Lower Rice Creek
Stormwater Retrofit Analysis

Prepared by:

ANOKA CONSERVATION DISTRICT

for the

RICE CREEK WATERSHED DISTRICT

Lower Rice Creek Stormwater Retrofit Analysis: 2021

Prepared for the Rice Creek Watershed District (RCWD) by:
Anoka Conservation District

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Disclaimer: At the time of printing, this report identifies and ranks potential BMPs for selected subwatersheds in the cities of Fridley and Spring Lake Park that drain to Lower Rice Creek. 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 Anoka Conservation District or the Rice Creek Watershed District.

Abstract

The Rice Creek Watershed District (RCWD) contracted Anoka Conservation District to complete this stormwater retrofit analysis (SRA) for the purpose of identifying and ranking water quality improvement projects throughout select drainage areas to Lower Rice Creek. The target areas consist of portions of northeast and central Fridley and eastern Spring Lake Park that drain to Lower Rice Creek. The RCWD specified total suspended solids (TSS) and total phosphorus (TP) as the target pollutants for the analysis. Because a TMDL does not exist for Lower Rice Creek, annual subwatershed-wide reduction goals for TP and TSS are not available.

This analysis is primarily intended to identify potential projects within the target areas to improve water quality in Lower Rice Creek through stormwater retrofits. 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). 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. 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.

Drainage areas within the 1,115-acre study area were consolidated into 25 catchments and three drainage networks (groups of catchments draining to a common priority waterbody). A WinSLAMM model was created for each of the three drainage networks, which included Norton Creek (560 acres), Lower Rice Creek (475 acres), and Anoka County (80 acres). Details of the volume and pollutant loading within each drainage network are provided in the Catchment Profile pages. A variety of stormwater retrofit approaches was identified and potential projects are organized from most cost-effective to least based on pollutants removed.

Table of Contents

List of Figures

List of Tables

Executive Summary

The Rice Creek Watershed District (RCWD) contracted 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 Lower Rice Creek. The subwatersheds are located in the cities of Fridley and Spring Lake Park and consist of mostly commercial, residential, and institutional land uses. Total suspended solids (TSS) and total phosphorus (TP) were the target parameters analyzed. Volume was also documented as a model output.

This analysis is primarily intended to identify potential projects within the target areas to improve water quality in Lower Rice Creek 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 comparing 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 report, 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 was identified. They included bioretention (bioinfiltration, biofiltration, and high-performance modular biofiltration systems), hydrodynamic devices, existing stormwater pond modifications, and new stormwater ponds. If all of the practices were installed, significant pollutant reductions could be accomplished. However, funding limitations and landowner interest make this goal unlikely. Rather, 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 should be considered by resource managers when pursuing projects.

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 a more detailed feasibility analysis and 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 1,115-acre target study area was consolidated into three drainage networks and 25 catchments. The tables in the Project Ranking and Selection section summarize potential projects ranked by cost-effectiveness with respect to both TSS and TP. Potential projects are organized from most cost-effective to least based on pollutants removed.

In summary, 145 projects were identified throughout the three drainage networks. Project types generally consisted of bioretention (107, 74% of total), hydrodynamic devices (25, 17% of total), infiltration basin installations or modifications (9, 6% of total), and stormwater pond installations or modifications (3, 2% of total). One streambank stabilization project was also identified in Norton Creek. The fully developed landscape limited opportunities for large, regional practices; the limited open space available within most of the drainage networks was more suitable for small-scale bioretention practices.

The effectiveness of these small-scale bioretention practices may be limited by slow draining, silty soils in portions of the study area. Soil borings should be conducted before selecting any site for bioretention installation. Most of these projects are located in residential neighborhoods with small drainage areas (typically 0.5-5 acres). In a residential setting with sandy soils, bioinfiltration practices with a 12-inch ponding depth were the most cost-effective retrofit option. In a residential setting with silty soils and less than two acres of contributing drainage area, bioinfiltration practices with a nine-inch ponding depth were the most cost-effective retrofit option. Given 0.2 in/hr infiltration rates, this reduced ponding depth facilitates drawdown in 45 hours, which is at the upper end of an acceptable wet period (i.e. 48 hours). Because of this lengthy drawdown time, biofiltration practices were preferred in the model if a catch basin tie-in was feasible. In similar settings with greater than two acres of drainage area, High-Performance Modular Biofiltration Systems (HPMBS) were the most cost-effective retrofit option, given the availability of an underdrain. These systems cost significantly more than similarly sized bioretention practices, but they offer better pollutant removal per dollar at sites where contributing drainage areas were larger than two acres. HPMBS systems also have significantly shorter drawdown periods because of a high media filtration rate.

In areas with existing regional stormwater treatment, the effectiveness of bioretention practices is diminished. The same guidance still generally applies in this scenario with infiltration practices in locations with sandy soils being the most cost-effective option. Biofiltration and HPMBS systems are often cost prohibitive in areas with existing treatment downstream and slow draining soils.

Overall, cost-effectiveness for TP removal ranged from ~$396/lb-TP to ~$16,550/lb-TP. The most cost-effective projects for TP removal were a streambank stabilization, infiltration basin retrofits, ponds, bioinfiltration basins, and high-performance modular biofiltration systems (in larger drainage areas). Cost-effectiveness for TSS removal ranged from ~$343/1,000 lbs-TSS to ~$40,366/1,000 lbs-TSS. Similar to TP, the most cost-effective projects for TSS removal were a streambank stabilization, infiltration basin retrofits, ponds, high-performance modular biofiltration systems, and bioinfiltration basins.

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 is available in the catchment profile pages of this report. Projects deemed infeasible 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 25 catchments distributed throughout three drainage networks and assigned unique identification numbers. For each catchment, the following information is detailed:

Drainage Network

Catchments were grouped into drainage networks based on their geographic distribution throughout the study area and drainage to a common waterbody (i.e. Norton Creek, Lower Rice Creek, and Anoka County). The drainage networks were used to further subdivide the report to aid with organization and clarity.

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 either RCWD, the City of Fridley, or the City of Spring Lake Park. 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 Opportunities

Retrofit opportunities 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 Fridley and the City of Spring Lake Park within the RCWD and drain to Lower Rice Creek via a variety of outfalls. The primary targets for water quality improvement are Lower Rice Creek, Locke Lake, and the Mississippi River. Because Locke Lake ultimately discharges to the Mississippi River, pollutant reductions associated with potential projects identified in this analysis will also benefit the Mississippi River.

The target area analyzed is heavily urbanized. Development throughout the Cities of Fridley and Spring Lake Park 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 Lower Rice Creek, as it was historically. However, the runoff is now captured by catch basins and directed underground before being discharged via stormwater pipes. This along with the impervious surfaces has caused increased volume and pollutant loading to Lower Rice Creek relative to natural, historical conditions.

The area analyzed was divided into three drainage networks and consists of 1,115 acres. Stormwater retrofits may provide cost-effective options for treatment of runoff, thereby improving water quality in the priority water bodies. The three drainage networks analyzed were Norton Creek, Lower Rice Creek, and Anoka County.

The largest contributing drainage area is from a tributary to Rice Creek named Norton Creek, which drains 560 acres of primarily residential and industrial land uses. Norton Creek was historically an open channel spanning from southern Spring Lake Park, through Fridley, and ultimately discharging into Rice Creek. As the subwatershed was developed, Norton Creek was transitioned from an open channel into underground stormwater infrastructure. The only remaining open channel portion is between 72nd Ave. NE and Norton Ave. NE.

The Lower Rice Creek drainage networks includes five outfalls into Rice Creek. The 475-acre area is primarily residential land use. Each outfall to the creek was individually modeled.

The Anoka County drainage network has a single outfall to Rice Creek. The 80-acre area largely straddles Central Ave. NE from southern Spring Lake Park, through Fridley, and discharges into Rice Creek. Land uses are a mix of industrial, residential, commercial, and institutional.

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. This SRA is intended to identify potential projects that will benefit the priority water bodies.

The RCWD contracted the ACD to complete this SRA for the purpose of identifying and analyzing projects to improve the quality of stormwater runoff from contributing drainage areas to Lower Rice

Creek. Overall subwatershed loading of TSS, TP, and stormwater volume were estimated for subdivided drainage networks throughout the focus area. 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, 2021).

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 that discharge directly into the target water body (i.e. Lower Rice Creek) with zero or limited existing treatment. Included are areas of residential, commercial, industrial, and institutional land uses. The focus areas were divided into 25 catchments using a combination of existing subwatershed mapping data, stormwater infrastructure maps, and observed topography.

The targeted pollutants for this study were TSS and TP, 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 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 particulate phosphorus (PP). As such, reductions in TSS will also result in TP reductions.
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 PP, which is bound to sediment and organic debris, and dissolved phosphorus (DP), which is in solution and readily available for plant growth (active).
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 treatment 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 in areas where the available GIS data were insufficient. 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 10.4.1), 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. 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. Drainage area delineations were used to model the land uses in each catchment. The drainage areas were consolidated into catchments using geographic information systems (specifically, ArcMap). 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 high-resolution 2020 aerial photography, the most recent available at the time of this analysis, as well as ground truthing, 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 study area were predominantly either sand or silt based on information available in the Anoka County soil survey and associated assumptions made for soils listed as 'cut and fill.' 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 Fridley and the City of Spring Lake Park (Figure 1, Figure 2, and Figure 3). For example, street cleaning with vacuum street sweepers, stormwater treatment ponds, hydrodynamic devices, and others were included in the "existing conditions" model if information was available.

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.

Bioretention retrofits were modeled as either biofiltration or bioinfiltration practices based on the underlying soil type assumptions and a particular practice's proximity to a structure that could receive an underdrain connection. In areas with sandy soils, bioinfiltration was modeled with a native soil infiltration rate of 1.63"/hour to estimate volume and pollutant reductions of the proposed retrofits. In areas with silty soils, biofiltration was modeled wherever possible with a native soil infiltration rate of 0.2"/hour. If a proposed project location had silty soils and connection of an underdrain to an existing stormwater structure was not possible, the maximum ponding depth of the proposed practice was reduced to achieve an acceptable maximum estimated drawdown time (i.e. <48 hours). All modeling details for proposed retrofits are available 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 2021 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** covers 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 could be pursued to achieve water quality goals. Project ranking tables are presented based on cost per 1,000 pounds of TSS and cost per pound of TP removed.

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

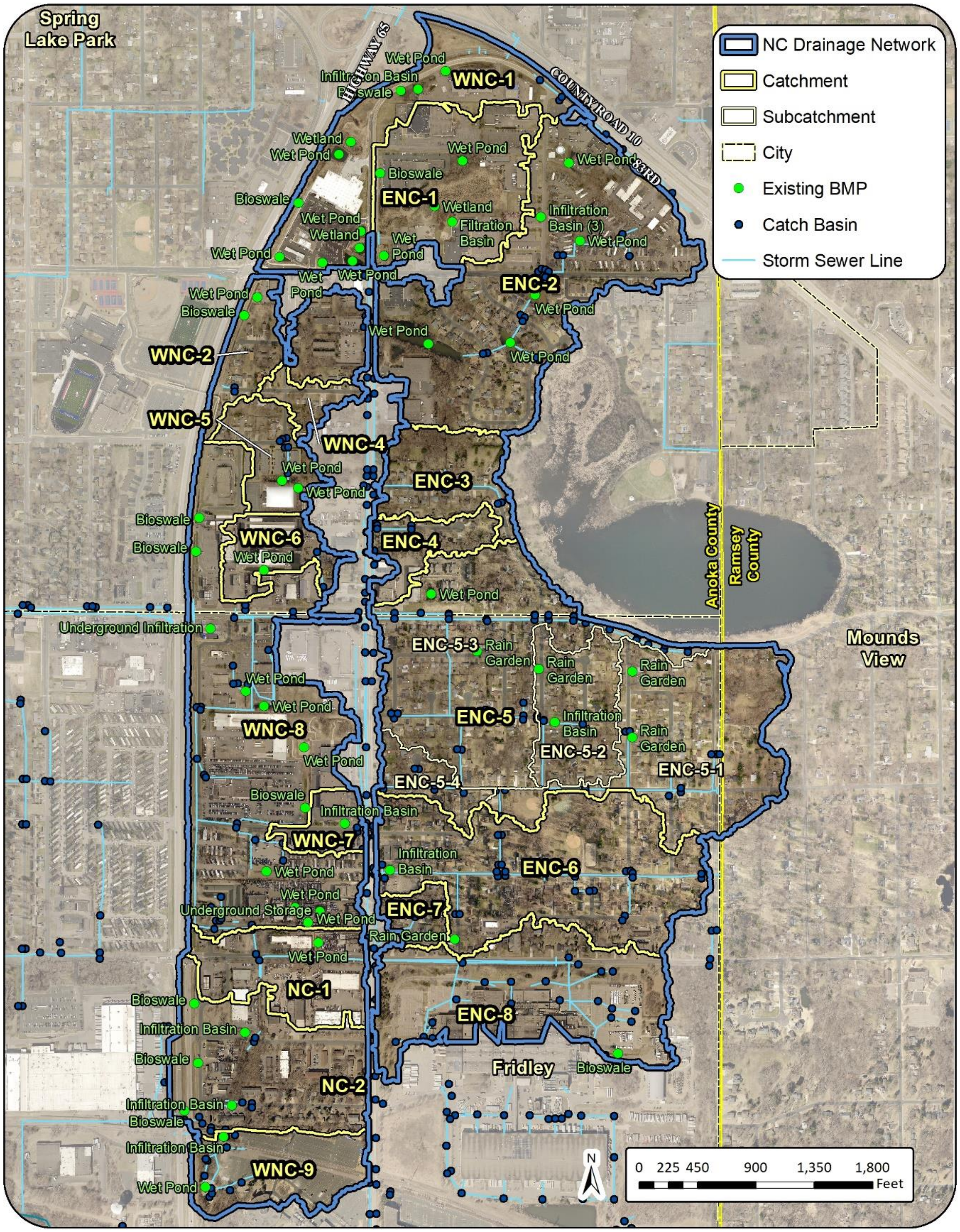


Figure 1: Norton Creek drainage network map showing existing BMPs included in the WinSLAMM model. Street sweeping is not shown on the map but was included throughout the study area.

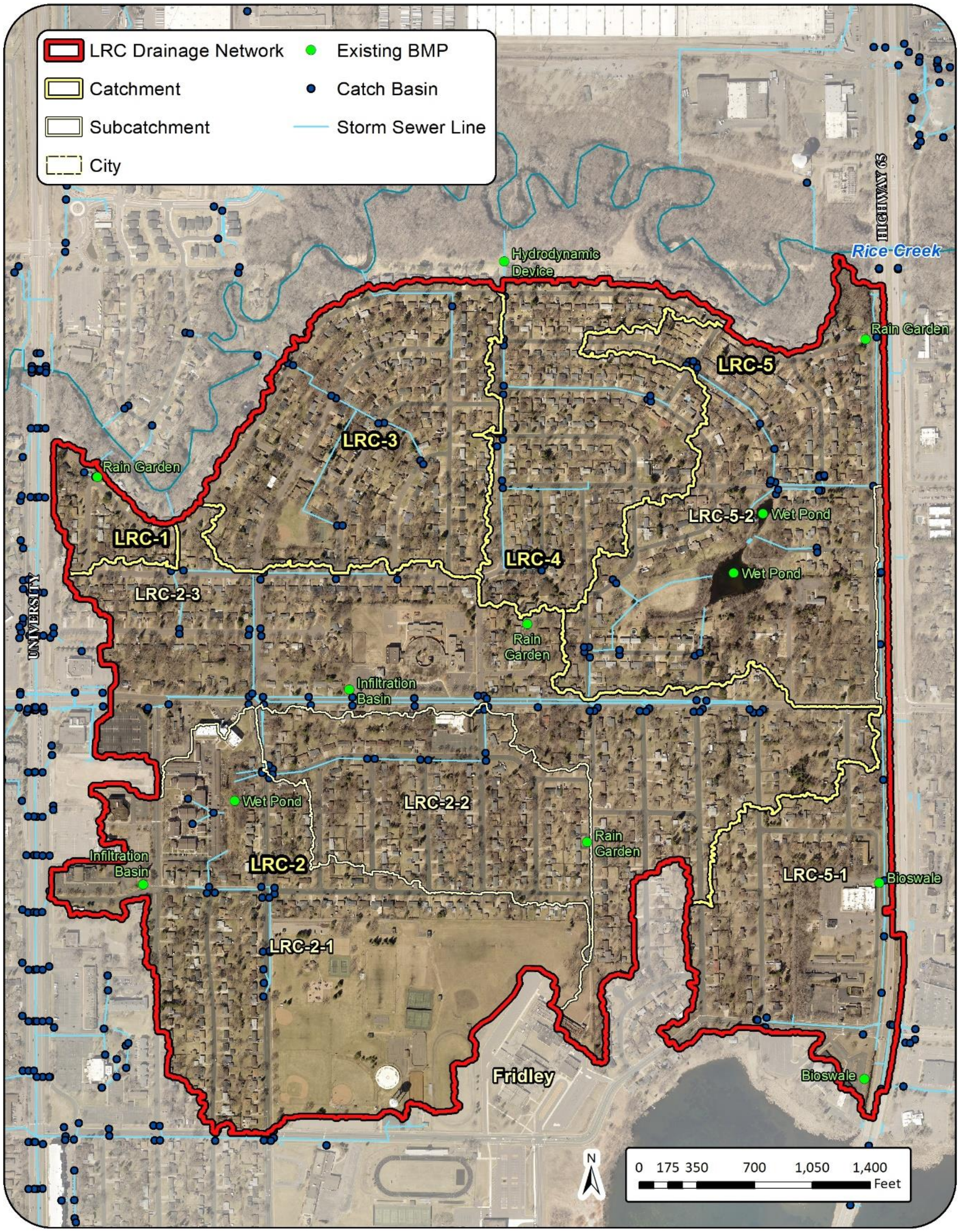


Figure 2: Lower Rice Creek drainage network map showing existing BMPs included in the WinSLAMM model. Street sweeping is not shown on the map but was included throughout the study area.

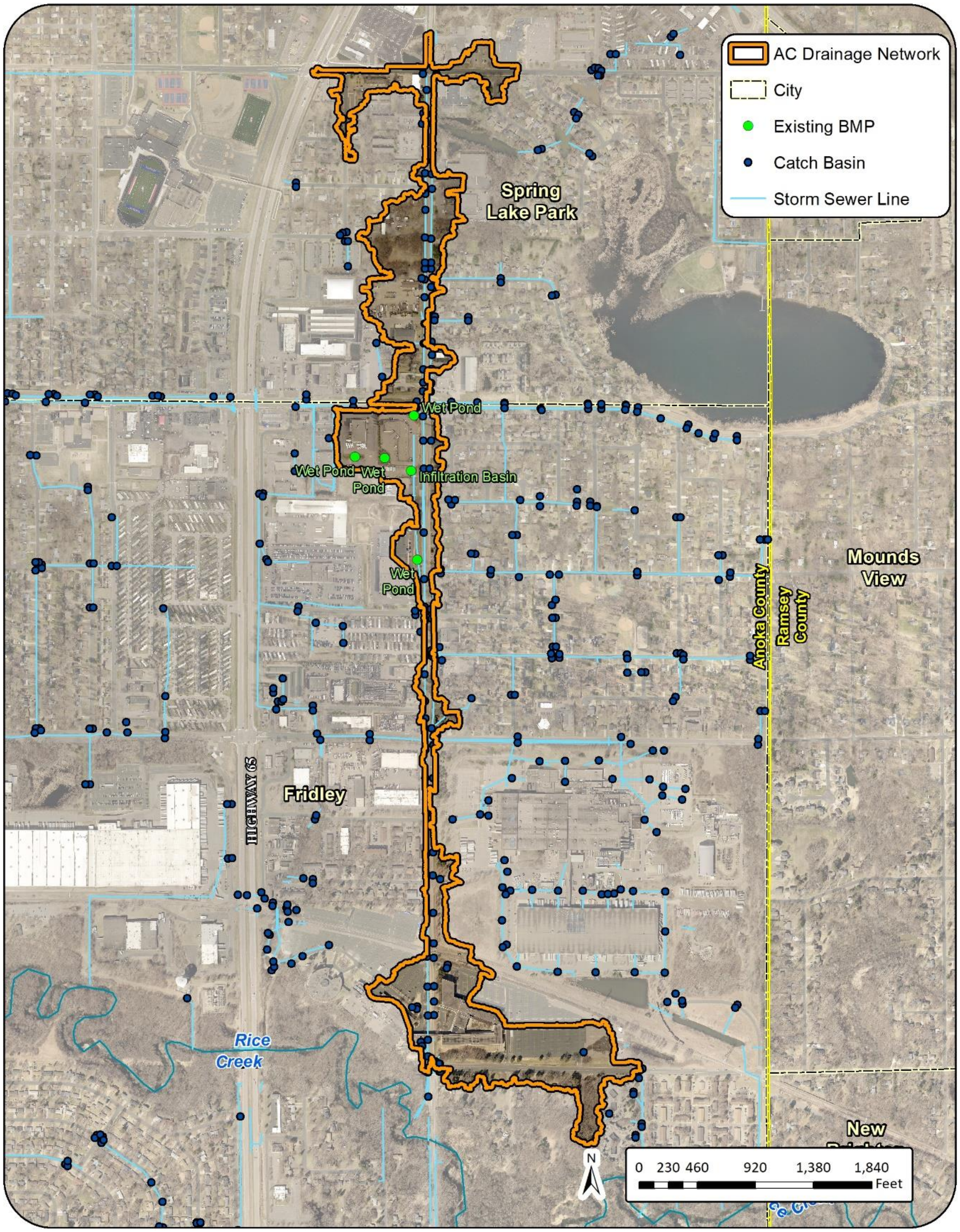


Figure 3: Anoka County drainage network map showing existing BMPs included in the WinSLAMM model. Street sweeping is not shown on the map but was included throughout the study area.

Project Ranking and Selection

The intent of this analysis is to provide the information necessary to enable local natural resource managers to 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.

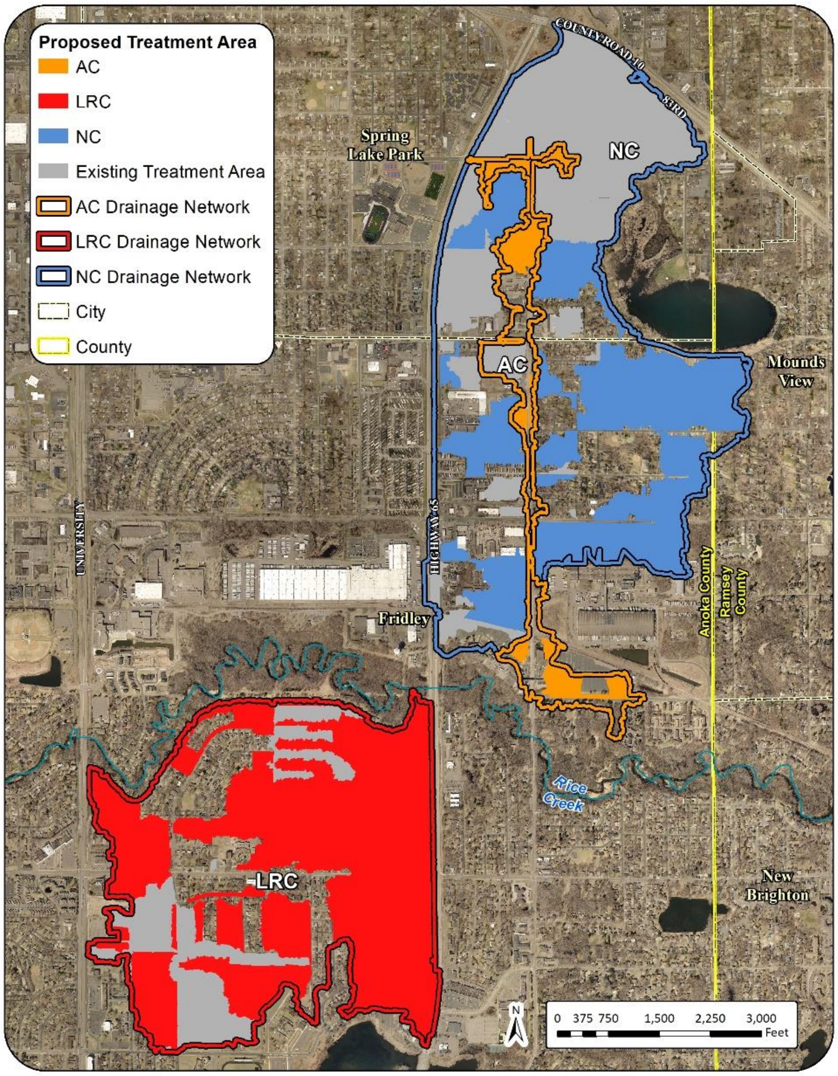


Figure 4: Drainage networks and areas with water quality treatment from existing and proposed BMPs.

Figure 4 shows portions of the drainage area that are currently treated by existing BMPs as well as the areas that could be treated with the retrofit opportunities identified in this report. Areas not covered by either existing or proposed BMPs are generally higher in elevation (i.e. there is not a large contributing drainage area) or they are heavily developed industrial areas.

Project Ranking

If all identified practices were installed, significant pollution reduction could be accomplished. However, funding limitations and landowner interest will likely be limiting factors for implementation. The tables on the following pages rank all modeled projects by cost-effectiveness.

Projects were ranked in two ways:

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

Table 2: Cost-effectiveness of retrofits with respect to TSS reduction. Projects ranked 1 – 16 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	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	NC-2 SS	116	Streambank Stabilization	NC-2	9.35	22000.00	n/a	$182,300	$1,460	$342.58
2	WNC-7 IB Retrofit	99	Existing IB Retrofit	WNC-7	0.59	365.00	0.76	$7,004	$0	$639.63
3	LRC-5 Pond	168	New Wet Pond	LRC-5	14.54	6430.00	0.00	$201,788	$281	$1,089.85
4	AC IB-Medtronic	177	Infiltration Basin	AC	0.6 - 1.6	369 - 1,042	0.67 - 1.88	$28,920	$225	$1,159.76 - $3,274.98
5	0.5 - 5 acres non site-specific	28	HPMBS	Any - w/o exist. trt.	0.16 - 1.96	62.1 - 791.9	0.01 - 0.02	$23,504	$742	$1,926 - $24,557
6	WNC-9 IB	109	Infiltration Basin	WNC-9	0.0 - 1.17	153 - 615	0.0 - 2.28	$29,504 - $33,504	$225.00 - $742.00	$1,964.99 - $7,898.47
7	ENC-5-2 Pond Retrofit	60	Existing Pond Retrofit	ENC-5-2	1.50	429.20	1.11	$16,150	$340	$2,046.44
8	LRC-2-3 IB-1	144	Infiltration Basin	LRC-2-3	0.60	312.00	0.85	$17,154	$225	$2,553.85
9	LRC-2-3 IB-2	145	Infiltration Basin	LRC-2-3	0.30 - 0.70	120 - 277	0.28 - 0.67	$15,204	$225	$2,641.88 - $6,098.33
10	0.5 - 5 acres non site-specific	28	12" Bioinfiltration (sand)	Any - w/o exist. trt.	0.23 - 0.67	70.28 - 210.9	0.18 - 0.51	$10,004	$225	$2,648 - $7,946
11	LRC-4 0.5 - 5 acres non site-specific	163	Bioretention	LRC-4	0.11 - 1.22	38 - 492	0.01 - 0.48	$10,004 - $23,504	$225.00 - 742.00	$3,019 - $28,782
12	LRC-2-2 IB	134	Infiltration Basin	LRC-2-2	0.16 - 0.4	68 - 168	0.20 - 0.39	$10,654	$225	$3,453 - $8,531
13	WNC-8 IB Retrofit	104	Existing IB Retrofit	WNC-8	0.14	63.00	0.28	$7,004	$0	$3,705.82
14	ENC-8 HD-1	79	Hydrodynamic Device	ENC-8	0.24	945.00	n/a	$111,750	$630	$4,608.47
15	AC Pond	176	New Wet Pond	AC	6.90	3706.00	0.00	$544,203	$280	$4,970.35
16	LRC-2-1 0.5 - 5 acres non site-specific	131	Bioretention	LRC-2-1	0.0 - 0.37	0.0 - 147	0.0 - 0.80	$10,004 - $23,504	$225.00 - 742.00	$5,941 - $117,344

[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 17 – 31 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	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]
17	NC-2 IB Retrofit	114	Existing IB Retrofit	NC-2	0.10	47.00	0.11	$7,004	$63	$6,307.80
18	ENC-8 HD-2	80	Hydrodynamic Device	ENC-8	0.81	673.00	n/a	$111,750	$630	$6,471.03
19	0.5 - 5 acres non site-specific	28	12" Biofiltration (silt)	Any - w/o exist. trt.	0.10 - 0.26	36.69 - 99.0	0.04 - 0.07	$12,004	$295	$7,021.55 - $18,946.13
20	0.5 - 5 acres non site-specific	28	9" Bioinfiltration (silt)	Any - w/o exist. trt.	0.14 - 0.21	43.75 - 69.0	0.10 - 0.16	$10,004	$225	$8,094 - $12,765
21	LRC-2-3 HD-3	141	Hydrodynamic Device	LRC-2	0.50	280.00	n/a	$57,750	$630	$9,125.00
22	AC HD	175	Hydrodynamic Device	AC	0.18	161.00	n/a	$30,750	$630	$10,279.50
23	NC-2 HD	115	Hydrodynamic Device	NC-2	0.47	228.00	n/a	$57,750	$630	$11,206.14
24	WNC-5 BR	94	Bioretention	WNC-5	0.06 - 0.21	23 - 47	0.07 - 0.49	$10,004 - $12,004	$225	$11,882.27 - $27,179.71
25	ENC-5-1 HD-3	56	Hydrodynamic Device	ENC-5-1	0.98	357.00	n/a	$111,750	$630	$12,198.88
26	ENC-3 HD	45	Hydrodynamic Device	ENC-3	0.92	352.00	n/a	$111,750	$630	$12,372.16
27	ENC-6 HD	72	Hydrodynamic Device	ENC-6	0.87	341.00	n/a	$111,750	$630	$12,771.26
28	LRC-2-1 BF-3	128	HPMBS	LRC-2-1	n/a	118	0.00	$23,504	n/a	$12,924.86
29	LRC-2-3 HD-5	143	Hydrodynamic Device	LRC-2	0.80	324.00	n/a	$111,750	$630	$13,441.36
30	LRC-5-2 HD	61	Hydrodynamic Device	LRC-5-2	0.81	319.00	n/a	$111,750	$630	$13,652.04
31	LRC-2-3 HD-1	139	Hydrodynamic Device	LRC-2	0.80	303.00	n/a	$111,750	$630	$14,372.94

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

Table 4: Cost-effectiveness of retrofits with respect to TSS reduction. Projects ranked 32 – 46 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	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]
32	WNC-8 HD	105	Hydrodynamic Device	WNC-8	0.53	299.00	n/a	$111,750	$630	$14,565.22
33	ENC-5-1 HD-2	55	Hydrodynamic Device	ENC-5-1	0.46	175.00	n/a	$57,750	$630	$14,600.00
34	ENC-5-3 HD-2	65	Hydrodynamic Device	ENC-5-3	0.81	292.00	n/a	$111,750	$630	$14,914.38
35	ENC-5-3 HD-1	64	Hydrodynamic Device	ENC-5-3	0.24	104.00	n/a	$30,750	$630	$15,913.46
36	LRC-1 HD	123	Hydrodynamic Device	LRC-1	0.40	159.90	n/a	$57,750	$630	$15,978.74
37	LRC-3 HD	152	Hydrodynamic Device	LRC-3	0.39	149.00	n/a	$57,750	$630	$17,147.65
38	LRC-2-3 HD-4	142	Hydrodynamic Device	LRC-2	0.40	147.00	n/a	$57,750	$630	$17,380.95
39	LRC-2-1 Wells Fargo IB	127	Infiltration Basin	LRC-2-1	600.00	0.10	49.00	$18,520	$225	$17,587.76
40	LRC-2-3 HD-2	140	Hydrodynamic Device	LRC-2	0.60	235.00	n/a	$111,750	$630	$18,531.91
41	ENC-5-1 HD-1	54	Hydrodynamic Device	ENC-5-1	0.34	133.00	n/a	$57,750	$630	$19,210.53
42	ENC-4 HD	50	Hydrodynamic Device	ENC-4	0.23	83.00	n/a	$30,750	$630	$19,939.76
43	WNC-7 HD	100	Hydrodynamic Device	WNC-7	0.19	83.00	n/a	$30,750	$630	$19,939.76
44	ENC-5-2 HD	167	Hydrodynamic Device	ENC-5-2	0.36	138.10	n/a	$111,750	$630	$31,535.12
45	LRC-4 HD-2	159	Hydrodynamic Device	LRC-4	0.33	121.00	n/a	$111,750	$630	$35,991.74
46	LRC-4 HD-1	158	Hydrodynamic Device	LRC-4	0.10	41.00	n/a	$30,750	$630	$40,365.85

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

Table 5: Cost-effectiveness of retrofits with respect to TP reduction. Projects ranked 1-16 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	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	WNC-7 IB Retrofit	99	Existing IB Retrofit	WNC-7	0.59	365	0.76	$7,004.00	$0.00	$396.38
2	LRC-5 Pond	168	New Wet Pond	LRC-5	14.54	6430	0.00	$201,787.60	$281.49	$481.96
3	ENC-5-2 Pond Retrofit	60	Existing Pond Retrofit	ENC-5-2	1.50	429	1.11	$16,150.00	$340.00	$586.61
4	WNC-8 IB Retrofit	104	Existing IB Retrofit	WNC-8	0.14	63	0.28	$7,004.00	$0.00	$1,667.62
5	AC IB-Medtronic	177	Infiltration Basin	AC	0.6 - 1.6	369 - 1,042	0.67 - 1.88	$29,504.00	$225.00	$755.29 - $2,157.98
6	0.5 - 5 acres non site-specific	28	HPMBS	Any - w/o exist. trt.	0.16 - 1.96	62.1 - 791.9	0.01 - 0.02	$23,504.00	$742.00	$776.71 - $9,689.19
7	NC-2 SS	116	Streambank Stabilization	NC-2	9.35	22000	n/a	$182,300.00	$1,460.00	$806.06
8	0.5 - 5 acres non site-specific	28	12" Bioinfiltration (sand)	Any - w/o exist. trt.	0.23 - 0.67	70.28 - 210.9	0.18 - 0.51	$10,004	$225.00	$838.54 - $2,446.41
9	LRC-4 0.5 - 5 acres non site-specific	163	Bioretention	LRC-4	0.11 - 1.22	38 - 492	0.01 - 0.48	$10,004 - $23,504	$225.00 - 742.00	$947 - $11,734
10	WNC-9 IB	109	Infiltration Basin	WNC-9	0.0 - 1.17	153 - 615	0.0 - 2.28	$29,504 - $33,504	$225.00 - $742.00	$1,032.00 - $3,975.22
11	LRC-2-3 IB-2	145	Infiltration Basin	LRC-2-3	0.30 - 0.70	120 - 277	0.28 - 0.67	$15,204.00	$225.00	$1,045.00 - $2,439.00
12	LRC-2-3 IB-1	144	Infiltration Basin	LRC-2-3	0.60	312	0.85	$17,154.00	$225.00	$1,328.00
13	LRC-2-2 IB	134	Infiltration Basin	LRC-2-2	0.16 - 0.4	68 - 168	0.20 - 0.39	$10,654	$225	$1,450 - $3,610
14	LRC-2-1 0.5 - 5 acres non site-specific	131	Bioretention	LRC-2-1	0.0 - 0.37	0.0 - 147	0.0 - 0.80	$10,004 - $23,504	$225.00 - 742.00	$1,509 - $17,378
15	0.5 - 5 acres non site-specific	28	9" Bioinfiltration (silt)	Any - w/o exist. trt.	0.14 - 0.21	43.75 - 69.0	0.10 - 0.16	$10,004	$225.00	$2,621.91 - 4,029.34
16	0.5 - 5 acres non site-specific	28	12" Biofiltration (silt)	Any - w/o exist. trt.	0.10 - 0.26	36.69 - 99.0	0.04 - 0.07	$12,004.00	$295.00	$2,643.09 - $6,855.36

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

Table 6: Cost-effectiveness of retrofits with respect to TP reduction. Projects ranked 17-31 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	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]
17	WNC-5 BR	94	Bioretention	WNC-5	0.06 - 0.21	23.0 - 47.0	0.07 - 0.49	$10,004 - $12,004	$225.00	$2,659.37 - $9,767.71
18	AC Pond	176	New Wet Pond	AC	6.90	3706	0.00	$544,203.20	$280.00	$2,669.58
19	NC-2 IB Retrofit	114	Existing IB Retrofit	NC-2	0.10	47	0.11	$7,004.00	$63.00	$2,964.67
20	ENC-8 HD-1	79	Hydrodynamic Device	ENC-8	0.24	945	n/a	$111,750.00	$630.00	$3,853.98
21	ENC-5-1 HD-3	56	Hydrodynamic Device	ENC-5-1	0.98	357	n/a	$111,750.00	$630.00	$4,443.88
22	ENC-3 HD	45	Hydrodynamic Device	ENC-3	0.92	352	n/a	$111,750.00	$630.00	$4,723.43
23	ENC-6 HD	72	Hydrodynamic Device	ENC-6	0.87	341	n/a	$111,750.00	$630.00	$5,005.75
24	LRC-2-2 HD-3	141	Hydrodynamic Device	LRC-2	0.50	280	n/a	$57,750.00	$630.00	$5,110.00
25	LRC-5-2 HD	61	Hydrodynamic Device	LRC-5-2	0.81	319	n/a	$111,750.00	$630.00	$5,376.54
26	ENC-5-3 HD-2	65	Hydrodynamic Device	ENC-5-3	0.81	292	n/a	$111,750.00	$630.00	$5,376.54
27	NC-2 HD	115	Hydrodynamic Device	NC-2	0.47	228	n/a	$57,750.00	$630.00	$5,436.17
28	ENC-8 HD-2	80	Hydrodynamic Device	ENC-8	0.81	673	n/a	$111,750.00	$630.00	$5,443.75
29	LRC-2-3 HD-1	139	Hydrodynamic Device	LRC-2	0.80	303	n/a	$111,750.00	$630.00	$5,443.75
30	LRC-2-3 HD-5	143	Hydrodynamic Device	LRC-2	0.80	324	n/a	$111,750.00	$630.00	$5,443.75
31	ENC-5-1 HD-2	55	Hydrodynamic Device	ENC-5-1	0.46	175	n/a	$57,750.00	$630.00	$5,554.35

[1][(Probable Project Cost) + 30*(Annual O&M)] / [30*(Annual TSS Reduction/1000)]

Table 7: Cost-effectiveness of retrofits with respect to TP reduction. Projects ranked 32-46 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	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]
32	LRC-2-3 HD-4	142	Hydrodynamic Device	LRC-2	0.40	147	n/a	$57,750.00	$630.00	$6,387.50
33	LRC-1 HD	123	Hydrodynamic Device	LRC-1	0.40	160	n/a	$57,750.00	$630.00	$6,387.50
34	LRC-3 HD	152	Hydrodynamic Device	LRC-3	0.39	149	n/a	$57,750.00	$630.00	$6,551.28
35	ENC-5-3 HD-1	64	Hydrodynamic Device	ENC-5-3	0.24	104	n/a	$30,750.00	$630.00	$6,895.83
36	LRC-2-3 HD-2	140	Hydrodynamic Device	LRC-2	0.60	235	n/a	$111,750.00	$630.00	$7,258.33
37	ENC-4 HD	50	Hydrodynamic Device	ENC-4	0.23	83	n/a	$30,750.00	$630.00	$7,323.01
38	ENC-5-1 HD-1	54	Hydrodynamic Device	ENC-5-1	0.34	133	n/a	$57,750.00	$630.00	$7,514.71
39	WNC-8 HD	105	Hydrodynamic Device	WNC-8	0.53	299	n/a	$111,750.00	$630.00	$8,216.98
40	LRC-2-1 Wells Fargo IB	127	Infiltration Basin	LRC-2-1	0.10	0	49.00	$18,520.00	$225.00	$8,618.00
41	WNC-7 HD	100	Hydrodynamic Device	WNC-7	0.19	83	n/a	$30,750.00	$630.00	$8,945.95
42	AC HD	175	Hydrodynamic Device	AC	0.18	161	n/a	$30,750.00	$630.00	$9,194.44
43	ENC-5-2 HD	167	Hydrodynamic Device	ENC-5-2	0.36	138	n/a	$111,750.00	$630.00	$12,164.80
44	LRC-4 HD-2	159	Hydrodynamic Device	LRC-4	0.33	121	n/a	$111,750.00	$630.00	$13,196.97
45	LRC-4 HD-1	158	Hydrodynamic Device	LRC-4	0.10	41	n/a	$30,750.00	$630.00	$16,550.00
46	LRC-2-1 BF-3	128	HPMBS	LRC-2-1	n/a	118	0.00	$23,504.00	$741.67	n/a

[1][(Probable Project Cost) + 30*(Annual O&M)] / [30*(Annual TSS Reduction/1000)]

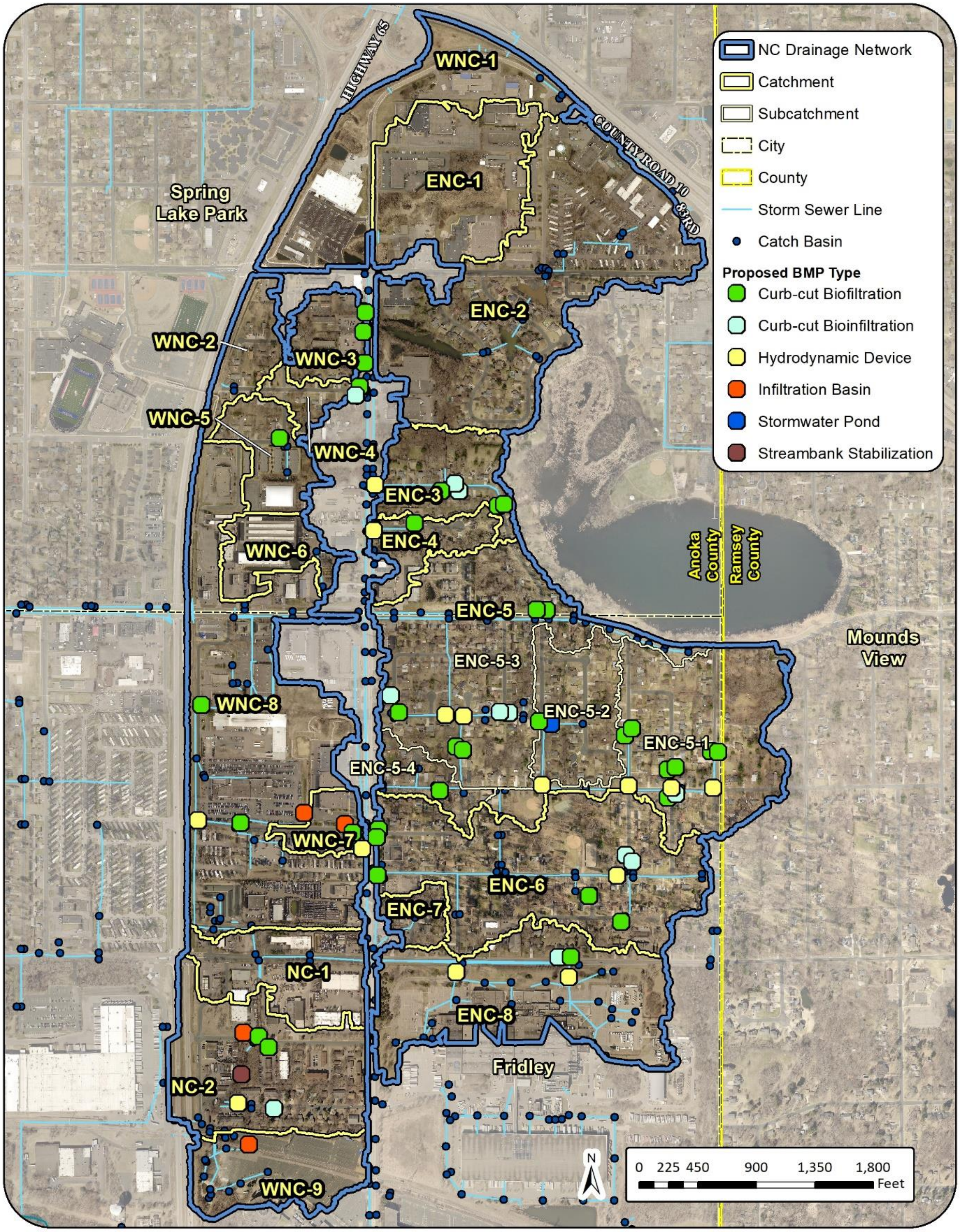


Figure 5: Study area map showing the proposed retrofits in the Norton Creek drainage network included in this report.

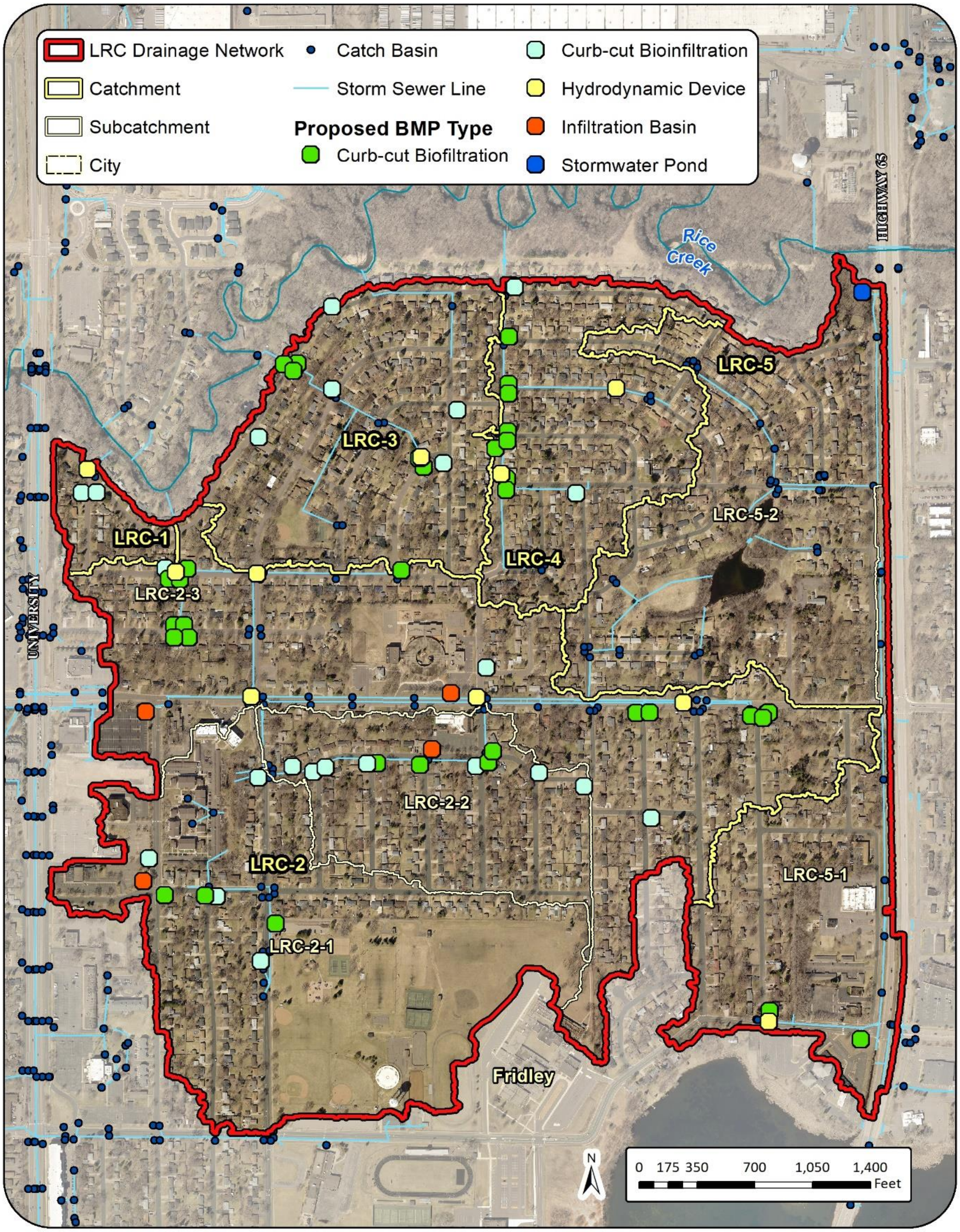


Figure 6: Study area map showing the proposed retrofits in the Lower Rice Creek drainage network included in this report.

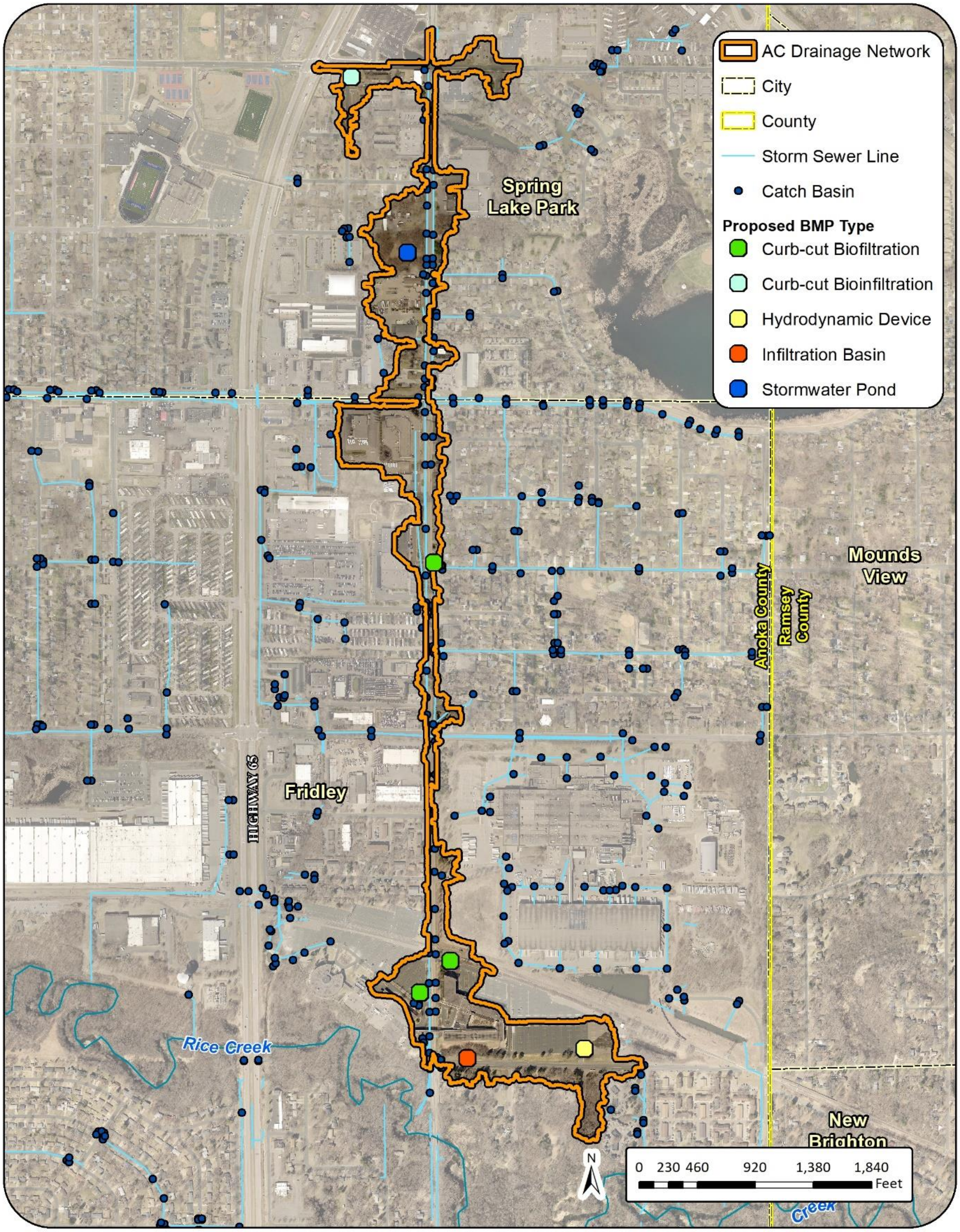


Figure 7: Study area map showing the proposed retrofits in the Anoka County drainage network included in this report.

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 could 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
- 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 Gardens (Biofiltration and Bioinfiltration)
    - High-Performance Modular Biofiltration Systems
    - Residential Bioretention Comparison
- Hydrodynamic Device
- Modification to an Existing Pond
- New Stormwater Pond

Bioretention

Bioretention BMPs utilize soil and vegetation to treat stormwater runoff from roads, driveways, rooftops, 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 8 conveys the general efficacy of the two types of bioretention (biofiltration and bioinfiltration) in terms of the three most common pollutants, total suspended solids (TSS), particular phosphorus (PP), dissolved phosphorus (DP), and stormwater volume.

Table 8: 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 estimate the total 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 (Biofiltration and Bioinfiltration)

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 upgradient of a catch basin serving a large drainage area.

In areas with quick draining sandy soils, bioinfiltration practices were proposed regardless of the location's proximity to a catch basin. In slower draining silty soils, biofiltration practices were preferred if site conditions allowed for proper space and proximity to a catch basin to facilitate basin draining via an underdrain. In both of these cases, a 12-inch ponding depth basin with a 250 sq-ft top footprint was modeled. In silty areas where siting did not allow for close proximity to a catch basin, a 9-inch ponding depth infiltration basin was proposed to allow complete drawdown of the basin within 48 hours following a storm event (Figure 8).

Figure 8: Rain garden before/after and during a rainfall event

All curb-cut rain gardens were presumed to have 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 gardens at years 10 and 20. Rehabilitation includes removal of accumulated sediment and supplemental planting. Annual maintenance was assumed to be completed by the landowner of the property at which the rain garden could be installed.

High-Performance Modular Biofiltration Systems (HPMBS)

HPMBS is a biofiltration system with fast draining, high-performance media (100 in/hr) that allows the filtration of large volumes of water within a small basin footprint. The high-performance media also has documented pollutant reductions through independent testing of 80% TSS (Specification High-Performance Modular Biofiltration System (HPMBS)). These systems were included as an optional replacement of a standard curb-cut biofiltration basin where space is limited. Proposed HPMBS were designed with a 12-inch ponding depth and a 100 sq.-ft. top footprint (Figure 2).

All HPMBS were presumed to have 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 gardens at year 15. Rehabilitation includes removal of accumulated sediment and supplemental planting. Annual maintenance was assumed to be completed by the landowner of the property at which the HPMBS could be installed.

Residential Bioretention Comparison

Biofiltration, bioinfiltration, and HPMBS practices can all be installed interchangeably with each other given proper space and soil drainage rates. HPMBS systems can treat larger volumes of water in a smaller footprint but may be cost-prohibitive to be utilized widely in a bioretention network. Standard biofiltration and bioinfiltration basins can be adequately sized to treat large volumes of water from large drainage areas but may be space prohibitive in certain settings.

Figure 9: An HPMBS basin installed at a parking lot catch basin. The total footprint of the practice basin is about the size of one parking space.

Siting of bioretention practices in this report is not intended to be prescriptive, but instead can be used as a starting point for more in-depth site reviews of specific locations. Practices mapped in this report were sited in locations with sufficient space and suitable slopes to facilitate bioretention installation. Locations were also selected with a focus on maximizing contributing drainage area in primarily residential neighborhoods. The drainage areas identified range from 0.5 – 12.9 acres, with the majority between 1.0 and 5.0 acres. Biofiltration (BF) practices were mapped at locations adjacent to a catch basin where an underdrain can be installed. Bioinfiltration (BI) practices were mapped at locations not adjacent to catch basins where an underdrain cannot be installed. The type of bioretention practice selected should be dependent primarily on soil borings conducted on a site-by-site basis, with a preference given to locations with well-draining soils and 12” bioinfiltration.

The flow chart below provides some guidance for selecting optimal bioretention configurations under different soil conditions and the presence or absence of a catch basin.

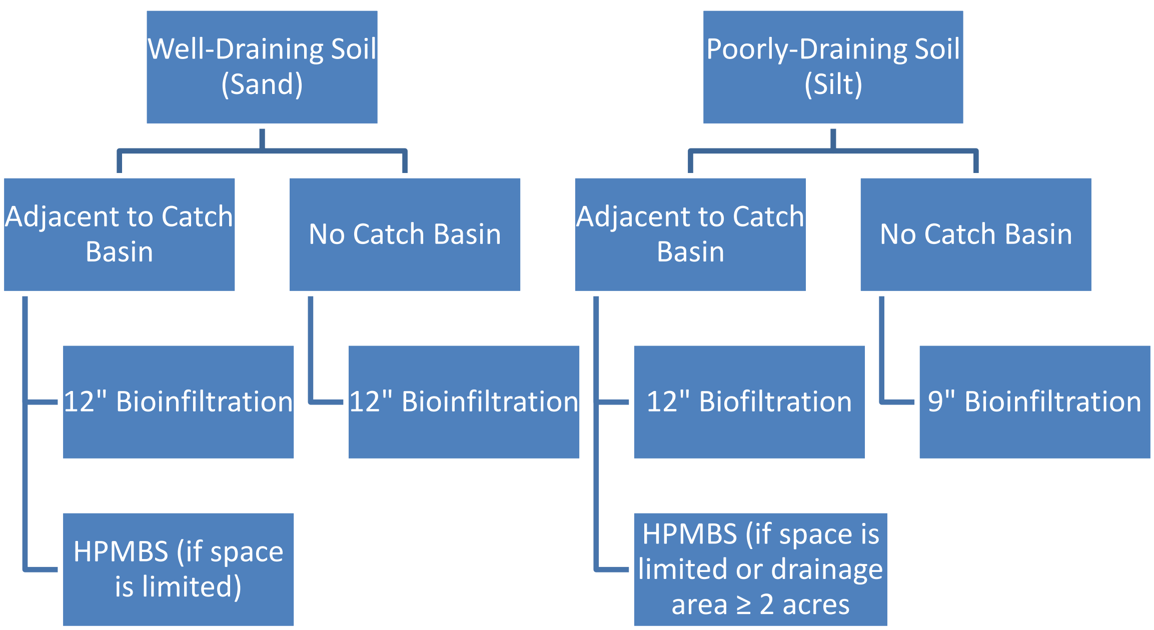


Table 9 below compares the performance of the four bioretention systems for TSS, TP, and volume reduction in various sized drainage areas given medium density residential land use and no current treatment of stormwater other than street cleaning.

Table 9: Estimated annual TP, TSS, and volume reduction for various bioretention basin types based on contributing drainage area with medium density residential land use and street cleaning twice in the spring and twice in the fall. Units are in lbs-TP, lbs-TSS, and ac-ft volume removed from the overall load annually. All scenarios run with a 0.2 in/hour native soil infiltration rate.

Drainage Area (acres)	*Non Site-Specific Bioretention Basin Type*											
	12” Biofiltration w/ underdrain			12” Bioinfiltration			9” Bioinfiltration			12” HPMBS*		
	250 sq-ft top area			250 sq-ft top area			250 sq-ft top area			100 sq-ft top area		
	TP (lbs)	TSS (lbs)	Vol (cu-ft)	TP (lbs)	TSS (lbs)	Vol (cu-ft)	TP (lbs)	TSS (lbs)	Vol (cu-ft)	TP (lbs)	TSS (lbs)	Vol (cu-ft)
0.5	0.10 40.0%	36.69 47.9%	1577 18.1%	0.23 90.0%	70.284 91.8%	7656 87.6%	0.14 54.7%	43.75 57.2%	4564 52.2%	0.16 62.1%	62.12 81.1%	456 5.2%
1	0.15 29.4%	55.08 36.0%	1961 11.2%	0.35 69.8%	110.3 72.0%	11731 67.1%	0.17 34.1%	54.87 35.8%	5745 32.9%	0.31 61.1%	123.4 80.6%	486 2.8%
2	0.20 19.6%	74.5 24.3%	2375 6.8%	0.49 48.1%	153.9 50.3%	16034 45.9%	0.19 18.5%	59.2 19.3%	6465 18.5%	0.61 60.3%	244.73 79.9%	527 1.5%
3	0.22 14.7%	84.6 18.4%	2640 5.0%	0.56 36.5%	175.9 38.3%	18326 35.0%	0.19 12.4%	59.4 12.9%	6607 12.6%	0.89 58.8%	358.8 78.1%	566 1.1%
4	0.24 11.7%	89.8 14.7%	2794 4.0%	0.60 29.3%	188.5 30.8%	19710 28.2%	0.19 9.4%	59.9 9.8%	6696 9.6%	1.16 57.1%	465.9 76.1%	595 0.9%
5	0.25 9.8%	93.7 12.2%	2931 3.4%	0.63 24.7%	198 25.9%	20766 23.8%	0.19 7.6%	60.7 7.9%	6788 7.8%	1.41 55.6%	567.1 74.1%	620 0.7%
7.5	0.26 6.9%	99 8.6%	3111 2.4%	0.67 17.5%	210.9 18.4%	22220 17.0%	0.21 5.3%	69 5.5%	6976 5.3%	1.96 51.6%	791.9 69.0%	702 0.5%

**High-Performance Modular Biofiltration System*

Table 10 below shows the cost-effectiveness TSS, TP, and volume reductions over 30-years for biofiltration, bioinfiltration, and HPMBS. Below are the cost assumptions used.

- Biofiltration – Indirect cost (8 hours at $73/hour), direct cost ($34/sq-ft for materials and labor + 40 hours at $73/hour), and maintenance ($220/year for rehabilitation at years 10 and 20 + $75/year for routine maintenance)
- Bioinfiltration – Indirect cost (8 hours at $73/hour), direct cost ($26/sq-ft for materials and labor + 40 hours at $73/hour), and maintenance ($150/year for rehabilitation at years 10 and 20 + $75/year for routine maintenance)
- HPMBS – Indirect cost (8 hours at $73/hour), direct cost ($200/sq-ft for materials and labor + 40 hours at $73/hour), and maintenance ($200/year for rehabilitation at year 15 + $75/year for routine maintenance)

Table 10: Cost-effectiveness of TP, TSS, and volume reduction over 30-years for various bioretention basin types based on contributing drainage area with medium density residential land use and street cleaning twice in the spring and twice in the fall. Units are in dollars/lb-TP, dollars/lb-TSS, and dollars/ac-ft volume removed from the overall load annually. All scenarios run with a 0.2 in/hour native soil infiltration rate.

Drainage Area (acres)	***Non Site-Specific Bioretention Basin Type***											
	12” Biofiltration w/ underdrain			12” Bioinfiltration			9” Bioinfiltration			12” HPMBS*		
	250 sq-ft top area			250 sq-ft top area			250 sq-ft top area			100 sq-ft top area		
	Cost/ lb-TP	Cost/ 1,000 lbs-TSS	Cost/ ac-ft-Vol	Cost/ lb-TP	Cost/ 1,000 lbs-TSS	Cost/ ac-ft-Vol	Cost/ lb-TP	Cost/ 1,000 lbs-TSS	Cost/ ac-ft-Vol	Cost/ lb-TP	Cost/ 1,000 lbs-TSS	Cost/ ac-ft-Vol
0.5	$6,527	$18,946	$18,280	$2,446	$7,946	$3,177	$4,029	$12,765	$5,330	$9,689	$24,557	$145,722
1	$4,445	$12,620	$14,701	$1,578	$5,063	$2,074	$3,234	$10,178	$4,234	$4,924	$12,362	$136,727
2	$3,337	$9,331	$12,138	$1,145	$3,629	$1,517	$2,975	$9,434	$3,763	$2,496	$6,233	$126,090
3	$2,954	$8,217	$10,920	$1,005	$3,175	$1,327	$2,955	$9,402	$3,682	$1,707	$4,252	$117,402
4	$2,781	$7,741	$10,318	$939	$2,963	$1,234	$2,924	$9,323	$3,633	$1,317	$3,274	$111,680
5	$2,658	$7,419	$9,836	$892	$2,821	$1,171	$2,879	$9,200	$3,584	$1,082	$2,690	$107,176
7.5	$2,643	$7,022	$9,733	$839	$2,648	$1,095	$2,622	$8,094	$3,487	$777	$1,926	$94,657

**High-Performance Modular Biofiltration System*

Hydrodynamic Devices

In heavily urbanized settings, stormwater is immediately intercepted with 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 option is a hydrodynamic device (Figure 10). Hydrodynamic devices are installed in line with the existing storm sewer network and can provide treatment for up to 10-15 acres of upland drainage area. 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 cost-effectiveness, the cost of each project had to be estimated. Cost estimation included labor costs for project outreach, promotion, design, administration, and maintenance over the anticipated life of the practice were considered in addition to actual material and construction costs. Load reduction estimates for these projects are noted in the Catchment Profiles section.

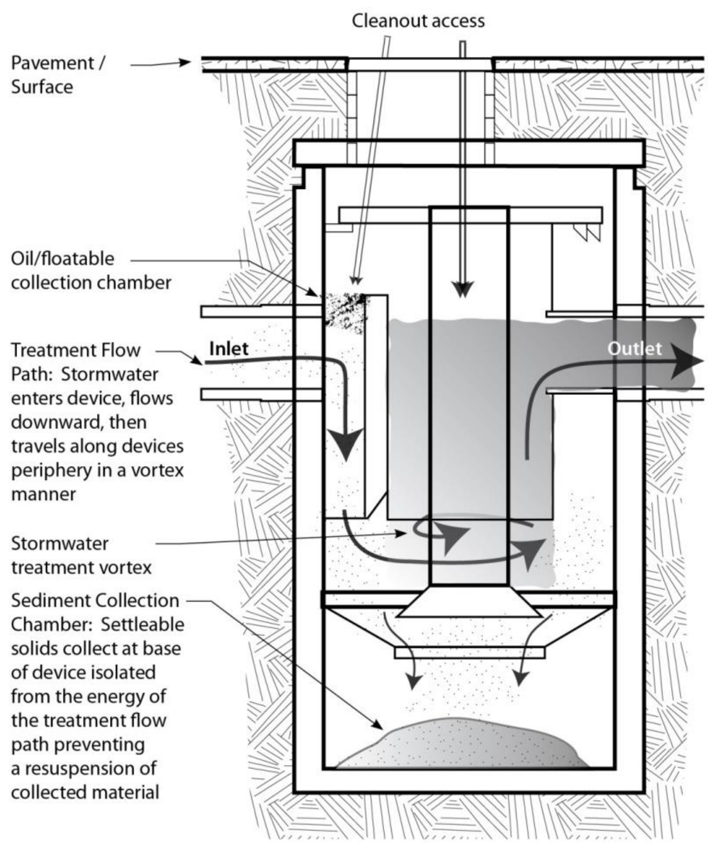


Figure 10: Schematic of a typical hydrodynamic device

Modification to an Existing Pond

Developments prior to enactment of contemporary stormwater rules often included wet detention ponds that 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 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 six strategies that 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
- Route additional drainage area to the pond and increase storage
- Modify the riser
- 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. Costs associated with specific projects are listed in Appendix B – Project Cost Estimates.

New Stormwater Pond

If properly designed, wet retention ponds have controlled outflows to manage discharge rates and are sized to achieve predefined water quality goals. Wet retention ponds treat stormwater through a variety of processes, but primarily through sedimentation. Ponds are most often designed to contain a permanent pool storage depth; it is this permanent pool of water that separates the practice from most other stormwater BMPs, including detention ponds (Figure 11).

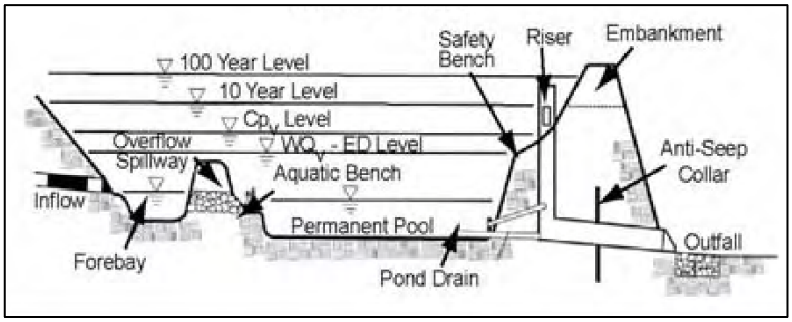


Figure 11: Schematic of a stormwater retention pond.

