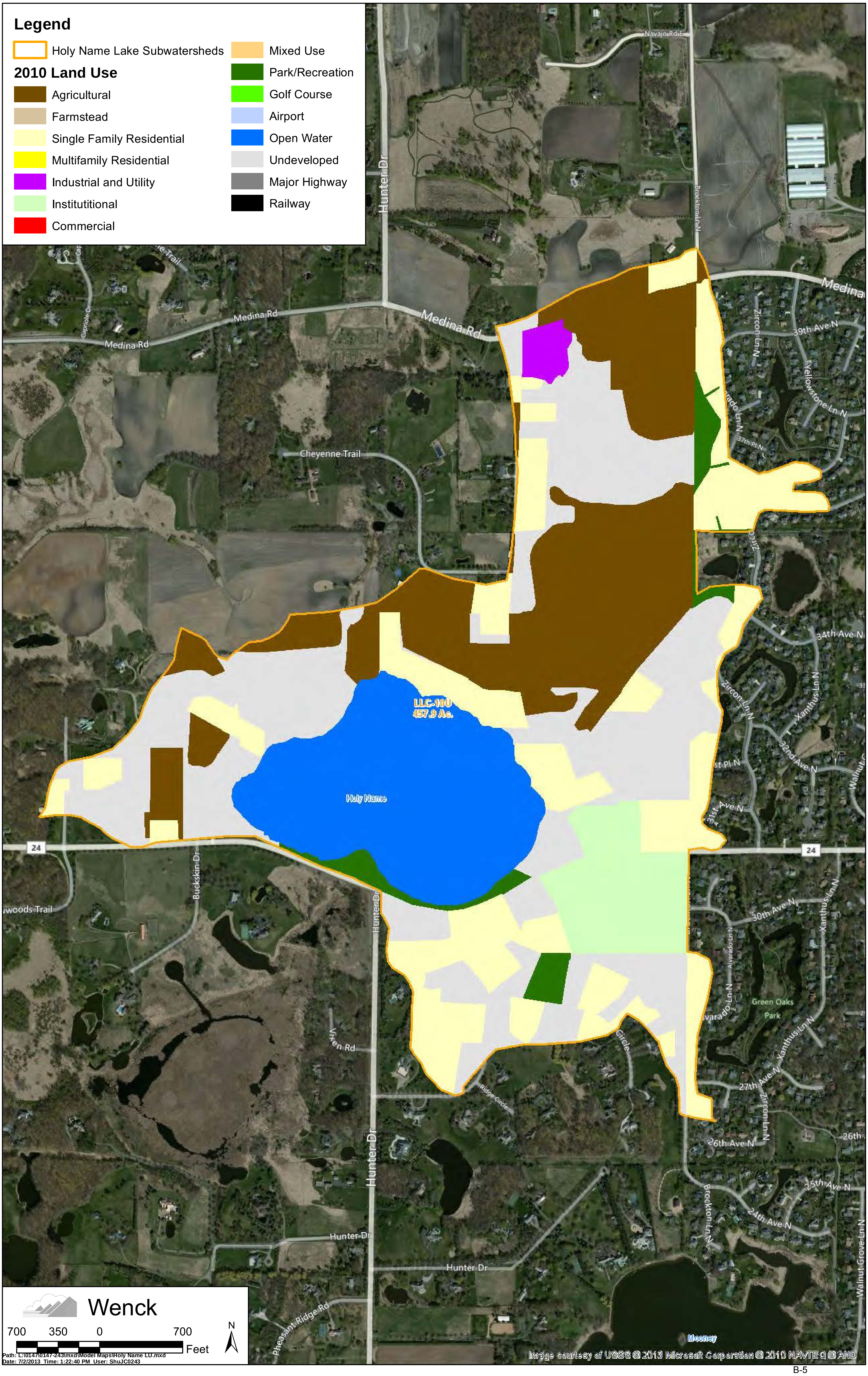


SMC-16 43 Ac.
SMC-17 46.5 Ac.
SMC-18 791.4 Ac.
SMC-22 523.7 Ac.
SMC-21 89.3 Ac.
SMC-20 180.8 Ac.
SMC-24 130.9 Ac.
SMC-23 84.6 Ac.
SMC-25 118.4 Ac.
SMC-15 145.7 Ac.
SMC-14 578.2 Ac.
SMC-27 361.9 Ac.
SMC-13 71.4 Ac.
SMC-26 70.8 Ac.
SMC-11 385.9 Ac.
SMC-10 58.1 Ac.
SMC-9 130 Ac.
SMC-12 180 Ac.
SMC-6 105.4 Ac.
SMC-7 263.2 Ac.
SMC-8 200.8 Ac.
SMC-5 905.4 Ac.
SMC-1 1,200.1 Ac.
SMC-3 94.3 Ac.
SMC-4 238 Ac.
SMC-2 399.1 Ac.
Legend
East Auburn Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
Wenck
2,000 1,000 0 2,000
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\East Auburn LU.mxd
Date: 7/2/2013 Time: 1:14:04 PM User: ShuJC0243

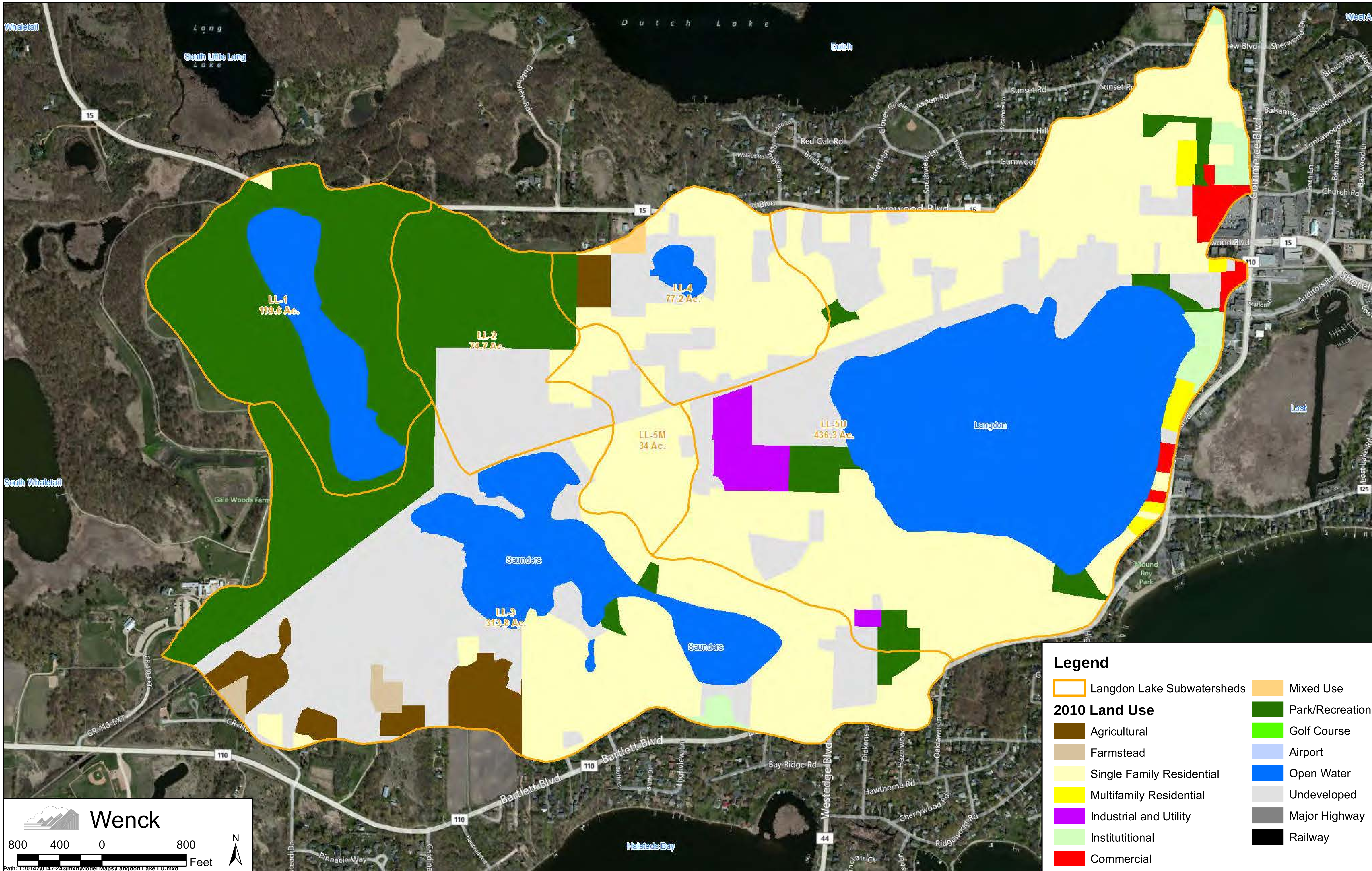


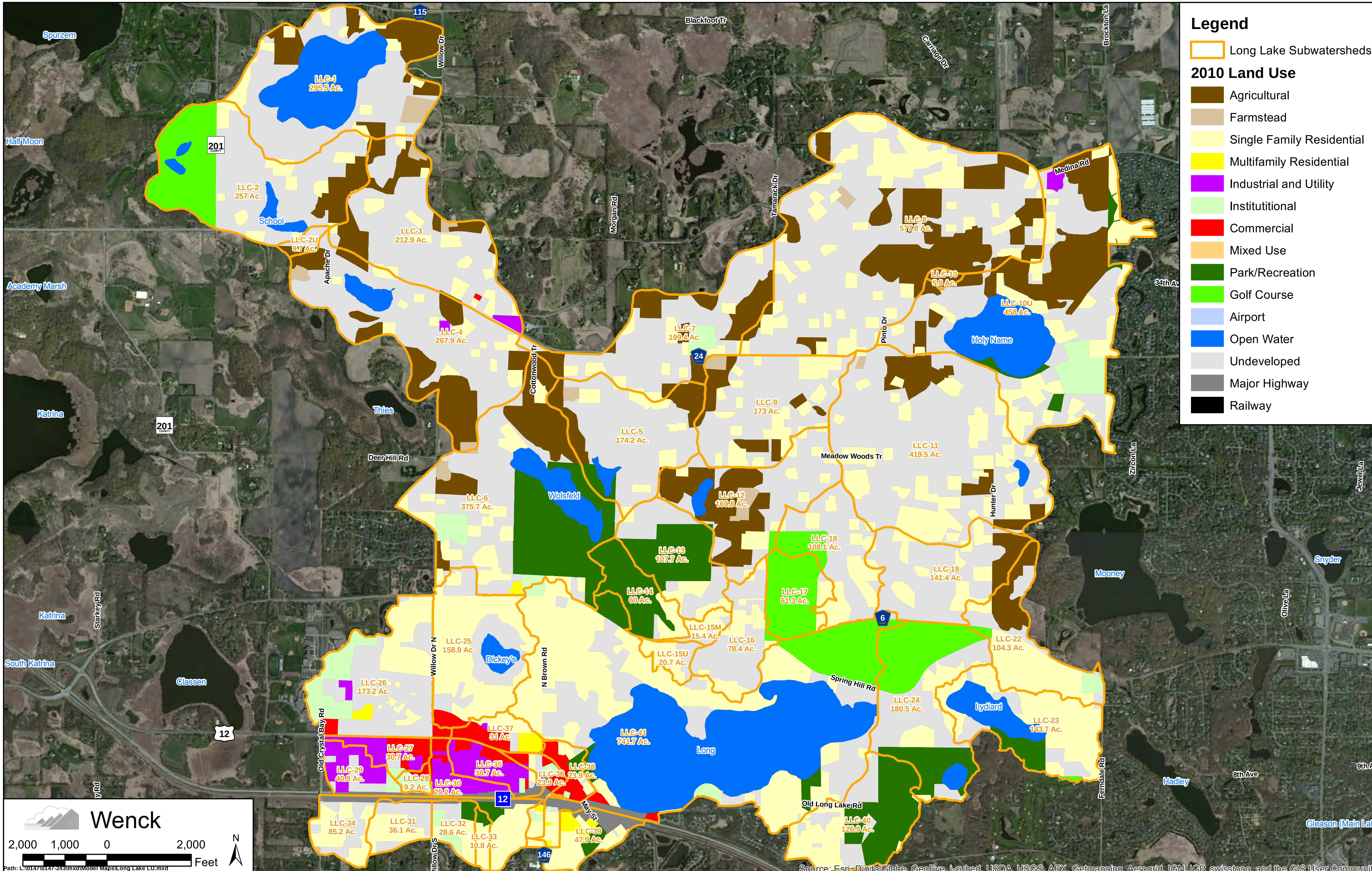
Legend
Forest Lake Subwatersheds
Impaired Streams in Study
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
FL-1
295.1 Ac.
FL-2
193.8 Ac.
FL-3M
30.2 Ac.
FL-3U
425 Ac.
Forest
North Arm
Stubbs Bay
Maxwell Bay
Jennings Bay
West Arm
Burl Oaks Golf Club
N Arm Dr
W Branch Rd
Bayside Rd
N Shore Dr
Tonkawa Rd
Minneapolis Ave
Ridgewood Cove
Eastview Ave
Wenck
950 475 0 950
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Forest Lake LU.mxd
Date: 7/2/2013 Time: 1:14:40 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

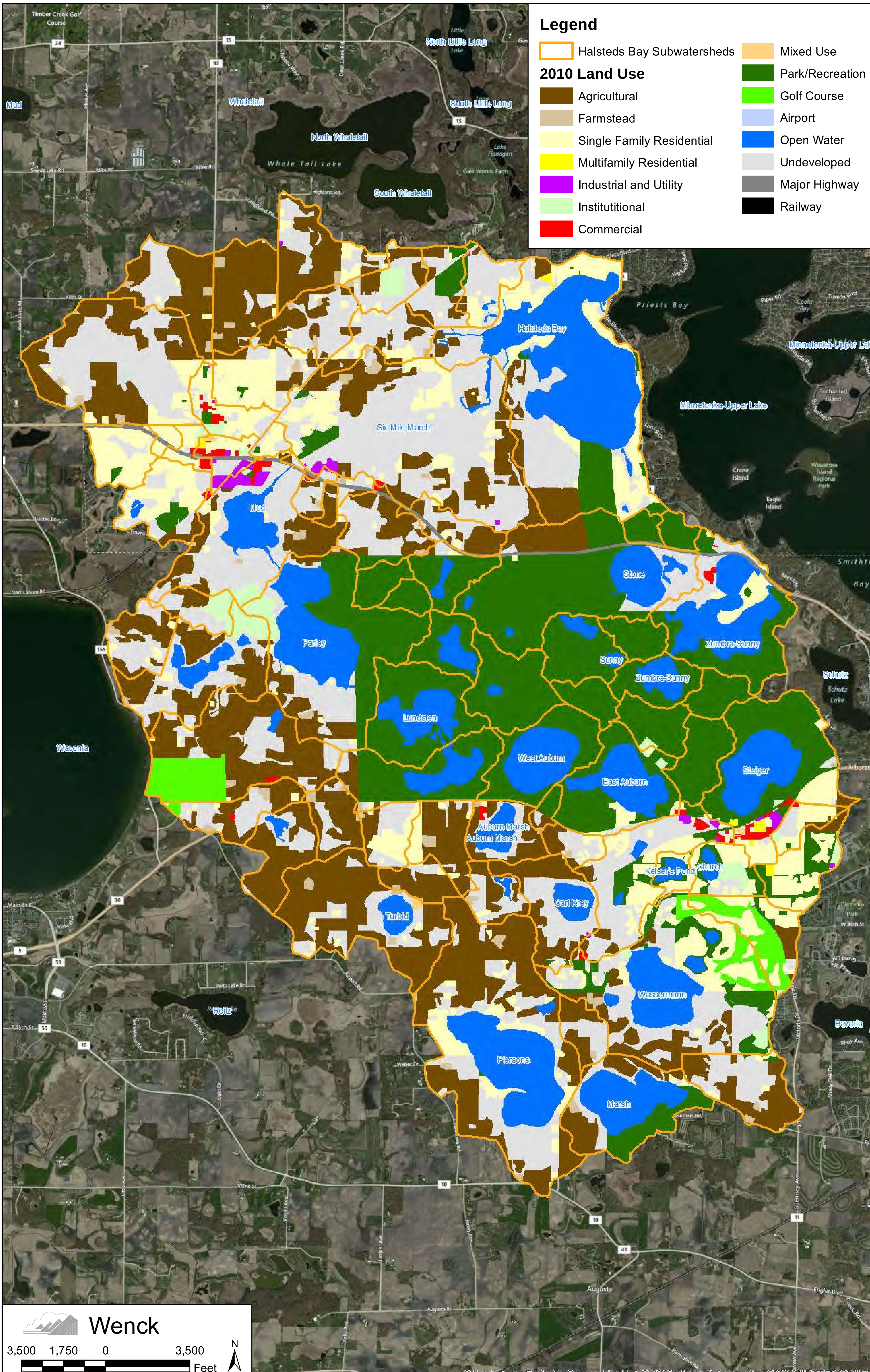

Legend
Gleason Lake Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
GLC-1
283.3 Ac.
GLC-2
11.2 Ac.
GLC-2U
90.3 Ac.
GLC-3
341.6 Ac.
GLC-4
309.8 Ac.
GLC-5
406.5 Ac.
GLC-6
206 Ac.
GLC-7M
61 Ac.
GLC-7U
284.2 Ac.
GLC-8
157.8 Ac.
GLC-9
460.3 Ac.
Snyder
Mooney
Hadley
Parkers
Gleason (Main Lake)
Olson Memorial Hwy
City Center
Parkers Lake Park
Queensland Park
Klapprich Park
Wenck
1,300 650 0 1,300
Feet
N
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND
Date: 7/2/2013

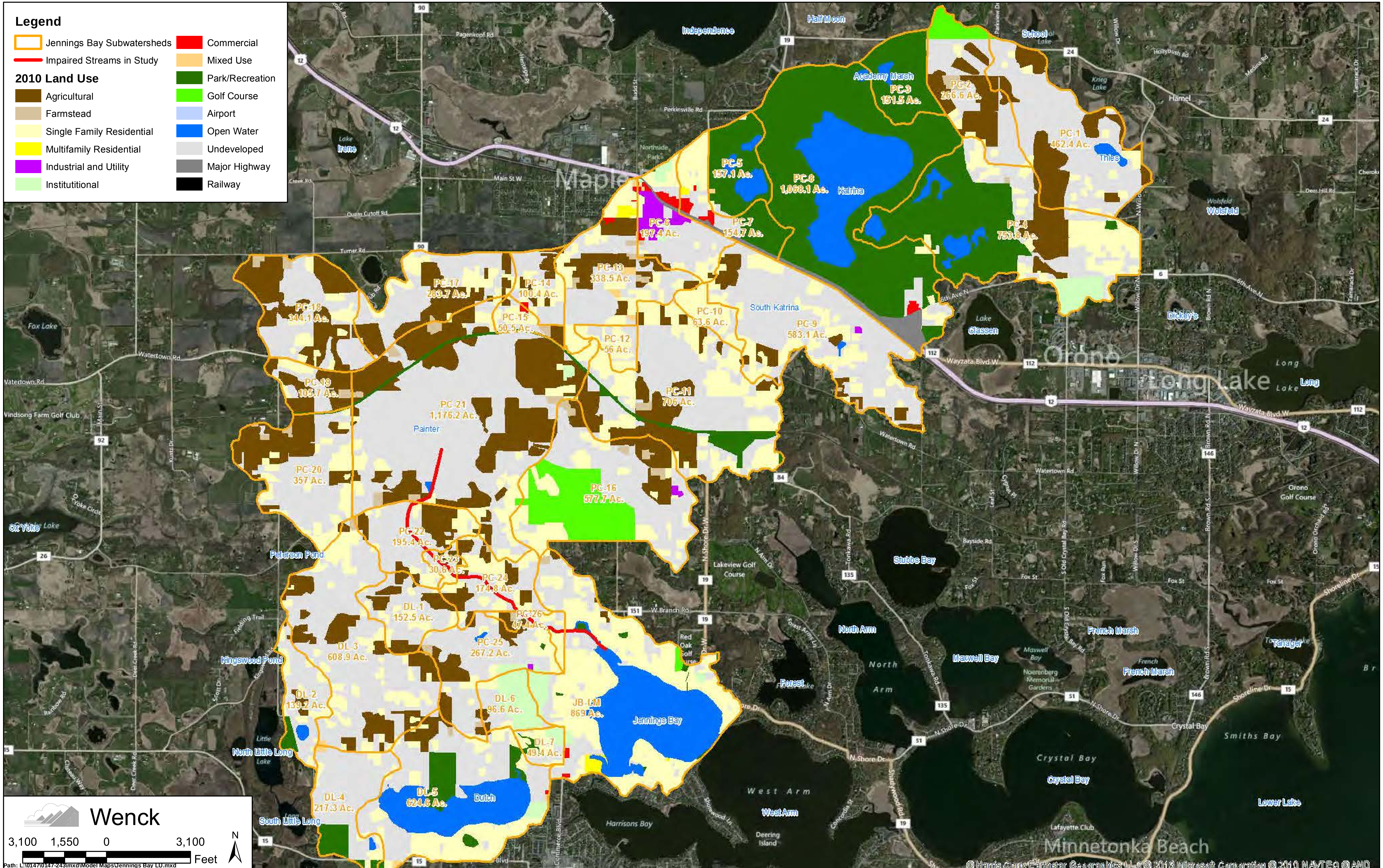


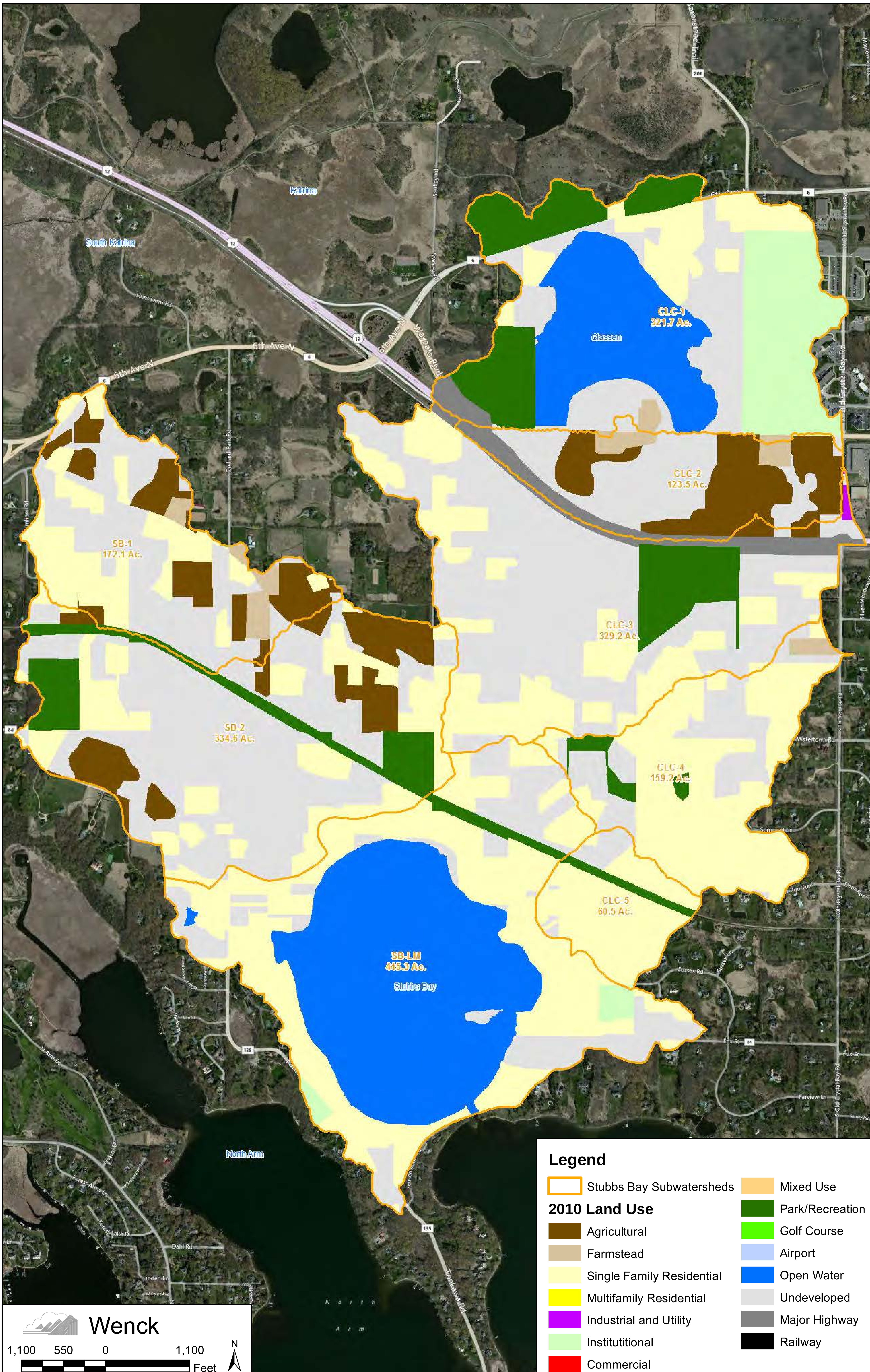
Legend
Holy Name Lake Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
LLC-10U
457.9 Ac.
Holy Name
Medina Rd
Hunter Dr
Cheyenne Trail
Brockton Ln N
Buckskin Dr
24
Wenck
700 350 0 700
Feet
N
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

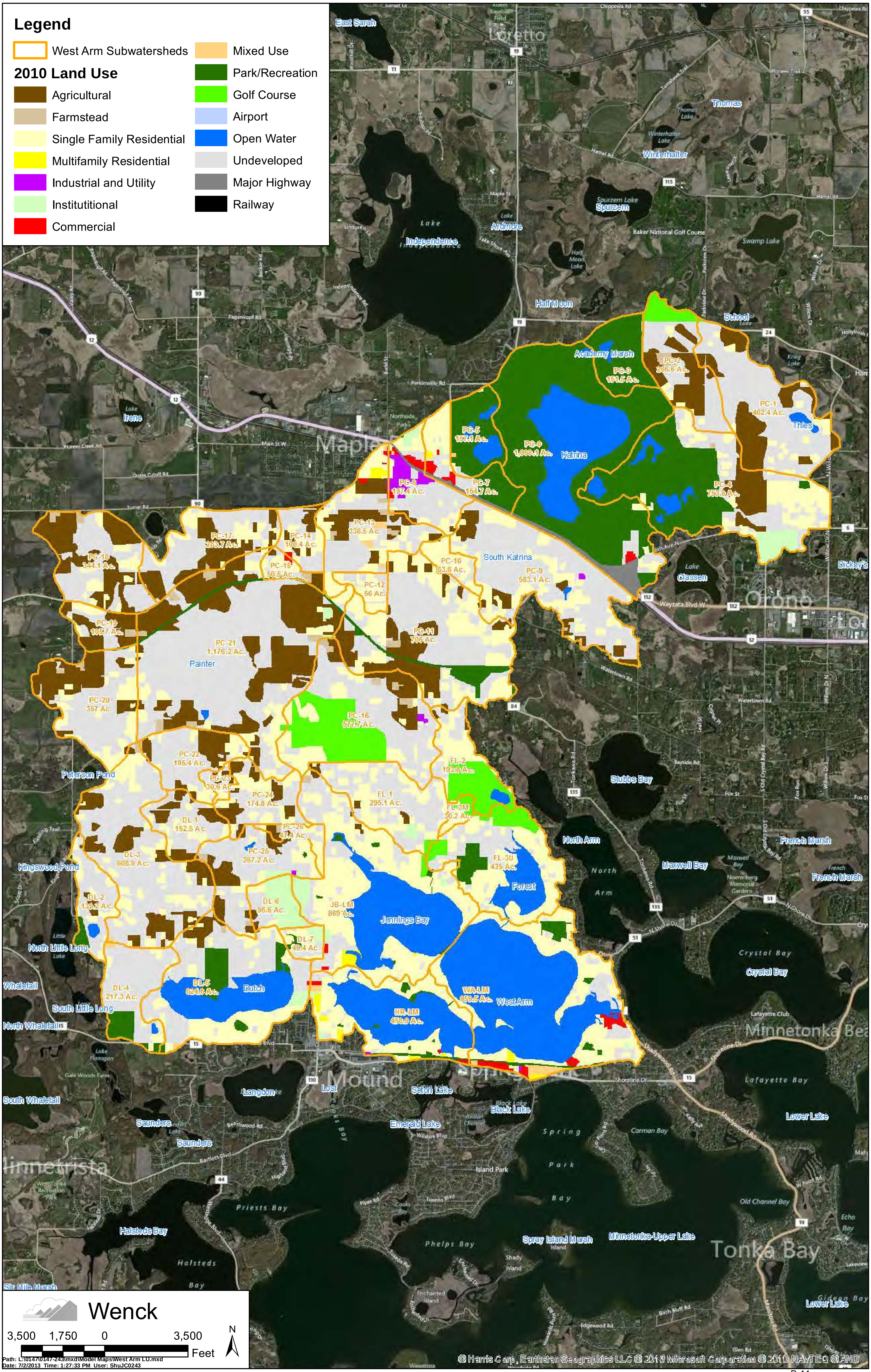

LL-1
119.6 Ac.
LL-2
74.7 Ac.
LL-3
313.8 Ac.
LL-4
77.2 Ac.
LL-5M
34 Ac.
LL-5U
436.3 Ac.
Langdon
Saunders
Dutch Lake
Legend
Langdon Lake Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
Wenck
800 400 0 800
Feet
N

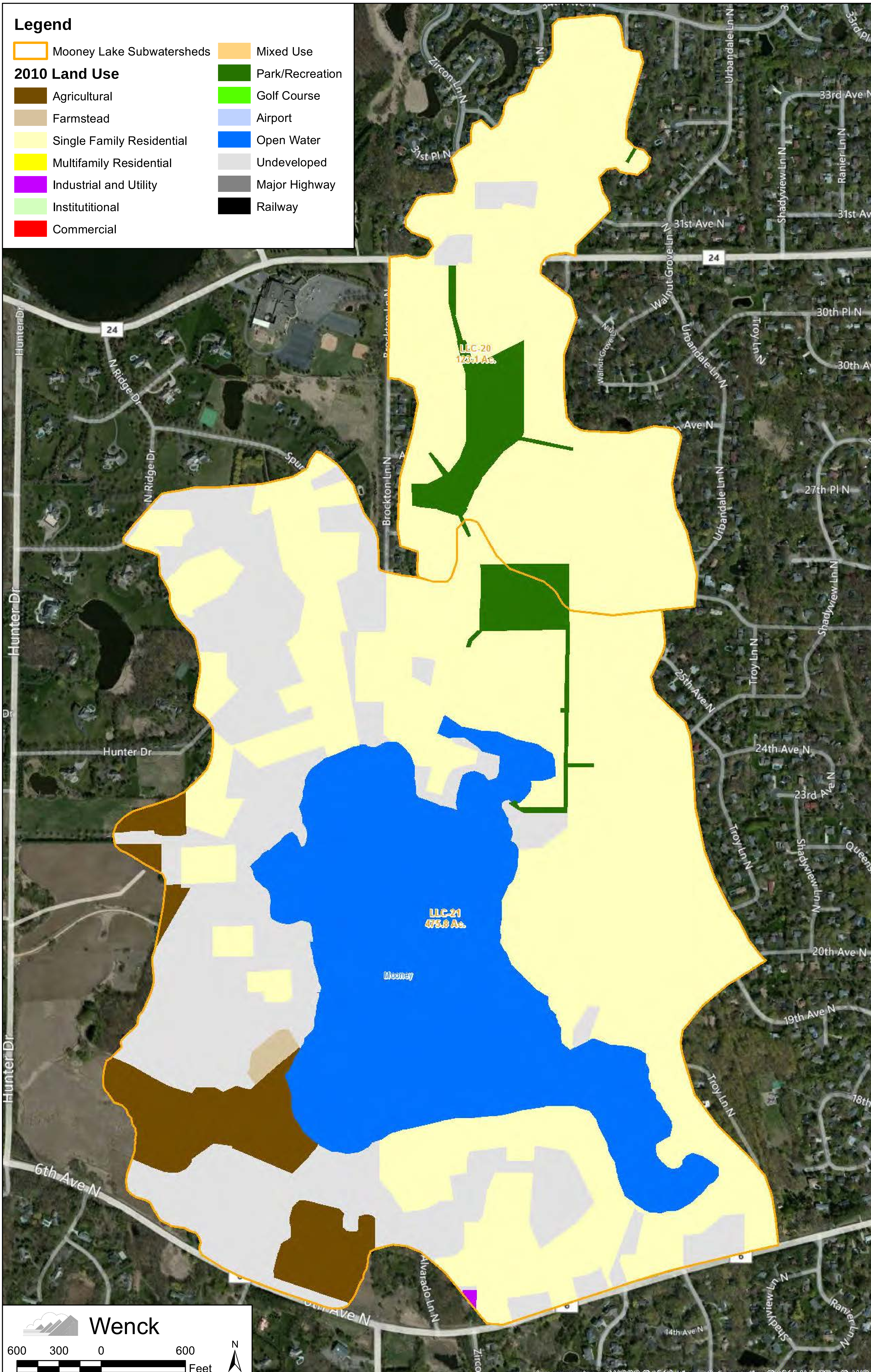

Legend
Long Lake Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
LLC-1 295.5 Ac.
LLC-2 257 Ac.
LLC-2U 9.7 Ac.
LLC-3 212.9 Ac.
LLC-4 267.9 Ac.
LLC-5 174.2 Ac.
LLC-6 375.7 Ac.
LLC-7 199.4 Ac.
LLC-8 577.8 Ac.
LLC-9 173 Ac.
LLC-10 5.9 Ac.
LLC-10U 458 Ac.
LLC-11 419.5 Ac.
LLC-12 169.8 Ac.
LLC-13 107.7 Ac.
LLC-14 60 Ac.
LLC-15M 15.4 Ac.
LLC-15U 20.7 Ac.
LLC-16 78.4 Ac.
LLC-17 61.3 Ac.
LLC-18 108.1 Ac.
LLC-19 141.4 Ac.
LLC-22 104.3 Ac.
LLC-23 143.7 Ac.
LLC-24 180.5 Ac.
LLC-25 158.9 Ac.
LLC-26 173.2 Ac.
LLC-27 30.7 Ac.
LLC-28 9.2 Ac.
LLC-29 40.8 Ac.
LLC-30 29.2 Ac.
LLC-31 36.1 Ac.
LLC-32 28.6 Ac.
LLC-33 10.8 Ac.
LLC-34 85.2 Ac.
LLC-35 38.7 Ac.
LLC-36 23.9 Ac.
LLC-37 31 Ac.
LLC-38 23.9 Ac.
LLC-39 47.9 Ac.
LLC-40 126.9 Ac.
LLC-41 741.7 Ac.
Spurzem
Half Moon
Academy Marsh
Katrina
South Katrina
Classen
School
Thies
Wolsfeld
Dickey's
Long
Lydiard
Holy Name
Mooney
Snyder
Hadley
Gleason (Main Lake)
Blackfoot Tr
Willow Dr
Carriage Dr
Brockton La
Medina Rd
Morgan Rd
Tamarack Dr
Pinto Dr
Apache Dr
Cottonwood Tr
Deer Hill Rd
Meadow Woods Tr
Hunter Dr
Zircon La
Jewel La
34th Av
Olive La
Spring Hill Rd
Old Long Lake Rd
Ferndale Rd
Old Crystal Bay Rd
Willow Dr N
Willow Dr S
N Brown Rd
Starkey Rd
May St
9th Ave
8th Ave
115
201
24
6
12
146
Wenck
2,000 1,000 0 2,000
Feet
N
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Path: L:\0147\0147-243\mxd\Model Maps\Long Lake LU.mxd
Date: 3/5/2014 Time: 7:36:25 AM User: shujc0243

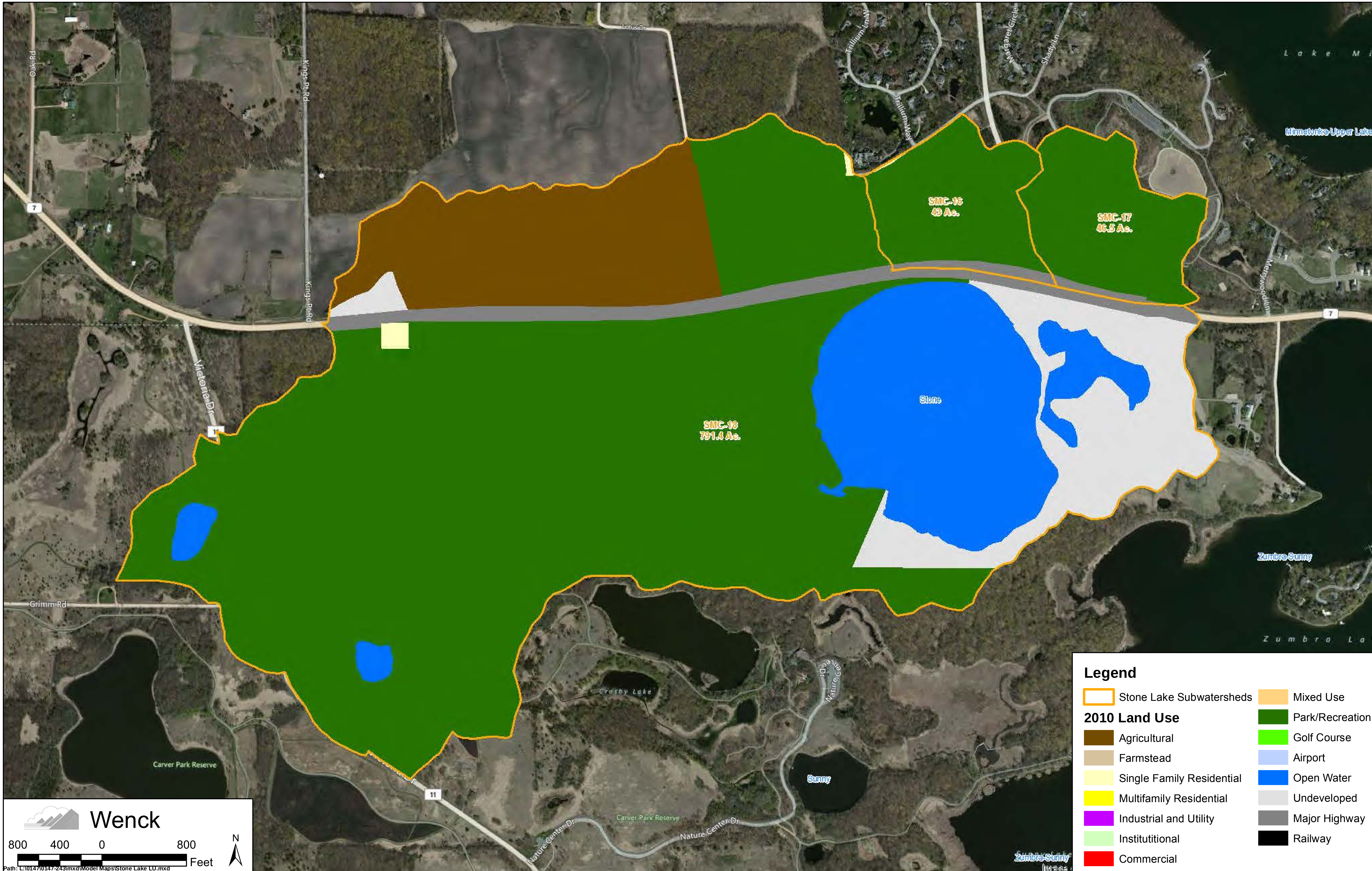

Legend
Halsteds Bay Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
North Little Long
Mud
Whaletail
South Little Long
North Whaletail
Whale Tail Lake
South Whaletail
Halsteds Bay
Priests Bay
Minnetonka-Upper Lake
Six Mile Marsh
Mud
Stone
Parley
Zumbra-Sunny
Sunny
Schutz
Lundsten
Waconia
West Auburn
East Auburn
Steiger
Auburn Marsh
Keiser's Pond
Church
Turbid
Carl Krey
Wassermann
Reitz
Bavaria
Piersons
Marsh
Wenck
3,500 1,750 0 3,500
Feet
N
Path: L:\0147\0147-248\mxd\Model Maps\Halsteds Bay LU.mxd
Date: 7/2/2013 Time: 1:22:16 PM User: ShuJC0243
© Harris Corp, Earthstar Geographics LLC © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

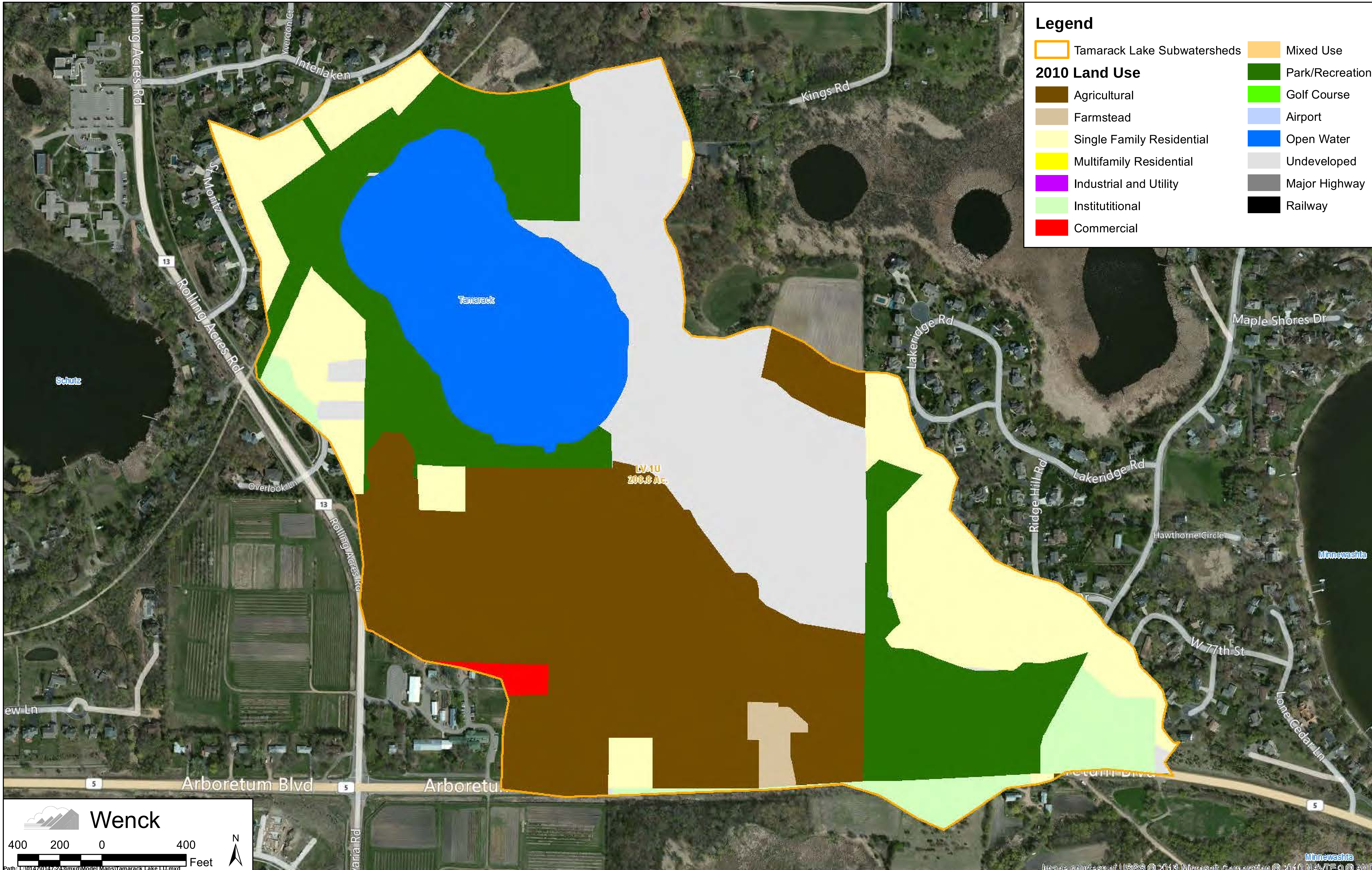

Legend
Jennings Bay Subwatersheds
Impaired Streams in Study
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
PC-1 462.4 Ac.
PC-2 266.6 Ac.
PC-3 151.5 Ac.
PC-4 753.8 Ac.
PC-5 157.1 Ac.
PC-6 197.4 Ac.
PC-7 154.7 Ac.
PC-8 1,068.1 Ac.
PC-9 583.1 Ac.
PC-10 63.6 Ac.
PC-11 706 Ac.
PC-12 56 Ac.
PC-13 338.5 Ac.
PC-14 100.4 Ac.
PC-15 50.5 Ac.
PC-16 577.7 Ac.
PC-17 289.7 Ac.
PC-18 344.1 Ac.
PC-19 103.7 Ac.
PC-20 357 Ac.
PC-21 1,176.2 Ac.
PC-22 195.4 Ac.
PC-23 30.6 Ac.
PC-24 174.8 Ac.
PC-25 267.2 Ac.
PC-26 47.4 Ac.
DL-1 152.5 Ac.
DL-2 139.2 Ac.
DL-3 608.9 Ac.
DL-4 217.3 Ac.
DL-5 624.6 Ac.
DL-6 96.6 Ac.
DL-7 49.4 Ac.
JB-LM 869 Ac.
Jennings Bay
Dutch
Painter
South Katrina
Katrina
Academy Marsh
Independence
Half Moon
School
Thies
Maple
Orono
Long Lake
Wenck
3,100 1,550 0 3,100
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Jennings Bay LU.mxd
Date: 7/2/2013 Time: 1:22:52 PM User: ShuJC0243
© Harris Corp, Earthstar Geographics LLC © 2013 Microsoft Corporation © 2010 NAVTEQ © AND


