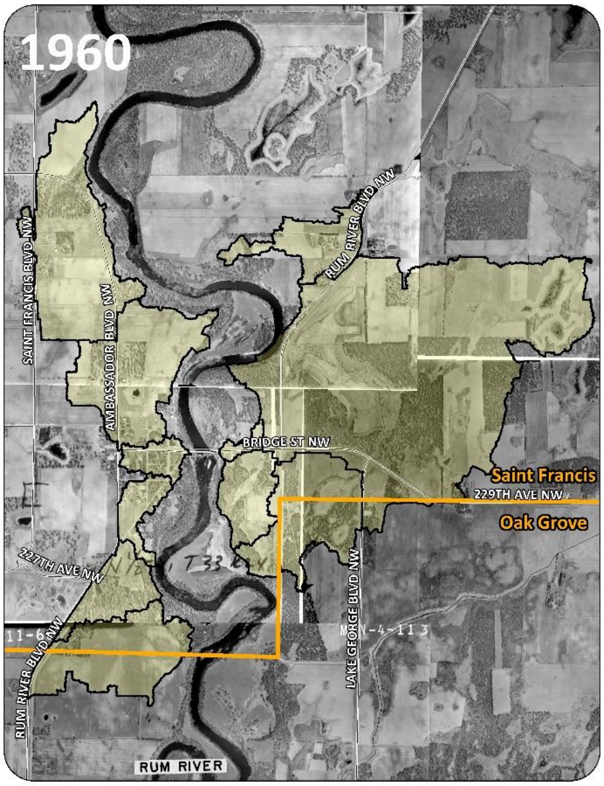

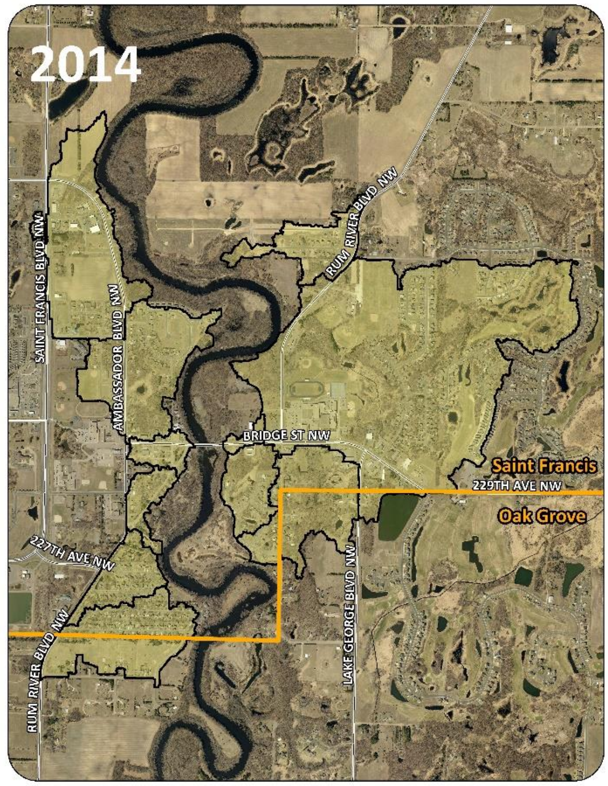

City of St. Francis
Stormwater Retrofit Analysis

Prepared by:

ANOKA CONSERVATION DISTRICT

for the

CITY OF ST. FRANCIS

August 2016

Cover photo: Aerial photos from 1960 and 2014 showing the change in land use within the subwatersheds analyzed in this report.

Disclaimer: At the time of printing, this report identifies and ranks potential BMPs for selected subwatersheds in the City of St. Francis that drain to the Rum River. This list of practices is not all-inclusive and does not preclude adding additional priority BMPs in the future. An updated copy of the report shall be housed at either the Anoka Conservation District or the City of St. Francis.

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Executive Summary

The City of St. Francis contracted the Anoka Conservation District (ACD) to complete this stormwater retrofit analysis (SRA) for the purpose of identifying and ranking water quality improvement projects in selected subwatersheds that drain to the Rum River. The subwatersheds are located on the western and eastern side of the Rum River and consist of residential, commercial, industrial, and undeveloped land uses. Total phosphorus (TP), total suspended solids (TSS), and volume were the target parameters analyzed.

This analysis is primarily intended to identify potential projects within the target area to improve water quality in the Rum River through stormwater retrofits. Stormwater retrofits refer to best management practices (BMPs) that are added to an already developed landscape where little open space exists. The process is investigative and creative. Stormwater retrofits can be improperly judged by the total number of projects installed or by comparing costs alone. Those approaches neglect to consider how much pollution is removed per dollar spent. In this SRA, both costs and pollutant reductions were estimated and used to calculate cost-effectiveness for each potential retrofit identified.

Water quality benefits associated with the installation of each identified project were individually modeled using the Source Loading and Management Model for Windows (WinSLAMM). WinSLAMM uses an abundance of stormwater data from the Upper-Midwest and elsewhere to quantify runoff volumes and pollutant loads from urban areas. It has detailed accounting of pollutant loading from various land uses, and allows the user to build a model "landscape". WinSLAMM uses rainfall and temperature data from a typical year (1959 data from Minneapolis for this analysis), routing stormwater through the user's model for each storm.

WinSLAMM estimates volume and pollutant loading based on acreage, land use, and soils information. Therefore, the volume and pollutant estimates in this report are not waste load allocations, nor does this report serve as a TMDL for the study area. The WinSLAMM model was not calibrated and was only used as an estimation tool to provide relative ranking across potential retrofit projects. Specific model inputs (e.g. pollutant probability distribution, runoff coefficient, particulate solids concentration, particle residue delivery, and street delivery files) are detailed in Appendix A – Modeling Methods.

The costs associated with project design, administration, promotion, land acquisition, opportunity costs, construction oversight, installation, and maintenance were estimated. The total costs over the assumed effective life of each project were then divided by the modeled benefits over the same time period to enable ranking by cost-effectiveness.

A variety of stormwater retrofit approaches were identified. They included:

- Bioretention,
- Hydrodynamic devices,
- Permeable Pavement,
- Iron enhanced sand filter pond benches,
- Iron-enhanced sand filter check dam,
- Existing stormwater pond modifications, and

- Water reuse.

If all of these practices were installed, significant volume and pollutant reductions could be accomplished. However, funding limitations and landowner interest make this goal unlikely. Instead, it is recommended that projects be installed in order of cost effectiveness (pounds of pollution reduced per dollar spent). Other factors, including a project's educational value/visibility, construction timing, total cost, or non-target pollutant reduction also affect project installation decisions and need to be weighed by resource managers when selecting projects to pursue.

For each type of recommended retrofit, conceptual siting is provided in the project profiles section. The intent of these figures is to provide an understanding of the approach. If a project is selected, site-specific designs must be prepared. In addition, many of the proposed retrofits (e.g. new ponds) will require engineered plan sets if selected. This typically occurs after committed partnerships are formed to install the project. Committed partnerships must include willing landowners, both public and private.

The 736-acre study area was divided into 11 catchments. Based on WinSLAMM model results, the study area contributes an estimated 252 acre-feet of runoff, 59,493 pounds of TSS, and 214 pounds of TP annually.

The tables in the Project Ranking and Selection section (pages 13-14) summarize potential projects ranked by cost effectiveness with respect to either TP or TSS. Potential projects are organized from most cost effective to least based on pollutants removed.

Installation of projects in series will result in lower total treatment than the simple sum of treatment achieved by the individual projects due to treatment train effects. Reported treatment levels are dependent upon optimal site selection and sizing. More detail about each project can be found in the catchment profile pages of this report (pages 31-76). Projects that were deemed unfeasible due to prohibitive size, number, or expense were not included in this report.

Document Organization

This document is organized into five sections, plus references and appendices. Each section is briefly discussed below.

Background

The background section provides a brief description of the landscape characteristics within the study area.

Analytical Process and Elements

The analytical process and elements section overviews the procedures that were followed when analyzing the subwatershed. It explains the processes of retrofit scoping, desktop analysis, field investigation, modeling, cost/treatment analysis, project ranking, and project selection. Refer to Appendix A – Modeling Methods for a detailed description of the modeling methods.

Project Ranking and Selection

The project ranking and selection section describes the methods and rationale for how projects were ranked. Local resource management professionals will be responsible to select and pursue projects, taking into consideration the many possible ways to prioritize projects. Several considerations in addition to project cost-effectiveness for prioritizing installation are included. Project funding opportunities may play a large role in project selection, design, and installation.

This section also ranks stormwater retrofit projects across all catchments to create a prioritized project list. The list is sorted by the amount of pollutant removed by each project over 30 years. The final cost per pound treatment value includes installation and maintenance costs over the estimated life of the project. If a practice's effective life was expected to be less than 30 years, rehabilitation or reinstallation costs were included in the cost estimate. There are many possible ways to prioritize projects, and the list provided in this report is merely a starting point.

BMP Descriptions

For each type of project included in this report, there is a description of the rationale for including that type of project, the modeling method employed, and the cost calculations used to estimate associated installation and maintenance expenses.

Catchment Profiles

The drainage areas targeted for this analysis were consolidated into 11 catchments and assigned unique identification numbers. For each catchment, the following information is detailed:

Drainage Network

The cumulative estimated volume and pollutant loading from the 11 catchments is presented.

Catchment Description

Within each catchment profile is a table that summarizes basic catchment information including acres, land cover, parcels, and estimated annual pollutant and volume loads under existing conditions. Existing conditions included notable stormwater treatment practices for which information was available from the City of St. Francis. Small, site-specific practices (e.g. rain-leader disconnect rain gardens) were not included in the existing conditions model. A brief description of the land cover, stormwater infrastructure, and any other important general information is also described in this section. Notable existing stormwater practices are explained and their estimated effectiveness presented.

Retrofit Recommendations

Retrofit recommendations are presented for each catchment and include a description of the proposed BMP, cost-effectiveness table including modeled volume and pollutant reductions, and an overview map showing the contributing drainage area for each BMP.

References

This section identifies various sources of information synthesized to produce the protocol used in this analysis.

Appendices

This section provides supplemental information and/or data used during the analysis.

Background

Many factors are considered when choosing which subwatersheds to analyze for stormwater retrofits. Water quality monitoring data, non-degradation report modeling, and TMDL studies are just a few of the resources available to help determine which water bodies are a priority. Stormwater retrofit analyses supported by a Local Government Unit with sufficient capacity (staff, funding, available GIS data, etc.) to greater facilitate the process also rank highly. For some communities a stormwater retrofit analysis complements their MS4 stormwater permit. The focus is always on a high priority waterbody.

The drainage areas studied for this analysis are located in the City of St. Francis and discharge to the Rum River. The total area of the 11 catchments is 736 acres. Six of the catchments lie on the western side of the Rum River and are roughly bound by Ambassador Boulevard to the north and 224th Avenue NW to the south. The remaining five catchments are on the eastern side of the Rum River. These catchments are bound roughly by 235th Avenue NW to the north and 227th Avenue NW to the south. These catchments were selected for analysis because they drain to a high priority waterbody, and existing treatment in many of the catchments is lacking. Stormwater retrofits may provide cost-effective options for additional treatment of runoff, thereby improving water quality in the Rum River.

The catchments analyzed are urbanized. Development throughout the City of St. Francis has resulted in the installation of subsurface drainage systems (i.e. stormwater infrastructure) to convey stormwater runoff, which increased due to the coverage of impervious surfaces throughout the catchments. The runoff generated within the areas targeted for this analysis is still conveyed to the Rum River, as it was historically. However, the runoff is now captured by catch basins and directed underground before being discharged to the Rum River via stormwater pipes.

Stormwater runoff from impervious surfaces can carry a variety of pollutants. While stormwater treatment to remove these pollutants is adequate in some areas, other areas were built prior to modern-day stormwater treatment technologies and requirements. The City of St. Francis contracted the ACD to complete this SRA for the purpose of identifying and analyzing projects to improve the quality of stormwater runoff to the Rum River. Overall subwatershed loading of TP, TSS, and stormwater volume were estimated for selected drainage areas. Proposed retrofits were modeled to estimate each practice's capability for removing pollutants and reducing volume. Finally, each project was ranked based on the estimated cost-effectiveness of the project to reduce pollutants.

Analytical Process and Elements

This stormwater retrofit analysis is a watershed management tool to identify and prioritize potential stormwater retrofit projects by performance and cost-effectiveness. This process helps maximize the value of each dollar spent. The process used for this analysis is outlined in the following pages and was modified from the Center for Watershed Protection's Urban Stormwater Retrofit Practices, Manuals 2 and 3 (Schueler & Kitchell, 2005 and Schueler et al. 2007). Locally relevant design considerations were also incorporated into the process (Technical Documents, Minnesota Stormwater Manual, 2014).

Scoping includes determining the objectives of the retrofits (volume reduction, target pollutant, etc.) and the level of treatment desired. It involves meeting with local stormwater managers, city staff and watershed management organization members to determine the issues in the subwatershed. This step also helps to define preferred retrofit treatment options and retrofit performance criteria. In order to create a manageable area to analyze in large subwatersheds, a focus area may be determined.

In this analysis, the focus areas were the contributing drainage areas to storm sewer outfalls directly into the Rum River. More specifically, outfalls with limited existing treatment were selected. Included are areas of residential, commercial, industrial, institutional and undeveloped land uses. Existing stormwater infrastructure maps and topography data were used to determine drainage boundaries for the 11 catchments included in this analysis.

The targeted pollutants for this study were TP and TSS, though volume was also estimated and reported. Volume of stormwater was tracked throughout this study because it is necessary for pollutant loading calculations and potential retrofit project considerations. Table 1 describes the target pollutants and their role in water quality degradation. Projects that effectively reduce loading of multiple target pollutants can provide greater immediate and long-term benefits.

Table 1: Target Pollutants

Target Pollutant	Description
Total Phosphorus (TP)	Phosphorus is a nutrient essential to plant growth and is commonly the factor that limits the growth of plants in surface water bodies. TP is a combination of particulate phosphorus (PP), which is bound to sediment and organic debris, and dissolved phosphorus (DP), which is in solution and readily available for plant growth (active).
Total Suspended Solids (TSS)	Very small mineral and organic particles that can be dispersed into the water column due to turbulent mixing. TSS loading can create turbid and cloudy water conditions and carry with it PP. As such, reductions in TSS will also result in TP reductions.
Volume	Higher runoff volumes and velocities can carry greater amounts of TSS to receiving water bodies. It can also exacerbate in-stream erosion, thereby increasing TSS loading. As such, reductions in volume may reduce TSS loading and, by extension, TP loading.

Desktop analysis involves computer-based scanning of the subwatershed for potential retrofit catchments and/or specific sites. This step also identifies areas that do not need to be analyzed because of existing stormwater infrastructure or disconnection from the target water body. Accurate GIS data are extremely valuable in conducting the desktop retrofit analysis. Some of the most important GIS layers include: 2-foot or finer topography (Light Detection and Ranging [LiDAR] was used for this analysis), surface hydrology, soils, watershed/subwatershed boundaries, parcel boundaries, high-resolution aerial photography and the stormwater drainage infrastructure (with invert elevations).

Field investigation is conducted after potential retrofits are identified in the desktop analysis to evaluate each site and identify additional opportunities. During the investigation, the drainage area and surface stormwater infrastructure mapping data were verified. Site constraints were assessed to determine the most feasible retrofit options as well as eliminate sites from consideration. The field investigation may have also revealed additional retrofit opportunities that could have gone unnoticed during the desktop search.

Modeling involves assessing multiple scenarios to estimate pollutant loading and potential reductions by proposed retrofits. WinSLAMM (version 10.2.0), which allows routing of multiple catchments and stormwater treatment practices, was used for this analysis. This is important for estimating treatment train effects associated with multiple BMPs in series. Furthermore, it allows for estimation of volume and pollutant loading at the outfall point to the waterbody, which is the primary point of interest in this type of study.

WinSLAMM estimates volume and pollutant loading based on acreage, land use, and soils information. Therefore, the volume and pollutant estimates in this report are not waste load allocations, nor does this report serve as a TMDL for the study area. The WinSLAMM model was not calibrated and was only used as an estimation tool to provide relative ranking across potential retrofit projects. Soils throughout the study area were predominantly sandy based on the information available in the Anoka County soil survey. Specific model inputs (e.g. pollutant probability distribution, runoff coefficient, particulate solids concentration, particle residue delivery, and street delivery files) are detailed in Appendix A – Modeling Methods.

The initial step was to create a “base” model which estimates pollutant loading from each catchment in its present-day state without taking into consideration any existing stormwater treatment. To accurately model the land uses in each catchment, drainage area delineations were completed using the watershed delineation tool in ArcSWAT. The drainage areas were then consolidated into catchments using geographic information systems (specifically ArcGIS). Land use data (based on 2010 Metropolitan Council land use file) were used to calculate acreages of each land use type within each catchment. Each land use polygon classification was compared with 2014 aerial photography (the most recent available) and corrected if land use had changed since 2010. This process addressed recent development throughout the study area by reclassifying land use types accordingly. Soil types throughout the subwatershed were modeled as sand and silt in this analysis based on the information available in the Anoka County soil survey. Entering the acreages, land use, and soil data into WinSLAMM ultimately resulted in a model that included estimates of the acreage of each type of source area (roof, road, lawn, etc.) in each catchment.

Once the “base” model was established, an “existing conditions” model was created by incorporating notable existing stormwater treatment practices in the catchment for which data were available from the City of St. Francis (Figure 1 and Figure 2). For example, street cleaning with mechanical or vacuum street sweepers, stormwater treatment ponds, hydrodynamic devices, and others were included in the “existing conditions” model if information was available.

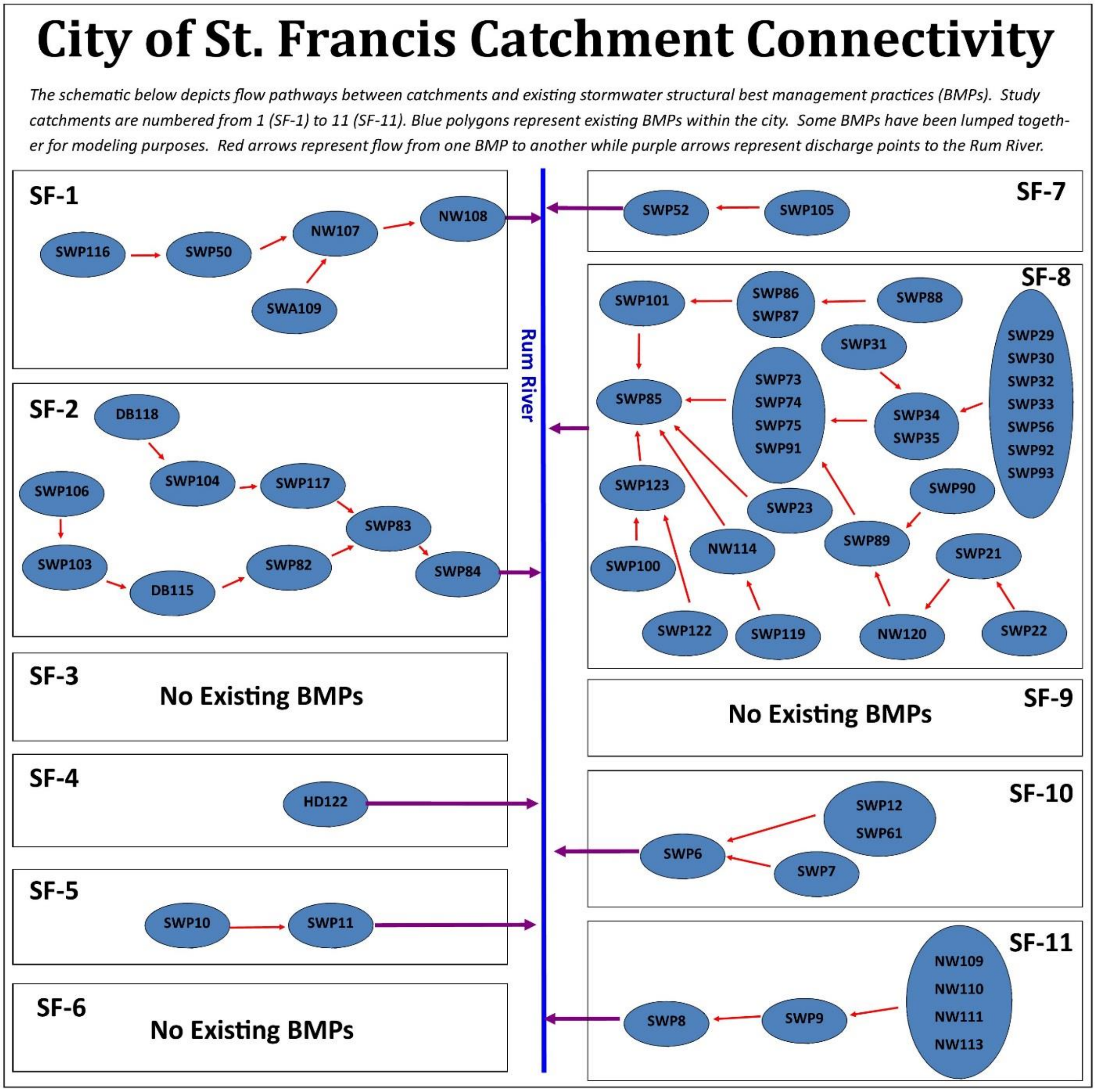


Figure 1: Schematic showing the existing BMPs in each catchment and their connectivity.

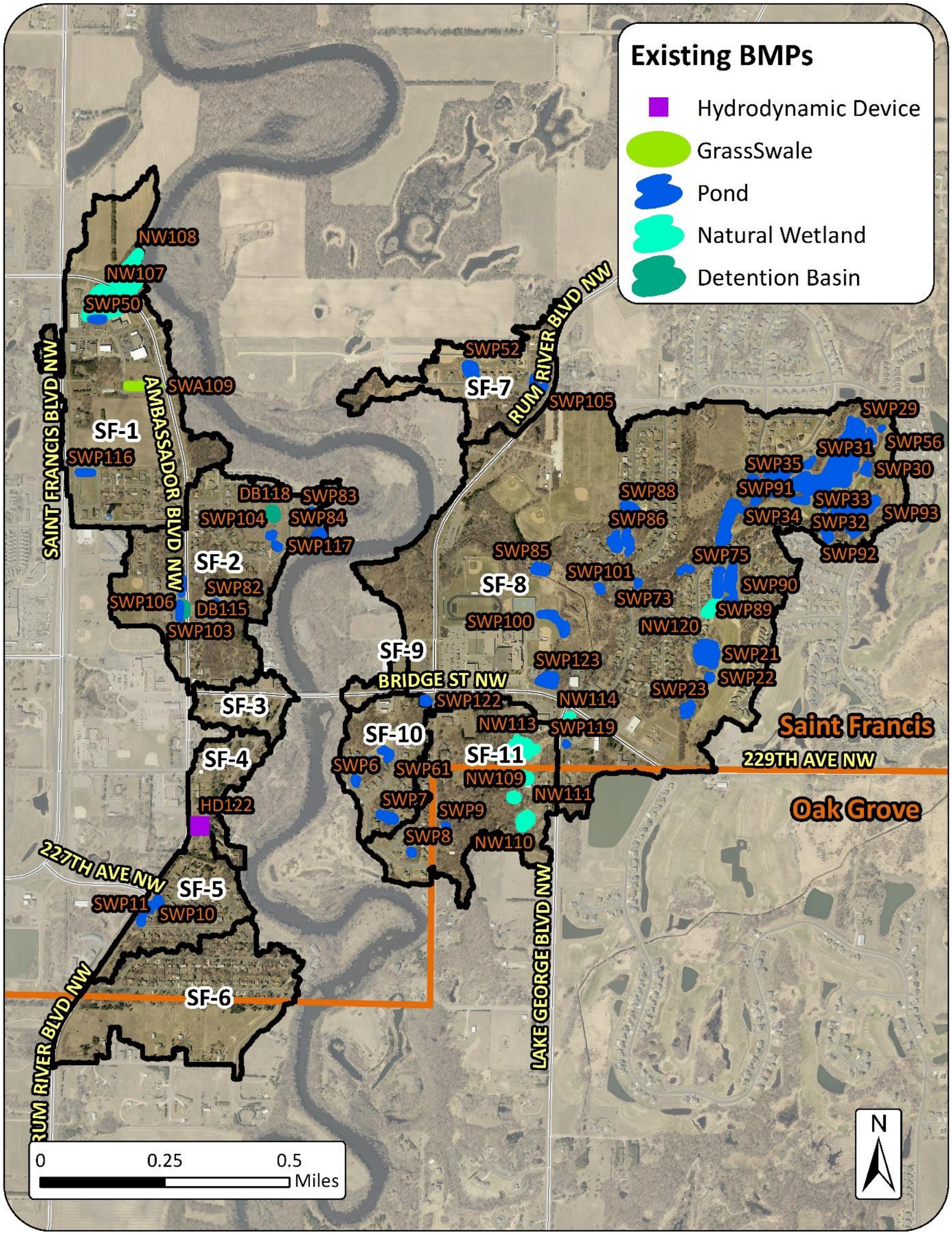


Figure 2: Study area map showing existing BMPs included in the WinSLAMM model. Street cleaning is not shown on the map but was included throughout the study area.

Finally, each proposed stormwater retrofit practice was added individually to the “existing conditions” model and pollutant reductions were estimated. Because neither a detailed design of each practice nor in-depth site investigation was completed, a generalized design for each practice was used. Whenever possible, site-specific parameters were included. Design parameters were modified to obtain various levels of treatment. It is worth noting that each practice was modeled individually, and the benefits of projects may not be additive, especially if serving the same area (i.e. treatment train effects). Reported treatment levels are dependent upon optimal site selection and sizing. Additional information on the WinSLAMM models can be found in Appendix A – Modeling Methods.

Cost estimating is essential for the comparison and ranking of projects, development of work plans, and pursuit of grants and other funds. All estimates were developed using 2016 dollars. Costs throughout this report were estimated using a multitude of sources. Costs were derived from The Center for Watershed Protection’s Urban Subwatershed Restoration Manuals (Schueler & Kitchell, 2005 and Schueler et al. 2007) and recent installation costs and cost estimates provided to the ACD by personal contacts. Cost estimates were annualized costs that incorporated the elements listed below over a 30-year period.

> **Project promotion and administration** includes local staff efforts to reach out to landowners, administer related grants, and complete necessary administrative tasks.
> **Design** includes site surveying, engineering, and construction oversight.
> **Land or easement acquisition** cover the cost of purchasing property or the cost of obtaining necessary utility and access easements from landowners.
> **Construction** calculations are project specific and may include all or some of the following: grading, erosion control, vegetation management, structures, mobilization, traffic control, equipment, soil disposal, and rock or other materials.
> **Maintenance** includes annual inspections and minor site remediation such as vegetation management, structural outlet repair and cleaning, and washout repair.

In cases where promotion to landowners is important, such as rain gardens, those costs were included as well. In cases where multiple, similar projects are proposed in the same locality, promotion and administration costs were estimated using a non-linear relationship that accounted for savings with scale. Design assistance from an engineer is assumed for practices in-line with the stormwater conveyance system, involving complex stormwater treatment interactions, or posing a risk for upstream flooding. It should be understood that no site-specific construction investigations were done as part of this stormwater retrofit analysis, and therefore cost estimates account for only general site considerations. Detailed feasibility analyses may be necessary for some projects.

Project ranking is essential to identify which projects may be pursued to achieve water quality goals. Project ranking tables are presented based on cost per pound of TP and per 1,000 pounds of TSS removed.

Project selection involves considerations other than project ranking, including but not limited to total cost, treatment train effects, social acceptability, and political feasibility.

Project Ranking and Selection

The intent of this analysis is to provide the information necessary to enable local natural resource managers to successfully secure funding for the most cost-effective projects to achieve water quality goals. This analysis ranks potential projects by cost-effectiveness to facilitate project selection. There are many possible ways to prioritize projects, and the list provided in this report is merely a starting point. Local resource management professionals will be responsible to select projects to pursue. Several considerations in addition to project cost-effectiveness for prioritizing installation are included.

Project Ranking

If all identified practices were installed (Figure 3), significant pollution reduction could be accomplished. However, funding limitations and landowner interest will be a limiting factor in implementation. The tables on the following pages rank all modeled projects by cost-effectiveness.
Projects were ranked in two ways:

1) Cost per pound of total phosphorus removed (Table 2) and
2) Cost per 1,000 pounds of total suspended solids removed (Table 3).

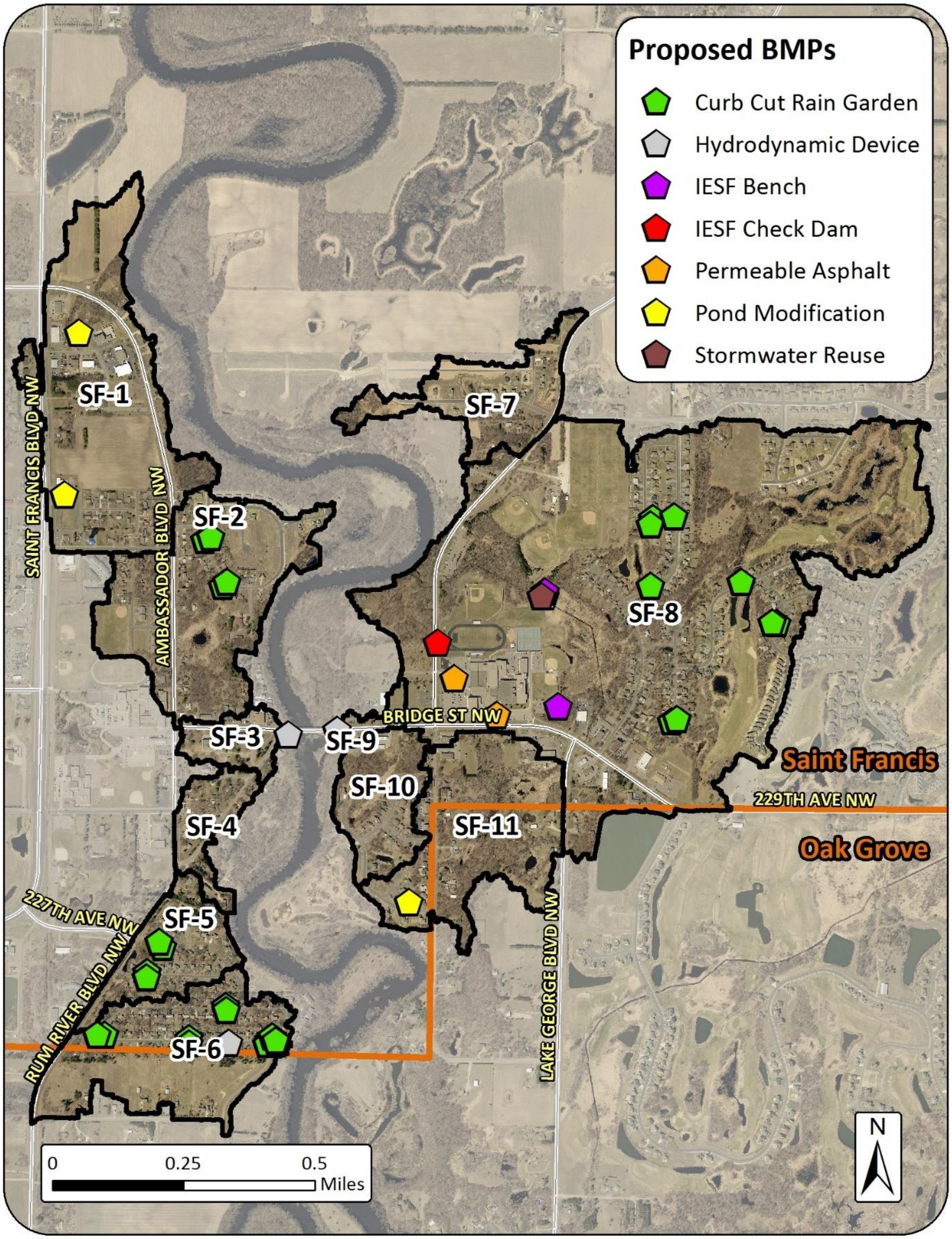


Figure 3: Catchment-wide map showing the proposed retrofits included in this report.

Table 2: Cost-effectiveness of retrofits with respect to TP reduction. Projects ranked 1 – 17 are shown on this table. TSS and volume reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost	Estimated Annual Operations & Maintenance	Estimated cost/ lb-TP/year (30-year)[1]
1	8-H	69	IESF Check Dam	Rum River Blvd. & Park Rd.	8	1.8	459	0	$15,448	$365	$500
2	6-A	54	Curb-Cut Rain Garden	Various locations in catchment	6	0.9-7.4	223-1,906	0.9-4.5	$15,844-$90,112	$225-$2,250	$710-$837
3	8-E	66	IESF Bench	St. Francis High School	8	8.5	0	0	$191,075	$689	$830
4	8-A	62	Curb-Cut Rain Garden	Various locations in catchment	8	0.5-3.7	82-659	1.1-3.8	$32,348-$81,860	$675-$2,025	$1,285-$3,507
5	5-A	50	Curb-Cut Rain Garden	227th Ct. & 227th Ave.	5	0.4-1.6	56-358	0.5-1.7	$8,982-$35,928	$225-$900	$1,311-$1,498
6	1-A	34	Pond Modification	St. Francis Blvd. & Stark Dr.	1	3.1	1,760	0	$122,840-$170,840	$1,300	$1,740-$2,256
6	8-D	65	Pond Modification	St. Francis High School	8	3.1	1,760	0	$122,840-$170,840	$1,300	$1,740-$2,256
8	8-G	68	Stormwater Reuse	St. Francis High School	8	12.3	2,434	20.7	$608,760	$3,000	$1,894
9	2-A	39	Curb-Cut Rain Garden	Woodbine St. & 232nd Ave.	2	0.3-1.1	69-270	0.4-1.5	$15,844-$40,600	$225-$900	$2,048-$2,510
10	1-B	35	Pond Modification	St. Francis Blvd. & 233rd Ave.	1	1.9	782	0	$116,840-$155,840	$1,300	$2,734-$3,418
11	6-B	55	Hydrodynamic Device	225th Lane	6	1.2	433	0	$109,752	$630	$3,574
12	8-F	67	IESF Bench	St. Francis High School	8	1.8	0	0	$179,775	$574	$3,648
13	11-A	79	Pond Modification	227th Ave. & Poppy St.	11	0.9	343	0	$104,840-$125,840	$1,300	$5,327-$6,105
14	3-A	43	Hydrodynamic Device	Bridge St. & Rum River Blvd.	3	0.7	374	0	$109,752	$630	$6,126
15	9-A	72	Hydrodynamic Device	Bridge Street	9	0.2	103	0	$28,752	$630	$7,942
16	8-B	63	Permeable Pavement	St. Francis High School	8	5.3	1,586	4.1	$643,796	$48,000	$13,106
17	8-C	64	Permeable Pavement	St. Francis High School	8	1.4	420	1.9	$313,796	$23,250	$24,078

1 [(Probable Project Cost) + 30*(Annual O&M)] / [30*(Annual TP Reduction)]

Table 3: Cost-effectiveness of retrofits with respect to TSS reduction. Projects ranked 1 – 17 are shown on this table. TP and volume reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost	Estimated Annual Operations & Maintenance	Estimated cost/ 1,000lb-TSS/year (30-year)[1]
1	8-H	69	IESF Check Dam	Rum River Blvd. & Park Rd.	8	1.8	459	0	$15,448	$365	$1,917
2	6-A	54	Curb-Cut Rain Garden	Various locations in catchment	6	0.9-7.4	223-1,906	0.9-4.5	$15,844-$90,112	$225-$2,250	$2,756-$3,377
3	1-A	34	Pond Modification	St. Francis Blvd. & Stark Dr.	1	3.1	1,760	0	$122,840-$170,840	$1,300	$3,065-$3,974
3	8-D	65	Pond Modification	St. Francis High School	8	3.1	1,760	0	$122,840-$170,840	$1,300	$3,065-$3,974
5	5-A	50	Curb-Cut Rain Garden	227th Ct. & 227th Ave.	5	0.4-1.6	56-358	0.5-1.7	$8,982-$35,928	$225-$900	$5,859-$9,364
6	1-B	35	Pond Modification	St. Francis Blvd. & 233rd Ave.	1	1.9	782	0	$116,840-$155,840	$1,300	$6,643-$8,305
7	8-A	62	Curb-Cut Rain Garden	Various locations in catchment	8	0.5-3.7	82-659	1.1-3.8	$32,348-$81,860	$675-$2,025	$7,213-$21,381
8	2-A	39	Curb-Cut Rain Garden	Woodbine St. & 232nd Ave.	2	0.3-1.1	69-270	0.4-1.5	$15,844-$40,600	$225-$900	$8,346-$10,915
9	8-G	68	Stormwater Reuse	St. Francis High School	8	12.3	2,434	20.7	$608,760	$3,000	$9,569
10	6-B	55	Hydrodynamic Device	225th Lane	6	1.2	433	0	$109,752	$630	$9,904
11	3-A	43	Hydrodynamic Device	Bridge St. & Rum River Blvd.	3	0.7	374	0	$109,752	$630	$11,466
12	11-A	79	Pond Modification	227th Ave. & Poppy St.	11	0.9	343	0	$104,840-$125,840	$1,300	$13,979-$16,019
13	9-A	72	Hydrodynamic Device	Bridge Street	9	0.2	103	0	$28,752	$630	$15,421
14	8-B	63	Permeable Pavement	St. Francis High School	8	5.3	1,586	4.1	$643,796	$48,000	$43,796
15	8-C	64	Permeable Pavement	St. Francis High School	8	1.4	420	1.9	$313,796	$23,250	$80,262
17	8-E	66	IESF Bench	St. Francis High School	8	8.5	0	0	$191,075	$689	N/A
17	8-F	67	IESF Bench	St. Francis High School	8	1.8	0	0	$179,775	$574	N/A

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [30*(Annual TSS Reduction/1,000)]

Project Selection

The combination of projects selected for pursuit could strive to achieve TSS and TP reductions in the most cost-effective manner possible. Several other factors affecting project installation decisions should be weighed by resource managers when selecting projects to pursue. These factors include but are not limited to the following:

- Total project costs,
- Cumulative treatment,
- Availability of funding,
- Economies of scale,
- Landowner willingness,
- Project combinations with treatment train effects,
- Non-target pollutant reductions,
- Timing coordination with other projects to achieve cost savings,
- Stakeholder input,
- Number of parcels (landowners) involved,
- Project visibility,
- Educational value, and
- Long-term impacts on property values and public infrastructure.

BMP Descriptions

BMP types proposed throughout the target areas are detailed in this section. This was done to reduce duplicative reporting. For each BMP type, the method of modeling, assumptions made, and cost estimate considerations are described.

BMPs were proposed for a specific site within the research area. Each of these projects, including site location, size, and estimated cost and pollutant reduction potential are noted in detail in the Catchment Profiles section. Project types included in the following sections are:

- Bioretention,
    - Curb-Cut Rain Garden
- Hydrodynamic Device,
- Permeable Pavement,
- Iron-Enhanced Sand Filter Pond Bench,
- Iron-Enhanced Sand Filter Check Dam,
- Modification to an Existing Pond, and
- Stormwater Reuse.

Bioretention

Bioretention is a BMP that uses soil and vegetation to treat stormwater runoff from roads, driveways, roof tops, and other impervious surfaces. Differing levels of volume and/or pollutant reductions can be achieved depending on the type of bioretention selected.

Bioretention can function as either filtration (biofiltration) or infiltration (bioinfiltration). Biofiltration BMPs are designed with a buried perforated drain tile that allows water in the basin to discharge to the stormwater drainage system after having been filtered through the soil. Bioinfiltration BMPs have no underdrain, ensuring that all water that enters the basins will either infiltrate into the soil or be evapotranspired into the air. Bioinfiltration provides 100% retention and treatment of captured stormwater, whereas biofiltration basins provide excellent removal of particulate contaminants but limited removal of dissolved contaminants, such as DP (Table 4).

Table 4: Matrix describing curb-cut rain garden efficacy for pollutant removal based on type.

Curb-cut Rain Garden Type	TSS Removal	PP Removal	DP Removal	Volume Reduction	Size of Area Treated	Site Selection and Design Notes
Bioinfiltration	High	High	High	High	High	Optimal sites are low enough in the landscape to capture most of the watershed but high enough to ensure adequate separation from the water table for treatment purposes. Higher soil infiltration rates allow for deeper basins and may eliminate the need for underdrains.
Biofiltration	High	Moderate	Low	Low	High	

The treatment efficacy of a particular bioretention project depends on many factors, including but not limited to the pollutant of concern, the quality of water entering the project, the intensity and duration of storm events, project size, position of the project in the landscape, existing downstream treatment, soil and vegetation characteristics, and project type (i.e. bioinfiltration or biofiltration). Optimally, new bioretention will capture water that would otherwise discharge into a priority waterbody untreated.

The volume and pollutant removal potential of each bioretention practice was estimated using WinSLAMM. In order to calculate cost-benefit, the cost of each project had to be estimated. To fully estimate the cost of project installation, labor costs for project outreach and promotion, project design, project administration, and project maintenance over the anticipated life of the practice were considered in addition to actual construction costs. If multiple projects were installed, cost savings could be achieved on the administration and promotion costs (and possibly the construction costs for a large and competitive bid).

Please note infiltration examples included in this section would require site specific investigations to verify soils are appropriate for infiltration.

Curb-cut Rain Gardens

Curb-cut rain gardens capture stormwater that is in roadside gutters and redirects it into shallow roadside basins. These curb-cut rain gardens can provide treatment for impervious surface runoff from one to many properties and can be located anywhere sufficient space is available. Because curb-cut rain gardens capture water that is already part of the stormwater drainage system, they are more likely to provide higher benefits. Generally, curb-cut rain gardens were proposed in areas without sufficient existing stormwater treatment and located immediately up-gradient of a catch basin serving a large drainage area. Bioinfiltration was solely proposed (as opposed to biofiltration) as the available soil information suggested infiltration rates could be sufficient to allow complete draw-down within 24-48 hours following a storm event (Figure 4).

Figure 4: Rain garden before/after and during a rainfall event

All curb-cut rain gardens were presumed to have a 12" ponding depth, pretreatment, mulch, and perennial ornamental and native plants. The useful life of the project was assumed to be 30 years and so all costs are amortized over that time period. Additional costs were included for rehabilitation of the garden at years 10 and 20. Annual maintenance was assumed to be completed by the landowner of the property at which the rain garden could be installed.

Hydrodynamic Devices

In heavily urbanized settings stormwater is immediately intercepted along roadway catch basins and conveyed rapidly via storm sewer pipes to its destination. Once stormwater is intercepted by catch basins, it can be very difficult to supply treatment without large end-of-pipe projects such as regional ponds. One of the possible solutions is the hydrodynamic device (Figure 5). These are installed in-line with the existing storm sewer network and can provide treatment for up to 10-15 acres of upland drainage. This practice applies some form of filtration, settling, or hydrodynamic separation to remove coarse sediment, litter, oil, and grease. These devices are particularly useful in small but highly urbanized drainage areas and can be used as pretreatment for other downstream stormwater BMPs.

Each device's pollutant removal potential was estimated using WinSLAMM. Devices were sized based on upstream drainage area to ensure peak flow does not exceed each device's design guidelines. For this analysis, Downstream Defender devices were modeled based on available information and to maintain continuity across other SRAs. Devices were proposed along particular storm sewer lines and often just upstream of intersections with another, larger line. Model results assume the device is receiving input from all nearby catch basins noted.

In order to calculate the cost-benefit, the cost of each project had to be estimated. To fully estimate the cost of project installation, labor costs for project outreach, promotion, design, administration, and maintenance over the anticipated life of the practice were considered in addition to actual construction costs. Load reduction estimates for these projects are noted in the Catchment Profiles section.

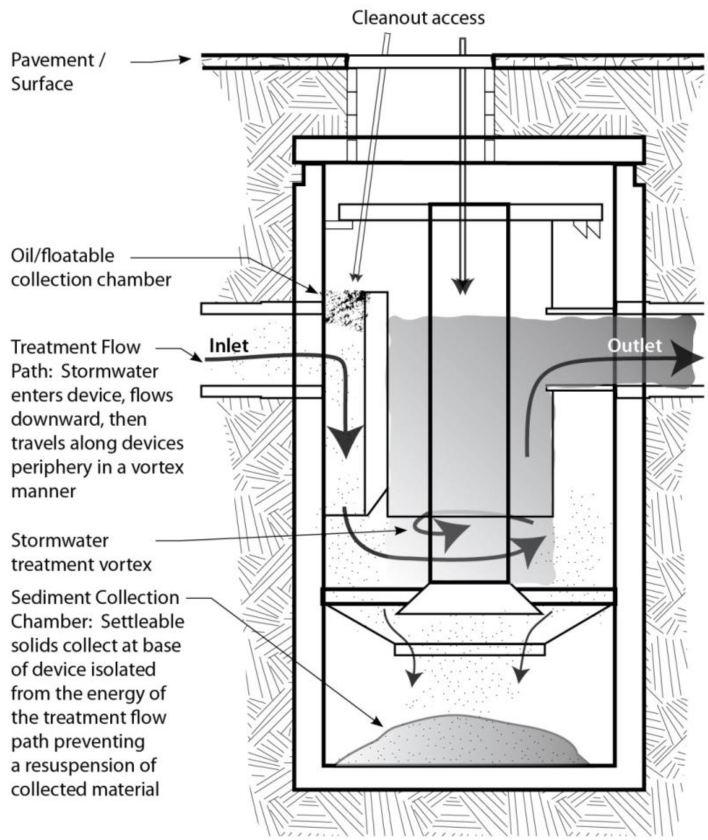


Figure 5: Schematic of a typical hydrodynamic device

Permeable Pavement

Relatively flat, low traffic areas provide a suitable location for diverting stormwater runoff from impervious surfaces to porous pavement. Void space between concrete pavers or within permeable asphalt and concrete allow water to percolate through the surface to an underlying layer(s) of coarse aggregate rock (Figure 6). This aggregate can act as a reservoir providing water quality and quantity benefits by filtering the stormwater and creating storage. From here water can either be stored temporarily or can infiltrate into the ground to recharge local groundwater aquifers. Many designs include permeable geotextile fabric to separate the un-compacted soil subgrade from the coarse aggregate and to facilitate infiltration. If soils do not allow for infiltration, a liner can be installed with an underdrain attached to nearby storm sewers or additional stormwater BMPs. This still allows for filtration through the pavement and aggregate, and reduces the peak discharge from the site.

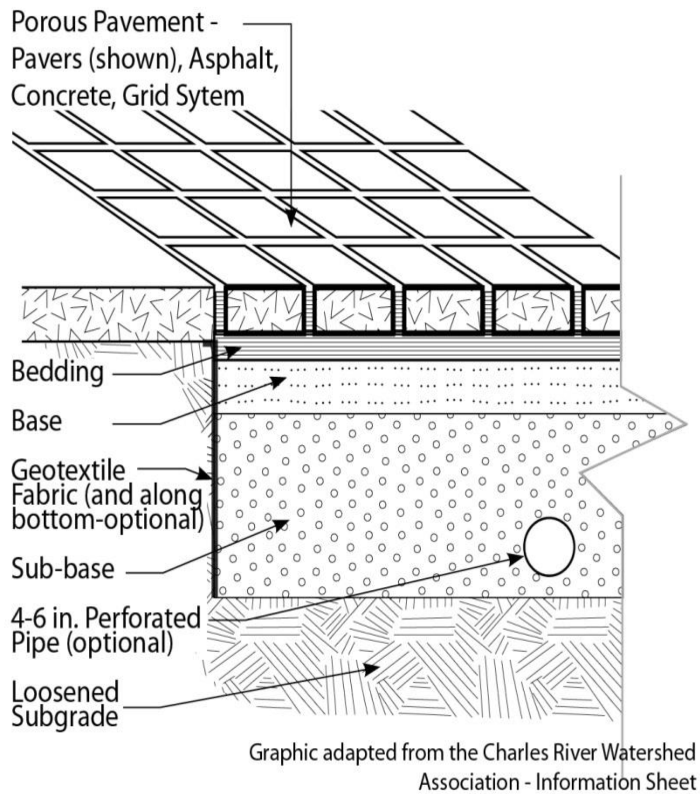


Figure 6: Schematic of typical permeable pavement surface and subgrade.

