SECTION 4
PHOSPHORUS

4.01 OBJECTIVE

The 2009 *Lake Wingra*: *A Vision for the Future,* prepared by the FOLW, identifies addressing excessive pollutants that cause frequent algae blooms (namely TP and sediment/TSS) in the Lake Wingra watershed as a critical element of Goal 2, clean, clear water. For purposes of this plan, the objective in working toward this goal is described in terms of the following short-term and long-term goals.

1. Short-Term Goal: 50 percent reduction in TP compared to no pollutant reduction controls.

2. Long-Term Goal: 80 percent reduction in TP compared to no pollutant reduction controls. This goal is consistent with the Rock River Total Maximum Daily Load (TMDL) and the City's requirement for redevelopment sites. The Rock River TMDL (Reach 64) requires a 61 percent and 73 percent TSS and TP load reduction, respectively.

In an effort to achieve these goals, this portion of the management plan:

1. Describes the Lake Wingra surface water watershed including current estimated phosphorus and TSS loads to Lake Wingra.

2. Identifies primary TP and TSS contributors.

3. Performs an alternatives analysis that identifies ways to achieve the short-term goal of 50 percent reduction in TP in the watershed compared to baseline conditions without pollutant reduction controls.

4. Seeks to achieve the infiltration and TP reduction short-term goals through projects that jointly provide an infiltration and TP reduction benefit.

5. Reviews management changes that have the potential to achieve the short-term pollutant reduction goal.

6. Recommends management changes to pursue.

7. Provides discussion on potential strategies for meeting the long-term goal.

4.02 BACKGROUND

A. Sources of Sediment and Phosphorus

The Wingra Watershed is predominantly a fully built-out urban environment from which sediment and phosphorus originate. Urban stormwater runoff carries with it sediments that wash off impervious areas (parking lots, roadways, driveways, and sidewalks), pervious areas (lawns, golf courses, landscaped areas), streambank erosion, and construction sites. Phosphorus in that runoff exists in both a particulate and dissolved state. Sources of phosphorus include organic matter (i.e., leaves, pollen, buds, grass clippings, and yard waste), legacy lawn fertilizer, starter fertilizer for new lawns, soil, windblown soil, pet waste, waterfowl waste, streambank erosion, and construction sites. Figure 4.02-1 shows an example of phosphorus and sediment discharging just upstream of Lake Wingra at Manitou Pond.

Source: David Liebl

Figure 4.02-1 Phosphorus and Sediment-Laden Stormwater Entering Manitou Pond

Source: David Liebl

Figure 4.02-2 Sediment Islands on West End of Lake Wingra

B. <u>Effects of Sediment and Phosphorus on Lake Wingra</u>

1. **Sediment–**Signs of sediment in Lake Wingra include ever increasing lake bottom sediments, buildup of sediment at storm sewer outfalls, and a number of sediment islands on the west end of Lake Wingra created by slow moving water settling out sediment as shown in Figure 4.02-2. These sediments can cover spawning habitat and carry with them pollutants such as phosphorus and pesticides that are harmful to aquatic plants and animals**.**

2. **Phosphorus**–Nutrients such as phosphorus are essential, naturally occurring elements for plant growth but increased levels of these nutrients can jeopardize water quality. High phosphorus levels in water bodies can lead to excessive algae and aquatic plant growth that can harm aquatic life and impair recreational use. It can cause toxic algae blooms, reduce water clarity, and deplete oxygen levels. Low water oxygen levels can stress or kill fish and other aquatic animals.

   Signs of phosphorus in Lake Wingra include algae blooms as shown in Figure 4.02-3 and excessive aquatic plant growth that are both unsightly and unhealthy, leading to reduced recreational use of the lake. Coupled with bacteria in stormwater runoff, phosphorus has also contributed to Vilas Park Beach closures as shown in Figure 4.02-4**.**

Source: Mike Kakuska

Figure 4.02-3 Algae Bloom on Lake Wingra

Figure 4.02-4 Vilas Park Beach Closure

C. <u>Previous Efforts to Control Phosphorus in the Wingra Watershed</u>

The negative effects of sediment and phosphorus have not gone unheeded. Over the years, various initiatives have moved forward to control urban pollutants both upstream of the lake and within the lake as follows. The effect of many of the structural controls is reflected in the City's P8 stormwater quality model discussed in Section 4.03.

1. Upstream Phosphorus Initiatives

   a. *Fertilizer Phosphorus Bans*–On January 1, 2005, Dane County Ordinance Chapter 80 became effective. This ordinance prohibits the use of phosphorus-containing lawn fertilizer for residential, commercial, and golf course applications, unless a soil test shows that phosphorus is necessary or when starting a new lawn. It also prohibits the retail display of phosphorus-containing lawn fertilizers. On April 1, 2010, Chapter 94.643 of the Wisconsin Administrative Code became effective which bans the use and sale of phosphorus and phosphate-containing fertilizer in Wisconsin. Both of these initiatives are positive for the state and Lake Wingra, though legacy phosphorus on lawns and golf course will continue to contribute phosphorus until phosphorus levels naturally decrease.

   b. *UW-Madison Arboretum Stormwater Best Management Practices (BMPs)*–Stormwater detention ponds constructed in the 1980s within the UW-Madison Arboretum that protected the lake from urban pollutants had degraded or filled up with sediment by the early 2000s. The UW-Madison embarked on an ambitious plan to rehabilitate and/or upgrade these facilities over the last decade. Funding for completion of these projects was garnered through an intermunicipal agreement between UW-Madison, City of Madison, Town of Madison, and City of Fitchburg. Figure 4.02-5 shows a picture of rehabilitated Secret Pond and Channel in the fall of 2013, and Table 4.02-1 provides a listing of the BMPs in the UW-Madison Arboretum.

c. *Wisconsin Department of Transportation (Verona Road/Beltline Reconstruction)*–In 2013, the Wisconsin Department of Transportation constructed a wet detention pond along the Southwest Commuter Bike Path near the southeast corner of the Odana Hills Golf Course. For purposes of this plan, 105.85-acre watershed W102-C-0324-H-MAD-C was split into two watersheds (8.33-acre W102-C-0324**A**-H-MAD-C not draining through the pond and 97.52-acre W102-C-0324**B**-H-MAD-C draining through the pond).

Figure 4.02-5 Secret Pond and Channel Rehabilitation

Facility	Year Constructed	Comments
Marion-Dunn Pond	2003	Pond dredging and forebay construction.
Secret Pond Channel Energy Dissipater	2003	Field stone energy dissipater at storm outfall to Secret Pond Channel.
Pond 2 and Wetland Basin	2009	In-line stormwater treatment device on Waste Management property constructed by Waste Management, Pond 2 dredging, and wetland creation.
Pond 4	2009	Pond dredging, expansion and rehabilitation with sediment forebay. Drains downstream of Lake Wingra.
Secret Pond	2011	Secret Pond dredging and conversion to wetland stilling basin, Secret Pond Channel restoration and meandering, and Manitou Pond wet pond construction.
Pond 3	2012	City of Madison-funded project providing pretreatment of flows to Pond 3, dredging and expansion of Pond 3, and storm sewer. Drains downstream of Lake Wingra.
Sand and Trash Collector Upstream of Curtis Pond	2014	WisDOT-funded project providing pretreatment for Curtis Pond.
Curtis Pond	Pending	Pond dredging and replacement of damaged concrete flume with storm sewer.

Table 4.02-1 UW-Arboretum and WisDOT Stormwater BMPs

d. *Stormwater and Erosion Control Regulatory Requirements*–Both the City of Madison (Chapter 37) and Dane County (Chapter 14) have ordinances to control runoff from construction sites and postconstruction sites. Current City ordinances for new development projects require an 80 percent TSS reduction compared to no runoff management controls. Likewise, current City ordinances for redevelopment projects within the Rock River TMDL require an 80 percent TSS reduction compared to existing conditions of the site before redevelopment.

e. *Marion-Dunn Pond Alum Pilot Project*–In 2013, the City of Madison initiated a pilot project at the Marion-Dunn Pond to look at the feasibility of dosing stormwater flows with alum upstream of detention ponds. Alum may make the pond more efficient at removing phosphorus by precipitating out dissolved phosphorus that normally would pass through the pond.

2. In-Lake Phosphorus Initiatives

a. *Carp Harvesting*–In March of 2008, project partners, Friends of Lake Wingra, Wisconsin WDNR, UW-Extension, Dane County, City of Madison Parks, Dane County Fishing Expo, and the Madison Muskie Club collaborated on a carp harvesting project (see Figure 4.02-6). This initiative entailed harvesting carp using remote control submarines below the ice surface. Lake Wingra water quality in the past five years has been noticeably improved resulting from a reduction in carp-induced sediment resuspension and improved aquatic vegetation coverage.

Source: David Liebl

Figure 4.02-6 Winter 2008 Lake Wingra Carp Harvesting

Figure 4.02-7 Weed Cutter

b. Weed Cutting by Dane County–Dane County has a program for weed harvesting in Lake Wingra (see Figure 4.02-7). It has been reported that increased water clarity resulting from carp harvesting has allowed macrophyte (aquatic plant) growth to increase. Increased weed cutting will likely be required as water quality continues to improve. Removal of the cut weeds also removes an in-lake phosphorus source.

c. UW-Madison Lake Wingra Response Model (March 2015 Draft Report)–The UW-Madison and the City partnered to create a lake response model that estimates the various controlling factors for water quality in Lake Wingra including phosphorus loads from surface runoff and sediment resuspension from wind/waves and carp. This model assists in targeting the right contributing factor for lake water quality. Preliminary results of this effort suggest that carp are the main contributor to sediment in the lake water column during summer months while wind resuspension has the least impact (owing to dense vegetation and low wind speeds in the summer, though spring and late fall could increase significantly with sparse vegetation and higher winds, especially along the north lake shoreline). Preliminary results also suggest that TP loadings in the lake are governed by both storm runoff and carp, while orthophosphorus (i.e., dissolved phosphorus) loading in the lake is governed by storm runoff. Sediment resuspension did not result in significant increases in orthophosphorus.

D. Factors Affecting Sediment and Phosphorus Loads

Several factors affect sediment and phosphorus loads in the Lake Wingra watershed:

1. Amount of pervious/impervious area.
2. Soil types.
3. Infiltration rate of pervious surfaces.
4. Amount of surface runoff.
5. Amount of pet waste and waterfowl waste.
6. Management of grass clippings and leaves.
7. Construction site erosion control effectiveness.
8. Streambank or stormwater conveyance channel erosion rates.
9. Dedicated postconstruction BMPs in the surface water watershed.

4.03 CONTRIBUTING WATERSHED CHARACTERISTICS

The primary contributor of stormwater pollutants (TSS and TP) to Lake Wingra is development in the watershed. Various development types contribute different quantities of runoff and associated pollutants depending on their characteristics. These varying pollutant loads are estimated using the City's P8 model. The P8 model aggregates all urban pollutant sources as loads from a particular watershed without differentiating the specific source that includes varying proportions of the following: lawns, streets, sidewalks, roofs, leaves, streambank erosion, construction sites, and pet waste. Within this study, we provide information on the City's P8 model output and how management of some of the specific sources can provide reduced stormwater pollutant loads in the Lake Wingra watershed. Appendix C includes a schematic of the watershed model.

A. Watershed

1. Surface Water Watershed–The official watershed boundary for the management plan is shown in Figure 3.02-3. It includes areas that drain to Wingra Creek as well as to the Gardner Marsh. While the study boundary includes these eastern areas, these areas do not drain into Lake Wingra and, therefore, do not affect TP and TSS loads to the lake. In that regard, the two blue-shaded areas within Figure 3.02-3 illustrate the tributary area directly draining into the lake, the tributary area that affects TP and TSS loads to the lake. Taking this into account, the Lake Wingra surface water watershed (both blue areas on Figure 3.02-3) encompasses a total of 3,636 acres with 1,105 of these acres first draining through the Odana Hills Golf Course pond before draining to Lake Wingra.

   The watershed generally drains from west to east via a system of storm sewers, open channels, and ditches as shown on Figure 4.03-1. Six stormwater detention ponds surround Lake Wingra including Pond 2/Wetland Basin, Coyote Pond (a natural seepage depression also fed by upstream storm sewers), Curtis Pond, Secret Pond, Marion-Dunn Pond, and Ho-Nee-Um Pond. Each pond provides some level of stormwater quality treatment of runoff before discharge into Lake Wingra but generally does not provide appreciable infiltration of stormwater runoff. Two ponds, Pond 4 and Pond 3, drain downstream of the lake to Wingra Creek.

B. Baseline Pollutant Loads

The City-provided P8 model (September 18, 2013 revision) was used to determine the locations within the watershed that contribute the highest pollutant loading rates for both TP and TSS. Table 4.03-1 and Figures 4.03-2 and 4.03-3 illustrate the highest pollutant loading rates for TP and TSS, respectively, under baseline (no BMP controls) conditions.