Wet retention pond depth generally ranges from 3'-8' deep. If ponds are less than 3' deep, winds can increase mixing through the full water depth and re-suspend sediments, thereby increasing turbidity. Scour may also occur during rain events following dry periods. If more than 8' deep, thermal stratification can occur, creating a layer of low dissolved oxygen near the sediment that can release bound phosphorus. Above the permanent pool depth is the flood depth, which provides water quality treatment directly following storm events. Separating the permanent pool depth and the flood depth is the primary outlet control, which is often designed to control outflow rate. Configurations for the outlet control may include a V-notch or circular weir, multiple orifices, or a multiple-stage weir. Each of these can be configured within a skimmer structure or trash rack to provide additional treatment for larger, floatable items. Above the flood depth is the emergency control structure, which is available to bypass water from the largest rainfall events, such as the 100-year precipitation event. Ponds also often include a pretreatment practice, either a forebay or sedimentation basin adjacent to the pond or storm sewer sumps, hydrodynamic devices, or other basins upstream of the practice to simplify maintenance and extend the effective life of the pond.

Outside of sedimentation, other important processes occurring in ponds are nutrient assimilation and evapotranspiration by plants. The addition of shoreline plants to pond designs has increased greatly since the 1980's because of the positive effects these plants were found to have for both water quality purposes and increasing terrestrial and aquatic wildlife habitat. The ability of the pond to regulate discharge rates should also be noted. This can reduce downstream in-channel erosion, thereby decreasing TSS and TP loading from within the channel.

With the multitude of considerations for these practices, ponds must be designed by professional engineers. This report provides a rudimentary description of ponding opportunities and cost estimates for project planning purposes. Ponds proposed in this analysis are designed (using a minimum of 1,800 cubic feet of permanent pool volume per acre of drainage area to the pond if sufficient space was available) and simulated within the water quality model WinSLAMM, which takes into account upland pollutant loading, pond bathymetry, and outlet control device(s) to estimate stormwater volume, TSS, and TP retention capacity. The model was run with and without the identified project and the difference in pollutant loading was calculated.

In order to calculate cost-benefit, the cost of each project had to be estimated. All new stormwater ponds were assumed to involve excavation and disposal of soil, installation of inlet and outlet control structures and emergency overflow, land acquisition, erosion control, and vegetation management. Additionally, project engineering, promotion, administration, construction oversight, and long-term maintenance (including annual inspections and removal of accumulated sediment/debris from the pretreatment area) had to be considered in order to capture the true cost of the effort. Complete pond dredging is not included in the long-term maintenance cost because project life is estimated to be 30 years. Load reduction estimates for these projects are noted in the Catchment Profiles section. Additional costs associated with specific projects are listed in Appendix B – Project Cost Estimates

Catchment Profiles

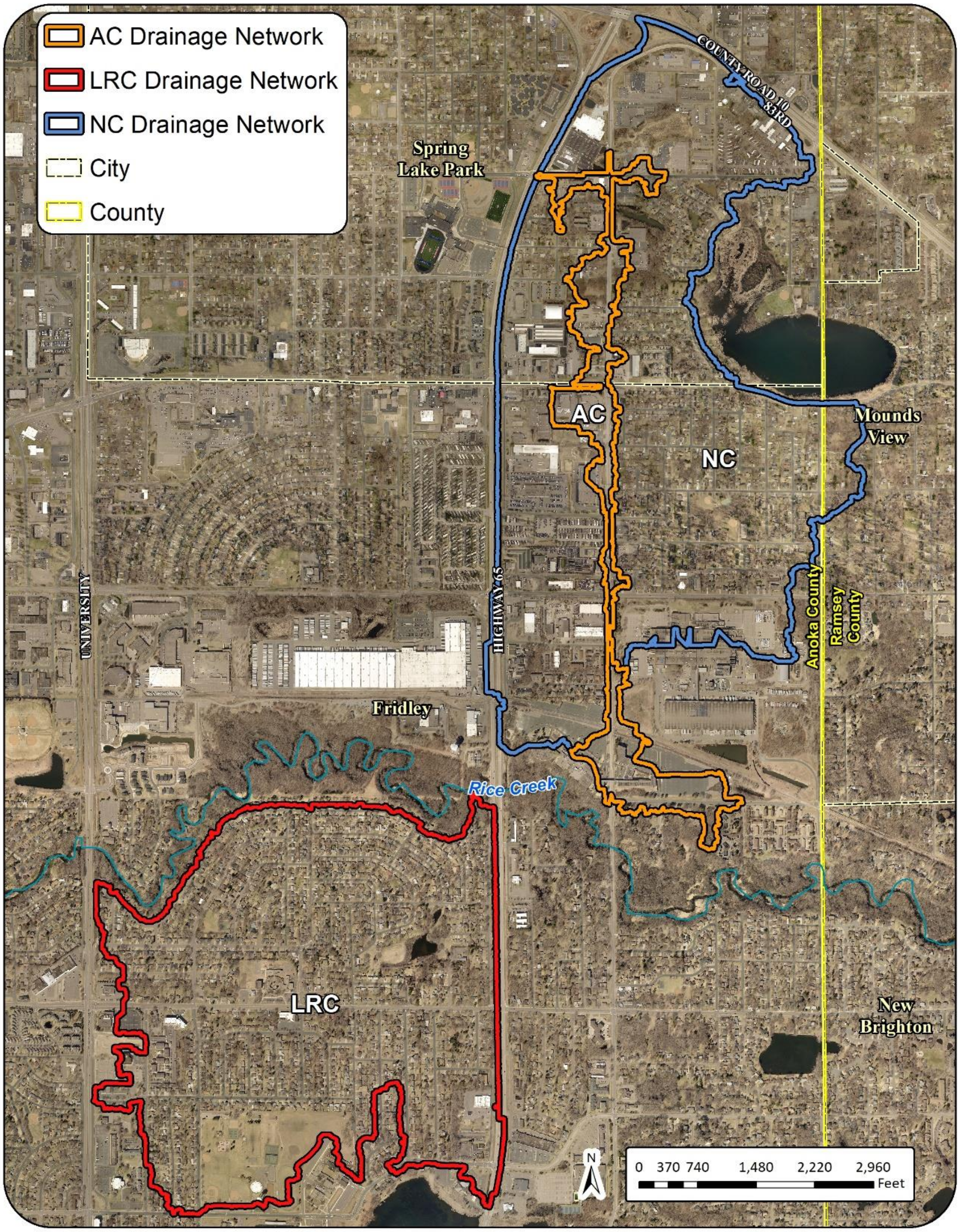
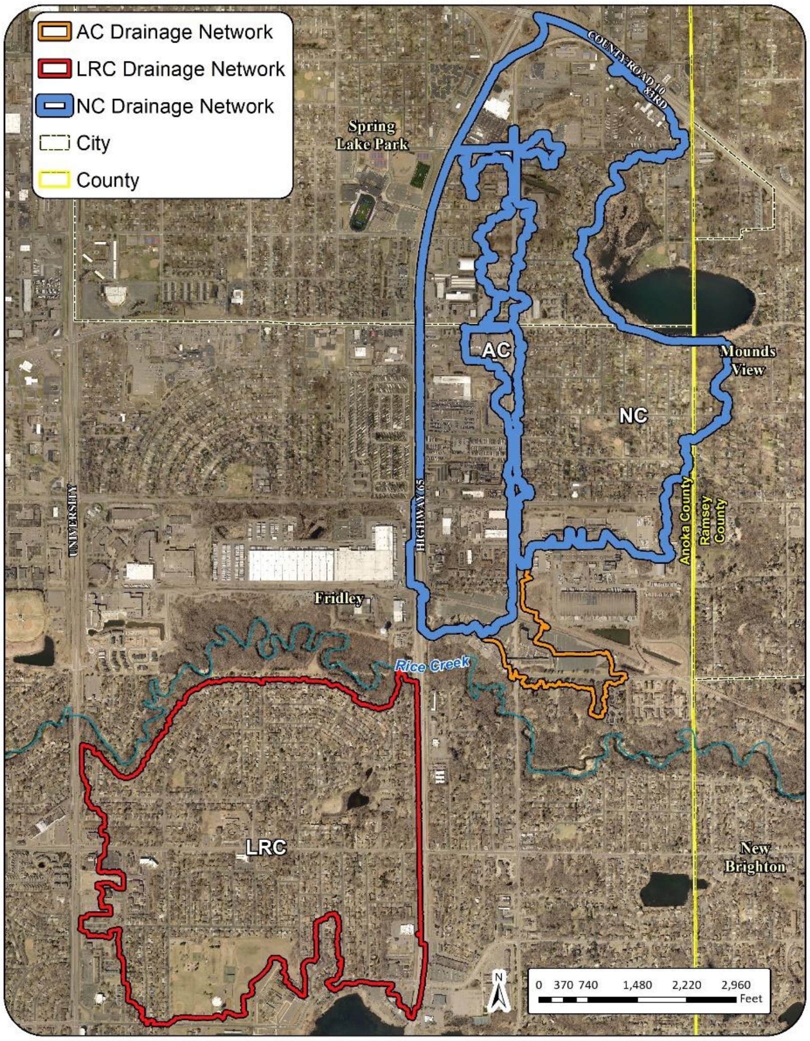


Figure 12: The 1,115-acre drainage area was divided into three drainage networks for this analysis. Catchment profiles on the following pages provide additional information.

Norton Creek Drainage Network

Catchment ID	Page
ENC-1	39
ENC-2	41
ENC-3	43
ENC-4	48
ENC-5	52
ENC-6	70
ENC-7	75
ENC-8	77
WNC-1	82
WNC-2	84
WNC-3	86
WNC-4	89
WNC-5	92
WNC-6	95
WNC-7	97
WNC-8	102
WNC-9	107
NC-1	110
NC-2	112



Existing Network Summary	
Acres	560
Dominant Land Cover	Residential
Volume (ac-ft/yr)	344
TP (lb/yr)	292
TSS (lb/yr)	111,787

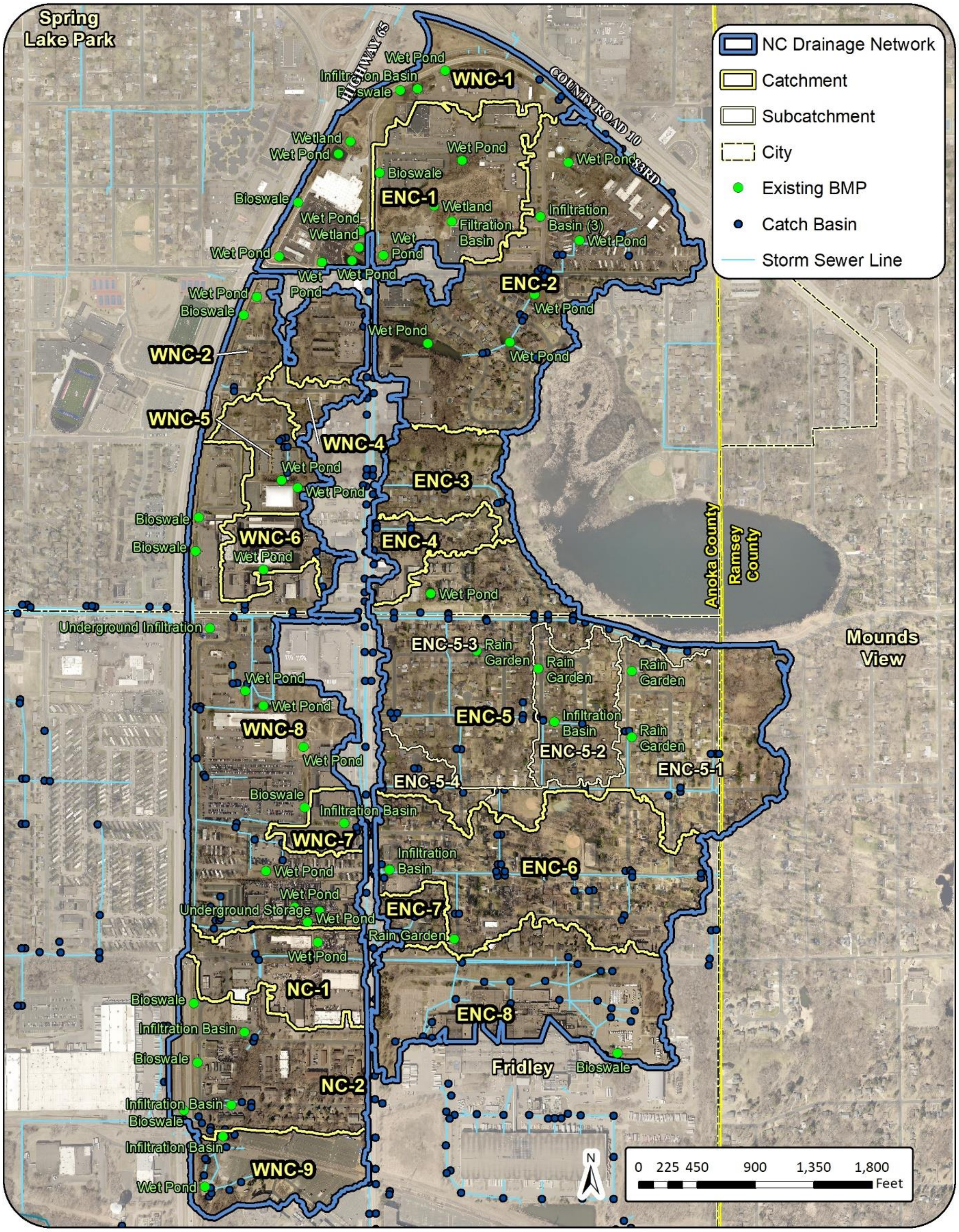
DRAINAGE NETWORK SUMMARY

The Norton Creek drainage network extends from Rice Creek north to County Road 10. The western boundary is Highway 65 and the eastern boundary is near the Anoka and Ramsey County boundary. There are 19 catchments throughout the drainage area that converge into Norton Creek before discharging into Rice Creek. Catchment size varies from approximately 5 acres up to over 100 acres. Notable areas in the drainage network include the Spring Lake Park Hy-Vee in the northern area, a variety of industrial businesses in the west central area, residential properties in the east central area, and portions of the Cummins and Medtronic campuses in the south.

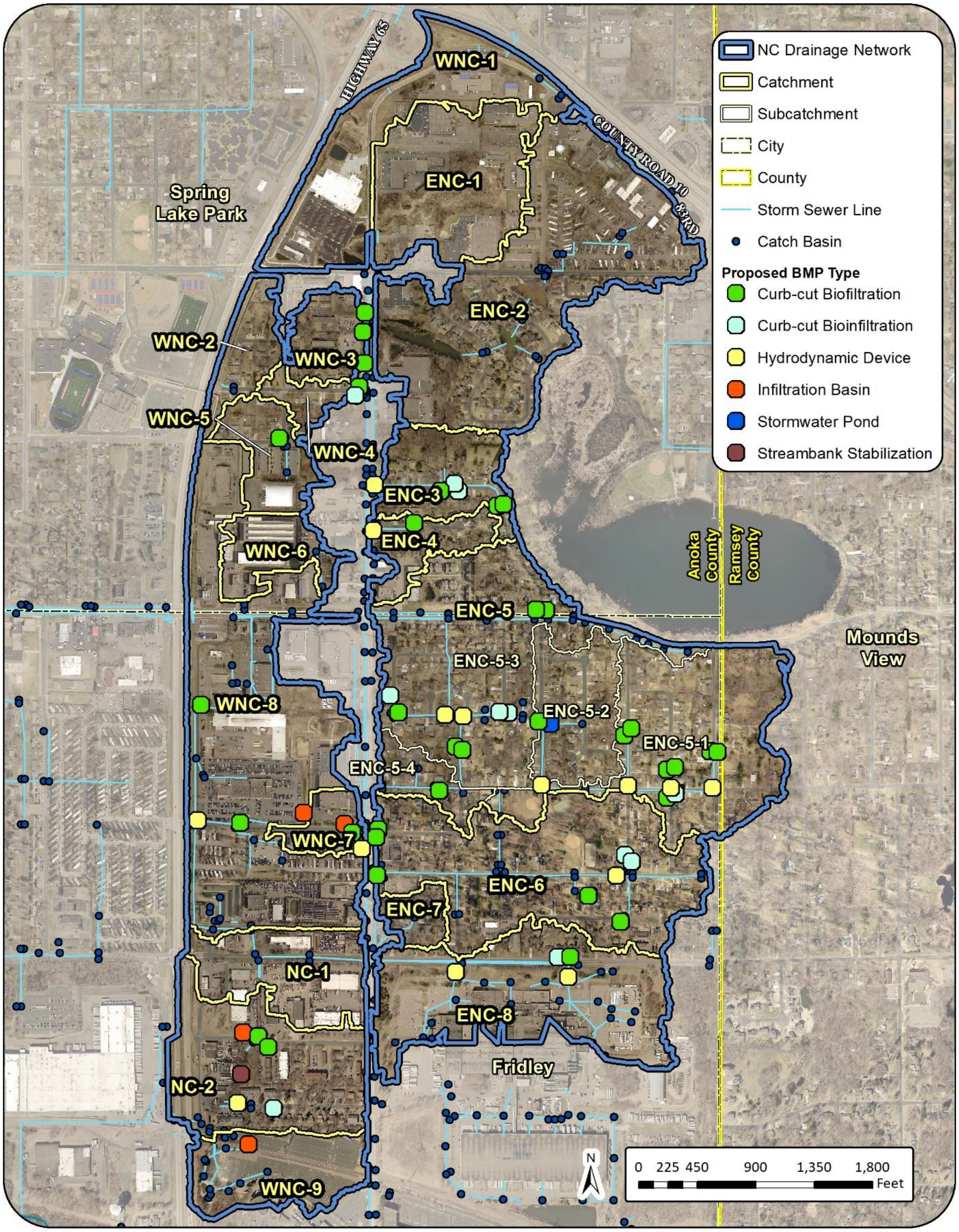
EXISTING STORMWATER TREATMENT

Substantial stormwater treatment exists throughout this drainage network. There are many ponds, infiltration basins, and swales. The City of Fridley and the City of Spring Lake Park also conduct street cleaning three times per year throughout the Norton Creek drainage network. Additional detail is provided in the Catchment Profiles.

NETWORK EXISTING STORMWATER TREATMENT

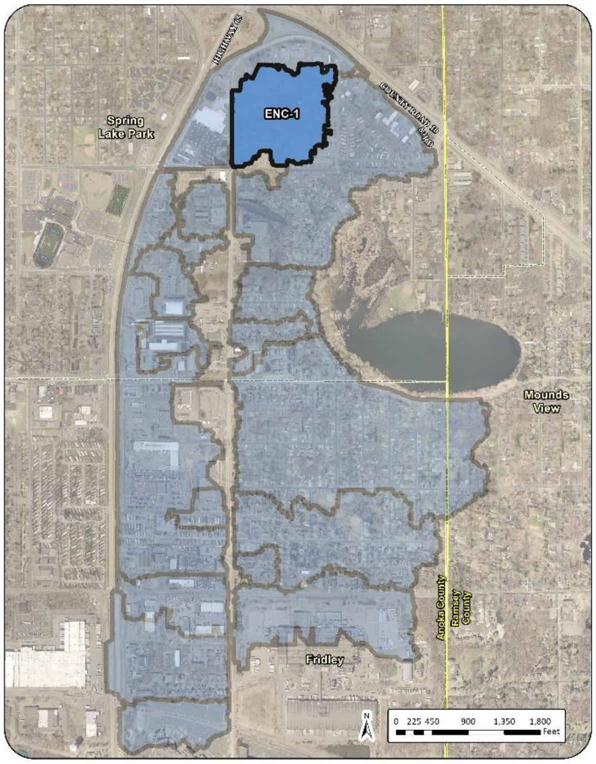


NETWORK RETROFIT OPPORTUNITIES



Catchment ENC-1

Existing Catchment Summary	
Acres	30.7
Parcels	37
Land Cover	51.4% Industrial 26.0% Open Space 22.1% Institutional 0.5% Shopping



CATCHMENT DESCRIPTION

This catchment is located in Spring Lake Park and includes Substance Church, some industrial properties, and the northern half of the Spring Lake Park Administration campus. Stormwater runoff is routed to the large wetland in the center of the catchment via curb-cuts in the parking lots; there is no mapped underground stormwater infrastructure.

EXISTING STORMWATER TREATMENT

There are two wet ponds, a large wetland, a bioswale, and a filtration basin that provide stormwater treatment within this catchment. In addition, street cleaning is conducted three times per year by the City of Spring Lake Park. 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	Street Cleaning, Wet Pond (2), Wetland, Ditch Swale, Filtration Basin			
	TP (lb/yr)	22.0	9.3	42%	**12.7**
	TSS (lb/yr)	10,756	5,794	54%	**4,962**
	Volume (acre-feet/yr)	23.0	3.9	17%	**19.2**

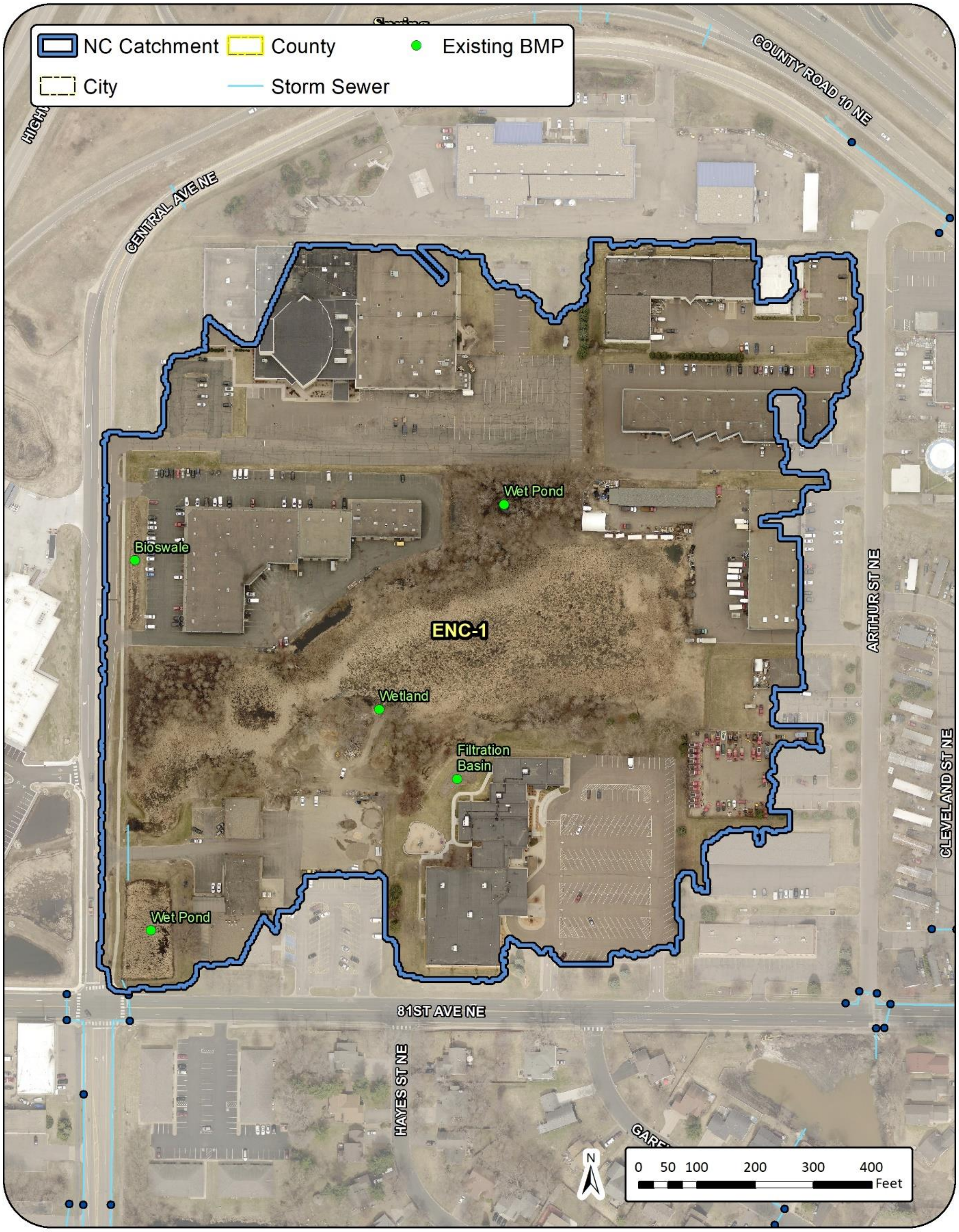
RETROFIT OPPORTUNITIES OVERVIEW

No retrofits were modeled in this catchment.

RETROFITS CONSIDERED BUT REJECTED

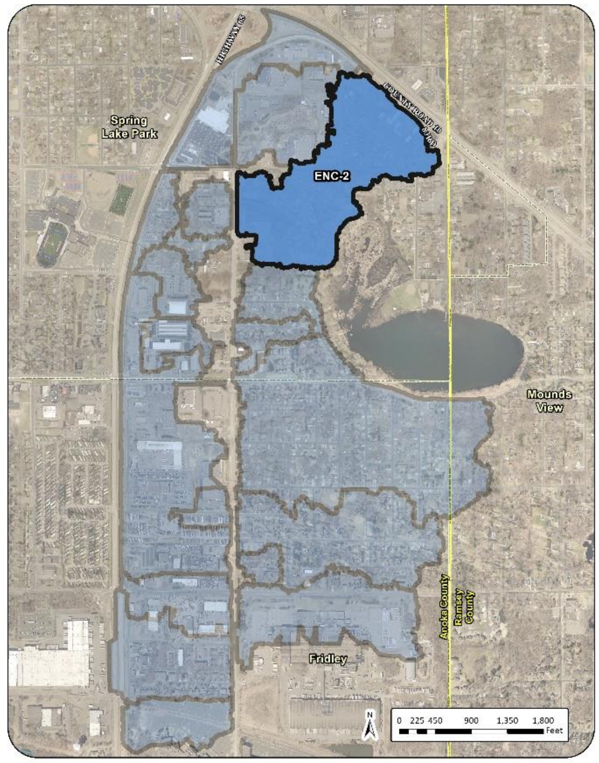
A wetland enhancement was considered, but monitoring data collected at the outlet of the wetland is recommended prior to pursuing a project. Wetland export of TP can be variable based on wetland type and hydrologic conditions that have been modified as a result of development. The wetland in its current state likely provides effective TSS removal.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Catchment ENC-2

Existing Catchment Summary	
Acres	66.9
Parcels	184
Land Cover	42.3% Residential 23.1% Mobile Home 16.1% Industrial 6.4% Office Park 6.1% Shopping 3.2% Open Space 1.7% Water 1.1% Institutional



CATCHMENT DESCRIPTION

This catchment is located in Spring Lake Park and includes industrial properties and a mobile home park in the northeast and residential properties in the southwest. Stormwater runoff is routed via catch basins and storm sewer lines from the northeast to the southwest where it eventually passes through a series of three wet ponds.

EXISTING STORMWATER TREATMENT

There are five wet ponds and three infiltration basins that provide stormwater treatment in this catchment. The majority of runoff is routed through a series of three ponds located in the southwest portion of the catchment. The upstream pond, Garfield Pond, was recently modified to enhance stormwater treatment. The City of Spring Lake Park also conducts street cleaning three times per year. 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	9			
	BMP Types	Street Cleaning, Wet Pond (5), Infiltration Basin (3)			
	TP (lb/yr)	49.1	28.0	57%	**21.1**
	TSS (lb/yr)	18,534	14,006	76%	**4,528**
	Volume (acre-feet/yr)	47.2	1.8	4%	**45.4**

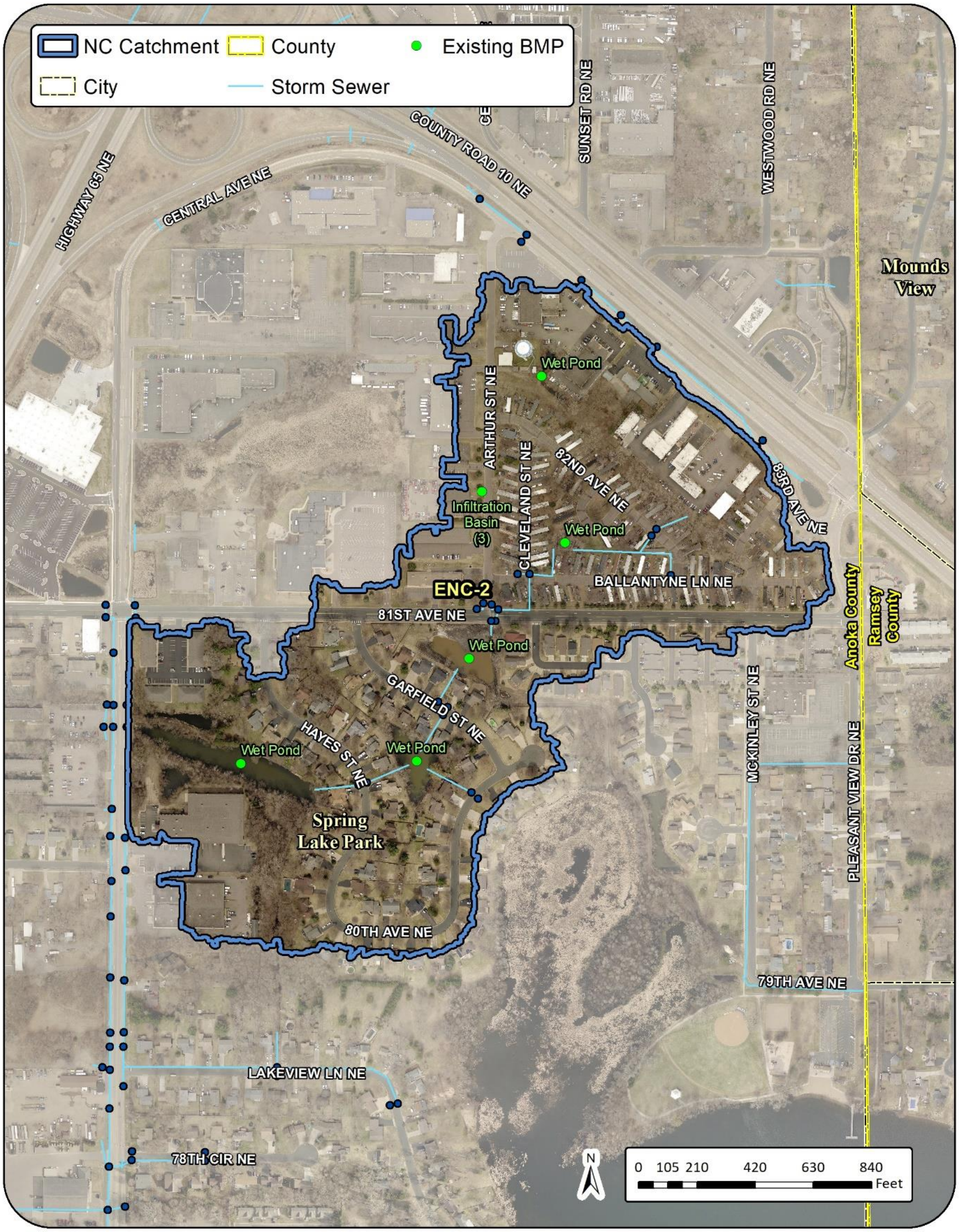
RETROFIT OPPORTUNITIES OVERVIEW

No stormwater retrofits are recommended for this catchment because of the existing treatment train provided by the stormwater ponds.

RETROFITS CONSIDERED BUT REJECTED

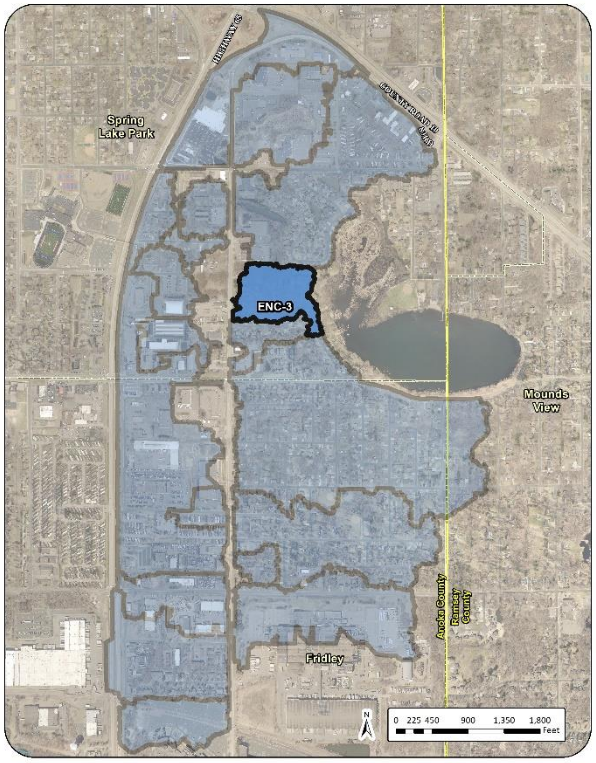
Pond modifications and iron-enhanced sand filters were considered for the existing ponds, but space was extremely limited because the ponds are entirely surrounded by either residential or industrial properties.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Catchment ENC-3

Existing Catchment Summary	
Acres	15.1
Parcels	49
Land Cover	97.8% Residential 2.2% Industrial



CATCHMENT DESCRIPTION

This catchment is located in Spring Lake Park and includes a portion of Lakeview Lane NE just east of Central Ave. NE. Stormwater runoff is routed from east to west, toward Central Ave. NE via catch basins and storm sewer lines. The majority of the land use in this catchment is categorized as residential.

EXISTING STORMWATER TREATMENT

The primary stormwater treatment in the catchment is street cleaning, conducted three times per year by the City of Spring Lake Park. Present-day stormwater pollutant loading and treatment is summarized in the table below.

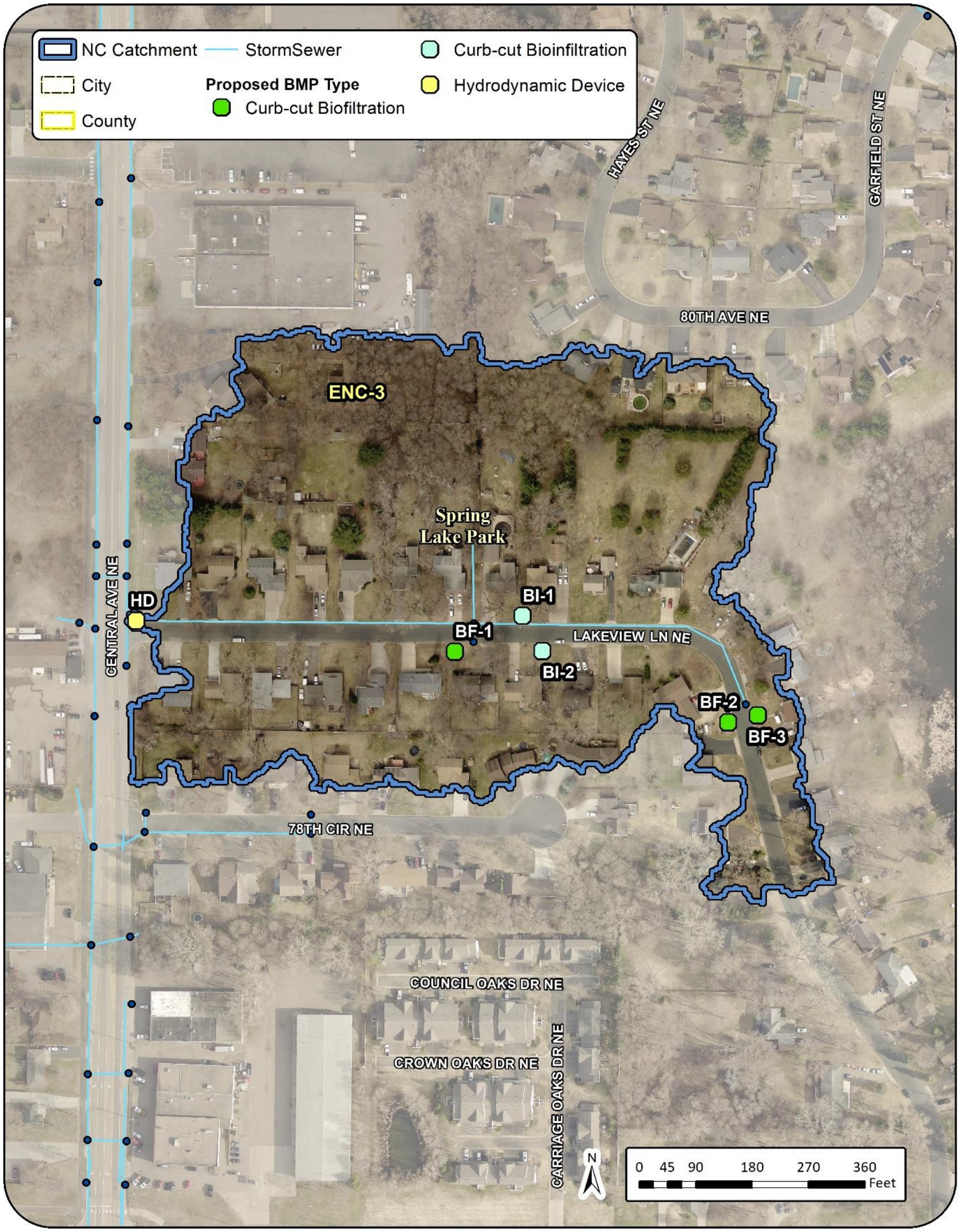
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	11.4	0.8	7%	**10.7**
	TSS (lb/yr)	3,212	330	10%	**2,882**
	Volume (acre-feet/yr)	7.4	0.0	0%	**7.4**

RETROFIT OPPORTUNITIES OVERVIEW

Six BMPs are proposed within this catchment. They included one hydrodynamic device, and five bioretention practices on residential properties.

The hydrodynamic device is positioned to provide treatment for the entire catchment. For the bioretention practices, underlying soils will determine whether biofiltration or bioinfiltration practices could be installed. The proposed bioretention locations adjacent to catch basins were shown as biofiltration practices to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Project ID: ENC-3 HD

Central Ave. and Lakeview Ln.
Hydrodynamic Device

Drainage Area – 15.12 acres
Location – Intersection of Central Ave. NE and Lakeview Ln. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on Lakeview Ln. NE. A device at this location would provide treatment to runoff from the entire catchment. The table below provides pollutant removals and estimated costs.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	10	ft diameter
	TP (lb/yr)	0.92	8.6%
	TSS (lb/yr)	352	12.2%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***		$3,750
	Design & Construction Costs**		$108,000
	Total Estimated Project Cost (2021)		**$111,750**
	Annual O&M***		$630
Efficiency	**30-yr Average Cost/lb-TP**	**$4,723**	
	30-yr Average Cost/1,000lb-TSS	**$12,372**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

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

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

Project ID: ENC-3 BF/BI

Multiple Locations
Bioretention Basins

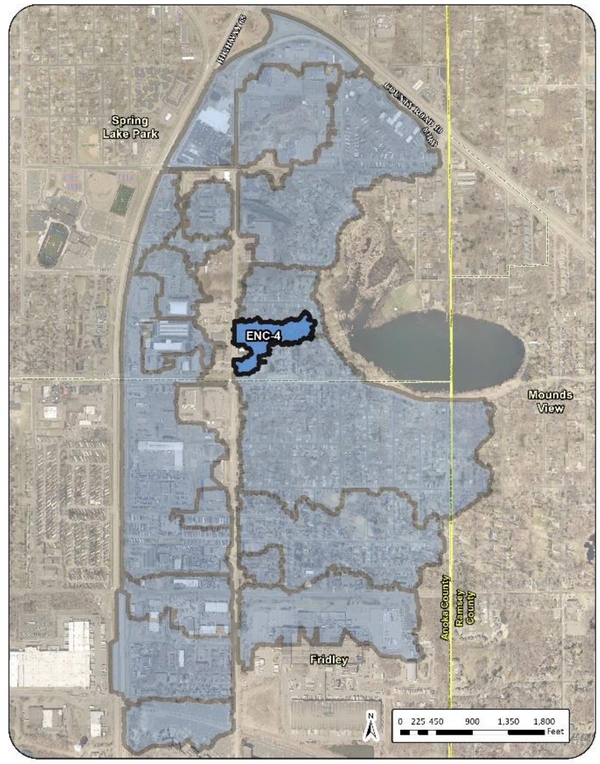
Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See 'Residential Bioretention Comparison' in the 'BMP Descriptions' section for additional details and estimated benefits and cost-effectiveness.

Project ID:
ENC-3 BF and BI

Multiple Locations
Bioretention Basins

Catchment ENC-4

Existing Catchment Summary	
Acres	8.6
Parcels	42
Land Cover	71.9% Residential 28.1% Industrial



CATCHMENT DESCRIPTION

Catchment ENC-4 is located in Spring Lake Park. Land use is predominantly residential but there is some industrial land use in the southern portion of the catchment. Stormwater runoff is routed west toward Central Ave. NE via catch basins and storm sewer.

EXISTING STORMWATER TREATMENT

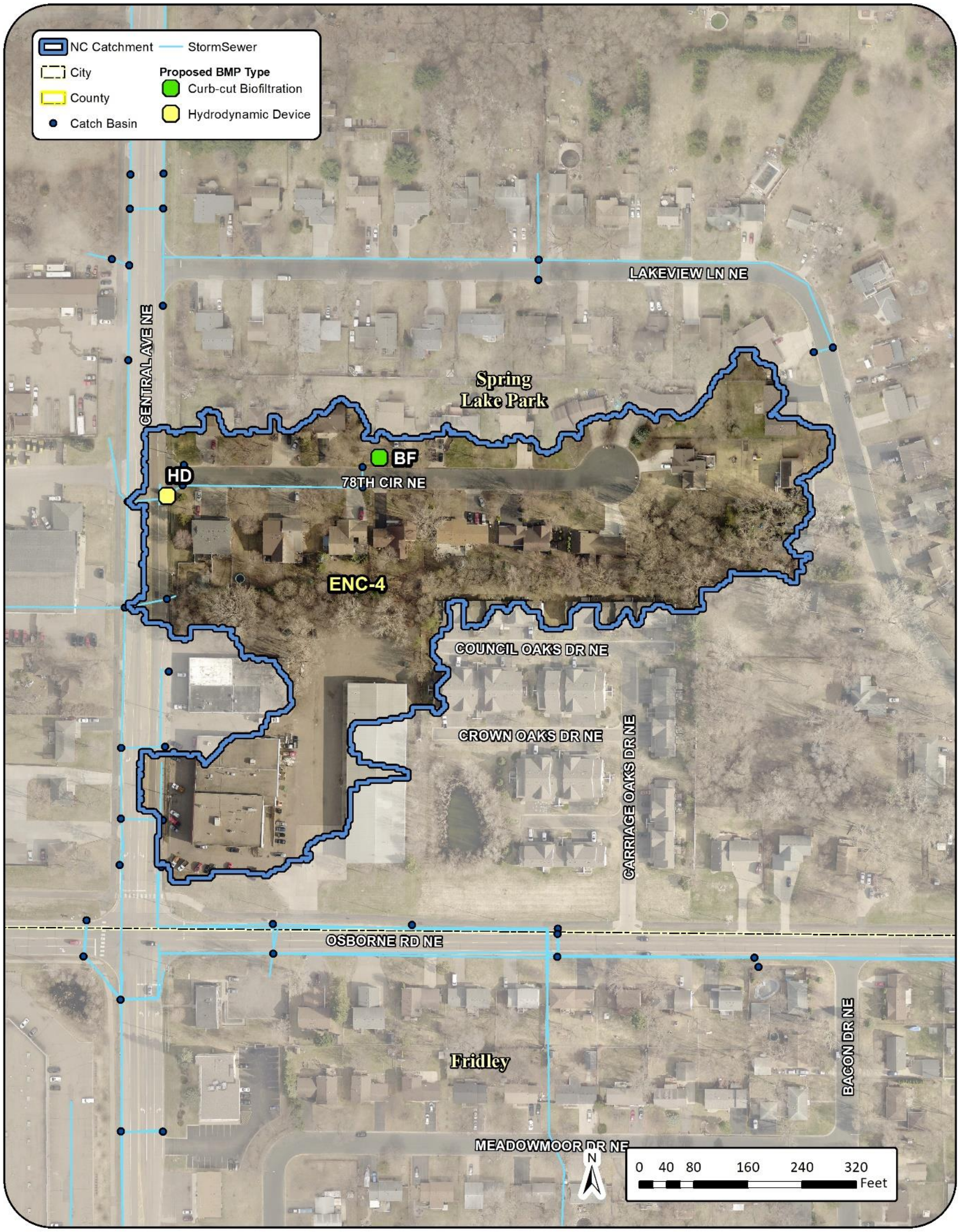
The primary stormwater treatment in the catchment is street cleaning, which is conducted by the City of Spring Lake Park three times per year. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	7.1	0.4	5%	**6.7**
	TSS (lb/yr)	2,597	190	7%	**2,407**
	Volume (acre-feet/yr)	5.8	0.0	0%	**5.8**

RETROFIT OPPORTUNITIES OVERVIEW

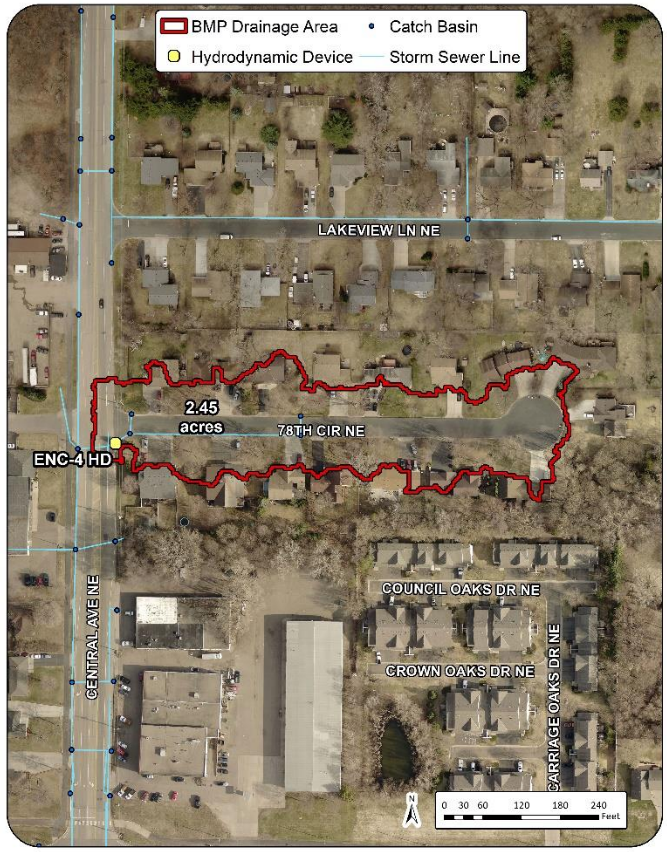
One hydrodynamic device and one bioretention basin are proposed. The hydrodynamic device is positioned to provide treatment for runoff flowing west on 78th Circle NE. For the bioretention practice, underlying soils will determine whether a biofiltration or bioretention practice could be installed. The proposed bioretention location is adjacent to a catch basin, so it is shown as a biofiltration practice to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Project ID: ENC-4 HD

Central Ave. and 78th Circle
Hydrodynamic Device



Drainage Area – 2.45 acres
Location – Southeast corner of Central Ave. NE and 78th Circle NE intersection
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on 78th Circle NE. A device at this location would provide treatment to runoff flowing west from 78th Circle NE. The table below provides pollutant removals and estimated costs.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	6	ft diameter
	TP (lb/yr)	0.23	3.4%
	TSS (lb/yr)	83	3.4%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***		$3,750
	Design & Construction Costs**		$27,000
	Total Estimated Project Cost (2021)		**$30,750**
	Annual O&M***		$630
Efficiency	**30-yr Average Cost/lb-TP**	**$7,323**	
	30-yr Average Cost/1,000lb-TSS	**$19,940**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

**Direct Cost: ($18,000 for materials) + ($9,000 for labor and installation costs)

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

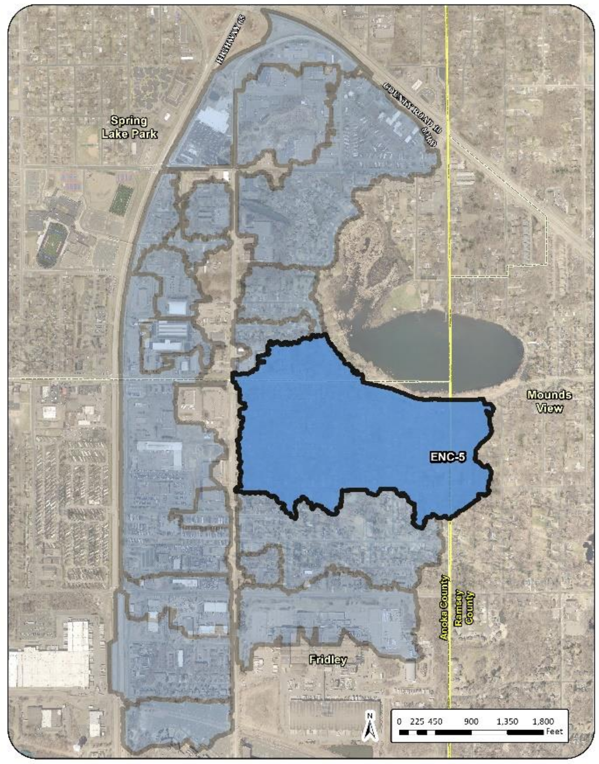
Project ID: ENC-4 BF or BI

78th Circle NE
Bioretention Basin

Drainage Area – 0.62 acres
Location – 78th Circle NE
Property Ownership – Private
Site Specific Information – An opportunity for bioretention, either bioinfiltration or biofiltration, exists within this catchment. See ‘Residential Bioretention Comparison’ in the ‘BMP Descriptions’ section for additional details and estimated benefits and cost-effectiveness.

Catchment ENC-5

Existing Catchment Summary	
Acres	114.3
Parcels	333
Land Cover	93.9% Residential 2.9% Park 1.4% Industrial 1.3% Open Space 0.5% Office Park



CATCHMENT DESCRIPTION

This catchment is the largest in the Norton Creek drainage network and includes the cities of Spring Lake Park, Fridley, and Mounds View. Land use within the catchment is primarily residential, and stormwater is routed from east to west. The catchment was divided into three subcatchments, 5-1, 5-2, and 5-3. Retrofit opportunities are presented at the subcatchment scale in the following pages.

EXISTING STORMWATER TREATMENT

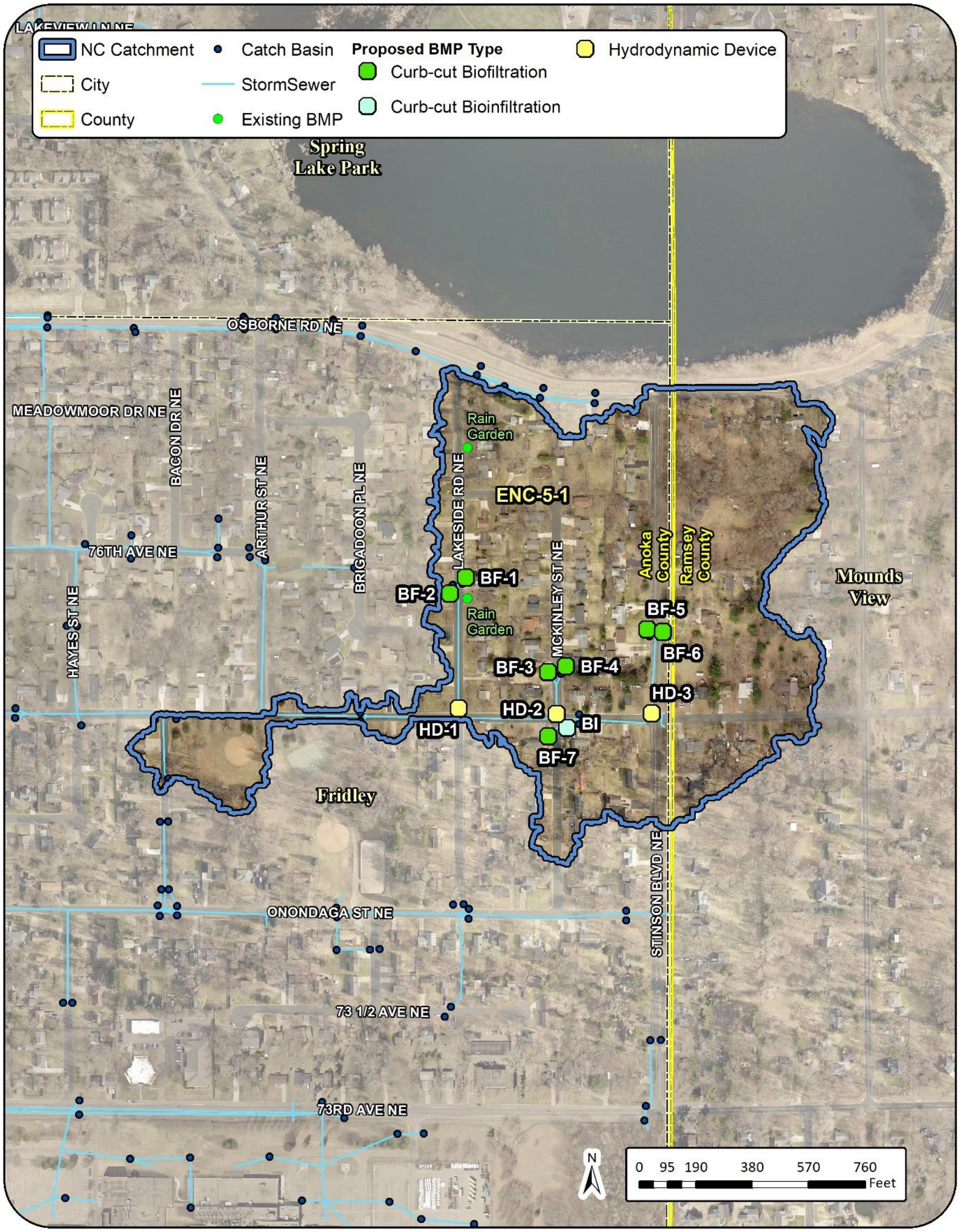
There are four curb-cut rain gardens, one infiltration basin, and one wet pond present in Catchment ENC-5. In addition, street cleaning is conducted three times per year by the City of Fridley. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	7			
	BMP Types	Street Cleaning, Rain Garden (4), Infiltration Basin, Wet Pond			
	TP (lb/yr)	76.8	15.1	20%	**61.8**
	TSS (lb/yr)	22,395	5,413	24%	**16,982**
	Volume (acre-feet/yr)	51.7	5.8	11%	**45.9**

RETROFIT OPPORTUNITIES OVERVIEW

A total of 24 retrofits are proposed in catchment ENC-5 including five hydrodynamic devices, 18 bioretention basins, and a pond retrofit. The hydrodynamic devices are positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The bioretention basins were sited to maximize contributing drainage areas and at properties with sufficient space and slope to accommodate a basin. For the bioretention practices, underlying soils will determine whether biofiltration or bioinfiltration practices could be installed. The proposed bioretention locations adjacent to catch basins were shown as biofiltration practices to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

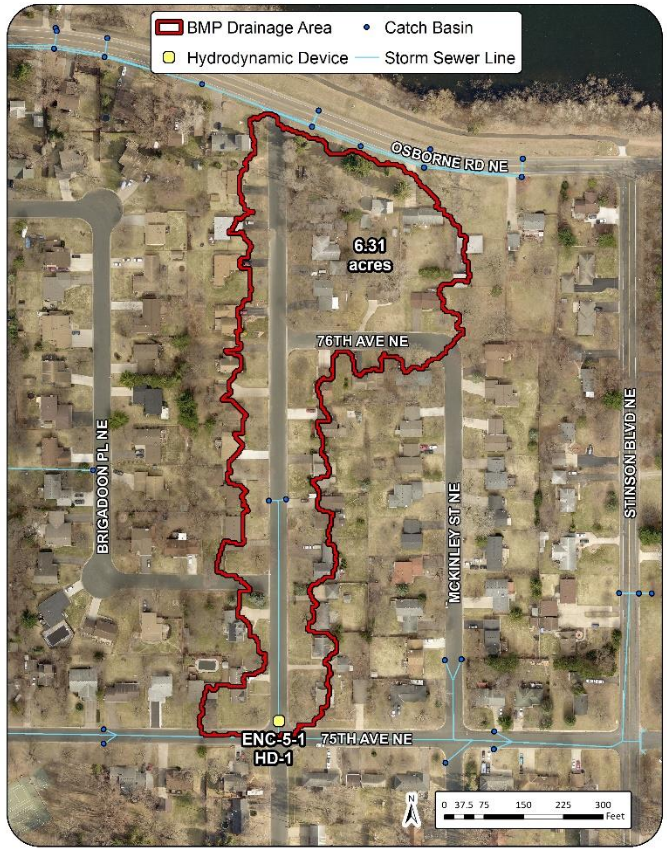
EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES (SUBCATCHMENT 5-1)



Project ID: ENC-5-1 HD-1

Lakeside Rd. and 75th Ave.
Hydrodynamic Device

Drainage Area – 6.31 acres
Location – Intersection of Lakeside Rd. and 75th Ave. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on Lakeside Rd. NE. This hydrodynamic device is positioned prior to convergence with the storm sewer line along 75th Ave. NE to ensure flow does not exceed the device's capacity. The table below provides pollutant removals and estimated costs.



	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	8	ft diameter
	TP (lb/yr)	0.34	1.4%
	TSS (lb/yr)	133	2.0%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***		$3,750
	Design & Construction Costs**		$54,000
	Total Estimated Project Cost (2021)		**$57,750**
	Annual O&M***		$630
Efficiency	**30-yr Average Cost/lb-TP**	**$7,515**	
	30-yr Average Cost/1,000lb-TSS	**$19,211**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

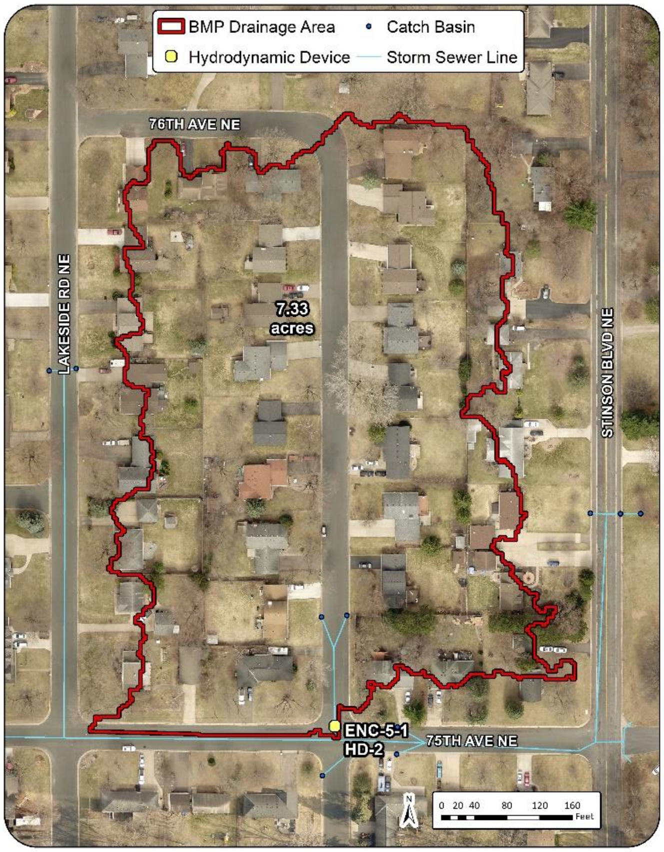
**Direct Cost: ($36,000 for materials) + ($18,000 for labor and installation costs)

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

Project ID:
ENC-5-1 HD-2

McKinley St. and 75th Ave. NE
Hydrodynamic Device

Drainage Area – 7.33 acres
Location – Intersection of McKinley St. NE and 75th Ave. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on McKinley St. NE. This hydrodynamic device is positioned prior to convergence with the storm sewer line along 75th Ave. NE to ensure flow does not exceed the device's capacity. The table below provides pollutant removals and estimated costs.



	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	Total Size of BMP	8	ft diameter
	TP (lb/yr)	0.46	1.9%
	TSS (lb/yr)	175	2.7%
	Volume (acre-feet/yr)	n/a	n/a
Cost	Administration & Promotion Costs*	$3,750	
	Design & Construction Costs**	$54,000	
	Total Estimated Project Cost (2021)	**$57,750**	
	Annual O&M***	$630	
Efficiency	30-yr Average Cost/lb-TP	**$5,554**	
	30-yr Average Cost/1,000lb-TSS	**$14,600**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

**Direct Cost: ($36,000 for materials) + ($18,000 for labor and installation costs)

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

Project ID: ENC-5-1 HD-3

Stinson Blvd. and 75th Ave. Hydrodynamic Device

Drainage Area – 16.89 acres
Location – Intersection of Stinson Blvd. NE and 75th Ave. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on Stinson Blvd. NE. This hydrodynamic device is positioned prior to convergence with the storm sewer line along 75th Ave. NE to ensure flow does not exceed the device's capacity. The table below provides pollutant removals and estimated costs.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	10	ft diameter
	TP (lb/yr)	0.98	4.0%
	TSS (lb/yr)	357	5.4%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***		$3,750
	Design & Construction Costs**		$108,000
	Total Estimated Project Cost (2021)		**$111,750**
	Annual O&M***		$630
Efficiency	**30-yr Average Cost/lb-TP**	**$4,444**	
	30-yr Average Cost/1,000lb-TSS	**$12,199**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

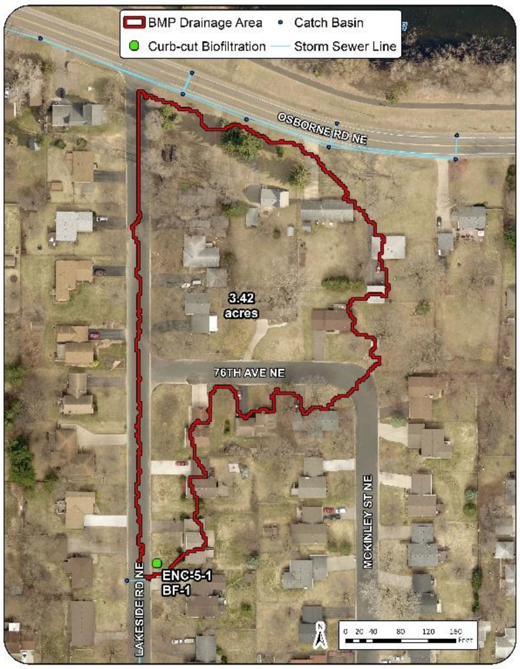
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

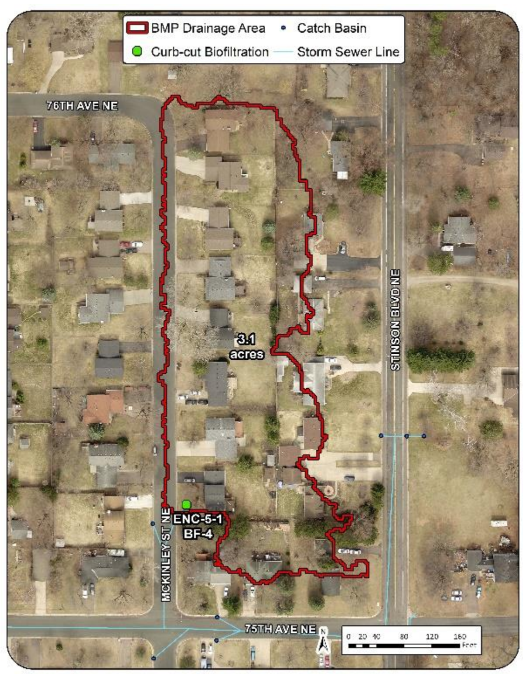
***Per BMP: (3 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: ENC-5-1 BF/BI

Multiple Locations
Bioretention Basins

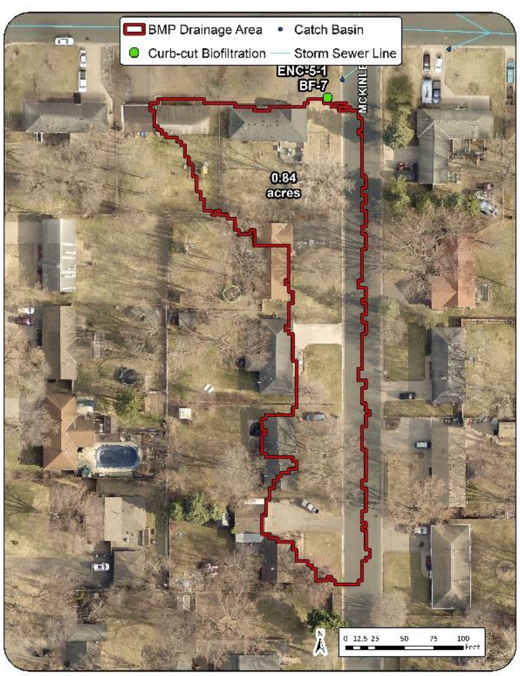
Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See 'Residential Bioretention Comparison' in the 'BMP Descriptions' section for additional details and estimated benefits and cost-effectiveness.

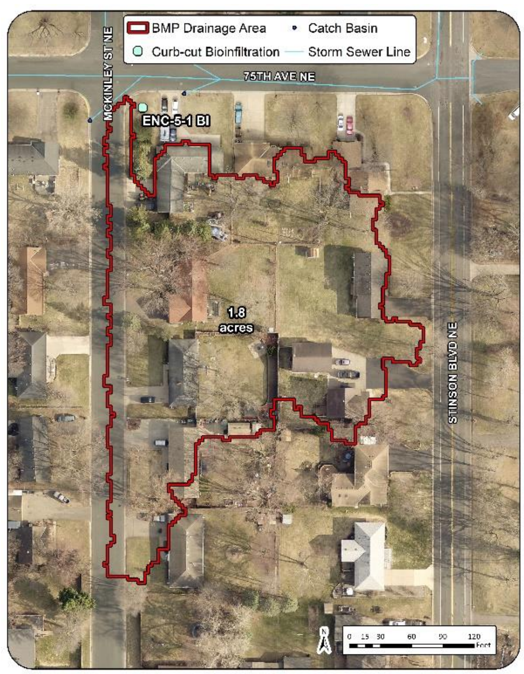




Project ID: ENC-5-1 BF/BI

Multiple Locations
Bioretention Basins

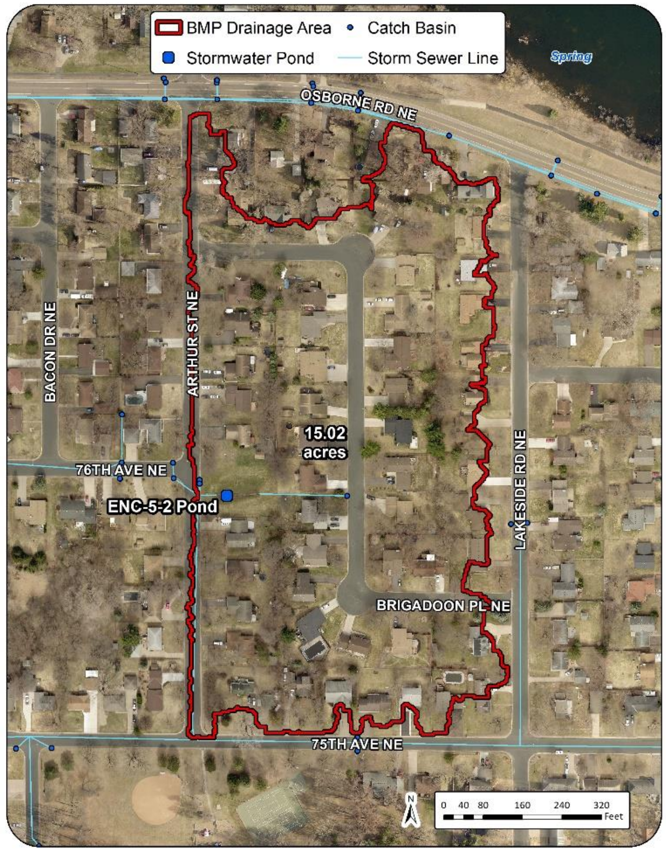




EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES (SUBCATCHMENT 5-2)

Project ID: ENC-5-2 POND

Arthur St. and 76th Ave.
Pond Retrofit



Drainage Area – 15.02 acres
Location – East side of intersection between Arthur St. NE and 76th Ave. NE
Property Ownership – Private
Site Specific Information – The existing stormwater pond, which functions largely as an infiltration basin based on field observations, is proposed to have two curb-cut inlets along Arthur St. NE. The curb-cuts will direct runoff from the northern and southern extents of Arthur St. NE into the existing pond. Currently stormwater along Arthur St. NE enters catch basins and bypasses the pond. The table below provides pollutant removals and estimated costs.