Katrina
South Katrina
Claassen
CLC-1
321.7 Ac.
CLC-2
123.5 Ac.
CLC-3
329.2 Ac.
CLC-4
159.2 Ac.
CLC-5
60.5 Ac.
SB-1
172.1 Ac.
SB-2
334.6 Ac.
SB-LM
445.3 Ac.
Stubbs Bay
North Arm
6th Ave N
Wayzata Blvd
Hunt Farm Rd
Legend
Stubbs Bay Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
Wenck
1,100 550 0 1,100
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Stubbs Bay LU.mxd
Date: 7/2/2013 Time: 1:26:00 PM User: ShuJC0243

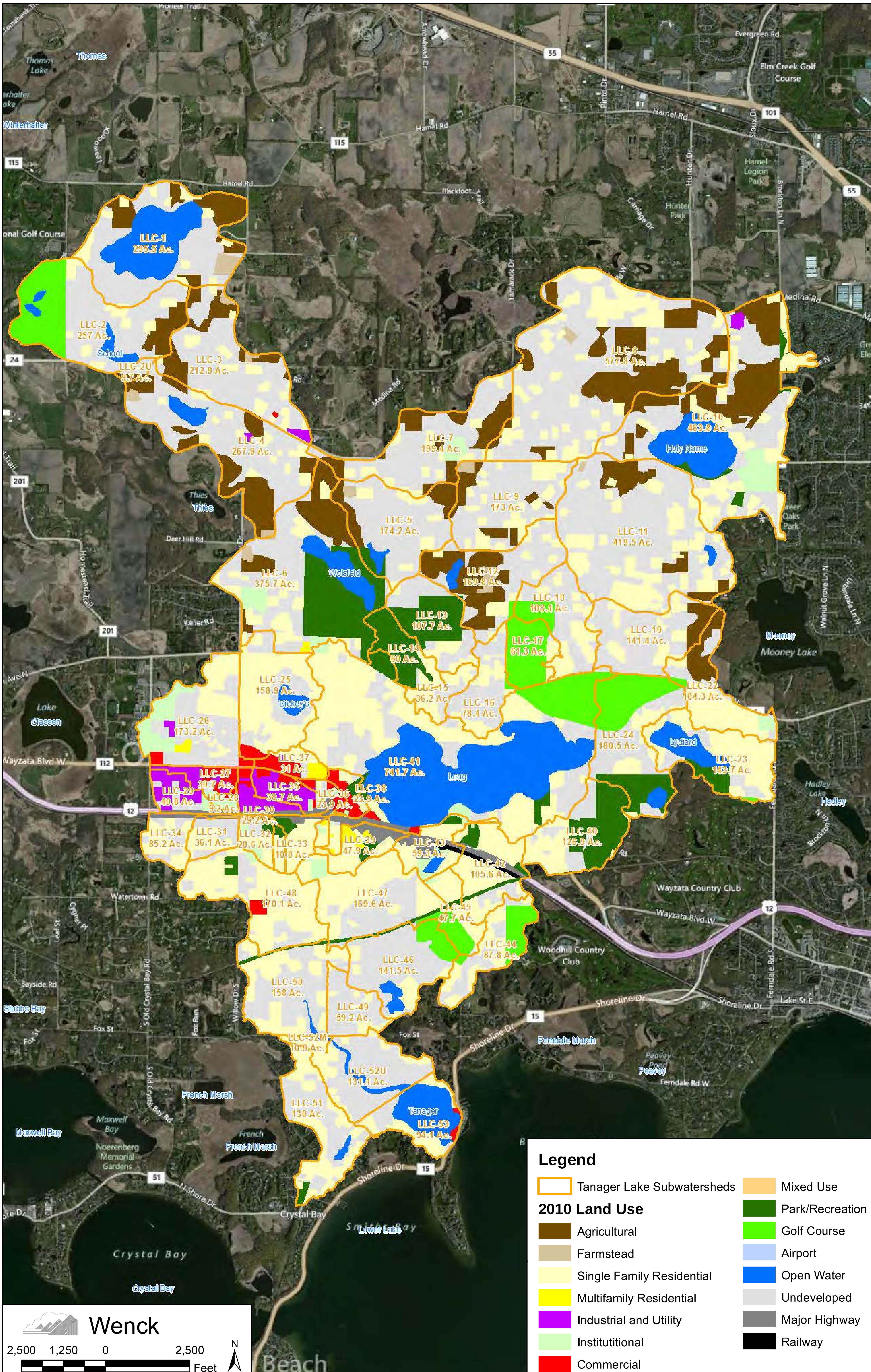

Legend
West Arm Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
Loretto
East Sarah
Thomas
Winterhalter
Spurzem
Lake Independence
Ardmore
Half Moon
School
Academy Marsh
Katrina
Thies
Irene
Maple
South Katrina
Classen
Orono
Painter
Peterson Pond
Kingswood Pond
North Little Long
Whaletail
South Little Long
North Whaletail
Stubbs Bay
North Arm
Maxwell Bay
French Marsh
Forest
Jennings Bay
Dutch
West Arm
Crystal Bay
Minnetonka Beach
Lafayette Bay
Lower Lake
Mound
Langdon
Lost
Seton Lake
Emerald Lake
Black Lake
South Whaletail
Saunders
Minnetrista
Halsteds Bay
Spray Island Marsh
Minnetonka-Upper Lake
Tonka Bay
Six Mile Marsh
PC-1 462.4 Ac.
PC-2 266.6 Ac.
PC-3 191.5 Ac.
PC-4 753.6 Ac.
PC-5 157.1 Ac.
PC-6 1,161.1 Ac.
PC-7 154.7 Ac.
PC-8 137.4 Ac.
PC-9 583.1 Ac.
PC-10 63.6 Ac.
PC-11 706 Ac.
PC-12 56 Ac.
PC-13 338.5 Ac.
PC-14 100.4 Ac.
PC-15 50.5 Ac.
PC-16 577.7 Ac.
PC-17 263.7 Ac.
PC-18 144.1 Ac.
PC-19 106.7 Ac.
PC-20 357 Ac.
PC-21 1,176.2 Ac.
PC-22 195.4 Ac.
PC-23 30.6 Ac.
PC-24 174.8 Ac.
PC-25 267.2 Ac.
PC-26 47.4 Ac.
FL-1 295.1 Ac.
FL-2 193.8 Ac.
FL-3M 30.2 Ac.
FL-3U 425 Ac.
DL-1 152.5 Ac.
DL-2 138.2 Ac.
DL-3 608.9 Ac.
DL-4 217.3 Ac.
DL-5 624.6 Ac.
DL-6 86.6 Ac.
DL-7 49.4 Ac.
JB-LM 869 Ac.
HB-LM 456.9 Ac.
WA-LM 959.5 Ac.
Wenck
3,500 1,750 0 3,500
Feet
N
Path: L:\0147\0147-24\mxd\Model Maps\West Arm LU.mxd
Date: 7/2/2013 Time: 1:27:33 PM User: ShuJC0243
© Harris Corp, Earthstar Geographics LLC © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

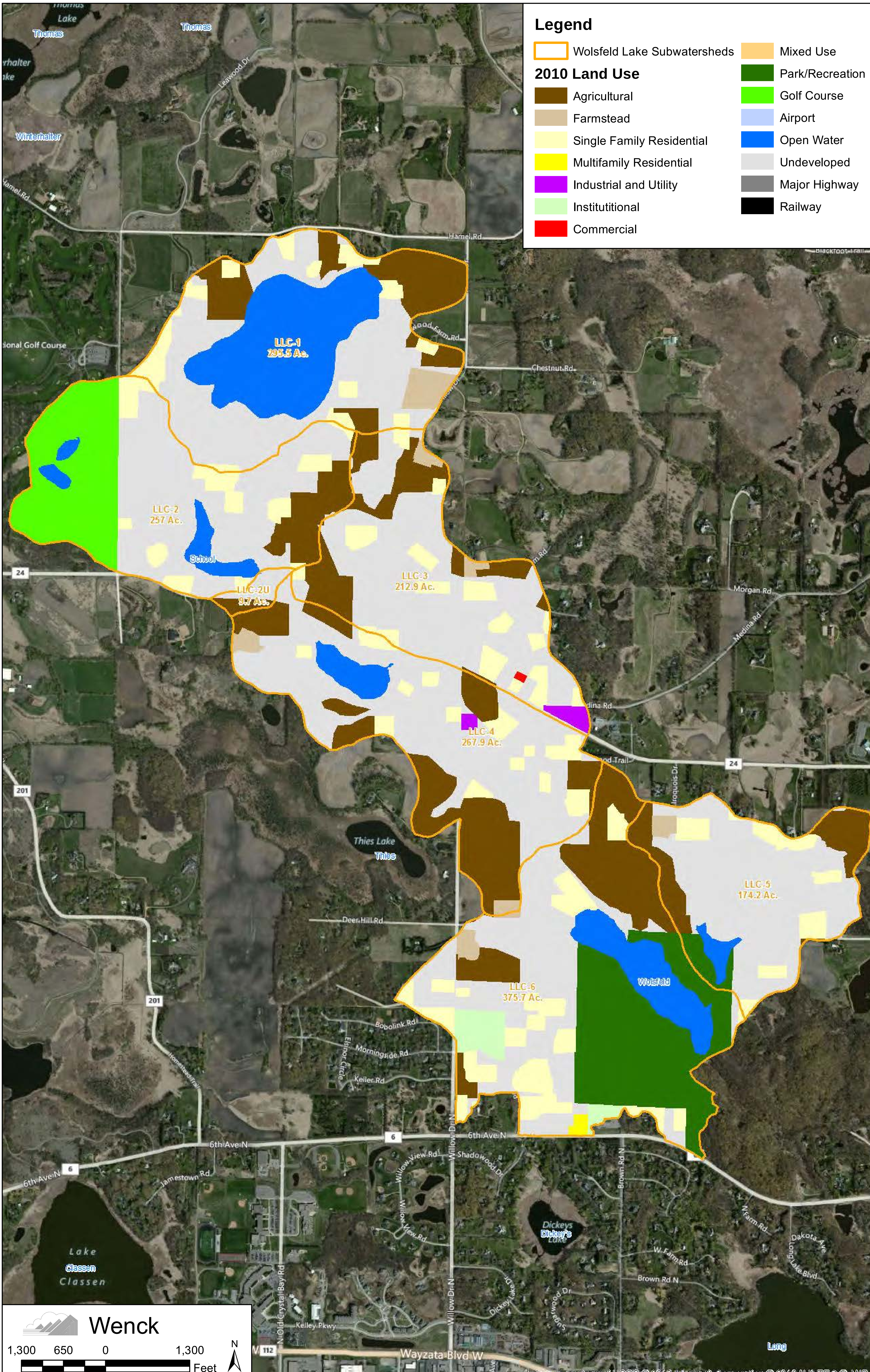

Legend
Mooney Lake Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
LLC-20
123.1 Ac.
LLC-21
475.6 Ac.
Mooney
24
6
Hunter Dr
N Ridge Dr
Brockton Ln N
Zircon Ln N
31st Pl N
31st Ave N
Urbandale Ln N
Walnut Grove Ln N
33rd Ave N
Shadyview Ln N
Ranier Ln N
30th Pl N
Troy Ln N
27th Pl N
25th Ave N
24th Ave N
23rd Ave N
20th Ave N
19th Ave N
6th Ave N
Alvarado Ln N
Wenck
600 300 0 600
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Mooney Lake LU.mxd
Date: 7/2/2013 Time: 1:24:00 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

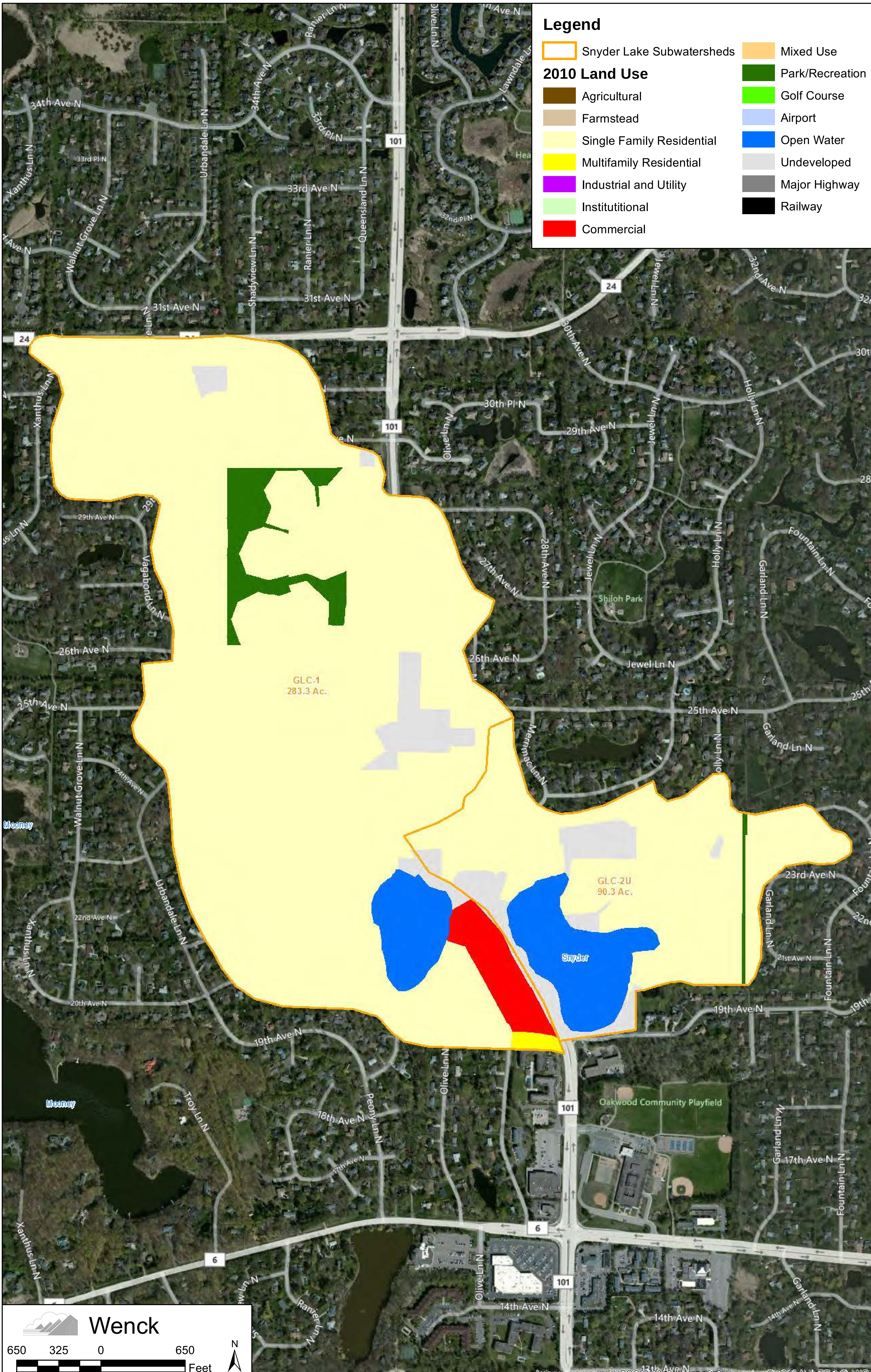

SMC-16
43 Ac.
SMC-17
46.5 Ac.
SMC-18
791.4 Ac.
Stone
Minnetonka-Upper Lake
Zumbra-Sunny
Sunny
Crosby Lake
Carver Park Reserve
Grimm Rd
Victoria Dr
Kings Pt Rd
Oak Rd
Lotus Dr
Nature Center Dr
Legend
Stone Lake Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
Wenck
800 400 0 800
Feet
N
Date: 7/2/2013 Time: 1:25:36 PM User: ShuJC0243

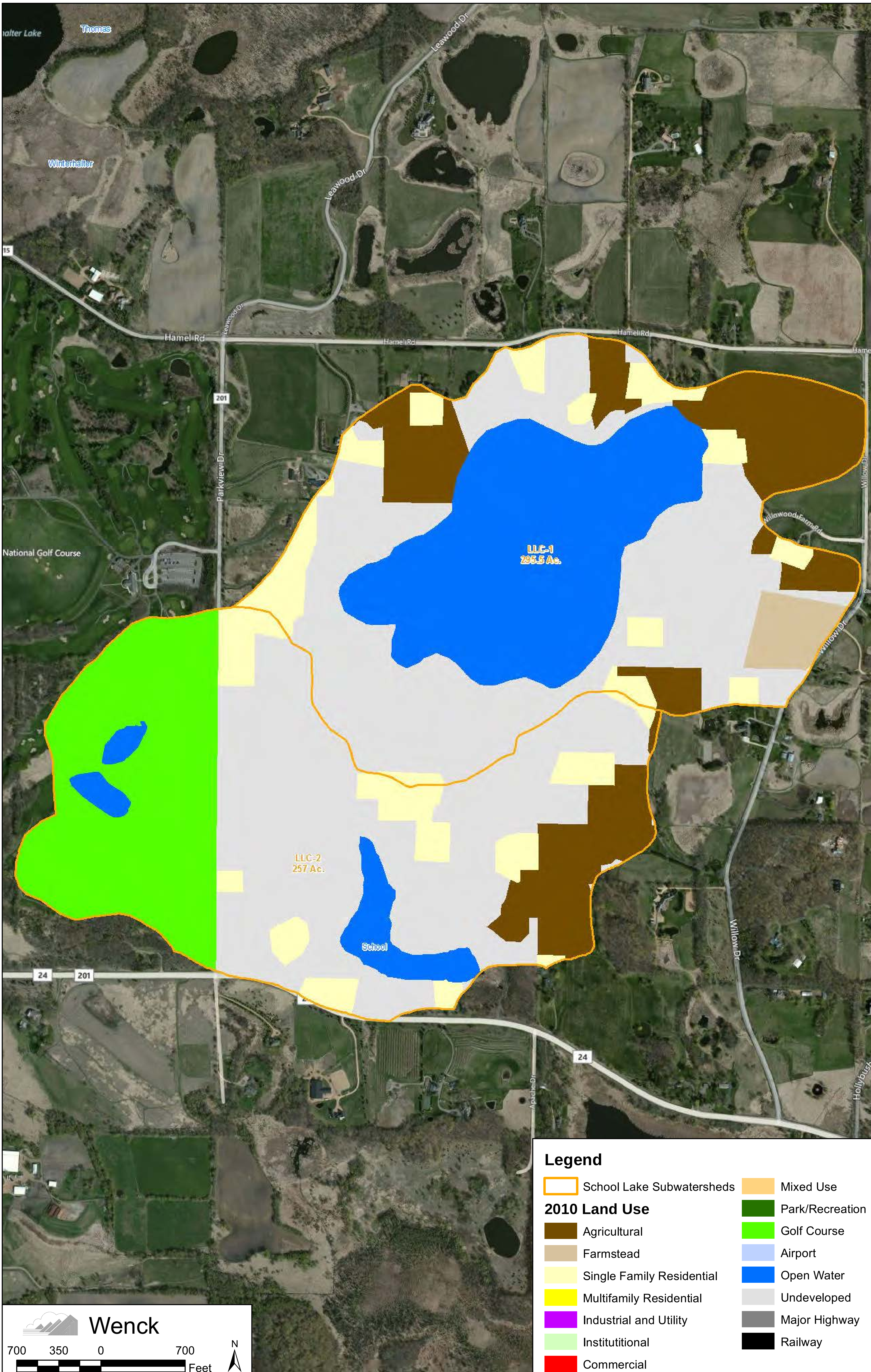


Legend
Tamarack Lake Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
Tamarack
Schutz
Minnewashta
LV-1U
208.6 Ac.
Interlaken
Kings Rd
Rolling Acres Rd
St Moritz
Overlook Ln
Lakeridge Rd
Ridge Hill Rd
Maple Shores Dr
Hawthorne Circle
W 77th St
Lone Cedar Ln
Arboretum Blvd
13
5
Wenck
400 200 0 400
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Tamarack Lake LU.mxd
Date: 7/2/2013 Time: 1:26:28 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

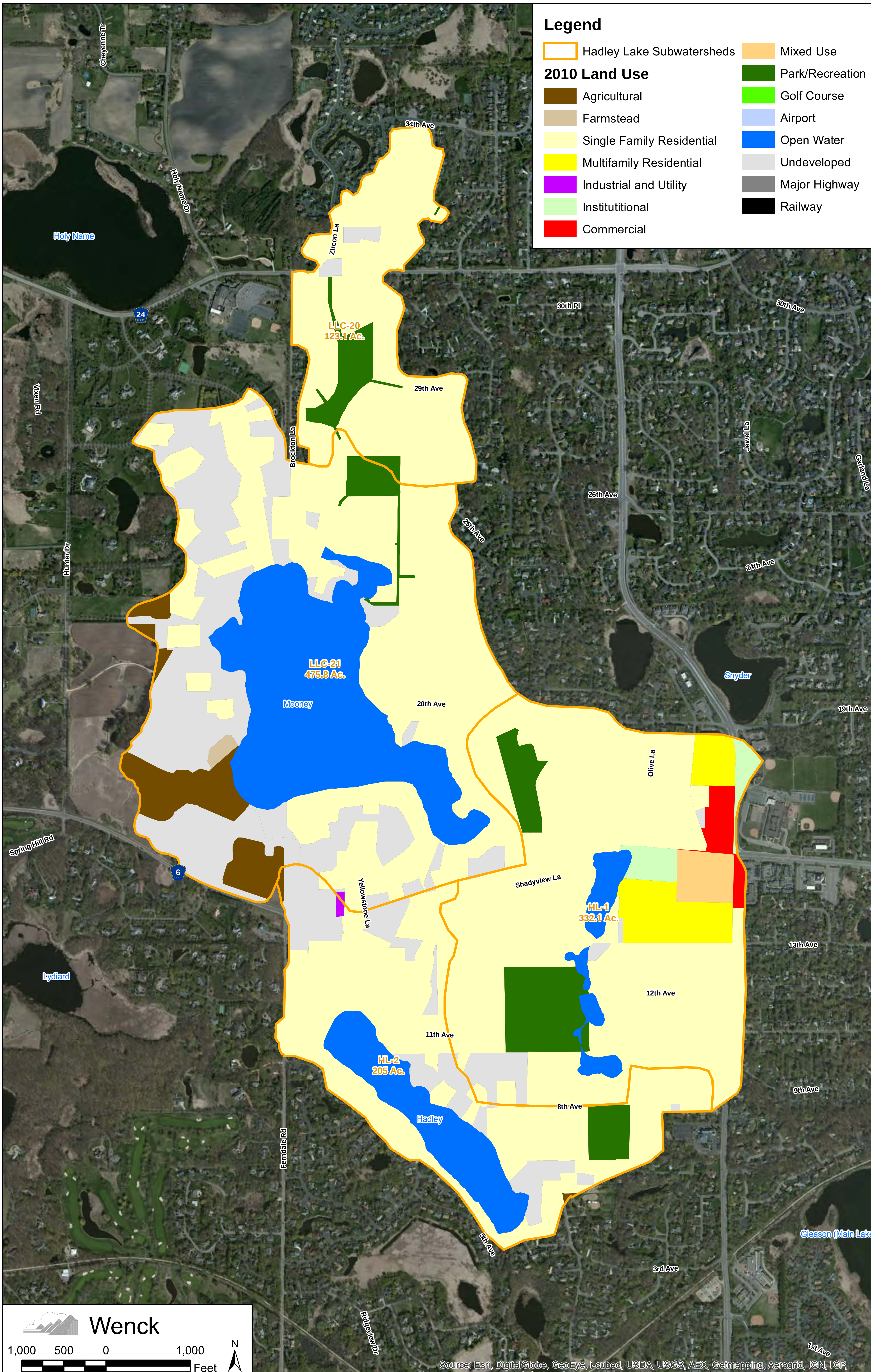

Legend
Tanager Lake Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
Wenck
2,500 1,250 0 2,500
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Tanager Lake LU.mxd
Date: 7/2/2013 Time: 1:26:41 PM User: ShuJC0243
LLC-1 295.5 Ac.
LLC-2 257 Ac.
LLC-2U 9.7 Ac.
LLC-3 212.9 Ac.
LLC-4 267.9 Ac.
LLC-5 174.2 Ac.
LLC-6 375.7 Ac.
LLC-7 199.4 Ac.
LLC-8 577.8 Ac.
LLC-9 173 Ac.
LLC-10 463.8 Ac.
LLC-11 419.5 Ac.
LLC-12 169.8 Ac.
LLC-13 107.7 Ac.
LLC-14 60 Ac.
LLC-15 36.2 Ac.
LLC-16 78.4 Ac.
LLC-17 61.3 Ac.
LLC-18 108.1 Ac.
LLC-19 141.4 Ac.
LLC-22 104.3 Ac.
LLC-23 143.7 Ac.
LLC-24 180.5 Ac.
LLC-25 158.9 Ac.
LLC-26 173.2 Ac.
LLC-27 30.7 Ac.
LLC-28 9.2 Ac.
LLC-29 40.8 Ac.
LLC-30 29.2 Ac.
LLC-31 36.1 Ac.
LLC-32 28.6 Ac.
LLC-33 10.8 Ac.
LLC-34 85.2 Ac.
LLC-35 38.7 Ac.
LLC-36 23.9 Ac.
LLC-37 31 Ac.
LLC-38 23.9 Ac.
LLC-39 47.9 Ac.
LLC-40 126.9 Ac.
LLC-41 741.7 Ac.
LLC-42 105.6 Ac.
LLC-43 59.3 Ac.
LLC-44 87.8 Ac.
LLC-45 47.7 Ac.
LLC-46 141.5 Ac.
LLC-47 169.6 Ac.
LLC-48 170.1 Ac.
LLC-49 59.2 Ac.
LLC-50 158 Ac.
LLC-51 130 Ac.
LLC-52M 10.9 Ac.
LLC-52U 131.1 Ac.
LLC-53 94.1 Ac.
Holy Name
Wolsfeld
Long
Lydiard
Dickey's
Tanager
Mooney Lake
Lake Classen
Crystal Bay
Hamel Rd
Wayzata Blvd W
Shoreline Dr
Wayzata Country Club
Woodhill Country Club
Elm Creek Golf Course
French Marsh
Stubbs Bay
Maxwell Bay
Noerenberg Memorial Gardens
Ferndale Marsh
Peavey
Beach


Legend
Wolsfeld Lake Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
LLC-1
295.5 Ac.
LLC-2
257 Ac.
LLC-2U
9.7 Ac.
LLC-3
212.9 Ac.
LLC-4
267.9 Ac.
LLC-5
174.2 Ac.
LLC-6
375.7 Ac.
School
Wolsfeld
Thies Lake
Hamel Rd
Chestnut Rd
Morgan Rd
Medina Rd
Deer Hill Rd
Bobolink Rd
Morningside Rd
Keller Rd
6th Ave N
Jamestown Rd
Willow Dr N
Brown Rd N
Wayzata Blvd W
Lake Classen
Wenck
1,300 650 0 1,300
Feet
N
Path: L:\0147\0147-24\mxd\Model Maps\Wolsfeld Lake LU.mxd
Date: 7/2/2013 Time: 1:28:11 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

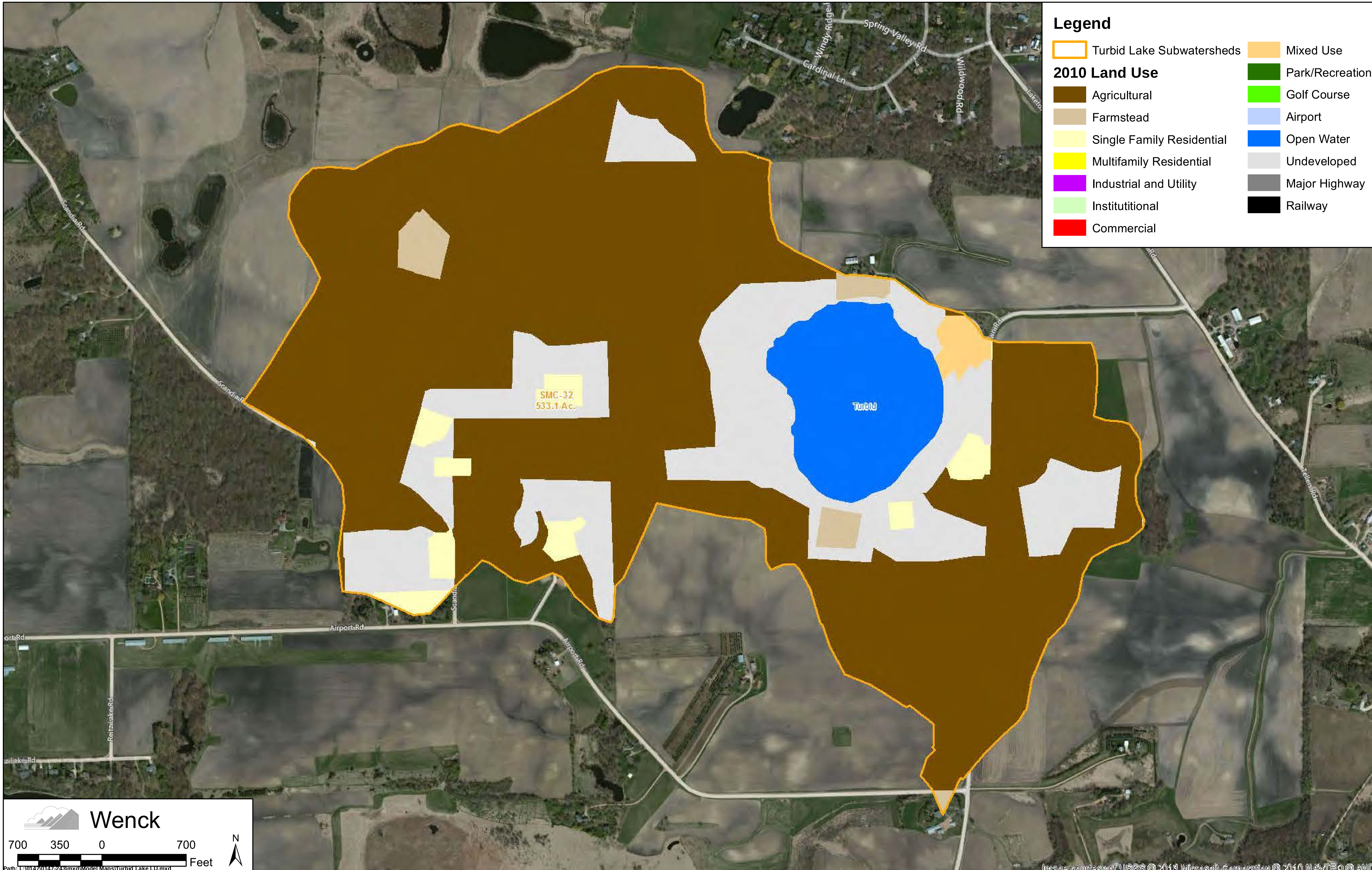

Legend
Snyder Lake Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
GLC-1
283.3 Ac.
GLC-2U
90.3 Ac.
Snyder
Mooney
Shiloh Park
Oakwood Community Playfield
Wenck
650 325 0 650
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Snyder Lake LU.mxd
Date: 7/2/2013 Time: 1:25:24 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

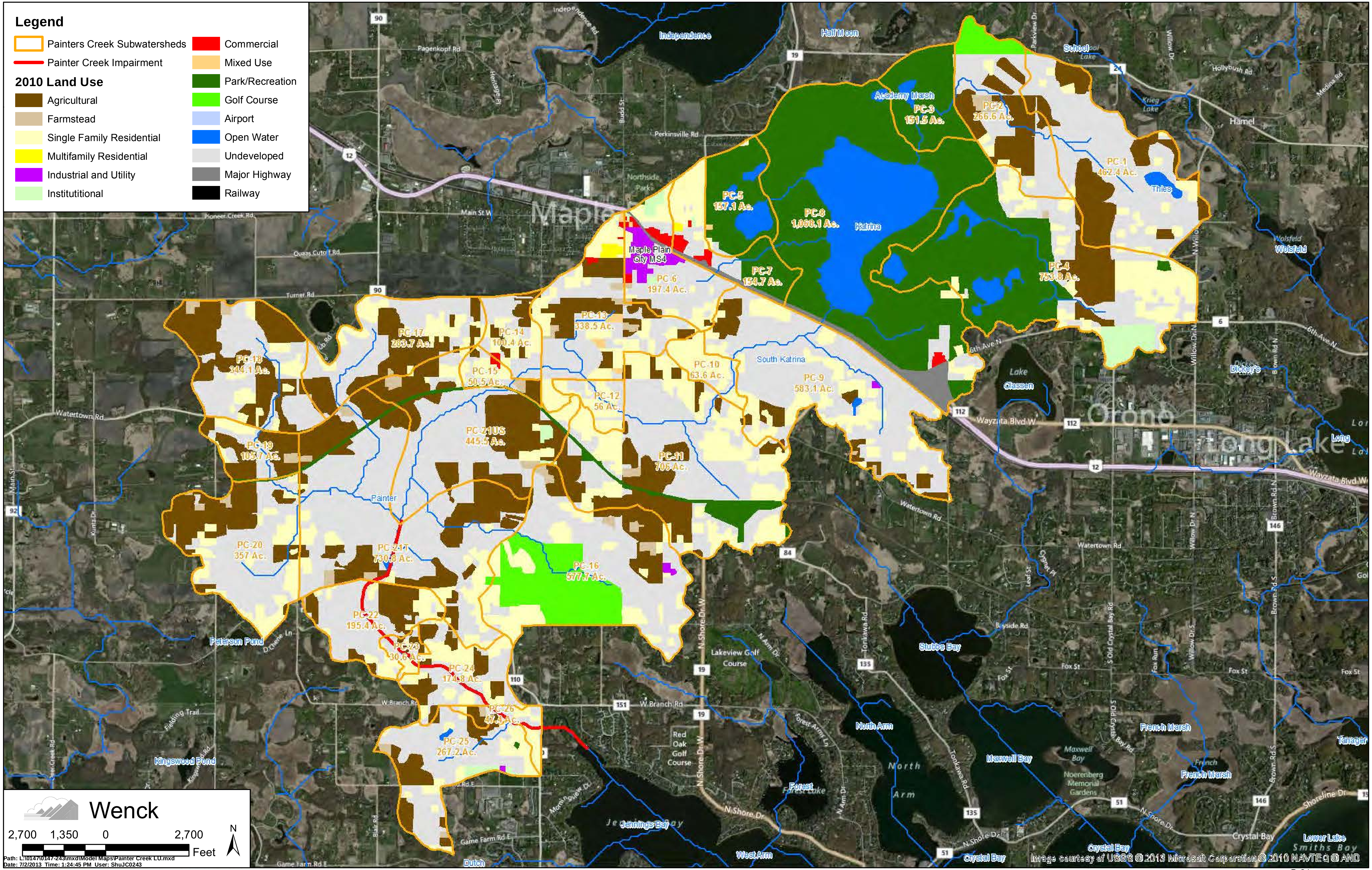


Thomas
Winterhalter
Leawood Dr
Hamel Rd
Parkview Dr
National Golf Course
Willow Dr
Willowood Farm Rd
LLC-1
295.5 Ac.
LLC-2
257 Ac.
School
Apple Dr
Hollybush Rd
Legend
School Lake Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
Wenck
700 350 0 700
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\School Lake LU.mxd
Date: 7/2/2013 Time: 1:25:03 PM User: ShuJC0243



Legend
Hadley Lake Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
LLC-20
123.1 Ac.
LLC-21
475.8 Ac.
HL-1
332.1 Ac.
HL-2
205 Ac.
Holy Name
Mooney
Snyder
Lydiard
Hadley
Gleason (Main Lake)
34th Ave
30th Pl
30th Ave
29th Ave
26th Ave
25th Ave
24th Ave
20th Ave
19th Ave
13th Ave
12th Ave
11th Ave
9th Ave
8th Ave
5th Ave
3rd Ave
1st Ave
Cheyenne Tr
Holy Name Dr
Zircon La
Brockton La
Vixen Rd
Hunter Dr
Jewel La
Garland La
Olive La
Shadyview La
Yellowstone La
Spring Hill Rd
Ferndale Rd
Ridgeview Dr
24
6
Wenck
1,000 500 0 1,000
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Hadley Lake LU.mxd
Date: 3/5/2014 Time: 7:27:48 AM User: shujc0243
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

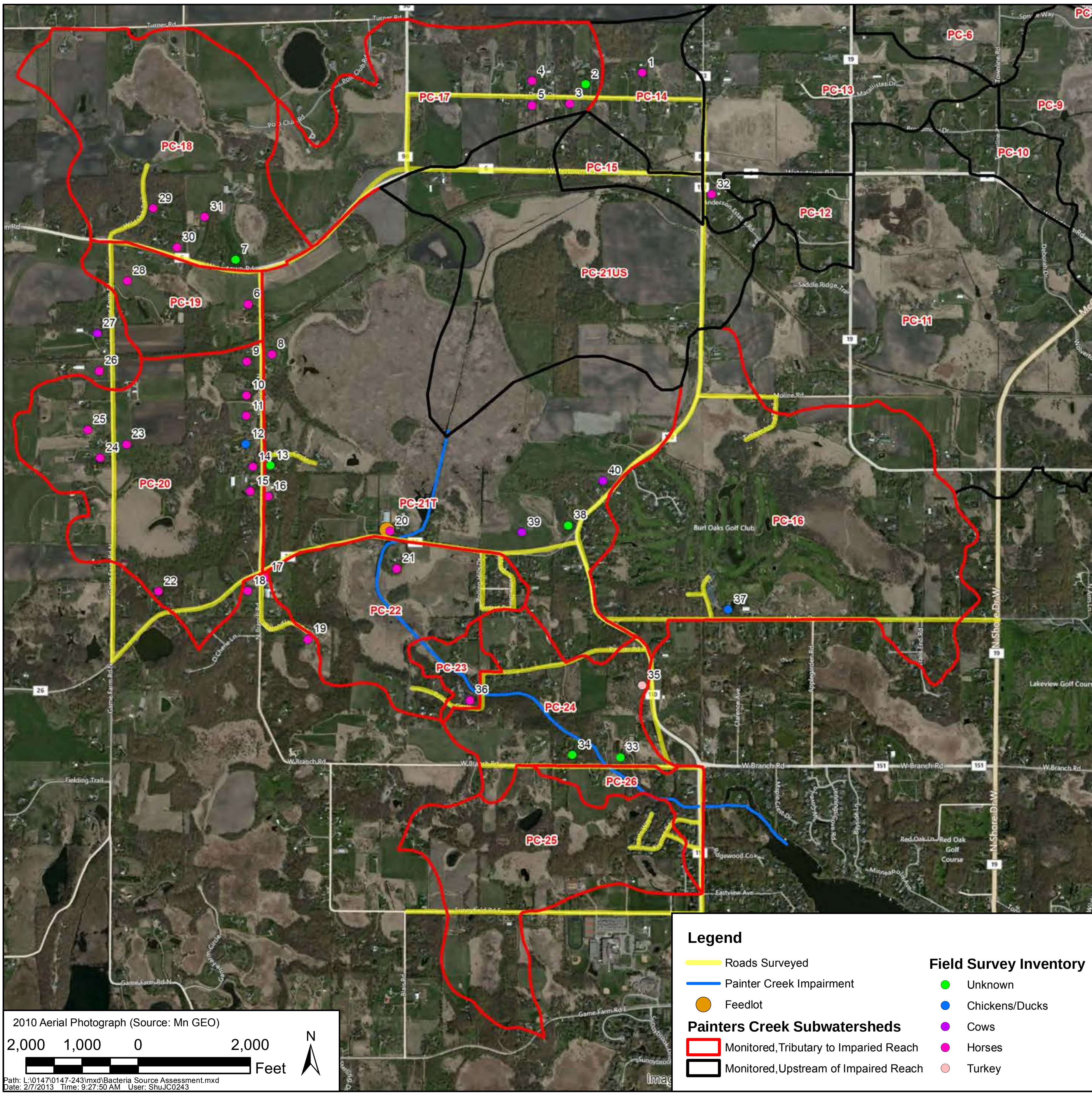

Legend
Turbid Lake Subwatersheds
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
SMC-32
533.1 Ac.
Turbid
Spring Valley Rd
Cardinal Ln
Windy Ridge
Wildwood Rd
Scandia Rd
Airport Rd
Reitz Lake Rd
Tellers Rd
Wenck
700 350 0 700
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Turbid Lake LU.mxd
Date: 7/2/2013 Time: 1:27:36 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND



Legend
Painters Creek Subwatersheds
Painter Creek Impairment
2010 Land Use
Agricultural
Farmstead
Single Family Residential
Multifamily Residential
Industrial and Utility
Institutitional
Commercial
Mixed Use
Park/Recreation
Golf Course
Airport
Open Water
Undeveloped
Major Highway
Railway
PC-1 462.4 Ac.
PC-2 266.6 Ac.
PC-3 151.5 Ac.
PC-4 753.8 Ac.
PC-5 157.1 Ac.
PC-6 197.4 Ac.
PC-7 154.7 Ac.
PC-8 1,068.1 Ac.
PC-9 583.1 Ac.
PC-10 63.6 Ac.
PC-11 706 Ac.
PC-12 56 Ac.
PC-13 338.5 Ac.
PC-14 100.4 Ac.
PC-15 50.5 Ac.
PC-16 577.7 Ac.
PC-17 289.7 Ac.
PC-18 344.1 Ac.
PC-19 105.7 Ac.
PC-20 357 Ac.
PC-21T 730.8 Ac.
PC-21US 445.5 Ac.
PC-22 195.4 Ac.
PC-23 30.6 Ac.
PC-24 174.8 Ac.
PC-25 267.2 Ac.
PC-26 47.4 Ac.
Maple Plain City MS4
Katrina
South Katrina
Painter
Academy Marsh
Independence
Half Moon
School Lake
Krieg Lake
Thies
Hamel
Wolsfeld
Lake Classen
Dickey's
Orono
Long Lake
Peterson Pond
Kingswood Pond
Lakeview Golf Course
Red Oak Golf Course
Stubbs Bay
North Arm
Maxwell Bay
French Marsh
Forest Lake
Jennings Bay
West Arm
Crystal Bay
Lower Lake
Tanager
Wenck
2,700 1,350 0 2,700
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Painter Creek LU.mxd
Date: 7/2/2013 Time: 1:24:45 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

Appendix C

Painter Creek Bacteria Source Assessment



Note #	Note	Animal	# of Visible Animals
1	Paddock with 1 horse and 1 Shetland pony. Paddock in good condition. Paddock location is on North side of Drake.	Horse	2
2	North side lot w/ paddock. Paddock in good condition - hasn't been recently used. No horses visible	-	-
3	South side of Drake. Two horses. Manure hasn't been spread in a while. Paddock is on ditch w/ low lying area. Wetland vegetation - dry right now.	Horse	2
4	1 horse visible in back of house. Difficult to see from road.	Horse	1
5	Two paddocks visible on parcel. Not mowed or recently used. Horse trailer on yard.	Horse	-
6	South on Ingerson from Cty 6. 5 horses in paddock on south side of cty 6, 4 in adjacent paddock. More horses visible in back by buildings. Paddock is in decent condition.	Horse	16
7	Empty paddock in good condition.	-	-
8	1 horse in paddock (surrounds single family home). Feedlot on steep slope adjacent to Painter Creek. Bare lot with visible excrement.	Horse	1
9	2 horses in paddock. Paddock in good condition.	Horse	2
10	3 horses in sloped paddock. Paddock in good condition.	Horse	3
11	2 horses in a feeding area. Paddock is adjacent in wetland area on steep slope that drains to tributary.	Horse	2
12	Chickens present. ~5 visible. Lot looks fenced for horses.	Chickens	5
13	Paddock fenced but doesn't appear to have been recently used.	-	-
14	Heavily used paddock - not raked recently.	Horse	-
15	Horse trailer. Lots of fenced paddocks adjacent to creek tributary. Mostly excluded by fence but right up to trib. Bare paddock with visible excrement. Lots of horse trailers/barns.	Horse	-
14	Visible horse excrement on Ingerson Road - Horse crossing signage.	Horse	
15	Visible horse excrement on Ingerson Road - Horse crossing signage.	Horse	-
16	7 horses on small paddock. Decent condition. Several small fenced paddocks with very short grass.	Horse	7
17	Horse trailers, horse ring, hay visible. Multiple paddocks with 7+ horses visible.	Horse	7
18	Paddock, no horse visible. Recently graded.	Horse	-
19	Abandoned paddock; new home construction.	Horse	-

Note #	Note	Animal	# of Visible Animals
20	Located on N ide of Hwy 26. Paddock fencing for horses.	Horse	-
21	South side of road; paddock fencing and single family home.	Horse	-
22	Paddock but no horses visible.	Horse	-
23	Electric paddock fencing in two locations. No horses visible but has been recently grazed.	Horse	-
24	3 horses visible	Horse	3
25	Paddocks w/ horse jumps. Hilly grade. 3 horses visible.	Horse	3
26	4 horses visible on back of parcel. Front paddock not recently used.	Horse	4
27	4 cows visible on parcel.	Cows	4
28	4 horses visible on recently used paddock.	Horses	4
29	Horse paddock - no visible animals.	Horse	-
30	Horses in paddock.	Horse	
31	Horses in paddock.	Horse	-
32	Horse paddocks. Good condition. 1 horse visible.	Horse	1
33	Fencing on parcel; likely pasture or paddock. No animals visible.	-	-
34	Paddock on parcel. Looks unused; no visible animals; deteriorated fencing.	-	-
35	10-12 wild turkeys on side of road	Turkey	12
36	Horse paddock with bare spots. No visible animals. Took two pictures of the creek on either side of the road.	Horse	-
37	Pond w/ ducks	Ducks	10
38	Pastures/paddocks on parcel. Good condition. No visible animals but likely recently used. On the N side of the driveway is an older unused pasture.	-	-
39	8 cows visible in pasture. Pasture is in good condition. Cows are directly adjacent to the wetland. One cow is in the wetland.	Cows	8
40	40 to 50 cows on pasture. Pasture is in good condition.	Cows	50

MINNEHAHA CREEK WATERSHED DISTRICT

Bacteria Source Assessment Roadside Survey

Wenck

Engineers - Scientists
Business Professionals
www.wenck.com

1800 Pioneer Creek Center
Maple Plain, MN 55359-0429
1-800-472-2232

FEB 2013

Figure 1

Appendix D

Groundwater Contribution Calculation Method

Groundwater Contribution Calculation Method

Contribution to the lake phosphorous load from groundwater (GW) was calculated as described below:

1) The lake surface elevation was taken as the Ordinary High Water Level as listed on the DNR LakeFinder website (http://www.dnr.state.mn.us/lakefind/index.html). For lakes not listed on the website, the surface elevation was estimated from LiDAR/topographic mapping.
2) GW elevation beneath the listed lakes within Hennepin County was interpreted from the Hennepin County, MN Geologic Atlas published by the Minnesota Geological Survey, 1989. Surficial geology was also interpreted from the Geologic Atlas. GW elevation beneath Stone and East Auburn Lakes (Carver County) was interpreted from well logs of surficial aquifer wells drilled in the vicinity of the lake (data accessed from the County Well Index) and surficial geology was interpreted from the Carver County, MN Geologic Atlas published by the Minnesota Geological Survey, 2009.
3) Based on the elevation difference between the lake surface and groundwater and the surficial geology for each lake, each lake was identified as either a source or sink of water. The quantity of water contributed to or lost from each lake was determined using the following equation:

   Q=KiA

   Where Q is the flow, K is the hydraulic conductivity (3.28 x 10^-11 ft/s for clay soils and 3.28 x 10^-8 ft/s for other soil types), i is the difference in lake surface and GW elevation divided by 10 feet, and A is the lake area.