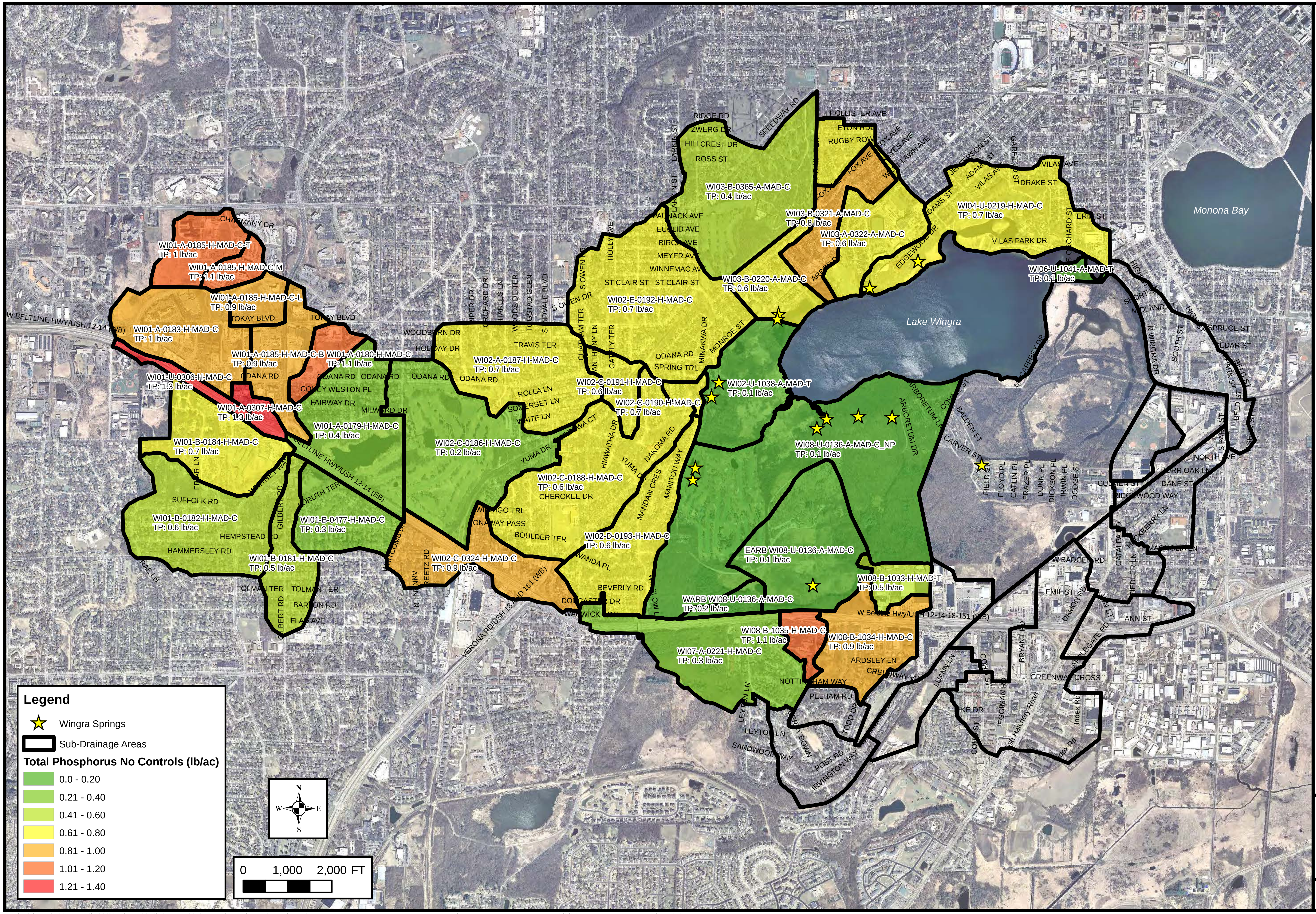
These figures show that the highest baseline pollutant loads generally originate from commercial, business, institutional, and multifamily residential areas in the watershed. They also show that open areas such as the UW-Madison Arboretum have the lowest pollutant loads in the watershed and thus the least amount of need for stormwater treatment. More telling, then, are the pollutant loading rates with existing stormwater quality BMPs in place as is discussed in the next section.

WATERSHED MAP

LAKE WINGRA WATERSHED MANAGEMENT PLAN
CITY OF MADISON
DANE COUNTY, WISCONSIN

STRAND ASSOCIATES

FIGURE 4.03-1
1020.065



LAKE WINGRA TOTAL PHOSPHORUS UNIT LOADS
P8 MODELING - BASELINE WITH NO CONTROLS

LAKE WINGRA WATERSHED MANAGEMENT PLAN
CITY OF MADISON
DANE COUNTY, WISCONSIN

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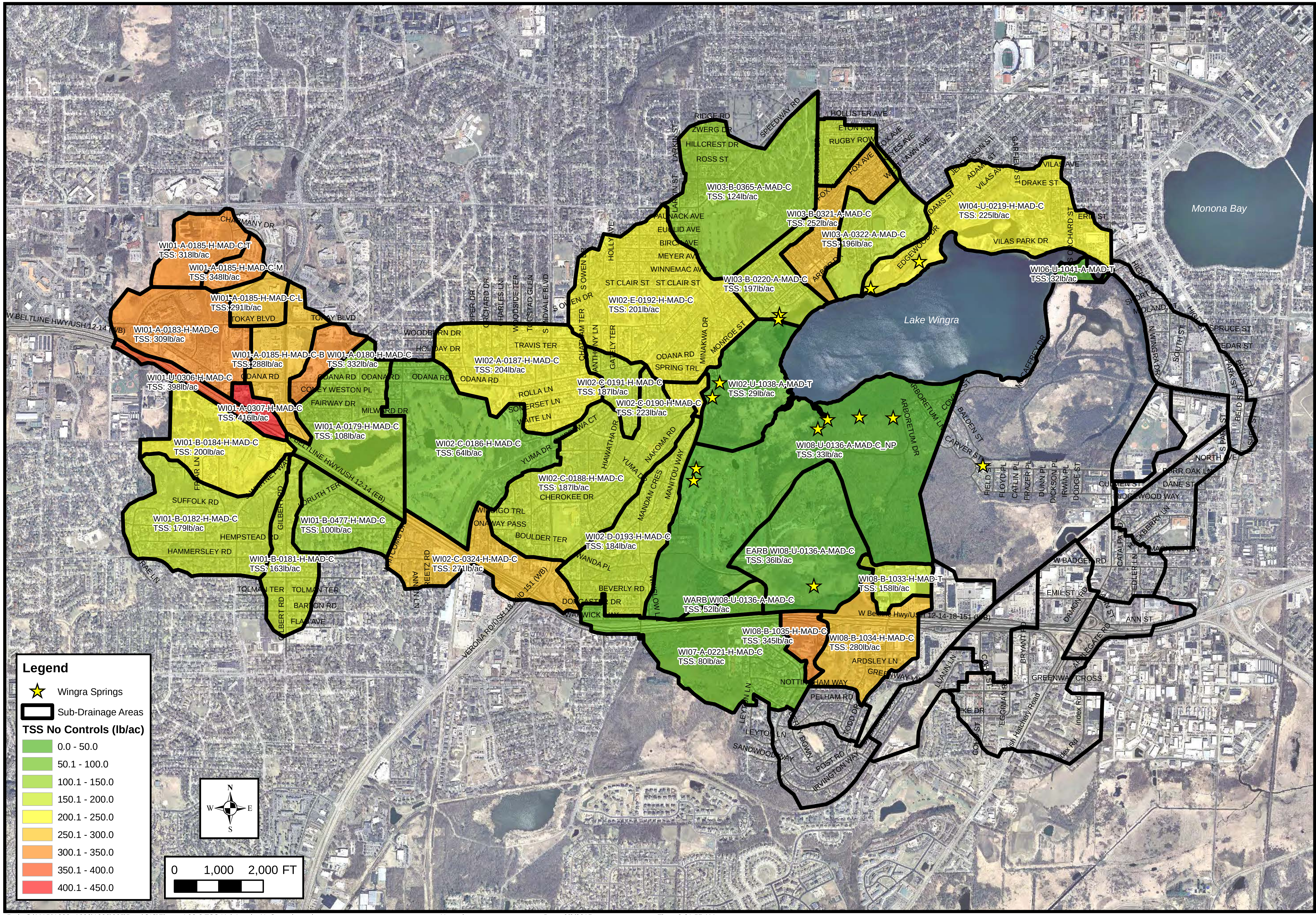
FIGURE 4.03-2
1020.065



LAKE WINGRA TOTAL SUSPENDED SOLIDS UNIT LOADS
P8 MODELING - BASELINE WITH NO CONTROLS

LAKE WINGRA WATERSHED MANAGEMENT PLAN
CITY OF MADISON
DANE COUNTY, WISCONSIN

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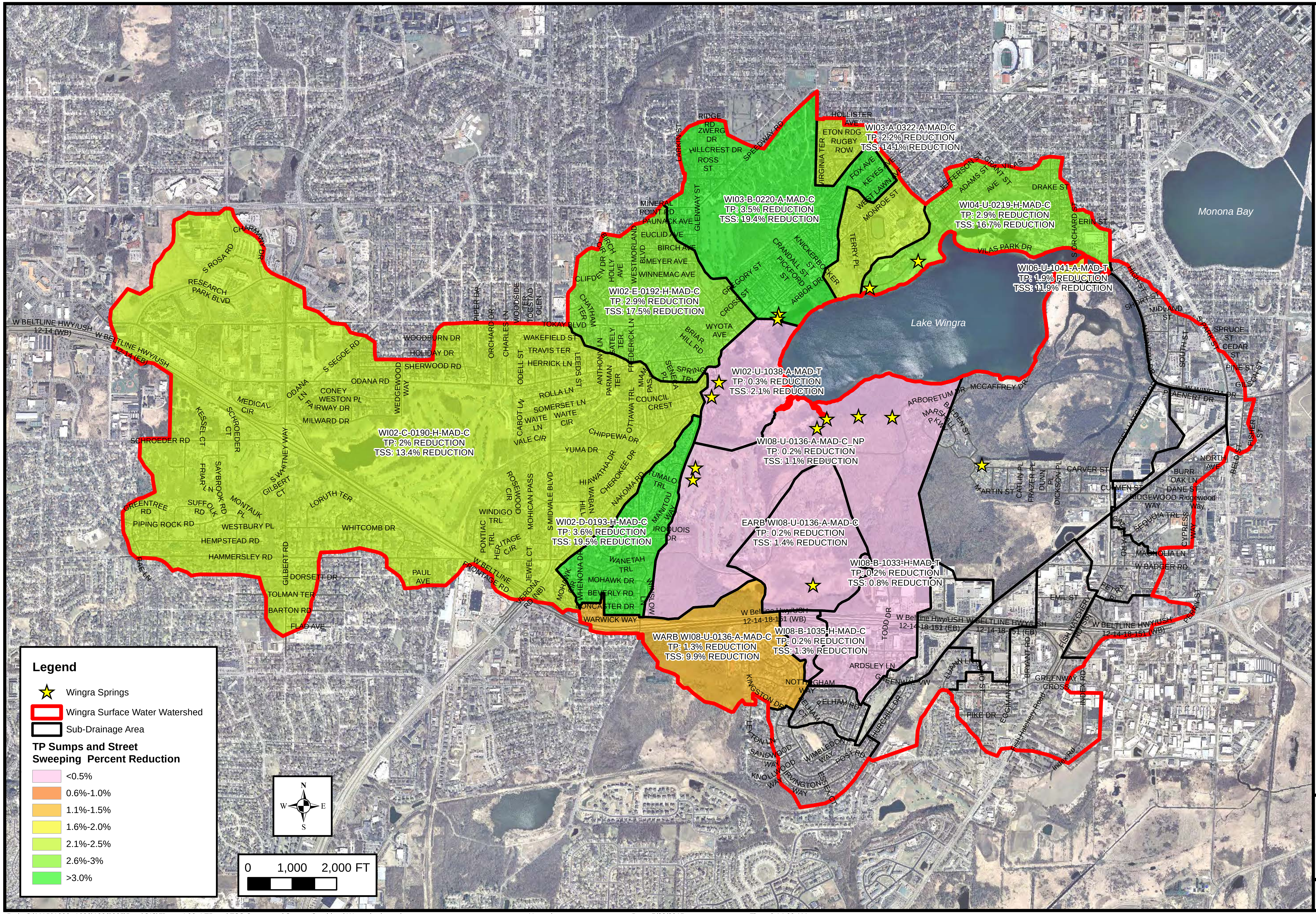
FIGURE 4.03-3
1020.065

Path: S:\MAD\1000--1099\1020\065\Data\GIS\Figure 4.03-3 TSS Unit Loads_NoControls.mxd User: danc Date: 6/3/2015 Time: 9:21:57 AM

C. Existing Pollutant Loads and Phosphorus Reduction Goal

Tables 4.03-2 and 4.03-3 show the watershed-wide performance under existing conditions (with BMP controls that have been implemented to date) for TP and TSS, respectively. The table includes performance for two scenarios: (1) sumps and street sweeping and (2) sumps, street sweeping, and ponds/bioretention basins (i.e., all BMPs). Figure 4.03-4 shows the watershed-wide performance for scenario 1 for TP and TSS. Figure 4.03-5 shows the watershed-wide performance for scenario 2 for TP and TSS. This allows for the contribution from ponds/bioretention basins to be evaluated. As can be seen, the watershed-wide TP and TSS reduction is 38.3 percent and 63.3 percent, respectively, compared to no pollutant controls. Table 4.03-4 provides the TSS and TP reduction performance of existing BMPs modeled in P8.

Figure 4.03-5 also shows drainage basins that are underserved in terms of stormwater quality treatment, namely basins W102-D-0193-H-MAD-C, W103-B-0220-A-MAD-C, W103-A-0322-A-MAD-C, and W104-U-0219-H-MAD-C. It should be noted that the basins (W102-U-1038-A-MAD-T, W108-U-0136-A-MAD-C_NP, EARB W108-U-0136-A-MAD-C) in the UW-Madison Arboretum show little treatment; however, because of their location in the UW-Madison Arboretum, they have little pollutant load. Targeting the underserved basins for proposed stormwater controls will allow additional stormwater quality treatment to be pursued for areas in need. Figure 4.03-6 shows the same condition as Figure 4.03-5 but also shows potential projects to gain additional stormwater quality treatment for underserved basins. Potential projects to gain additional stormwater quality treatment for underserved basins are described in Section 4.03 C. and shown in Figure 4.03-6. Identification and analysis of structural improvements has targeted these areas to the extent possible. Additional non-structural-type BMPs (wetland harvesting, modified leaf collection methods, waterfowl management, enhanced construction site erosion control enforcement, modified street sweeping methods/schedule, and pet waste enforcement) should be targeted for the following basins since they currently have not been analyzed to be served by a structural BMP: W103-B-0321-A-MAD-C and W104-U-0219-H-MAD-C. In general, modified leaf collection methods and modified street sweeping methods/schedule that address dissolved phosphorus should target all basins.