	Pond Retrofit		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMPs**	0.34	acres
	TP (lb/yr)	1.50	68.6%
	TSS (lb/yr)	429	69.6%
	Volume (acre-feet/yr)	1.1	69.5%
Cost	**Administration & Promotion Costs***		$730
	Design & Construction Costs**		$15,420
	Total Estimated Project Cost (2021)		**$16,150**
	Annual O&M***		$340
Efficiency	**30-yr Average Cost/lb-TP**	**$587**	
	30-yr Average Cost/1,000lb-TSS	**$2,046**	
	30-yr Average Cost/ac-ft Vol.	**$792**	

*Indirect Cost: (10 hours at $73/hour)

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

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

Project ID: ENC-5-2 HD

Arthur St. and 75th Ave.
Hydrodynamic Device

Drainage Area – 16.62 acres
Location – Intersection of Arthur St. NE and 75th Ave. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on Arthur St. NE. This hydrodynamic device is positioned prior to convergence with the storm sewer line along 75th Ave. NE to ensure flow does not exceed the device's capacity. The table below provides pollutant removals and estimated costs.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	Total Size of BMP	10	ft diameter
	TP (lb/yr)	0.36	16.4%
	TSS (lb/yr)	138	22.4%
	Volume (acre-feet/yr)	n/a	n/a
Cost	Administration & Promotion Costs*	$3,750	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2021)	**$111,750**	
	Annual O&M***	$630	
Efficiency	30-yr Average Cost/lb-TP	**$12,165**	
	30-yr Average Cost/1,000lb-TSS	**$31,535**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

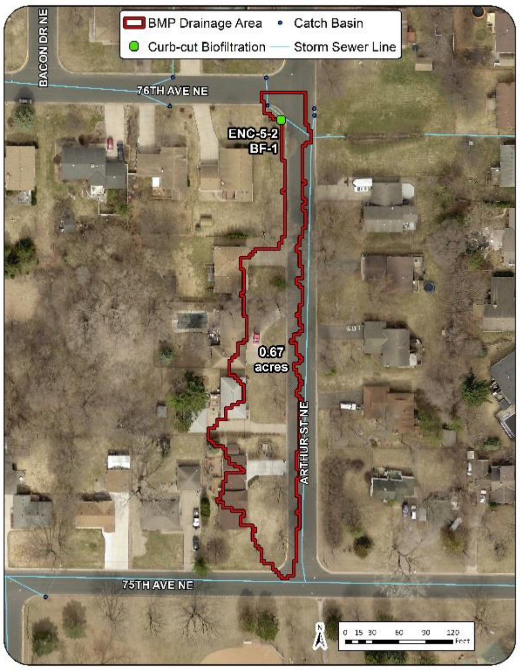
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

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

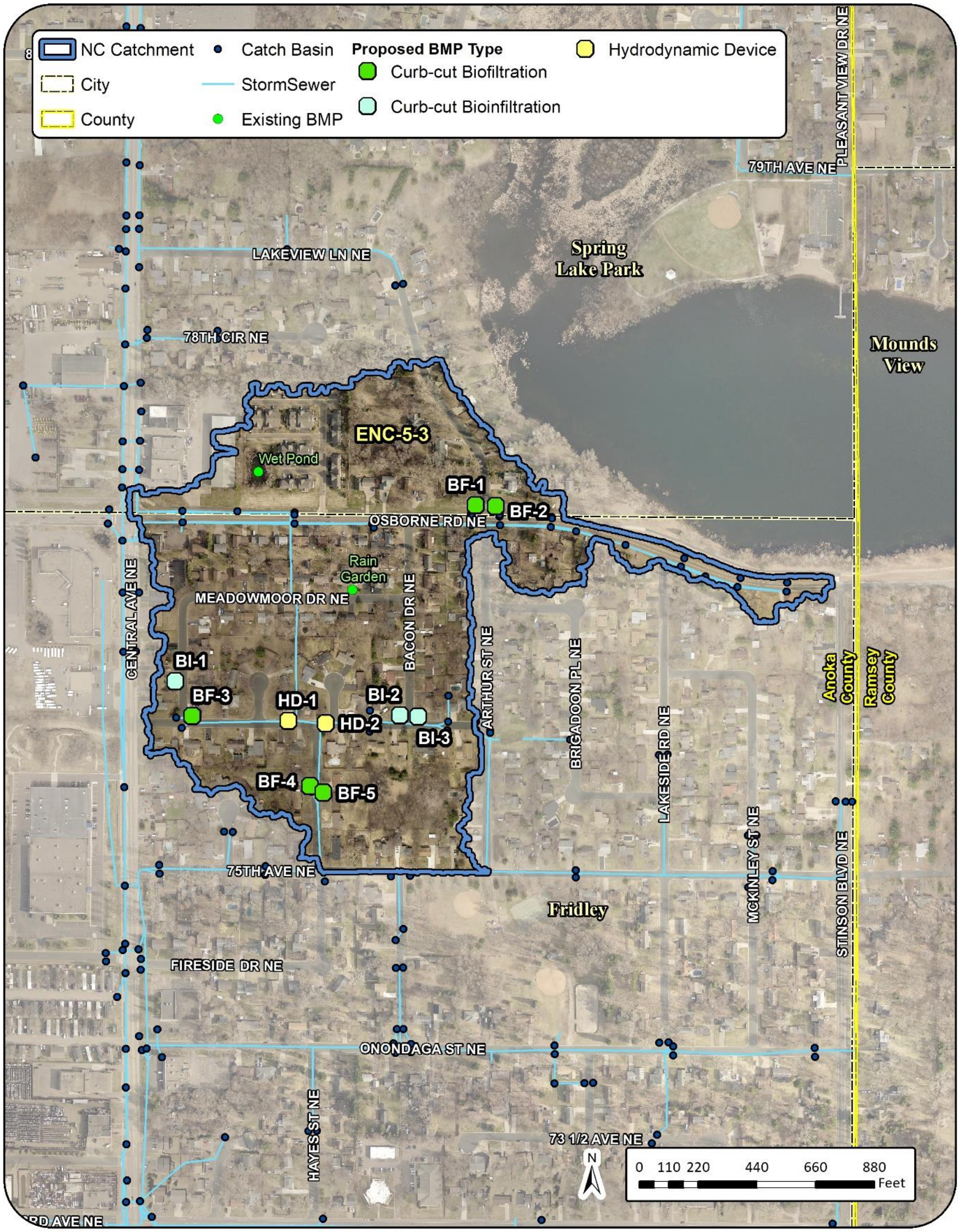
Project ID: ENC-5-2 BF or BI

Arthur St. NE and 76th Ave. NE
Bioretention Basin

Drainage Area – 0.67 acres
Location – Arthur St. NE and 76th Ave. NE
Property Ownership – Private
Site Specific Information – An opportunity for bioretention, either bioinfiltration or biofiltration, exists within this catchment. See 'Residential Bioretention Comparison' in the 'BMP Descriptions' section for additional details and estimated benefits and cost-effectiveness.



EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES (SUBCATCHMENT 5-3)



Project ID: ENC-5-3 HD-1

76th Ave. and 76th Ave. Hydrodynamic Device

Drainage Area – 3.92 acres
Location – East of the intersection between 76th Ave. NE and the 76th Ave. NE cul-de-sac just west of Meadowmoor Dr. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on 76th Ave. NE. This hydrodynamic device is positioned prior to convergence with the storm sewer line from the north to ensure flow does not exceed the device's capacity. The table below provides pollutant removals and estimated costs.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	6	ft diameter
	TP (lb/yr)	0.24	0.8%
	TSS (lb/yr)	104	1.2%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***		$3,750
	Design & Construction Costs**		$27,000
	Total Estimated Project Cost (2021)		**$30,750**
	Annual O&M***		$630
Efficiency	**30-yr Average Cost/lb-TP**	**$6,896**	
	30-yr Average Cost/1,000lb-TSS	**$15,913**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

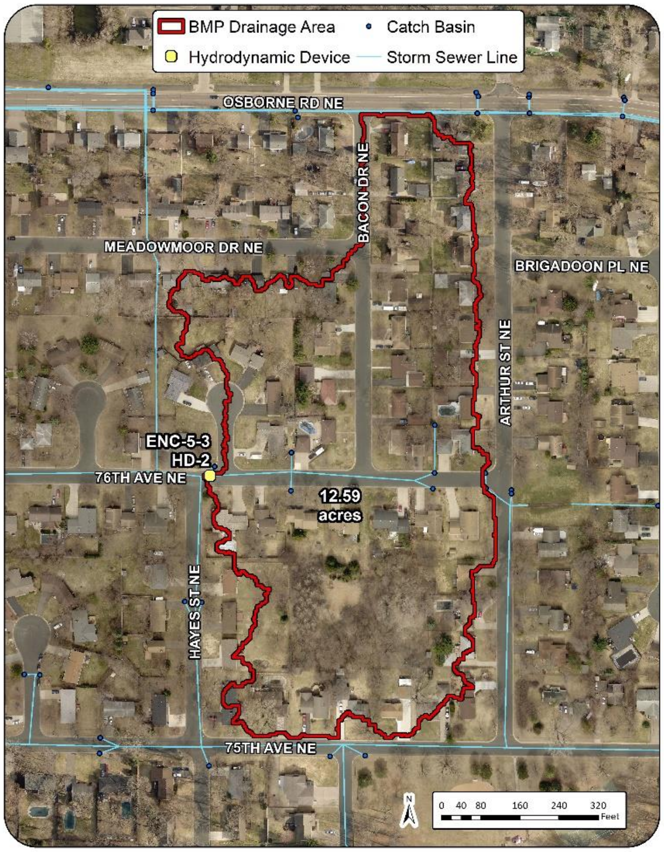
*Indirect Cost: (25 hours at $150/hour)

**Direct Cost: ($18,000 for materials) + ($9,000 for labor and installation costs)

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

Project ID:
ENC-5-3 HD-2

Hayes St. and 76th Ave.
Hydrodynamic Device



Drainage Area – 12.59 acres
Location – Intersection of Hayes St. NE and 76th Ave. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on 76th Ave. NE. This hydrodynamic device is positioned prior to convergence with the storm sewer line along Hayes St. NE to ensure flow does not exceed the device's capacity. The table below provides pollutant removals and estimated costs.

Hydrodynamic Device

	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	10	ft diameter
	TP (lb/yr)	0.81	2.6%
	TSS (lb/yr)	292	3.4%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***		$3,750
	Design & Construction Costs**		$108,000
	Total Estimated Project Cost (2021)		**$111,750**
	Annual O&M***		$630
Efficiency	**30-yr Average Cost/lb-TP**	**$5,377**	
	30-yr Average Cost/1,000lb-TSS	**$14,914**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

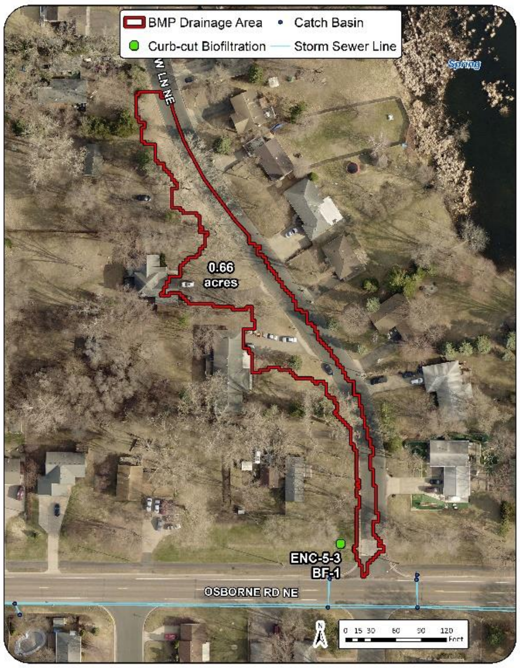
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

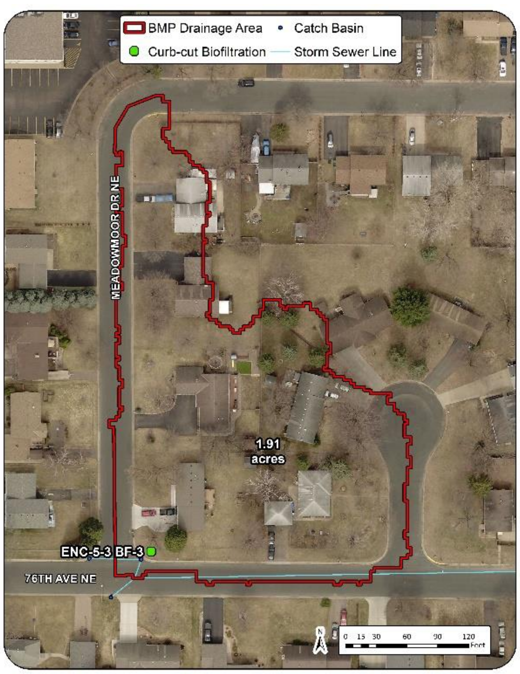
***Per BMP: (3 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: ENC-5-3 BF/BI

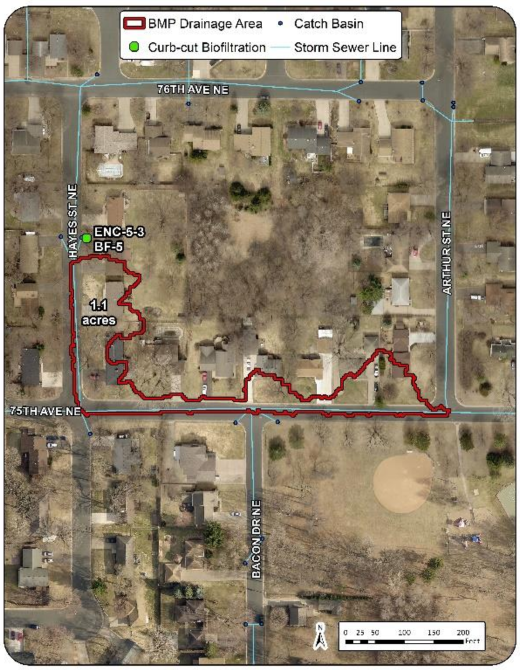
Multiple Locations
Bioretention Basins

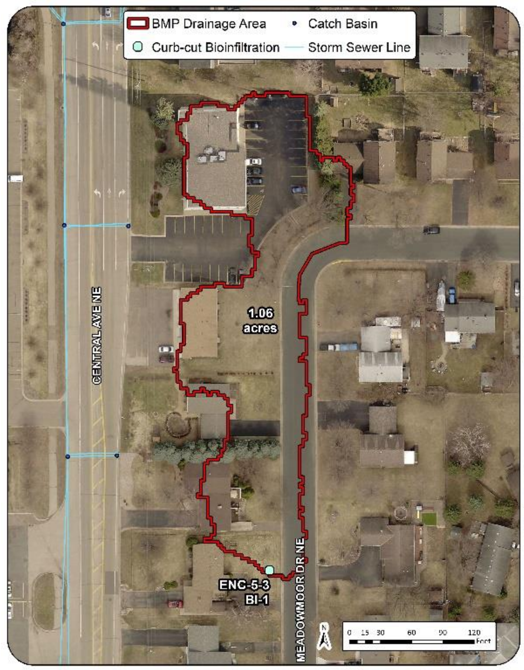
Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See 'Residential Bioretention Comparison' in the 'BMP Descriptions' section for additional details and estimated benefits and cost-effectiveness.

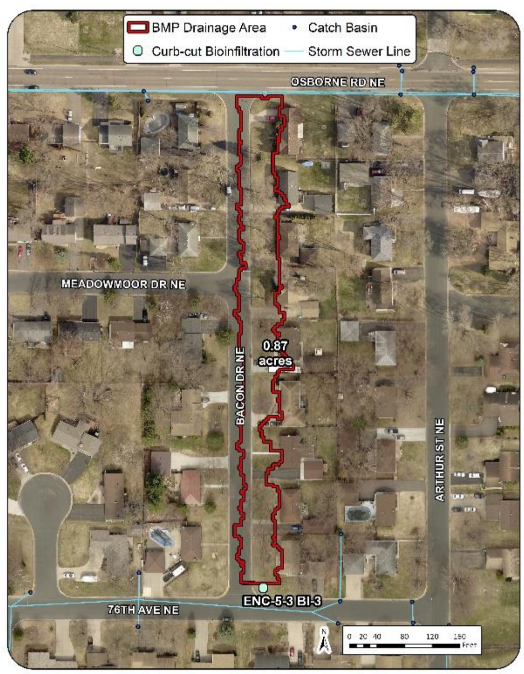




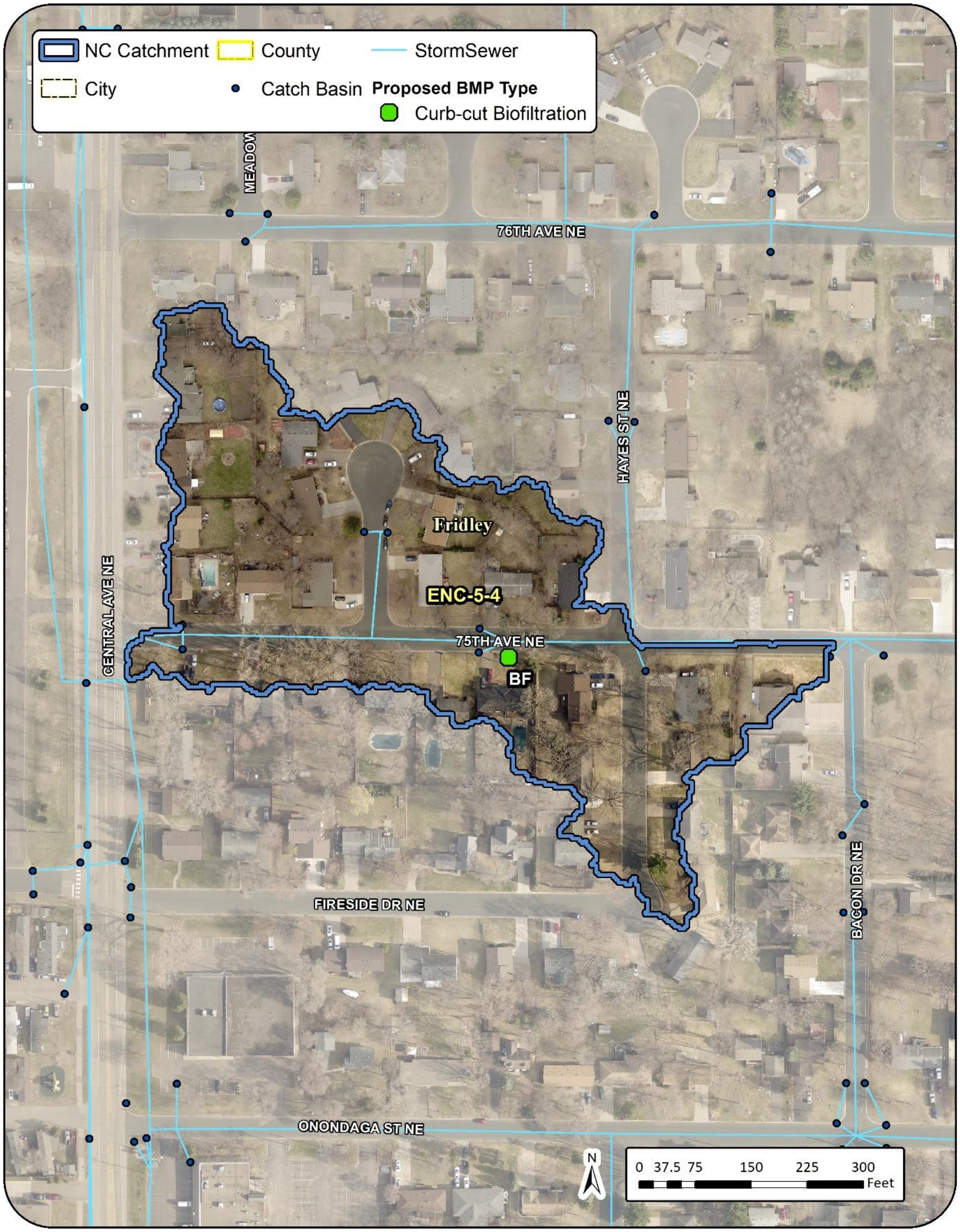
Project ID:
ENC-5-3 BF/BI
Multiple Locations
Bioretention Basins







EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES (SUBCATCHMENT 5-4)



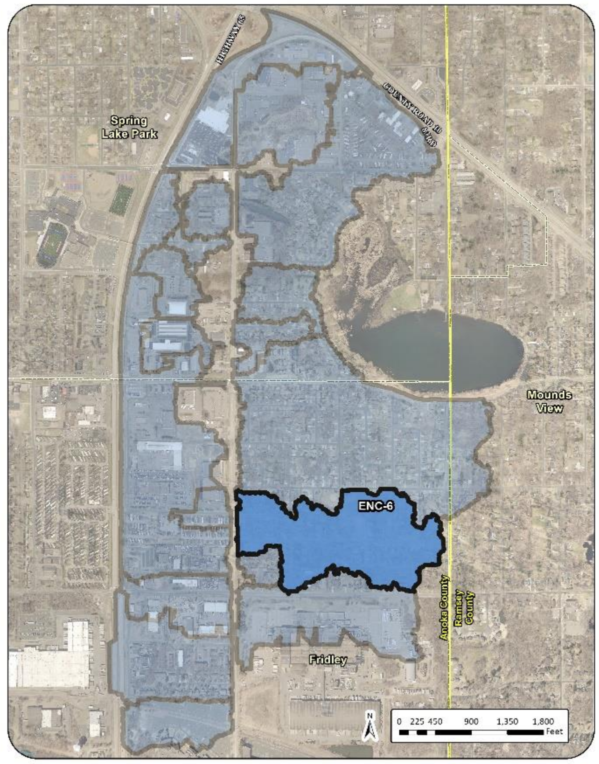
Project ID:
ENC-5-4 BF or BI

75th Ave. NE
Bioretention Basin

Drainage Area – 0.96 acres
Location – 75th Ave. NE
Property Ownership – Private
Site Specific Information – An opportunity for bioretention, either bioinfiltration or biofiltration, exists within this catchment. See 'Residential Bioretention Comparison' in the 'BMP Descriptions' section for additional details and estimated benefits and cost-effectiveness.

Catchment ENC-6

Existing Catchment Summary	
Acres	52.9
Parcels	149
Land Cover	84.2% Residential 9.9% Park 3.1% Industrial 2.4% Shopping 0.4% Open Space



CATCHMENT DESCRIPTION

Catchment ENC-6 is centered on Onondaga St. NE within the City of Fridley. Stormwater is routed from east to west toward Central Ave. NE. Land use is primarily residential with Flanery Park near the east-central area of the catchment.

EXISTING STORMWATER TREATMENT

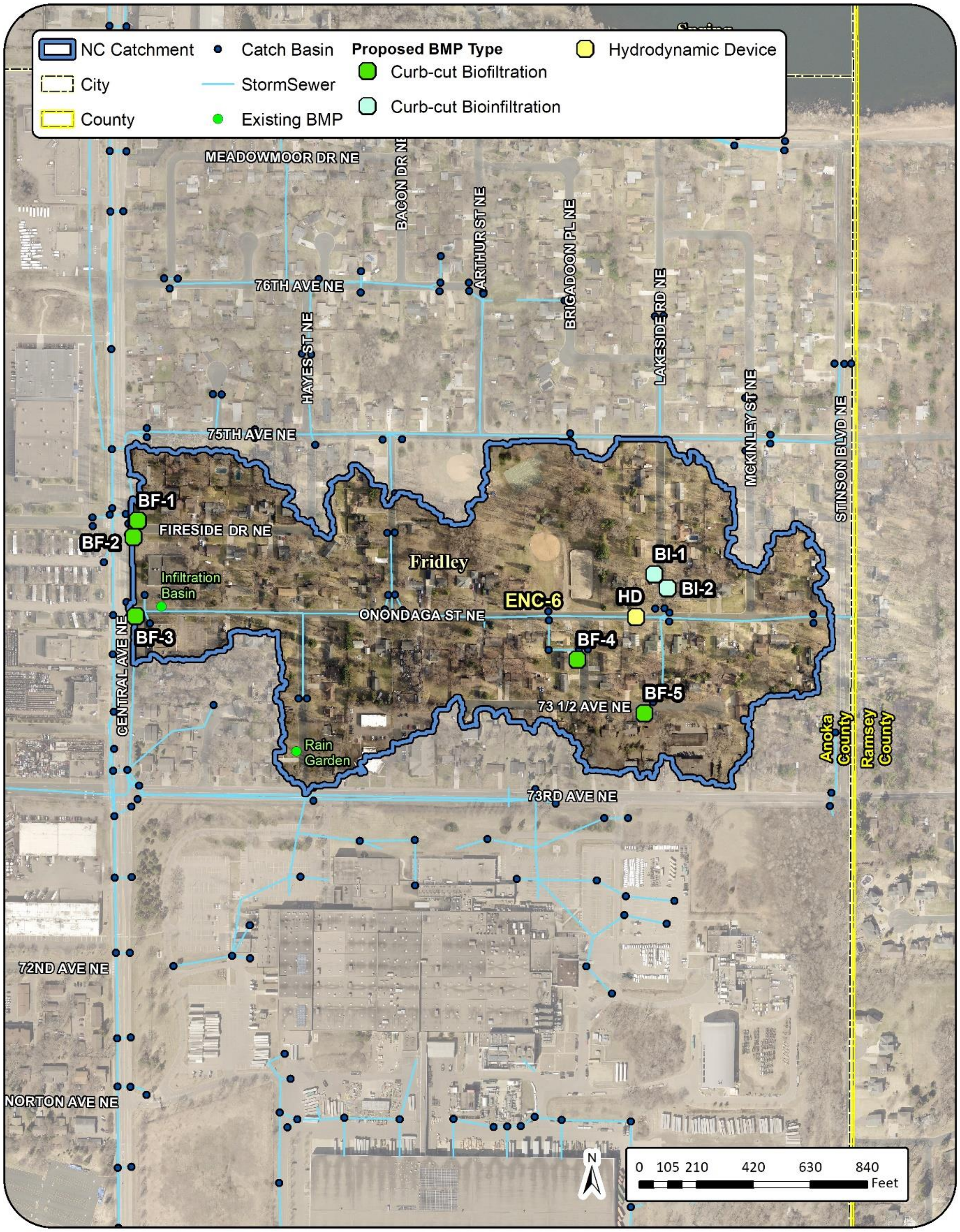
There are two bioretention basins within Catchment ENC-6, and street cleaning is conducted three times per year by the City of Fridley. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	3			
	BMP Types	Street Cleaning, Infiltration Basin, Rain Garden			
	TP (lb/yr)	32.3	2.9	9%	**29.5**
	TSS (lb/yr)	10,436	1,217	12%	**9,219**
	Volume (acre-feet/yr)	24.8	0.3	1%	**24.4**

RETROFIT OPPORTUNITIES OVERVIEW

One hydrodynamic device and seven bioretention basins are proposed in catchment ENC-6. The hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The bioretention basins were sited to maximize contributing drainage areas and at properties with sufficient space and slope to accommodate a basin. For the bioretention practices, underlying soils will determine whether biofiltration or bioinfiltration practices could be installed. The proposed bioretention locations adjacent to catch basins were shown as biofiltration practices to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

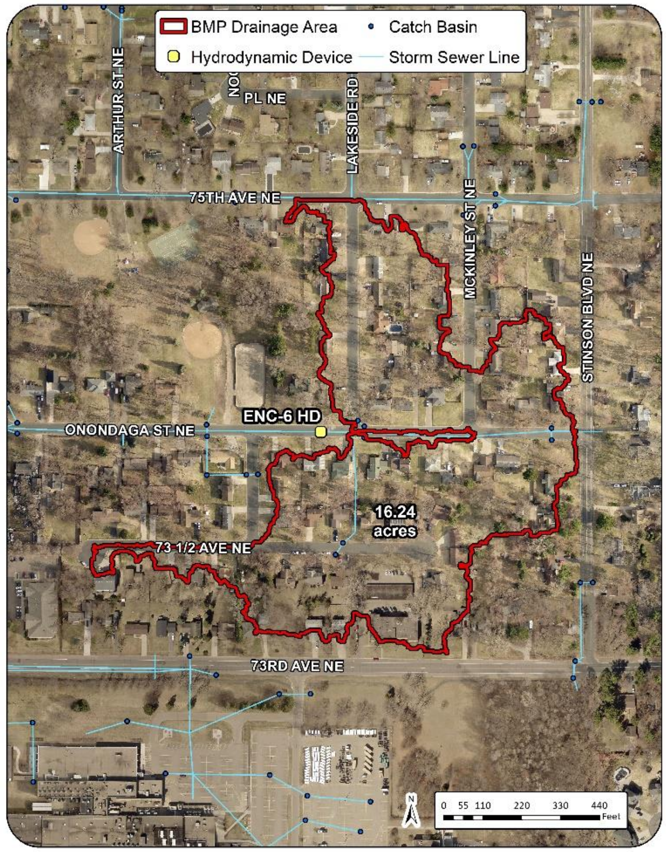
EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Project ID: ENC-6 HD

Lakeside Rd. and Onondaga St. Hydrodynamic Device

Drainage Area – 16.24 acres
Location – West side of the intersection between Lakeside Rd. NE and Onondaga St. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on Onondaga St. NE. The device is positioned just west of Lakeside Rd. NE in order to capture runoff from the catch basins at the southern extent of Lakeside Rd. NE. The table below provides pollutant removals and estimated costs.



	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	10	ft diameter
	TP (lb/yr)	0.87	3.0%
	TSS (lb/yr)	341	3.7%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***	$3,750	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2021)	**$111,750**	
	Annual O&M***	$630	
Efficiency	**30-yr Average Cost/lb-TP**	**$5,006**	
	30-yr Average Cost/1,000lb-TSS	**$12,771**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

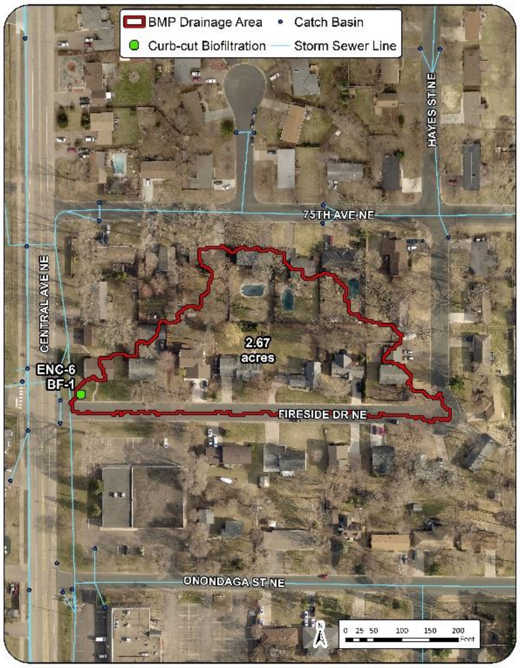
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

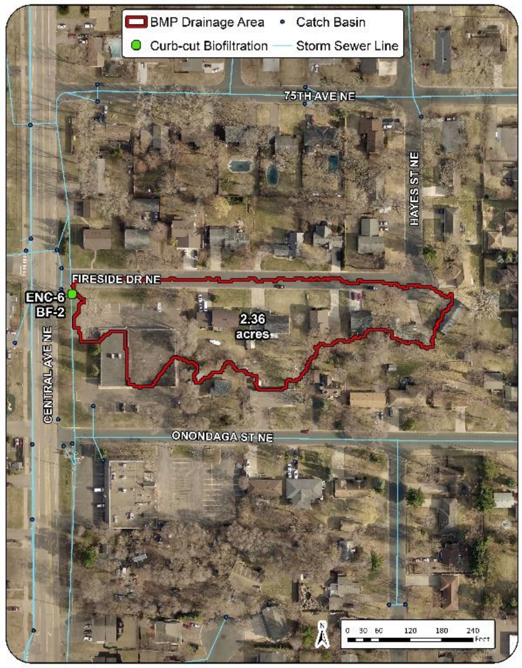
***Per BMP: (3 cleanings/year)*(3 hours/cleaning)*($70/hour)

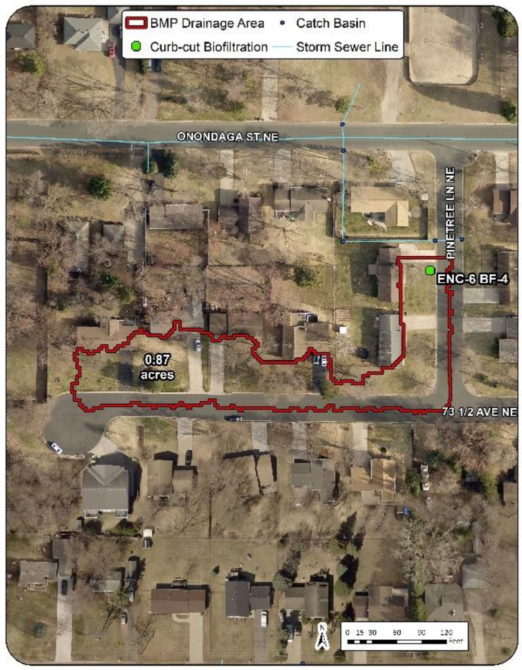
Project ID: ENC-6 BF/BI

Multiple Locations
Bioretention Basins

Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See 'Residential Bioretention Comparison' in the 'BMP Descriptions' section for additional details and estimated benefits and cost-effectiveness.





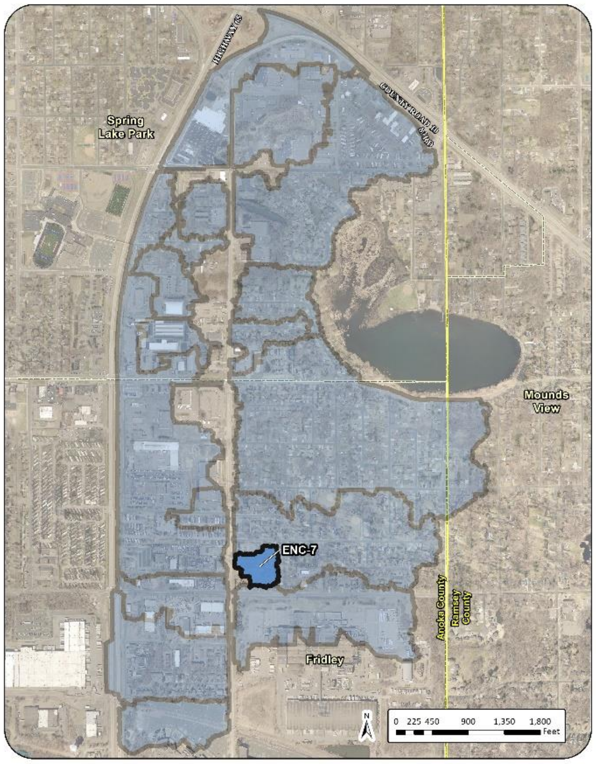


Project ID: ENC-6 BF/BI

Multiple Locations
Bioretention Basins

Catchment ENC-7

Existing Catchment Summary	
Acres	4.6
Parcels	22
Land Cover	99.1% Residential 0.9% Shopping



CATCHMENT DESCRIPTION

Catchment ENC-7 is located in Fridley and encompasses the Evert Ct. NE cul-de-sac. The land use is entirely residential, and stormwater runoff flows north to a single catch basin at the north end of Evert Ct. NE.

EXISTING STORMWATER TREATMENT

The primary stormwater treatment in the catchment is street cleaning, which is conducted three times per year by the City of Fridley. 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)	3.1	0.3	9%	**2.8**
	TSS (lb/yr)	1,031	115	11%	**916**
	Volume (acre-feet/yr)	3.0	0.0	0%	**3.0**

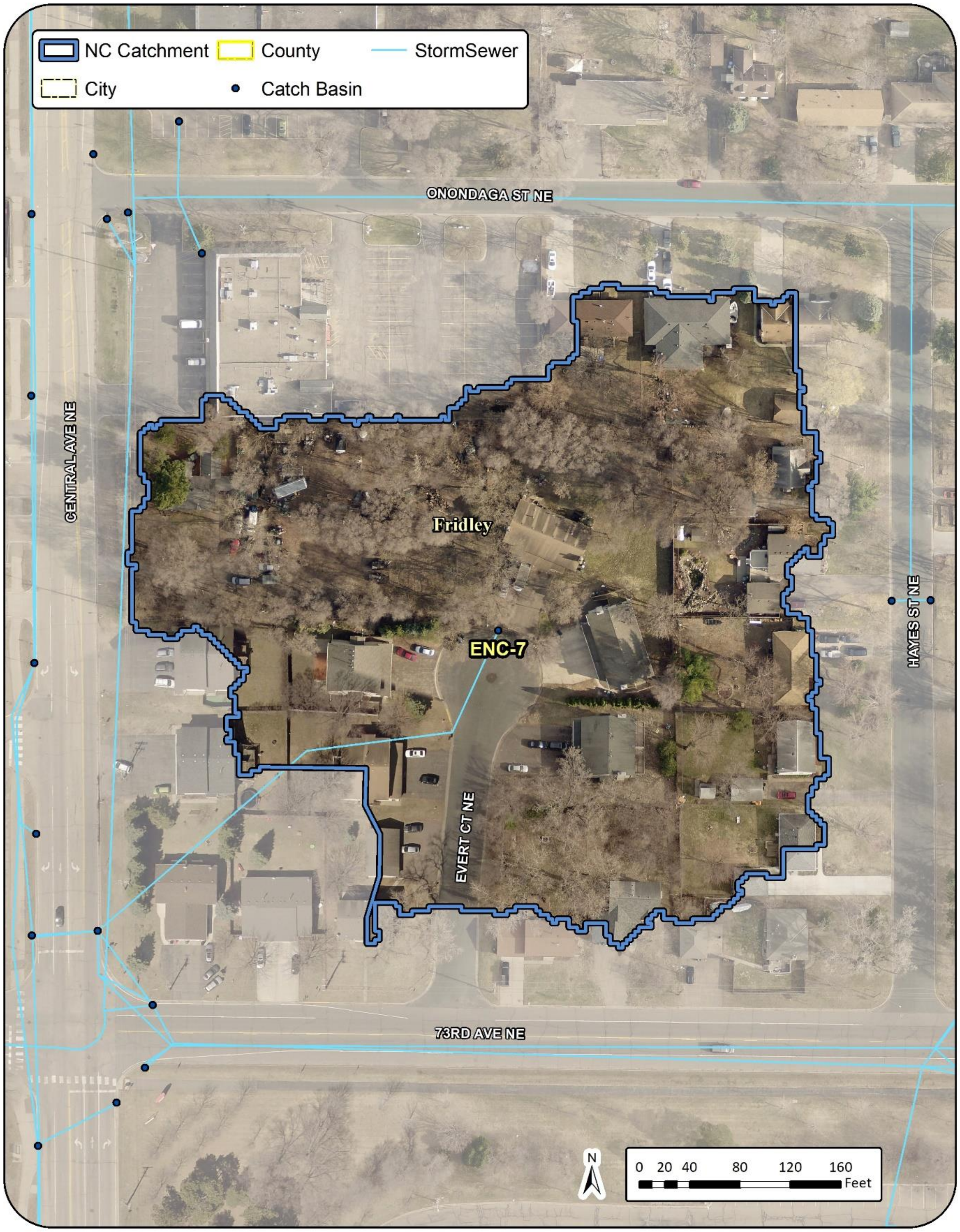
RETROFIT OPPORTUNITIES OVERVIEW

No retrofit opportunities were modeled in catchment ENC-7.

RETROFITS CONSIDERED BUT REJECTED

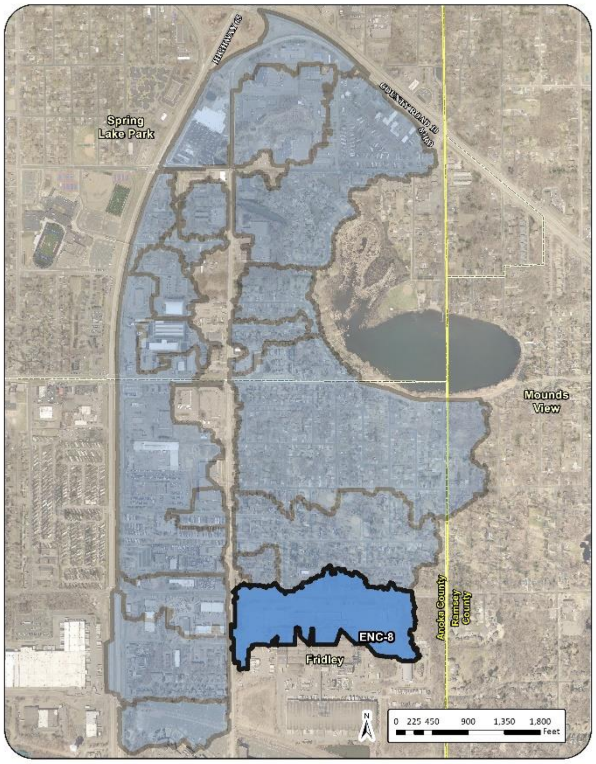
Bioretention basins were considered, but due to space and slope limitations no opportunities were proposed.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Catchment ENC-8

Existing Catchment Summary	
Acres	41.9
Parcels	33
Land Cover	81.5% Industrial 17.4% Residential 1.1% Open Space



CATCHMENT DESCRIPTION

Catchment ENC-8 encompasses the northern extent of the Cummins campus in Fridley. Stormwater runoff from the Cummins campus is routed north to 73rd Ave. NE where it then flows west toward Central Ave. NE.

EXISTING STORMWATER TREATMENT

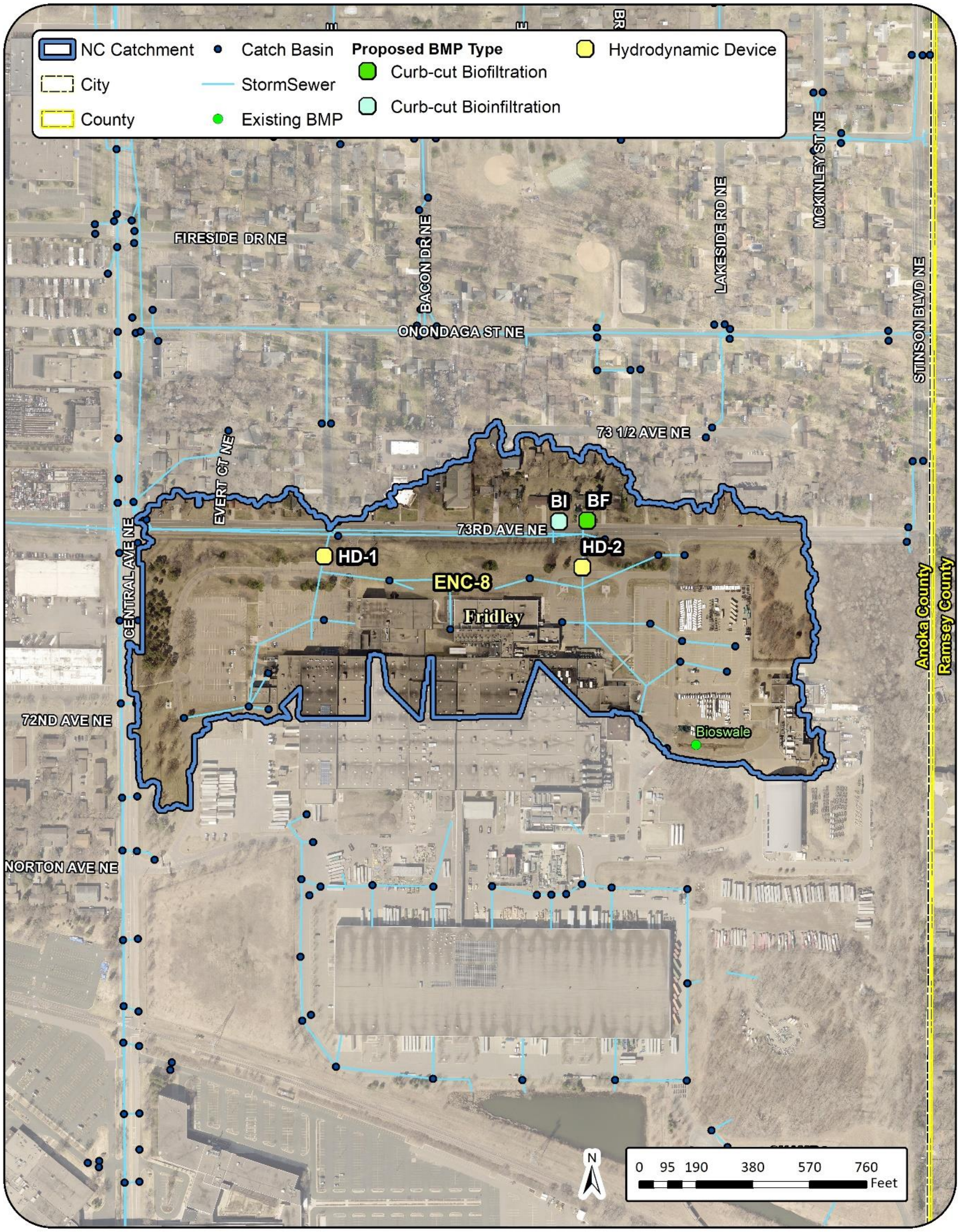
There is a bioswale on the Cummins campus and street cleaning is conducted three times per year by the City of Fridley. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	2			
	BMP Types	Street Cleaning, Bio-Swale			
	TP (lb/yr)	32.4	2.8	9%	**29.6**
	TSS (lb/yr)	18,498	1,939	10%	**16,559**
	Volume (acre-feet/yr)	37.3	1.7	5%	**35.5**

RETROFIT OPPORTUNITIES OVERVIEW

Two hydrodynamic devices and two bioretention basins are proposed in catchment ENC-8. The hydrodynamic devices are positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The bioretention basins were sited to maximize contributing drainage areas and at properties with sufficient space and slope to accommodate a basin. For the bioretention practices, underlying soils will determine whether biofiltration or bioinfiltration practices could be installed. The proposed bioretention locations adjacent to catch basins were shown as biofiltration practices to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

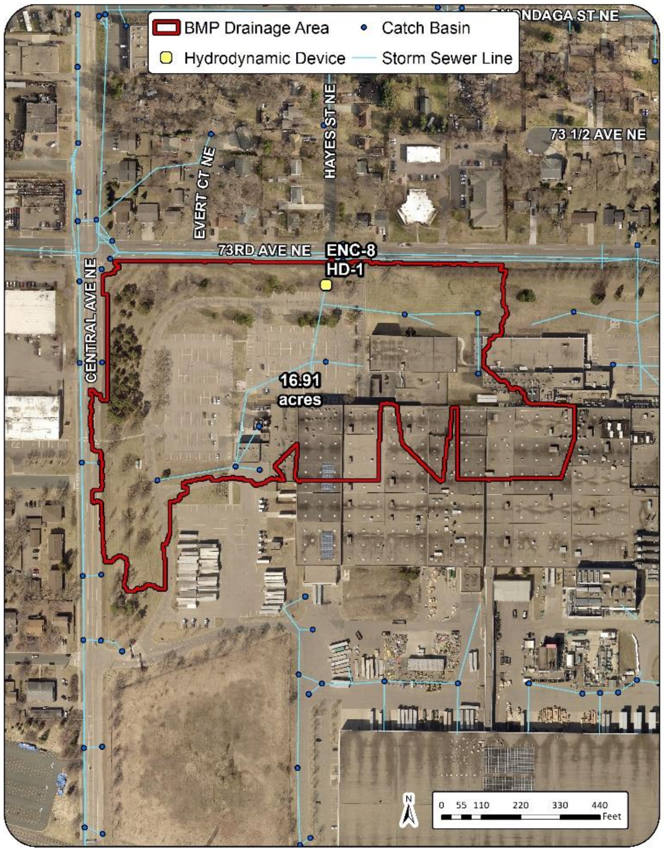
EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Project ID: ENC-8 HD-1

Hayes St. and 73rd Ave.
Hydrodynamic Device

Drainage Area – 16.91 acres
Location – Near the intersection of Hayes St. NE and 73rd Ave. NE
Property Ownership – Private
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line that drains the northwestern area of the Cummins campus. This hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The table below provides pollutant removals and estimated costs.



	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	Total Size of BMP	10	ft diameter
	TP (lb/yr)	1.13	3.8%
	TSS (lb/yr)	945	5.7%
	Volume (acre-feet/yr)	n/a	n/a
Cost	Administration & Promotion Costs*	$3,750	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2021)	**$111,750**	
	Annual O&M***	$630	
Efficiency	30-yr Average Cost/lb-TP	**$3,854**	
	30-yr Average Cost/1,000lb-TSS	**$4,608**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

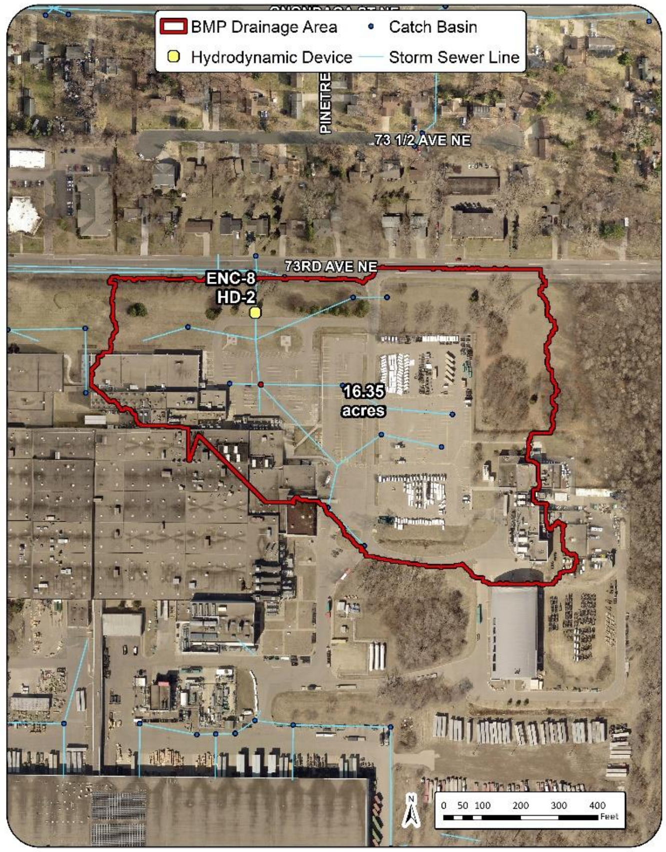
*Indirect Cost: (25 hours at $150/hour)

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

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

Project ID: ENC-8 HD-2

Cummins Campus and 73rd Ave.
Hydrodynamic Device



Drainage Area – 15.3 acres
Location – East of the intersection between Hayes St. NE and 73rd Ave. NE
Property Ownership – Private
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line that drains the northeastern area of the Cummins campus. This hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The table below provides pollutant removals and estimated costs.

Hydrodynamic Device

	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	10	ft diameter
	TP (lb/yr)	0.80	2.7%
	TSS (lb/yr)	673	4.1%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***		$3,750
	Design & Construction Costs**		$108,000
	Total Estimated Project Cost (2021)		**$111,750**
	Annual O&M***		$630
Efficiency	**30-yr Average Cost/lb-TP**	**$5,444**	
	30-yr Average Cost/1,000lb-TSS	**$6,471**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

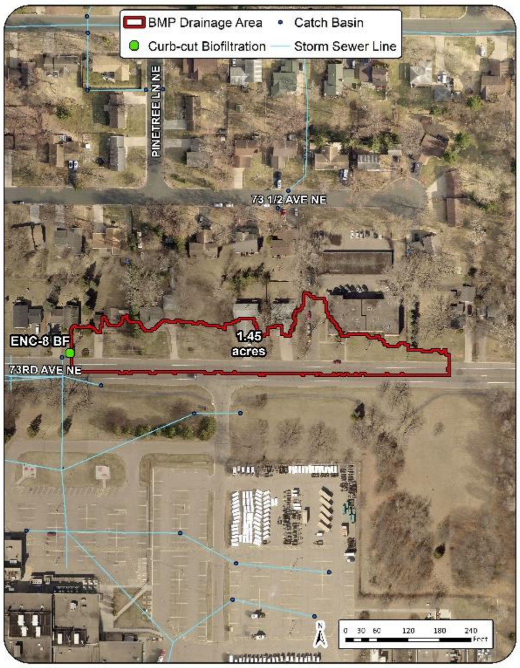
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

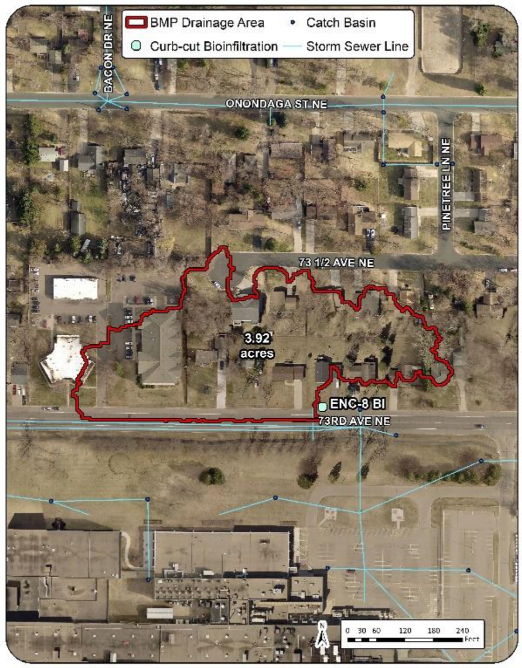
***Per BMP: (3 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: ENC-8 BF/BI

Multiple Locations
Bioretention Basins

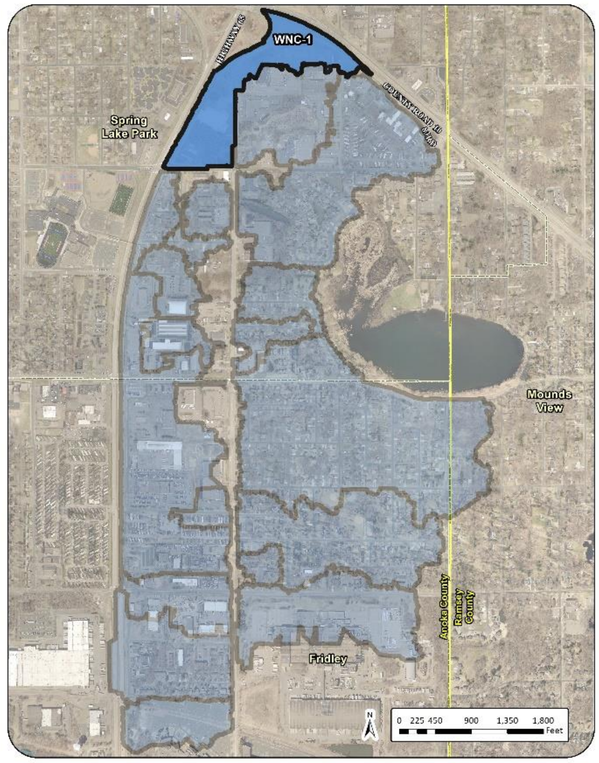
Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See 'Residential Bioretention Comparison' in the 'BMP Descriptions' section for additional details and estimated benefits and cost-effectiveness.





Catchment WNC-1

Existing Catchment Summary	
Acres	32.5
Parcels	7
Land Cover	39.9% Shopping 28.5% Industrial 25.1% Freeway 6.5% Open Space



CATCHMENT DESCRIPTION

WNC-1 is the northern most catchment of the Norton Creek drainage network. It is in the City of Spring Lake Park and includes the Hy-Vee campus. Stormwater runoff in this catchment is routed from north to south through multiple BMPs. The predominant land use is commercial shopping, but significant areas of industrial and freeway land uses are also present.

EXISTING STORMWATER TREATMENT

This catchment has the highest level of existing stormwater treatment in the analysis. A total of 12 BMPs are present, including street cleaning conducted by the City of Spring Lake Park three times per year. 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	12			
	BMP Types	Street Cleaning, Ditch Swale (2), Wet Pond (6), Wetland(2), Infiltration Basin			
	TP (lb/yr)	27.5	23.8	87%	**3.7**
	TSS (lb/yr)	12,991	11,718	90%	**1,273**
	Volume (acre-feet/yr)	31.5	18.8	60%	**12.7**

RETROFIT OPPORTUNITIES OVERVIEW

No stormwater retrofits are recommended for this catchment because of the treatment train provided by the existing BMPs. Existing BMPs provide nearly 90% removal of both TP and TSS.

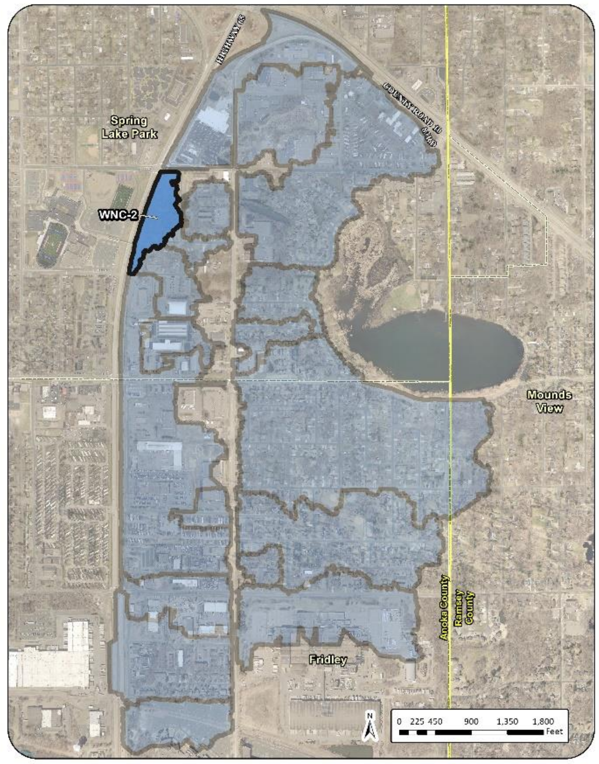
RETROFITS CONSIDERED BUT REJECTED

Pond modifications and iron-enhanced sand filters were considered for the existing ponds, but space was limited and many of the ponds were recently installed with the construction of the Hy-Vee campus.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES

Catchment WNC-2

Existing Catchment Summary	
Acres	8.9
Parcels	18
Land Cover	59.8% Residential 27.0% Freeway 7.6% Shopping 4.2% Open Space 1.4% Office Park



CATCHMENT DESCRIPTION

Catchment WNC-2 is just east of Highway 65 and south of 81st Ave. NE in Spring Lake Park. Stormwater runoff flows from east to west, and then from south to north through the Highway 65 ditch. Land use is primarily residential with a significant portion of freeway as well.

EXISTING STORMWATER TREATMENT

The ditch along the east side of Highway 65 serves as a vegetated bioswale, an office building has a wet pond that discharges to a small infiltration basin, and the City of Spring Lake Park conducts street cleaning three times per year. 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	Street Cleaning, Wet Pond, Ditch Swale			
	TP (lb/yr)	7.1	6.5	91%	**0.6**
	TSS (lb/yr)	12,991	12,824	99%	**167**
	Volume (acre-feet/yr)	5.4	4.8	90%	**0.6**

RETROFIT OPPORTUNITIES OVERVIEW

No stormwater retrofits are recommended for this catchment because of the treatment provided by the vegetated bioswale in the eastern ditch of Highway 65 and the pond paired with an infiltration basin.

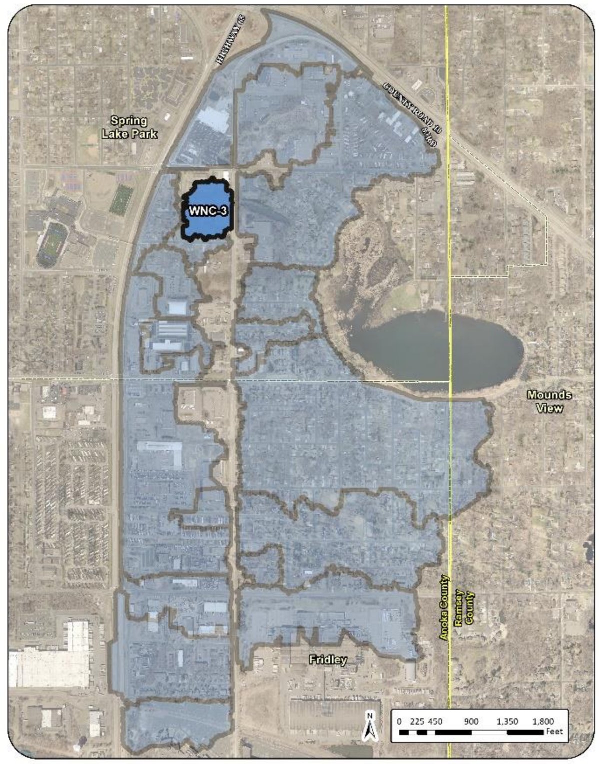
RETROFITS CONSIDERED BUT REJECTED

Bioretention basins were considered at the western extents of both Wyldwood Ln. NE and 80th Ave. NE, but the treatment provided by the vegetated bioswale made them unnecessary.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES

Catchment WNC-3

Existing Catchment Summary	
Acres	8.7
Parcels	21
Land Cover	89.2% Residential 10.8% Industrial



CATCHMENT DESCRIPTION

This catchment is located in Spring Lake Park and includes the Fireside Apartments campus. Stormwater is routed from west to east toward Central Ave. NE via overland flow. The primary land use is residential.

EXISTING STORMWATER TREATMENT

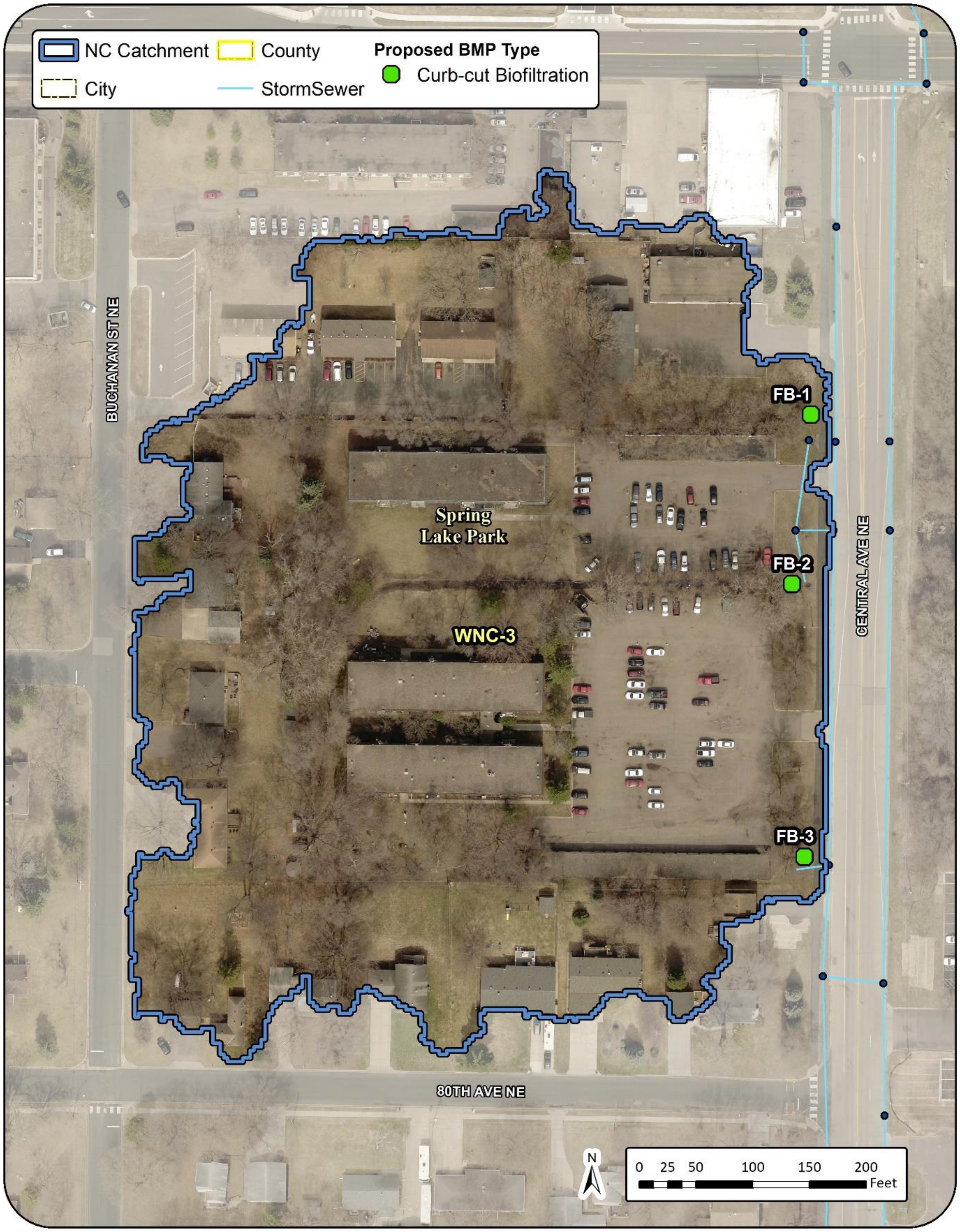
The primary stormwater treatment in the catchment is street cleaning, which is conducted by the City of Spring Lake Park three times per year. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	7.6	0.5	7%	**7.1**
	TSS (lb/yr)	2,714	240	9%	**2,474**
	Volume (acre-feet/yr)	7.1	0.2	3%	**6.9**

RETROFIT OPPORTUNITIES OVERVIEW

Three bioretention basins are proposed in catchment WNC-3. The bioretention basins were sited to maximize contributing drainage areas and at properties with sufficient space and slope to accommodate a basin. Underlying soils will determine whether biofiltration or bioinfiltration practices could be installed. The proposed bioretention locations adjacent to catch basins were shown as biofiltration practices to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



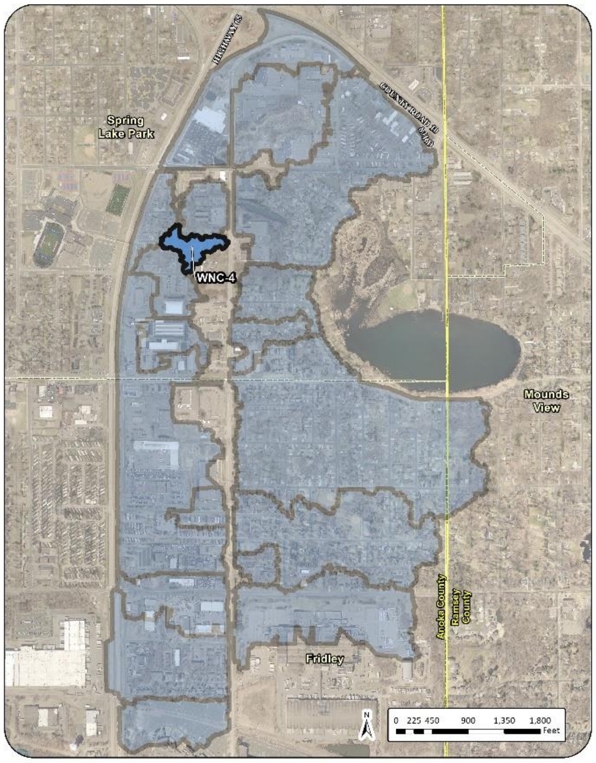
Project ID: WNC-3 BF/BI

Multiple Locations
Bioretention Basins

Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See 'Residential Bioretention Comparison' in the 'BMP Descriptions' section for additional details and estimated benefits and cost-effectiveness.

