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Staring Lake Watershed Basin Inventory and Maintenance Assessment

Prepared for:

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Table of Contents

Table of Contents (Cont.)

Table of Contents (Cont.)

TABLES

Table of Contents (Cont.)

FIGURES

Acronyms

AF	Acre-feet
BMP	Best Management Practice
BWSR	Board of Water and Soil Resources
DNR	Department of Natural Resources
EPA	Environmental Protection Agency
GIS	Geographical Information System
HUC	Hydrologic Unit Code: 8-digit HUC fourth-level (cataloguing unit)
MDH	Minnesota Department of Health
MnDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NPDES	National Pollutant Discharge Elimination System
NURP	Nationwide Urban Runoff Program
PAHs	Polycyclic Aromatic Hydrocarbons
PCCA	Purgatory Creek Conservation Area
SCS	Soil Conservation Service
SDS	State Disposal System
SWPPP	Stormwater Pollution Prevention Plan
TIN	Triangulated Irregular Networks
TP	Total phosphorus
TSS	Total Suspended Solids
WCA	Wetland Conservation Act

Executive Summary

The City of Eden Prairie, MN (population 62,409) is a suburb of Minneapolis with an area of approximately 36 square miles. The City's stormwater system consists of approximately 970 water bodies or basins. These include constructed stormwater ponds, wetlands, wetland mitigation areas, lakes, infiltration BMPs, drainage swales or ditches, and creek segments. Following NPDES requirements, the City inspects each publically-owned constructed pond and receiving basin a minimum of once in a 5-year period. The Minnesota Pollution Control Agency (MPCA), however, has asked the City to take an additional step to evaluate the treatment effectiveness of key water treatment basins (constructed ponds, infiltration BMPs, creeks and wetlands which receive stormwater). For this analysis, the City included basins that are either City-owned, included within a drainage easement, receive public drainage or are within City right-of-way.

BASIN INVENTORY & ASSESSMENT

The City chose to begin the study in the Staring Lake watershed because the local watershed district started a water quality improvement project in 2011, which included removal of invasive carp species. The City expects that the outcome of this study will help prioritize watershed district projects within the Staring Lake watershed. The remaining basins in the city will be evaluated in subsequent phases over the next 10-12 years by lake or creek watershed.

The basin inventory completed by the City identified over 237 basins within the Staring Lake project area. The first step in the process was to determine which of the 237 basins were considered "public" by determining which ones are located on City property, within City right-of-way, within a drainage and utility easement, or on private property but receiving runoff from public right-of-way. In the end, a total of 167 basins were identified as "public" in the Staring Lake project area.

A total of 172 basins were assessed for functionality and sedimentation. Of the inventoried basins, there were 58 constructed ponds, 7 mitigation wetlands, and 87 stormwater wetlands. Stormwater wetlands are defined as wetlands that receive water from developed areas and were modified to add inlet and/or outlet structures. One basin did not receive stormwater, 9 were determined to be swales and not excavated basins, and 10 were segments of Purgatory Creek.

SEDIMENTATION SURVEY

The sedimentation survey was conducted using a survey-grade sub-centimeter GPS unit to complete bathymetric surveys of the basins. A "Stormwater System Follow-up Checklist was developed to document information collected during the field survey. The following information was collected in the field:

- Bottom elevation of each basin
- Estimated accumulated sediment depth
- Approximate percent coverage of the permanent pool surface that appeared to be regularly covered by aquatic vegetation
- Water surface elevation
- Basin outlet/overflow data, including elevations and location
- Basin length and width (approximate)
- Photographs of key features of the basins

During the field review, Wenck also documented any "plain-sight" maintenance needs on the worksheets. This included items such as erosion, accumulation of debris on trash guards, damaged structures and others.

The City also provided storm sewer, grading and as-built plans when available for use during the field evaluation. The plans were taken into the field with the inspector to allow for easy comparison between proposed and constructed facilities.

Bathymetric surveys were conducted using cross-sections surveyed throughout each basin. At each survey point in the cross-section, the basin bottom elevation and the top of accumulated sediment were estimated. Sediment depth was determined by advancing a rod into the basin muck until resistance is felt (the original basin bottom). The bathymetric surveys were also used to improve information obtained from as-builts, which are not always accurate.

BASIN ANALYSIS

Data collected from the sedimentation survey was used to estimate sedimentation amounts and calculate pollutant removal effectiveness and sediment removal rates. The load-based removal efficiency was calculated and compared to Nationwide Urban Runoff Program (NURP) design standards. Maintenance needs were prioritized by sediment volume, proximity to public waters, location within the stormwater treatment system, potential water quality benefits, and budget available.

The project area was broken into several smaller subwatersheds that represent basins in series to better evaluate critical basins and the overall treatment in that subwatershed prior to discharge into their receiving waters. A total of 25 subwatersheds were identified in the project area. A total of 26 constructed ponds and stormwater wetlands were identified as potential candidates for expansion or cleanout to improve water quality performance within the Staring Lake watershed.

WATER QUALITY AND LAKE-RESPONSE MODELS

The tasks and analysis discussed above provide the City with an assessment of individual basin performance throughout much of the Staring Lake watershed. It does not, however, indicate whether there is an adequate level of pollutant removal for Staring Lake and what the overall benefit to the lake would be as a result of key projects. Therefore, a watershed-wide P8 model and a lake-response model were created for Staring Lake.

RESULTS

The basin inventory and assessment identified 22 basins as high priority basins that should be routinely inspected. These basins were identified based on evidence of potential sedimentation and location in the treatment train. Eleven constructed ponds and 8 stormwater wetlands were identified as possible projects for cleanout or expansion through as-built comparisons and sedimentation surveying. The BATHTUB lake response model indicates that in order to meet State standards, Staring Lake requires 2,829 lbs/yr of phosphorus reduction. If all the proposed projects are completed, 36 lbs TP/year, or <3% of the total phosphorus reduction required, is projected. The estimated cost of the proposed projects is $1.2 million, equating to $33,333 per pound of phosphorus removed. To meet the standard, a reduction of 50% from all watersheds, including upstream of Eden Prairie, is required.

1.0 Introduction

1.1 BACKGROUND

The City of Eden Prairie, MN (population 62,409; Figure 1.1) is a suburb of Minneapolis with an area of approximately 36 square miles. The City's stormwater system is quite extensive and consists of approximately 181 miles of pipe and appurtenant structures, approximately 970 basins including constructed ponds, stormwater wetlands, natural wetlands, lakes, infiltration BMPs, drainage swales or ditches, and creek segments. Stormwater wetlands are defined as wetlands that receive water from developed areas and were modified to add inlet and/or outlet structures. The system also includes 657 sump manholes that require routine inspection and clean out. In 2011, over 167 yards of material were removed from sump manholes in the City. This system has been designed to be used for flood control and water quality treatment for many years. Some constructed ponds and stormwater wetlands are now over 20 years old and may have reached a point where dredging of accumulated sediment is needed to retain their effectiveness.

The City operates the stormwater management system under the General NPDES Permit for Municipal Separate Storm Sewer Systems (MS4). Following NPDES requirements, the City must manage, operate, and maintain the stormwater management system in a manner as to reduce the discharge of pollutants to the maximum extent practicable. To this end, the City inspects a minimum of 20% of their basins annually and recently completed an inventory to identify and help track of all the basins in the City.

In 2009, the Minnesota Pollution Control Agency (MPCA) asked the City to take an additional step to monitor the basins that are either City-owned, within a drainage easement, receive public drainage or are within a City right-of-way. The City chose to begin this process in the Staring Lake watershed (Figure 1.2). The Riley-Purgatory-Bluff Creek Watershed District (RPBCWD) began an in-lake improvement project within Staring Lake in 2011. The intent of this study was to supplement the RPBCWD in-lake improvement project by evaluating the upstream stormwater system to identify stormwater management needs and potential projects within the watershed.

1.2 PURPOSE

The purpose of this study was to enhance the understanding of the City's maintenance responsibilities, assist City staff with scheduling and budgeting resources, and maintain compliance with the City's MS4 SWPPP. As described below, this assessment included three main components to achieve these objectives:

- Inventory and Assess Stormwater Systems – identify basins to be maintained by the City; visually inspect City-maintained basins for routine maintenance issues; perform bathymetric survey of City-maintained basins.
- Evaluate Data – evaluate sediment depths and volumes in City-maintained basins; identify key basins and their water quality effectiveness; evaluate the effects of these basins on receiving waters such as Staring Lake and Purgatory Creek.
- Recommend Improvements – identify improvements/maintenance action items; complete cost estimates for sediment removal; prioritize basin maintenance efforts.

1.3 PROJECT AREA

The project area includes the drainage area north and west of Staring Lake, as shown in Figures 1.2 and 1.3, including the Purgatory Creek Park Area. Staring Lake (DNR Lake ID 27-0078) is an in-line lake on Purgatory Creek, which is tributary to the Minnesota River. Located in Hennepin County, Staring Lake is just north of the Flying Cloud Airport and Pioneer Trail and east of Staring Lake Parkway (HUC 7020012.) Staring Lake has a surface area of 159 acres and a maximum depth of 15 feet.

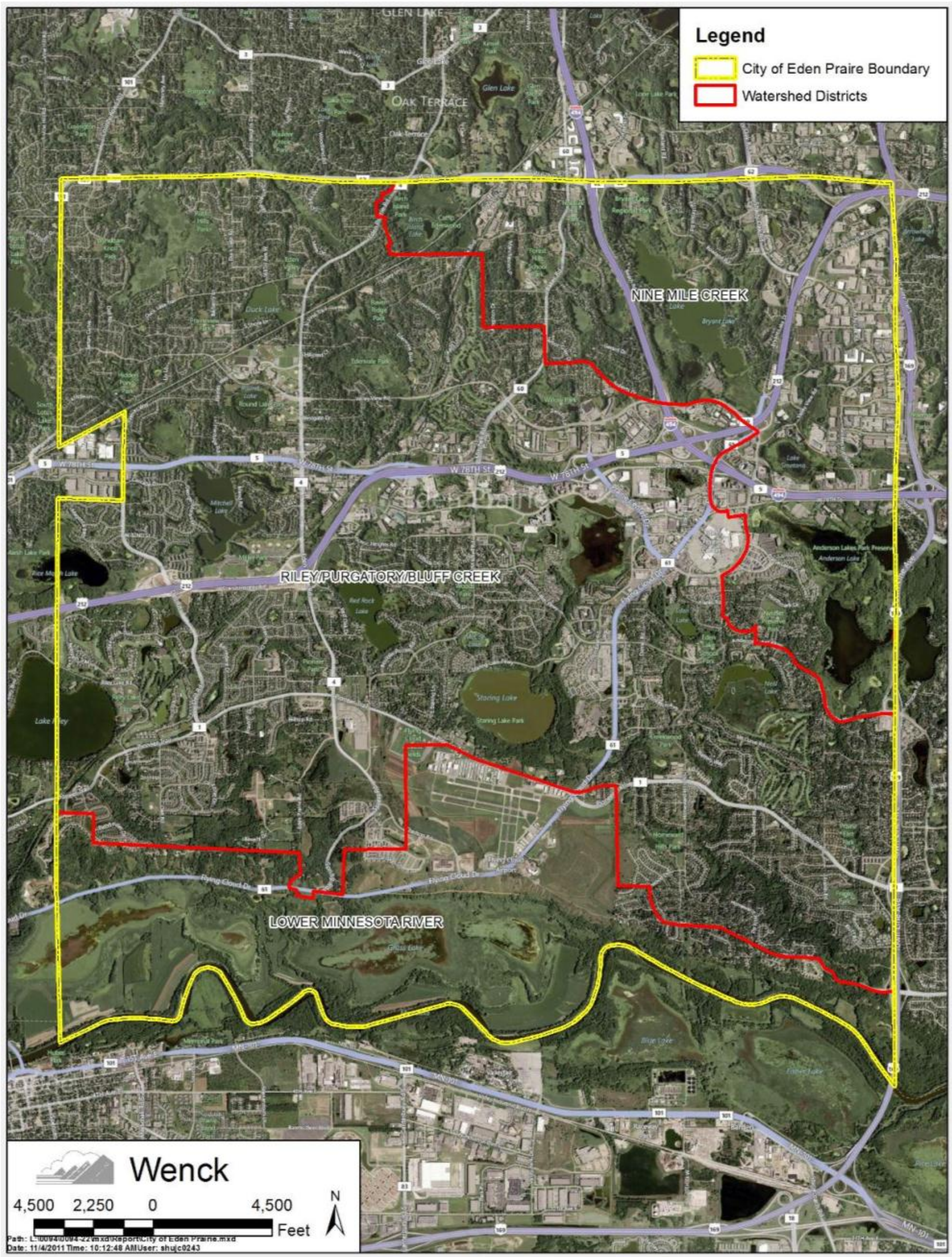

Figure 1.1. City of Eden Prairie.

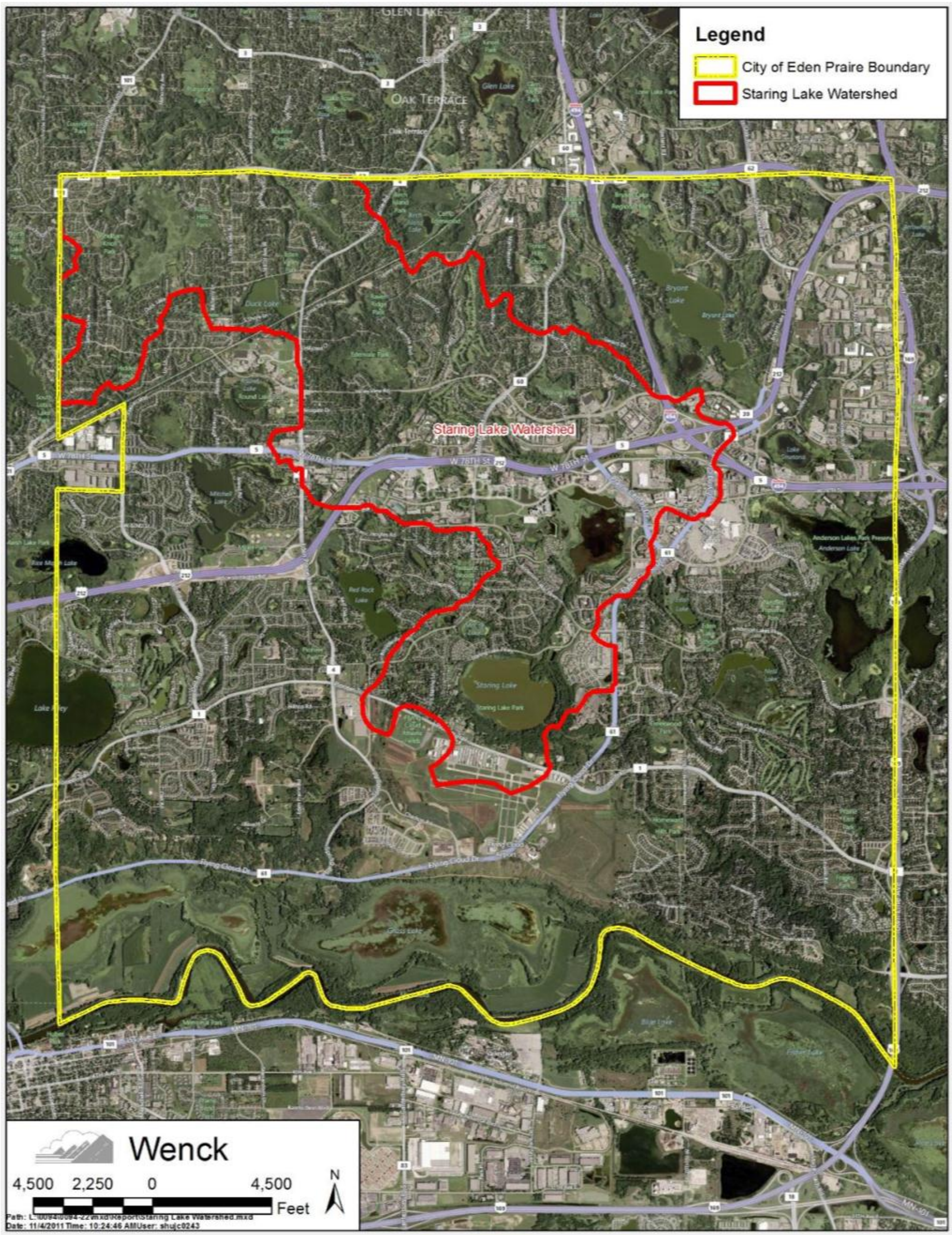

Figure 1.2. Staring Lake watershed.

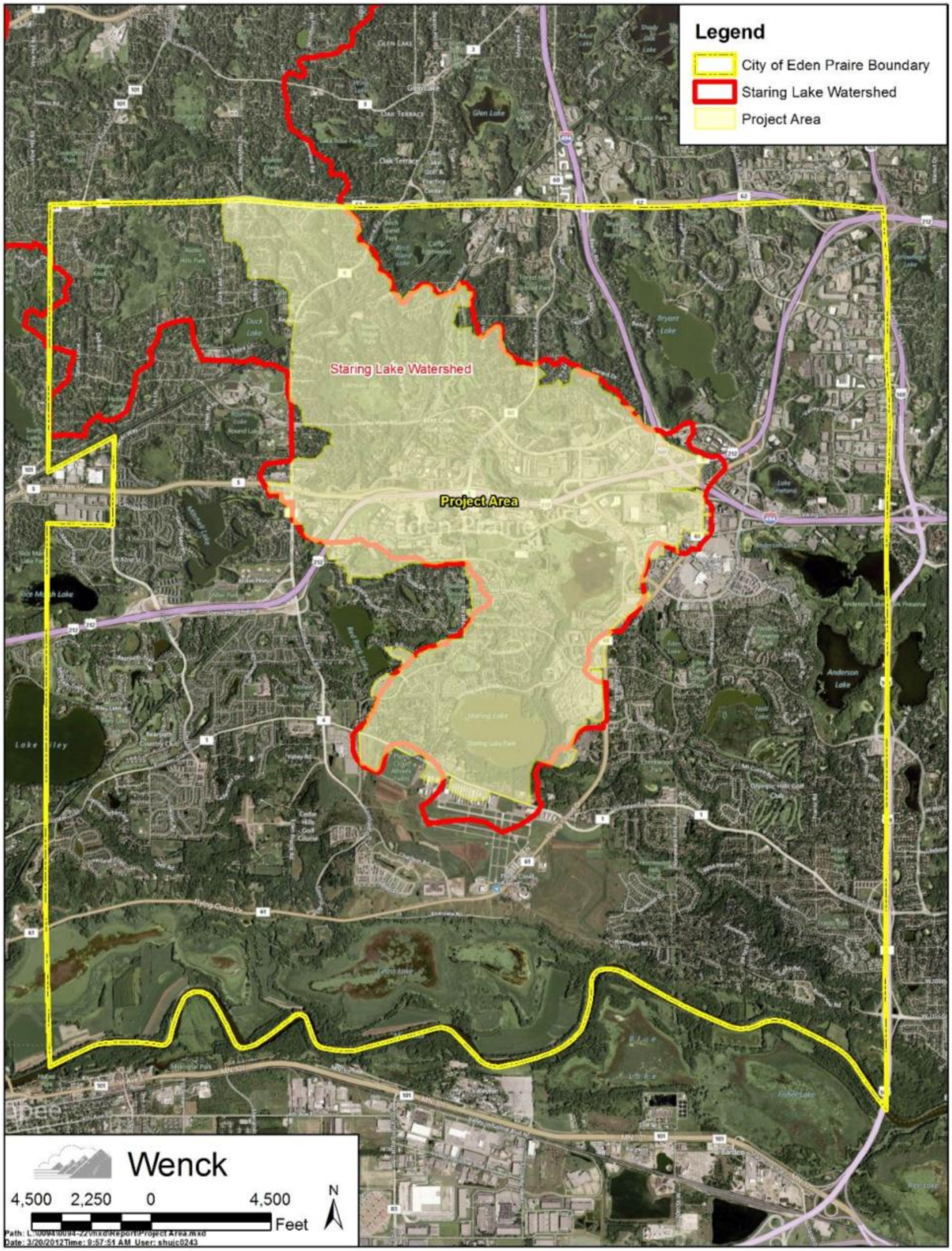

Figure 1.3. Project area.

2.0 Stormwater System Assessment Methodology

2.1 BASIN INVENTORY AND ASSESSMENT

In 2010, the City completed a Phase 1 stormwater basin inventory in the Staring Lake-Purgatory Creek watershed and identified over 176 basins that were designated for stormwater management. In 2011, the City completed a Phase II stormwater basin inventory that included the Upper Purgatory Creek section of the Staring Lake watershed. An additional 61 stormwater basins were identified in the Phase II study. The basins were further researched to determine which could be categorized as public. The criteria to be considered a public basin included one or more of the following:

- Located on City property
- Within a City right-of-way
- Within a drainage and/or utility easement
- Private property but receiving runoff from a public right-of-way

Research efforts involved reviewing design and record drawings to locate easements, using geographic information system (GIS) based parcel information to determine ownership, and delineating subwatersheds using two foot contours. Ultimately, a total of 167 basins (116 in Phase 1 and 51 in Phase II; Figure 2.1) were given a public designation in the Staring Lake watershed.

Each of the 167 basins was visually inspected and site surveys were completed to help assess the maintenance needs and existing storage capacities. This data was needed to estimate sediment volumes, complete water quality modeling, provide cost estimates, and prioritize maintenance activities.

Prior to conducting basin surveys, Wenck and City of Eden Prairie staff reviewed design and as-built plans of the basins, when available. Information obtained from the design or as-built plans included basin outlet elevations; basin flood or high water level elevations; size, type, and material of outlet structure; and basin length and width. Using a planimeter to obtain distances and areas from the design or as-built plans, staff also calculated permanent pool and flood pool areas and volumes for each basin.

2.1.1 Visual Inspections

During each basin survey, Wenck also conducted a visual inspection based on the City's "Stormwater System Follow-Up Checklist." Wenck completed the checklist by documenting the overall condition of the basin, including the condition of structures, the presence of erosion, maintenance needs, the presence of trash or debris, and aquatic vegetation coverage. Information

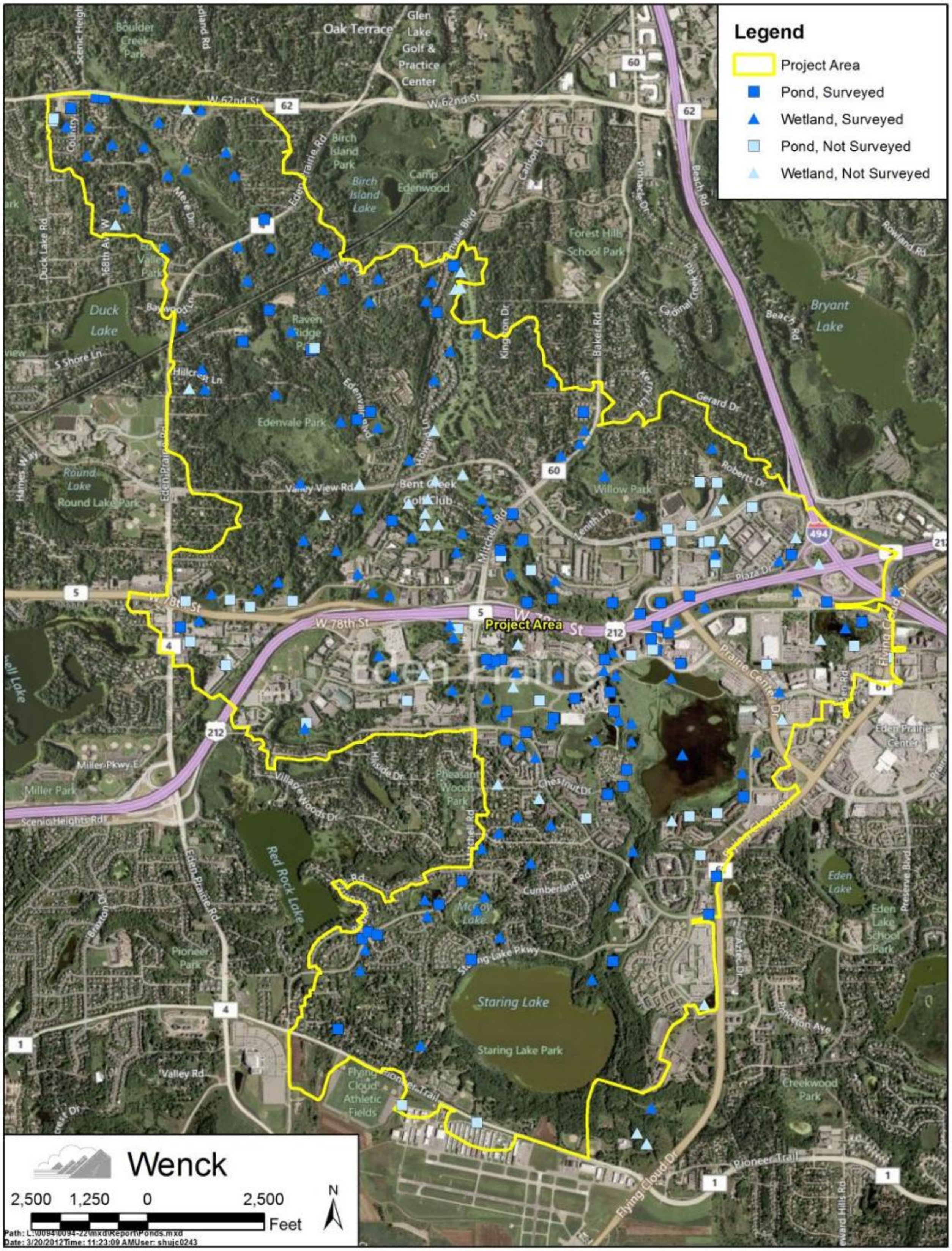

Figure 2.1. Basins in the survey area of the City of Eden Prairie determined to receive public drainage.