LAKE WINGRA TOTAL PHOSPHORUS AND SUSPENDED SOLIDS PERCENT REDUCTIONS
P8 MODELING (WITH EXISTING SUMPS AND STREET SWEEPING ONLY)

LAKE WINGRA WATERSHED MANAGEMENT PLAN
CITY OF MADISON
DANE COUNTY, WISCONSIN

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FIGURE 4.03-4
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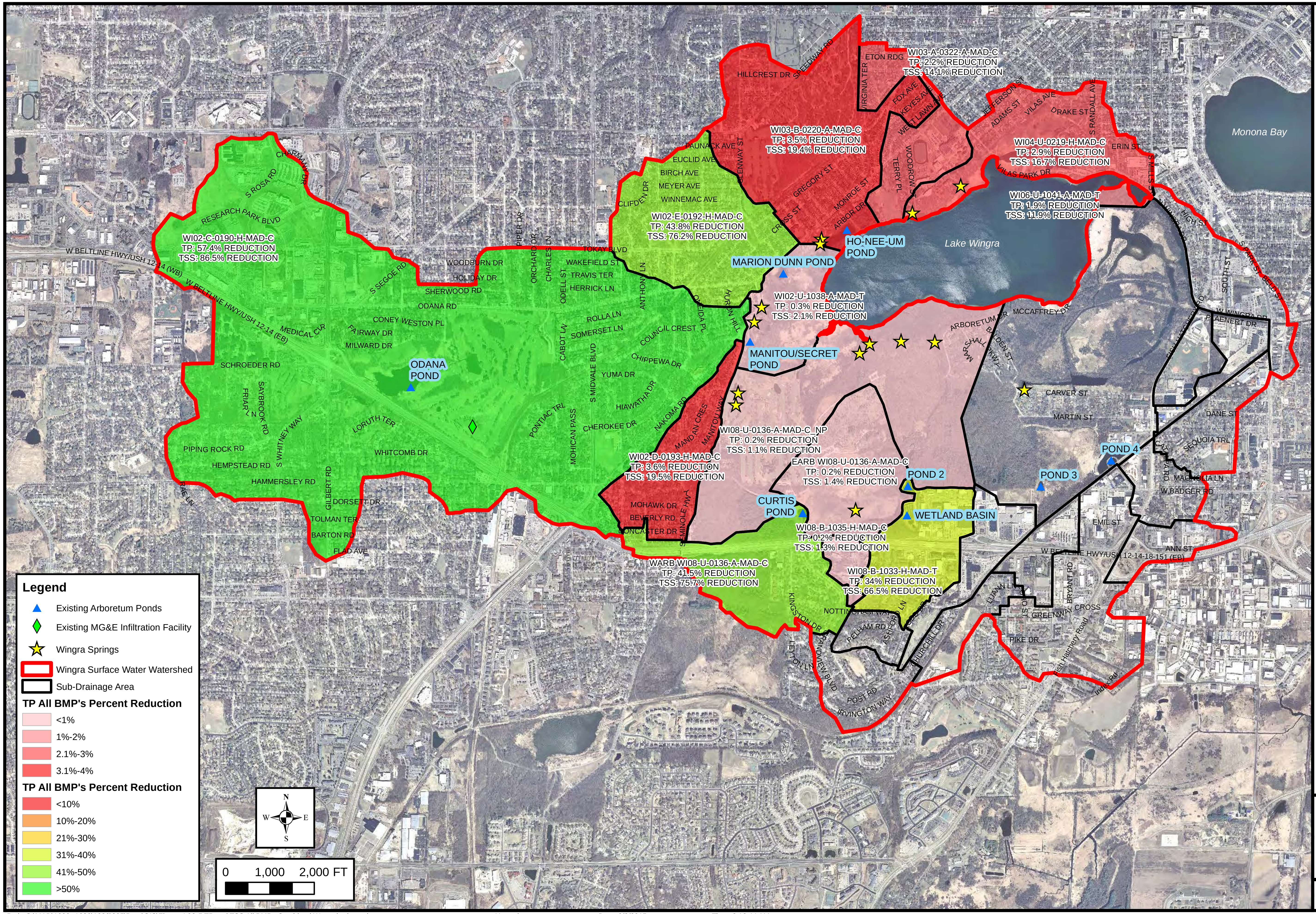
Path: S:\MAD\1000--1099\1020\065\Data\GIS\Figure 4.03-4 TP and TSS Sumps and Streets Combined Watersheds.mxd User: danc Date: 5/28/2015 Time: 9:14:09 AM



LAKE WINGRA TOTAL PHOSPHORUS AND SUSPENDED SOLIDS PERCENT REDUCTIONS
P8 MODELING (WITH ALL EXISTING BMPs)

LAKE WINGRA WATERSHED MANAGEMENT PLAN
CITY OF MADISON
DANE COUNTY, WISCONSIN

STRAND ASSOCIATES®

FIGURE 4.03-5
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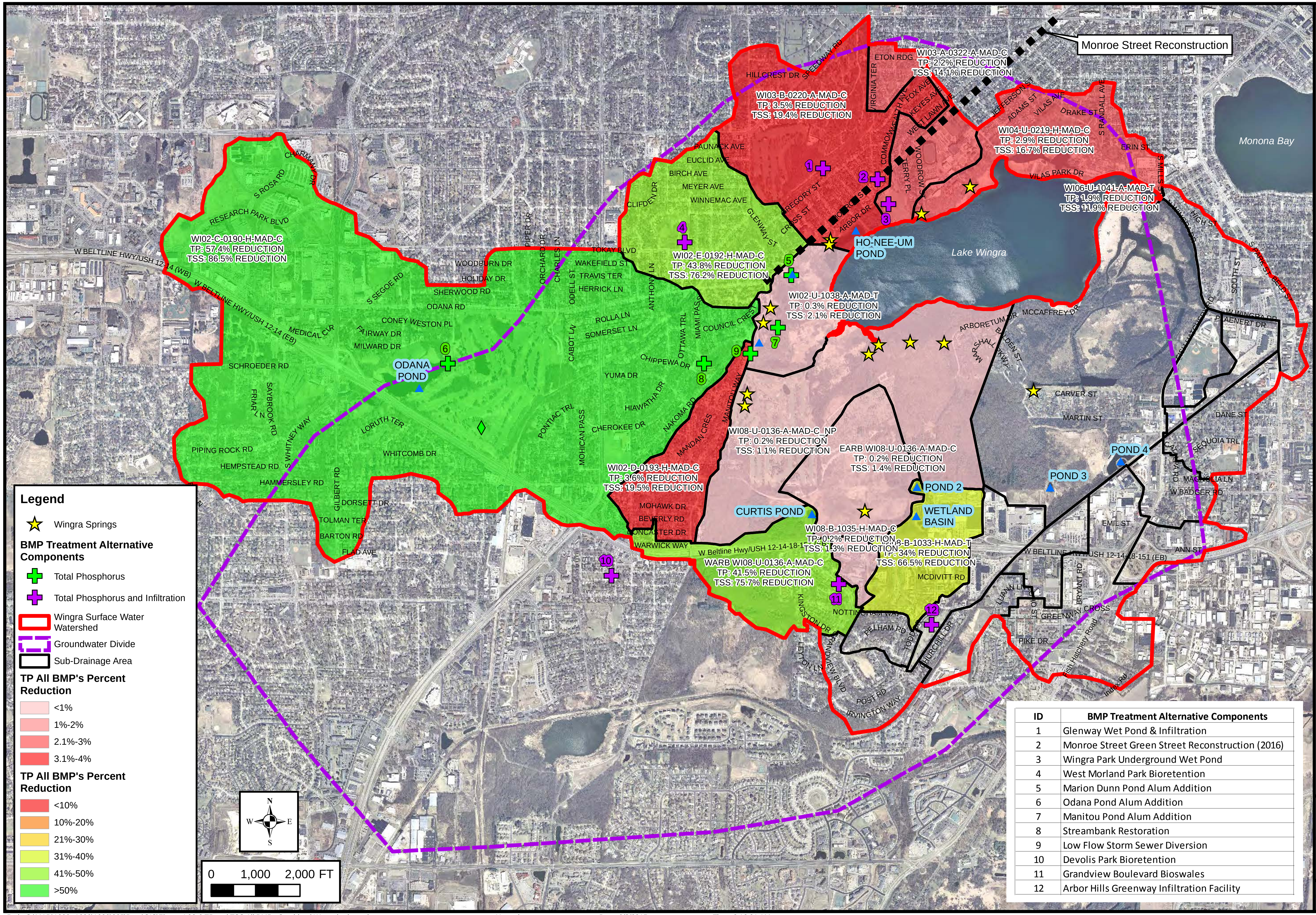
Path: S:\MAD\1000--1099\1020\065\Data\GIS\Figure 4.03-5 TP and TSS All BMPs Combined Watersheds.mxd User: danc Date: 6/3/2015 Time: 8:12:44 AM



ID	BMP Treatment Alternative Components
1	Glenway Wet Pond & Infiltration
2	Monroe Street Green Street Reconstruction (2016)
3	Wingra Park Underground Wet Pond
4	West Morland Park Bioretention
5	Marion Dunn Pond Alum Addition
6	Odana Pond Alum Addition
7	Manitou Pond Alum Addition
8	Streambank Restoration
9	Low Flow Storm Sewer Diversion
10	Devolis Park Bioretention
11	Grandview Boulevard Bioswales
12	Arbor Hills Greenway Infiltration Facility

LAKE WINGRA TOTAL PHOSPHORUS AND SUSPENDED SOLIDS PERCENT REDUCTIONS
P8 MODELING (WITH ALL EXISTING BMPs) - SHOWING PROPOSED PROJECTS

LAKE WINGRA WATERSHED MANAGEMENT PLAN
CITY OF MADISON
DANE COUNTY, WISCONSIN

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FIGURE 4.03-6
1020.065

Table 4.03-1 TP and TSS Baseline (No Controls) Loading Rates

Basin	Acres	Baseline TP Load	Baseline TP Load/Acre	Baseline TSS Load	Baseline TSS Load/Acre
WI02-U-1038-A-MAD-T (P8 File)					
WI02-U-1038-A-MAD-T	100.8	11.7	0.1	2,942	29.2
WI02-D-0193-H-MAD-C	120.7	72.9	0.6	22,181	183.8
WI02-E-0192-H-MAD-C	230.9	152.3	0.7	46,334	200.7
WI01-A-0185-H-MAD-C-T	55.6	57.1	1.0	17,662	317.6
WI01-A-0185-H-MAD-C-M	22.2	25.0	1.1	7,741	348.1
WI01-A-0185-H-MAD-C-L	31.3	29.5	0.9	9,122	291.1
WI01-A-0185-H-MAD-C-B	68.5	63.5	0.9	19,726	287.8
WI01-A-0180-H-MAD-C	29.7	31.7	1.1	9,844	331.6
WI01-A-0183-H-MAD-C	116.0	115.2	1.0	35,826	308.9
WI01-U-0306-H-MAD-C	18.1	22.8	1.3	7,176	397.6
WI01-A-0307-H-MAD-C	16.9	22.3	1.3	7,010	416.0
WI01-B-0181-H-MAD-C	67.2	36.0	0.5	10,925	162.7
WI01-B-0182-H-MAD-C	156.2	92.2	0.6	27,987	179.1
WI01-B-0477-H-MAD-C	74.7	25.4	0.3	7,473	100.1
WI01-B-0184-H-MAD-C	100.4	65.9	0.7	20,111	200.3
WI01-A-0179-H-MAD-C	141.8	52.1	0.4	15,374	108.4
WI02-C-0186-H-MAD-C	206.6	47.0	0.2	13,295	64.4
WI02-C-0324-H-MAD-C	105.9	92.7	0.9	28,711	271.2
WI02-A-0187-H-MAD-C	153.1	101.9	0.7	31,234	204.0
WI02-C-0188-H-MAD-C	203.5	125.2	0.6	38,122	187.3
WI02-C-0191-H-MAD-C	32.4	19.9	0.6	6,051	186.7
WI02-C-0190-H-MAD-C	11.6	8.5	0.7	2,592	222.9
WI08-U-0136-A-MAD-C (P8 File)					
WI07-A-0221-H-MAD-C	153.3	42.3	0.3	12,266	80.0
WARB WI08-U-0136-A-MAD-C	18.1	3.4	0.2	931	51.5
WI08-B-1034-H-MAD-C	93.8	84.7	0.9	26,287	280.2
WI08-B-1033-H-MAD-T	28.6	15.7	0.5	4,509	157.9
WI08-B-1035-H-MAD-C	24.7	27.5	1.1	8,517	344.8
EARB WI08-U-0136-A-MAD-C	151.0	20.6	0.1	5,393	35.7
WI08-U-0136-A-MAD-C_NP	412.8	53.2	0.1	13,777	33.4
WI03-B-0220-A-MAD-C (P8 File)					
WI03-B-0220-A-MAD-C	57.4	37.2	0.6	11,332	197.4
WI03-B-0321-A-MAD-C	64.5	52.9	0.8	16,283	252.4
WI03-B-0365-A-MAD-C	202.8	84.6	0.4	25,152	124.0
Individual P8 Files					
WI03-A-0322-A-MAD-C	112.5	71.9	0.6	22,011	195.7
WI04-U-0219-H-MAD-C	179.1	132.9	0.7	40,298	225.0
WI06-U-1041-A-MAD-T	8.7	1.1	0.1	279	31.9
Total	**3571.1**	**1,898.6**		**574,474**	

Table 4.03-2 TP Reduction from Existing Controls

Major Watershed	Location in Watershed	Incoming TP Load (lbs)	From Street Sweeping and Sumps Outgoing TP Load (lbs)	With All BMPs Outgoing TP Load (lbs)	From Street Sweeping and Sumps Load Reduction (%)	With All BMPs Load Reduction (%)
WI02-C-0190-H-MAD-C	Western Basins including Areas Draining Through UW Research Park BMPs, Odana Ponds Incl/Infiltration Facility, Manitou Pond, Secret Pond, and WisDOT Pond	1034	1013	440	2.0%	57.4%
W102-E-0192-H-MAD-C	Marion Dunn Pond and Westmorland Rain Garden Area	152	148	86	2.9%	43.8%
W102-D-0193-H-MAD-C	Seminole Highway/Manitou Way Area	73	70	70	3.6%	3.6%
WI03-B-0220-A-MAD-C	Ho-Nee-Um Pond Area	175	169	169	3.5%	3.5%
WI03-A-0322-A-MAD-C	Edgewood College Area	72	70	70	2.2%	2.2%
WI04-U-0219-H-MAD-C	Vilas Park Area	133	129	129	2.9%	2.9%
WI06-U-1041-A-MAD-T	South Side of Wingra Dam	1	1	1	1.9%	1.9%
WARB W108-U-1036-A-MAD-C	Curtis Pond Area	46	45	27	1.3%	41.5%
W108-B-1035-H-MAD-C	Coyote Pond	27	27	27	0.2%	0.2%
W108-B-1033-H-MAD-C	Pond 2 and Wetland Basin	100	100	66	0.2%	34.0%
EARB W108-U-0136-A-MAD-C	Central Arboretum	21	21	21	0.2%	0.2%
W108-U-0136-A-MAD-C_NP	Northern Arboretum and Nakoma Golf Course	53	53	53	0.2%	0.2%
W102-U-1038-A-MAD-T	Downstream of Manitou and Secret Pond	12	12	12	0.3%	0.3%
	Total	**1,899**	**1,858**	**1,171**	**2.2%**	**38.3%**

Table 4.03-3 TSS Reduction from Existing Controls

Major Watershed	Location in Watershed	Incoming TSS Load (lbs)	From Street Sweeping and Sumps Outgoing TSS Load (lbs)	With All BMPs Outgoing TSS Load (lbs)	From Street Sweeping and Sumps Load Reduction (%)	With All BMPs Load Reduction (%)
WI02-C-0190-H-MAD-C	Western Basins including Areas Draining Through UW Research Park BMPs, Odana Ponds Incl/Infiltration Facility, Manitou Pond, Secret Pond, and WisDOT Pond	315,982	273,683	42,763	13.4%	86.5%
W102-E-0192-H-MAD-C	Marion Dunn Pond and Westmorland Rain Garden Area	46,334	38,217	11,011	17.5%	76.2%
W102-D-0193-H-MAD-C	Seminole Highway/Manitou Way Area	22,181	17,848	17,848	19.5%	19.5%
WI03-B-0220-A-MAD-C	Ho-Nee-Um Pond Area	52,768	42,549	42,549	19.4%	19.4%
WI03-A-0322-A-MAD-C	Edgewood College Area	22,011	18,903	18,903	14.1%	14.1%
WI04-U-0219-H-MAD-C	Vilas Park Area	40,298	33,577	33,577	16.7%	16.7%
WI06-U-1041-A-MAD-T	South Side of Wingra Dam	279	246	246	11.9%	11.9%
WARB W108-U-1036-A-MAD-C	Curtis Pond Area	13,197	11,888	3,205	9.9%	75.7%
W108-B-1035-H-MAD-C	Coyote Pond	8,517	8,405	8,405	1.3%	1.3%
W108-B-1033-H-MAD-C	Pond 2 and Wetland Basin	30,796	30,547	10,322	0.8%	66.5%
EARB W108-U-0136-A-MAD-C	Central Arboretum	5,393	5,320	5,320	1.4%	1.4%
W108-U-0136-A-MAD-C_NP	Northern Arboretum and Nakoma Golf Course	13,777	13,625	13,625	1.1%	1.1%
W102-U-1038-A-MAD-T	Downstream of Manitou and Secret Pond	2,942	2,880	2,880	2.1%	2.1%
	Total	**574,474**	**497,689**	**210,655**	**13.4%**	**63.3%**