4) A mean groundwater concentration of 84 ug/L was used for lake response modeling as listed in Table A.17 of *Baseline Water Quality of Minnesota's Principal Aquifers: Twin Cities Metropolitan Region* (a MPCA publication).

Appendix E

Internal Load Calculation Method

Internal Load Calculation Method

Temperature and dissolved oxygen profiles were used to determine the volume of lake water under anoxic conditions. The volume of the lake with anoxic conditions was used to calculate an anoxic factor (Nürnberg 2004) normalized over the lake basin and reported as a number of days.

For lakes where temperature and DO data had not been collected, the average annual anoxic factor was predicted using the following equation (Nürnberg 2005):

$AF_{pred} = -35.4 + 44.2 \log(TP) + 0.95\ z/A^{0.5}$ where TP is the long term average total phosphorus concentration of the lake, z is the mean depth (m) and A the lake surface area in km^2.

Table E.1 Anoxic factor determination method.

Lake	Anoxic Factor Determination Method
Dutch	Temp/DO Profiles
East Auburn	Shallow Lakes Equation
Forest	Temp/DO Profiles
Gleason	Shallow Lakes Equation
Holy Name	Shallow Lakes Equation
Langdon	Temp/DO Profiles
Long	Temp/DO Profiles
Halsteds Bay	Temp/DO Profiles
Jennings Bay	Temp/DO Profiles
Stubbs Bay	Temp/DO Profiles
West Arm	Temp/DO Profiles
Mooney	Shallow Lakes Equation
Stone	Shallow Lakes Equation
Tamarack	Shallow Lakes Equation
Tanager	Temp/DO Profiles
Wolsfeld	Shallow Lakes Equation
Snyder	Shallow Lakes Equation
School	Shallow Lakes Equation
Hadley	Shallow Lakes Equation
Turbid	Shallow Lakes Equation

Internal load is calculated using the following equation:

Internal load = AF x RR

Where AF is the anoxic factor and RR is the release rate of phosphorus from the lake sediments. The anoxic factor is reported in days and the release rate is reported in mg/m^2-day. Release rates can be obtained by collecting sediment cores from a lake and conducting an experiment in the lab to measure total phosphorus release rate from the sediment cores. For this project, lab determined release rates were only available for Langdon, East Auburn, Stone, and Turbid Lakes. Literature value release rates were used for the remaining lakes. The literature value release rates that have been developed based on lake trophic state (Figure E.1) were used for the other lakes (Nürnberg 1997).

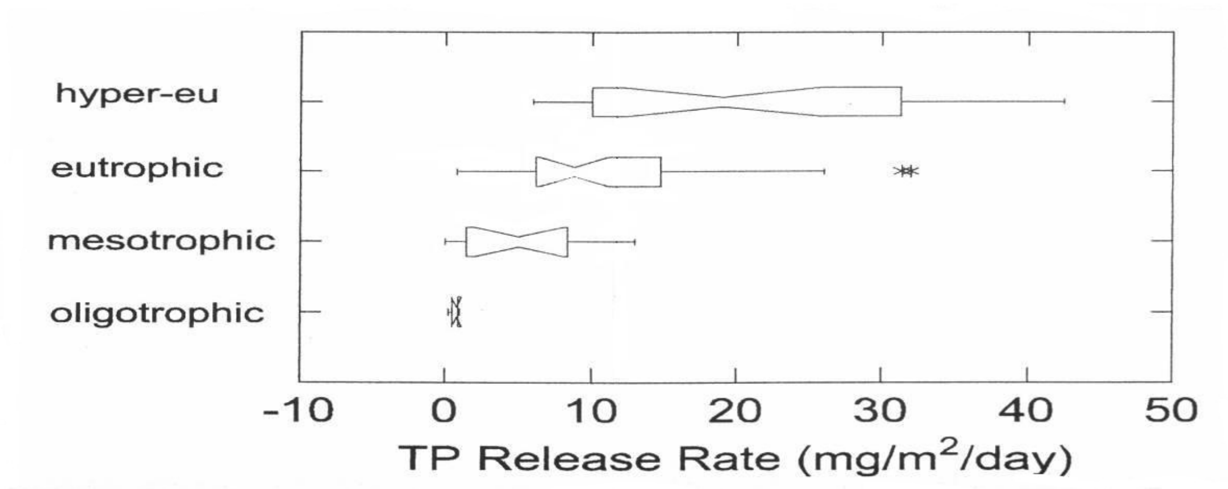


Figure E.1 Literature value phosphorus release rates (used for lake response modeling).

Release rates were then adjusted during calibration of the Canfield-Bachmann lake response model for each lake. The monitoring data quantified watershed loads. The quantified watershed loads, in-lake water quality, and periods of anoxia (modeled or predicted dependent on the lake) were used in combination with the Canfield-Bachmann lake response model to back-calculate sediment release rates.

Appendix F

Lake Response Model Results

Average Loading Summary for Dutch Lake — Years 2005-2011

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 CDU02	901	6.3	476	192.5	1.0	249
2 Direct	666	5.1	284	103.9	1.0	80
3					1.0	
4					1.0	
5					1.0	
Summation	*1,567*	*5.8*	*760*	*159.4*		*330*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 CDU02	901					
2 Direct	666	30	25%	6.1	0.1	46
3						
4						
5						
Summation	*1566*	*30*	*25%*			*46*
Inflow from Upstream Lakes						
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1			--	-	1.0	
2				-	1.0	
3				-	1.0	
Summation			*0*	-		*0*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
176	29.3	29.3	--	0.239	1.0	42
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
176	0.0		0.00	0	1.0	0
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
176	44.3			2.50	1.0	174
			Net Discharge [ac-ft/yr] = 760			**Net Load [lb/yr] = 591**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Dutch Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	591	[lb/yr]
		Q (lake outflow) =	760	[ac-ft/yr]
		V (modeled lake volume) =	2,463	[ac-ft]
		T = V/Q =	3.2	[yr]
		P_i = W/Q =	286.0	[ug/l]
Model Predicted In-Lake [TP]			**56.2**	**[ug/l]**
Observed In-Lake [TP]			**54.8**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$				
		P_{sed} (phosphorus sedimentation) =	**475**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**116**	**[lb/yr]**

Average Load Reduction Table for Dutch Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS			TROPHIC STATE INDICES (Carlson, 1980)
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**
0%	**591**	56	475	**116**	62.3
5%	**562**	54	449	**113**	61.8
10%	**532**	53	423	**109**	61.3
15%	**503**	51	398	**105**	60.8
20%	**473**	49	372	**101**	60.2
25%	**444**	47	347	**97**	59.6
30%	**414**	45	321	**93**	59.0
35%	**384**	43	296	**88**	58.3
40%	**355**	41	271	**84**	57.5
45%	**325**	38	246	**79**	56.7
50%	**296**	36	221	**74**	55.8
55%	**266**	34	197	**69**	54.8
60%	**237**	31	172	**64**	53.7
65%	**207**	28	148	**59**	52.4
70%	**177**	26	125	**53**	50.9
75%	**148**	23	101	**47**	49.1
80%	**118**	19	78	**40**	46.9
85%	**89**	16	56	**33**	44.0
90%	**59**	12	35	**24**	39.7
95%	**30**	7	15	**15**	32.3

TMDL Loading Summary for Dutch Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 CDU02	901	6.3	476	192.5	1.0	249
2 Direct	666	5.1	284	103.9	1.0	80
3					1.0	
4					1.0	
5					1.0	
Summation	*1,567*	*5.8*	*760*	*71.7*	*0.45*	*148*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 CDU02	900.6					
2 Direct	665.9	30	0%	6.1	0.0	0.0
3						
4						
5						
Summation	*1566.5*	*30*	*0%*			*0.0*
Inflow from Upstream Lakes						
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1			--	-	1.0	
2				-	1.0	
3				-	1.0	
Summation			*0*	-		*0*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
176	29.3	29.3	--	0.239	1.0	42
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
176	0.0		0.00	0	1.0	0
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
176	44.3			2.50	0.90	157
			Net Discharge [ac-ft/yr] = 760		**Net Load [lb/yr] =**	**347**

TMDL Lake Response Modeling for Dutch Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	347	[lb/yr]
		Q (lake outflow) =	760	[ac-ft/yr]
		V (modeled lake volume) =	2,463	[ac-ft]
		T = V/Q =	3.24	[yr]
		P_i = W/Q =	167.8	[ug/l]
Model Predicted In-Lake [TP]			**40.0**	**[ug/l]**
Goal In-Lake [TP]			**40.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$				
		P_{sed} (phosphorus sedimentation) =	**264**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**83**	**[lb/yr]**

Average Loading Summary for East Auburn — 2008, 2010, 2012

Water Budgets | Phosphorus Loading

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 East Auburn	214	12.9	230	32.4	1.0	20
2 SMC-26	71	9.3	55	35.1	1.0	5
3 SMC-15	146	7.3	89	1,122.0	1.0	271
4 SMC-25	118	9.7	96	1,582.1	1.0	413
5 SMC-11	342	10.0	285	807.9	1.0	627
Summation	*891*	10.2	*755*			*1,337*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 East Auburn	214	3	0	6	0.0	5
2 SMC-26	71		25%	6.1		
3 SMC-15	146		25%	6.1		
4 SMC-25	118		25%	6.1		
5 SMC-11	342	1	25%	6.1	0.0	2
Summation	*891*	*4*				*6*

Inflow from Upstream Lakes

Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Carl Krey	224	28.5	1.0	17
2 Church	250	94.5	1.0	64
3 Kelzer	17	35.0	1.0	2
3 Stieger	735	38.6	1.0	77
4 Wassermann	1,849	72.2	1.0	363
3 Sunny	1,145	50.0	1.0	156
Summation	*4,220*	*53.1*		*680*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
148	30.7	30.7	0.00	0.24	1.0	35

Dry-year total P deposition =	0.222
Average-year total P deposition =	0.239
Wet-year total P deposition =	0.259
(Barr Engineering 2004)	

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
148	0.0	0	0	1.0	0

Internal

Lake Area [km²]	Anoxic Factor [days]		Release Rate [mg/m²-day]	Calibration Factor [--]	Load [lb/yr]
0.60		Oxic		1.0	
0.60	44.4	Anoxic	7.0	0.1	41
Summation					41

Net Discharge [ac-ft/yr] =	**4,975**	**Net Load [lb/yr] =**	**2,099**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for East Auburn

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	C_P =	2.29	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	2,099	[lb/yr]
		Q (lake outflow) =	4,975	[ac-ft/yr]
		V (modeled lake volume) =	1,781	[ac-ft]
		T = V/Q =	0.36	[yr]
		P_i = W/Q =	155.1	[μg/l]
Model Predicted In-Lake [TP]			**49.4**	**[ug/l]**
Observed In-Lake [TP]			**49.4**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$			
		P_{sed} (phosphorus sedimentation) =	**1,431**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**668**	**[lb/yr]**

LOAD			MODELED IN-LAKE WATER QUALITY PARAMETERS
REDUC-TION	NET LOAD	NET LOAD	[TP]
[%]	[kg]	[lb]	[ug/L]
0%	952	2,099	49.4
5%	904	1,994	47.6
10%	857	1,889	45.9
15%	809	1,784	44.1
20%	762	1,679	42.3
25%	714	1,574	40.4
30%	666	1,469	38.5
35%	619	1,364	36.5
40%	571	1,259	34.5
45%	524	1,154	32.4
50%	476	1,049	30.3
55%	428	945	28.1
60%	381	840	25.8
65%	333	735	23.4
70%	286	630	20.8
75%	238	525	18.2
80%	190	420	15.3
85%	143	315	12.3
90%	95	210	8.9
95%	48	105	5.0

TMDL Loading Summary for East Auburn

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Reduction Factor	Load
Name	[acre]	[in/yr]	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1 East Auburn	214	12.9	230	32.4	1.0	20
2 SMC-26	71	9.3	55	35.1	1.0	5
3 SMC-15	146	7.3	89	740.5	0.66	179
4 SMC-25	118	9.7	96	791.1	0.50	207
5 SMC-11	342	10.0	285	751.3	0.93	583
Summation	*891*	10.2	*755*			*994*

Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 East Auburn	214	3	0	6	0.0	0
2 SMC-26	71		0%	6.1		
3 SMC-15	146		0%	6.1		
4 SMC-25	118		0%	6.1		
5 SMC-11	342		0%	6.1		
Summation	*891*	*3*				*0*

Inflow from Upstream Lakes				
	Discharge	Estimated P Concentration	Reduction Factor	Load
Name	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1 Carl Krey	224	28.5	1.0	17
2 Church	250	40.0	0.42	27
3 Kelzer	17	35.0	1.0	2
3 Stieger	735	38.6	1.0	77
4 Wassermann	1,849	40.0	0.55	201
3 Sunny	1,145	50.0	1.0	156
Summation	*4,220*	*38.7*		*480*

Atmosphere						
Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Reduction Factor	Load
[acre]	[in/yr]	[in/yr]	[ac-ft/yr]	[lb/ac-yr]	[--]	[lb/yr]
148	30.7	30.7	0.00	0.24	1.0	35
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			

Groundwater					
Lake Area	Groundwater Flux	Net Inflow	Phosphorus Concentration	Reduction Factor	Load
[acre]	[m/yr]	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
148	0.0	0	0	1.0	0

Internal					
Lake Area	Anoxic Factor		Release Rate	Reduction Factor	Load
[km^2]	[days]		[mg/m^2-day]	[--]	[lb/yr]
0.60		Oxic		1.0	
0.60	44.4	Anoxic	7.0	0.1	41
Summation					41
		Net Discharge [ac-ft/yr] =	**4,975**	**Net Load [lb/yr] =**	**1,551**

TMDL Lake Response Modeling for East Auburn

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$		C_P =	2.29	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	1,550.8	[lb/yr]
		Q (lake outflow) =	4,975	[ac-ft/yr]
		V (modeled lake volume) =	1,781	[ac-ft]
		T = V/Q =	0.36	[yr]
		P_i = W/Q =	114.6	[µg/l]
Model Predicted In-Lake [TP]			**40.0**	**[ug/l]**
Goal In-Lake [TP]			**40.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$				
		P_{sed} (phosphorus sedimentation) =	**1,010**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**541**	**[lb/yr]**

Average Loading Summary for Forest Lake 2005-2011

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 CFO01	325	9.2	249	203.7	1.0	138
2 Direct	529	5.1	226	104.0	1.0	64
3					1.0	
4					1.0	
5					1.0	
Summation	*855*	*6.7*	*474*	*156.3*		*202*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 CFO01	325	0				
2 Direct	529	0				
3						
4						
5						
Summation	*855*	*0*				*0*

Inflow from Upstream Lakes

Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1	--	-	1.0	0
2		-	1.0	
3		-	1.0	
Summation	*0*	-		*0*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
90	31.2	31.2	21	0.239	1.0	21

Dry-year total P deposition =	0.222
Average-year total P deposition =	0.239
Wet-year total P deposition =	0.259
(Barr Engineering 2004)	

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
90	0.0	0	0	1.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
90	43.5	3.00	1.0	104

Net Discharge [ac-ft/yr] =	**496**	**Net Load [lb/yr] =**	**327**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Forest Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	327	[lb/yr]
		Q (lake outflow) =	475	[ac-ft/yr]
		V (modeled lake volume) =	1,227.5	[ac-ft]
		T = V/Q =	2.6	[yr]
		P_i = W/Q =	253.6	[ug/l]
Model Predicted In-Lake [TP]			**57.3**	**[ug/l]**
Observed In-Lake [TP]			**58.7**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$			
		P_{sed} (phosphorus sedimentation) =	**253**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**74**	**[lb/yr]**

Average Load Reduction Table for Forest Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS			TROPHIC STATE INDICES (Carlson, 1980)
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**
0%	**327**	57	253	**74**	62.5
5%	**311**	55	239	**72**	62.1
10%	**295**	54	225	**69**	61.6
15%	**278**	52	212	**67**	61.0
20%	**262**	50	198	**64**	60.4
25%	**245**	48	184	**61**	59.8
30%	**229**	45	170	**59**	59.2
35%	**213**	43	157	**56**	58.5
40%	**196**	41	143	**53**	57.7
45%	**180**	39	130	**50**	56.9
50%	**164**	36	117	**47**	56.0
55%	**147**	34	104	**44**	54.9
60%	**131**	31	91	**40**	53.8
65%	**115**	28	78	**37**	52.4
70%	**98**	26	65	**33**	50.9
75%	**82**	23	53	**29**	49.1
80%	**65**	19	41	**25**	46.8
85%	**49**	16	29	**20**	43.8
90%	**33**	12	18	**15**	39.5
95%	**16**	7	8	**9**	31.8

TMDL Loading Summary for Forest Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 CFO01	325	9.2	249	204	1.0	138
2 Direct	529	5.1	226	104.0	1.0	64
3					1.0	
4					1.0	
5					1.0	
Summation	*855*	*6.7*	*474*	*70.3*	*0.45*	*91*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 CFO01	325	0				
2 Direct	529	0				
3						
4						
5						
Summation	*855*	*0*				*0*
Inflow from Upstream Lakes						
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1			--	-	1.0	0
2				-	1.0	
3				-	1.0	
Summation			*0*	-		*0*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
90	31.2	31.2	21	0.239	1.0	21
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
90	0.0		0	0	1.0	0
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
90	43.5			3.00	0.74	77
			Net Discharge [ac-ft/yr] = 496		**Net Load [lb/yr] =**	**189**

TMDL Lake Response Modeling for Forest Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
	$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	189	[lb/yr]
		Q (lake outflow) =	475	[ac-ft/yr]
		V (modeled lake volume) =	1,228	[ac-ft]
		T = V/Q =	2.59	[yr]
		P_i = W/Q =	147	[ug/l]
Model Predicted In-Lake [TP]			**40.0**	**[ug/l]**
Goal In-Lake [TP]			**40.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$			
		P_{sed} (phosphorus sedimentation) =	**138**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**52**	**[lb/yr]**

Average Loading Summary for Gleason Lake 2005-2011

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 CGL03	1,329	4.0	443	157.3	1.0	190
2 Direct	734	5.1	313	159.1	1.0	135
3					1.0	
4					1.0	
5					1.0	
Summation	*2,063*	*4.4*	*756*	*158.0*		*325*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 CGL03	1,329	0				
2 Direct	734	0				
3						
4						
5						
Summation	*2,063*	*0*				*0*

Inflow from Upstream Lakes

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Snyder Lake	374	4.0	125	157.4	1.0	53
2				-	1.0	
3				-	1.0	
Summation			*125*	*157.4*		*53*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
169	31.9	31.9	0	0.239	1.0	40

Dry-year total P deposition =	0.222
Average-year total P deposition =	0.239
Wet-year total P deposition =	0.259
(Barr Engineering 2004)	

Groundwater

Lake Area [acre]	Groundwater Flux [in/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
169	7.3	103	84.0	1.0	23

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
169	55.0	5.00	1.0	414

Net Discharge [ac-ft/yr] =	**983**	**Net Load [lb/yr] =**	**856**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Gleason Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$		as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	856	[lb/yr]
		Q (lake outflow) =	984	[ac-ft/yr]
		V (modeled lake volume) =	1,009	[ac-ft]
		T = V/Q =	1.03	[yr]
		P_i = W/Q =	320.1	[ug/l]
Model Predicted In-Lake [TP]			**96.8**	**[ug/l]**
Observed In-Lake [TP]			**97.8**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$				
		P_{sed} (phosphorus sedimentation) =	**597**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**259**	**[lb/yr]**

Average Load Reduction Table for Gleason Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS			TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED
REDUCTION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMENTATION [lb]**	**TP OUTFLOW [lb]**	**TSI [TP] [--]**
0%	**856**	97	597	**259**	70.1
5%	**814**	93	563	**250**	69.6
10%	**771**	90	530	**241**	69.1
15%	**728**	87	496	**232**	68.5
20%	**685**	83	463	**222**	67.9
25%	**642**	79	430	**213**	67.2
30%	**599**	76	397	**203**	66.5
35%	**557**	72	364	**192**	65.8
40%	**514**	68	332	**182**	65.0
45%	**471**	64	300	**171**	64.1
50%	**428**	60	268	**160**	63.1
55%	**385**	55	237	**148**	62.0
60%	**343**	51	206	**136**	60.8
65%	**300**	46	176	**124**	59.4
70%	**257**	41	147	**110**	57.8
75%	**214**	36	118	**96**	55.8
80%	**171**	30	90	**81**	53.4
85%	**128**	24	63	**65**	50.2
90%	**86**	18	38	**47**	45.6
95%	**43**	10	16	**27**	37.5

TMDL Loading Summary for Gleason Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 CGL03	1,329	4.0	443	157.3	1.0	190
2 Direct	734	5.1	313	159.1	1.0	135
3					1.0	
4					1.0	
5					1.0	
Summation	*2,063*	*4.4*	*756*	*68.0*	*0.43*	*140*

Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 CGL03	1,329	0				
2 Direct	734	0				
3						
4						
5						
Summation	*2,063*	*0*				*0*

Inflow from Upstream Lakes						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 Snyder Lake	374	4.0	125	60.0	1.0	20
2				-	1.0	
3				-	1.0	
Summation			*125*	*60.0*		*20*

Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
169	31.9	31.9	0	0.239	1.0	40
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			

Groundwater						
Lake Area [acre]	Groundwater Flux [in/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
169	7.3		103	84.0	1.0	23

Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
169	55.0			5.00	0.50	207
			Net Discharge [ac-ft/yr] = 983			**Net Load [lb/yr] = 431**

TMDL Lake Response Modeling for Gleason Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
		as f(W,Q,V) from Canfield & Bachmann (1981)	
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	431 [lb/yr]
		Q (lake outflow) =	984 [ac-ft/yr]
		V (modeled lake volume) =	1,009 [ac-ft]
		T = V/Q =	1.03 [yr]
		P_i = W/Q =	161.1 [ug/l]
Model Predicted In-Lake [TP]			**60.0 [ug/l]**
Goal In-Lake [TP]			**60.0 [ug/l]**
PHOSPHORUS SEDIMENTATION RATE			
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$		
		P_{sed} (phosphorus sedimentation) =	**270 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
W-P_{sed} =			**161 [lb/yr]**

Average Loading Summary for Holy Name Lake 2006-2008

Water Budgets | **Phosphorus Loading**

Inflow from Drainage Areas

	Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1	Watershed Total	388	5.1	166	159.2	1.0	72
2						1.0	
3						1.0	
4						1.0	
5						1.0	
	Summation	*388*	*5.1*	*166*	*159.1*		*72*

Failing Septic Systems

	Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1	Direct	388	0				
2							
3							
4							
5							
	Summation	*388*	*0*				*0*

Inflow from Upstream Lakes

	Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1		--	-	1.0	0
2			-	1.0	
3			-	1.0	
	Summation	*0*	-		*0*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
70	27.3	27.3	0	0.239	1.0	17
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
70	0.0	0	0	1.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
70	61.0	9.50	1.0	362

Net Discharge [ac-ft/yr] =	**166**	**Net Load [lb/yr] =**	**450**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Holy Name Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
$P = P_i \Big/ \left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)$		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	450	[lb/yr]
		Q (lake outflow) =	166	[ac-ft/yr]
		V (modeled lake volume) =	340	[ac-ft]
		T = V/Q =	2.05	[yr]
		P_i = W/Q =	1,000.1	[ug/l]
Model Predicted In-Lake [TP]			**150.1**	**[ug/l]**
Observed In-Lake [TP]			**149.5**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$				
		P_{sed} (phosphorus sedimentation) =	**383**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**68**	**[lb/yr]**

Average Load Reduction Table for Holy Name Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS			TROPHIC STATE INDICES (Carlson, 1980)
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**
0%	**450**	150	383	**68**	76.4
5%	**428**	145	362	**65**	76.0
10%	**405**	141	342	**63**	75.5
15%	**383**	136	322	**61**	75.0
20%	**360**	131	301	**59**	74.4
25%	**338**	126	281	**57**	73.9
30%	**315**	121	261	**54**	73.2
35%	**293**	115	241	**52**	72.6
40%	**270**	109	221	**49**	71.9
45%	**248**	104	201	**47**	71.1
50%	**225**	98	181	**44**	70.2
55%	**203**	91	162	**41**	69.2
60%	**180**	85	142	**38**	68.2
65%	**158**	78	123	**35**	66.9
70%	**135**	70	103	**32**	65.5
75%	**113**	62	84	**28**	63.8
80%	**90**	54	66	**24**	61.7
85%	**68**	44	48	**20**	58.9
90%	**45**	34	30	**15**	54.8
95%	**23**	21	13	**9**	47.7

TMDL Loading Summary for Holy Name Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 Watershed Total	388	5.1	166	159.2	1.0	72
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*388*	*5.1*	*166*	*31.8*	*0.20*	*14*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Direct	388	0				
2						
3						
4						
5						
Summation	*388*	*0*				*0*
Inflow from Upstream Lakes						
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1			--	-	1.0	0
2				-	1.0	
3				-	1.0	
Summation			*0*	-		*0*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
70	27.3	27.3	0	0.239	1.0	17
		Dry-year total P deposition =		0.222		
		Average-year total P deposition =		0.239		
		Wet-year total P deposition =		0.259		
		(Barr Engineering 2004)				
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
70	0.0		0	0	1.0	0
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
70	61.0			9.50	0.21	75
		Net Discharge [ac-ft/yr] =	**166**		**Net Load [lb/yr] =**	**106**

TMDL Lake Response Modeling for Holy Name Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	106	[lb/yr]
		Q (lake outflow) =	166	[ac-ft/yr]
		V (modeled lake volume) =	340	[ac-ft]
		T = V/Q =	2.05	[yr]
		P_i = W/Q =	235.0	[ug/l]
Model Predicted In-Lake [TP]			**60.0**	**[ug/l]**
Goal In-Lake [TP]			**60.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$			
		P_{sed} (phosphorus sedimentation) =	**79**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**27**	**[lb/yr]**

Average Loading Summary for Langdon Lake 2009-2011

Water Budgets				**Phosphorus Loading**		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1						
2 Direct	913	5.1	390	158.9	1.0	168
3					1.0	
4					1.0	
5					1.0	
Summation	*913*	*5*	*390*	*158.8*		*168*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1						
2 Direct	913	0				
3						
4						
5						
Summation	*913*	*0*				*0*

Inflow from Upstream Lakes

Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1	--	-	1.0	0
2		-	1.0	
3		-	1.0	
Summation	*0*	-		*0*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
142	31.4	31.4	0	0.239	1.0	34
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
142	0.0	0	0	1.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
142	15.5	9.70	1.0	191

Net Discharge [ac-ft/yr] =	**390**	**Net Load [lb/yr] =**	**393**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Langdon Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$		as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	393	[lb/yr]
		Q (lake outflow) =	390	[ac-ft/yr]
		V (modeled lake volume) =	1,208	[ac-ft]
		T = V/Q =	3.10	[yr]
		P_i = W/Q =	371	[ug/l]
Model Predicted In-Lake [TP]			**67.6**	**[ug/l]**
Observed In-Lake [TP]			**64.7**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$				
		P_{sed} (phosphorus sedimentation) =	**322**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**72**	**[lb/yr]**

Average Load Reduction Table for Langdon Lake					
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**			**TROPHIC STATE INDICES (Carlson, 1980)**
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**
0%	**393**	68	322	**72**	64.9
5%	**374**	65	304	**69**	64.4
10%	**354**	63	287	**67**	63.9
15%	**334**	61	270	**65**	63.4
20%	**315**	59	252	**62**	62.9
25%	**295**	56	235	**60**	62.3
30%	**275**	54	218	**57**	61.7
35%	**256**	51	201	**55**	61.0
40%	**236**	49	184	**52**	60.2
45%	**216**	46	167	**49**	59.4
50%	**197**	43	151	**46**	58.5
55%	**177**	41	134	**43**	57.5
60%	**157**	38	118	**40**	56.4
65%	**138**	34	101	**36**	55.2
70%	**118**	31	85	**33**	53.7
75%	**98**	27	69	**29**	51.9
80%	**79**	24	54	**25**	49.7
85%	**59**	19	39	**20**	46.8
90%	**39**	14	24	**15**	42.7
95%	**20**	9	10	**9**	35.3

TMDL Loading Summary for Langdon Lake

Water Budgets | **Phosphorus Loading**

Inflow from Drainage Areas

	Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1							
2	Direct	913	5.1	390	131.9	0.83	140
3						1.0	
4						1.0	
5						1.0	
	Summation	*913*	*5.1*	*390*	*131.8*		*140*

Failing Septic Systems

	Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1							
2	Direct	913	0				
3							
4							
5							
	Summation	*913*	*0*				*0*

Inflow from Upstream Lakes

	Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1		--	-	1.0	0
2			-	1.0	
3			-	1.0	
	Summation	*0*	-		*0*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
142	31.4	31.4	0	0.239	1.0	34

Dry-year total P deposition =	0.222
Average-year total P deposition =	0.239
Wet-year total P deposition =	0.259
(Barr Engineering 2004)	

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
142	0.0	0	0	1.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
142	15.5	9.70	0.794	152

Net Discharge [ac-ft/yr] =	**390**	**Net Load [lb/yr] =**	**325**

TMDL Lake Response Modeling for Langdon Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	325	[lb/yr]
		Q (lake outflow) =	390	[ac-ft/yr]
		V (modeled lake volume) =	1,208	[ac-ft]
		T = V/Q =	3.10	[yr]
		P_i = W/Q =	307	[ug/l]
Model Predicted In-Lake [TP]			**60.0**	**[ug/l]**
Goal In-Lake [TP]			**60.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$			
		P_{sed} (phosphorus sedimentation) =	**262**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**64**	**[lb/yr]**

Average Loading Summary for Long Lake 2005-2011

	Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas							
	Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor (CF)[1] [--]	Load [lb/yr]
1	CLO05	1,729	4.3	624	176.3	1.0	299
2	Direct	2,030	5.1	866	159.1	1.0	375
3						1.0	
4						1.0	
5						1.0	
	Summation	*3,758*	*4.8*	*1,490*	*166.2*		*674*

Failing Septic Systems							
	Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1	CLO05	1,729					
2	Direct	2,030	0				
3							
4							
5							
	Summation	*3,758*	*0*				*0*

Inflow from Upstream Lakes							
	Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1	Dickeys	159	7.9	68	42.8	1.0	8
2							
3	Wolsfeld	1,593	4.3	575	176.4	1.0	276
4	Holy Name	458	4.3	165	176.4	1.0	79
	Summation	*2,210*		*808*	*165.2*		*363*

Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
287	31.2	31.2	0	0.239	1.0	69
		Dry-year total P deposition =		0.222		
		Average-year total P deposition =		0.239		
		Wet-year total P deposition =		0.259		
		(Barr Engineering 2004)				

Groundwater						
Lake Area [acre]	Groundwater Flux [in/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
287	7.1		169	84	1.0	39

Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
287	41.9			3.00	1.0	322
		Net Discharge [ac-ft/yr] =	**2,466**		**Net Load [lb/yr] =**	**1,465**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Long Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
	$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$	C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	1,465	[lb/yr]
		Q (lake outflow) =	2,467	[ac-ft/yr]
		V (modeled lake volume) =	3,984	[ac-ft]
		T = V/Q =	1.61	[yr]
		P_i = W/Q =	218.4	[ug/l]
Model Predicted In-Lake [TP]			**62.8**	**[ug/l]**
Observed In-Lake [TP]			**61.4**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$			
		P_{sed} (phosphorus sedimentation) =	**1,044**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**422**	**[lb/yr]**

Average Load Reduction Table for		Long Lake			
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**			**TROPHIC STATE INDICES (Carlson, 1980)**
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**
0%	**1,465**	63	1044	**422**	63.9
5%	**1,392**	61	985	**407**	63.4
10%	**1,319**	59	926	**393**	62.8
15%	**1,246**	56	868	**378**	62.3
20%	**1,172**	54	810	**362**	61.7
25%	**1,099**	52	752	**347**	61.0
30%	**1,026**	49	695	**331**	60.4
35%	**952**	47	638	**314**	59.6
40%	**879**	44	582	**297**	58.8
45%	**806**	42	526	**280**	57.9
50%	**733**	39	471	**261**	57.0
55%	**659**	36	417	**243**	55.9
60%	**586**	33	363	**223**	54.7
65%	**513**	30	310	**203**	53.3
70%	**440**	27	258	**181**	51.7
75%	**366**	24	208	**158**	49.7
80%	**293**	20	159	**134**	47.3
85%	**220**	16	112	**108**	44.2
90%	**147**	12	68	**79**	39.7
95%	**73**	7	28	**45**	31.6

TMDL Loading Summary for Long Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 CLO05	1,729	4.3	624	176.3	1.0	299
2 Direct	2,030	5.1	866	159.1	1.0	375
3					1.0	
4					1.0	
5					1.0	
Summation	*3,758*	*4.8*	*1,490*	*73.1*	*0.44*	*296*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 CLO05	1,729					
2 Direct	2,030	0				
3						
4						
5						
Summation	*3,758*	*0*				*0*
Inflow from Upstream Lakes						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 Dickeys	159	7.9	68	40.0	1.0	7
2						
3 Wolsfeld	1,593	4.3	575	40.0	1.0	63
4 Holy Name	458	4.3	165	60.0	1.0	27
Summation	*1,752*		*808*	*44.1*		*97*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
287	31.2	31.2	0	0.239	1.0	69
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			
Groundwater						
Lake Area [acre]	Groundwater Flux [in/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
287	7.1		169	84.0	1.0	39
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
287	41.9			3.00	0.81	261
		Net Discharge [ac-ft/yr] =	**2,466**		**Net Load [lb/yr] =**	**761**

TMDL Lake Response Modeling for Long Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
	$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	761	[lb/yr]
		Q (lake outflow) =	2,467	[ac-ft/yr]
		V (modeled lake volume) =	3,984	[ac-ft]
		T = V/Q =	1.61	[yr]
		P_i = W/Q =	113.4	[ug/l]
Model Predicted In-Lake [TP]			**40.0**	**[ug/l]**
Goal In-Lake [TP]			**40.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$			
		P_{sed} (phosphorus sedimentation) =	**492**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
$W\text{-}P_{sed}$ =			**269**	**[lb/yr]**

Average Loading Summary for Halsteds Bay 2005-2011

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 CSI02	15,267	5.4	6,852	146.2	1.0	2,724
2 Direct	3,494	5.1	1,491	159.1	1.0	645
3					1.0	
4					1.0	
5					1.0	
Summation	*18,760*	*5.3*	*8,342*	*148.4*		*3,369*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 CSI02	15,267	0				
2 Direct	3,494	0				
3						
4						
5						
Summation	*18,760*	*0*				*0*

Inflow from Upstream Lakes

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1					1.0	0
2					1.0	
3					1.0	
4					1.0	
Summation	*0*		*0*	-		*0*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
561	31.2	31.2	0	0.239	1.0	134
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			

Groundwater

Lake Area [acre]	Groundwater Flux [in/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
561	13.2		617	84.0	1.0	141

Internal

Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
561	28.0			18.00	1.0	2,527
		Net Discharge [ac-ft/yr] =	**8,960**		**Net Load [lb/yr] =**	**6,171**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Halsteds Bay

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
	$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	6,171	[lb/yr]
		Q (lake outflow) =	8,963	[ac-ft/yr]
		V (modeled lake volume) =	7,404	[ac-ft]
		T = V/Q =	0.83	[yr]
		P_i = W/Q =	253.2	[ug/l]
Model Predicted In-Lake [TP]			**89.1**	**[ug/l]**
Observed In-Lake [TP]			**88.5**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$			
		P_{sed} (phosphorus sedimentation) =	**4,000**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**2,171**	**[lb/yr]**

Average Load Reduction Table for Halsteds Bay					
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**			**TROPHIC STATE INDICES (Carlson,**
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**
0%	**6,171**	89	4000	**2171**	68.9
5%	**5,863**	86	3769	**2094**	68.4
10%	**5,554**	83	3538	**2016**	67.8
15%	**5,246**	79	3310	**1936**	67.2
20%	**4,937**	76	3083	**1854**	66.6
25%	**4,629**	73	2858	**1770**	65.9
30%	**4,320**	69	2635	**1685**	65.2
35%	**4,011**	66	2415	**1597**	64.5
40%	**3,703**	62	2196	**1507**	63.6
45%	**3,394**	58	1981	**1414**	62.7
50%	**3,086**	54	1768	**1318**	61.7
55%	**2,777**	50	1558	**1219**	60.6
60%	**2,469**	46	1352	**1117**	59.3
65%	**2,160**	41	1150	**1010**	57.9
70%	**1,851**	37	953	**898**	56.2
75%	**1,543**	32	762	**781**	54.1
80%	**1,234**	27	578	**656**	51.6
85%	**926**	21	403	**522**	48.3
90%	**617**	15	241	**376**	43.6
95%	**309**	9	98	**210**	35.2

TMDL Loading Summary for Halsteds Bay

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 CSI02	15,267	5.4	6,852	146.2	1.0	2,724
2 Direct	3,494	5.1	1,491	159.1	1.0	645
3					1.0	
4					1.0	
5					1.0	
Summation	*18,760*	*5.3*	*8,342*	*45.4*	*0.31*	*1,031*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 CSI02	15,267	0				
2 Direct	3,494	0				
3						
4						
5						
Summation	*18,760*	*0*				*0.0*

Inflow from Upstream Lakes

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1					1.0	0
2					1.0	
3					1.0	
4					1.0	
Summation	*0*		*0*	-		*0*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
561	31.2	31.2	0	0.239	1.0	134
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			

Groundwater

Lake Area [acre]	Groundwater Flux [in/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
561	13.2		617	84	1.0	141

Internal

Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
561	28.0			18.00	0.30	758

		Net Discharge [ac-ft/yr] =	**8,960**		**Net Load [lb/yr] =**	**2,064**

TMDL Lake Response Modeling for Halsteds Bay

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	2,064	[lb/yr]
		Q (lake outflow) =	8,963	[ac-ft/yr]
		V (modeled lake volume) =	7,404	[ac-ft]
		T = V/Q =	0.83	[yr]
		P_i = W/Q =	85	[ug/l]
Model Predicted In-Lake [TP]			**40.0**	**[ug/l]**
Goal In-Lake [TP]			**40.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$				
		P_{sed} (phosphorus sedimentation) =	**1,088**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**976**	**[lb/yr]**

Average Loading Summary for Jennings Bay 2005-2011

Water Budgets | **Phosphorus Loading**

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 CPA05	8670	4.8	3499	229.1	1.0	2181
2 CDU01	146	4.9	59	108.6	1.0	18
3 Direct	563	5.1	240	159.1	1.0	104
4					1.0	
5					1.0	
Summation	*9379*	*4.9*	*3799*	*222.8*		*2303*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 CPA05	8670	0				
2 CDU01	146	0				
3 Direct	563	0				
4						
5						
Summation	*9379*	*0*				*0*