Catchment WNC-4

Existing Catchment Summary	
Acres	4.6
Parcels	22
Land Cover	93.2% Residential 6.8% Industrial



CATCHMENT DESCRIPTION

Catchment WNC-4 is centered on 80th Ave. NE in Spring Lake Park. Stormwater runoff is routed from west to east toward Central Ave. NE. The primary land use in the contributing drainage area is residential.

EXISTING STORMWATER TREATMENT

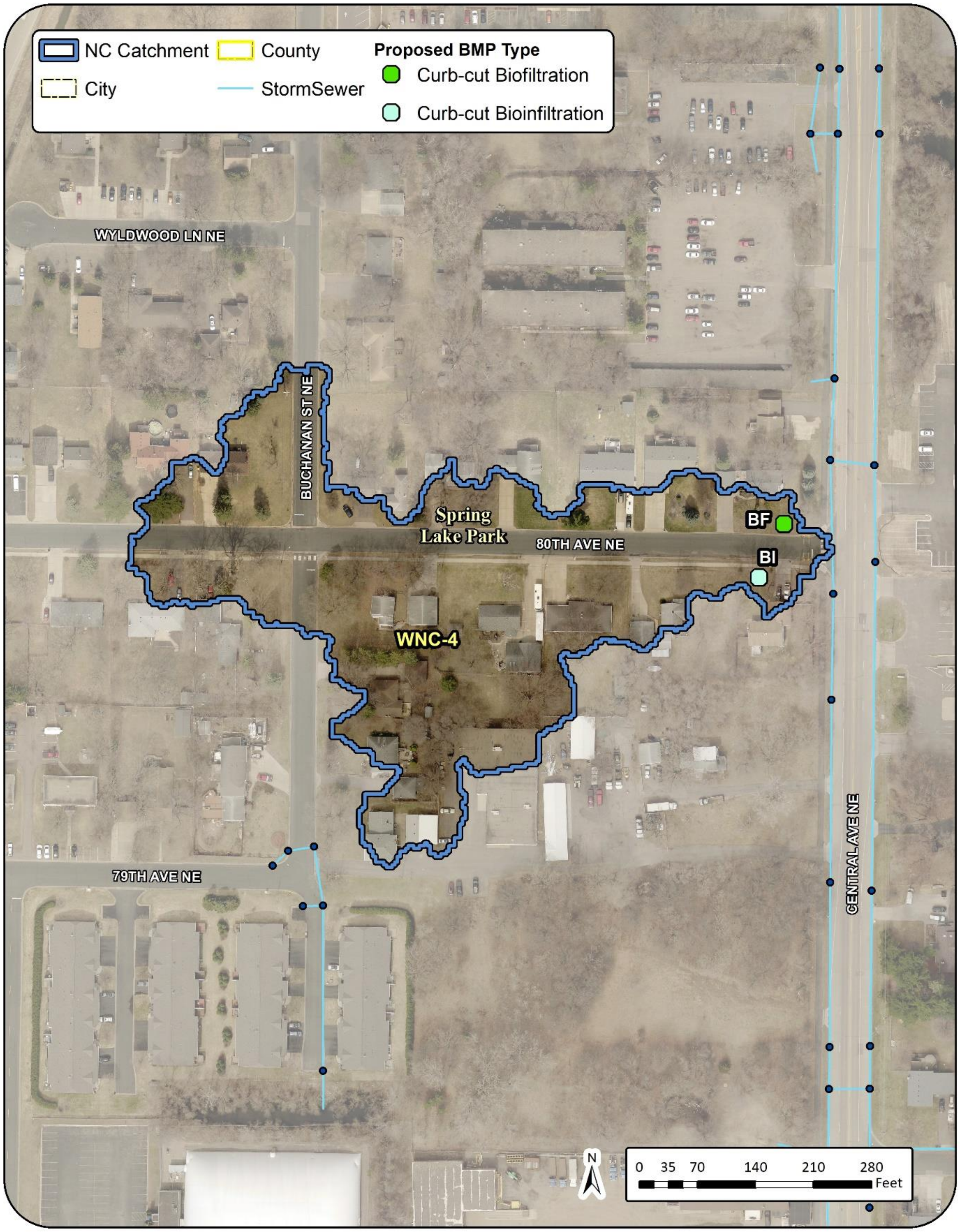
The primary stormwater treatment in the catchment is street cleaning, which is conducted by the City of Spring Lake Park three times per year. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	2.9	0.2	8%	**2.6**
	TSS (lb/yr)	934	98	11%	**836**
	Volume (acre-feet/yr)	2.1	0.0	0%	**2.1**

RETROFIT OPPORTUNITIES OVERVIEW

Two bioretention basins are proposed in catchment WNC-4. The bioretention basins were sited to maximize contributing drainage areas and at properties with sufficient space and slope to accommodate a basin. Underlying soils will determine whether biofiltration or bioinfiltration practices could be installed. The proposed bioretention locations adjacent to catch basins were shown as biofiltration practices to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

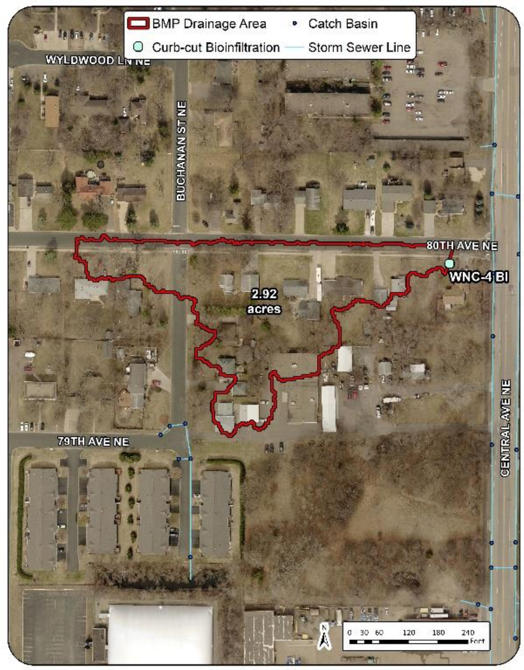
EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Project ID: WNC-4 BF/BI

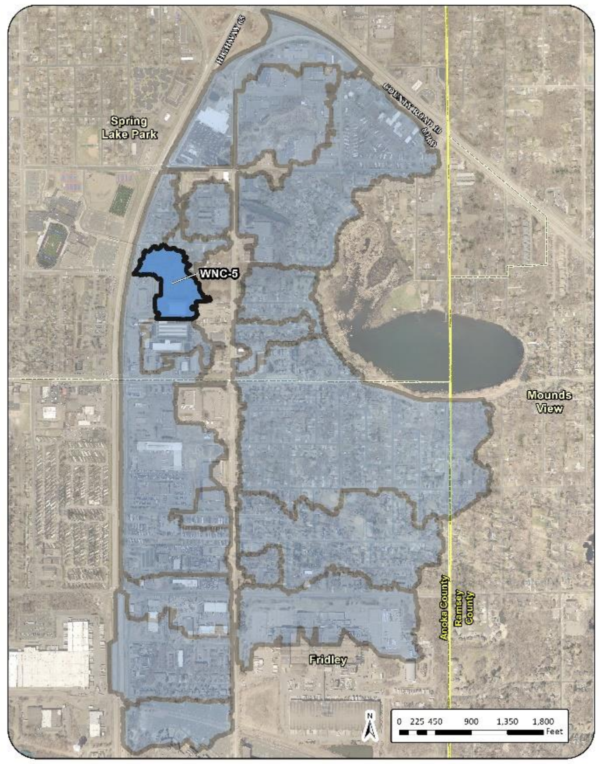
Multiple Locations
Bioretention Basins

Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See ‘Residential Bioretention Comparison’ in the ‘BMP Descriptions’ section for additional details and estimated benefits and cost-effectiveness.



Catchment WNC-5

Existing Catchment Summary	
Acres	10.6
Parcels	31
Land Cover	61.0% Residential 23.7% Shopping 8.5% Open Space 3.7% Office Park 3.1% Industrial



CATCHMENT DESCRIPTION

Catchment WNC-5 is located in Spring Lake Park east of Highway 65 and just south of 80th Ave. NE. The catchment includes single-family residential, townhomes, and the Public Indoor Tennis campus. Stormwater is routed from north to south.

EXISTING STORMWATER TREATMENT

Two wet ponds are present on the Public Indoor Tennis campus that receive all runoff generated in the catchment. In addition, the City of Spring Lake Park conducts street cleaning three times per year. 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	Street Cleaning, Wet Pond (2)			
	TP (lb/yr)	8.7	4.2	48%	**4.5**
	TSS (lb/yr)	3,259	1,918	59%	**1,341**
	Volume (acre-feet/yr)	9.0	0	3%	**8.7**

RETROFIT OPPORTUNITIES OVERVIEW

One bioretention basin is proposed in catchment WNC-5. The bioretention basin is sited to maximize contributing drainage areas and at a property with sufficient space and slope to accommodate a basin. Underlying soils will determine whether a biofiltration or bioinfiltration practice could be installed. The proposed bioretention location is adjacent to a catch basin and is shown as a biofiltration practice to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES

Project ID: WNC-5 BR

Buchanan St. and 79th Ave. Bioretention Basin

Drainage Area – 3.82 acres
Location – Northwest corner of the intersection between Buchanan St. NE and 79th Ave. NE
Property Ownership – Private
Site Specific Information – Single-family residential lots in this catchment provide opportunities for bioretention. Both a bioinfiltration and a biofiltration basin were modeled at the optimal location in this catchment. The potential site for this basin is adjacent to an existing catch basin, which could serve as the connection point for the underdrain outlet. The table below provides pollutant removals and estimated costs.

Curb-Cut Bioretention

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction
Treatment		Sandy Soils - 12" IB		Silty Soils - 12" BF	
	Total Size of BMPs	250	sq-ft	250	sq-ft
	TP (lb/yr)	0.21	4.6%	0.06	1.4%
	TSS (lb/yr)	47	3.5%	23	1.7%
	Volume (acre-feet/yr)	0.49	5.6%	0.07	0.8%
Cost	Administration & Promotion Costs*	$584		$584	
	Design & Construction Costs**	$9,420		$11,420	
	Total Estimated Project Cost (2021)	**$10,004**		**$12,004**	
	Annual O&M***	$225		$225	
Efficiency	30-yr Average Cost/lb-TP	**$2,659**		**$9,768**	
	30-yr Average Cost/1,000lb-TSS	**$11,882**		**$27,180**	
	30-yr Average Cost/ac-ft Vol.	**$1,140**		**$8,996**	

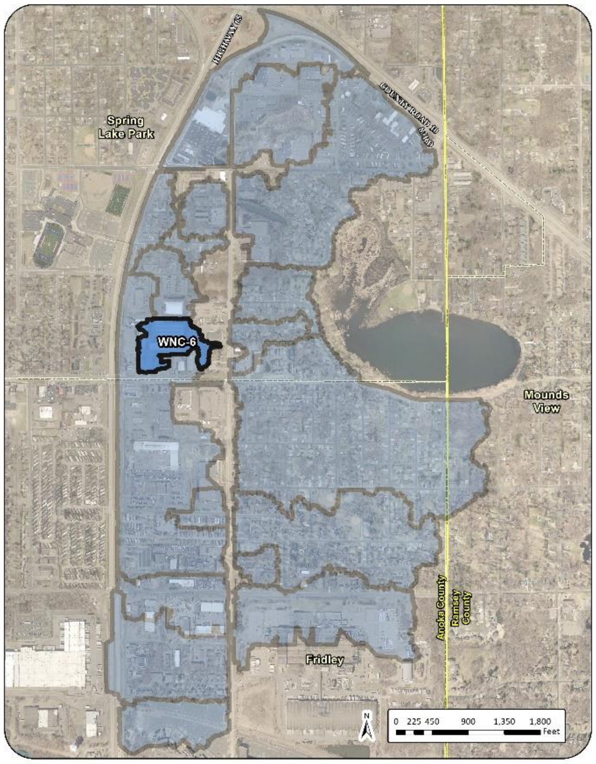
*Indirect Cost: (8 hours at $73/hour base cost)

**Direct Cost: ($26/sq-ft for materials and labor) + (40 hours at $73/hour for design)

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

Catchment WNC-6

Existing Catchment Summary	
Acres	9.7
Parcels	13
Land Cover	77.7% Industrial 21.6% Shopping 0.7% Residential



CATCHMENT DESCRIPTION

Catchment WNC-6 is in the City of Spring Lake Park and includes a public storage campus. Stormwater is routed from west to east toward Central Ave. NE. The land use is predominantly industrial.

EXISTING STORMWATER TREATMENT

A wet pond exists on the south side of the public storage campus, and street cleaning is conducted by the City of Spring Lake Park three times per year. 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	Street Cleaning, Wet Pond			
	TP (lb/yr)	8.4	4.5	54%	**3.9**
	TSS (lb/yr)	4,847	3337	69%	**1,510**
	Volume (acre-feet/yr)	10.2	8.9	87%	**1.3**

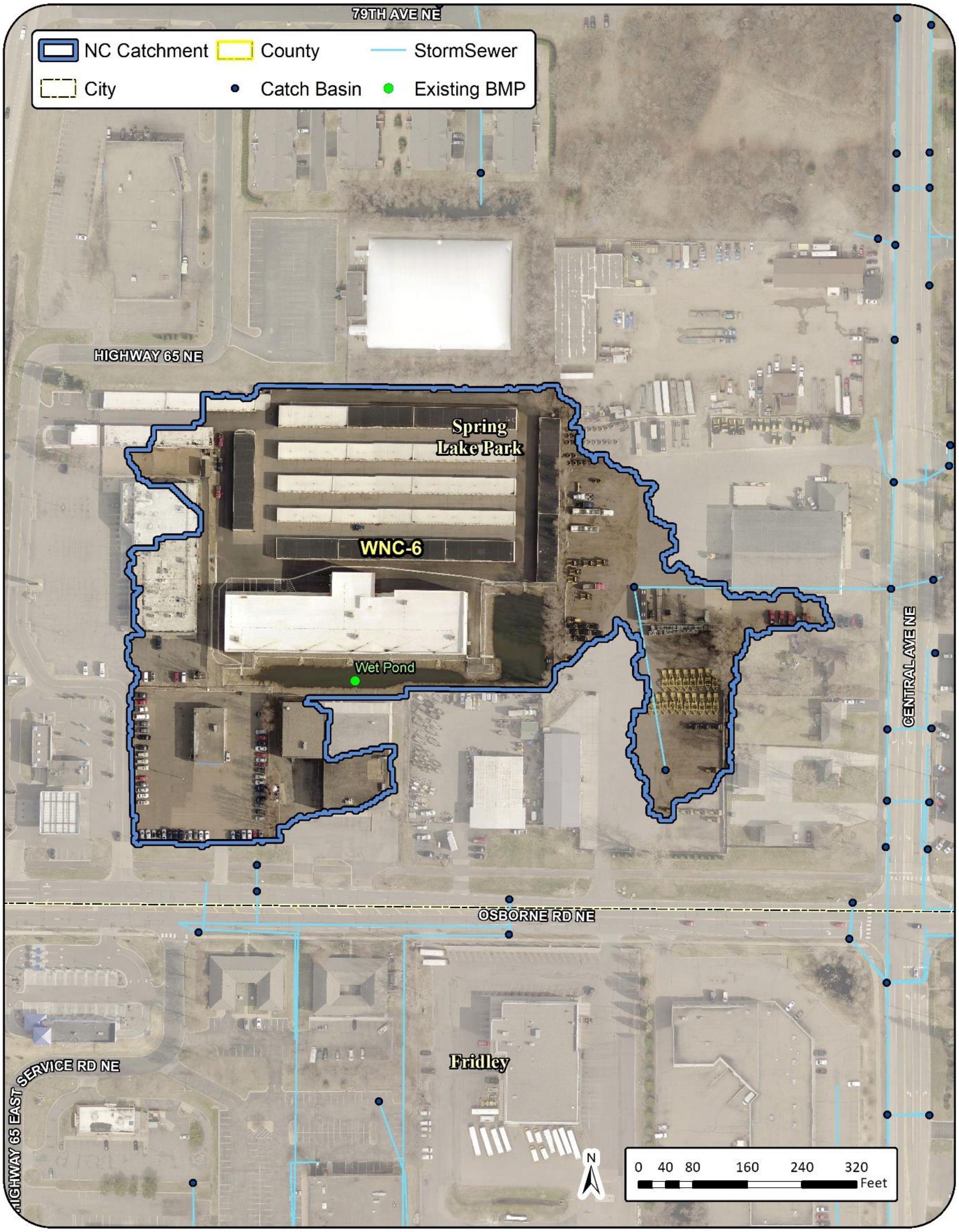
RETROFIT OPPORTUNITIES OVERVIEW

No stormwater retrofits are recommended for this catchment because of the treatment provided by the existing pond.

RETROFITS CONSIDERED BUT REJECTED

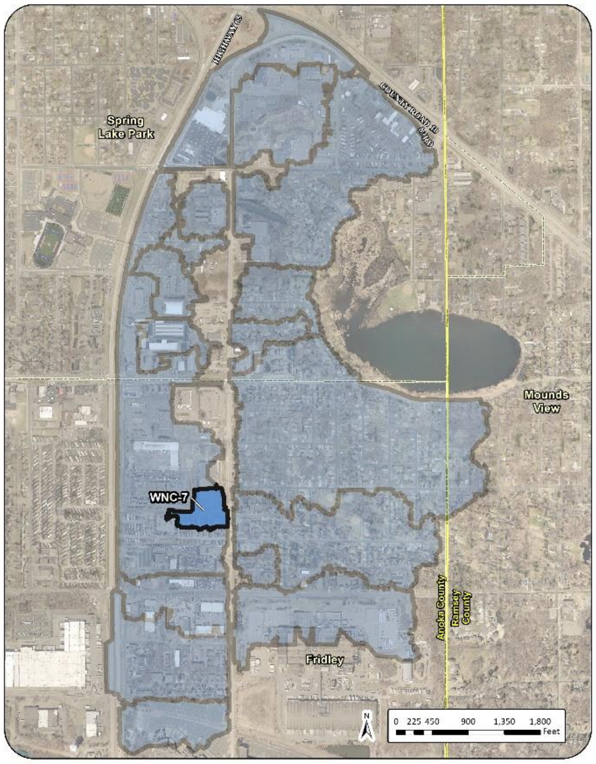
Pond retrofits were considered but space was extremely limited.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Catchment WNC-7

Existing Catchment Summary	
Acres	5.6
Parcels	4
Land Cover	50.4% Industrial 40.5% Mobile Home 9.1% Shopping



CATCHMENT DESCRIPTION

Catchment WNC-7 is in the City of Fridley and is centered on Fireside Dr. NE. The southern portion of the Brenk Brothers campus and the northern extent of a mobile home park comprise most of the contributing drainage area.

EXISTING STORMWATER TREATMENT

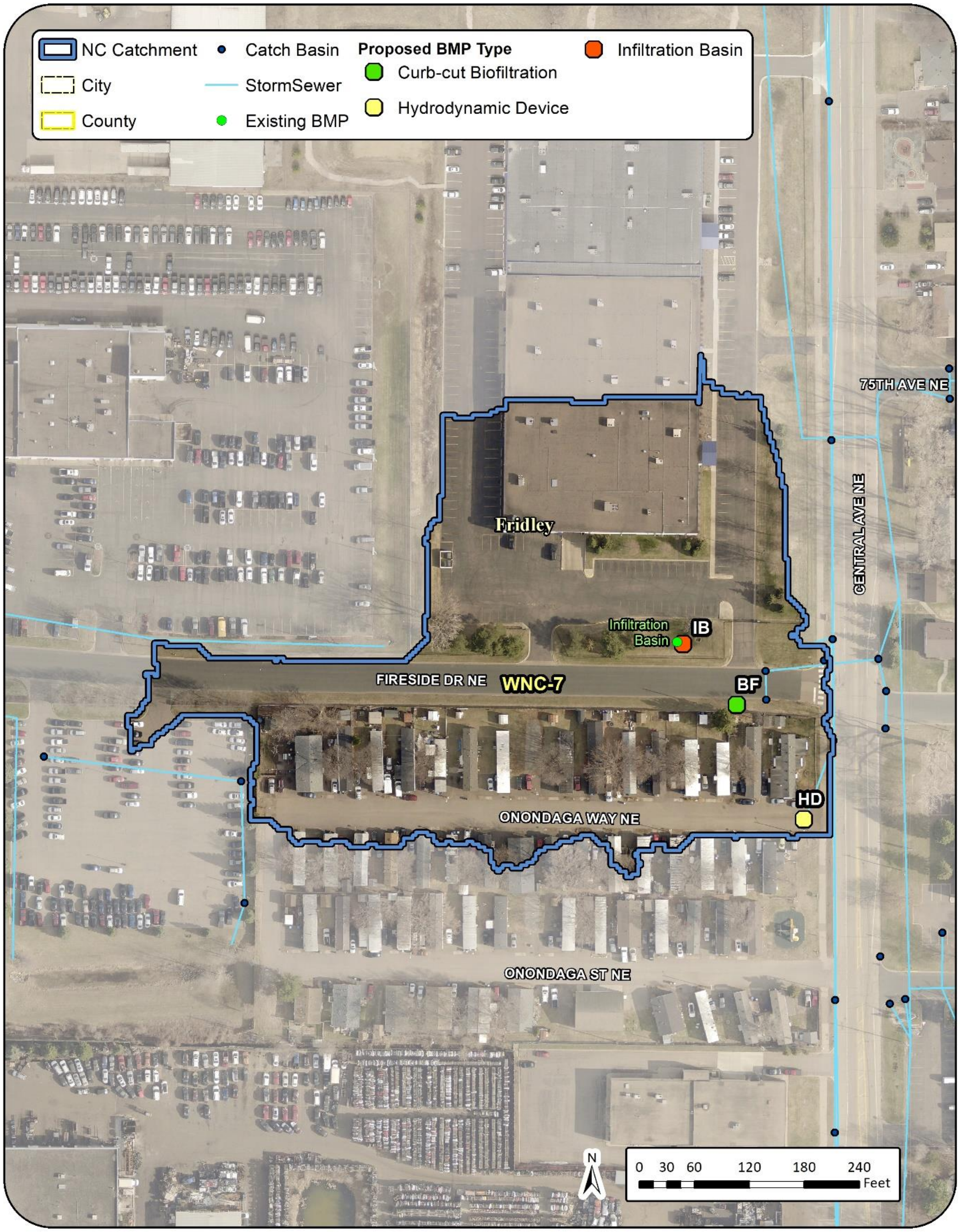
The primary stormwater treatment in the catchment is street cleaning, which the City of Fridley conducts three times per year. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	2			
	BMP Types	Street Cleaning, Infiltration Basin			
	TP (lb/yr)	3.9	0.8	20%	**3.1**
	TSS (lb/yr)	2,027	522	26%	**1,505**
	Volume (acre-feet/yr)	5.0	0.9	18%	**4.1**

RETROFIT OPPORTUNITIES OVERVIEW

Three projects were proposed catchment WNC-7. One hydrodynamic device is proposed to provide treatment of the mobile home park due to extremely limited space. A retrofit to the existing infiltration basin on the Brenk Brothers campus and one bioretention basin on the south side of Fireside Dr. NE are also proposed. For the bioretention practice, underlying soils will determine whether biofiltration or bioinfiltration could be installed. The proposed bioretention location is adjacent to a catch basin and shown as a biofiltration practice to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

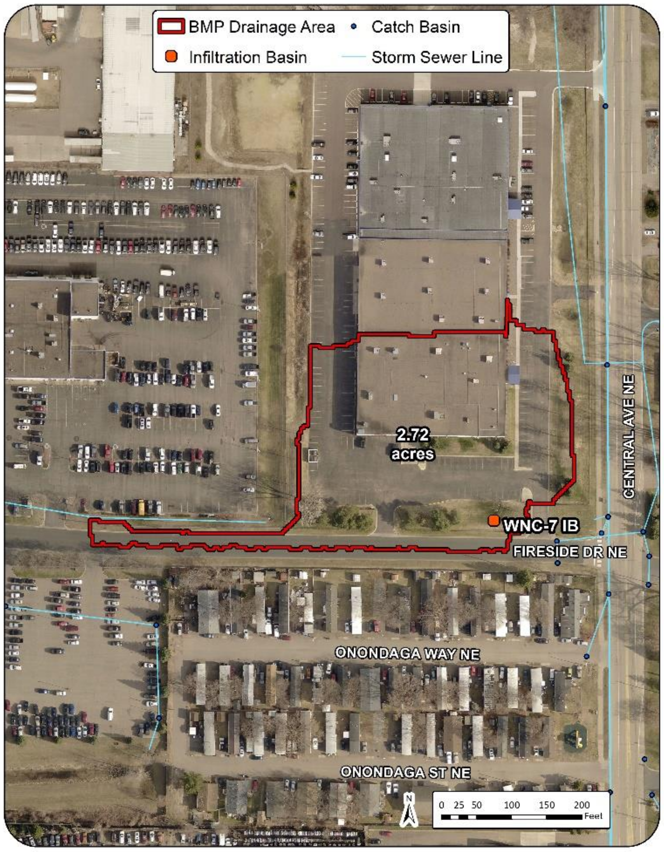
EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Project ID: WNC-7 IB

Central Ave. and Fireside Dr. Infiltration Basin

Drainage Area – 2.72 acres
Location – South eastern extent of Brenk Brothers property along Fireside Dr. NE
Property Ownership – Private
Site Specific Information – The existing infiltration basin on the Brenk Brothers campus could be retrofit to increase ponding depth. A riser could be added to the existing outlet to increase ponding depth to 18”. The table below provides pollutant removals and estimated costs.



Infiltration Basin Retrofit

	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	Total Size of BMPs	2,000	sq-ft
	TP (lb/yr)	0.59	18.8%
	TSS (lb/yr)	365	24.3%
	Volume (acre-feet/yr)	0.8	18.5%
Cost	Administration & Promotion Costs*		$584
	Design & Construction Costs**		$6,420
	Total Estimated Project Cost (2021)		**$7,004**
	Annual O&M***		$0
Efficiency	30-yr Average Cost/lb-TP	**$396**	
	30-yr Average Cost/1,000lb-TSS	**$640**	
	30-yr Average Cost/ac-ft Vol.	**$307**	

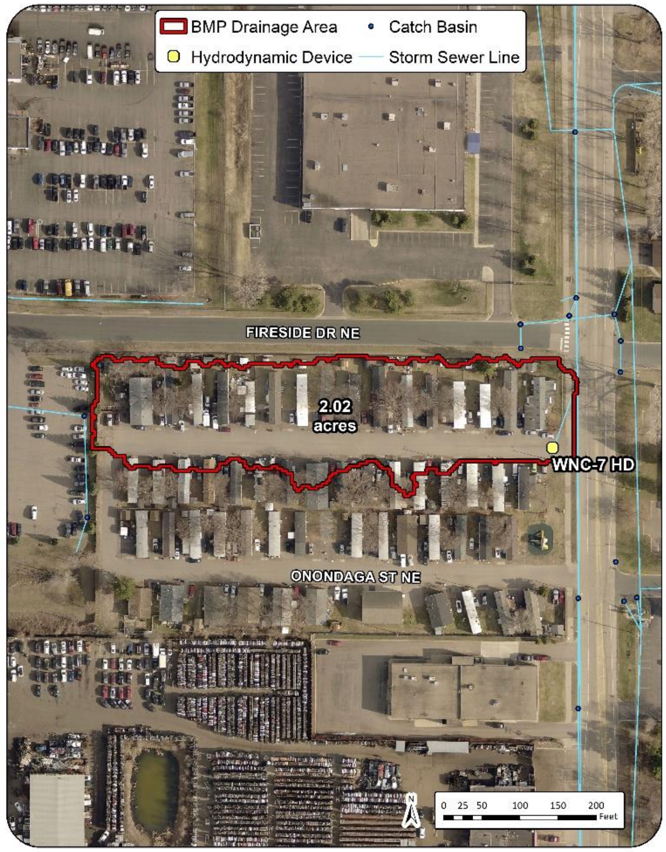
*Indirect Cost: (8 hours at $73/hour base cost)

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

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

Project ID: WNC-7 HD

Central Ave. and Onondaga Way
Hydrodynamic Device



Drainage Area – 2.02 acres
Location – Intersection between Central Ave. NE and Onondaga Way NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on Onondaga Way NE. This hydrodynamic device is positioned at the eastern extent of the mobile home park. The table below provides pollutant removals and estimated costs.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	Total Size of BMP	6	ft diameter
	TP (lb/yr)	0.19	5.9%
	TSS (lb/yr)	83	5.5%
	Volume (acre-feet/yr)	n/a	n/a
Cost	Administration & Promotion Costs*	$3,750	
	Design & Construction Costs**	$27,000	
	Total Estimated Project Cost (2021)	**$30,750**	
	Annual O&M***	$630	
Efficiency	30-yr Average Cost/lb-TP	**$8,946**	
	30-yr Average Cost/1,000lb-TSS	**$19,940**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

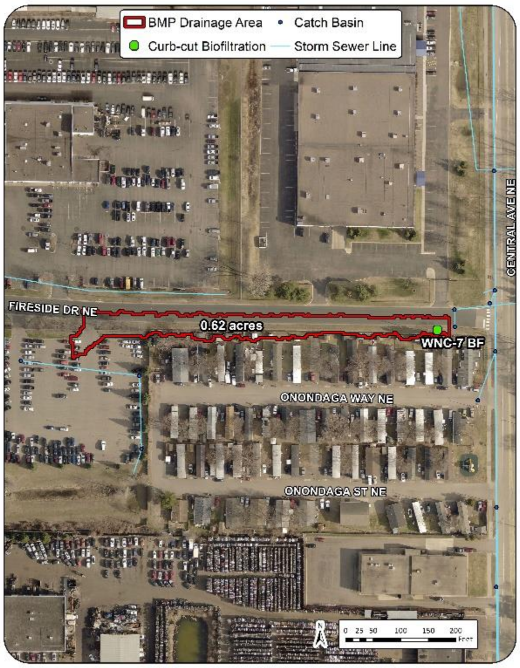
**Direct Cost: ($18,000 for materials) + ($9,000 for labor and installation costs)

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

Project ID: WNC-7 BF or BI

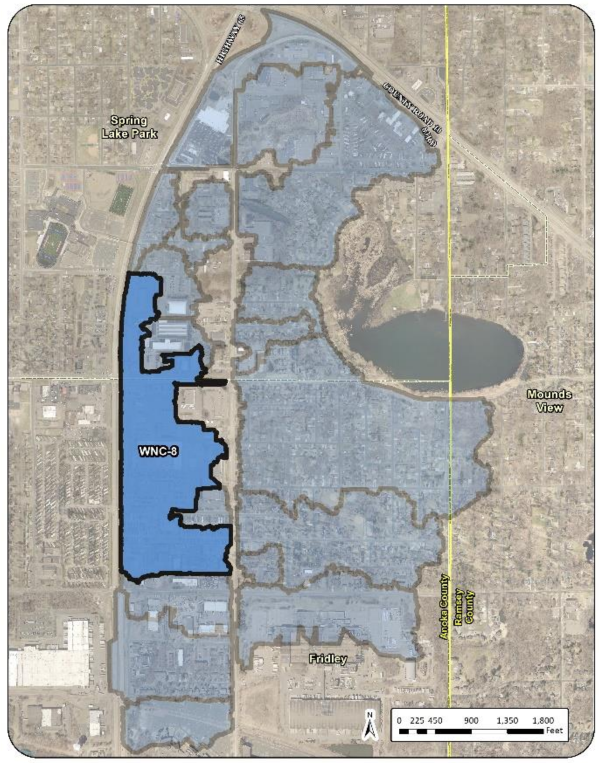
Fireside Dr. NE
Bioretention Basin

Drainage Area – 0.62 acres
Location – Fireside Dr. NE
Property Ownership – Private
Site Specific Information – An opportunity for bioretention, either bioinfiltration or biofiltration, exists within this catchment. See 'Residential Bioretention Comparison' in the 'BMP Descriptions' section for additional details and estimated benefits and cost-effectiveness.



Catchment WNC-8

Existing Catchment Summary	
Acres	74.1
Parcels	64
Land Cover	35.5% Industrial 33.0% Shopping 9.2% Mobile Home 8.9% Freeway 5.0% Institutional 4.3% Office Park 3.3% Open Space 0.8% Residential



CATCHMENT DESCRIPTION

Catchment WNC-8 includes areas in both Spring Lake Park and Fridley. It is positioned just east of Highway 65 from approximately Osborne Rd. NE on the north end to 73 ½ Ave. NE on the south end. Stormwater runoff is routed from north to south. A wide variety of land uses are present, but industrial and commercial shopping comprise the majority.

EXISTING STORMWATER TREATMENT

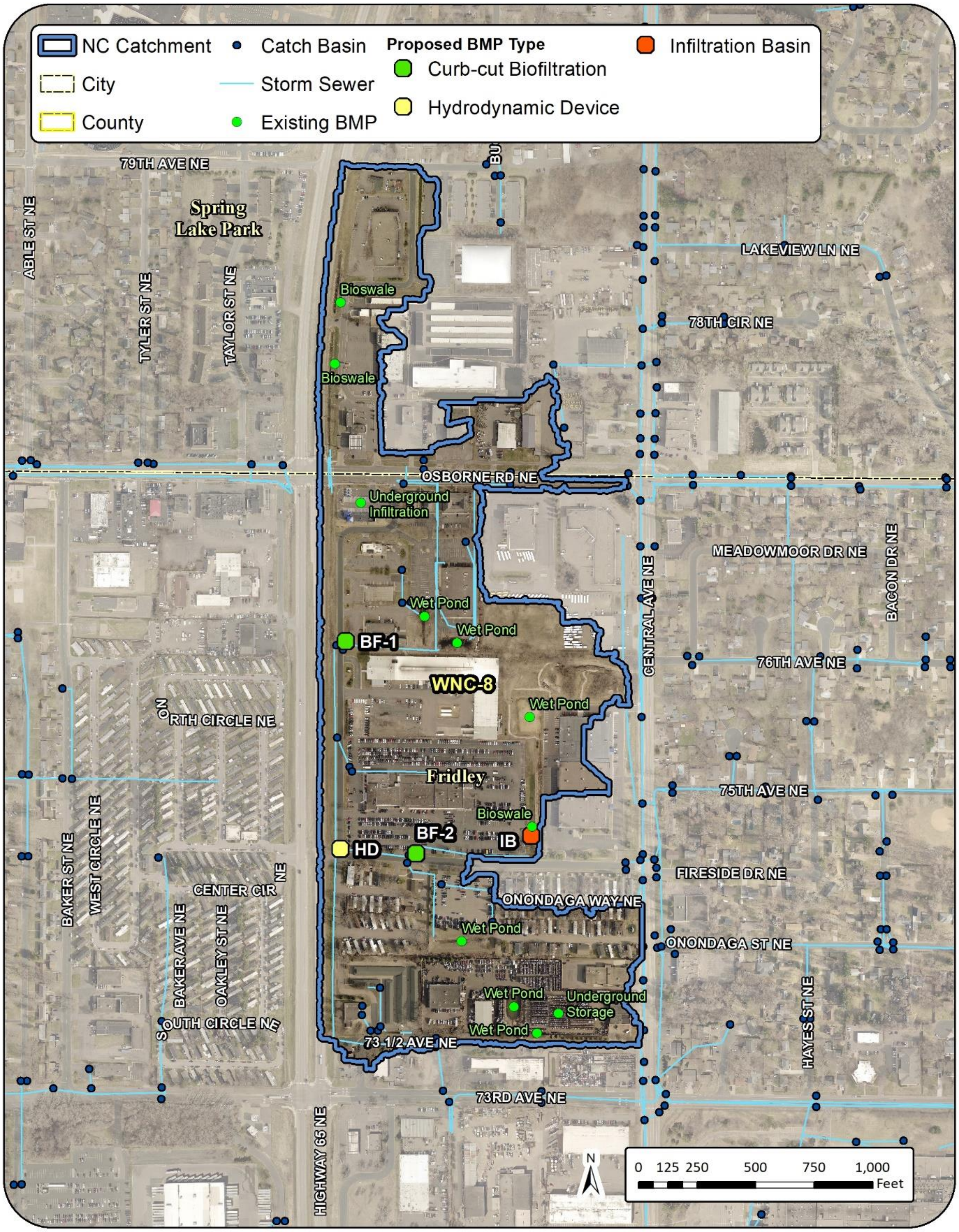
Nine BMPs in addition to street cleaning are present in catchment WNC-8. The cities of Fridley and Spring Lake Park conduct street cleaning three times per year. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	10			
	BMP Types	Street Cleaning, Road Swale (2), Wet Pond (4), Bio-Swale, Underground Storage, Underground Infiltration			
	TP (lb/yr)	63.6	20.2	32%	**43.4**
	TSS (lb/yr)	31,483	10,876	35%	**20,607**
	Volume (acre-feet/yr)	75.3	0.0	0%	**58.3**

RETROFIT OPPORTUNITIES OVERVIEW

One hydrodynamic device, one infiltration basin retrofit, and two bioretention basins are proposed in catchment WNC-8. The hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The infiltration basin retrofit is proposed to increase ponding and increase volume and pollutant removals. The bioretention basins were sited to maximize contributing drainage areas and at properties with sufficient space and slope to accommodate a basin. For the bioretention practices, underlying soils will determine whether biofiltration or bioinfiltration practices could be installed. The proposed bioretention locations adjacent to catch basins were shown as biofiltration practices to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

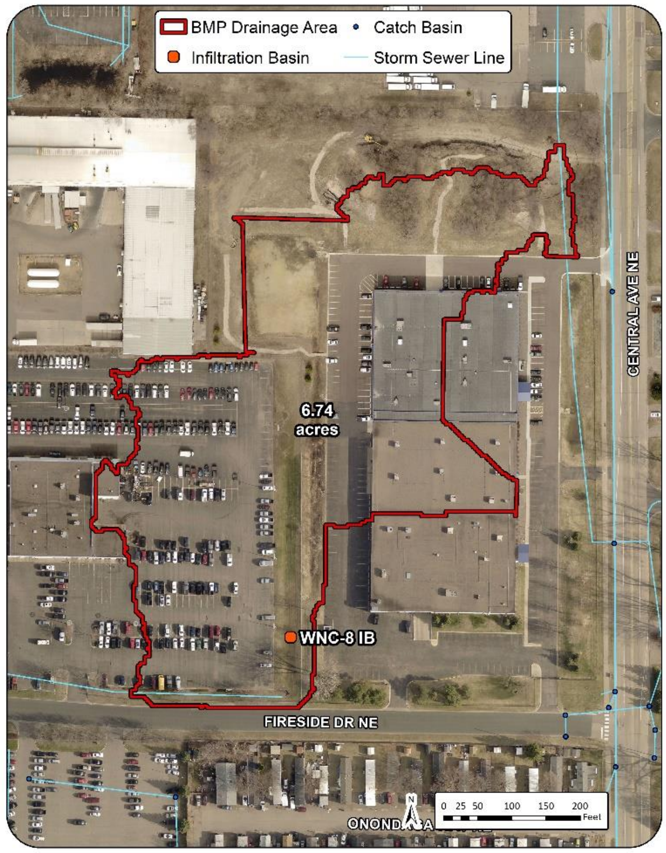
EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Project ID: WNC-8 IB

Friendly Chevrolet Campus Infiltration Basin

Drainage Area – 6.74 acres
Location – East side of Friendly Chevrolet campus parking lot
Property Ownership – Private
Site Specific Information – A large infiltration basin exists on the east side of the Friendly Chevrolet campus. A riser on the outlet structure is proposed to increase the ponding depth to 15". The table below provides pollutant removals and estimated costs.



	Infiltration Basin Retrofit		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMPs**	12,000	sq-ft
	TP (lb/yr)	0.14	0.3%
	TSS (lb/yr)	63	0.3%
	Volume (acre-feet/yr)	0.3	0.5%
Cost	**Administration & Promotion Costs***		$584
	Design & Construction Costs**		$6,420
	Total Estimated Project Cost (2021)		**$7,004**
	Annual O&M***		$0
Efficiency	**30-yr Average Cost/lb-TP**	**$1,668**	
	30-yr Average Cost/1,000lb-TSS	**$3,706**	
	30-yr Average Cost/ac-ft Vol.	**$847**	

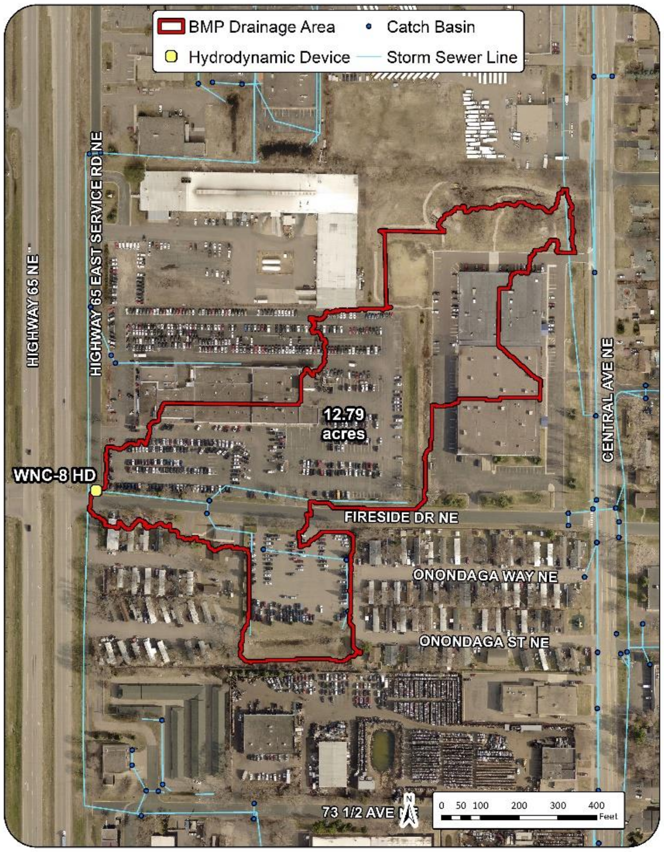
*Indirect Cost: (8 hours at $73/hour base cost)

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

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

Project ID: WNC-8 HD

Highway 65 and Fireside Dr.
Hydrodynamic Device



Drainage Area – 12.79 acres
Location – Intersection between Highway 65 and Fireside Dr. NE.
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on Fireside Dr. NE. This hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The table below provides pollutant removals and estimated costs.

Hydrodynamic Device			
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	10	ft diameter
	TP (lb/yr)	0.53	1.2%
	TSS (lb/yr)	299	1.5%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***		$3,750
	Design & Construction Costs**		$108,000
	Total Estimated Project Cost (2021)		**$111,750**
	Annual O&M***		$630
Efficiency	**30-yr Average Cost/lb-TP**	**$8,217**	
	30-yr Average Cost/1,000lb-TSS	**$14,565**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

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

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

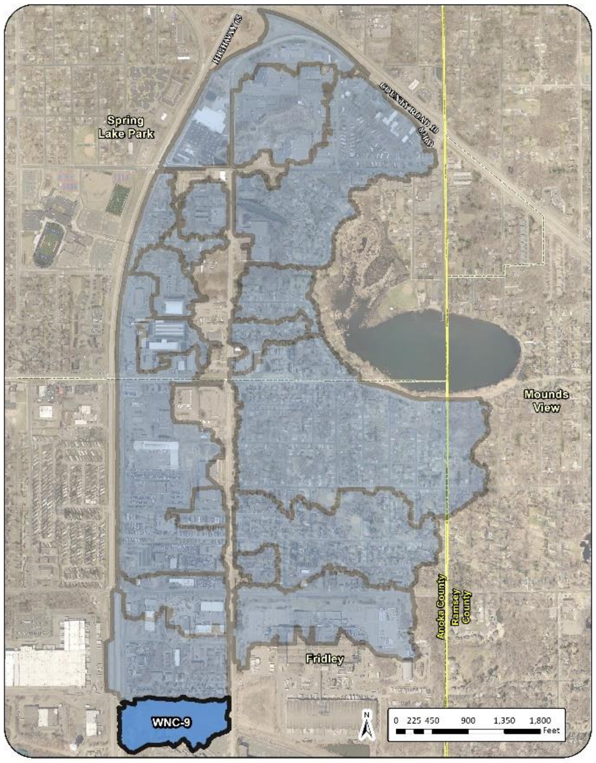
Project ID: WNC-8 BF/BI

Multiple Locations
Bioretention Basins

Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See 'Residential Bioretention Comparison' in the 'BMP Descriptions' section for additional details and estimated benefits and cost-effectiveness.

Catchment WNC-9

Existing Catchment Summary	
Acres	17.3
Parcels	2
Land Cover	92.2% Industrial 7.2% Freeway 0.6% Residential



CATCHMENT DESCRIPTION

Catchment WNC-9 includes the northern extent of the Medtronic Rice Creek West campus in the City of Fridley. Stormwater runoff flows from east to west, and land use is predominantly industrial.

EXISTING STORMWATER TREATMENT

One wet pond and one infiltration are present on the campus in addition to the street cleaning conducted by the City of Fridley three times per year. 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	Street Cleaning, Wet Pond, Infiltration Basin			
	TP (lb/yr)	13.4	3.3	25%	**10.0**
	TSS (lb/yr)	8,158	2,735	34%	**5,423**
	Volume (acre-feet/yr)	15.9	0.0	0%	**15.6**

RETROFIT OPPORTUNITIES OVERVIEW

One infiltration basin is proposed to treat runoff generated by the parking lots north of the railroad tracks on the campus.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES

Project ID: WNC-9 BR

Medtronic Rice Creek West Bioretention Basin

Drainage Area – 4.52 acres
Location – West side of northern parking lots on the Medtronic Rice Creek West campus
Property Ownership – Private
Site Specific Information – An infiltration basin is proposed to treat runoff that flows from east to west within the parking lots on the north portion of the campus. Multiple options were modeled to provide options for a variety of soil types that may be found. The table below provides pollutant removals and estimated costs.

	Curb-Cut Bioretention						
	Cost/Removal Analysis	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**
Treatment		**Sandy Soils - 12" BI**		**Silty Soils - 9" BI**		**HPMBS**	
	Total Size of BMPs	1,000	sq-ft	1,000	sq-ft	100	sq-ft
	TP (lb/yr)	1.17	11.7%	0.30	3.0%	0.0	0.0%
	TSS (lb/yr)	615	11.3%	153	2.8%	316	5.8%
	Volume (acre-feet/yr)	2.28	14.6%	0.65	4.2%	0.00	0.0%
Cost	**Administration & Promotion Costs***	$584		$584		$584	
	Design & Construction Costs**	$28,920		$28,920		$32,920	
	Total Estimated Project Cost (2021)	**$29,504**		**$29,504**		**$33,504**	
	Annual O&M***	$225		$225		$742	
Efficiency	**30-yr Average Cost/lb-TP**	**$1,032**		**$3,975**		**n/a**	
	30-yr Average Cost/1,000lb-TSS	**$1,965**		**$7,898**		**$5,881**	
	30-yr Average Cost/ac-ft Vol.	**$530**		**$1,863**		**n/a**	

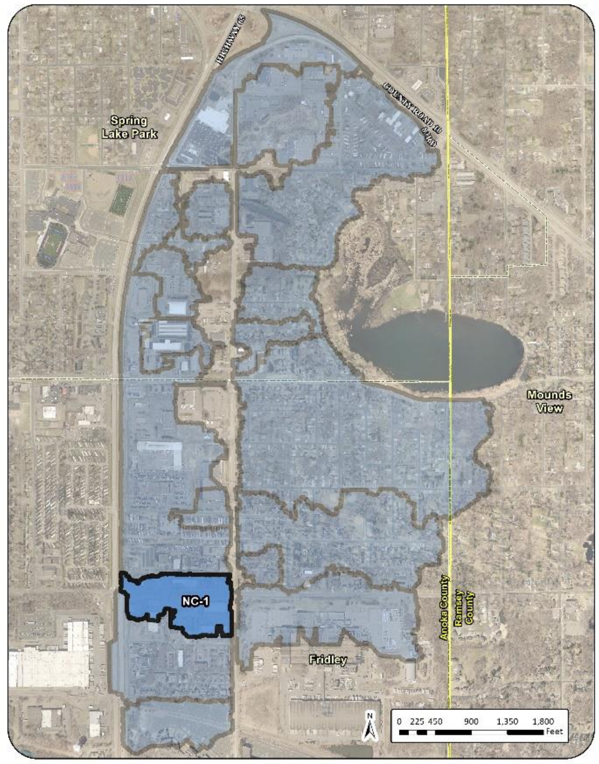
*Indirect Cost: (8 hours at $73/hour base cost)

**Direct Cost: ($26/sq-ft for materials and labor) + (40 hours at $73/hour for design)

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

Catchment NC-1

Existing Catchment Summary	
Acres	19.4
Parcels	18
Land Cover	87.1% Industrial 10.3% Shopping 2.2% Freeway 0.4% Open Space



CATCHMENT DESCRIPTION

Catchment NC-1 is centered along 73rd Ave. NE in the City of Fridley. This catchment includes the convergence of the ENC and WNC catchments into a single line that flows south to Rice Creek. Land use within the catchment is predominantly industrial.

EXISTING STORMWATER TREATMENT

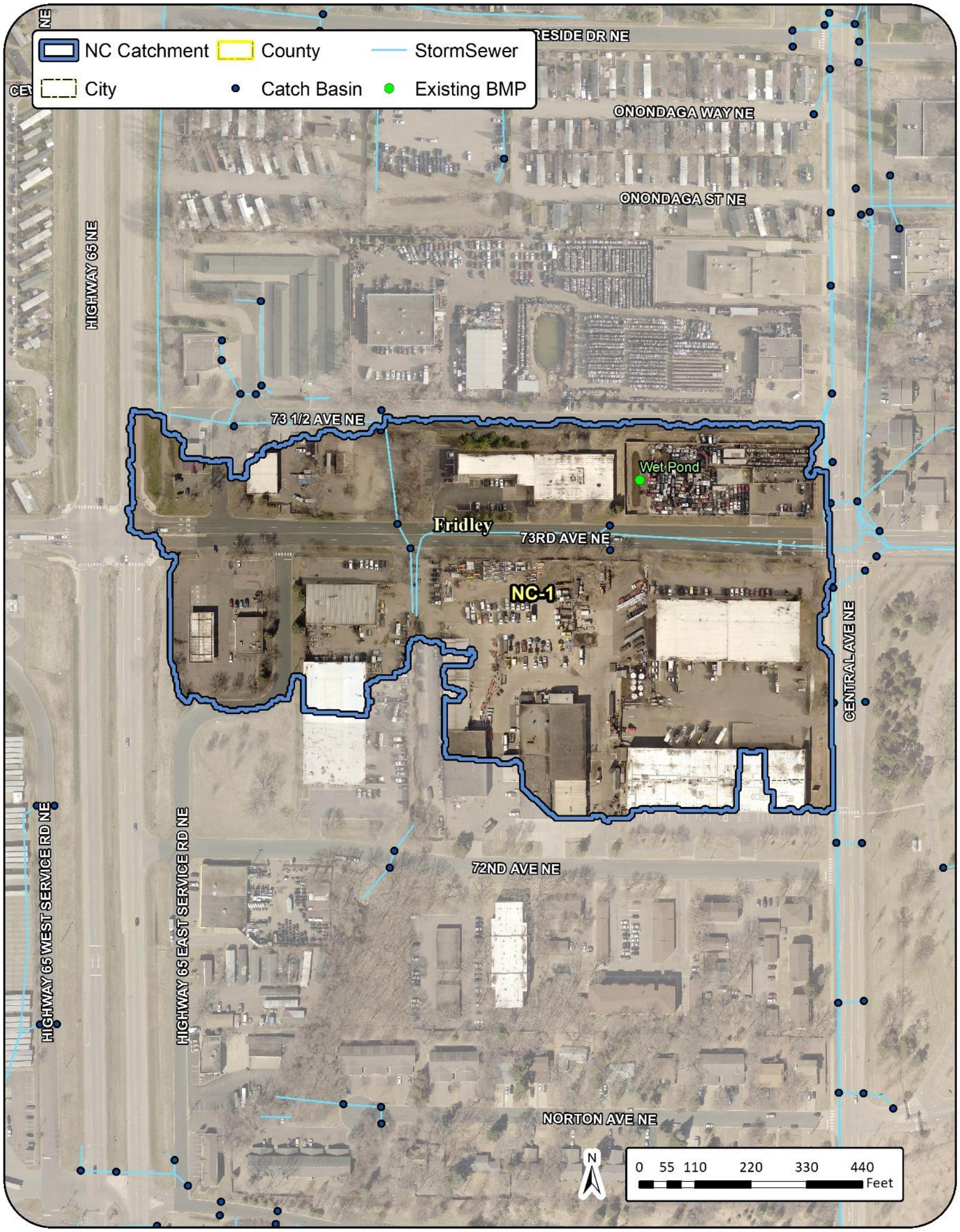
One wet pond is present on the west side of the Sam's Auto Parts campus, and the City of Fridley conducts street cleaning three times per year. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	2			
	BMP Types	Street Cleaning, Wet Pond			
	TP (lb/yr)	16.0	1.0	6%	**15.0**
	TSS (lb/yr)	9,449	832	9%	**8,617**
	Volume (acre-feet/yr)	19.3	0.0	0%	**19.3**

RETROFIT OPPORTUNITIES OVERVIEW

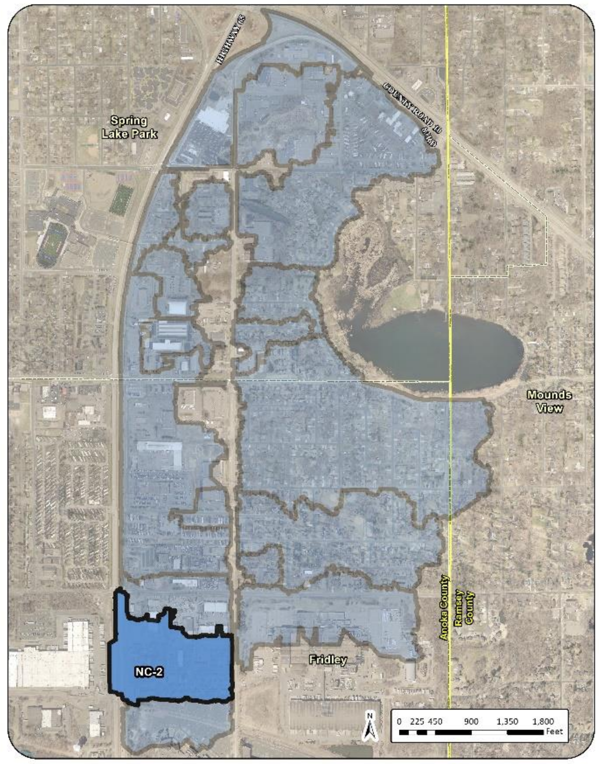
No stormwater retrofits are recommended for this catchment because of the limited space.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Catchment NC-2

Existing Catchment Summary	
Acres	33.4
Parcels	73
Land Cover	46.9% Residential 18.2% Industrial 17.8% Freeway 12.0% Shopping 4.0% Open Space 1.1% Office Park



CATCHMENT DESCRIPTION

Catchment NC-2 is in the City of Fridley and includes the only open channel section of Norton Creek. Norton Creek flows from north to south in the center of the catchment, and stormwater is routed to the channel from both sides of the catchment. Land use is predominantly residential, but industrial, freeway, and commercial shopping also comprise a significant amount of the catchment.

EXISTING STORMWATER TREATMENT

Bioswales along Highway 65, two infiltration basins, and street cleaning conducted by the City of Fridley three times per year provide the existing stormwater treatment in the 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	6			
	BMP Types	Street Cleaning, Road Swale (3), Infiltration Basin (2)			
	TP (lb/yr)	26.3	5.5	21%	**20.8**
	TSS (lb/yr)	10,971	2,342	21%	**8,629**
	Volume (acre-feet/yr)	28.4	4.0	14%	**24.4**

RETROFIT OPPORTUNITIES OVERVIEW

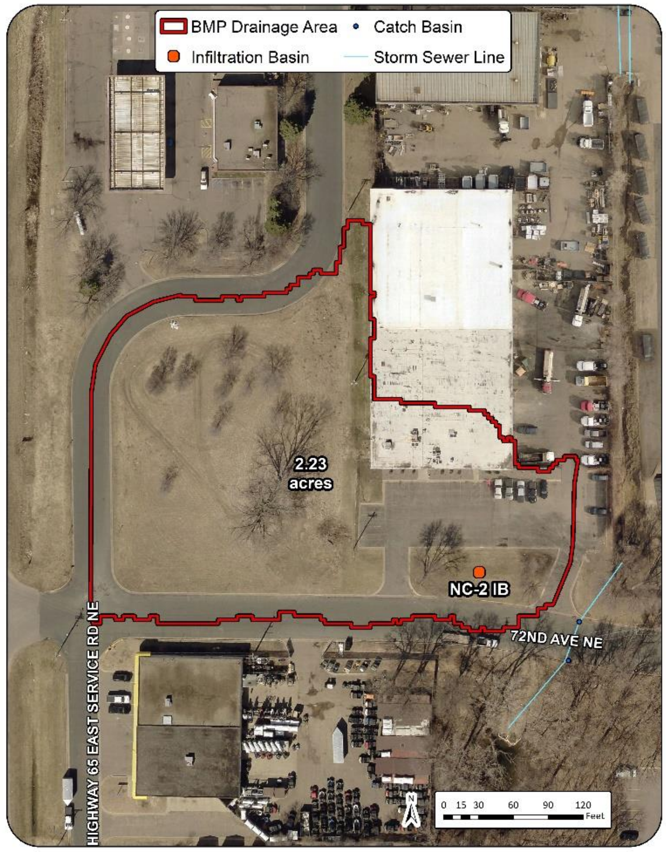
A total of six retrofits are proposed in catchment NC-2 including one hydrodynamic device, three bioretention basins, one infiltration basin, and a streambank stabilization. The hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The bioretention basins were sited to maximize contributing drainage areas and at properties with sufficient space and slope to accommodate a basin. For the bioretention practices, underlying soils will determine whether biofiltration or bioinfiltration practices could be installed. The proposed bioretention locations adjacent to catch basins were shown as biofiltration practices to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES

Project ID: NC-2 IB

Hydraulic Specialty Property Infiltration Basin Retrofit

Drainage Area – 2.23 acres
Location – South side of Hydraulic Specialty, Inc. property along 72nd Ave. NE
Property Ownership – Private
Site Specific Information – The existing infiltration basin is proposed to be retrofit with curb-cut to receive additional road runoff and a riser to increase ponding depth to 24". The table below provides pollutant removals and estimated costs.



	Infiltration Basin Retrofit		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMPs**	0.06	acres
	TP (lb/yr)	0.10	0.5%
	TSS (lb/yr)	47	0.5%
	Volume (acre-feet/yr)	0.1	0.5%
Cost	**Administration & Promotion Costs***		$584
	Design & Construction Costs**		$6,420
	Total Estimated Project Cost (2021)		**$7,004**
	Annual O&M***		$63
Efficiency	**30-yr Average Cost/lb-TP**	**$2,965**	
	30-yr Average Cost/1,000lb-TSS	**$6,308**	
	30-yr Average Cost/ac-ft Vol.	**$2,583**	

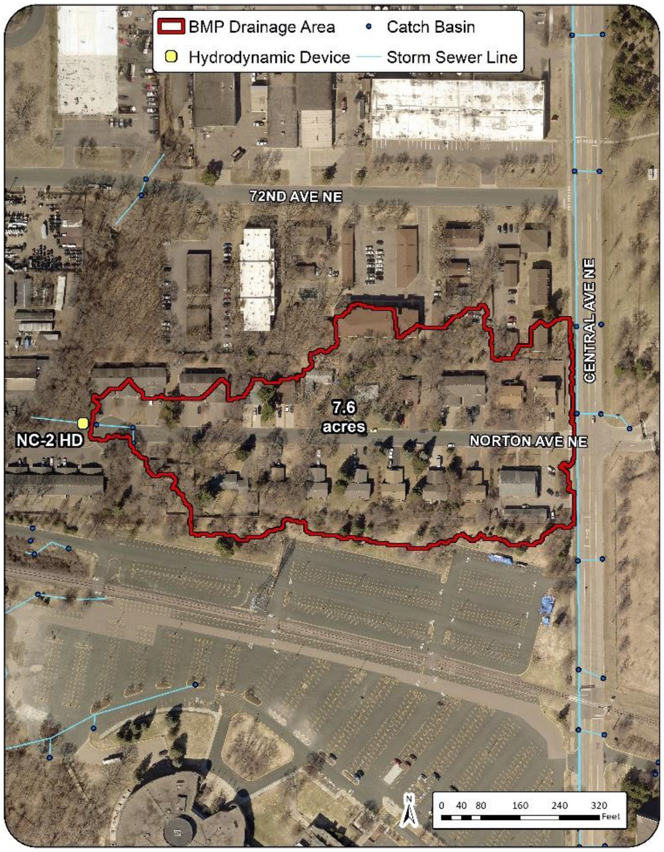
*Indirect Cost: (8 hours at $73/hour base cost)

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

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

Project ID: NC-2 HD

Norton Ave. NE
Hydrodynamic Device



Drainage Area – 7.6 acres
Location – Western extent of Norton Ave. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on Norton Ave. NE. This hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The proposed location is adjacent to the open channel portion of Norton Creek. The table below provides pollutant removals and estimated costs.

Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Total Size of BMP	8	ft diameter
Treatment	TP (lb/yr)	0.47	2.3%
Treatment	TSS (lb/yr)	228	2.6%
Treatment	Volume (acre-feet/yr)	n/a	n/a
Cost	Administration & Promotion Costs*		$3,750
Cost	Design & Construction Costs**		$54,000
Cost	Total Estimated Project Cost (2021)		**$57,750**
Cost	Annual O&M***		$630
Efficiency	30-yr Average Cost/lb-TP	**$5,436**	
Efficiency	30-yr Average Cost/1,000lb-TSS	**$11,206**	
Efficiency	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

**Direct Cost: ($36,000 for materials) + ($18,000 for labor and installation costs)

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

Project ID: NC-2 SS

Norton Creek Open Channel Streambank Stabilization

Drainage Area – N/A
Location – Open channel section of Norton Creek between 72nd Ave. NE and Norton Ave. NE
Property Ownership – Public and Private
Site Specific Information – Transitioning Norton Creek to a piped system has significantly altered hydrologic and hydraulic conditions. Increased flow rates within the channel have led to severe erosion along much of the open channel. The proposed stabilization assumes riprap on both sides of the approximately 500 linear foot channel. Existing pollutant loading assumed 500 linear feet of channel, both sides of the channel are eroding similarly, 2 ft. bank height, 0.1 ft/yr lateral recession rate, and 110 lbs-TSS/cubic-foot (i.e. 500' channel * 2 sides * 2' bank height * 0.1 ft/yr recession rate * 110 lbs-TSS/cubic-foot = 22,000 lbs-TSS; associated TP was estimated using the Board of Water and Soil Resources' Water Erosion Pollution Reduction Estimator). The tables below provide estimated existing pollutant loads and estimated pollutant removals and costs.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	0			
	BMP Types	n/a			
	TP (lb/yr)	9.4	0.0	0%	**9.4**
	TSS (lb/yr)	22,000	0	0%	**22,000**
	Volume (acre-feet/yr)	n/a	0.0	0%	**n/a**

Streambank Stabilization

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Total Size of BMPs	1,000	feet
	TP (lb/yr)	9.35	100.0%
	TSS (lb/yr)	22,000	100.0%
	Volume (acre-feet/yr)	n/a	n/a
Cost	Administration & Promotion Costs*	$7,300	
	Design & Construction Costs**	$175,000	
	Total Estimated Project Cost (2021)	**$182,300**	
	Annual O&M***	$1,460	
Efficiency	30-yr Average Cost/lb-TP	**$806**	
	30-yr Average Cost/1,000lb-TSS	**$343**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

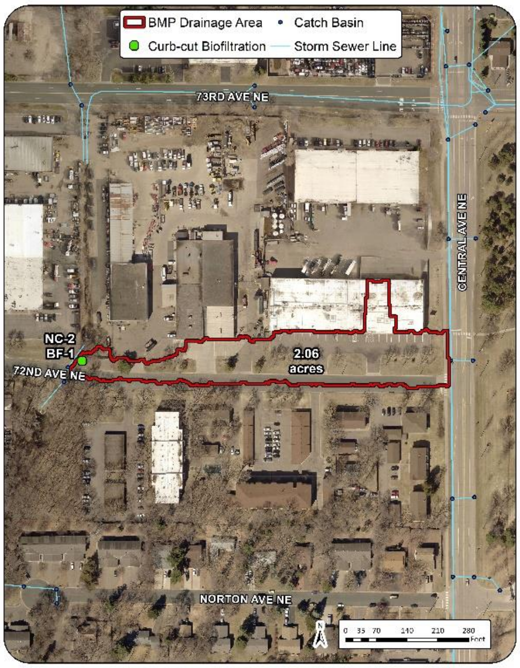
*Indirect Cost: (100 hours at $73/hour)

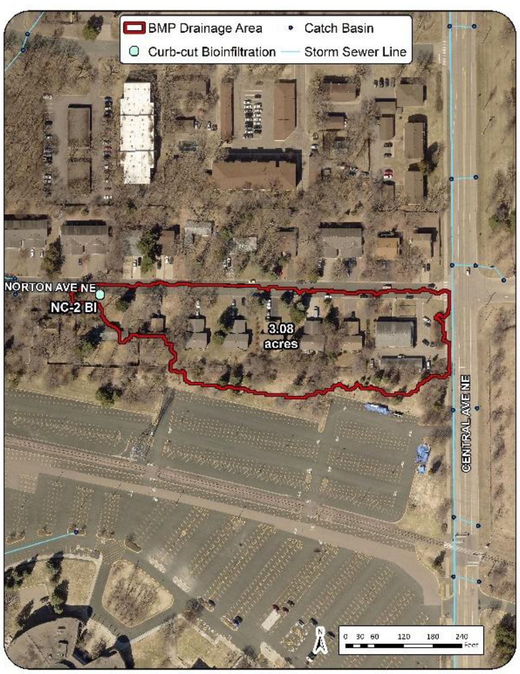
**Direct Cost: See Appendix B for detailed cost information

***20 hours/year at $73/hour - Annual inspection and vegetation management periodically

Project ID:
NC-2 BF/BI
Multiple Locations
Bioretention Basins

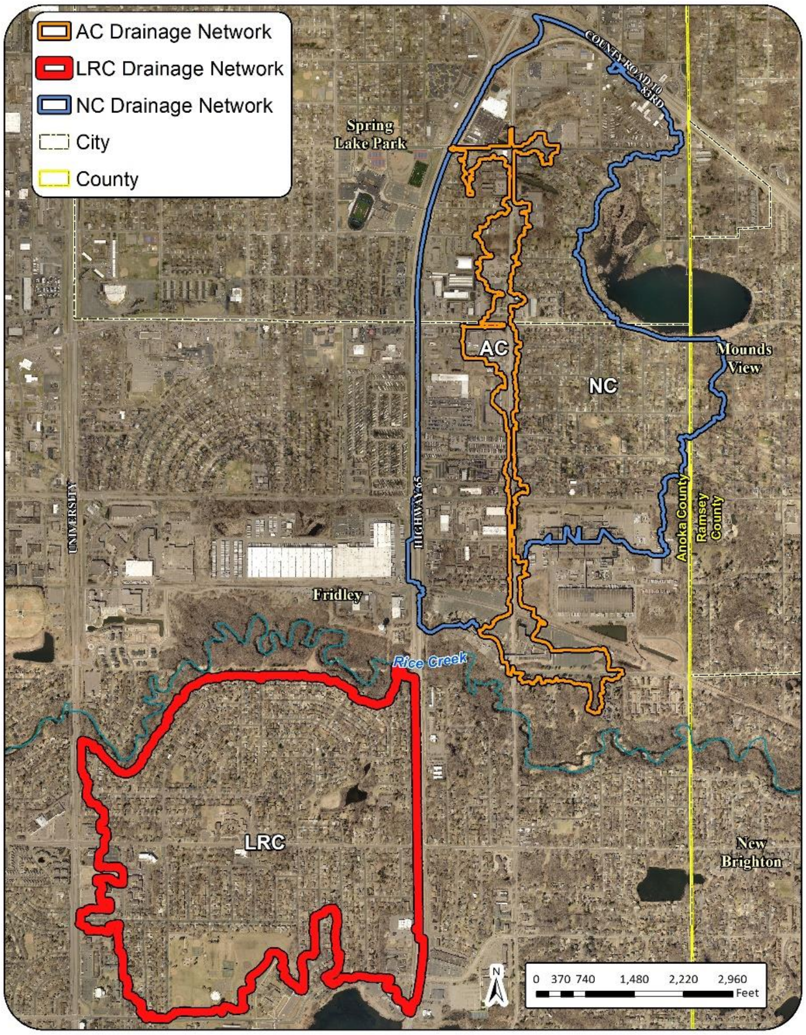
Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See ‘Residential Bioretention Comparison’ in the ‘BMP Descriptions’ section for additional details and estimated benefits and cost-effectiveness.