Table 4.03-4 Existing BMPs Performance

BMP	TSS				TP			
	Incoming TSS Load (lbs)	Outgoing TSS Load (lbs)	TSS Load Reduction (lbs)	TSS Load Reduction (%)	Incoming TP Load (lbs)	Outgoing TP Load (lbs)	TP Load Reduction (lbs)	TP Load Reduction (%)
Marion-Dunn Pond	35,502	11,011	24,491	69.0%	146	86	60	41.3%
C UW Research Park West Ponds	17,433	4,821	12,611	72.3%	57	34	23	40.8%
SE UW Research Park West Ponds	12,379	5,239	7,140	57.7%	59	43	15	26.1%
S UW Research Park West Ponds	14,316	8,677	5,639	39.4%	73	64	9	11.9%
SW UW Research Park West Ponds	35,523	16,138	19,385	54.6%	115	91	24	20.7%
South Odana Hills Pond	39,834	10,829	29,005	72.8%	150	85	65	43.2%
North Odana Hills West Pond	111,527	10,073	101,455	91.0%	497	223	274	55.1%
North Odana Hills Infiltration	9,808	7,618	2,190	22.3%	223	195	28	12.7%
North Odana Hills East Pond	20,604	8,531	12,072	58.6%	239	212	27	11.4%
WisDOT Pond	26,064	9,644	16,421	63.0%	85	58	28	32.3%
Manitou Pond	84,363	50,564	33,799	40.1%	524	462	62	11.9%
Secret Pond	50,564	42,763	7,801	15.4%	462	440	22	4.7%
Curtis Pond	11,888	3,205	8,683	73.0%	45	27	18	40.8%
Wetland Basin	26,038	12,365	13,673	52.5%	85	65	20	23.1%
Pond 2	16,874	10,322	6,552	38.8%	81	66	14	17.8%
Total (Wetland Basin and Pond 2)	**38,952**	**10,322**	**28,630**	**73.5%**	**100**	**66**	**34**	**33.9%**

C. Existing Stormwater BMPs Not Accounted For in City P8 Model

As described in Section 3.03 D of this report, there are 36 existing residential rain gardens, 4 existing public rain gardens (City of Madison), 10 existing institutional rain gardens (Arboretum, Edgewood College, Henry David Thoreau School), 32 existing street terrace rain gardens, and 13 existing permitted private rain gardens/bioretention basins that are not accounted for in the City P8 model. Table 4.03-5 provides a TP reduction credit for these existing BMPs, which lessens the additional reduction needed to meet the *Short-Term Goal.*

	TP Reduction Performance (lb) at Varying Infiltration Rates		
Facility	**0.3 in/hr**	**0.5 in/hr**	**1.0 in/hr**
Structural Improvements			
36 Existing Residential Rain Gardens	0	0	0
4 Existing Public Rain Gardens (City of Madison)	0.4	0.4	0.4
10 Existing Institutional Rain Gardens (Arboretum, Edgewood College, Henry David Thoreau School)	1.0	1.0	1.1
32 Existing Terrace Rain Gardens	0.3	0.3	0.3
13 Existing Permitted Bioretention Basins	1.3	1.3	1.4
Total	**3.0**	**3.0**	**3.1**

Table 4.03-5 TP Reduction Performance of Existing Infiltration Facilities in Watershed

D. Phosphorus Reduction Goal

Table 4.03-6 shows the additional TP reduction necessary in the watershed to meet both the short-term and long-term TP reduction goals. Figure 4.03-7 shows a bar chart comparing the short-term and long-term TP reduction goals to the no controls and existing controls conditions.

Condition	**TP Load (lbs)**
No Control TP Load	**1,899**
Existing Controls TP Load (Modeled in P8)	**1,171**
TP Load Reduction Due to Existing Controls (Modeled in P8)	**728**
TP Load Reduction Due to Existing Controls (Not Modeled in P8)	**3**
Total TP Load Reduction Due to Existing Controls	**731**
Total TP % Reduction Due to Existing Controls	**38.5%**
*Short-Term Goal: 50 Percent Reduction Compared to No Controls (1,899 * 0.5)*	**950**
Additional Reduction Necessary to Meet Short-Term Goal (950-731)	**218**
*Long-Term Goal: 80 Percent Reduction Compared to No Controls (1,899*0.2)*	**1,519**
Additional Reduction Necessary to Meet Long-Term Goal (1,519-731-218)	**570**

Table 4.03-6 Existing TP Reduction and TP Reduction Goals

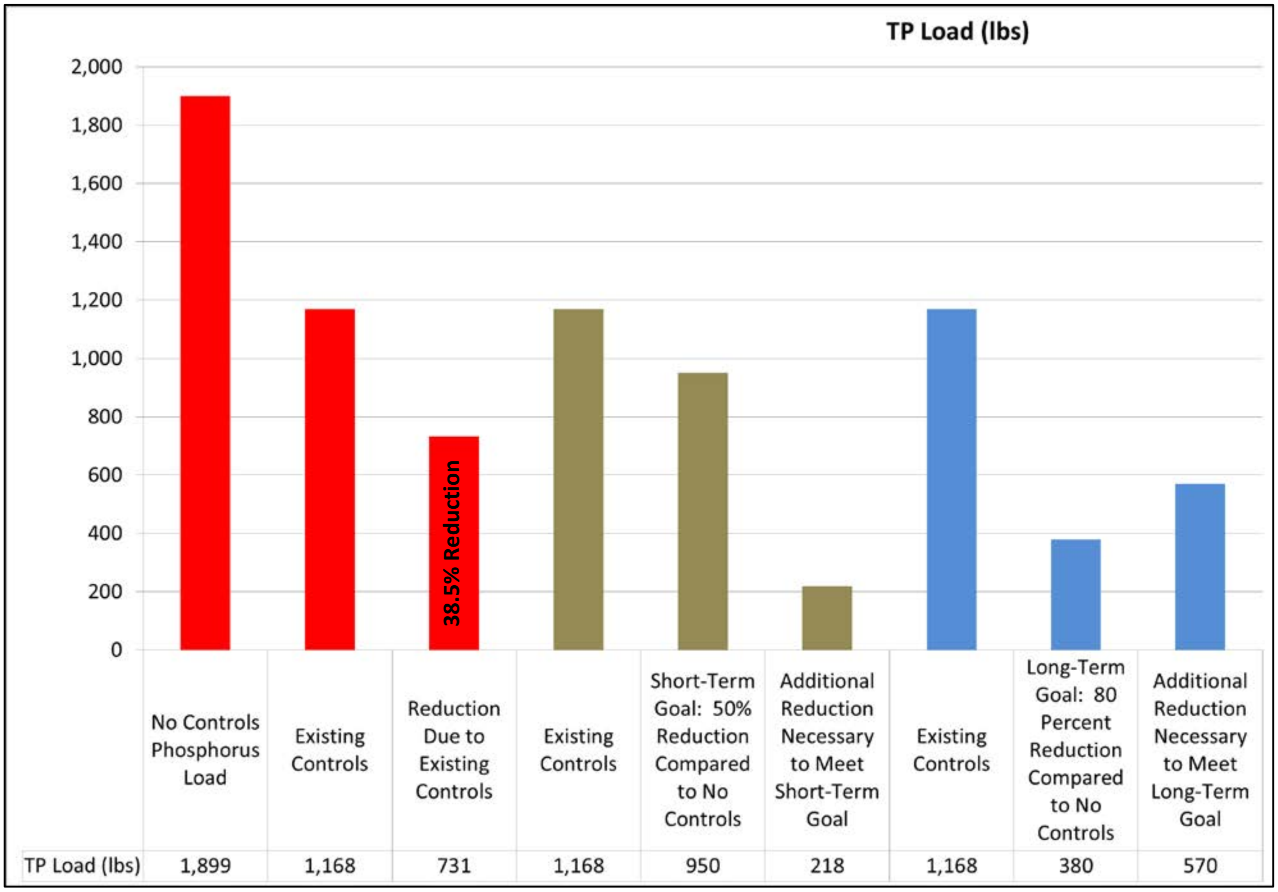


Figure 4.03-7 Comparison of Existing TP Reduction and TP Reduction Goals

E. Proposed TP Reduction Facilities in Watershed

As described in Section 3.03 D of this report, all infiltration facilities proposed would need to be completed to meet the infiltration short-term goal. These facilities also would provide TP reduction as shown in Table 4.03-7 and would reduce the TSS gap for consideration of additional BMPs in the watershed. Table 4.03-7 retains the infiltration cost-effectiveness order from Section 4. Approximately 97 additional pounds of TP needs to be removed from the watershed to meet the short-term goal.

Facility	TP Reduction Performance (lb) at Varying Infiltration Rates				Total 20-Year Present Worth	20-Year NPW Cost/lb (@ 0.5 in/hr)
	0.3 in/hr	0.5 in/hr	1.0 in/hr	% of Total		
Westmorland Park Bioretention Basin	14.7	15.5	17	11.5%	$ 367,640	$ 1,186
Downspout Disconnection Program (35% Watershed Participation)	7.8	7.8	7.8	5.8%	$ 877,124	$ 5,623
Rain Barrel Program (25% Watershed Participation)	2.1	2.1	2.1	1.6%	$ 377,697	$ 8,993
1,000 Terrace Rain Gardens	8.0	8.0	8.0	5.9%	$ 2,184,378	$ 13,652
1,000 Private Residential Rain Gardens (Serving Roofs Only)	8.6	8.9	8.9	6.6%	$ 1,654,205	$ 9,293
Devolis Park (Axel Avenue) Bioretention *(Not in Lake Wingra Surface Water Watershed)*	*5.8*	*5.9*	*6.0*	*4.4%*	*$ 479,671*	*$ 4,065*
Arbor Hills Greenway Infiltration *(Not in Lake Wingra Surface Water Watershed) @ 1.63 in/hr*	*7.6*	*7.6*	*7.6*	*5.6%*	*$ 1,279,398*	*$ 8,417*
Glenway Wet Pond & Infiltration	43.2	43.2	43.2	32.0%	$ 1,952,764	$ 2,260
Grandview Boulevard Bioswale	7.1	7.2	7.3	5.3%	$ 893,405	$ 6,204
60 Private Commercial Rain Gardens (Serving Roofs Only)	1.0	1.1	1.0	0.8%	$ 417,396	$ 18,973
Monroe Street Green Street	7.8	8.2	9.1	6.1%	$ 835,587	$ 5,095
4 Acres Porous Pavement (Serving 12 acres)	19.6	19.6	19.6	14.5%	$ 3,143,409	$ 8,019
TOTAL	**133.3**	**135.1**	**137.8**	**100%**	$14,462,675	$5,352 (avg)
TOTAL TO LAKE	**119.9**	**121.6**	**124.2**		$12,703,606	$5,223 (avg)
TP Reduction Gap to Meet Short-Term Goal	219.0	218.0	218.0			
Difference	99.1	96.4	93.8			

Table 4.03-7 Phosphorus Reduction Performance and Cost-Effectiveness of Proposed Infiltration Facilities

4.04 ALTERNATIVES ANALYSIS

A. Alternatives Analysis Overview

This section discusses alternatives analyzed to meet the short-term TP reduction goal of a 50 percent reduction in TP compared to no pollutant reduction controls. All projects identified would need to be completed to achieve the goal, depending on the infiltration rate of in situ soils. Table 3.03-10 showed the cost-effectiveness of each project in terms of a cost (planning level opinion of probable construction cost) per cubic feet of infiltrated stormwater. There is a wide range of cost-effectiveness. This information allows for prioritizing project implementation. It is envisioned the most cost-effective projects would be completed first.

Costs presented were estimated using historical bid costs, where available, and supplemented by other reference sources. All estimated project costs include allowances for engineering (15 percent) and construction contingencies (15 percent) and soils investigation where necessary. Land acquisition or easement costs, if needed, have not been included. The goal of this section is to provide the City of Madison personnel with the information required to initiate the budgeting and planning phase for facilities improvements. All costs are presented in 1st quarter 2014 dollars. Future construction costs should be adjusted for inflation when final project schedules are determined. Opinions of probable construction cost will be updated during the design phase; Appendix B contains detailed cost spreadsheets.

The costs for excavation assume there will be off-site disposal of the excavated material. If an on-site source of disposal is identified, this cost will be reduced. As appropriate, costs for soil investigation and wetland delineation are included. This information will provide important design information and determine regulatory constraints.

A total 20-year net present worth (NPW) for each project has been calculated that includes provisions for long-term maintenance of the various alternative components.

B. Alternative Components

Table 4.04-1 lists structural and nonstructural practices that could be implemented to remove the additional 90 to 98 pounds of TP to meet the short-term goal. These alternative components are packaged together in the next section as five alternatives to collectively meet both the short-term infiltration and phosphorus reduction goals.

At the public meetings for this project, it was suggested that interpretive signage be included on all structural practices to engage the public.