Inflow from Upstream Lakes

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Dutch	1743	4.9	710	108.6	1.0	210
2				-	1.0	
3				-	1.0	
Summation			*710*	*108.6*		*210*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
306	31.2	31.2	0	0.239	1.0	73

Dry-year total P deposition =	0.222
Average-year total P deposition =	0.239
Wet-year total P deposition =	0.259
(Barr Engineering 2004)	

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
306	0.0	0	0	1.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m²-day]	Calibration Factor [--]	Load [lb/yr]
306	21.1	16.00	1.0	920

Net Discharge [ac-ft/yr] =	**4509**	**Net Load [lb/yr] =**	**3505**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Jennings Bay

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	3505	[lb/yr]
		Q (lake outflow) =	4511	[ac-ft/yr]
		V (modeled lake volume) =	3750	[ac-ft]
		T = V/Q =	0.83	[yr]
		P_i = W/Q =	285.8	[ug/l]
Model Predicted In-Lake [TP]			**96.8**	**[ug/l]**
Observed In-Lake [TP]			**97.4**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$			
		P_{sed} (phosphorus sedimentation) =	**2319**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**1187**	**[lb/yr]**

Average Load Reduction Table for					*Jennings Bay*
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**			**TROPHIC STATE INDICES (Carlson, 1980)**
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMEN-TATION [lb]**	**TP OUT- [lb]**	**TSI [TP] [--]**
0%	**3,505**	97	2319	**1187**	70.1
5%	**3,330**	93	2185	**1145**	69.6
10%	**3,155**	90	2053	**1102**	69.0
15%	**2,980**	86	1921	**1059**	68.4
20%	**2,804**	83	1790	**1015**	67.8
25%	**2,629**	79	1660	**969**	67.2
30%	**2,454**	75	1531	**923**	66.5
35%	**2,279**	71	1404	**875**	65.7
40%	**2,103**	67	1277	**826**	64.9
45%	**1,928**	63	1152	**776**	63.9
50%	**1,753**	59	1029	**724**	62.9
55%	**1,577**	55	908	**670**	61.8
60%	**1,402**	50	788	**614**	60.6
65%	**1,227**	45	671	**556**	59.1
70%	**1,052**	40	557	**495**	57.5
75%	**876**	35	446	**431**	55.5
80%	**701**	30	339	**362**	53.0
85%	**526**	24	237	**289**	49.7
90%	**351**	17	142	**209**	45.0
95%	**175**	10	58	**117**	36.7

TMDL Loading Summary for Jennings Bay

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 CPA05	8,670	4.8	3,499	229.1	1.0	2,181
2 CDU01	146	4.9	59	108.6	1.0	18
3 Direct	563	5.1	240	159.1	1.0	104
4					1.0	
5					1.0	
Summation	*9,379*	*4.9*	*3,799*	*66.8*	*0.30*	*691*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 CPA05	8,670	0				
2 CDU01	146	0				
3 Direct	563	0				
4						
5						
Summation	*9,379*	*0*				*0*

Inflow from Upstream Lakes

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 Dutch	1,743	4.9	710	40.0	1.0	77
2				-	1.0	
3				-	1.0	
Summation			*710*	*40.0*		*77*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
306	31.2	31.2	0	0.239	1.0	73
		Dry-year total P deposition =		0.222		
		Average-year total P deposition =		0.239		
		Wet-year total P deposition =		0.259		
		(Barr Engineering 2004)				

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
306	0.0		0	0	1.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
306	21.1			16.00	0.22	198
		Net Discharge [ac-ft/yr] =	**4,509**		**Net Load [lb/yr] =**	**1,039**

TMDL Lake Response Modeling for Jennings Bay

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$		as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	1,039	[lb/yr]
		Q (lake outflow) =	4,511	[ac-ft/yr]
		V (modeled lake volume) =	3,750	[ac-ft]
		T = V/Q =	0.83	[yr]
		P_i = W/Q =	84.7	[ug/l]
Model Predicted In-Lake [TP]			**40.0**	**[ug/l]**
Goal In-Lake [TP]			**40.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$				
		P_{sed} (phosphorus sedimentation) =	**549**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**490**	**[lb/yr]**

Average Loading Summary for Stubbs Bay 2005-2011

Water Budgets					Phosphorus Loading		

Inflow from Drainage Areas

	Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1	CCL01	994	4.9	403	113.3	1.0	124
2	CST01	507	5.0	213	255.6	1.0	148
3	Direct	247	5.1	105	104.0	1.0	30
4						1.0	
5						1.0	
	Summation	*1,748*	*5.0*	*722*	*153.9*		*302*

Failing Septic Systems

	Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1	CCL01	994					
2	CST01	507					
3	Direct	247	30	25%	6.1	0.2	46
4							
5							
	Summation	*1,748*	*30*				*46*

Inflow from Upstream Lakes

	Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1		0.0	-	1.0	
2			-	1.0	
3			-	1.0	
	Summation	*0*	-		*0*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
199	31.2	31.2	0	0.239	1.0	47

Dry-year total P deposition =	0.222
Average-year total P deposition =	0.239
Wet-year total P deposition =	0.259
(Barr Engineering 2004)	

Groundwater

Lake Area [acre]	Groundwater Flux [in/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
199	13.2	218	84.0	1.0	50

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m²-day]	Calibration Factor [--]	Load [lb/yr]
199	39.4	2.00	1.0	140

Net Discharge [ac-ft/yr] =	**940**	**Net Load [lb/yr] =**	**585**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Stubbs Bay

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
	$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$	C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	585	[lb/yr]
		Q (lake outflow) =	940	[ac-ft/yr]
		V (modeled lake volume) =	2,778	[ac-ft]
		T = V/Q =	2.95	[yr]
		P_i = W/Q =	228.7	[ug/l]
Model Predicted In-Lake [TP]			**50.7**	**[ug/l]**
Observed In-Lake [TP]			**49.9**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$			
		P_{sed} (phosphorus sedimentation) =	**455**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**130**	**[lb/yr]**

Average Load Reduction Table for Stubbs Bay					
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**			**TROPHIC STATE INDICES (Carlson, 1980)**
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**
0%	**585**	51	455	**130**	60.8
5%	**556**	49	430	**126**	60.3
10%	**526**	47	405	**121**	59.8
15%	**497**	46	380	**117**	59.3
20%	**468**	44	356	**112**	58.7
25%	**439**	42	331	**108**	58.1
30%	**409**	40	306	**103**	57.4
35%	**380**	38	282	**98**	56.7
40%	**351**	36	258	**93**	56.0
45%	**322**	34	234	**88**	55.1
50%	**292**	32	210	**82**	54.2
55%	**263**	30	187	**77**	53.2
60%	**234**	28	163	**71**	52.0
65%	**205**	25	140	**65**	50.7
70%	**175**	23	117	**58**	49.2
75%	**146**	20	95	**51**	47.3
80%	**117**	17	73	**44**	45.1
85%	**88**	14	52	**35**	42.1
90%	**58**	10	32	**26**	37.8
95%	**29**	6	14	**15**	30.1

TMDL Loading Summary for Stubbs Bay

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Reduction Factor	Load
Name	[acre]	[in/yr]	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1 CCL01	994	4.9	403	113.3	1.0	124
2 CST01	507	5.0	213	255.6	1.0	148
3 Direct	247	5.1	105	104.0	1.0	30
4					1.0	
5					1.0	
Summation	*1,748*	*5.0*	*722*	*86.2*	*0.56*	*169*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 CCL01	994					
2 CST01	507					
3 Direct	247	30	0%	6.1	0.0	0
4						
5						
Summation	*1,748*	*30*				*0*
Inflow from Upstream Lakes						
			Discharge	Estimated P Concentration	Reduction Factor	Load
Name			[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1			0	-	1.0	
2				-	1.0	
3				-	1.0	
Summation			*0*	-		*0*
Atmosphere						
Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Reduction Factor	Load
[acre]	[in/yr]	[in/yr]	[ac-ft/yr]	[lb/ac-yr]	[--]	[lb/yr]
199	31.2	31.2	0	0.239	1.0	47
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			
Groundwater						
Lake Area	Groundwater Flux		Net Inflow	Phosphorus Concentration	Reduction Factor	Load
[acre]	[in/yr]		[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
199	13.2		218	84.0	1.0	50
Internal						
Lake Area	Anoxic Factor			Release Rate	Reduction Factor	Load
[acre]	[days]			[mg/m^2-day]	[--]	[lb/yr]
199	39.4			2.00	1.00	140
			Net Discharge [ac-ft/yr] = 940		**Net Load [lb/yr] =**	**406**

TMDL Lake Response Modeling for Stubbs Bay

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
$P = P_i \Big/ \left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)$		as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	406	[lb/yr]
		Q (lake outflow) =	940	[ac-ft/yr]
		V (modeled lake volume) =	2,778	[ac-ft]
		T = V/Q =	2.95	[yr]
		P_i = W/Q =	158.8	[ug/l]
Model Predicted In-Lake [TP]			**40.0**	**[ug/l]**
Goal In-Lake [TP]			**40.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$				
		P_{sed} (phosphorus sedimentation) =	**304**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**102**	**[lb/yr]**

Average Loading Summary for West Arm 2005-2011

Water Budgets				**Phosphorus Loading**		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor (CF)[1] [--]	Load [lb/yr]
1					1.0	
2 Direct	596	5.1	254	214.1	1.0	148
3					1.0	
4					1.0	
5					1.0	
Summation	*596*	*5.1*	*254*	*214.0*		*148*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1	0					
2 Direct	596	0				
3						
4						
5						
Summation	*596*	*0*				*0*
Inflow from Upstream Lakes						
Name	Area [ac]		Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Jenning's Bay	11,427		4,856	97.4	1.0	1,287
2 Forest Lake	944		724	58.7	1.0	116
3				-	1.0	
Summation	*12,371*		*5,580*	*78.1*		*1,403*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
822	31.2	31.2	0	0.239	1.0	197
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			
Groundwater						
Lake Area [acre]	Groundwater Flux [in/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
822	0.0		0	0	1.0	0
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
822	19.8			11.5	1.0	1,673
		Net Discharge [ac-ft/yr] =	**5,835**		**Net Load [lb/yr] =**	**3,421**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for West Arm

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
	$P = P_i \Big/ \left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)$	as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	3,421	[lb/yr]
		Q (lake outflow) =	5,835	[ac-ft/yr]
		V (modeled lake volume) =	10,685	[ac-ft]
		T = V/Q =	1.83	[yr]
		P_i = W/Q =	215.6	[ug/l]
Model Predicted In-Lake [TP]			**59.3**	**[ug/l]**
Observed In-Lake [TP]			**59.8**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$			
		P_{sed} (phosphorus sedimentation) =	**2,480**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**941**	**[lb/yr]**

Average Load Reduction Table for West Arm					
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**			**TROPHIC STATE INDICES (Carlson, 1980)**
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**
0%	**3,421**	59	2480	**941**	63.0
5%	**3,250**	57	2340	**909**	62.5
10%	**3,079**	55	2202	**877**	62.0
15%	**2,908**	53	2064	**844**	61.5
20%	**2,737**	51	1927	**810**	60.9
25%	**2,565**	49	1790	**775**	60.2
30%	**2,394**	47	1655	**740**	59.5
35%	**2,223**	44	1520	**703**	58.8
40%	**2,052**	42	1387	**665**	58.0
45%	**1,881**	39	1255	**626**	57.2
50%	**1,710**	37	1124	**586**	56.2
55%	**1,539**	34	995	**544**	55.1
60%	**1,368**	32	867	**501**	53.9
65%	**1,197**	29	742	**455**	52.6
70%	**1,026**	26	619	**408**	51.0
75%	**855**	22	498	**357**	49.0
80%	**684**	19	382	**303**	46.7
85%	**513**	15	269	**244**	43.5
90%	**342**	11	164	**178**	39.0
95%	**171**	6	69	**103**	31.1

TMDL Loading Summary for West Arm

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1					1.0	
2 Direct	596	5.1	254	214	1.0	148
3					1.0	
4					1.0	
5					1.0	
Summation	*596*	*5.1*	*254*	*154.1*	*0.72*	*107*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1	0					
2 Direct	596	0				
3						
4						
5						
Summation	*596*	*0*				*0*

Inflow from Upstream Lakes

Name	Area [ac]		Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 Jenning's Bay	11,427		4,856	40.0	1.0	528
2 Forest Lake	944		724	40.0	1.0	79
3				-	1.0	
Summation	*12,371*		*5,580*	*40.0*		*607*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
822	31.2	31.2	0	0.239	1.0	197
		Dry-year total P deposition =		0.222		
		Average-year total P deposition =		0.239		
		Wet-year total P deposition =		0.259		
		(Barr Engineering 2004)				

Groundwater

Lake Area [acre]	Groundwater Flux [in/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
822	0.0		0	0	1.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
822	19.8			11.50	0.60	1,004
		Net Discharge [ac-ft/yr] =	**5,835**		**Net Load [lb/yr] =**	**1,915**

TMDL Lake Response Modeling for West Arm

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	1,915	[lb/yr]
		Q (lake outflow) =	5,835	[ac-ft/yr]
		V (modeled lake volume) =	10,685	[ac-ft]
		T = V/Q =	1.83	[yr]
		P_i = W/Q =	120.7	[ug/l]
Model Predicted In-Lake [TP]			**40.0**	**[ug/l]**
Goal In-Lake [TP]			**40.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$			
		P_{sed} (phosphorus sedimentation) =	**1,281**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**634**	**[lb/yr]**

Average Loading Summary for Mooney Lake — *2006-2008, 2011*

	Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

	Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1	Direct	486	5.1	207	132.1	1.0	74
2						1.0	
3						1.0	
4						1.0	
5						1.0	
	Summation	*486*	*5.1*	*207*	*132.0*		*74*

Failing Septic Systems

	Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1	Direct	486	7	25%	6.1	0.0	11
2							
3							
4							
5							
	Summation	*486*	*7*				*11*

Inflow from Upstream Lakes

	Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1		0	-	1.0	
2			-	1.0	
3			-	1.0	
	Summation	*0*	-		*0*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
113	27.4	27.4	0	0.239	1.0	27
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			

Groundwater

Lake Area [acre]	Groundwater Flux [in/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
113	-10.0	-94	0	0.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m²-day]	Calibration Factor [--]	Load [lb/yr]
113	48.0	2.00	1.0	97

Net Discharge [ac-ft/yr] =	**113**	**Net Load [lb/yr] =**	**209**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Mooney Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	209	[lb/yr]
		Q (lake outflow) =	113	[ac-ft/yr]
		V (modeled lake volume) =	565	[ac-ft]
		T = V/Q =	4.98	[yr]
		P_i = W/Q =	677.2	[ug/l]
Model Predicted In-Lake [TP]			**78.2**	**[ug/l]**
Observed In-Lake [TP]			**78.2**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$			
		P_{sed} (phosphorus sedimentation) =	**185**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**24**	**[lb/yr]**

Average Load Reduction Table for Mooney Lake					
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**			**TROPHIC STATE INDICES (Carlson, 1980)**
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**
0%	**209**	78	185	**24**	67.0
5%	**198**	76	175	**23**	66.6
10%	**188**	73	165	**23**	66.1
15%	**178**	71	156	**22**	65.6
20%	**167**	68	146	**21**	65.1
25%	**157**	66	136	**20**	64.5
30%	**146**	63	127	**19**	63.9
35%	**136**	60	117	**19**	63.3
40%	**125**	58	108	**18**	62.6
45%	**115**	55	98	**17**	61.8
50%	**104**	52	89	**16**	61.0
55%	**94**	48	79	**15**	60.1
60%	**84**	45	70	**14**	59.0
65%	**73**	41	60	**13**	57.8
70%	**63**	38	51	**12**	56.4
75%	**52**	33	42	**10**	54.8
80%	**42**	29	33	**9**	52.7
85%	**31**	24	24	**7**	50.1
90%	**21**	18	15	**6**	46.2
95%	**10**	12	7	**4**	39.4

TMDL Loading Summary for Mooney Lake

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 Direct	486	5.1	207	132.1	1.0	74
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*486*	*5.1*	*207*	*27.1*	*0.21*	*15*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Direct	486	7	0%	6.1	0.0	0
2						
3						
4						
5						
Summation	*486*	*7*				*0*

Inflow from Upstream Lakes

Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1	0	-	1.0	
2		-	1.0	
3		-	1.0	
Summation	*0*	-		*0*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
113	27.4	27.4	0	0.239	1.0	27
		Dry-year total P deposition =		0.222		
		Average-year total P deposition =		0.239		
		Wet-year total P deposition =		0.259		
		(Barr Engineering 2004)				

Groundwater

Lake Area [acre]	Groundwater Flux [in/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
113	-10.0	-94	0	0.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
113	48.0	2.00	0.95	92

Net Discharge [ac-ft/yr] =	**113**	**Net Load [lb/yr] =**	**134**

TMDL Lake Response Modeling for Mooney Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	134	[lb/yr]
		Q (lake outflow) =	113	[ac-ft/yr]
		V (modeled lake volume) =	565	[ac-ft]
		T = V/Q =	4.98	[yr]
		P_i = W/Q =	435.0	[ug/l]
Model Predicted In-Lake [TP]			**60.0**	**[ug/l]**
Goal In-Lake [TP]			**60.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$			
		P_{sed} (phosphorus sedimentation) =	**116**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**19**	**[lb/yr]**

Average Loading Summary for Stone *2000, 2002, 2007-2008, 2010-2012*

Water Budgets | **Phosphorus Loading**

Inflow from Drainage Areas

	Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1	Stone	692	8.5	491	32	1.0	43
2	SMC-16	43	5.0	18	40.0	1.0	2
3	SMC-17	46	9.7	38	71.5	1.0	7
4							
5							
	Summation	*782*	*23*	*546*			*52*

Failing Septic Systems

	Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1	Stone	692					
2	SMC-16	43		0%	0.0		
3	SMC-17	46		0%	0.0		
4							
5							
	Summation	*782*	*0*				*0*

Inflow from Upstream Lakes

	Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1			-	1.0	
2			-	1.0	
3			-	1.0	
	Summation	*0*	-		*0*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
99	30.7	30.7	0	0.24	1.0	24

Dry-year total P deposition =	0.222
Average-year total P deposition =	0.239
Wet-year total P deposition =	0.259
(Barr Engineering 2004)	

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
99	0.0	0	0	1.0	0

Internal

Lake Area [km^2]	Anoxic Factor [days]		Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
0.40		Oxic		1.0	
0.40	41.9	Anoxic	3.5	1.0	130
Summation					130

Net Discharge [ac-ft/yr] =	**546**	**Net Load [lb/yr] =**	**206**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Stone

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$		C_P =	1.03	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	206	[lb/yr]
		Q (lake outflow) =	546	[ac-ft/yr]
		V (modeled lake volume) =	1009	[ac-ft]
		T = V/Q =	1.85	[yr]
		P_i = W/Q =	138	[µg/l]
Model Predicted In-Lake [TP]			**42.9**	**[ug/l]**
Observed In-Lake [TP]			**42.9**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$				
		P_{sed} (phosphorus sedimentation) =	**142**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**64**	**[lb/yr]**

LOAD			MODELED IN-LAKE WATER QUALITY PARAMETERS
REDUC-TION	NET LOAD	NET LOAD	[TP]
[%]	[kg]	[lb]	[ug/L]
0%	93	206	42.9
5%	89	195	41.4
10%	84	185	39.9
15%	79	175	38.4
20%	75	164	36.8
25%	70	154	35.2
30%	65	144	33.5
35%	61	134	31.8
40%	56	123	30.1
45%	51	113	28.3
50%	47	103	26.4
55%	42	92	24.5
60%	37	82	22.5
65%	33	72	20.4
70%	28	62	18.2
75%	23	51	15.9
80%	19	41	13.4
85%	14	31	10.7
90%	9	21	7.8
95%	5	10	4.4

TMDL Loading Summary for Stone

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 Stone	692	8.5	491	32	1.0	43
2 SMC-16	43	5.0	18	40.0	1.0	2
3 SMC-17	46	9.7	38	71.5	1.0	7
4						
5						
Summation	*782*	*23*	*546*			*52*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Stone	692					
2 SMC-16	43		0%	0.0		
3 SMC-17	46		0%	0.0		
4						
5						
Summation	*782*	*0*				*0.0*
Inflow from Upstream Lakes						
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1				-	1.0	
2				-	1.0	
3				-	1.0	
Summation			*0*	-		*0*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
99	30.7	30.7	0	0.24	1.0	24
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
99	0.0		0	0	1.0	0
Internal						
Lake Area [km^2]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
0.40			Oxic		1.0	
0.40	41.9		Anoxic	3.0	1.0	110
Summation						110
		Net Discharge [ac-ft/yr] =	**546**		**Net Load [lb/yr] =**	**186**

TMDL Lake Response Modeling for Stone

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$		C_P =	1.03	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	186	[lb/yr]
		Q (lake outflow) =	546	[ac-ft/yr]
		V (modeled lake volume) =	1009	[ac-ft]
		T = V/Q =	1.85	[yr]
		P_i = W/Q =	125	[µg/l]
Model Predicted In-Lake [TP]			**40.0**	**[ug/l]**
Goal In-Lake [TP]			**40.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$				
		P_{sed} (phosphorus sedimentation) =	**126**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**59**	**[lb/yr]**

Average Loading Summary for Tamarack Lake 2005-2011

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Direct	179	5.1	76	104.0	1.0	22
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*179*	*5.1*	*76*	*104.0*		*22*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Direct	179	0	0%	0.0	0.0	0
2						
3						
4						
5						
Summation	*179*	*0*				*0*

Inflow from Upstream Lakes

Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1	0	-	1.0	
2		-	1.0	
3		-	1.0	
Summation	*0*	-		*0*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
30	31.2	31.2	0	0.239	1.0	7
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			

Groundwater

Lake Area [acre]	Groundwater Flux [in/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
30	0.0	0	0	0.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
30	55.7	3.00	1.0	45

Net Discharge [ac-ft/yr] =	**76**	**Net Load [lb/yr] =**	**73**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Tamarack Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	73	[lb/yr]
		Q (lake outflow) =	76	[ac-ft/yr]
		V (modeled lake volume) =	761	[ac-ft]
		T = V/Q =	9.98	[yr]
		P_i = W/Q =	353.7	[ug/l]
Model Predicted In-Lake [TP]			**38.1**	**[ug/l]**
Observed In-Lake [TP]			**38.9**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$			
		P_{sed} (phosphorus sedimentation) =	**65**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**8**	**[lb/yr]**

Average Load Reduction Table for Tamarack Lake					
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**			**TROPHIC STATE INDICES (Carlson, 1980)**
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**
0%	**73**	38	65	**8**	56.6
5%	**70**	37	62	**8**	56.2
10%	**66**	36	59	**7**	55.7
15%	**62**	35	55	**7**	55.3
20%	**59**	33	52	**7**	54.7
25%	**55**	32	48	**7**	54.2
30%	**51**	31	45	**6**	53.6
35%	**48**	29	42	**6**	52.9
40%	**44**	28	38	**6**	52.2
45%	**40**	27	35	**6**	51.5
50%	**37**	25	31	**5**	50.7
55%	**33**	24	28	**5**	49.7
60%	**29**	22	25	**5**	48.7
65%	**26**	20	21	**4**	47.5
70%	**22**	18	18	**4**	46.1
75%	**18**	16	15	**3**	44.5
80%	**15**	14	12	**3**	42.5
85%	**11**	12	9	**2**	39.8
90%	**7**	9	5	**2**	36.0
95%	**4**	6	2	**1**	29.3

TMDL Loading Summary for Tamarack Lake

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 Direct	179	5.1	76	104.0	1.0	22
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*179*	*5.1*	*76*	*104.0*	*1.0*	*22*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Direct	179	0	0%	0.0	0.0	0
2						
3						
4						
5						
Summation	*179*	*0*				*0*

Inflow from Upstream Lakes

Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1	0	-	1.0	
2		-	1.0	
3		-	1.0	
Summation	*0*	-		*0*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
30	31.2	31.2	0	0.239	1.0	7

Dry-year total P deposition =	0.222
Average-year total P deposition =	0.239
Wet-year total P deposition =	0.259
(Barr Engineering 2004)	

Groundwater

Lake Area [acre]	Groundwater Flux [in/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
30	0.0	0	0	0.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
30	55.7	3.00	1.0	45

Net Discharge [ac-ft/yr] =	**76**	**Net Load [lb/yr] =**	**73**

TMDL Lake Response Modeling for Tamarack Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
$P = P_i \Big/ \left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)$		as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	73	[lb/yr]
		Q (lake outflow) =	76	[ac-ft/yr]
		V (modeled lake volume) =	761	[ac-ft]
		T = V/Q =	9.98	[yr]
		P_i = W/Q =	353.7	[ug/l]
Model Predicted In-Lake [TP]			**38.1**	**[ug/l]**
Goal In-Lake [TP]			**40.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$				
		P_{sed} (phosphorus sedimentation) =	**65**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
$W\text{-}P_{sed}$ =			**8**	**[lb/yr]**

Average Loading Summary for Tanager Lake 2005-2011

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 CLO03	1010	4.5	382	114.4	1.0	119
2 Direct	302	5.1	129	159.1	1.0	56
3					1.0	
4					1.0	
5					1.0	
Summation	*1311*	*4.7*	*511*	*125.7*		*175*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 CLO03	1010					
2 Direct	302	0				
3						
4						
5						
Summation	*1311*	*0*				*0*

Inflow from Upstream Lakes

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Long Lake	6254	4.5	2367	114.5	1.0	737
2				-	1.0	
3				-	1.0	
Summation			*2367*	*114.5*		*737*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
54	31.2	31.2	0	0.239	1.0	13
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			

Groundwater

Lake Area [acre]	Groundwater Flux [in/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
54	13.6		61	84	1.0	14

Internal

Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
54	27.7			18.00	1.0	239
		Net Discharge [ac-ft/yr] =	**2939**		**Net Load [lb/yr] =**	**1178**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Tanager Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	1178	[lb/yr]
		Q (lake outflow) =	2939	[ac-ft/yr]
		V (modeled lake volume) =	512	[ac-ft]
		T = V/Q =	0.17	[yr]
		P_i = W/Q =	147.3	[ug/l]
Model Predicted In-Lake [TP]			**91.0**	**[ug/l]**
Observed In-Lake [TP]			**92.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$			
		P_{sed} (phosphorus sedimentation) =	**450**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**728**	**[lb/yr]**

Average Load Reduction Table for Tanager Lake					
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**			**TROPHIC STATE INDICES (Carlson, 1980)**
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**
0%	**1,178**	91	450	**728**	69.2
5%	**1,119**	87	421	**697**	68.6
10%	**1,060**	83	393	**667**	67.9
15%	**1,001**	80	365	**636**	67.3
20%	**942**	76	338	**604**	66.5
25%	**883**	72	310	**573**	65.7
30%	**824**	68	284	**540**	64.9
35%	**765**	64	258	**508**	64.0
40%	**707**	59	232	**474**	63.0
45%	**648**	55	207	**440**	62.0
50%	**589**	51	183	**406**	60.8
55%	**530**	46	159	**371**	59.5
60%	**471**	42	136	**335**	58.0
65%	**412**	37	114	**298**	56.3
70%	**353**	33	93	**260**	54.4
75%	**294**	28	73	**222**	52.1
80%	**236**	23	54	**182**	49.2
85%	**177**	18	36	**140**	45.5
90%	**118**	12	21	**97**	40.1
95%	**59**	6	8	**51**	30.8

TMDL Loading Summary for Tanager Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 CLO03	1,010	4.5	382	114.4	1.0	119
2 Direct	302	5.1	129	159.1	1.0	56
3					1.0	
4					1.0	
5					1.0	
Summation	*1,311*	*4.7*	*511*	*65.3*	*0.5*	*91*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 CLO03	1,010					
2 Direct	302	0				
3						
4						
5						
Summation	*1,311*	*0*				*0*
Inflow from Upstream Lakes						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 Long Lake	6,254	4.5	2,367	40	1.0	258
2				-	1.0	
3				-	1.0	
Summation			*2,367*	*40.0*		*258*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
54	31.2	31.2	0	0.239	1.0	13
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			
Groundwater						
Lake Area [acre]	Groundwater Flux [in/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
54	13.6		61	84	1.0	14
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
54	27.7			18.00	0.30	72
			Net Discharge [ac-ft/yr] = 2,939			**Net Load [lb/yr] = 447**

TMDL Lake Response Modeling for Tanager Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	447	[lb/yr]
		Q (lake outflow) =	2,939	[ac-ft/yr]
		V (modeled lake volume) =	512	[ac-ft]
		T = V/Q =	0.17	[yr]
		P_i = W/Q =	55.9	[ug/l]
Model Predicted In-Lake [TP]			**40.0**	**[ug/l]**
Goal In-Lake [TP]			**40.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$			
		P_{sed} (phosphorus sedimentation) =	**127**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**320**	**[lb/yr]**

Average Loading Summary for Wolsfeld Lake 2006-2008

	Water Budgets				**Phosphorus Loading**		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Direct	1,000	5.1	427	159.1	1.0	185
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*1,000*	*5.1*	*427*	*159.0*		*185*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Direct	1,000	2	25%	6	0.0	3
2						
3						
4						
5						
Summation	*1,000*	*2*				*3*

Inflow from Upstream Lakes

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 School	553	5	236	159.1	1.0	102
2				-	1.0	
3				-	1.0	
Summation			*236*	*159.1*		*102*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
40	27.3	27.3	0	0.239	1.0	10
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			

Groundwater

Lake Area [acre]	Groundwater Flux [in/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
40	3.3		11	84	1.0	3

Internal

Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
40	55.0			3.00	1.0	59
		Net Discharge [ac-ft/yr] =	**673**		**Net Load [lb/yr] =**	**361**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Wolsfeld Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
$P = P_i \Big/ \left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)$		as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	361	[lb/yr]
		Q (lake outflow) =	674	[ac-ft/yr]
		V (modeled lake volume) =	380	[ac-ft]
		T = V/Q =	0.56	[yr]
		P_i = W/Q =	197.1	[ug/l]
Model Predicted In-Lake [TP]			**84.4**	**[ug/l]**
Observed In-Lake [TP]			**80.1**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$				
		P_{sed} (phosphorus sedimentation) =	**207**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**155**	**[lb/yr]**

Average Load Reduction Table for Wolsfeld Lake					
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**			**TROPHIC STATE INDICES (Carlson, 1980)**
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**
0%	**361**	84	207	**155**	68.1
5%	**343**	81	194	**149**	67.6
10%	**325**	78	182	**143**	67.0
15%	**307**	75	170	**137**	66.4
20%	**289**	71	158	**131**	65.7
25%	**271**	68	146	**125**	65.0
30%	**253**	65	134	**118**	64.3
35%	**235**	61	123	**112**	63.5
40%	**217**	57	111	**105**	62.6
45%	**199**	54	100	**98**	61.6
50%	**181**	50	89	**92**	60.6
55%	**162**	46	78	**84**	59.4
60%	**144**	42	68	**77**	58.0
65%	**126**	38	57	**69**	56.5
70%	**108**	33	47	**61**	54.7
75%	**90**	29	37	**53**	52.6
80%	**72**	24	28	**44**	50.0
85%	**54**	19	19	**35**	46.6
90%	**36**	13	11	**25**	41.6
95%	**18**	7	5	**13**	32.9

TMDL Loading Summary for Wolsfeld Lake

Water Budgets | **Phosphorus Loading**

Inflow from Drainage Areas

	Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1	Direct	1,000	5.1	427	159.1	1.0	185
2						1.0	
3						1.0	
4						1.0	
5						1.0	
	Summation	*1,000*	*5.1*	*427*	*39.8*	*0.25*	*46*

Failing Septic Systems

	Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1	Direct	1,000	2	0%	6	0.0	0
2							
3							
4							
5							
	Summation	*1,000*	*2*				*0*

Inflow from Upstream Lakes

	Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1	School	553	5	236	60.0	1.0	38
2					-	1.0	
3					-	1.0	
	Summation			*236*	*60.0*		*38*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
40	27.3	27.3	0	0.239	1.0	10
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			

Groundwater

Lake Area [acre]	Groundwater Flux [in/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
40	3.3		11	84	1.0	3

Internal

Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
40	55.0			3.0	0.66	39

Net Discharge [ac-ft/yr] =	**673**
Net Load [lb/yr] =	**136**

TMDL Lake Response Modeling for Wolsfeld Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
	$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$	C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	136	[lb/yr]
		Q (lake outflow) =	674	[ac-ft/yr]
		V (modeled lake volume) =	380	[ac-ft]
		T = V/Q =	0.56	[yr]
		P_i = W/Q =	74.2	[ug/l]
Model Predicted In-Lake [TP]			**40.0**	**[ug/l]**
Goal In-Lake [TP]			**40.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$			
		P_{sed} (phosphorus sedimentation) =	**63**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**73**	**[lb/yr]**

Average Loading Summary for Snyder Lake 2006-2008

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Direct	95	5.1	41	104.0	1.0	11
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*95*	*5.1*	*41*	*104.0*		*11*

Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Direct	95	0				
2						
3						
4						
5						
Summation	*95*	*0*				*0*

Inflow from Upstream Lakes						
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Kreatz	266		113	118.9	1.0	37
2				-	1.0	
3				-	1.0	
Summation			*113*	*118.9*		*37*

Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
12	27.3	27.3	0	0.24	1.0	3
		Dry-year total P deposition =		0.222		
		Average-year total P deposition =		0.239		
		Wet-year total P deposition =		0.259		
		(Barr Engineering 2004)				

Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
12	0.0		0	0	1.0	0

Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m²-day]	Calibration Factor [--]	Load [lb/yr]
12	54.6			3.00	1.0	18
		Net Discharge [ac-ft/yr] =	**154**		**Net Load [lb/yr] =**	**69**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Snyder Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$		as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	69	[lb/yr]
		Q (lake outflow) =	154	[ac-ft/yr]
		V (modeled lake volume) =	72	[ac-ft]
		T = V/Q =	0.47	[yr]
		P_i = W/Q =	163.8	[ug/l]
Model Predicted In-Lake [TP]			**77.6**	**[ug/l]**
Observed In-Lake [TP]			**71.6**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$				
		P_{sed} (phosphorus sedimentation) =	**36**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**32**	**[lb/yr]**

Average Load Reduction Table for					*Snyder Lake*
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**			**TROPHIC STATE INDICES (Carlson, 1980)**
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**
0%	**69**	78	36	**32**	66.9
5%	**65**	75	34	**31**	66.3
10%	**62**	72	32	**30**	65.7
15%	**58**	69	30	**29**	65.1
20%	**55**	65	27	**27**	64.4
25%	**51**	62	25	**26**	63.7
30%	**48**	59	23	**25**	63.0
35%	**45**	56	21	**23**	62.1
40%	**41**	52	19	**22**	61.2
45%	**38**	49	17	**20**	60.2
50%	**34**	45	15	**19**	59.1
55%	**31**	42	13	**17**	57.9
60%	**27**	38	12	**16**	56.6
65%	**24**	34	10	**14**	55.0
70%	**21**	30	8	**13**	53.2
75%	**17**	26	6	**11**	51.0
80%	**14**	21	5	**9**	48.3
85%	**10**	17	3	**7**	44.8
90%	**7**	12	2	**5**	39.8
95%	**3**	6	1	**3**	30.9

TMDL Loading Summary for Snyder Lake

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 Direct	95	5.1	41	104.0	1.0	11
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*95*	*5.1*	*41*	*91.5*	*0.88*	*10*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Direct	95	0				
2						
3						
4						
5						
Summation	*95*	*0*				*0*

Inflow from Upstream Lakes

Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 Kreatz	266		113	60.0	0.50	18
2				-	1.0	
3				-	1.0	
Summation			*113*	*60.0*		*18*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
12.00	27.3	27.3	0	0.24	1.0	3
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
12	0.0		0	0	1.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
12	54.6			3.00	1.0	18
		Net Discharge [ac-ft/yr] =	**154**		**Net Load [lb/yr] =**	**49**

TMDL Lake Response Modeling for Snyder Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	49	[lb/yr]
		Q (lake outflow) =	154	[ac-ft/yr]
		V (modeled lake volume) =	72	[ac-ft]
		T = V/Q =	0.47	[yr]
		P_i = W/Q =	117.0	[ug/l]
Model Predicted In-Lake [TP]			**60.0**	**[ug/l]**
Goal In-Lake [TP]			**60.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$			
		P_{sed} (phosphorus sedimentation) =	**24**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
	W-P_{sed} =		**25**	**[lb/yr]**

Average Loading Summary for School Lake 2009-2010

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Direct	541	5.1	231	159.1	1.0	100
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*541*	*5.1*	*231*	*159.1*		*100*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Direct	541	7	25%	6.1	0.0	11
2						
3						
4						
5						
Summation	*541*	*7*				*11*
Inflow from Upstream Lakes						
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1			0.0	-	1.0	
2				-	1.0	
3				-	1.0	
Summation			*0*	-		*0*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
11	33.1	33.1	0	0.239	1.0	3
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
11	0.0		0	0	1.0	0
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
11	72.0			18.00	1.0	128
			Net Discharge [ac-ft/yr] = 231		**Net Load [lb/yr] =**	**242**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for School Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
	$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$	C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	242	[lb/yr]
		Q (lake outflow) =	231	[ac-ft/yr]
		V (modeled lake volume) =	90	[ac-ft]
		T = V/Q =	0.39	[yr]
		P_i = W/Q =	384.6	[ug/l]
Model Predicted In-Lake [TP]			**155.1**	**[ug/l]**
Observed In-Lake [TP]			**157.7**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$			
		P_{sed} (phosphorus sedimentation) =	**144**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**97**	**[lb/yr]**

Average Load Reduction Table for School Lake					
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**			**TROPHIC STATE INDICES (Carlson, 1980)**
REDUCTION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMENTATION [lb]**	**TP OUTFLOW [lb]**	**TSI [TP] [--]**
0%	**242**	155	144	**97**	76.9
5%	**229**	149	136	**94**	76.3
10%	**217**	144	127	**90**	75.8
15%	**205**	138	119	**87**	75.2
20%	**193**	132	111	**83**	74.5
25%	**181**	126	102	**79**	73.8
30%	**169**	119	94	**75**	73.1
35%	**157**	113	86	**71**	72.3
40%	**145**	106	78	**67**	71.4
45%	**133**	100	70	**63**	70.5
50%	**121**	93	63	**58**	69.4
55%	**109**	85	55	**54**	68.3
60%	**97**	78	48	**49**	67.0
65%	**85**	70	40	**44**	65.5
70%	**72**	62	33	**39**	63.7
75%	**60**	54	27	**34**	61.6
80%	**48**	45	20	**28**	59.1
85%	**36**	36	14	**22**	55.7
90%	**24**	25	8	**16**	50.8
95%	**12**	14	3	**9**	42.2

TMDL Loading Summary for School Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1 Direct	541	5.1	231	159.1	1.0	100
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*541*	*5*	*231*	*44.5*	*0.28*	*28*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Direct	541	7	0%	6.1	0.0	0
2						
3						
4						
5						
Summation	*541*	*7*				*0*
Inflow from Upstream Lakes						
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
1			0.0	-	1.0	
2				-	1.0	
3				-	1.0	
Summation			*0*	-		*0*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Reduction Factor [--]	Load [lb/yr]
11	33.1	33.1	0	0.239	1.0	3
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Reduction Factor [--]	Load [lb/yr]
11	0.0		0	0	1.0	0
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Reduction Factor [--]	Load [lb/yr]
11	72.0			18.00	0.30	38.5
			Net Discharge [ac-ft/yr] = 231			**Net Load [lb/yr] = 69**

TMDL Lake Response Modeling for School Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	69	[lb/yr]
		Q (lake outflow) =	231	[ac-ft/yr]
		V (modeled lake volume) =	90	[ac-ft]
		T = V/Q =	0.39	[yr]
		P_i = W/Q =	110.1	[ug/l]
Model Predicted In-Lake [TP]			**60.0**	**[ug/l]**
Goal In-Lake [TP]			**60.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$			
		P_{sed} (phosphorus sedimentation) =	**31**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**38**	**[lb/yr]**

Average Loading Summary for Hadley Lake (2006-2008)

	Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas							
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Direct	502	5.1	214	104.0	1.0	61
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*502*	*5.1*	*214*	*104.0*		*61*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Direct	502	0	0%	0	0.0	0
2						
3						
4						
5						
Summation	*502*	*0*				*0*
Inflow from Upstream Lakes						
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1			0	-	1.0	
2				-	1.0	
3				-	1.0	
Summation			*0*	-		*0*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
35	27.3	27.3	0	0.239	1.0	8
		Dry-year total P deposition =		0.222		
		Average-year total P deposition =		0.239		
		Wet-year total P deposition =		0.259		
		(Barr Engineering 2004)				
Groundwater						
Lake Area [acre]	Groundwater Flux [in/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
35	-1.7		-5	0	1.0	0
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
35	55.7			5.00	1.0	88
		Net Discharge [ac-ft/yr] =	**209**		**Net Load [lb/yr] =**	**157**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Hadley Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	157	[lb/yr]
		Q (lake outflow) =	209	[ac-ft/yr]
		V (modeled lake volume) =	600	[ac-ft]
		T = V/Q =	2.87	[yr]
		P_i = W/Q =	275.5	[ug/l]
Model Predicted In-Lake [TP]			**57.9**	**[ug/l]**
Observed In-Lake [TP]			**58.2**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$			
		P_{sed} (phosphorus sedimentation) =	**124**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**33**	**[lb/yr]**

Average Load Reduction Table for Hadley Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS			TROPHIC STATE INDICES (Carlson, 1980)
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**
0%	**157**	58	124	**33**	62.7
5%	**149**	56	117	**32**	62.2
10%	**141**	54	110	**31**	61.7
15%	**133**	52	104	**30**	61.2
20%	**125**	50	97	**29**	60.6
25%	**118**	48	90	**27**	60.0
30%	**110**	46	84	**26**	59.4
35%	**102**	44	77	**25**	58.7
40%	**94**	42	70	**24**	57.9
45%	**86**	39	64	**22**	57.1
50%	**78**	37	57	**21**	56.2
55%	**71**	34	51	**20**	55.2
60%	**63**	32	45	**18**	54.0
65%	**55**	29	38	**16**	52.7
70%	**47**	26	32	**15**	51.2
75%	**39**	23	26	**13**	49.4
80%	**31**	20	20	**11**	47.1
85%	**24**	16	14	**9**	44.2
90%	**16**	12	9	**7**	39.9
95%	**8**	7	4	**4**	32.3

TMDL Loading Summary for Hadley Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Reduction Factor	Load
Name	[acre]	[in/yr]	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1 Direct	502	5.1	214	104.0	1.0	61
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*502*	*5.1*	*214*	*68.6*	*0.66*	*40*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Direct	502	0	0%	0	0.0	0
2						
3						
4						
5						
Summation	*502*	*0*				*0*
Inflow from Upstream Lakes						
			Discharge	Estimated P Concentration	Reduction Factor	Load
Name			[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1			0	-	1.0	
2				-	1.0	
3				-	1.0	
Summation			*0*	-		*0*
Atmosphere						
Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Reduction Factor	Load
[acre]	[in/yr]	[in/yr]	[ac-ft/yr]	[lb/ac-yr]	[--]	[lb/yr]
35	27.3	27.3	0	0.239	1.0	8
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			
Groundwater						
Lake Area	Groundwater Flux		Net Inflow	Phosphorus Concentration	Reduction Factor	Load
[acre]	[in/yr]		[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
35	-1.7		-5	0	1.0	0
Internal						
Lake Area	Anoxic Factor			Release Rate	Reduction Factor	Load
[acre]	[days]			[mg/m^2-day]	[--]	[lb/yr]
35	55.7			5.00	0.46	40
		Net Discharge [ac-ft/yr] =	**209**		**Net Load [lb/yr] =**	**89**