This practice is well suited for small drainage areas flowing to low traffic pavement surfaces (Figure 7). For a residential property, roof runoff can be diverted via rain leaders to a permeable driveway. On a commercial property, parking spaces within a large parking lot could be converted to permeable pavement to capture runoff from the parking lot, sidewalks, and any buildings on the property. On a residential roadway, parking spaces on either side of the street could be converted to permeable pavement. In this case the practice could treat not just the roadway but multiple properties along the

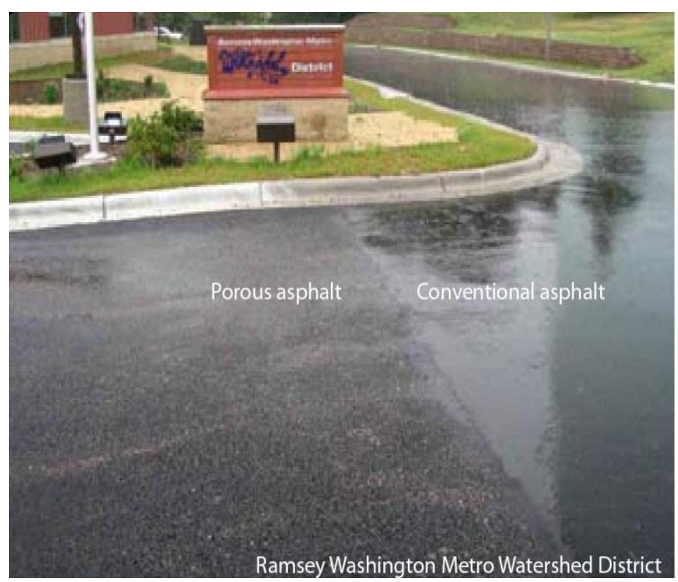


Figure 7: Photo comparing conventional and permeable asphalt

street. Permeable pavement can be used for many other scenarios in areas where soil type, seasonal water table, and frost line allow for groundwater recharge.

The capacity for this practice is completely dependent on the reservoir size within the aggregate and whether or not infiltration can occur on the site. In most cases the permeable pavement treats stormwater received from just the surface itself and adjacent impervious surfaces. A general design guideline used in this analysis is a ratio between the permeable pavement surface area and the area of the impervious surface draining to the practice of 1:2. Other than reservoir capacity, this ratio also depends on the infiltration rate (in the case that the BMP allows for infiltration) or drainage time (if an underdrain is installed) and how well the practice is maintained as clogging can greatly decrease the ability of the practice to capture runoff.

The pollutant removal potential of permeable pavement was estimated using WinSLAMM. A detailed account of the methodologies used is included in Appendix A – Modeling Methods. In order to calculate cost-benefit, the cost of each project had to be estimated. To fully estimate the cost of project installation, labor costs for project outreach, promotion, design, administration, and maintenance over the anticipated life of the practice were considered in addition to actual construction costs. Load reduction estimates for these projects are noted in the Catchment Profiles section.

Iron-Enhanced Sand Filter Pond Bench

Wet retention ponds, although very effective in treating stormwater for suspended sediment and nutrients bound to sediment, have shown a limited ability at retaining dissolved species of nutrients. This is most notable for phosphorus, which easily adsorbs to sediment when in particulate form. Median values for pollutant removal percentage by wet retention ponds are 84% for TSS and 50% for TP (MN Stormwater Manual). For the case of phosphorus, dissolved species typically constitute 40-50% of TP in urban stream systems, but only 34% (median efficiency; Weiss et al., 2005) of dissolved phosphorus is treated by the pond. Thus, a majority of the phosphorus escaping wet retention ponds is in dissolved form. This has important effects downstream as dissolved phosphorus is a readily available nutrient for algal uptake in waterbodies and can be a main cause for nutrient eutrophication.

To address this deficiency, researchers at the University of Minnesota developed a method to augment phosphorus retention within a sand filter. They've named this technology the "Iron Enhanced Sand Filter" (IESF; Figure 8). Locally, this practice has also gone by the name "Minnesota Filter." IESFs rely on the properties of iron to bind dissolved phosphorus as it passes through an iron rich medium. Depending on topographic characteristics of the installation sites, IESFs can rely on gravitational flow and natural water level fluctuation, or water pumping to hydrate the IESF. IESFs must be designed to prevent anoxic conditions in the filter medium because such conditions will release the bound phosphorus. Because IESFs are intended to remove dissolved phosphorus and not organic phosphorus, they are typically constructed just downstream of stormwater ponds, minimizing the amount of suspended solids that could compromise their efficacy and drastically increase maintenance. As an alternative to an IESF, a ferric-chloride injection system could be installed to bind dissolved phosphorus into a flocculent, which would settle in the bottom of the new pond.

Figure 8 shows an IESF that is installed at an elevation slightly above the normal water level of the pond so that following a storm event the increase in depth of the pond would be first diverted to the IESF. The filter would have drain tile installed along the base of the trench and would outlet downstream of the current pond outlet. Large storm events that overwhelm the IESF's capacity would exit the pond via the existing outlet.

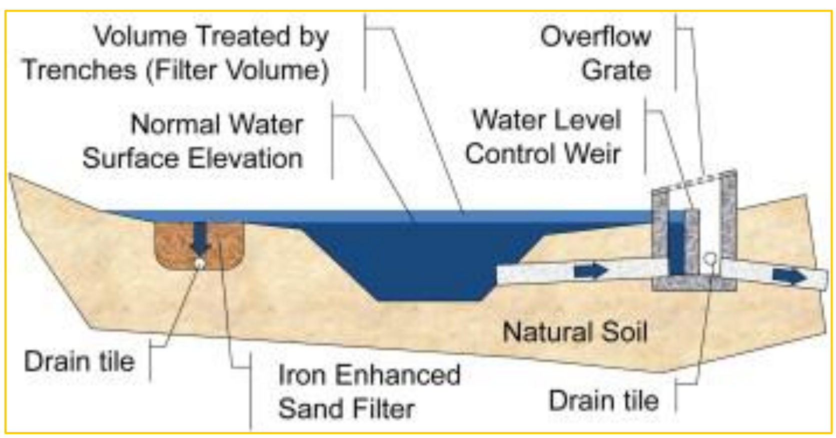


Figure 8: Iron Enhanced Sand Filter Concept (Erickson & Gulliver, 2010)

Benefits for stormwater ponds were modeled utilizing WinSLAMM. After selecting an optimal pond configuration in terms of cost-benefit, or by using the existing pond configuration if no updates are needed, modeling for an IESF was also completed in WinSLAMM. WinSLAMM is able to calculate flow through constructed features such as rain gardens with underdrains, soil amendments, and controlled overflow elevations. An IESF works much the same way. Storm event based discharge volumes and phosphorus concentrations estimated by WinSLAMM at the pond outlet were entered into WinSLAMM as inputs into the IESF. Various iterations of IESFs were modeled to identify an optimal treatment level compared to construction costs and space available. A detailed account of the methodologies used is included in Appendix A – Modeling Methods.

To account for the DP treated by the IESF, an additional 80% DP removal was assumed for each IESF in addition to any removal by the pond. This value is based on laboratory and field tests performed by the University of Minnesota (Erickson & Gulliver, 2010) and assumes only removal of DP species within the device. Load reduction estimates for these projects are noted in the Catchment Profiles sections.

In order to calculate cost-benefit, the cost of each project had to be estimated. IESF projects were assumed to involve some excavation and disposal of soil, land acquisition (if necessary), erosion control, and vegetation management. Additionally, project engineering, promotion, administration, construction oversight, and long-term maintenance had to be considered in order to capture the true cost of the effort. Annual maintenance costs were estimated to be $10,000 per acre of IESF based on information received from local, private consulting firms. Additional costs associated with specific projects are listed in Appendix B – Project Cost Estimates.

Iron Enhanced Sand Filter Check Dam

Permeable check dams provide additional treatment for pollutants within ditches and grassed waterways through two processes. First, the dams act as a barrier to flow through the channel, allowing sediment and particulate pollutants to drop out of solution upstream of the dam. This promotes infiltration and evaporation of stormwater as well. Second, any water retained behind the dam can seep through a sand filter located within the rock dam. The sand, mixed with iron filings (similar to an IESF pond bench), creates an opportunity for dissolved pollutant species to be filtered out of the stormwater runoff.

Figure 9: Rock check dams in a small ditch (www.casfm.org/stormwater_committee/LID-Summary.htm)

These practices are often installed in a series, from two to a dozen practices depending on the length and slope of the ditch or waterway (Figure 9). For short ditch lengths a single check dam is often sufficient. The dams include an inner sand filter mixed with iron filings. The ratio of iron filings to sand should be between 5-8% by weight and these should be mixed thoroughly prior to installation. The sand-iron mix should be encased within a permeable membrane allowing for flow in and out of the filter. This filter is surrounded by rocks to promote settling and inhibit clogging of the filter.

It is recommended that these dams are installed such that the buried rock toe of the upstream dam is at the same elevation as the top of any downstream dams (Figure 10). This reduces the likelihood of scouring downstream of dams as water flowing over the dam intercepts ponded water rather than erodible soil. Also, the top of the most upstream dam should be installed below the outlet elevation of any pipe draining to the practice to ensure water does not back up into the upstream storm sewer infrastructure.

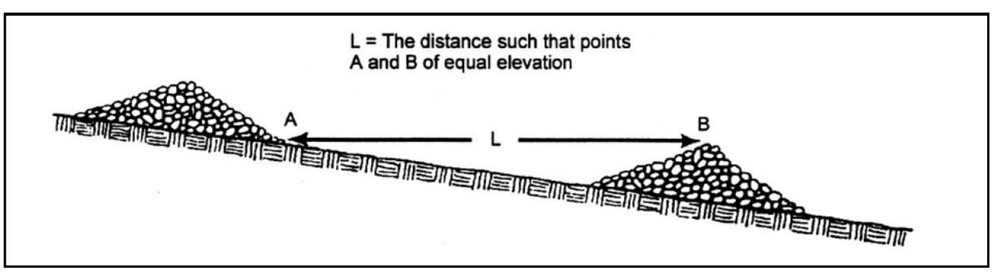


Figure 10: Check dam schematic (MPCA 2000)

The pollutant removal potential of permeable check dams was estimated using WinSLAMM. The ponding volume behind the dams was determined using LIDAR. Based on results of other IESFs, it was assumed that 80% of DP flowing through the dam was retained (Erickson & Gulliver, 2010). In order to calculate cost-benefit, the cost of each project had to be estimated. To fully estimate the cost of project installation, labor costs for project outreach, promotion, design, administration, and maintenance over the anticipated life of the practice were considered in addition to actual construction costs. Load reduction estimates for these projects are noted in the Catchment Profiles section.

Modification to an Existing Pond

Developments prior to enactment of contemporary stormwater rules often included wet detention ponds which were frequently designed purely for flood control based on the land use, impervious cover, soils, and topography of the time. Changes to stormwater rules since the early 1970's have greatly altered the way ponds are designed.

Enactment of the National Pollution Discharge Elimination System (NPDES) in 1972 followed by research conducted by the Environmental Protection Agency in the early 1980's as part of the Nationwide Urban Runoff Program (NURP) set standards by which stormwater best management practices should be designed. Municipal Separate Storm Sewer System (MS4) guidelines issued in 1990 (affecting cities with more than 100,000 residents) and 1999 (for cities with less than 100,000 residents) required municipalities to obtain an NPDES permit and develop a plan for managing their stormwater.

Listed below are five strategies which exist for retrofitting a stormwater pond to increase pollutant retention (modified from *Urban Stormwater Retrofit Practices*):

- Excavate pond bottom to increase permanent pool storage,
- Raise the embankment to increase flood pool storage,
- Widen pond area to increase both permanent and flood pool storage,
- Modify the riser, and
- Update pool geometry or add pretreatment (e.g. forebay).

These strategies can be employed separately or together to improve BMP effectiveness. Each strategy is limited by cost-effectiveness and constraints of space on the current site. Pond retrofits are preferable to most new BMPs as additional land usually does not need to be purchased, stormwater easements already exist, maintenance issues change little following project completion, and construction costs are greatly cheaper. There can also be a positive effect on reducing the rate of overflow from the pond, thereby reducing the risk for erosion (and thus further pollutant generation) downstream.

For this analysis, all existing ponds were modeled in the water quality model WinSLAMM to estimate their effectiveness based on best available information for pond characteristics and land use and soils. One proposed modification, excavating the pond bottom to increase storage, often has a very wide range in expected cost due to the nature of the excavated soil. If the soil has been contaminated and requires landfilling, the cost for disposal can quickly lead to a doubling in project cost. For this reason, projects which include the excavation of ponds have been priced based on the following criteria:

- Management Level 1: Dredged pond soil is suitable for use or reuse on properties with a residential or recreational use,
- Management Level 2: Dredged pond soil is suitable for use or reuse on properties with an industrial use, or
- Management Level 3: Dredged pond soil is considered significantly contaminated and must be managed specifically for the contaminants present

Costs within each of these levels can even range widely, but were estimated to be $20/cu-yd., $35/cu-yd., and $50/cu-yd. for levels 1, 2, and 3, respectively. Additional costs associated with specific projects are listed in Appendix B – Project Cost Estimates.

Stormwater Reuse

Some of the major water resource issues today include improving stormwater treatment (quantity and quality), increasing groundwater recharge, and decreasing public water usage. Stormwater reuse is a powerful BMP strategy that can be applied to address each of these on a scale ranging from a single property to an entire neighborhood. Stormwater reuse allows for the utilization of stormwater to supplement potable sources, in applications that do not require water to be at a standard set for consumption. An example of this might be using captured stormwater to irrigate a golf course or recreational fields.

Benefits from this practice are twofold. First, stormwater runoff is given multiple opportunities for treatment. Treatment through settling, filtering, or hydrodynamic separation at the BMP site provides initial treatment of particulates, litter, and other debris. Application of the stormwater as irrigation allows for infiltration through the soil layer and treatment of the dissolved load of pollutants that may have remained. The second benefit is the reduced usage of potable water. As there is no need for highly treated water when irrigating a lawn, the stress placed on water treatment facilities and the water distribution network can be reduced.

The concept for this practice at its smallest scale is that of a rain barrel on a residential property. Runoff from the impervious roof is captured by gutters and diverted to the rain barrel until it is needed for watering the lawn or garden. At a larger scale, runoff from roofs, driveways, sidewalks, and roadways is diverted to roadway catch basins and to the storm sewer network. A cistern or similar containment unit holds water from storm sewers until it is needed for irrigation. These structures can vary in size from tens of gallons to hundreds of thousands of gallons. Stormwater detention and retention ponds are also popular choices as construction and maintenance costs are often much cheaper than underground cisterns.

These practices often require significant capital investment as updates to the local stormwater infrastructure may be needed. Large cisterns, whether made of concrete or plastic, can require hefty transportation and installation costs. Additional infrastructure may also be necessary, including a foundation to sustain the weight of the cistern (whether above or below ground), pump, and conveyance system. A detailed maintenance plan is also necessary even if other forms of pretreatment (e.g. hydrodynamic device, baffle, etc.) are installed. Lastly, during dry periods potable water may still be needed to supplement stormwater when the containment unit is empty.

The pollutant removal potential of stormwater reuse devices was estimated using the stormwater model WinSLAMM. In order to calculate cost-benefit, the cost of each project had to be estimated. To fully estimate the cost of project installation, labor costs for project outreach, promotion, design, administration, and maintenance over the anticipated life of the practice were considered in addition to actual construction costs. Costs for projects are listed in detail in Appendix B – Project Cost Estimates. Load reduction estimates for these projects are noted in the Catchment Profiles section.

Catchment Profiles

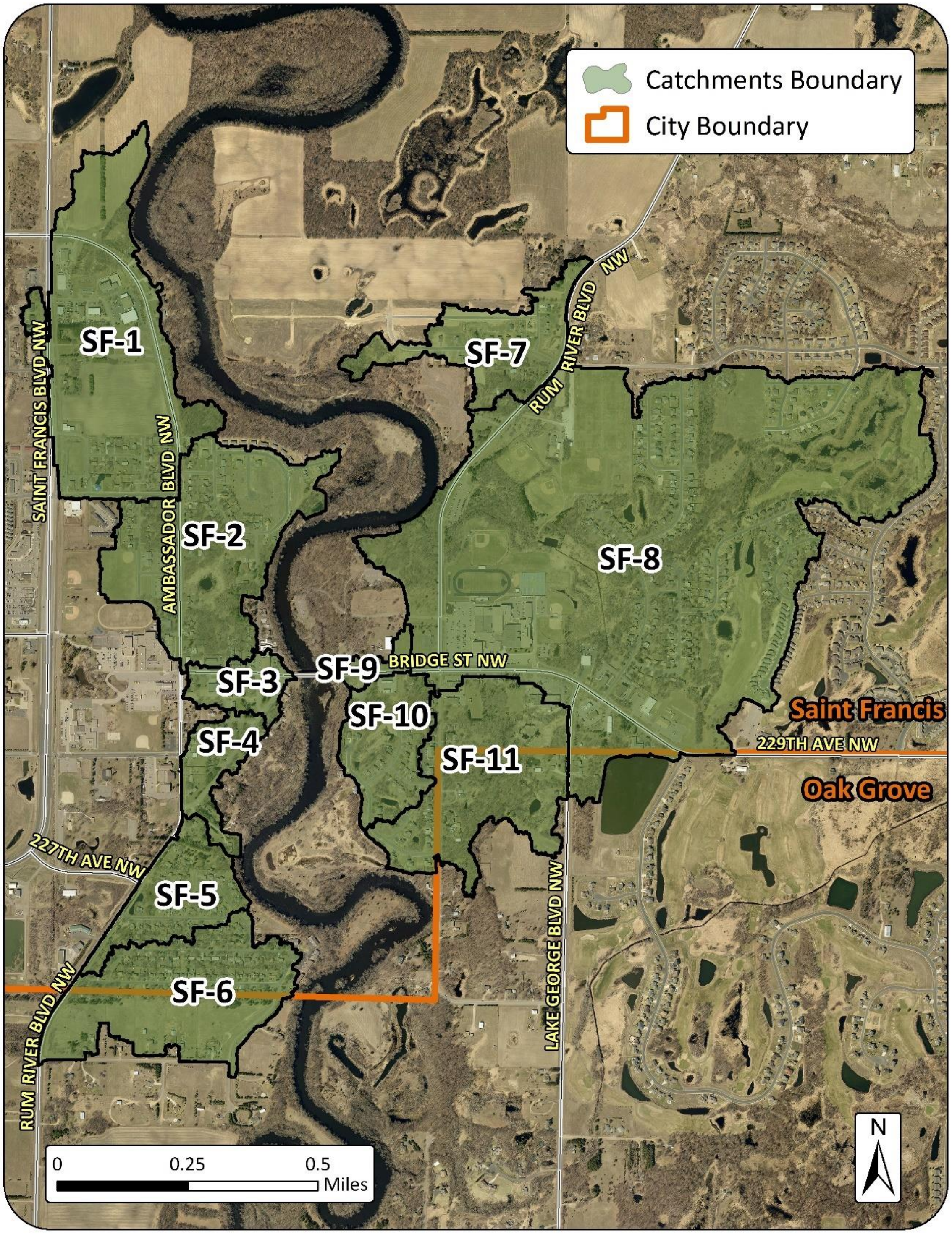
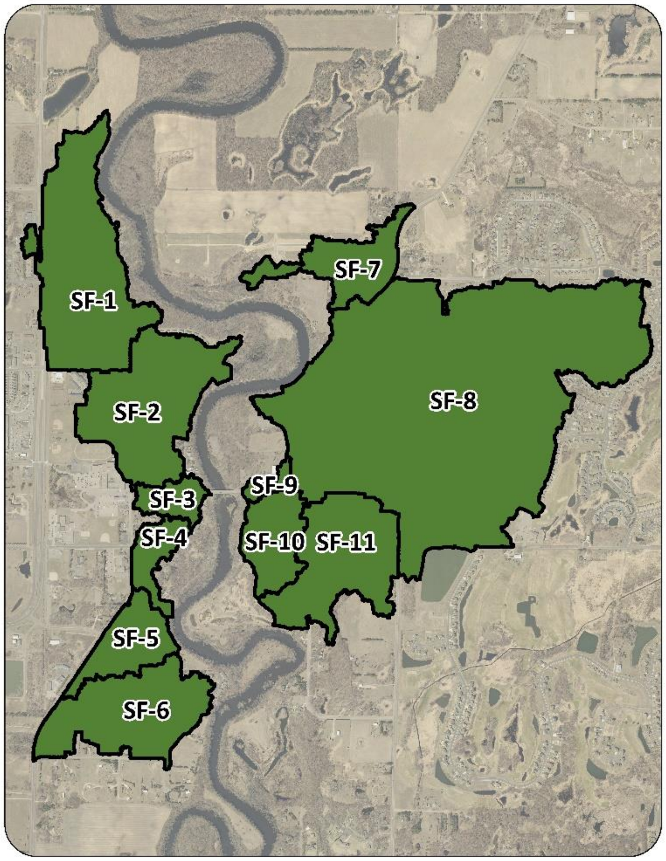


Figure 11: The 736-acre drainage area was divided into 11 catchments for this analysis. Catchment profiles on the following pages provide additional information.

St. Francis Research Area Drainage Network



Existing Network Summary	
Acres	735.8
Dominant Land Cover	Residential
Volume (ac-ft/yr)	252.3
TP (lb/yr)	214.2
TSS (lb/yr)	59,493

DRAINAGE NETWORK SUMMARY

The research area chosen for this stormwater retrofit analysis includes developed areas of the City of St. Francis draining directly to the Rum River. Generally speaking, this has excluded areas draining to Seelye Brook (west of the Rum River) or Anoka County Ditch 18 (east of the Rum River). Taking into account these factors, 735.8 acres were included for analysis. Catchments were chosen based on each major outfall to the Rum River, and were numbered in order from the western Rum River banks to the eastern Rum River banks and from north to south on each bank. The outfalls on the western banks of the Rum River are located at the outlet of natural wetland NW108 (Catchment SF-1), at the outlet of retention pond SWP84 (SF-2), southeast of the Rum River Boulevard - Bridge Street intersection (SF-3), southeast of the Rum River Boulevard – River Drive intersection (SF-4), northeast of the Vintage Street – 227th Avenue intersection (SF-5), and east of the Tulip Street – 225th Lane, intersection. The outfalls on the eastern banks are located southwest of 235th Avenue – 235th Lane intersection (SF-7), west of Rum River Boulevard within Rum River North Park (SF-8), southwest of Bridge Street (SF-9), southwest of the Silverado Street - Quay Street intersection, and southwest of the Poppy Street – 227th Avenue intersection (SF-10).

Land use in the catchments contributing stormwater pollutants to the river system (Catchments SF-1 to SF-11) are predominantly single family and multi-family residential. Other land uses include commercial, institutional (primarily the high school), industrial, and park. The land use in the catchment is 43%

residential, 6% institutional, 4% commercial, 2% industrial, and the remaining 45% is open space, park or water. Soils in the area are generally sandy but also include hydric zones in and around major wetland complexes (such as in Catchment SF-8).

EXISTING STORMWATER TREATMENT

Forty-four existing BMPs were identified within the study area and modeled in WinSLAMM. SF-1 has two natural wetlands (NW108 and NW107), a grass swale (SWA109), and two stormwater ponds (SWP50 and SWP116). All the stormwater runoff generated within this 92-acre catchment receives some treatment from one of the mentioned BMPs.

Nine existing BMPs are within SF-2. These BMPs include two infiltration basins (DB118 and DB115) and seven stormwater ponds (SWP103, SWP106, SWP82, SWP117, SWP104, SWP83, and SWP84). All of the stormwater runoff generated within this 72-acre catchment receives some treatment from one of these BMPs.

SF-4 has an existing hydrodynamic device (HD122), which treats stormwater runoff from 11.6 acres of the 14.3-acre catchment.

SF-5 has two existing stormwater ponds (SWP10 and SWP11), which treat stormwater runoff from the majority of the 25.6-acre catchment.

SF-7 has two existing stormwater ponds (SWP52 and SWP105), which treat stormwater from 26 acres of the 31-acre catchment.

Thirty existing BMPs are in SF-8 and nineteen individual BMPs were modeled (hydrologically connected BMPs were modeled as a single BMP). These BMPs include two natural wetlands (NW114 and NW120), and seventeen stormwater ponds (SWP101, SWP86/SWP87, SWP88, SWP31, SWP29/SWP30/SWP32/SWP33/SWP56/SWP92/SWP93, SWP34/SWP35, SWP73/SWP74/SWP75/SWP91, SWP85, SWP123, SWP23, SWP90, SWP100, SWP89, SWP21, SWP22, SWP119, and SWP122). Stormwater generated from all but 86.3 acres of the 341.7-acre catchment receives some treatment by these existing BMPs.

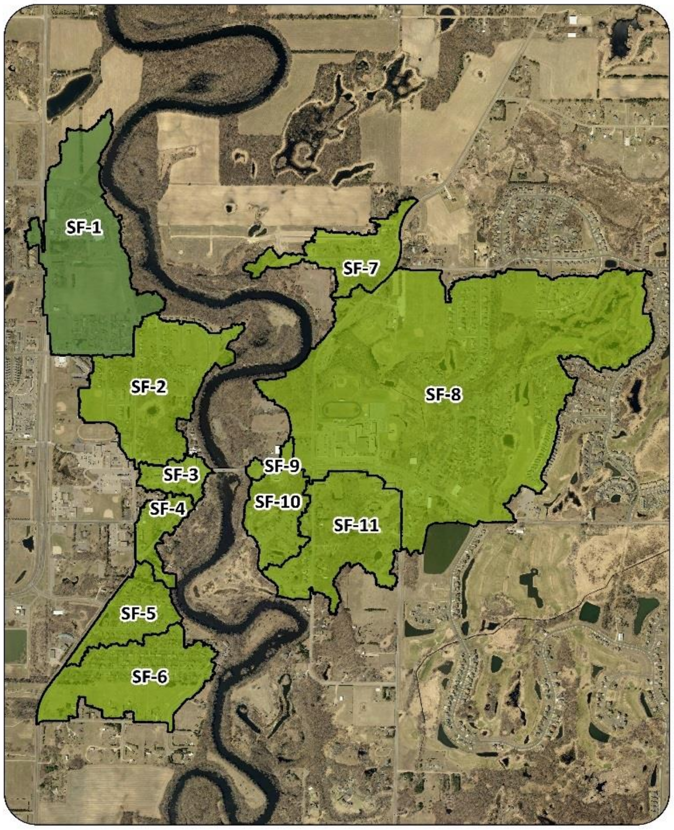
SF-10 has four existing stormwater ponds (SWP6, SWP7, and SWP12/SWP61), two of which were modeled as one stormwater pond in WinSLAMM. All the stormwater runoff generated within the 25.6-acre catchment receives some treatment by these stormwater ponds.

SF-11 has two existing stormwater ponds (SWP8 and SWP9) and four natural wetlands (NW109, NW110, NW111, and NW113). The wetlands were modeled as a single BMP in WinSLAMM due to their hydrologic connectivity. These existing BMPs treat stormwater runoff generated from 58.1 acres of the 59.3-acre catchment.

SF-3, SF-6, and SF-9 do not have any existing BMPs.

Catchment SF-1

Existing Catchment Summary	
Acres	92.1
Dominant Land Cover	Open
Parcels	68
Volume (ac-ft/yr)	31.9
TP (lb/yr)	23.7
TSS (lb/yr)	7,687



CATCHMENT DESCRIPTION

Catchment SF-1 is the northernmost catchment in this analysis and includes a variety of land uses such as single family residential, commercial, industrial, agricultural, and undeveloped parcels. The catchment is bound by Ambassador Boulevard (and its adjacent properties) to the north and east, 233rd Avenue to the south, and St. Francis Boulevard to the west. The northern border includes approximately 13 acres of agricultural land which drains to the NW108 wetland. Soils in the catchment are generally sandy, with loamy fine sands (Braham series; hydrologic group B) near 233rd Avenue and loamy sands (Zimmerman and Nymore Series, hydrologic group A) to the north. Wetland soils (Seelyeville series; hydrologic group A/D) are also prevalent within natural wetlands NW107 and NW108.

EXISTING STORMWATER TREATMENT

A series of four BMPs, including two retention ponds (SWP 50 and SWP116) and two natural wetlands (NW107 and NW108), treat a storm sewer line draining residential, commercial, and industrial properties between 233rd Avenue and Ambassador Drive. A grass swale (SWA109) also treats residential and industrial properties along Zea St. prior to discharging into a ditch along Ambassador Drive. In addition to these five structural BMPs, street cleaning is provided by the City of St. Francis twice per year using mechanical sweepers.

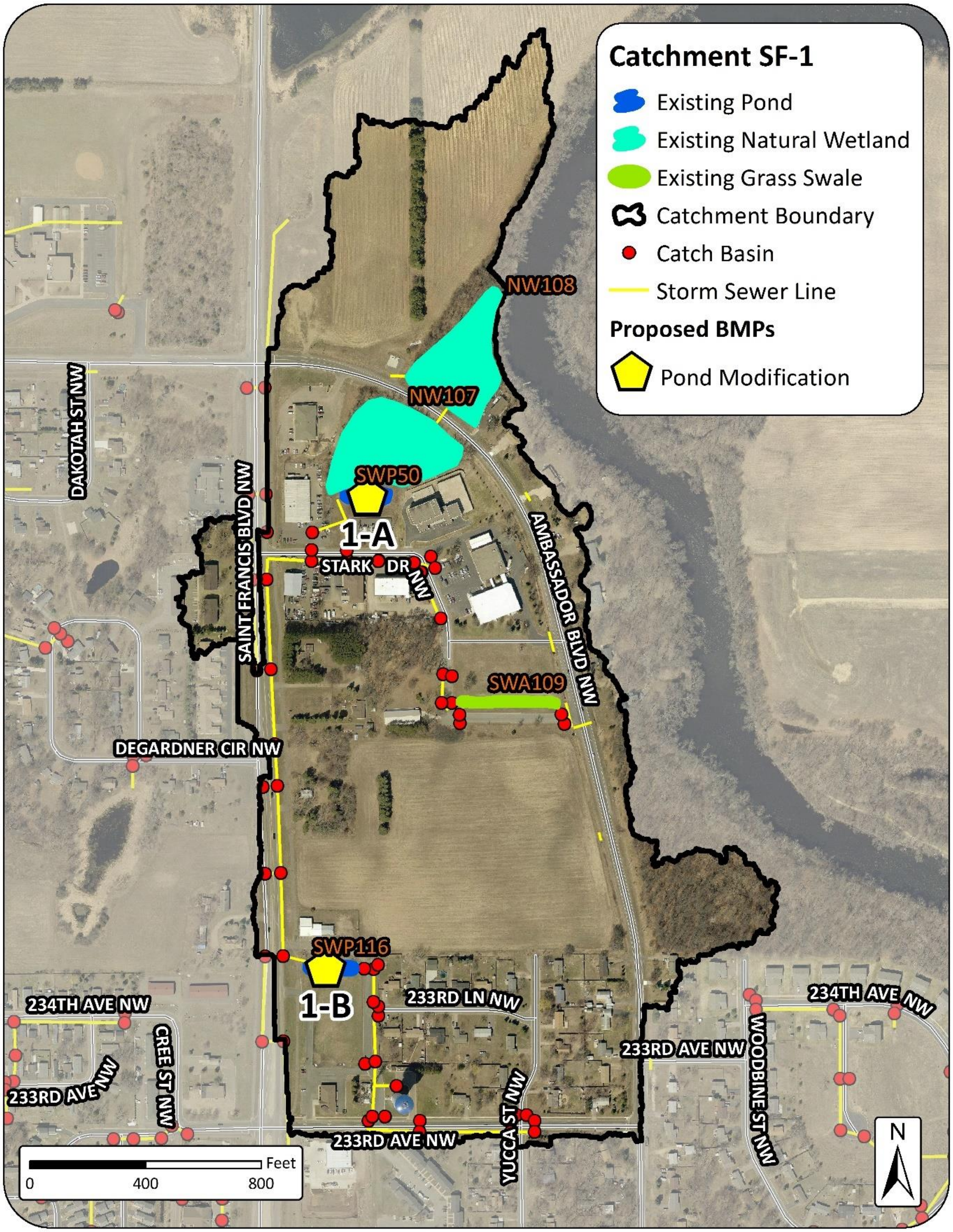
Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	6			
	BMP Types	2 Wetlands, 2 Ponds, 1 Grass Swale, Street Cleaning			
	TP (lb/yr)	36.9	13.2	36%	**23.7**
	TSS (lb/yr)	14,770	7,083	48%	**7,687**
	Volume (acre-feet/yr)	33.3	1.4	4%	**31.9**

PROPOSED RETROFITS OVERVIEW

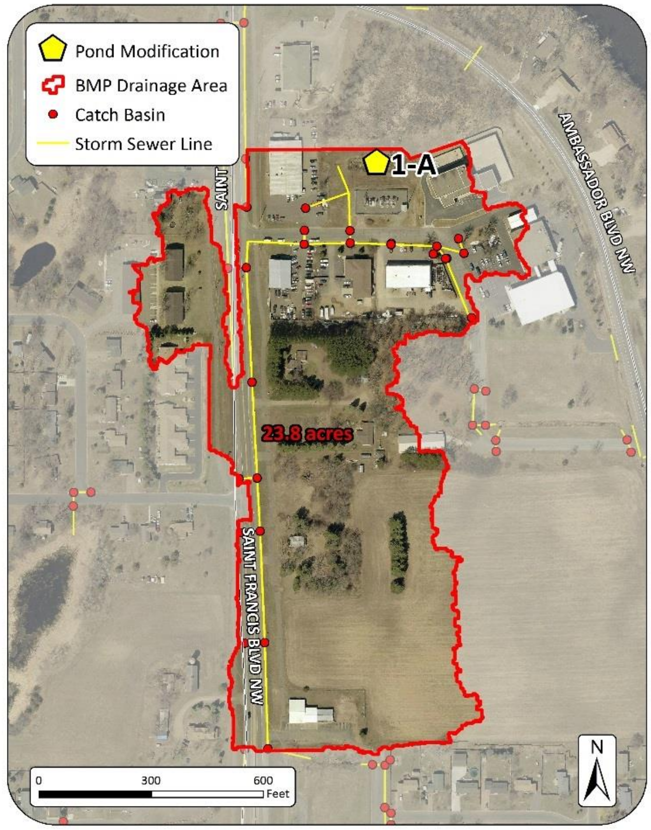
Modifications to stormwater retention ponds SWP50 and SWP116 were proposed to take advantage of available area and ponding depth, which was not currently being utilized. These modifications could improve the treatment efficiency of the stormwater ponds and the increased storage will improve volume reductions within the catchment.

RETROFIT RECOMMENDATIONS



Project ID: 1-A

St. Francis Blvd. & Stark Dr.
Pond Modification



Drainage Area – 23.8 acres
Location – SWP50
Property Ownership – Private (Connexus Energy)
Site Specific Information – A modification is proposed for SWP50, which is located on Connexus Energy Property, roughly at St. Francis Boulevard and Stark Drive. This pond currently treats water from 23.8 acres but is undersized relative to the contributing drainage area. Excavating 1,600 cubic yards of material could increase the size of the pond and improve the treatment efficiency. The price of the pond modification is shown below with three different management levels based on the contamination of the excavated soil.

BMP Modification

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Pond Management Level	1		2		3	
	Amount of Soil Excavated	1,600	cu-yards	1,600	cu-yards	1,600	cu-yards
	TP (lb/yr)	3.1	13.1%	3.1	13.1%	3.1	13.1%
	TSS (lb/yr)	1,760	22.9%	1,760	22.9%	1,760	22.9%
	Volume (acre-feet/yr)	0.0	0.1%	0.0	0.1%	0.0	0.1%
Cost	Administration & Promotion Costs*	$5,840		$5,840		$5,840	
	Design & Construction Costs**	$117,000		$141,000		$165,000	
	Total Estimated Project Cost (2016)	**$122,840**		**$146,840**		**$170,840**	
	Annual O&M***	$1,300		$1,300		$1,300	
Efficiency	30-yr Average Cost/lb-TP	**$1,740**		**$1,998**		**$2,256**	
	30-yr Average Cost/1,000lb-TSS	**$3,065**		**$3,520**		**$3,974**	
	30-yr Average Cost/ac-ft Vol.	**N/A**		**N/A**		**N/A**	

*Indirect Cost: 80 hours at $73/hour

**Direct Cost: See Appendix B for detailed cost information

***$1,000/acre of pond surface area - Annual inspection and sediment/debris removal from pretreatment area

Project ID: 1-B

St. Francis Blvd. & 233rd Ave. Pond Modification

Drainage Area – 15.8 acres
Location – SWP116
Property Ownership – Public (City of St. Francis)
Site Specific Information – A modification is proposed for SWP116, which is located on City of St. Francis property, roughly at St. Francis Boulevard and 233rd Drive. This pond currently treats water from 15.8 acres but is undersized relative to the contributing drainage area. Excavating 1,300 cubic yards of material could increase the size of the pond and improve the treatment efficiency. The price of the pond modification is shown below with three different management levels based on the contamination of the soil.

	BMP Modification						
	Cost/Removal Analysis	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**
Treatment	**Pond Management Level**	1		2		3	
	Amount of Soil Excavated	1,300	cu-yards	1,300	cu-yards	1,300	cu-yards
	TP (lb/yr)	1.9	8.0%	1.9	8.0%	1.9	8.0%
	TSS (lb/yr)	782	10.2%	782	10.2%	782	10.2%
	Volume (acre-feet/yr)	0.0	0.0%	0.0	0.0%	0.0	0.0%
Cost	**Administration & Promotion Costs***	$5,840		$5,840		$5,840	
	Design & Construction Costs**	$111,000		$130,500		$150,000	
	Total Estimated Project Cost (2016)	**$116,840**		**$136,340**		**$155,840**	
	Annual O&M***	$1,300		$1,300		$1,300	
Efficiency	**30-yr Average Cost/lb-TP**	**$2,734**		**$3,076**		**$3,418**	
	30-yr Average Cost/1,000lb-TSS	**$6,643**		**$7,474**		**$8,305**	
	30-yr Average Cost/ac-ft Vol.	**N/A**		**N/A**		**N/A**	

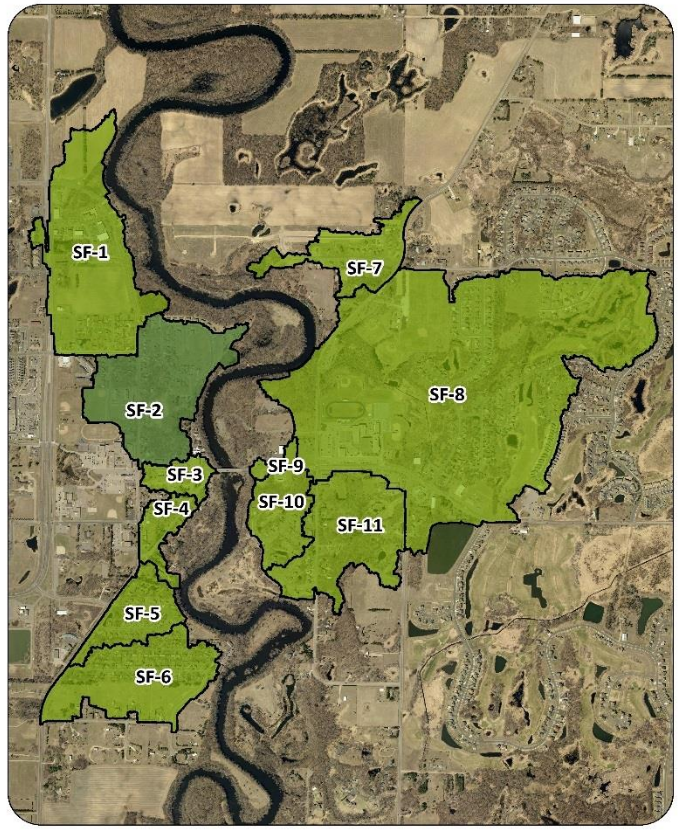
*Indirect Cost: 80 hours at $73/hour

**Direct Cost: See Appendix B for detailed cost information

***$1,000/acre of pond surface area - Annual inspection and sediment/debris removal from pretreatment area

Catchment SF-2

Existing Catchment Summary	
Acres	72.1
Dominant Land Cover	Residential
Parcels	201
Volume (acre-feet/yr)	24.6
TP (lb/yr)	13.9
TSS (lb/yr)	1,988



CATCHMENT DESCRIPTION

Catchment SF-2 spans from portions of St. Francis Middle School in the west to the Rum River in the east. Land use in the catchment is primarily single family residential. Other land uses include multi-family residential apartments west of Ambassador Boulevard., St. Francis Middle School, and undeveloped parcels scattered throughout the catchment. One of these undeveloped areas, the Rum River Terrace Development, has been parceled-out and may see development soon. Upland soils in SF-2 are exclusively of the sandy Braham and Zimmerman series.

EXISTING STORMWATER TREATMENT

A total of ten BMPs treat stormwater throughout the catchment. Multi-family and single family residential properties west of Ambassador Boulevard. are treated by retention ponds SWP103 and SWP106. These ponds flow through the detention basin DB115 before passing into the pond/wetland SWP82. This pond eventually overflows into the 232nd Avenue storm sewer network and into retention pond SWP83.

In the Rum River Terrace Development three retention ponds, SWP83, SWP104, and SWP117, as well as infiltration basin DB118 all treat drainage from developed and as of yet undeveloped parcels. SWP83, the furthest downstream, overflows into retention pond SWP84, which subsequently discharges directly into the Rum River.

In addition to these ponds, street cleaning is provided by the City of St. Francis twice per year using street sweepers.

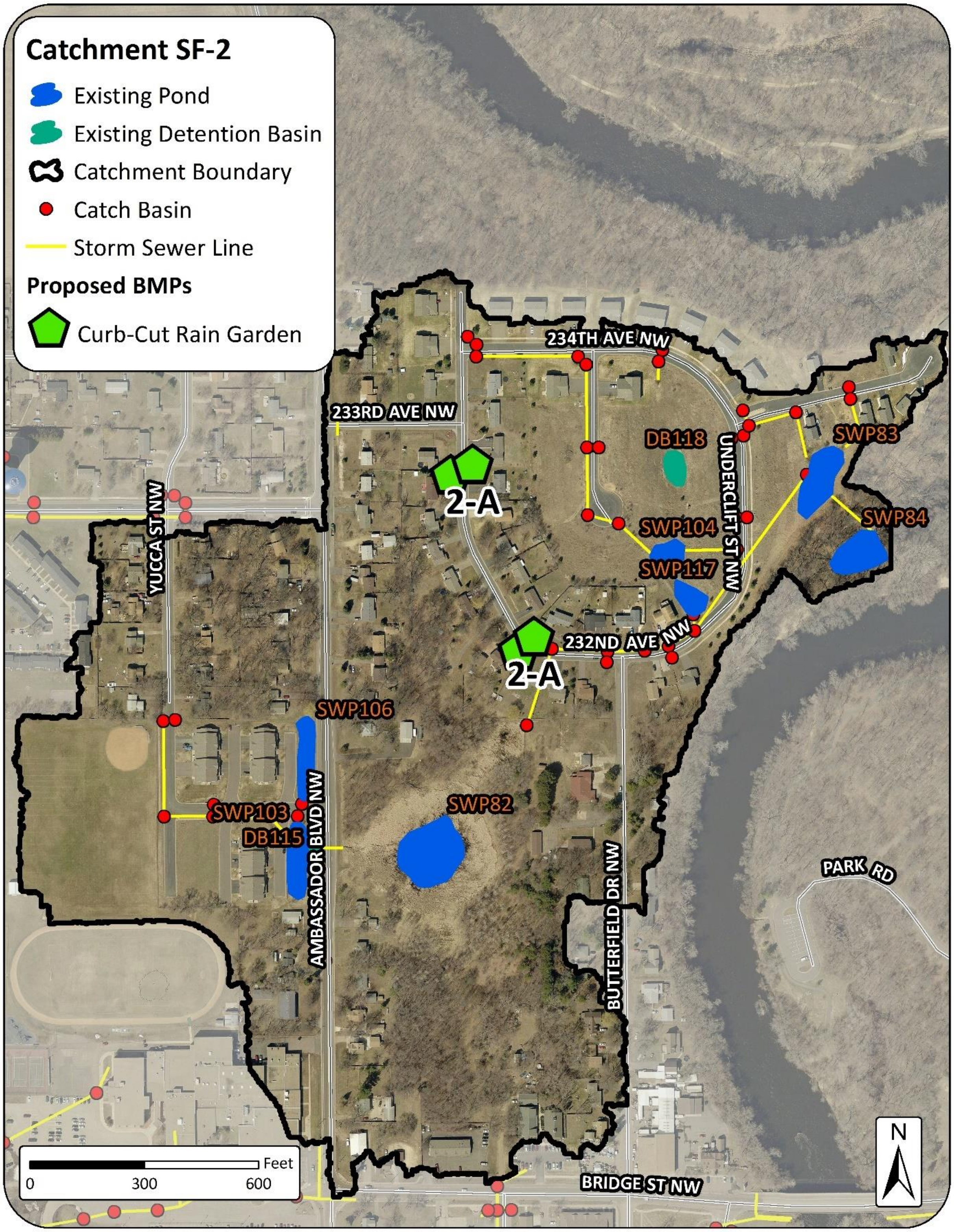
Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	10			
	BMP Types	2 Bioretention Basins, 7 Ponds, Street Cleaning			
	TP (lb/yr)	37.4	23.5	63%	**13.9**
	TSS (lb/yr)	11,176	9,188	82%	**1,988**
	Volume (acre-feet/yr)	27.0	2.3	9%	**24.6**

PROPOSED RETROFITS OVERVIEW

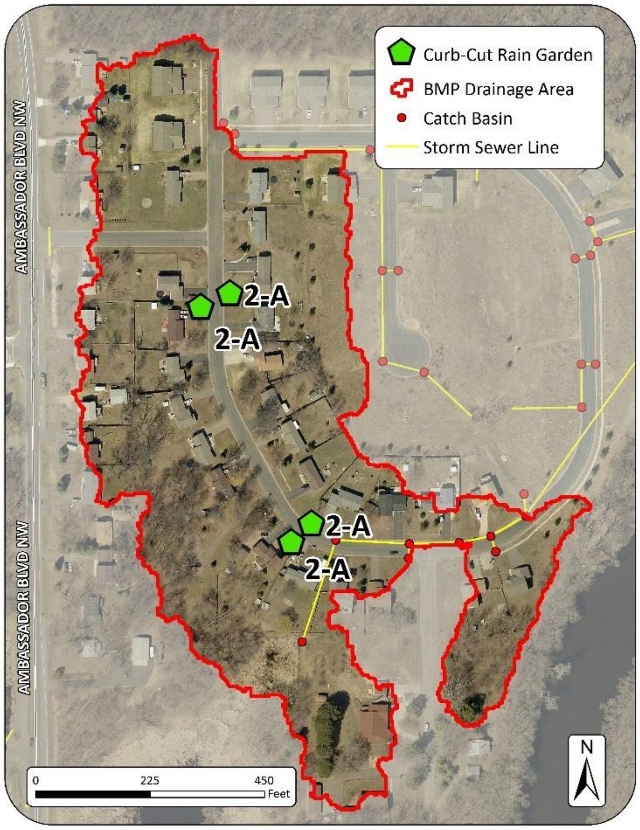
Curb-cut rain gardens are proposed in the developed areas of Rum River Terrace where soils are conducive to infiltration practices. Up to four rain gardens were proposed along Woodbine Street and 232nd Avenue.