2.1.2 Sedimentation Surveys

Sedimentation surveys were conducted at each basin during 2010. Wenck used a Trimble R8 survey-grade GPS unit with sub-centimeter accuracy to collect elevation and location data at each basin. The survey included a bathymetric survey of the basin in which cross-sections were surveyed throughout each basin from the basin bottom, recording the water surface elevation, and extending beyond the flood elevation.

At each survey point, Wenck collected the basin bottom elevation and the top of the accumulated sediment. Sediment depth was estimated by advancing a rod through the sediment until refusal. The inverts of outlets, inlets, or other structures, and water level elevations were surveyed. Representative photos of each basin and structures within the basin were also taken.

2.1.2.1 Estimation of Sediment Quantities

Wenck used ArcMap 10 GIS software to process the GPS data collected during the sedimentation survey and estimate sediment deposition in each basin. The GIS software allowed Wenck to calculate the surface area of each basin, as well as the permanent pool and flood volumes. Basin volumes were calculated from elevation contours generated using ArcMap. The volume of sediment in each basin was determined by using the sediment depth measured in the field at survey points or by comparing the survey volumes to the as-built or design volumes.

Figure 2.2 shows the plan view of a typical stormwater basin. Each survey point collected was geographically-referenced and an elevation was recorded. Survey points represent water surfaces, basin bottom transects, and overflow location points. This data was combined with data from a digital elevation model to create Triangulated Irregular Networks (TINs). The differences between various TINs were used to generate estimates of various volumes.

The permanent pool, or dead storage volume, is the volume below the outlet elevation. The flood pool is the volume between the outlet and the overflow point. If no outlet is present, the permanent pool was calculated as the volume below the overflow point.

The extent of sediment deposition in the stormwater ponds was estimated by comparing the existing permanent pool volume to the estimated "original" permanent pool volume for each pond. Determining the original permanent pool volume of a basin can be a challenge, as accurate data on the "as-built" construction of the basin is not often readily available. In fact, errors in the as-builts often resulted in negative values for changes in permanent pool volume, though some positive values were noted. Since it is unlikely that permanent pool volumes increased, it was determined that these values were likely associated with inaccuracies in the as-built documents.

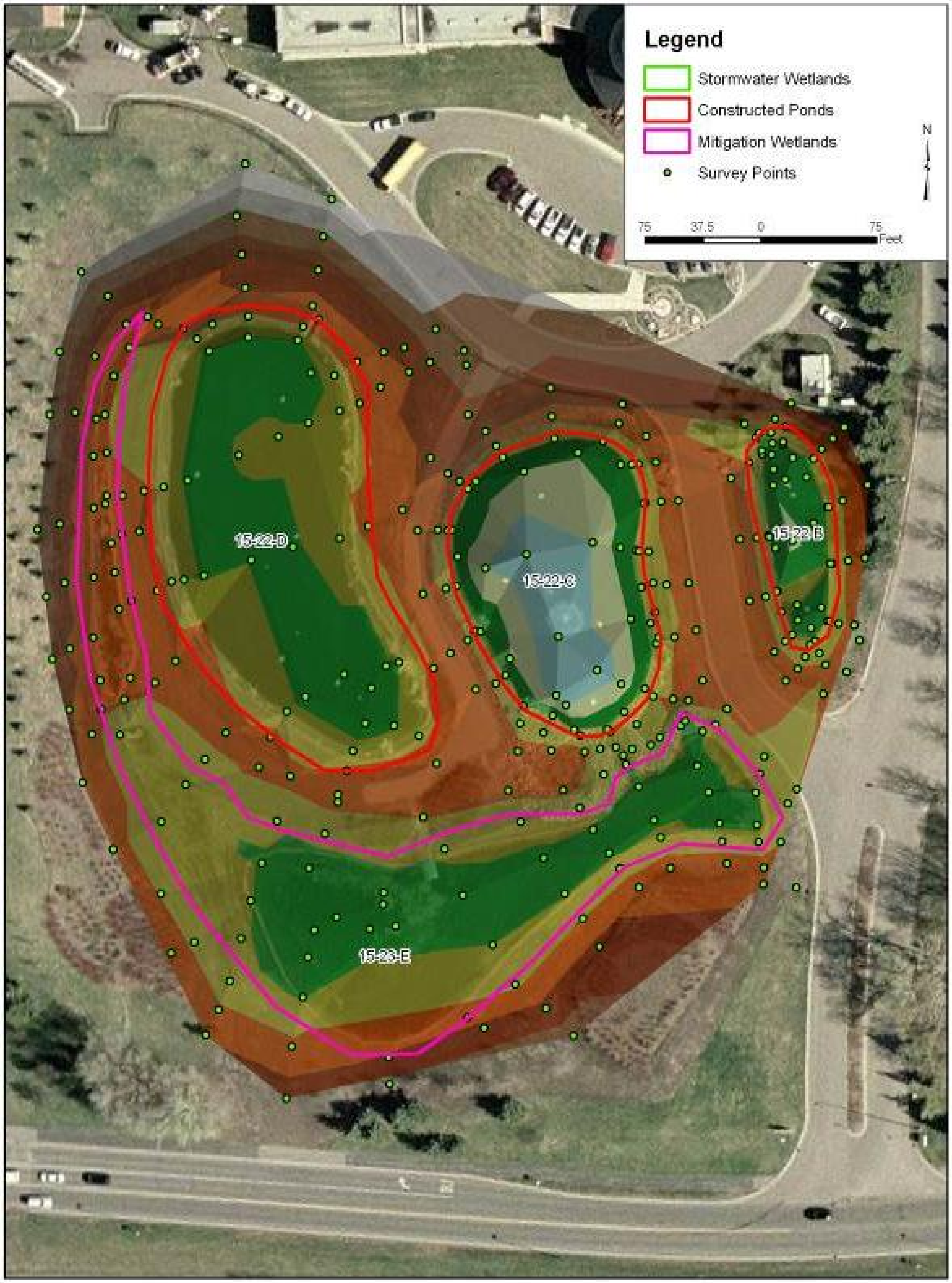

Figure 2.2. Plan view of a typical stormwater basin.

2.1.2.2 NURP Evaluation

The Environmental Protection Agency's (EPA) Nationwide Urban Runoff Program (NURP) focuses on detention basin design criteria related to phosphorus removal from urban watersheds. Sources from urban areas such as fertilizers, leaves, grass, bird droppings, pet waste or erosion around the basins contribute to increased total phosphorus loadings. Because basin depth and permanent storage capacities have been linked to Total Suspended Solids (TSS) and Total Phosphorus (TP) removal efficiencies, NURP standards require stormwater detention basins to have a permanent storage volume equal to or greater than the runoff from a 2.5-inch, 24-hour storm event. The permanent pool storage volume needed to meet NURP standards was calculated for each basin using the estimated impervious surface area, pervious surface area based on soil types and vegetative cover, and the subwatershed area tributary to each basin. The purpose of this evaluation was to determine the optimal areas that could be improved to provide additional treatment within the Staring Lake watershed.

2.1.3 Planning Level Sediment Removal Cost Estimates

Planning level sediment removal costs were developed for the removal of accumulated sediments or for expansion of basins (Table 2.1). The cost estimates are based on past experience with basin expansions and construction as well as discussions with local contractors. The cost estimates include mobilization, site preparation, sediment excavation and disposal, minor storm sewer or structural work, and erosion control. The cost estimates also include an additional 30% for engineering and 30% for contingencies.

These costs do not include laboratory analysis, wetland mitigation, sediment characterization, major structural work or land/easement acquisition. The costs also do not account for disposal of contaminated sediments if sediment analysis results conclude the sediments are not appropriate for standard disposal.

Table 2.1. Planning level costs for basin excavation.

Basin Excavation Volume (AF)	Approximate Unit Cost ($ per acre-foot)
0 to 0.5	$138,560
0.5 to 1	$107,315
1 to 5	$51,207

2.1.4 Sediment Characterization Costs

Basin sediments need to be characterized to determine disposal options. This analysis includes particle size analysis, laboratory analysis for potential contaminates, and determination of the number of samples to be collected. Excavated material that is mostly sand and/or gravel (>93%) is unlikely to be contaminated and chemical laboratory analysis would typically not be required.

If lab sediment analysis is required, sediment samples must be analyzed for a list of parameters established by the MPCA. Based on recent MPCA guidance, Managing Dredged Materials in the State of Minnesota (June 2009), sediment samples from urban stormwater basins must be analyzed for copper, arsenic, and Polycyclic Aromatic Hydrocarbons (PAHs). The historic land use within the drainage area of a stormwater basin must also be reviewed to help determine the likelihood of other pollutants being present in the sediment.

The recommended number of sediment samples to be collected is dependent upon the estimated volume of material to be excavated. Table 2.2 summarizes the minimum recommended number of samples to be collected for urban stormwater basins, based on the MPCA's most recent guidance (MPCA, 2009).

Table 2.2. MPCA recommended number of samples for sediment characterization.

Estimated Volume of Dredge Material (cubic yards)	Minimum Recommended Number of Samples for Analysis
0 to 100	0
100 to 500	1
500 to 3,000	2
3,000 – 30,000	3
30,000 – 100,000	5
100,000- 500,000	6
500,000-1,000,000	8
>1,000,000	>8

Costs for sediment analysis including collection and lab processing can range from $2,000 to $4,000. These costs are included in the planning level cost assessment.

2.2 P8 MODEL

2.2.1 Model Construction

The P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds, IEP, Inc., 1990) Model is a computer model used for predicting the generation and transport of stormwater runoff pollutants in urban watersheds. The P8 model was used in this study to simulate the hydrology, total suspended solids, and phosphorus loads introduced from the watershed of each basin and the transport of phosphorus throughout the stormwater system. P8 is a useful diagnostic tool for evaluating and designing watershed improvements and best management practices (BMPs). The model requires user input on watershed characteristics, basin attributes, local precipitation and temperature, and other parameters relating to water quality and basin removal performances.

Examination of the watershed characteristics for each basin being modeled involved assessment of soil type, land use and residential density, and the impervious fraction of the land in the watershed. Arcview GIS software was used extensively in assessing watershed characteristics.

In P8, pervious and impervious areas are modeled separately. Runoff volumes from pervious areas are computed using the Soil Conservation Services (SCS) Curve Number method. Runoff from impervious areas begins once the cumulative storm rainfall exceeds the specified depression storage, with the runoff rate equal to the rainfall intensity.

Because P8 calculates runoff separately from pervious and impervious areas, it was necessary to determine the impervious fraction of each watershed. For the P8 models, the impervious area was assumed to be all directly connected. An impervious area is considered directly connected if runoff flows directly from it into the drainage system via continuous paved areas. The directly-connected impervious fraction was calculated for each watershed based on the land use(s), with each land use having an assumed impervious percent. The assumed impervious percent is listed in Table 2.3.

Watershed runoff volumes from pervious areas were computed for P8 by using the SCS Curve Number (CN) method. Within each watershed a pervious CN was calculated based on the soil type and land use. The pervious CN was area weighted in each subwatershed using the values in Table 2.3.

Table 2.3. Assumed impervious percent and pervious curve numbers for land uses in Eden Prairie.

	Impervious Fraction	**Pervious Curve Number**			
Land Use	**percent**	**A**	**B**	**C**	**D**
Agriculture	5	49	69	79	84
Airports	30	68	79	86	89
Commercial	67	49	69	79	84
Eden Prairie Wetlands	0	85	85	85	85
Industrial	50	68	79	86	89
Major Highway	50	49	69	79	84
Multi-Family Residential	60	39	61	74	80
Parks and Recreation Areas	10	39	61	74	80
Public/Semi Public	32	39	61	74	80
Railway	20	68	79	86	89
Single Family Residential	25	39	61	74	80
Vacant	5	39	61	74	80

The P8 model requires an hourly precipitation record (rain and snowfall) and daily temperature record. Precipitation and temperature data were obtained from the Minneapolis-St. Paul International Airport.

The NURP50 file was selected for the P8 models. The component concentrations in the NURP 50 file represent the 50th percentile (median) values compiled in the EPA's Nationwide Urban Runoff Program (NURP).

The treatment devices in P8 provide collection, storage, and/or treatment of watershed discharges. A variety of treatment devices can be modeled in P8, including detention ponds (wet or dry), infiltration basins, swales, buffers, aquifers, and pipes. For this study, nearly all ponds and wetlands were modeled as detention basins. The user-defined characteristics of these basins are described in the following sections.

2.3 BATHTUB MODEL

A BATHTUB lake response model was developed for Staring Lake to assess the potential impacts of various improvement projects on in-lake water quality. The purposes of the model are to develop a phosphorus budget for each lake, identify the major factors influencing current and future water quality, and provide an understanding of the level and magnitude of project implementation required to meet identified water quality goals.

A publicly available model, BATHTUB was developed by William W. Walker for the U.S. Army Corps of Engineers (Walker 1999). BATHTUB has been used successfully in many lake studies in Minnesota and throughout the United States. It is a steady-state annual or seasonal model that predicts a lake's summer (June-September) mean surface water quality. Its annual time-scale is appropriate because watershed P loads are determined on an annual or seasonal basis, and the summer season is critical for lake use and ecological health.

BATHTUB has built-in statistical calculations that account for data variability and provide a means for estimating confidence in model predictions. It accounts for water and P inputs from tributaries, watershed runoff, the atmosphere, sources internal to the lake, and (if appropriate) groundwater; and accounts for outputs through the lake outlet, groundwater (if appropriate), water loss via evaporation, and P sedimentation and retention in the lake sediments.

BATHTUB allows choice among several different mass-balance P models. For deep lakes in Minnesota, the option of the Canfield-Bachmann lake formulation (Canfield and Bachmann 1981) has proven to be appropriate in most cases. For shallow Minnesota lakes, other options have often been more useful.

BATHTUB's in-lake water quality predictions include two response variables, chlorophyll-*a* concentration and Secchi depth, in addition to TP concentration. A response variable is a measured outcome from changes in nutrient loading. For example, increases in total phosphorus are typically followed by increases in chlorophyll-*a* because phosphorus limits the growth of algae. Increases in algae lead to a decrease in water clarity or Secchi depth which is another response to changes in phosphorus loading. Empirical relationships between in-lake TP, chlorophyll-*a*, and Secchi depth form the basis for predicting the two response variables.

2.4 SEDIMENT RELEASE RATE ASSESSMENT

Wenck collected four intact sediment cores (undisturbed) from the deepest part of Staring Lake. At the same location, data was collected to develop dissolved oxygen, pH and temperature profiles at the time of sampling. The samples were analyzed to estimate the anoxic and oxic release of phosphorus from the sediments.

These results were combined with dissolved oxygen and temperature profiles from Staring Lake to develop a component of the annualized phosphorus loads from the sediments of Staring Lake (internal load).

3.0 Stormwater System Conditions

3.1 BASIN IDENTIFICATION

The City of Eden Prairie maintains a database of basins within the City. This database was used along with a review of aerial photographs to identify potential basins in the project area. Over 237 basins were identified in the Staring Lake watershed that were designated for stormwater management.

Wenck delineated the subwatersheds of the 237 stormwater basins to determine whether they receive public stormwater drainage from the City or were wholly private. Ultimately, a total of 167 basins (Figure 2.1) were given a public designation in the Staring Lake watershed.

Of the 237 designated basins, 15 were MnDOT basins with 9 of those basins receiving City stormwater as well as highway runoff (Figure 3.1). Fourteen of the 15 MNDOT basins were field surveyed. Two of these were identified as swales. MNDOT basins that were surveyed but do not receive City drainage are included even though the City is not responsible for basins that do not receive City drainage to ensure the most accurate model possible.

A total of 172 basins were assessed for functionality and sedimentation. Of the inventoried basins in Phase 1, 43 were designated as constructed ponds, 5 as mitigation wetlands, and 58 as stormwater wetlands. One basin was determined to not receive stormwater, 2 were determined to be swales and not excavated basins, and 5 were creek segments. In Phase II, 11 were constructed ponds, 25 were stormwater wetlands, 2 were mitigation wetlands, 7 were swales, and 5 were Purgatory Creek segments. Four constructed ponds and 4 stormwater wetlands were designated as private.

Figure 3.1. MnDOT ponds and wetlands in the Staring Lake study area.

3.1.1 Constructed Ponds

A total of 92 constructed stormwater ponds were identified in the project area, with 54 shown to receive City drainage and 37 designated as private ponds that do not receive City drainage. Constructed ponds are those ponds designed and built specifically for the purpose of stormwater control including either flooding or water quality. Constructed ponds do not include wetlands modified to treat stormwater.

3.1.2 Stormwater Wetlands

The project area contained a total of 118 stormwater wetlands, with 85 shown to receive City drainage and 33 designated as private. A stormwater wetland is defined as any natural wetland that receives stormwater from impervious or developed areas. Stormwater inflow may be from an open channel (overland flow) or pipe. The majority of the wetlands in the City receive some stormwater from City streets and/or property and therefore are categorized as stormwater wetlands.

The purpose of the wetland survey was to identify those wetlands used for stormwater management and evaluate their current condition and performance. Because this analysis was focused on sedimentation, only the open water areas of the wetlands were surveyed. Additionally, all of the inlets and outlets were inspected for maintenance needs. For wetland areas that did not have significant open water, the perimeter of the wetland was surveyed. Many of these do not have as-builts or grading plans available for comparison.

3.1.3 Creek Segments

Eleven of the basins in the City database were segments of Purgatory Creek. For these segments, the perimeter of the basin was walked and all inlets were surveyed and inspected. No water surveys or cross-sections were completed.

3.1.4 Swales

Nine of the identified basins in the City database were classified as swales. Swales are defined as vegetated depressions used for the conveyance and treatment of stormwater and are not used for stormwater treatment and therefore not included in the assessment.

3.2 STORMWATER BASIN VISUAL INSPECTION

Visual inspections were conducted at each of the basins in the survey to identify any structural maintenance needs at each basin. Visual inspections included any signs of erosion, sedimentation, failing infrastructure or clogged inlets and outlets. Basins listed in poor or fair condition are provided in Table 3.1. All results where issues were identified are presented in Appendix A. A rating of good meant that the pond inlets and outlets were in operating condition and there was little erosion. A rating of fair indicated that there was some obstruction of inlets and outlets, and/or some bank erosion. A rating of poor meant that the inlets or outlets were clogged or not functioning and/or bank erosion was severe

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Table 3.1. Selected visual inspection results for the Staring Lake watershed basin survey.

Basin ID	Priority	Overall Condition	Erosion Concern	Sediment Concern	Sediment Delta	Vegetation Overgrowth	Debris Concerns	Notes/Other issues
05-11-B	High	Poor	Yes	Yes	Yes	Yes	Yes	Densely covered by vegetation
05-21-A	High	Poor				Yes	Yes	Outlet plugged with debris
05-21-D	High	Poor	Yes					Bottom worn through
09-12-C*	High	Poor	Yes					Filled with rocks and eroded, couldn't find in 2010
09-33-B	High	Poor		Yes	Yes			Approximately 1' of sediment completely fills inlet pipe
21-13-A	High	Poor		Yes			Yes	Leaves, sediment deposition, and mixed trash debris in Flared End Section (FES)
16-23-A	High	Poor	Yes					Erosion gully formed at base of structure. Undercutting FES. Riprap displaced.
15-31-A	High	Poor				Yes	Yes	Much trash/debris behind TG, a large tree has fallen on TG and is bending rebar
14-33-B*	High	Poor		Yes			Yes	FES 95% blocked by debris
10-44-D*	High	Poor			Yes	Yes	Yes	
10-43-B*	High	Poor		Yes				
10-14-A	High	Poor		Yes				
09-41-D	High	Poor	Yes	Yes	Yes			Leaf mat blocking opening up 10 inches from FES invert. Trash guard detached from N side of FES
10-32-B	High	Poor	Yes	Yes	Yes	Yes		
05-12-C	High	Fair	Yes	Yes	Yes			
05-11-C	High	Fair	Yes					Erosion at end fairly bad, leads approximately 25' to pond via erosion gully

Table 3.1., cont. Selected visual inspection results for the Staring Lake watershed basin survey.

Basin ID	Priority	Overall Condition	Erosion Concern	Sediment Concern	Sediment Delta	Vegetation Overgrowth	Debris Concerns	Notes/Other issues
04-23-A*	High	Fair	Yes	Yes	Yes		Yes	Approximately 4" of sediment, debris blocking flow in FES
04-31-D	High	Fair		Yes			Yes	50% inhibited w/sediment and debris, couldn't find in 2010/2011
21-31-B*	High	Fair	Yes	Yes				Sediment in FES, erosion gully where inlet stream meets ponding area
15-43-A*	High	Fair	Yes					Undercutting base of pipe structure
15-32-C*	High	Fair	Yes					Undercutting at FES
15-32-B*	High	Fair	Yes	Yes				Approximately 8" of sediment buildup in FES
04-32-D*	Medium	Fair		Yes		Yes	Yes	Conditions at inlet
22-11-B*	Medium	Fair		Yes				Approximately 6" of sediment buildup in FES
21-11-D*	Medium	Fair		Yes		Yes		Erosion at base of FES
15-24-A	Medium	Fair		Yes				Approximately 6-12" of sediment buildup in FES
10-24-C	Medium	Fair	Yes				Yes	erosion at base of structure
05-14-B	Medium	Fair		Yes				Approximately 9" of sediment at edge of FES

* Constructed Pond

3.3 BASIN SEDIMENTATION

Constructed ponds and stormwater wetlands were evaluated for sediment deposition by comparing the existing permanent pool volume to the estimated original permanent pool volume for each constructed pond or stormwater wetland. Estimating the original permanent pool volume was accomplished by reviewing as-builts where available. Basin sedimentation was also evaluated using field collected sediment depth data for all of the stormwater basins and wetlands. To assess sediment depths, a rod was pushed into basin sediments to refusal. Surface contours were then developed for the refusal depths and the sediment surface to determine sediment volumes.

There are a few considerations that must be taken into to account when interpreting the results of the survey including:

1. Estimating the original permanent pool volume is difficult and highly dependent on the accuracy of the as-built information or design plans. Furthermore, many of the ponds and wetlands do not have design plans or as-built information available. The absence of accurate design plans or as-built information for estimating the original permanent pool volumes can result in significant error in the sedimentation analysis. Consequently, results should be used cautiously in light of the uncertainty.

2. The depth to refusal may or may not represent sediment that has accumulated in the basin. Some or all of the sediment may be original basin or wetland sediment. However, there is no accurate way to distinguish between the original sediment and accumulated sediment.

3. Construction information is not readily available for all basins, so it is unsure whether all stormwater wetlands are natural wetlands or constructed ponds.

3.3.1 Constructed Ponds and Stormwater Wetlands with As-Built Information

There are 64 stormwater basins with at least partial design or as-built information with 34 designated as constructed ponds and the remaining 30 as stormwater wetlands. Table 3.2 presents the basins with complete as-built information, both permanent pool and flood pool volumes, and lists the basins in downstream order. In contrast, there were 73 constructed ponds and 125 stormwater wetlands without any as-built information. To evaluate the usefulness of comparing as-built dead pool storage to field surveyed dead pool storage, the basin surface areas were first compared.

In almost all of the cases, the field surveyed dead pool area was significantly less than the as-built dead pool areas ranging from 0 to 98% difference. Data for constructed ponds was more reliable than data for stormwater wetlands likely due to changes in wetland vegetation over time.

Those basins with field surveyed dead pool areas less than the design or as-built dead pool areas may offer an opportunity to increase basin storage and improve water quality treatment.

Table 3.2. Pond and wetland characteristics for basins with as-built or design information.