TMDL Lake Response Modeling for Hadley Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
		as f(W,Q,V) from Canfield & Bachmann (1981)		
	$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$	C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	89	[lb/yr]
		Q (lake outflow) =	209	[ac-ft/yr]
		V (modeled lake volume) =	600	[ac-ft]
		T = V/Q =	2.87	[yr]
		P_i = W/Q =	156.0	[ug/l]
Model Predicted In-Lake [TP]			**40.0**	**[ug/l]**
Goal In-Lake [TP]			**40.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$			
		P_{sed} (phosphorus sedimentation) =	**66**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**23**	**[lb/yr]**

Average Loading Summary for Turbid 2008, 2011, 2012

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF)[1]	Load
Name	[acre]	[in/yr]	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1 Turbid	533	8.2	366	89.6	1.0	89
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*533*	*8.2*	*366*			*89*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Turbid	533	10	0	6	0.0	15
2						
3						
4						
5						
Summation	*533*	*10*				*15*
Inflow from Upstream Lakes						
			Discharge	Estimated P Concentration	Calibration Factor	Load
Name			[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1				-	1.0	
2				-	1.0	
3				-	1.0	
Summation			*0*	-		*0*
Atmosphere						
Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
[acre]	[in/yr]	[in/yr]	[ac-ft/yr]	[lb/ac-yr]	[--]	[lb/yr]
40	30.7	30.7	0	0.24	1.0	10
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			
Groundwater						
Lake Area	Groundwater Flux		Net Inflow	Phosphorus Concentration	Calibration Factor	Load
[acre]	[m/yr]		[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
40	0.0		0	0	1.0	0
Internal						
Lake Area	Anoxic Factor			Release Rate	Calibration Factor	Load
[km^2]	[days]			[mg/m^2-day]	[--]	[lb/yr]
0.16			Oxic		1.0	
0.16	40.9		Anoxic	9.3	1.0	135
Summation						135
		Net Discharge [ac-ft/yr] =	**366**		Net Load [lb/yr] =	**249**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Lake Response Modeling for Turbid

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$		as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.26	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	249	[lb/yr]
$$Qs = Max(Z/T, 4)$$		Q (lake outflow) =	366	[ac-ft/yr]
		V (modeled lake volume) =	417	[ac-ft]
		T = V/Q =	1.14	[yr]
		P_i = W/Q =	250.7	[µg/l]
Model Predicted In-Lake [TP]			**66.8**	**[ug/l]**
Observed In-Lake [TP]			**66.8**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$				
		P_{sed} (phosphorus sedimentation) =	**183**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**66**	**[lb/yr]**

LOAD			MODELED IN-LAKE WATER QUALITY PARAMETER
REDUC-TION	NET LOAD	NET LOAD	[TP]
[%]	[kg]	[lb]	[ug/L]
0%	113	249	66.8
5%	107	237	64.6
10%	102	224	62.3
15%	96	212	59.9
20%	90	199	57.5
25%	85	187	55.1
30%	79	175	52.6
35%	74	162	50.0
40%	68	150	47.3
45%	62	137	44.6
50%	57	125	41.7
55%	51	112	38.8
60%	45	100	35.7
65%	40	87	32.5
70%	34	75	29.1
75%	28	62	25.5
80%	23	50	21.6
85%	17	37	17.5
90%	11	25	12.8
95%	6	12	7.4

TMDL Loading Summary for Turbid

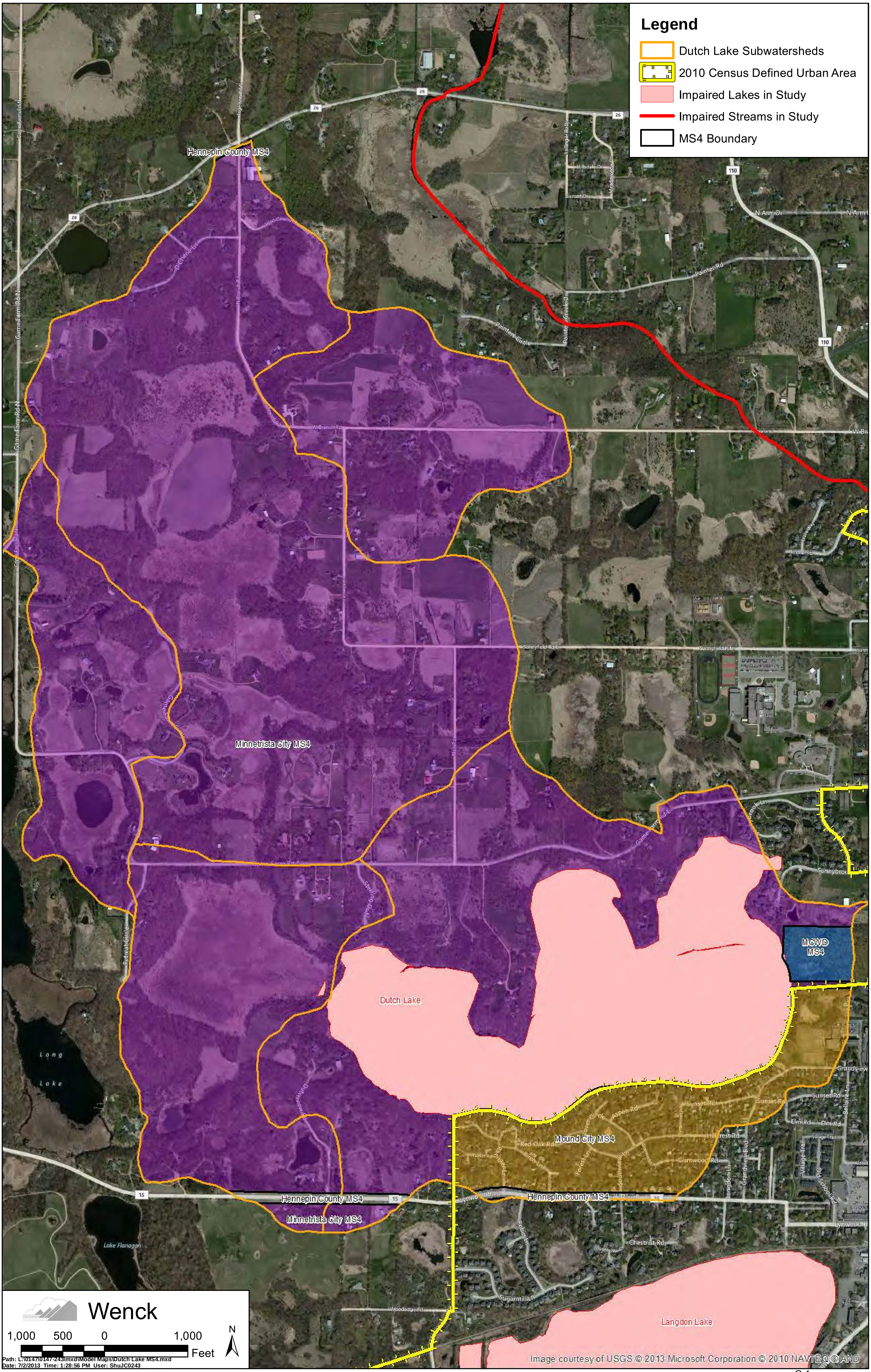
Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Reduction Factor	Load
Name	[acre]	[in/yr]	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1 Turbid	533	8.2	366	77.2	0.86	77
2						
3						
4						
5						
Summation	*533*	*8.2*	*366*			*77*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Turbid	533	10	0	6	0.0	0
2						
3						
4						
5						
Summation	*533*	*10*				*0*
Inflow from Upstream Lakes						
			Discharge	Estimated P Concentration	Reduction Factor	Load
Name			[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1				-	1.0	
2				-	1.0	
3				-	1.0	
Summation			*0*	-		*0*
Atmosphere						
Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Reduction Factor	Load
[acre]	[in/yr]	[in/yr]	[ac-ft/yr]	[lb/ac-yr]	[--]	[lb/yr]
40	30.7	30.7	0	0.24	1.0	10
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			
Groundwater						
Lake Area	Groundwater Flux		Net Inflow	Phosphorus Concentration	Reduction Factor	Load
[acre]	[m/yr]		[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
40	0.0		0	0	1.0	0
Internal						
Lake Area	Anoxic Factor			Release Rate	Reduction Factor	Load
[km^2]	[days]			[mg/m^2-day]	[--]	[lb/yr]
0.16			Oxic		1.0	
0.16	40.9		Anoxic	2.13	1.0	31
Summation						31
		Net Discharge [ac-ft/yr] =	**366**		**Net Load [lb/yr] =**	**117**

TMDL Lake Response Modeling for Turbid

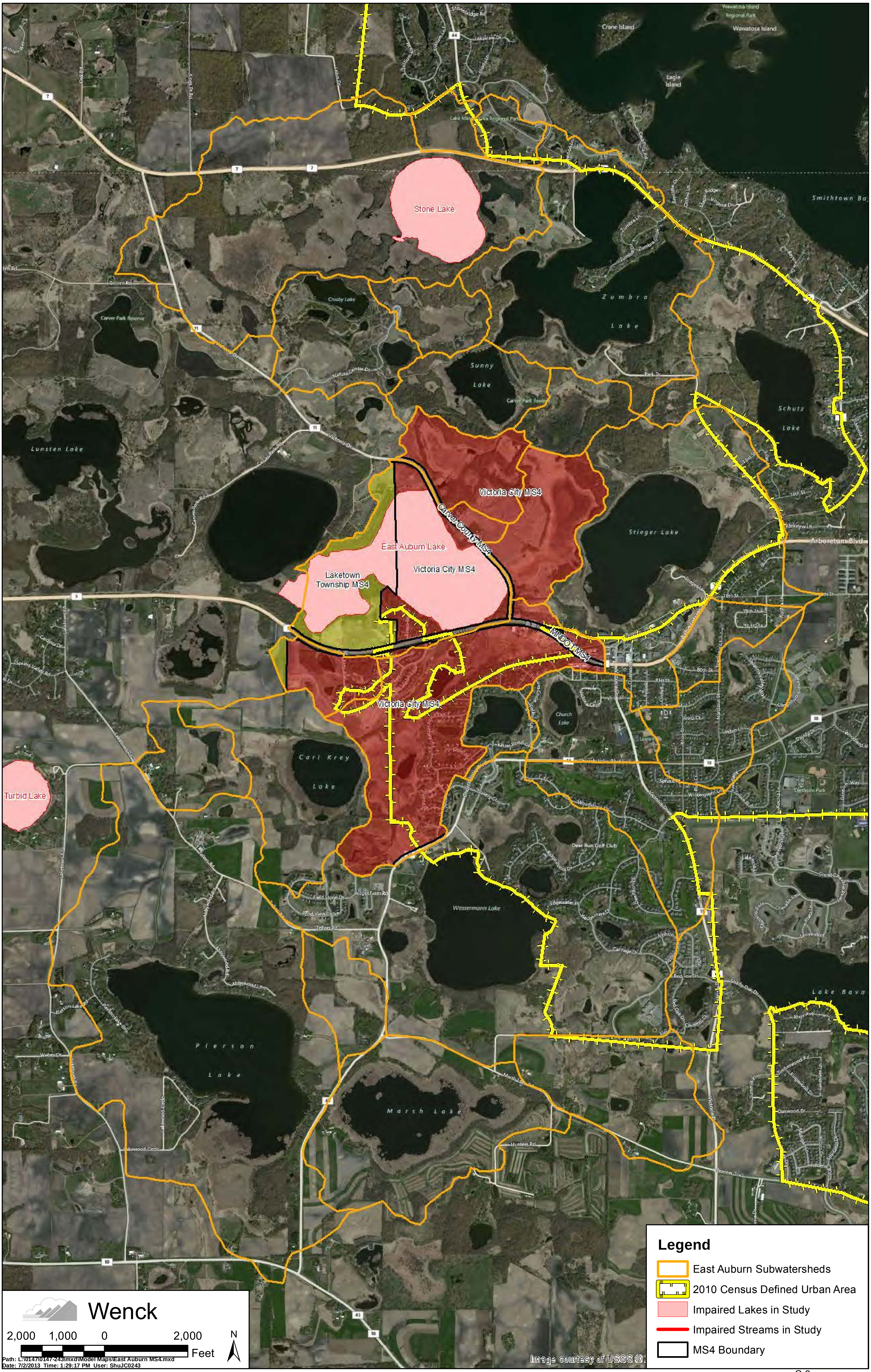
Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.26	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	117	[lb/yr]
	$Qs = Max(Z/T, 4)$	Q (lake outflow) =	366	[ac-ft/yr]
		V (modeled lake volume) =	417	[ac-ft]
		T = V/Q =	1.14	[yr]
		P_i = W/Q =	118.0	[µg/l]
Model Predicted In-Lake [TP]			**40.0**	**[ug/l]**
Goal In-Lake [TP]			**40.0**	**[ug/l]**
PHOSPHORUS SEDIMENTATION RATE				
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$			
		P_{sed} (phosphorus sedimentation) =	**78**	**[lb/yr]**
PHOSPHORUS OUTFLOW LOAD				
W-P_{sed} =			**40**	**[lb/yr]**

Appendix G

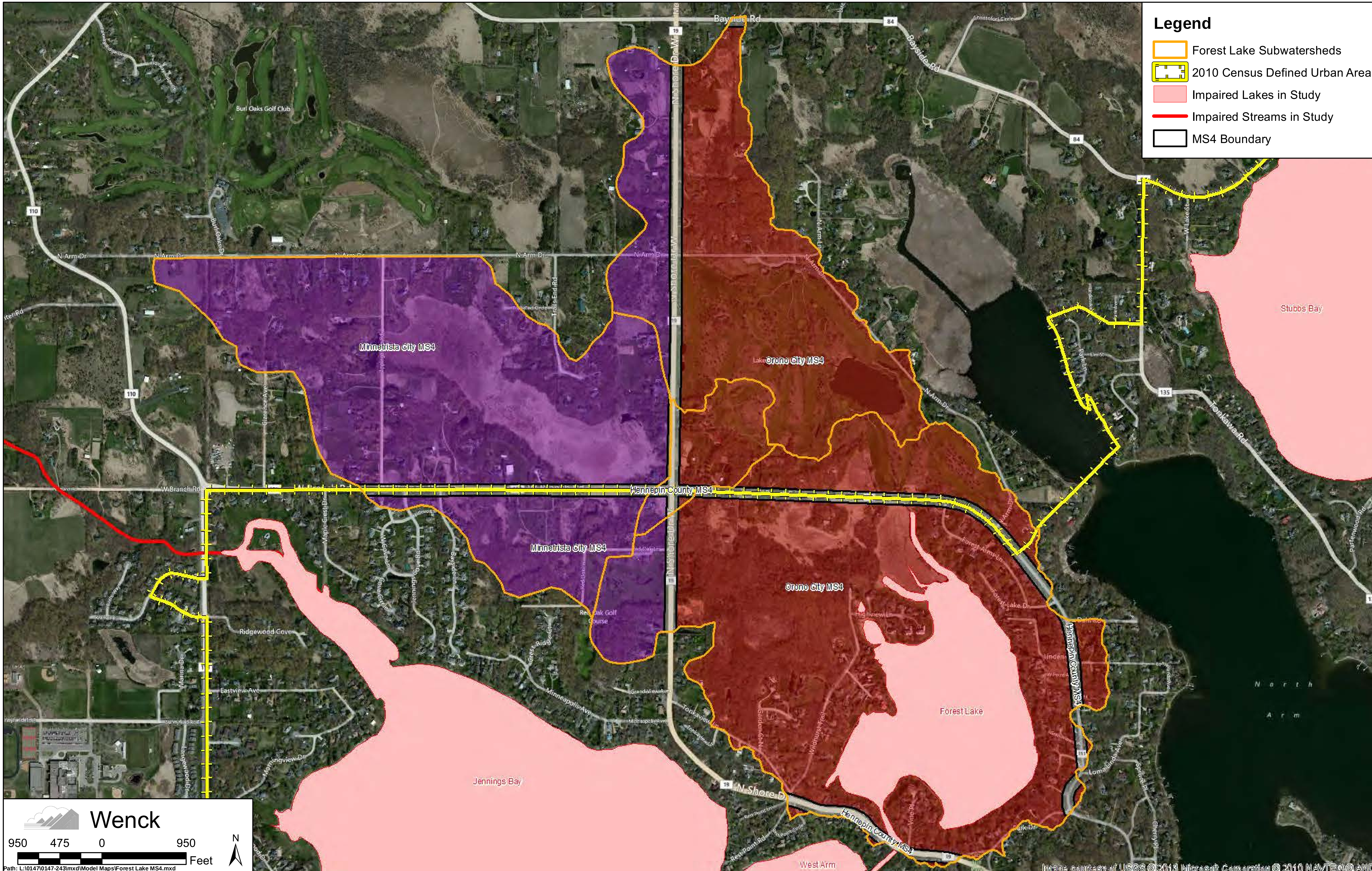
MS4 Figures

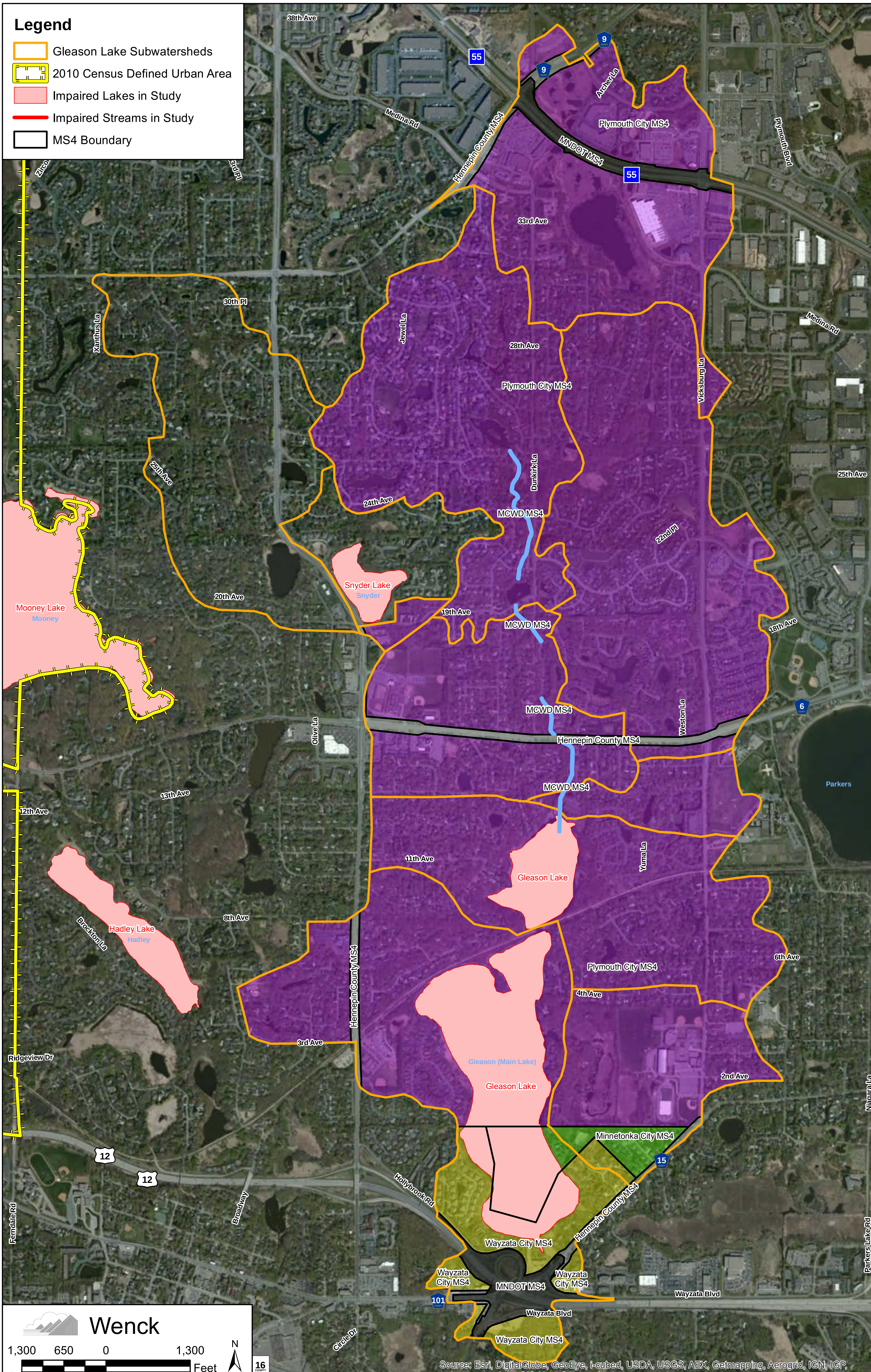


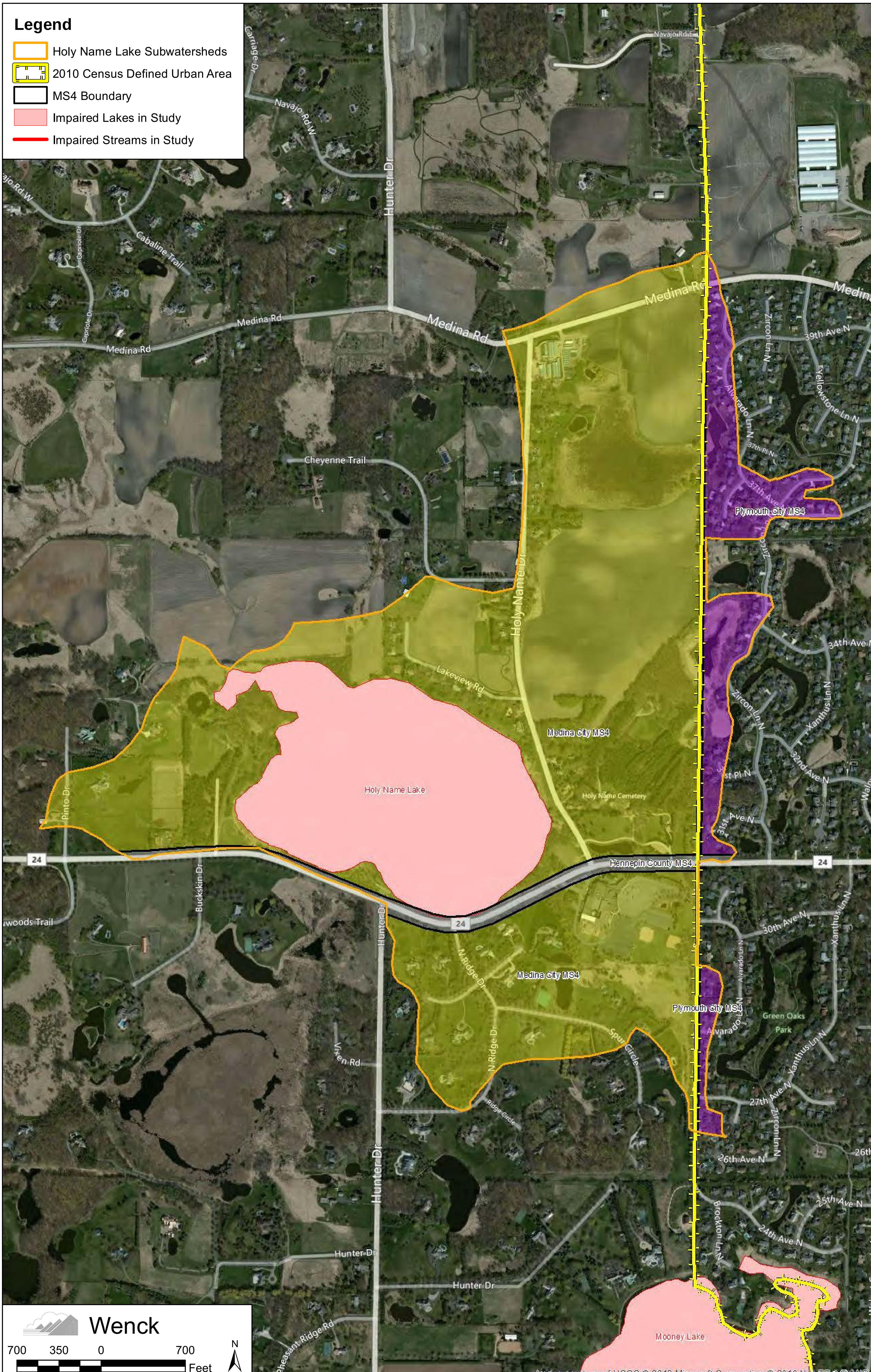
Path: L:\0147\0147-243\mxd\Model Maps\Dutch Lake MS4.mxd
Date: 7/2/2013 Time: 1:28:56 PM User: ShuJC0243

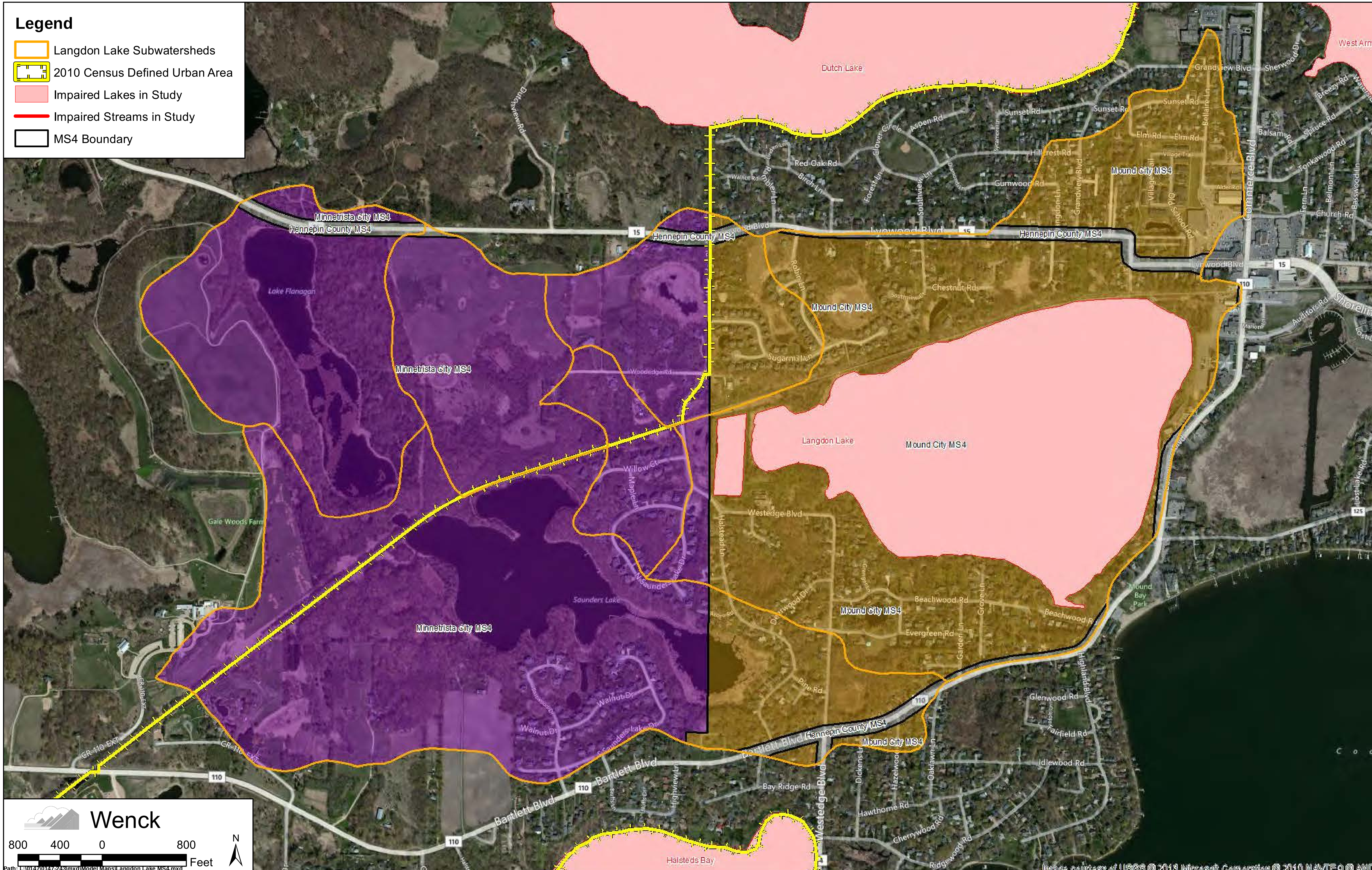


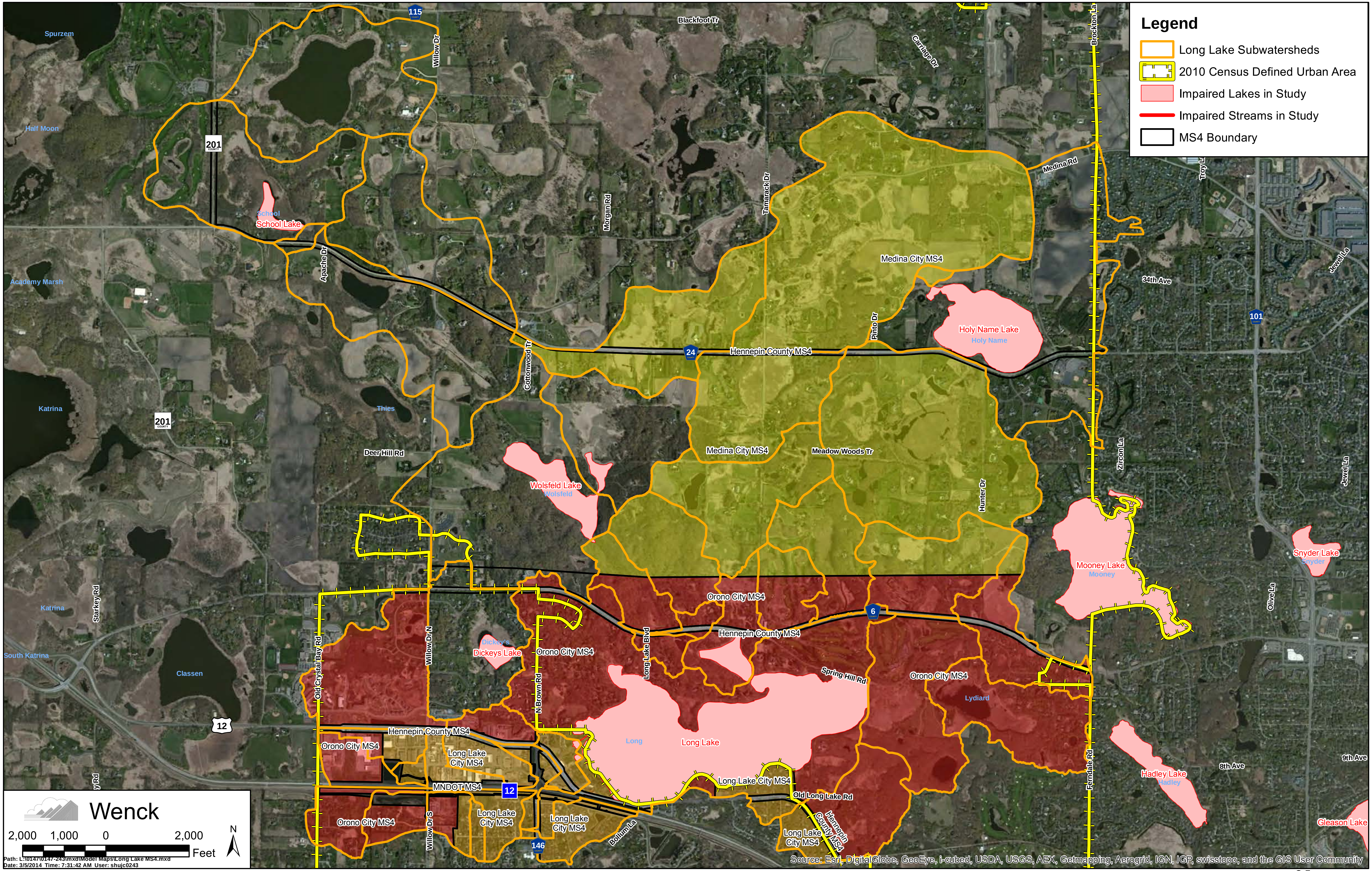
Stone Lake
Zumbra Lake
Sunny Lake
Crosby Lake
Lunsten Lake
Schutz Lake
Stieger Lake
Victoria City MS4
Carver County MS4
East Auburn Lake
Laketown Township MS4
MNDOT MS4
Church Lake
Carl Krey Lake
Turbid Lake
Wassermann Lake
Pierson Lake
Marsh Lake
Crane Island
Eagle Island
Wawatosa Island
Smithtown Bay
Lake Bavaria
Deer Run Golf Club
Arboretum Blvd
Legend
East Auburn Subwatersheds
2010 Census Defined Urban Area
Impaired Lakes in Study
Impaired Streams in Study
MS4 Boundary
Wenck
2,000 1,000 0 2,000
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\East Auburn MS4.mxd
Date: 7/2/2013 Time: 1:29:17 PM User: ShuJC0243
Image courtesy of USGS


Legend
Forest Lake Subwatersheds
2010 Census Defined Urban Area
Impaired Lakes in Study
Impaired Streams in Study
MS4 Boundary
Minnetrista City MS4
Orono City MS4
Hennepin County MS4
Forest Lake
Jennings Bay
Stubbs Bay
West Arm
North Arm
Burl Oaks Golf Club
Red Oak Golf Course
Bayside Rd
N Arm Dr
W Branch Rd
Ridgewood Cove
Eastview Ave
Minneapolis Ave
Tonkawa Rd
N Shore Dr
Wenck
950 475 0 950
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Forest Lake MS4.mxd
Date: 7/2/2013 Time: 1:29:41 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

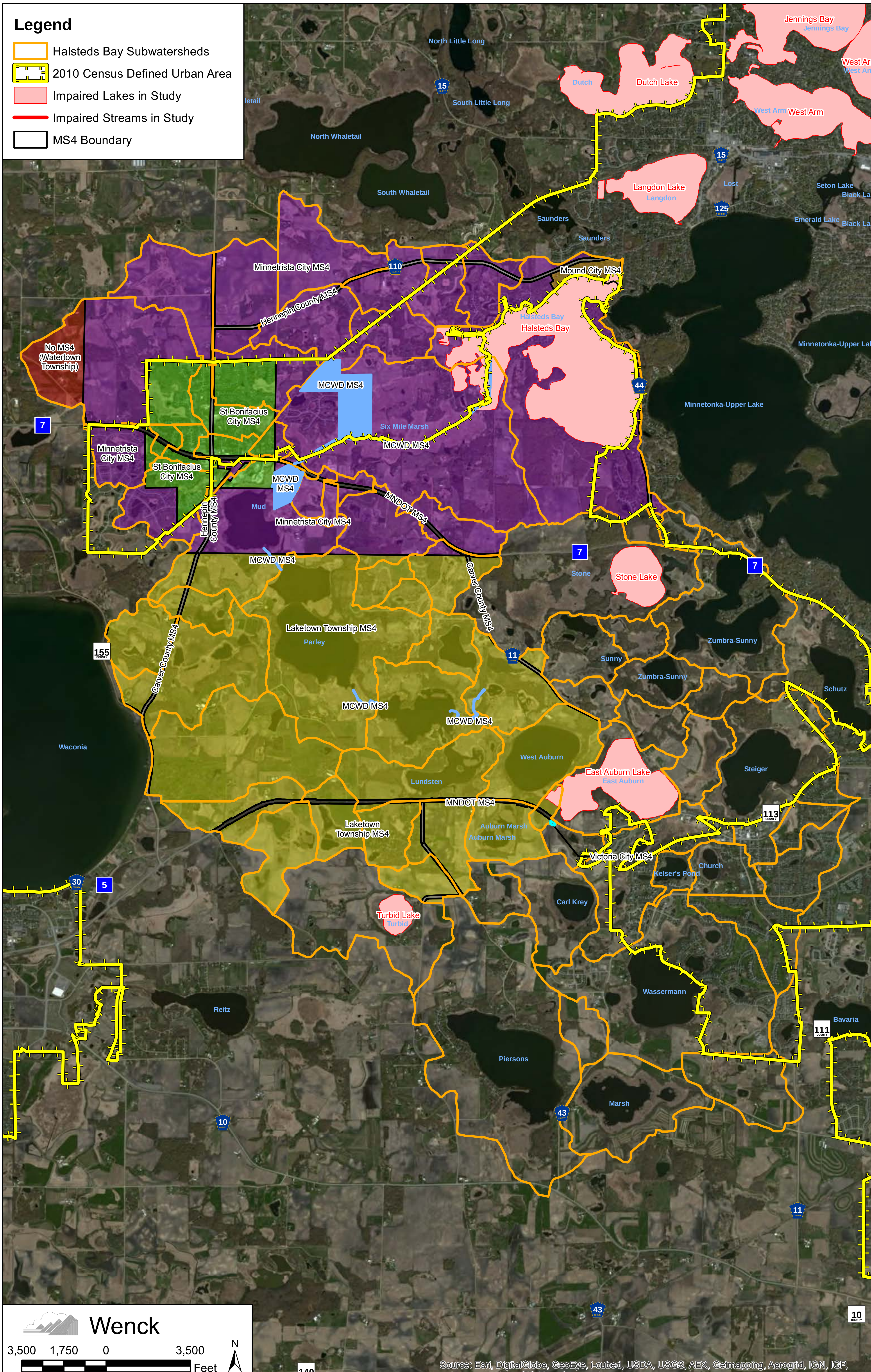

Legend
Gleason Lake Subwatersheds
2010 Census Defined Urban Area
Impaired Lakes in Study
Impaired Streams in Study
MS4 Boundary
Plymouth City MS4
MNDOT MS4
Hennepin County MS4
MCWD MS4
Minnetonka City MS4
Wayzata City MS4
Mooney Lake
Mooney
Snyder Lake
Snyder
Hadley Lake
Hadley
Gleason Lake
Gleason (Main Lake)
Parkers
38th Ave
Medina Rd
Archer La
Plymouth Blvd
33rd Ave
30th Pl
Xanthus La
Jewel La
28th Ave
Vicksburg La
25th Ave
Dunkirk La
24th Ave
22nd Pl
20th Ave
19th Ave
18th Ave
Weston La
Olive La
13th Ave
12th Ave
11th Ave
Yuma La
8th Ave
Brockton La
6th Ave
4th Ave
3rd Ave
2nd Ave
Ridgeview Dr
Niagara La
Hollybrook Rd
Broadway
Ferndale Rd
Parkers Lake Rd
Wayzata Blvd
Circle Dr
Wenck
1,300 650 0 1,300
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Gleason Lake MS4.mxd
Date: 3/5/2014 Time: 7:31:44 AM User: shujc0243
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community


Legend
Holy Name Lake Subwatersheds
2010 Census Defined Urban Area
MS4 Boundary
Impaired Lakes in Study
Impaired Streams in Study
Holy Name Lake
Mooney Lake
Medina City MS4
Plymouth City MS4
Hennepin County MS4
Holy Name Cemetery
Green Oaks Park
Medina Rd
Hunter Dr
Holy Name Dr
Cheyenne Trail
Lakeview Rd
Navajo Rd W
Cabaline Trail
Pinto Dr
Buckskin Dr
N Ridge Dr
Spur Circle
Ridge Circle
Vixen Rd
Pheasant Ridge Rd
Carriage Dr
Zircon Ln N
Alvarado Ln N
Xanthus Ln N
Yellowstone Ln N
39th Ave N
37th Ave
34th Ave N
32nd Ave N
31st Ave N
30th Ave N
27th Ave N
26th Ave N
25th Ave N
24th Ave N
Brockton Ln N
Walnut Grove Ln N
24
Wenck
700 350 0 700
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Holy Name MS4.mxd
Date: 7/2/2013 Time: 1:30:46 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

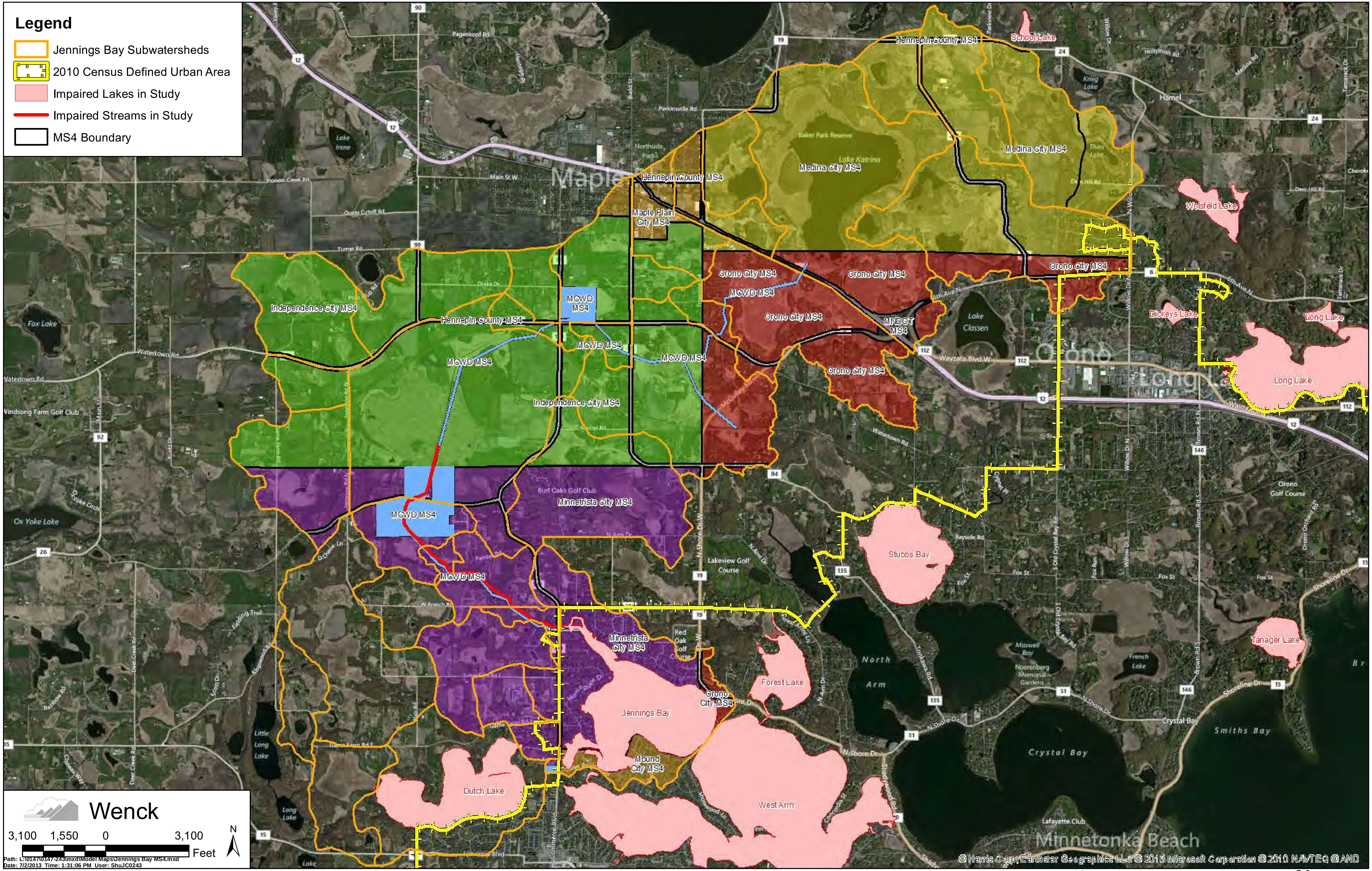

Legend
Langdon Lake Subwatersheds
2010 Census Defined Urban Area
Impaired Lakes in Study
Impaired Streams in Study
MS4 Boundary
Dutch Lake
West Arm
Lake Flanagan
Langdon Lake
Saunders Lake
Halsteds Bay
Minnetrista City MS4
Hennepin County MS4
Mound City MS4
Lynwood Blvd
Bartlett Blvd
Commerce Blvd
Westedge Blvd
Shoreline
Gale Woods Farm
Mound Bay Park
Wenck
800 400 0 800
Feet
N
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND
Path: L:\0147\0147-243\mxd\Model Maps\Langdon Lake MS4.mxd
Date: 7/2/2013 Time: 1:32:35 PM User: ShuJC0243