RETROFIT RECOMMENDATIONS



Project ID: 2-A

Curb-Cut Rain Gardens



Drainage Area – 1.5 – 6.0 acres
Location – Woodbine Street NW and 232nd Avenue NW
Property Ownership – Private
Site Specific Information – Single-family lots in the northeastern portion of the catchment provide various locations for curb-cut rain gardens to treat stormwater pollutants originating from private properties. Considering typical landowner participation rates, scenarios with one, two, and four rain gardens were analyzed to treat the drainage area.

	Curb-Cut Rain Garden						
	Cost/Removal Analysis	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1		2		4	
	Total Size of BMPs	250	sq-ft	500	sq-ft	1,000	sq-ft
	TP (lb/yr)	0.3	2.2%	0.6	4.3%	1.1	7.9%
	TSS (lb/yr)	69	3.5%	136	6.8%	270	13.6%
	Volume (acre-feet/yr)	0.4	1.6%	0.8	3.2%	1.5	6.1%
Cost	**Administration & Promotion Costs***	$1,606		$3,212		$6,424	
	Design & Construction Costs**	$7,376		$14,752		$29,504	
	Total Estimated Project Cost (2016)	**$8,982**		**$17,964**		**$35,928**	
	Annual O&M***	$225		$450		$900	
Efficiency	**30-yr Average Cost/lb-TP**	**$1,748**		**$1,748**		**$1,907**	
	30-yr Average Cost/1,000lb-TSS	**$7,600**		**$7,712**		**$7,769**	
	30-yr Average Cost/ac-ft Vol.	**$1,345**		**$1,384**		**$1,408**	

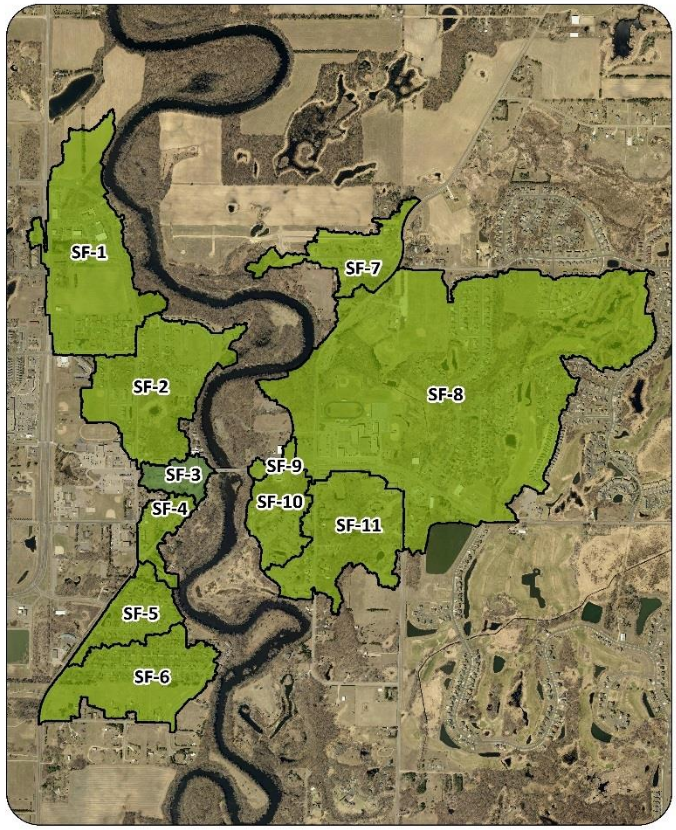
*Indirect Cost: (10 hours/BMP at $73/hour base cost) + (12 hours/BMP at $73/hour)

**Direct Cost: ($26/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Catchment SF-3

Existing Catchment Summary	
Acres	11.6
Dominant Land Cover	Commercial
Parcels	38
Volume (acre-feet/yr)	7.6
TP (lb/yr)	6.5
TSS (lb/yr)	2,475



CATCHMENT DESCRIPTION

Catchment SF-3 includes all of the geographical area that drains stormwater to an outfall just south of Bridge Street. The catchment includes commercial, institutional, single family residential, multi-family residential, park, and undeveloped land uses. Due to the high density of businesses and residences in SF-3, this is one of the more impervious catchments in this analysis.

EXISTING STORMWATER TREATMENT

Street cleaning is provided by the City of St. Francis twice per year using street sweepers. No structural stormwater devices exist within this catchment.

Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	6.8	0.3	4%	**6.5**
	TSS (lb/yr)	2,650	175	7%	**2,475**
	Volume (acre-feet/yr)	7.6	0.0	0%	**7.6**

PROPOSED RETROFITS OVERVIEW

A hydrodynamic device was proposed upstream of the Bridge Street outfall. As proposed, this device could treat the full 11.6 acres draining to the Rum River outfall in Catchment SF-3.

RETROFITS CONSIDERED BUT REJECTED

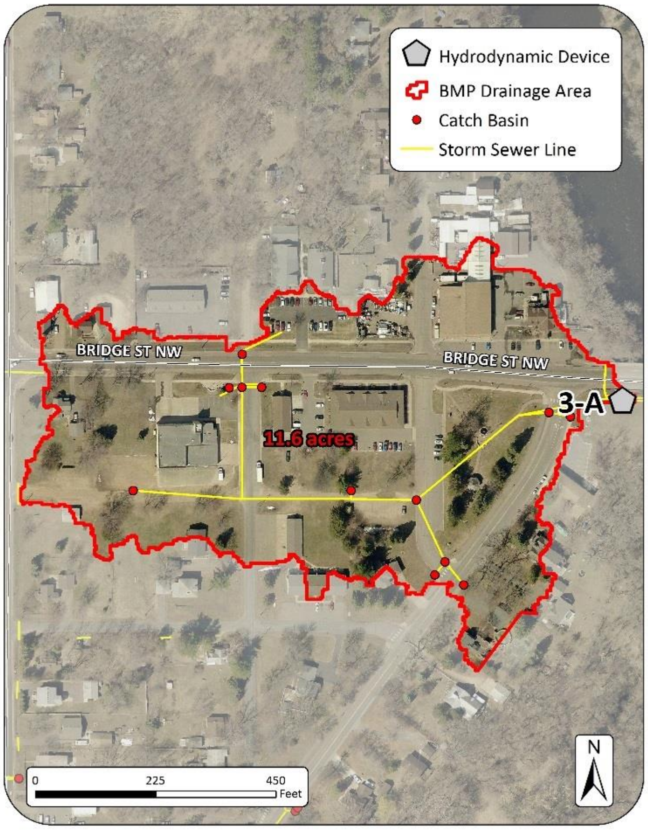
Bioretention practices, including curb-cut rain gardens and boulevard bioswales, were considered for various public and private properties across the catchment. These BMPs were not proposed as the drainage areas to these practices were not large enough to justify the installation of the BMP.

RETROFIT RECOMMENDATIONS

Project ID: 3-A

Bridge St. & Rum River Blvd.
Hydrodynamic Device

Drainage Area – 11.6 acres
Location – Bridge Street NW and Rum River Boulevard NW
Property Ownership – Public
Site Specific Information – A hydrodynamic device could be installed on the southeast corner of Bridge Street and Rum River Boulevard. This device would accept runoff from the entire catchment. It could remove TP and TSS from stormwater runoff prior to discharging into the Rum River.



	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	0.7	10.8%
	TSS (lb/yr)	374	15.1%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2016)	**$109,752**	
	Annual O&M***	$630	
Efficiency	**30-yr Average Cost/lb-TP**	**$6,126**	
	30-yr Average Cost/1,000lb-TSS	**$11,466**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

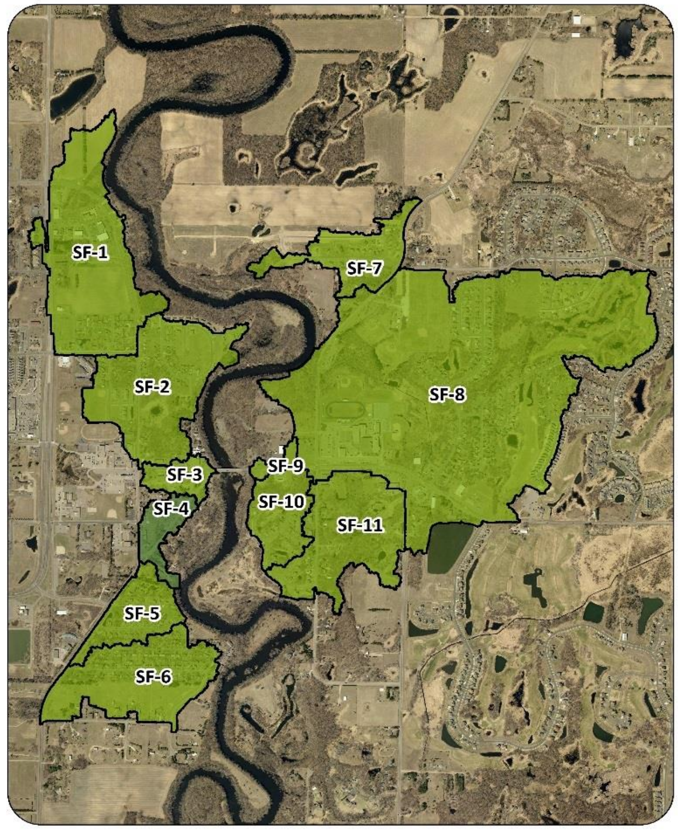
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (3 cleanings/year)*(3 hours/cleaning)*($70/hour)

Catchment SF-4

Existing Catchment Summary	
Acres	14.3
Dominant Land Cover	Residential
Parcels	28
Volume (acre-feet/yr)	7.6
TP (lb/yr)	9.4
TSS (lb/yr)	2,520



CATCHMENT DESCRIPTION

Catchment SF-4 extends from 229th Avenue in the north to River Drive in the south and from Ambassador Boulevard. in the west to Rum River Boulevard. in the east. The catchment is predominantly single family lots overlying sandy soils.

EXISTING STORMWATER TREATMENT

Stormwater generated within the catchment first flows to either (1) the ditch east of Ambassador Boulevard or (2) the storm sewer line below Rum River Boulevard. At the Ambassador Boulevard – Rum River Boulevard intersection stormwater from both the ditch and the Rum River Boulevard storm sewer line are directed through a hydrodynamic device (HD122). Storm flow leaving the device is discharged into the Rum River approximately 600' east of the BMP.

In addition to the hydrodynamic device, street cleaning is provided twice annually by the City of St. Francis with mechanical sweepers.

Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	2			
	BMP Types	Hydrodynamic Device, Street Cleaning			
	TP (lb/yr)	10.8	1.4	13%	**9.4**
	TSS (lb/yr)	3,101	581	19%	**2,520**
	Volume (acre-feet/yr)	7.6	0.0	0%	**7.6**

PROPOSED RETROFITS OVERVIEW

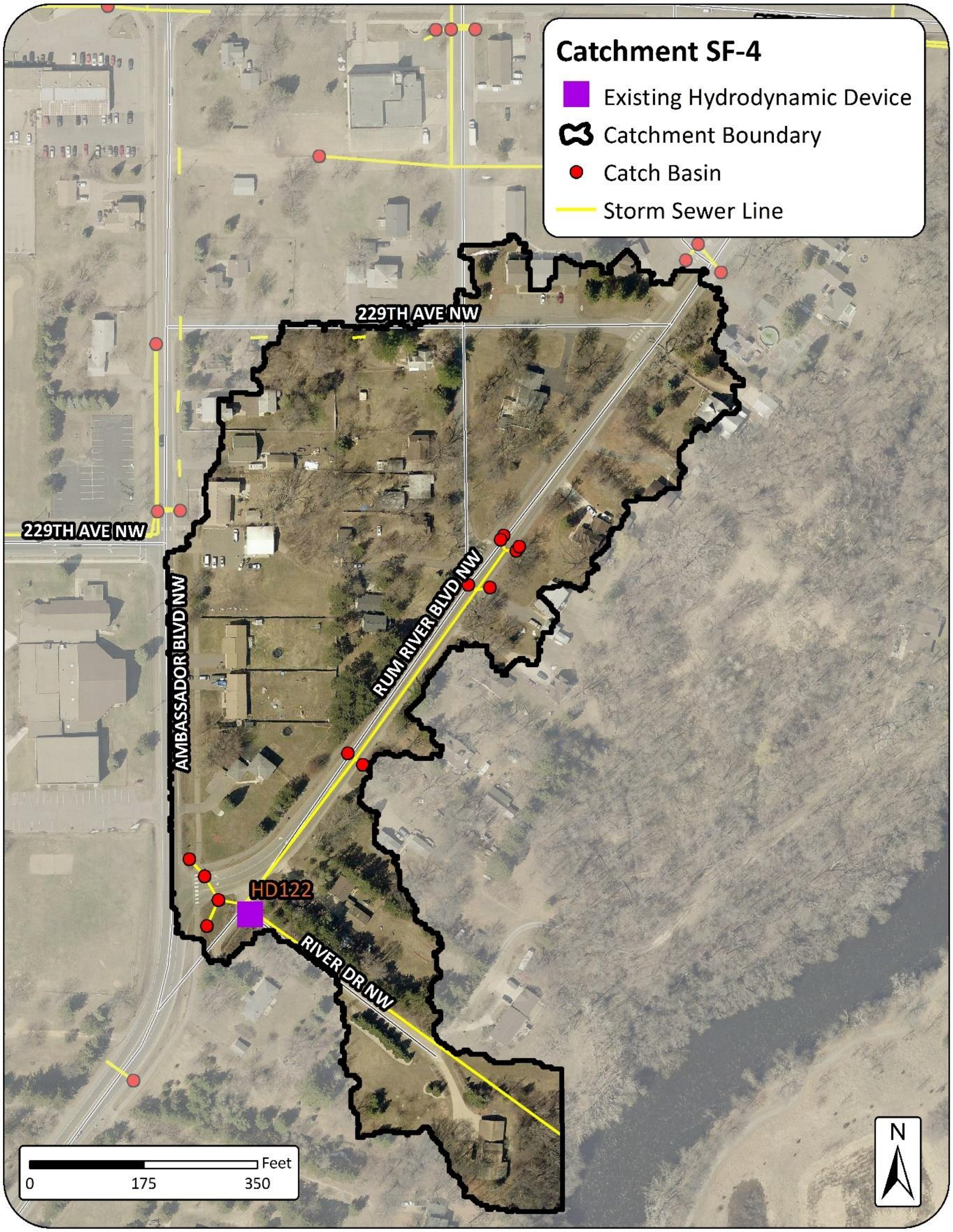
No stormwater retrofits were proposed in this catchment.

RETROFITS CONSIDERED BUT REJECTED

Bioretention practices, including curb-cut rain gardens and boulevard bioswales, were considered for various private properties across the catchment. These BMPs were not proposed as the drainage areas and the amount of impervious surface upstream of these practices were not large enough to justify the installation of the BMP.

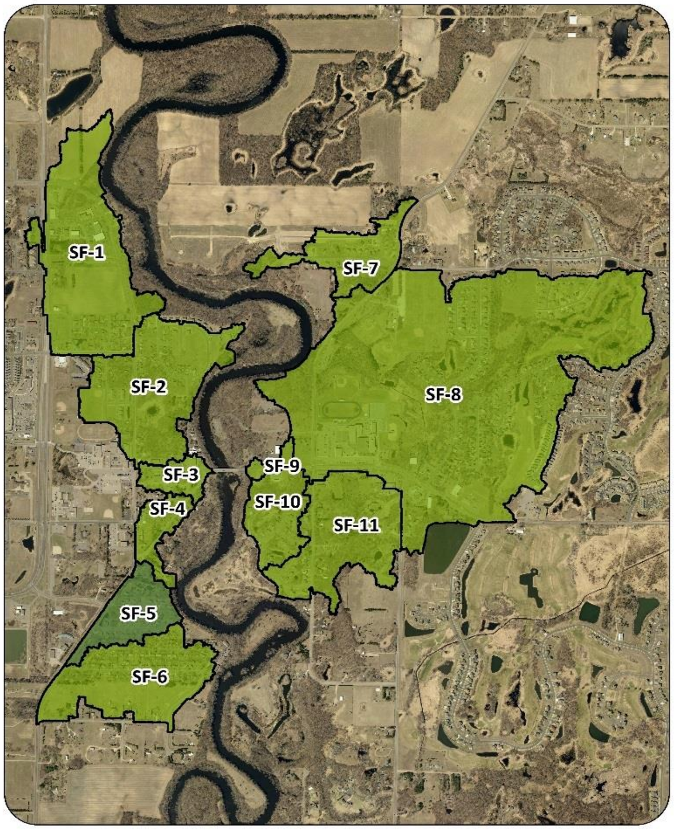
Therefore, the map below was included solely to provide additional detail of the catchment boundary, associated land uses, and streets.

RETROFIT RECOMMENDATIONS



Catchment SF-5

Existing Catchment Summary	
Acres	25.6
Dominant Land Cover	Residential
Parcels	62
Volume (acre-feet/yr)	10.3
TP (lb/yr)	10.9
TSS (lb/yr)	2,184



CATCHMENT DESCRIPTION

Catchment SF-5 includes all of the geographical area draining stormwater to the Rum River outfall located east of the Vintage Street – 227th Avenue intersection. Outside of a few open lots the 26-acre catchment is exclusively single family residences on sandy Zimmerman and Braham Soils.

EXISTING STORMWATER TREATMENT

Roadway and residential stormwater runoff from 227th Avenue and Rum River Boulevard flows to retention pond SWP10. SWP10 overflows into retention pond SWP11, which also collects runoff from residences along 227th Court and Vintage Street. SWP11 discharges into a storm sewer line running east below 227th Avenue and eventually outlets into the Rum River east of Vintage Street.

In addition to the pair of retention ponds, street cleaning conducted by the City of St. Francis provides stormwater treatment on residential roads. This service is provided twice annually using mechanical sweepers.

Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	3			
	BMP Types	2 Ponds, Street Cleaning			
	TP (lb/yr)	17.1	6.2	36%	**10.9**
	TSS (lb/yr)	4,514	2,330	52%	**2,184**
	Volume (acre-feet/yr)	10.4	0.1	1%	**10.3**

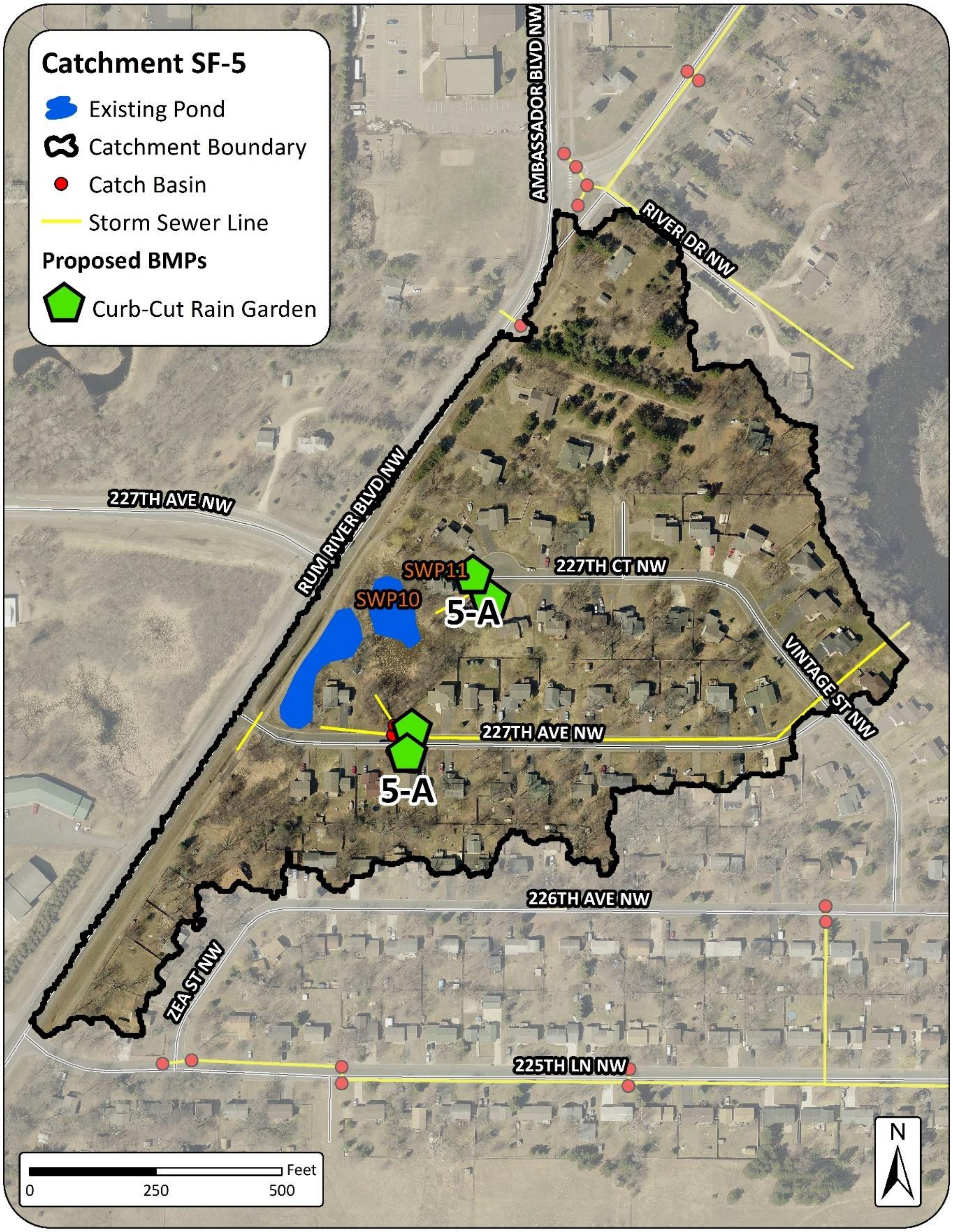
PROPOSED RETROFITS OVERVIEW

Up to four curb-cut rain gardens were proposed on 227th Court and 227th Avenue to treat stormwater prior to discharge into the ponds. The curb-cut rain gardens should be installed as close to the roadway catch basins as possible to maximize their drainage areas.

RETROFITS CONSIDERED BUT REJECTED

A single hydrodynamic device was proposed at the intersection of Vintage Street and 227th Avenue. However, due to the presence of existing BMPs, SWP10 and SWP11, WinSLAMM estimated this device would capture minimal quantities of TSS and TP and did not warrant the cost of installation.

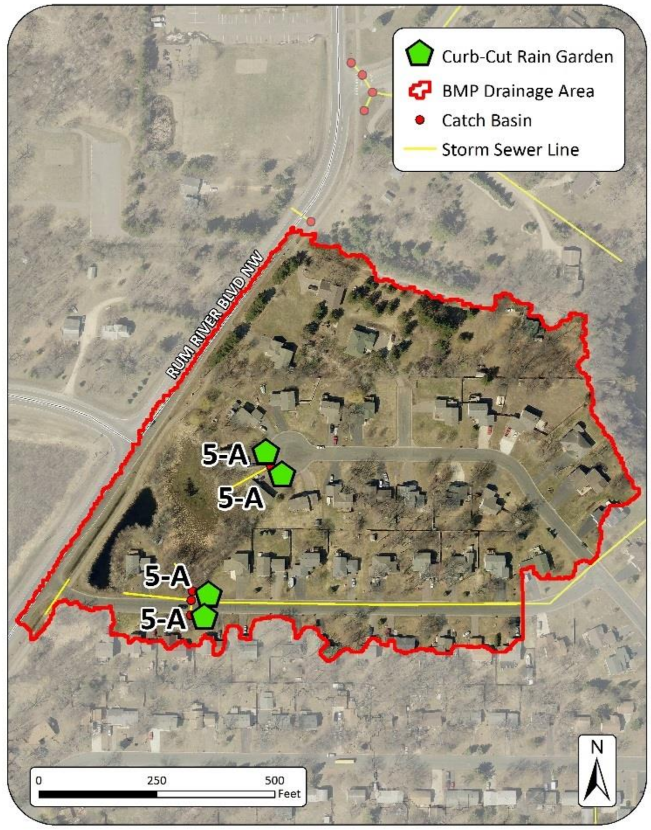
RETROFIT RECOMMENDATIONS



Project ID: 5-A

Curb-Cut Rain Gardens

Drainage Area – 1.5-6.0 acres
Location – 227th Court NW and 227th Avenue NW
Property Ownership – Private
Site Specific Information – Single-family lots within the catchment provide various locations for curb-cut rain gardens to treat stormwater pollutants originating from private property. Considering typical landowner participation rates, scenarios with one, two, and four rain gardens were analyzed to treat the catchment.



	Curb-Cut Rain Garden						
	Cost/Removal Analysis	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1		2		4	
	Total Size of BMPs	250	sq-ft	500	sq-ft	1,000	sq-ft
	TP (lb/yr)	0.4	3.7%	0.7	6.4%	1.6	14.7%
	TSS (lb/yr)	56	2.6%	169	7.7%	358	16.4%
	Volume (acre-feet/yr)	0.5	4.7%	0.8	7.7%	1.7	16.5%
Cost	**Administration & Promotion Costs***	$1,606		$3,212		$6,424	
	Design & Construction Costs**	$7,376		$14,752		$29,504	
	Total Estimated Project Cost (2016)	**$8,982**		**$17,964**		**$35,928**	
	Annual O&M***	$225		$450		$900	
Efficiency	**30-yr Average Cost/lb-TP**	**$1,311**		**$1,498**		**$1,311**	
	30-yr Average Cost/1,000lb-TSS	**$9,364**		**$6,206**		**$5,859**	
	30-yr Average Cost/ac-ft Vol.	**$1,077**		**$1,250**		**$1,217**	

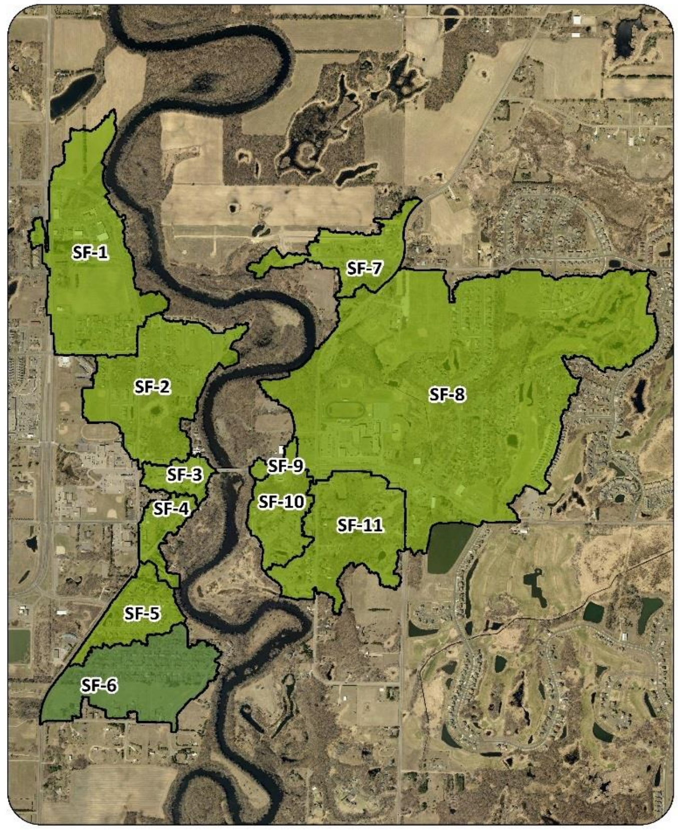
*Indirect Cost: (10 hours/BMP at $73/hour base cost) + (12 hours/BMP at $73/hour)

**Direct Cost: ($26/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Catchment SF-6

Existing Catchment Summary	
Acres	58.2
Dominant Land Cover	Residential
Parcels	119
Volume (acre-feet/yr)	17.6
TP (lb/yr)	25.7
TSS (lb/yr)	6,541



CATCHMENT DESCRIPTION

Catchment SF-6 is bounded by Rum River Boulevard. to the west, 224th Avenue to the south, Tulip Street to the east, and 227th Avenue to the north. The catchment is exclusively single family residential lots. These parcels are 1/8-acre in size along 226th Avenue and 225th Lane but grow to nearly 5-acres per parcel along 224th Avenue. Soils in the catchment are primarily Braham (hydrologic group B) and Zimmerman (hydrologic group A) well-drained, loamy sand soils, but also include some Blomford (hydrologic group B/D) poorly-drained, fine sand soils.

EXISTING STORMWATER TREATMENT

Street cleaning is provided by the City of St. Francis twice per year with mechanical sweepers. No structural stormwater devices exist within this catchment. Present-day stormwater pollutant loading and treatment is summarized in the table below.

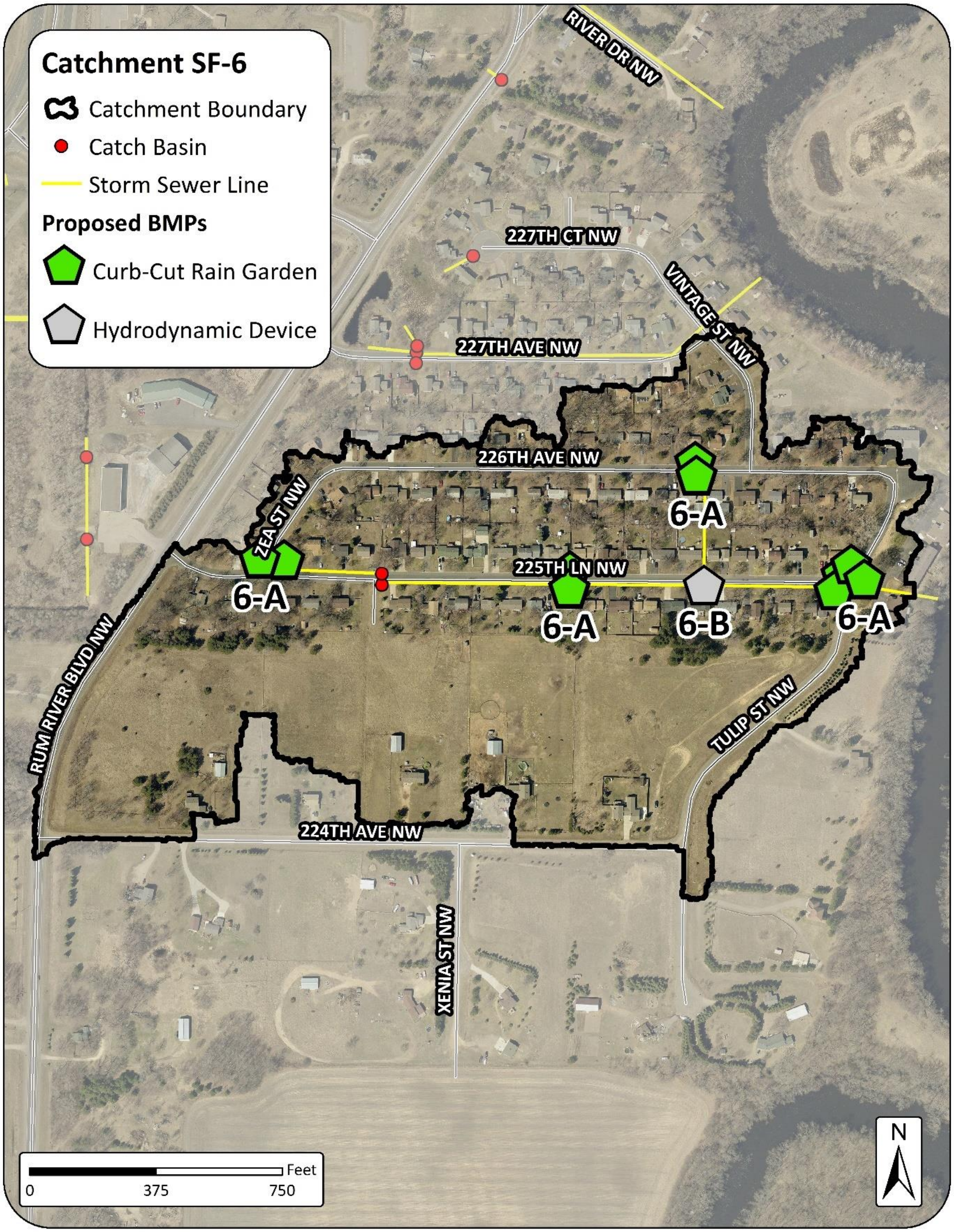
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	27.7	2.0	7%	**25.7**
	TSS (lb/yr)	7,419	878	12%	**6,541**
	Volume (acre-feet/yr)	17.6	0.0	0%	**17.6**

PROPOSED RETROFITS OVERVIEW

Up to 10 curb-cut rain gardens were proposed in this catchment to facilitate infiltration of stormwater volume and retention of pollutants. These were located upstream of catch basins to maximize drainage area and, where possible, outside of areas with poorly-drained soils. Soil tests should be conducted prior to installation to ensure sufficient drainage.

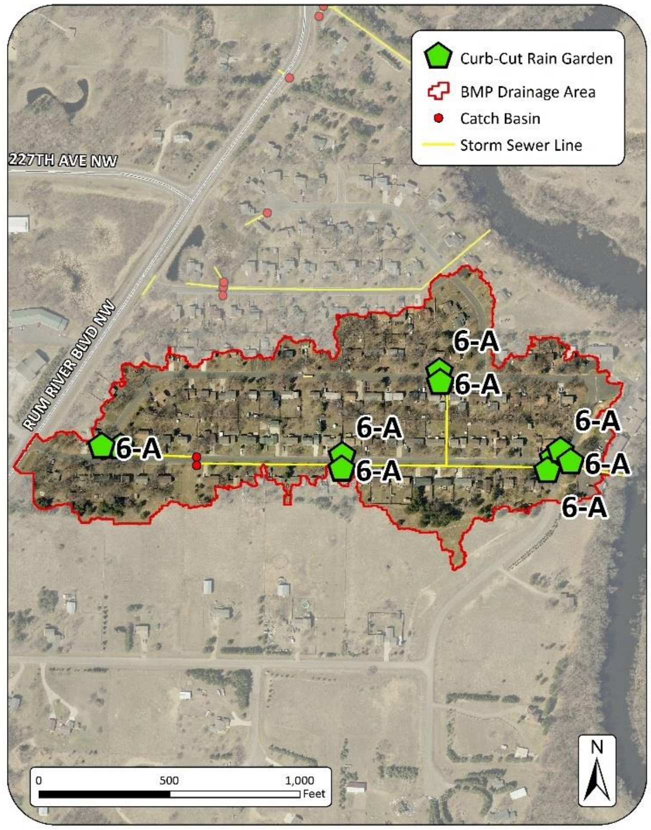
In addition to the curb-cut rain gardens, a hydrodynamic device was proposed along 225th Lane to treat stormwater from only the 225th Lane pipe. This practice was placed upstream of the connection with the 226th Avenue storm sewer pipe to reduce the potential for resuspension from high peak discharges.

RETROFIT RECOMMENDATIONS



Project ID: 6-A

Curb-Cut Rain Gardens



Drainage Area – 1.5-15.0 acres
Location – Various locations throughout catchment
Property Ownership – Private
Site Specific Information – Single-family lots within the catchment provide various locations for curb-cut rain gardens to treat stormwater pollutants originating from private properties. Considering typical landowner participation rates, scenarios with one, five, and ten rain gardens were analyzed to treat the catchment.

	Curb-Cut Rain Garden						
	Cost/Removal Analysis	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**
Treatment	Number of BMPs	1		5		10	
	Total Size of BMPs	250	sq-ft	1,250	sq-ft	2,500	sq-ft
	TP (lb/yr)	0.9	3.5%	3.2	12.5%	7.4	28.8%
	TSS (lb/yr)	223	3.4%	871	13.3%	1,906	29.1%
	Volume (acre-feet/yr)	0.9	5.1%	2.1	12.0%	4.5	25.6%
Cost	Administration & Promotion Costs*	$8,468		$11,972		$16,352	
	Design & Construction Costs**	$7,376		$36,880		$73,760	
	Total Estimated Project Cost (2016)	**$15,844**		**$48,852**		**$90,112**	
	Annual O&M***	$225		$1,125		$2,250	
Efficiency	30-yr Average Cost/lb-TP	**$837**		**$860**		**$710**	
	30-yr Average Cost/1,000lb-TSS	**$3,377**		**$3,161**		**$2,756**	
	30-yr Average Cost/ac-ft Vol.	**$837**		**$1,298**		**$1,159**	

*Indirect Cost: (104 hours at $73/hour base cost) + (12 hours/BMP at $73/hour)

**Direct Cost: ($26/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

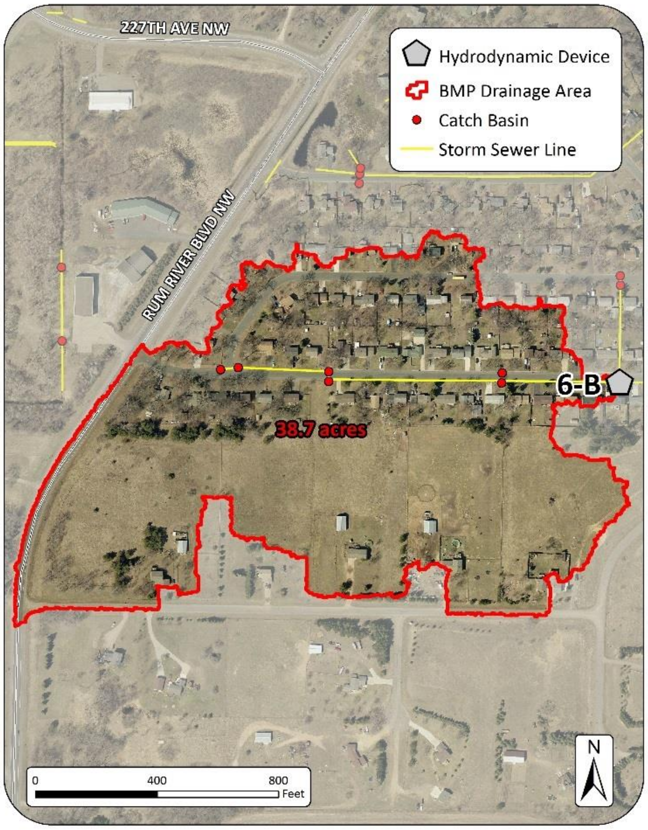
***Per BMP: ($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Project ID: 6-B

225th LN.

Hydrodynamic Device

Drainage Area – 38.7 acres
Location – 225th Lane NW
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed for 225th Lane between Tulip Street and Zea Street. This device could be installed to treat 38.7 acres of runoff from residential and open land uses.



Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
Treatment	Total Size of BMPs	10	ft diameter
Treatment	TP (lb/yr)	1.2	4.7%
Treatment	TSS (lb/yr)	433	6.6%
Treatment	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
Cost	Design & Construction Costs**	$108,000	
Cost	Total Estimated Project Cost (2016)	**$109,752**	
Cost	Annual O&M***	$630	
Efficiency	30-yr Average Cost/lb-TP	**$3,574**	
Efficiency	30-yr Average Cost/1,000lb-TSS	**$9,904**	
Efficiency	30-yr Average Cost/ac-ft Vol.	**N/A**	

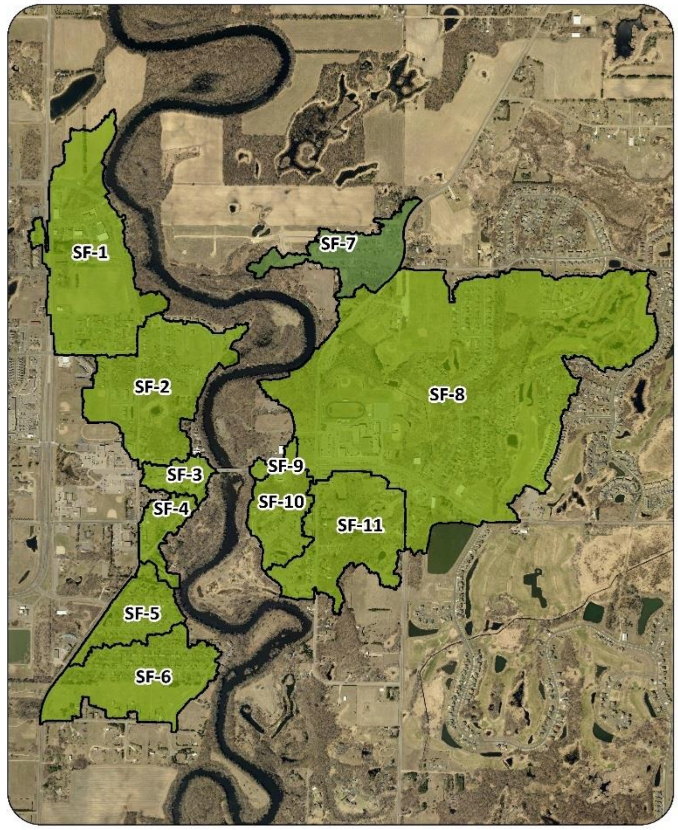
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (3 cleanings/year)*(3 hours/cleaning)*($70/hour)

Catchment SF-7

Existing Catchment Summary	
Acres	31.0
Dominant Land Cover	Residential
Parcels	70
Volume (acre-feet/yr)	9.0
TP (lb/yr)	7.7
TSS (lb/yr)	1,714



CATCHMENT DESCRIPTION

Catchment SF-7 includes portions of the new Rum River Bluffs Development west of Rum River Boulevard. The catchment includes all of the area in the development and along Rum River Boulevard. draining to the 235th Avenue storm sewer. This pipe carries runoff from single family residential lots to an outfall south and west of the development. Soils in the catchment are predominantly coarse sand (Zimmerman series; hydrologic group A) with more poorly-drained wetland soils (Rifle and Kratka series; hydrologic groups A/D and B/D, respectively) within the Rum River corridor to the west. Additional, undeveloped portions of the development north of the Catchment SF-7 boundary were not included in this analysis as the final plat and stormwater infrastructure plan were yet completed at the time of this analysis.

EXISTING STORMWATER TREATMENT

Two structural stormwater BMPs provide treatment to stormwater prior to discharge into the Rum River. The first of these, a stormwater retention pond on the northwestern corner of the Rum River Boulevard – 235th Avenue intersection, treats 10.9 acres of properties on Rum River Boulevard., 235th Avenue, 235th Lane, and Marigold Street. This pond discharges into the 235th Avenue storm sewer line and into another pond 600' to the west. This western pond, SWP52, also treats stormwater from 15.2 acres of residential properties in the development.

In addition to these ponds, street cleaning is provided by the City of St. Francis twice per year with mechanical sweepers.

Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	3			
	BMP Types	2 Ponds, Street Cleaning			
	TP (lb/yr)	13.2	5.5	42%	**7.7**
	TSS (lb/yr)	3,942	2,228	57%	**1,714**
	Volume (acre-feet/yr)	9.0	0.1	1%	**9.0**

PROPOSED RETROFITS OVERVIEW

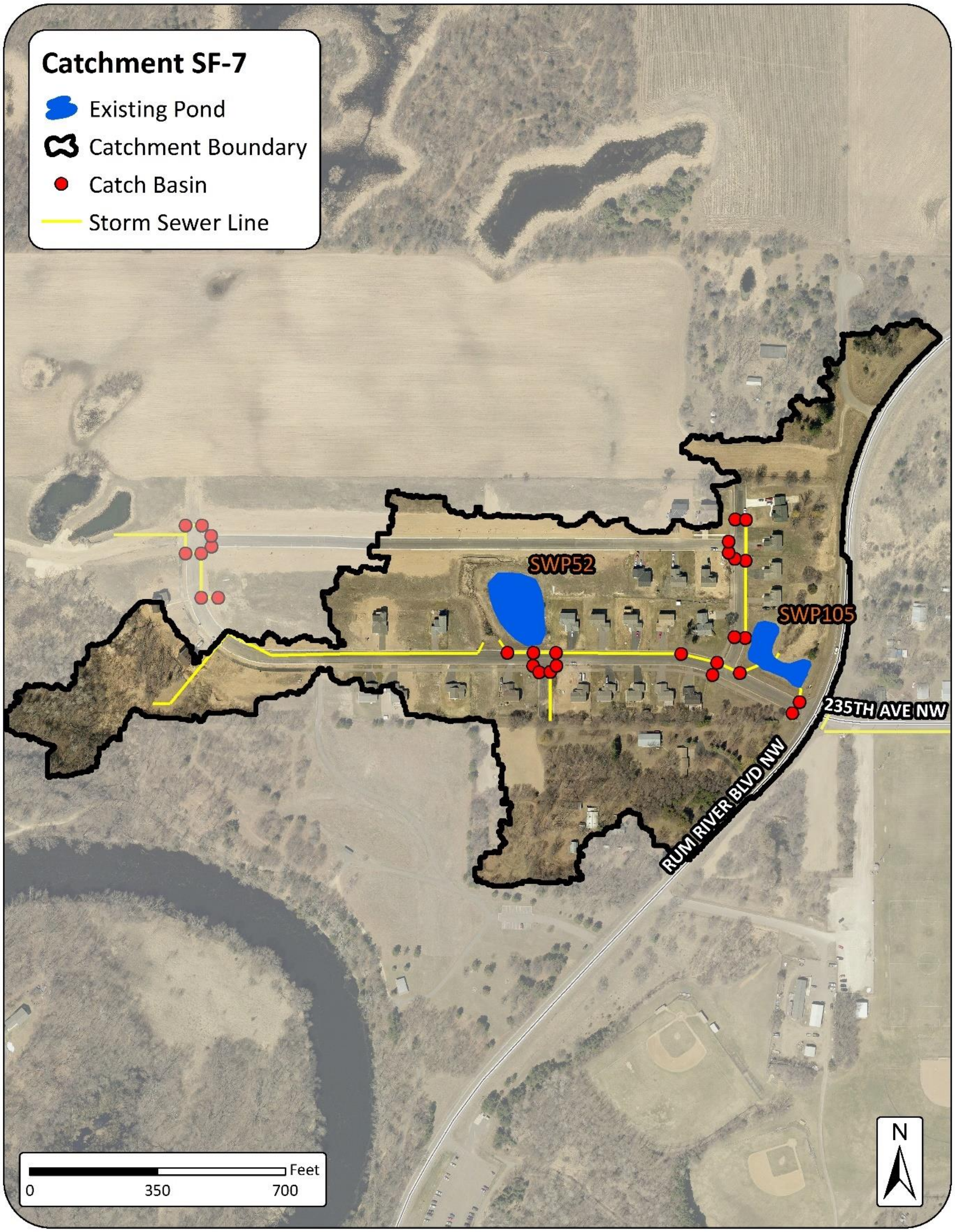
No retrofits were proposed in this catchment due to the treatment already provided by municipal street cleaning and the pair of retention ponds.

RETROFITS CONSIDERED BUT REJECTED

Bioretention practices, such as curb-cut rain gardens and boulevard bioswales, were considered but are not practical because of the high density of roadway catch basins. The higher density of catch basins in the catchment reduces the drainage area to each practice, thereby making bioretention basins cost-prohibitive.

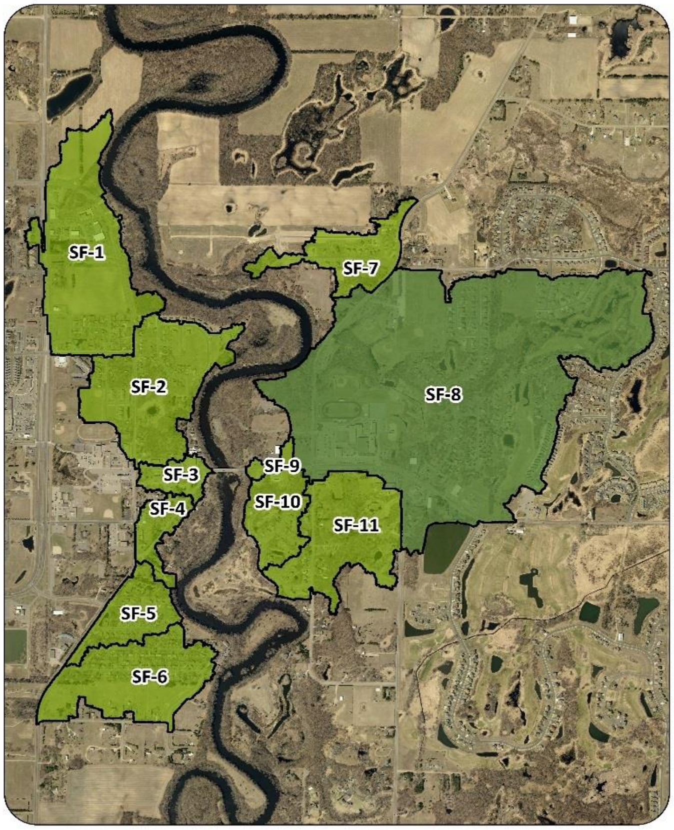
Therefore, the map below was included solely to provide additional detail of the catchment boundary, associated land uses, and streets.