Facility	Annual TP Reduction Performance (lb)	Opinion of Probable Construction Cost	Total 20-Year Present Worth Cost	20-Year NPW Cost/lb	Double Counting Potential
Structural Improvements					
Alum Addition At Manitou Pond	139.4	$ 287,300	$ 817,200	$ 293	No
Alum Addition At Marion Dunn Pond	64.7	$ 279,500	$ 720,900	$ 557	No
Diversion of Basin W102-D-0193-H-MAD-C to Manitou Pond	10.3	$ 232,900	$ 276,800	$ 672	No
Streambank Restoration at Henry David Thoreau School	13.9	$ 296,200	$ 299,300	$ 1,006	Yes
Streambank Restoration on Cherokee Drive (Yuma Drive to Chippewa Drive)	13.3	$ 369,000	$ 369,100	$ 1,391	Yes
Wingra Park Wet Pond (60% TSS Reduction)	20.6	$ 1,771,100	$ 1,827,400	$ 4,435	No
Subtotal	**262.3**				
Nonstructural Improvements		**Annual Cost**			
Wetland Harvesting (4.6 acres)	41.4	$ 43,000	$ 97,600	$ 119	No
Modified Leaf Collection Methods ($47,000 Year 1 Capital Cost + $10,000 Annual Operation Cost, therafter)	84.6	$ 57,000	$ 229,100	$ 135	Yes
Waterfowl Management (50 Geese Per Year)	8.5	$ 2,500	$ 42,400	$ 249	
Construction Site (12.3 Acres) Erosion Control Enforcement (Enhanced)	138.7	$ 55,000	$ 931,900	$ 335	Yes
Modified Street Sweeping Methods/Schedule	39.0	$ 47,500	$ 804,900	$ 1,032	Yes
Pet Waste Enforcement	27.3	$ 45,000	$ 726,400	$ 1,396	Yes
Subtotal	**339.5**				
TOTAL	**601.8**				

Table 4.04-1 Alternative Components Performance and Cost-Effectiveness for TP Reduction

1. Alum Addition–Alum, $Al_2(SO_4)_3$, is a coagulant often used for coagulation, flocculation, and settling in drinking water and wastewater treatment processes. Alum is commonly used for phosphorus removal in wastewater treatment. Alum treatment of stormwater to remove phosphorus, bacteria, and both dissolved and suspended solids has been employed in more than 60 locations in Florida. It has also been used in Europe to treat tributary streams for water quality improvement of drinking water reservoirs. The WDNR recognizes alum addition as a method for treating lakes to inactivate phosphorus in bottom sediments and it has been used sporadically for this purpose since the 1970s. The City's Marion Dunn Pond alum pilot project is one of the first uses of alum for removal of TSS and phosphorus from stormwater or lake inflows in Wisconsin. There are a few projects in Wisconsin using alum to treat a whole lake, and there has been some use throughout the Midwest. The low usage rate may be because alum treatment of stormwater is generally more costly than other methods for removing TSS to the 20 percent removal levels required for Wisconsin municipal separate storm sewer systems (MS4s). Now that Wisconsin TMDLs and clean lakes initiatives will require much greater removal rates for phosphorus and TSS, alum (or other chemicals such as ferric, lime, or rare earth metals) may be worth further consideration. A schematic of the alum treatment process is shown in Figure 4.04-1.

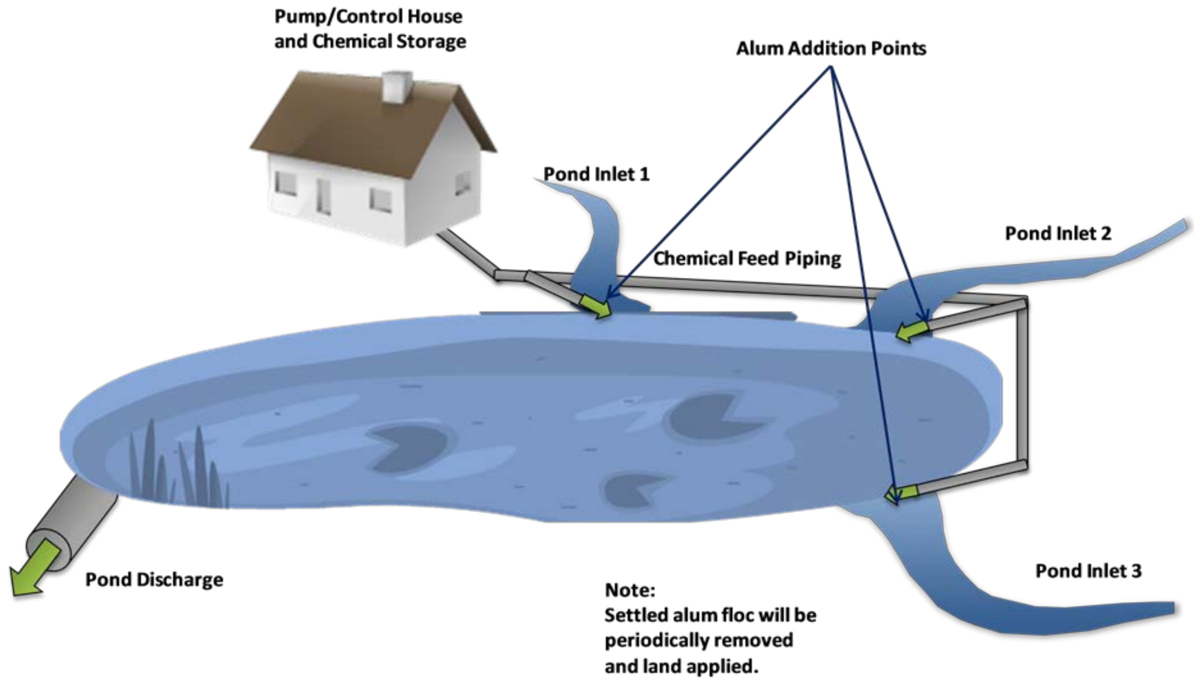


Figure 4.04-1 Typical Stormwater Pond Alum Treatment

Since alum and similar chemicals have not been used extensively for stormwater treatment in Wisconsin, detailed planning and additional pilot testing are recommended at a few sites before more widespread implementation. Three potential urban stormwater projects in the Lake Wingra watershed have been identified: Marion Dunn Pond, Manitou Pond, and Odana Pond. Background information and budgetary costs for the projects are presented in Table 4.04-2.

Project Location	Average Flow (ft^3/sec)	Average Influent Phosphorus Concentration (mg/L)[1]	Additional Annual Phosphorus Removal (lb/year)	Total 20-Year Present Worth Cost	Total 20-Year NPW Cost/ Pound
Marion Dunn Pond	4.3	0.32	65	$720,900	$557
Manitou Pond	13.1	0.20	139	$817,000	$293
Odana Pond	15.6	0.32	146	$1,317,000	$451

[1]From WinSLAMM modeling.

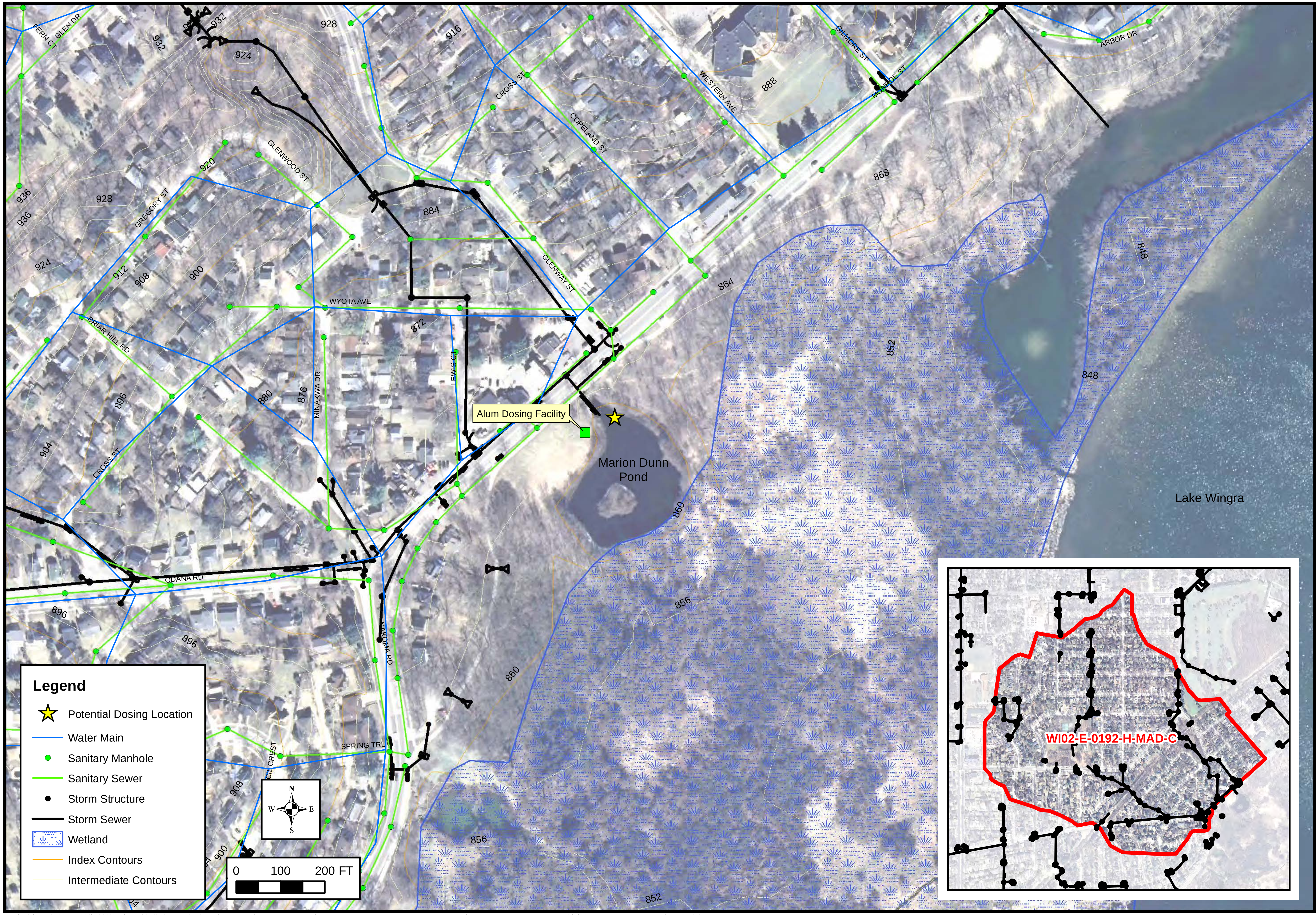
Table 4.04-2 Background Information and Budgetary Costs for Proposed Stormwater Pond Alum Treatment Projects

a. Marion-Dunn Pond is located on the east side of Lake Wingra near the intersection of Monroe Street and Glenway Street. The pond has one inlet and two outlets. Figure 4.04-2 shows the vicinity of Marion-Dunn Pond and the proposed dosing facility and dosing location. To compare the Marion-Dunn Pond project to the other proposed treatment projects, the costs presented in Table 4.04-2 assume a new structure would be constructed and new equipment would be installed. The costs would likely be significantly reduced if the existing pilot project is converted to a permanent, full-scale project.

b. Manitou Pond is located on the north side of the Nakoma Golf Club near the intersection of Manitou Way and Nakoma Road. The pond has two inlets and one outlet. An alum dosing facility would be constructed and alum would be pumped to each inlet (if deemed necessary). Figure 4.04-3 shows the vicinity of Manitou Pond and the proposed dosing facility and dosing location.

c. Odana Pond is located on the west side of the Odana Hills Municipal Golf Course near the intersection of Whitney Way and the Beltline Highway. The pond has four inlets and one outlet. For this project, one alum dosing facility would be constructed and alum would be pumped to each of the four inlets (if deemed necessary). Figure 4.04-4 shows the vicinity of Odana Pond and the proposed dosing facility and dosing locations. It should be noted that there are two Odana Ponds, the upstream Main Odana Pond and the downstream Secondary Odana Pond. The upstream Main Odana Pond is considered a water of the state and is the pond from which water is drawn to feed the Odana Golf Course Infiltration Facility. As a water of the state, it is anticipated that there would be significant regulatory hurdles associated with an alum treatment facility at the upstream Main Odana Pond. Likewise, chemical dosing of water that will feed the Odana Golf Course Infiltration Facility is also a concern. For purposes of this plan, the upstream Main Odana Pond has been removed from further consideration as an alum treatment facility. However, chemical dosing of the downstream Secondary Odana Pond may still present opportunities for chemical treatment of stormwater based on the understanding that it is not a water of the state and that water is not drawn from it for the Odana Golf Course Infiltration Facility.

It is anticipated that each pond would be dosed so that the majority of the settling would occur in the forebay. The sediment would remain in the pond and be periodically removed by dredging. The costs presented in Table 4.04-2 assume sediment would be hauled and spread on agricultural land to an area of low soil test phosphorus or outside the watershed.



MARION-DUNN POND ALUM TREATMENT

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FIGURE 4.04-2
1020.065

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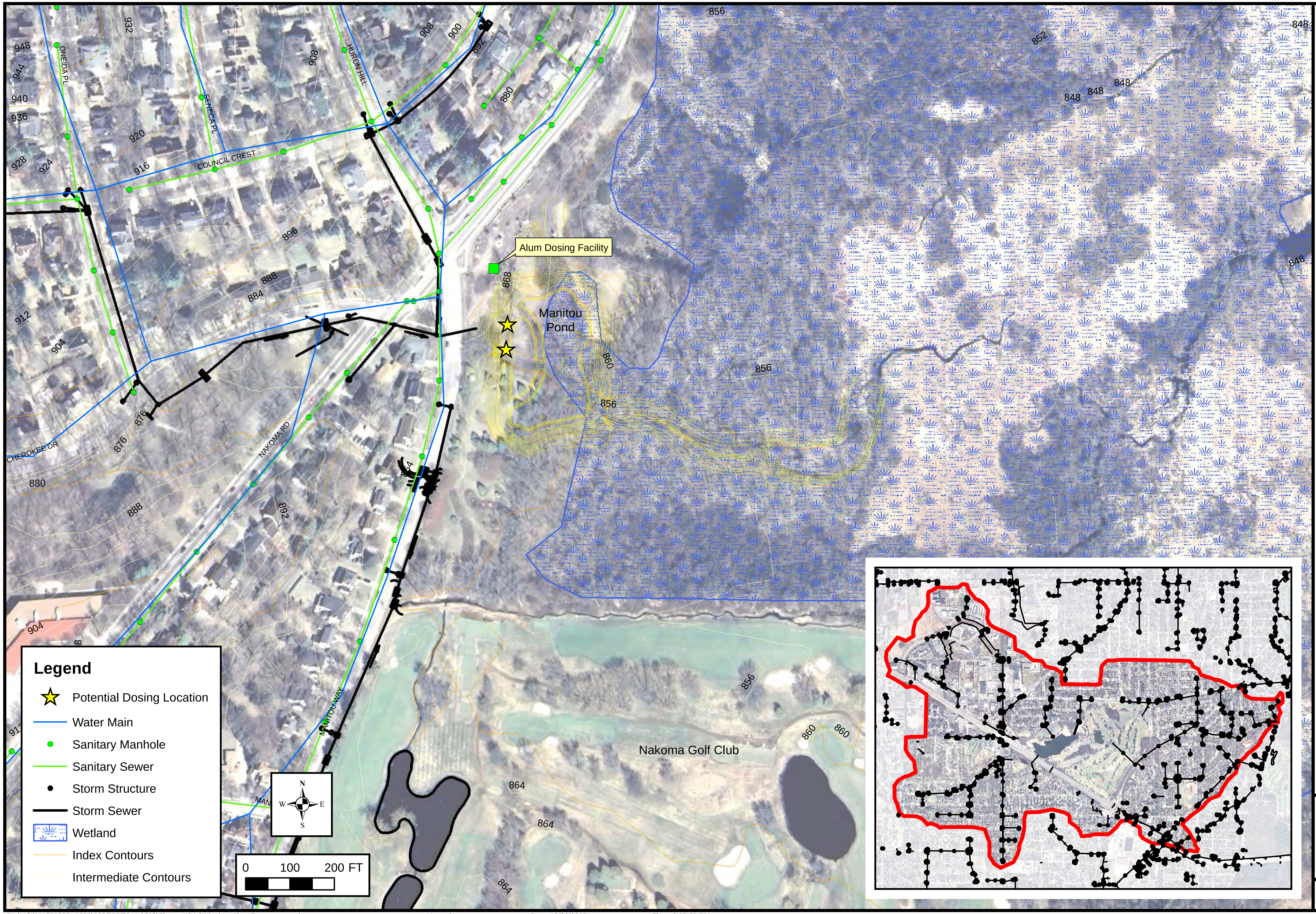