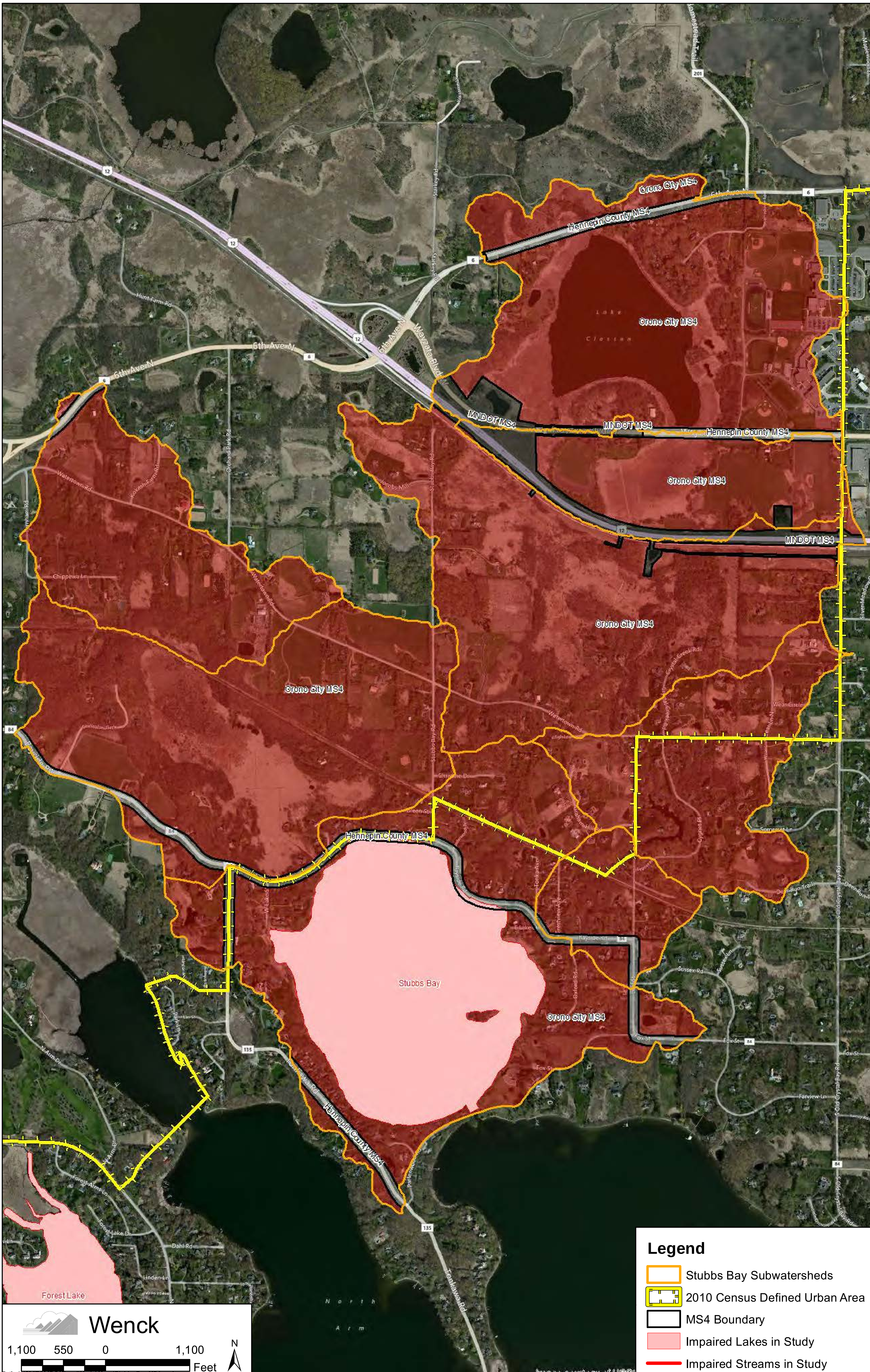


Legend
Long Lake Subwatersheds
2010 Census Defined Urban Area
Impaired Lakes in Study
Impaired Streams in Study
MS4 Boundary
Medina City MS4
Hennepin County MS4
Orono City MS4
Long Lake City MS4
MNDOT MS4
School Lake
Holy Name Lake
Wolsfeld Lake
Mooney Lake
Snyder Lake
Dickeys Lake
Long Lake
Hadley Lake
Gleason Lake
Lydiard
Spurzem
Half Moon
Academy Marsh
Katrina
Thies
Classen
South Katrina
Blackfoot Tr
Willow Dr
Carriage Dr
Brockton La
Medina Rd
Troy La
Jewel La
34th Ave
Tamarack Dr
Morgan Rd
Apache Dr
Pinto Dr
Cottonwood Tr
Deer Hill Rd
Meadow Woods Tr
Hunter Dr
Zircon La
Olive La
Starkey Rd
Old Crystal Bay Rd
Willow Dr N
N Brown Rd
Long Lake Blvd
Spring Hill Rd
Old Long Lake Rd
Willow Dr S
Bollum La
Fernbrook La
8th Ave
9th Ave
Wenck
2,000 1,000 0 2,000
Feet
N
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

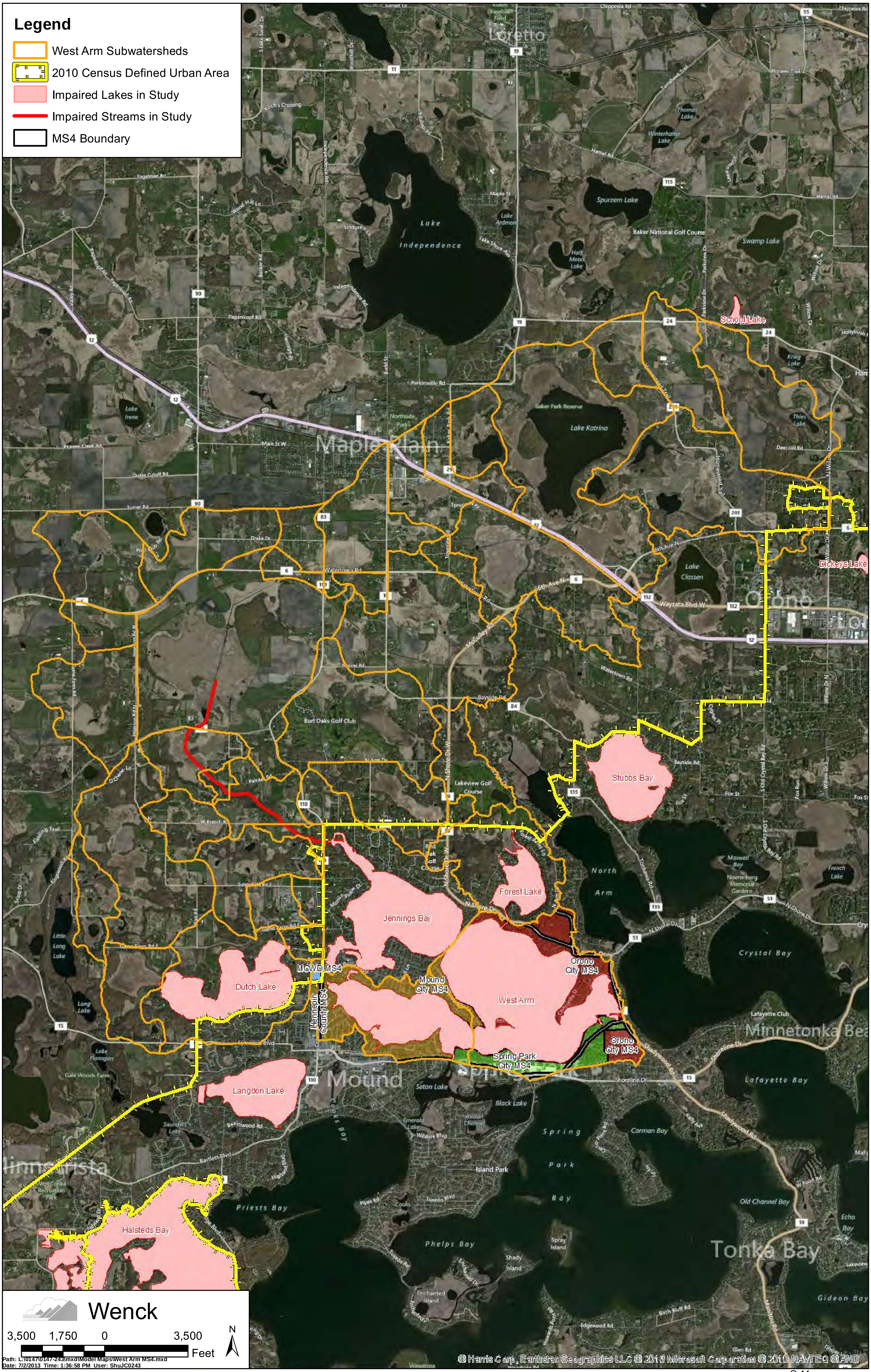


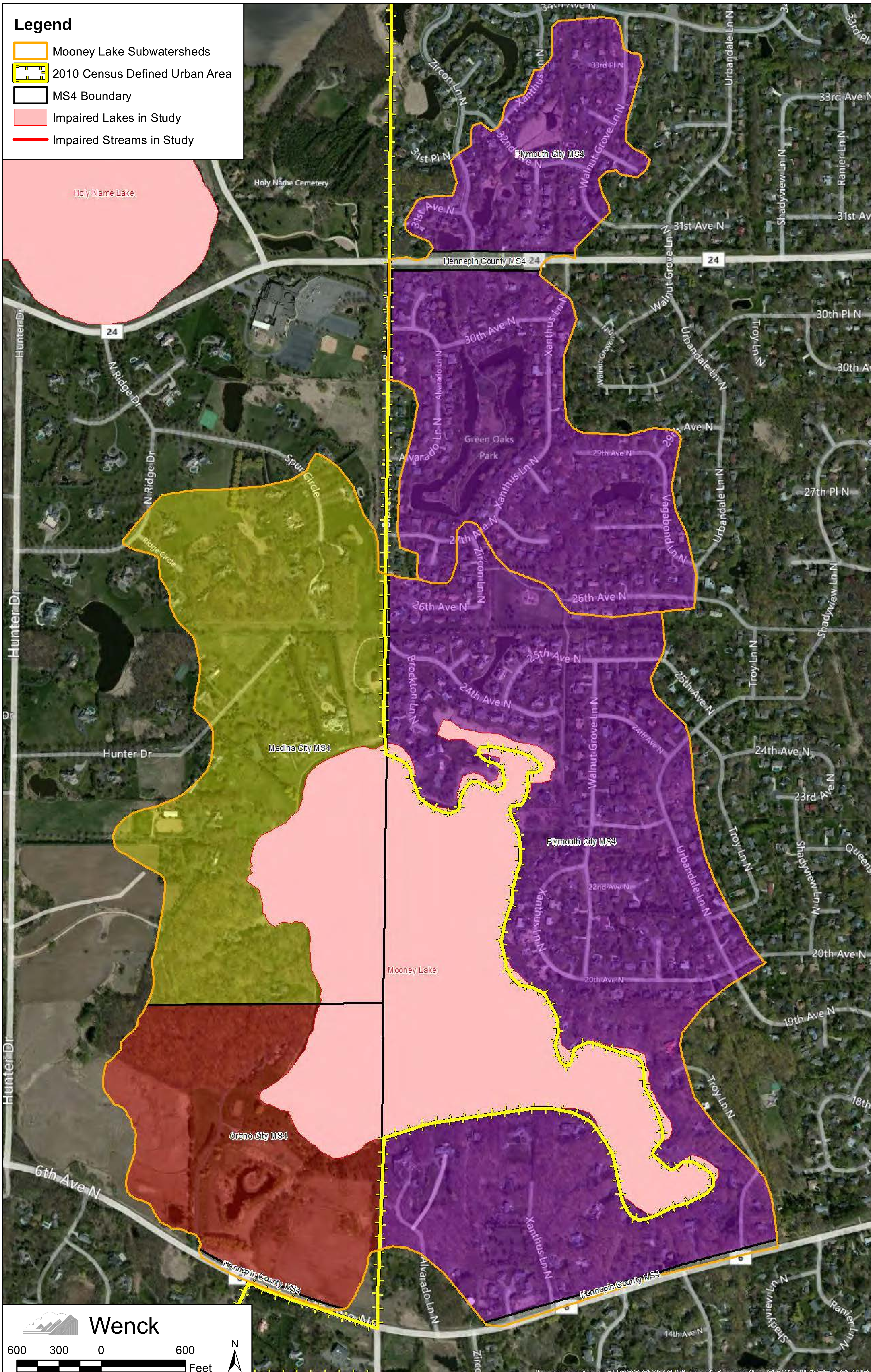
Legend
Halsteds Bay Subwatersheds
2010 Census Defined Urban Area
Impaired Lakes in Study
Impaired Streams in Study
MS4 Boundary
Minnetrista City MS4
Hennepin County MS4
Mound City MS4
Halsteds Bay
No MS4 (Watertown Township)
St Bonifacius City MS4
MCWD MS4
Six Mile Marsh
Minnetrista City MS4
St Bonifacius City MS4
MCWD MS4
Mud
Hennepin County MS4
MNDOT MS4
Carver County MS4
Laketown Township MS4
Parley
Carver County MS4
MCWD MS4
West Auburn
East Auburn Lake
East Auburn
Lundsten
MNDOT MS4
Laketown Township MS4
Auburn Marsh
Victoria City MS4
Turbid Lake
Turbid
Stone Lake
Stone
Langdon Lake
Langdon
Dutch Lake
Dutch
Jennings Bay
West Arm
North Little Long
South Little Long
North Whaletail
South Whaletail
Saunders
Lost
Seton Lake
Black Lake
Emerald Lake
Minnetonka-Upper Lake
Zumbra-Sunny
Sunny
Schutz
Steiger
Church
Kelser's Pond
Carl Krey
Wassermann
Bavaria
Piersons
Marsh
Reitz
Waconia
Wenck
3,500 1,750 0 3,500
Feet
N
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Date: 3/5/2014 Time: 7:15:36 AM User: shujc0243

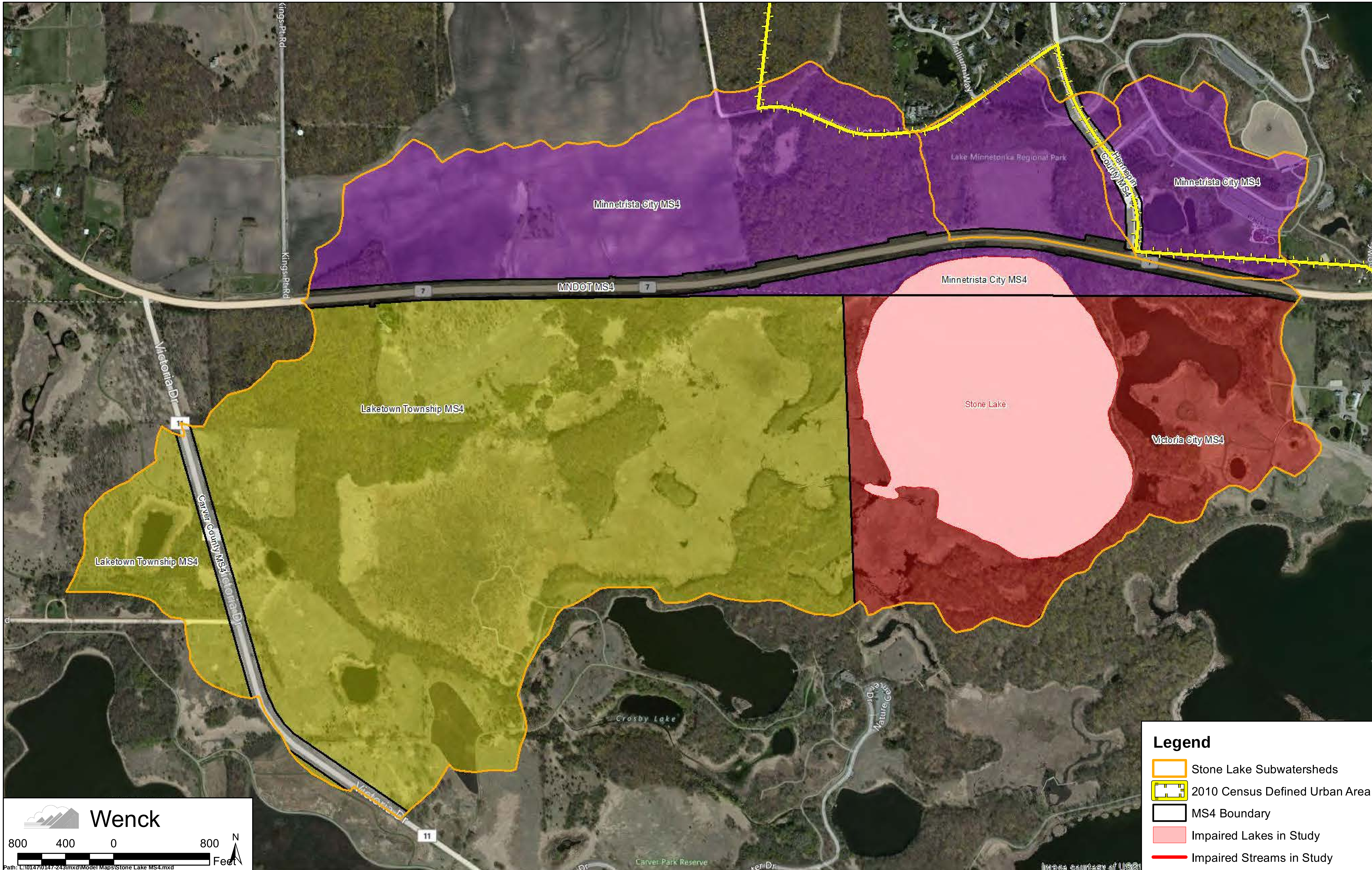

Legend
Jennings Bay Subwatersheds
2010 Census Defined Urban Area
Impaired Lakes in Study
Impaired Streams in Study
MS4 Boundary
Hennepin County MS4
Medina City MS4
Maple Plain City MS4
Orono City MS4
MCWD MS4
MNDOT MS4
Independence City MS4
Minnetrista City MS4
Mound City MS4
School Lake
Wolsfeld Lake
Dickeys Lake
Long Lake
Stubbs Bay
Forest Lake
Jennings Bay
Dutch Lake
West Arm
Tanager Lake
Lake Katrina
Baker Park Reserve
Lake Classen
North Arm
Crystal Bay
Smiths Bay
Minnetonka Beach
Burl Oaks Golf Club
Lakeview Golf Course
Red Oak Golf Course
Wenck
3,100 1,550 0 3,100
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Jennings Bay MS4.mxd
Date: 7/2/2013 Time: 1:31:06 PM User: ShuJC0243
© Harris Corp, Earthstar Geographics LLC © 2013 Microsoft Corporation © 2010 NAVTEQ © AND



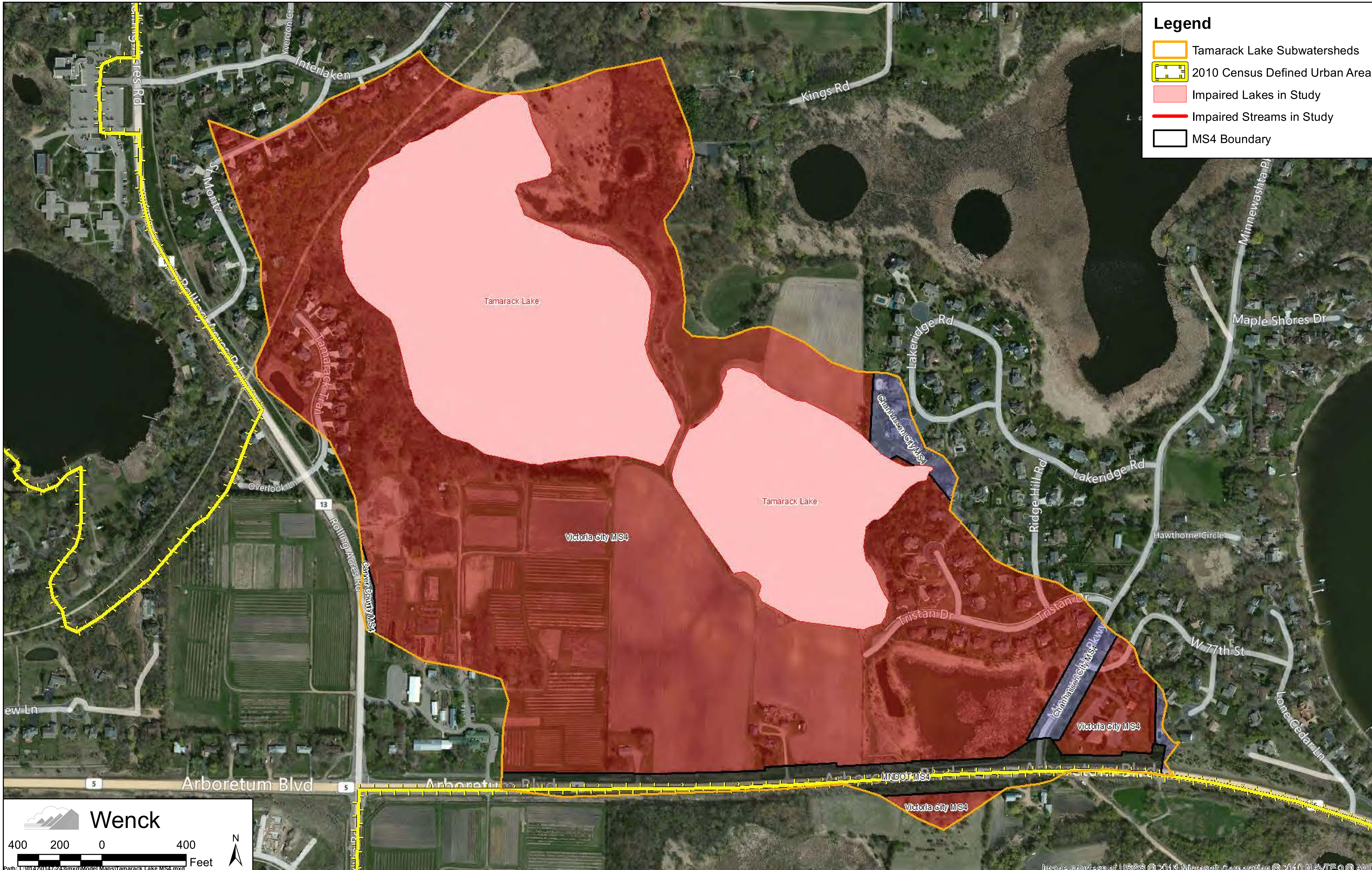
Legend
Stubbs Bay Subwatersheds
2010 Census Defined Urban Area
MS4 Boundary
Impaired Lakes in Study
Impaired Streams in Study
Wenck
1,100 550 0 1,100
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Stubbs Bay MS4.mxd
Date: 7/2/2013 Time: 1:34:44 PM User: ShuJC0243
Image courtesy of USGS
Orono City MS4
Hennepin County MS4
MNDOT MS4
Stubbs Bay
Lake Classen
Forest Lake
North Arm
6th Ave N
Wayzata Blvd
Watertown Rd
Stubbs Bay Rd
Tonkawa Rd
Fox St

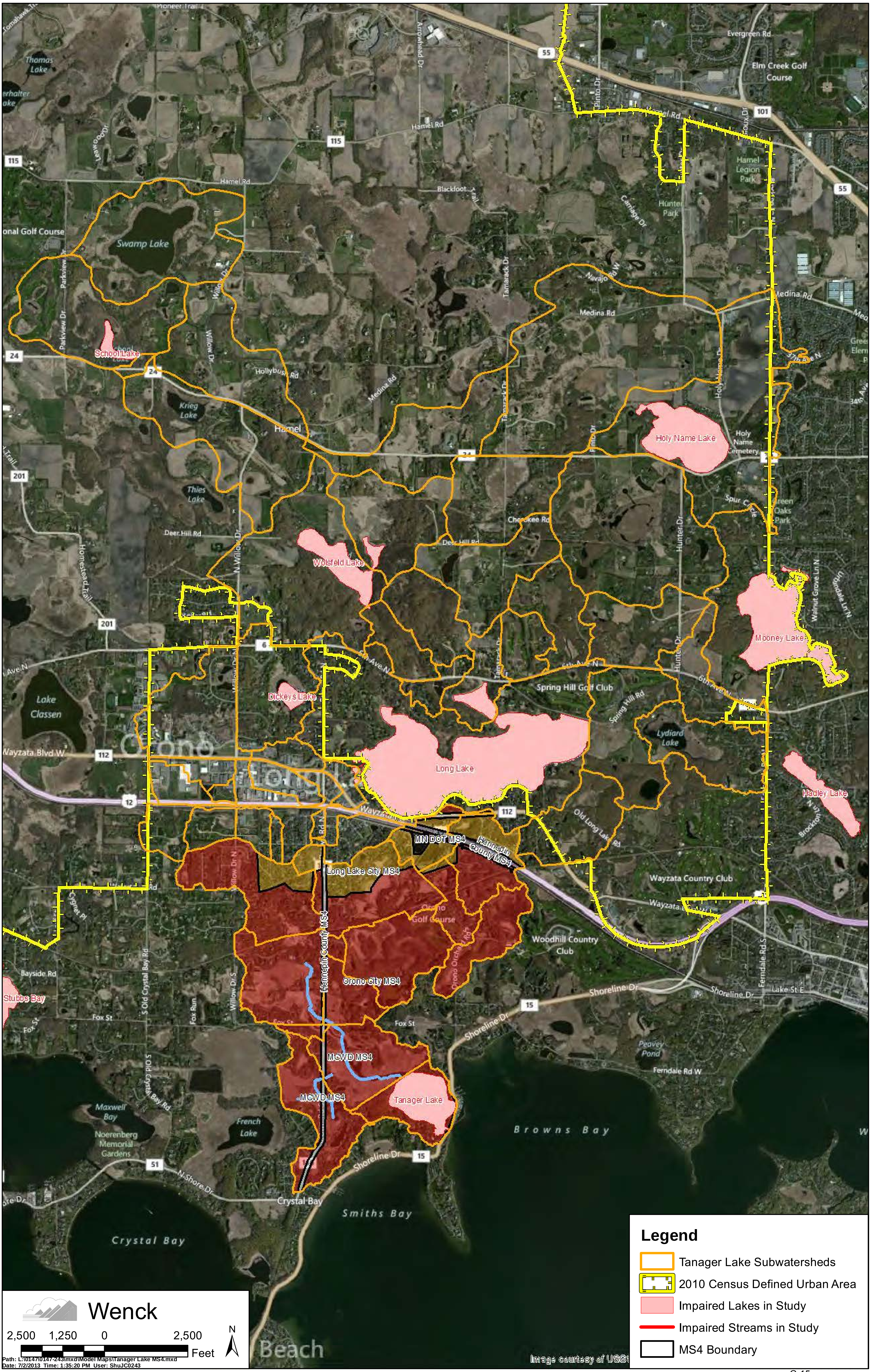

Legend
West Arm Subwatersheds
2010 Census Defined Urban Area
Impaired Lakes in Study
Impaired Streams in Study
MS4 Boundary
Loretto
Lake Independence
Spurzem Lake
Swamp Lake
School Lake
Baker Park Reserve
Lake Katrina
Maple Plain
Lake Classen
Orono
Dickeys Lake
Stubbs Bay
Forest Lake
Jennings Bay
North Arm
Crystal Bay
Dutch Lake
MCWD MS4
Hennepin County MS4
Mound City MS4
Orono City MS4
West Arm
Spring Park City MS4
Langdon Lake
Mound
Minnetonka Beach
Lafayette Bay
Spring Park Bay
Priests Bay
Phelps Bay
Minnetrista
Halsteds Bay
Tonka Bay
Wenck
3,500 1,750 0 3,500
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\West Arm MS4.mxd
Date: 7/2/2013 Time: 1:36:58 PM User: ShuJC0243
© Harris Corp, Earthstar Geographics LLC © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

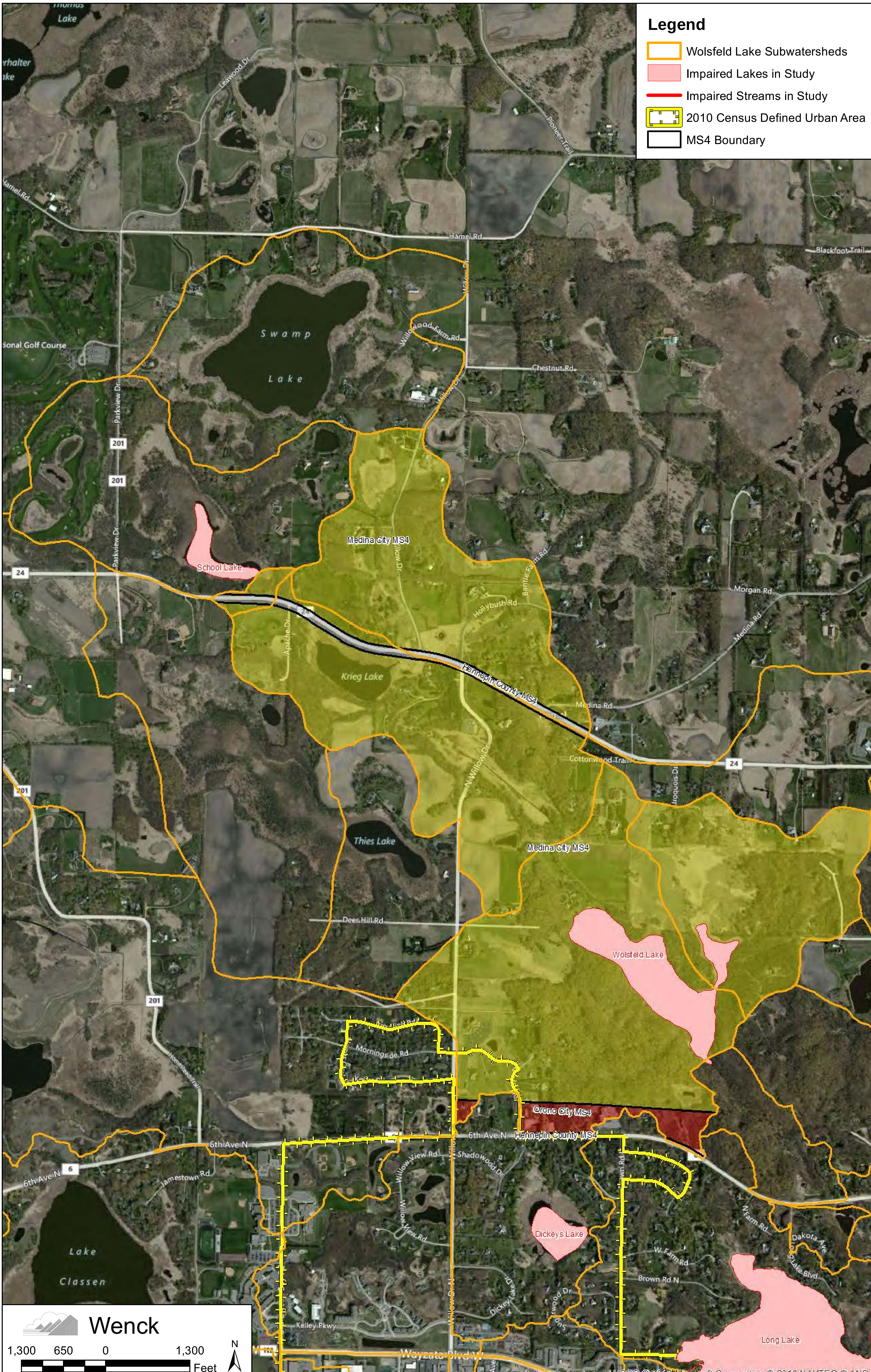

Legend
Mooney Lake Subwatersheds
2010 Census Defined Urban Area
MS4 Boundary
Impaired Lakes in Study
Impaired Streams in Study
Holy Name Lake
Holy Name Cemetery
Plymouth City MS4
Hennepin County MS4
Medina City MS4
Orono City MS4
Mooney Lake
Green Oaks Park
Wenck
600 300 0 600
Feet
N
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND
Path: L:\0147\0147-243\mxd\Model Maps\Mooney Lake MS4.mxd
Date: 7/2/2013 Time: 1:33:25 PM User: ShuJC0243



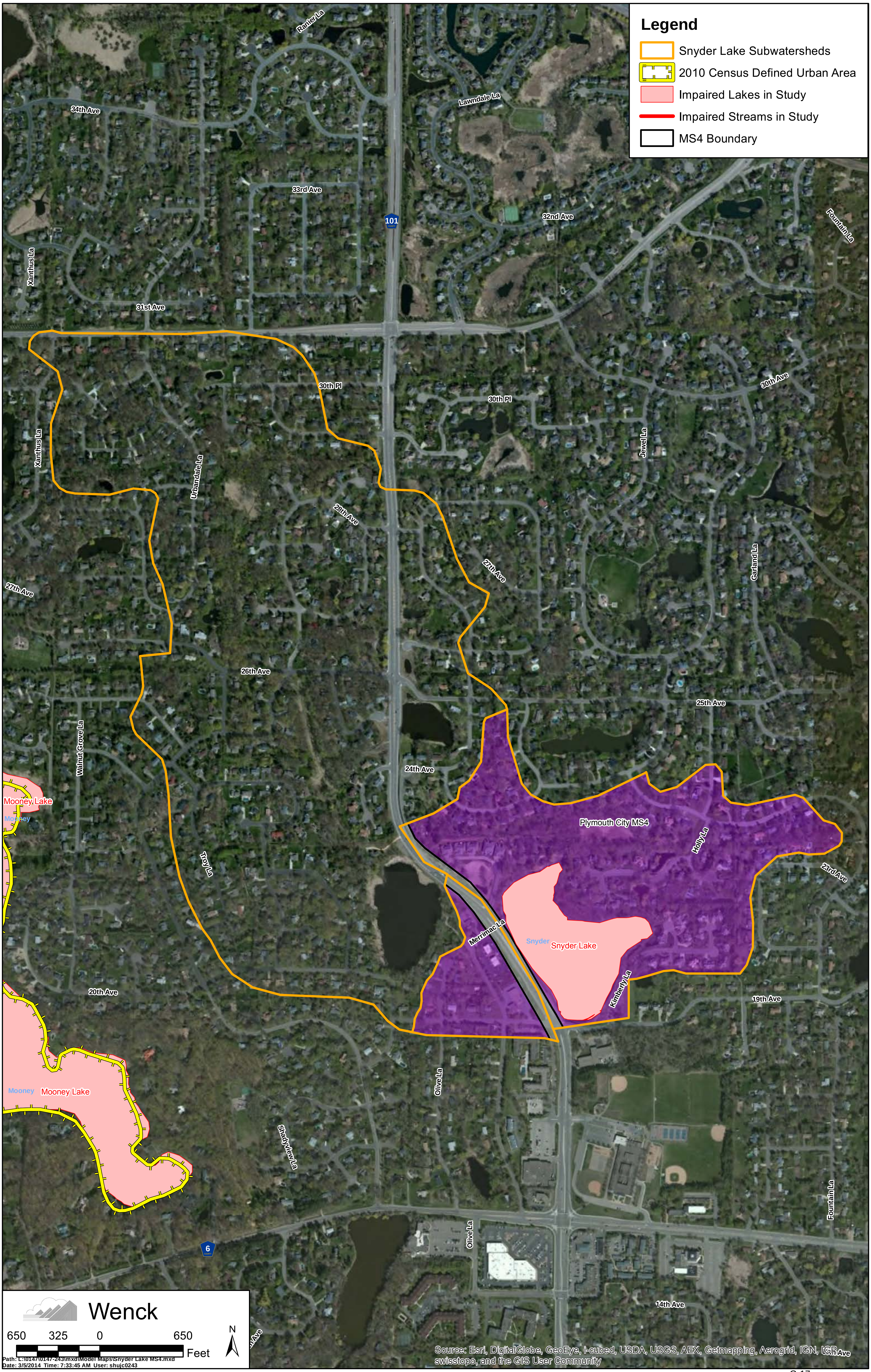
Minnetrista City MS4
Lake Minnetonka Regional Park
Hennepin County MS4
Minnetrista City MS4
MNDOT MS4
Minnetrista City MS4
Stone Lake
Victoria City MS4
Laketown Township MS4
Laketown Township MS4
Carver County MS4
Victoria Dr
Kings Pt Rd
Trillium Way
Crosby Lake
Carver Park Reserve
Legend
Stone Lake Subwatersheds
2010 Census Defined Urban Area
MS4 Boundary
Impaired Lakes in Study
Impaired Streams in Study
Wenck
800 400 0 800
Feet
N
Image courtesy of USGS
Path: L:\0147\0147-243\mxd\Model Maps\Stone Lake MS4.mxd
Date: 7/2/2013 Time: 1:34:35 PM User: ShuJC0243

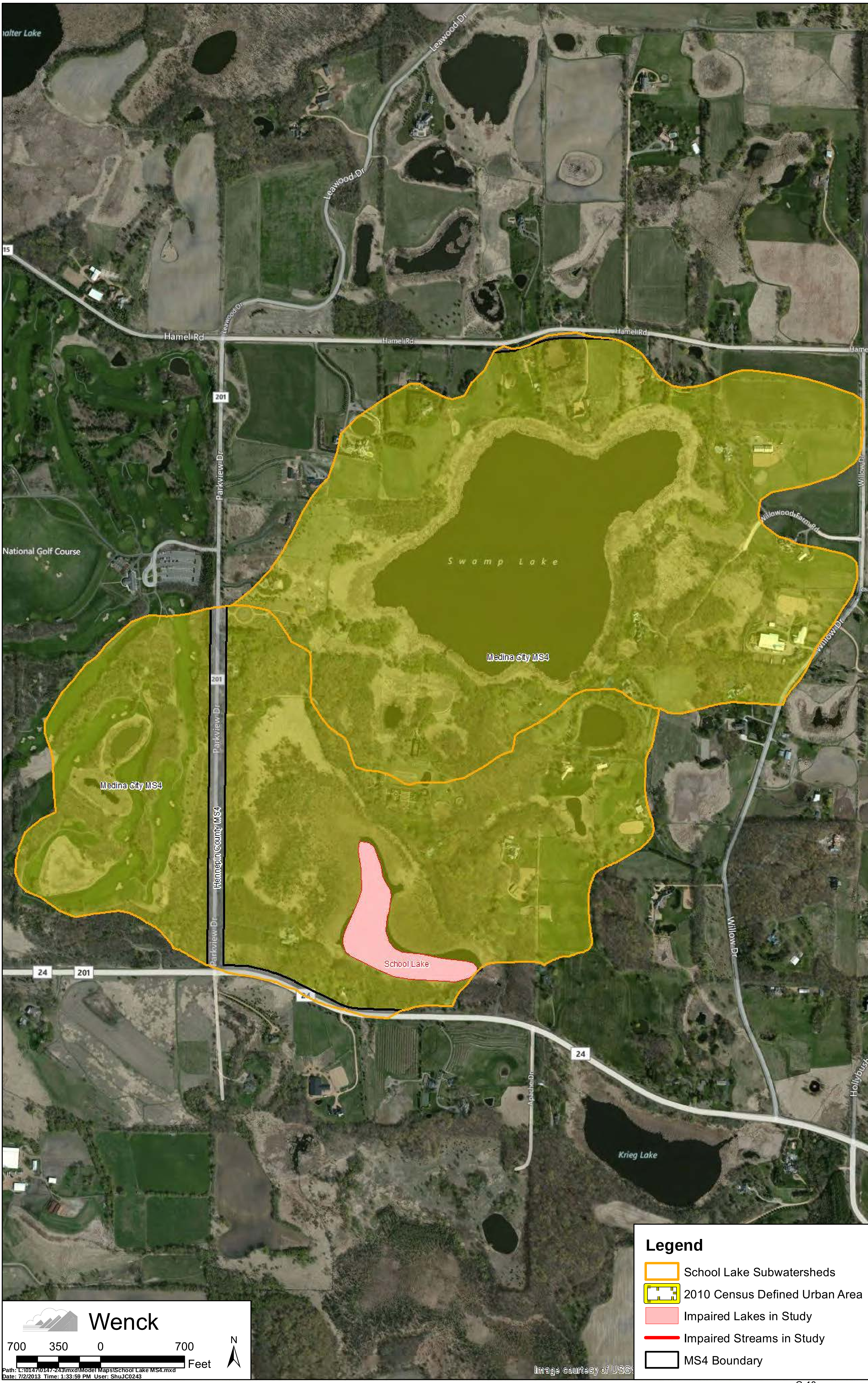

Legend
Tamarack Lake Subwatersheds
2010 Census Defined Urban Area
Impaired Lakes in Study
Impaired Streams in Study
MS4 Boundary
Tamarack Lake
Tamarack Lake
Victoria City MS4
Victoria City MS4
Victoria City MS4
Chanhassen City MS4
Chanhassen City MS4
Carver County MS4
MNDOT MS4
Interlaken
Kings Rd
St Moritz
Tamarack Trail
Overlook Ln
Rolling Acres Rd
Arboretum Blvd
Lakeridge Rd
Lakeridge Rd
Ridge Hill Rd
Maple Shores Dr
Minnewashta Pl
Hawthorne Circle
Tristan Dr
Tristan Dr
W 77th St
Lone Cedar Ln
13
5
5
Wenck
400 200 0 400
Feet
N
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND


Swamp Lake
School Lake
Krieg Lake
Thies Lake
Hamel
Wolsfeld Lake
Dickey's Lake
Lake Classen
Long Lake
Holy Name Lake
Holy Name Cemetery
Mooney Lake
Lydiard Lake
Hadley Lake
Spring Hill Golf Club
Wayzata Country Club
Woodhill Country Club
Elm Creek Golf Course
Hamel Legion Park
Hunter Park
Green Oaks Park
Orono Golf Course
MN DOT MS4
Hennepin County MS4
Long Lake City MS4
Orono City MS4
MCWD MS4
Tanager Lake
Stubbs Bay
Maxwell Bay
Noerenberg Memorial Gardens
French Lake
Peavey Pond
Browns Bay
Smiths Bay
Crystal Bay
Thomas Lake
Hamel Rd
Medina Rd
Deer Hill Rd
Cherokee Rd
Wayzata Blvd W
Shoreline Dr
Fox St
Bayside Rd
Legend
Tanager Lake Subwatersheds
2010 Census Defined Urban Area
Impaired Lakes in Study
Impaired Streams in Study
MS4 Boundary
Wenck
2,500 1,250 0 2,500
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Tanager Lake MS4.mxd
Date: 7/2/2013 Time: 1:35:20 PM User: ShuJC0243
Image courtesy of USGS