RETROFIT RECOMMENDATIONS



Catchment SF-8

Existing Catchment Summary	
Acres	341.70
Dominant Land Cover	Residential
Parcels	350
Volume (acre-feet/yr)	126.6
TP (lb/yr)	104.3
TSS (lb/yr)	25,698



CATCHMENT DESCRIPTION

Catchment SF-8 is the largest catchment. The catchment is defined as all of the geographic area draining to a ditch east of the high school. This ditch crosses Rum River Boulevard through a culvert directly west of the high school baseball field and flows through Rum River North County Park, eventually draining into the Rum River 400' northwest of the Rum River Blvd. crossing.

The 368.7-acre catchment is primarily residential, but also includes a wide variety of commercial, institutional, park, and undeveloped parcels. Soils are predominantly silty sands, and range in size from fine loams (Lino series; hydrologic group B) to fine sands (Zimmerman series; hydrologic group A). The extensive wetland network upstream and adjacent to the ditch overlays more poorly-drained soils (Isanti and Rifle series; hydrologic group A/D).

EXISTING STORMWATER TREATMENT

The catchment is composed of 24.8 acres of open water, which includes natural wetlands and constructed features such as stormwater retention ponds and detention/infiltration basins. Both the natural and constructed features provide stormwater treatment, and each were modeled within WinSLAMM to determine their impact on downstream water quality. A total of 30 distinct features were located and deemed large enough to include in this analysis. Basins that were closely hydrologically connected were grouped together for modeling purposes. Figure 1 shows all 30 BMPs, and the hydrologic connections and flow pathways between these connections. Those listed within the same polygon were lumped together and modeled as a single retention device. In total, 19 different retention devices were modeled in WinSLAMM in Catchment SF-8.

In addition to the retention devices, street cleaning is provided by the City of St. Francis twice per year with mechanical sweepers.

Present-day stormwater pollutant loading and treatment is summarized in the table below.

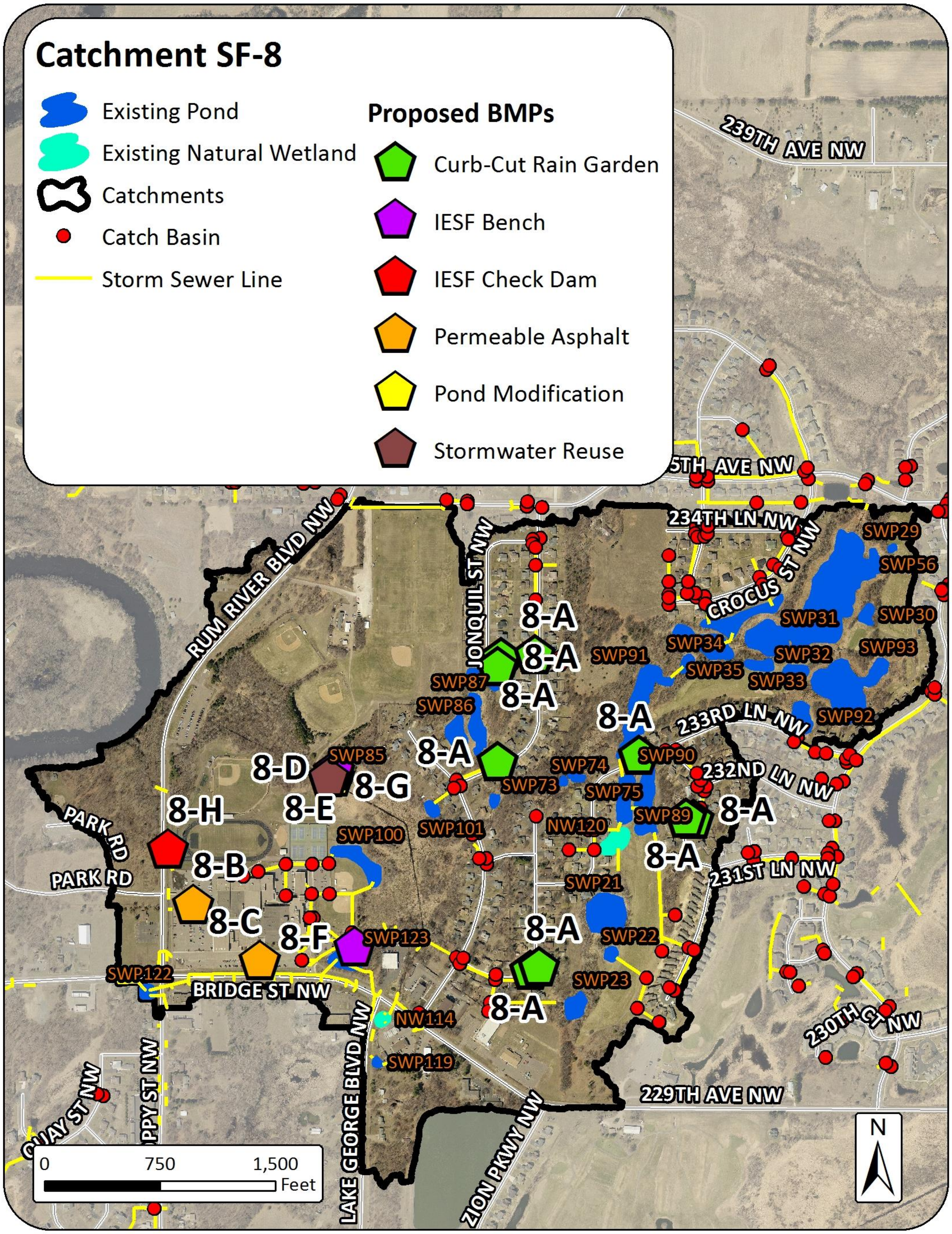
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	31			
	BMP Types	2 Wetlands, 28 Ponds, Street Cleaning			
	TP (lb/yr)	166.2	61.9	37%	**104.3**
	TSS (lb/yr)	51,389	25,691	50%	**25,698**
	Volume (acre-feet/yr)	128.0	1.4	1%	**126.6**

PROPOSED RETROFITS OVERVIEW

A variety of stormwater practices were proposed throughout the catchment, the largest of which are proposed at SWP85, which is located on St. Francis High School property. At this stormwater pond, three different practices were proposed. The first is a pond modification to increase the size of the pond based on available space, in order for the pond to store more water and to more effectively treat TP and TSS. The second practice is an IESF bench to assist the pond in treating dissolved phosphorus. The third practice would reuse stormwater by pumping it from the pond to use as irrigation in nearby recreational fields.

On the St Francis High School property four additional practices were proposed. One iron-enhanced sand filter check dam within the Rum River Boulevard eastern ditch could better reduce high flows through the roadway ditch by increasing retention time and the iron-enhanced sand filter would help to reduce TP. Two permeable pavement practices were also proposed on the high school property to reduce runoff from the site and increase infiltration. Additionally, at stormwater pond, SWP123, which is located on the southeast side of the St. Francis High School property, an iron enhanced sand filter bench was proposed to treat dissolved phosphorus.

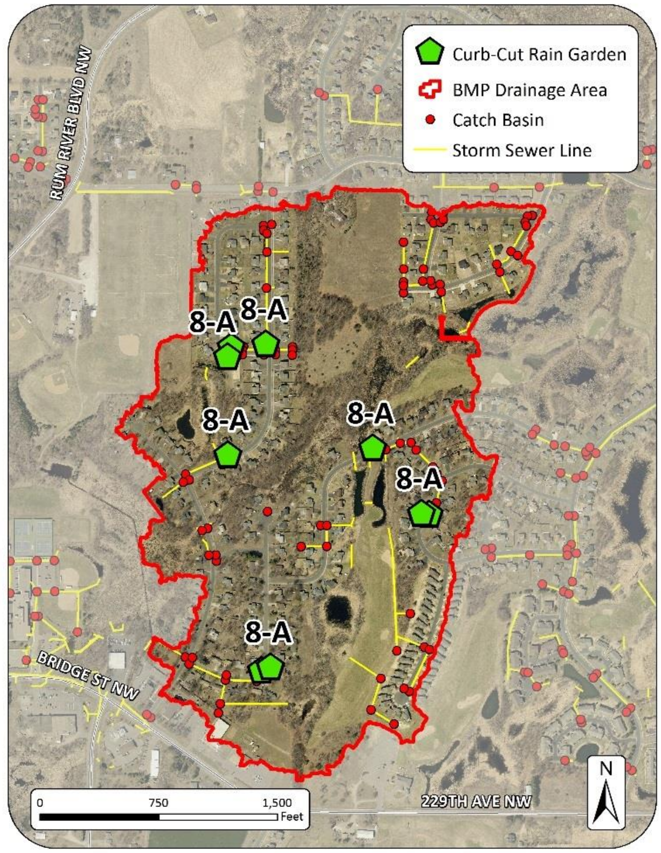
Lastly, up to nine curb-cut rain gardens were proposed throughout the catchment. These were proposed adjacent to catch basins as poorly-drained soils and a high water table across the catchment could require the installation of an underdrain within each garden.


Catchment SF-8
Existing Pond
Existing Natural Wetland
Catchments
Catch Basin
Storm Sewer Line
Proposed BMPs
Curb-Cut Rain Garden
IESF Bench
IESF Check Dam
Permeable Asphalt
Pond Modification
Stormwater Reuse
239TH AVE NW
234TH LN NW
CROCUS ST NW
RUM RIVER BLVD NW
JONQUIL ST NW
233RD LN NW
232ND LN NW
231ST LN NW
230TH CT NW
229TH AVE NW
PARK RD
BRIDGE ST NW
LAKE GEORGE BLVD NW
ZION PKWY NW
QUAY ST NW
8-A
8-B
8-C
8-D
8-E
8-F
8-G
8-H
SWP29
SWP56
SWP30
SWP31
SWP93
SWP34
SWP32
SWP35
SWP33
SWP92
SWP91
SWP87
SWP86
SWP85
SWP90
SWP74
SWP73
SWP75
SWP89
SWP101
SWP100
NW120
SWP21
SWP22
SWP23
SWP123
SWP122
NW114
SWP119
0
750
1,500
Feet
N

Project ID: 8-A

Curb-Cut Rain Gardens

Drainage Area – 1.5 – 6.0 acres
Location – Various locations throughout catchment
Property Ownership – Private
Site Specific Information – Single-family lots within the catchment provide various locations for curb-cut rain gardens to treat stormwater pollutants originating from private property. Considering typical landowner participation rates, scenarios with three, five, and nine rain gardens were analyzed to treat the catchment.



	Curb-Cut Rain Garden						
	Cost/Removal Analysis	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	3		5		9	
	Total Size of BMPs	750	sq-ft	1,250	sq-ft	2,250	sq-ft
	TP (lb/yr)	0.5	0.5%	1.7	1.6%	3.7	3.5%
	TSS (lb/yr)	82	0.3%	313	1.2%	659	2.6%
	Volume (acre-feet/yr)	1.1	0.9%	2.1	1.7%	3.8	3.0%
Cost	**Administration & Promotion Costs***	$10,220		$11,972		$15,476	
	Design & Construction Costs**	$22,128		$36,880		$66,384	
	Total Estimated Project Cost (2016)	**$32,348**		**$48,852**		**$81,860**	
	Annual O&M***	$675		$1,125		$2,025	
Efficiency	**30-yr Average Cost/lb-TP**	**$3,507**		**$1,620**		**$1,285**	
	30-yr Average Cost/1,000lb-TSS	**$21,381**		**$8,797**		**$7,213**	
	30-yr Average Cost/ac-ft Vol.	**$1,558**		**$1,333**		**$1,240**	

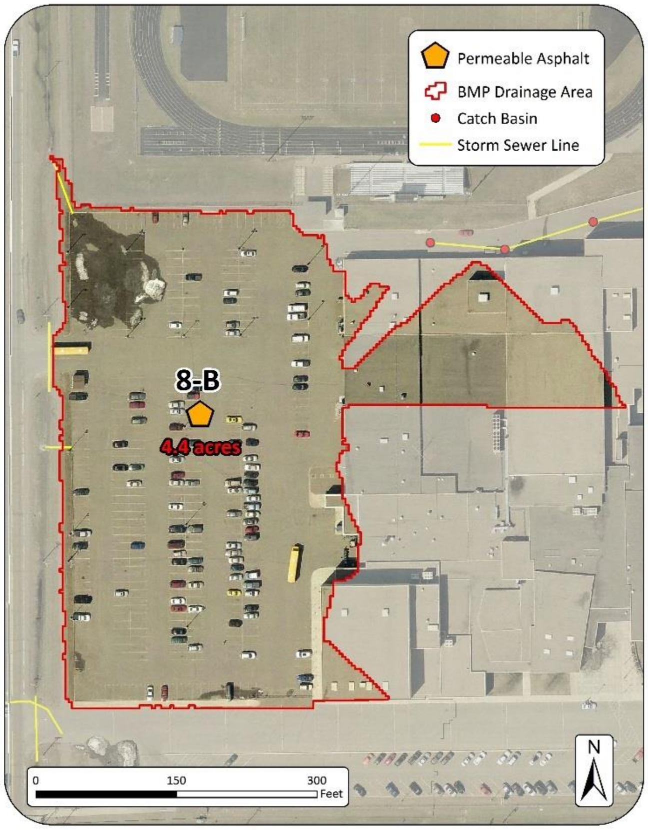
*Indirect Cost: (104 hours at $73/hour base cost) + (12 hours/BMP at $73/hour)

**Direct Cost: ($26/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Project ID: 8-B

St. Francis High School
Permeable Pavement



Drainage Area – 4.4 acres
Location – Large western parking lot at St. Francis High School on Rum River Boulevard and Park Road
Property Ownership – Public
Site Specific Information – Permeable pavement is proposed for the large western parking lot of St. Francis High School. This practice allows the treatment of a large surface area with minimal impact on the usable space. In order to treat the 4.4-acre drainage area, 64,000 sq.-ft. of permeable pavement is proposed.

Permeable Pavement

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMP	64,000	sq-ft
	TP (lb/yr)	5.3	5.1%
	TSS (lb/yr)	1,586	6.2%
	Volume (acre-feet/yr)	4.1	3.2%
Cost	Administration & Promotion Costs*	$2,920	
	Design & Construction Costs**	$640,876	
	Total Estimated Project Cost (2016)	**$643,796**	
	Annual O&M***	$48,000	
Efficiency	30-yr Average Cost/lb-TP	**$13,106**	
	30-yr Average Cost/1,000lb-TSS	**$43,796**	
	30-yr Average Cost/ac-ft Vol.	**$17,096**	

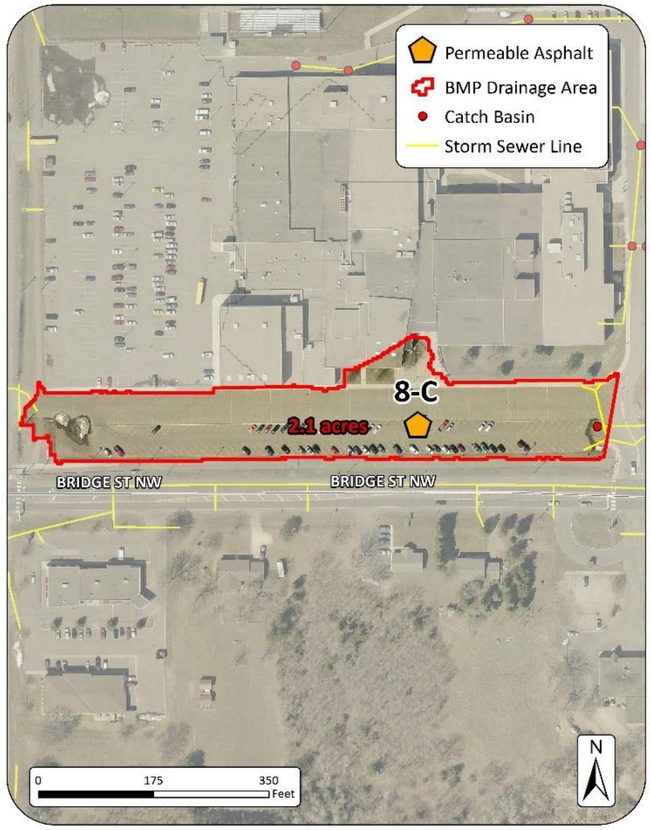
*Indirect Cost: 40 hours at $73/hour

**Direct Cost: ($10/sq-ft for materials and labor) + (12 hours at $73/hour for design)

***($0.75/sq-ft for routine maintenance)

Project ID: 8-C

St. Francis High School
Permeable Pavement



Drainage Area – 2.1 acres
Location – Southern parking lot at St. Francis High School on Rum River Boulevard and Bridge Street
Property Ownership – Public
Site Specific Information – Permeable pavement is proposed for the southern parking lot of St. Francis High School. This practice allows the treatment of a large surface area with minimal impact on the usable space. In order to treat the 2.1-acre drainage area, 31,000 sq.-ft. of permeable pavement is proposed.

	Permeable Pavement		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMP	31,000	sq-ft
	TP (lb/yr)	1.4	1.3%
	TSS (lb/yr)	420	1.6%
	Volume (acre-feet/yr)	1.9	1.5%
Cost	**Administration & Promotion Costs***	$2,920	
	Design & Construction Costs**	$310,876	
	Total Estimated Project Cost (2016)	**$313,796**	
	Annual O&M***	$23,250	
Efficiency	**30-yr Average Cost/lb-TP**	**$24,078**	
	30-yr Average Cost/1,000lb-TSS	**$80,262**	
	30-yr Average Cost/ac-ft Vol.	**$18,124**	

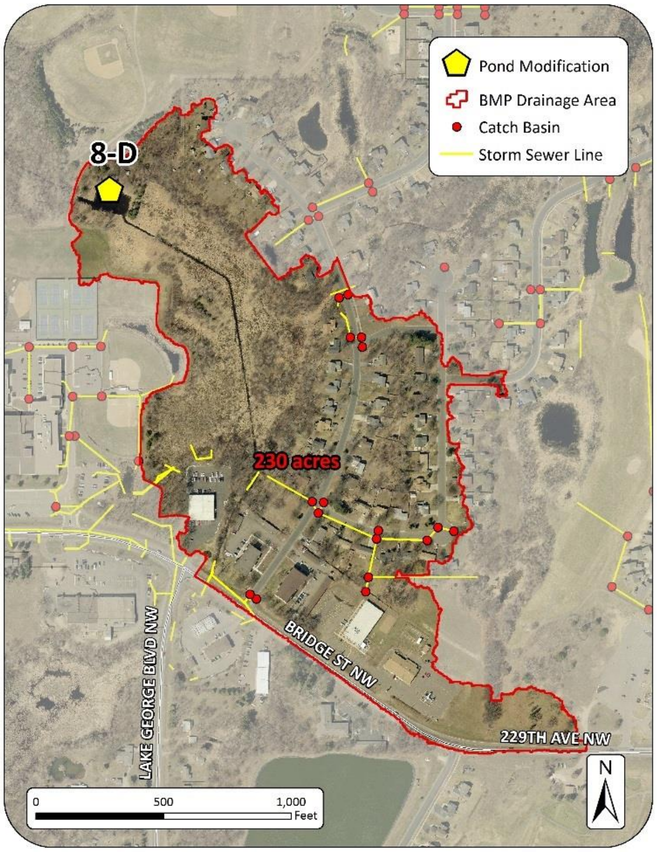
*Indirect Cost: 40 hours at $73/hour

**Direct Cost: ($10/sq-ft for materials and labor) + (12 hours at $73/hour for design)

***($0.75/sq-ft for routine maintenance)

Project ID: 8-D

St. Francis High School
Pond Modification



Drainage Area – 230.0 acres
Location – SWP85
Property Ownership – Public (School District)
Site Specific Information – A modification is proposed for SWP85, which is located on St. Francis High School property, between Rum River Boulevard and Kerry Street. This pond currently treats stormwater generated from 230 acres and is undersized to provide proper treatment for the contributing drainage area. Excavating 1,600 cubic yards of material could increase the size of the pond and improve the treatment efficiency. The price of the pond modification is shown below with three different management levels based on the contamination of the soil.

	BMP Modification						
	Cost/Removal Analysis	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**
Treatment	**Pond Management Level**	1		2		3	
	Amount of Soil Excavated	1,600	cu-yards	1,600	cu-yards	1,600	cu-yards
	TP (lb/yr)	3.1	3.0%	3.1	3.0%	3.1	3.0%
	TSS (lb/yr)	1,760	6.8%	1,760	6.8%	1,760	6.8%
	Volume (acre-feet/yr)	0.0	0.0%	0.0	0.0%	0.0	0.0%
Cost	**Administration & Promotion Costs***	$5,840		$5,840		$5,840	
	Design & Construction Costs**	$117,000		$141,000		$165,000	
	Total Estimated Project Cost (2016)	**$122,840**		**$146,840**		**$170,840**	
	Annual O&M***	$1,300		$1,300		$1,300	
Efficiency	**30-yr Average Cost/lb-TP**	**$1,740**		**$1,998**		**$2,256**	
	30-yr Average Cost/1,000lb-TSS	**$3,065**		**$3,520**		**$3,974**	
	30-yr Average Cost/ac-ft Vol.	**N/A**		**N/A**		**N/A**	

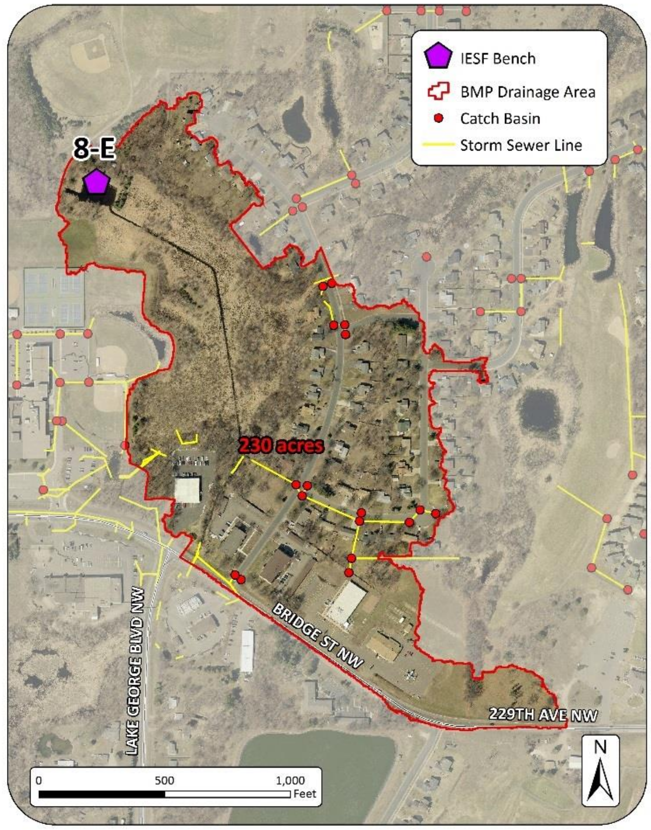
*Indirect Cost: 80 hours at $73/hour

**Direct Cost: See Appendix B for detailed cost information

***$1,000/acre of pond surface area - Annual inspection and sediment/debris removal from pretreatment area

Project ID: 8-E

St. Francis High School North
IESF Bench



Drainage Area – 230.0 acres
Location – SWP85
Property Ownership – Public (School District)
Site Specific Information – An IESF bench is proposed as an improvement to stormwater pond, SWP85. The pond currently provides treatment through retention and settling. However, the addition of an IESF could increase removal of dissolved phosphorus. The project is proposed on the northern shore of the pond. The IESF was sized to 3,000 sq.-ft. based on available space between the existing pond and the path.

IESF Bench			
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	3,000	sq-ft
	TP (lb/yr)	8.5	8.1%
	TSS (lb/yr)	0	0.0%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$5,475	
	Design & Construction Costs**	$185,600	
	Total Estimated Project Cost (2016)	**$191,075**	
	Annual O&M***	$689	
Efficiency	**30-yr Average Cost/lb-TP**	**$830**	
	30-yr Average Cost/1,000lb-TSS	**N/A**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: 75 hours at $73/hour

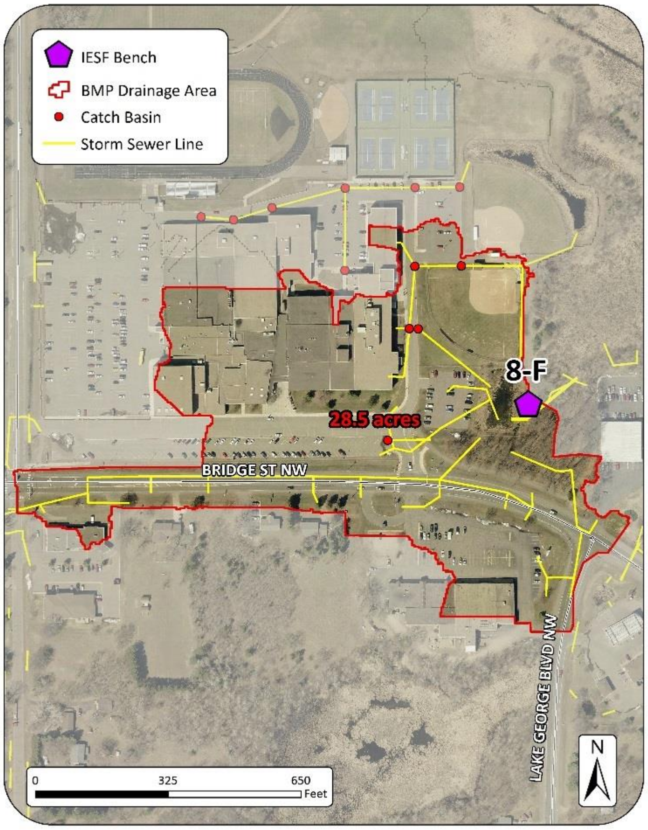
**Direct Cost: See Appendix B for detailed cost information

***$10,000/acre for IESF

Project ID: 8-F

St. Francis High School East
IESF Bench

Drainage Area – 28.5 acres
Location – SWP123
Property Ownership – Public (School District)
Site Specific Information – An IESF bench is proposed as an improvement to the existing pond, SWP123, which is located north of Bridge Street and west of Kerry Street. The pond currently provides treatment through retention and settling. However, the addition of an IESF could increase removal of dissolved phosphorus. The project is proposed on the eastern shore of the pond. The IESF was sized to 2,500 sq.-ft. based on available space between the existing pond and the parking lot.



	IESF Bench		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	2,500	sq-ft
	TP (lb/yr)	1.8	1.7%
	TSS (lb/yr)	0	0.0%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$5,475	
	Design & Construction Costs**	$174,300	
	Total Estimated Project Cost (2016)	**$179,775**	
	Annual O&M***	$574	
Efficiency	**30-yr Average Cost/lb-TP**	**$3,648**	
	30-yr Average Cost/1,000lb-TSS	**N/A**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

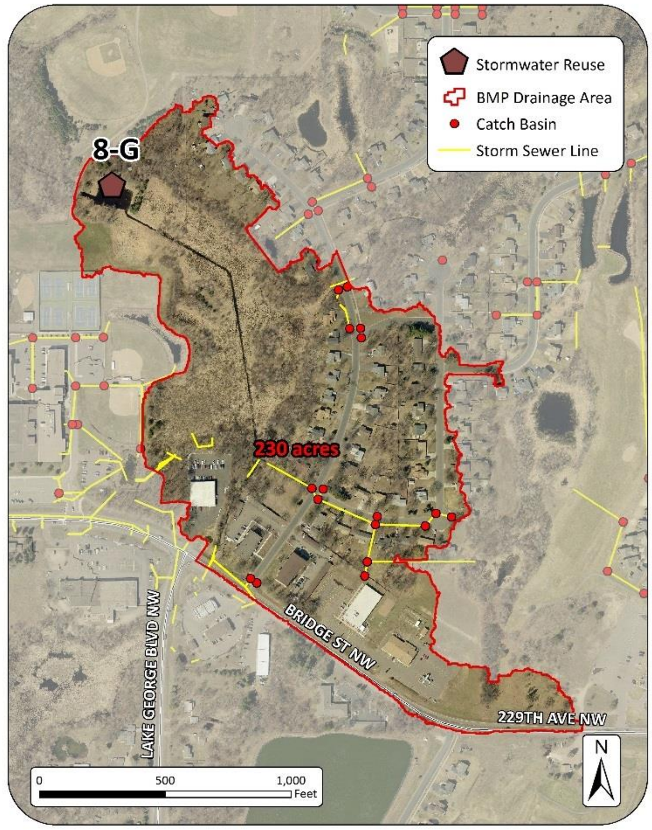
*Indirect Cost: 75 hours at $73/hour

**Direct Cost: See Appendix B for detailed cost information

***$10,000/acre for IESF

Project ID: 8-G

St. Francis High School
Stormwater Reuse



Drainage Area – 230.0 acres
Location – SWP85
Property Ownership – Public (School District)
Site Specific Information – Stormwater reuse is proposed for SWP85, which is located on St. Francis High School property, between Rum River Boulevard and Kerry Street. St. Francis High School could reuse the runoff captured in this pond to irrigate approximately 20-acres of the high school fields. This practice would provide water quality treatment as well as water conservation benefits.

	Stormwater Reuse		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	500,000	gallons
	TP (lb/yr)	12.3	11.8%
	TSS (lb/yr)	2,434	9.5%
	Volume (acre-feet/yr)	20.7	16.3%
Cost	**Administration & Promotion Costs***	$8,760	
	Design & Construction Costs**	$600,000	
	Total Estimated Project Cost (2016)	**$608,760**	
	Annual O&M***	$3,000	
Efficiency	**30-yr Average Cost/lb-TP**	**$1,894**	
	30-yr Average Cost/1,000lb-TSS	**$9,569**	
	30-yr Average Cost/ac-ft Vol.	**$1,125**	

*120 hours at $73/hour

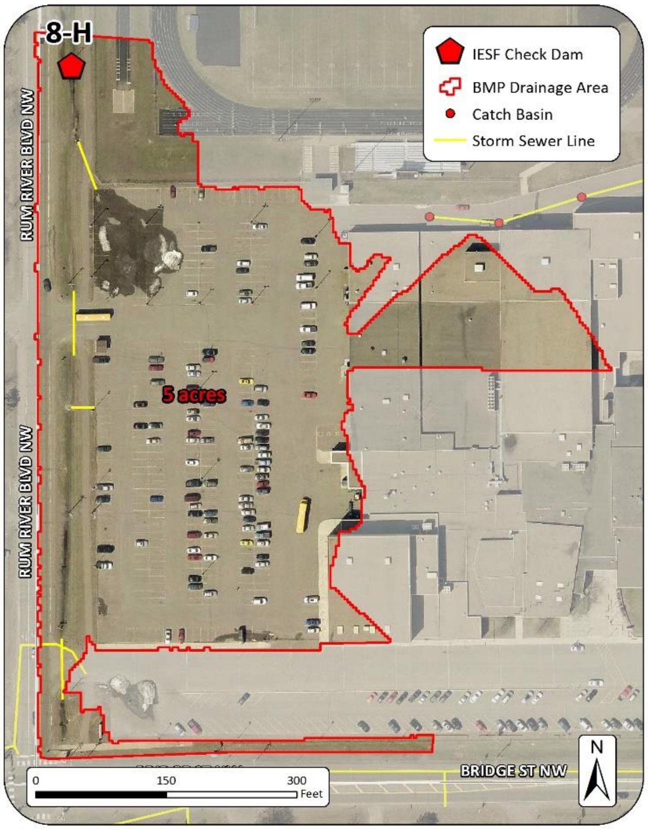
**See Appendix B for detailed cost information

***Includes cleaning of unit and disposal of sediment/debris

Project ID: 8-H

Rum River Blvd. & Park Rd.
IESF Check Dam

Drainage Area – 5.0 acres
Location – Rum River Blvd. eastern ditch
Property Ownership – Public
Site Specific Information – One IESF check dam is proposed as an improvement to the Rum River Boulevard eastern ditch, adjacent to St. Francis High School. An IESF check dam could increase dissolved phosphorous removal and could increase the retention time of stormwater within the ditch. Increased retention time would promote some additional settling of TSS and TP.



IESF Check Dam

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMP	150	cu-ft
	TP (lb/yr)	1.8	1.7%
	TSS (lb/yr)	459	1.8%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$2,920	
	Design & Construction Costs**	$12,528	
	Total Estimated Project Cost (2015)	**$15,448**	
	Annual O&M***	$365	
Efficiency	30-yr Average Cost/lb-TP	**$500**	
	30-yr Average Cost/1,000lb-TSS	**$1,917**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

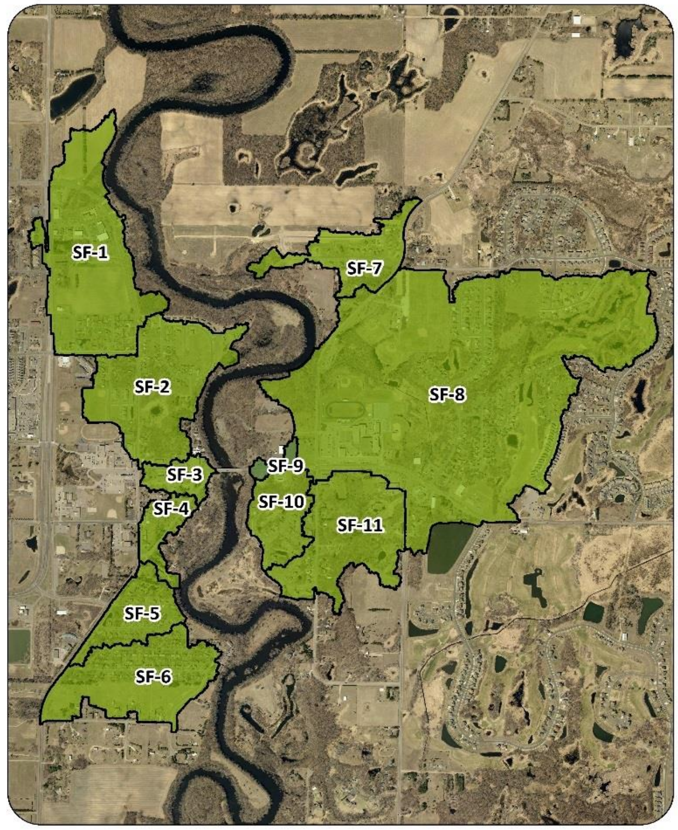
*Indirect Cost: 40 hours at $73/hour

**Direct Cost: See Appendix B for detailed cost information

***(5 hours for each dam at $73/hour for cleaning sediment/debris and maintenance)

Catchment SF-9

Existing Catchment Summary	
Acres	4.3
Dominant Land Cover	Residential
Parcels	9
Volume (acre-feet/yr)	1.6
TP (lb/yr)	1.5
TSS (lb/yr)	585



CATCHMENT DESCRIPTION

Catchment SF-9 is the smallest catchment. It is just 4.3 acres in size. This small area was separated as a distinct catchment because all of the area within the catchment boundary conveys stormwater to a single outfall south of Bridge Street. The catchment includes residential, commercial, industrial, and undeveloped land uses. Soils are exclusively fine Zimmerman series sands.

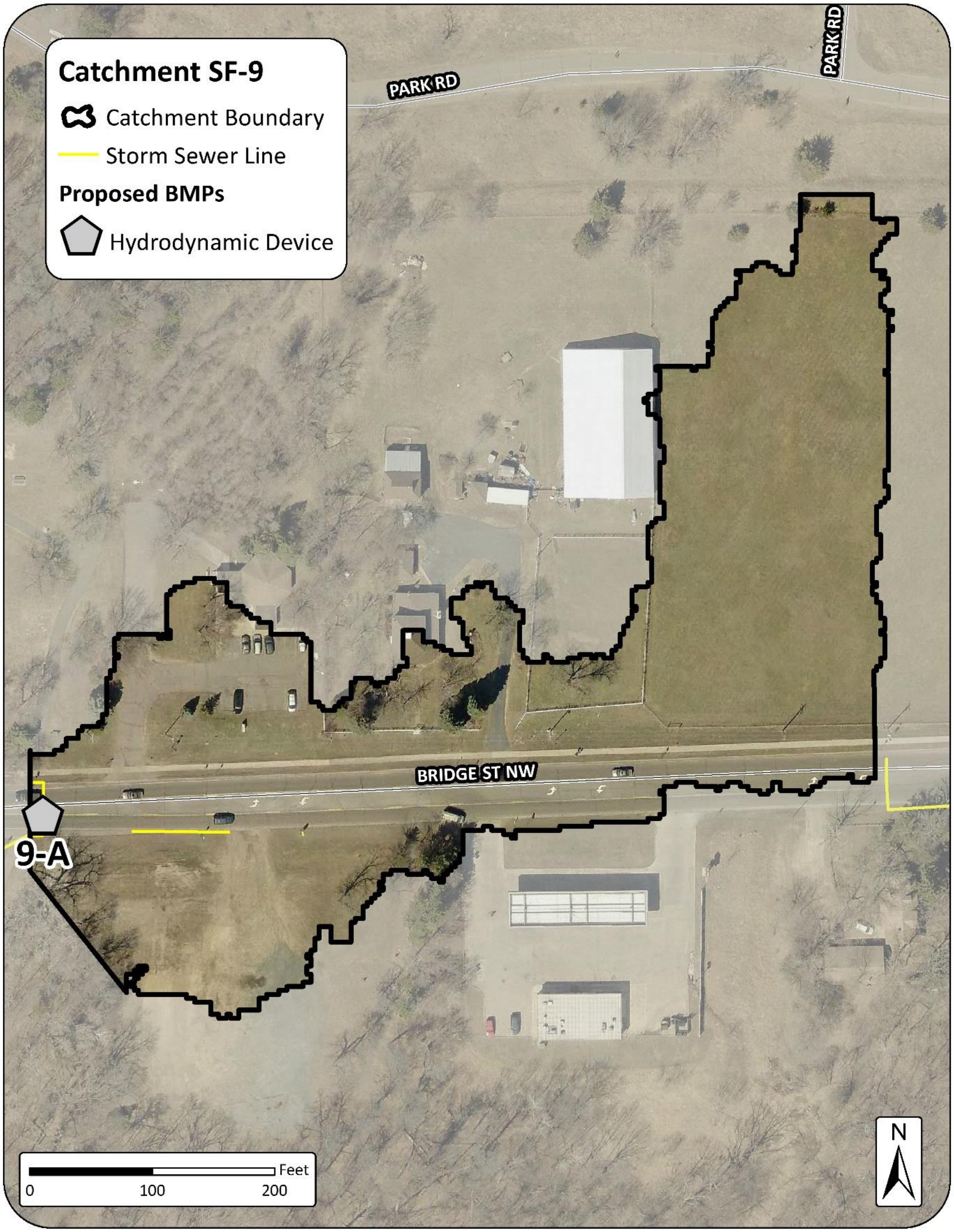
EXISTING STORMWATER TREATMENT

Street cleaning is provided by the City of St. Francis twice per year with mechanical sweepers. No structural stormwater devices exist within this catchment. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	1.6	0.1	6%	**1.5**
	TSS (lb/yr)	638	53	8%	**585**
	Volume (acre-feet/yr)	1.6	0.0	0%	**1.6**

PROPOSED RETROFITS OVERVIEW

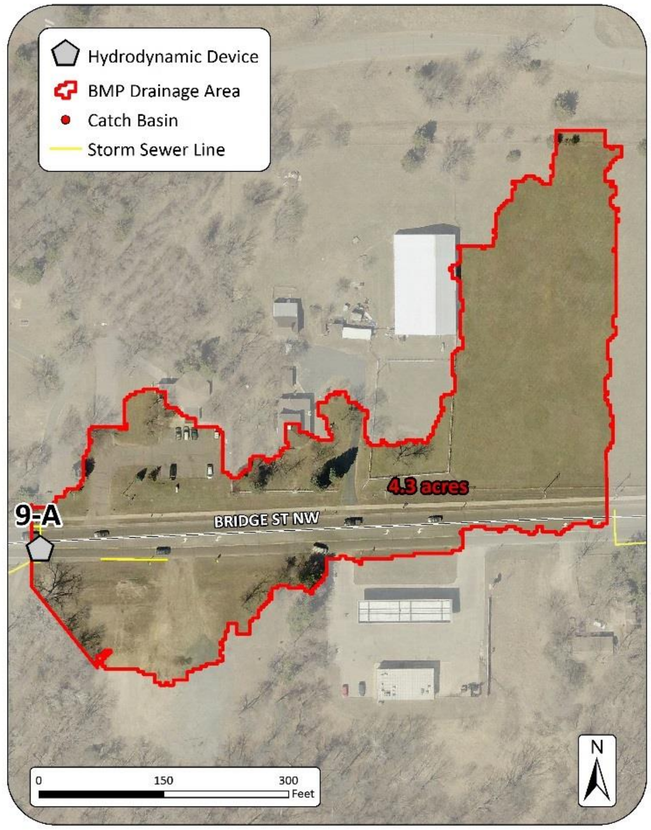
A single hydrodynamic device is proposed upstream of the Rum River outfall to treat the stormwater runoff generated within the catchment.


Catchment SF-9
Catchment Boundary
Storm Sewer Line
Proposed BMPs
Hydrodynamic Device
PARK RD
PARK RD
BRIDGE ST NW
9-A
Feet
0
100
200
N

Project ID: 9-A

Bridge Street
Hydrodynamic Device

Drainage Area – 4.3 acres
Location – Bridge Street NW
Property Ownership – Public
Site Specific Information- A hydrodynamic device is proposed for Bridge Street. The device would accept runoff from the entire catchment before discharging into the Rum River.



Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	6	ft diameter
	TP (lb/yr)	0.2	13.3%
	TSS (lb/yr)	103	17.6%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$27,000	
	Total Estimated Project Cost (2016)	**$28,752**	
	Annual O&M***	$630	
Efficiency	30-yr Average Cost/lb-TP	**$7,942**	
	30-yr Average Cost/1,000lb-TSS	**$15,421**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

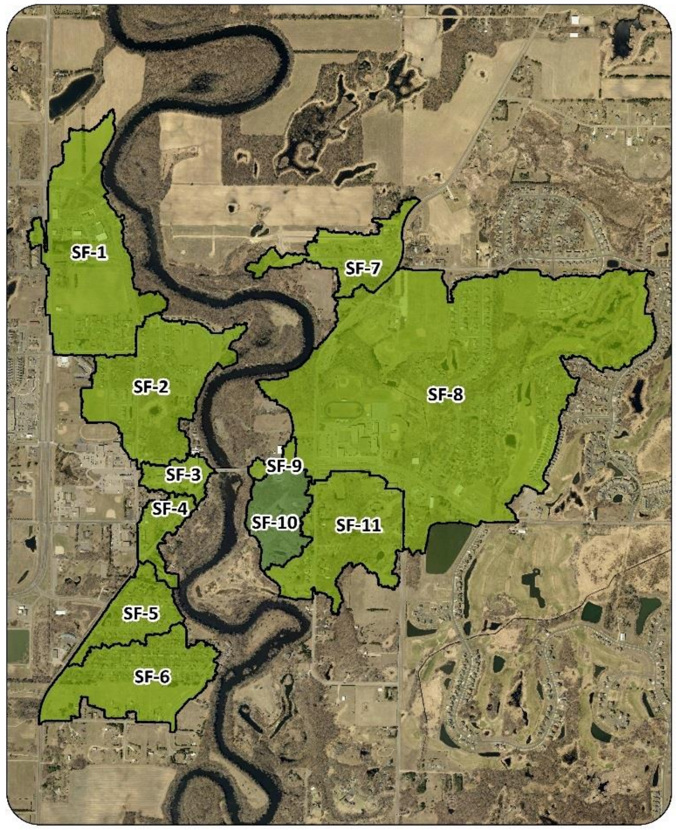
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (3 cleanings/year)*(3 hours/cleaning)*($70/hour)

Catchment SF-10

Existing Catchment Summary	
Acres	25.6
Dominant Land Cover	Residential
Parcels	57
Volume (acre-feet/yr)	8.0
TP (lb/yr)	4.5
TSS (lb/yr)	692



CATCHMENT DESCRIPTION

Catchment SF-10 is bounded by Bridge Street to the north, Poppy Street to the east, Silverod Street to the south, and the Rum River corridor to the west. Stormwater runoff generated on the single family and multi-family lots of the catchment flow to roadway catch basins and a series of four waterbodies: SWP6, SWP7, SWP12, and SWP61. Upland soils in the catchment are exclusively fine Zimmerman Sands.

EXISTING STORMWATER TREATMENT

Stormwater retention ponds SWP12 and SWP61 were determined to be hydrologically connected during storm events and were therefore modeled as a single waterbody in WinSLAMM. These BMPs provide stormwater treatment to runoff from primarily single family residential lots along Quay Street and 229th Lane. These ponds, along with runoff from Silverod Street, Quay Street, and 228th Avenue as well as overflow from SWP7, discharge into retention pond SWP6. Pond SWP6 provides treatment to the full 25.6 acres of Catchment SF-10.

In addition to these ponds, the City of St. Francis conducts street cleaning twice per year using mechanical sweepers.

Present-day stormwater pollutant loading and treatment is summarized in the table below.