Lower Rice Creek Drainage Network

Existing Network Summary	
Acres	475
Dominant Land Cover	Residential
Volume (ac-ft/yr)	247
TP (lb/yr)	246
TSS (lb/yr)	72,998



DRAINAGE NETWORK SUMMARY

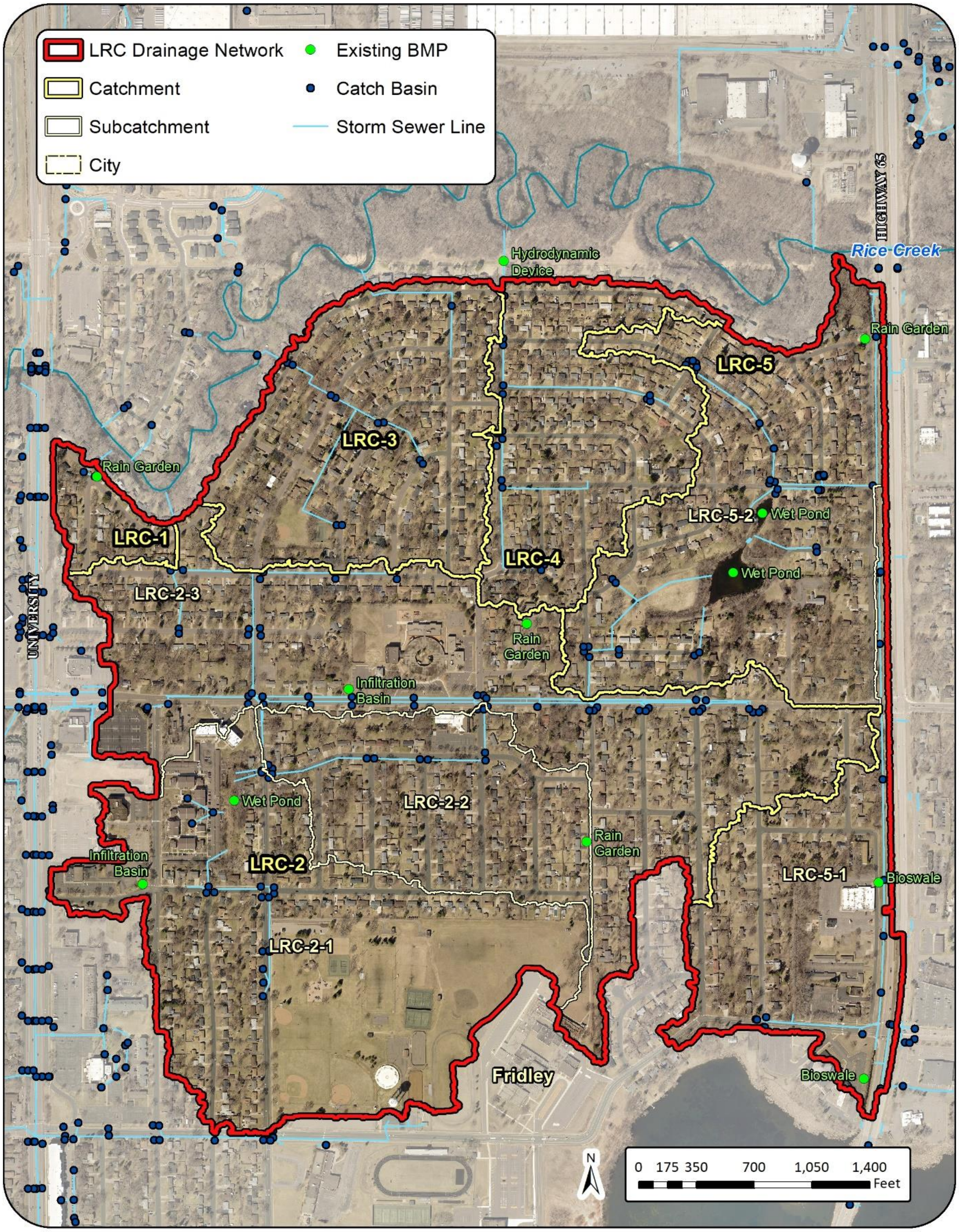
The Lower Rice Creek drainage network includes five catchments that each discharge to Rice Creek via a dedicated outfall. Catchment size varies from 8 acres up to 240 acres. The drainage network extends from Rice Creek in the north to 61st Ave. NE at the southern extent. It is bounded on the west by University Ave. NE and Highway 65 on the east.

Most of the drainage network is comprised of residential land use. Notable areas of the drainage network include Terrace Park and Meadowlands Park in the northern area, Hayes Elementary School in the center, and portions of Commons Park and Fridley Middle School in the south.

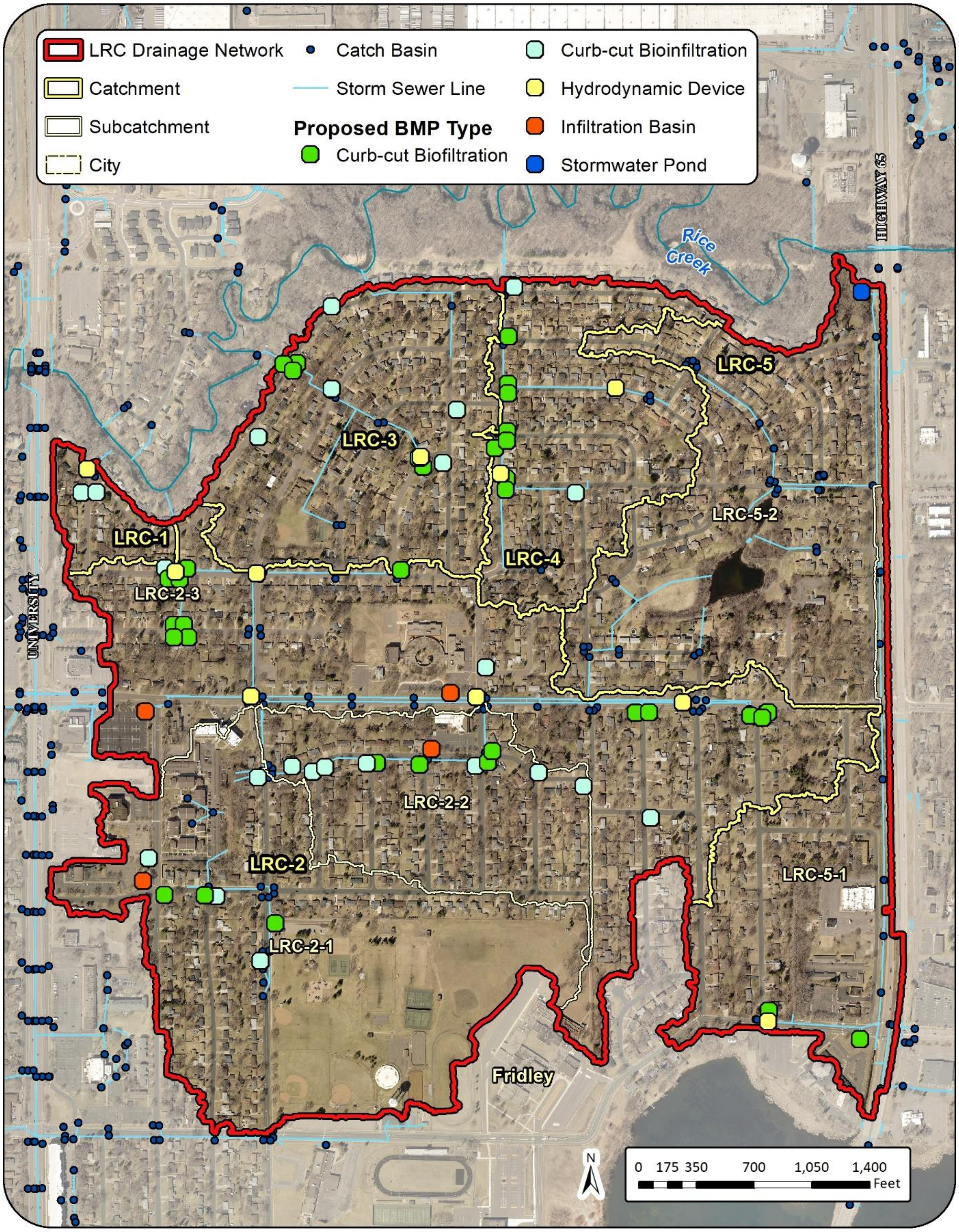
EXISTING STORMWATER TREATMENT

Existing treatment consists of wet ponds and infiltration basins scattered throughout the catchments. The City of Fridley and the City of Spring Lake Park also conduct street cleaning three times per year. Additional detail is provided in the Catchment Profiles.

NETWORK EXISTING STORMWATER TREATMENT

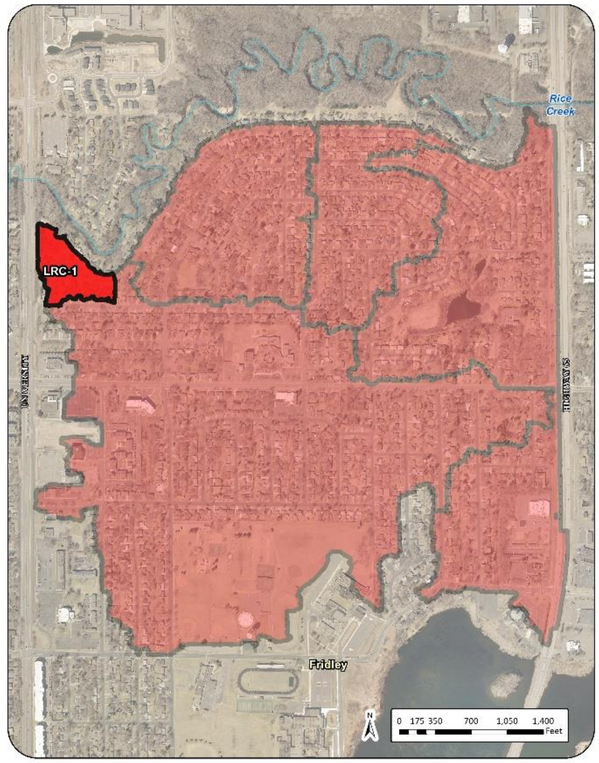


NETWORK RETROFIT OPPORTUNITIES



Catchment LRC-1

Existing Catchment Summary	
Acres	7.8
Parcels	29
Land Cover	100% Residential



CATCHMENT DESCRIPTION

Catchment LRC-1 is located in the City of Fridley just east of University Ave. NE and on the south side of Rice Creek. Stormwater runoff drains from south to north prior to being piped via a single outfall to the creek. Land use is entirely residential.

EXISTING STORMWATER TREATMENT

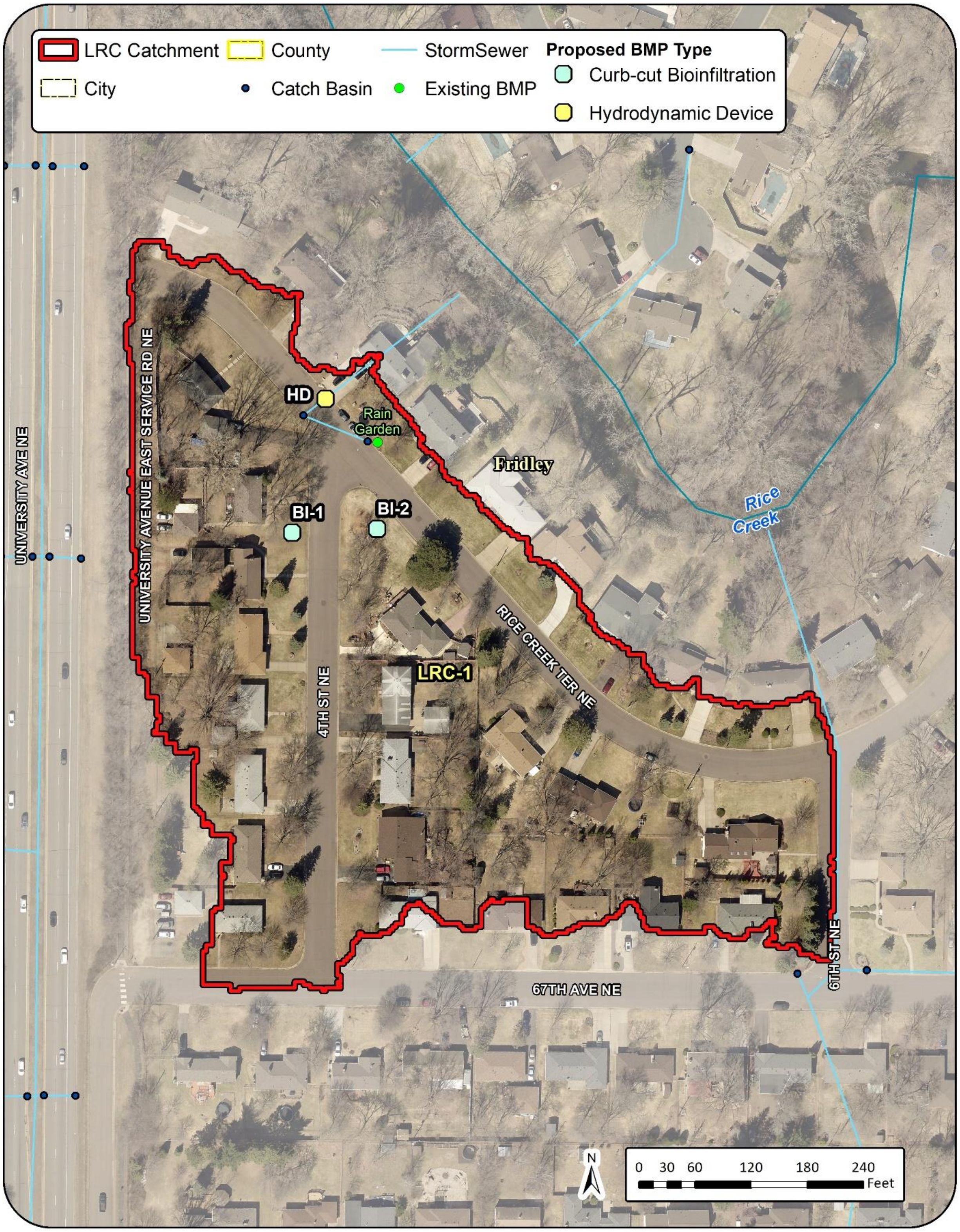
The primary stormwater treatment in the catchment is street cleaning, which is conducted by the City of Fridley three times per year. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	4.3	0.5	12%	**3.8**
	TSS (lb/yr)	1,361	206	15%	**1,155**
	Volume (acre-feet/yr)	3.1	0.1	3%	**3.0**

RETROFIT OPPORTUNITIES OVERVIEW

One hydrodynamic device and two bioretention basins are proposed in catchment LRC-1. The hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The bioretention basins were sited to maximize contributing drainage areas and at properties with sufficient space and slope to accommodate a basin. For the bioretention practices, underlying soils will determine whether biofiltration or bioinfiltration practices could be installed. The proposed bioretention locations adjacent to catch basins were shown as biofiltration practices to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Project ID: LRC-1 HD

4th St. and Rice Creek Terrace Hydrodynamic Device

Drainage Area – 7.79 acres
Location – Intersection of 4th St. NE and Rice Creek Terrace NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on Rice Creek Terrace NE. This hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The table below provides pollutant removals and estimated costs.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	8	ft diameter
	TP (lb/yr)	0.40	10.4%
	TSS (lb/yr)	160	13.8%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***	$3,750	
	Design & Construction Costs**	$54,000	
	Total Estimated Project Cost (2021)	**$57,750**	
	Annual O&M***	$630	
Efficiency	**30-yr Average Cost/lb-TP**	**$6,388**	
	30-yr Average Cost/1,000lb-TSS	**$15,979**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

**Direct Cost: ($36,000 for materials) + ($18,000 for labor and installation costs)

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

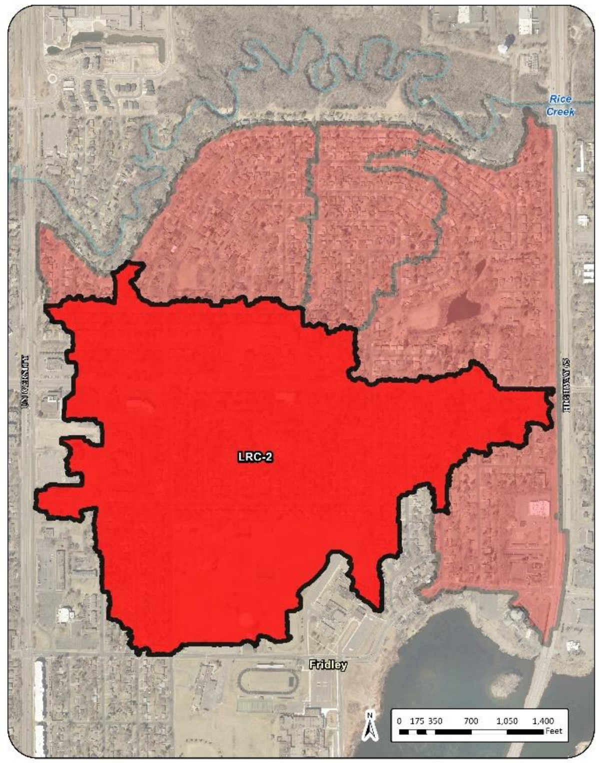
Project ID:
LRC-1 BI

Multiple Locations
Bioinfiltration Basins

Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioinfiltration exist throughout this catchment. See 'Residential Bioretention Comparison' in the 'BMP Descriptions' section for additional details and estimated benefits and cost-effectiveness.

Catchment LRC-2

Existing Catchment Summary	
Acres	239.8
Parcels	585
Land Cover	72.0% Residential 24.0% Institutional 2.6% Office Park 1.4% Shopping



CATCHMENT DESCRIPTION

This catchment is the largest in the Lower Rice Creek drainage network and is located in the City of Fridley. Land use within the catchment is primarily residential but significant areas of institutional land use are also present. Stormwater runoff is largely routed from south to north toward Rice Creek and discharges via a single outfall. The catchment was divided into three subcatchments, 2-1, 2-2, and 2-3. Retrofit opportunities are presented at the subcatchment scale in the following pages.

EXISTING STORMWATER TREATMENT

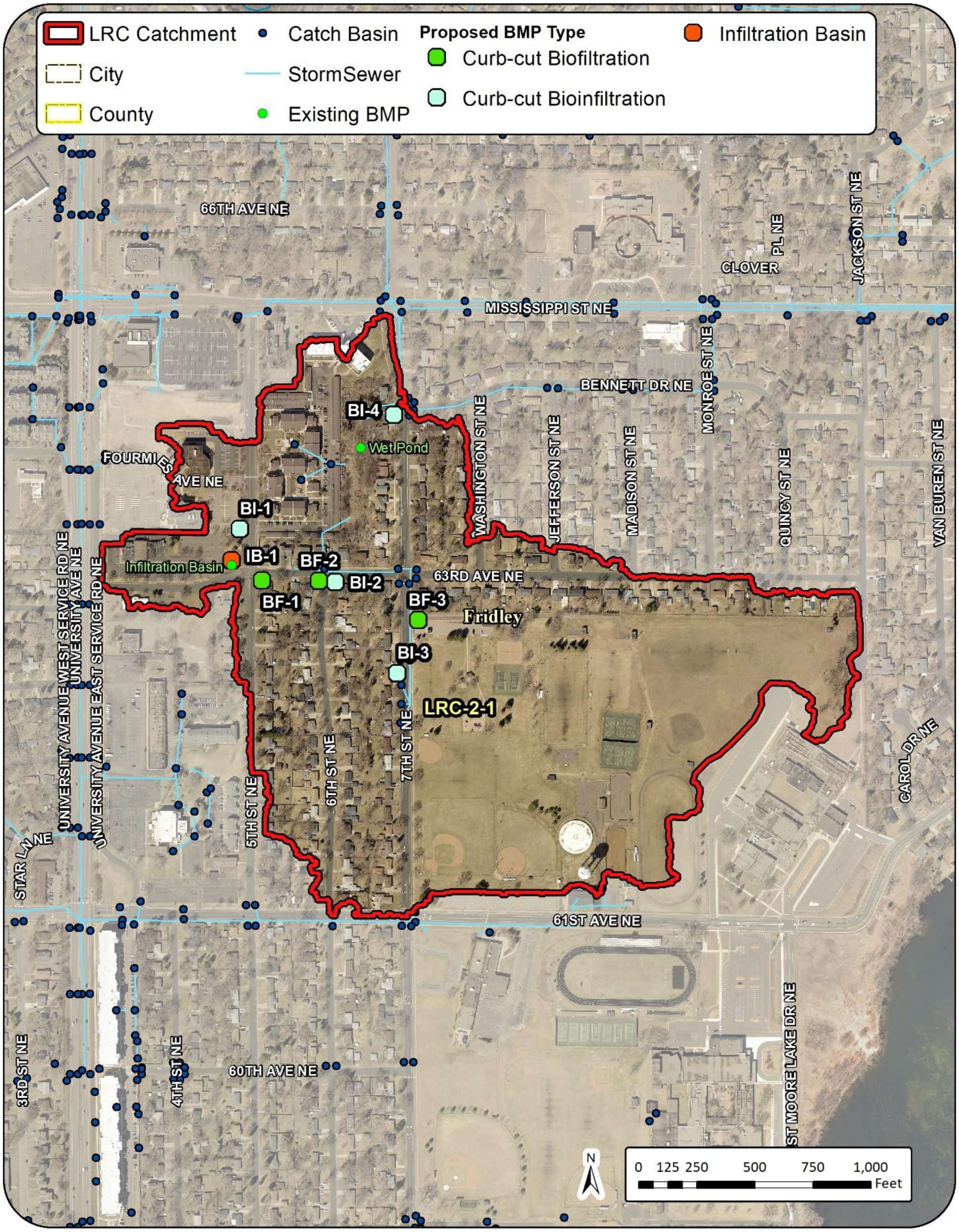
There are two curb-cut rain gardens, two infiltration basins, and one wet pond present in Catchment LRC-2. In addition, street cleaning is conducted three times per year by the City of Fridley. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning, Wet Pond, Infiltration Basin (2), Rain Garden (2)			
	TP (lb/yr)	5.4	0.3	6%	**5.1**
	TSS (lb/yr)	2,363	182	8%	**2,181**
	Volume (acre-feet/yr)	137.0	0.7	1%	**136.3**

RETROFIT OPPORTUNITIES OVERVIEW

A total of 43 retrofits are proposed in catchment LRC-2 including 5 hydrodynamic devices, 34 bioretention basins, two infiltration basins, and two infiltration basin retrofits. The hydrodynamic devices are positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The bioretention basins were sited to maximize contributing drainage areas and at properties with sufficient space and slope to accommodate a basin. For the bioretention practices, underlying soils will determine whether biofiltration or bioinfiltration practices could be installed. The proposed bioretention locations adjacent to catch basins were shown as biofiltration practices to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES (SUBCATCHMENT 2-1)



Project ID: LRC-2-1 IB

Wells Fargo Parking Lot Infiltration Basin

Drainage Area – 1.48 acres
Location – Eastern side of Wells Fargo campus parking lot near the corner of 63rd Ave. NE and 5th St. NE
Property Ownership – Private
Site Specific Information – An infiltration basin is proposed on the Wells Fargo property that could provide treatment for most of the parking lot. The table below provides pollutant removals and estimated costs.

Infiltration Basin

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment		Sandy Soils - 12" IB	
	Total Size of BMPs	600	sq-ft
	TP (lb/yr)	0.10	2.0%
	TSS (lb/yr)	49	2.2%
	Volume (acre-feet/yr)	0.30	0.2%
Cost	Administration & Promotion Costs*	$584	
	Design & Construction Costs**	$18,520	
	Total Estimated Project Cost (2021)	**$19,104**	
	Annual O&M***	$225	
Efficiency	30-yr Average Cost/lb-TP	**$8,618**	
	30-yr Average Cost/1,000lb-TSS	**$17,588**	
	30-yr Average Cost/ac-ft Vol.	**$2,888**	

*Indirect Cost: (8 hours at $73/hour base cost)

**Direct Cost: ($26/sq-ft for materials and labor) + (40 hours at $73/hour for design)

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

Project ID: LRC-2-1 BF-3

Commons Park Parking Lot
HPMBS Basin

Drainage Area – 19.7 acres
Location – Northwest corner of Commons Park within the public parking lot
Property Ownership – Public
Site Specific Information – A bioretention basin is proposed in the public parking lot at the northwest corner of Commons Park along 7th St. NE. Because of limited space, a HPMBS is proposed. The table below provides pollutant removals and estimated costs.

Parking Lot HPMBS

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Total Size of BMP	100	sq-ft
	TP (lb/yr)	0.0	0.0%
	TSS (lb/yr)	118	5.4%
	Volume (acre-feet/yr)	0.00	0.0%
Cost	Administration & Promotion Costs*		$584
	Design & Construction Costs**		$22,920
	Total Estimated Project Cost (2021)		**$23,504**
	Annual O&M***		$742
Efficiency	30-yr Average Cost/lb-TP	n/a	
	30-yr Average Cost/1,000lb-TSS	$12,925	
	30-yr Average Cost/ac-ft Vol.	n/a	

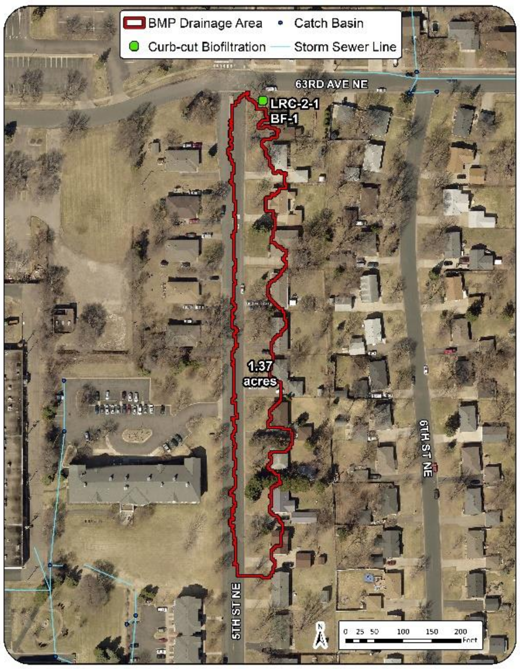
*Indirect Cost: (8 hours at $73/hour base cost)

**Direct Cost: ($200/sq-ft materials and labor) + (40 hours at $73/hour design)

***Per BMP: ($200/sq-ft at year 15 for media replacement) + ($75/year for routine maintenance)

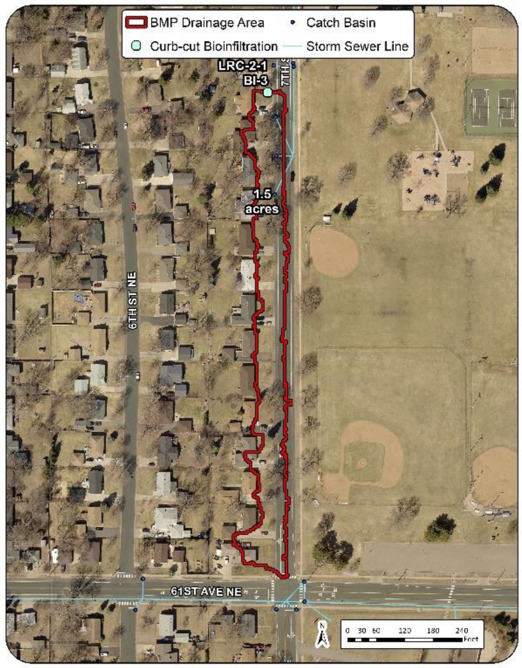
Project ID:
LRC-2-1 BF/BI
Multiple Locations
Bioretention Basins

Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See catchment-specific ranking tables below for estimated benefits and cost-effectiveness.



Project ID: LRC-2-1 BF/BI

Multiple Locations
Bioretention Basins



Project ID: LRC-2-1 BF/BI

Multiple Locations
Bioretention Basins

LRC-2-1 site-specific bioretention volume and pollutant removals were modeled separately because of the presence of Village Green Pond, which is a regional treatment practice that overlaps with the proposed bioretention basins.

Drainage Area (acres)	***LRC-2-1 Site-Specific Bioretention Basin Type***											
	12" Biofiltration w/ underdrain			12" Bioinfiltration			9" Bioinfiltration			12" HPMBS*		
	250 sq-ft top area			250 sq-ft top area			250 sq-ft top area			100 sq-ft top area		
	TP (lbs)	TSS (lbs)	Vol (cu-ft)	TP (lbs)	TSS (lbs)	Vol (cu-ft)	TP (lbs)	TSS (lbs)	Vol (cu-ft)	TP (lbs)	TSS (lbs)	Vol (cu-ft)
0.5	0.04 0.1%	15.00 0.1%	14000 0.5%	0.14 0.4%	38.00 0.4%	20000 0.68%	0.08 0.2%	22.00 0.2%	4564 52.2%	0.0 0.0%	13.00 0.1%	0.0 0.0%
1	0.07 0.2%	24.00 0.2%	14000 0.5%	0.22 0.6%	59.00 0.5%	24000 0.8%	0.10 0.3%	27.00 0.3%	5745 32.9%	0.0 0.0%	26.00 0.2%	0.0 0.0%
2	0.10 0.3%	33.00 0.3%	15000 0.5%	0.29 0.7%	78.00 0.7%	28000 1.0%	0.10 0.3%	27.00 0.3%	6465 18.5%	0.0 0.0%	54.00 0.5%	0.0 0.0%
3	0.11 0.3%	38.00 0.4%	15000 0.5%	0.33 0.8%	86.00 0.8%	31000 1.1%	0.10 0.3%	27.00 0.3%	6607 12.6%	0.0 0.0%	79.00 0.7%	0.0 0.0%
4	0.11 0.3%	40.00 0.4%	15000 0.5%	0.34 0.9%	89.00 0.8%	32000 1.1%	0.10 0.3%	26.00 0.2%	6696 9.6%	0.0 0.0%	103.00 1.0%	0.0 0.0%
5	0.11 0.3%	41.00 0.4%	15000 0.5%	0.36 0.9%	92.00 0.9%	33000 1.1%	0.10 0.3%	25.00 0.2%	6788 7.8%	0.0 0.0%	118.00 1.1%	0.0 0.0%
7.5	0.12 0.3%	42.00 0.4%	15000 0.5%	0.37 1.0%	94.00 0.9%	35000 1.2%	0.10 0.3%	25.00 0.2%	6788 7.8%	0.0 0.0%	147.00 1.4%	0.0 0.0%

**High-Performance Modular Biofiltration System*

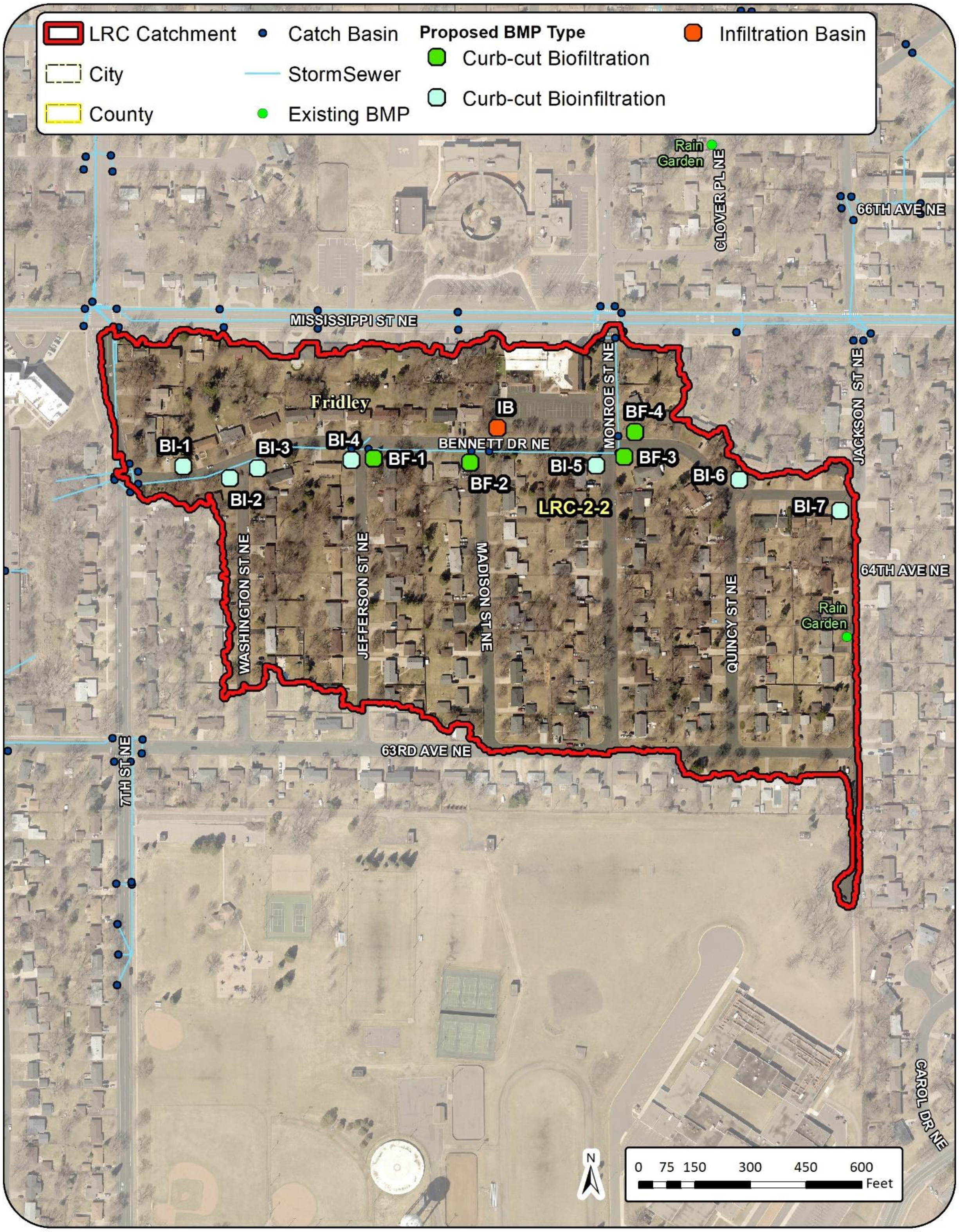
Project ID: LRC-2-1 BF/BI

Multiple Locations
Bioretention Basins

Drainage Area (acres)	LRC-2-1 Site-Specific Bioretention Basin Type											
	12" Biofiltration w/ underdrain			12" Bioinfiltration			9" Bioinfiltration			12" HPMBS*		
	250 sq-ft top area			250 sq-ft top area			250 sq-ft top area			100 sq-ft top area		
	Cost/ lb-TP	Cost/ 1,000 lbs-TSS	Cost/ ac-ft-Vol	Cost/ lb-TP	Cost/ 1,000 lbs-TSS	Cost/ ac-ft-Vol	Cost/ lb-TP	Cost/ 1,000 lbs-TSS	Cost/ ac-ft-Vol	Cost/ lb-TP	Cost/ 1,000 lbs-TSS	Cost/ ac-ft-Vol
0.5	$17,378	$46,342	$2,163	$3,989	$14,696	$1,216	$6,981	$25,385	$1,431	-	$117,344	-
1	$9,930	$28,964	$2,163	$2,538	$9,466	$1,014	$5,585	$20,684	$1,351	-	$58,672	-
2	$6,951	$21,065	$2,019	$1,926	$7,160	$869	$5,585	$20,684	$1,280	-	$28,249	-
3	$6,319	$18,293	$2,019	$1,692	$6,494	$785	$5,585	$20,684	$1,280	-	$19,310	-
4	$6,319	$17,378	$2,019	$1,643	$6,275	$760	$5,585	$21,479	$1,280	-	$14,810	-
5	$6,319	$16,954	$2,019	$1,551	$6,070	$737	$5,585	$22,339	$1,216	-	$12,928	-
7.5	$5,793	$16,551	$2,019	$1,509	$5,941	$695	$5,585	$22,339	$1,216	-	$10,377	-

**High-Performance Modular Biofiltration System*

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES (SUBCATCHMENT 2-2)



Project ID: LRC-2-2 IB

Fridley United Methodist Church Infiltration Basin

Drainage Area – 0.93 acres
Location – Southwest corner of the Fridley United Methodist Church parking lot
Property Ownership – Private
Site Specific Information – An infiltration basin is proposed in the southwest corner of the parking lot that will treat runoff from the entire parking lot and a portion of the building. Scenarios for both sandy and silty soils were modeled, and the table below provides associated volume and pollutant removals and estimated costs.

Curb-Cut Bioinfiltration

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction
Treatment		Sandy Soils - 12" IB		Silty Soils - 9" IB	
	Total Size of BMPs	275	sq-ft	275	sq-ft
	TP (lb/yr)	0.40	7.9%	0.16	3.2%
	TSS (lb/yr)	168	7.7%	68	3.1%
	Volume (acre-feet/yr)	0.39	0.3%	0.20	0.1%
Cost	Administration & Promotion Costs*	$584		$584	
	Design & Construction Costs**	$10,070		$10,070	
	Total Estimated Project Cost (2021)	**$10,654**		**$10,654**	
	Annual O&M***	$225		$225	
Efficiency	30-yr Average Cost/lb-TP	**$1,450**		**$3,610**	
	30-yr Average Cost/1,000lb-TSS	**$3,453**		**$8,531**	
	30-yr Average Cost/ac-ft Vol.	**$1,487**		**$2,901**	

*Indirect Cost: (8 hours at $73/hour base cost)

**Direct Cost: ($26/sq-ft for materials and labor) + (40 hours at $73/hour for design)

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

Project ID: LRC-2-2 BF/BI

Multiple Locations
Bioretention Basins

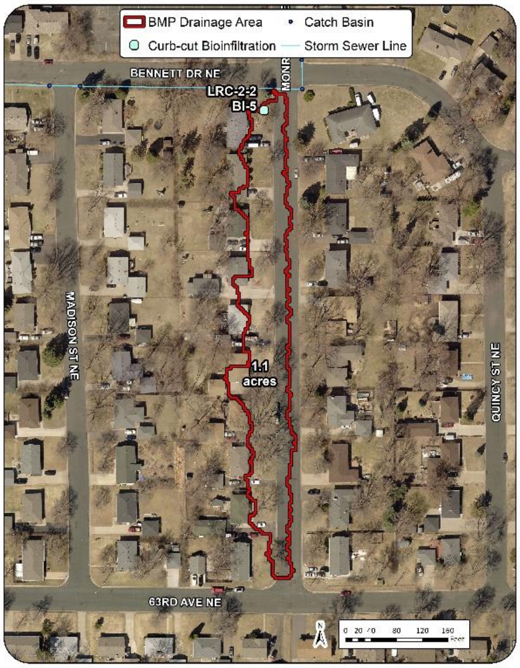
Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See 'Residential Bioretention Comparison' in the 'BMP Descriptions' section for additional details and estimated benefits and cost-effectiveness.

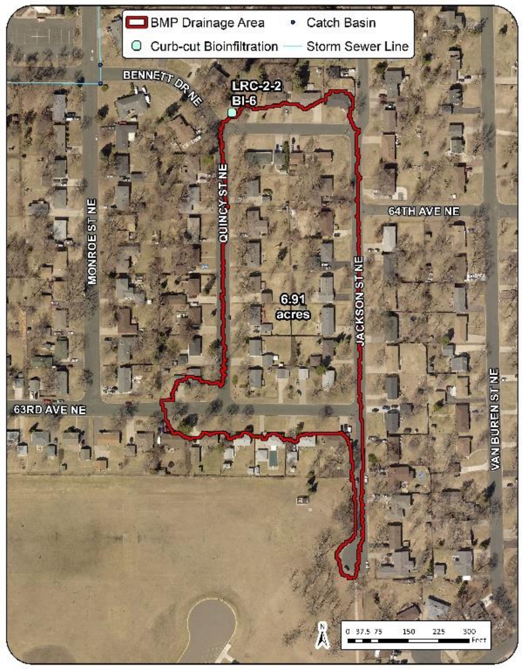
Project ID: LRC-2-2 BF/BI

Multiple Locations
Bioretention Basins

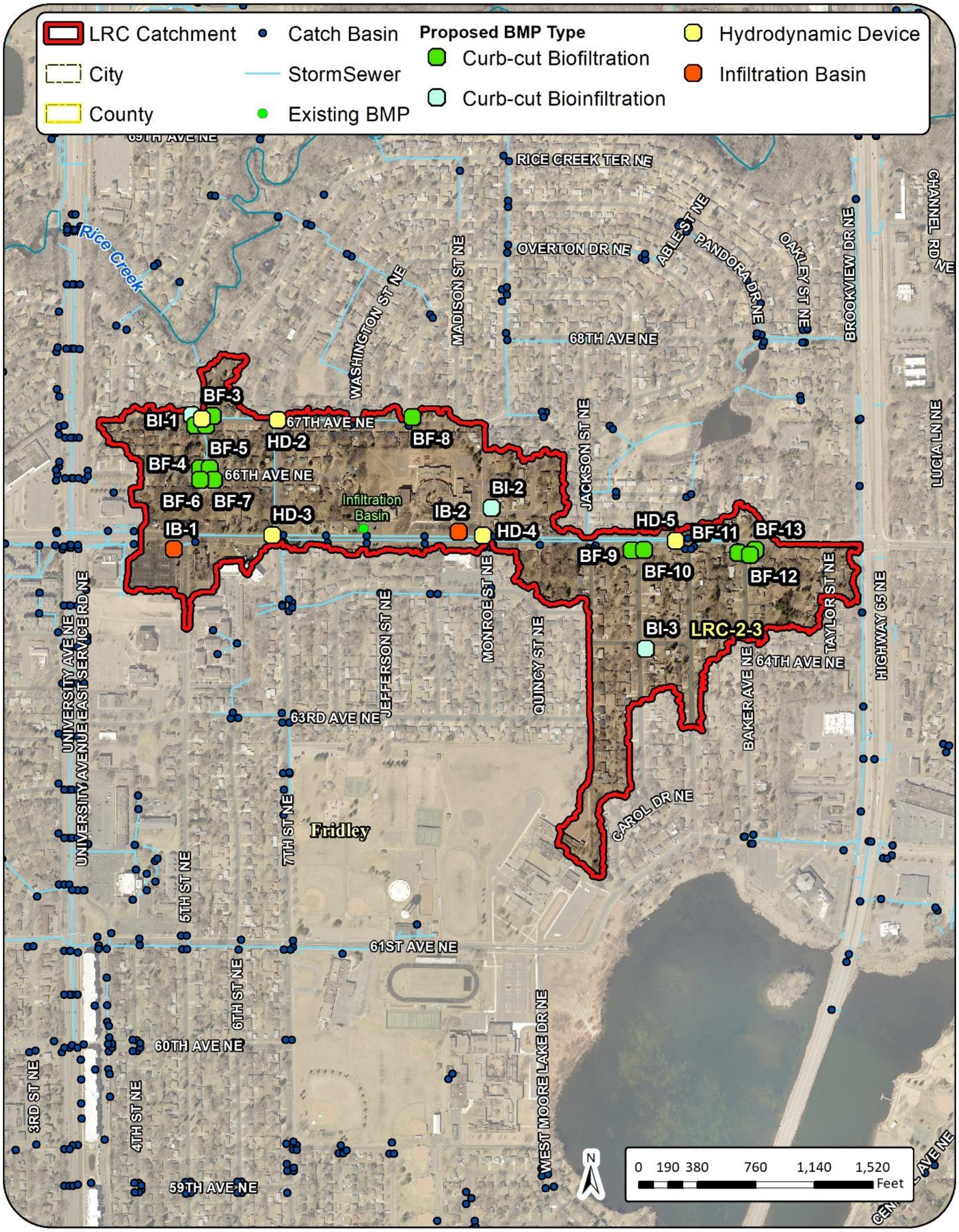
Project ID:
LRC-2-2 BF/BI

Multiple Locations
Bioretention Basins



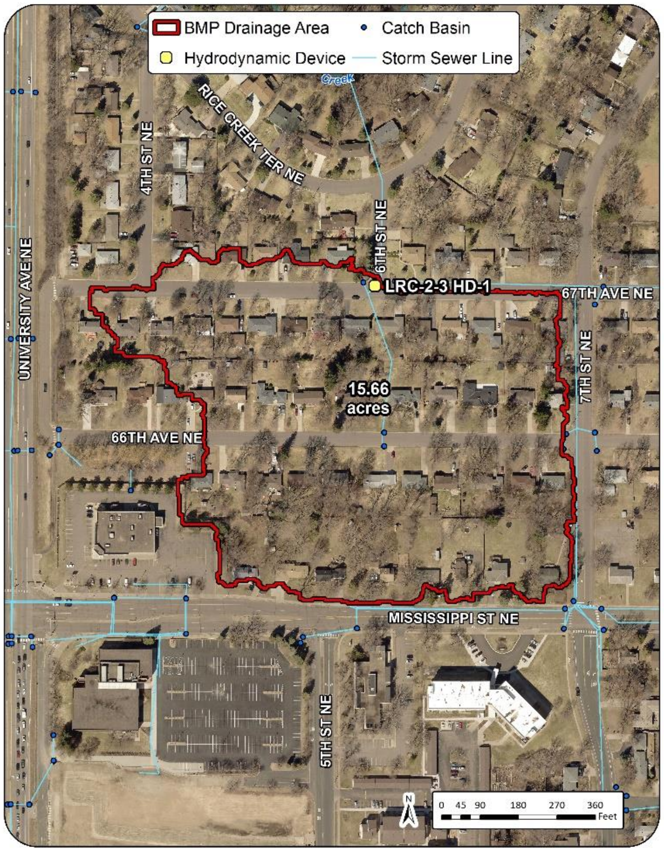


EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES (SUBCATCHMENT 2-3)



Project ID: LRC-2-3 HD-1

67th Ave. and 6th St.
Hydrodynamic Device



Drainage Area – 15.66 acres
Location – Intersection of 67th Ave. NE and 6th St. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on 67th Ave. NE. This hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The table below provides pollutant removals and estimated costs.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	10	ft diameter
	TP (lb/yr)	0.80	15.8%
	TSS (lb/yr)	303	13.9%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***	$3,750	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2021)	**$111,750**	
	Annual O&M***	$630	
Efficiency	**30-yr Average Cost/lb-TP**	**$5,444**	
	30-yr Average Cost/1,000lb-TSS	**$14,373**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

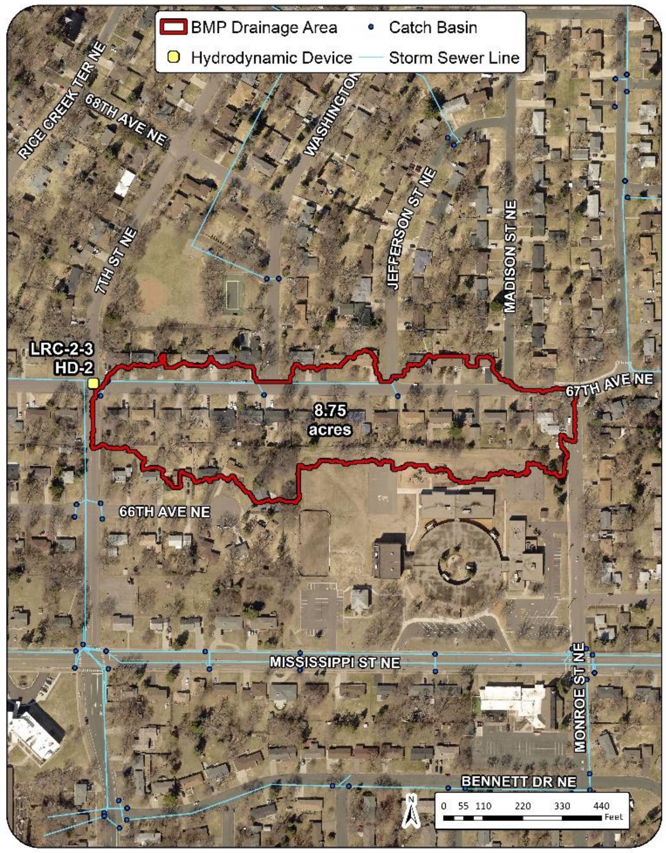
*Indirect Cost: (25 hours at $150/hour)

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

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

Project ID: LRC-2-3 HD-2

67th Ave. and 7th St.
Hydrodynamic Device



Drainage Area – 8.75 acres
Location – Intersection of 67th Ave. NE and 7th St. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on 67th Ave. NE. This hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The table below provides pollutant removals and estimated costs.

Hydrodynamic Device			
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	10	ft diameter
	TP (lb/yr)	0.60	11.8%
	TSS (lb/yr)	235	10.8%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***		$3,750
	Design & Construction Costs**		$108,000
	Total Estimated Project Cost (2021)		**$111,750**
	Annual O&M***		$630
Efficiency	**30-yr Average Cost/lb-TP**	**$7,258**	
	30-yr Average Cost/1,000lb-TSS	**$18,532**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

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

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

Project ID: LRC-2-3 HD-3

7th St. and Mississippi St.
Hydrodynamic Device

Drainage Area – 6.86 acres
Location – Intersection of 7th St. NE and Mississippi St. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on Mississippi St. NE. This hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The table below provides pollutant removals and estimated costs.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	8	ft diameter
	TP (lb/yr)	0.50	9.9%
	TSS (lb/yr)	280	12.8%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***		$3,750
	Design & Construction Costs**		$54,000
	Total Estimated Project Cost (2021)		**$57,750**
	Annual O&M***		$630
Efficiency	**30-yr Average Cost/lb-TP**	**$5,110**	
	30-yr Average Cost/1,000lb-TSS	**$9,125**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

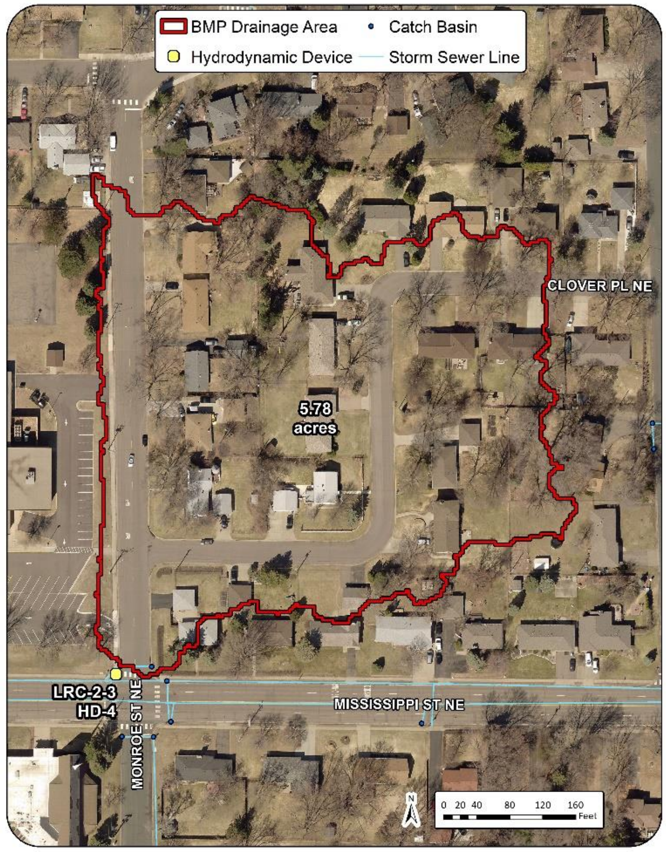
*Indirect Cost: (25 hours at $150/hour)

**Direct Cost: ($36,000 for materials) + ($18,000 for labor and installation costs)

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

Project ID: LRC-2-3 HD-4

Monroe St. and Mississippi St.
Hydrodynamic Device



Drainage Area – 5.78 acres
Location – Intersection of Mississippi St. NE and Monroe St. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on Monroe St. NE. This hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The table below provides pollutant removals and estimated costs.

Hydrodynamic Device			
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	8	ft diameter
	TP (lb/yr)	0.40	7.9%
	TSS (lb/yr)	147	6.7%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***	$3,750	
	Design & Construction Costs**	$54,000	
	Total Estimated Project Cost (2021)	**$57,750**	
	Annual O&M***	$630	
Efficiency	**30-yr Average Cost/lb-TP**	**$6,387**	
	30-yr Average Cost/1,000lb-TSS	**$17,381**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

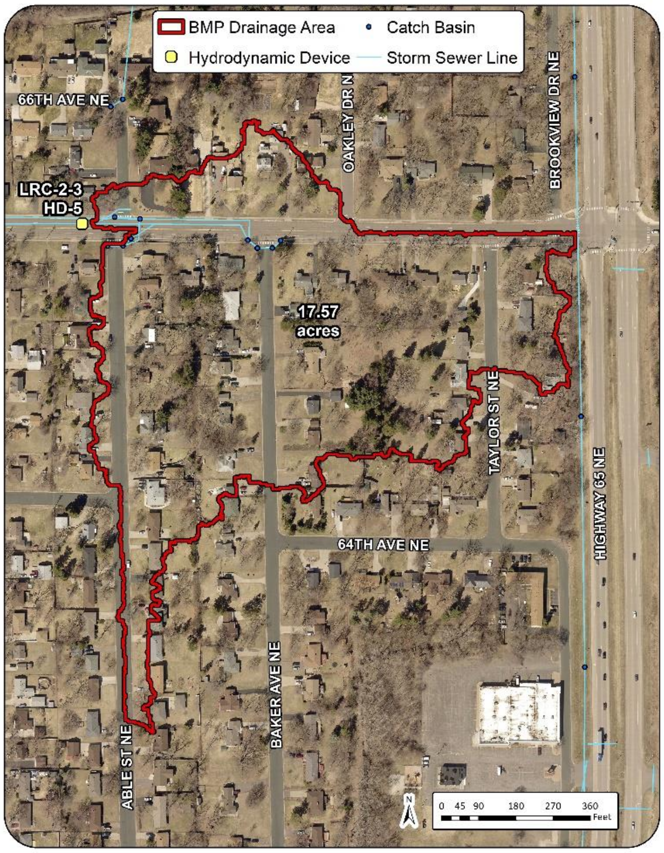
**Direct Cost: ($36,000 for materials) + ($18,000 for labor and installation costs)

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

Project ID: LRC-2-3 HD-5

Mississippi St. and Able St.
Hydrodynamic Device

Drainage Area – 17.57 acres
Location – Intersection of Mississippi St. NE and Able St. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on Mississippi St. NE. This hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The table below provides pollutant removals and estimated costs.



Hydrodynamic Device			
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	10	ft diameter
	TP (lb/yr)	0.80	15.8%
	TSS (lb/yr)	324	14.9%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***	$3,750	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2021)	**$111,750**	
	Annual O&M***	$630	
Efficiency	**30-yr Average Cost/lb-TP**	**$5,444**	
	30-yr Average Cost/1,000lb-TSS	**$13,441**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

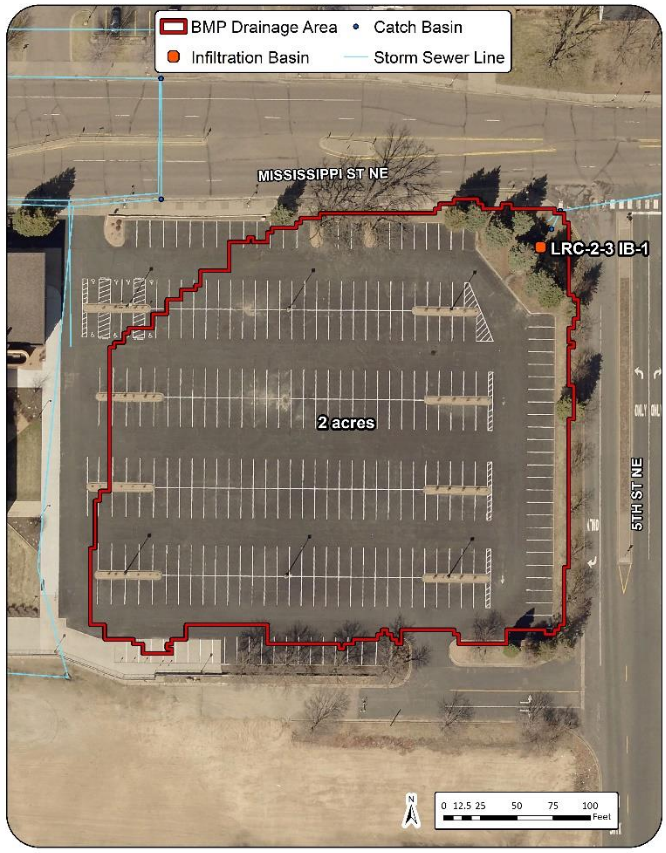
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

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

Project ID: LRC-2-3 IB-1

Pipeline Foods Parking Lot Infiltration Basin

Drainage Area – 2.0 acres
Location – Northeast corner of the Pipeline Foods parking lot near the intersection of Mississippi St. NE and 5th St. NE
Property Ownership – Private
Site Specific Information – An infiltration basin is proposed in the northeast corner of the parking lot. A curb-cut exists in the parking lot, but a depression could be created to provide volume and pollutant reductions. The table below provides pollutant removals and estimated costs.



	Curb-Cut Bioinfiltration		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment		**Sandy Soils - 12" IB**	
	Total Size of BMPs	525	sq-ft
	TP (lb/yr)	0.60	11.8%
	TSS (lb/yr)	312	14.3%
	Volume (acre-feet/yr)	0.85	0.6%
Cost	**Administration & Promotion Costs***		$584
	Design & Construction Costs**		$16,570
	Total Estimated Project Cost (2021)		**$17,154**
	Annual O&M***		$225
Efficiency	**30-yr Average Cost/lb-TP**	**$1,328**	
	30-yr Average Cost/1,000lb-TSS	**$2,554**	
	30-yr Average Cost/ac-ft Vol.	**$938**	

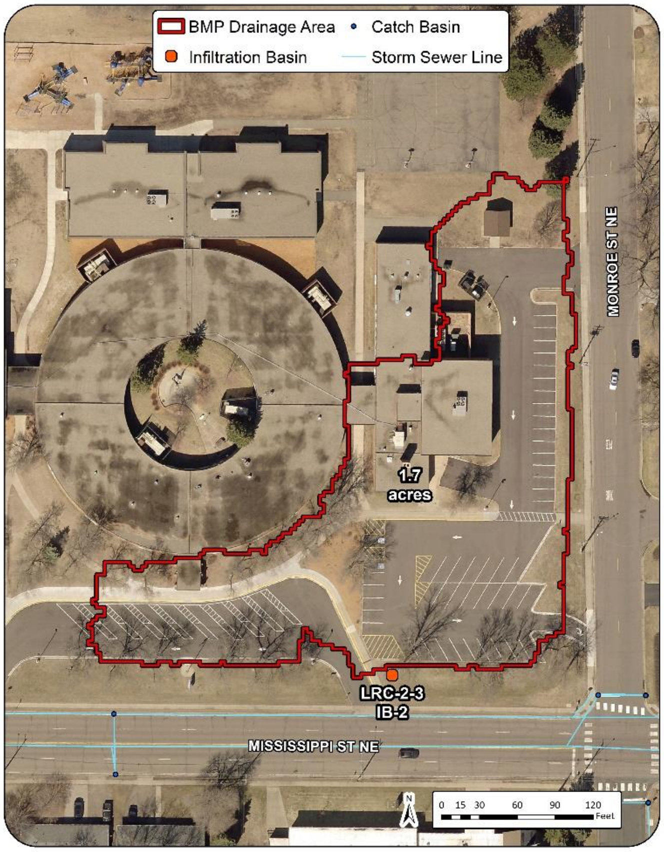
*Indirect Cost: (8 hours at $73/hour base cost)

**Direct Cost: ($26/sq-ft for materials and labor) + (40 hours at $73/hour for design)

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

Project ID: LRC-2-3 IB-2

Hayes Elementary School Infiltration Basin



Drainage Area – 1.7 acres
Location – Southeastern side of Hayes Elementary School campus near the corner of Mississippi St. NE and Monroe St. NE
Property Ownership – Public
Site Specific Information – An infiltration basin is proposed on the Hayes Elementary School that could provide treatment for most of the parking lot. Scenarios for both sandy and silty soils were modeled, and the table below provides associated volume and pollutant removals and estimated costs.

	Curb-Cut Bioinfiltration				
	Cost/Removal Analysis	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**
Treatment		**Sandy Soils - 12" IB**		**Silty Soils - 9" IB**	
	Total Size of BMPs	450	sq-ft	450	sq-ft
	TP (lb/yr)	0.70	13.8%	0.30	5.9%
	TSS (lb/yr)	277	12.7%	120	5.5%
	Volume (acre-feet/yr)	0.67	0.5%	0.28	0.2%
Cost	**Administration & Promotion Costs***	$584		$584	
	Design & Construction Costs**	$14,620		$14,620	
	Total Estimated Project Cost (2021)	**$15,204**		**$15,204**	
	Annual O&M***	$225		$225	
Efficiency	**30-yr Average Cost/lb-TP**	**$1,045**		**$2,439**	
	30-yr Average Cost/1,000lb-TSS	**$2,642**		**$6,098**	
	30-yr Average Cost/ac-ft Vol.	**$1,099**		**$2,656**	

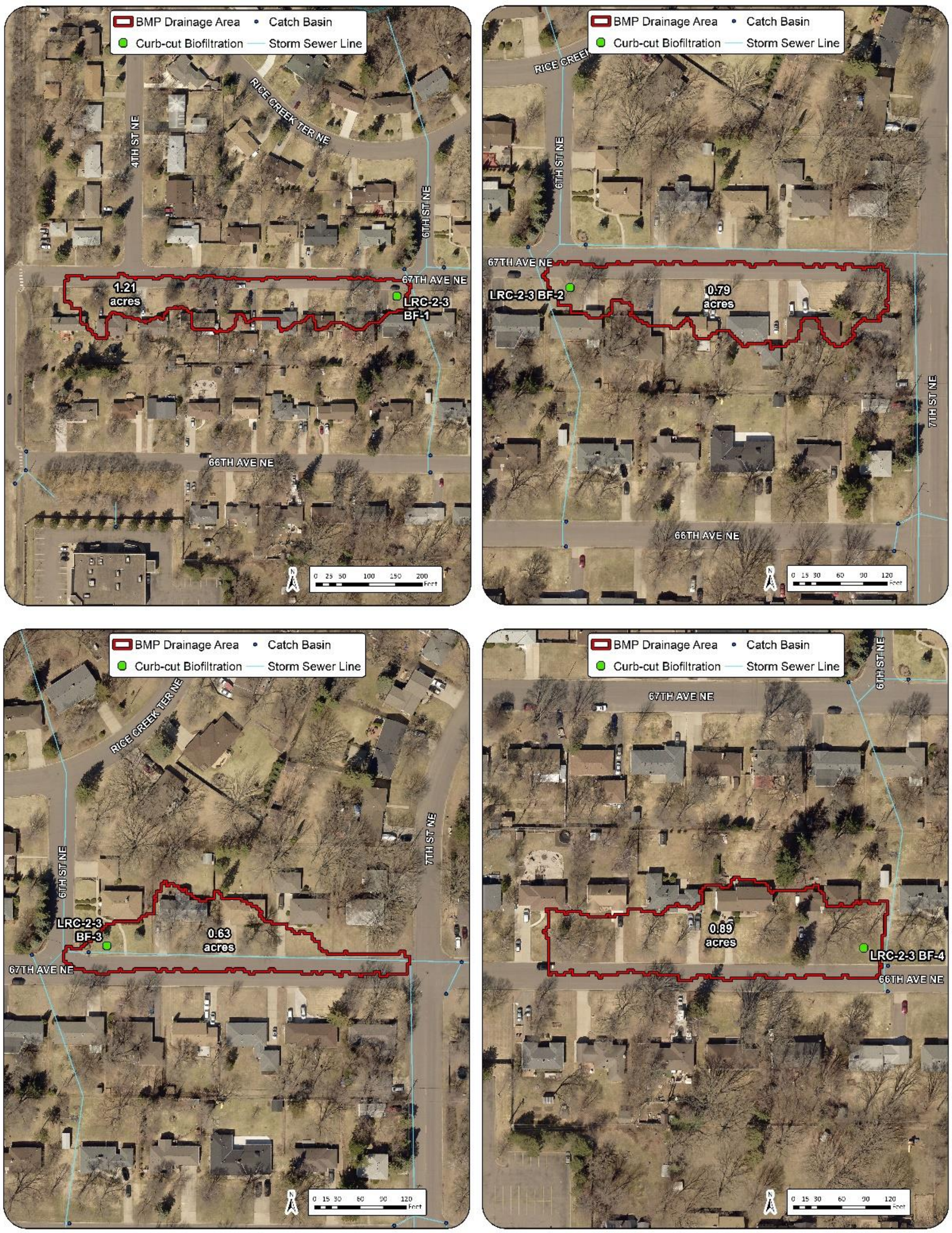
*Indirect Cost: (8 hours at $73/hour base cost)

**Direct Cost: ($26/sq-ft for materials and labor) + (40 hours at $73/hour for design)

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

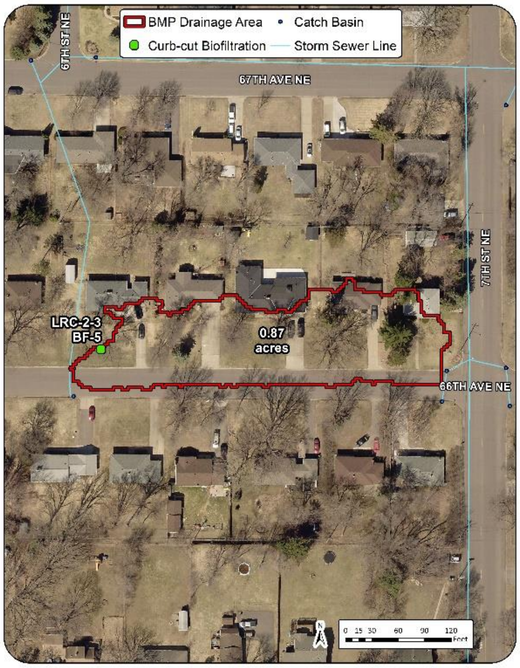
Project ID:
LRC-2-3 BF/BI
Multiple Locations
Bioretention Basins

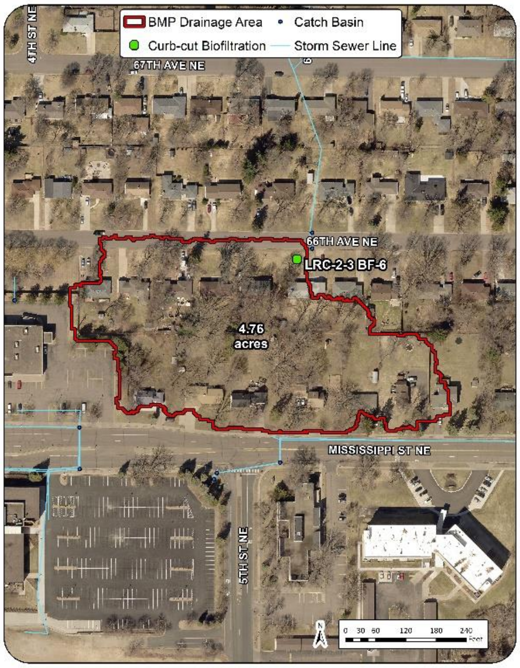
Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See 'Residential Bioretention Comparison' in the 'BMP Descriptions' section for additional details and estimated benefits and cost-effectiveness.