MANITOU POND ALUM TREATMENT

LAKE WINGRA WATERSHED MANAGEMENT PLAN
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FIGURE 4.04-3
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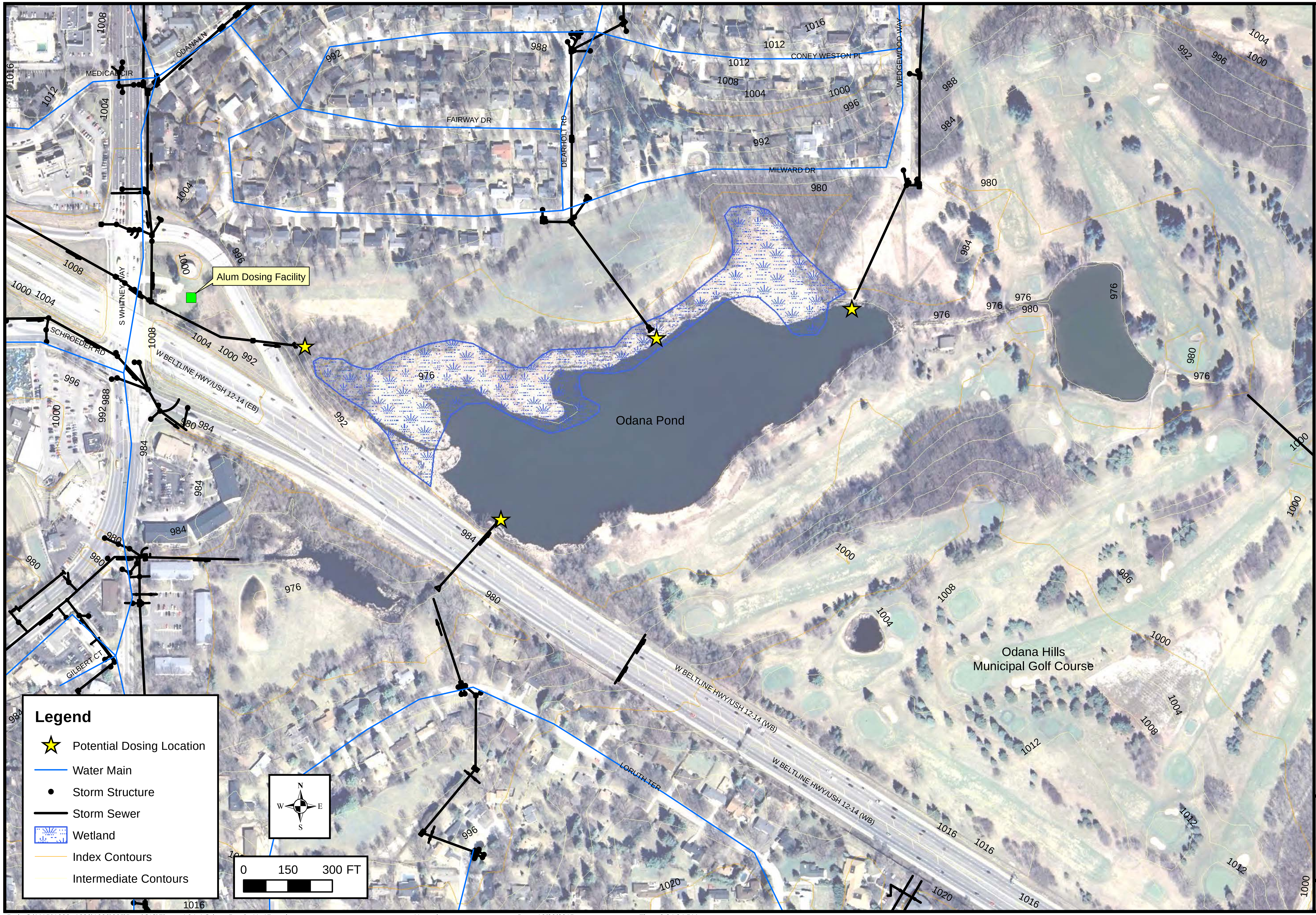

ODANA POND ALUM TREATMENT

LAKE WINGRA WATERSHED MANAGEMENT PLAN
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FIGURE 4.04-4
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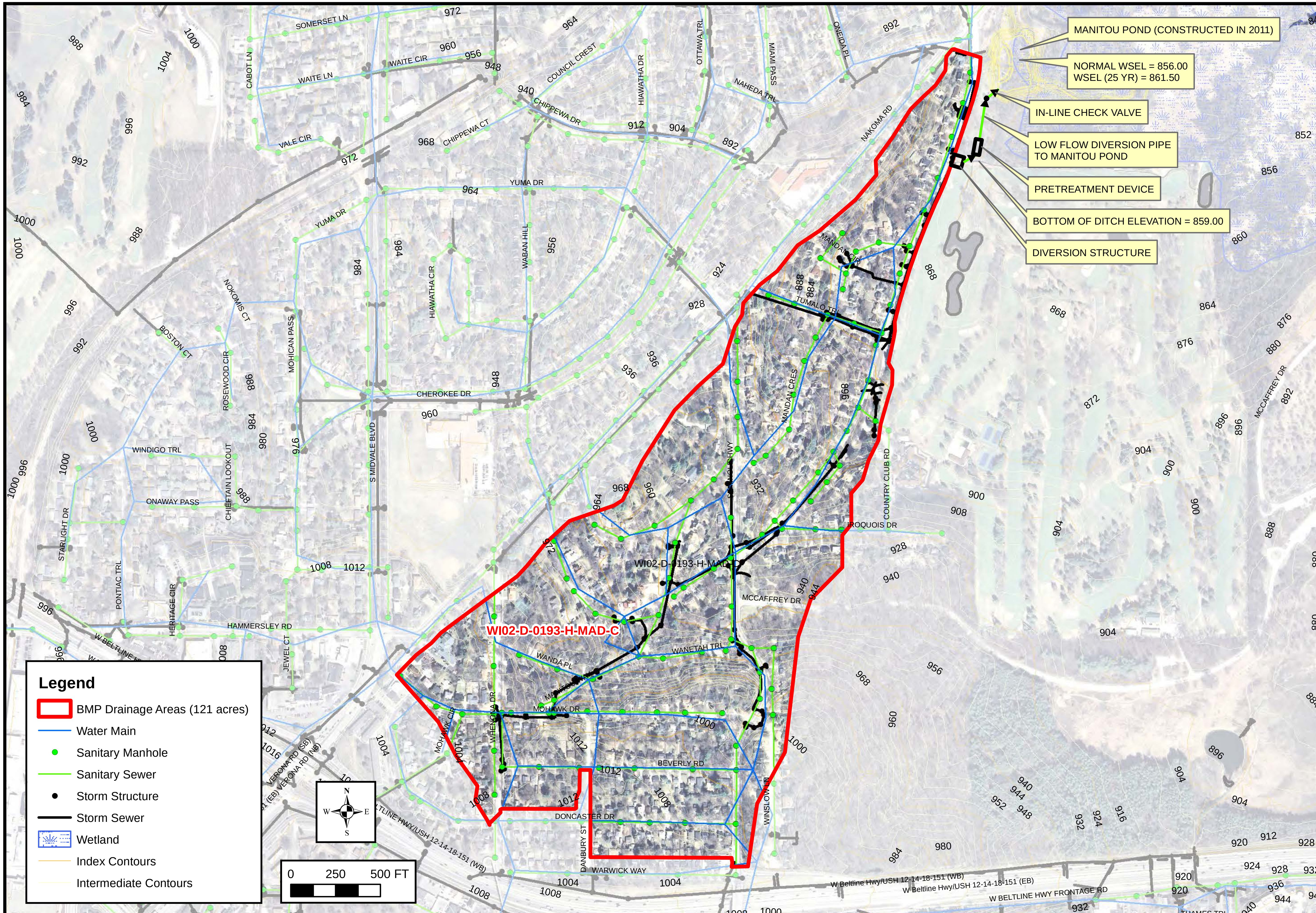
2. Diversion of Basin W102-D-0193-H-MAD-C to Manitou Pond–Currently an underserved basin, Basin W102-D-0193-H-MAD-C achieves a 3.6 percent TP and 19.5 percent TSS reduction resulting from street sweeping and sumps. Providing additional treatment to this drainage basin by way of diversion of low flows from this basin to Manitou Pond appears to be a cost-effective way to provide additional stormwater quality treatment to this drainage basin. Figure 4.04-4a shows Manitou Pond that was constructed in 2011 and Figure 4.04-5 shows the drainage basin and improvements necessary to provide the diversion. A stormwater pretreatment device (that removes sand, floatables, and oil and grease) is proposed to reduce dredging maintenance needs in the pond.

Figure 4.04-4a Manitou Pond

3. Streambank Restoration–Field reconnaissance was completed in the fall of 2013 to determine areas of significant erosion of streambanks. Two locations were identified along Cherokee Drive in the general vicinity of Thoreau Elementary School where open channels convey stormwater. Restoration of these channel segments will reduce the TP and TSS loads to Manitou Pond and ultimately to Lake Wingra. Figures 4.04-6 and 4.04-7 show pictures of the areas experiencing streambank erosion. Figure 4.04-8 shows the watershed draining to these streambanks and the area proposed for restoration.

Figure 4.04-6 Streambank Erosion Along Cherokee Drive (Yuma Drive to Chippewa Drive)

Figure 4.04-7 Streambank Erosion Along Cherokee Drive (Thoreau Elementary School Property)



MANITOU POND DIVERSION

LAKE WINGRA WATERSHED MANAGEMENT PLAN
CITY OF MADISON
DANE COUNTY, WISCONSIN

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FIGURE 4.04-5
1020.065

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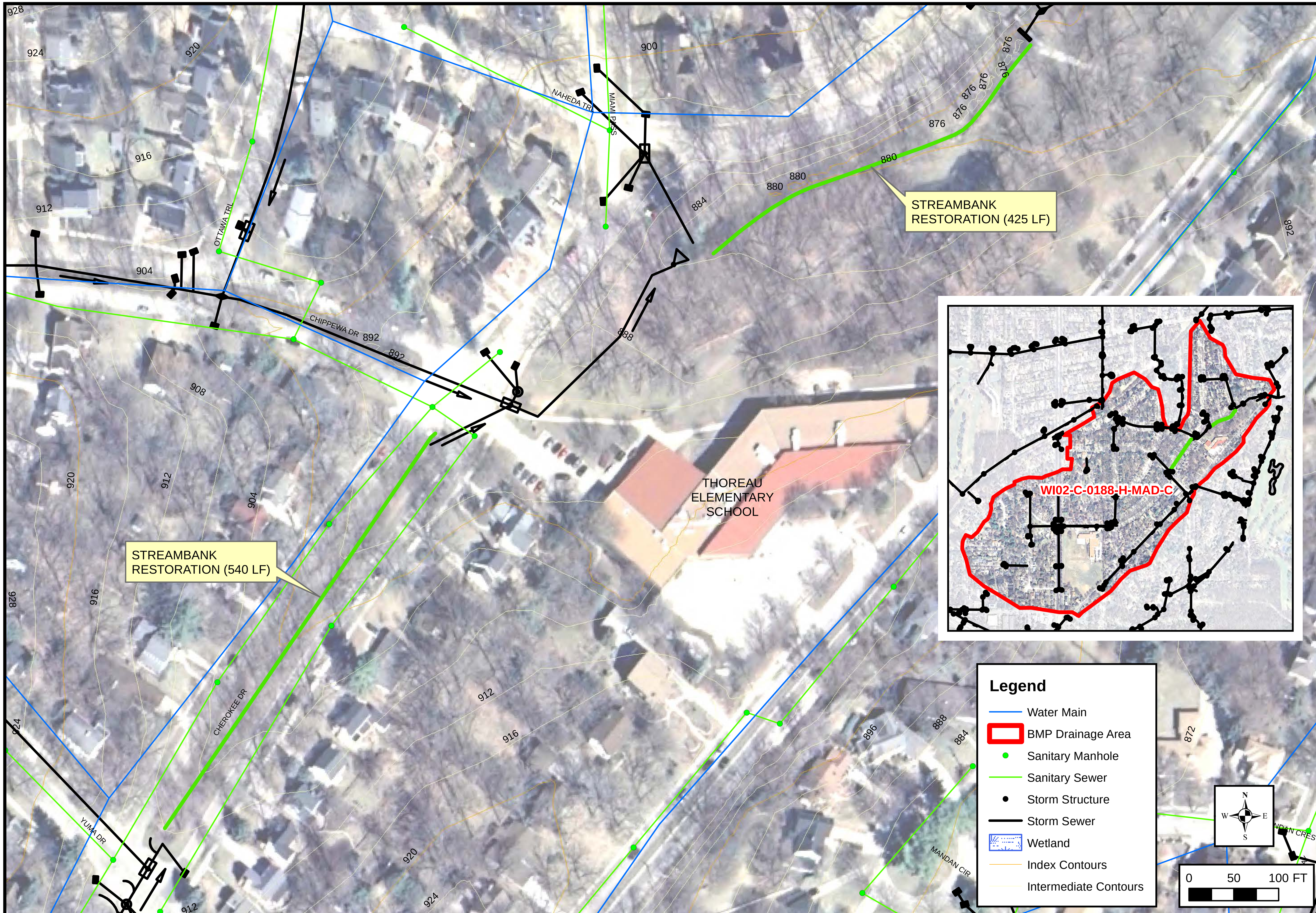

STREAMBANK RESTORATION

LAKE WINGRA WATERSHED MANAGEMENT PLAN
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FIGURE 4.04-8
1020.065

At the public meetings for this project, it was suggested that the City consider incorporation of the Regenerative Stormwater Conveyance (RSC) concept into the Cherokee Drive project area. This is a relatively new stormwater management concept consisting of a step pool conveyance system incorporating specifically designed media (i.e., wood chips and sand) focused on nutrient removal. The City recently incorporated this concept into a streambank restoration project in Owen Park. While not specifically identified in this report, it was also discussed that Glenwood Park is in need of streambank restoration but that consensus is needed on a streambank restoration technique.