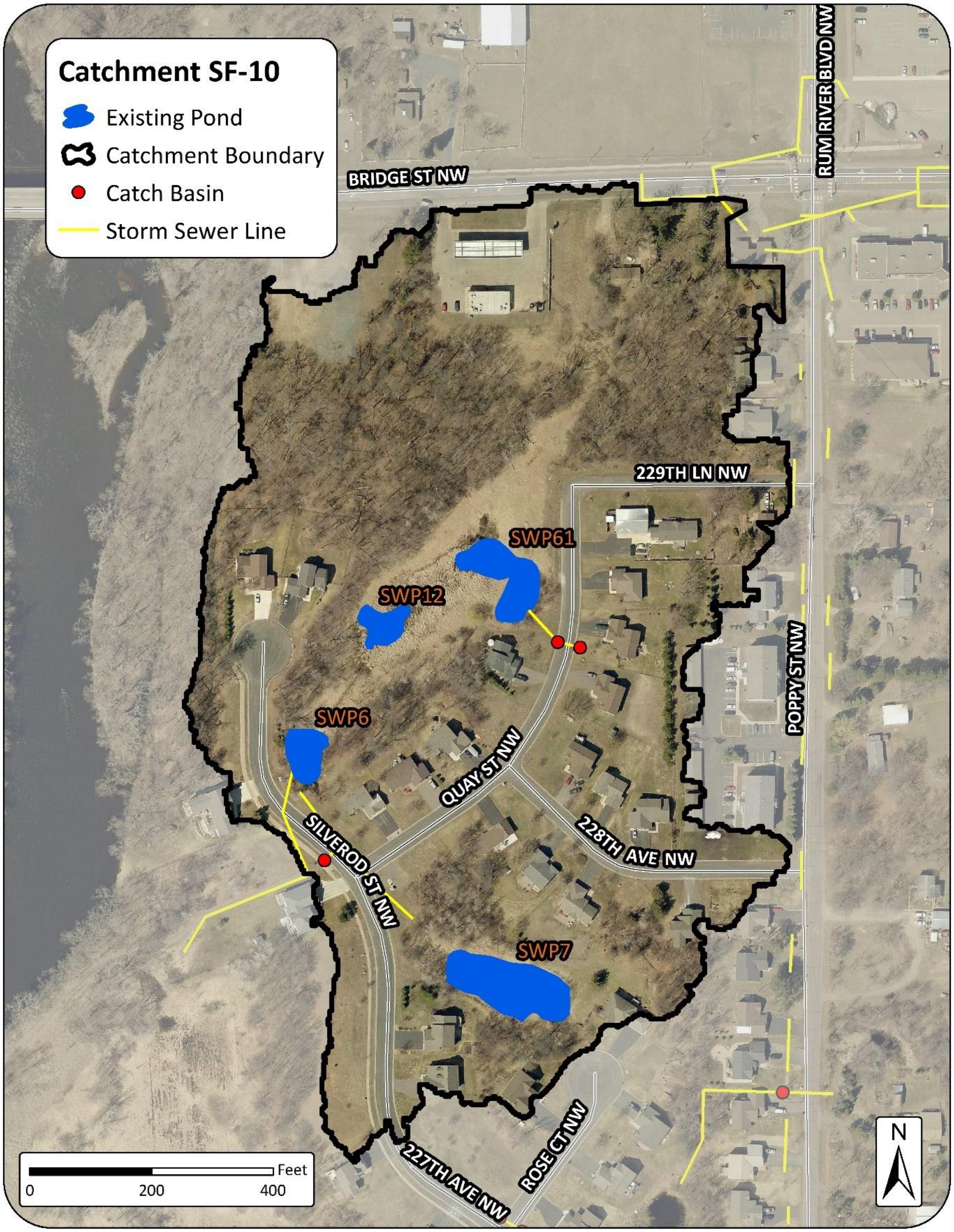
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	4			
	BMP Types	3 Ponds, Street Cleaning			
	TP (lb/yr)	10.5	6.0	57%	**4.5**
	TSS (lb/yr)	3,437	2,745	80%	**692**
	Volume (acre-feet/yr)	8.0	0.0	1%	**8.0**

RETROFITS CONSIDERED BUT REJECTED

A single hydrodynamic device was proposed upstream of the Rum River outfall to supply treatment. However, because of the four retention ponds already in the catchment this device showed to reduce minimal TP and TSS and therefore was not cost effective.

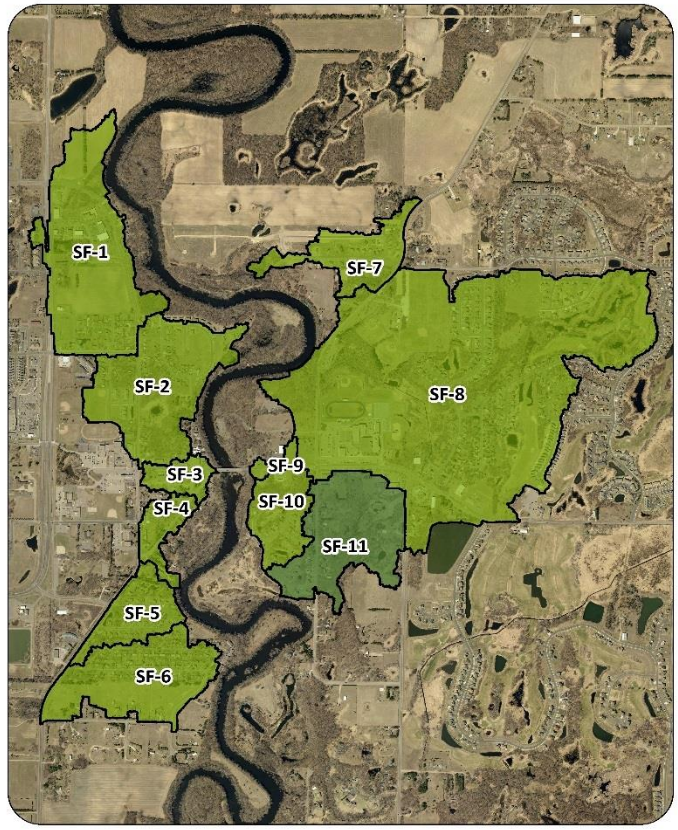
Therefore, the map below was included solely to provide additional detail of the catchment boundary, associated land uses, and streets.

RETROFIT RECOMMENDATIONS



Catchment SF-11

Existing Catchment Summary	
Acres	59.3
Dominant Land Cover	Open
Parcels	65
Volume (acre-feet/yr)	7.6
TP (lb/yr)	6.1
TSS (lb/yr)	1,409



CATCHMENT DESCRIPTION

This catchment includes two major land uses. The first is undeveloped land behind properties on Lake George Boulevard., Bridge Street, and Poppy Street. Within these parcels are five waterbodies, including four natural wetlands (NW109, NW110, NW111, and NW113) and a stormwater retention pond (SWP9). The second major land use is residential properties along Poppy Street and 227th Avenue. These parcels drain to a stormwater pond (SWP8) north of 227th Avenue, which subsequently outlets into the Rum River south of 227th Avenue. Soils in the catchment are poorly-drained Markey and Isanti series (hydrologic group A/D) within the wetland-pond complex and well-drained, Zimmerman fine sands on the upland properties surrounding the wetlands and ponds.

EXISTING STORMWATER TREATMENT

As noted in the Catchment Description, stormwater retention ponds SWP8 and SWP9 as well as NW109, NW110, NW111, and NW113 all provide treatment to stormwater generated within the catchment. The four natural wetlands were modeled as a single BMP within WinSLAMM as they were deemed hydrologically connected.

In addition to these ponds and wetlands, street cleaning is provided by the City of St. Francis twice per year with mechanical sweepers.

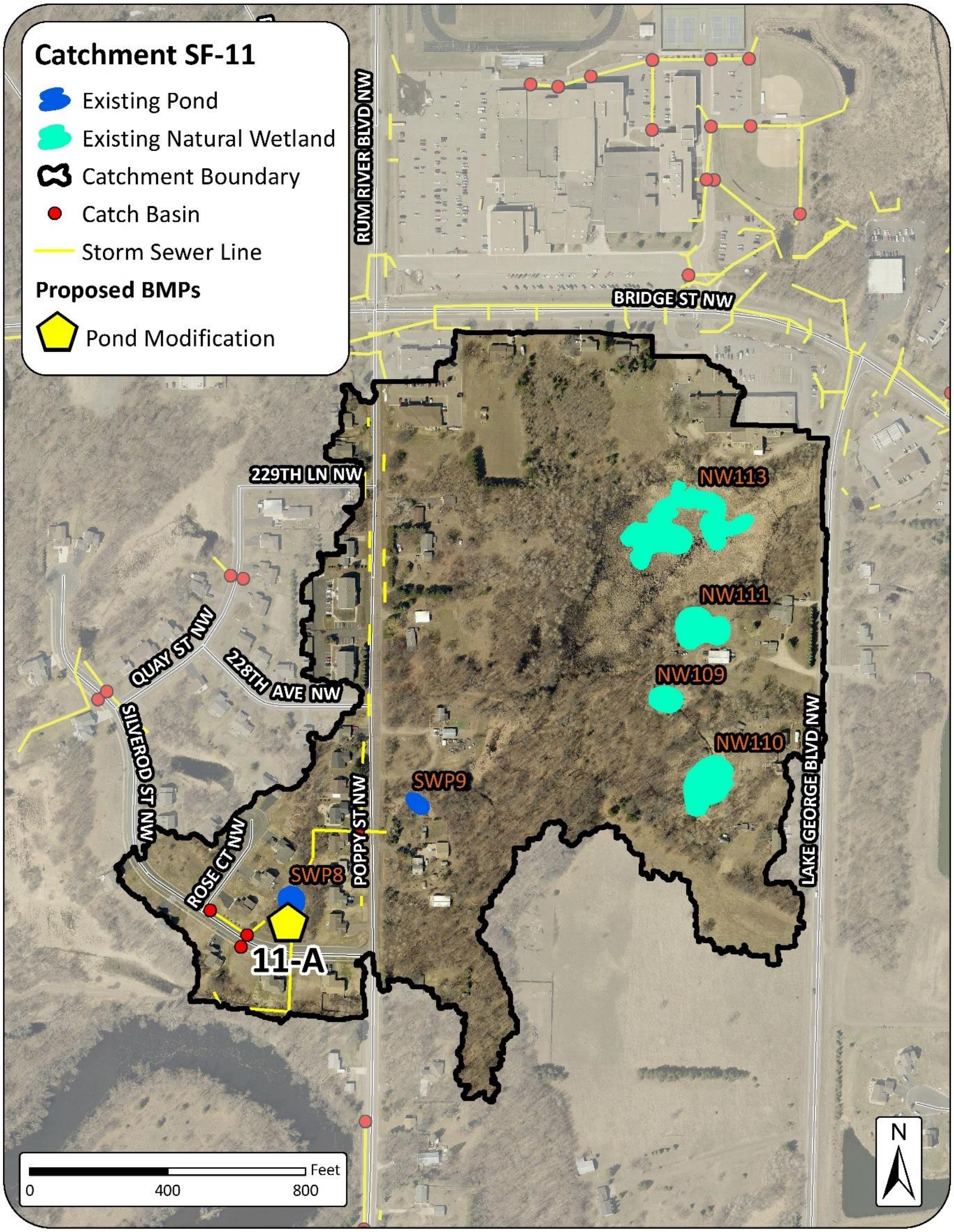
Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment	Existing Loading
Treatment	**Number of BMPs**	7			
	BMP Types	4 Wetlands, 2 Ponds, Street Cleaning			
	TP (lb/yr)	22.2	16.1	73%	**6.1**
	TSS (lb/yr)	6,858	5,449	79%	**1,409**
	Volume (acre-feet/yr)	17.8	10.2	57%	**7.6**

PROPOSED RETROFITS OVERVIEW

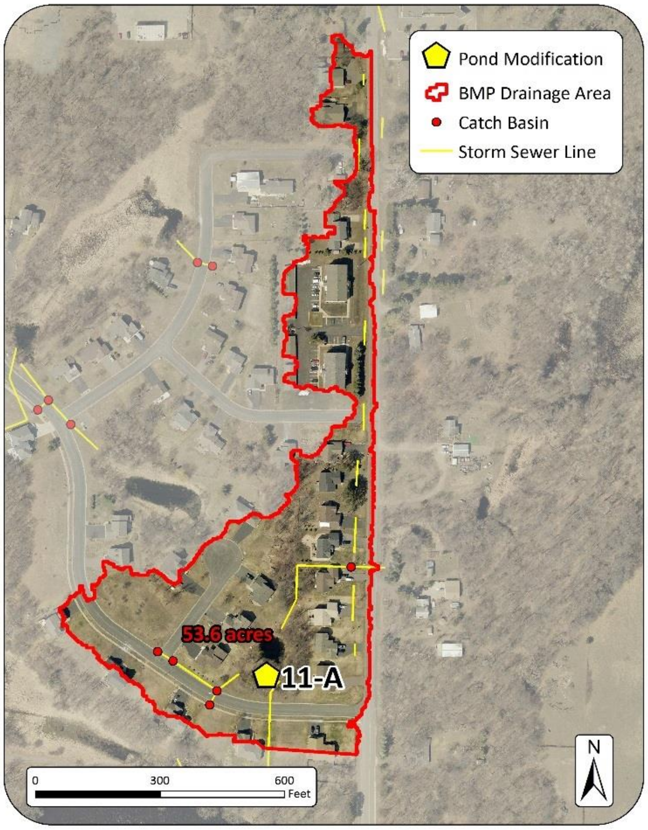
A pond modification was proposed for stormwater retention pond SWP8 to take better advantage of available area and storage. The existing pond outlet is set very low, providing little dead storage for sedimentation. The proposed practice would replace the pond outlet with another that would increase the outlet elevation by three feet. Because of the location of this BMP, at the most downstream point within the catchment, a retrofit to this pond could improve stormwater treatment catchment-wide.

RETROFIT RECOMMENDATIONS



Project ID: 11-A

227th Ave. & Poppy St.
Pond Modification



Drainage Area – 53.6 acres
Location – SWP8
Property Ownership – Private
Site Specific Information – A modification is proposed for SWP8, which is located on private property at the intersection of 227th Avenue NW and Poppy Street NW. This pond currently treats water from 53.6 acres but is undersized relative to the contributing drainage area. Excavating 700 cubic yards of material could increase the size of the pond and improve the treatment efficiency. The price of the pond modification is shown below with three different management levels based on the contamination of the excavated soil.

BMP Modification

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Pond Management Level	1		2		3	
	Amount of Soil Excavated	700	cu-yards	700	cu-yards	700	cu-yards
	TP (lb/yr)	0.9	14.8%	0.9	14.8%	0.9	14.8%
	TSS (lb/yr)	343	24.3%	343	24.3%	343	24.3%
	Volume (acre-feet/yr)	0.0	0.0%	0.0	0.0%	0.0	0.0%
Cost	Administration & Promotion Costs*	$5,840		$5,840		$5,840	
	Design & Construction Costs**	$99,000		$109,500		$120,000	
	Total Estimated Project Cost (2016)	**$104,840**		**$115,340**		**$125,840**	
	Annual O&M***	$1,300		$1,300		$1,300	
Efficiency	30-yr Average Cost/lb-TP	**$5,327**		**$5,716**		**$6,105**	
	30-yr Average Cost/1,000lb-TSS	**$13,979**		**$14,999**		**$16,019**	
	30-yr Average Cost/ac-ft Vol.	**N/A**		**N/A**		**N/A**	

*Indirect Cost: 80 hours at $73/hour

**Direct Cost: See Appendix B for detailed cost information

***$1,000/acre of pond surface area - Annual inspection and sediment/debris removal from pretreatment area

References

Erickson, A.J., and J.S. Gulliver. 2010. *Performance Assessment of an Iron-Enhanced Sand Filtration Trench for Capturing Dissolved Phosphorus*. University of Minnesota St. Anthony Falls Laboratory Engineering, Environmental and Geophysical Fluid Dynamics Project Report No. 549. Prepared for the City of Prior Lake, Prior Lake, MN.

Minnesota Pollution Control Agency (MPCA). 2014. *Design Criteria for Stormwater Ponds*. Web.

New York City Environmental Protection. 2013. *NYC Green Infrastructure 2013 Annual Report*. 36 pp.

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Schueler, T., D. Hirschman, M. Novotney, and J. Zielinski. 2007. *Urban Stormwater Retrofit Practices. Manual 3, Urban Subwatershed Restoration Manual Series. Center for Watershed Protection*. Ellicott City, MD.

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Appendix A – Modeling Methods

The following sections include WinSLAMM model details for each type of best management practice modeled for this analysis.

WinSLAMM

Pollutant and volume reductions were estimated using the stormwater model Source Load and Management Model for Windows (WinSLAMM). WinSLAMM uses an abundance of stormwater data from the Upper-Midwest and elsewhere to quantify runoff volumes and pollutant loads from urban areas. It offers detailed accounting of pollutant loading from various land uses, and allows the user to build a model "landscape". WinSLAMM uses rainfall and temperature data from a typical year (1959 data from Minneapolis for this analysis), routing stormwater through the user's model for each storm. WinSLAMM version 10.2.0 was used for this analysis to estimate volume and pollutant loading and reductions. Additional inputs for WinSLAMM are provided in Table 5.

Table 5: General WinSLAMM Model Inputs (i.e. Current File Data)

Parameter	File/Method
Land use acreage	ArcMap, Metropolitan Council 2010 Land Use
Precipitation/Temperature Data	Minneapolis 1959 – best approximation of a typical year
Winter season	Included in model. Winter dates are 11-4 to 3-13.
Pollutant probability distribution	WI_GEO01.ppd
Runoff coefficient file	WI_SL06 Dec06.rsv
Particulate solids concentration file	WI_AVG01.psc
Particle residue delivery file	WI_DLV01.prr
Street delivery files	WI files for each land use

Existing Conditions

Existing stormwater BMPs were included in the WinSLAMM model for which information was available from the state (MNDOT), county (Anoka County), and the City of St. Francis. The practices listed below were included in the existing conditions model.

Grass Swale

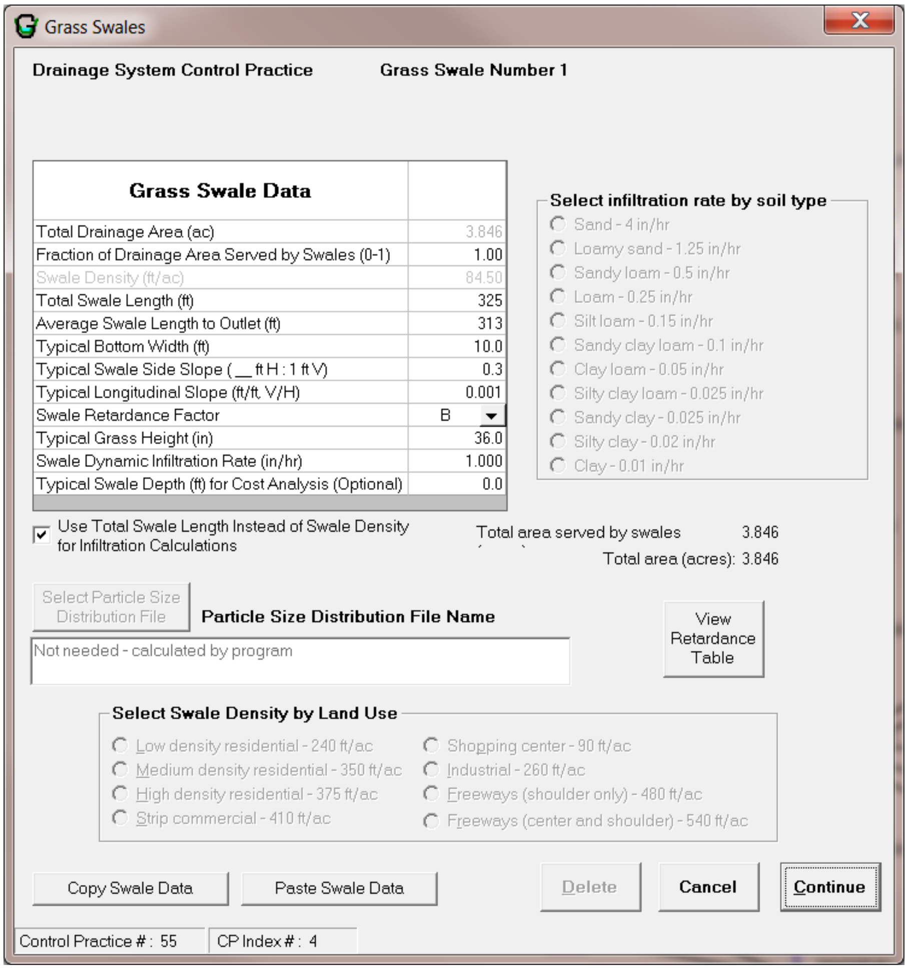

Figure 12: Grass Swale SWA109 in SF-1 (WinSLAMM).

Detention Basin

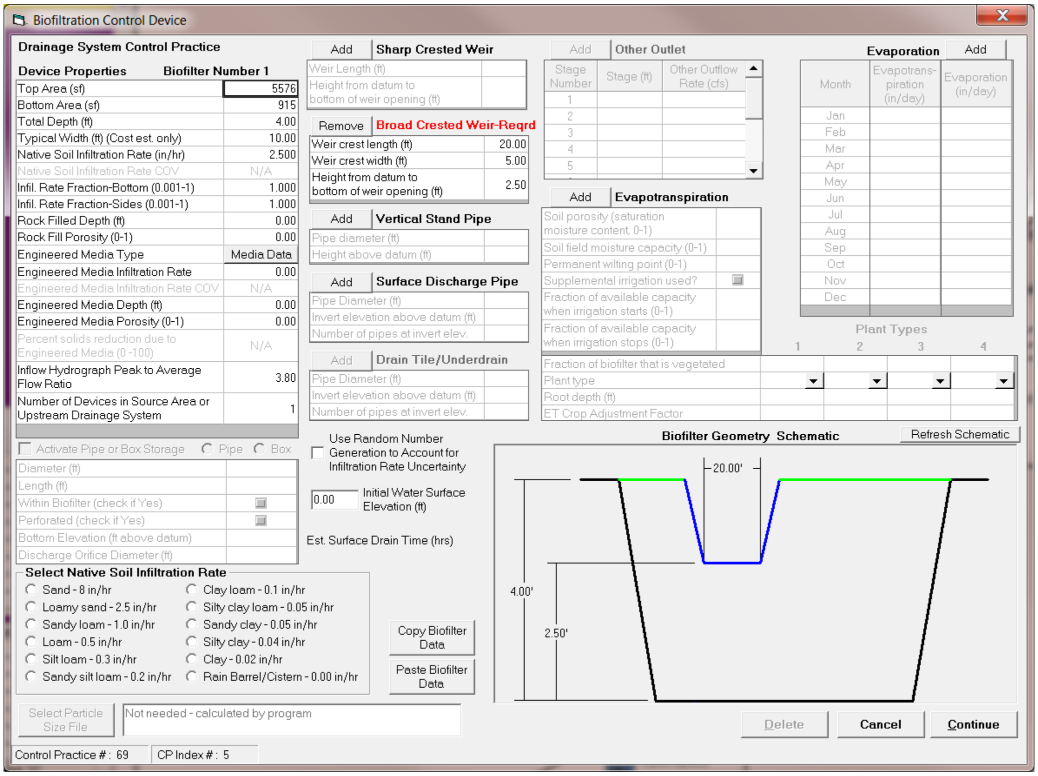

Figure 13: Detention Basin DB118 in SF-2 (WinSLAMM).

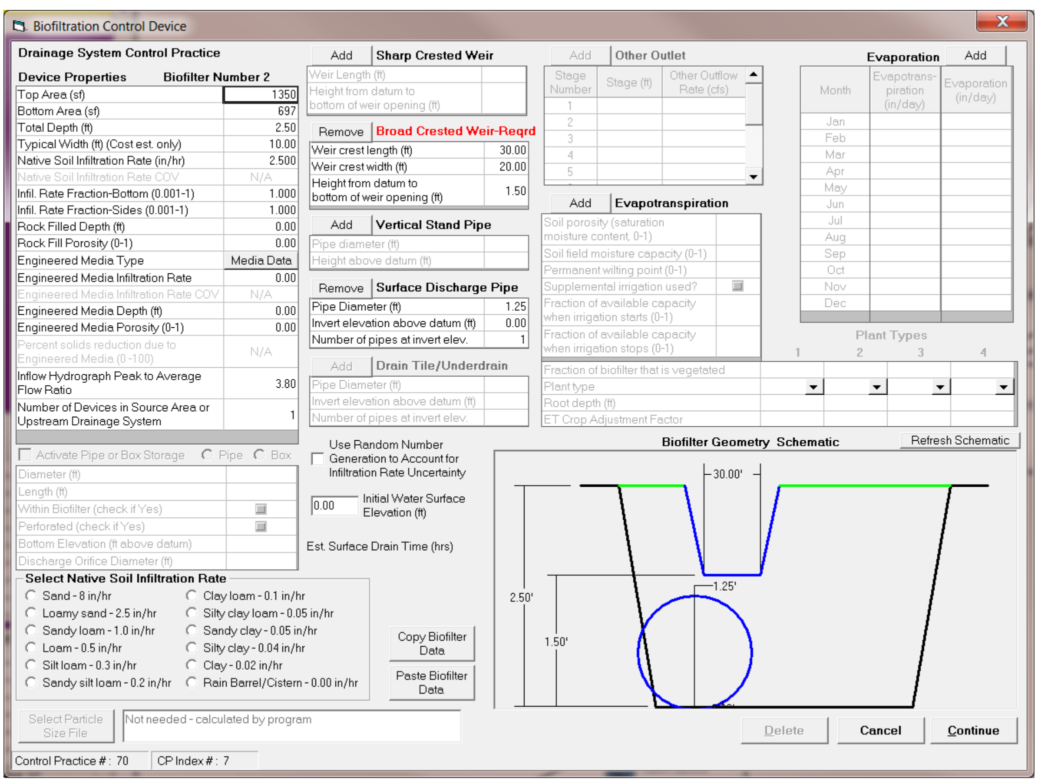

Figure 14: Detention Basin DB115 in SF-2 (WinSLAMM).

Hydrodynamic Device

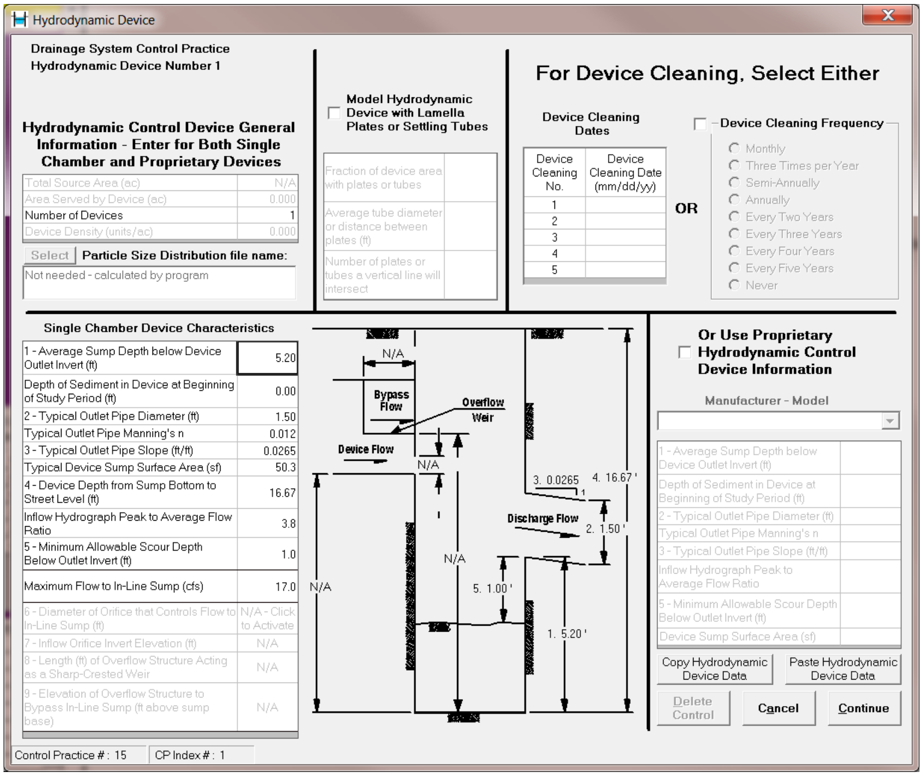

Figure 15: Hydrodynamic Device at River Drive and Rum River Boulevard in SF-2 (WinSLAMM).

Ponds

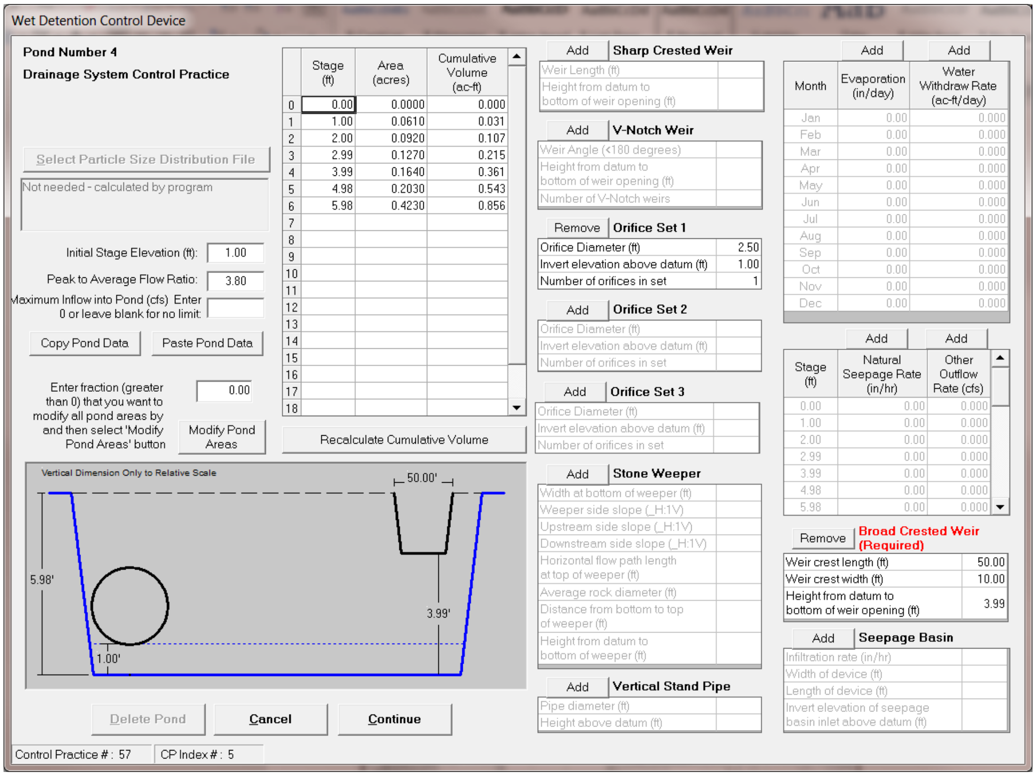

Figure 16: Stormwater Pond SWP116 in SF-1 (WinSLAMM).

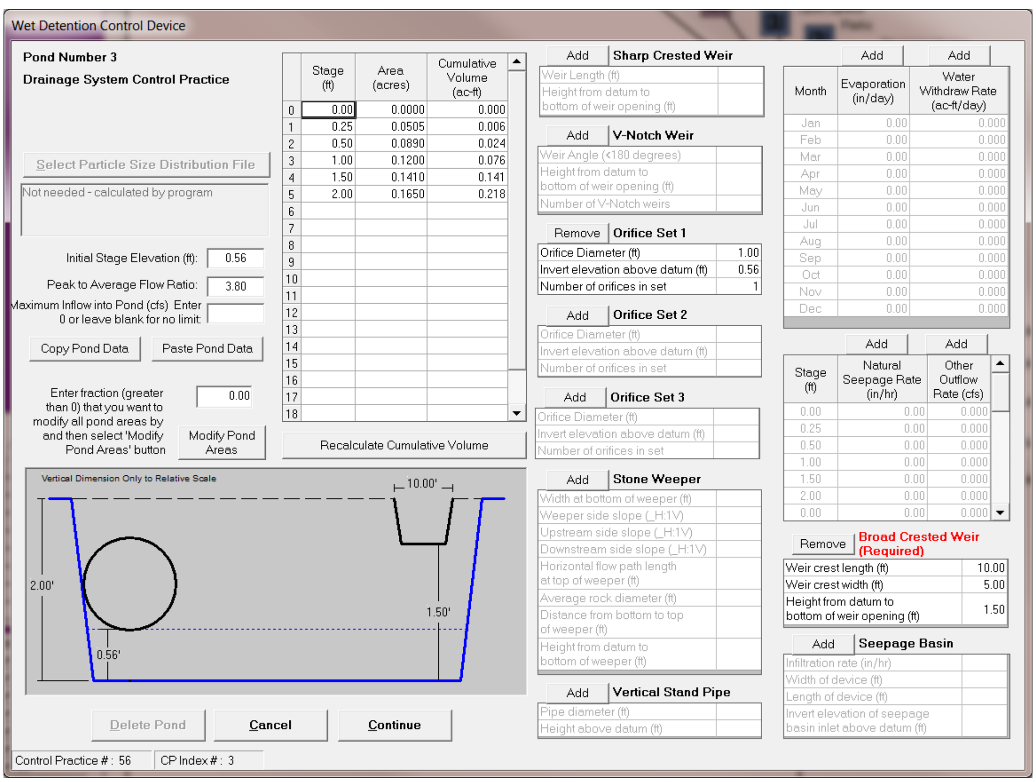

Figure 17: Stormwater Pond SWP50 in SR-1 (WinSLAMM).

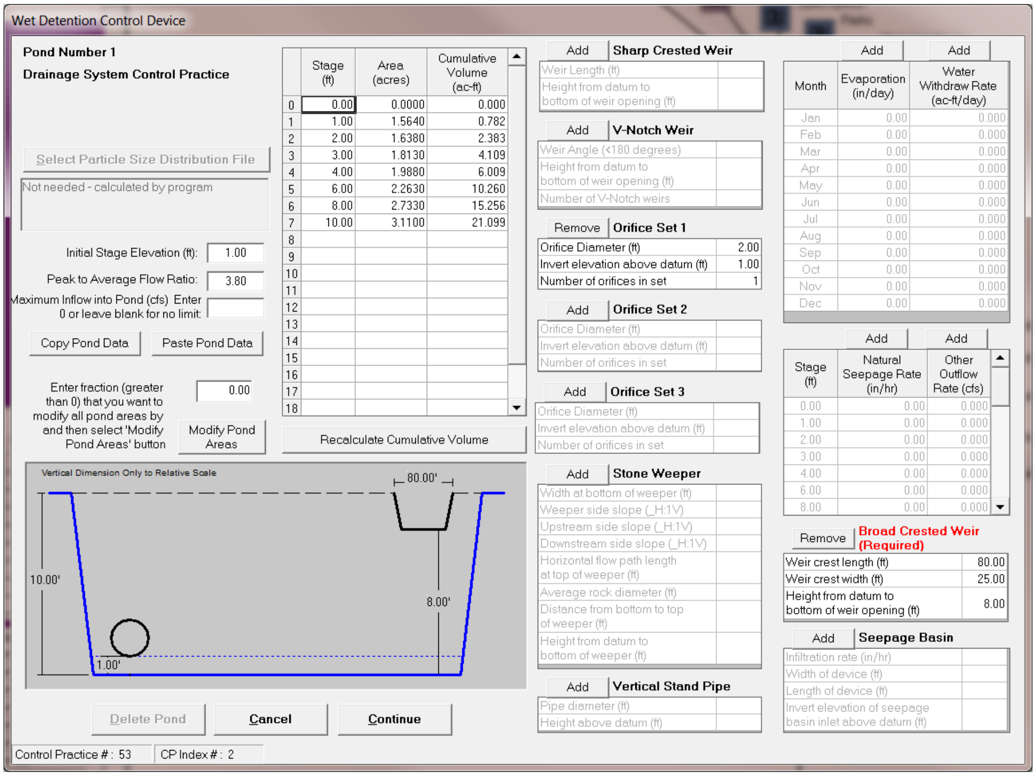

Figure 18: Stormwater Pond NW107 in SF-1 (WinSLAMM).

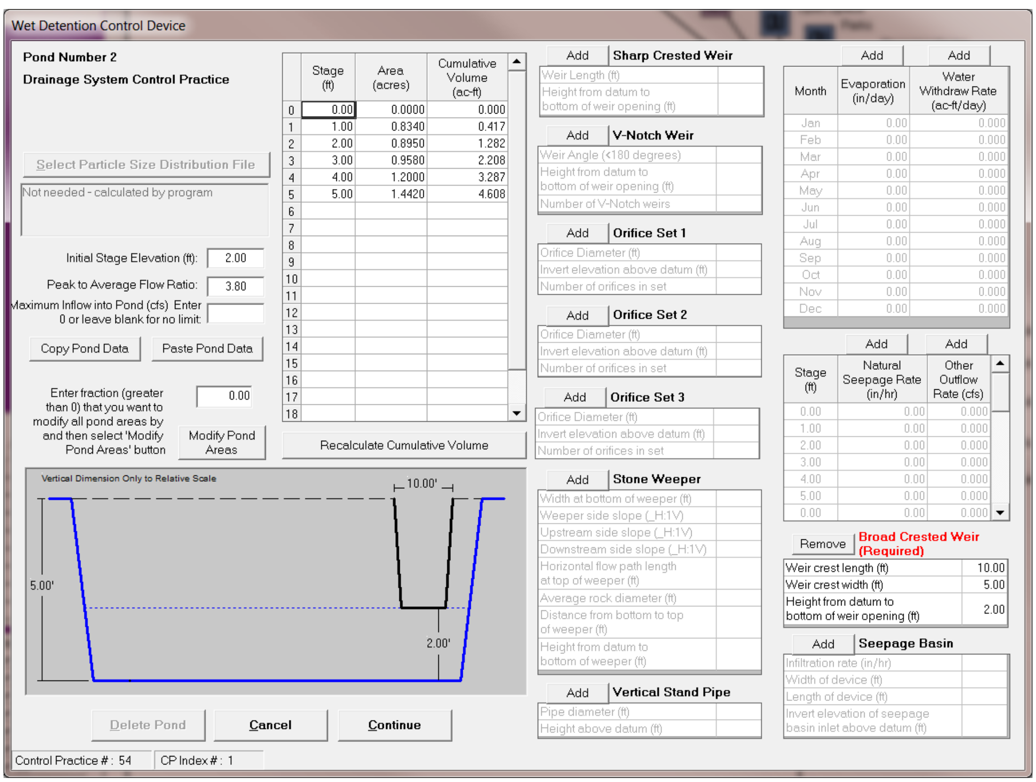

Figure 19: Stormwater Pond NW108 in SF-1 (WinSLAMM).

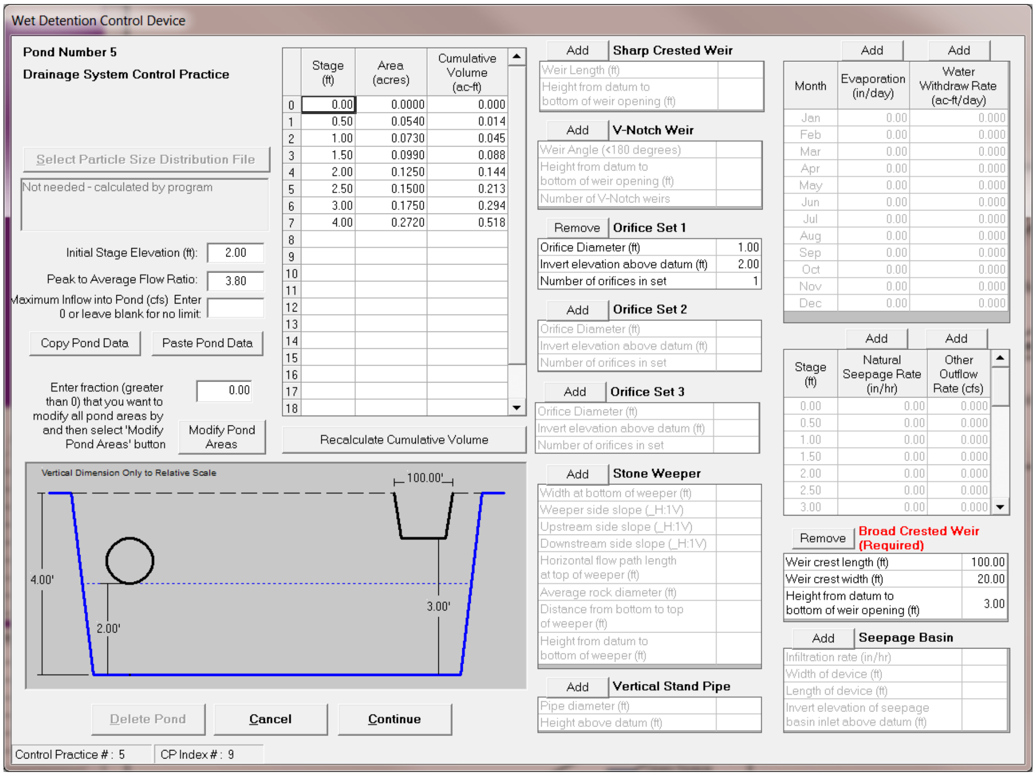

Figure 20: Stormwater Pond SWP106 in SF-2 (WinSLAMM).

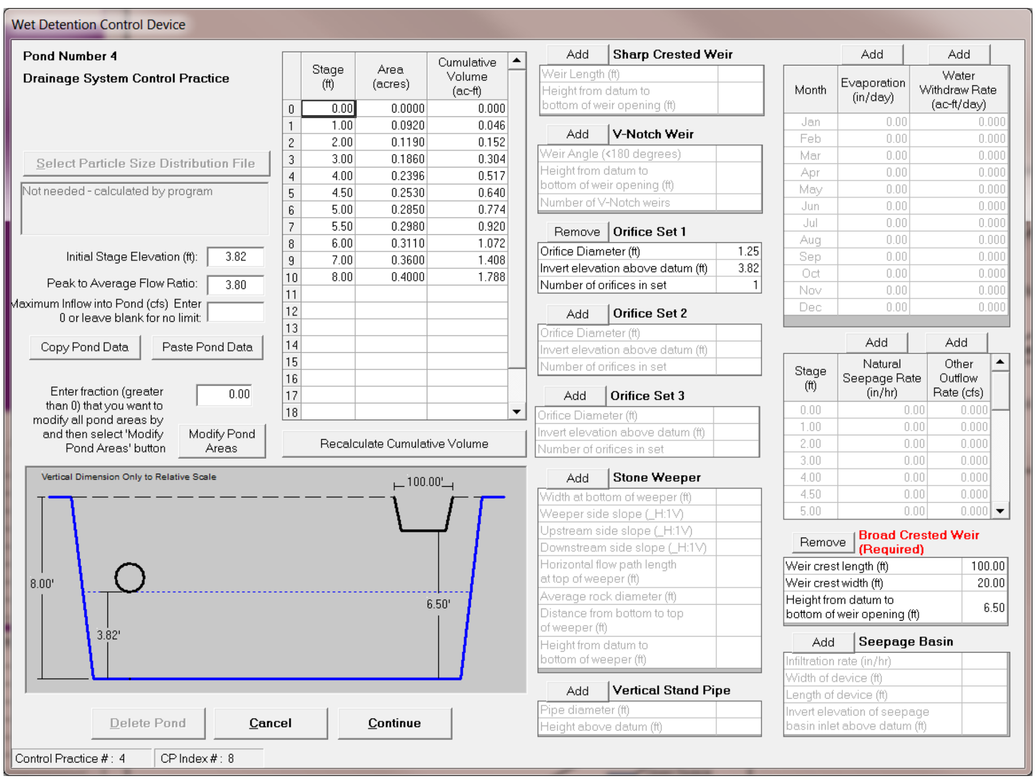

Figure 21: Stormwater Pond SWP103 in SF-2 (WinSLAMM).

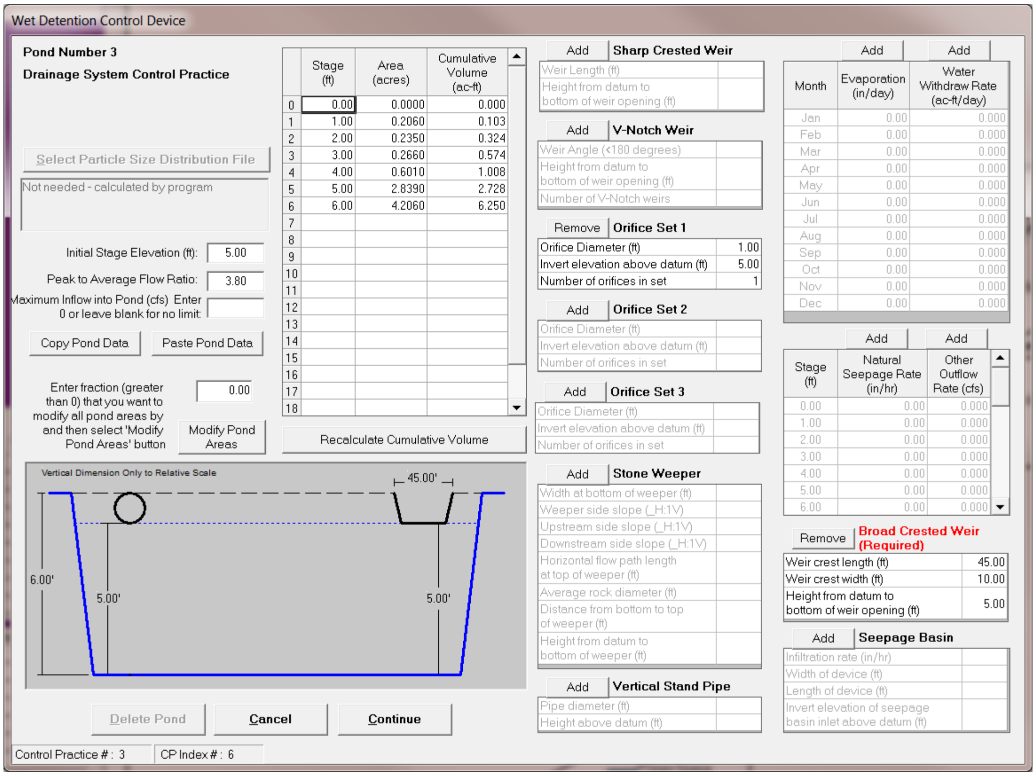

Figure 22: Stormwater Pond SWP82 in SF-2 (WinSLAMM).

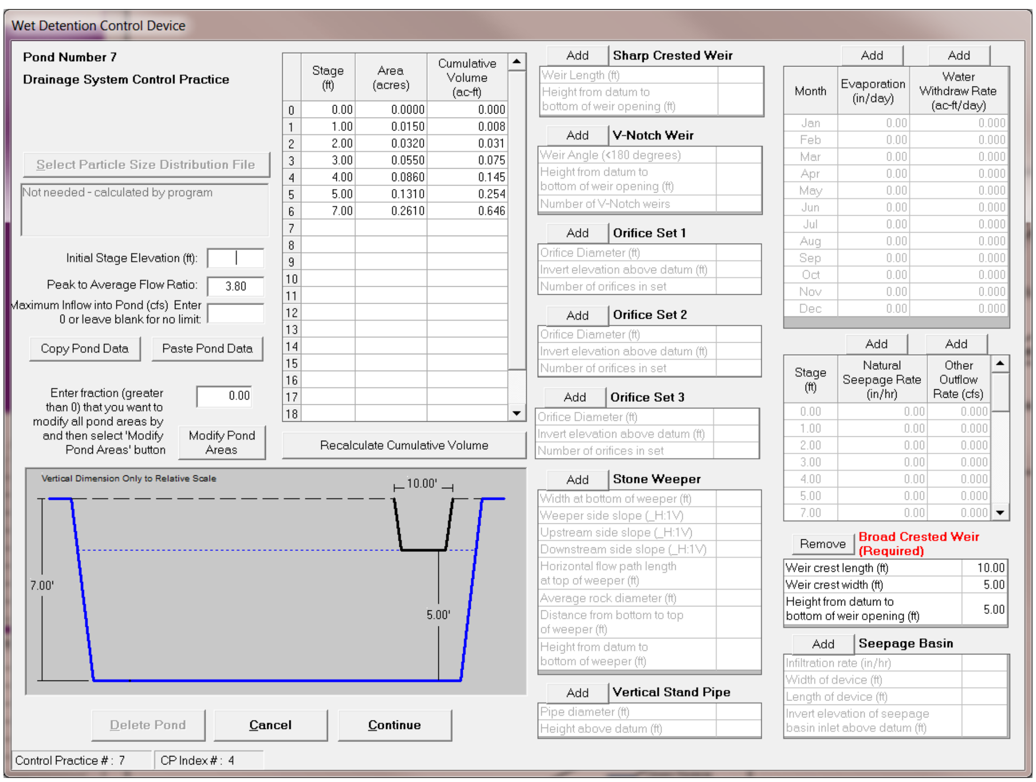

Figure 23: Stormwater Pond SWP104 in SF-2 (WinSLAMM).