Basin ID	As-Built Permanent Pool (acres)	Surveyed Permanent Pool Area (acres)	As-Built Permanent Pool Volume (AF)	Surveyed Permanent Pool Volume (AF)	Surveyed minus As Built Permanent Pool[1] (AF)	Accumulated Sediment Volume (AF)	Sediment Percent of Permanent Pool
Constructed Ponds							
05-21-G	0.10	0.07	0.16	0.07	0.09	0.02	11.33
04-23-A	0.04	0.06	0.13	0.03	0.10	0.00	0.00
04-31-E	0.12	0.09	0.31	0.09	0.22	0.00	0.00
04-32-D	0.19	0.15	0.45	0.20	0.25	0.01	3.31
22-13-B	1.53	1.26	7.47	5.36	2.11	0.54	7.25
15-11-D	0.66	0.48	3.45	1.65	1.80	0.15	4.21
10-42-A	0.34	0.17	1.71	0.22	1.49	0.0004	0.02
15-13-C	1.26	1.33	6.81	5.62	1.19	0.03	0.42
15-42-A	0.43	0.27	1.62	0.48	1.14	0.14	8.84
15-24-D	0.44	0.42	1.81	1.01	0.80	0.02	1.33
09-42-E	0.32	0.11	0.89	0.17	0.72	0.00	0.00
15-13-D	0.27	0.27	1.38	0.88	0.50	0.05	3.90
21-31-B	0.41	0.15	0.58	0.13	0.45	0.00	0.00
14-21-C	0.20	0.04	0.46	0.03	0.44	0.03	6.88
11-34-C	0.19	0.11	0.59	0.28	0.30	0.01	2.30
10-43-C	0.26	0.17	0.85	0.56	0.29	0.00	0.00
15-22-B	0.11	0.06	0.34	0.06	0.28	0.00	0.00
21-14-C	0.03	0.01	0.24	0.001	0.24	0.00	0.00
15-22-C	0.43	0.43	2.37	2.18	0.19	0.00	0.00
04-44-B	0.33	0.22	1.09	0.92	0.16	0.00	0.00
15-23-F	0.36	0.32	1.15	0.99	0.16	0.00	0.00
10-32-D	0.20	0.20	0.92	0.76	0.16	0.07	7.71
15-32-C	0.35	0.30	0.99	0.86	0.13	0.09	9.29
10-21-A	0.17	0.12	0.37	0.24	0.13	0.00	0.00
21-11-D	0.05	0.004	0.12	0.0005	0.12	0.00	0.00
15-32-B	0.21	0.30	0.66	0.65	0.02	0.01	0.76
Wetlands							
05-12-C	0.53	0.42	1.89	0.66	1.23	0.38	20.18
05-14-B	0.28	0.00	0.97	0.00	0.97	0.00	0.00
05-11-C	1.79	0.92	2.15	1.02	1.13	0.38	17.73
09-12-A	4.28	4.93	4.62	7.26	-2.64	2.46	53.35
14-32-A	0.75	0.36	3.44	0.62	2.82	0.06	1.84
15-13-E	0.90	0.64	1.49	0.66	0.82	0.00	0.00
15-23-A	0.79	0.36	0.98	0.24	0.73	0.00	0.00
14-23-A	0.39	0.31	1.45	0.77	0.69	0.12	8.54
22-22-B	0.39	0.03	0.67	0.01	0.66	0.00	0.00
10-33-E	0.18	0.00	0.43	0.00	0.43	0.00	0.35
09-43-B	0.12	0.02	0.33	0.01	0.31	0.00	0.48
04-44-A	0.44	0.14	0.36	0.12	0.25	0.00	0.00

Table 3.2, cont. Pond and wetland characteristics for basins with as-built or design information.

Basin ID	As-Built Permanent Pool (acres)	Surveyed Permanent Pool Area (acres)	As-Built Permanent Pool Volume (AF)	Surveyed Permanent Pool Volume (AF)	Surveyed minus As Built Permanent Pool[1] (AF)	Accumulated Sediment Volume (AF)	Sediment Percent of Permanent Pool
Wetlands, cont.							
15-23-E	0.82	0.50	0.56	0.40	0.16	0.00	0.00
21-14-A	0.20	0.28	0.52	0.48	0.04	0.13	25.65
09-13-A	1.07	1.25	6.13	6.12	0.01	0.23	3.67
21-13-B	0.42	0.58	1.05	1.14	-0.09	0.08	7.84
04-41-A	1.99	1.58	10.37	11.02	-0.65	0.00	0.00
09-43-A	2.21	2.95	8.29	9.62	-1.34	0.23	2.76
15-23-D	1.30	2.57	0.00	4.80	-4.80	0.00	0.00
15-14-B	12.33	18.08	68.90	87.20	-18.30	1.75	2.54

[1]Negative values indicate that the surveyed volume was larger than the as-built volume.

3.4 CRITICAL STORMWATER BASINS

Basin performance was evaluated for the basins in series using P8 and by evaluating NURP requirements cumulatively for each basin. Stormwater basin performance was evaluated by comparing surveyed permanent pool volumes to the required permanent storage volume to meet NURP standards. The number is presented as a ratio where values less than one do not meet NURP standards and values greater than one exceed NURP standards. For our purposes, NURP standards are defined as having a permanent pool volume equal to the 2.5 inch runoff volume (Table 3.3).

The term "NURP pond" refers to retention basins (also called "wet ponds") that capture sediment from stormwater runoff as it is detained, and that are designed to perform to the level of the more effective ponds observed in the NURP studies. Some practitioners may assume that a "NURP pond" design conforms to some particular standard issued by EPA, but in fact EPA has issued no regulations or other requirements regarding the design of stormwater basins. However, some states and municipalities have issued stormwater design manuals, and these publications may include a reference to a "NURP pond."

Table 3.3. Typical Minnesota pond design standards.

Parameter	Standard Design
Permanent Pool Depth	4 to 10 feet
Permanent Pond Surface Area	Greater of 2% of watershed’s impervious area and 1% of the watershed
Permanent Pool Length to Width Ratio	3:1 or greater with an irregularly shaped shoreline
Side Slopes	10:1 for 10-foot bench centered on the normal water elevation and between 3:1 and 20:1 elsewhere

Table 3.3, cont. Typical Minnesota pond design standards.

Parameter	Standard Design
Side Slope Stabilization	Native seed with MnDOT 310, BWSR W2 or equivalent between NWL and HWL, provide 10' buffer where possible with MnDOT 330 (short) or MnDOT 340 (tall).
Floatable Removal	Skimming device discharging at no greater than 0.5 fps during the 1-year event or a submerged outlet with a minimum 0.5 feet from the normal water level to the crown of the outlet pipe.
Sediment Accumulation Area	Provide maintenance pads to remove sediment deltas at inlets.
Permanent Pool Volume	A 4-foot mean depth and equal to 2.5-inch rain over the watershed.

Source: Protecting Water Quality in Urban Areas (MPCA 2000)

All of the tables are organized so that the ponds and wetlands move from the top of the watershed to the bottom of the watershed as you move down the table.

3.4.1 North Purgatory Creek Area

The North Purgatory Creek area includes the basins south of County Rd 62 and north of Eden Prairie Road (Figure 3.2). The area was grouped into five areas based on drainage patterns in the subwatershed. All the basins in the area eventually drain to Purgatory Creek (05-14-A).

The group 1 chain is a series of basins that drain an area just south of Highway 62. Constructed pond 05-11-A is over sized for its watershed (Table 3.4). As-built information for stormwater basin 05-12-C indicates that the permanent pool should be twice its current size. This basin could be considered for expansion.

In the group 2 chain, stormwater wetland 05-11-C serves a relatively large watershed and then drains through a swale to Purgatory Creek. Stormwater wetland 05-11-C is currently undersized according to NURP criteria; however, the current permanent pool is half of as-built documents. It is recommended that stormwater wetland 05-11-C be excavated to the as-built permanent pool if it is determined to be a constructed pond. If it is determined to be a natural wetland, additional analysis should be conducted to determine the extent of natural soils to develop plans.

Constructed pond 04-23-A is undersized and was under-built according to as-built documents. 04-23-A should be considered for expansion to the as-built standards.

In general, the group 3 chain is a collection of shallow stormwater wetlands that provide little or no water quality treatment because they have no permanent pool storage, the bottom elevation is equal to the outlet elevation. Because these are natural stormwater wetlands, there is little opportunity to expand or excavate any of the basins.

As-built information for constructed pond 05-14-B, group 4, included a permanent pool but the field survey showed the outlet elevation equal to the bottom elevation. This basin could be considered for expansion.

The group 5 chain discharges through constructed pond 05-21-F which is over sized for its watershed (Table 3.4). No expansion is needed to meet NURP ratio in sequence in this group.

Table 3.4. Pond and wetland characteristics for the North Purgatory Creek subwatershed.

Basin ID	Surveyed Permanent Pool Volume (AF)	NURP ratio[1]	Sediment Volume (AF)	P8 Predicted TSS (mg/L)	P8 TSS removal (%)	P8 Predicted TP (µg/L)	P8 TP removal (%)	Basin Type[2]
Discharges in sequence to 05-14-A (Group 1)								
05-11-A	1.71	2.40	0.12	6	92	99	59	SW
05-11-B[3]	--	--	--	30	0	141	0	SW
05-12-C	0.66	0.22	0.38	13	77	117	36	SW
Discharges in sequence to 05-14-A (Group 2)								
05-11-C	1.02	0.50	0.38	10	88	111	53	SW
05-11-D	Swale			15	54	126	17	SW
Discharges to 05-14-A (Group 2)								
04-23-A	0.03	0.22	0.00	20	77	131	42	CP
Discharges in sequence to 05-14-A (Group 3)								
05-21-G	0.07	0.50	0.02	14	84	114	49	CP
05-21-B	0[4]	--	--	21	64	143	28	SW
05-21-D	0[4]	--	--	34	52	176	17	SW
05-12-A	0.01	0.00	0.00	25	58	155	27	SW
05-12-B	Swale			22	28	147	11	SW
Discharges in sequence to 05-12-A (Group 3a)								
05-13-B	0[4]	--	--	61	29	230	5	SW
05-13-A[3]	--	--	--	39	42	191	16	SW
Discharges in sequence to 05-12-A (Group 3b)								
05-21-A	0.12	0.41	0.16	12	86	116	51	SW
Discharges to 05-14-A (Group 4)								
04-32-C	0.08	0.52	0.00	17	80	124	46	SW
05-14-B	0[4]	--	--	58	32	222	6	CP
Discharges in sequence to 05-14-A (Group 5)								
05-21-E	0.22	0.60	0.10	16	82	125	48	CP
05-21-F	0.61	2.12	0.06	4	82	89	32	CP

[1] The NURP ratio is based on the cumulative area and dead storage to account for basins in sequence. Values over 1 meet NURP standards and values under 1 do not meet NURP standards.
[2]CP=Constructed Pond;W=Stormwater Wetland;MW=Mitigation Wetland; PW=Private Wetland; PP=Private Pond
[3] Unable to Survey
[4] Surveyed outlet elevation equal to or below surveyed bottom elevation

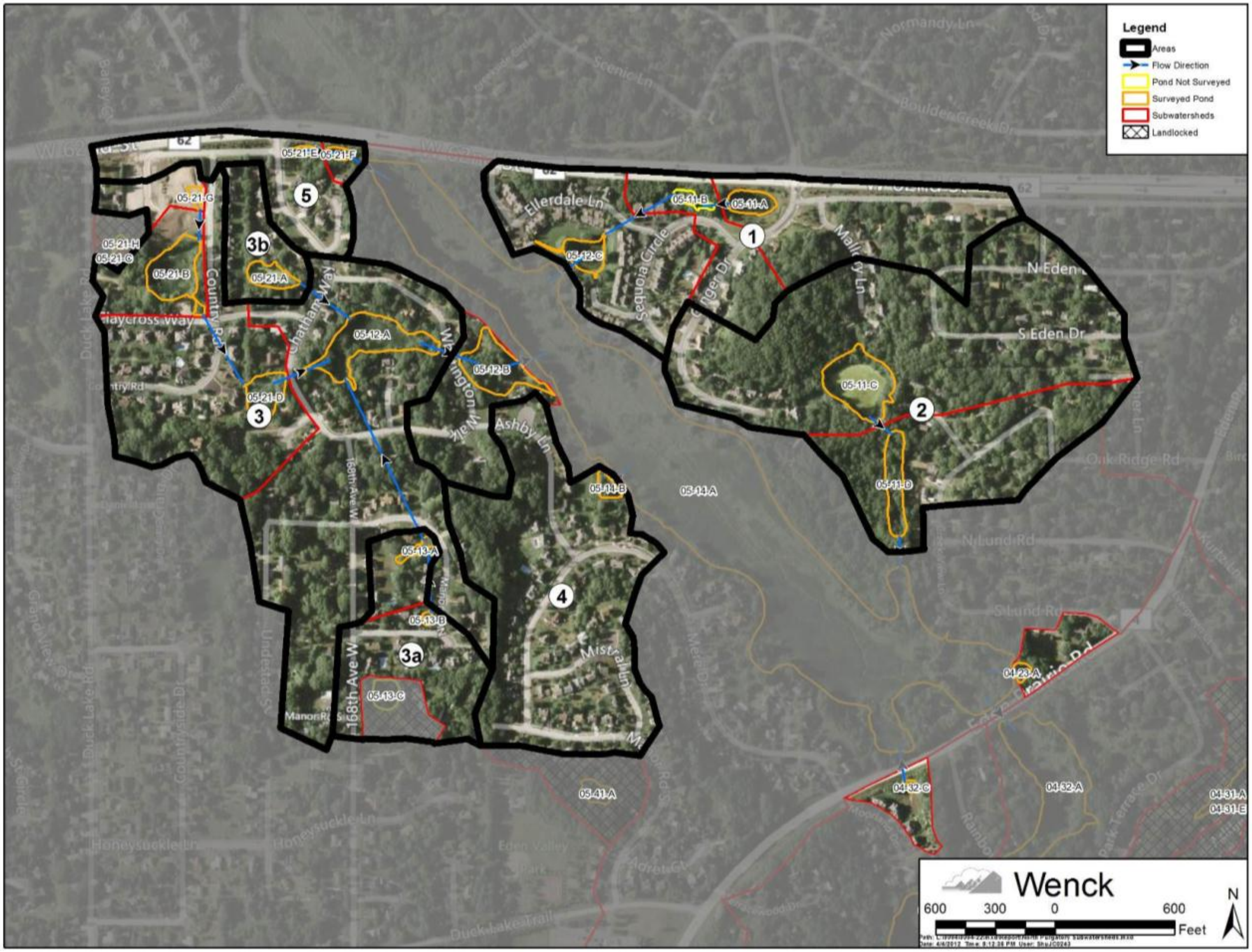

Figure 3.2. Ponds, wetlands and flow patterns in the North Purgatory Creek subwatershed.

3.4.2 Edenvale Park Area

The Edenvale Park Area includes basins south of Eden Prairie Road and north of Valley View Road (Figure 3.3). The interconnected basins were grouped into four areas based on critical basins and drainage patterns in the subwatershed. All of the basins drain to Purgatory Creek (04-33-A).

Group 1 includes two stormwater wetlands in series that exceed NURP standards by more than a 2:1 ratio (Table 3.5). These basins are in good shape even though they demonstrate some sediment accumulation.

Group 2 comprises four small watersheds that discharge directly to Purgatory Creek. 04-32-D and 04-33-C are constructed ponds which are both undersized according to NURP standards. Constructed pond 04-32-D was under built and could be expanded enough to meet NURP standards. 04-33-C does not have any as-built information and does not demonstrate any sediment accumulation. Stormwater wetland 05-44-A is appropriately sized even with a small amount of sediment accumulation.

Group 3 is a shallow wetland (04-31-D) connected to a swale (04-33-B). Because these both appear to be natural wetlands, there is little opportunity to make any improvements in these basins.

Group 4 mostly drains through a large stormwater wetland (09-12-A) that is oversized, almost 1.5 times the required permanent pool storage. All the area below this is well-forested and drains through a swale, so the area is well protected for water quality.

Table 3.5. Pond and wetland characteristics for the Edenvale Park Area subwatershed.

Basin ID	Surveyed Permanent Pool Volume (AF)	NURP ratio[1]	Sediment Volume (AF)	P8 Predicted TSS (mg/L)	P8 TSS removal (%)	P8 Predicted TP (µg/L)	P8 TP removal (%)	Basin Type[2]
Discharges in sequence to 04-33-A (Group 1)								
08-11-A	1.71	3.51	0.54	5	95	92	61	PW
08-11-B	0.76	2.11	0.51	7	86	102	43	PW
Discharges to 04-33-A (Group 2)								
04-32-D	0.20	0.48	0.01	15	83	121	48	CP
04-33-C	0.08	0.02	0.01	32	63	169	29	CP
05-44-A	1.36	1.04	0.34	5	94	93	60	SW
Discharges in sequence to 04-33-A (Group 3)								
04-31-D	0[4]	--	--	35	66	182	34	SW
04-33-B	Swale			35	57	180	24	SW
04-34-B[3]	--	--	--	91	0	248	0	CP
Discharges in sequence to 04-33-A (Group 4)								
09-12-B	0.09	1.49	0.00	8	94	77	70	CP
09-12-A	7.26	1.47	2.46	8	91	102	58	SW
09-12-C[3]	--	--	--	8	2	102	0	CP
09-21-A	Swale			15	48	122	14	SW
Discharges to 04-33-A (Group 2)								
09-31-B	Swale			33	62	176	28	SW

[1] The NURP ratio is based on the cumulative area and dead storage to account for basins in sequence. Values over 1 meet NURP standards and values under 1 do not meet NURP standards.
[2]CP=Constructed Pond;W=Stormwater Wetland;MW=Mitigation Wetland; PW=Private Wetland; PP=Private Pond
[3] Unable to Survey
[4] Surveyed outlet elevation equal to or below surveyed bottom elevation

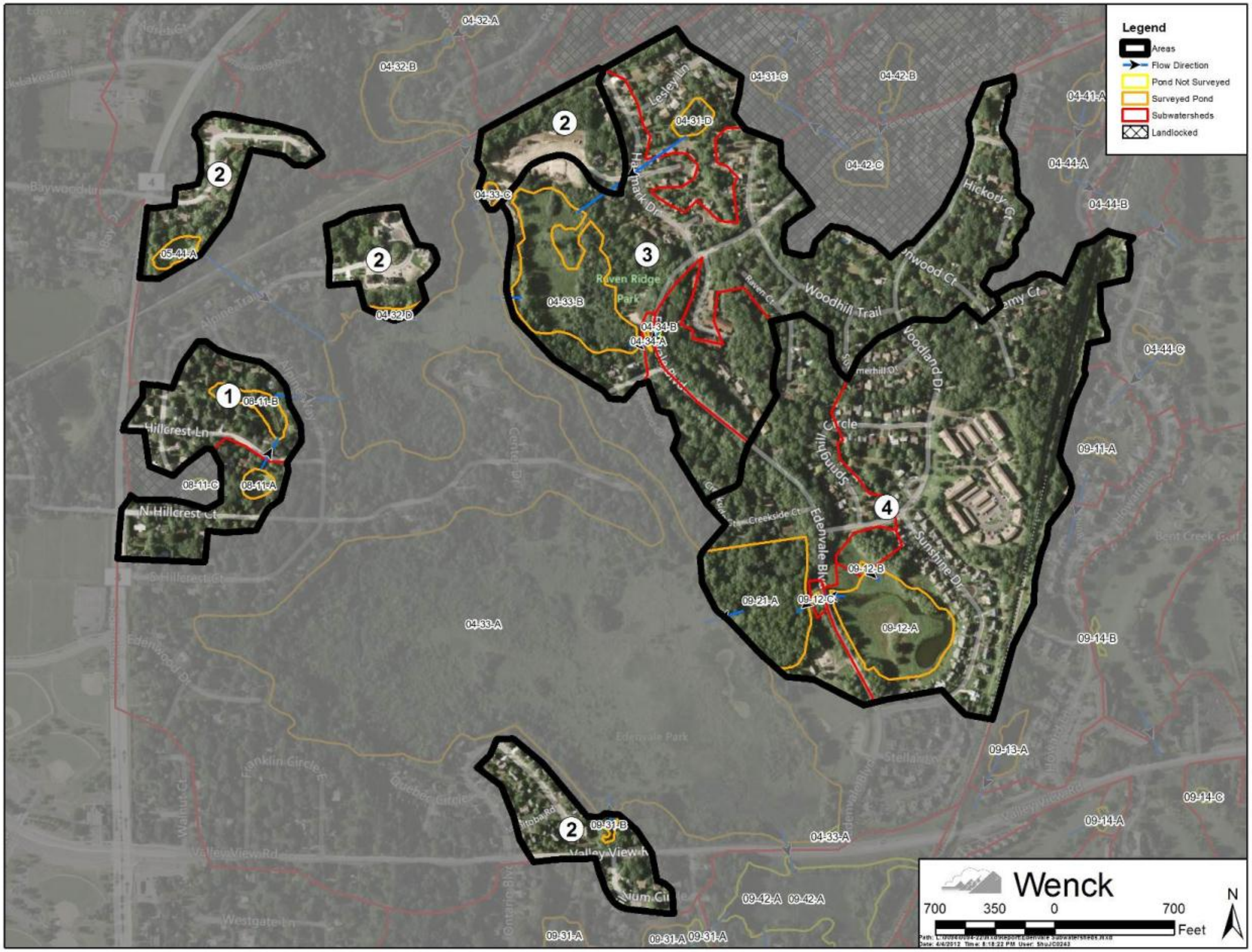

Figure 3.3. Ponds, wetlands and flow patterns in the Edenvale Park Area subwatershed.

3.4.3 South Purgatory Creek Area

The South Purgatory Creek Area includes basins south of Valley View road and north of Highway 5 (Figure 3.4). All of the basins drain to Purgatory Creek (09-42-A).

Stormwater wetland 08-44-A receives drainage from a fairly large impervious area that is serviced by a number of private ponds. Stormwater wetland 08-44-A is large enough to treat the entire drainage area with a NURP ratio of 1.6 (Table 3.6). Below 08-44-A, stormwater flows through a shallow swale and then to a large mitigation wetland (09-33-B). Because of the positive impacts of the upstream wetland, 09-33-B is large enough to treat stormwater from its direct drainage. In general, the watershed is well ponded and provides adequate water quality treatment.

Table 3.6. Pond and wetland characteristics for the South Purgatory Creek subwatershed.

Basin ID	Surveyed Permanent Pool Volume (AF)	NURP ratio[1]	Sediment Volume (AF)	P8 Predicted TSS (mg/L)	P8 TSS removal (%)	P8 Predicted TP (µg/L)	P8 TP removal (%)	Basin Type[2]
Discharge in Sequence to 09-42-A								
17-11-D	0.00	0.01	0.00	41	69	194	44	MW
17-11-A	0[3]	--	--	32	55	173	20	CP
08-44-A	5.89	1.60	1.51	13	82	119	47	SW
09-33-A	Swale			9	27	14	29	121
09-33-B	2.62	0.32	0.17	9	42	108	14	MW
09-31-A	0[3]	--	--	13	44	118	10	SW
Discharge to 09-42-A								
09-34-A	Swale			2	0	232	0	SW
Discharge to 17-11-A								
17-11-C	--	--	--	18	82	131	51	PP
17-11-B[4]	--	--	--	91	0	248	0	CP
Discharge to 08-44-A								
08-44-B[4]	--	--	--	37	60	185	27	CP
08-44-C[4]	--	--	--	93	0	251	0	CP
Discharge in Sequence to 09-33-A								
09-33-D[4]	--	--	--	2	0	246	0	CP
Discharge to 09-33-A								
09-33-C	--	--	--	91	0	242	0	PP

[1] The NURP ratio is based on the cumulative area and dead storage to account for basins in sequence. Values over 1 meet NURP standards and values under 1 do not meet NURP standards.
[2]CP=Constructed Pond;SW=Stormwater Wetland;MW=Mitigation Wetland; PW=Private Wetland; PP=Private Pond
[3] Surveyed outlet elevation equal to or below surveyed bottom elevation
[4]To be re-evaluated in Phase III

Figure 3.4. Ponds, wetlands and flow patterns in the South Purgatory Creek Area subwatershed.

3.4.4 Purgatory Creek Park Area

The Purgatory Creek Park Area includes a series of basins that drain areas on the west side of the Park area (Figure 3.2). The interconnected basins were grouped into four areas based on critical basins and drainage patterns in the subwatershed. Almost all of the basins drain through two large wetlands (15-31-A and 15-13-G) prior to discharging to the Purgatory Creek Park area.

The Purgatory Creek Park area subwatershed was broken into four groupings based on drainage patterns and potentially key basins.

Group 1 is at the headwaters of the subwatershed and is a series of four wetlands that drain in series prior to discharging to 15-31-A. The third wetland in the series (15-33-A) is a flood control basin with no permanent pool (Table 3.7). In general, this area is undertreated for water quality (Table 3.6). However, the entire drainage flows through 15-31-G which is large enough to treat the entire subwatershed. No projects are recommended at this time.

Group 2 is a series of ponds and wetlands that drain through 15-32-B before draining through two large downstream wetlands (15-31-A and 15-13-G) prior to reaching the PCCA. The key basins in this series are 15-32-A, 15-32-B and 15-31-B. Wetland 15-32-A and 15-31-demonstrated some signs of sedimentation, however they are large wetlands where accumulated sediments and peat are difficult to differentiate. Because it is at the most downstream end of the group, wetland 15-31-B should be considered for clean out.

Group 3 includes the two large wetlands at the bottom of the watershed. Wetland 15-13-G demonstrated some signs of sediment accumulation although it is a large wetland where accumulated sediments and peat are difficult to differentiate. Wetland 15-13-G should be considered for clean out.

Group 4 drains independently to the Purgatory Creek Park. All of the ponds and wetlands are oversized compared to NURP standards and demonstrate few signs of sediment accumulation. No projects are recommended for the group 4 basins.