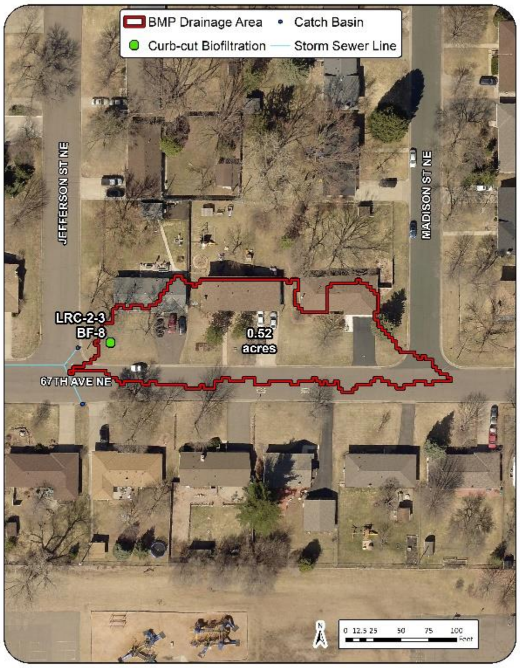


Project ID:
LRC-2-3 BF/BI

Multiple Locations
Bioretention Basins

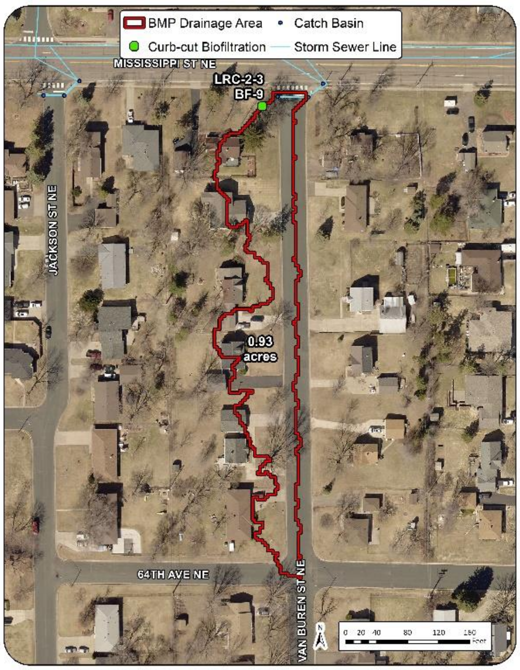


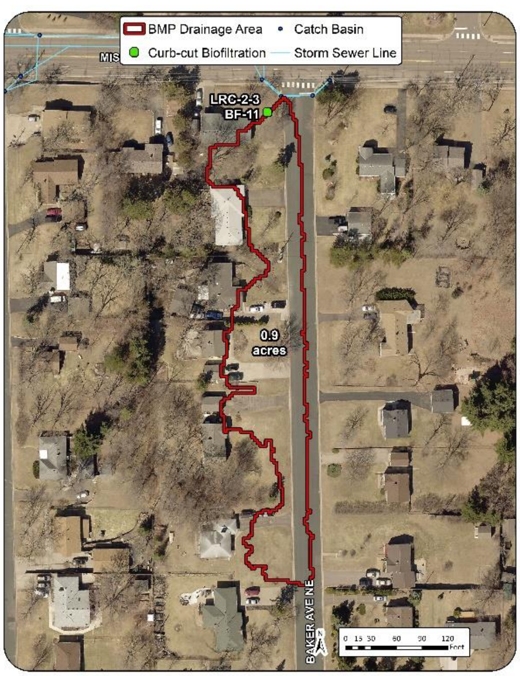


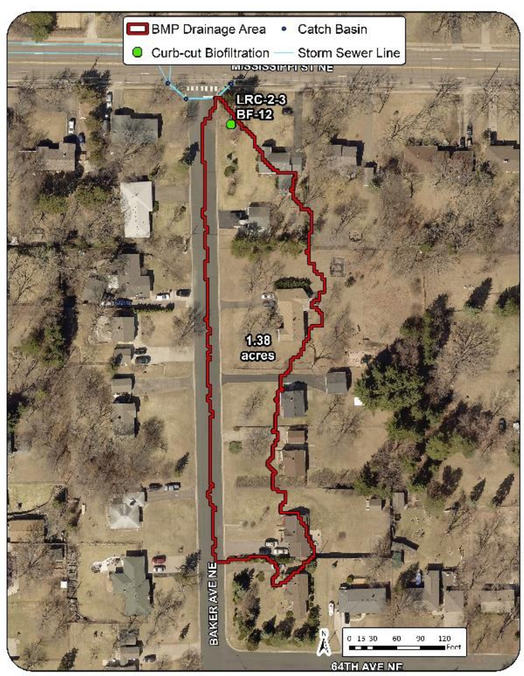


Project ID:
LRC-2-3 BF/BI

Multiple Locations
Bioretention Basins



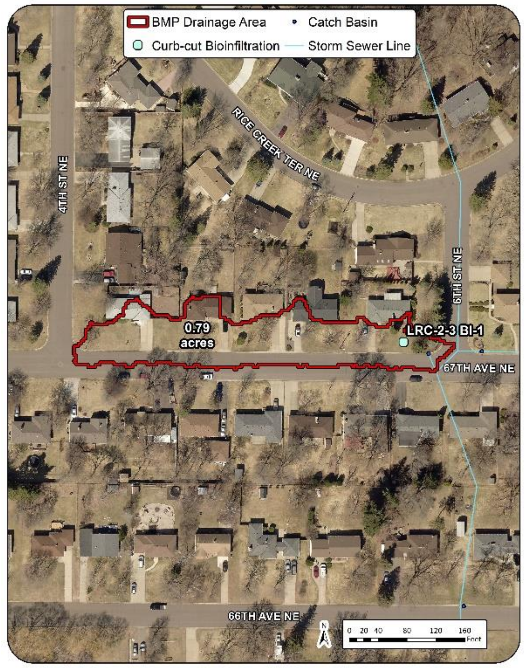


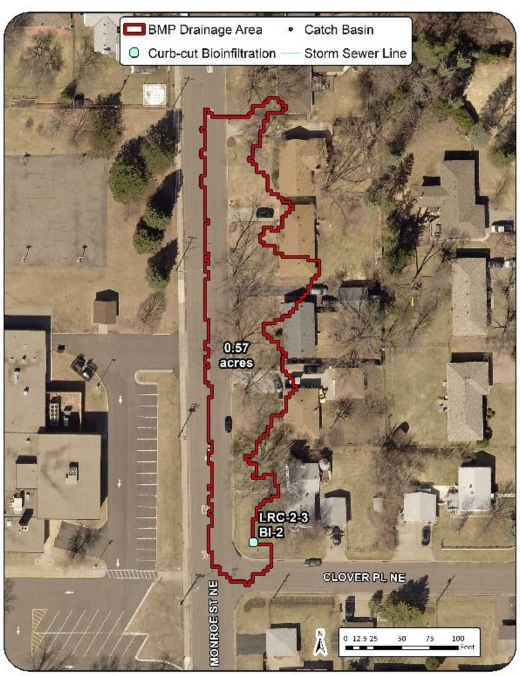


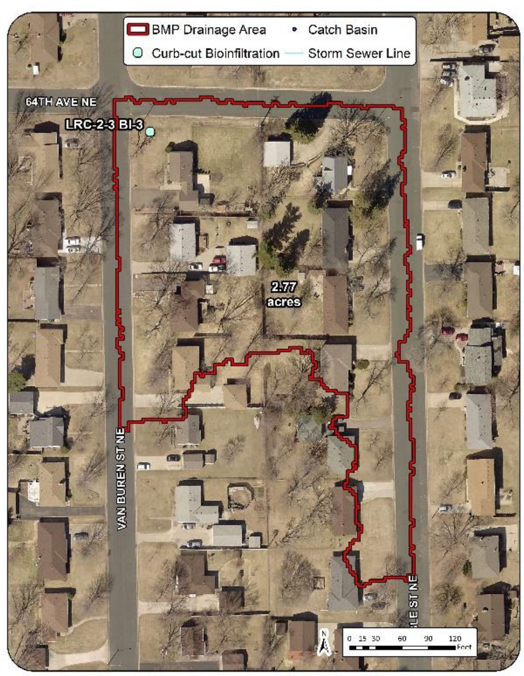
Project ID: LRC-2-3 BF/BI

Multiple Locations

Bioretention Basins

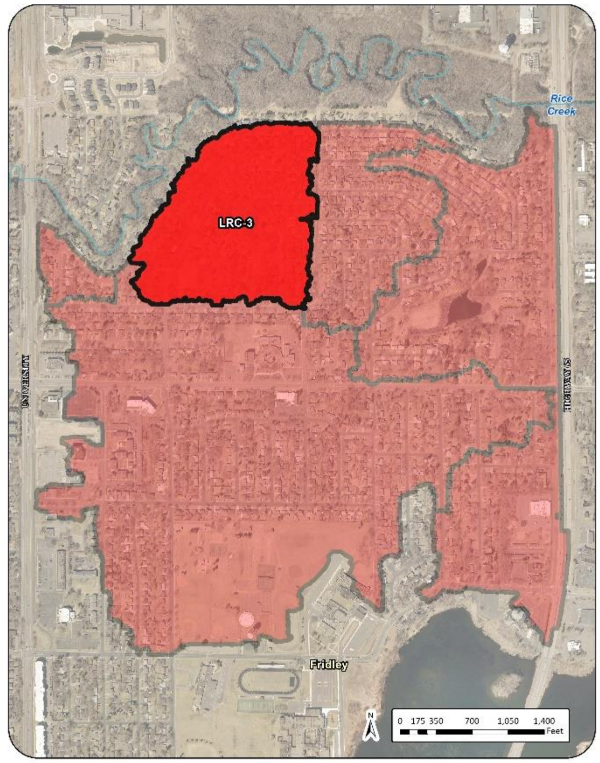






Catchment LRC-3

Existing Catchment Summary	
Acres	57.1
Parcels	203
Land Cover	95.6% Residential 4.4% Park



CATCHMENT DESCRIPTION

Catchment LRC-3 is located in the City of Fridley and stormwater runoff is discharged to Rice Creek via a single outfall. Land use within the catchment is predominantly residential with the exception of Terrace Park. Stormwater is generally routed to the creek from the southeast to the northwest.

EXISTING STORMWATER TREATMENT

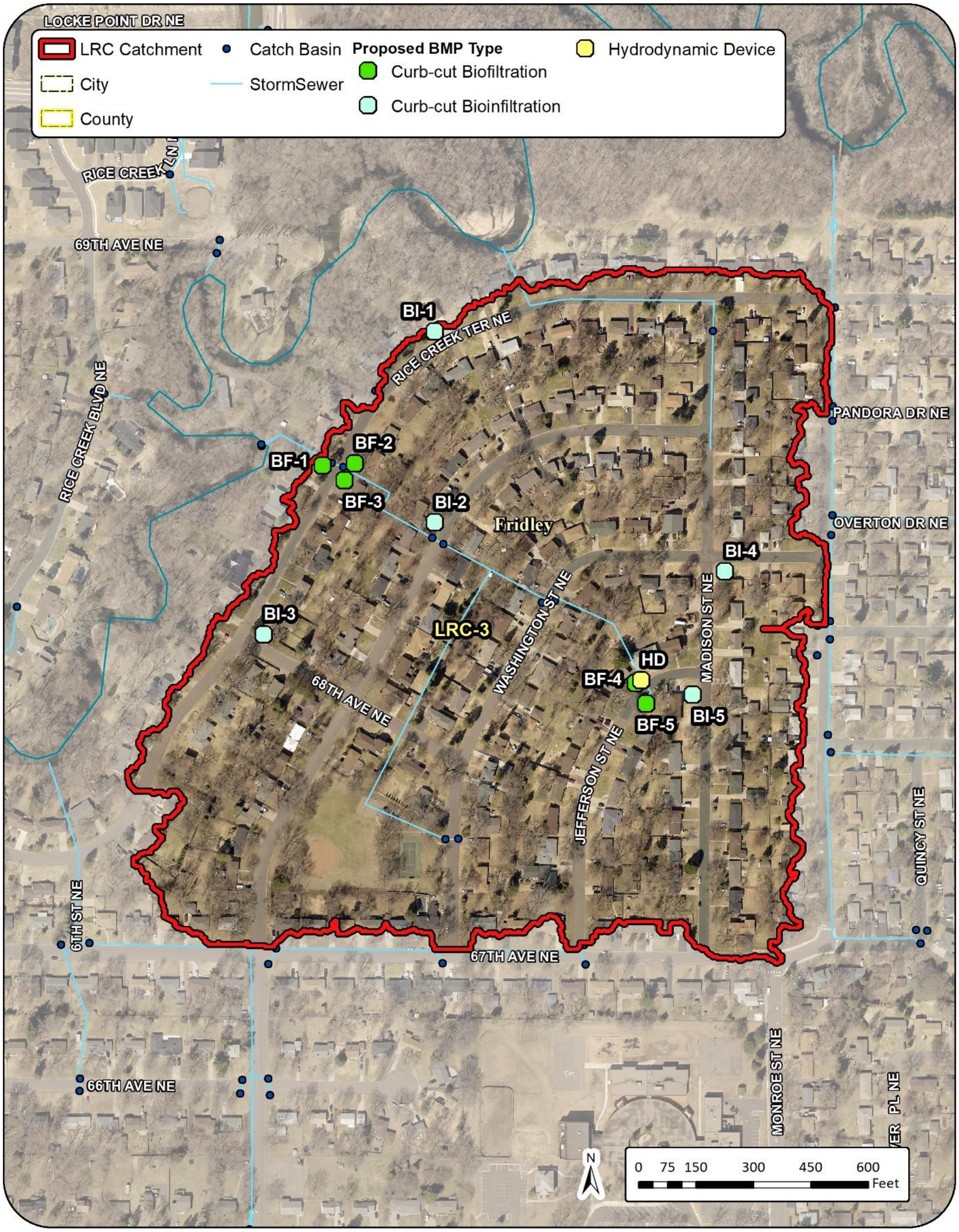
The primary stormwater treatment in the catchment is street cleaning, which the City of Fridley conducts three times per year. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	36.6	2.8	8%	**33.8**
	TSS (lb/yr)	10,560	1,194	11%	**9,366**
	Volume (acre-feet/yr)	24.1	0.0	0%	**24.1**

RETROFIT OPPORTUNITIES OVERVIEW

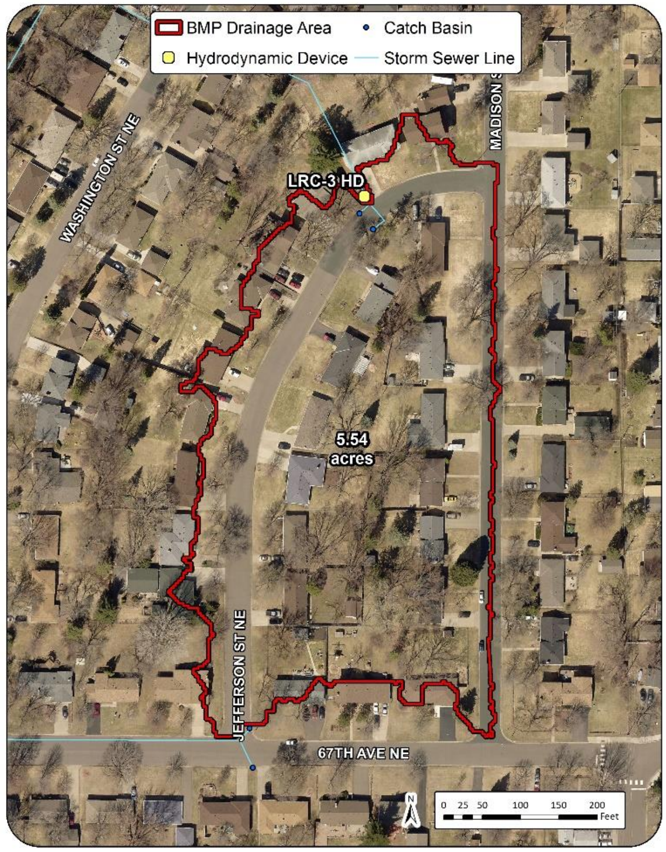
A total of 11 retrofits are proposed in catchment LRC-3 including one hydrodynamic device and 10 bioretention basins. The hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The bioretention basins were sited to maximize contributing drainage areas and at properties with sufficient space and slope to accommodate a basin. For the bioretention practices, underlying soils will determine whether biofiltration or bioinfiltration practices could be installed. The proposed bioretention locations adjacent to catch basins were shown as biofiltration practices to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Project ID: LRC-3 HD

Jefferson St. and Madison St.
Hydrodynamic Device



Drainage Area – 5.54 acres
Location – Jefferson St. NE just west of the intersection with Madison St. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on Jefferson St. This hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The table below provides pollutant removals and estimated costs.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	8	ft diameter
	TP (lb/yr)	0.39	1.2%
	TSS (lb/yr)	149	1.6%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***		$3,750
	Design & Construction Costs**		$54,000
	Total Estimated Project Cost (2021)		**$57,750**
	Annual O&M***		$630
Efficiency	**30-yr Average Cost/lb-TP**	**$6,551**	
	30-yr Average Cost/1,000lb-TSS	**$17,148**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

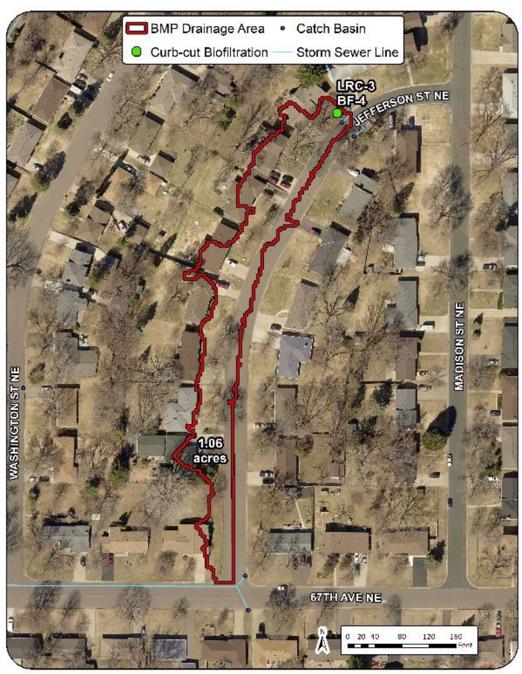
**Direct Cost: ($36,000 for materials) + ($18,000 for labor and installation costs)

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

Project ID: LRC-3 BF/BI

Multiple Locations
Bioretention Basins

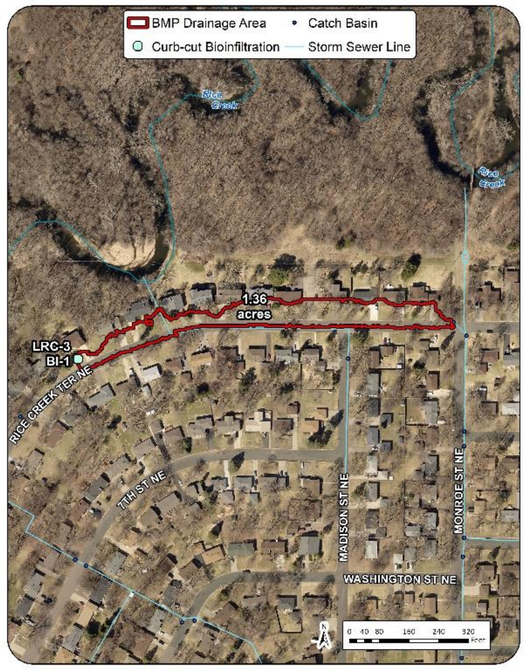
Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See 'Residential Bioretention Comparison' in the 'BMP Descriptions' section for additional details and estimated benefits and cost-effectiveness.



Project ID:
LRC-3 BF/BI

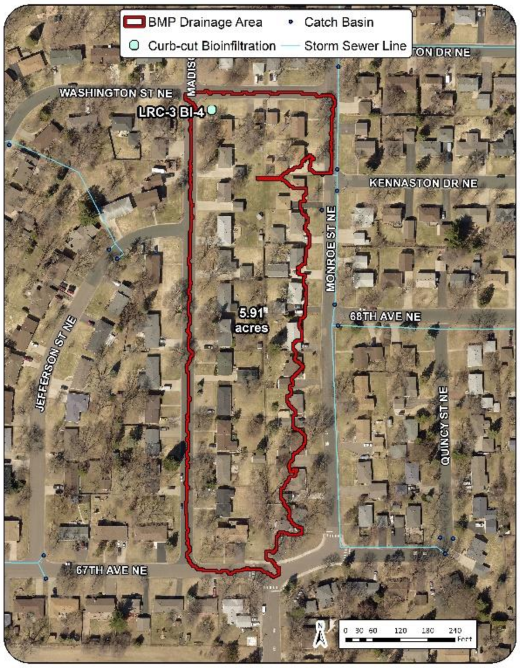
Multiple Locations

Bioretention Basins



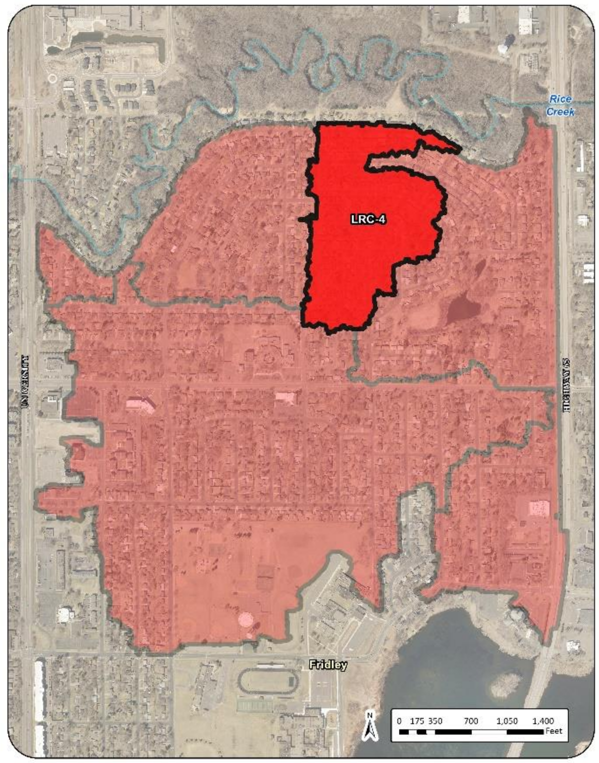
Project ID:
LRC-3 BF/BI

Multiple Locations
Bioretention Basins



Catchment LRC-4

Existing Catchment Summary	
Acres	45.6
Parcels	201
Land Cover	100% Residential



CATCHMENT DESCRIPTION

Catchment LRC-4 is located in the City of Fridley and discharges to Rice Creek via a single outfall. Runoff from the catchment is routed from east to west and then north via a storm sewer line along Monroe St. NE. Land use within the catchment is entirely residential.

EXISTING STORMWATER TREATMENT

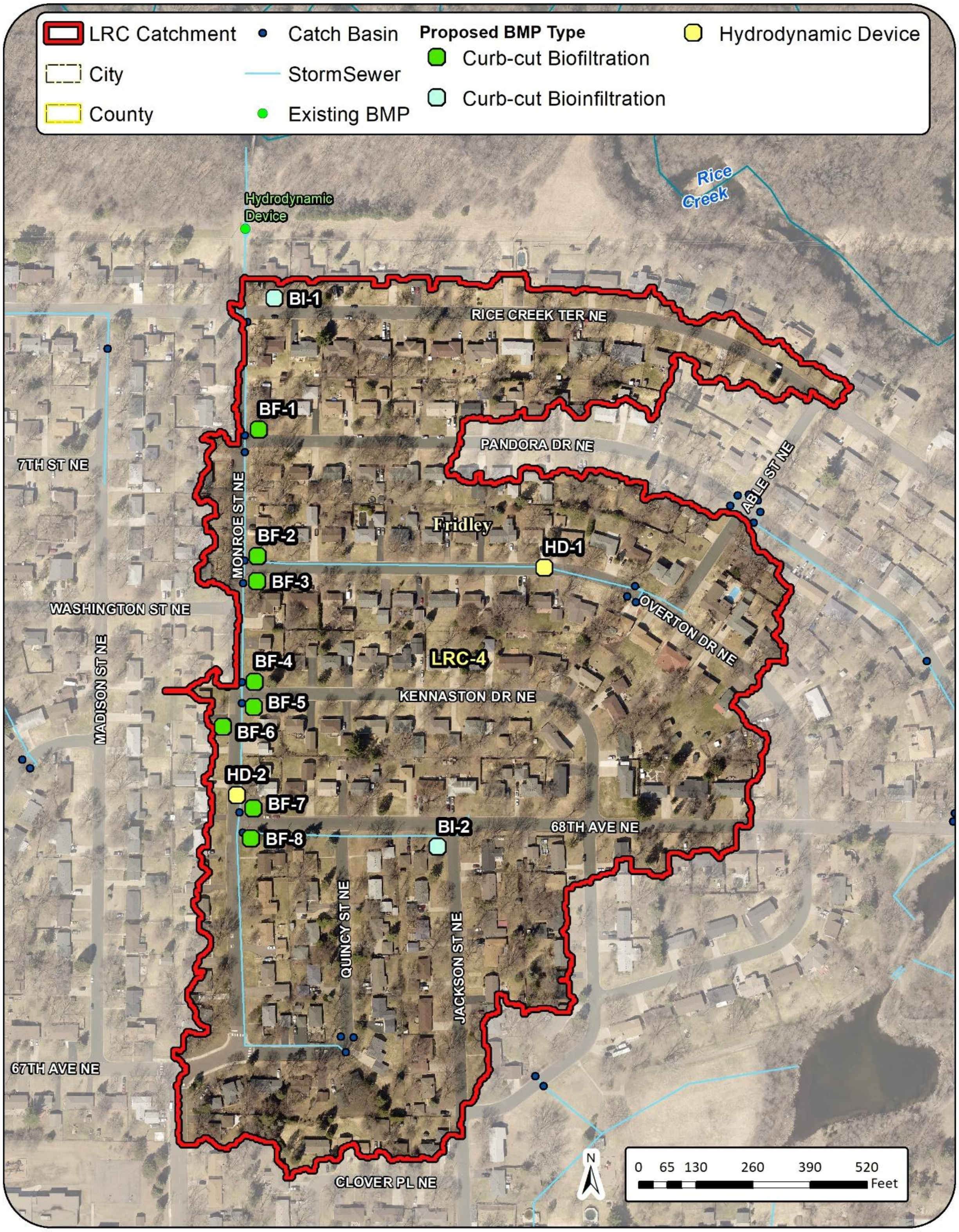
A hydrodynamic device exists at the outfall to Rice Creek, thereby providing treatment for the entire catchment. In addition, the City of Fridley conducts street cleaning three times per year. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	2			
	BMP Types	Street Cleaning, Hydrodynamic Device			
	TP (lb/yr)	26.4	3.6	14%	**22.8**
	TSS (lb/yr)	8,090	1,516	19%	**6,574**
	Volume (acre-feet/yr)	18.6	0	0%	**18.6**

RETROFIT OPPORTUNITIES OVERVIEW

A total of 12 retrofits are proposed in catchment LRC-4 including two hydrodynamic devices and 10 bioretention basins. The hydrodynamic devices are positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The bioretention basins were sited to maximize contributing drainage areas and at properties with sufficient space and slope to accommodate a basin. For the bioretention practices, underlying soils will determine whether biofiltration or bioinfiltration practices could be installed. The proposed bioretention locations adjacent to catch basins were shown as biofiltration practices to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Project ID: LRC-4 HD-1

Overton Dr. and Able St. Hydrodynamic Device

Drainage Area – 3.59 acres
Location – Overton Dr. NE west of the intersection with Able St. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on Overton Dr. NE. This hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The table below provides pollutant removals and estimated costs.

Hydrodynamic Device

	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	6	ft diameter
	TP (lb/yr)	0.10	0.4%
	TSS (lb/yr)	41	0.6%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***	$3,750	
	Design & Construction Costs**	$27,000	
	Total Estimated Project Cost (2021)	**$30,750**	
	Annual O&M***	$630	
Efficiency	**30-yr Average Cost/lb-TP**	**$16,550**	
	30-yr Average Cost/1,000lb-TSS	**$40,366**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

**Direct Cost: ($18,000 for materials) + ($9,000 for labor and installation costs)

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

Project ID: LRC-4 HD-2

Monroe St. and 68th Ave.
Hydrodynamic Device

Drainage Area – 14.93 acres
Location – Intersection of Monroe St. NE and 68th Ave. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on Monroe St. NE. This hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The table below provides pollutant removals and estimated costs.

Hydrodynamic Device

	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	10	ft diameter
	TP (lb/yr)	0.33	1.4%
	TSS (lb/yr)	121	1.8%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***	$3,750	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2021)	**$111,750**	
	Annual O&M***	$630	
Efficiency	**30-yr Average Cost/lb-TP**	**$13,197**	
	30-yr Average Cost/1,000lb-TSS	**$35,992**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

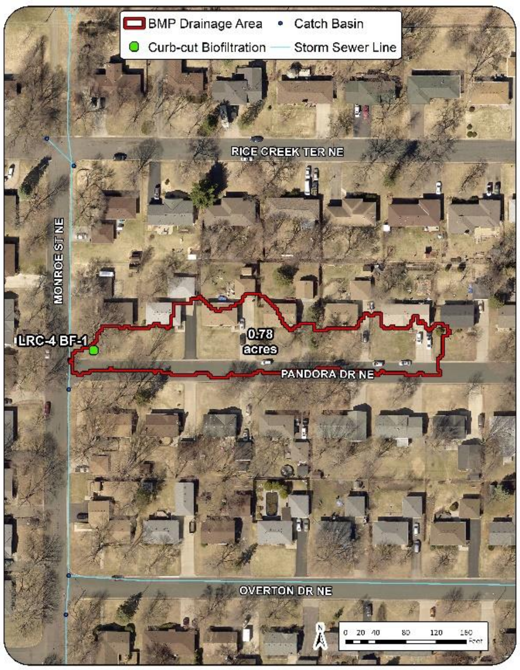
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

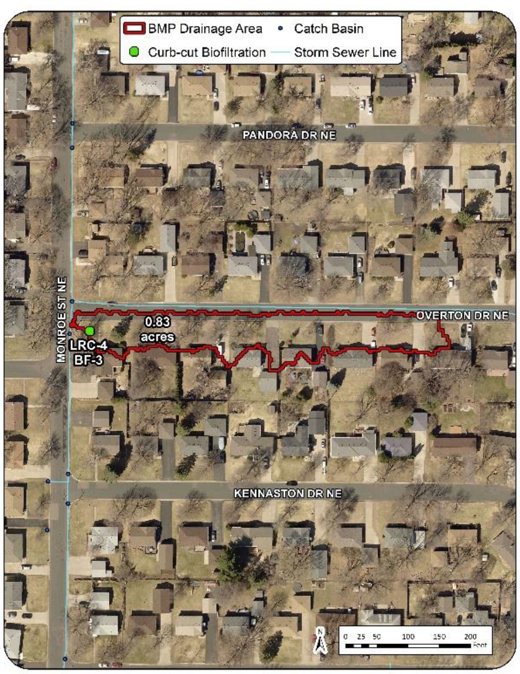
***Per BMP: (3 cleanings/year)*(3 hours/cleaning)*($70/hour)

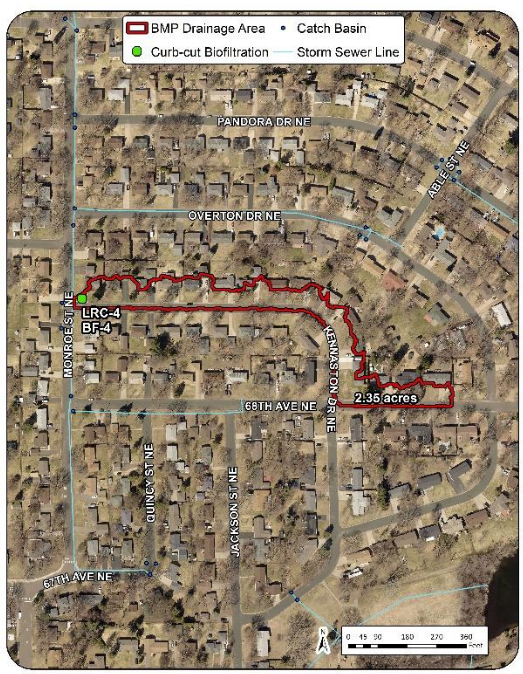
Project ID: LRC-4 BF/BI

Multiple Locations
Bioretention Basins

Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See catchment-specific ranking tables below for estimated benefits and cost-effectiveness.

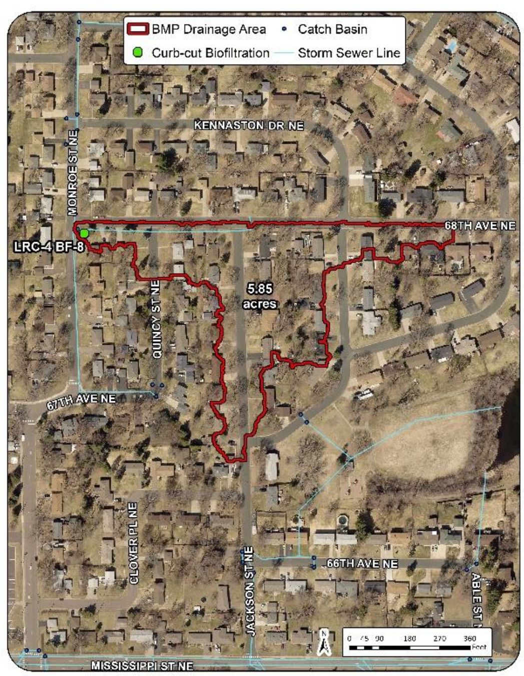




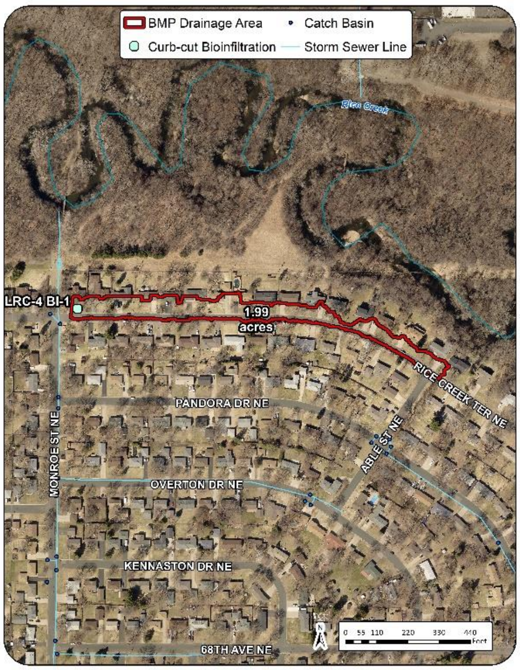


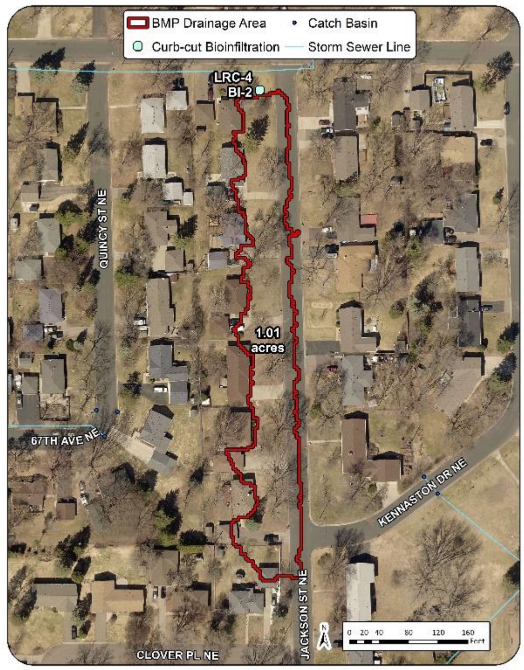
Project ID:
LRC-4 BF/BI

Multiple Locations
Bioretention Basins



Project ID:
LRC-4 BF/BI
Multiple Locations
Bioretention Basins





Project ID:
LRC-4 BF/BI

Multiple Locations
Bioretention Basins

LRC-4 site-specific bioretention volume and pollutant removals were modeled separately because of the existing hydrodynamic device, which is a catchment-wide treatment practice that overlaps with the proposed bioretention basins.

Drainage Area (acres)	***LRC-4 Site-Specific Bioretention Basin Type***											
	12” Biofiltration w/ underdrain			12” Bioinfiltration			9” Bioinfiltration			12” HPMBS*		
	250 sq-ft top area			250 sq-ft top area			250 sq-ft top area			100 sq-ft top area		
	TP (lbs)	TSS (lbs)	Vol (cu-ft)	TP (lbs)	TSS (lbs)	Vol (cu-ft)	TP (lbs)	TSS (lbs)	Vol (cu-ft)	TP (lbs)	TSS (lbs)	Vol (cu-ft)
0.5	0.11 0.5%	38.00 0.6%	1579 0.2%	0.22 1.0%	68.00 1.0%	7660 0.95%	0.13 0.6%	42.00 0.6%	4564 0.6%	0.13 0.6%	53.00 0.8%	462 0.1%
1	0.16 0.7%	58.00 0.9%	1962 0.2%	0.34 1.5%	105.00 1.6%	11731 1.4%	0.16 0.7%	52.00 0.8%	5746 0.7%	0.27 1.2%	106.00 1.6%	488 0.1%
2	0.20 0.9%	75.00 1.1%	2377 0.3%	0.47 2.1%	146.00 2.2%	16039 2.0%	0.18 0.8%	56.00 0.9%	6470 0.8%	0.52 2.3%	211.00 3.2%	526 0.1%
3	0.21 0.9%	81.00 1.2%	2639 0.3%	0.53 2.3%	166.00 2.5%	18328 2.3%	0.18 0.8%	55.00 0.8%	6612 0.8%	0.77 3.4%	311.00 4.7%	566 0.1%
4	0.22 1.0%	81.00 1.2%	2796 0.3%	0.57 2.5%	177.00 2.7%	19712 2.4%	0.18 0.8%	56.00 0.9%	6699 0.8%	1.01 4.4%	405.00 6.2%	599 0.1%
5	0.22 1.0%	81.00 1.2%	2929 0.4%	0.59 2.6%	185.00 2.8%	20768 2.6%	0.18 0.8%	56.00 0.9%	6790 0.8%	1.22 5.4%	492.00 7.5%	623 0.1%

**High-Performance Modular Biofiltration System*

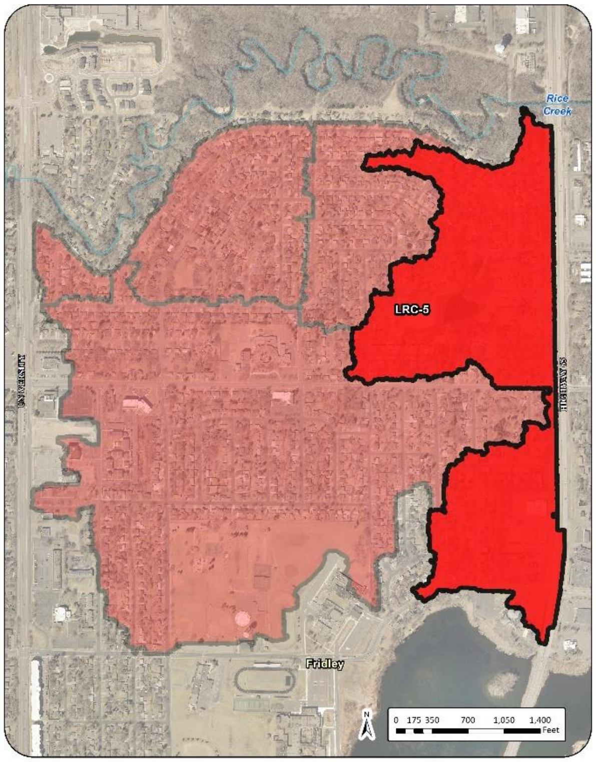
Project ID:
LRC-4 BF/BI
Multiple Locations
Bioretention Basins

Drainage Area (acres)	*LRC-4 Site-Specific Bioretention Basin Type*											
	12" Biofiltration w/ underdrain			12" Bioinfiltration			9" Bioinfiltration			12" HPMBS*		
	250 sq-ft top area			250 sq-ft top area			250 sq-ft top area			100 sq-ft top area		
	Cost/ lb-TP	Cost/ 1,000 lbs-TSS	Cost/ ac-ft-Vol	Cost/ lb-TP	Cost/ 1,000 lbs-TSS	Cost/ ac-ft-Vol	Cost/ lb-TP	Cost/ 1,000 lbs-TSS	Cost/ ac-ft-Vol	Cost/ lb-TP	Cost/ 1,000 lbs-TSS	Cost/ ac-ft-Vol
0.5	$6,319	$18,293	$19,177	$2,538	$8,213	$3,176	$4,296	$13,297	$5,330	$11,734	$28,782	$143,830
1	$4,345	$11,985	$15,433	$1,643	$5,319	$2,074	$3,490	$10,740	$4,234	$5,650	$14,391	$136,167
2	$3,476	$9,268	$12,739	$1,188	$3,825	$1,517	$3,103	$9,973	$3,760	$2,934	$7,230	$126,330
3	$3,310	$8,582	$11,474	$1,054	$3,364	$1,327	$3,103	$10,154	$3,679	$1,981	$4,905	$117,402
4	$3,160	$8,582	$10,830	$980	$3,155	$1,234	$3,103	$9,973	$3,631	$1,510	$3,767	$110,934
5	$3,160	$8,582	$10,338	$947	$3,019	$1,171	$3,103	$9,973	$3,583	$1,250	$3,101	$106,660

**High-Performance Modular Biofiltration System*

Catchment LRC-5

Existing Catchment Summary	
Acres	124.4
Parcels	317
Land Cover	70.1% Residential 9.6% Freeway 8.8% Park 6.6% Shopping 2.9% Institutional 2.0% Office Park



CATCHMENT DESCRIPTION

Catchment LRC-5 is located in the City of Fridley. Land use within the catchment is primarily residential but significant areas of freeway, park, commercial shopping, and institutional land use are also present. Meadowlands Park is located in the north central portion of the catchment. Stormwater runoff is largely routed from south to north toward Rice Creek and discharges via a single outfall. The catchment was divided into two subcatchments, 5-1 and 5-2.

EXISTING STORMWATER TREATMENT

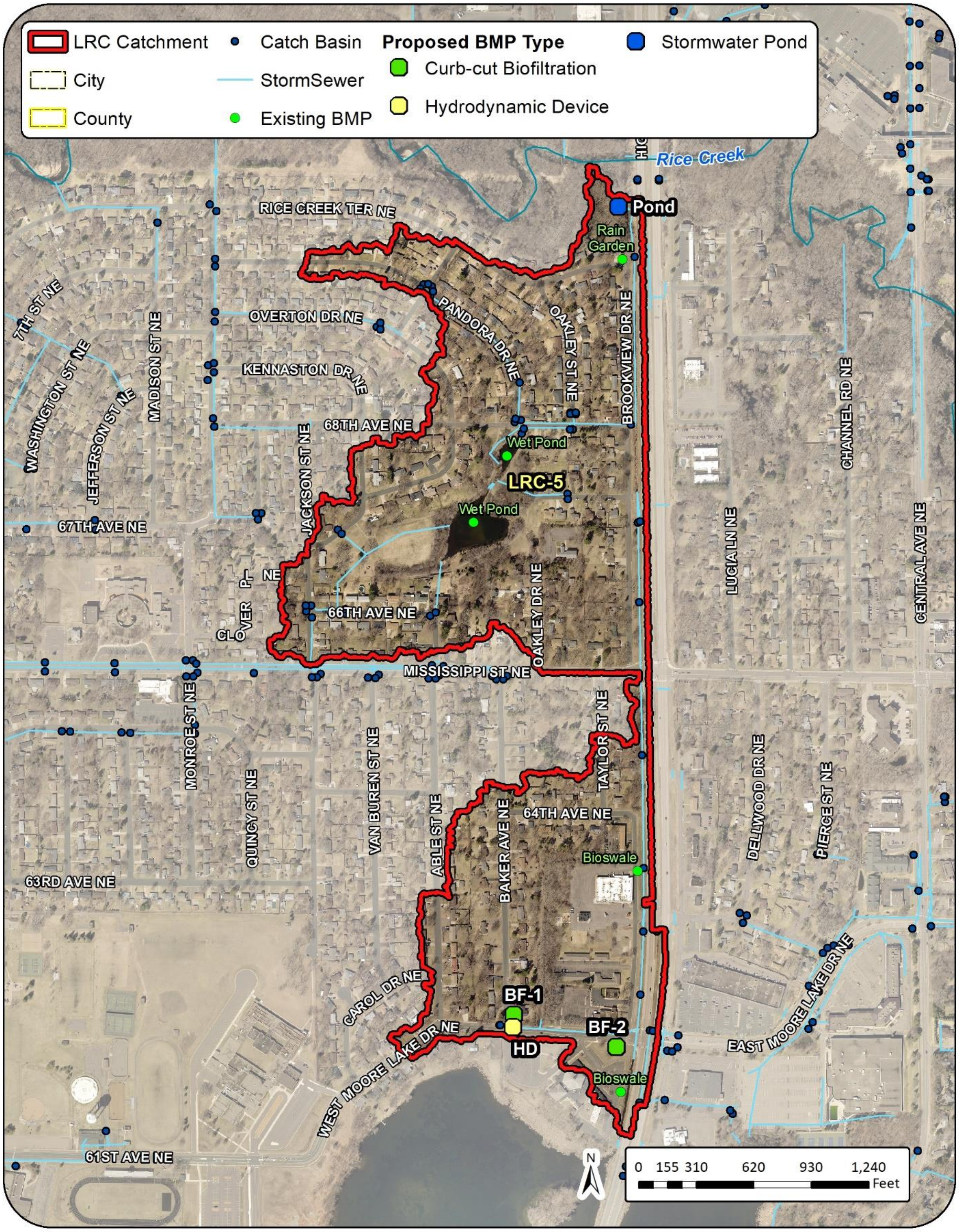
Two wet ponds, two ditch bioswales, and an infiltration basin currently exist in catchment LRC-5. In addition, the City of Fridley conducts street cleaning three times per year.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	6			
	BMP Types	Street Cleaning, Wet Pond (2), Ditch Swale (2), Infiltration Basin			
	TP (lb/yr)	89.4	26.0	29%	**63.4**
	TSS (lb/yr)	29,199	10,303	35%	**18,896**
	Volume (acre-feet/yr)	65.3	1	1%	**64.6**

RETROFIT OPPORTUNITIES OVERVIEW

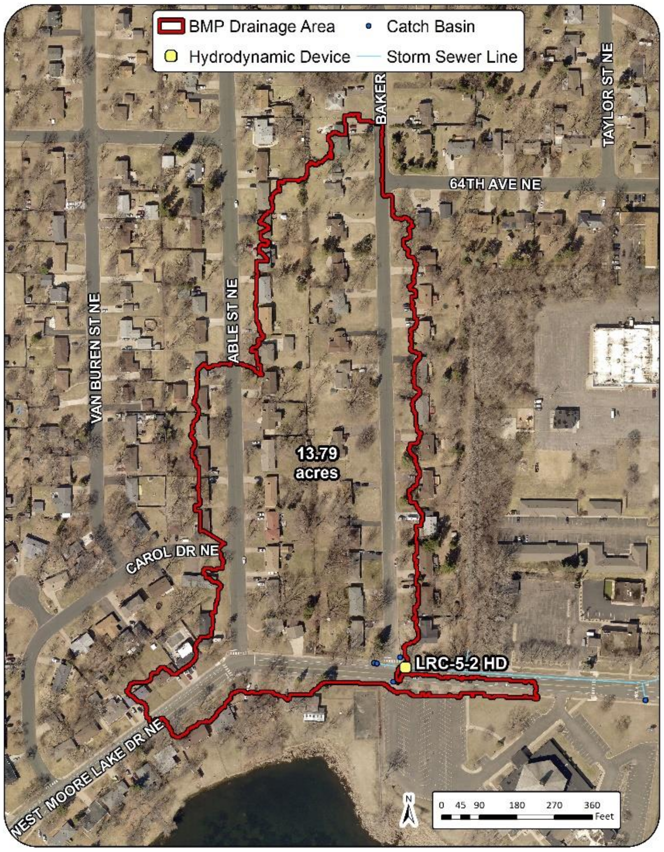
One hydrodynamic device, one new wet pond, and two bioretention basins are proposed in catchment LRC-5. The hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The bioretention basins were sited to maximize contributing drainage areas and at properties with sufficient space and slope to accommodate a basin. For the bioretention practices, underlying soils will determine whether biofiltration or bioinfiltration practices could be installed. The proposed bioretention locations adjacent to catch basins were shown as biofiltration practices to indicate the possibility of an underdrain connection to the storm sewer infrastructure if necessary.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Project ID: LRC-5-2 HD

Baker Ave. and W. Moore Lake Dr.
Hydrodynamic Device



Drainage Area – 13.79 acres
Location – Intersection between Baker Ave. NE and West Moore Lake Dr. NE
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line on West Moore Lake Dr. NE. This hydrodynamic device is positioned at the convergence of multiple storm sewer lines in order to treat the largest contributing drainage area possible for the corresponding device size. The table below provides pollutant removals and estimated costs.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	10	ft diameter
	TP (lb/yr)	0.81	1.3%
	TSS (lb/yr)	319	1.7%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***	$3,750	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2021)	**$111,750**	
	Annual O&M***	$630	
Efficiency	**30-yr Average Cost/lb-TP**	**$5,377**	
	30-yr Average Cost/1,000lb-TSS	**$13,652**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

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

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

Project ID: LRC-5 POND

Highway 65 and Rice Creek Wet Pond

Drainage Area – 124.38 acres
Location – Catchment LRC-5 outfall located just west of the intersection between Highway 65 and Rice Creek
Property Ownership – Public
Site Specific Information – A new regional stormwater pond is proposed to treat all runoff from catchment LRC-5. A detailed engineering analysis would be required to determine siting and configuration. The table below provides estimated pollutant removals and costs.

	New Wet Pond		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMPs**	0.28	acres
	TP (lb/yr)	14.54	22.9%
	TSS (lb/yr)	6,430	34.0%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$7,300	
	Design & Construction Costs**	$194,488	
	Total Estimated Project Cost (2021)	**$201,788**	
	Annual O&M***	$281	
Efficiency	**30-yr Average Cost/lb-TP**	**$482**	
	30-yr Average Cost/1,000lb-TSS	**$1,090**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (100 hours at $73/hour)

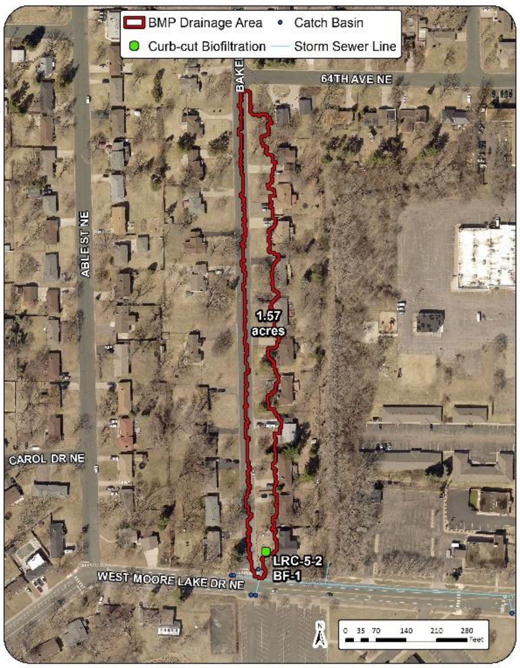
**Direct Cost: See Appendix B for detailed cost information

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

Project ID: LRC-5 BF/BI

Multiple Locations
Bioretention Basins

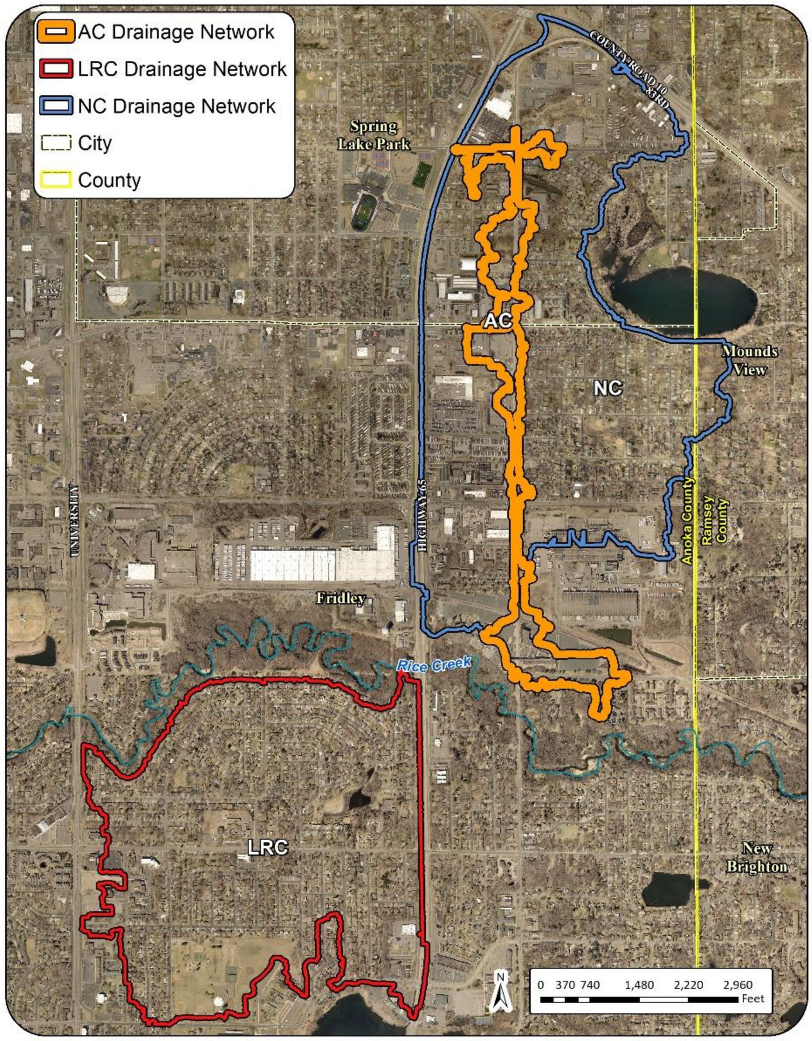
Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See 'Residential Bioretention Comparison' in the 'BMP Descriptions' section for additional details and estimated benefits and cost-effectiveness.



Anoka County Drainage Network

Catchment ID	Page
AC	173

Existing Network Summary	
Acres	80
Dominant Land Cover	Industrial
Volume (ac-ft/yr)	68
TP (lb/yr)	56
TSS (lb/yr)	28,414



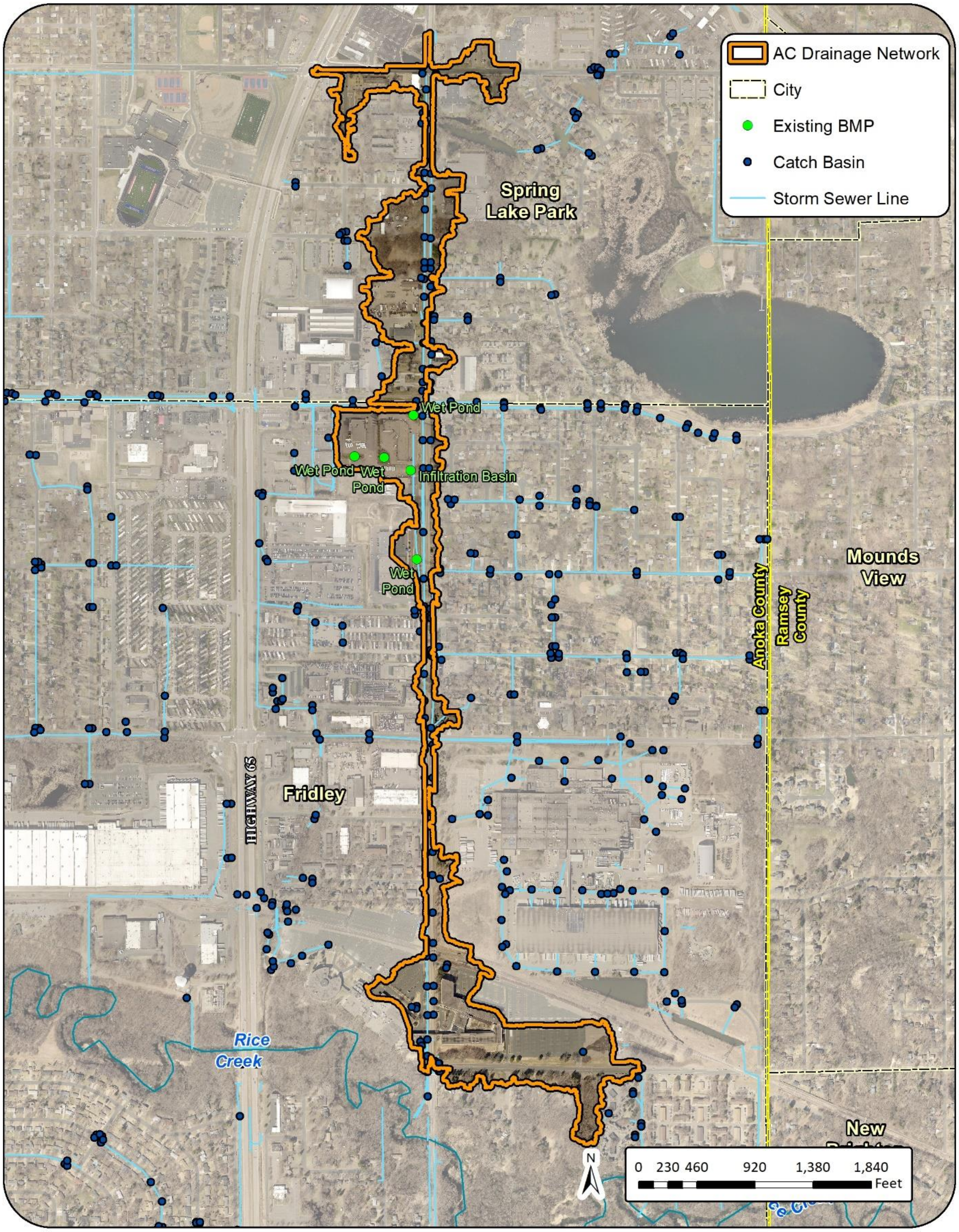
DRAINAGE NETWORK SUMMARY

Anoka County has stormwater infrastructure that discharges to Rice Creek. The 80-acre contributing drainage area is centered along Central Ave. NE and extends north to approximately 81st Ave. NE and south to Rice Creek.

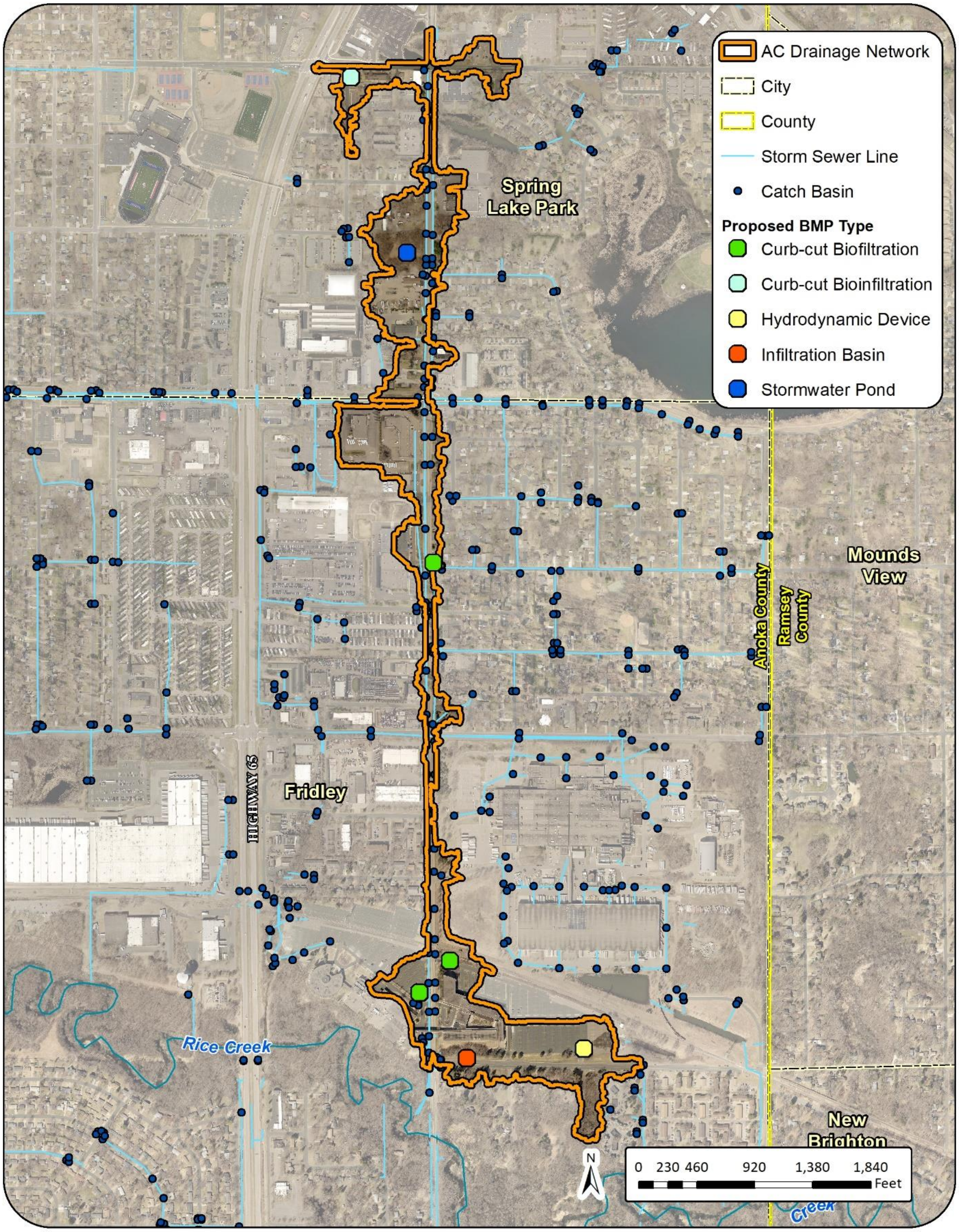
EXISTING STORMWATER TREATMENT

Existing treatment includes four wet ponds, one infiltration basin, and street cleaning. The catchment profile provides additional detail.

NETWORK EXISTING STORMWATER TREATMENT

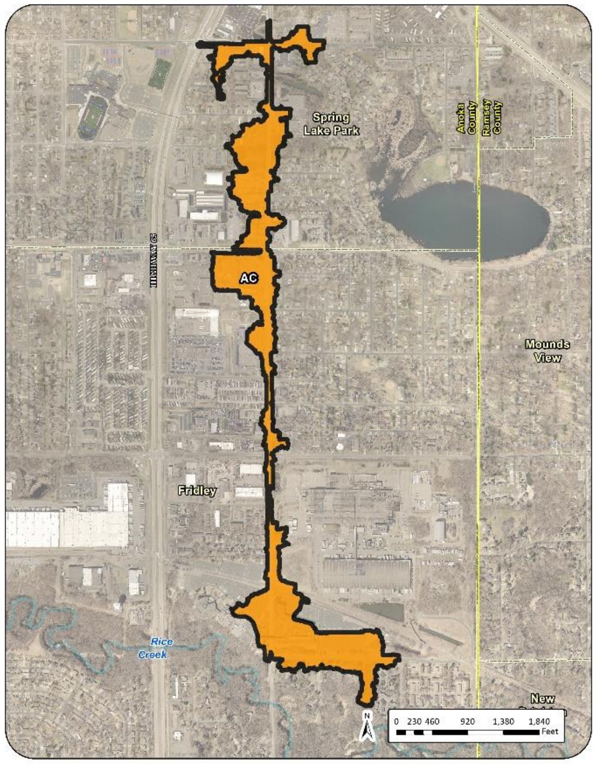


NETWORK RETROFIT OPPORTUNITIES



Catchment AC

Existing Catchment Summary	
Acres	80.0
Parcels	119
Land Cover	59.7% Industrial 21.1% Residential 6.8% Shopping 5.0% Open Space 2.6% Park 2.3% Institutional 2.0% Office Park 0.5% Mobile Home



CATCHMENT DESCRIPTION

Anoka County has stormwater infrastructure that discharges to Rice Creek. The 80-acre contributing drainage area is centered along Central Ave. NE and extends north to approximately 81st Ave. NE and south to Rice Creek. The southernmost extent of the area includes portions of the Medtronic Rice Creek East campus.

EXISTING STORMWATER TREATMENT

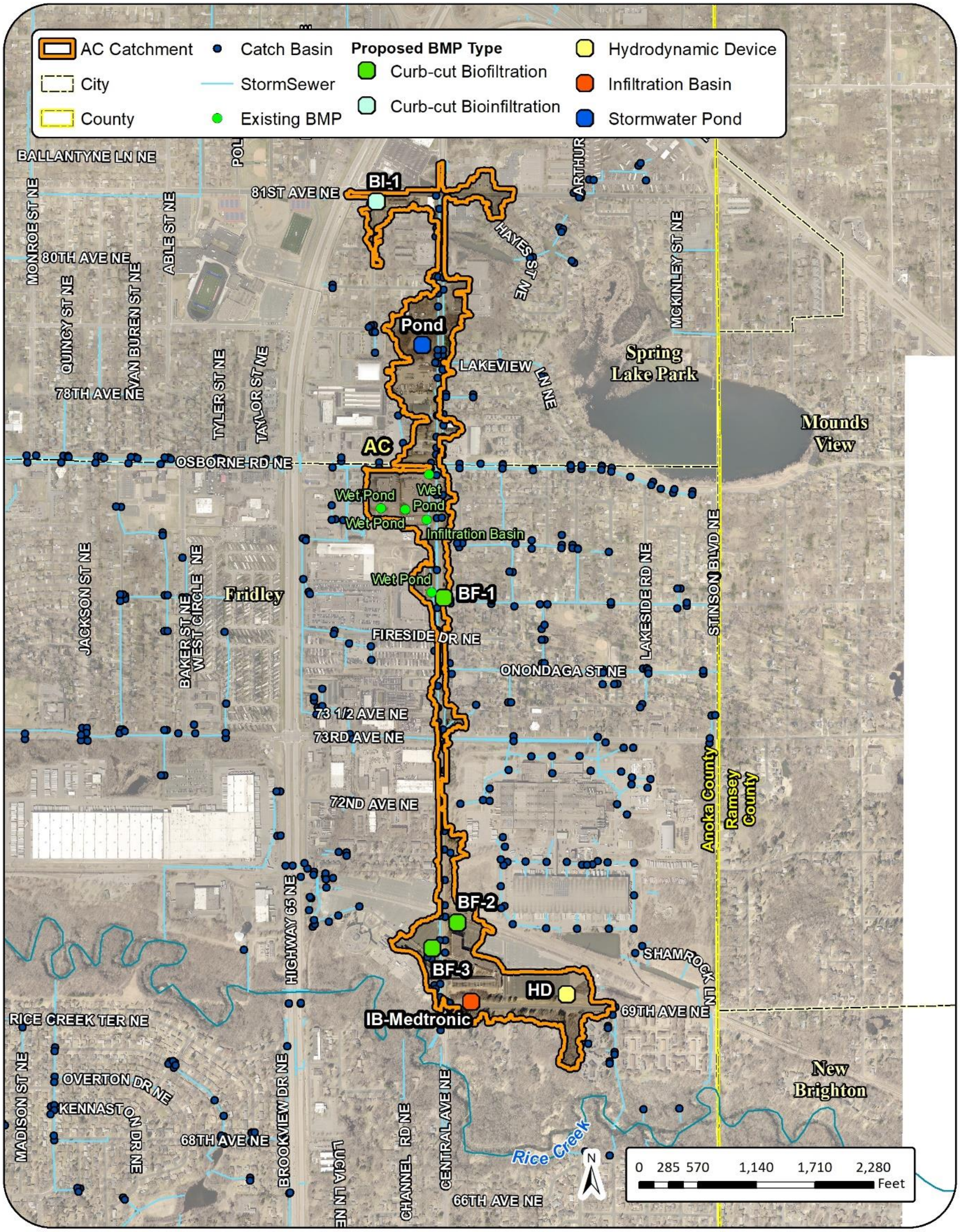
Wet ponds are present at a number of properties including Brenk Brothers and Parkbrook Center. There is also an existing infiltration basin on the Brenk Brothers property. The City of Fridley and the City of Spring Lake Park conduct street cleaning three times per year. Present-day stormwater pollutant 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	Street Cleaning, Wet Pond (4), Rain Garden			
	TP (lb/yr)	62.0	6.3	10%	**55.7**
	TSS (lb/yr)	32,243	3,829	12%	**28,414**
	Volume (acre-feet/yr)	69.3	1	2%	**68.2**

RETROFIT OPPORTUNITIES OVERVIEW

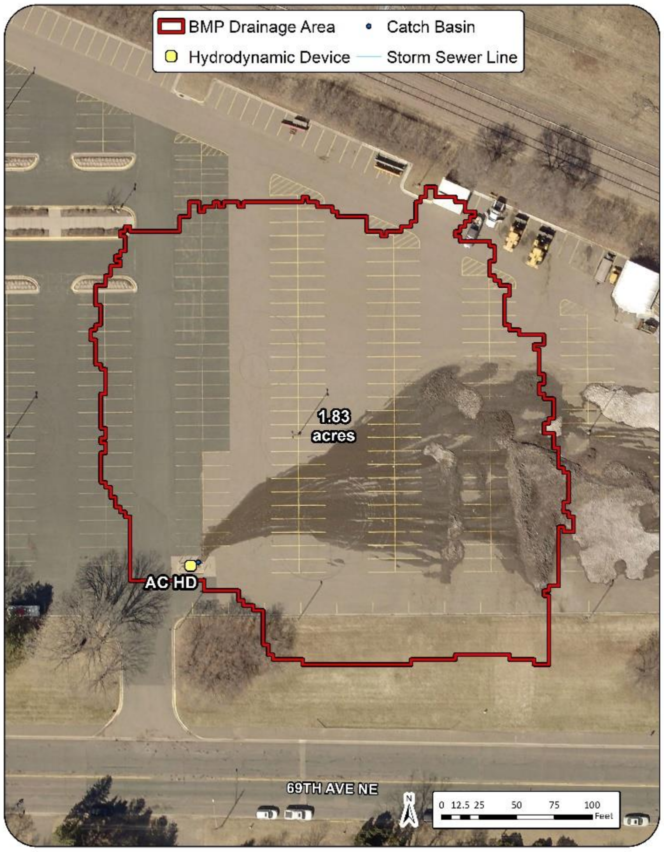
A new stormwater pond, two bioinfiltration basins, three biofiltration basins, and a hydrodynamic device were proposed in catchment AC. Details are provided in the following project profile pages.