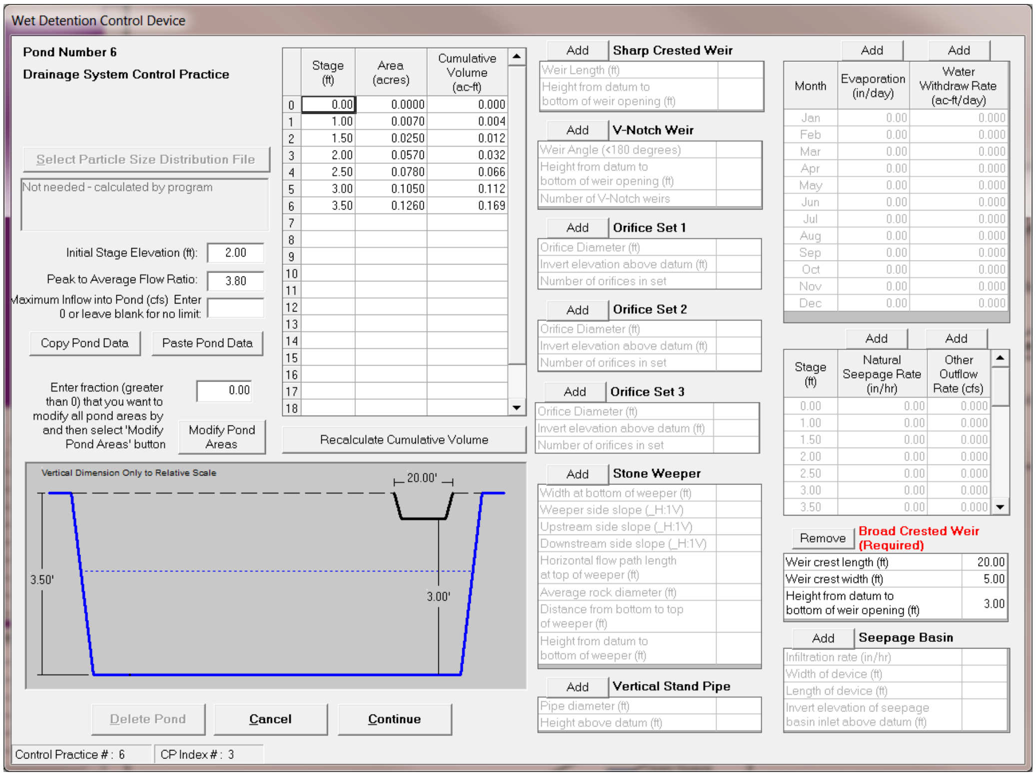

Figure 24: Stormwater Pond SWP117 in SF-2 (WinSLAMM).

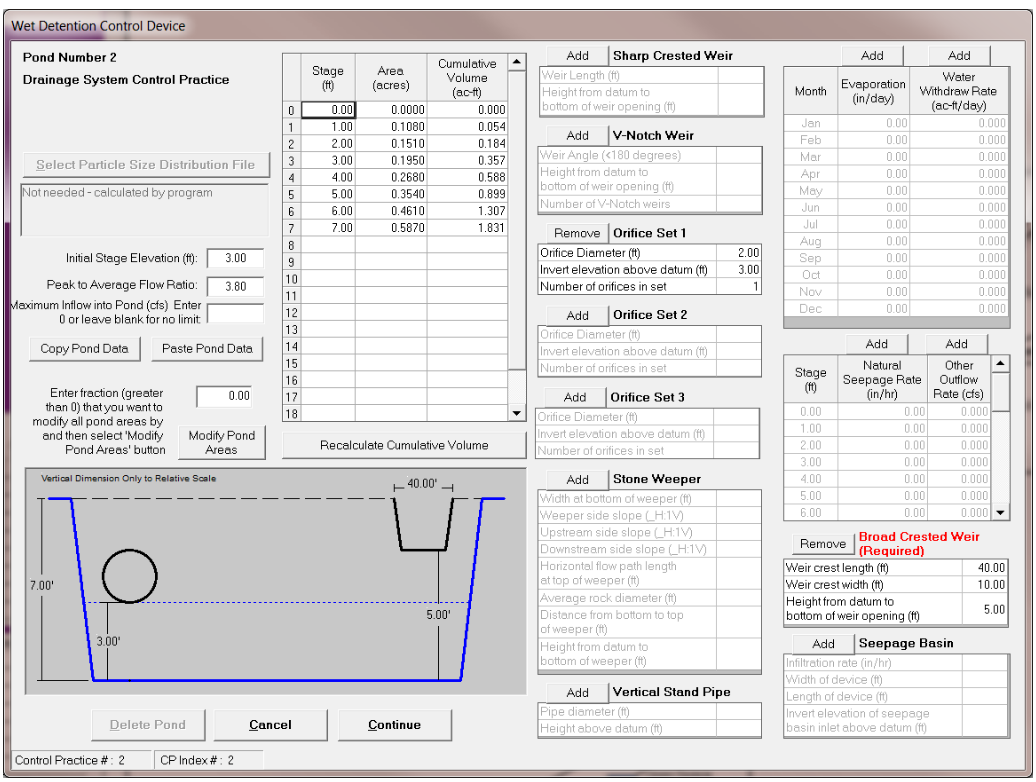

Figure 25: Stormwater Pond SWP83 in SF-2 (WinSLAMM).

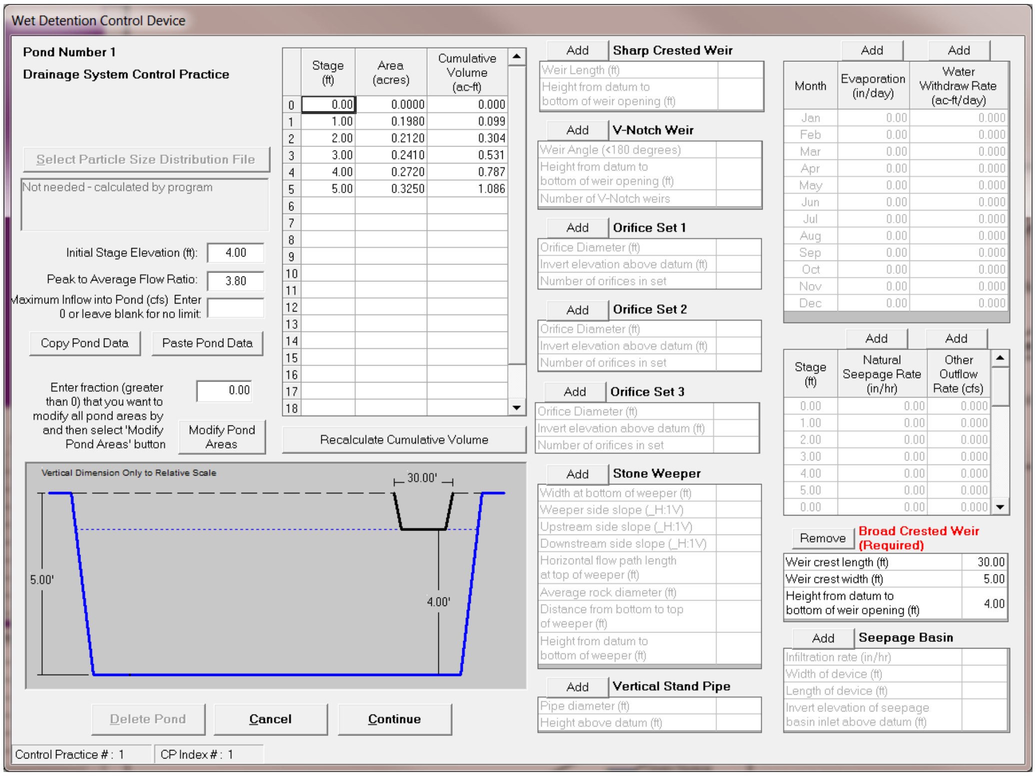

Figure 26: Stormwater Pond SWP84 in SF-2 (WinSLAMM).

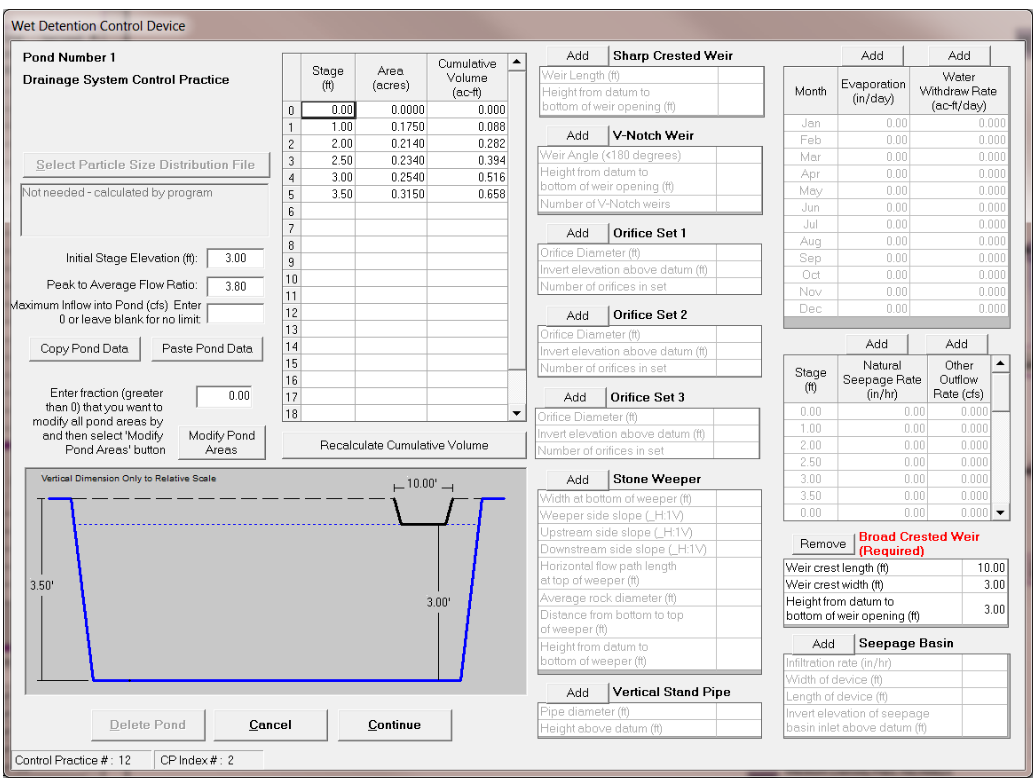

Figure 27: Stormwater Pond SWP10 in SF-5 (WinSLAMM).

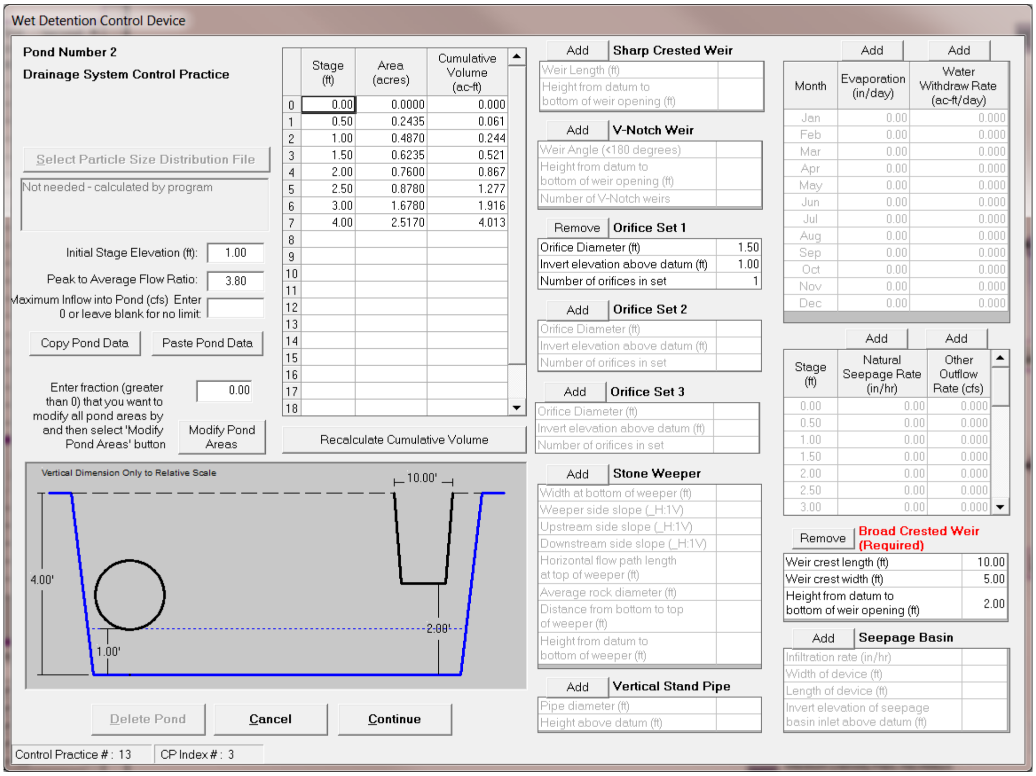

Figure 28: Stormwater Pond SWP11 in SF-5 (WinSLAMM).

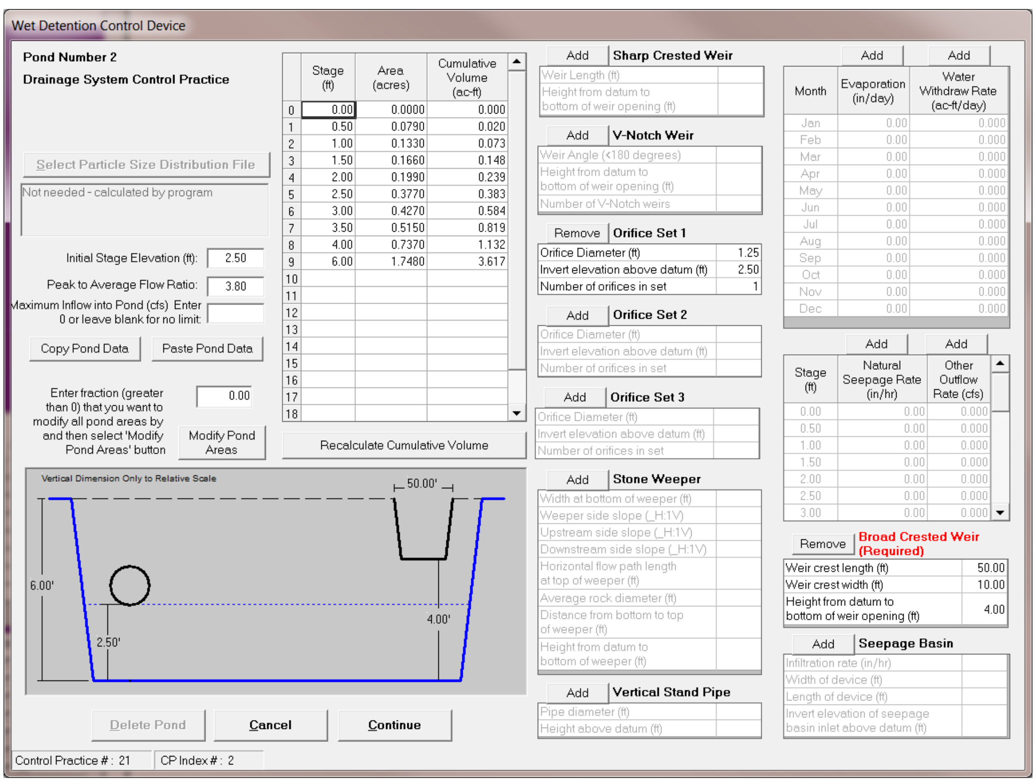

Figure 29: Stormwater Pond SWP105 in SF-7 (WinSLAMM).

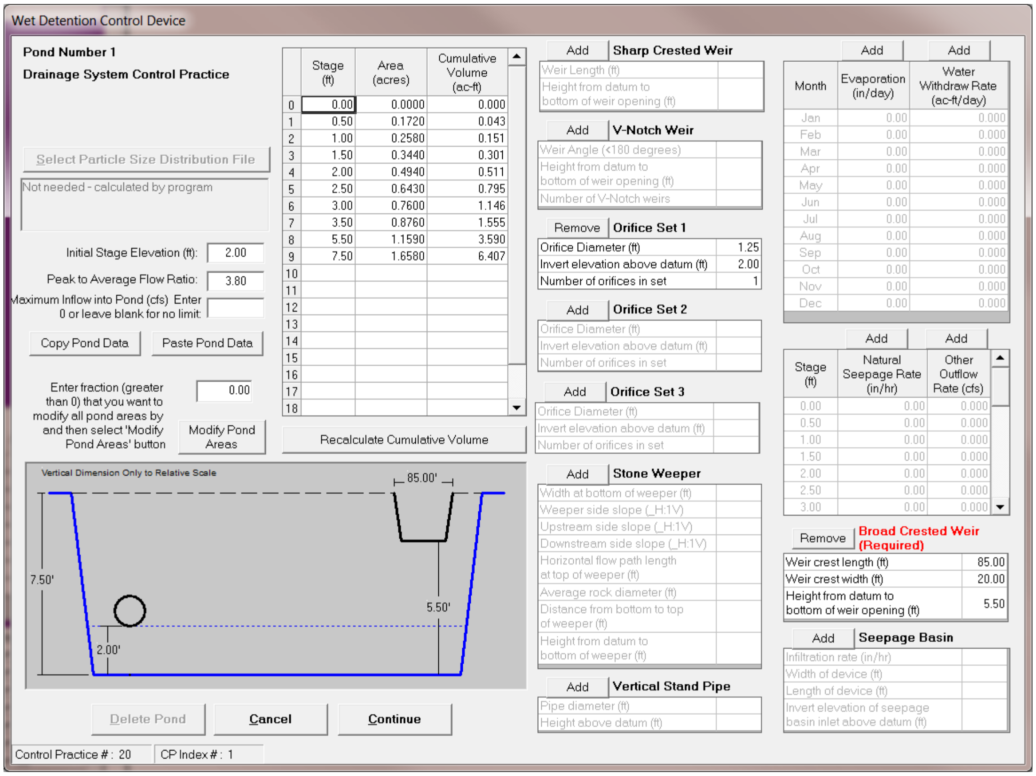

Figure 30: Stormwater Pond SWP52 in SF-7 (WinSLAMM).

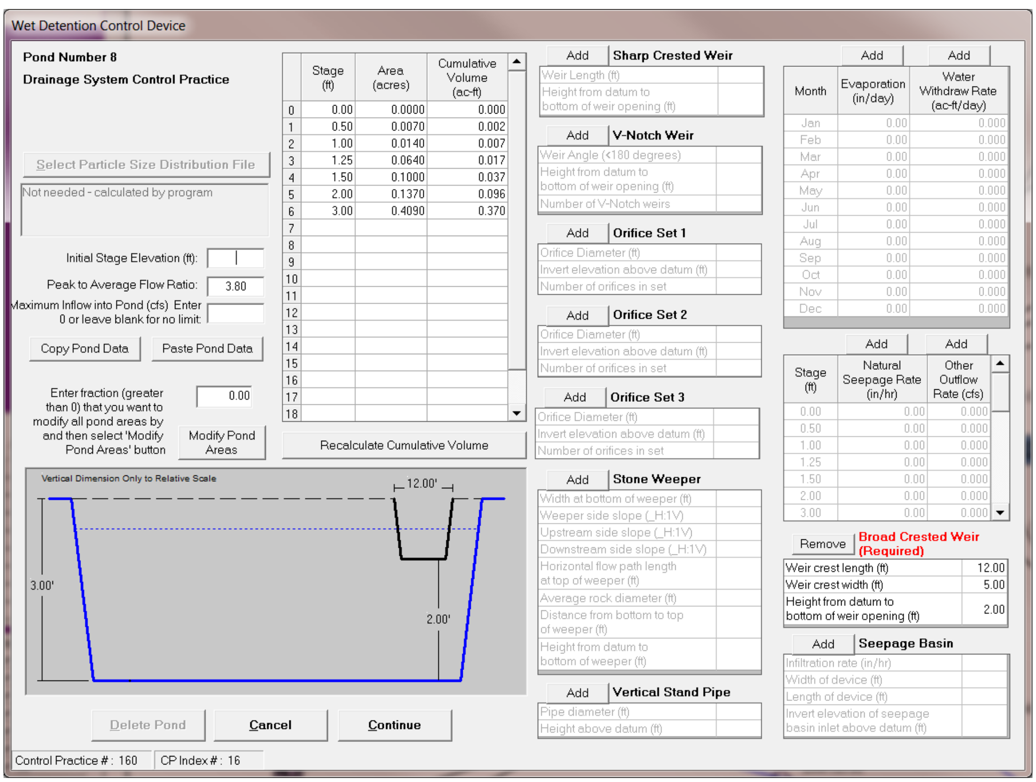

Figure 31: Stormwater Pond SWP22 in SF-8 (WinSLAMM).

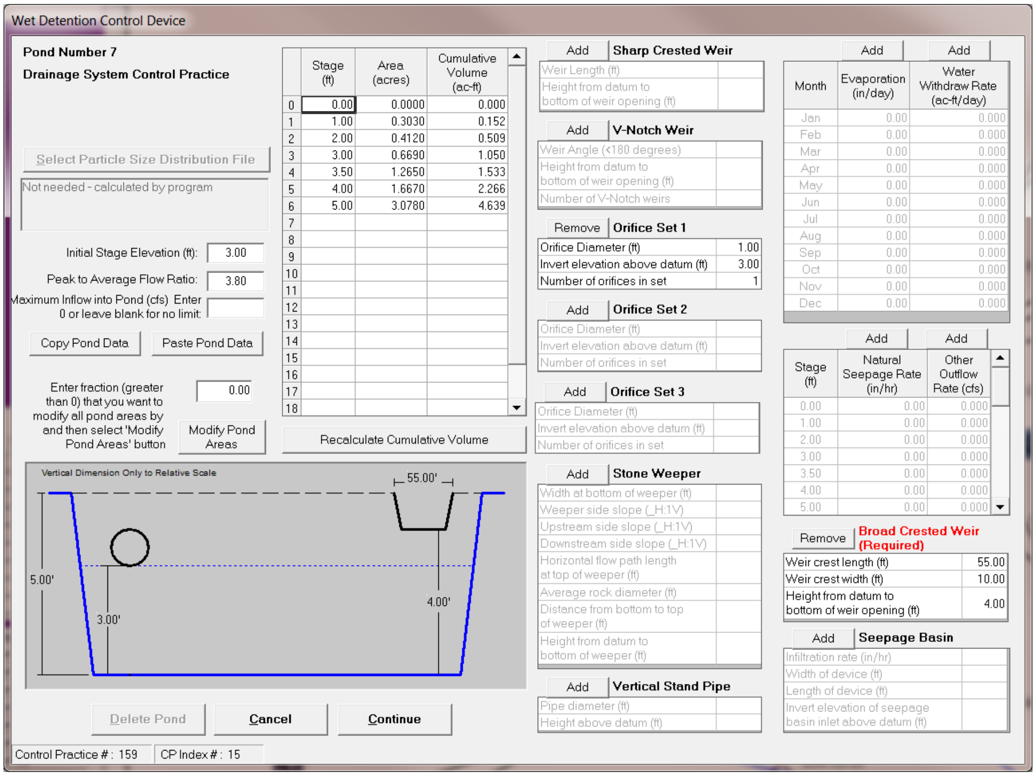

Figure 32: Stormwater Pond SWP21 in SF-8 (WinSLAMM).

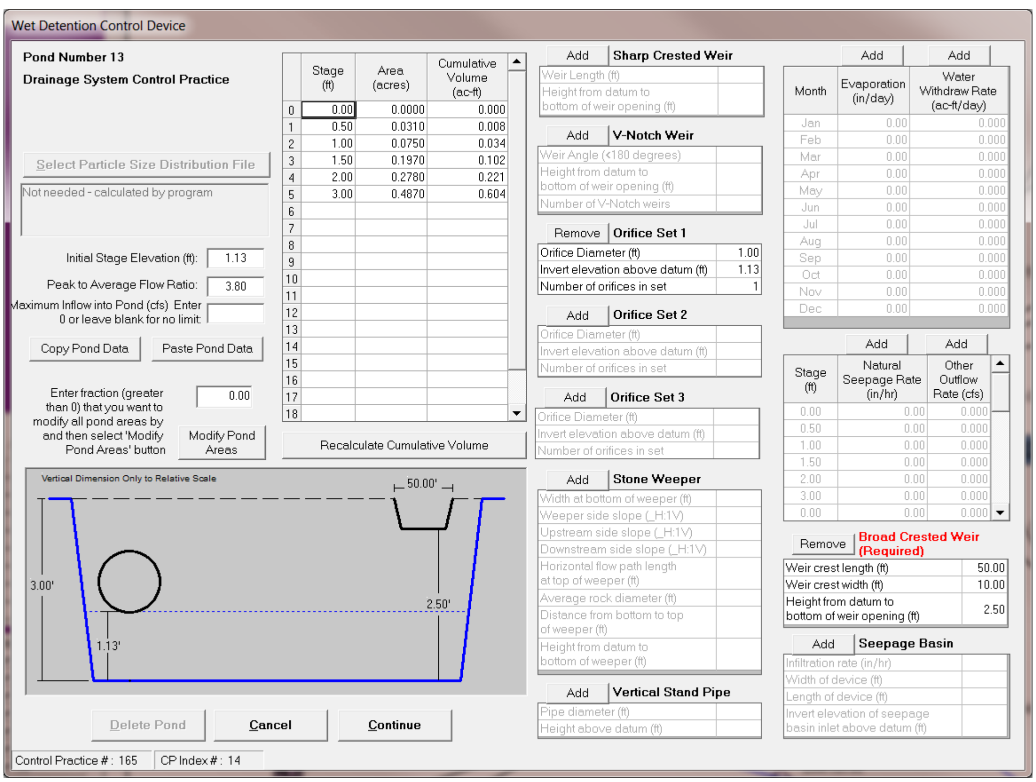

Figure 33: Stormwater Pond NW120 in SF-8 (WinSLAMM).

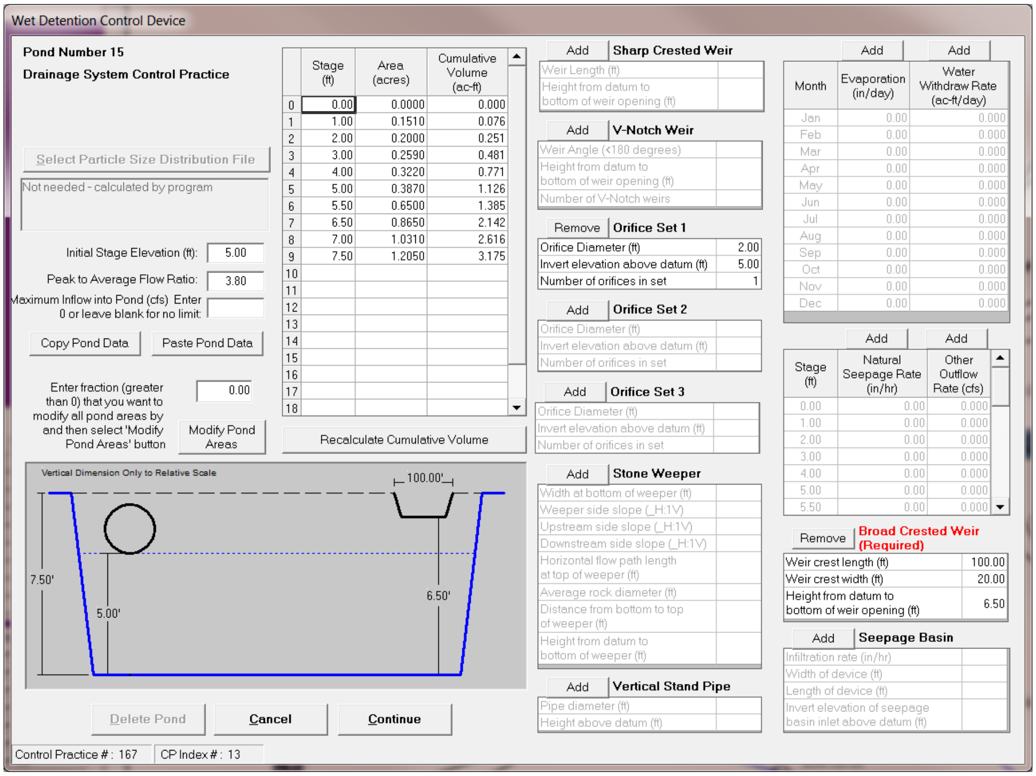

Figure 34: Stormwater Pond SWP90 in SF-8 (WinSLAMM).

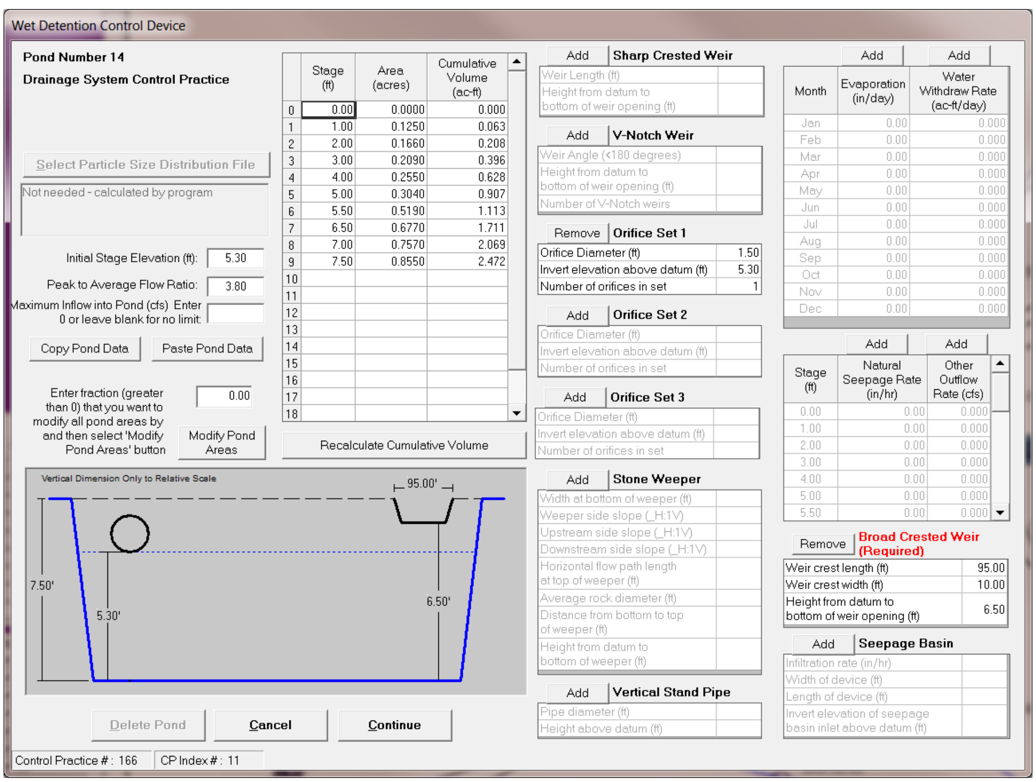

Figure 35: Stormwater Pond SWP89 in SF-8 (WinSLAMM).

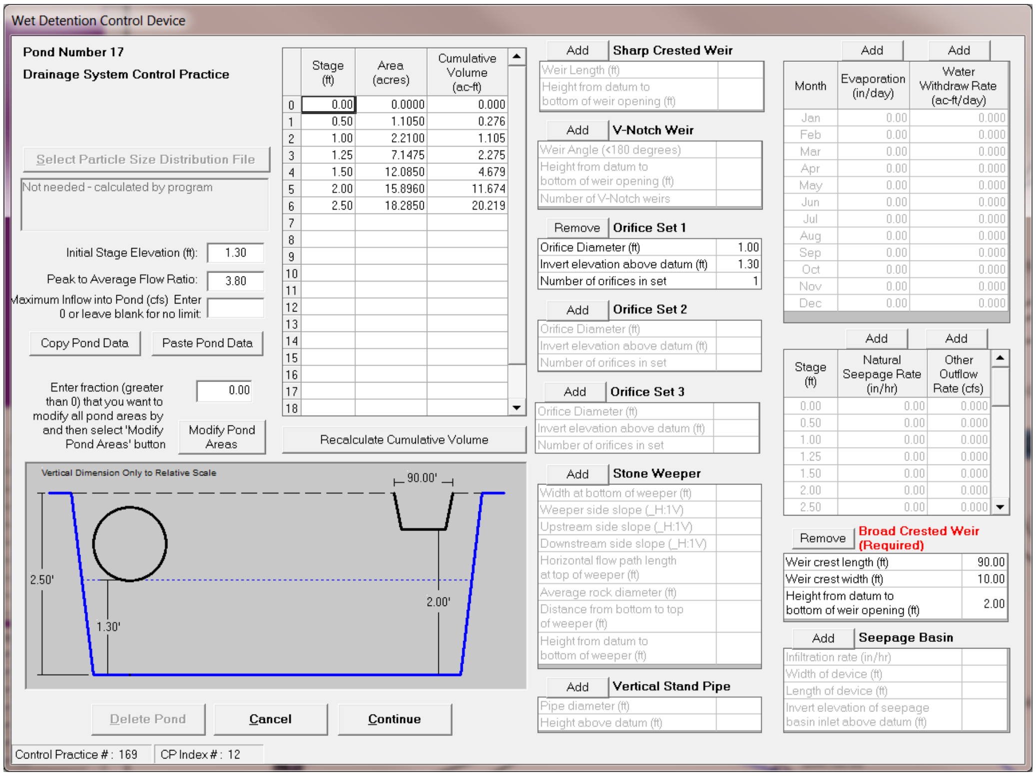

Figure 36: Stormwater Pond SWP29, SWP30, SWP32, SWP33, SWP56, SWP92, SWP93 in SF-8 (WinSLAMM).

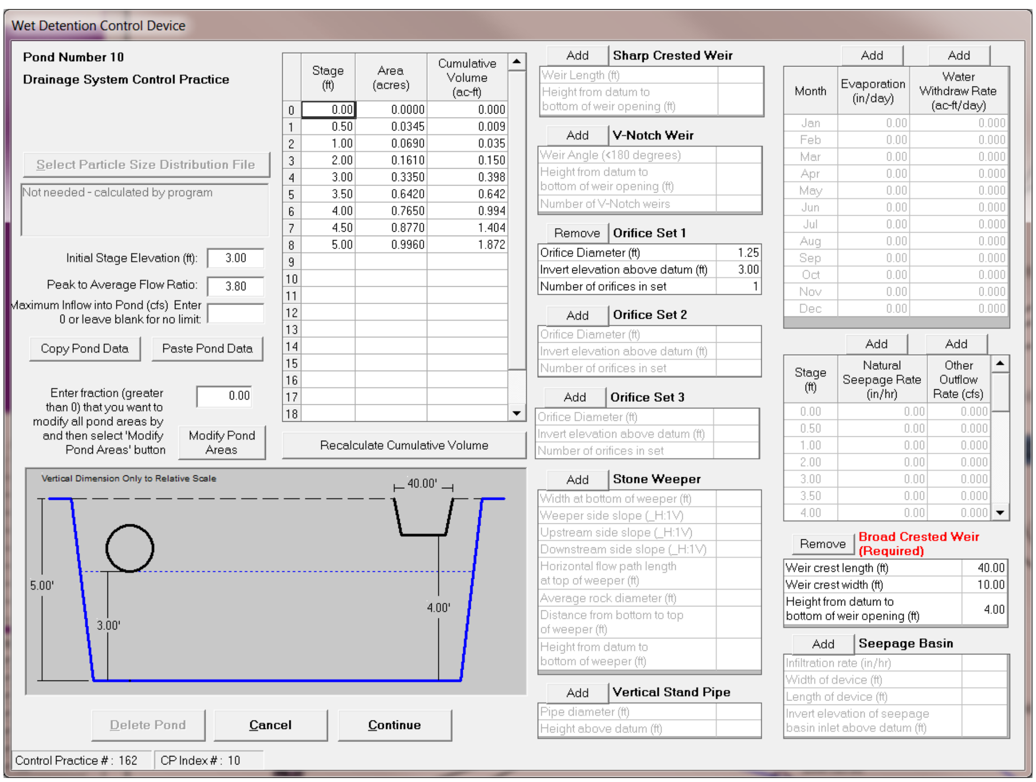

Figure 37: Stormwater Pond SWP31 in SF-8 (WinSLAMM).

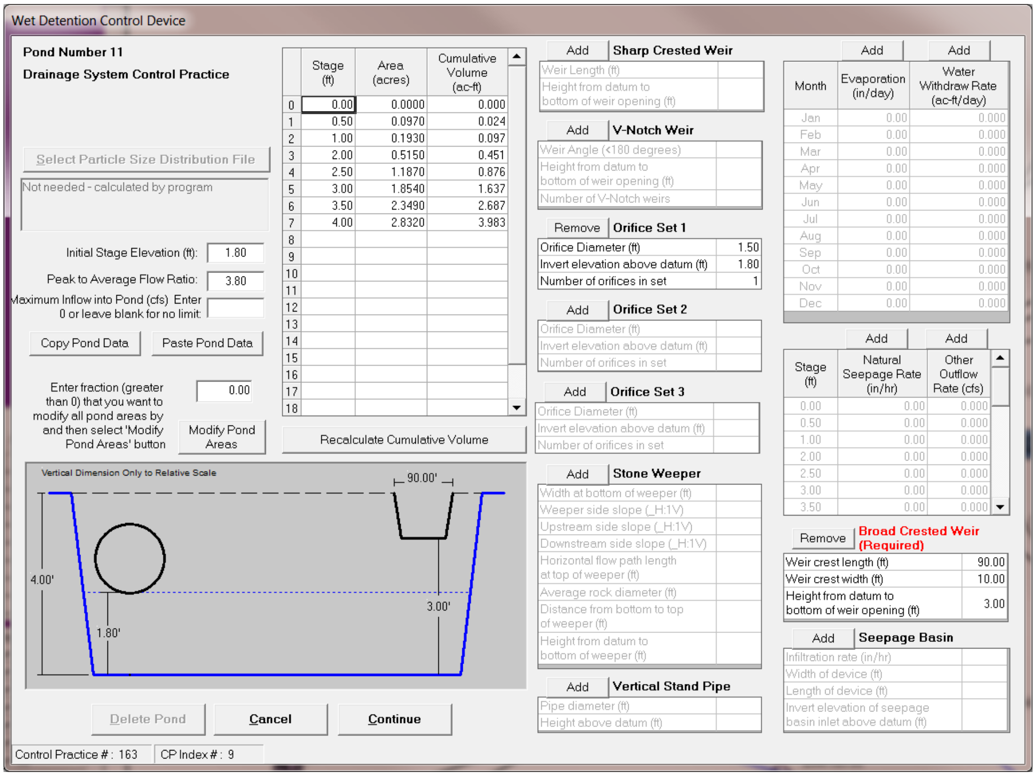

Figure 38: Stormwater Pond SWP34, SWP35 in SF-8 (WinSLAMM).

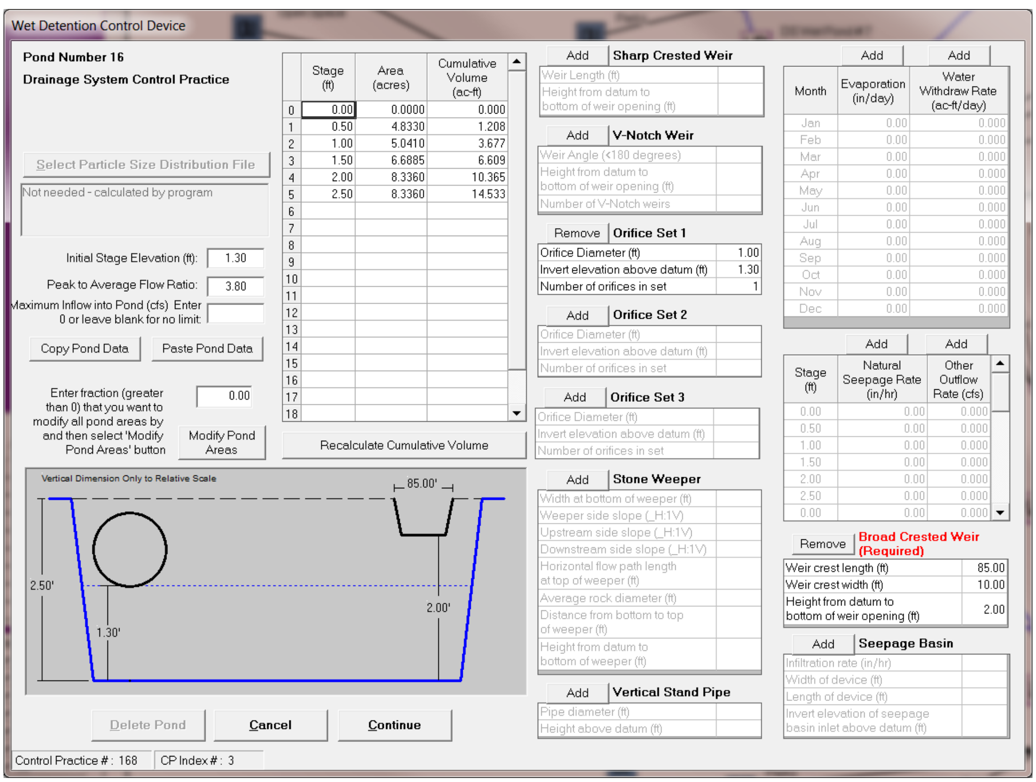

Figure 39: Stormwater Pond SWP73, SWP74, SWP75, SWP91 in SF-8 (WinSLAMM).

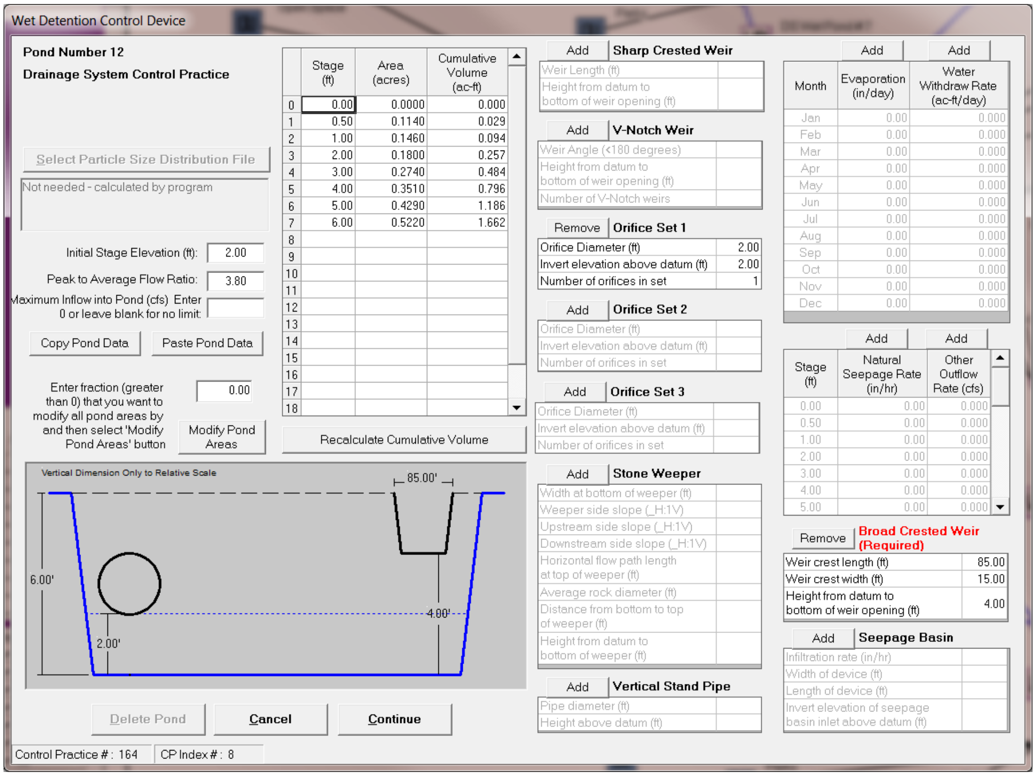

Figure 40: Stormwater Pond SWP88 in SF-8 (WinSLAMM).

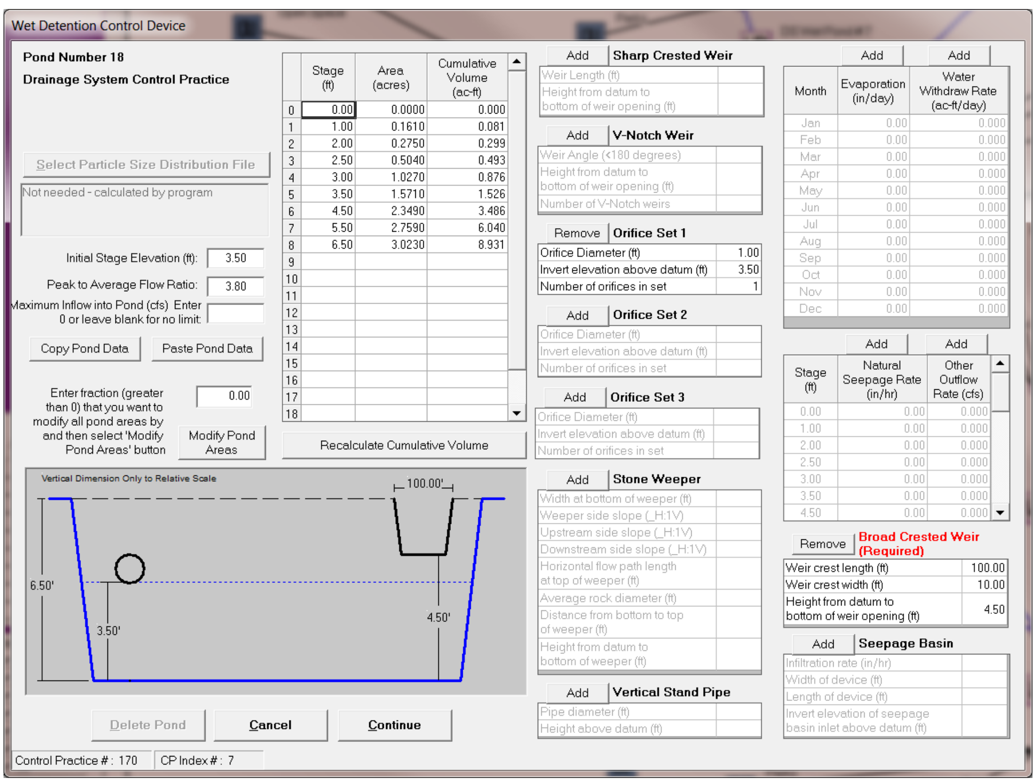

Figure 41: Stormwater Pond SWP86, SWP87 in SF-8 (WinSLAMM).

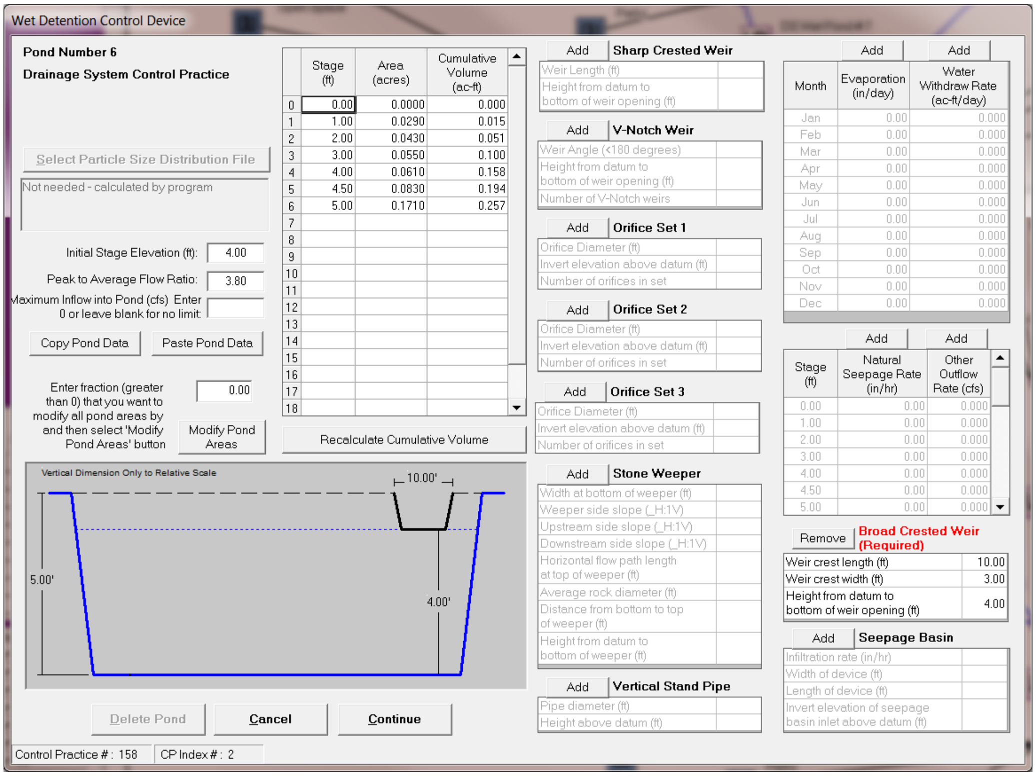

Figure 42: Stormwater Pond SWP101 in SF-8 (WinSLAMM).