Table 3.7. Pond and wetland characteristics for the PCCA Park subwatershed.

Basin ID	Surveyed Permanent Pool Volume (AF)	NURP ratio[1]	Sediment Volume (AF)	P8 Predicted TSS (mg/L)	P8 TSS Removal (%)	P8 Predicted TP (mg/L)	P8 TP Removal (%)	Basin Type[2]
Discharge Directly to 15-31-A (Group 1)								
15-33-C	0.90	4.69	--	33	62	173	26	PW
15-33-B	0.01	1.70	0	35	60	182	25	SW
15-33-A	0[3]	0.34	0	52	36	220	7	SW
15-34-D	Swale			38	42	192	18	192
Discharge Directly to 15-32-A (Group 2)								
15-31-D	0.03	0.21	0	22	77	146	43	SW
15-32-C	0.86	0.50	0.09	20	79	138	45	CP
Discharge in Sequence to 15-32-B (group 2)								
15-23-F	0.99	4.60	0	6	94	97	64	CP
15-23-C	1.33	2.43	--	12	87	114	53	PW
Discharge in Sequence to 15-32-B (Group 2)								
15-32-A	0.28	0.52	0.21	13	57	119	23	SW
15-32-B	0.65	0.94	0.01	16	54	126	18	CP
Discharge in Sequence to 15-31-A (Group 2)								
15-24-E	1.06	0.71	0	10	91	106	61	PP
15-31-B	1.86	0.88	0.46	14	53	121	18	SW
Drains to 15-31-A (Group 3)								
15-32-D	--	--	--	0	--	0	--	PW
Discharge in Sequence to Purgatory Creek Park Area Area (Group 3)								
15-31-A	9.61	0.75	0	5	90	95	50	SW
15-13-G	9.06	1.72	0.23	3	52	90	9	SW
Discharge in Sequence to Purgatory Creek Park Area (Group 4)								
15-13-D	0.88	2.22	0.05	11	90	112	59	CP
15-31-C	0.73	3.30	0.002	5	82	92	32	MW
15-13-F	1.13	4.39	0	3	88	88	33	MW

[1]The NURP ratio is based on the cumulative area and dead storage to account for basins in sequence. Values over 1 exceed NURP standards and values under 1 do not meet NURP standards.
[2]CP=Constructed Pond;SW=Stormwater Wetland;MW=Mitigation Wetland; PW=Private Wetland; PP=Private Pond
[3] Flood control pond so there is no permanent pool

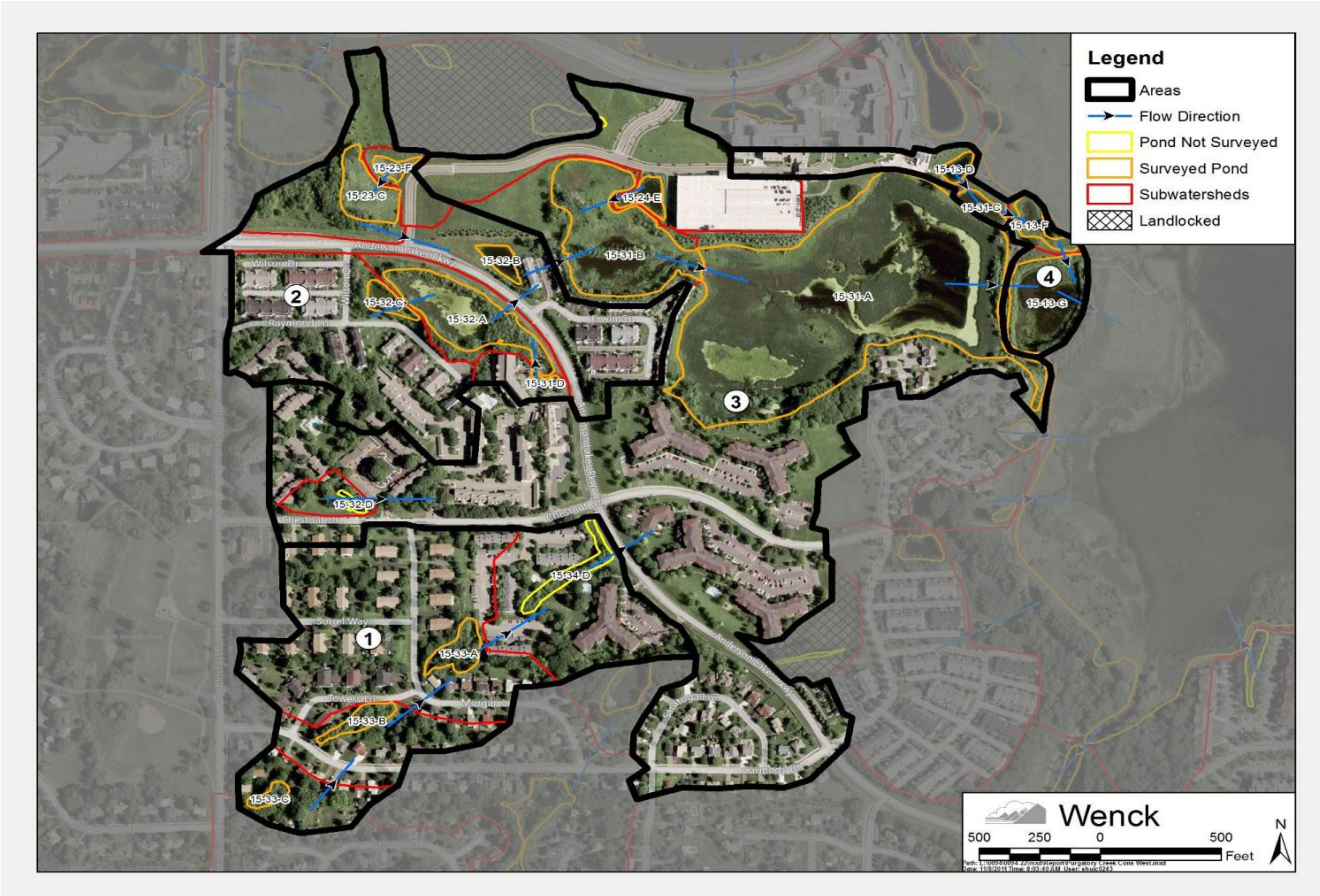

Figure 3.5. Ponds, wetlands and flow patterns in the Purgatory Creek Park Area subwatershed.

3.4.5 City Hall Drainage Area

The City Hall drainage area starts at the intersection for Mitchell Road and Anderson Lakes Parkway and drains along Anderson Lakes Parkway down to the Purgatory Creek Park Area (Figure 3.3). The area was broken into four groupings based on the drainage basins and potentially key basins.

Group 1 is well served by the basins in the watershed and none of the surveyed basins demonstrated signs of sedimentation (Table 3.8). Basin 15-23-D was a stormwater wetland that was excavated for stormwater treatment in the past and is now significantly larger than shown on the as-builts.

Group 2 includes a series of basins that serve Eden Prairie’s Water Treatment Plant and some of the surrounding impervious area. The Water Treatment Plant basins significantly over-treat the impervious area around the Water Treatment Plant when considered in series. Basin 15-23-A is under sized for its direct drainage and field surveyed conditions are significantly smaller than the as-builts. Basin 15-23-A could be considered for expansion; however, it appears that it is a natural wetland which would limit potential expansion.

Group 3 receives water from Groups 1 and 2 as well as its local drainage area before discharging to a swale which flows towards Purgatory Creek and then the Purgatory Creek Park Area. Basin 15-24-A is a natural wetland that accepts stormwater. It is quite large and is capable of treating the entire upstream drainage area alone. No signs of sedimentation were identified during the field review. Basin 15-24-A is a critical basin to monitor for sedimentation going forward.

Group 4 includes basin 15-13-B, which is a stormwater wetland that drains directly to Purgatory Creek. Although it demonstrates some signs of sedimentation, it still exceeds NURP standards for permanent pool volumes. Basin 15-13-B should be monitored for sedimentation in the future.

Table 3.8. Pond and wetland characteristics for the City Hall Drainage Area subwatershed.

Basin ID	Surveyed Permanent Pool Volume (AF)	NURP ratio[1]	Sediment Volume (AF)	P8 Predicted TSS (mg/L)	P8 TSS Removal (%)	P8 Predicted TP (mg/L)	P8 TP Removal (%)	Basin Type[2]
Discharge to 15-23-D then 15-23-A (Group 1)								
16-14-A	--	--	--	--	--	--	--	PP
16-13-B	--	0.70	--	13	86	117	54	PP
16-14-B	6.14	0.78	0	9	89	107	55	W
15-23-D	4.80	1.21	0	5	76	94	25	W
Discharge to 15-23-A then 15-24-A (Group 2)								
15-22-B	0.06	0.13	0	30	67	165	32	CP
15-22-D	3.61	26.55	0	53	40	215	11	CP
15-23-E	0.40	8.29	0	11	80	113	44	MW
15-22-C	2.18	11.37	0	3	82	88	28	CP
15-23-A	0.24	1.61	0	8	49	103	9	W
Discharge to 15-24-A then Purgatory Creek (Group 3)								
15-24-D	1.01	1.25	0.02	15	86	123	54	CP
15-24-A	48.09	4.18	0	5	89	95	45	W
15-13-A	Swale			6	16	96	2	96
Discharge Directly to Purgatory Creek (Group 4)								
15-13-B	0.38	1.06	0.07	10	88	108	55	CP

[1]The NURP ratio is based on the cumulative area and dead storage to account for basins in sequence. Values over 1 exceed NURP standards and values under 1 do not meet NURP standards.
[2]CP=Constructed Pond;W=Stormwater Wetland;MW=Mitigation Wetland; PW=Private Wetland; PP=Private Pond

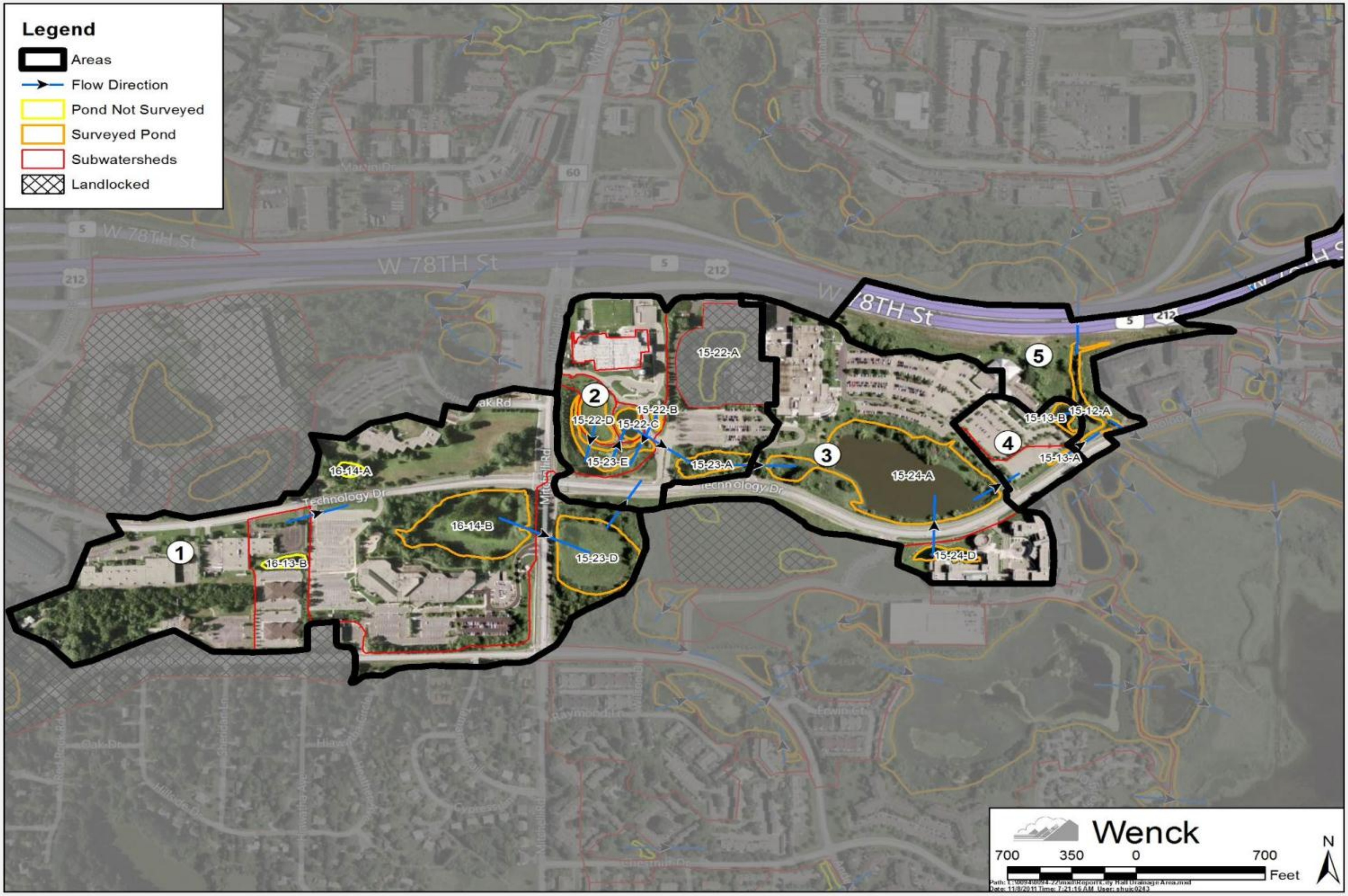

Figure 3.6. Ponds, wetlands and flow patterns in the City Hall Drainage Area subwatershed.

3.4.6 Highway 5 and Mitchell Road

The Highway 5 and Mitchell Road area contains a sequence of basins in the southwest corner of the intersection which, along with a large portion of the highway and Mitchell Road, ultimately drain to constructed pond 10-33-F (Figure 3.4). When evaluated in series, the upstream ponds and stormwater wetlands are appropriately sized for NURP except for stormwater wetland 16-11-A (Table 3.9). However, the entire chain performs quite well for water quality purposes and does not need any improvements.

Constructed pond 10-33-F demonstrates some accumulated sediment and services the entire drainage area. This constructed pond should be monitored for sediment accumulation and considered for cleaning and expansion. However, it is important to note that this pond is owned by MNDOT and they have the final say in whether the pond could be excavated or expanded.

Table 3.9. Pond and wetland characteristics for the Highway 5 and Mitchell Road subwatershed.

Basin ID	Surveyed Permanent Pool Volume (AF)	NURP ratio[1]	Sediment Volume (AF)	P8 Predicted TSS (mg/L)	P8 TSS Removal (%)	P8 Predicted TP (mg/L)	P8 TP Removal (%)	Basin Type[2]
16-11-D	--	--	--	9	90	105	57	PP
16-11-B	2.66	1.78	0	10	88	108	53	SW
16-11-A*	0.09	2.78	0	21	51	141	15	SW
10-33-F*	1.32	3.78	0.42	19	69	137	33	CP

[1]The NURP ratio is based on the cumulative area and dead storage to account for basins in sequence. Values over 1 exceed NURP standards and values under 1 do not meet NURP standards.
[2]CP=Constructed Pond;W=Stormwater Wetland;MW=Mitigation Wetland; PW=Private Wetlands; PP=Private Pond
*MNDOT Flood control ponds and wetlands

Figure 3.7. Ponds, wetlands and flow patterns in the Highway 5 and Mitchell Road subwatershed.

3.4.7 Highway 5 and Highway 212 Interchange

The Highway 5 and Highway 212 interchange area receives drainage from both highways, the Central Middle School property and some highly impervious areas north of the highways (Figure 3.5). Basin 09-43-C is a mitigation wetland that is part of 09-43-A and therefore was not considered for improvements.

The Central Middle School and the highway interchange drain through two stormwater wetlands, 09-43-A and 09-42-D, prior to discharging to Purgatory Creek. Both of these wetlands demonstrate fair amounts of sediment with basin 09-42-D having an equal amount of sediment and permanent pool storage suggesting that a large amount of the treatment capacity has been reduced (Table 3.10). Basin 09-43-A is owned by MNDOT and they have the final say in whether the pond could be excavated or expanded.

Stormwater wetlands 09-42-D and 09-43-B should be considered for cleanout (Table 3.10) because they do not currently perform to NURP standards either alone or in series. Excavation of the accumulated sediment should bring the entire basin series up to NURP standards.

Table 3.10. Pond and wetland characteristics for the Highway 5 and Highway 212 Interchange subwatershed.

Basin ID	Surveyed Permanent Pool Volume (AF)	NURP ratio[1]	Sediment Volume (AF)	P8 Predicted TSS (mg/L)	P8 TSS Removal (%)	P8 Predicted TP (mg/L)	P8 TP Removal (%)	Basin Type[2]
09-43-C*	Mitigation Wetland that is part of 09-43-A							
09-43-A*	9.62	0.79	0.23	15	84	123	50	SW
09-43-B	0.01	0.74	0.002	52	44	221	13	SW
09-42-E	0.17	0.67	0	47	57	213	25	CP
09-42-D	0.32	0.52	0.30	27	34	158	8	SW

[1]The NURP ratio is based on the cumulative area and dead storage to account for basins in sequence. Values over 1 exceed NURP standards and values under 1 do not meet NURP standards.
[2]CP=Constructed Pond;W=Stormwater Wetland;MW=Mitigation Wetland; PW=Private Wetlands; PP=Private Pond
*MNDOT Flood control ponds and wetlands

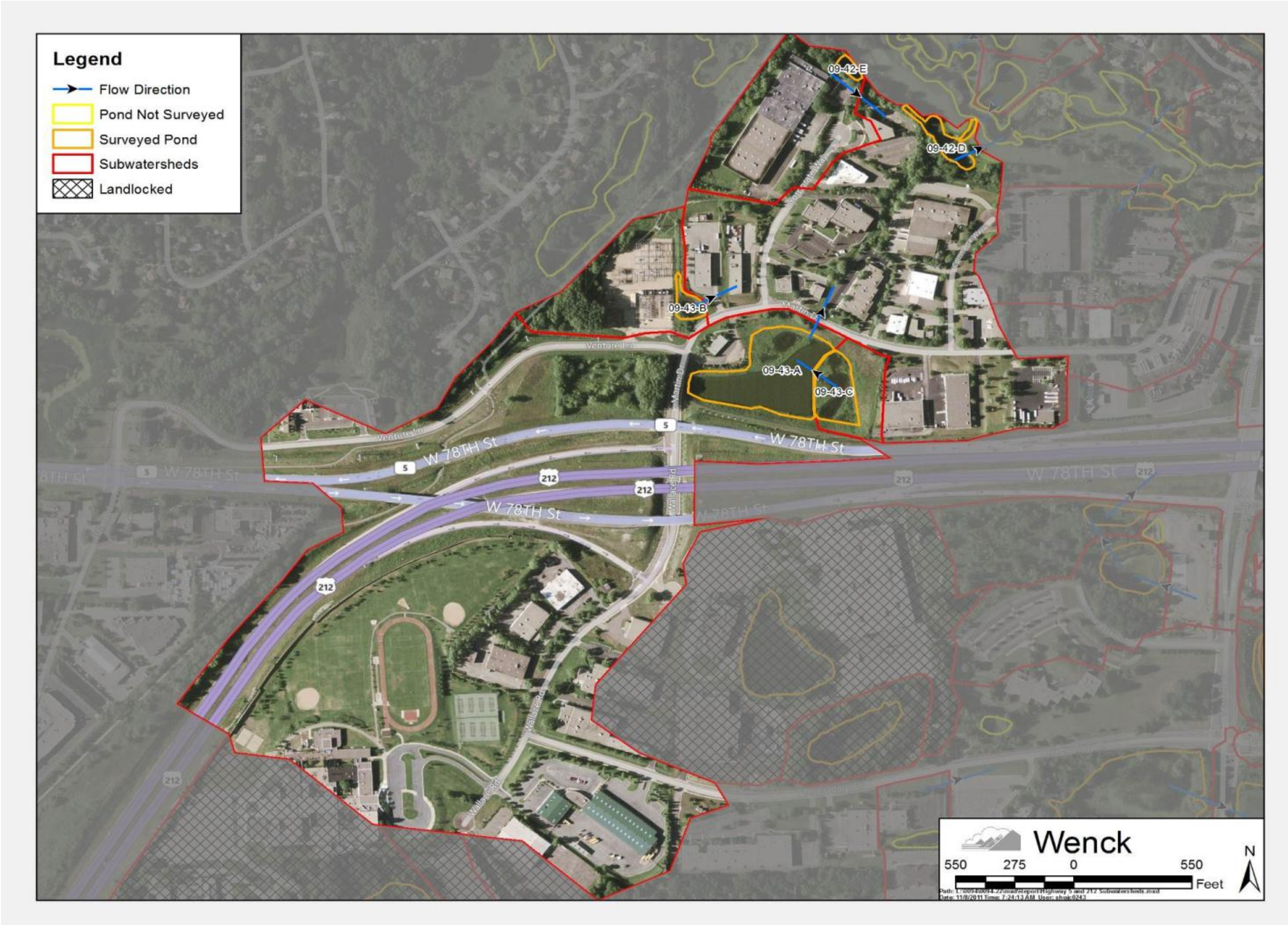

Figure 3.8. Ponds, wetlands and flow patterns in the Highway 5 and Highway 212 Interchange subwatershed.

3.4.8 Purgatory Creek from Valley View Road to Highway 5

The Purgatory Creek watershed from Valley View Road to Highway 5 includes a number of small subwatersheds draining directly or in short series to Purgatory Creek (Figure 3.9). Over half of the basins are private and were not included in this study. None of the surveyed basins meet NURP standards.

Constructed pond 10-43-C was smaller than the as-built information and could potentially be expanded (Table 3.11).

As-built information for stormwater wetland 10-33-E included a permanent pool but the field survey showed the outlet elevation equal to the bottom elevation so the basin could potentially be considered for expansion. However, this may be a natural wetland which would limit what could potentially be done within this basin.

Constructed pond 10-34-A demonstrated signs of sediment accumulation and could potentially be cleaned out to provide additional water quality treatment for this subwatershed.

Table 3.11. Pond and wetland characteristics for the Purgatory Creek from Valley View Road to Highway 5 subwatershed.

Basin ID	Surveyed Permanent Pool Volume (AF)	NURP ratio[1]	Sediment Volume (AF)	P8 Predicted TSS (mg/L)	P8 TSS Removal (%)	P8 Predicted TP (mg/L)	P8 TP Removal (%)	Basin Type[2]
Discharge Directly to Purgatory Creek								
09-14-B	--	--	--	--	--	--	--	PW
09-41-C	--	--	--	--	--	--	--	PW
09-41-D	0.0019	0.01	0	45	53	209	20	SW
09-44-A	0.0018	0	0	54	50	229	18	SW
10-33-D	--	--	--	8	91	103	59	PP
10-33-E	0[3]	0	0	65	31	240	5	SW
10-34-A	1.28	0.44	0.17	28	71	158	39	CP
10-43-C	0.56	0.56	0	27	73	157	41	CP
Discharge in Sequence to Purgatory Creek								
10-32-E	0.0011	0	0	46	54	214	20	CP
10-32-F	0	0	0	44	17	210	5	SW
Discharge in Sequence to Purgatory Creek								
09-41-A	--	--	--	--	--	--	--	PW
09-41-B	--	--	--	--	--	--	--	PW
Discharge in Sequence to Purgatory Creek								
09-14-A	--	--	--	--	--	--	--	PW
09-42-C	--	--	--	--	--	--	--	PW
Discharge in Sequence to Purgatory Creek								
10-33-B	--	--	--	--	--	--	--	CP
10-33-C	--	--	--	--	--	--	--	CP

[1]The NURP ratio is based on the cumulative area and dead storage to account for basins in sequence. Values over 1 exceed NURP standards and values under 1 do not meet NURP standards.
[2]CP=Constructed Pond;SW=Stormwater Wetland;MW=Mitigation Wetland; PW=Private Wetland; PP=Private Pond
[3]Although the as-built showed a permanent pool volume, the surveyed outlet elevation was the same as the inlet elevation

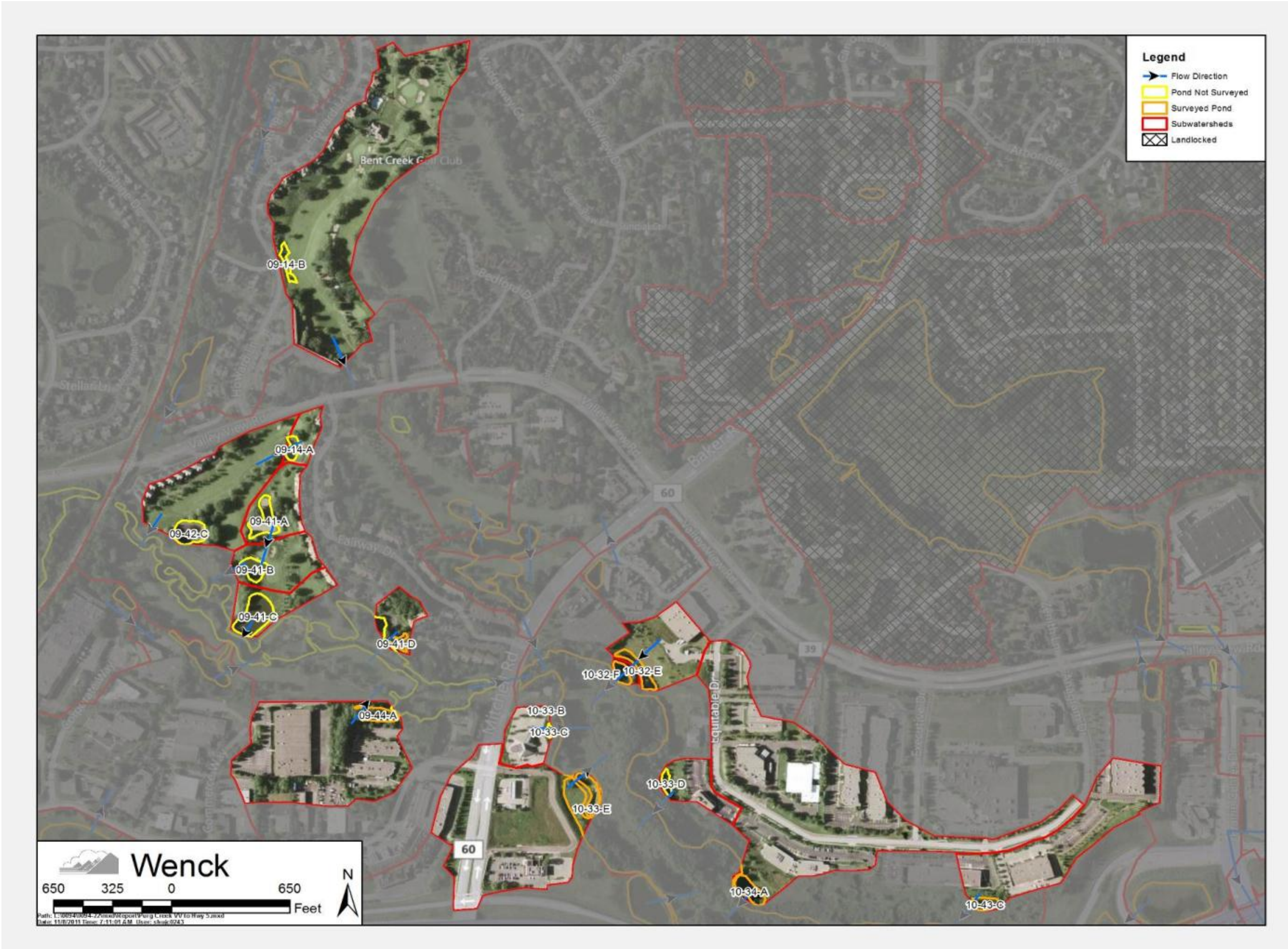

Figure 3.9. Ponds, wetlands and flow patterns in the Purgatory Creek from Valley View Road to Highway 5 subwatershed.