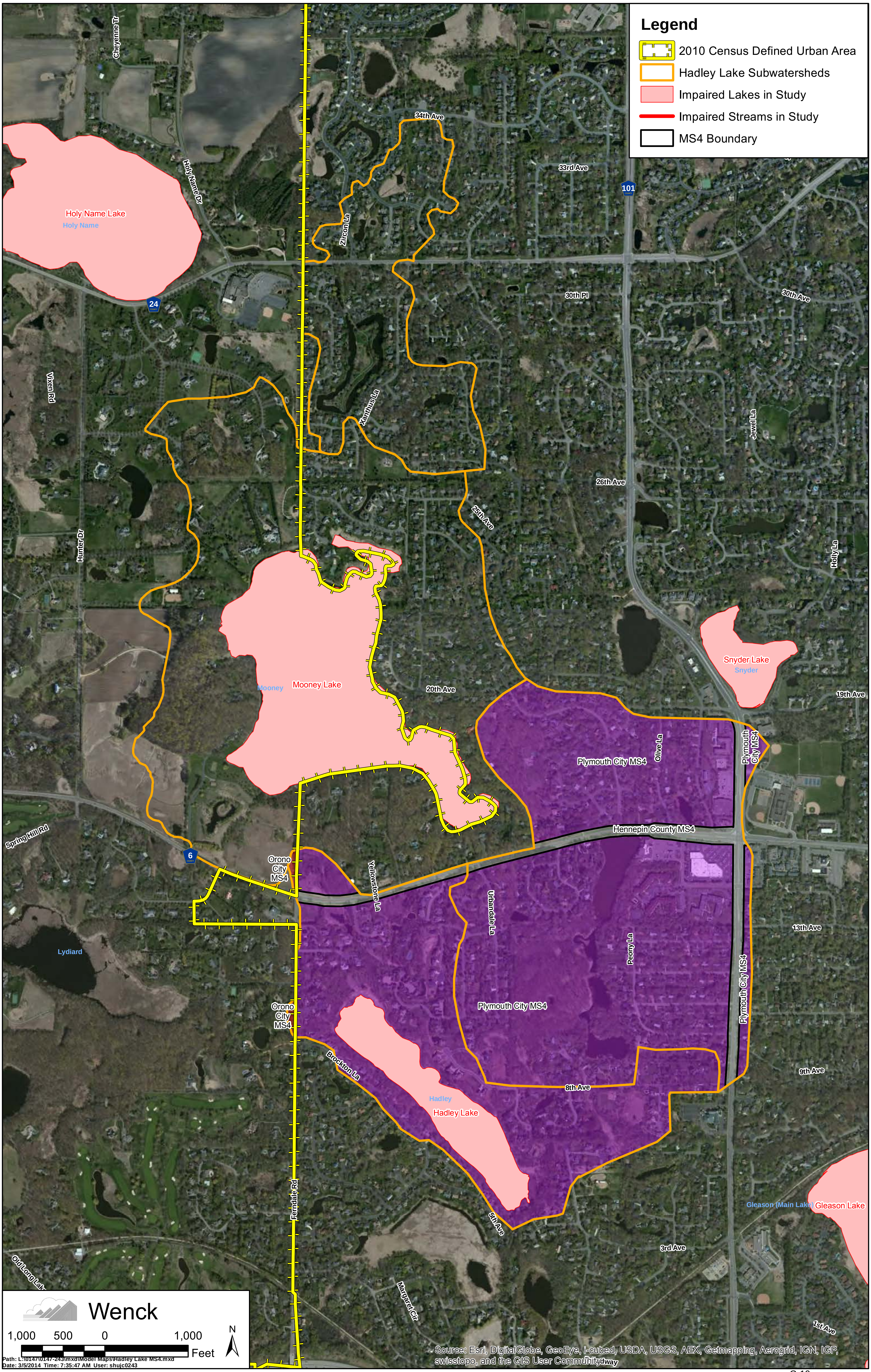


Legend
Wolsfeld Lake Subwatersheds
Impaired Lakes in Study
Impaired Streams in Study
2010 Census Defined Urban Area
MS4 Boundary
Swamp Lake
School Lake
Krieg Lake
Thies Lake
Wolsfeld Lake
Dickeys Lake
Long Lake
Lake Classen
Medina City MS4
Hennepin County MS4
Orono City MS4
Hamel Rd
Chestnut Rd
Morgan Rd
Medina Rd
Cottonwood Trail
Deer Hill Rd
6th Ave N
Wayzata Blvd W
Wenck
1,300 650 0 1,300
Feet
N
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND
Path: L:\0147\0147-243\mxd\Model Maps\Wolsfeld Lake MS4.mxd
Date: 7/2/2013 Time: 1:37:35 PM User: ShuJC0243

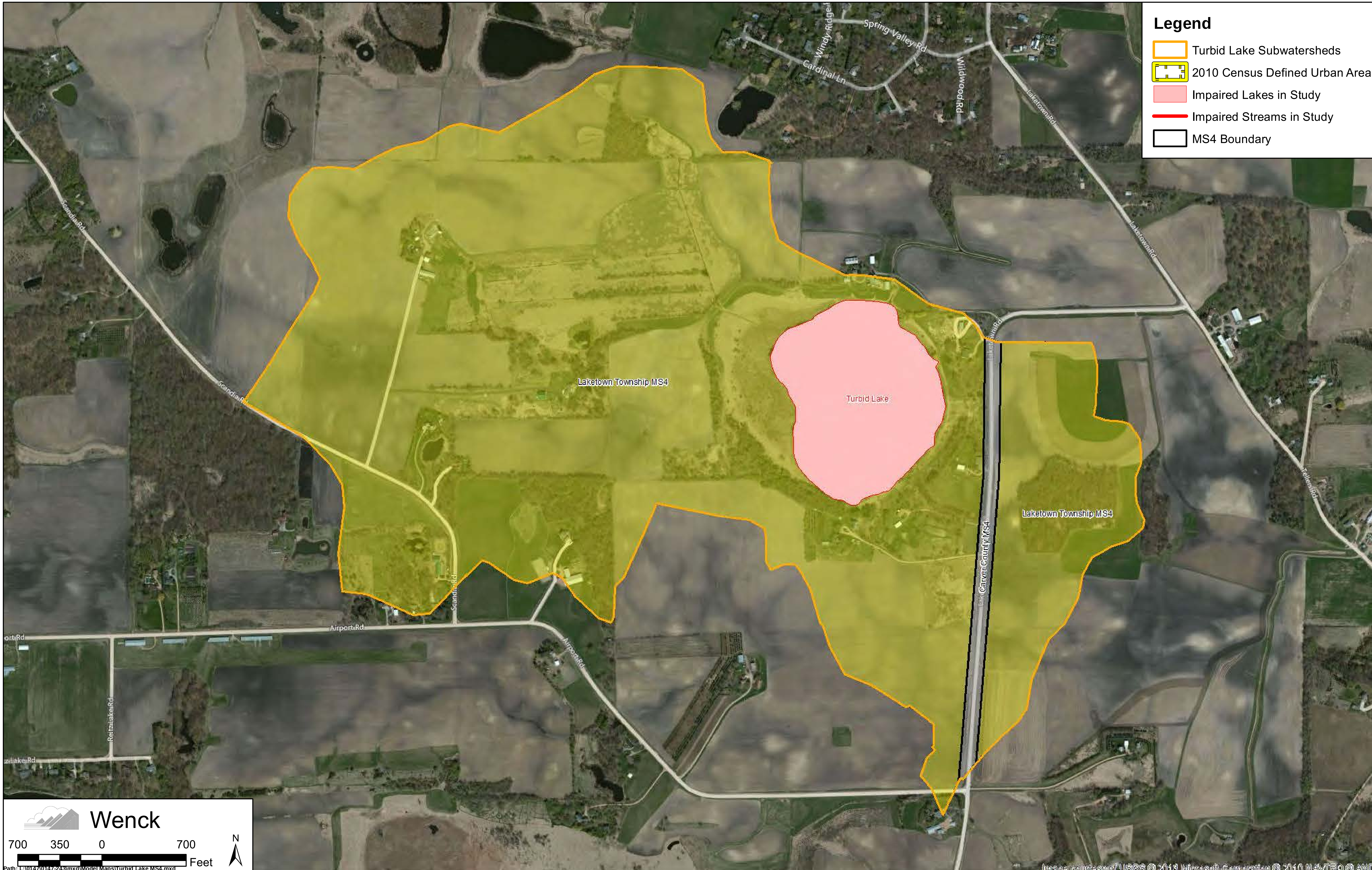

Legend
Snyder Lake Subwatersheds
2010 Census Defined Urban Area
Impaired Lakes in Study
Impaired Streams in Study
MS4 Boundary
Plymouth City MS4
Snyder
Snyder Lake
Mooney Lake
Mooney
Ranier La
34th Ave
Lawndale La
33rd Ave
32nd Ave
Fountain La
Xanthus La
31st Ave
30th Pl
30th Ave
Jewel La
Urbandale La
28th Ave
27th Ave
Garland La
26th Ave
25th Ave
24th Ave
Walnut Grove La
Holly La
23rd Ave
Troy La
Merrimac La
Kimberly La
19th Ave
20th Ave
Olive La
Shadyview La
14th Ave
101
6
Wenck
650 325 0 650
Feet
N
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Path: L:\0147\0147-243\mxd\Model Maps\Snyder Lake MS4.mxd
Date: 3/5/2014 Time: 7:33:45 AM User: shujc0243

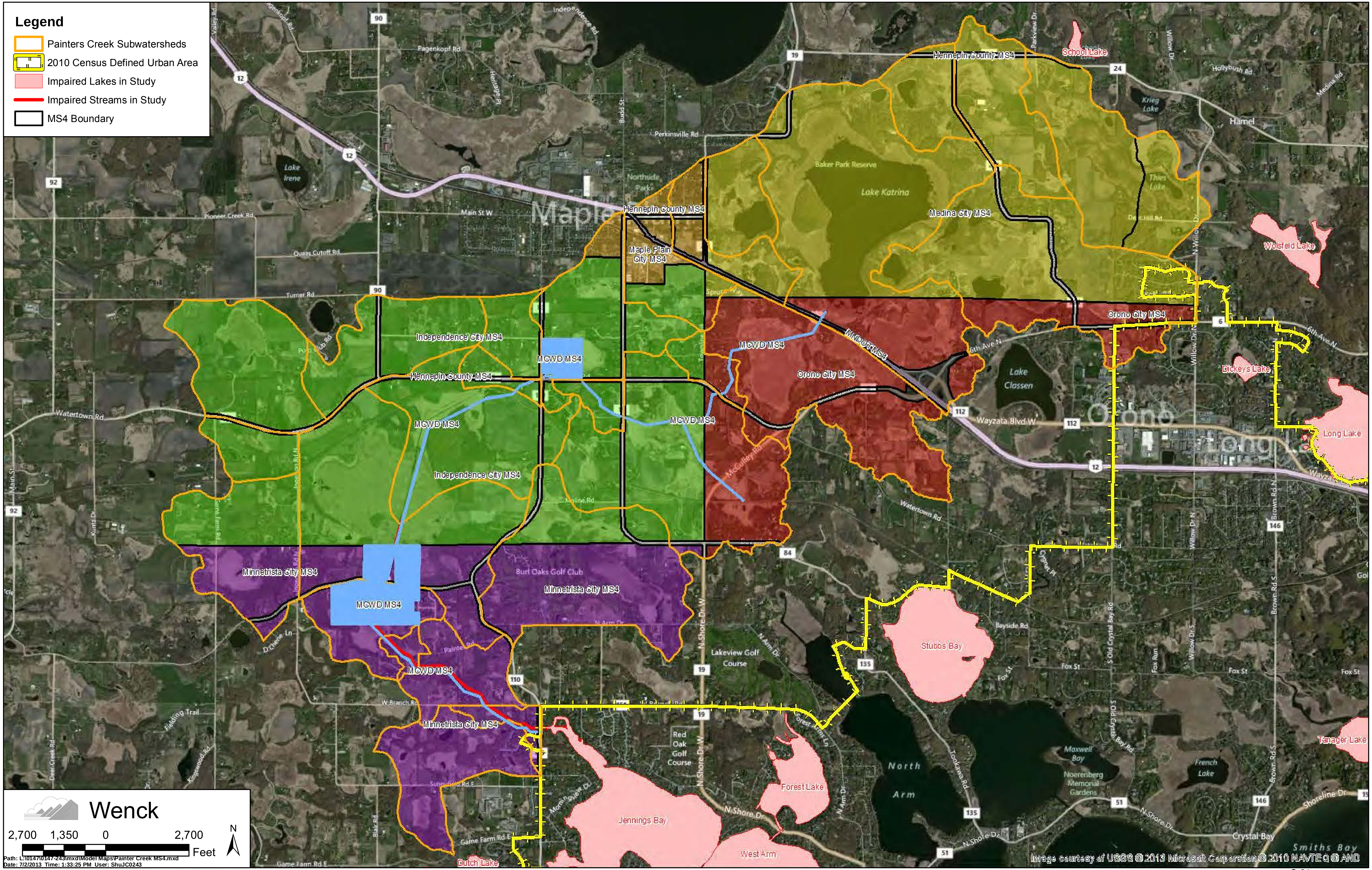


Leawood Dr
Hamel Rd
Parkview Dr
Willow Dr
Willowood Farm Rd
National Golf Course
Swamp Lake
Medina City MS4
Medina City MS4
Hennepin County MS4
School Lake
Krieg Lake
Apache Dr
Hollybush Rd
24
201
Legend
School Lake Subwatersheds
2010 Census Defined Urban Area
Impaired Lakes in Study
Impaired Streams in Study
MS4 Boundary
Wenck
700 350 0 700
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\School Lake MS4.mxd
Date: 7/2/2013 Time: 1:33:59 PM User: ShuJC0243
Image courtesy of USGS



Legend
2010 Census Defined Urban Area
Hadley Lake Subwatersheds
Impaired Lakes in Study
Impaired Streams in Study
MS4 Boundary
Holy Name Lake
Holy Name
Mooney Lake
Mooney
Snyder Lake
Snyder
Hadley Lake
Hadley
Gleason Lake
Gleason (Main Lake)
Lydiard
Plymouth City MS4
Hennepin County MS4
Orono City MS4
Cheyenne Tr
Holy Name Dr
Zircon La
34th Ave
33rd Ave
30th Pl
30th Ave
Vixen Rd
Xanthus La
Jewel La
26th Ave
25th Ave
Hunter Dr
Holly La
20th Ave
19th Ave
Olive La
Spring Hill Rd
Yellowstone La
Urbandale La
Peony La
13th Ave
9th Ave
8th Ave
Brockton La
5th Ave
Ferndale Rd
3rd Ave
Margaret Cir
1st Ave
24
6
101
Wenck
1,000 500 0 1,000
Feet
N
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Date: 3/5/2014 Time: 7:35:47 AM User: shujc0243


Legend
Turbid Lake Subwatersheds
2010 Census Defined Urban Area
Impaired Lakes in Study
Impaired Streams in Study
MS4 Boundary
Turbid Lake
Laketown Township MS4
Laketown Township MS4
Carver County MS4
Spring Valley Rd
Windy Ridge
Cardinal Ln
Wildwood Rd
Laketown Rd
Scandia Rd
Airport Rd
Reitz Lake Rd
Teller Rd
Wenck
700 350 0 700
Feet
N
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND



Legend
Painters Creek Subwatersheds
2010 Census Defined Urban Area
Impaired Lakes in Study
Impaired Streams in Study
MS4 Boundary
Hennepin County MS4
Medina City MS4
Maple Plain City MS4
Orono City MS4
MnDOT MS4
MCWD MS4
Independence City MS4
Minnetrista City MS4
Baker Park Reserve
Lake Katrina
School Lake
Wolsfeld Lake
Dickeys Lake
Long Lake
Lake Classen
Stubbs Bay
Jennings Bay
West Arm
Forest Lake
Tanager Lake
Dutch Lake
North Arm
Maxwell Bay
French Lake
Crystal Bay
Smiths Bay
Lake Irene
Krieg Lake
Burl Oaks Golf Club
Lakeview Golf Course
Red Oak Golf Course
Noerenberg Memorial Gardens
Hamel
Watertown Rd
Wayzata Blvd W
Wenck
2,700 1,350 0 2,700
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Painter Creek MS4.mxd
Date: 7/2/2013 Time: 1:33:25 PM User: ShuJC0243
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

Appendix H

WLA Partitioning Methods

WLA Partitioning Methods

Determination of MS4 Boundaries. The first step in the process was division of each lake watershed by MS4 permit holder. All areas within each watershed were potentially under the jurisdiction of an MS4 permit holder and subject to a potential WLA with the exception of approximately 166 acres located in Watertown Township in the Halsted's Bay subwatershed. City and township MS4 permit boundaries were established by the MPCA. Mn/DOT and Carver County provided information regarding the roadways under their jurisdiction. For Hennepin County, a 66 foot buffer from the centerline of any county road was used to represent the MS4 permit boundary.

MCWD is also included as an MS4 permit holder. A ditch inventory performed in 2003 was used to determine the MCWD MS4 permitted area. For MCWD jurisdictional ditches, the MS4 permitted area was determined by applying a buffer of 1 rod (16.5 feet) on either side of each ditch centerline. The ditches include only the existing (as observed on aerial photos) open channel segments of the ditch plans. Land under fee title of MCWD in each lake subwatershed was also considered part of the MS4 permitted area. Permit areas for Mn/DOT, Hennepin County, Carver County, and MCWD were incorporated into the same file as the city and township MS4 data to calculate permitted areas for each MS4 permit holder within each lake sub-watershed.

Partitioning Between WLA and LA. The next step was to determine which MS4 discharges to include in the WLA and which to include in the Load Allocation (LA). It is important to note that the 2010 Census Defined Urban Area was the dividing factor for the majority of the MS4 permitted areas. The decision making process is detailed as follows:

1. All area inside the defined urban area was considered part of the WLA (with exceptions detailed in items number 3 and 4 below).
2. For Mn/DOT, MCWD, and County MS4 permitted areas, the area outside of the defined urban area was included in the LA (regardless of landuse).
3. Areas inside the defined urban area with agricultural land use draining directly to the impaired water body were included in the LA. Areas inside the defined urban area with undeveloped or park, recreational, or preserve land use within wetland areas identified by the MCWD's Functional Assessment of Wetlands (FAW) that drain directly to the lake were also included in the LA. These areas were determined as explained in item number 5 below.
4. Ditches under MCWD's jurisdiction which follow a natural water course were excluded from the WLA as they are potentially waters of the state and could be assessed for impairment. To determine which conveyances under MCWD jurisdiction fall into that category, topographic maps of the watershed dating from 1901 to 1909 were reviewed. All of MCWD's ditches in the TMDL study area follow a natural water course with the exception of several conveyances which drain to Gleason Lake. Ditches following a natural water course were included in the LA regardless of the defined urban area.
5. For all other MS4 permitted areas, the area outside of the defined urban area was included in the WLA with the exception of areas with an agriculture land use designation or undeveloped and park, recreational or preserve land use designation with undevelopable wetlands. These undevelopable wetlands were examined on a case by case basis for inclusion in the WLA. If the area was determined to likely drain to a regulated conveyance prior to reaching the lake, it was included in the WLA. If the area in question was discharging directly to the lake, or not through a regulated conveyance (for example a wetland in a City MS4 permitted area but outside the Urban Service Area draining through an unregulated County or Mn/DOT culvert prior to

discharging to the lake), it was included in the LA. These determinations were based on a map review of the lake sub-watershed (topographic maps, land use maps, and aerial photos indicating flow direction). MCWD's Functional Assessment of Wetlands (FAW) was reviewed for the determination of wetland areas to include in the LA. The agricultural areas and undeveloped/park, recreational, and preserve areas excluded from the WLA are listed in Tables H.1 and H.2, respectively. Figures depicting the areas are also included at the end of this appendix.

Table H.1 Lakeshed excluded agricultural land.

Lake	Excluded Agricultural Land Area (acres)	MS4
East Auburn	6.63	Laketown Township MS4
	17.58	Victoria City MS4
Holy Name	106.25	Medina City MS4
	0.03	Plymouth City MS4
Mooney	4.01	Medina City MS4
	25.07	Orono City MS4
School	72.93	Medina City MS4
Stone	87.00	Minnetrista City MS4
Tamarack	57.52	Victoria City MS4
Turbid	349.36	Laketown Township MS4
Wolsfeld	119.89	Medina City MS4
Halsteds Bay	189.79	Minnetrista City MS4
	160.34	Laketown Township MS4
	55.30	MCWD

Table H.2 Lakeshed excluded undevelopable wetlands.

Lake	Excluded Undevelopable Wetland Area (acres)	Landuse	MS4
East Auburn	60.85	Undeveloped	Victoria City MS4
East Auburn	6.47	Park, Recreational, or Preserve	Victoria City MS4
East Auburn	79.72	Park, Recreational, or Preserve	Laketown Township MS4
Mooney	1.77	Undeveloped	Orono City MS4
School	97.64	Undeveloped	Medina City MS4
Stone	6.32	Undeveloped	Minnetrista City MS4
Stone	12.01	Park, Recreational, or Preserve	Minnetrista City MS4
Stone	58.32	Undeveloped	Victoria City MS4
Stone	29.13	Park, Recreational, or Preserve	Victoria City MS4
Stone	368.19	Park, Recreational, or Preserve	Laketown Township MS4
Tamarack	0.03	Park, Recreational, or Preserve	Chanhassen City MS4
Tamarack	14.96	Park, Recreational, or Preserve	Victoria City MS4
Tamarack	26.36	Undeveloped	Victoria City MS4
Turbid	45.67	Undeveloped	Laketown Township MS4
Wolsfeld	62.42	Undeveloped	Medina City MS4
Wolsfeld	32.47	Park, Recreational, or Preserve	Medina City MS4
Wolsfeld	1.25	Undeveloped	Orono City MS4
Dutch	4.46	Park, Recreational, or Preserve	Minnetrista City MS4
Dutch	71.40	Undeveloped	Minnetrista City MS4
Forest	24.23	Undeveloped	Orono City MS4
Halsteds Bay	375.56	Undeveloped	Minnetrista City MS4
Halsteds Bay	16.18	Park, Recreational, or Preserve	Minnetrista City MS4
Halsteds Bay	9.43	Undeveloped	St Bonifacius City MS4
Halsteds Bay	0.66	Park, Recreational, or Preserve	St Bonifacius City MS4
Halsteds Bay	147.58	Undeveloped	Laketown Township MS4
Halsteds Bay	196.87	Park, Recreational, or Preserve	Laketown Township MS4
Halsteds Bay	32.47	Undeveloped	MCWD
Langdon	5.02	Park, Recreational, or Preserve	Mound City MS4
Langdon	21.47	Undeveloped	Mound City MS4
Long	21.75	Undeveloped	Orono City MS4
Snyder	2.52	Undeveloped	Plymouth City MS4

6. Areas with Open Water as the designated land use were excluded from the WLA/LA partitioning and calculations.

Existing Watershed Load Partitioning. The existing conditions watershed load was partitioned between wasteload and load, and the wasteload was partitioned between the MS4s contributing to the wasteload, based on their respective runoff volume from a 1.3-inch precipitation event (the "water quality" event). Runoff was calculated using the SCS method. Composite curve numbers (CN) for each MS4 area, non-MS4 area, and area contributing to load but not wasteload were developed by assigning a CN to each Met Council land use category within the watershed based on literature values; the predominant hydrologic soil group (HSG B in all cases); and the percent impervious surface calculated for each area (derived as described in the following section). A composite CN was calculated by multiplying the respective CN and area by land use type; summing those products; and dividing by the total area. The MNDOT MS4 area composite CN was determined based on information provided by MNDOT. The calculated composite CNs for each area were then used to calculate surface water runoff (SRO) for the 1.3-inch rainfall event using the SCS Method:

$$SRO= (P-0.2S)^2/(P+0.8S)$$

Where P is precipitation and P=1.3 inch rainfall event and

$$S= (1000/CN) -10$$

The calculated SRO was converted to a runoff volume for each MS4, non-MS4 area and areas contributing to the load but not the wasteload by multiplying the SRO by the area. The existing annual phosphorus load to each lake was partitioned between these areas based on their percentage of the total runoff volume.

The 1.3-inch rainfall event was chosen for this calculation based on research findings (Pitt, 1999):

- Rains of less than 0.5" are relatively low in pollutants but are key conveyances of bacteria. Those small events should be captured and infiltrated.
- Rains between 0.5" and 1.5" convey 75% of the annual pollutant load.
- Rains greater than 1.5" are responsible for only a small percent of the annual pollutant load.

Events of almost 1.3-inches convey approximately 85% of the annual total suspended solids (TSS) load and almost 90% of the annual TP load (Figure H.1).

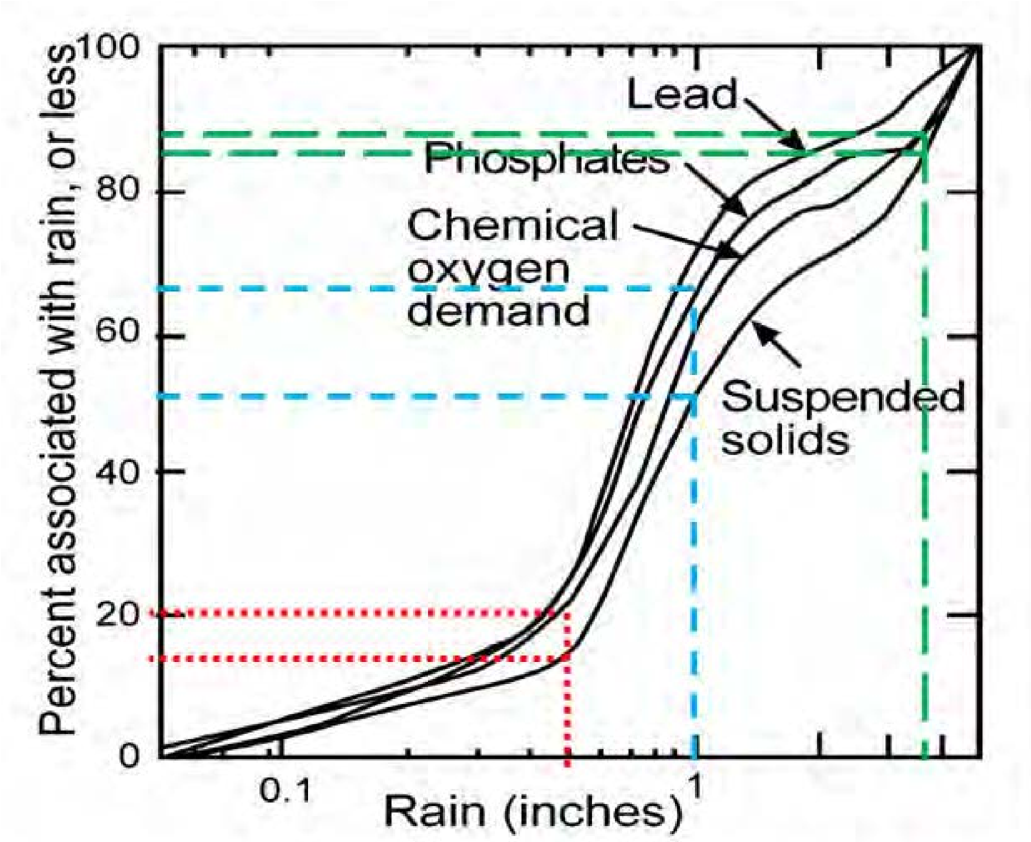


Figure H.1. Annual Pollutant Loading by Rain Event

Source: Pitt, "Small Storm Hydrology and Why it is Important for the Design of Stormwater Control Practices," *Advances in Modeling the Management of Stormwater Impacts, Volume 7*. (Edited by W. James). Computational Hydraulics International, Guelph, Ontario and Lewis Publishers/CRC Press. 1999.

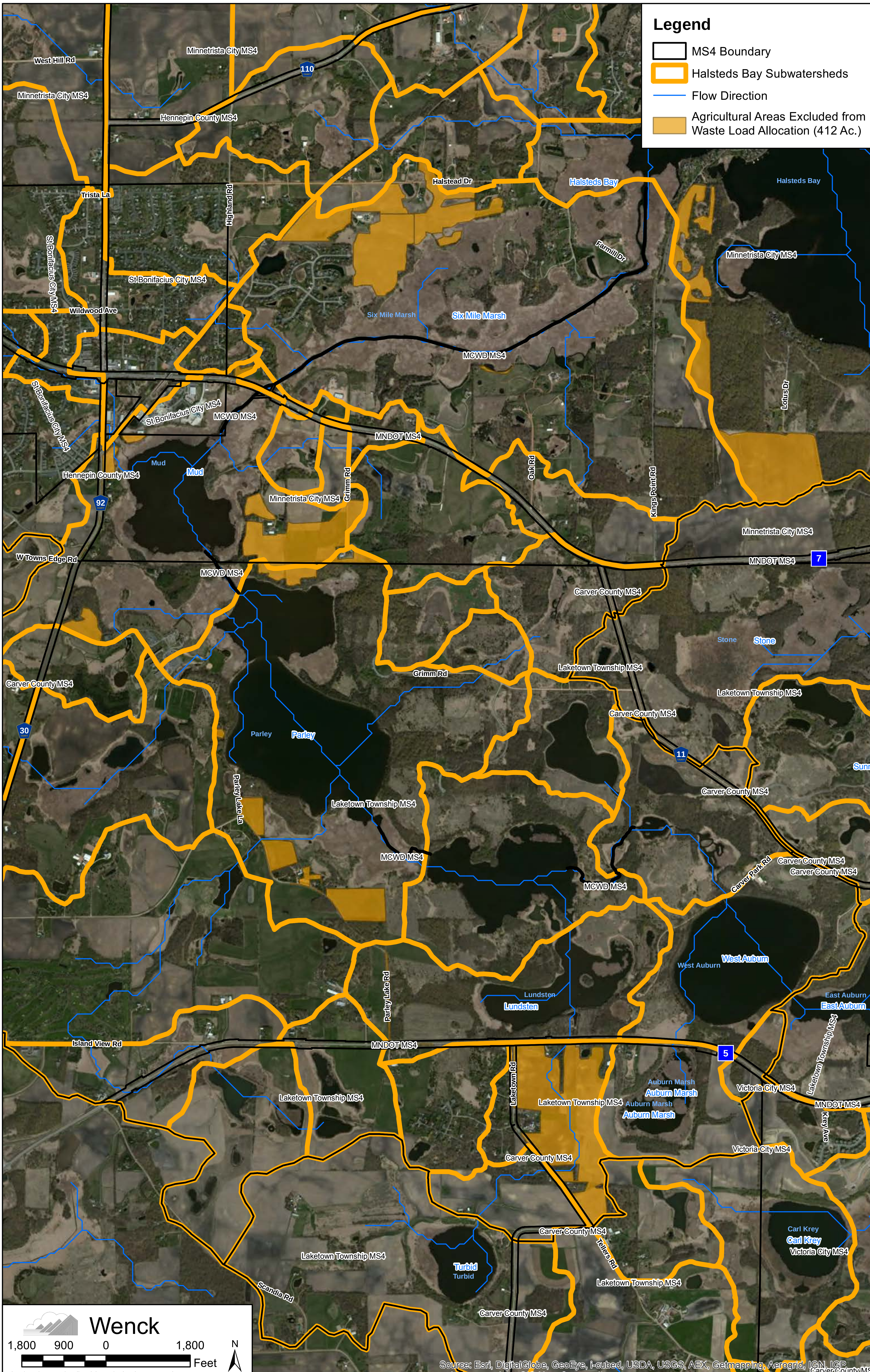
Percent Impervious Calculations. The percent impervious surface was calculated using the data from the HHPLS modeling performed in 2003 using the Pload method, which uses land use to estimate the volume of runoff and mass of pollutant loading. The PLoad modeling used MLCCS land cover data for each sub-watershed and applied an estimated percent impervious surface to each land use. For the TMDL WLA calculations, 2010 Met Council land use data was merged with the most recent MLCCS land use data. The percent impervious surface from the HHPLS PLoad modeling was then applied to the 2010 Met Council land use data based on the associated updated MLCCS land use.

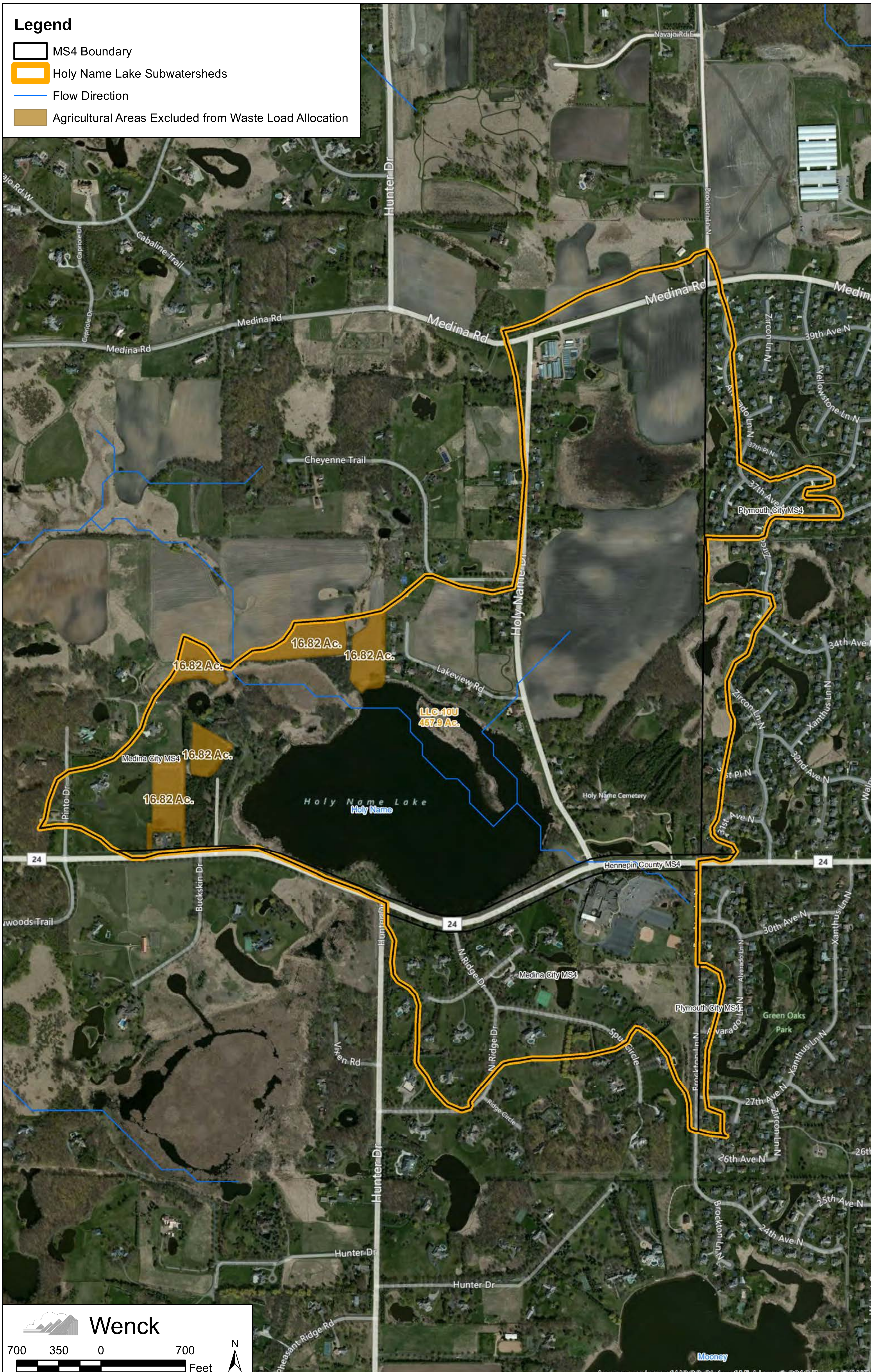
For example, the 2010 land use of a particular area might be Single Family Residential. However, the MLCCS might identify sub-areas within that Single Family Residential as 11-25% impervious cover or 26-50% impervious cover, or a large vacant lot as grassland with sparse trees. Each of the MLCCS classifications has an assumed percent impervious. A composite percent impervious surface was calculated for each 2010 Met Council land use category based on the imperviousness of the MLCCS subareas by area within that land use category.

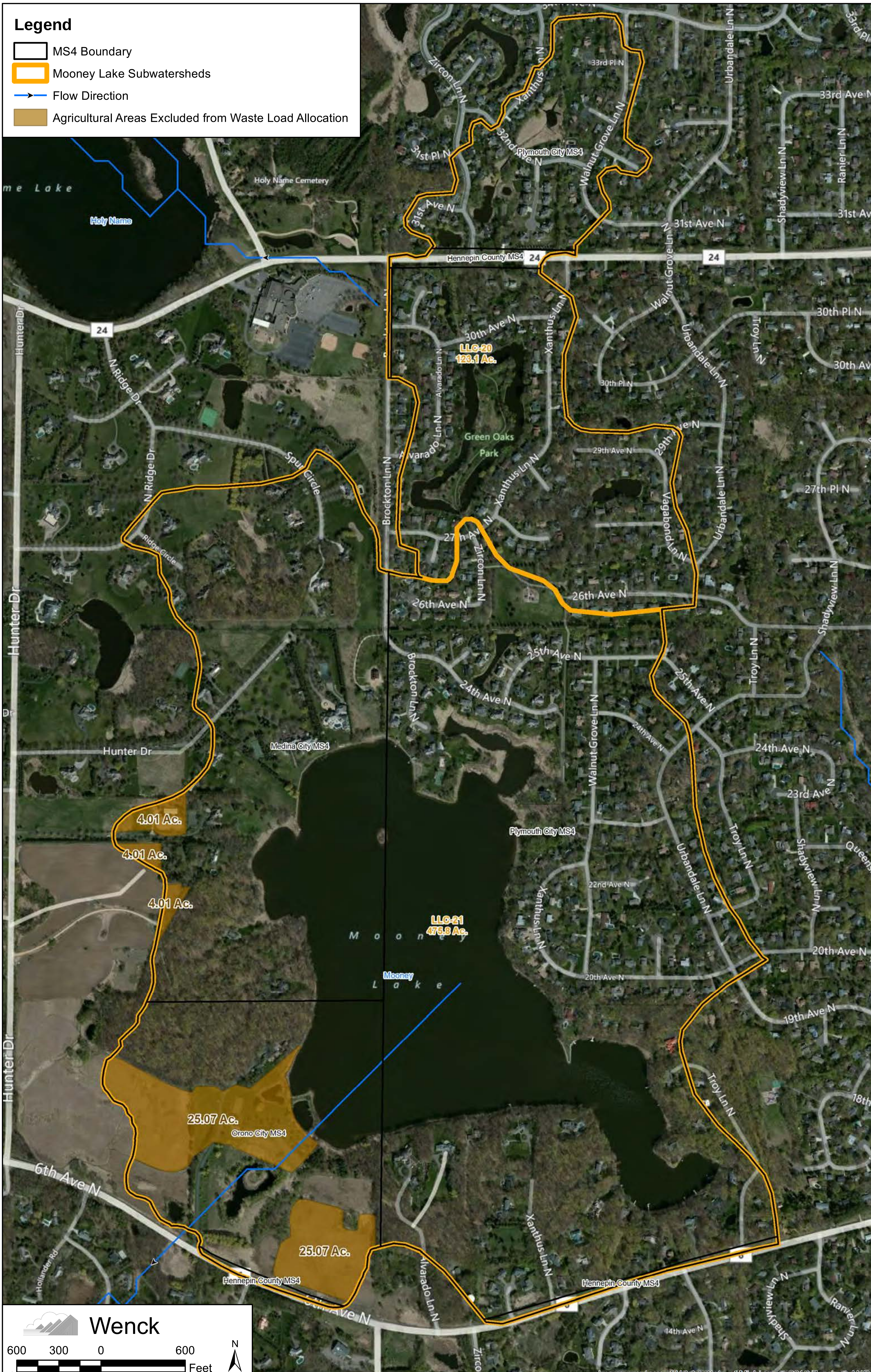
For the MNDOT MS4 area, the percent impervious surface was provided by MNDOT.