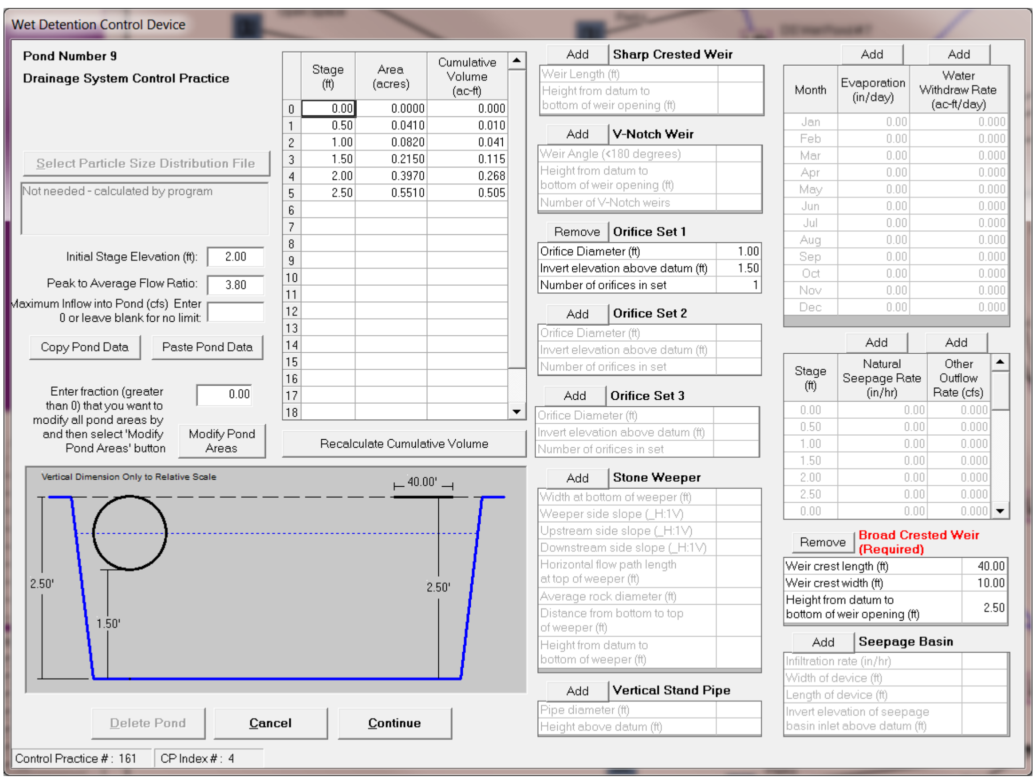

Figure 43: Stormwater Pond SWP23 in SF-8 (WinSLAMM).

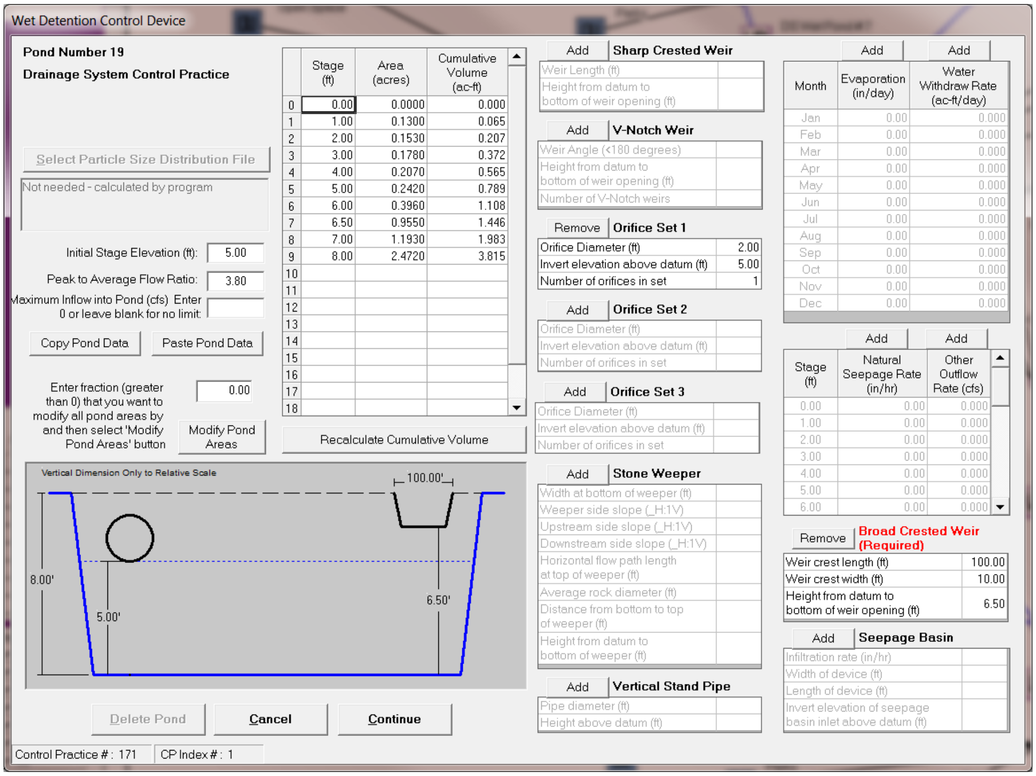

Figure 44: Stormwater Pond SWP85 in SF-8 (WinSLAMM).

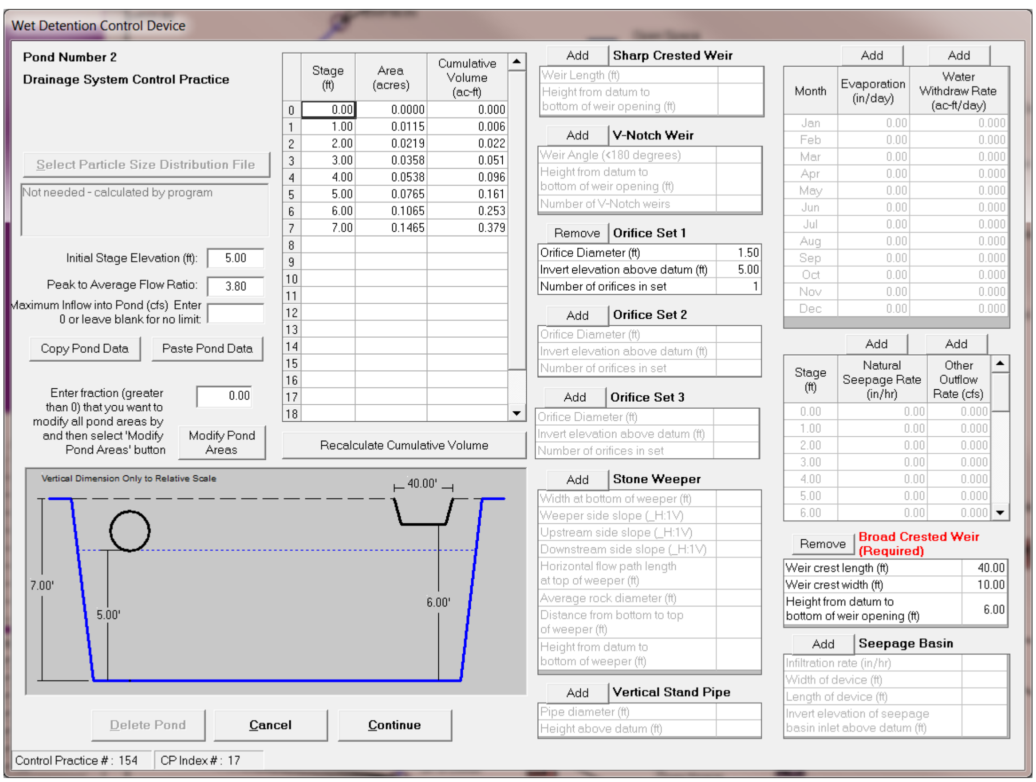

Figure 45: Stormwater Pond SWP119 in SF-8 (WinSLAMM).

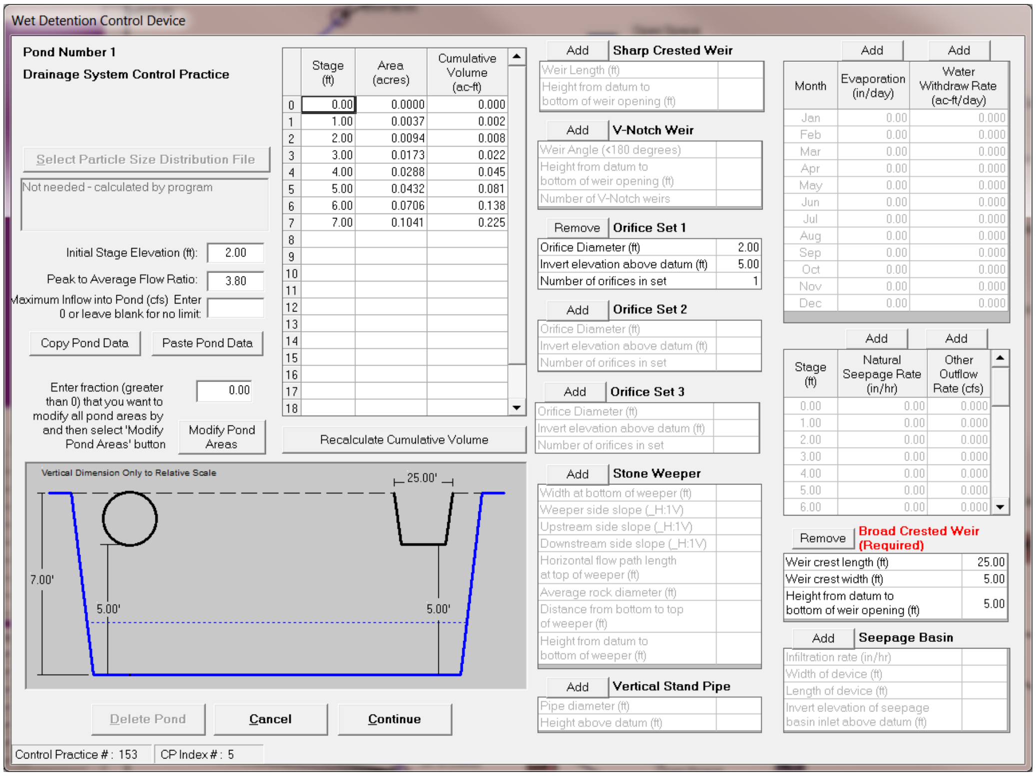

Figure 46: Stormwater Pond NW114 in SF-8 (WinSLAMM).

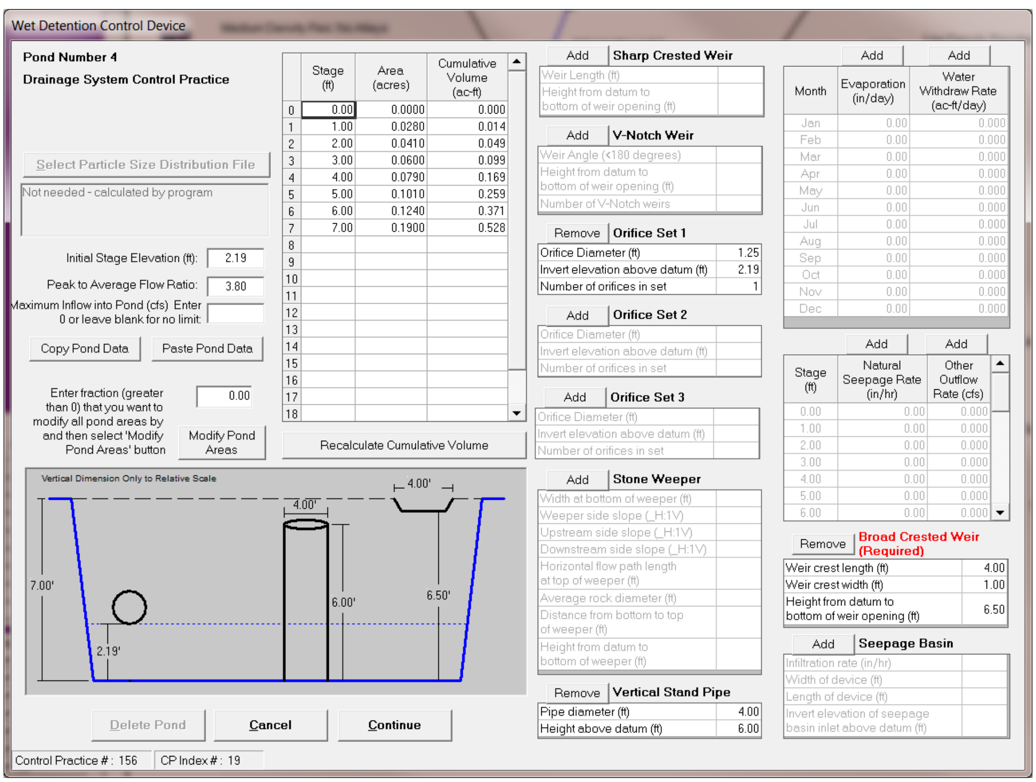

Figure 47: Stormwater Pond SWP122 in SF-8 (WinSLAMM).

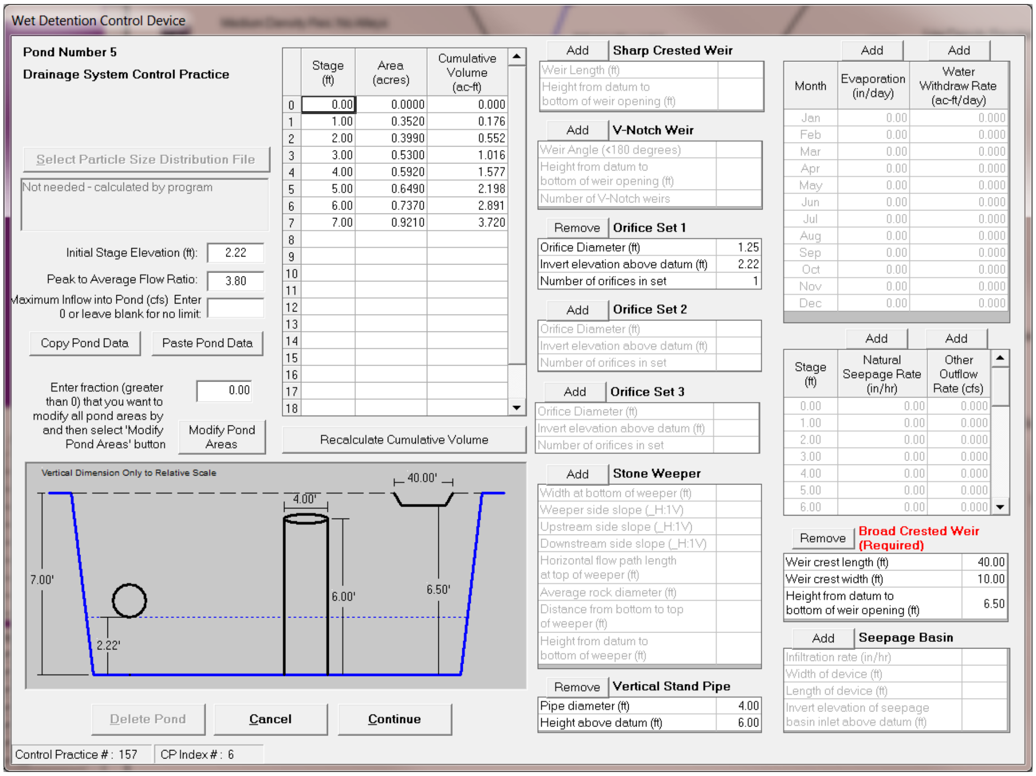

Figure 48: Stormwater Pond SWP123 in SF-8 (WinSLAMM).

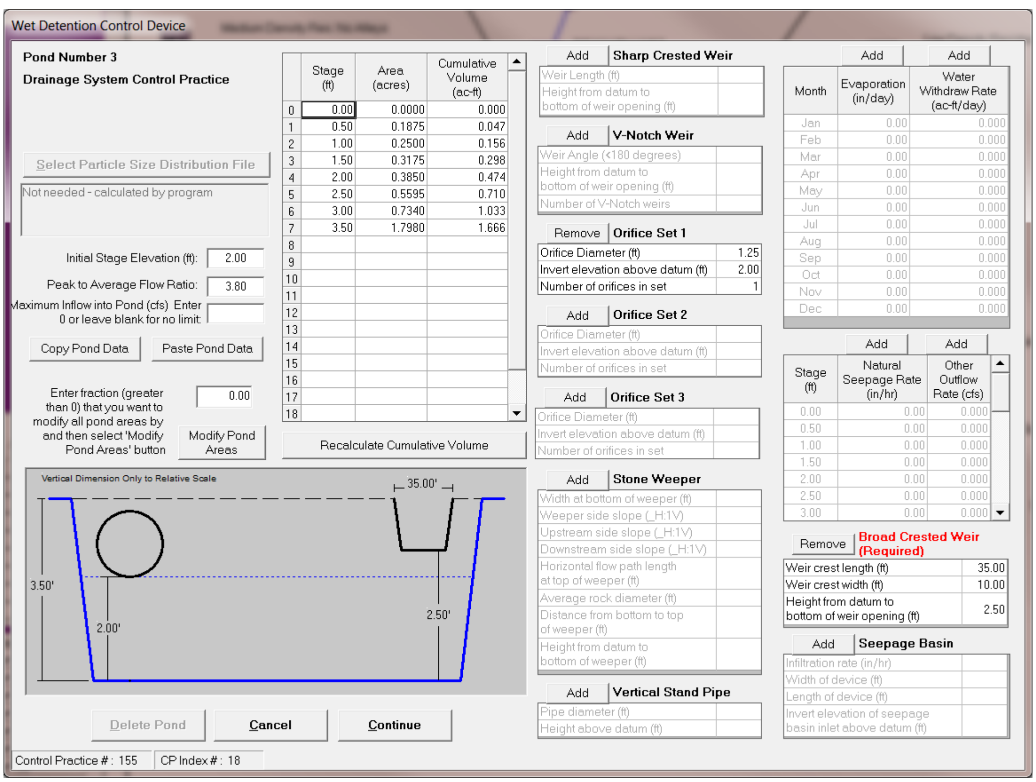

Figure 49: Stormwater Pond SWP100 in SF-8 (WinSLAMM).

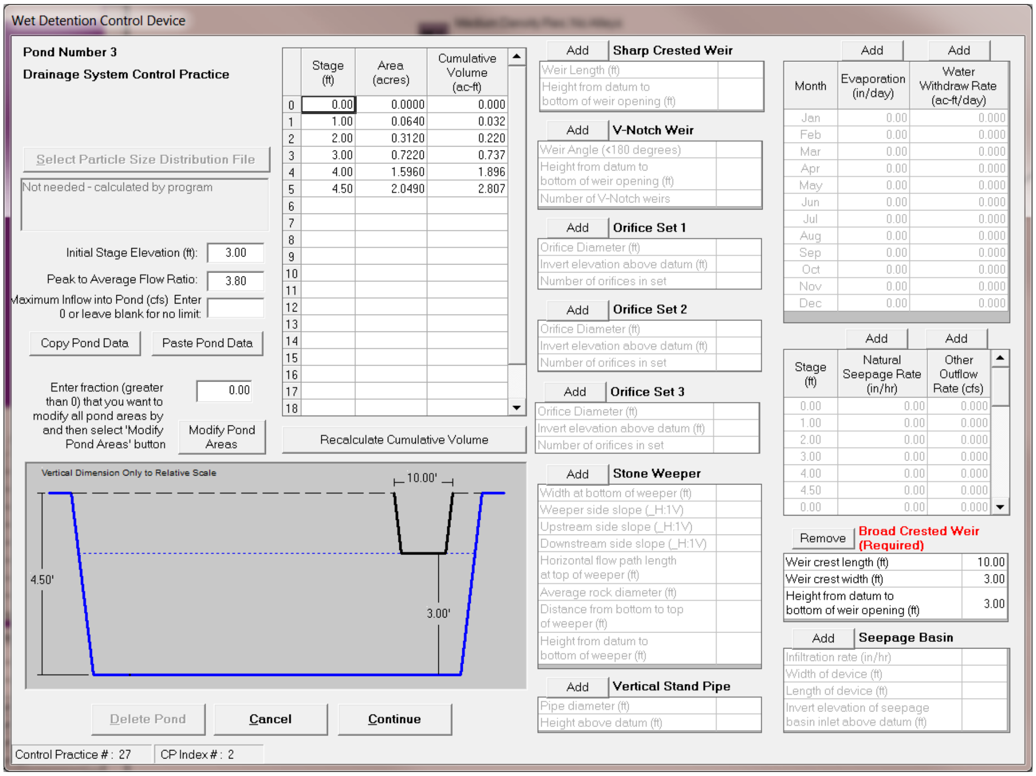

Figure 50: Stormwater Pond SWP12, SWP61 in SF-10 (WinSLAMM).

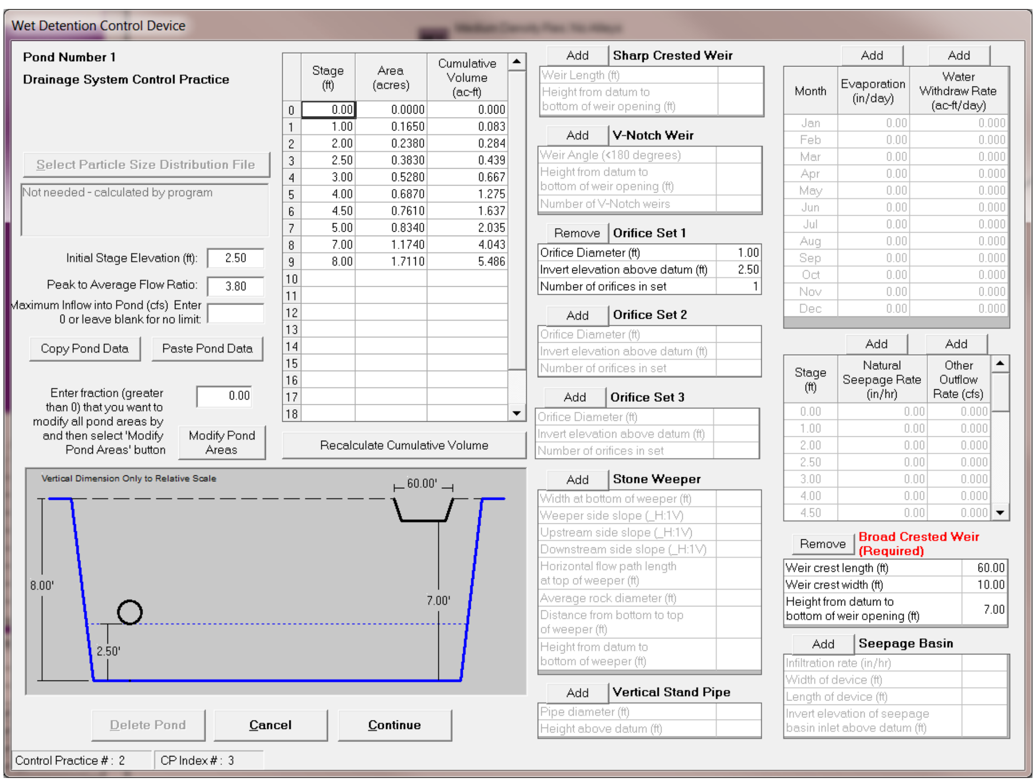

Figure 51: Stormwater Pond SWP7 in SF-10 (WinSLAMM).

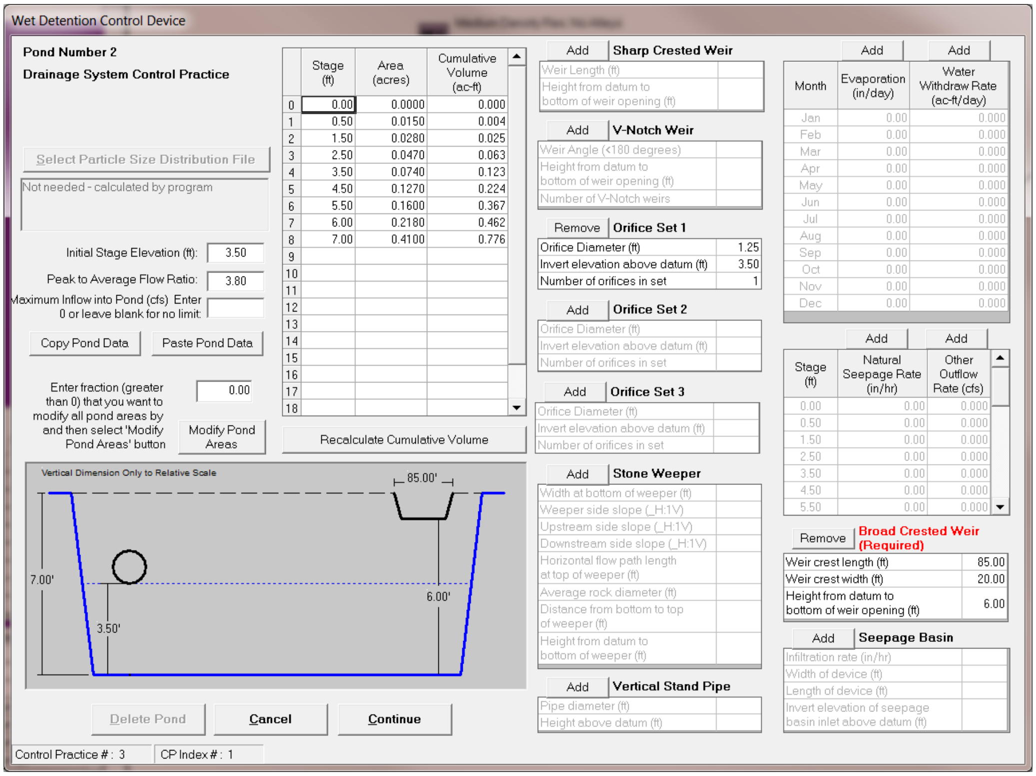

Figure 52: Stormwater Pond SWP6 in SF-10 (WinSLAMM).

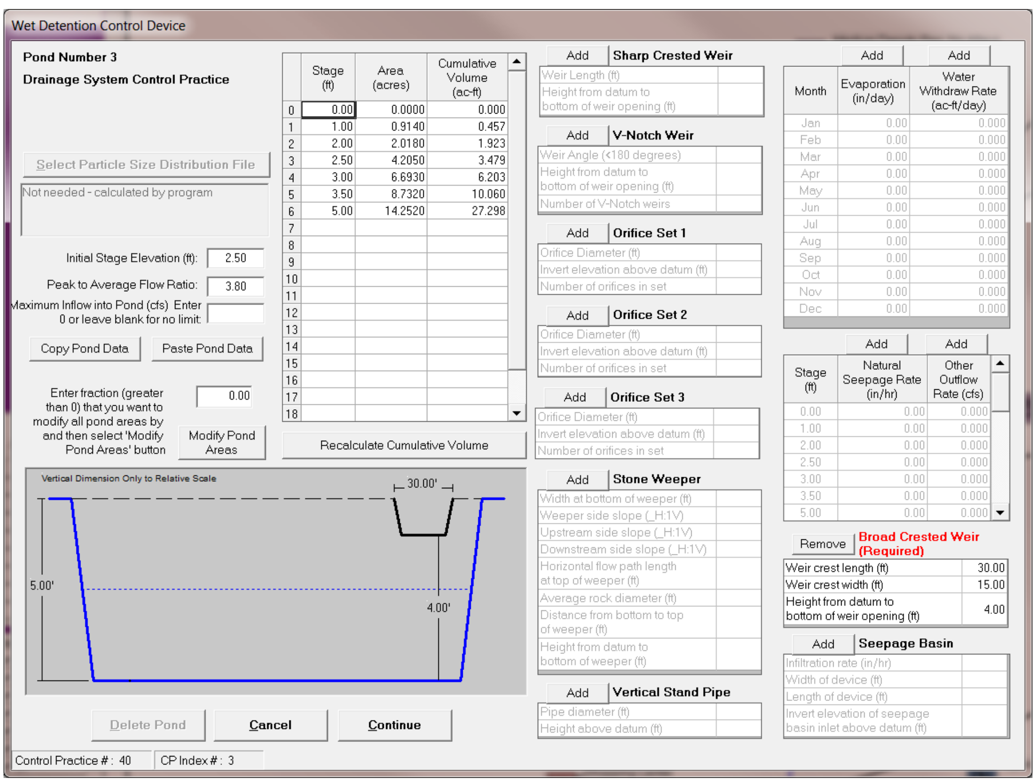

Figure 53: Stormwater Pond NW109, NW110, NW111, NW113 in SF-11 (WinSLAMM).

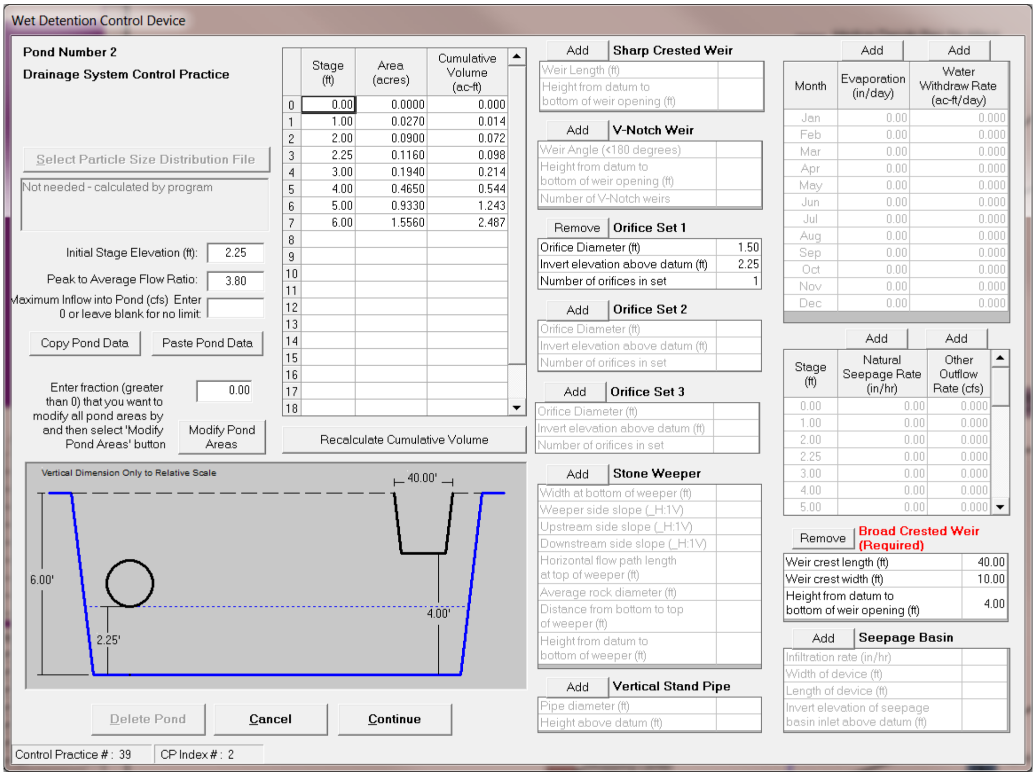

Figure 54: Stormwater Pond SWP9 in SF-11 (WinSLAMM).

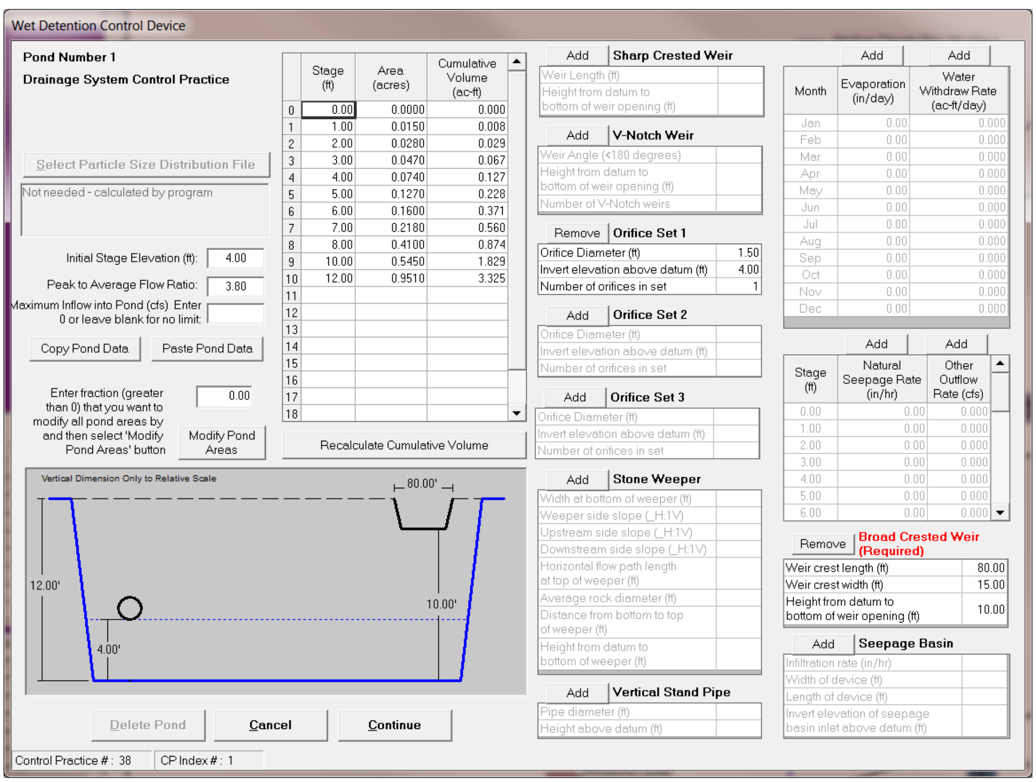

Figure 55: Stormwater Pond SWP8 in SF-11 (WinSLAMM).

Street Cleaning

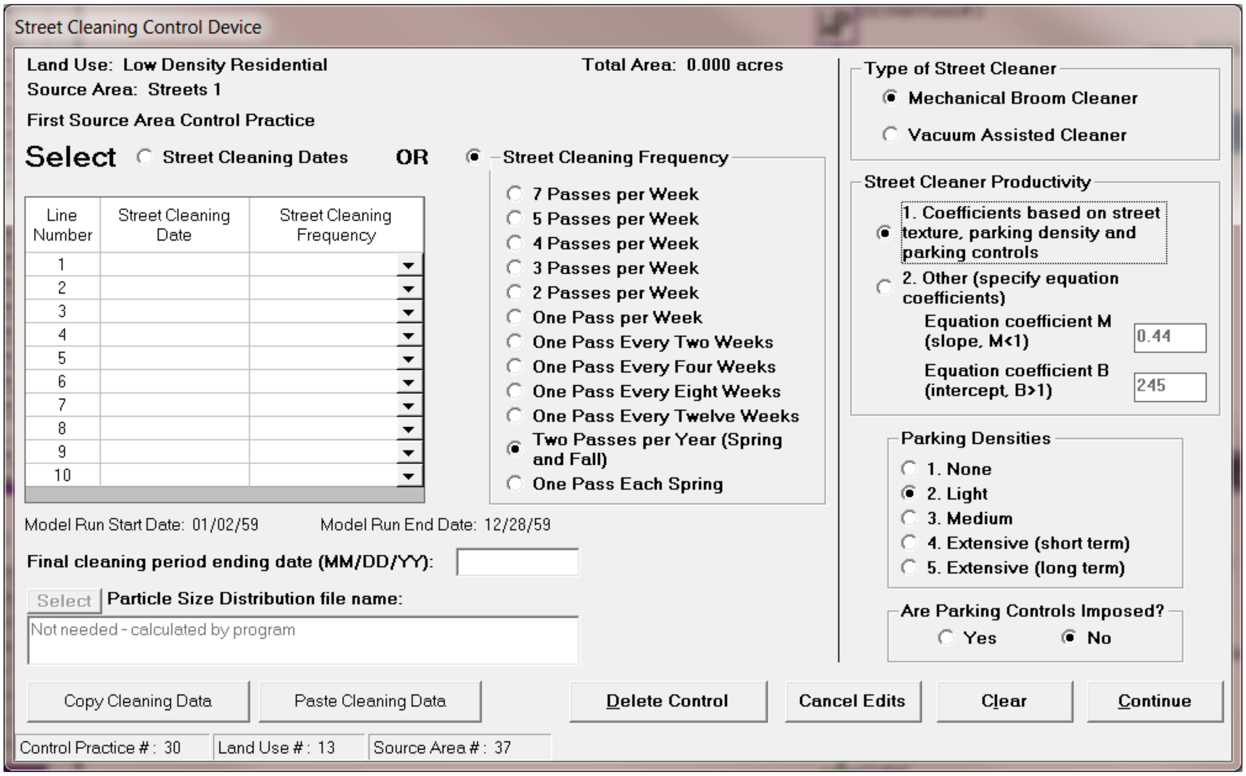

Figure 56: Street cleaning parameters used in all the catchments (SF-1 to SF-11) (WinSLAMM).

Proposed Conditions

Curb-Cut Rain Garden

Curb-cut rain gardens were modeled as drainage area control practices within WinSLAMM. Each was modeled without an underdrain based on available soil information. If based on soil tests it is determined that an underdrain would be necessary, then estimated reductions for volume, TP, and TSS will be lower.

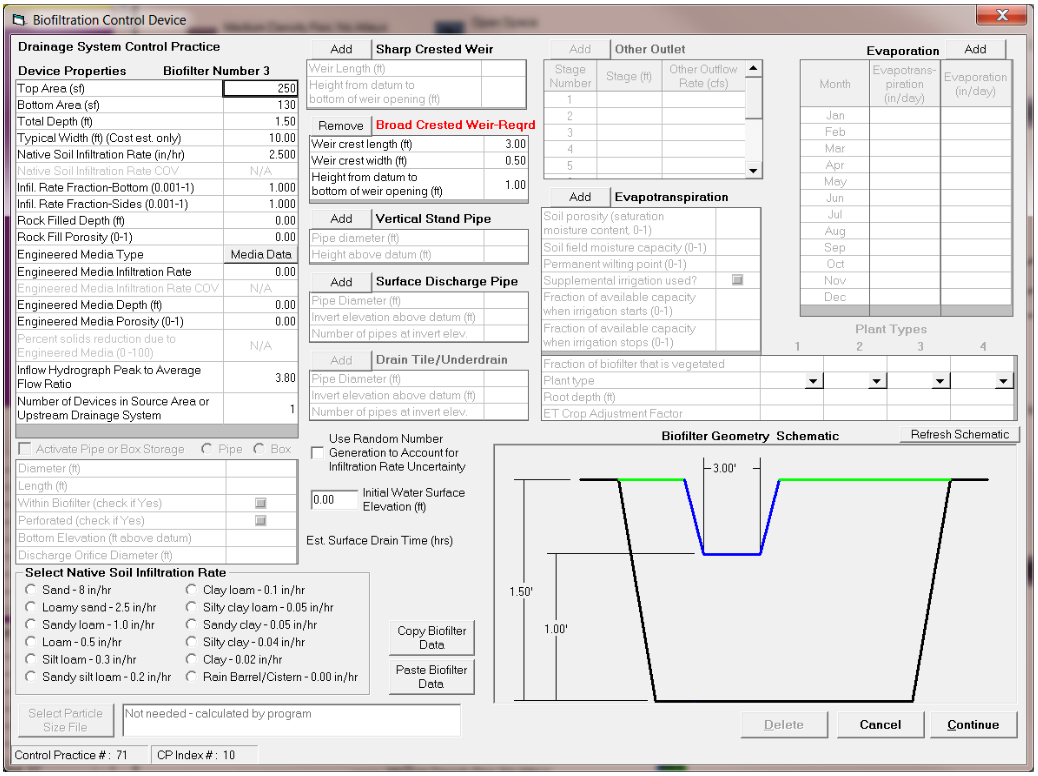

Figure 57: Curb-Cut Rain Garden (WinSLAMM).

Hydrodynamic Device

Table 6: Hydrodynamic Device Sizing Criteria

Drainage Area (acres)	Peak Q (cfs)	Hydrodynamic Device Diameter (ft.)
1	1.97	4
2	3.90	6
3	5.83	6
4	7.77	6
5	9.72	8
6	11.68	8
7	13.65	8
≥8	15.63	10

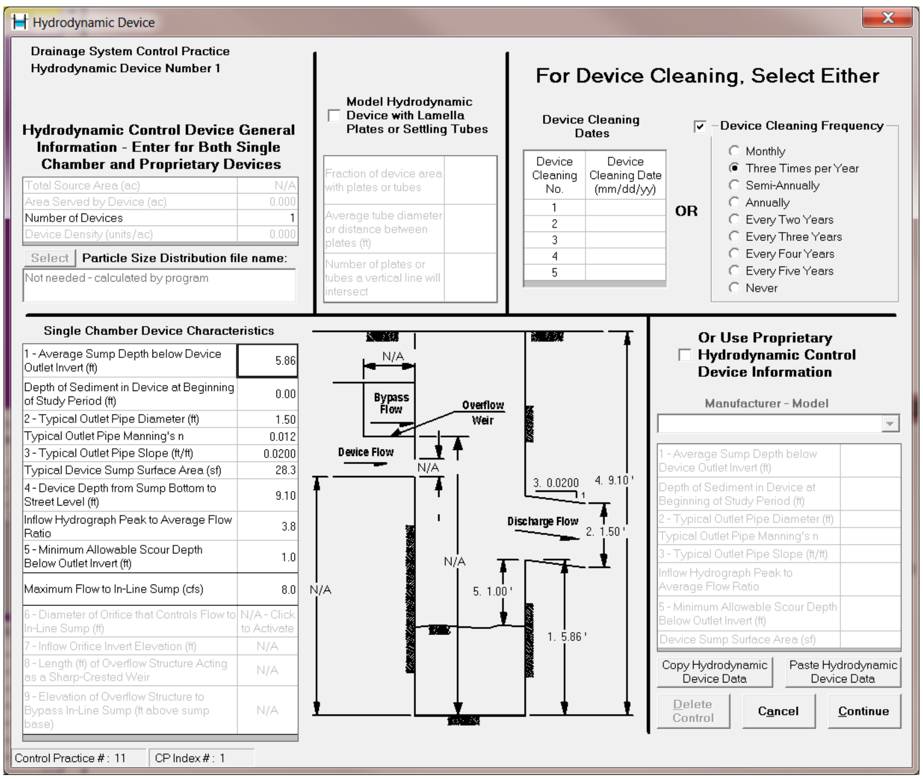

Figure 58: Hydrodynamic Device - 6' diameter modeled in SF-9 (WinSLAMM).

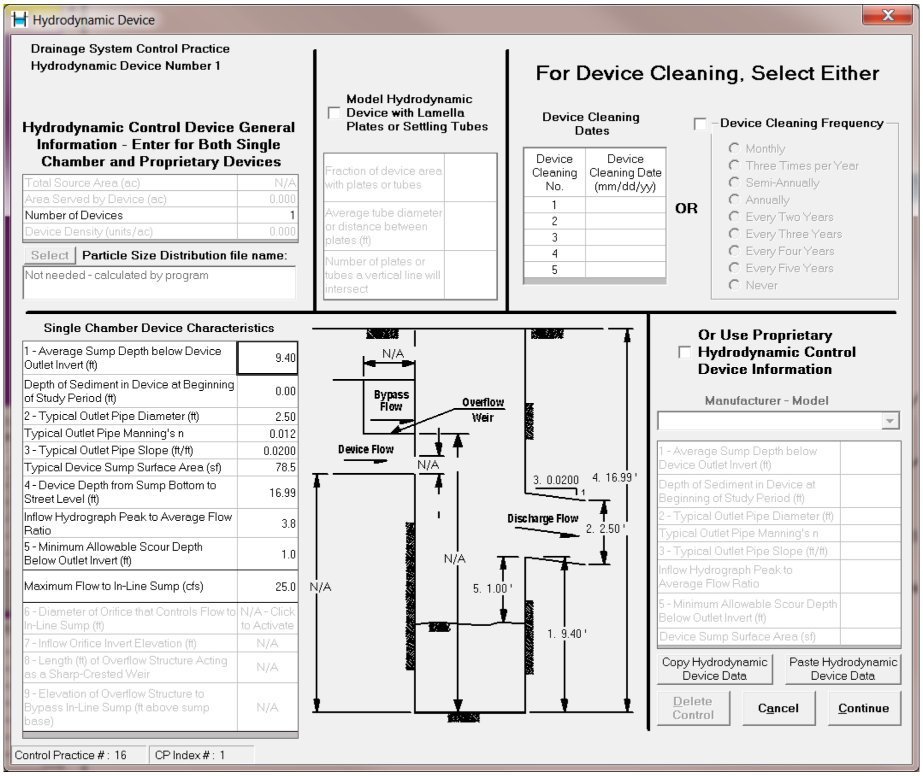

Figure 59: Hydrodynamic Device - 10' diameter modeled in SF-3 and SF-6 (WinSLAMM).

BMP Modification

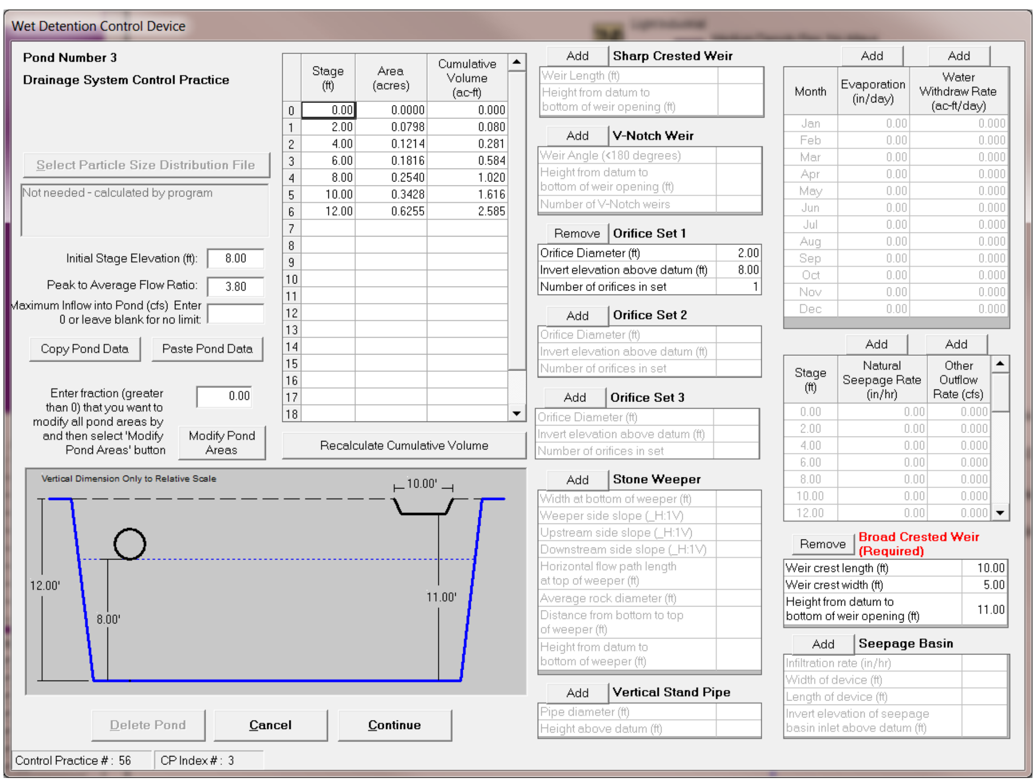

Figure 60: Stormwater pond modification at SWP 50 in SF-1 (WinSLAMM).