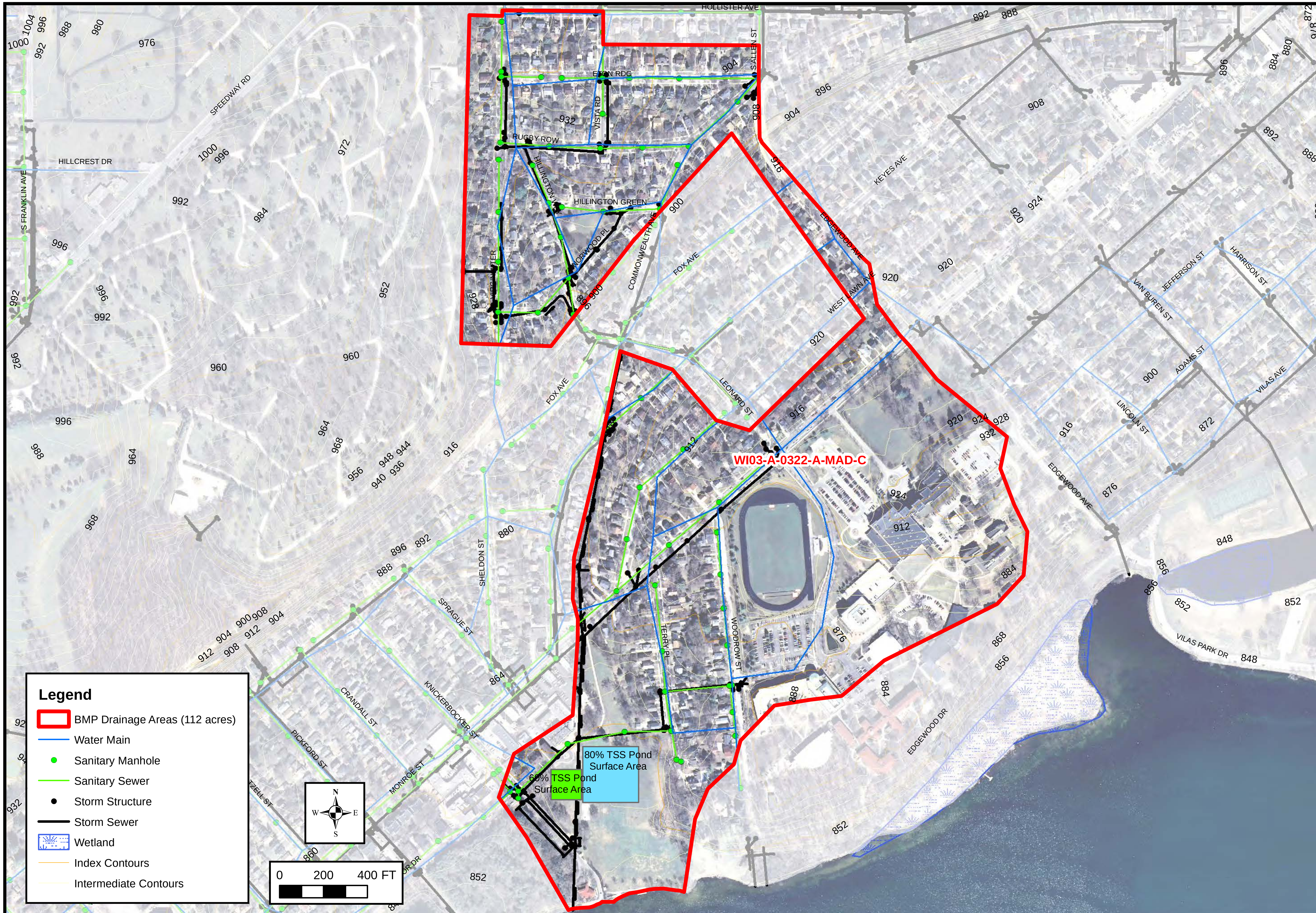
4. Wingra Park Wet Pond–As shown on Figure 4.03-5, Basin W103-A-0322-A-MAD-C is currently an underserved basin achieving a 2.2 percent TP and 14.1 percent TSS reduction. An underground wet detention basin achieving a 60 percent TSS reduction and a 44 percent TP reduction is proposed as shown in Figure 4.04-9. Figure 4.04-10 shows a picture of the approximate location of the underground wet detention basin. This basin could be an aboveground basin if dedication of this land for stormwater treatment would be considered acceptable.

Figure 4.04-10 Wingra Park Underground Detention Location

5. Modified Leaf Collection Methods–There have been a number of studies on the impact of urban pollen, seed, and leaf management on water quality, including one completed in the Madison area. Generally, these studies have shown that when trees shed pollen, seeds, and leaves onto impervious surfaces and rainfall then occurs, phosphorus leaches from the plant materials and is carried with the stormwater. Certain rainfall events can also transport the leaves directly to waterbodies. Table 4.04-3 shows the assumptions made for purposes of this report regarding modified leaf collection methods.

Condition	TP (lbs)
Phosphorus Content in Leaves Collected Annually	564 lbs
Assumed Portion of Phosphorus Collected Leached Out Before Collection (30 percent)	169 lbs
Additional Phosphorus Collected Because of Modified Leaf Collection Methods (50 percent of Currently Leached Before Collection)	85 lbs
Estimated Current Annual Leaf Collection Cost in Wingra Watershed	$70,148
Estimated Increased Annual Cost For Modified Leaf Collection Methods (50 percent Increase)	$57,000
Total 20-Year Present Worth	$229,065
Cost Per Pound Phosphorus Removed	$135

Table 4.04-3 Wingra Watershed Leaf Collection



WINGRA PARK POND

LAKE WINGRA WATERSHED MANAGEMENT PLAN
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DANE COUNTY, WISCONSIN

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FIGURE 4.04-9
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Figure 4.04-11 Typical Fall Leaf Collection View

In Madison, citizens are asked to keep their leaves in piles on their lawn near the street (or on the "terrace"); see Figure 4.04-11. This delivers the leached phosphorus to the soils where it tends to remain and may benefit the lawn. Leaves are picked up every two to three weeks so the residents need to manage the piles and try to keep them from blowing into the street. Fitchburg requires residents to bag their leaves, which helps prevent blowing and nutrient leaching and, in Fitchburg's case, also helps with collection. The City of Champaign, Illinois, also requires city-wide bagging of leaves in 32-gallon paper "yard waste" bags collected by a contractor hired by the City. This was prompted by budget and staffing cuts and was less expensive than traditional leaf collection methods. More details can be found at the following Web site: http://ci.champaign.il.us/departments/public-works/residents/yard-waste-collection/

Models that are currently used for stormwater management planning in the watershed (SLAMM and P8) do not provide credit for phosphorous removal through leaf management. This is an area that requires further study and quantification so that municipalities can obtain appropriate credit for the TSS and TP reductions, for example to assist with compliance with the Rock River TMDL waste load allocations. The quantity of phosphorus diverted should be refined as additional information becomes available from ongoing studies. For purposes of this study, we made some assumptions about phosphorus content of leaves, delivery factors, and cost of additional collection per pound of phosphorous diverted from the lakes; this should be refined following additional studies.

The City is participating with the WDNR and USGS in a pilot study of leaf collection techniques in three residential neighborhoods. Each neighborhood has its leaves managed differently. The first is a minimal level of service to show what would happen if the city and the residents did next to nothing beyond picking up the leaves occasionally. The second is the current level of service employing regular street sweeping, leaves stored on the terrace, and street sweepers following the collection activities as closely as possible. The third is the maximum level of service to reduce leaf-related runoff where residents would be asked to collect leaves from their lawns and the gutters and bag them in compostable bags that would be hauled away by the city. The results of this pilot study should be used to support adding this method of phosphorus diversion into stormwater management planning models.

At the public meetings for this project, there was discussion relative to methods that could be considered for improved leaf collection including having a leaf mulcher/bagger available for rental at the Sequoya Library (perhaps owned by the Friends of Lake Wingra) and identification of volunteer groups that would be available for leaf bagging assistance (i.e., high school students). Additionally, there was discussion relative to investigation into a manufactured product that is more environmentally friendly than bags for leaf bagging and promotion of covering leaf piles with tarps to keep leaves in place.

6. Modified Street Sweeping Methods/Schedule–According to WDNR-supplied data, many MS4s in the Yahara River watershed sweep streets (16 communities) and many, mostly towns, do not sweep (six communities) or have not recorded the data (one community). This data is valuable in calculating an amount of phosphorus currently being diverted from the watershed and that is already accounted for in the baseline loadings for each lake. By assuming that a 20 percent increase in the amount of street sweeping completed is feasible, an additional amount of phosphorus reduction can be calculated. Assuming that street sweepings contain approximately 0.03 percent phosphorus, calculations show that a modest amount of additional phosphorus can be diverted from the lakes. Table 4.04-4 shows the assumptions made for purposes of this report regarding modified street sweepings collection methods.

Condition	TP (lbs)
Phosphorus Content in Street Sweepings Collected Annually	194 lbs
Additional Phosphorus Collected Because of Modified Street Sweepings Collection Methods (20 Percent)	39 lbs
Estimated Current Annual Street Sweeping Cost in Wingra Watershed	$95,008
Estimated Increased Annual Cost For Modified Street Sweeping Methods (50 Percent Increase)	$47,504
Total 20-Year Present Worth	$804,900
Cost Per Pound Phosphorus Removed	$1,032

Table 4.04-4 Wingra Watershed Street Sweepings Collection

Street sweepings generally consist of street dirt accumulation and sand applied as part of municipal deicing operations. Studies have been completed documenting the effectiveness or lack of effectiveness of street sweeping at providing significant stormwater quality benefit. Calculations herein show that increasing street sweeping by 20 percent has a small potential for phosphorus reduction with a low cost-effectiveness when compared to other BMPs. Current street sweeping efforts (Figure 4.04-12), by keeping our communities clean and providing a modest stormwater quality benefit, should continue.

Figure 4.04-12 Street Sweeper

At the public meetings for this project, it was suggested that winter parking regulations should be in effect year-round to support street sweeping efforts, especially in areas with no downstream wet detention basins.

7. Pet Waste Enforcement–Although our citizens already do a very good job of collecting pet waste in the watershed, even further reduction could be seen through increased regulation/enforcement or improved access to pet waste disposal locations in popular dog walking areas. A stricter ordinance combined with better education (Figure 4.04-13), a convenient way to dispose of the waste, and enforcement could reduce phosphorus loadings significantly. This may particularly be true during runoff events when the ground is frozen, since studies have found that many pet owners do not remove pet wastes from their yards in the winter. For purposes of this study, it is assumed that only 10 percent of pet owners do not pick up pet waste, and that through ordinance and stricter enforcement, this could be reduced. It is assumed that one limited-term employee at a total municipal cost of $45,000 a year would be required to administer this program. The staff costs are lower because the necessary qualifications for this position are lower than other positions. Enforcement of this action item may be challenging unless, or even if, ordinances are carefully written. A social marketing campaign whereby public behaviors are changed may provide better cost-effectiveness.

Figure 4.04-13 Example Pet Waste Signage

At the public meetings for this project, it was discussed that consideration should be given to the environmental effects of bagging waste (i.e.: bag and pet waste, not just pet waste). This may include logistics related to flushing pet waste down the toilet.

8. Wetland Harvesting–Wetlands clean stormwater, provide green space in an urban environment, and provide wildlife habitat. The accumulation of phosphorus in the wetland soils occurs as the wetland cleanses stormwater. Some of this phosphorus is taken up by wetland plants, which provides an opportunity to lower the level of phosphorus in the soil by "mining down" soil phosphorus levels through harvesting the plants. For purposes of this study, we have assumed that equipment, similar to that shown in Figure 4.04-14, would need to be purchased (and replaced after 10 years) and that urban wetlands designated for phosphorus collection and mining in either existing wetlands or new areas would be harvested once every year for a period of 20 years for each unit of application. Harvested wetland plants may be used for a beneficial use such as a biomass aggregator (e.g.: Virent, Inc.) or other end-user. Compared to other urban BMPs, harvesting wetland plants may be a relatively cost-effective means of reducing phosphorus to the lakes.

At public meetings for this project, it was discussed that the following items should be considered with wetland harvesting:

a. Sensitivity to timing in relation to wildlife impacts.
b. Align harvesting with invasive species control.
c. Align program with harvestable buffer program regarding end-use of materials.
d. Potential to feed a biodigester.

Canadian researcher Richard Grosshans built this cattail harvester that's towed by an 8-wheel Argo amphibious vehicle.

Figure 4.04-14 Cattail Harvester

From a delivery factor standpoint, phosphorus sequestered in wetlands is not considered significantly mobile other than potentially after more extreme storm events. Therefore, a delivery factor of 0.03 was used for this action item.

For purposes of this plan, performance of cattail harvesting was evaluated with the assumptions shown in Table 4.04-4a.

Measure	Assumptions
Wetland harvesting	▪ Wetlands surrounding Lake Wingra = 23 acres ▪ Harvest 20% of these wetlands to mine down TP in soils ▪ Dry biomass/acre yield = 18.2 tons/acre ▪ Plant P content = 0.824% of dry biomass weight ▪ P removed = 1,380 lbs ▪ Delivery Factor= 0.03 ▪ P removed from being mobile = 41.4 lbs

Table 4.04-4a Wetland Harvesting Assumptions

9. Waterfowl Management–The City has been actively monitoring, studying, and managing giant Canada geese populations in select locations within the City (Figure 4.04-15). This has included oiling of eggs and active management of geese, for example actively managing 200 geese in the summer of 2011. Continuation of this program to manage 50 geese in the Wingra Watershed was considered. Calculations were completed for active management of 50 geese with research showing that goose droppings contain approximately 0.175 lb/phosphorus/year/goose.

Figure 4.04-15 Geese Along the Shore of Lake Wingra

Active management of geese or other waterfowl is an effective strategy in removing what might be considered a nuisance or to reduce bacteria levels near beaches. Waterfowl management is an important tool to address beach contamination from *E. coli*. However, the small amount of phosphorus in goose droppings, the corresponding number of geese that would need to be actively managed to gain significant phosphorus reduction, and the potential public opposition in expanding this program make this action a non-cost-effective means of achieving significant phosphorus reduction.

10. Construction Site Erosion Control Enforcement–This action item involves increased staff support (one limited-term employee). The associated cost to the City was assumed to be $45,000. The impact of this activity on phosphorus diversion is difficult to quantify; however, a cost per pound of phosphorus diverted was developed based primarily on assumptions from the Yahara CLEAN MOU staff.

There will be a point of diminishing returns on erosion control inspection and enforcement that the City may eventually reach and that could reduce the annual pounds diverted from the lakes in the future. Either initially or when that point of diminishing returns is reached, it may be appropriate to scale back City staff time and require self-reporting instead. A self-reporting example provided by the City staff is the WDNR Green Tier program in which contractors self-report and provide weekly photo documentation of the site. The City currently requires this for sites with more than 20,000 feet of disturbance, as well.

Figure 4.04-16 Example Construction Site Erosion Control BMP

An example of a construction site erosion control BMP is shown in Figure 4.04-16.

For purposes of this plan, performance of porous pavement was evaluated with the assumptions shown in Table 4.04-4b.