3.4.9 Regional Trail Area

The Regional Trail Area basins drain in sequence along the Southwest Regional Trail (Figure 3.10). All of the basins drain through stormwater wetland 09-13-A prior to discharging to Purgatory Creek. Consequently, 09-13-A is a critical basin in the sequence.

Basin 09-13-A has a large enough permanent pool to treat the entire watershed to NURP standards (Table 3.12). Basin 09-13-A demonstrated some signs of sedimentation, however the sediment volume was only 4% of the permanent pool volume. Future sedimentation surveys should focus on basin 09-13-A since it services the entire subwatershed. However, as this is a natural wetland, future maintenance would be limited due to Wetland Conservation Act requirements.

The surveyed permanent pool (0.12 acre-feet) for stormwater wetland 04-44-A was significantly smaller than as-built document (0.36 acre-feet) which suggests that the wetland could be expanded to meet the as-built conditions. However, because there is adequate ponding downstream and the basin exceeds NURP standards, it is not recommended that the City pursue any action pertaining to this wetland at this time.

Table 3.12. Pond and wetland characteristics for the Regional Trail Area subwatershed.

Basin ID	Surveyed Permanent Pool Volume (AF)	NURP ratio[1]	Sediment Volume (AF)	P8 Predicted TSS (mg/L)	P8 TSS Removal (%)	P8 Predicted TP (mg/L)	P8 TP Removal (%)	Basin Type[2]
04-41-F	--	0	0	46	48	208	14	CP
04-41-A	11.02	12.64	0	2	97	84	61	SW
04-44-A	0.12	7.37	0	12	66	116	22	SW
04-44-B	0.92	6.02	0	10	70	109	27	CP
04-44-C	--	3.70	--	20	48	138	13	SW
09-11-A	0.42	3.38	0.23	13	52	121	20	SW
09-13-A	6.12	3.34	0.15	7	83	101	39	SW

[1]The NURP ratio is based on the cumulative area and dead storage to account for basins in sequence. Values over 1 exceed NURP standards and values under 1 do not meet NURP standards.
[2]CP=Constructed Pond;SW=Stormwater Wetland;MW=Mitigation Wetland; PW=Private Wetland; PP=Private Pond

Figure 3.10. Ponds, wetlands and flow patterns in the Regional Trail Area subwatershed.

3.4.10 Bent Creek

Bent Creek is a private golf course within the drainage area for Purgatory Creek. In the Bent Creek area, the upstream basins drain to stormwater wetland 10-32-B and then through stormwater wetland 10-32-A prior to discharging to Purgatory Creek (Figure 3.11).

The upstream basins are appropriately sized; however, both of the downstream stormwater wetlands are significantly undersized. In addition, stormwater wetland 10-32-B is demonstrating some signs of sedimentation (Table 3.13).

In general, the watershed as a whole only has 30% of the NURP-required dead storage.

The infrastructure linking stormwater wetlands 10-32-A and 10-32-B was repaired in 2010. However, wetland 10-32-B should be evaluated to determine if the wetland can be cleaned out of accumulated sediment in the future.

Table 3.13. Pond and wetland characteristics for the Bent Creek subwatershed.

Basin ID	Surveyed Permanent Pool Volume (AF)	NURP ratio[1]	Sediment Volume (AF)	P8 Predicted TSS (mg/L)	P8 TSS Removal (%)	P8 Predicted TP (mg/L)	P8 TP Removal (%)	Basin Type[2]
09-14-C	--	--	--	--	--	--	--	PW
10-32-C	0.73	1.34	0	--	--	--	--	PW
10-32-D	0.76	1.13	0.07	15	84	123	52	CP
10-32-B	0.49	0.15	0.19	39	54	188	21	SW
10-32-A	0.56	0.19	0	30	26	169	11	SW

[1]The NURP ratio is based on the cumulative area and dead storage to account for basins in sequence. Values over 1 exceed NURP standards and values under 1 do not meet NURP standards.
[2]CP=Constructed Pond;SW=Stormwater Wetland;MW=Mitigation Wetland; PW=Private Wetlands; PP=Private Pond

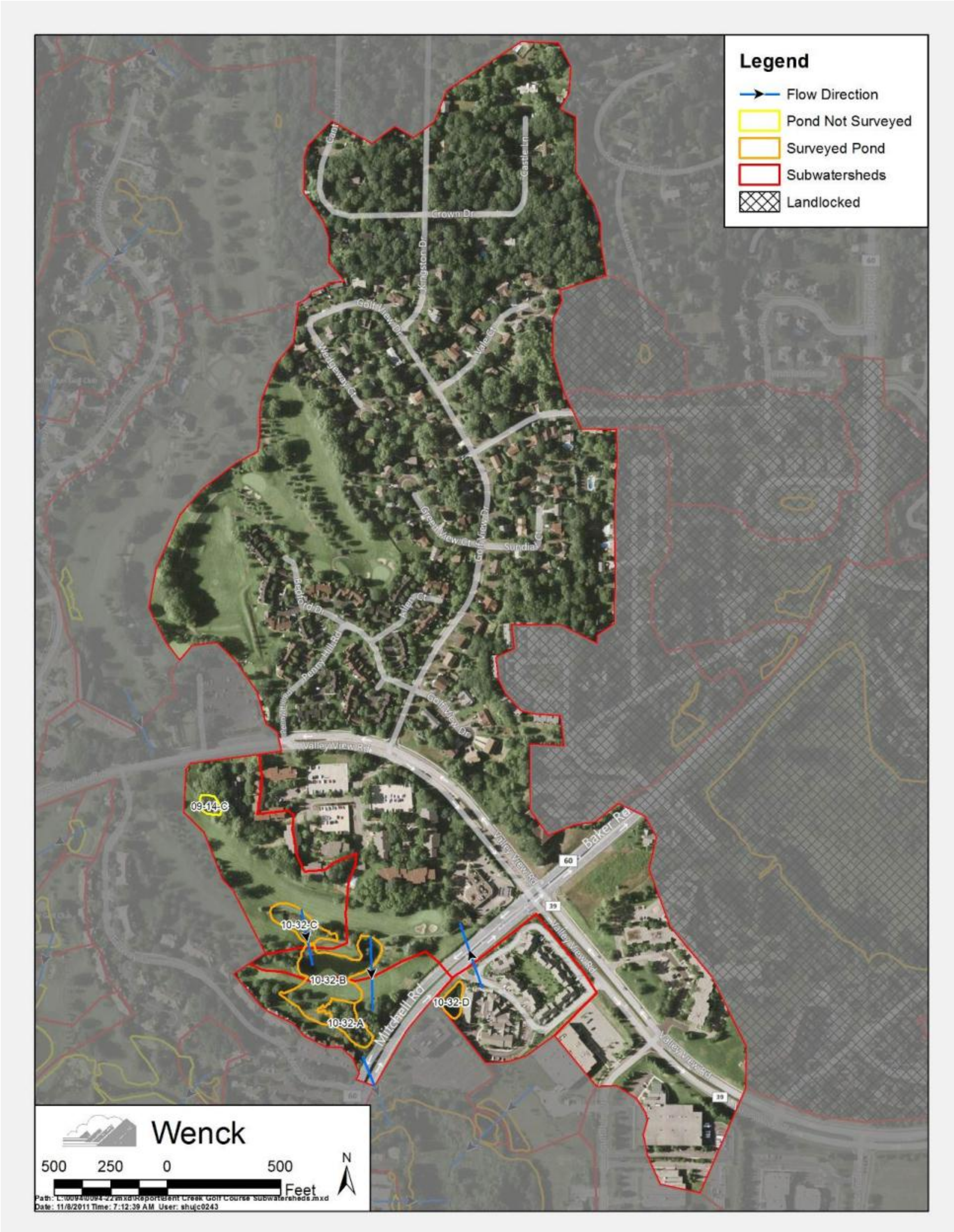

Figure 3.11. Ponds, wetlands, and flow patterns in the Bent Creek subwatershed.

3.4.11 Valley View Road and Highway 494 Interchange

The Valley View Road and Highway 494 Interchange area is a complex drainage network of basins that receive drainage from the Eden Prairie Mall area and the Highway 494 and Highway 5 interchange (Figure 3.12). The area also includes Lake Idlewild.

This drainage area ultimately drains into stormwater wetland 15-14-B that was excavated as a RPBCWD project in 2007. From there, the water discharges to Purgatory Creek Park Area prior to discharging to Staring Lake. A number of the basins in this drainage area belong to MnDOT. However, they were included in the study since they receive City drainage.

This drainage area was broken up into 6 groups based on key collection points and drainage areas.

Group 1 includes Lake Idlewild (14-21-A), which collects drainage from a large area prior to discharging to a small constructed pond that is within a conservation easement and then into MnDOT-owned basin 14-21-C (Table 3.14). Constructed ponds 14-21-C and 11-34-C are smaller than indicated in the as-built information. Some sediment accumulation was noted. However, because constructed pond 11-34-C receives drainage from Lake Idlewild which provides adequate treatment for this group, it is not recommended that this pond be considered for expansion.

Constructed pond 14-21-C should be considered for expansion. However, the pond is on private property and lies along the shoreline of Lake Idlewild which would likely limit expansion possibilities.

Group 2 collects drainage from the Highway 494 and Highway 5 interchange and all the basins are owned by MnDOT or are on private property and do not receive public runoff.

Group 3 includes a number of basins that drain to stormwater wetland 10-44-A prior to draining to stormwater wetland 10-44-D in Group 6. Constructed pond 10-42-A is smaller than the as-builts, however since it drains to a much larger basin (10-43-D), there is no need to expand the pond (Table 3.14).

Stormwater wetland 10-43-D does demonstrate some sediment accumulation. However, the permanent pool is still larger than the required NURP volume to treat the entire upstream watershed. It is recommended that future sediment accumulation be monitored.

Groups 4 and 5 collect all of the water from the previously described groups and discharges through basins 15-11-B and 15-11-C, both MnDOT ponds, prior to discharging to stormwater wetland 10-44-A in Purgatory Creek Park. Wetland 10-44-A is a key collection point but does not provide any permanent pool storage.

This part of the watershed appears to be relatively undertreated according to NURP standards. However, most of the basins are privately owned (Table 3.14).

Although 11-33-C is a MnDOT pond, it does receive City drainage and does demonstrate some signs of sediment accumulation. The basin should be considered for cleanout, but the City will need to consult with MnDOT before proceeding with any work.

Group 6 is the final set of basins prior to discharge to Purgatory Creek Park. Constructed pond 15-12-D receives stormwater from a large area and is undersized for the drainage area. However, there is not sufficient room to consider expansion.

All of Group 6 drains into stormwater wetland 15-14-B which is large enough to service the entire watershed to NURP standards (Table 3.14). Although it shows some signs of sediment accumulation, the permanent pool volume is still almost three times the required NURP volume so no cleanout is necessary.

Table 3.14. Pond and wetland characteristics for the Valley View Road and Highway 494 Interchange subwatershed.

Basin ID	Surveyed Permanent Pool Volume (AF)	NURP ratio[1]	Sediment Volume (AF)	P8 Predicted TSS (mg/L)	P8 TSS Removal (%)	P8 Predicted TP (mg/L)	P8 TP Removal (%)	Basin Type[2]
Group 1 - Discharge in Sequence to 11-33-C (Area 1)								
14-21-C	0.03	0.09	0	33	64	180	30	CP
14-12-B	--	--	0.02	8	91	101	59	PP
14-21-D	--	--	--	--	--	--	--	PP
14-21-A	63.15	6.77	7.96	3	97	88	66	SW
11-34-C	0.28	0.55	0.01	26	75	157	42	CP
11-33-B*	--	--	--	--	--	--	--	SW
Group 2 - Discharge in Sequence to 11-33-C (Area 2)								
11-34-D	--	--	--	--	--	--	--	PP
11-31-A	--	--	--	19	80	133	47	PP
11-34-A*	--	--	--	--	--	--	--	SW
11-33-A*	--	--	--	27	62	159	28	SW
Group 3a - Discharge in Sequence to 10-44-A (Area 3)								
10-42-A	0.22	0.45	0	18	81	133	48	CP
10-43-D	7.50	1.28	0.96	12	86	114	53	CP
Group 3b - Discharge Independently to 10-44-A (Area 3)								
10-41-A	0.42	1.62	0.01	9	91	108	59	PP
10-41-B	1.25	0.75	0.06	16	82	128	49	PP
10-41-C	--	--	--	23	75	142	43	PP
10-41-D	--	--	--	13	86	116	54	PW
10-41-E	--	--	--	1	98	141	62	PP
10-41-F	--	--	--	3	97	115	61	PP
10-44-C	--	--	--	17	82	127	49	PP

Table 3.14, cont. Pond and wetland characteristics for the Valley View Road and Highway 94 Interchange subwatershed.

Basin ID	Surveyed Permanent Pool Volume (AF)	NURP ratio[1]	Sediment Volume (AF)	P8 Predicted TSS (mg/L)	P8 TSS Removal (%)	P8 Predicted TP (mg/L)	P8 TP Removal (%)	Basin Type[2]
10-44-E*	--	--	--	16	83	129	50	SW
10-44-D*	0[3]	0.01	0	42	55	198	20	CP
Group 4 - Discharge Independently to 15-11-B (Area 4)								
10-44-A	0[3]	0.48	0	31	39	166	8	SW
11-33-C*	2.12	0.09	0.46	25	41	152	13	SW
15-11-B*	0[3]	1.09	0	19	27	137	11	SW
Group 5a - Discharge in Sequence to 15-11-C (Area 5)								
10-43-A	1.60	1.11	0.10	7	92	103	60	CP
10-43-B	0.73	0.85	0.04	11	78	111	35	CP
Group 5b - Discharge Independently to 15-11-C (Area 5)								
15-11-A	0[3]	0.00	0	59	37	230	9	CP
15-11-C	0.02	0.16	0.02	18	4	135	1	CP
Group 6a - Discharge Independently to 15-12-D (Area 6)								
15-12-B	0.02	0.11	0	21	78	143	44	PP
15-12-E	--	--	--	8	92	109	60	PP
15-12-D	3.14	0.26	0.04	16	13	130	5	CP
Group 6b - Discharge Independently to 15-14-B (Area 6)								
15-11-D	1.65	1.25	0.15	11	88	113	56	CP
15-12-C	--	--	--	27	72	157	39	PP
15-14-B	87.20	NA[4]	1.75	10	66	109	28	SW

[1]The NURP ratio is based on the cumulative area and dead storage to account for basins in sequence. Values over 1 exceed NURP standards and values under 1 do not meet NURP standards.
[2]CP=Constructed Pond;SW=Stormwater Wetland;MW=Mitigation Wetland; PW=Private Wetlands; PP=Private Pond
[3] Flood control pond so there is no permanent pool
[4]Could not be calculated because Purgatory Creek runs through the pond
*MNDOT controlled ponds and wetlands

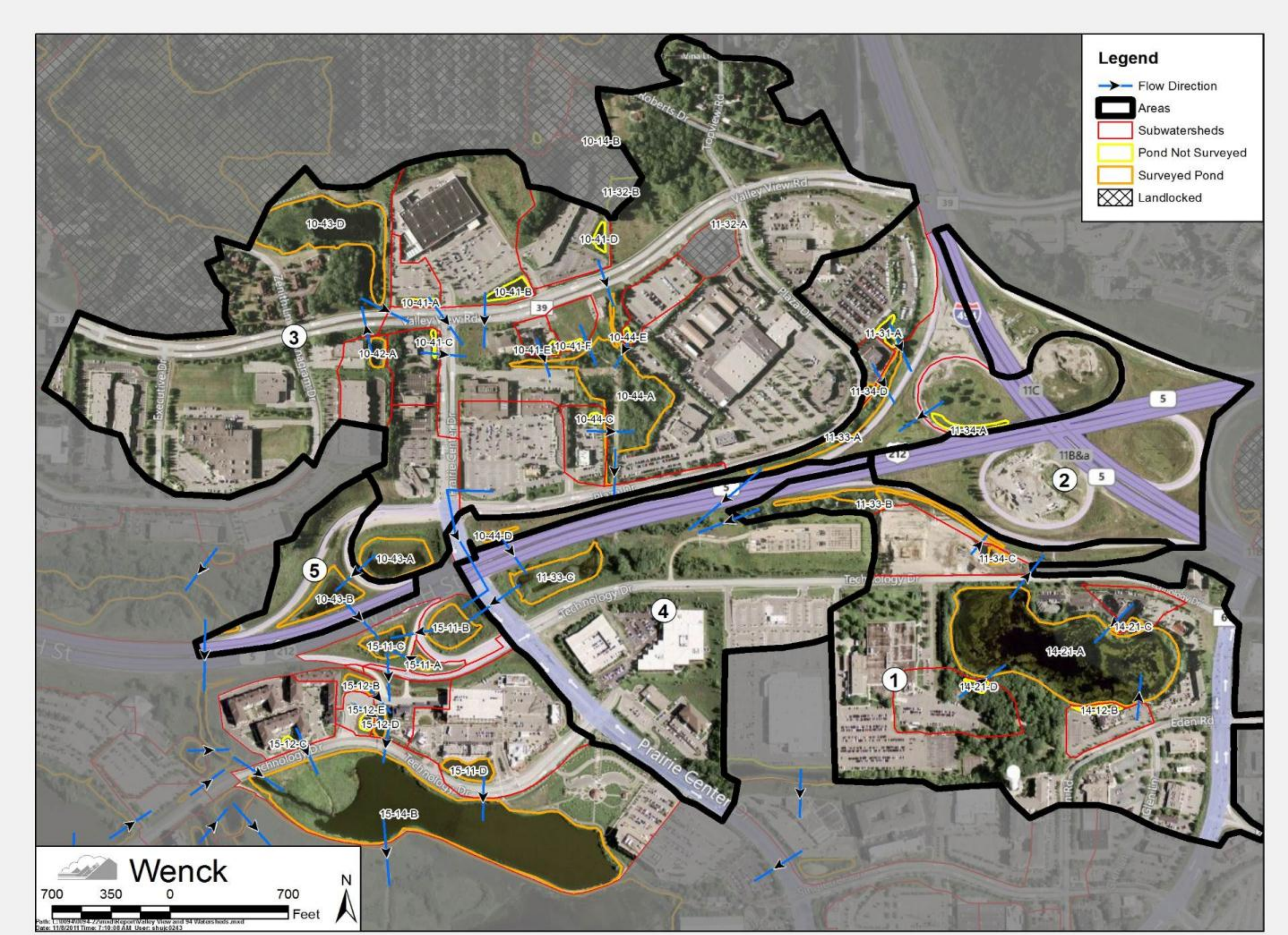

Figure 3.12. Ponds, wetlands and flow patterns in the Valley View Road and 494 Interchange subwatershed.

3.4.12 Purgatory Creek Park Direct

A number of basins discharge directly or in short sequences to Purgatory Creek Park (Figure 3.13). Most of the basins are undersized according to NURP standards though only a few demonstrate signs of sedimentation (Table 3.15).

Constructed pond 15-42-A and stormwater wetlands 14-32-A, 15-13-E, and 14-23-A had surveyed permanent pool volumes less than as-built documents and should be considered for expansion. Wetland 14-23-A also showed some signs of sedimentation though expansion or clean out would be limited to the Wetland Conservation Act requirements.

A number of the private ponds had as-builts but were not surveyed as a part of this study. These ponds were included in the P8 analysis using the as-built information.

Table 3.15. Ponds and wetland characteristics for the Purgatory Creek Park Direct subwatershed.

Basin ID	Surveyed Permanent Pool Volume (AF)	NURP ratio[1]	Sediment Volume (AF)	P8 Predicted TSS (mg/L)	P8 TSS Removal (%)	P8 Predicted TP (mg/L)	P8 TP Removal (%)	Basin Type[2]
Discharge Directly to Purgatory Creek Park Area								
14-23-B	0.69	0.43	0.06	23	75	146	42	PW
15-42-A	0.48	0.43	0.14	20	78	138	45	CP
15-42-B	0.00	0	0	53	42	218	11	CP
15-43-A	0.12	0.06	0	35	63	183	28	CP
15-44-A	--	--	--	6	94	99	62	PP
15-44-B	--	--	--	11	88	114	55	PP
15-44-C	--	--	--	21	78	138	45	PW
Discharge in Sequence to Purgatory Creek Park Area								
22-11-A	--	--	--	24	74	148	40	PP
14-33-B	2.08	0.64	0.01	18	79	131	46	CP
Discharge in Sequence to Purgatory Creek Park Area								
14-23-C	--	--	--	4	96	89	63	PP
14-23-A	0.77	0.20	0.12	23	66	147	29	CP
Discharge in Sequence to Purgatory Creek Park Area								
14-32-B	0.21	0.32	0	50	45	218	13	SW
14-32-A	0.62	0.57	0.06	18	75	133	43	SW
Discharge in Sequence to Purgatory Creek Park Area								
15-13-C	5.62	9.20	0.03	3	97	91	67	CP
15-13-E	0.66	8.00	0	3	87	86	28	MW

[1]The NURP ratio is based on the cumulative area and dead storage to account for basins in sequence. Values over 1 exceed NURP standards and values under 1 do not meet NURP standards.
[2]CP=Constructed Pond;SW=Stormwater Wetland;MW=Mitigation Wetland; PW=Private Wetland; PP=Private Pond

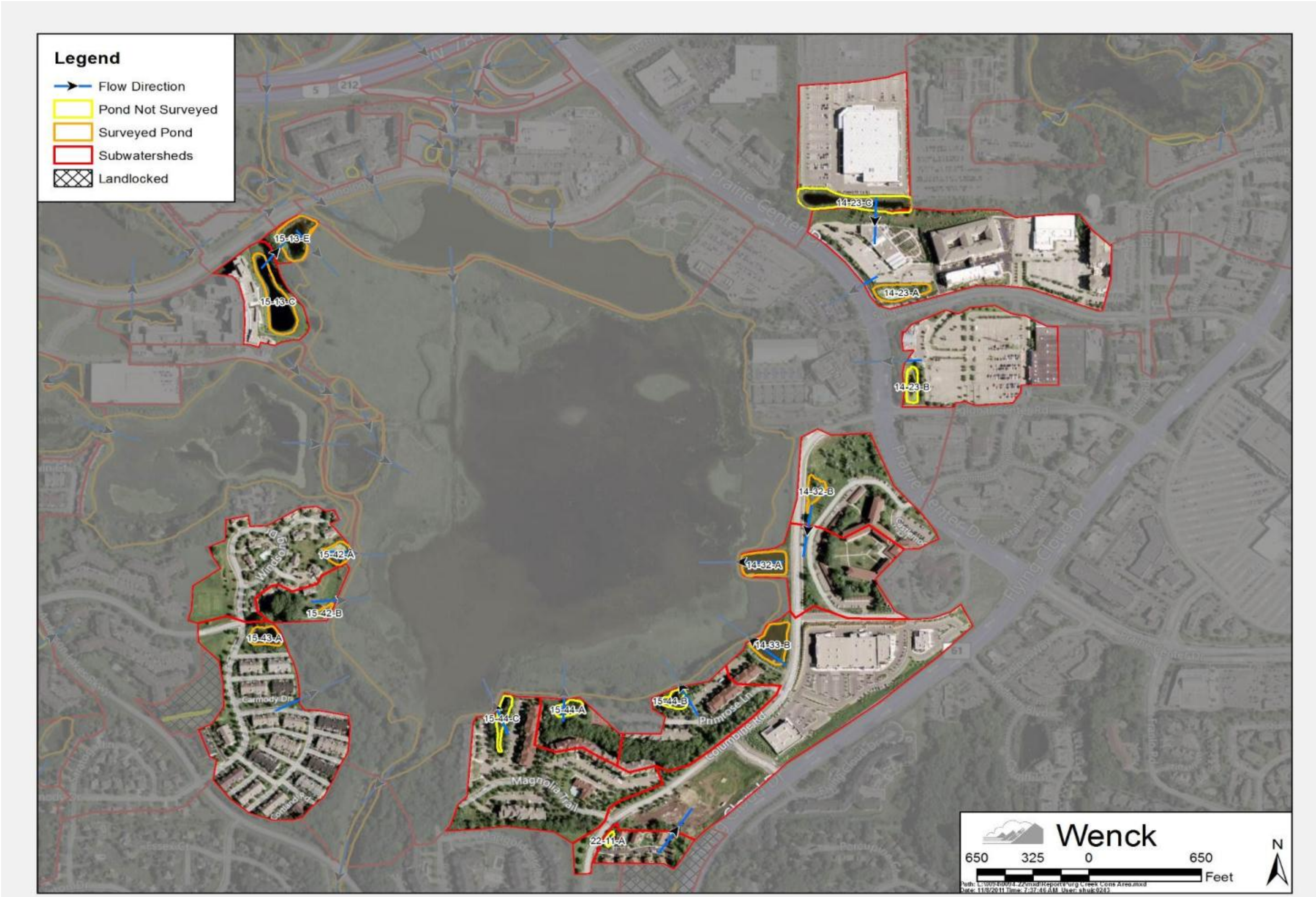

Figure 3.13. Ponds, wetlands and flow patterns in the Purgatory Creek Park Direct subwatershed.