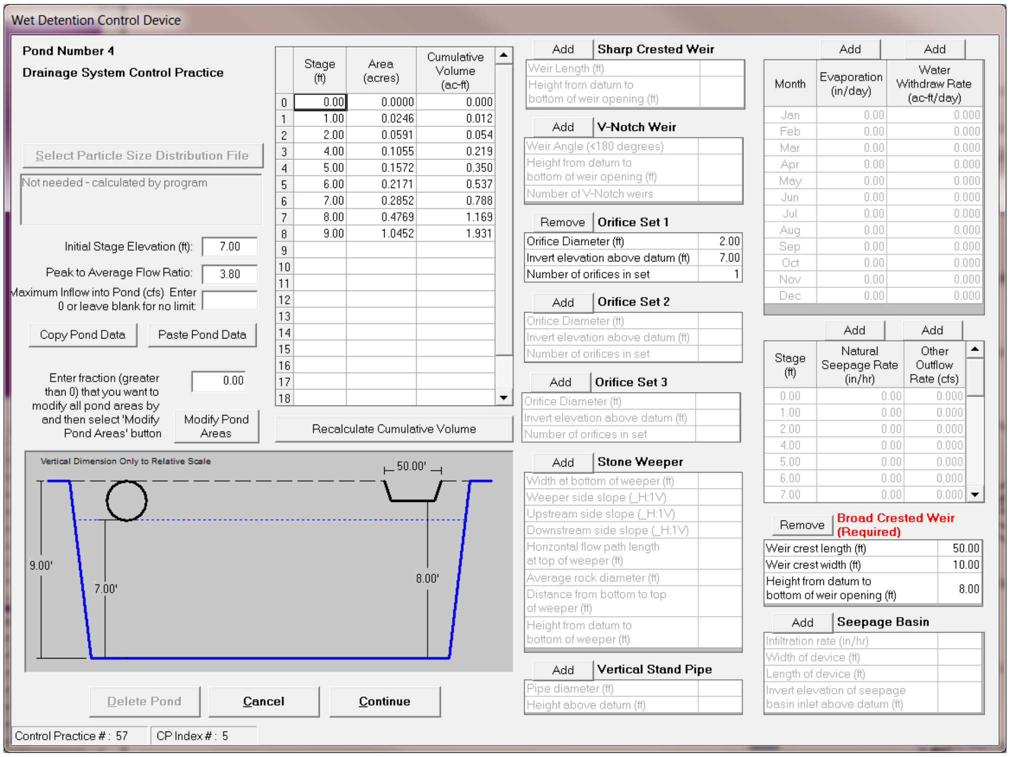

Figure 61: Stormwater pond modification at SWP116 in SF-1 (WinSLAMM).

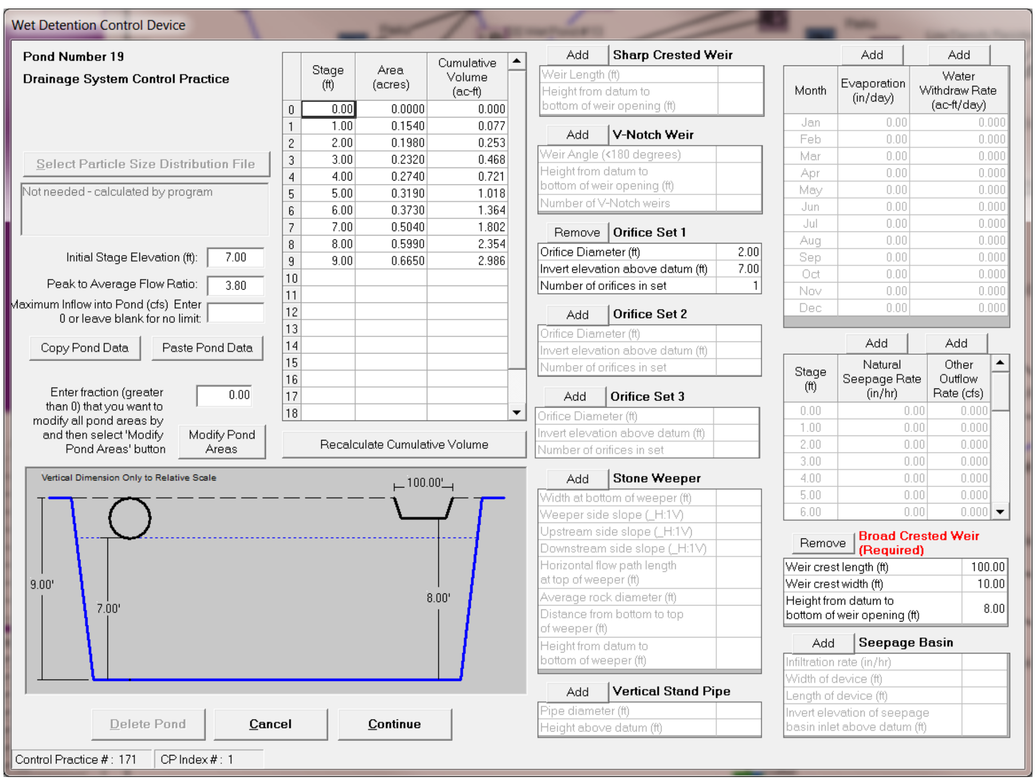

Figure 62: Stormwater pond modification at SWP85 in SF-8 (WinSLAMM).

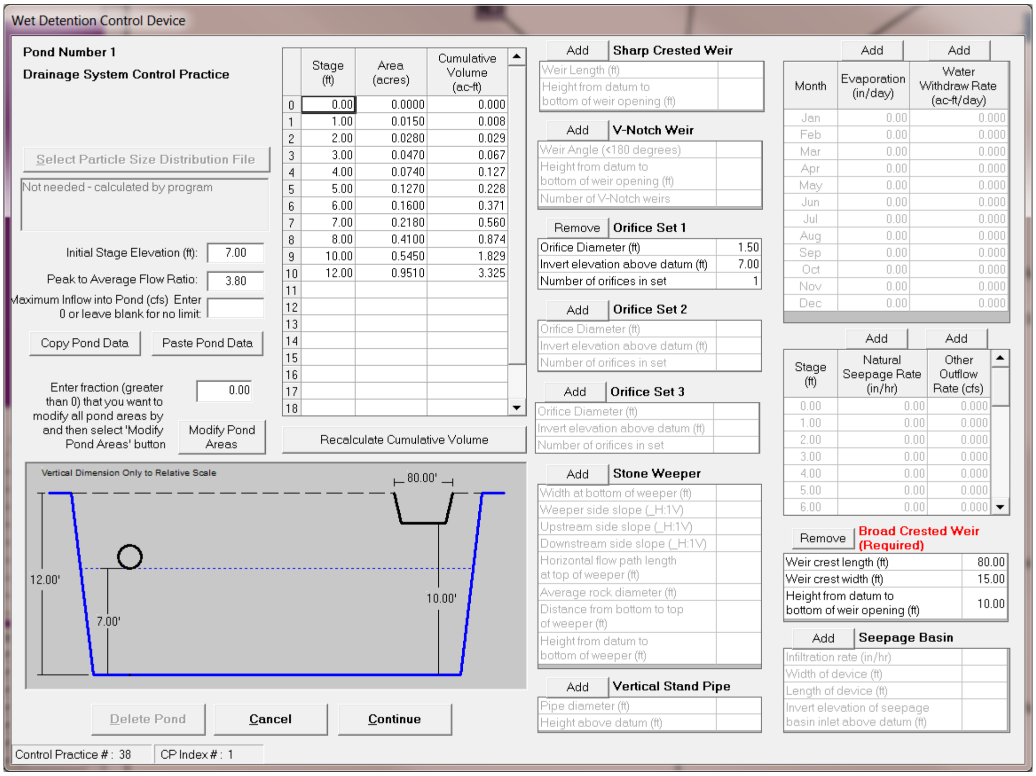

Figure 63: Stormwater pond modification at SWP8 in SF-11 (WinSLAMM).

Iron Enhanced Sand Filter

Wet ponds, by design, allow for sediments and other bound pollutants to drop out of suspension. This practice, though, often allows dissolved pollutants to advect through the system untreated. Iron-enhanced sand filters (IESF) can be retrofitted to or installed with wet ponds to treat this dissolved load.

During a storm event, the pond increases from its permanent-pond stage to its flood stage. The IESF is designed to accept input from the wet pond during storm events, allowing for infiltration of water through its iron rich media, where dissolved pollutants (particularly dissolved phosphorus (DP)) adsorb to the iron filings. DP is then retained within the media while the stormwater can seep into an underdrain. Lastly, the underdrain discharges downstream of the wet pond. IESFs can be installed without ponds, although it is recommended that some form of pretreatment is available to remove sediment, which can deposit within the pore space of the filter and clog the practice over time.

There is currently no drainage practice input for these features in WinSLAMM. As they behave similarly to a bioretention cell, they can be modeled as such. But, as they often operate in tandem with stormwater ponds, estimating when and how much water and pollutants they will receive can be challenging. WinSLAMM was utilized to estimate what percentage of the stormflow could be treated by the filter. Stormflow input into the practice is most dependent upon the volume which can be passed through the system's underdrains. Stormflow treated by the device is a function of total area, depth, infiltration rate, and engineered media characteristics.

Field tests of installed sand trenches conducted by the University of Minnesota concluded that a sand media mixed with 5% iron filings is capable of retaining 80% (or more) of the DP load of stormwater flowing through the media (Erickson and Gulliver, 2010). Thus, DP retention by the IESF can be estimated by the equation,

$$P_{RET} = 0.8 * [P_{IN}] * q_S$$

where P_{RET} is the DP load removed by the IESF, $[P_{IN}]$ is the concentration of the DP input, and q_S is the volume of stormflow passing through the IESF. q_S is a function of the storm event duration and intensity, stormwater pond storage (if in-line with a pond), and IESF storage volume (bottom area, top area, and depth). The 0.8 multiplier assumes the IESF removes 80% of the DP load.

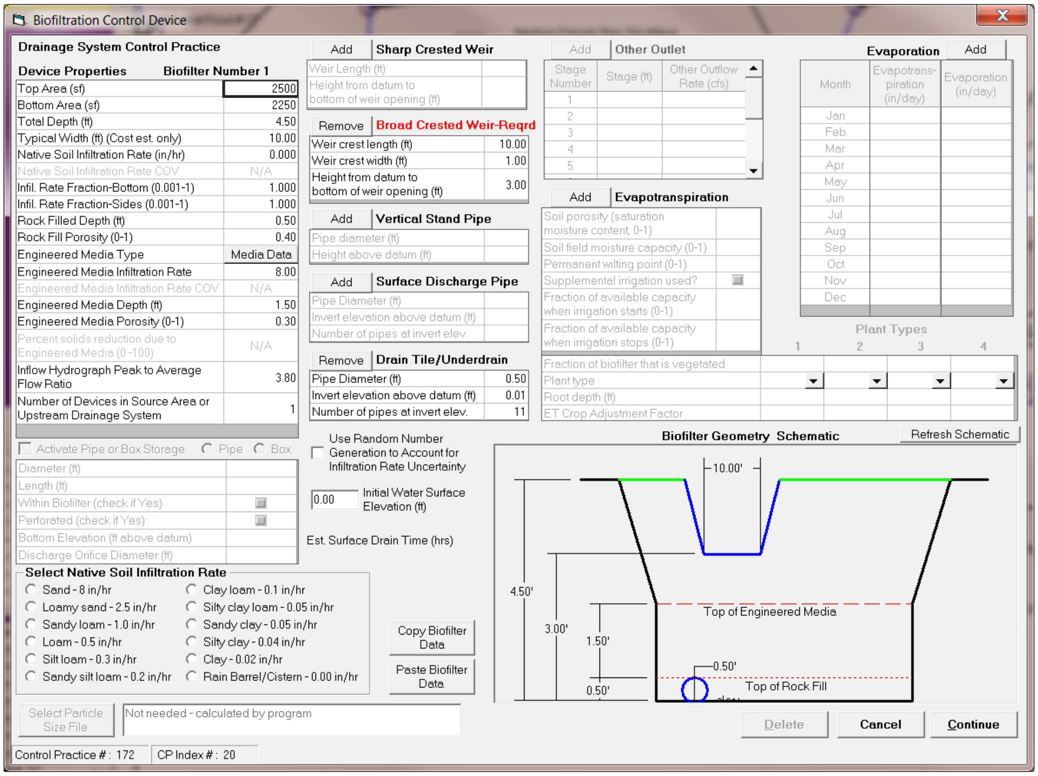

Figure 64: Iron enhanced sand filter pond bench at SWP123 in SF-8 (WinSLAMM).

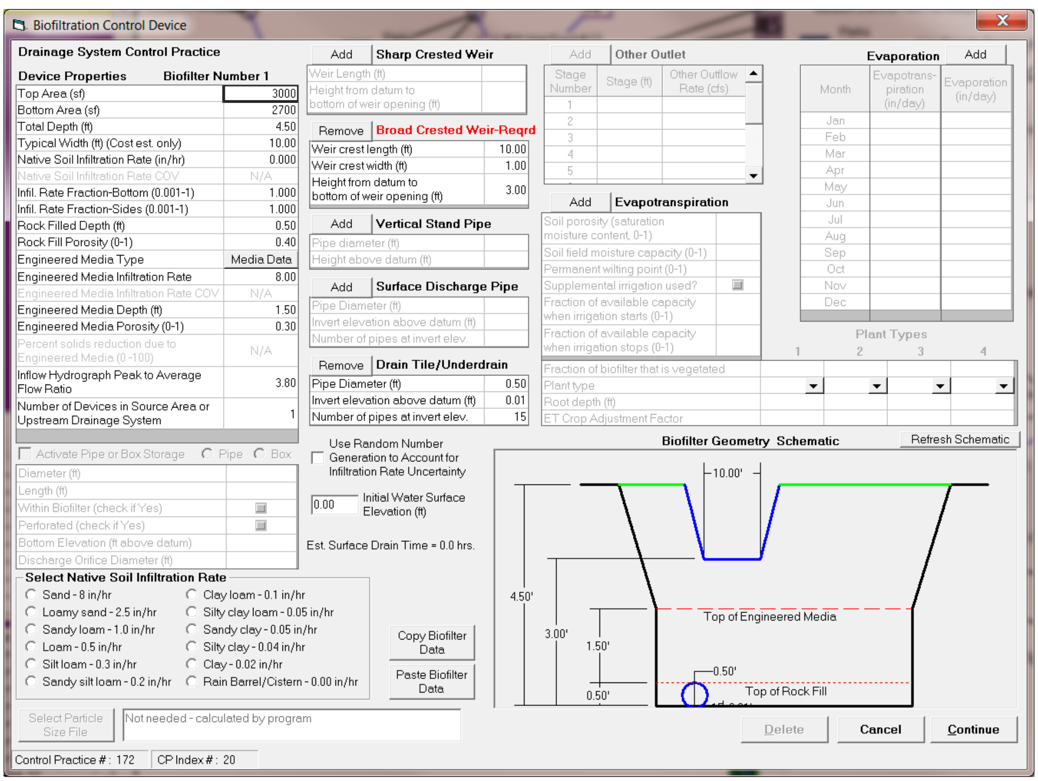

Figure 65: Iron enhanced sand filter pond bench at SWP85 in SF-8 (WinSLAMM).

Iron-enhanced Sand Filter Check Dam

With this BMP there are two processes that drive pollutant retention within the practice. First, the practice detains stormwater behind the dam, dropping particulate pollutants out of suspension. Secondly, any water that has been impounded by the dam can either pass through the dam (and its IESF) or be evapotranspired prior to passing through the dam. To mimic these processes within WinSLAMM two different models were created, each with the same land use, soil, and existing stormwater infrastructure conditions. Within both models a biofiltration drainage area control practice was installed.

To model the effect of detaining water behind the dam, a biofiltration control practice with the same ponding storage as the check dams was modeled. This practice did not have an underdrain and assumed very silty soils with no infiltration (Figure 66). Volume, TSS, and particulate phosphorus retention were determined from this model. For water passing through the filter, a similarly sized biofiltration control practice was modeled, but in this case was modeled with an underdrain (Figure 67). Dissolved phosphorus retention was determined from this model assuming that 80% of dissolved phosphorus flowing through the dam was retained (Erickson & Gulliver, 2010). Total phosphorus reduction was the summation of particulate and dissolved phosphorus reductions between the two models.

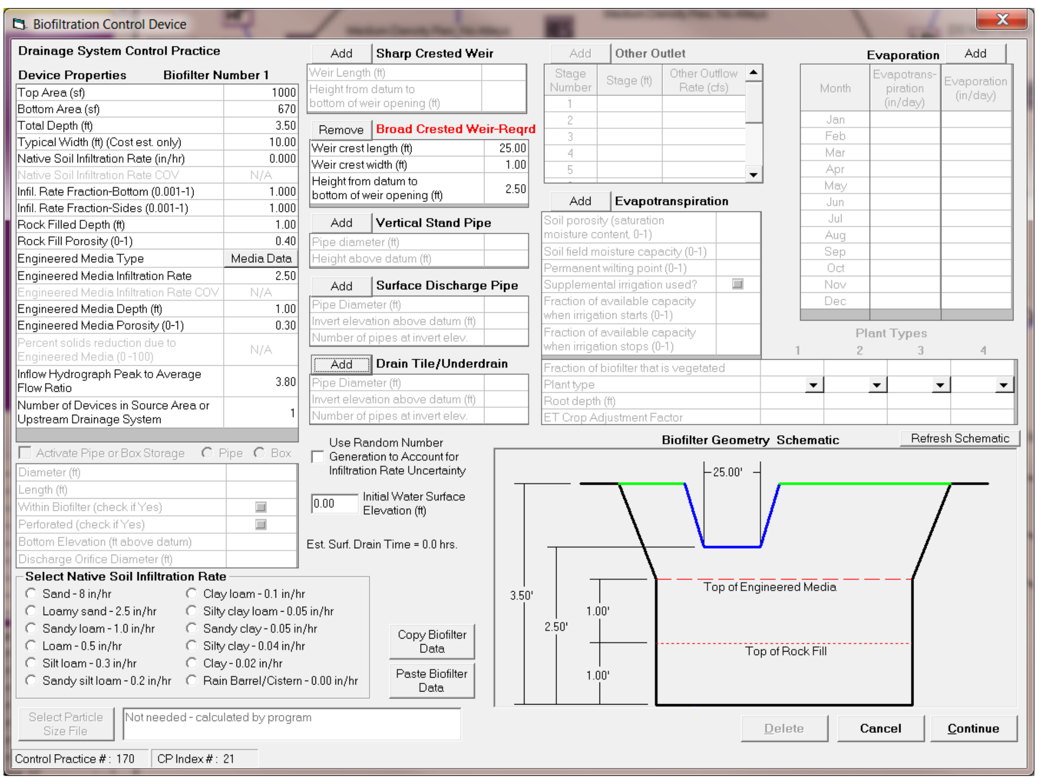

Figure 66: Iron-enhanced sand filter check dam in SF-8. Parameters model dam behind the iron-enhanced sand filter (WinSLAMM).

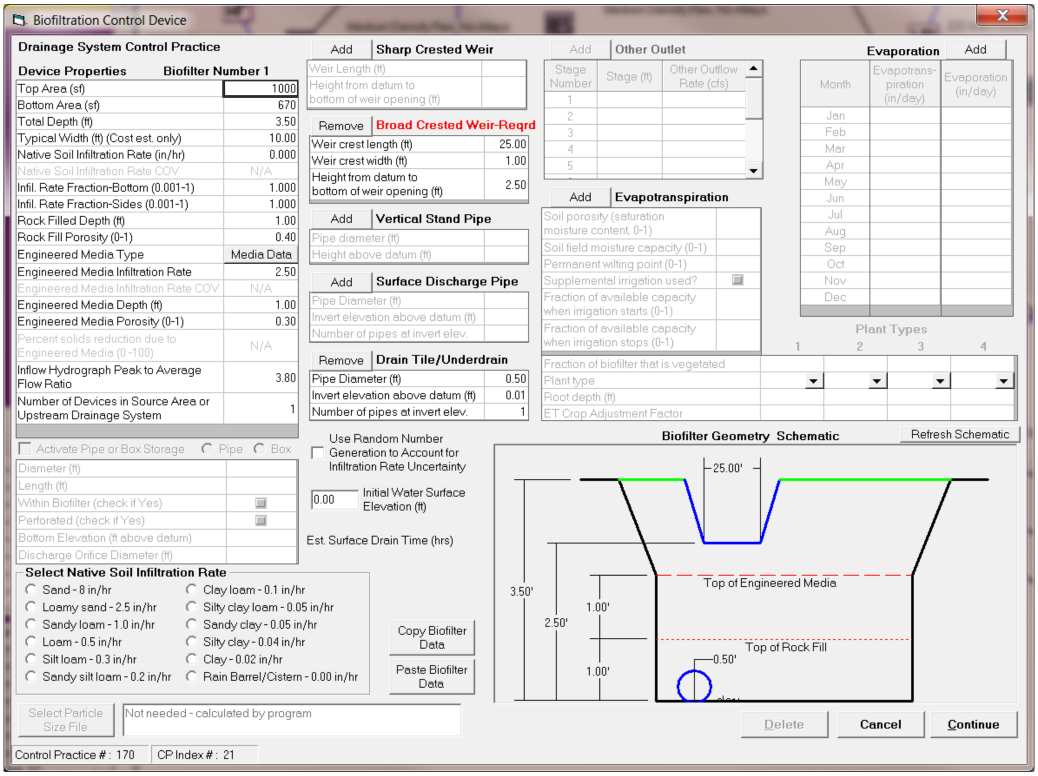

Figure 67: Iron-enhanced sand filter check dam in SF-8. Parameters model the iron-enhanced sand filter (WinSLAMM).

Permeable Pavement

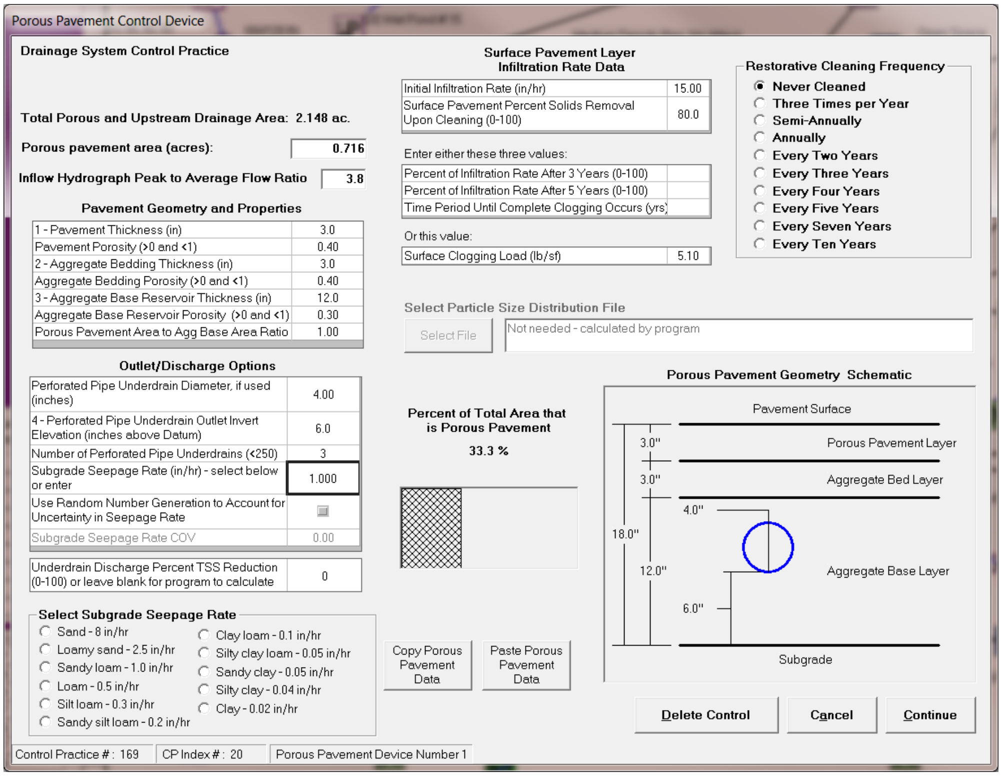

Figure 68: Permeable pavement at St. Francis High School, side parking lot in SF-8 (WinSLAMM).

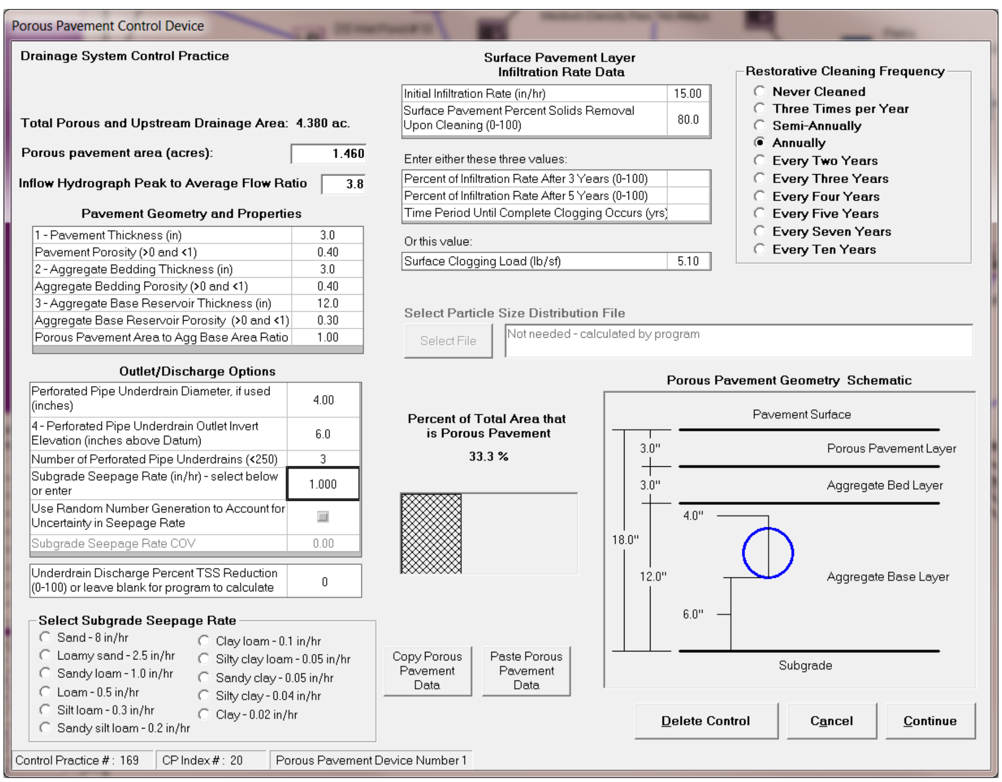

Figure 69: Permeable pavement at St. Francis High School, main parking lot in SF-8 (WinSLAMM).

Stormwater Reuse

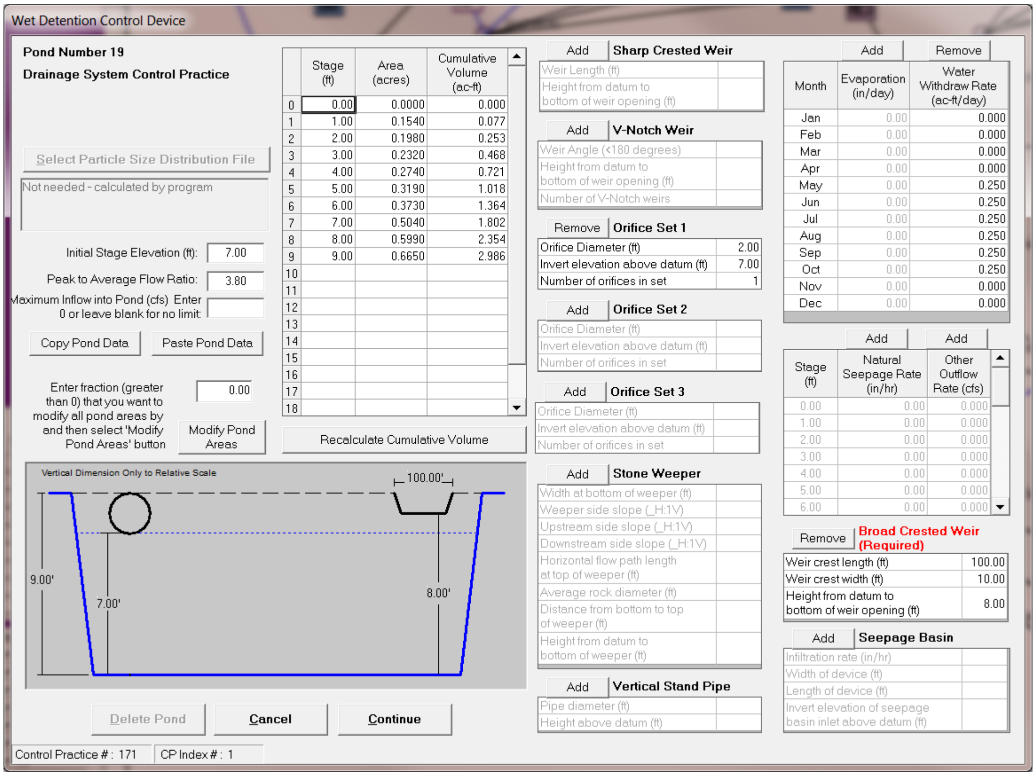

Figure 70: Stormwater Reuse at SWP85 in SF-8 (WinSLAMM).

Appendix B – Project Cost Estimates

Introduction

The ‘Cost Estimates’ section on page 10 explains the elements of cost that were considered and the amounts and assumptions that were used. In addition, each project type concludes with budget assumptions listed in the footnotes. This appendix is a compilation of tables that shows in greater detail the calculations made and quantities used to arrive at the cost estimates for practices where the information provided elsewhere in the document is insufficient to reconstruct the budget. This section includes ponds, iron enhanced sand filters, and stormwater reuse.

BMP Modification

Table 7: Catchment SF-1 – Pond Modification at SWP50.

Activity	Units	Unit Price	Quantity	Unit Price
Feasibility Study and Project Design	Each	$ 15,000.00	1	$ 15,000.00
Mobilization	Each	$ 10,000.00	1	$ 10,000.00
Site Prep	Each	$ 10,000.00	1	$ 10,000.00
Brush Removal	Each	$ 15,000.00	1	$ 15,000.00
Sediment Testing	Each	$ 10,000.00	1	$ 10,000.00
Existing Infrastructure Retrofit	Each	$ 5,000.00	1	$ 5,000.00
Outlet Control Structure	Each	$ 10,000.00	1	$ 10,000.00
Site Restoration	Each	$ 10,000.00	1	$ 10,000.00
	Project Total Before Excavation =			$ 85,000.00

Activity	Management Levels		
	1	2	3
Soil To Excavate (cu-yds)	1,600	1,600	1,600
Cost To Excavate ($/cu-yd)	$20	$35	$50
Cost To Excavate (Total $)	$32,000	$56,000	$80,000
Other Construction Costs ($)	$85,000	$85,000	$85,000
Total Project Cost ($)	$117,000	$141,000	$165,000

Table 8: Catchment SF-1 – Pond Modification at SWP116.

Activity	Units	Unit Price	Quantity	Unit Price
Feasibility Study and Project Design	Each	$ 15,000.00	1	$ 15,000.00
Mobilization	Each	$ 10,000.00	1	$ 10,000.00
Site Prep	Each	$ 10,000.00	1	$ 10,000.00
Brush Removal	Each	$ 15,000.00	1	$ 15,000.00
Sediment Testing	Each	$ 10,000.00	1	$ 10,000.00
Existing Infrastructure Retrofit	Each	$ 5,000.00	1	$ 5,000.00
Outlet Control Structure	Each	$ 10,000.00	1	$ 10,000.00
Site Restoration	Each	$ 10,000.00	1	$ 10,000.00
	Project Total Before Excavation =			$ 85,000.00

Activity	Management Levels		
	1	2	3
Soil To Excavate (cu-yds)	1,300	1,300	1,300
Cost To Excavate ($/cu-yd)	$20	$35	$50
Cost To Excavate (Total $)	$26,000	$45,500	$65,000
Other Construction Costs ($)	$85,000	$85,000	$85,000
Total Project Cost ($)	$111,000	$130,500	$150,000

Table 9: Catchment SF-8 – Pond Modification at SWP85.

Activity	Units	Unit Price	Quantity	Unit Price
Feasibility Study and Project Design	Each	$ 15,000.00	1	$ 15,000.00
Mobilization	Each	$ 10,000.00	1	$ 10,000.00
Site Prep	Each	$ 10,000.00	1	$ 10,000.00
Brush Removal	Each	$ 15,000.00	1	$ 15,000.00
Sediment Testing	Each	$ 10,000.00	1	$ 10,000.00
Existing Infrastructure Retrofit	Each	$ 5,000.00	1	$ 5,000.00
Outlet Control Structure	Each	$ 10,000.00	1	$ 10,000.00
Site Restoration	Each	$ 10,000.00	1	$ 10,000.00
	Project Total Before Excavation =			$ 85,000.00

Activity	Management Levels		
	1	2	3
Soil To Excavate (cu-yds)	1,600	1,600	1,600
Cost To Excavate ($/cu-yd)	$20	$35	$50
Cost To Excavate (Total $)	$32,000	$56,000	$80,000
Other Construction Costs ($)	$85,000	$85,000	$85,000
Total Project Cost ($)	$117,000	$141,000	$165,000

Table 10: Catchment SF-11 – Pond Modification at SWP8.

Activity	Units	Unit Price	Quantity	Unit Price
Feasibility Study and Project Design	Each	$ 15,000.00	1	$ 15,000.00
Mobilization	Each	$ 10,000.00	1	$ 10,000.00
Site Prep	Each	$ 10,000.00	1	$ 10,000.00
Brush Removal	Each	$ 15,000.00	1	$ 15,000.00
Sediment Testing	Each	$ 10,000.00	1	$ 10,000.00
Existing Infrastructure Retrofit	Each	$ 5,000.00	1	$ 5,000.00
Outlet Control Structure	Each	$ 10,000.00	1	$ 10,000.00
Site Restoration	Each	$ 10,000.00	1	$ 10,000.00
	Project Total Before Excavation =			$ 85,000.00

Activity	Management Levels		
	1	2	3
Soil To Excavate (cu-yds)	700	700	700
Cost To Excavate ($/cu-yd)	$20	$35	$50
Cost To Excavate (Total $)	$14,000	$24,500	$35,000
Other Construction Costs ($)	$85,000	$85,000	$85,000
Total Project Cost ($)	$99,000	$109,500	$120,000

Iron Enhanced Sand Filters

Table 11: Catchment SF- 8 – IESF Pond Bench at SWP85.

Activity	Units	Unit Price	Quantity	Unit Price
Design/Bidding/Construction Oversight	Each	$ 40,000.00	1	$ 40,000.00
Mobilization	Each	$ 20,000.00	1	$ 20,000.00
Clearing, Removal of Existing Infrastructure, and Pond Dewatering	Each	$ 12,000.00	1	$ 12,000.00
Common Excavation & Disposal	cu-yards	$ 40.00	440	$ 17,600.00
IESF Materials and Installation	sq-ft	$ 17.00	3,000	$ 51,000.00
Outlet/Inlet Control Structures	Each	$ 30,000.00	1	$ 30,000.00
Site Restoration	Each	$ 15,000.00	1	$ 15,000.00
		Total for project =		$ 185,600.00

Table 12: Catchment SF-8 – IESF Pond Bench at SWP123.

Activity	Units	Unit Price	Quantity	Unit Price
Design/Bidding/Construction Oversight	Each	$ 40,000.00	1	$ 40,000.00
Mobilization	Each	$ 20,000.00	1	$ 20,000.00
Clearing, Removal of Existing Infrastructure, and Pond Dewatering	Each	$ 12,000.00	1	$ 12,000.00
Common Excavation & Disposal	cu-yards	$ 40.00	370	$ 14,800.00
IESF Materials and Installation	sq-ft	$ 17.00	2,500	$ 42,500.00
Outlet/Inlet Control Structures	Each	$ 30,000.00	1	$ 30,000.00
Site Restoration	Each	$ 15,000.00	1	$ 15,000.00
		Total for project =		$ 174,300.00

Iron Enhanced Sand Filter Check Dams

Table 13: Catchment SF-8 – IESF Check Dam.

Activity	Units	Unit Price	Quantity	Unit Price
Design	each	$3,000.00	1	$3,000.00
Mobilization and Site Preparation	each	$3,000.00	1	$3,000.00
Engineered Soil Mix (5% iron by weight)	cu-yards	$275.00	3.1	$852.50
Rocks	cu-yards	$125.00	4.6	$575.00
Permeable Liner	per dam	$100.00	1	$100.00
Installation	per dam	$5,000.00	1	$5,000.00
			Total for Project =	$12,527.50

Stormwater Reuse

Table 14: Catchment SF-8 –Stormwater Reuse at SWP85.

Activity	Price
Project Planning	$ 30,000.00
Easement	$ 45,000.00
Design, Surveying and Permitting	$ 85,000.00
Construction Oversight	$ 30,000.00
Monitoring	$ 20,000.00
Construction	$ 390,000.00
Total for project =	$ 600,000.00

Appendix C – Volume Reduction Ranking Tables

Introduction

Volume reduction was not identified as a primary reduction target during the scoping phase of this project. This section is intended to serve as a quick reference if questions related to volume reduction arise. Projects are ranked based on cost per acre-foot of volume reduced.

Table 15: Cost-effectiveness of retrofits with respect to volume reduction. Projects 1 - 17. TP and TSS reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost	Estimated Annual Operations & Maintenance	Estimated cost/ ac-ft Vol./year (30-year)1
1	6-A	54	Curb-Cut Rain Garden	Various locations in catchment	6	0.9-7.4	223-1,906	0.9-4.5	$15,844-$90,112	$225-$2,250	$837-$1,298
4	5-A	50	Curb-Cut Rain Garden	227th Ct. & 227th Ave.	5	0.4-1.6	56-358	0.5-1.7	$8,982-$35,928	$225-$900	$1,077-$1,250
2	8-G	68	Stormwater Reuse	St. Francis High School	8	12.3	2,434	20.7	$608,760	$3,000	$1,125
3	8-A	62	Curb-Cut Rain Garden	Various locations in catchment	8	0.5-3.7	82-659	1.1-3.8	$32,348-$81,860	$675-$2,025	$1,240-$1,558
5	2-A	39	Curb-Cut Rain Garden	Woodbine St. & 232nd Ave.	2	0.3-1.1	69-270	0.4-1.5	$15,844-$40,600	$225-$900	$1,512-$1,931
6	8-B	63	Permeable Pavement	St. Francis High School	8	5.3	1,586	4.1	$643,796	$48,000	$17,096
7	8-C	64	Permeable Pavement	St. Francis High School	8	1.4	420	1.9	$313,796	$23,250	$18,124
17	1-A	34	Pond Modification	St. Francis Blvd. & Stark Dr.	1	3.1	1,760	0	$122,840-$170,840	$1,300	N/A
17	1-B	35	Pond Modification	St. Francis Blvd. & 233rd Ave.	1	1.9	782	0	$116,840-$155,840	$1,300	N/A
17	3-A	43	Hydrodynamic Device	Bridge St. & Rum River Blvd.	3	0.7	374	0	$109,752	$630	N/A
17	6-B	55	Hydrodynamic Device	225th Lane	6	1.2	433	0	$109,752	$630	N/A
17	8-D	65	Pond Modification	St. Francis High School	8	3.1	1,760	0	$122,840-$170,840	$1,300	N/A
17	8-E	66	IESF Bench	St. Francis High School	8	8.5	0	0	$191,075	$689	N/A
17	8-F	67	IESF Bench	St. Francis High School	8	1.8	0	0	$179,775	$574	N/A
17	8-H	69	IESF Check Dam	Rum River Blvd. & Park Rd.	8	1.8	459	0	$15,448	$365	N/A
17	9-A	72	Hydrodynamic Device	Bridge Street	9	0.2	103	0	$28,752	$630	N/A
17	11-A	79	Pond Modification	227th Ave. & Poppy St.	11	0.9	343	0	$104,840-$125,840	$1,300	N/A

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [30*(Annual Volume Reduction)]

Appendix D – Soil Information

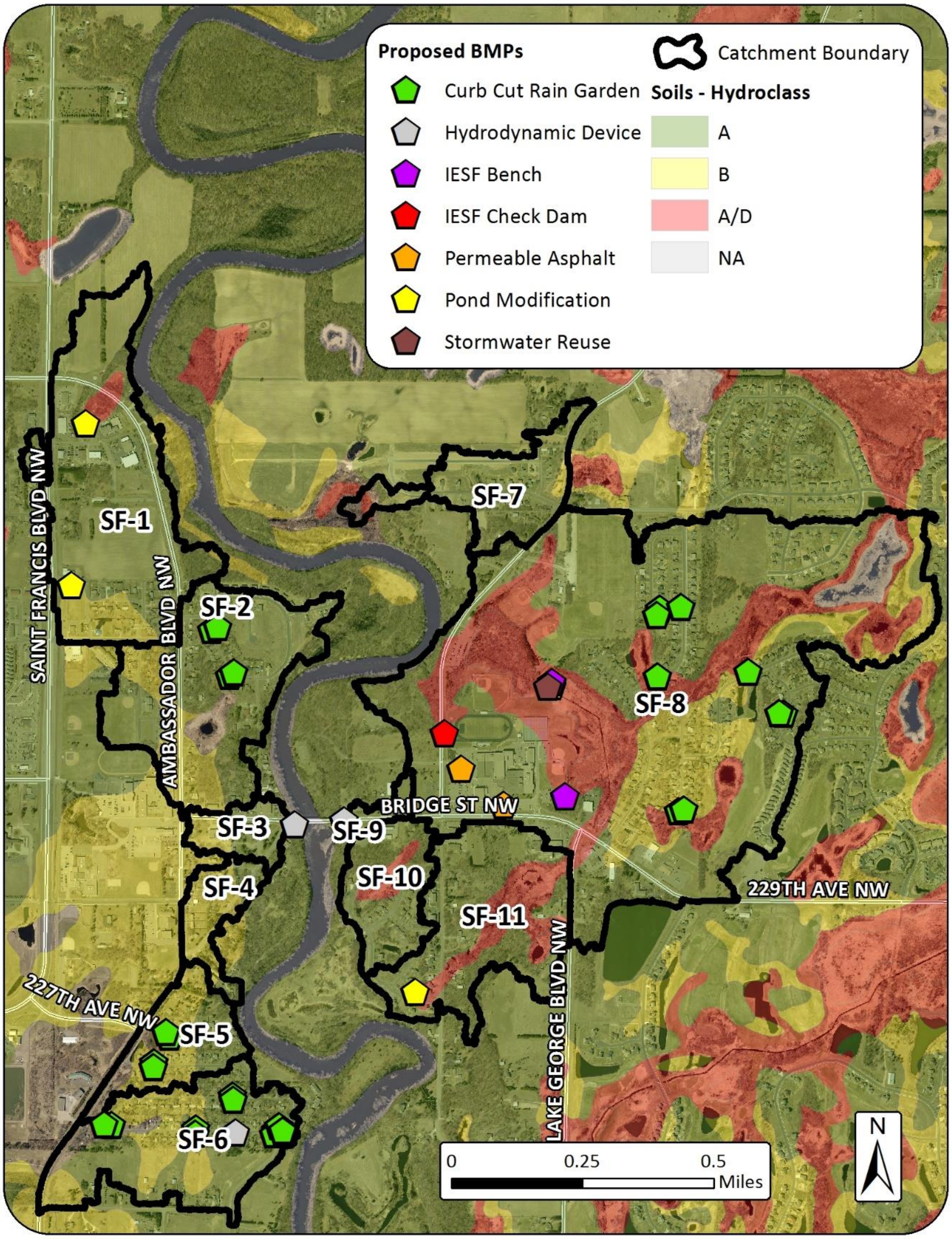

Figure 71: Soil hydroclass and proposed retrofit locations in the City of St. Francis.

Appendix E –Wellhead Protection Areas

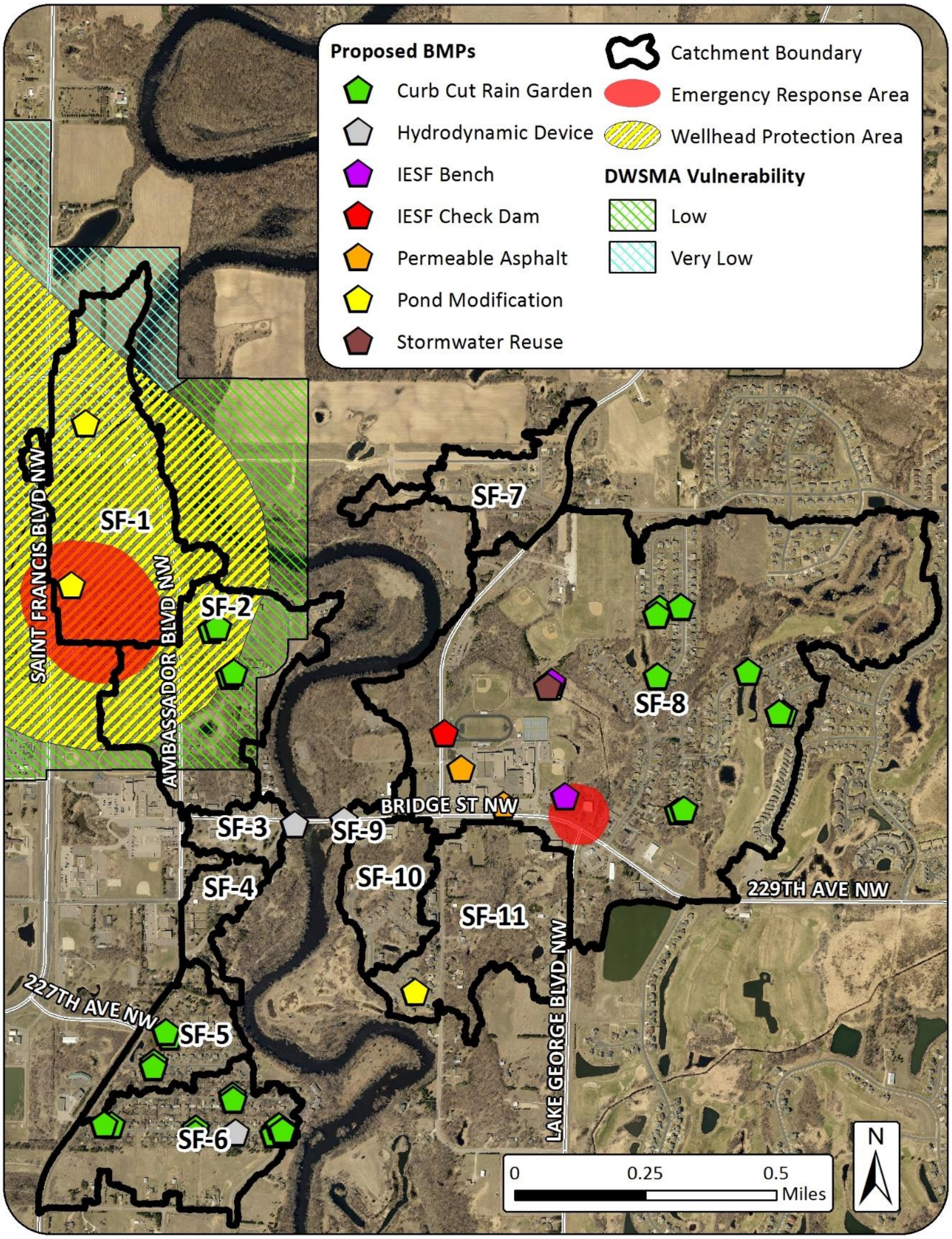

Figure 72: Wellhead protection areas and proposed retrofit locations in the City of St. Francis.