EXISTING STORMWATER TREATMENT AND RETROFIT OPPORTUNITIES



Project ID:
AC HD

Medtronic Eastern Parking Lot
Hydrodynamic Device



Drainage Area – 1.83 acres
Location – Eastern parking lot of Medtronic Rice Creek East campus
Property Ownership – Private
Site Specific Information – A hydrodynamic device is proposed in line with the storm sewer line within the Medtronic Rice Creek East campus parking lot. This hydrodynamic device is positioned to treat the largest contributing drainage area possible for the corresponding device size. The table below provides pollutant removals and estimated costs.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMP**	6	ft diameter
	TP (lb/yr)	0.18	0.3%
	TSS (lb/yr)	161	0.6%
	Volume (acre-feet/yr)	n/a	n/a
Cost	**Administration & Promotion Costs***	$3,750	
	Design & Construction Costs**	$27,000	
	Total Estimated Project Cost (2021)	**$30,750**	
	Annual O&M***	$630	
Efficiency	**30-yr Average Cost/lb-TP**	**$9,194**	
	30-yr Average Cost/1,000lb-TSS	**$10,280**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (25 hours at $150/hour)

**Direct Cost: ($18,000 for materials) + ($9,000 for labor and installation costs)

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

Project ID: AC POND

Central Ave. and Lakeview Ln. Wet Pond

Drainage Area – 19.37 acres
Location – West side of Central Ave. NE just north of the intersection with Lakeview Ln. NE
Property Ownership – Private
Site Specific Information – A new wet pond is proposed on the east side of Central Ave. NE to treat the northern extent of the Anoka County drainage network. A detailed engineering analysis would be required to determine siting and configuration. The table below provides estimated pollutant removals and costs.

	New Wet Pond		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Total Size of BMPs**	0.28	acres
	TP (lb/yr)	6.90	12.4%
	TSS (lb/yr)	3,706	13.0%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***		$7,300
	Design & Construction Costs**		$536,903
	Total Estimated Project Cost (2021)		**$544,203**
	Annual O&M***		$280
Efficiency	**30-yr Average Cost/lb-TP**	**$2,670**	
	30-yr Average Cost/1,000lb-TSS	**$4,970**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (100 hours at $73/hour)

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

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

Project ID: AC IB

Medtronic Rice Creek East Infiltration Basin

Drainage Area – 7.36 acres
Location – Southwest side of the Medtronic Rice Creek East campus just east of the intersection between Central Ave. NE and 69th Ave. NE
Property Ownership – Private
Site Specific Information – An infiltration basin is proposed to treat runoff from the Medtronic Rice Creek East campus buildings and parking lot as well as runoff from 69th Ave. NE. Scenarios for both sandy and silty soils were modeled, and the table below provides associated volume and pollutant removals and estimated costs.

Curb-Cut Bioinfiltration

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction
Treatment		Sandy Soils - 12" IB		Silty Soils - 9" IB	
	Total Size of BMPs	1,000	sq-ft	1,000	sq-ft
	TP (lb/yr)	1.60	2.9%	0.56	1.0%
	TSS (lb/yr)	1,042	3.7%	369	1.3%
	Volume (acre-feet/yr)	1.88	2.8%	0.67	1.0%
Cost	Administration & Promotion Costs*	$584		$584	
	Design & Construction Costs**	$28,920		$28,920	
	Total Estimated Project Cost (2021)	**$29,504**		**$29,504**	
	Annual O&M***	$225		$225	
Efficiency	30-yr Average Cost/lb-TP	**$755**		**$2,158**	
	30-yr Average Cost/1,000lb-TSS	**$1,160**		**$3,275**	
	30-yr Average Cost/ac-ft Vol.	**$642**		**$1,815**	

*Indirect Cost: (8 hours at $73/hour base cost)

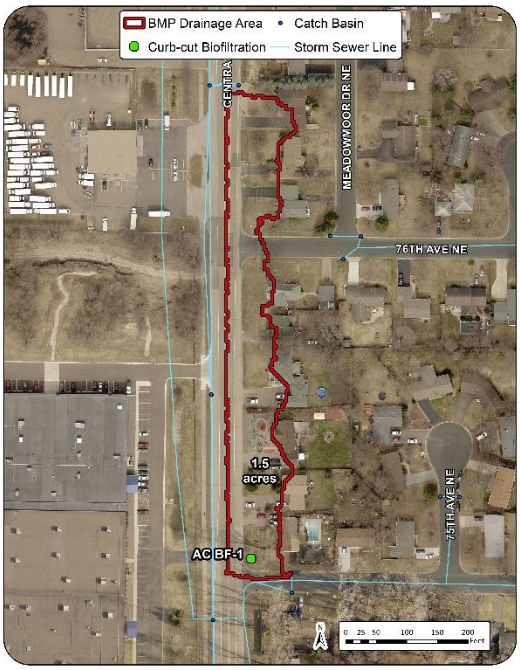
**Direct Cost: ($26/sq-ft for materials and labor) + (40 hours at $73/hour for design)

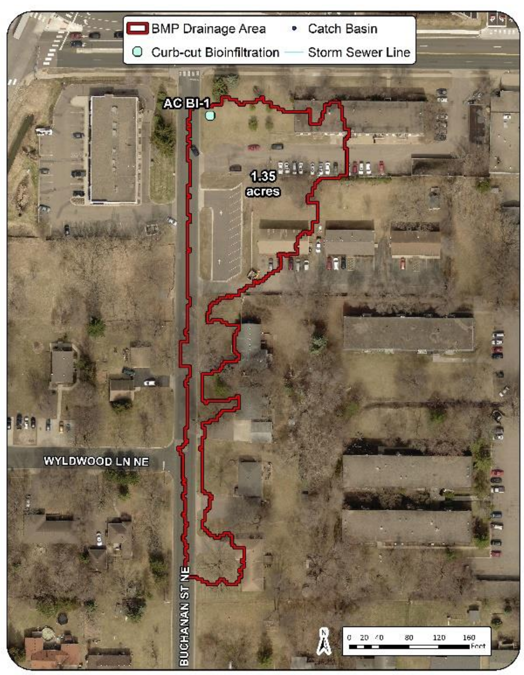
***Per BMP: ($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Project ID: AC BF/BI

Multiple Locations
Bioretention Basins

Drainage Area – Variable
Location – Multiple locations in catchment
Property Ownership – Variable
Site Specific Information – Opportunities for bioretention, both bioinfiltration and biofiltration exist throughout this catchment. See ‘Residential Bioretention Comparison’ in the ‘BMP Descriptions’ section for additional details and estimated benefits and cost-effectiveness.





References

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

Schueler, T. and A. Kitchell. 2005. *Methods to Develop Restoration Plans for Small Urban Watersheds. Manual 2, Urban Subwatershed Restoration Manual Series*. Center for Watershed Protection. Ellicott City, MD.

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.

Specification High-Performance Modular Biofiltration System (HPMBS). *Material, Performance and Installation Specification.* See Appendix E in this report for the full specification.

Technical documents. (2021). *Minnesota Stormwater Manual*.

Weiss, P.T., J.S. Gulliver, A.J. Erickson. 2005. The Cost and Effectiveness of Stormwater Management Practices. Minnesota Department of Transportation.

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 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 version 10.4.1 was used for this analysis to estimate volume and pollutant loading and reductions. Additional inputs for WinSLAMM are provided in Table 11.

Table 11: General WinSLAMM Model Inputs (i.e. Current File Data)

Parameter	File/Method
Land use acreage	ArcMap; Metropolitan Council 2010 Land Use, corrected using 2020 aerial photography
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. The practices listed below were included in the existing conditions models.

Hydrodynamic Devices

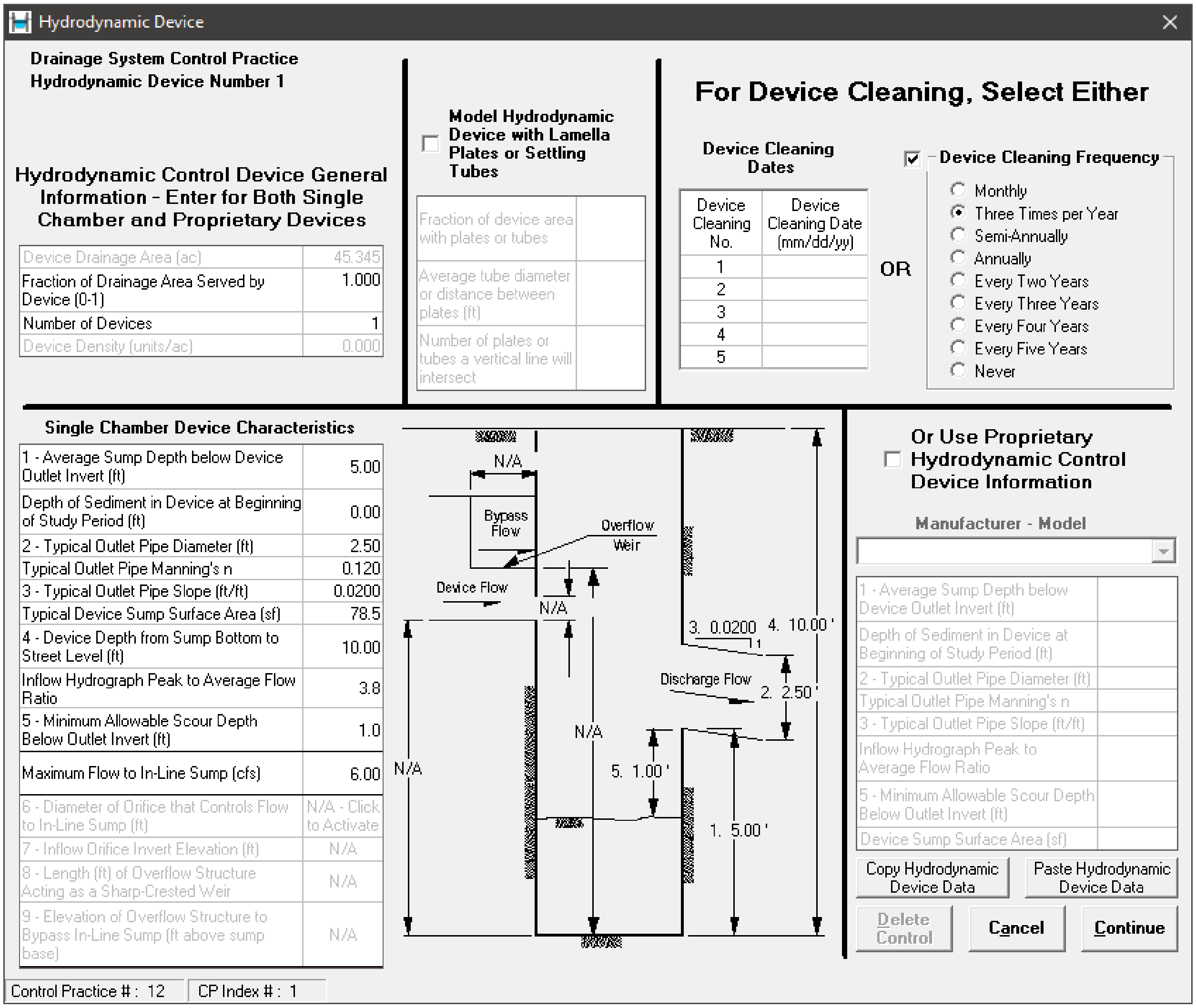


Figure 13: LRC-4 V2B1 Model 14 hydrodynamic device.

Infiltration Basins

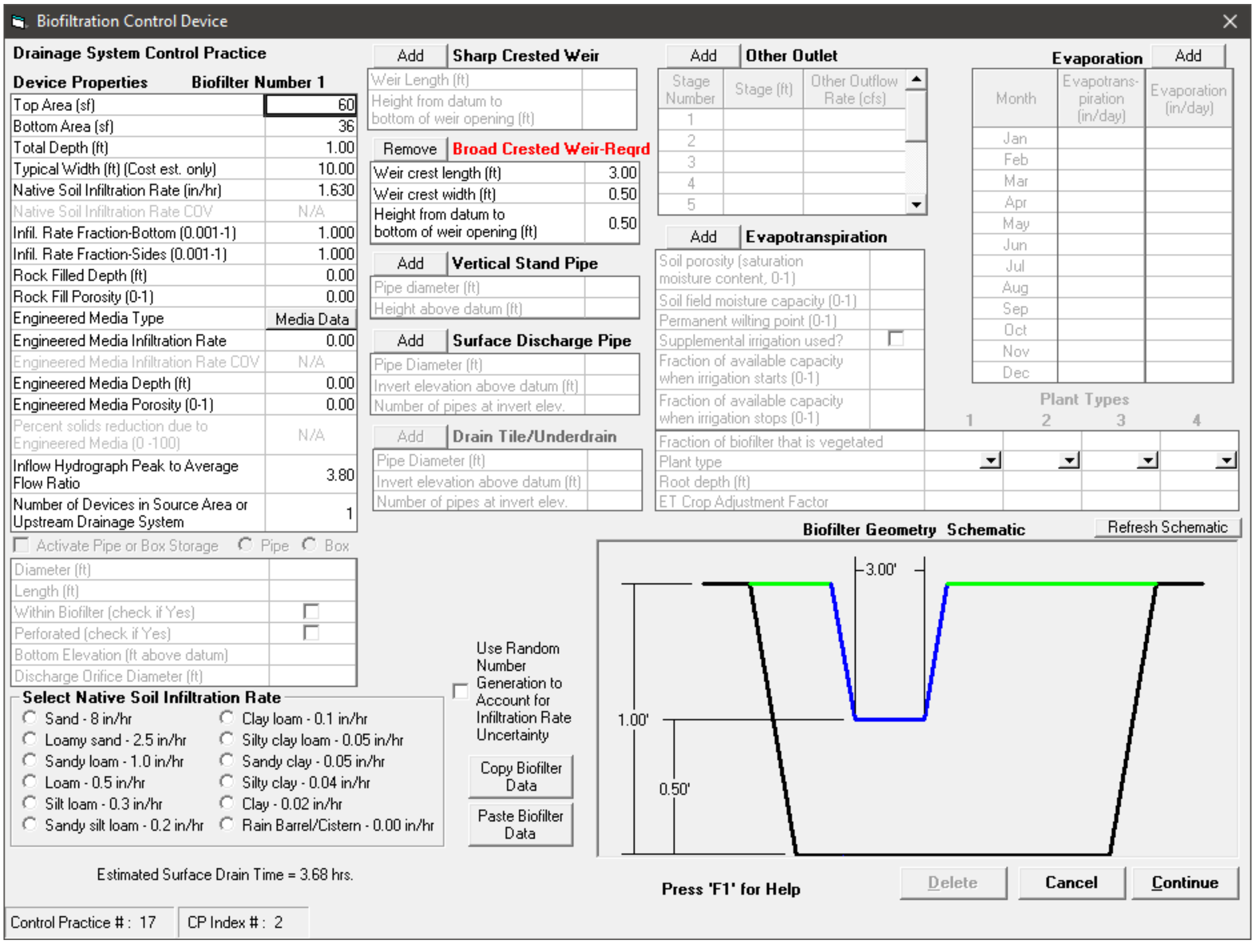


Figure 14: LRC-1 curb-cut rain garden.

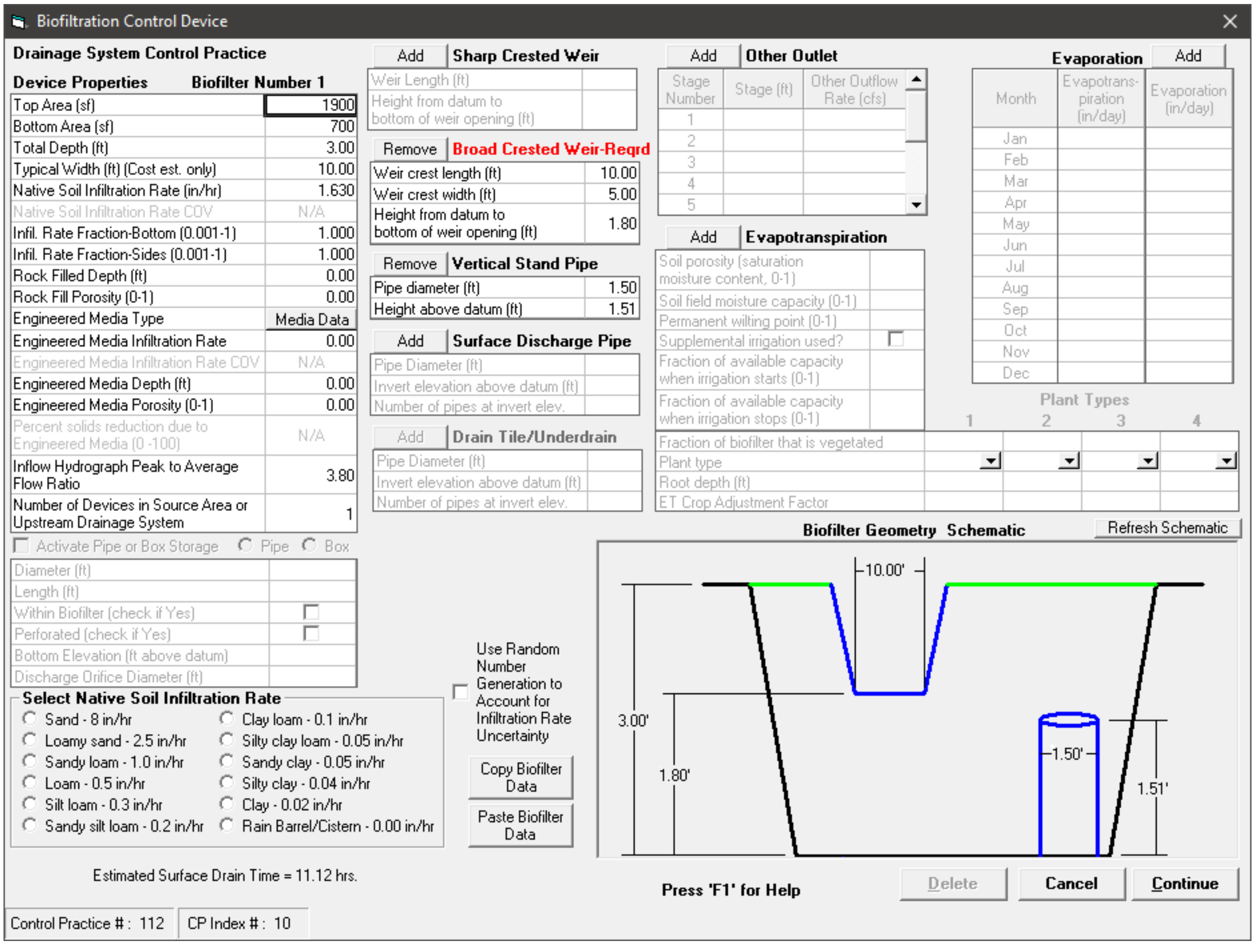


Figure 15: LRC-2-3 Historical Center infiltration basin.

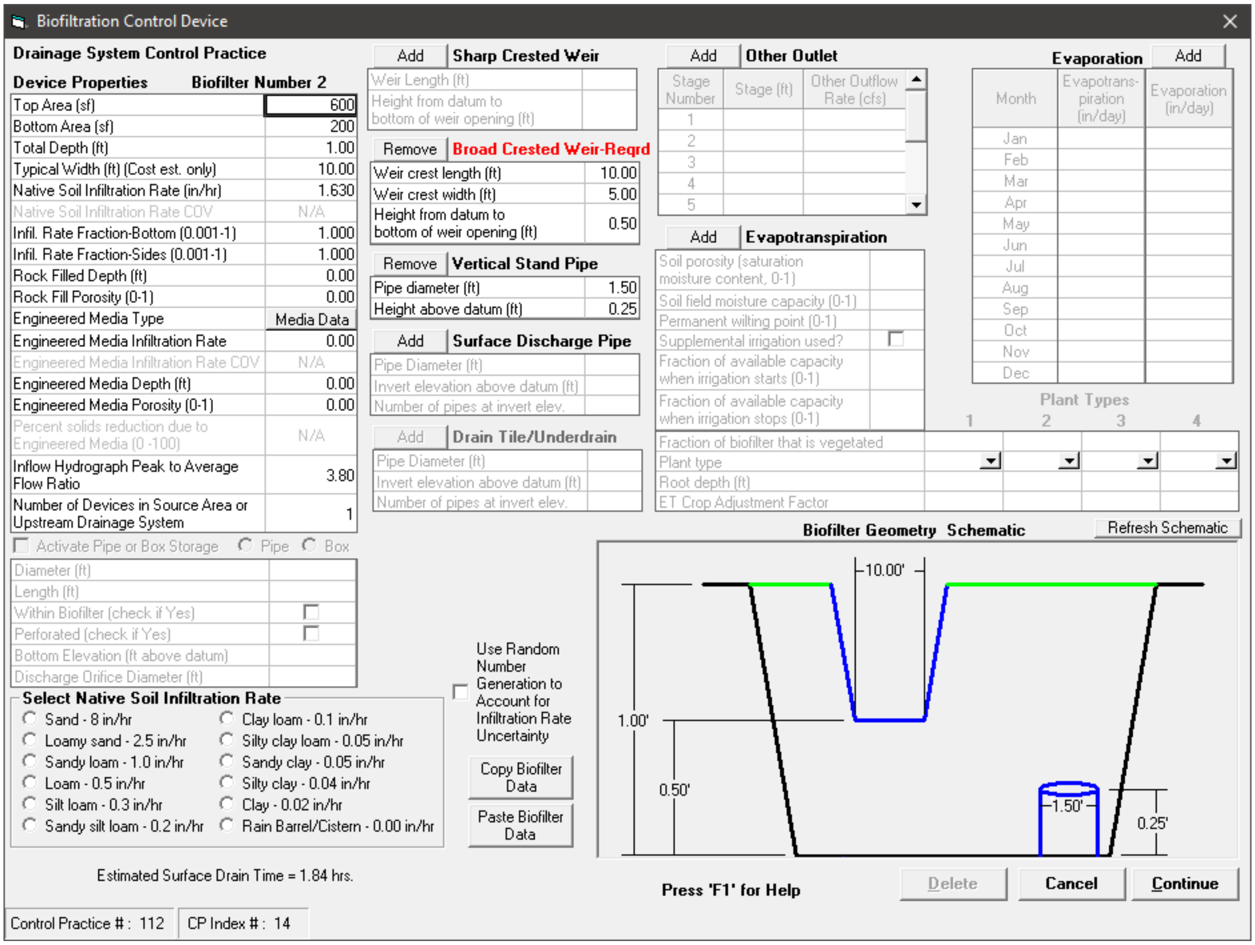


Figure 16: LRC-2-1 Wells Fargo infiltration basin.

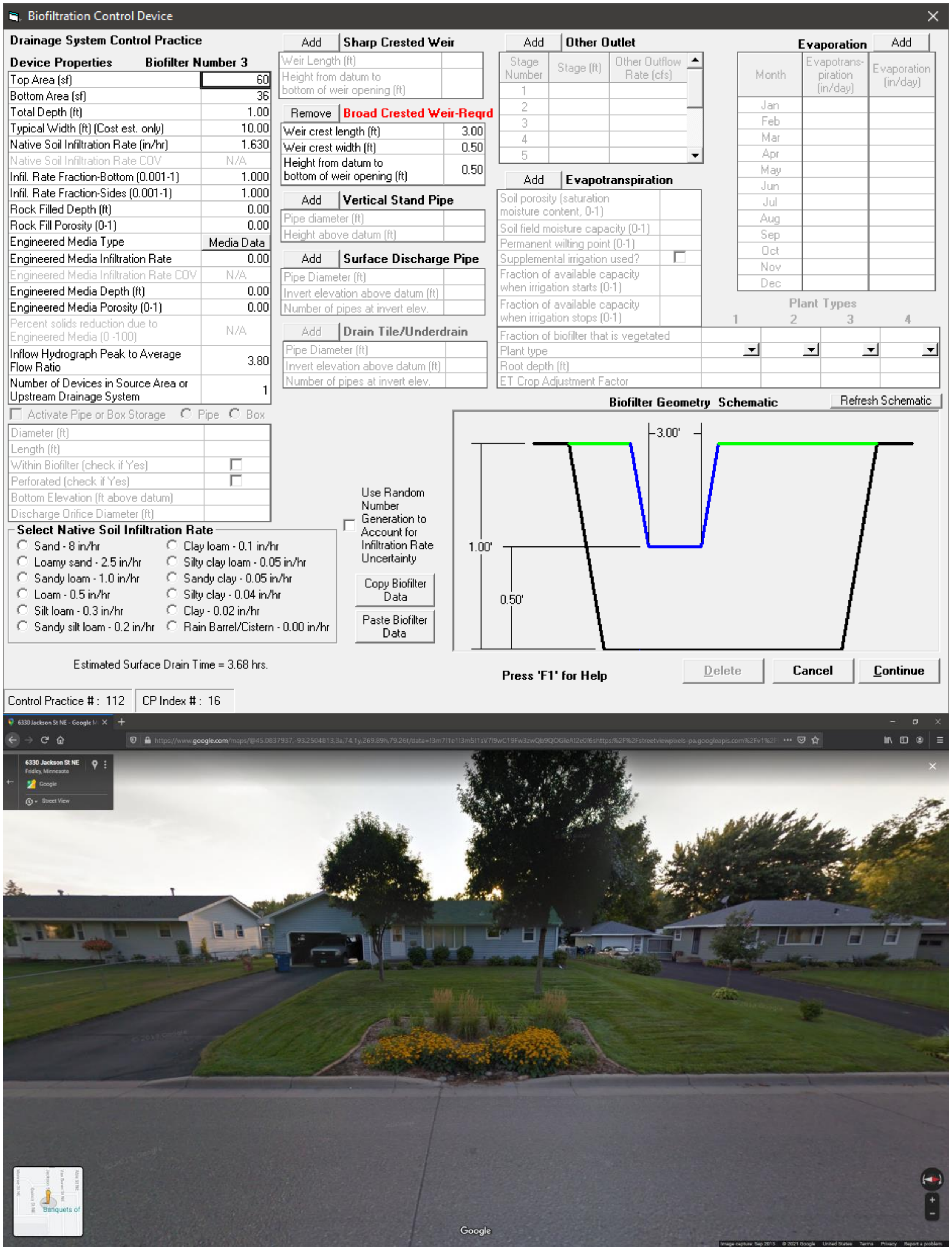


Figure 17: LRC-2-2 Jackson Street curb-cut rain garden.

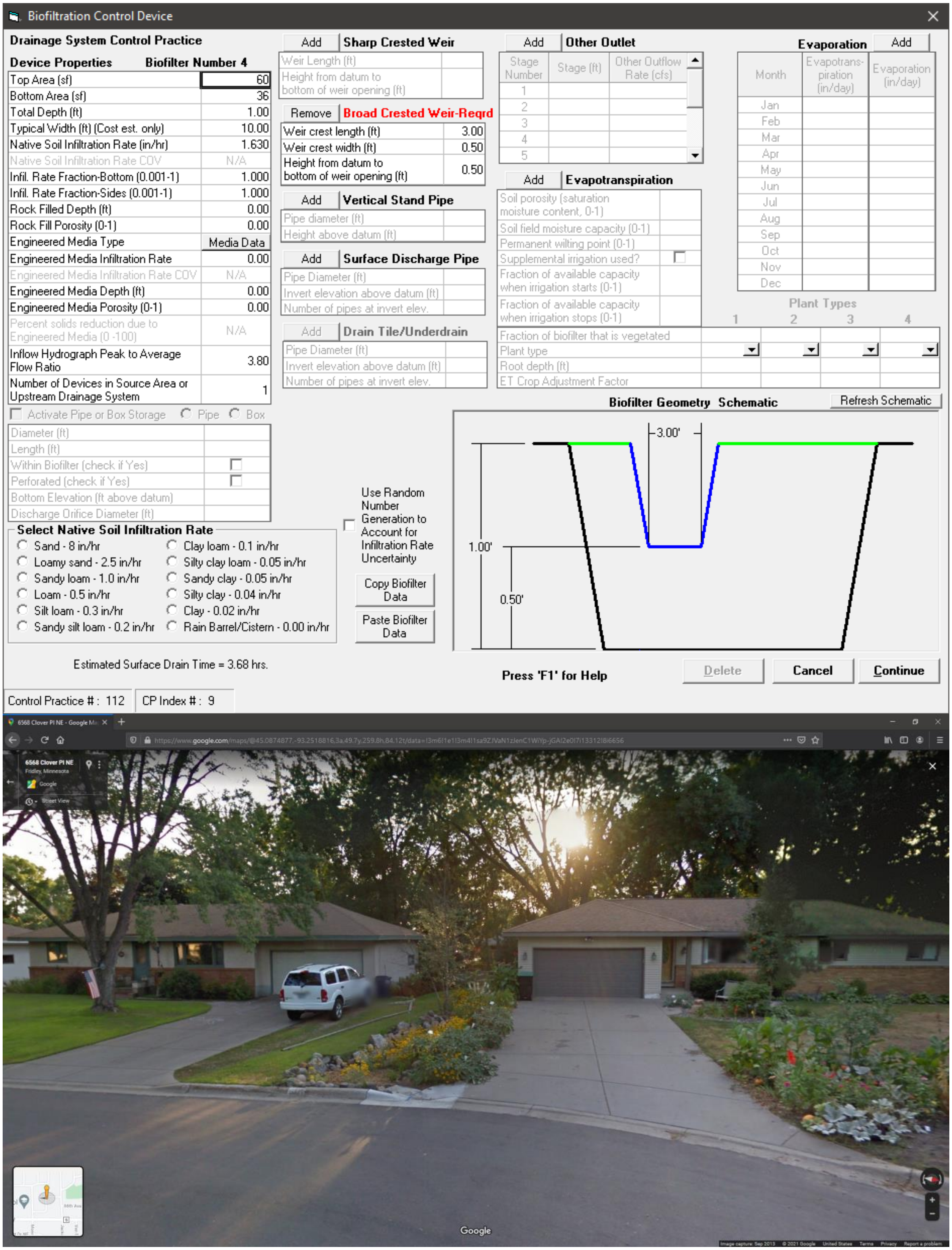


Figure 18: LRC-2-2 Clover Place curb-cut rain garden.

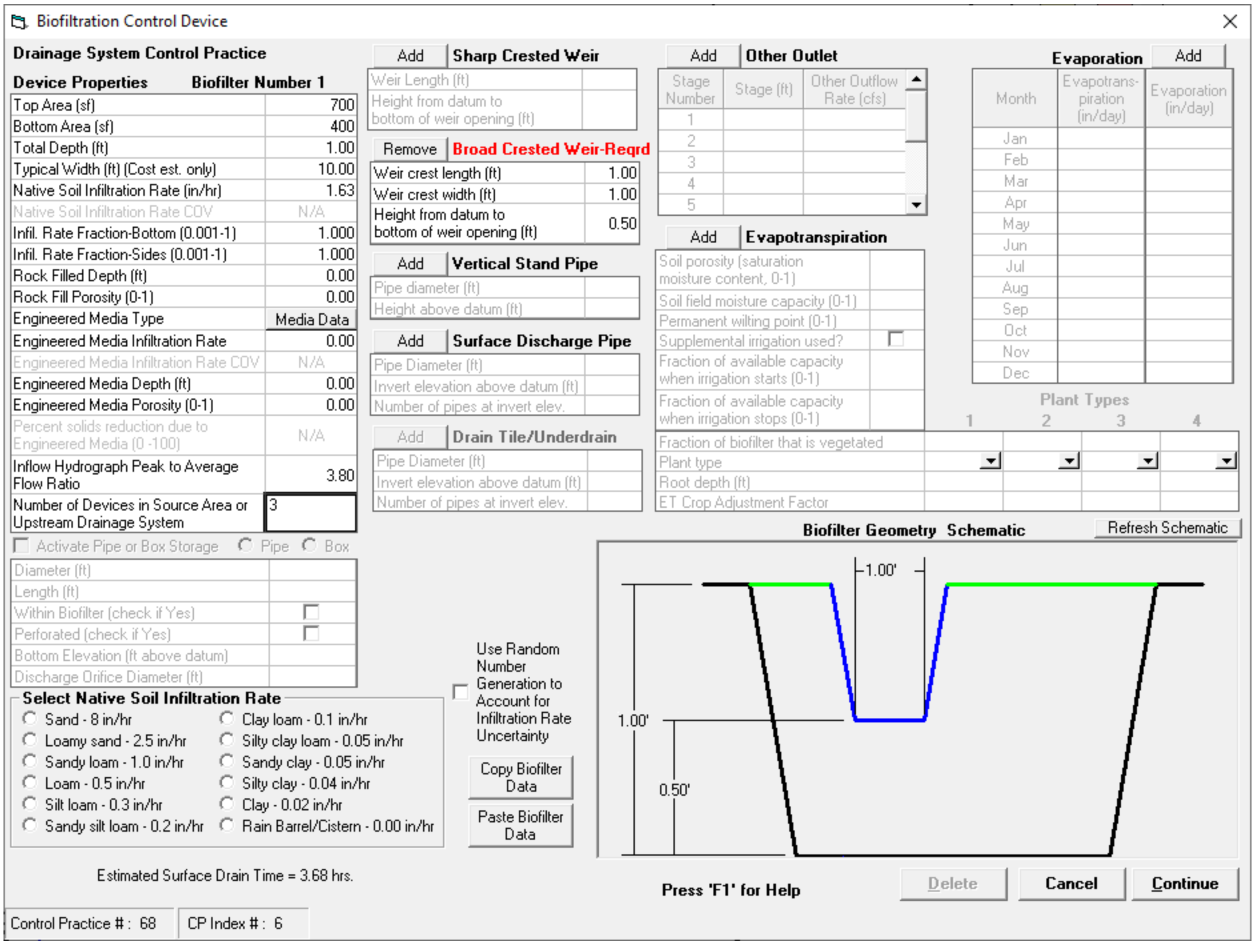


Figure 19: ENC-2 Arthur St. infiltration basins (x3)