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3.4.13 McCoy Lake Area

The McCoy Lake Area includes a number of basins that all drain to McCoy Lake prior to discharging into Staring Lake (Figure 3.14). Round Lake, Mitchell Lake and Red Rock Lake drain in series to 21-11-A and then McCoy Lake though they are not included on the map.

McCoy Lake is a non-public accessible, 10 acre, shallow (<2 feet deep) open water wetland with a fair amount of sediment. However, it is classified as a DNR protected wetland and it would be difficult to determine which sediments may be natural versus accumulated sediments.

A large portion of the subwatershed drains from the south to stormwater wetland 21-11-A prior to discharging into McCoy Lake (Areas 1 through 3). The entire drainage area is somewhat undertreated, even with the large wetland at the bottom of the drainage area (Table 3.16). It is important to note that this area eventually drains to McCoy Lake prior to discharging to Staring Lake and is therefore treated by McCoy Lake prior to discharge.

Wetland 21-11-A was noted as having accumulated sediment and could potentially benefit from a clean out. However, this is a large natural wetland that is a DNR protected basin and potential options for cleaning the wetland would have to be evaluated.

Additional ponding in the area may be obtained through expanding constructed pond 21-31-B, which was built much smaller than design plans and does not meet NURP standards. Another option to evaluate would be to clean out stormwater wetland 21-13-E which shows signs of sedimentation.

Groups 4 and 5 contain areas to the north of McCoy Lake. Constructed pond 21-11-D was built smaller than shown on the as-builts and could possibly be expanded. However, it is within a small outlot that is privately owned and has limited expansion potential.

Stormwater wetland 22-22-A demonstrated some signs of sediment accumulation and clean out may be beneficial.

Table 3.16. Pond and wetland characteristics for the McCoy Lake Area subwatershed.

Basin ID	Surveyed Permanent Pool Volume (AF)	NURP ratio[1]	Sediment Volume (AF)	P8 Predicted TSS (mg/L)	P8 TSS Removal (%)	P8 Predicted TP (mg/L)	P8 TP Removal (%)	Basin Type[2]
Group 1 - Discharge in Sequence to 21-11-A (Area 1)								
21-31-B	0.13	0.03	0	39	55	192	20	SW
21-13-A	0.00	0.00	0	30	50	171	21	SW
21-13-B	1.14	0.18	0.08	18	45	136	22	SW
21-13-E	0.73	0.27	0.12	9	90	108	57	CP
Group 2 - Discharge in Sequence to 21-11-A (Area 2)								
21-13-C	0.46	0.59	0.09	18	81	130	47	CP
21-13-D	0.18	0.51	0.03	40	55	175	27	CP
Group 3 - Discharge to 21-11-A then to McCoy Lake (Area 3)								
21-14-A	0.48	0.50	0.13	19	80	134	46	SW
21-11-A	4.76	0.81	1.58	24	74	148	40	SW
Group 4 - Discharge in Sequence to McCoy Lake (Area 4)								
15-34-B	1.42	8.31	0.04	1	98	76	65	SW
22-22-A	1.81	3.27	0.19	5	94	95	58	SW
Group 5 - Discharge Directly to McCoy Lake (Area 5)								
21-11-B	0.04	0.44	0	20	78	138	45	CP
22-22-B	0.01	0.06	0	31	66	173	31	SW
21-11-D	0.00	0	0	52	43	215	11	CP
22-23-A	Swale							SW
21-14-B	14.18	2.24	13.93	11	58	107	29	SW

[1]The NURP ratio is based on the cumulative area and dead storage to account for basins in sequence. Values over 1 exceed NURP standards and values under 1 do not meet NURP standards.
[2]CP=Constructed Pond;SW=Stormwater Wetland;MW=Mitigation Wetland; PW=Private Wetland; PP=Private Pond

Figure 3.14. Ponds, wetlands, and flow patterns in the McCoy Lake Area subwatershed.

3.4.14 Staring Lake Direct Drainage

The Staring Lake Direct Drainage area consists of four basins that drain directly into Staring Lake (Figure 3.15). It is important to note that this drainage area includes a large land area that drains to Staring Lake without pre-treatment.

Constructed pond 21-14-C drains directly to Staring Lake and is undersized when compared to the as-built and currently offers little water quality control. The basin should be considered for expansion.

Basin 21-44-B is a dry flood control wetland (Table 3.17) that is acting as an infiltration basin and therefore was not considered for improvements.

Basin 22-11-C was determined to be a shallow infiltration area and not an open-water basin so it was not surveyed.

Constructed pond 22-13-B services a large amount of impervious area. Some sediment accumulation was noted; however, the sediment volume is less than 10% of the overall permanent pool volume. The basin is slightly undersized and the surveyed basin area is less than the as-built suggesting it could potentially be expanded.

Table 3.17. Pond and wetland characteristics for the Staring Lake Direct subwatershed.

Basin ID	Surveyed Permanent Pool Volume (AF)	NURP ratio[1]	Sediment Volume (AF)	P8 Predicted TSS (mg/L)	P8 TSS Removal (%)	P8 Predicted TP (mg/L)	P8 TP Removal (%)	Basin Type[2]
21-14-C	0.001	0	0	65	31	239	6	CP
21-44-B	0.00	0	0	58	37	230	7	SW
22-11-C	Not a Basin							N/A
22-13-B	5.36	0.81	0.54	16	82	128	49	CP
22-41-B	--	--	--	66	30	241	5	PW

[1]The NURP ratio is based on the cumulative area and dead storage to account for basins in sequence. Values over 1 exceed NURP standards and values under 1 do not meet NURP standards.
[2]CP= Constructed Pond; MW=Mitigation Wetland; PW=Private Wetlands; PP=Private Pond

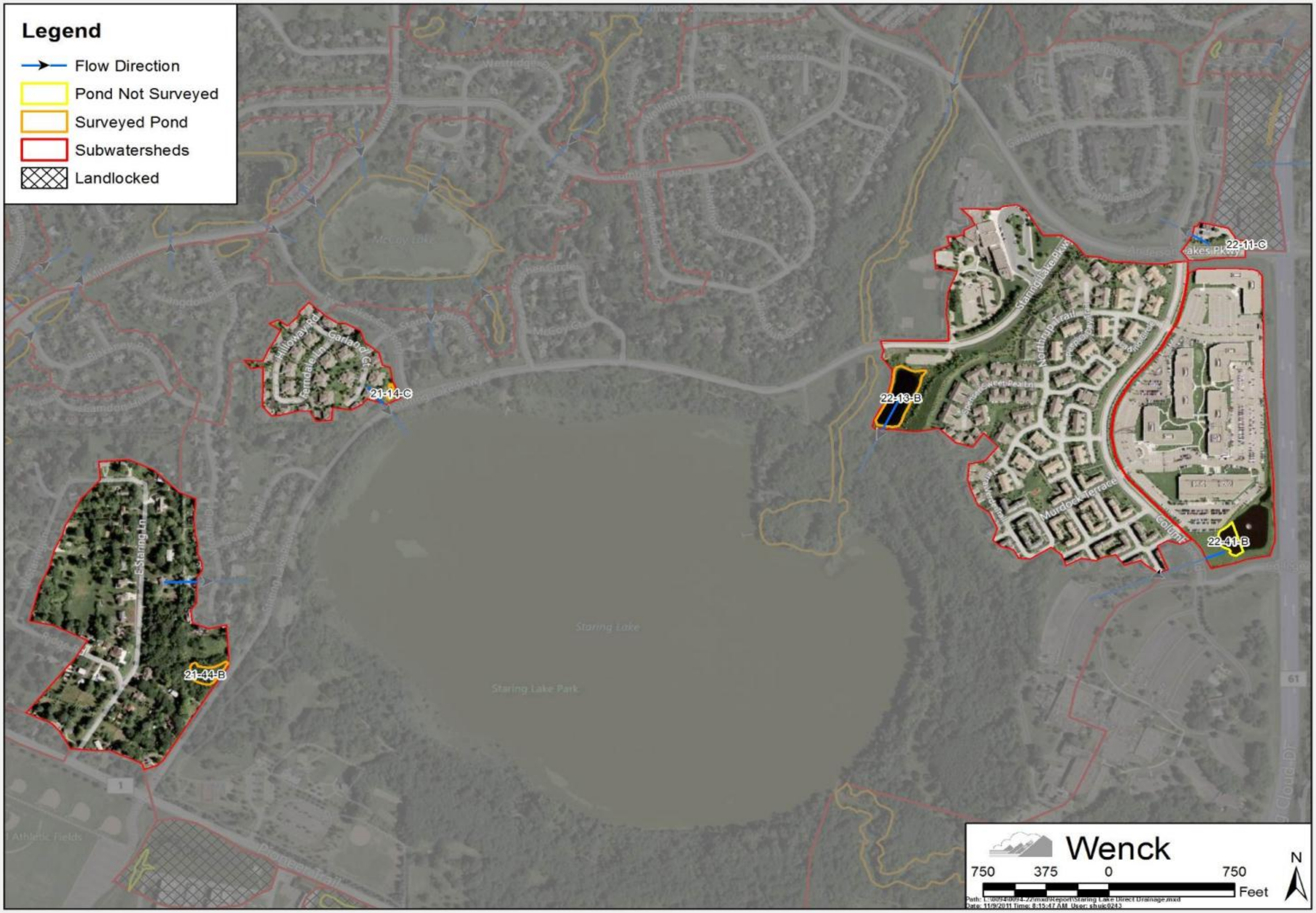

Figure 3.15. Ponds, wetlands and flow patterns in the Staring Lake Direct subwatershed.

4.0 Staring Lake Nutrient Budget

4.1 INTRODUCTION

A nutrient budget is critical in understanding the potential impacts of stormwater on the receiving water. To that end, a nutrient budget and lake response model were developed for Staring Lake to better understand the role of stormwater on the quality of Staring Lake.

It is important to note that not all of the drainage area for Staring Lake is within the City of Eden Prairie. A little less than half of the watershed lies within the City boundaries with the remaining watershed within the City of Minnetonka. As such, not all of the stormwater system was field surveyed and subwatershed estimated.

4.2 LAKE AND WATERSHED CHARACTERIZATION

Staring Lake (DNR Lake ID 27-0078) is an in-line lake on Purgatory Creek, a tributary of the Minnesota River. Located in Hennepin County, Staring Lake is just north of the Flying Cloud Airport and Pioneer Trail and east of Staring Lake Parkway (HUC 7020012). Staring Lake is a recreational lake surrounded by community parks, trails and a nature center (Staring Lake Outdoor Center). Staring Lake has a public access on the north side of the lake and a fishing pier on the west side and within the Outdoor Center to provide fishing opportunities to the community. Starling Lake was listed as impaired for nutrients by the MPCA in 2002 and has a TMDL target completion date of 2015.

4.2.1 Watershed Land Use and Hydrology

Purgatory Creek flows through Staring Lake which has a watershed that drains approximately 11,200 acres. Purgatory Creek is characterized by a number of in-line wetlands, or wetlands that the Creek is directly connected to, including one located within Purgatory Creek Park. The Purgatory Creek Park wetland is a large, shallow open water wetland that lies a short distance directly north of Staring Lake. Water quality in the Purgatory Creek Park Area will have direct impacts to Staring Lake due to its close proximity and the large proportion of the watershed that drains through the wetland. A few other lakes lie within the watershed including Silver Lake in the headwaters located in the City of Minnetonka and McCoy Lake and Lake Idlewild within the City of Eden Prairie. McCoy and Idlewild are listed as large wetlands and are really only designated as lakes by the City.

Land use in the Staring Lake watershed is predominantly residential (56%) with the remainder parks (14%) and open space (14%) if you include wetlands and open water (Table 4.1; Figure 4.1). The remaining 15% is a mix of commercial and industrial properties. The watershed contains two major highways, Trunk Highway 212 and Trunk Highway 5, with the Interstate 494 interchange in the eastern-most part of the watershed. The area is also characterized by pockets of commercial area including the Eden Prairie Mall that is surrounded by strip malls, retail stores and restaurants.

Table 4.1. Land use within the Staring Lake (Purgatory Creek) watershed.

Land Use	**Acres**	**Percent**
Single Family Detached	5,390	48%
Park, Recreational, or Preserve	1,529	14%
Undeveloped	1,046	9%
Single Family Attached	556	5%
Open Water	505	5%
Retail and Other Commercial	445	4%
Institutional	396	4%
Industrial and Utility	325	3%
Major Highway	324	3%
Multifamily	295	3%
Airport	141	1%
Office	127	1%
Golf Course	109	1%
Mixed Use Industrial	8	<1%
Mixed Use Commercial	3	<1%
Agricultural	2	<1%
Mixed Use Residential	1	<1%

4.2.2 Lake Morphometry

Staring Lake is a small, urban shallow lake with a surface area of 159 acres and a maximum depth of 15 feet (Table 4.2). The Minnesota Pollution Control Agency defines a shallow lake as any lake less than 15 feet in depth or with more than 80% capable of supporting submerged aquatic vegetation. The shallow nature of Staring Lake suggests that the lake should support submerged aquatic vegetation through most if not all of the lake. The area expected to support plant growth (less than 15 feet) is also defined as the littoral zone, the area where light penetration is deep enough to support submerged vegetation. Staring Lake has a short residence time with lake water being replaced by runoff approximately every 44 days. This suggests that the lake is sensitive to stormwater quality.

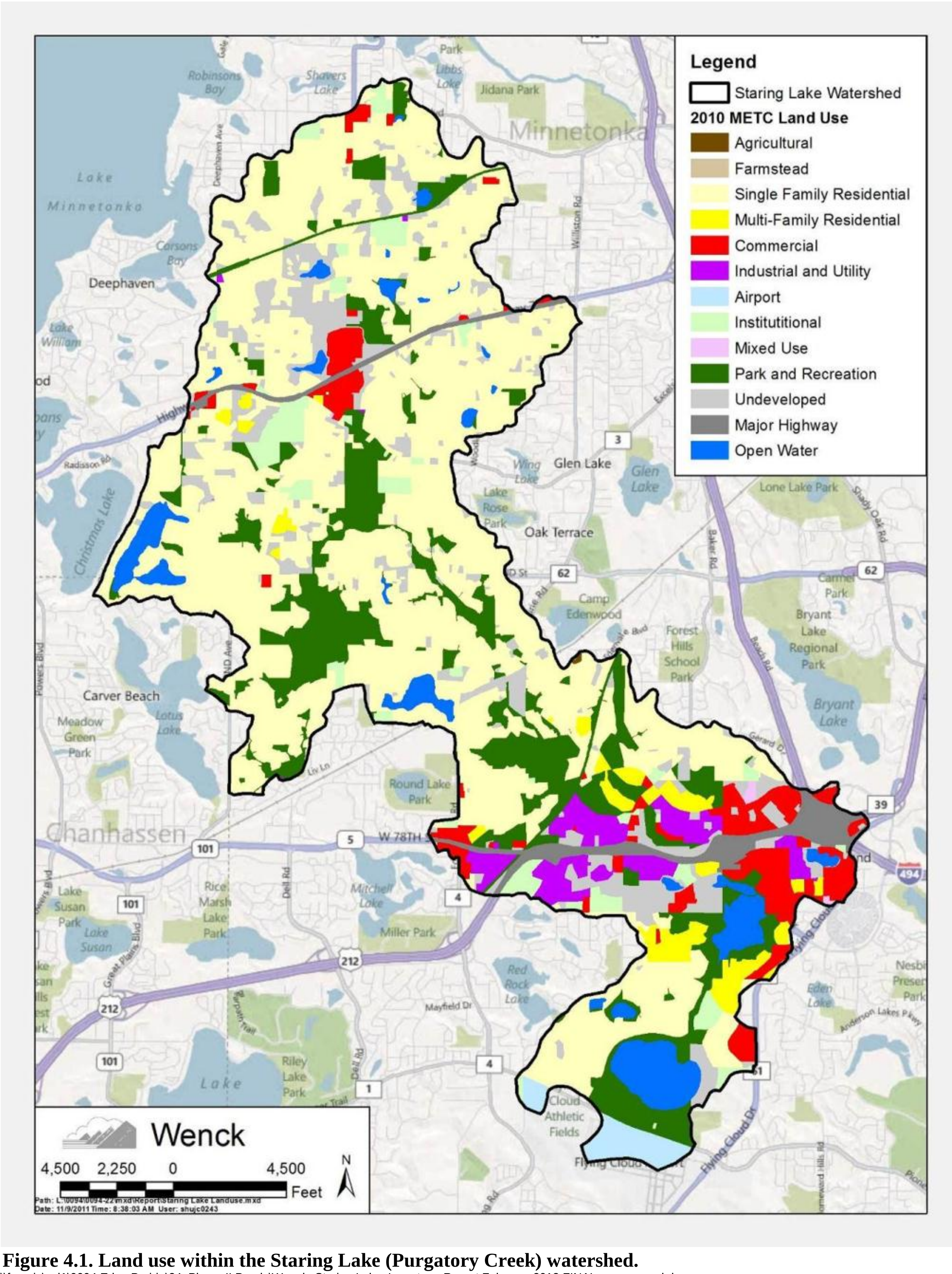

Figure 4.1. Land use within the Staring Lake (Purgatory Creek) watershed.

Table 4.2. Staring Lake characteristics.

Parameter	Staring Lake
Surface Area (acres)	159
Average Depth (feet)	7
Maximum Depth (feet)	15
Volume (acre-feet)	1,120
Residence Time (years)	0.12 (44 days)
Littoral Area (acres)	159
Littoral Area (%)	100
Watershed (acres)	11,204

Shallow lakes are ecologically different from deep lakes. In shallow lakes, there is a greater area of sediment-water interface, which can potentially allow larger sediment contributions to nutrient loads and potentially more sediment re-suspension resulting in decreased water clarity. Biological organisms also play a greater role in maintaining water quality in shallow lakes. Rough fish, especially carp, can uproot submerged aquatic vegetation and stir up sediment. Submerged aquatic vegetation stabilizes the sediment, reducing the amount that can be resuspended and cloud water clarity. Submerged aquatic vegetation also provides refugia (places to avoid predation) for zooplankton, a group of small crustaceans that consumes algae. Staring Lake is known to have a significant population of carp at this time.

All of these interactions reflect a lake existing in two alternative stable states: a clear water state and a turbid water state. The clear water state is characterized by a robust and diverse submerged aquatic vegetation community, balanced fish community and large daphnia (zooplankton that are very effective at consuming algae). Alternatively, the turbid water state typically lacks submerged aquatic vegetation, is dominated by rough fish, and is characterized by both sediment resuspension and algal productivity.

The state in which the lake persists depends on the biological community as well as the nutrient conditions in the lake. Therefore, lake management must focus on the biological community as well as the water quality of the lake.

4.2.3 Groundwater

Groundwater was not explicitly incorporated into the water budget of Staring Lake. Based on desktop review of available hydrogeological information, Staring Lake is at an average elevation of approximately 814 feet Above Mean Sea Level (AMSL), roughly 120 feet above the lakes within the adjacent Minnesota River valley. Its morphology suggests a kettle lake in the sandy outwash in the area. According to the Hennepin County Geologic atlas it is at the approximate level of the perched aquifer in the area. Lakes and wetlands immediately north are at higher elevations. Based on its proximity to the Minnesota River valley bluffs, and higher water levels to the north, it appears to be a flow-through lake where shallow groundwater enters along the northern perimeter and discharges from the southern perimeter. There are no perched aquifer wells in the vicinity, based on the Minnesota Department of Health (MDH) well database, so further refinement of the lake's relationship to the local water table is not possible at this time.

4.2.4 Water Quality

Lake water quality is typically measured by assessing the amount of algal growth and water clarity during the summer growing season. When excessive algae grows in a lake, water clarity is reduced and noxious smells can emit. These are symptoms of lake eutrophication. When lakes become hypereutrophic (excess nutrients leading to heavy algae growth), the entire food web is affected. Changes are found in the algal community and water quality, including depletion of dissolved oxygen and decreased water clarity. A healthy lake has a balanced growth of algae supporting the base of the food chain without degrading water quality or harming biological organisms.

Phosphorus

Algal growth (measured as total chlorophyll-*a*) is typically limited by the amount of phosphorus in the water column. Therefore, total phosphorus is considered the causative factor for algal growth. Water clarity is affected by the amount of algae as well as suspended and dissolved particles in the water column.

The Riley-Purgatory-Bluff Creek Watershed District (RPBCWD) and Metropolitan Council Environmental Services have collected water quality data from Staring Lake since the 1970's. Summer average total phosphorus concentrations ranged from 84 to 124 µg/L, exceeding the state shallow lake standards for the North Central Hardwood Forest Eco region (<60 µg/L) in all 12 monitored years (Figure 4.2). These concentrations can support large algal populations and maintain Staring Lake in a turbid water state.

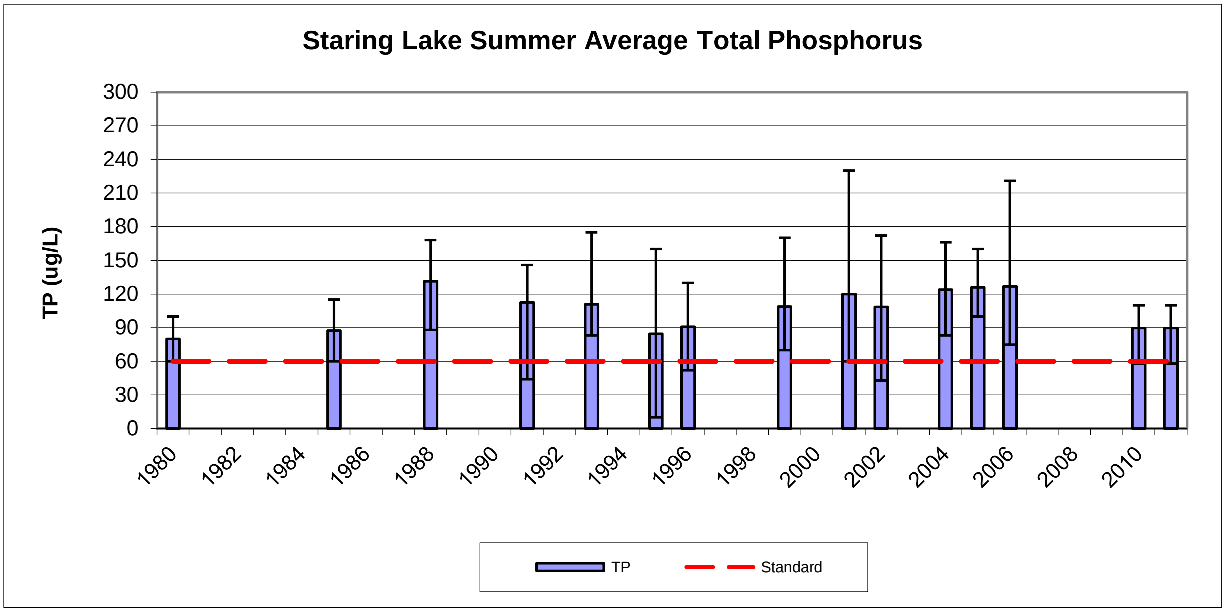

Figure 4.2. Summer (June 1 – September 30) average total phosphorus for Staring Lake.