Measure	Assumptions
Enhanced erosion control enforcement	▪ Yearly active construction site area open to disturbance = 12.33 acres (according to City of Madison records) ▪ Portion of active construction site area non-compliant = 2.5 ares ▪ Uncontrolled construction site sediment release = 30 T sediment/acre/year (per UW-Extension publication). ▪ Dane County Erosion Control Ordinance requires no greater than 7.5 T sediment/acre/year release. ▪ 100% compliance = 22.5 T sediment/acre/year (30-7.5) controlled ▪ 50% better compliance is achiveable on non-compliant acreage (22.5 x 0.5 = 1.25 T sediment/acre/year) ▪ 2.5 acres x 11.25 T sediment/acre/year x 5 lbs TP / T sediment = 139 lbs TP.

Table 4.04-4b Enhanced Erosion Control Enforcement Assumptions

C. Alternatives

A total of seven alternatives are described below. Alternatives 1 through 5 assume that all Infiltration BMPs described in Table 4.03-6 will be implemented in addition to the mix of phosphorus BMPs in the respective alternative. Alternative 6 (as a modification of Alternative 1) assumes 75 percent of the Infiltration of BMPs are implemented and that the remaining infiltration BMPs are implemented in a to-be-determined fashion at an increased cost (30 percent cost adder). Alternative 7 (as a modification of Alternative 1) assumes 50 percent of the infiltration of BMPs are implemented and that the remaining infiltration BMPs are implemented in a to-be-determined fashion at an increased cost (30 percent cost adder).

1. Alternative 1–Table 4.04-5 shows the components of Alternative 1.

Facility	TP Reduction Performance (lb)	OPCC	20-Year NPW Cost	20-Year NPW Cost/lb
All Infiltration BMPs (See Table 4.03-6)	121.6	$10,225,800	$ 14,462,700	$ 5,352
Diversion of Basin W102-D-0193-H-MAD-C to Manitou Pond	10.3	$ 232,900	$ 276,800	$ 672
Modified Leaf Collection Methods ($47,000 Year 1 Capital Cost + $10,000 Annual Operation Cost, therafter)	84.6	$ 57,000	$ 229,100	$ 135
Streambank Restoration at Henry David Thoreau School	13.9	$ 296,200	$ 299,300	$ 1,006
Total	**230.4**	**$10,811,900**	**$ 15,267,900**	**$ 3,310**
TP Reduction Gap to Meet Short-Term Goal	218			**(average)**
Difference	12.4			

Table 4.04-5 Alternative 1 Cost and Performance

2. Alternative 2–Table 4.04-6 shows the components of Alternative 2.

Facility	TP Reduction Performance (lb) at 0.5 in/hr	OPCC	20-Year NPW Cost	20-Year NPW Cost/lb
All Infiltration BMPs (See Table 4.03-6)	121.6	$ 10,225,800	$ 14,462,700	$ 5,352
Alum Addition At Manitou Pond	139.4	$ 287,300	$ 817,200	$ 293
Total	**261.0**	**$ 10,513,100**	**$ 15,279,900**	**$ 2,930**
TP Reduction Gap to Meet Short-Term Goal	218			**(average)**
Difference	43.0			

Table 4.04-6 Alternative 2 Cost and Performance

3. Alternative 3–Table 4.04-7 shows the components of Alternative 3.

Facility	TP Reduction Performance (lb) at 0.5 in/hr	OPCC	20-Year NPW Cost	20-Year NPW Cost/lb
All Infiltration BMPs (See Table 4.03-6)	121.6	$ 10,225,800	$ 14,462,700	$ 5,352
Alum Addition At Marion Dunn Pond	64.7	$ 279,500	$ 720,900	$ 557
Diversion of Basin W102-D-0193-H-MAD-C to Manitou Pond	10.3	$ 232,900	$ 276,800	$ 672
Streambank Restoration at Henry David Thoreau School	13.9	$ 296,200	$ 299,300	$ 1,006
Streambank Restoration on Cherokee Drive (Yuma Drive to Chippewa Drive)	13.3	$ 369,000	$ 369,100	$ 1,391
Total	**223.8**	**$ 11,403,400**	**$ 16,128,800**	**$ 3,600**
TP Reduction Gap to Meet Short-Term Goal	218			**(average)**
Difference	5.8			

Table 4.04-7 Alternative 3 Cost and Performance

4. Alternative 4–Table 4.04-8 shows the components of Alternative 4.

Facility	TP Reduction Performance (lb) at 0.5 in/hr	OPCC	20-Year NPW Cost	20-Year NPW Cost/lb
All Infiltration BMPs (See Table 4.03-6)	121.6	$ 10,225,800	$ 14,462,700	$ 5,352
Construction Site (12.3 Acres) Erosion Control Enforcement (Enhanced)	138.7	$ 55,000	$ 931,900	$ 335
Total	**260.3**	**$ 10,280,800**	**$ 15,394,600**	**$ 2,960**
TP Reduction Gap to Meet Short-Term Goal	218			**(average)**
Difference	42.3			

Table 4.04-8 Alternative 4 Cost and Performance

5. Alternative 5–Table 4.04-9 shows the components of Alternative 5.

Facility	TP Reduction Performance (lb) at 0.5 in/hr	OPCC	20-Year NPW Cost	20-Year NPW Cost/lb
All Infiltration BMPs (See Table 4.03-6)	121.6	$ 10,225,800	$ 14,462,700	$ 5,352
Wingra Park Wet Pond (60% TSS Reduction)	20.6	$ 1,771,100	$ 1,827,400	$ 4,435
Streambank Restoration at Henry David Thoreau School	13.9	$ 296,200	$ 299,300	$ 1,006
Streambank Restoration on Cherokee Drive (Yuma Drive to Chippewa Drive)	13.3	$ 369,000	$ 369,100	$ 1,391
Diversion of Basin W102-D-0193-H-MAD-C to Manitou Pond	10.3	$ 232,900	$ 276,800	$ 672
Wetland Harvesting (4.6 acres)	41.4	$ 43,000	$ 97,600	$ 119
Total	**221.1**	**$ 12,938,000**	**$ 17,332,900**	**$ 3,920**
TP Reduction Gap to Meet Short-Term Goal	218			**(average)**
Difference	3.1			

Table 4.04-9 Alternative 5 Cost and Performance

6. Alternative 6–Table 4.04-10 shows the components of Alternative 6.

Facility	TP Reduction Performance (lb)	OPCC	20-Year NPW Cost	20-Year NPW Cost/lb
75% of All Infiltration BMPs (See Table 4.03-6)	91.2	$ 7,669,400	$ 10,847,000	$ 5,352
25% of All Infiltration BMPs (at 30% Greater Cost)	30.4	$ 3,323,300	$ 4,700,400	$ 6,958
Diversion of Basin W102-D-0193-H-MAD-C to Manitou Pond	10.3	$ 232,900	$ 276,800	$ 672
Modified Leaf Collection Methods ($47,000 Year 1 Capital Cost + $10,000 Annual Operation Cost, therafter)	84.6	$ 57,000	$ 229,100	$ 135
Streambank Restoration at Henry David Thoreau School	13.9	$ 296,200	$ 299,300	$ 1,006
Total	**230.4**	**$11,578,800**	**$ 16,352,600**	**$ 3,550**
TP Reduction Gap to Meet Short-Term Goal	218			**(average)**
Difference	12.4			

Table 4.04-10 Alternative 6 Cost and Performance

7. Alternative 7–Table 4.04-11 shows the components of Alternative 7.

Facility	TP Reduction Performance (lb)	OPCC	20-Year NPW Cost	20-Year NPW Cost/lb
50% of All Infiltration BMPs (See Table 4.03-6)	60.8	$ 5,112,900	$ 7,231,300	$ 5,352
50% of All Infiltration BMPs (at 30% Greater Cost)	60.8	$ 6,646,800	$ 9,400,800	$ 6,958
Diversion of Basin W102-D-0193-H-MAD-C to Manitou Pond	10.3	$ 232,900	$ 276,800	$ 672
Modified Leaf Collection Methods ($47,000 Year 1 Capital Cost + $10,000 Annual Operation Cost, therafter)	84.6	$ 57,000	$ 229,100	$ 135
Streambank Restoration at Henry David Thoreau School	13.9	$ 296,200	$ 299,300	$ 1,006
Total	**230.4**	**$12,345,800**	**$ 17,437,300**	**$ 3,780**
TP Reduction Gap to Meet Short-Term Goal	218			**(average)**
Difference	12.4			

Table 4.04-11 Alternative 7 Cost and Performance

D. Alternatives Analysis

Table 4.04-12 provides a side-by-side comparison of Alternatives 1, 2, 3, 4, 5, 6, and 7. Additional alternatives may be considered by mixing and matching alternatives presented in Table 4.04-1. Of the seven alternatives considered, Alternative 2 and 4 have the lowest OPCC and 20-Year NPW costs. Alternative 2 relies upon the infiltration projects and alum addition at Manitou Pond. Alternative 4 relies upon the infiltration projects and enhanced erosion control enforcement. The next most cost-effective project is Alternative 1 that relies on the infiltration projects, two structural phosphorous projects (diversion to Manitou Pond and streambank restoration), and one nonstructural phosphorus project (modified leaf collection). Alternative 3 relies on the infiltration projects and four structural projects (alum addition at Marion-Dunn Pond, diversion to Manitou Pond, and two streambank restoration projects). Alternative 5 is the least cost-effective of the five alternatives while relying on the infiltration BMPs, four structural phosphorus projects (Wingra Park Wet Pond, two streambank restoration projects, and diversion to Manitou Pond), and one nonstructural phosphorus project (wetland harvesting). From a cost and performance standpoint, Alternatives 1, 2, and 4 can be considered very similar. As described above, Alternatives 6 and 7 (as modifications of Alternative 1) contemplate partial implementation of the Infiltration BMPs and replacement of the remaining infiltration BMPs with less cost-effective BMPs.

Facility	TP Reduction Performance (lb) at 0.5 in/hr	OPCC	20-Year NPW Cost	20-Year NPW Cost/lb
Alternative 1	230	$ 10,811,900	$ 15,267,900	$ 3,310
Alternative 2	261	$ 10,513,100	$ 15,279,900	$ 2,930
Alternative 3	224	$ 11,403,400	$ 16,128,800	$ 3,600
Alternative 4	260	$ 10,280,800	$ 15,394,600	$ 2,960
Alternative 5	221	$ 12,938,000	$ 17,332,900	$ 3,920
Alternative 6	230	$ 11,578,800	$ 16,352,600	$ 3,550
Alternative 7	230	$ 12,345,800	$ 17,437,300	$ 3,780

Table 4.04-12 Alternatives Comparison

E. Long-Term Goal Discussion

The long-term TP reduction goal is an 80 percent reduction in TP compared to no pollutant reduction controls. This is an ambitious goal that will serve to guide future efforts to further reduce TP loads in the watershed. Table 4.04-1 shows there are strategies and projects available that could contribute to achieving the long-term goal but not fully meet the goal, though some of the strategies have the potential to double-count the phosphorus reduction. Achievement of the goal may take major shifts in development patterns (e.g., conversion of curb and gutter streets to drainage via grass-lined swales), major implementation of source area phosphorus control BMPs (1000s of terrace rain gardens in the watershed) and/or identification and implementation of additional larger phosphorus control projects in the watershed. Once the short-term goal is met by providing 218 (121.6 from infiltration/phosphorus BMPs and 96.4 from phosphorus BMPs) pounds of TP removal, an additional 570 pounds of TP removal would be needed to meet the long-term goal as further described in Table 4.03-6.

4.05 SOCIAL MARKETING OPPORTUNITIES

In addition to Table 3.05-1, Table 4.05-1 lists the different alternative components to meet the short-term phosphorus reduction goal. These alternative components are a mix of projects and strategies. The projects and some of the strategies rely on City budgeting to provide a dedicated revenue source. Strategies such as modified leaf collection methods and pet waste enforcement rely on property owners to participate and lend themselves to social marketing strategies. The City's Stormwater Utility Rate Adjustment Policy currently provides incentives for construction of stormwater BMPs by way of a reduction in the stormwater utility charge. It is recommended that this policy be periodically reviewed for effectiveness.

Facility	Responsible Party	Social Marketing Opportunity	Pilot Project Opportunity
Structural Improvements			
Alum Addition At Manitou Pond	City of Madison	City Project	No
Alum Addition At Marion Dunn Pond	City of Madison	City Project	Current Project
Diversion of Basin W102-D-0193-H-MAD-C to Manitou Pond	City of Madison	City Project	No
Streambank Restoration at Henry David Thoreau School	City of Madison	City Project	No
Streambank Restoration on Cherokee Drive (Yuma Drive to Chippewa Drive)	City of Madison	City Project	No
Wingra Park Wet Pond (60% TSS Reduction)	City of Madison	City Project	No
Nonstructural Improvements			
Wetland Harvesting (4.6 acres)	UW-Madison Arboretum	No	No
Modified Leaf Collection Methods	**City of Madison/Residential Property Owners**	**Yes**	**Yes**
Waterfowl Management (50 Geese Per Year)	City of Madison	Maybe	No
Construction Site (12.3 Acres) Erosion Control Enforcement (Enhanced)	City of Madison	Maybe	Maybe
Modified Street Sweeping Methods/Schedule	City of Madison	No	No
Pet Waste Enforcement	**City of Madison**	**Yes**	**Yes**

Table 4.05-1 Phosphorus Project-Based Social Marketing Opportunities

4.06 PROPOSED MANAGEMENT CHANGES TO ACHIEVE SHORT-TERM TP REDUCTION GOAL

Similar to management measures described in Section 3.06 for meeting the short-term infiltration goal, Table 4.06-1 describes potential management measures that could be implemented to achieve the short-term phosphorus reduction goal in the Lake Wingra watershed. The table also rates their implementation feasibility, potential effectiveness, and implementation priority. These ratings are a qualitative assessment to help provide an understanding of potential prioritization. Table 4.04-10 describes the seven alternatives considered for meeting the short-term phosphorus reduction goal. Management changes from Table 4.06-1 necessary to implement the pursued alternative components should be given the highest priorities.

Management Measure	Implementation Feasibility	Potential Effectiveness	Implementation Priority
Implement Dedicated Funding For City Projects Interaction with City of Madison Public Works, Engineering, Parks Departments to promote Lake Wingra Watershed projects. Goal to prioritize projects for inclusion in Capital Improvement Plans. Interact with Town of Madison for the Grandview Boulevard project.	+++	+++	+++
Modified City Leaf Collection Methods Provide additional strategies to increase participation in the program.	+++	+++	+++
Modified Street Sweeping Methods/Schedule Provide additional strategies to increase participation in the program.	++	++	++
Miscellaneous City TP Reduction Strategies Initiatives such as waterfowl management, construction site erosion control, and pet waste enforcement could be enhanced.	++	++	+ (+++for construction site erosion control)

Table 4.06-1 Proposed Management Change