Appendix H Attached Figures:


Legend
East Auburn Subwatersheds
MS4 Boundary
Flow Direction
Agricultural Areas Excluded from Waste Load Allocation (24.2 Ac.)
West Auburn
Carver Park Reserve
East Auburn
Lake Auburn
Victoria City MS4
SMC-27
361.9 Ac.
Laketown Township MS4
Carver County MS4
MNDOT MS4
Arboretum
Auburn Marsh
SMC-26
70.8 Ac.
Acorn Run
Lakes Pkwy
Heron Ln
Acorn Pt
Krey Ave
SMC-10
58.1 Ac.
SMC-11
385.9 Ac.
SMC-6
105.4 Ac.
SMC-7
265.2 Ac.
Carl Krey Lake
SMC-1
1,200.1 Ac.
SMC-5
965.4 Ac.
Kelzer Pond Dr
Carver Park Rd
Wenck
600 300 0 600
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\East Auburn LU_LA.mxd
Date: 10/24/2013 Time: 2:34:44 PM User: ShuJC0243
Image courtesy of USGS State of Michigan © 2013 Nokia © AND

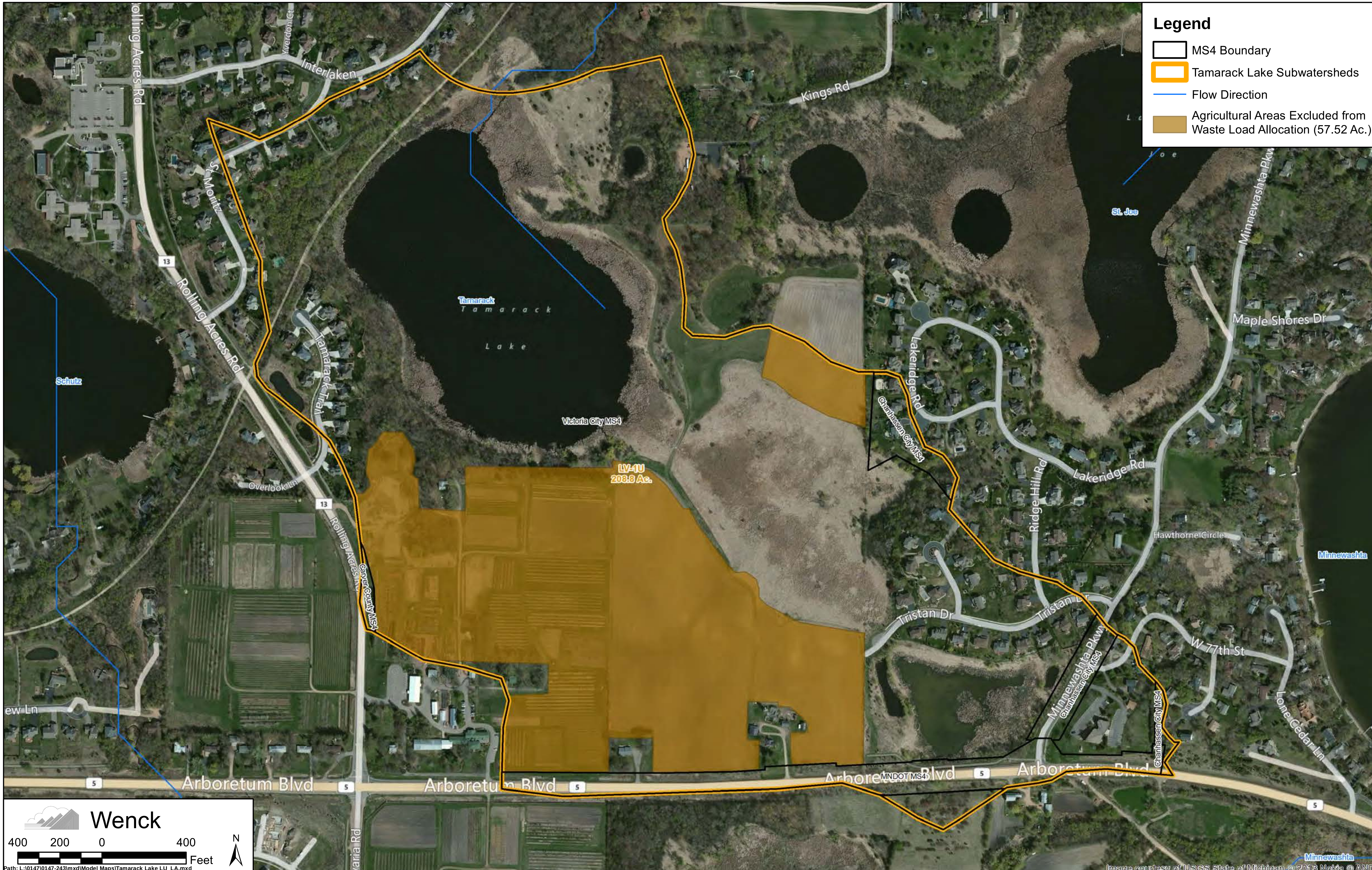

Legend
MS4 Boundary
Halsteds Bay Subwatersheds
Flow Direction
Agricultural Areas Excluded from Waste Load Allocation (412 Ac.)
West Hill Rd
Minnetrista City MS4
Hennepin County MS4
Trista La
Highland Rd
St Bonifacius City MS4
Wildwood Ave
Halstead Dr
Halsteds Bay
Farmhill Dr
Six Mile Marsh
MCWD MS4
MNDOT MS4
Mud
Grimm Rd
Oak Rd
Kings Point Rd
Lotus Dr
W Towns Edge Rd
Carver County MS4
Laketown Township MS4
Stone
Parley
Parley Lake La
Sunny
Carver Park Rd
West Auburn
East Auburn
Lundsten
Parley Lake Rd
Island View Rd
Laketown Rd
Auburn Marsh
Victoria City MS4
Krey Ave
Carl Krey
Tellers Rd
Turbid
Scandia Rd
Wenck
1,800 900 0 1,800
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Halsteds LU_LA.mxd
Date: 3/5/2014 Time: 8:04:02 AM User: shujc0243
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

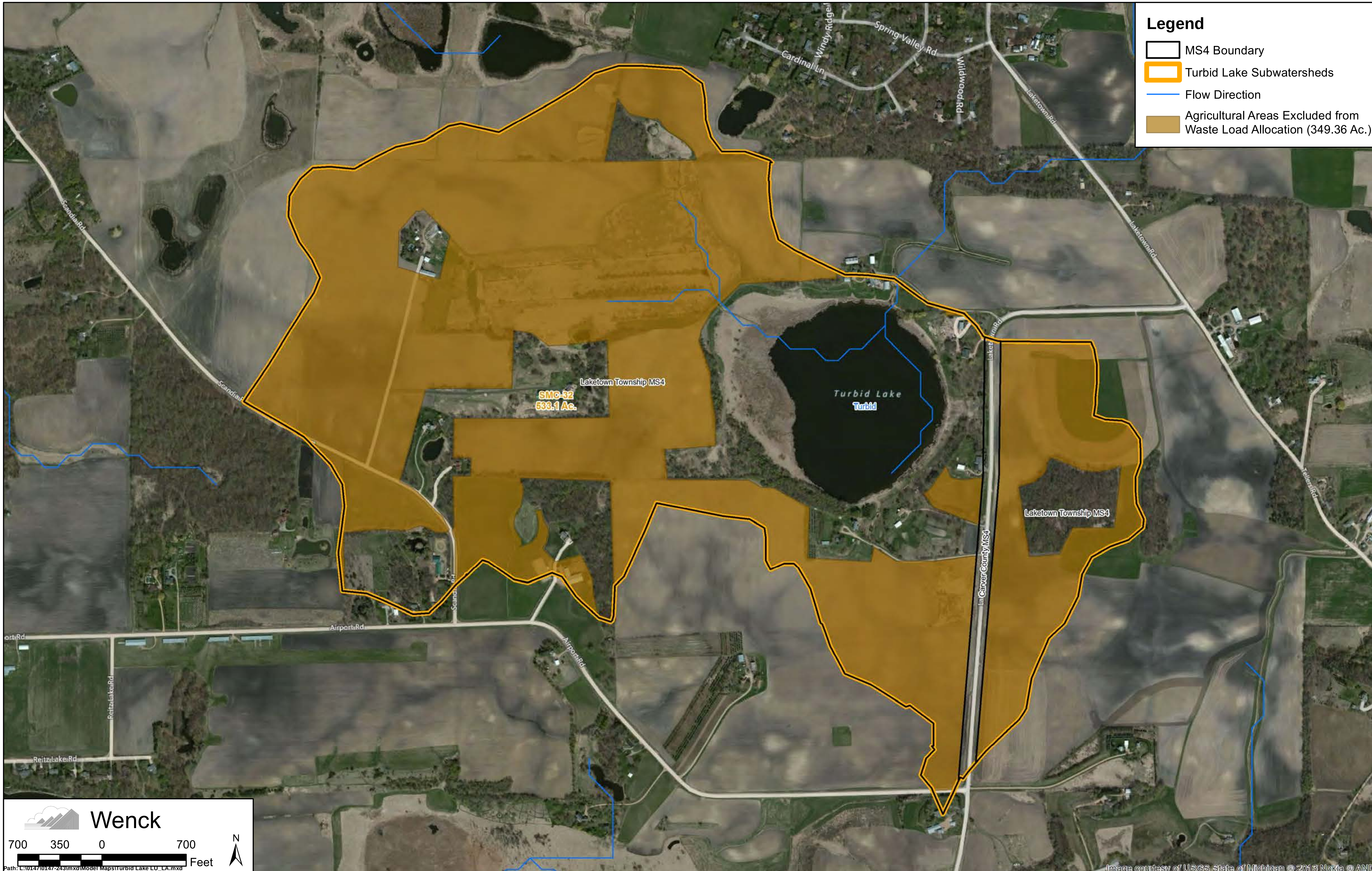

Legend
MS4 Boundary
Holy Name Lake Subwatersheds
Flow Direction
Agricultural Areas Excluded from Waste Load Allocation
Hunter Dr
Medina Rd
Cabaline Trail
Caprióle Dr
Navajo Rd E
Brockton Ln N
Cheyenne Trail
Holy Name Dr
Lakeview Rd
Zircon Ln N
39th Ave N
Yellowstone Ln N
Alvarado Ln N
37th Pl N
37th Ave N
Plymouth City MS4
34th Ave N
Xanthus Ln N
32nd Ave N
31st Ave N
Walnut Grove Ln N
16.82 Ac.
16.82 Ac.
16.82 Ac.
16.82 Ac.
16.82 Ac.
LLC-10U
457.9 Ac.
Medina City MS4
Holy Name Lake
Holy Name
Holy Name Cemetery
Pinto Dr
24
Hennepin County MS4
Buckskin Dr
N Ridge Dr
Medina City MS4
Spur Circle
Ridge Circle
Vivien Rd
30th Ave N
Plymouth City MS4
Green Oaks Park
27th Ave N
26th Ave N
25th Ave N
24th Ave N
Hunter Dr
Pheasant Ridge Rd
Mooney
Wenck
700 350 0 700
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Holy Name LU_LA.mxd
Date: 10/10/2013 Time: 8:56:39 AM User: ShuJC0243
Image courtesy of USGS State of Michigan © 2012 Zenrin © AND

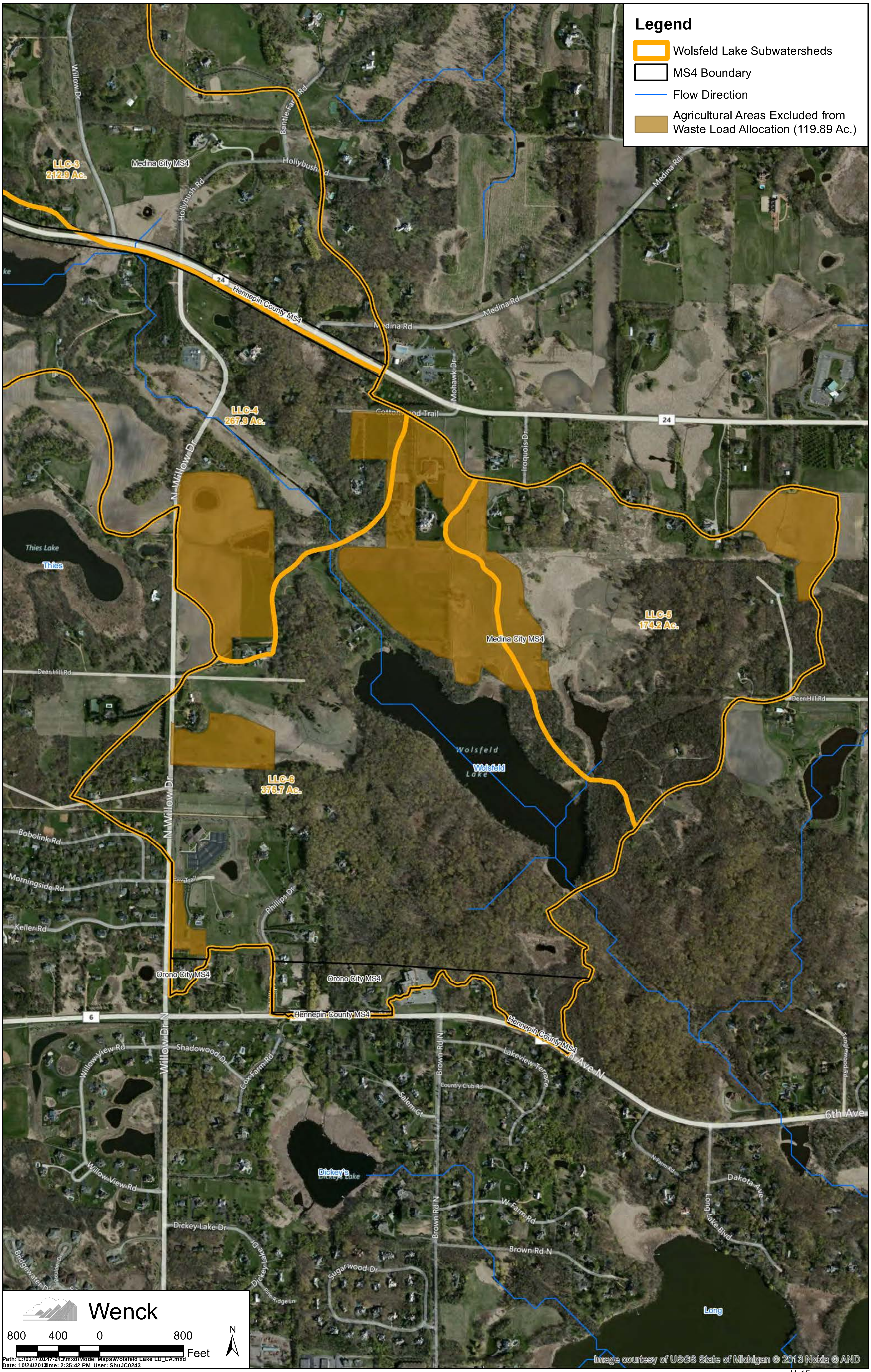

Legend
MS4 Boundary
Mooney Lake Subwatersheds
Flow Direction
Agricultural Areas Excluded from Waste Load Allocation
LLC-20
123.1 Ac.
LLC-21
478.8 Ac.
4.01 Ac.
4.01 Ac.
4.01 Ac.
25.07 Ac.
25.07 Ac.
Plymouth City MS4
Hennepin County MS4
Medina City MS4
Plymouth City MS4
Orono City MS4
Hennepin County MS4
Hennepin County MS4
Mooney Lake
Mooney
Holy Name
Holy Name Cemetery
Green Oaks Park
Hunter Dr
N Ridge Dr
Ridge Circle
Spur Circle
Brockton Ln N
Xanthus Ln N
Walnut Grove Ln N
Urbandale Ln N
Troy Ln N
Shadyview Ln N
Vagabond Ln N
Zircon Ln N
Alvarado Ln N
30th Ave N
26th Ave N
25th Ave N
24th Ave N
6th Ave N
Wenck
600 300 0 600
Feet
N
Image courtesy of USGS State of Michigan © 2012 Zenrin © AND


Thomas
Winterhalter
Leawood Dr
Hamel Rd
Parkview Dr
201
National Golf Course
Swamp
LLC-1
295.5 Ac.
Medina City MS4
Willowood Farm Rd
Willow Dr
LLC-2
257 Ac.
School Lake
Hennepin County MS4
24
Apache Dr
Krieg Lake
Hollybush Rd
Legend
MS4 Boundary
School Lake Subwatersheds
Flow Direction
Agricultural Areas Excluded from Waste Load Allocation (72.93 Ac.)
Wenck
700 350 0 700
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\School Lake LU_LA.mxd
Date: 10/24/2013 Time: 2:02:41 PM User: ShuJC0243


Legend
MS4 Boundary
Stone Lake Subwatersheds
Flow Direction
Agricultural Areas Excluded from Waste Load Allocation (87.0 Ac.)
Minnetrista City MS4
MNDOT MS4
Hennepin County MS4
Minnetrista City MS4
Minnetrista City MS4
Victoria City MS4
Laketown Township MS4
Laketown Township MS4
Carver County MS4
SMC-16
43 Ac.
SMC-17
46.5 Ac.
SMC-18
791.4 Ac.
Stone Lake
Stone
Crosby Lake
Sunny
Zumbra-Sunny
Zumbra-Sunny
Minnetonka-Upper Lake
Lake Minnetonka Regional Park
Carver Park Reserve
Lotus Dr
Kings Pt Rd
Victoria Dr
Trillium Way
Nature Center Dr
7
11
44
Wenck
700 350 0 700
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Stone Lake LU_LA.mxd
Date: 10/24/2013 Time: 2:36:33 PM User: ShuJC0243
Image courtesy of USGS State of Michigan © 2013 Nokia © AND

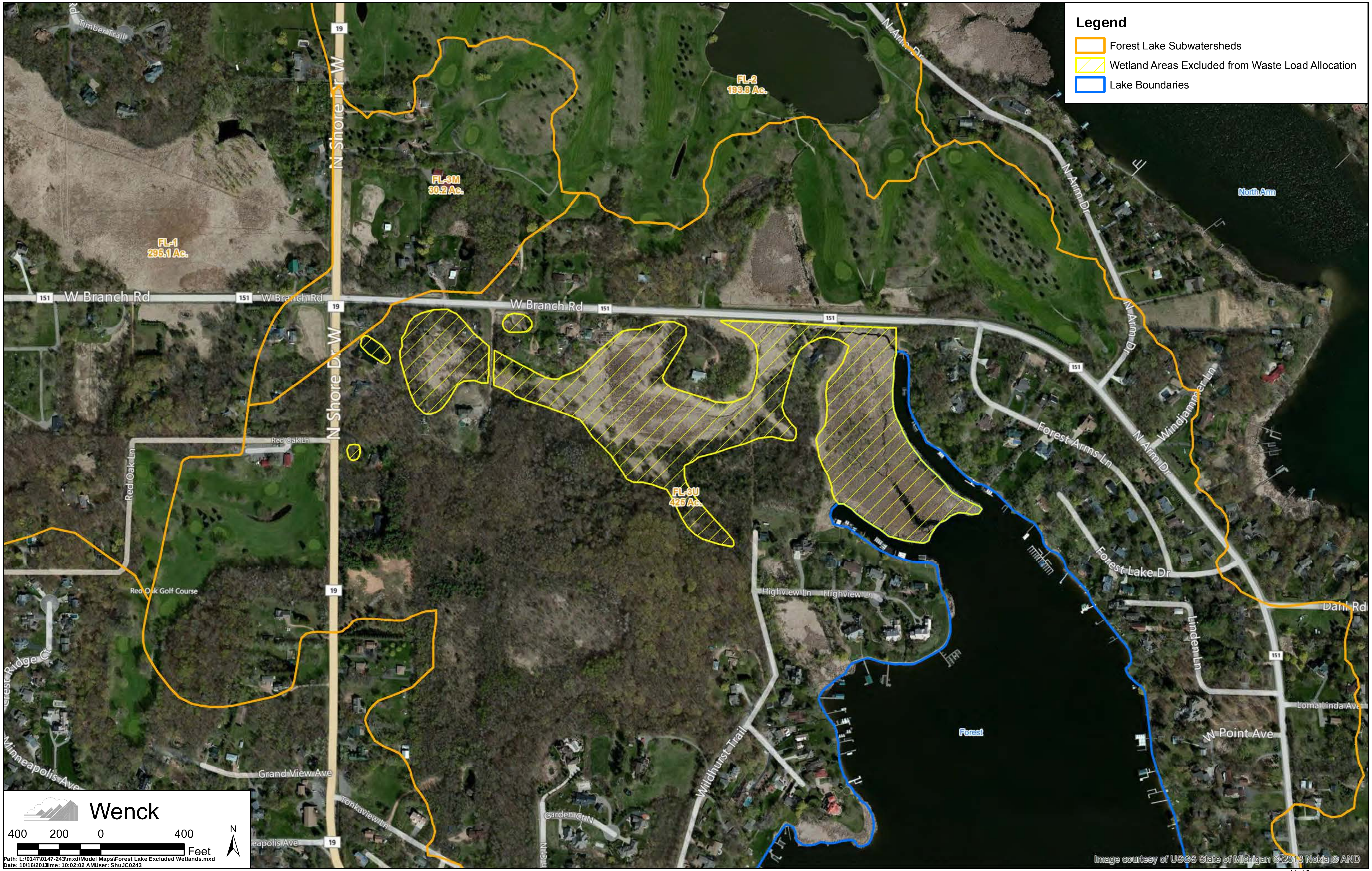

Legend
MS4 Boundary
Tamarack Lake Subwatersheds
Flow Direction
Agricultural Areas Excluded from Waste Load Allocation (57.52 Ac.)
Tamarack Lake
Victoria City MS4
LV-1U
208.8 Ac.
Schutz
St. Joe
Minnewashta
Chanhassen City MS4
Carver County MS4
MNDOT MS4
Arboretum Blvd
Rolling Acres Rd
Interlaken
Kings Rd
St Moritz
Tamarack Trail
Overlook Ln
Lakeridge Rd
Ridge Hill Rd
Maple Shores Dr
Minnewashta Pkwy
Hawthorne Circle
Tristan Dr
W 77th St
Lone Cedar Ln
Wenck
400 200 0 400
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Tamarack Lake LU_LA.mxd
Date: 10/24/2013 Time: 2:36:38 PM User: ShuJC0243
Image courtesy of USGS State of Michigan © 2013 Nokia © AND


Legend
MS4 Boundary
Turbid Lake Subwatersheds
Flow Direction
Agricultural Areas Excluded from Waste Load Allocation (349.36 Ac.)
SMC-32
533.1 Ac.
Laketown Township MS4
Laketown Township MS4
Carver County MS4
Turbid Lake
Turbid
Spring Valley Rd
Cardinal Ln
Windy Ridge
Wildwood Rd
Laketown Rd
Scandia Rd
Airport Rd
Reitz Lake Rd
Tellers Rd
Wenck
700 350 0 700
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Turbid Lake LU_LA.mxd
Date: 10/24/2013 Time: 2:21:02 PM User: ShuJC0243
Image courtesy of USGS State of Michigan © 2013 Nokia © AND

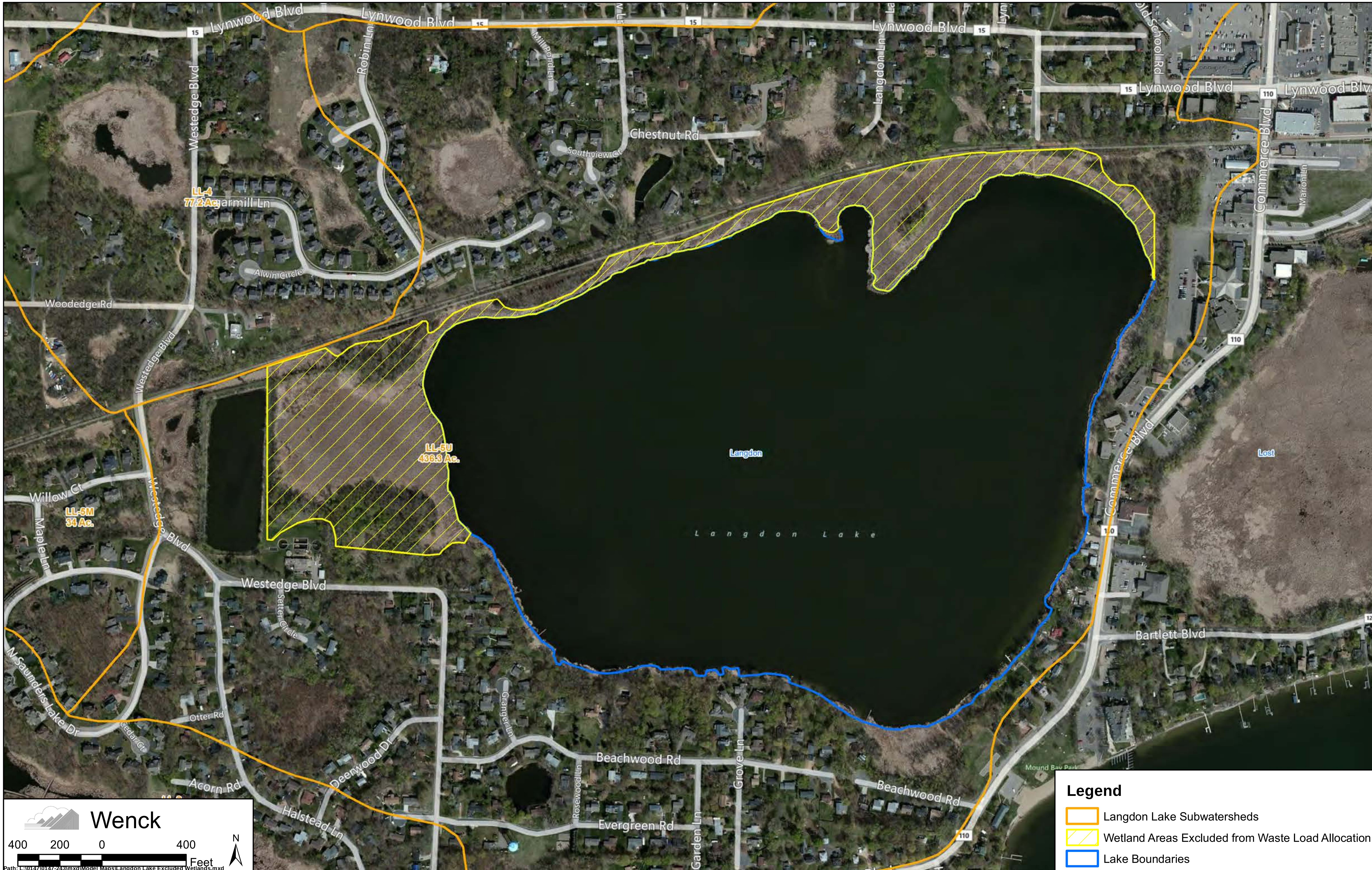

Legend
Wolsfeld Lake Subwatersheds
MS4 Boundary
Flow Direction
Agricultural Areas Excluded from Waste Load Allocation (119.89 Ac.)
LLC-3
212.9 Ac.
Medina City MS4
LLC-4
267.9 Ac.
LLC-5
174.2 Ac.
LLC-6
375.7 Ac.
Hennepin County MS4
Orono City MS4
Thies Lake
Thies
Wolsfeld Lake
Wolsfeld
Dickey's Lake
Dickey's
Long
Willow Dr
Hollybush Rd
Bantle Farm Rd
Medina Rd
Mohawk Dr
Iroquois Dr
Cottonwood Trail
N Willow Dr
Deer Hill Rd
Bobolink Rd
Morningside Rd
Keller Rd
Phillips Dr
Willow Dr N
Willow View Rd
Shadowood Dr
Cox Farm Rd
Brown Rd N
Country Club Rd
Salem Ct
Lakeview Terrace
6th Ave
6th Ave N
W Farm Rd
Dakota Ave
Long Lake Blvd
Dickey Lake Dr
Sugarwood Dr
Bridgewater Dr
24
6
Wenck
800 400 0 800
Feet
N
Image courtesy of USGS State of Michigan © 2013 Nokia © AND


Legend
Dutch Lake Subwatersheds
Impaired Streams in Study
Wetland Areas Excluded from Waste Load Allocation
Lake Boundaries
DL-2
139.2 Ac.
DL-3
608.9 Ac.
DL-4
217.3 Ac.
DL-5
624.6 Ac.
Game Farm Rd E
Retreat Circle
Sterling Dr N
Dutchview Rd
Dutch
South Little Long
15
Gale Woods Farm
Wenck
400 200 0 400
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Dutch Lake Excluded Wetlands.mxd
Image courtesy of USGS State of Michigan © 2013 Nokia © AND


SMC-20
180.8 Ac.
SMC-22
523.7 Ac.
Zumbra-Sunny
SMC-24
138.9 Ac.
SMC-23
84.6 Ac.
Carver Park Rd
11
SMC-14
578.2 Ac.
SMC-25
118.4 Ac.
Wisteria
West Auburn
SMC-15
145.7 Ac.
Steiger
East Auburn
SMC-27
361.9 Ac.
SMC-14
578.2 Ac.
Auburn Dr
Stieger Lake La
5
SMC-26
70.8 Ac.
Krey Ave
Trillium Cir
81st St
Kelzer Pond Dr
Church
SMC-9
130 Ac.
SMC-10
58.1 Ac.
Kelser's Pond
SMC-11
385.9 Ac.
Carl Krey
SMC-7
265.2 Ac.
SMC-8
200.8 Ac.
Woodstone Dr
43
Ridge Ponds Dr
SMC-5
965.4 Ac.
Wasserman
Legend
East Auburn Subwatersheds
Wetland Areas Excluded from Waste Load Allocation
Lake Boundaries
Wenck
800 400 0 800
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\East Auburn Excluded Wetlands.mxd
Date: 3/5/2014 Time: 8:04:43 AM User: shujc0243
Source: Esri, DigitalGlobe, G
swisstopo, and the GIS User

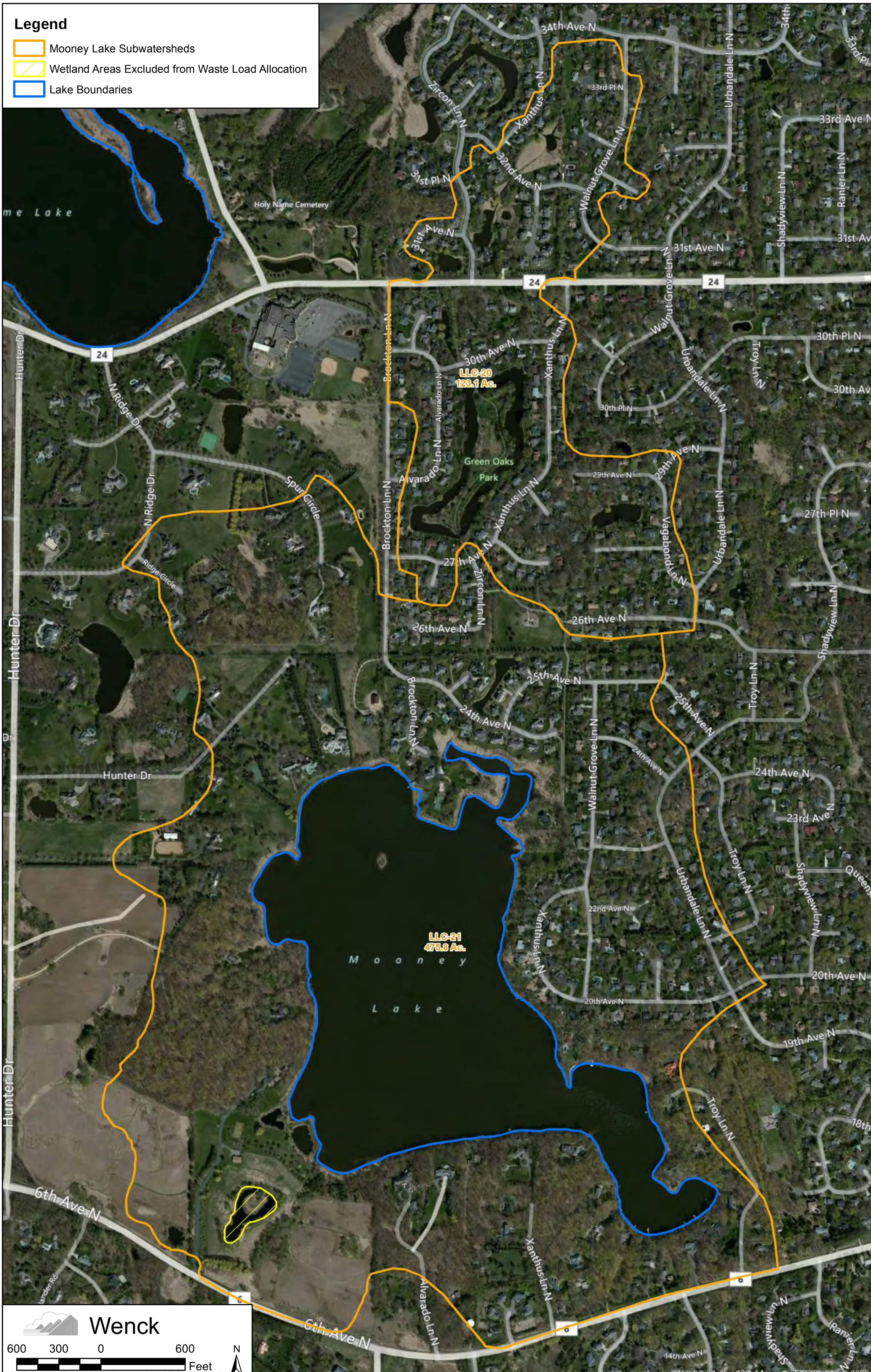

Legend
Forest Lake Subwatersheds
Wetland Areas Excluded from Waste Load Allocation
Lake Boundaries
FL-1
295.1 Ac.
FL-2
193.8 Ac.
FL-3M
30.2 Ac.
FL-3U
425 Ac.
North Arm
Forest
W Branch Rd
N Shore Dr W
N Arm Dr
Forest Arms Ln
Forest Lake Dr
Windjammer Ln
Linden Ln
Dahl Rd
Loma Linda Ave
W Point Ave
Highview Ln
Wildhurst Trail
Red Oak Ln
Red Oak Golf Course
Timber Trail
Crest Ridge Ct
Minneapolis Ave
Grand View Ave
Tonkaview Ln
Garden Ct N
Wenck
400 200 0 400
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Forest Lake Excluded Wetlands.mxd
Date: 10/16/2013 Time: 10:02:02 AM User: ShuJC0243
Image courtesy of USGS State of Michigan © 2013 Nokia © AND


Legend
Halsteds Bay Subwatersheds
Wetland Areas Excluded from Waste Load Allocation
Lake Boundaries
South Whaletail
Saunders
Saunders
Langdon
Halstead Ln
Highland Rd
Northview
110
HB-3 130.1 Ac.
HB-4 138.7 Ac.
HB-1 128.8 Ac.
Cardinal Cv
SMC-54 251.8 Ac.
SMC-53 245.6 Ac.
HB-5 194.1 Ac.
HB-6 169.3 Ac.
Minnetonka-Upper Lake
Halsteds Bay
Halstead Dr
Halstead Rd
SMC-55 688.4 Ac.
Trista La
SMC-62 215.6 Ac.
HB-LM 1,349.7 Ac.
44
Minnetonka-Upper Lake
SMC-63 120.2 Ac.
Wildwood Ave
Six Mile Marsh
SMC-66U 1,200.4 Ac.
SMC-58 48.1 Ac.
SMC-64 33.9 Ac.
SMC-60 80.6 Ac.
SMC-66M 11.3 Ac.
Lotus Dr
Trillium Ln
SMC-50 30.4 Ac.
SMC-52 49.4 Ac.
SMC-51 26.3 Ac.
SMC-59 215.9 Ac.
Mud
Oak Rd
Kings Point Rd
Grimm Rd
SMC-61 566.6 Ac.
SMC-49 199.8 Ac.
SMC-65 119.4 Ac.
SMC-16 43 Ac.
W Towns Edge Rd
7
SMC-44 136.1 Ac.
Stone
SMC-45 72.7 Ac.
SMC-18 791.4 Ac.
30
SMC-48 96.7 Ac.
SMC-46 48.3 Ac.
Grimm Rd
SMC-22 523.7 Ac.
SMC-42 153.3 Ac.
SMC-21 83.3 Ac.
Parley
SMC-47 823.7 Ac.
SMC-30 127.4 Ac.
SMC-20 180.8 Ac.
11
Sunny
SMC-43 406.3 Ac.
Parley Lake Ln
SMC-24 138.9 Ac.
SMC-31 236.2 Ac.
SMC-19 76.7 Ac.
SMC-37 346 Ac.
SMC-25 118.4 Ac.
Carver Park Rd
Wisteria
SMC-41 584.3 Ac.
West Auburn
SMC-29 295.8 Ac.
SMC-15 145.7 Ac.
Parley Lake Rd
Lundsten
SMC-36 312.5 Ac.
East Auburn
SMC-27 361.9 Ac.
Island View Rd
5
SMC-29U 33.1 Ac.
Auburn Dr
SMC-40 164.8 Ac.
SMC-38 126.9 Ac.
Auburn Marsh
SMC-28 163.5 Ac.
Auburn Marsh
SMC-35 121.3 Ac.
SMC-34 164.5 Ac.
SMC-39 191.4 Ac.
SMC-26 70.8 Ac.
SMC-10 58.1 Ac.
SMC-33 89.2 Ac.
SMC-11 385.9 Ac.
SMC-6 105.4 Ac.
Carl Krey
SMC-7 265.2 Ac.
SMC-10 58.1 Ac.
SMC-32 533.1 Ac.
Turbid
Laketown Rd
Scandia Rd
43
SMC-1 1,200.1 Ac.
Tellers Rd
SMC-5 965.4 Ac.
Wassermann
Wenck
2,000 1,000 0 2,000
Feet
N
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Path: L:\0147\0147-243\mxd\Model Maps\Halsteds Bay Excluded Wetlands.mxd
Date: 3/5/2014 Time: 7:45:47 AM User: shujc0243



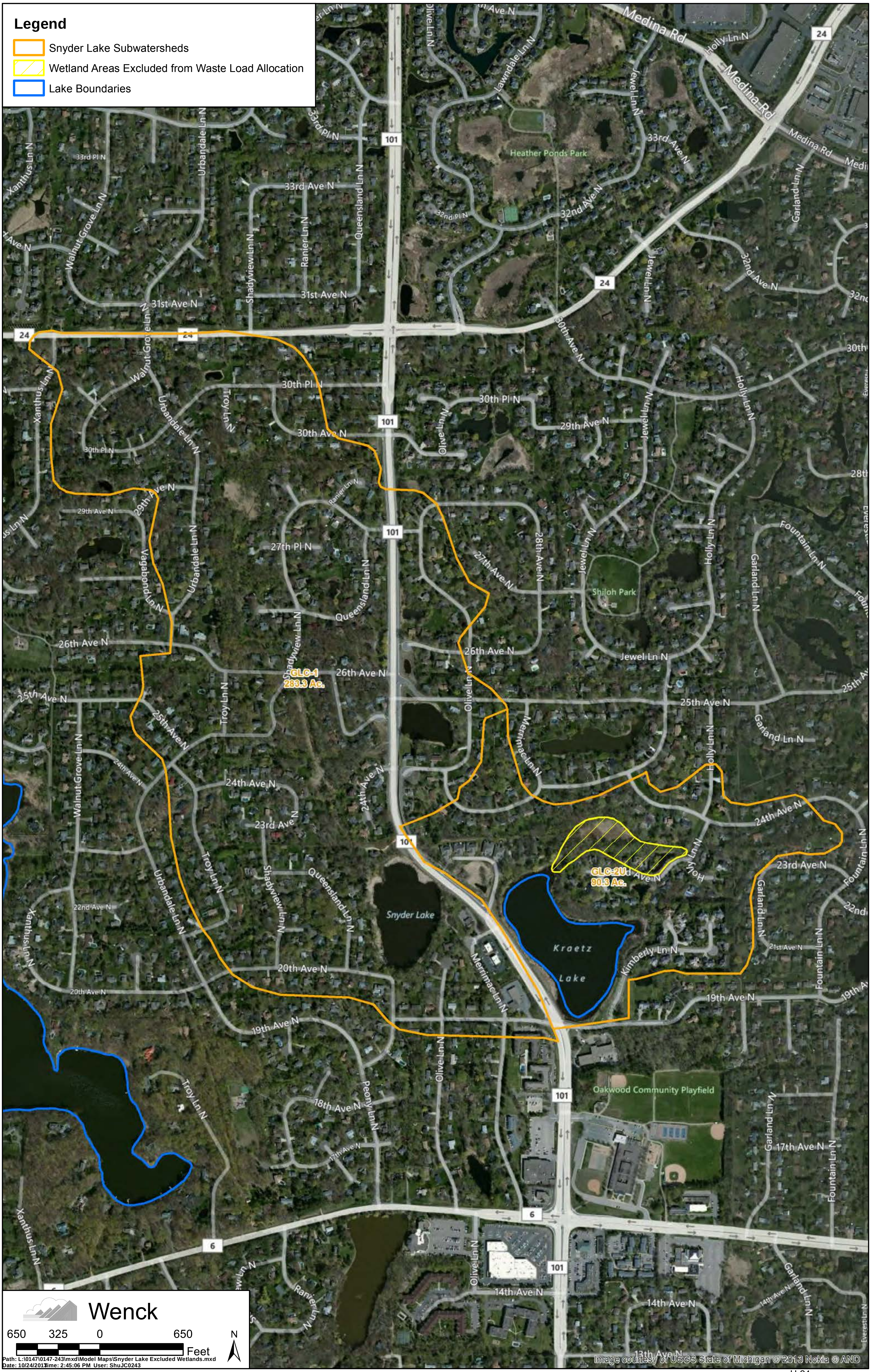
Path: L:\0147\0147-243\mxd\Model Maps\Langdon Lake Excluded Wetlands.mxd
Date: 10/16/2013 Time: 9:59:13 AM User: ShuJC0243

LLC-6
375.7 Ac.
LLC-14
60 Ac.
LLC-13
107.7 Ac.
LLC-12
169.8 Ac.
LLC-17
61.3 Ac.
LLC-18
108.1 Ac.
LLC-15M
15.4 Ac.
LLC-15U
20.7 Ac.
LLC-16
78.4 Ac.
LLC-41
741.7 Ac.
6th Ave N
Lakeview Terrace
N Farm Rd
W Farm Rd
Brown Rd N
Long Lake Blvd
Dakota Ave
Inglewood Rd
Knoll Manor Rd
Tamarack Dr
Wyndmere Rd
Spring Hill Rd
Long Lake
Wenck
400 200 0 400
Feet
N
Image courtesy of
Legend
Long Lake Subwatersheds
Wetland Areas Excluded from Waste Load Allocation
Lake Boundaries



Path: L:\0147\0147-243\mxd\Model Maps\Mooney Lake Excluded Wetlands.mxd
Date: 10/30/2013 Time: 9:37:25 AM User: ShuJC0243


Legend
School Lake Subwatersheds
Wetland Areas Excluded from Waste Load Allocation
Lake Boundaries
Leawood Dr
Hamel Rd
Parkview Dr
201
24
National Golf Course
LLC-1
296.5 Ac.
LLC-2
257 Ac.
School Lake
Willowood Farm Rd
Willow Dr
Apache Dr
Krieg Lake
Hollybush Rd
Wenck
700 350 0 700
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\School Lake Excluded Wetlands.mxd
Date: 10/24/2013 Time: 2:47:09 PM User: ShuJC0243
Image courtesy of USGS State of Michigan © 2013 Nokia © AND



Legend
Snyder Lake Subwatersheds
Wetland Areas Excluded from Waste Load Allocation
Lake Boundaries
GLC-1
283.3 Ac.
GLC-2
90.3 Ac.
Snyder Lake
Kraetz Lake
Heather Ponds Park
Shiloh Park
Oakwood Community Playfield
Medina Rd
Holly Ln N
Lawndale Ln N
Olive Ln N
Jewel Ln N
33rd Ave N
33rd Pl N
Urbandale Ln N
Xanthus Ln N
Walnut Grove Ln N
Shadyview Ln N
Ranier Ln N
Queensland Ln N
31st Ave N
32nd Ave N
32nd Pl N
Garland Ln N
30th Ave N
30th Pl N
29th Ave N
Troy Ln N
Vagabond Ln N
27th Pl N
27th Ave N
28th Ave N
Fountain Ln N
26th Ave N
Jewel Ln N
25th Ave N
Merrimac Ln N
24th Ave N
23rd Ave N
22nd Ave N
21st Ave N
20th Ave N
Kimberly Ln N
19th Ave N
18th Ave N
Peony Ln N
17th Ave N
14th Ave N
13th Ave N
Everest Ln N
101
24
6
Wenck
650 325 0 650
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Snyder Lake Excluded Wetlands.mxd
Date: 10/24/2013 Time: 2:45:06 PM User: ShuJC0243
Image courtesy of USGS State of Michigan © 2013 Nokia © AND


Lake Minnetonka-Upper Lake
Minnetonka-Upper Lake
Lotus Dr
Kings Pt Rd
Oak Rd
Trillium Ln W
Trillium Way
Margaret Circle
Shady Ln
Meadowood Ln
Lake Minnetonka Regional Park
SMC-16
43 Ac.
SMC-17
46.5 Ac.
SMC-18
791.4 Ac.
Stone Lake
Stone
Victoria Dr
Grimm Rd
Crosby Lake
Nature Center Dr
Zumbra-Sunny
Zumbra Lake
Sunny
Sunny Lake
Carver Park Reserve
Image courtesy of
Legend
Stone Lake Subwatersheds
Wetland Areas Excluded from Waste Load Allocation
Lake Boundaries
Wenck
800 400 0 800
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Stone Lake Excluded Wetlands.mxd
Date: 10/24/2013 Time: 2:38:55 PM User: ShuJC0243


Legend
Tamarack Lake Subwatersheds
Wetland Areas Excluded from Waste Load Allocation
Lake Boundaries
Tamarack Lake
Lake St Joe
LV-1U
208.8 Ac.
Rolling Acres Rd
Interlaken
St Moritz
Tamarack Trail
Overlook Ln
Kings Rd
Lakeridge Rd
Ridge Hill Rd
Tristan Dr
Maple Shores Dr
Minnewashta Pkwy
Hawthorne Circle
W 77th St
Lone Cedar Ln
Arboretum Blvd
Bavaria Rd
13
5
Wenck
400 200 0 400
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Tamarack Lake Excluded Wetlands.mxd
Date: 10/24/2013 Time: 2:48:42 PM User: ShuJC0243
Image courtesy of USGS State of Michigan © 2012 Zenrin © AND


Legend
Turbid Lake Subwatersheds
Wetland Areas Excluded from Waste Load Allocation
Lake Boundaries
Turbid Lake
SMC-32
533.1 Ac.
Spring Valley Rd
Cardinal Ln
Windy Ridge
Wildwood Rd
Laketown Rd
Scandia Rd
Airport Rd
Reitz Lake Rd
Tellers Rd
Wenck
700 350 0 700
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Turbid Lake Excluded Wetlands.mxd
Date: 10/24/2013 Time: 2:52:15 PM User: ShuJC0243
Image courtesy of USGS State of Michigan © 2012 Zenrin © AND


Legend
Wolsfeld Lake Subwatersheds
Wetland Areas Excluded from Waste Load Allocation
Lake Boundaries
Swamp Lake
LLC-1
296.5 Ac.
LLC-2
257 Ac.
School Lake
LLC-2U
9.7 Ac.
LLC-3
212.9 Ac.
Krieg Lake
LLC-4
267.9 Ac.
Thies Lake
LLC-5
174.2 Ac.
Wolsfeld Lake
LLC-6
375.7 Ac.
Dickeys Lake
Lake Classen
Hamel Rd
Pioneer Trail
Hamel
Arrowhead Dr
Blackfoot Trail
Willow Dr
Willowood Farm Rd
Chestnut Rd
Parkview Dr
Bartle Farm Rd
Hollybush Rd
Apache Dr
Morgan Rd
Medina Rd
Cottonwood Trail
Iroquois Dr
Deer Hill Rd
Bobolink Rd
Morningside Rd
Elsinor Circle
Keller Rd
Hometown Trail
6th Ave N
Jamestown Rd
Willow View Rd
Shadowood Dr
Brown Rd N
N Farm Rd
W Farm Rd
Dakota Ave
Long Lake Blvd
Tanglewood Rd
Old Crystal Bay Rd
Kelley Pkwy
Dickey Lake Dr
Sugarwood Dr
Wayzata Blvd W
Willow Dr N
115
201
24
6
112
Wenck
1,300 650 0 1,300
Feet
N
Path: L:\0147\0147-243\mxd\Model Maps\Wolsfeld Lake Excluded Wetlands.mxd
Date: 10/24/2013 Time: 2:50:15 PM User: ShuJC0243
Image courtesy of USGS State of Michigan © 2013 Nokia © AND