The red line indicates the State of Minnesota's standard for shallow lakes in the North Central Hardwood Forest Eco region. Error bars represent the minimum and maximum values. Only data with more than 4 summer samples are shown on the graph.

Chlorophyll-a

Chlorophyll-*a* is a measure of the amount of algal biomass in a basin at any given time. The greater the algal biomass and corresponding chlorophyll-*a* values, the more green and productive a lake appears with worst case scenarios including algal sums and foul odors. These conditions are considered nuisance algal blooms and are both aesthetically unpleasing but also potentially bad for fish and other biological organisms. Nuisance algal blooms cause poor smells and aesthetics and can lead to more severe problems such as summer fish kills. Ultimately, a shallow lake should have a modest amount of algal productivity with light penetrating approximately 15 feet into the water column.

Summer Average chlorophyll-*a* concentrations in Staring Lake are extremely high ranging from 49 to 100 µg/L (Figure 4.3) with all of the monitored years exceeding the state water quality standard for shallow lakes in the North Central Hardwood Forest Eco region (<20 µg/L as a summer average). These data clearly demonstrate that Staring Lake is in an algae dominated state where severe nuisance algal blooms occur.

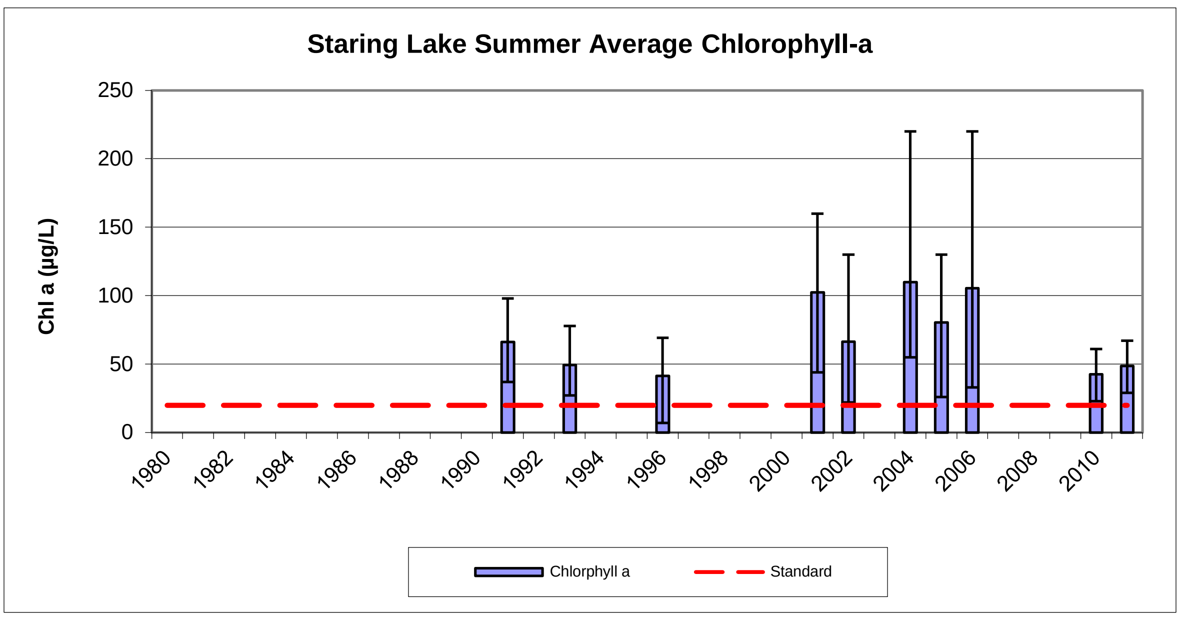

Figure 4.3. Summer (June 1 – September 30) average chlorophyll-*a* for Staring Lake.

The red line indicates the State of Minnesota's standard for shallow lakes in the North Central Hardwood Forest Eco region. Error bars represent the minimum and maximum values. Only data with more than 4 summer samples are shown on the graph.

Water Clarity

Water clarity in lakes is typically measured using a Secchi disk. A Secchi disk is a black and white disk that is lowered into the water column until it can no longer be seen. The depth at which the disk disappears is known as the Secchi depth and is considered the depth where 90% of the light is extinguished.

Water clarity in shallow lakes is controlled by several factors including the amount of algae in the water column as well as other suspended particles such as suspended sediment as a result of wind resuspension and bioturbation (such as carp). Since Staring Lake is a shallow lake, wind mixing can reach the sediments and stir up particles into the water column. Staring Lake also has a large carp population that feeds and roots around in the sediments causing a fair amount of sediment disturbance.

Water clarity is generally poor in Staring Lake with summer average Secchi depths less than 1 meter (Figure 4.4). The large algal biomass (see chlorophyll-*a* data) is clearly contributing to the poor clarity in Staring Lake, however due to the lack of submerged aquatic vegetation, a significant component of the lack of water clarity is likely resuspended sediment.

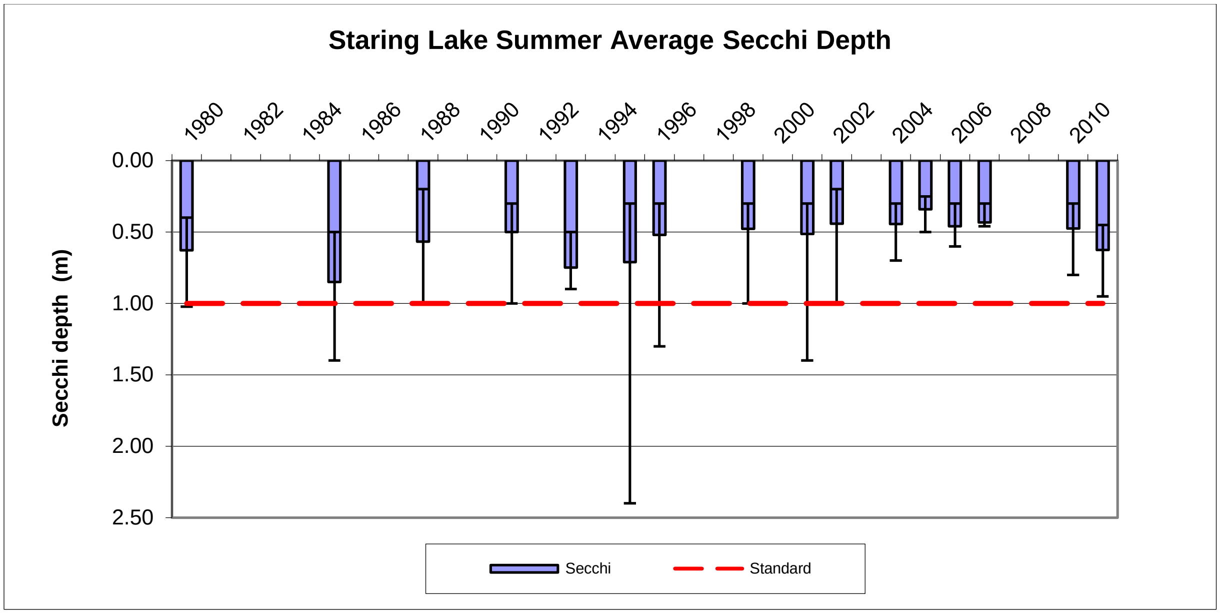

Figure 4.4. Summer (June 1 – September 30) average Secchi depth for Staring Lake.

The red line indicates the State of Minnesota's standard for shallow lakes in the North Central Hardwood Forest Eco region. Error bars represent the minimum and maximum values. Only data with more than 4 summer samples are shown on the graph.

4.2.5 Fisheries

The Minnesota DNR conducted a fish survey on Staring Lake in 2008. Based on the results of that survey, Staring Lake is dominated by pan fish, with bluegills being the most abundant species. Although blue gills are abundant, they are relatively small in size suggesting that the population may be stunted from a lack of top predators. Stunted bluegill populations can negatively affect water quality by reducing the number of cladocerans (zooplankton) that can effectively graze algae and help increase clarity in the water column.

The University of Minnesota has been studying carp populations in Staring Lake and connected basins since 2010. Based on their findings, Staring Lake is infested with common carp (490 kg/ha) which can negatively affect water quality by uprooting submerged aquatic vegetation and stirring up sediments. The lack of submerged aquatic vegetation points to a large carp population that is negatively impacting water quality.

4.2.6 Aquatic Vegetation

A submerged aquatic vegetation survey was completed on Staring Lake in June and August of 2011 by Blue Water Science. During the June visit, submerged aquatic vegetation were rare with the most common plant (Curly-leaf pondweed) showing up at only 10 of the 265 sites sampled. There were a total of 5 species of submerged aquatic vegetation present during the June visit which is considered to be low plant diversity. Aquatic plant coverage was about 15 of the 155 acres of Staring Lake.

During the August visit, 8 of the 155 acres had aquatic plant coverage though no submerged aquatic plants were found.

Staring Lake lacks a submerged aquatic vegetation community. Submerged aquatic vegetation are critical in shallow lakes because they stabilize lake sediments preventing wind resuspension of sediments and also provides refugia for cladocerans to avoid fish predation. To increase the aquatic vegetation, water clarity needs to increase to allow light to reach the bottom and roughfish populations need to decrease to allow plants to become established.

4.3 PHOSPHORUS SOURCES

One of the primary drivers for lake productivity or algal growth is phosphorus. To better understand what is driving water quality in Staring Lake, a detailed phosphorus budget needs to be developed to identify both the sources and magnitude of the phosphorus sources. Phosphorus sources to lakes include stormwater runoff, internal sediment release of phosphorus, and direct atmospheric deposition of phosphorus to the lakes surface. In this section, a brief description of the potential source of phosphorus to Staring Lake is provided.

4.3.1 Atmospheric Deposition

Precipitation picks up dust particles that contain phosphorus that can ultimately end up in Staring Lake as a result of direct input on the basin surface or as a part of stormwater runoff from impervious surfaces in the watershed. Although they must be accounted for in development of a nutrient budget, atmospheric inputs are difficult if not impossible to control and are usually small compared to other sources (internal and external).

Atmospheric inputs of phosphorus from wet and dry deposition are estimated using rates set forth in the MPCA report "Detailed Assessment of Phosphorus Sources to Minnesota Watersheds" (Barr Engineering, 2004), and are based on annual precipitation. The values used for dry (< 25 inches), average, and wet precipitation years (>38 inches) for atmospheric deposition are 24.9, 26.8, and 29.0 kg/km^2-year, respectively. These values are equivalent to 0.22, 0.24, and 0.26 pounds/acre-year for dry, average, and wet years in English units, respectively.

4.3.2 Stormwater

Phosphorus transported by stormwater represents one of the largest external contributors of phosphorus to surface waters in Minnesota. Impervious surfaces and storm sewer systems in the watershed improve the efficiency of runoff moving to streams, wetlands and lakes, resulting in increased transport of phosphorus into local basins. Phosphorus in stormwater is a result of leaves and grass clippings, fertilizers, sediments, pet waste, excessive lawn watering, automobiles and illicit sanitary sewer connections. Managing stormwater is a high-priority concern in urban watersheds.

Excess fertilizer applied to lawns is readily transported to local streams, wetlands and lakes during runoff events and is immediately available for algal growth. However, State law prohibits the use of lawn fertilizer containing phosphorus except when new lawns are being established by seeding or laying sod or when soil testing shows a need for additional phosphorus.

The majority of stormwater enters Staring Lake through the Purgatory Creek Park, representing 81% of the stormwater volume and 83% of the total phosphorus budget (Figure 4.5). Direct stormwater discharges flow into the lake without stormwater treatment (5%), through McCoy Lake (10%), or from some small watersheds with treatment (2%). These areas collectively represent about 17% of the watershed phosphorus load to Staring Lake. McCoy Lake drainage includes a series of lakes that flow into it including Round Lake, Mitchell Lake, and Red Rock Lake.

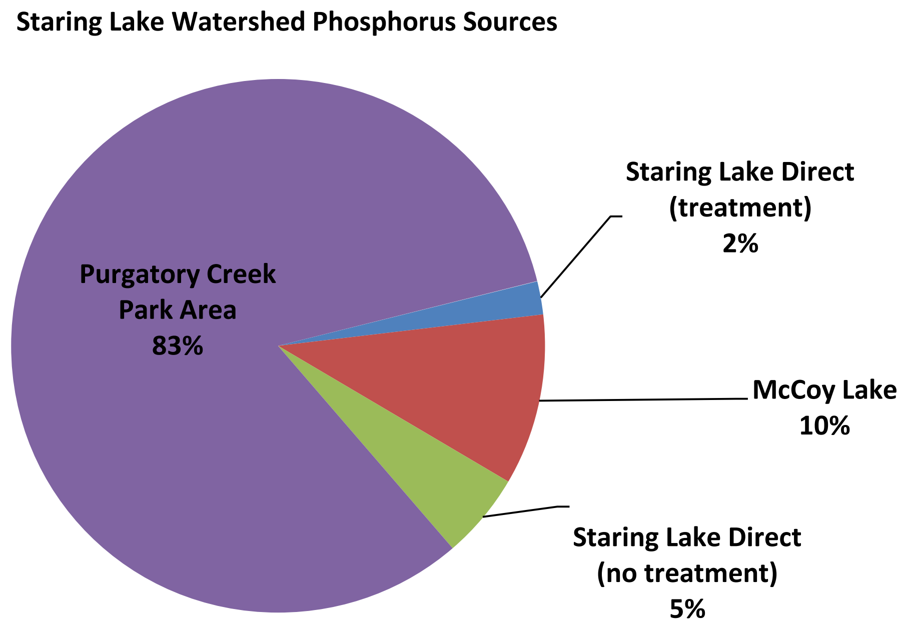

Figure 4.5. Watershed phosphorus sources for Staring Lake.

4.3.3 Internal Loading

Over time, basins tend to accumulate phosphorus in their bottom sediments. One of the primary bonds for phosphorus is with iron. When oxygen is depleted near the sediment surface (water concentration less than 2.0 mg/L), phosphorus-iron bonds and other chemical bonds are broken, releasing dissolved phosphorus for transport into the water column. This phosphorus is in a dissolved form that is readily available to algae and plants.

Internal phosphorus loading from sources already in basins has been demonstrated to be an important aspect of the phosphorus budgets of basins. However, measuring or estimating internal loads can be difficult, especially in shallow lakes that may mix many times throughout the year. To estimate internal loading, an anoxic factor (Nürnberg 2004), which estimates the period where anoxic conditions exist over the sediments, is estimated from the dissolved oxygen profile data. The anoxic factor is expressed in days but is normalized over the area of the lake. The anoxic factor is then used along with a sediment release rate to estimate the total phosphorus load from the sediments.

Because shallow lakes mix often, and dissolved oxygen data is typically collected every other week or monthly, a shallow lake equation that uses morphometry and lake water quality was applied to estimate internal load.

Phosphorus release rates were estimated by collecting cores from Staring Lake and incubating them in the lab under anoxic conditions (ACOE-ERD 2010; Appendix B). Table 4.3 summarizes the internal loading for Staring Lake.

Table 4.3. Internal phosphorus load summary for Staring Lake.

Year	Release Rate ($mg/m^2/day$)	AF	Gross Load ($mg/m^2/summer$)	Kilograms	Pounds
2001	6.2	59.0	366	235	517
2002	6.2	50.0	310	199	438
2004	6.2	60.0	372	239	526
2005	6.2	60.0	372	239	526
2006	6.2	60.0	372	239	526
2010	6.2	54.0	335	215	473
Average	6.2	58.0	354	231	501
Oxic	0.7	NA	85	55	121

4.4 SOURCE SUMMARY AND CURRENT PHOSPHORUS BUDGET

The following is a description of the primary sources of phosphorus to Staring Lake based on the phosphorus source inputs and lake response (BATHTUB) modeling.

4.4.1 BATHTUB Model Fit

Lake response modeling was conducted for six years (2001, 2002, 2004-06, and 2010), where good data were available for Staring Lake. Modeled in-lake total phosphorus concentrations were within 30% of measured values in all the modeled years, and within 15% in four out of the six years (Figure 4.6). Consequently, the model was determined to be a reasonably calibrated model.

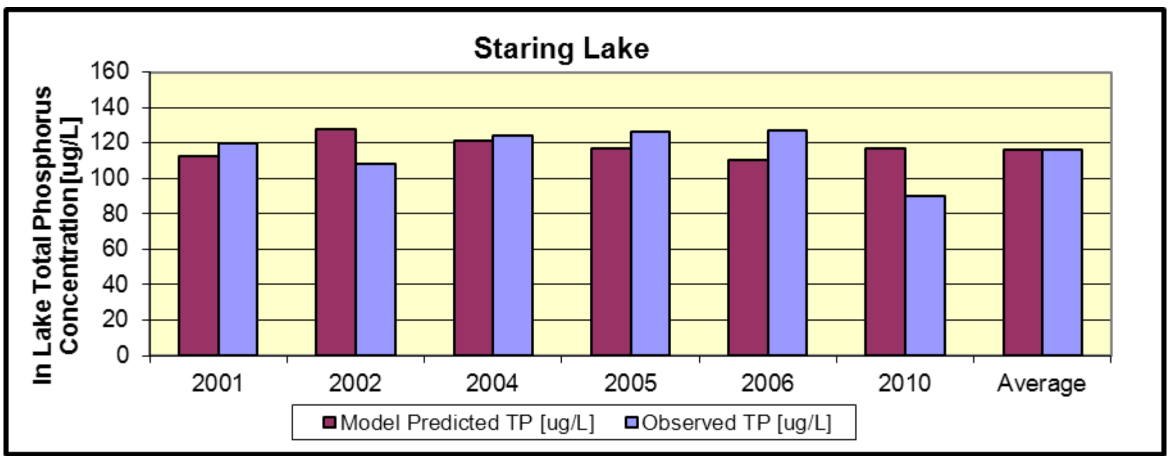

Figure 4.6. Modeled and monitored in-lake total phosphorus concentrations.

4.4.2 Lake Phosphorus Budget

An average of the six modeled years was used to develop an average total phosphorus budget for Staring Lake (Figure 4.7). Internal loading represents 10% of the total phosphorus inputs to

Staring Lake with stormwater comprising over 90% of the total phosphorus load. Stormwater is the dominant source of phosphorus to Staring Lake; however internal loading plays a significant role in the phosphorus budget.

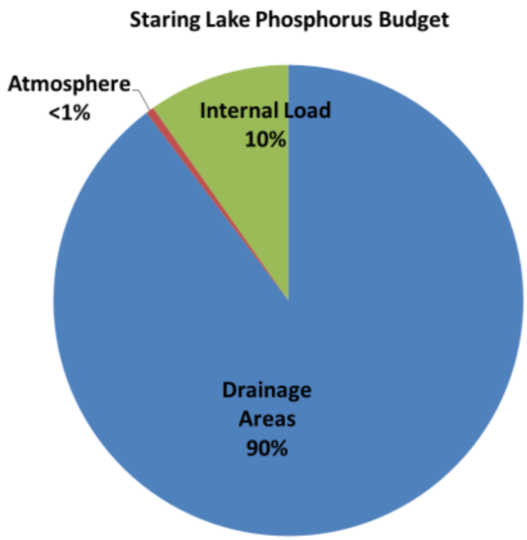

Figure 4.7. Phosphorus sources for Staring Lake.

4.4.3 Phosphorus Load Reductions

To determine the required phosphorus loads to meet State water quality standards for shallow lakes in the North Central Hardwood Forest Eco region (NCHF; Table 4.4), the baseline phosphorus budget was used to determine the response of Staring Lake to total phosphorus reductions.

Table 4.4. Numeric water quality goals for Staring Lake.

Intended Use	**Average June-September Values**		
	Total Phosphorus (µg/L)	**Chlorophyll-*a* (µg/L)**	**Secchi Depth (m)**
Indirect Contact Recreation	≤60	≤20	≥1

First, internal phosphorus loading was reduced to a rate of 0.5 $mg/m^2/day$ based on other reference shallow lakes. Then the watershed loads were reduced until the baseline lake response model predicted a summer average of 60 µg/L total phosphorus.

To meet this quality goal, modeling suggests a total reduction of 2,829 pounds of phosphorus loading to Staring Lake would need to occur with 2,368 pounds coming from the watershed and 461 pounds reduction through internal loading. Table 4.5 breaks the watershed loading reduction into smaller subwatershed reduction requirements.

Table 4.5. Current phosphorus loading and predicted phosphorus to meet the state water quality standards in Staring Lake.

	Current TP Load (pounds)	TP Load at the Standard (pounds)	Required Reduction (pounds)	Percent Reduction
Staring Direct	347	174	173	50%
McCoy Lake	515	259	256	50%
Upstream[1]	2,346	1,177	1,169	50%
Purgatory Creek[2]	1,548	778	770	50%
Internal Load	623	162	461	74%
Atmospheric	35	35	0	0%
TOTAL	5,414	2,585	2,829	53%

1 Upstream is considered to be Staring Lake watershed upstream of City of Eden Prairie boundary

2 Purgatory Creek Park is considered to be Staring Lake watershed within City of Eden Prairie before entering Staring Lake and does not include loading values associated with Upstream

It is important to note that the entire phosphorus loading to the Purgatory Creek Park does not come from the City of Eden Prairie. A large portion of the loading comes from the upper Purgatory Creek watershed that lies outside of the City boundary (Upstream, Table 4.5). The flow from the upper watershed flows through basin 15-14-B which removes a large amount of TSS and phosphorus prior to discharging to the Purgatory Creek Park Area.

5.0 Recommendations

5.1 INTRODUCTION

As part of their MS4 requirements, the City must inspect all outfalls, constructed ponds and stormwater wetlands each permit cycle. The City's current stormwater inventory includes more than 900 constructed ponds, wetlands, mitigation wetlands, infiltration BMPs, ditches, swales and creek segments that receive or route stormwater. For the purposes of this initial evaluation the City was divided up into a number of subwatersheds centering on lakes or creeks. Stormwater ponding areas (constructed ponds, infiltration BMPs and stormwater wetlands) that are either within a drainage easement, on public land, or receive public drainage were evaluated.

The purpose of this study was to enhance the understanding of the City's maintenance responsibilities, assist City staff with scheduling and budgeting resources, and maintain compliance with the City's MS4 SWPPP. To that end, the City will use this information to guide annual implementation and maintenance activities.

The results of the survey were used to identify needed maintenance issues, key basins in treatment trains, and basins that either need excavation due to sediment deposition or that can be expanded to improve the efficiency of the system.

5.2 INVENTORY CONTINUATION AND SCHEDULE

The intent of the survey was to identify key constructed ponds or stormwater wetlands that need maintenance or could be expanded; however the survey can also be used to identify key basins in a treatment train, basins that are experiencing sedimentation, and basins that are oversized or non-critical in protecting receiving water quality. Following are the goals of this assessment:

- Prioritize and schedule basins for future inspections and schedules.
- Routinely inspect all basins as required in the City's MS4 Permit for any visual signs of maintenance needs using the City's visual inspection protocol (City of Eden Prairie Stormwater Inventory, Maintenance, and Inspection Plan dated 3/18/11). These basins were identified based on evidence of potential sedimentation and location in the treatment train.
- Evaluate high-priority basins every inventory cycle for sediment accumulation estimates.
- Determine if the cycle could be adjusted based on the results.

- Other basins should be evaluated a minimum of once during every other inventory cycle, which is estimated as 12 years per cycle.

None of the basins demonstrated enough sediment accumulation to warrant a more frequent schedule based on the age of the basins versus the amount of sediment accumulated.

Table 5.1. Ponds and wetlands in each subwatershed identified for routine sediment deposition monitoring.

Drainage Group	Basin ID	Estimated Sediment (AF)	Basin Type
North Purgatory Creek Area	05-12-C	0.38	Stormwater Wetland
	05-11-C	0.38	Stormwater Wetland
Edenvale Park Area	05-44-A	0.34	Stormwater Wetland
South Purgatory Creek Area	08-44-A	1.51	Stormwater Wetland
Purgatory Creek Park Direct	14-23-A	0.12	Stormwater Wetland
	15-42-A	0.14	Constructed Pond
	14-33-B	0.01	Constructed Pond
	14-32-A	0.06	Stormwater Wetland
Purgatory Creek Valley View Road to Highway 5	10-34-A	0.17	Constructed Pond
Staring Lake West	21-13-D	0.03	Constructed Pond
	21-13-E	0.12	Constructed Pond
	22-22-A	0.19	Stormwater Wetland
	21-11-A	1.58	Stormwater Wetland
Purgatory Creek Park Area West	15-13-G	0.23	Stormwater Wetland
Valley View Road and 494 Interchange	15-14-B	1.75	Stormwater Wetland
Mitchell Road and Highway 5 Interchange	10-33-F	0.42	Constructed Pond
Highway 5 and Highway 212 Interchange	09-42-D	0.30	Stormwater Wetland
	09-43-A	0.23	Stormwater Wetland
Bent Creek Area	10-32-B	0.19	Stormwater Wetland
Regional Trail Drainage Area	09-13-A	0.15	Stormwater Wetland
Staring Lake Direct	21-14-C	0	Constructed Pond
	22-13-B	0.54	Constructed Pond

5.3 SEDIMENT REMOVAL MAINTENANCE

Basins were identified for maintenance based on their position in the watershed and treatment train, their permanent pool volume as compared to NURP requirements, and signs of sedimentation. Basins with as-built information were also considered for expansion when the as-built permanent pool was larger than the surveyed permanent pool.

Planning level cost estimates were developed for each potential project. The cost estimates include sediment characterization, mobilization, site preparation, dredging, sediment disposal, minor storm sewer work, site restoration, erosion control, permitting, and maintenance. Costs exclude wetland restoration/mitigation (about $10/square foot), major storm sewer work, and land/easement acquisition. Additional problems that might occur during projects that would add to the cost are dewatering and access issues such as steep banks and tree removal.

It is important to note that costs can vary greatly if sediments are determined to be contaminated under MPCA guidelines. The estimated excavation cost in Table 5.2 assumes moderate (Level 2) levels of contamination. Sediment characterization is discussed in more detail in Section 5.4.2.

Projects were prioritized based on their position in the watershed and the treatment train in that watershed, the overall effectiveness of the cleanout or expansion, the type of basin and potential impact to the lake. Typically, stormwater wetlands were considered as low priority if no as-built information was available since it is difficult to differentiate between sediments that already existed in the wetland versus new sediment from stormwater. However, a few wetlands were in critical locations and considered high priority for consideration even though the costs would likely be higher than the costs presented in this report due to potential requirements for wetland mitigation.

Table 5.2 presents identified projects for ponds and wetlands. Only a few of the basins demonstrated signs of sedimentation, so most of these would be considered expansions. If historic conditions can be established, excavation of storm sediment is exempted from needing additional permits. One basin (05-14-B) demonstrated a projected removal of 5.8 pounds of total phosphorus annually, while five basins were determined to achieve greater than two pounds of phosphorus annually. An additional 5 pounds of phosphorus would be removed annually if stormwater wetland 09-42-D were expanded. Compared to the needed phosphorus reductions to meet water quality standards in Staring Lake, these are quite small reductions in phosphorus loading. Basins 10-33-F and 11-33-C are owned by MNDOT which means they will have the final say as to whether or not the basins are excavated.

Figures 5.1 through 5.3 show the locations of the projects identified in Table 5.2. Cleanout volumes are associated with projects that were identified as having accumulated sediment and expansion volumes associated with basins that have as-built information available.

The total cost to complete all of these projects is approximately $1.2 million assuming a moderate level of contamination. The cost of these projects could increase to $1.4 million or more if sediments are determined to have Level 3 contamination levels. It is important to note that cost estimates are based on current rates which could increase in the future.

Table 5.2. Identified wetland and constructed pond projects including planning level costs.

Drainage Group	Basin ID	Surface Area of As-Built Permanent Pool (acres)	Surface Area of Surveyed Permanent Pool (acres)	Permanent Pool Volume Difference (AF)	Estimated Sediment Volume (AF)	Estimated Excavation Costs[1]	Priority	TSS Reduction (lbs/yr)	TP Reduction (lbs/yr)	Access Path Condition/ Obstruction
Constructed Ponds										
North Purgatory Creek	05-14-B	0.28	0.00	0.97	0.00	$107,006	High	2,485	5.8	Good/None
Highway 5/212 Interchange	09-42-E	0.32	0.11	0.72	0.00	$79,411	Medium	1,129	3.1	Good/None
Purgatory Creek to Highway 5	10-43-C	0.26	0.17	0.29	0.00	$41,367	High	233	0.7	Fair/None
	10-34-A	--	--	--	0.17	$23,452	High	94	0.3	Good/Steep
Highway 5 and Mitchell Road	10-33-F[3]	--	--	--	0.42	$58,367	High	184	0.6	Fair/Brush
Purgatory Creek Park Direct	15-42-A	0.43	0.27	1.14	0.14	$63,121	High[2]	404	1.2	Good/None
Valley View Road and Highway 494 Interchange	11-33-C[3]	--	--	--	0.46	$64,014	Medium	612	2.0	Good/Fence
	14-21-C	0.20	0.04	0.44	0.03	$61,484	Medium[2]	283	0.9	Good/Trees
Staring Lake Direct	21-14-C	0.03	0.01	0.24	0.00	$33,764	High	987	2.1	Good/None
	22-13-B	1.53	1.26	2.11	0.54	$116,550	High[2]	693	2.0	Good/Trees
McCoy Lake Area	21-11-D	0.05	0.00	0.12	0.00	$16,981	Medium	317	0.8	Good/None
Wetlands										
North Purgatory Creek	05-11-C	1.79	0.92	1.13	0.38	$62,213	High[2]	306	0.9	Fair/None
	05-12-C	0.74	0.42	1.23	0.38	$67,943	High[2]	330	1.0	Good/None
Highway 5/212 Interchange	10-33-E	0.18	0.00	0.43	0.00	$60,899	Medium	2,189	4.8	Poor/None
	09-43-B	0.12	0.02	0.31	0.00	$43,882	Medium	843	2.2	Good/None
	09-42-D	--	--	--	0.30	$41,963	High	1,700	5.1	Good/Brush
Bent Creek Area	10-32-B	--	--	--	0.19	$26,255	High	262	0.9	Good/None
Purgatory Creek Park Direct	14-32-A	0.75	0.36	2.82	0.06	$155,642	Medium[2]	592	1.7	Good/None
	14-23-A	0.39	0.31	0.69	0.12	$75,803	High[2]	608	1.7	Good/None

[1]Cost assumes Level 2 sediment contamination.
[2]Evaluate for expansion and cleanout
[3]MNDOT Flood control ponds and wetlands

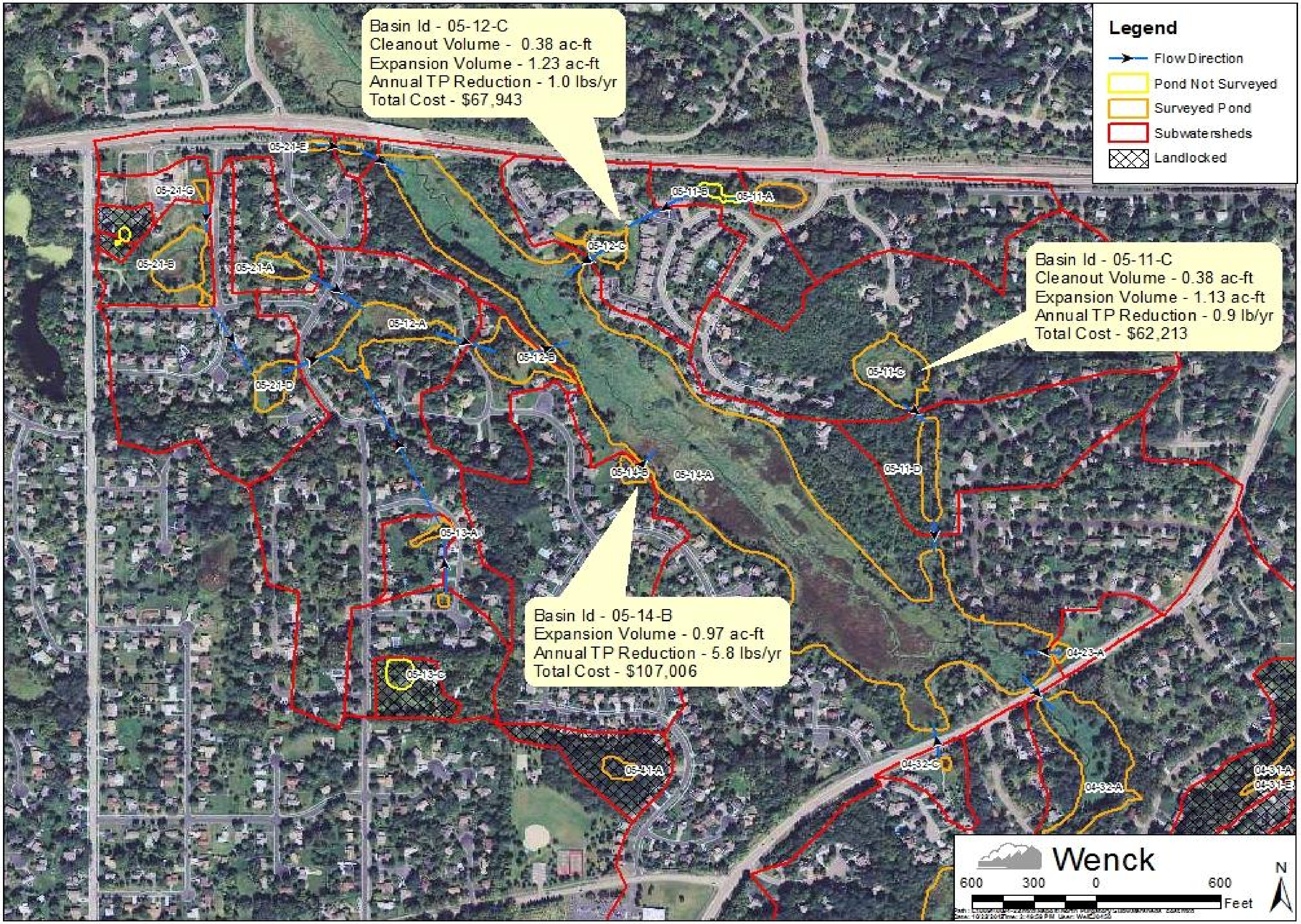

Figure 5.1. Northern Purgatory Creek improvement projects.

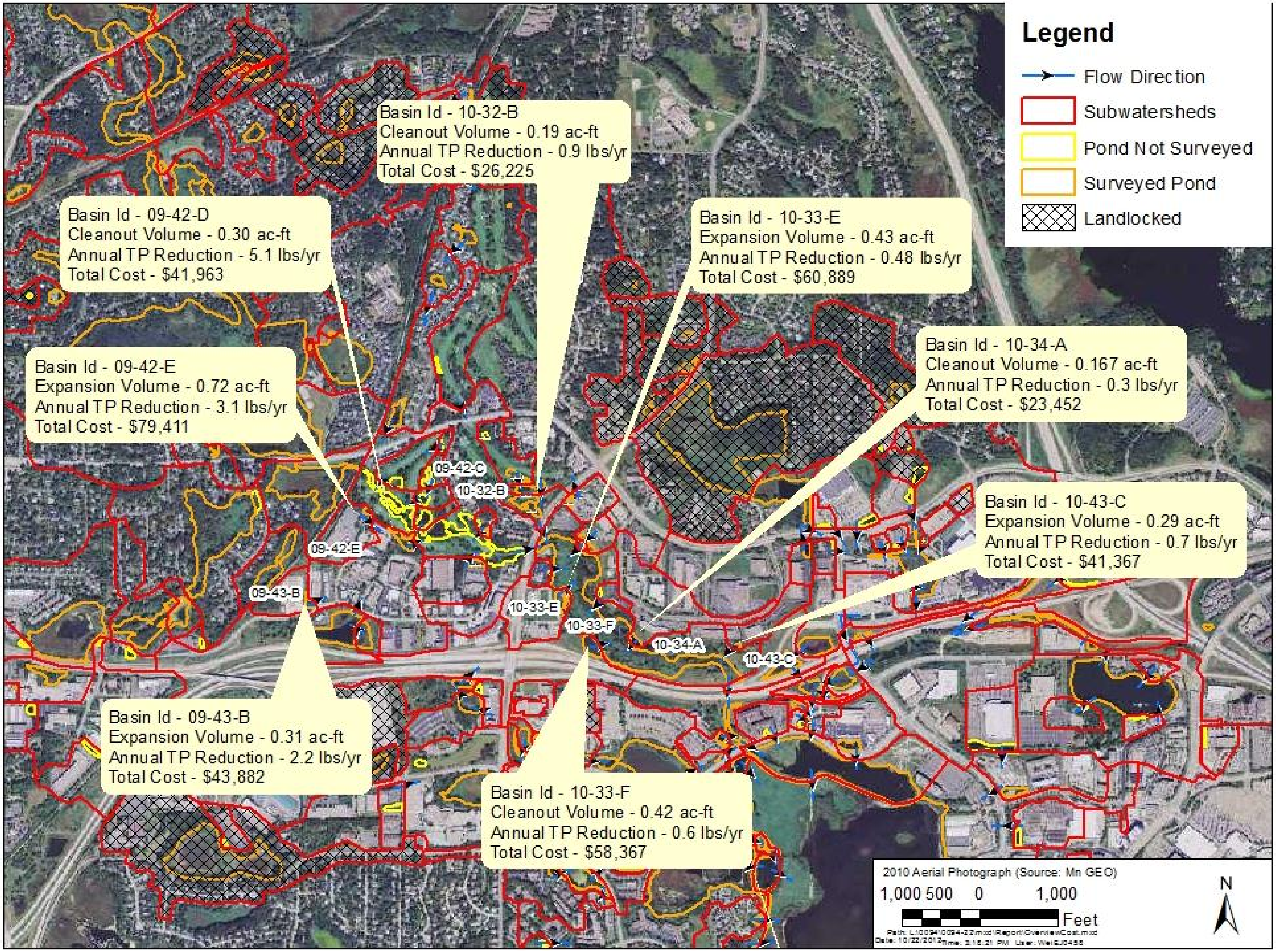

Figure 5.2. Central Purgatory Creek improvement projects.

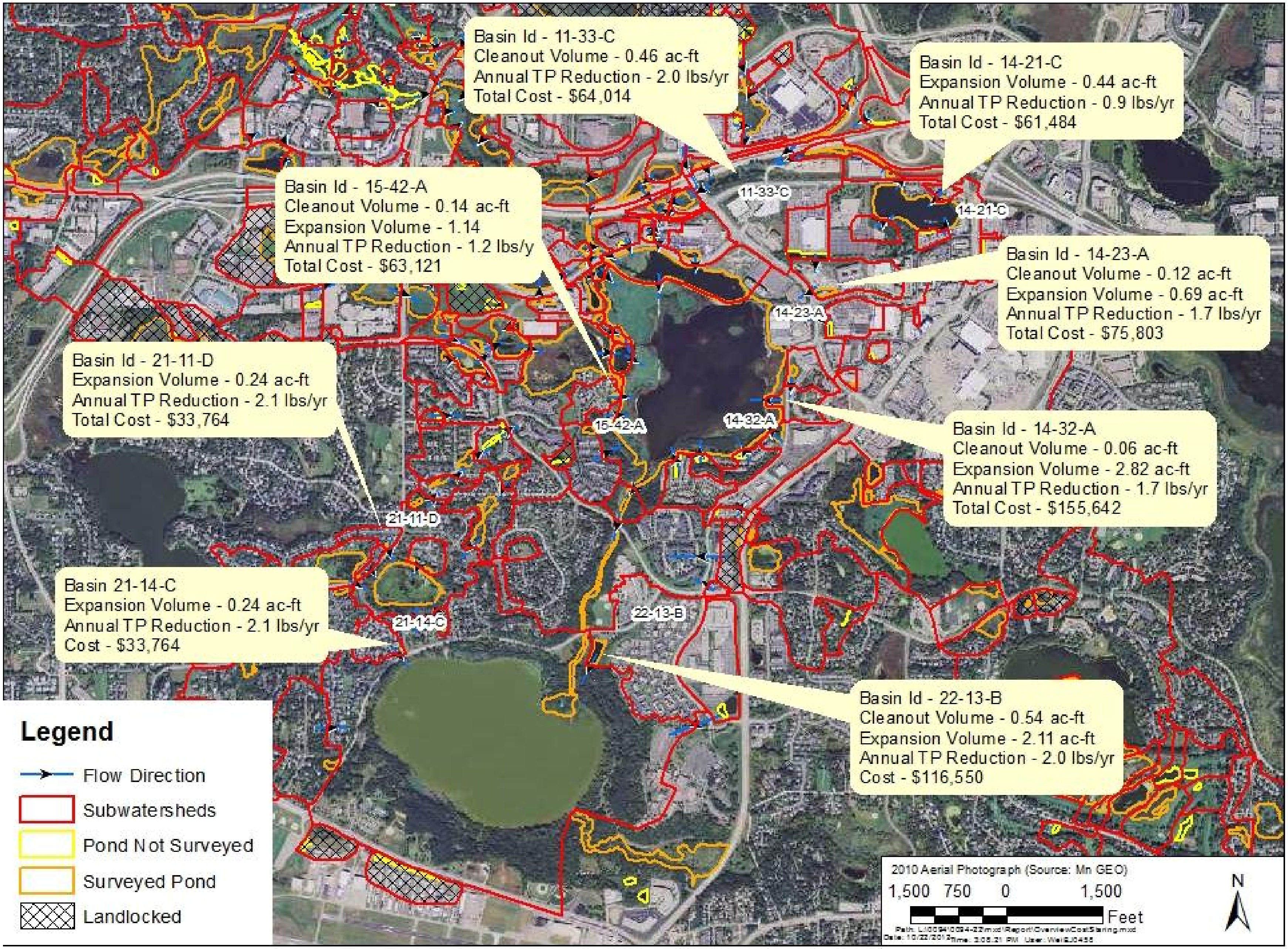

Figure 5.3. Southern Purgatory Creek improvement projects.

5.4 PERMITTING REQUIREMENTS

Several permitting requirements should be considered prior to initiating any pond and wetland excavation.

5.4.1 Wetlands

The Minnesota Wetland Conservation Act (WCA) requires replacement for excavation in Type 3, 4, or 5 wetlands, but provides an exemption for maintenance of wetland stormwater treatment basins if it is demonstrated that the wetlands/ponds were established prior to 1991. There is also a "No-Loss" exemption for excavation of deposited sediment for wetlands utilized for stormwater management (8420.0415 Item E). Required information includes engineering plans for the basin, materials that demonstrate the basin was designed and constructed as a stormwater treatment basin, outlet information, permits obtained for pond construction, or sediment measurements. Under the exemptions, the wetland stormwater treatment basin can be excavated to regain their original design or to remove deposited sediment. However, excavation which increases the pond's surface area or depth requires wetland replacement. Wetland replacement may also be required if the excavation will significantly disturb the wetland system, however it is the City's policy to avoid disturbing natural wetlands if at all possible.

5.4.2 MPCA Dredged Materials Management

The MPCA issues permits for the management of dredged materials under the National Discharge Elimination System (NPDES) and/or the State Disposal System (SDS). In June 2009, the MPCA released *Managing Dredged Materials in the State of Minnesota*, where specific guidance was provided for projects involving sediment removal from municipal or urban stormwater systems.

The MPCA does not require a permit or reporting of results for small maintenance projects where project maintenance activity is less than 3,000 cubic yards and chemical sample data indicate that the dredge material meets management level 1. Dredged material is divided into 3 management levels based on the amount of contamination and therefore has different restrictions on disposal of the material. Level 1 dredged material, which has the lowest levels of contamination, is suitable for use or reuse on properties with a residential or recreational use category. Materials categorized as Level 2 are suitable for use or reuse on properties with an industrial use category and level 3 dredged material is considered to be significantly contaminated and must be managed specifically for the contaminants present (MPCA, December 2011).

A sediment characterization needs to be completed to evaluate the risk and determine disposal options for the dredged sediment except for small removals of individual sediment deltas by basin inlets or outfalls. Sampling is recommended by the MPCA if maintenance is performed at multiple inlet locations and if the material consolidated at one location is greater than 500 cubic yards. Sediment from maintenance of individual stormwater inlets and outfalls may be combined for composite sampling as one project.

5.5 STARING LAKE RESTORATION

5.5.1 Watershed Load Targets

Based on the lake response modeling, required watershed load reductions to meet state water standards in Staring Lake were developed for the modeled years average (Table 5.4). A 50% reduction in the phosphorus loading to Purgatory Creek Park and Staring Lake or a total phosphorus load reduction of 2,368 pounds is required. This assumes that a 50% reduction is acquired upstream of Eden Prairie.

Table 5.3. Watershed loading and estimated reduction requirements for the 10-year average.

Main Watershed	Flow	Total Suspended Solids		Total Phosphorus		TP Reduction	
	AF	mg/L	lbs /yr	µg/L	lbs /yr	lbs /yr	%
Upstream[1]	5,253	58	821,456	164	2,346	1,169	50%
Purgatory Creek[2]	3,870	29	308,161	147	1,548	770	50%
Staring Direct	595	123	109,709	415	347	173	50%
McCoy Lake	1,560	16	68,195	121	515	256	50%
Staring Lake	11,278	185	1,307,521	693	4,756	2,368	50%

1 Upstream is considered to be Staring Lake watershed upstream of City of Eden Prairie boundary
2 Purgatory Creek Park is considered to be Staring Lake watershed within City of Eden Prairie before entering Staring Lake and does not include loading values associated with Upstream

In general, most of the proposed projects have only small benefits in total phosphorus loading to surface waters. If all of the projects were completed, the system would remove an additional 36 pounds of phosphorus and 14,488 pounds of total suspended solids. Considering Eden Prairie's stormwater phosphorus contribution to Staring Lake requires a 1,199 pound reduction, these small upgrades to the basins are a relatively minor step to meeting this goal (<3%). The total cost to complete the listed projects is approximately $1.2 million, equating to a cost of $33,333 per pound of phosphorus removal.

5.5.2 Internal Load Targets

A total internal load reduction of 461 pounds is required for Staring Lake to meet State water quality standards for shallow lakes in the North Central Hardwood Forest Eco region. Internal load reductions can be accomplished through a number of techniques including artificial circulation, aeration or alum addition.

5.5.3 Ecological Restoration

Shallow lakes are ecologically different from deep lakes. In shallow lakes, there is a greater area of sediment-water interface, allowing potentially larger sediment contributions to nutrient loads and higher potential sediment resuspension that can decrease water clarity. Biological organisms also play a greater role in maintaining water quality. Rough fish, especially carp, can uproot submerged aquatic vegetation and stir up sediment. Submerged aquatic vegetation stabilizes the sediment, reducing the amount that can be resuspended and cloud water clarity. Submerged aquatic vegetation also provides refugia for zooplankton, a group of small crustaceans that consumes algae.

All of these interactions reflect a lake being in two alternative stable states: a clear water state and a turbid water state. The clear water state is characterized by a robust and diverse submerged aquatic vegetation community, balanced fish community and large daphnia (zooplankton that are very effective at consuming algae). Alternatively, the turbid water state typically lacks submerged aquatic vegetation, is dominated by rough fish, and is characterized by both sediment resuspension and algal productivity. The state in which the lake persists depends on the biological community as well as the nutrient conditions in the lake. Therefore, lake management must focus on the biological community as well as the water quality of the lake.

The following five-step process for restoring shallow lakes that has been developed in Europe is also applicable here in the United States:

- Forward "switch" detection and removal
- External and internal nutrient control
- Bio manipulation (reverse "switch")
- Plant re-establishment
- Stabilizing and managing the restored system

The first step refers to identifying and eliminating those factors, also known as "switches," that are driving the lake into a turbid water state. These can include high nutrient loads, invasive species such as carp and curly leaf pondweed, altered hydrology, and direct physical impacts such as plant removal.

Once the switches have been eliminated, an acceptable nutrient load must be established.

After the first two steps, the lake is likely to remain in the turbid water state even though conditions have improved, and it must be forced back into the clear lake state by manipulating its biology (also known as bio manipulation). Bio manipulation typically includes whole lake drawdown and fish removal. Once the submerged aquatic vegetation has been established, management will focus on stabilizing the lake in the clear lake state (steps 4 and 5). For Staring Lake, a whole lake drawdown is not feasible due to the current outlet structure and its large watershed. Rather, plants will need to be reestablished through other lake restoration techniques such as alum treatment and carp removal and control. Purgatory Creek Park is being considered for drawdown.

Although the ecological restoration of Staring Lake is not a focus of this study, it is important to recognize that lake water quality will not be improved by only reducing nutrient loading to Staring Lake. Staring Lake has a large rough fish population that must be addressed prior to switching the lake back to a clear water state. The purpose of this study is to provide insight into nutrient management options to set the stage for a successful ecological restoration of the lakes. In addition, the study addresses the high cost and feasibility associated with the required load reduction.

The University of Minnesota is partnering with Riley-Purgatory-Bluff Creek Watershed District (SWD) to evaluate the rough fish population in Staring Lake in an effort to reduce or eliminate carp from the system. The goal of the project is to re-establish submerged aquatic vegetation and a clear-water state to Staring Lake. The City of Eden Prairie is working with the RPBCWD and the University of Minnesota to support the ecological restoration of Staring Lake and the Purgatory Creek Park Area.

6.0 References

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