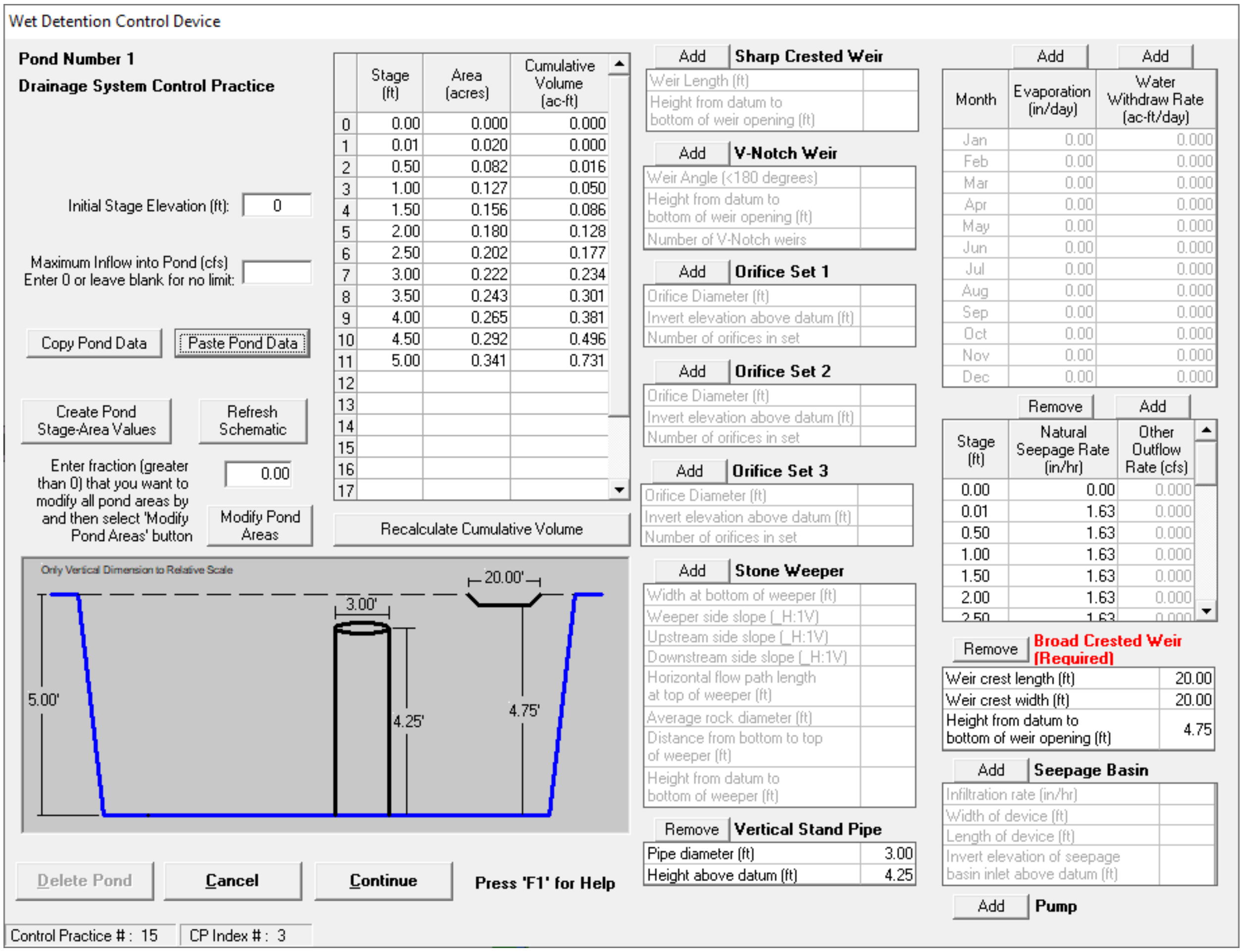


Figure 20: ENC-5-2 Arthur St. infiltration basin

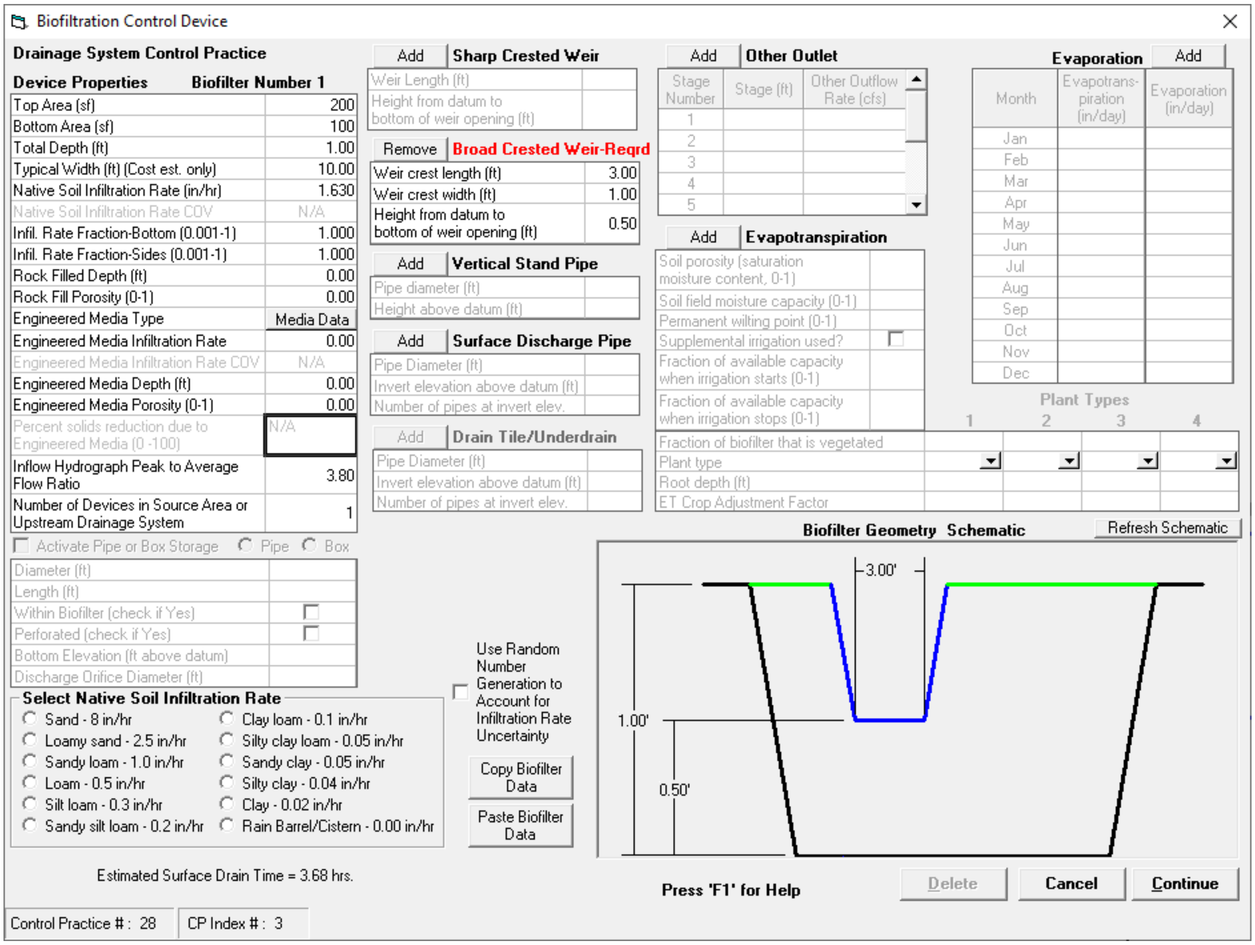


Figure 21: ENC-5-1 Lakeside Rd. curb-cut rain garden #1

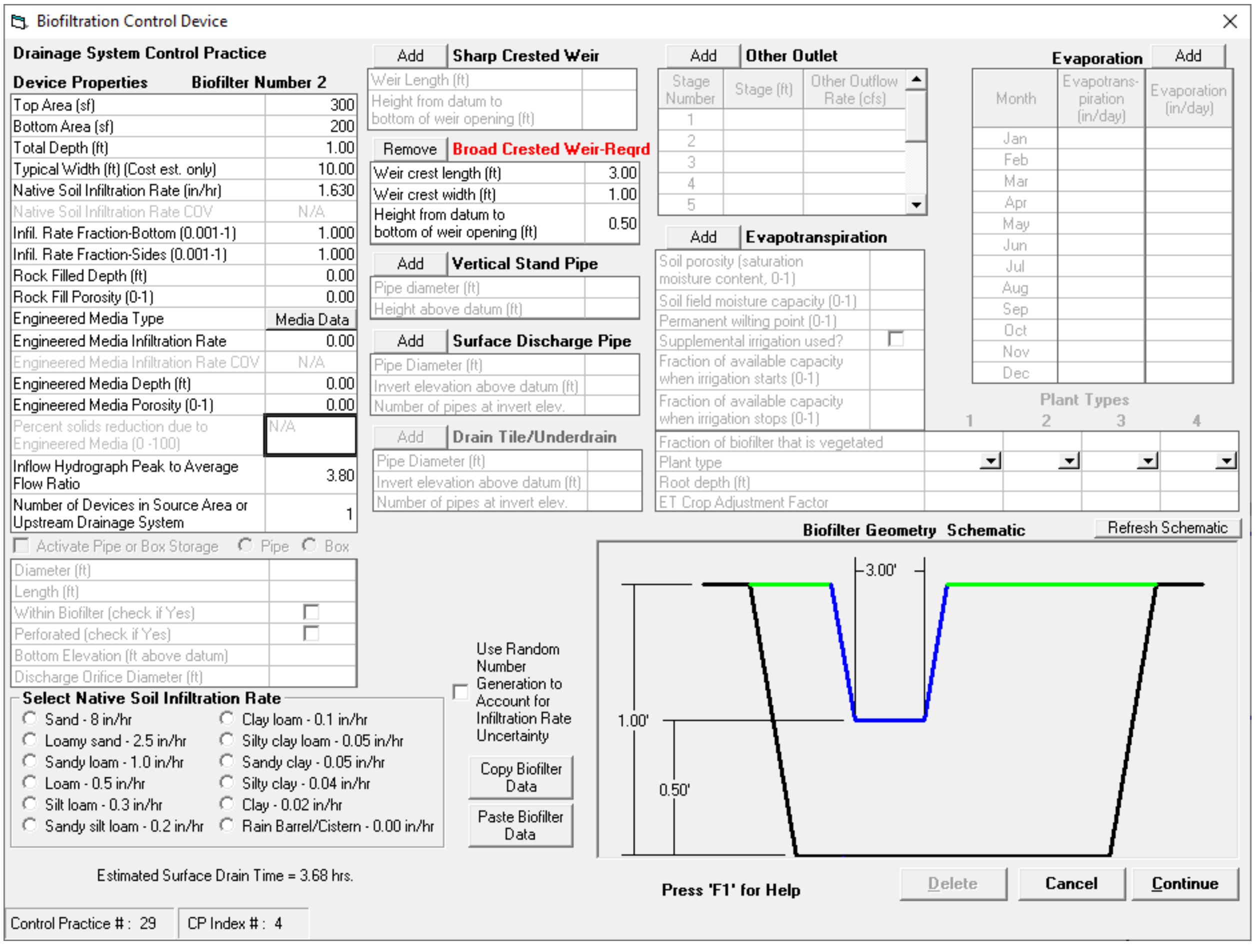


Figure 22: ENC-5-1 Lakeside Rd. curb-cut rain garden #2

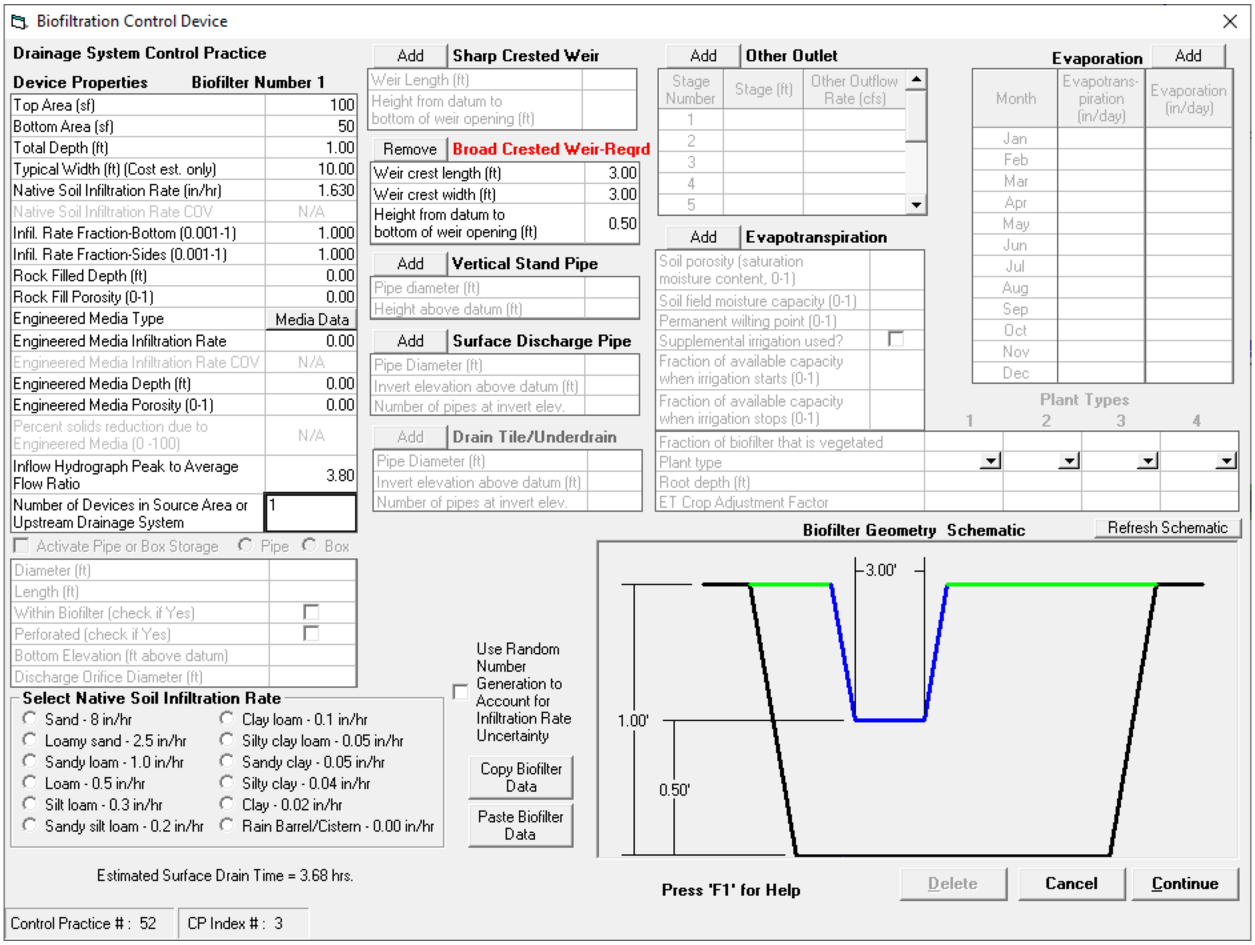


Figure 23: ENC-5-3 Meadowmoor Dr. curb-cut rain garden

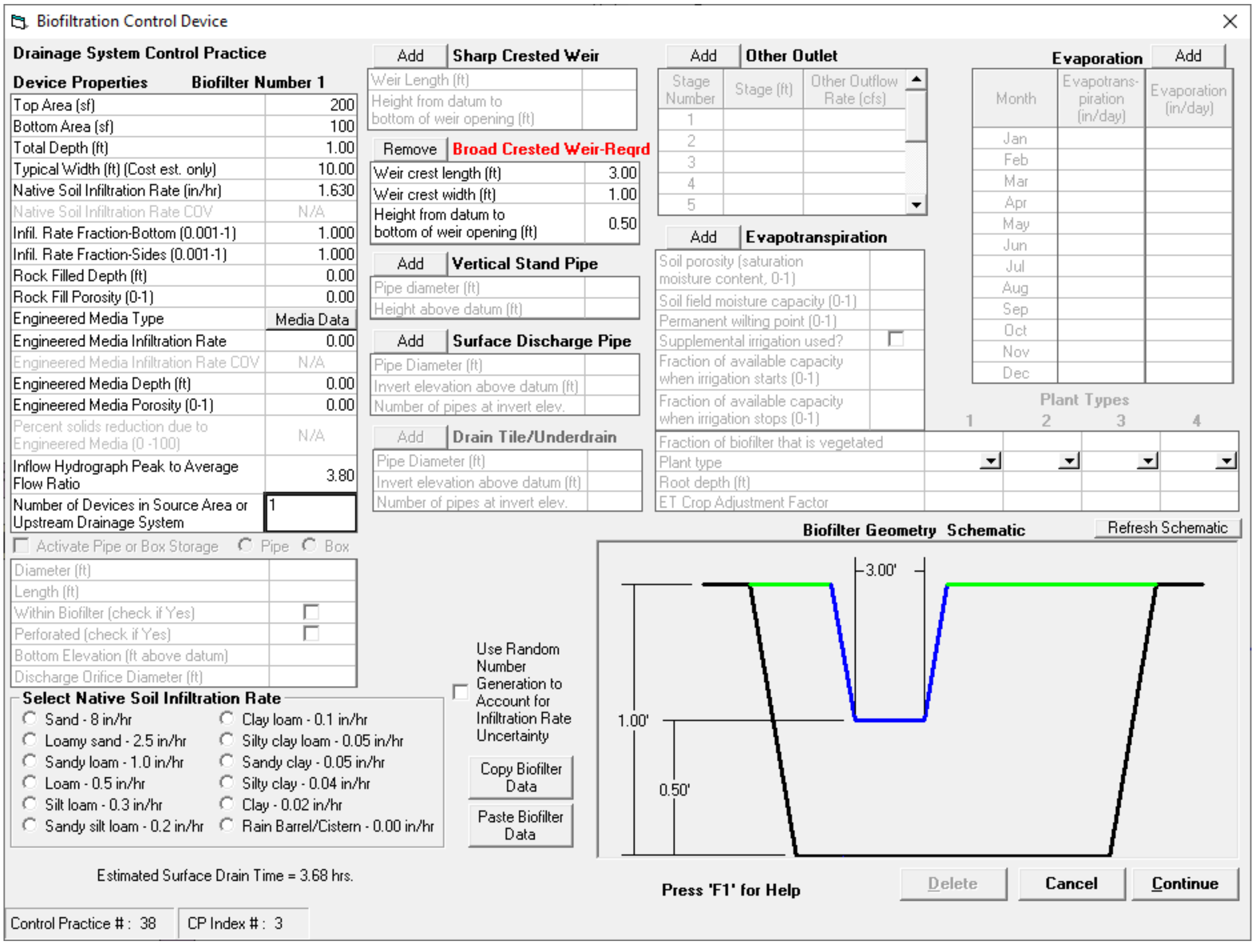


Figure 24: ENC-6 Hayes St. curb-cut rain garden

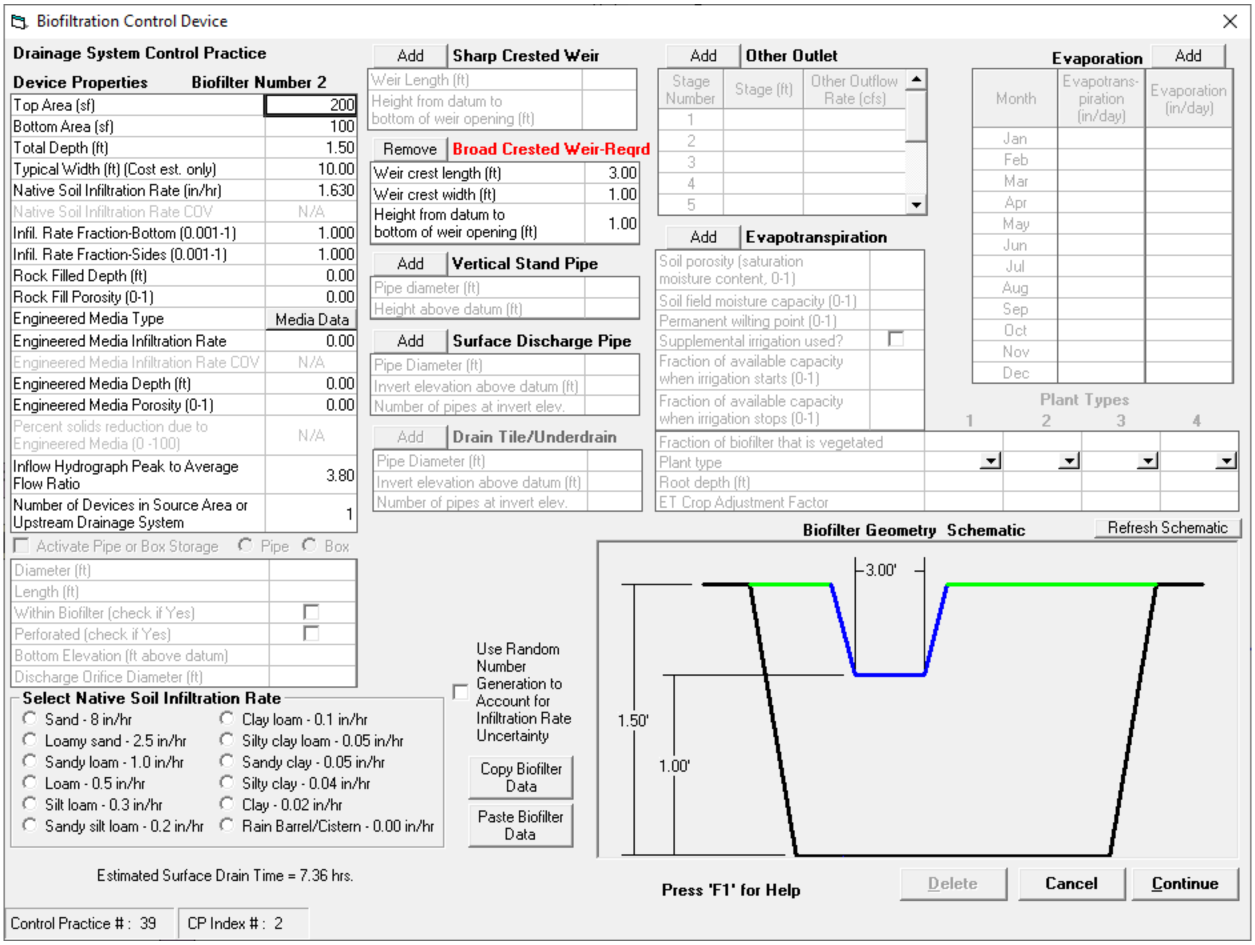


Figure 25: ENC-6 Onondaga St. curb-cut rain garden

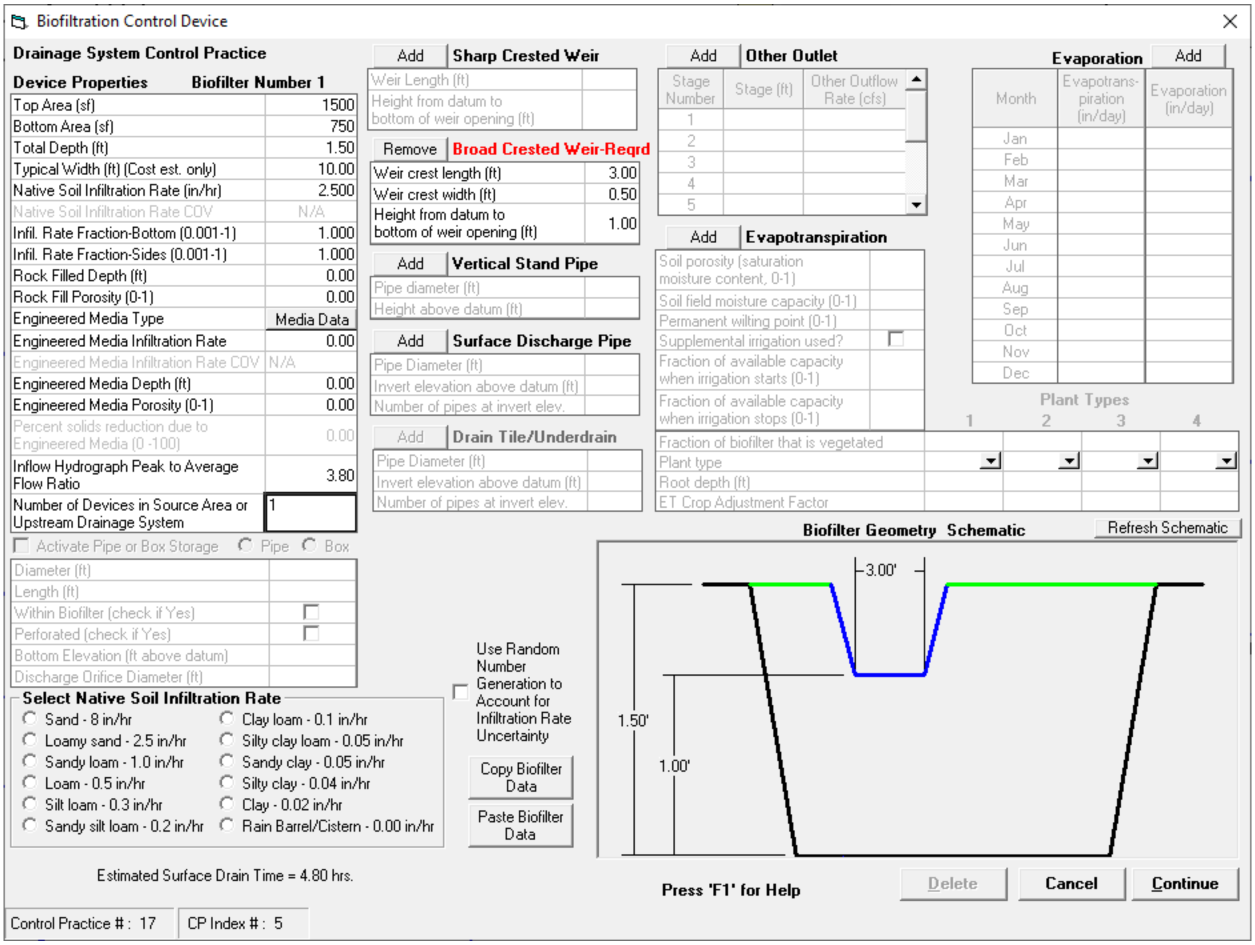


Figure 26: AC Voigt Bus East infiltration basin

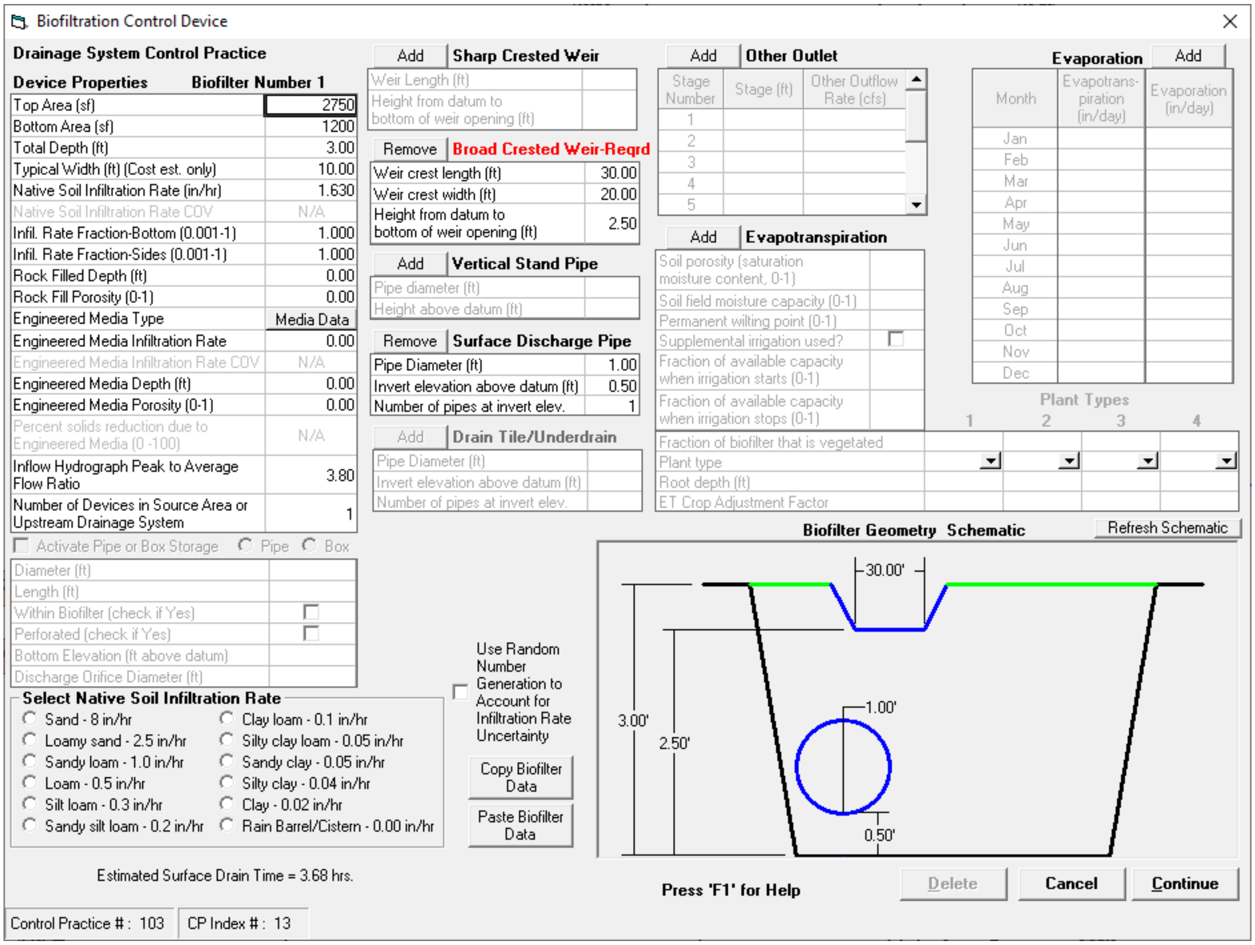


Figure 27: NC-2 72nd Ave. infiltration basin

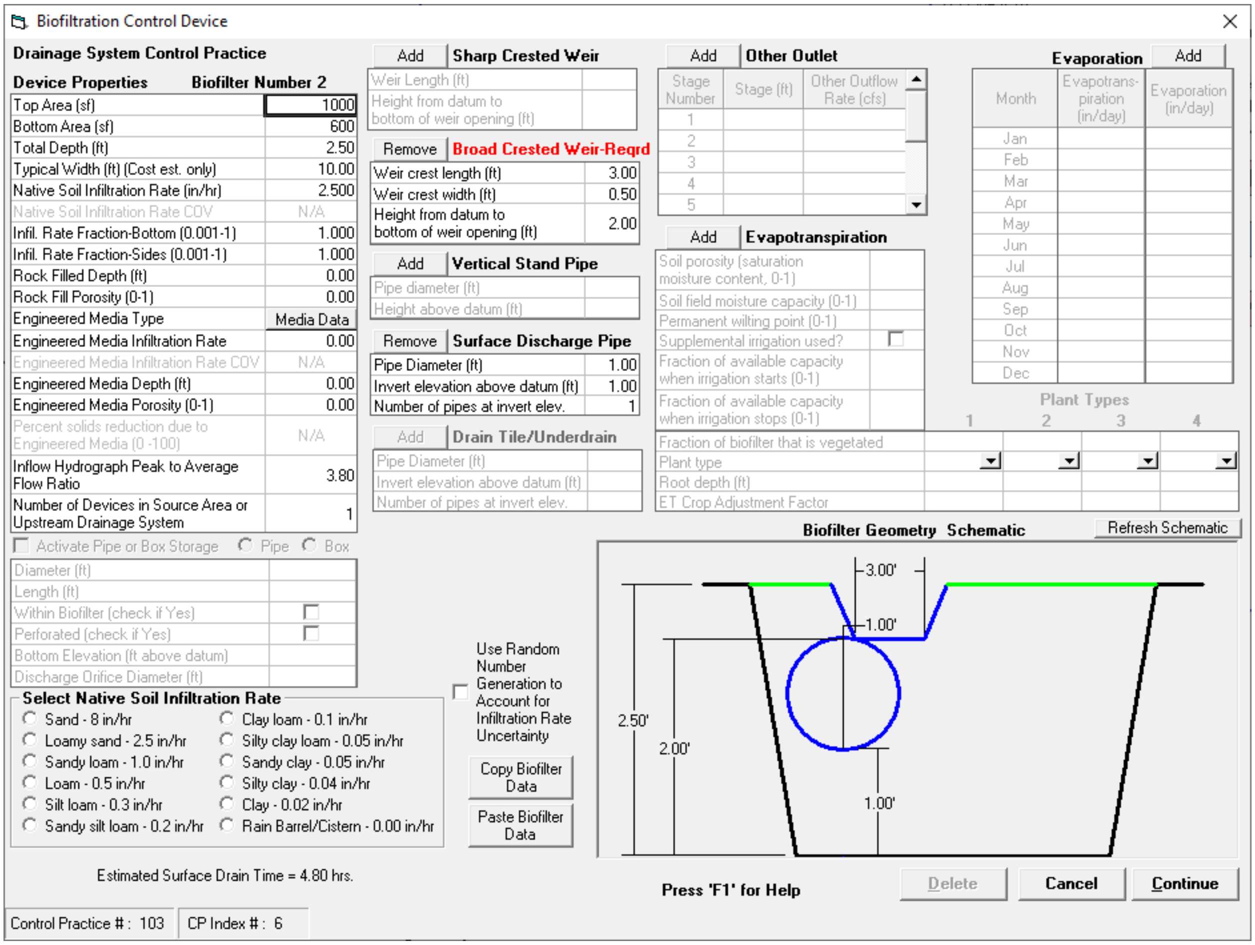


Figure 28: NC-2 Norton Ave. infiltration basin

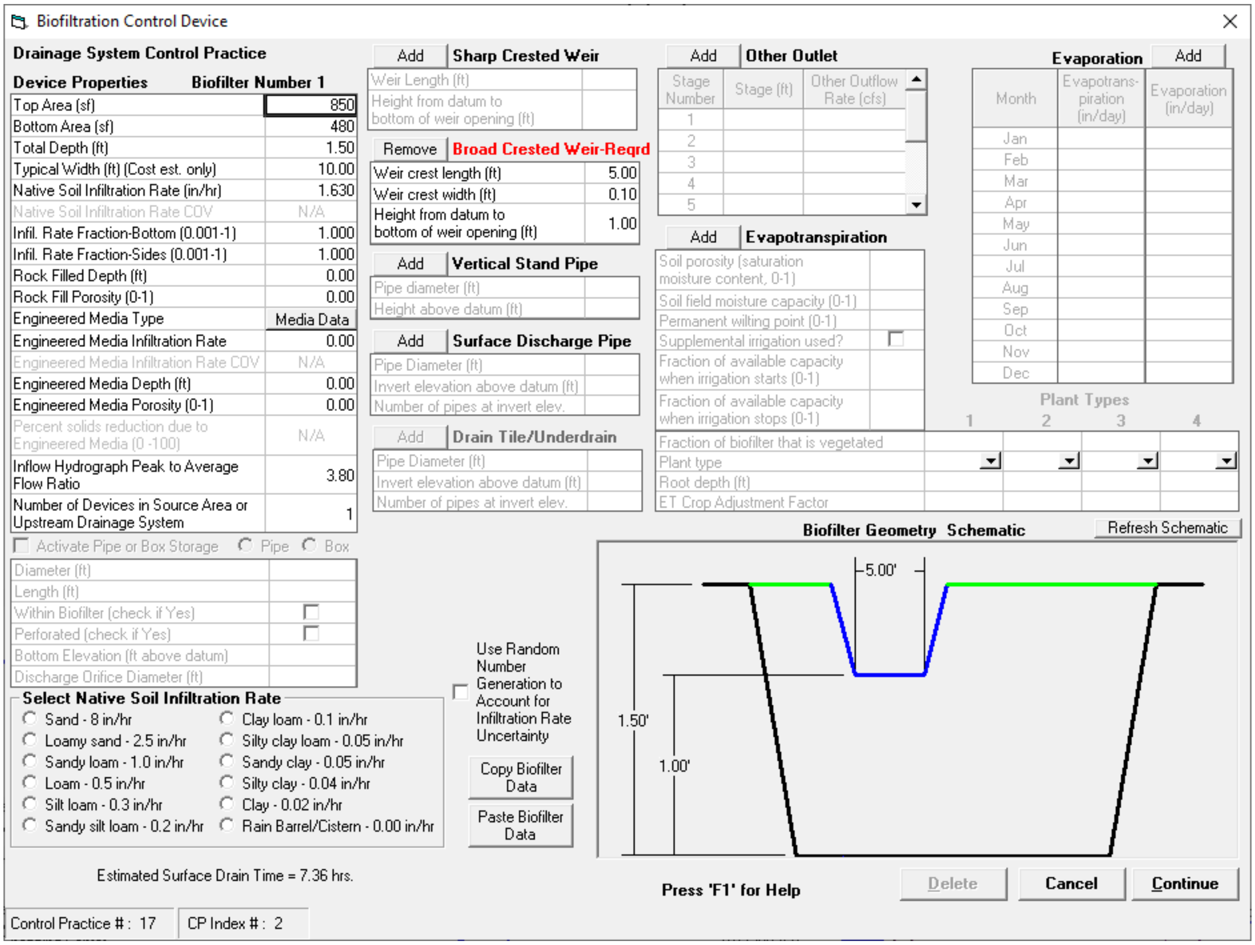


Figure 29: WNC-1 MNDOT infiltration basin

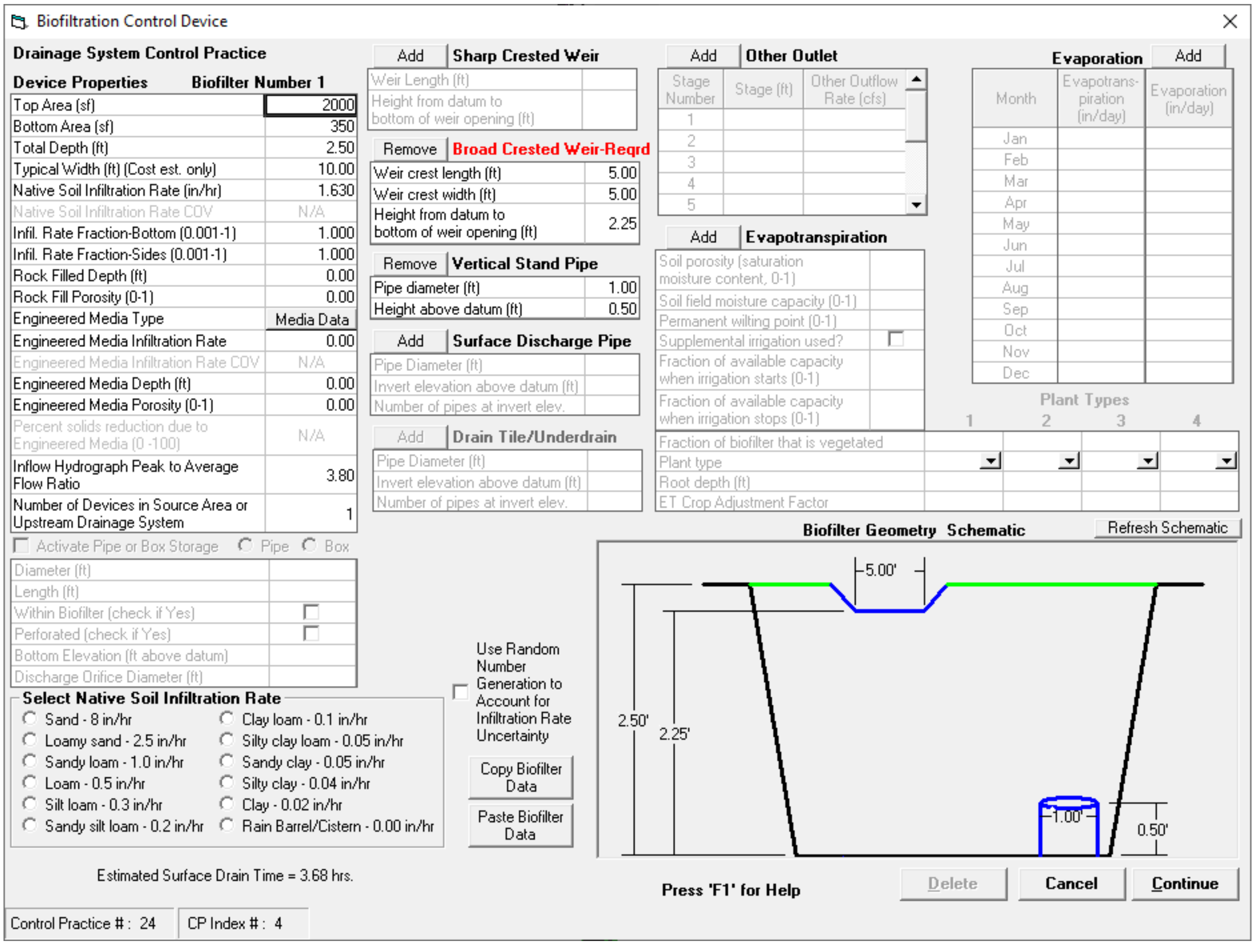


Figure 30: WNC-7 Brenk Brothers South infiltration basin

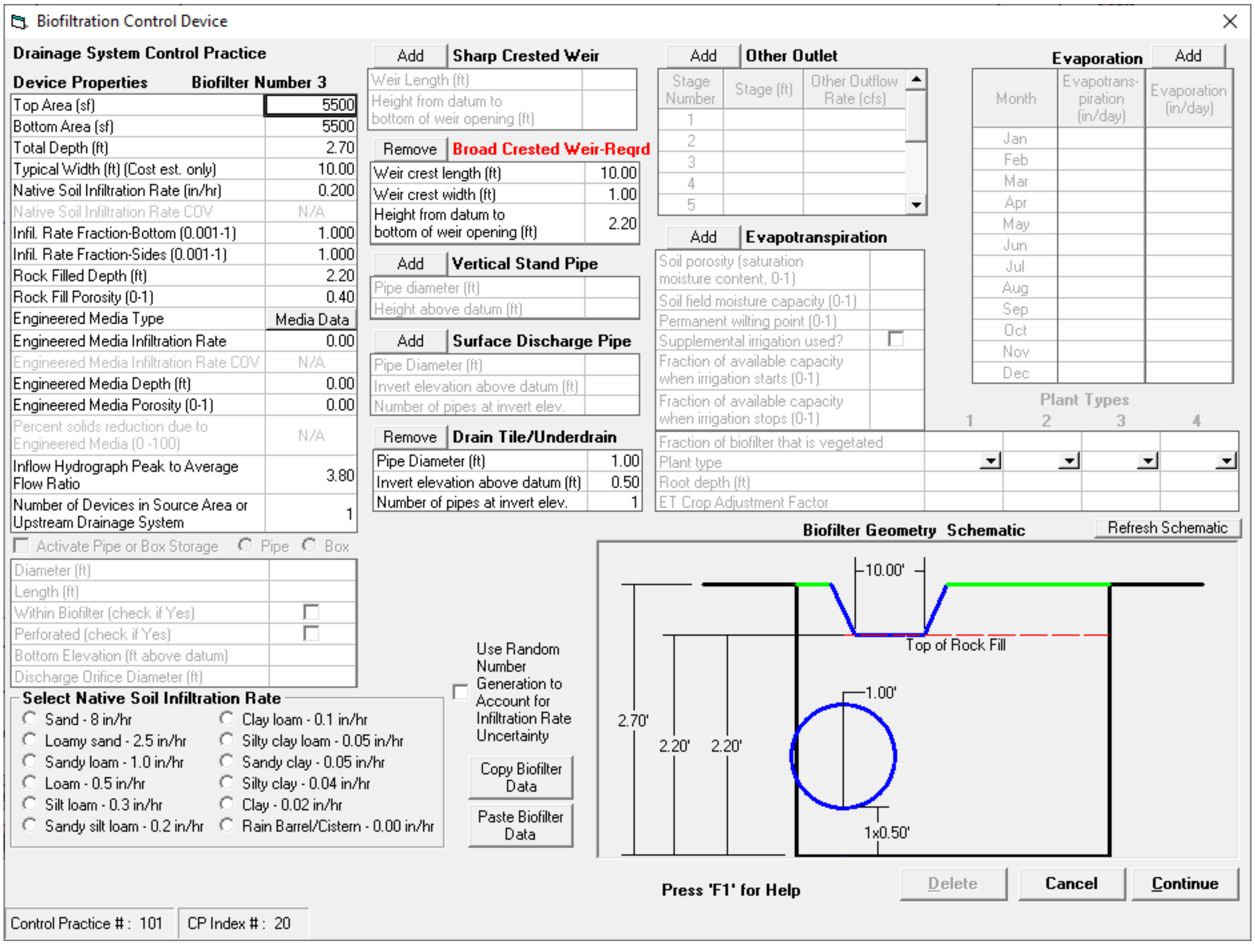


Figure 31: WNC-8 TopWash underground infiltration basin

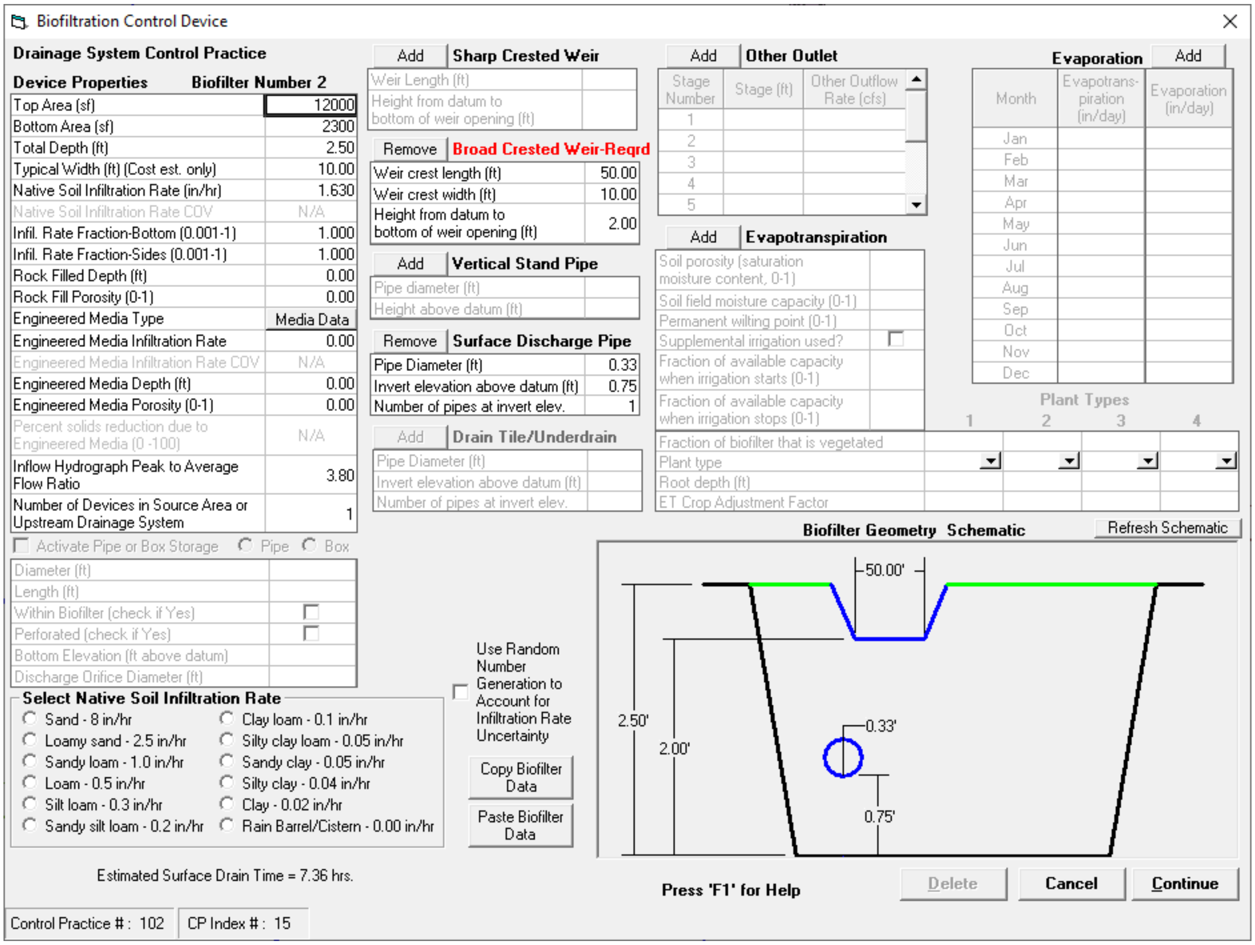


Figure 32: WNC-8 Friendly Chevrolet infiltration basin/swale

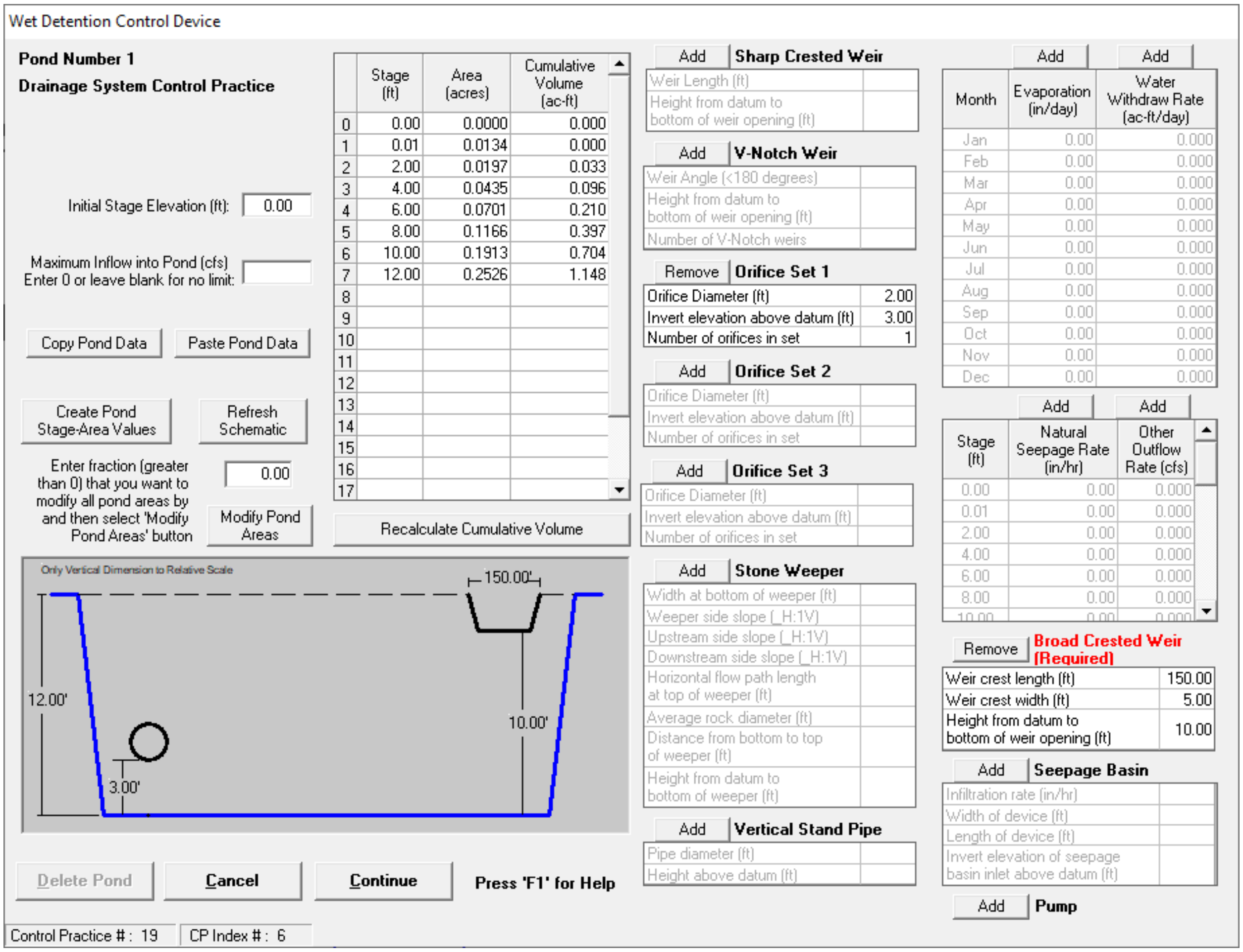


Figure 33: WNC-9 Medtronic infiltration basin

Underground Storage

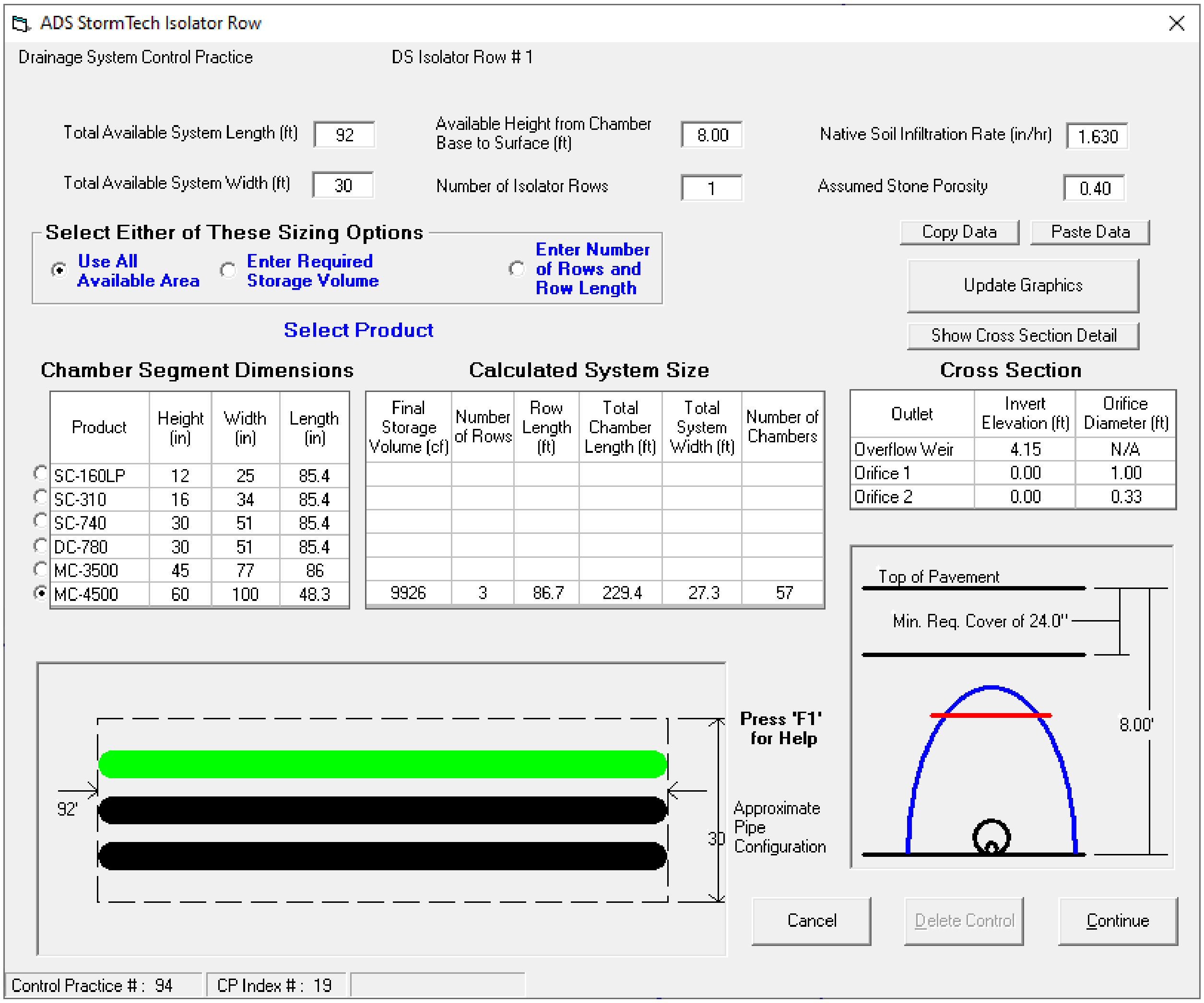


Figure 34: WNC-8 Aabco underground storage

Filtration Basins

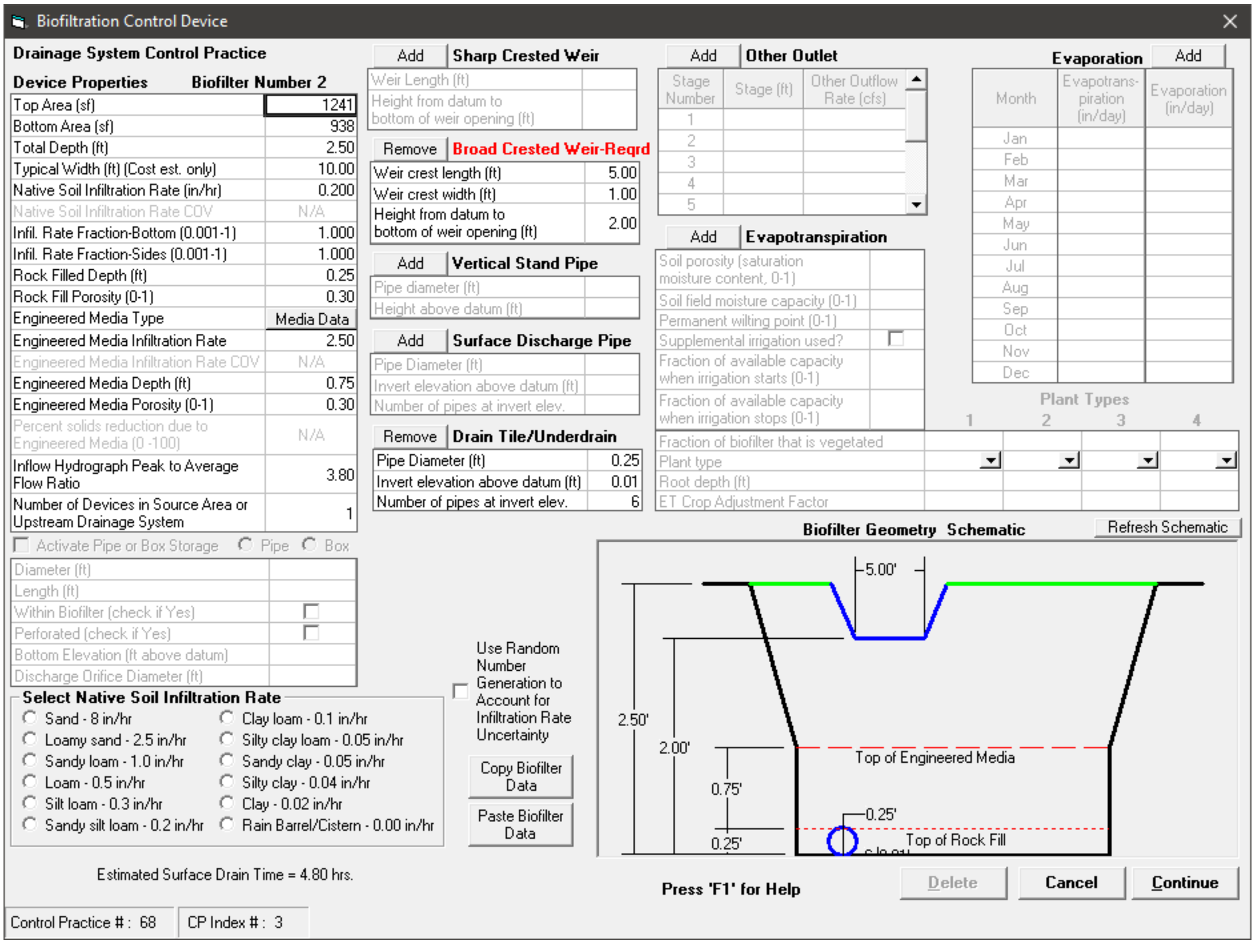


Figure 35: LRC-5-1 Locke 23 curb-cut rain garden.

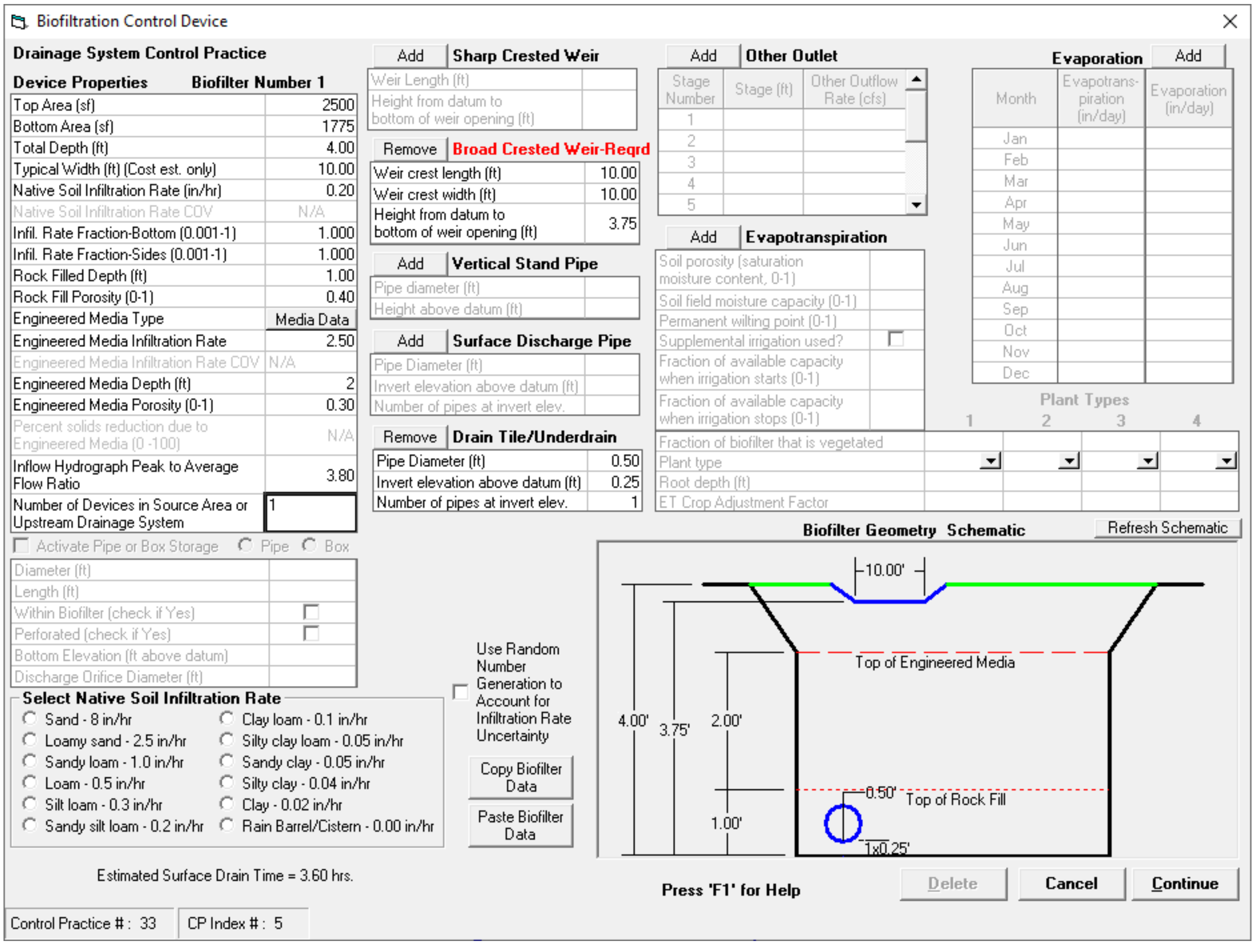


Figure 36: ENC-1 ECFE filtration basin

Street Cleaning

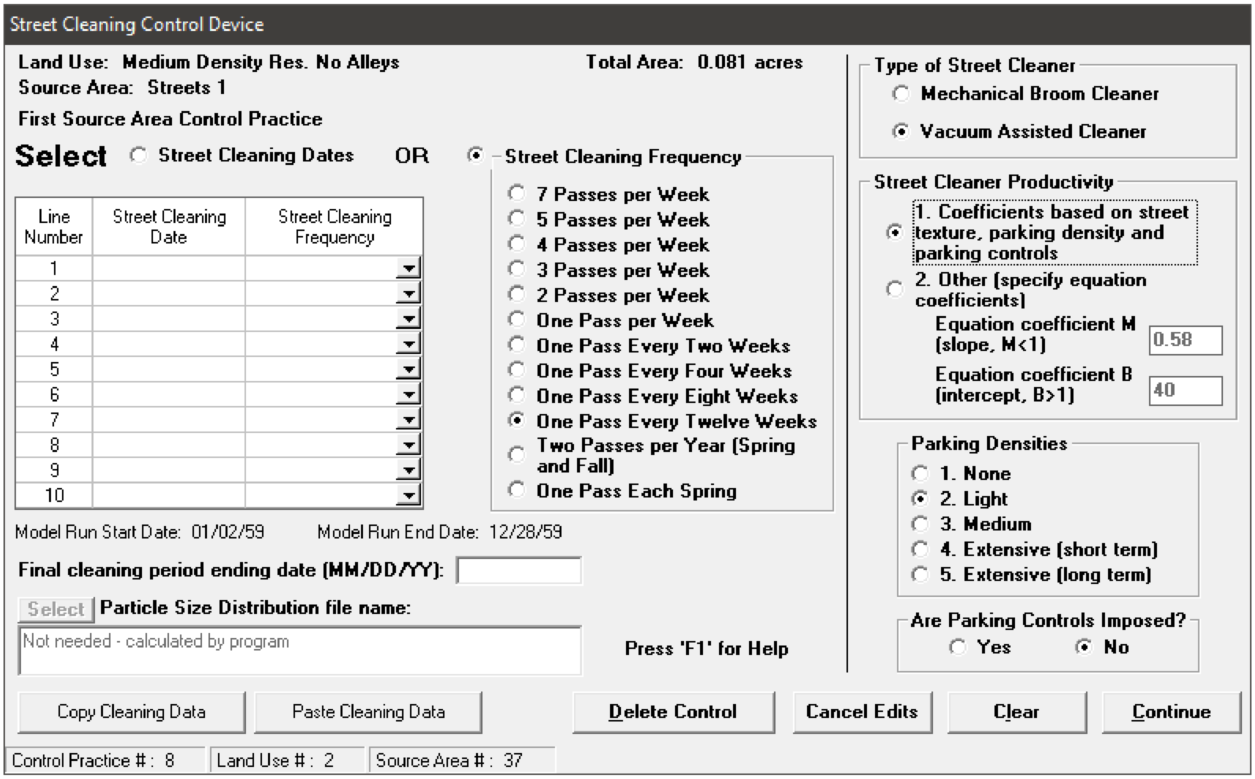


Figure 37: Street cleaning parameters used. Street cleaning occurs three times per year in the spring, summer, and fall.

Wet Ponds

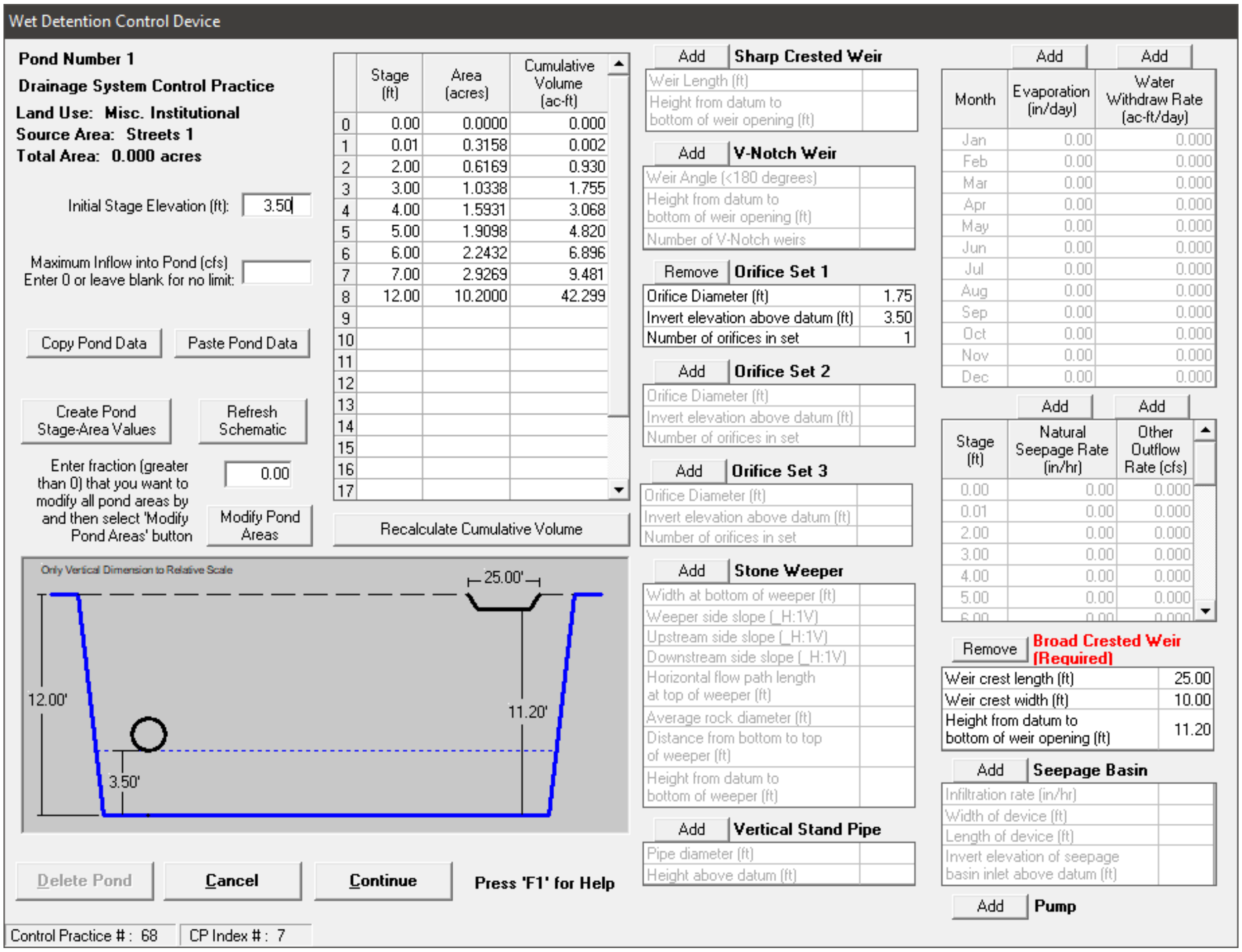


Figure 38: LRC-5-1 Meadowlands Pond South.

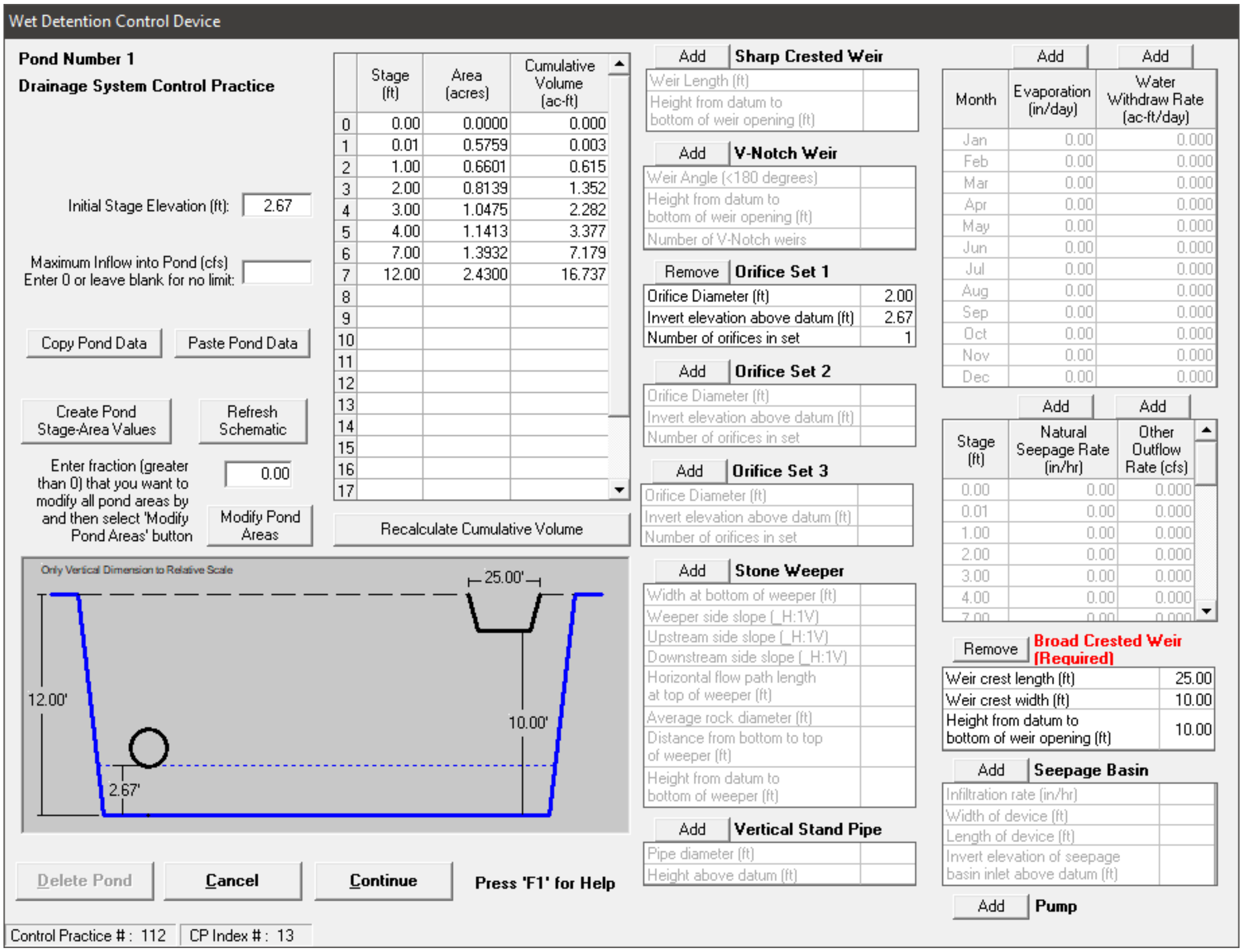


Figure 39: LRC-2-2 Village Green Apartments Pond.

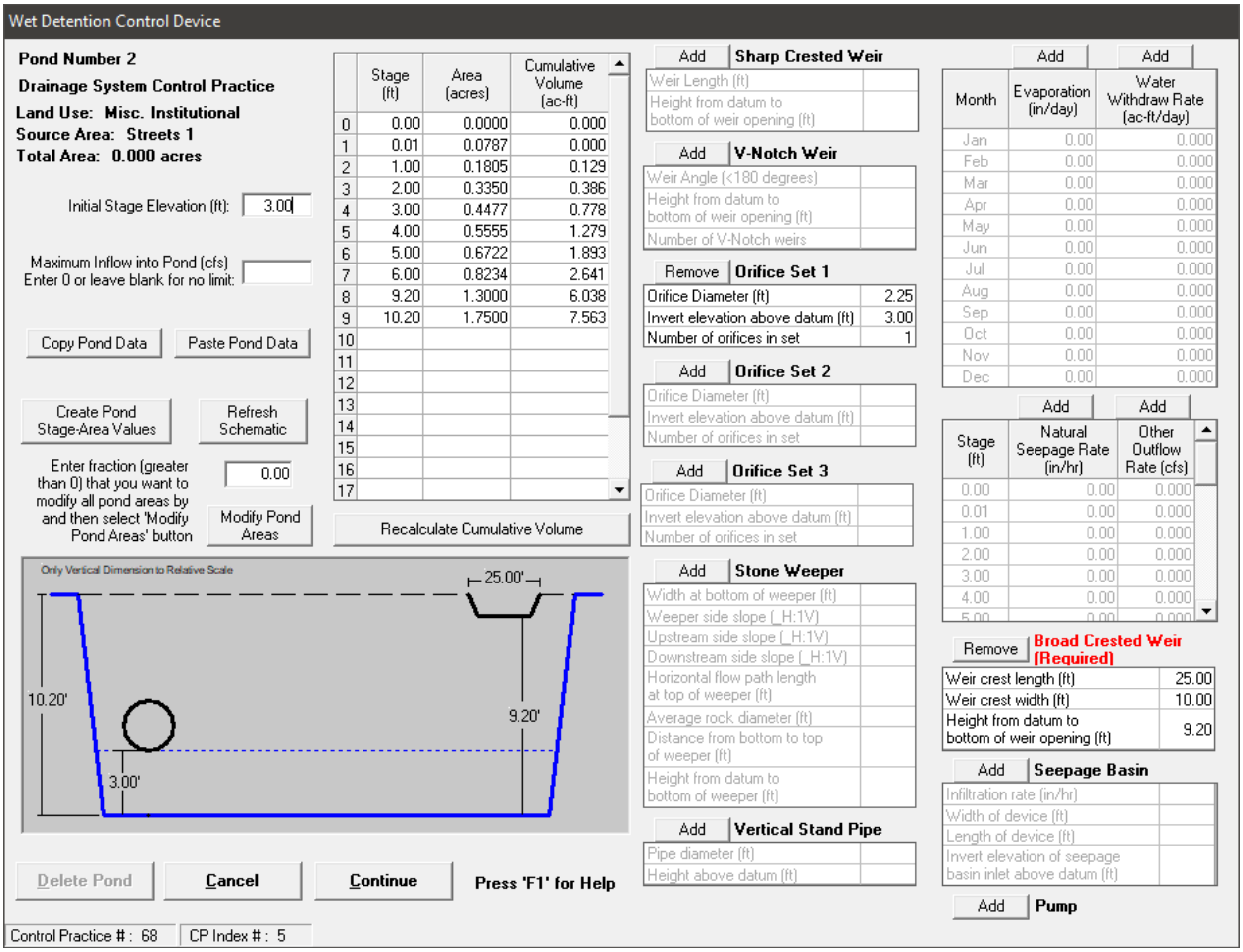


Figure 40: LRC-5-1 Meadowlands Pond North.

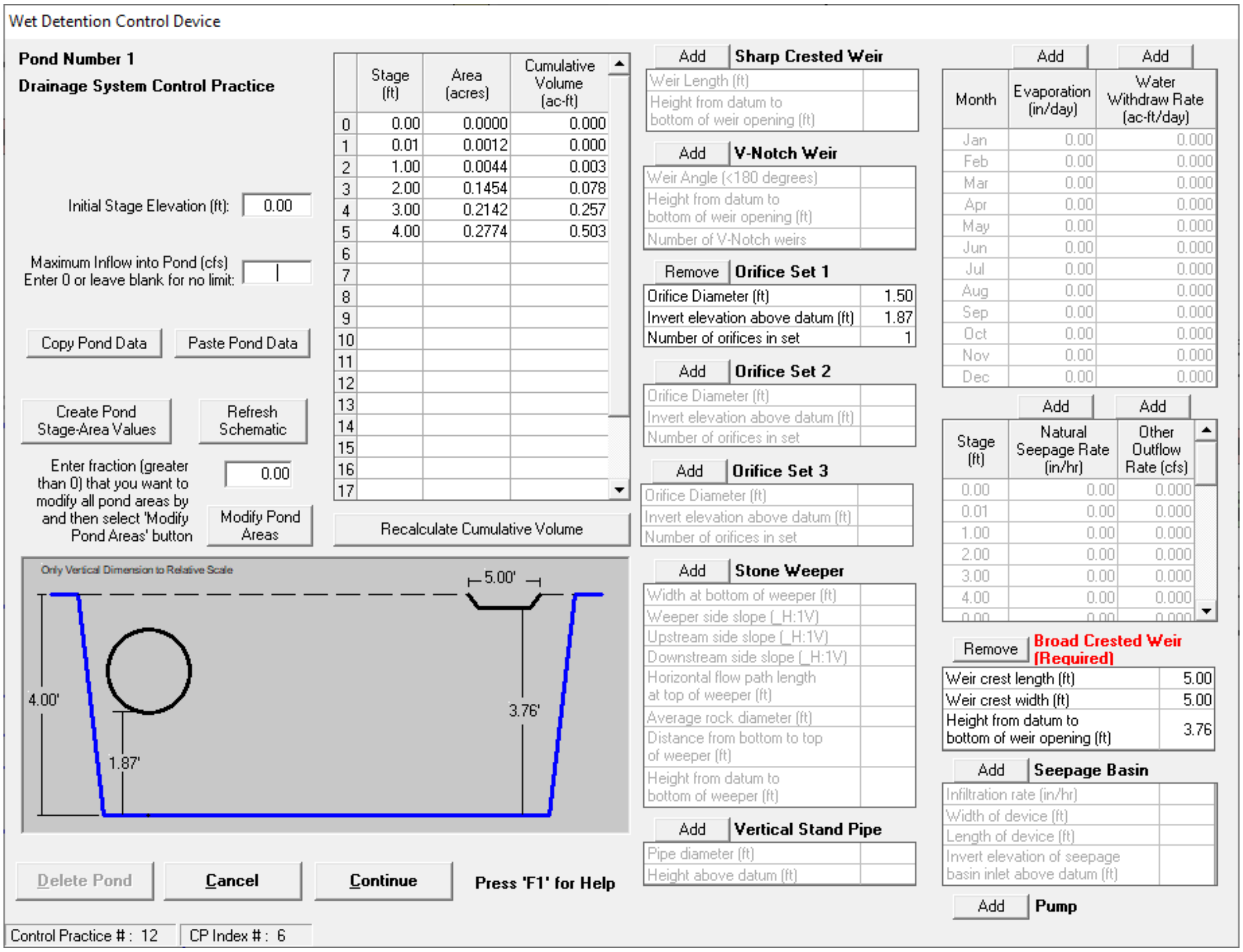


Figure 41: AC Brenk Brothers East Pond

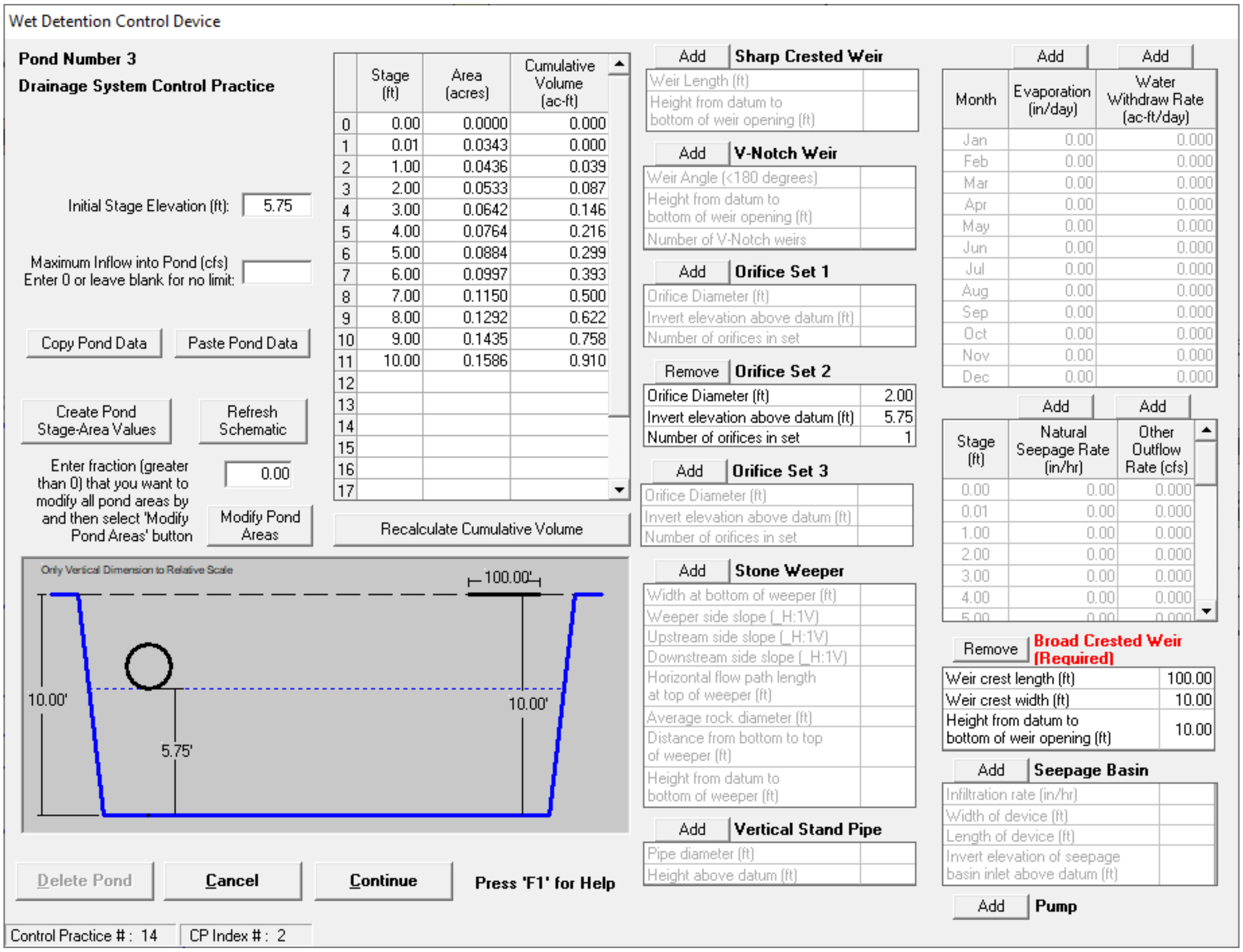


Figure 42: AC Parkbrook Center NE Pond

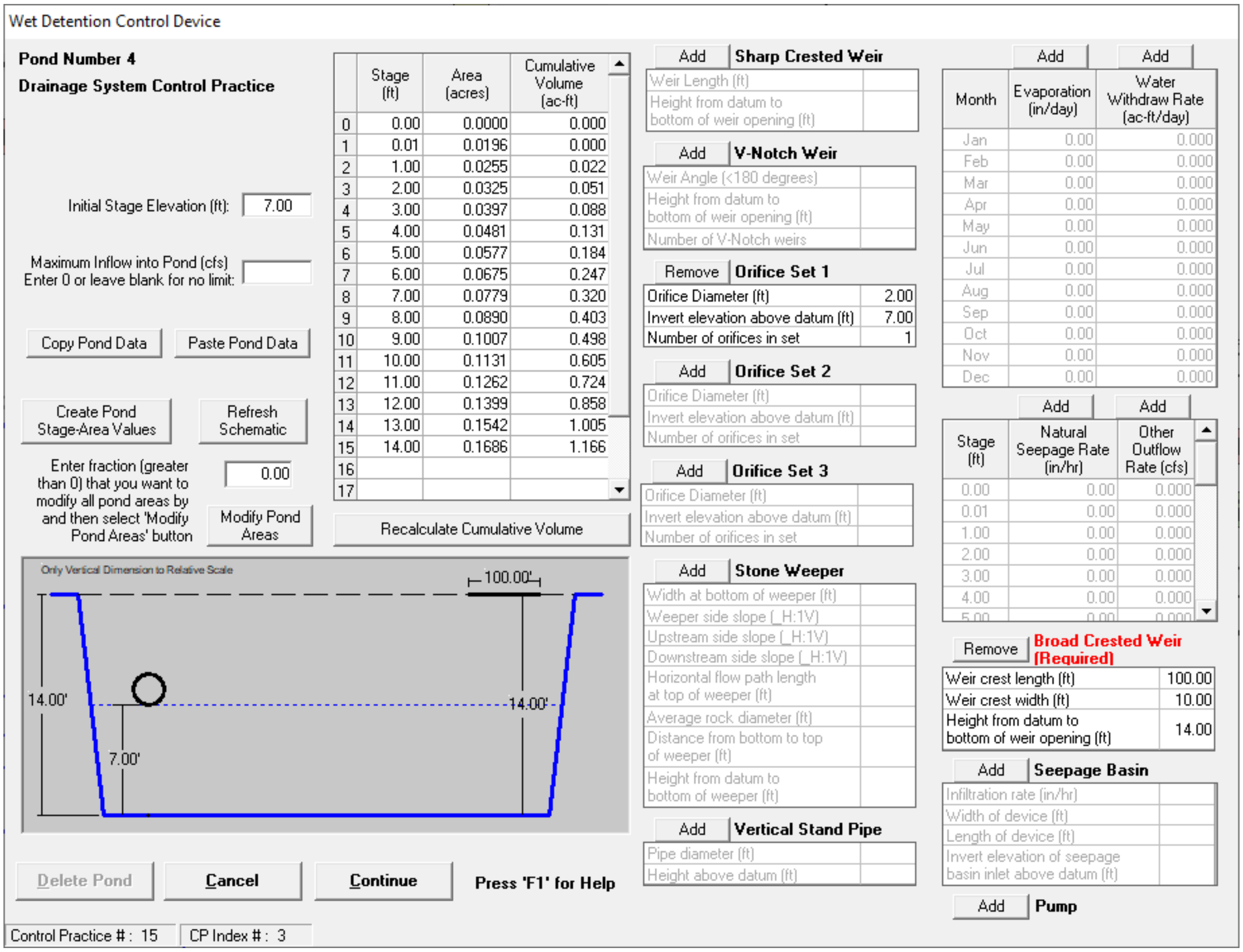
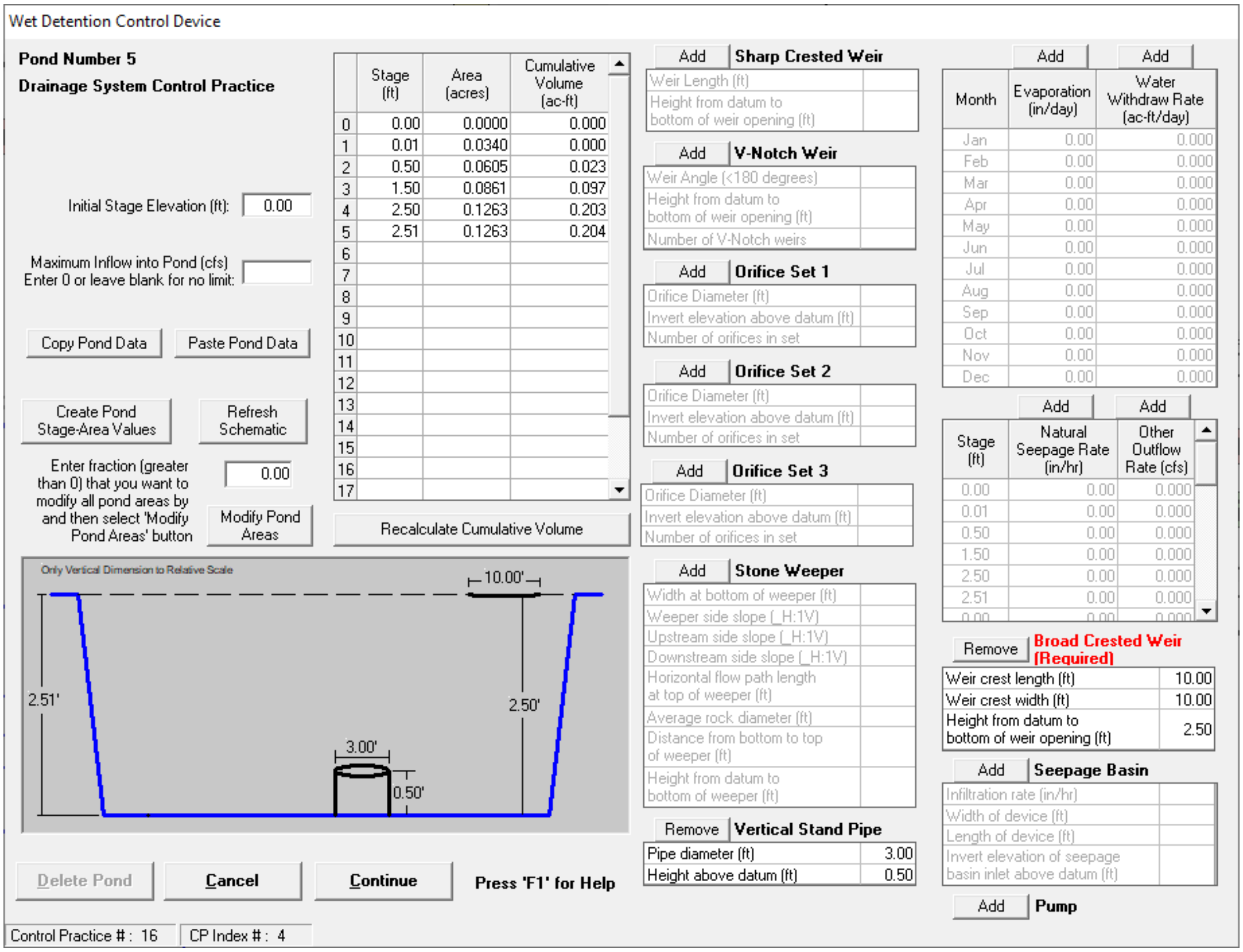


Figure 43: AC Parkbrook Center SW Pond


Wet Detention Control Device

Pond Number 5

Drainage System Control Practice

	Stage (ft)	Area (acres)	Cumulative Volume (ac-ft)
0	0.00	0.0000	0.000
1	0.01	0.0340	0.000
2	0.50	0.0605	0.023
3	1.50	0.0861	0.097
4	2.50	0.1263	0.203
5	2.51	0.1263	0.204
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			

Initial Stage Elevation (ft): 0.00

Maximum Inflow into Pond (cfs) Enter 0 or leave blank for no limit:

Copy Pond Data | Paste Pond Data

Create Pond Stage-Area Values | Refresh Schematic

Enter fraction (greater than 0) that you want to modify all pond areas by and then select 'Modify Pond Areas' button: 0.00 | Modify Pond Areas

Recalculate Cumulative Volume

Add **Sharp Crested Weir**
Weir Length (ft)
Height from datum to bottom of weir opening (ft)

Add **V-Notch Weir**
Weir Angle (<180 degrees)
Height from datum to bottom of weir opening (ft)
Number of V-Notch weirs

Add **Orifice Set 1**
Orifice Diameter (ft)
Invert elevation above datum (ft)
Number of orifices in set

Add **Orifice Set 2**
Orifice Diameter (ft)
Invert elevation above datum (ft)
Number of orifices in set

Add **Orifice Set 3**
Orifice Diameter (ft)
Invert elevation above datum (ft)
Number of orifices in set

Add **Stone Weeper**
Width at bottom of weeper (ft)
Weeper side slope (_H:1V)
Upstream side slope (_H:1V)
Downstream side slope (_H:1V)
Horizontal flow path length at top of weeper (ft)
Average rock diameter (ft)
Distance from bottom to top of weeper (ft)
Height from datum to bottom of weeper (ft)

Remove **Vertical Stand Pipe**

Pipe diameter (ft)	3.00
Height above datum (ft)	0.50

Month	Evaporation (in/day)	Water Withdraw Rate (ac-ft/day)
Jan	0.00	0.000
Feb	0.00	0.000
Mar	0.00	0.000
Apr	0.00	0.000
May	0.00	0.000
Jun	0.00	0.000
Jul	0.00	0.000
Aug	0.00	0.000
Sep	0.00	0.000
Oct	0.00	0.000
Nov	0.00	0.000
Dec	0.00	0.000

Stage (ft)	Natural Seepage Rate (in/hr)	Other Outflow Rate (cfs)
0.00	0.00	0.000
0.01	0.00	0.000
0.50	0.00	0.000
1.50	0.00	0.000
2.50	0.00	0.000
2.51	0.00	0.000
0.00	0.00	0.000

Remove **Broad Crested Weir (Required)**

Weir crest length (ft)	10.00
Weir crest width (ft)	10.00
Height from datum to bottom of weir opening (ft)	2.50

Add **Seepage Basin**
Infiltration rate (in/hr)
Width of device (ft)
Length of device (ft)
Invert elevation of seepage basin inlet above datum (ft)

Add **Pump**

Delete Pond | Cancel | Continue | **Press 'F1' for Help**

Control Practice # : 16 | CP Index # : 4

Figure 44: AC Voigt Bus Pond

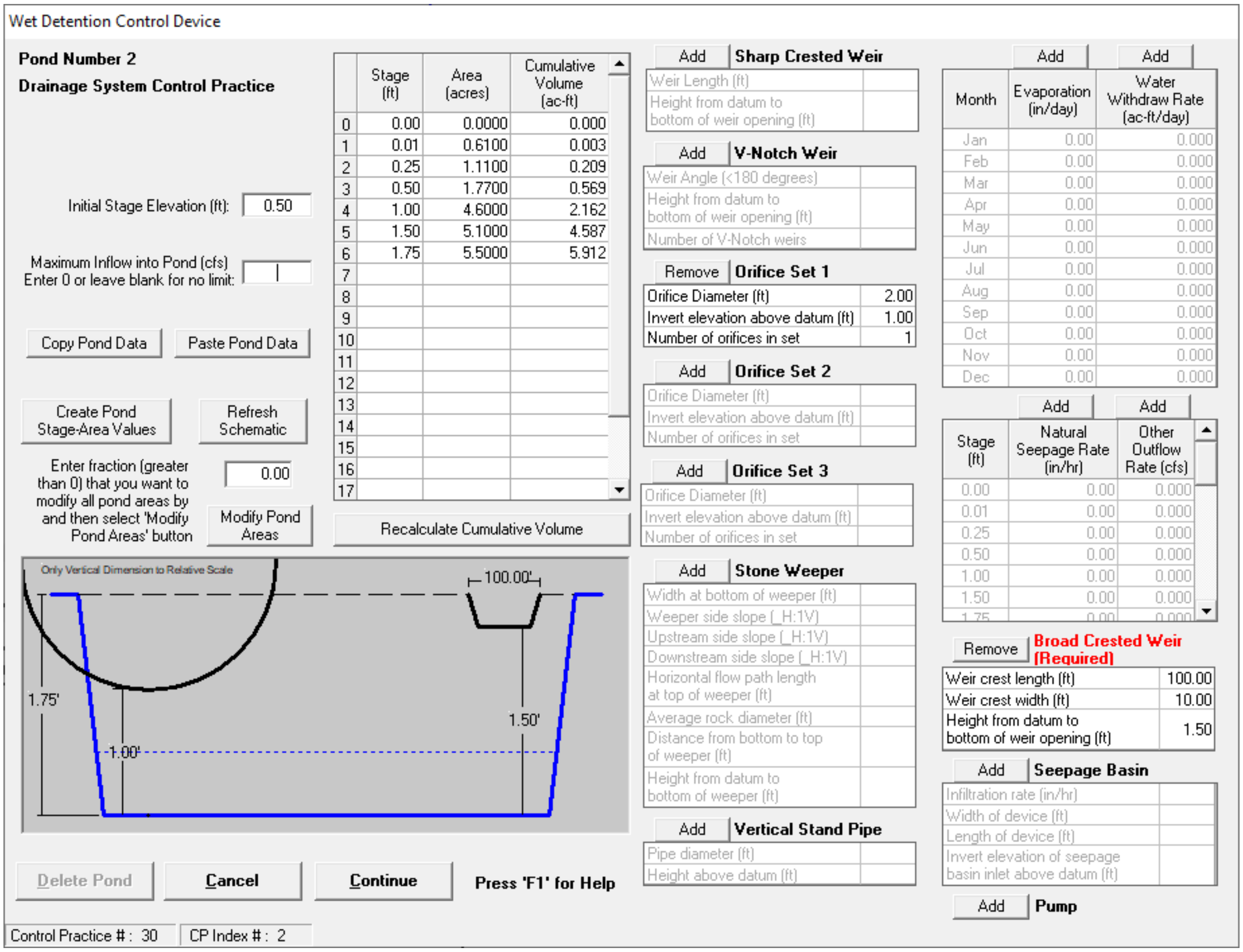


Figure 45: ENC-1 Spring Lake Park Wetland

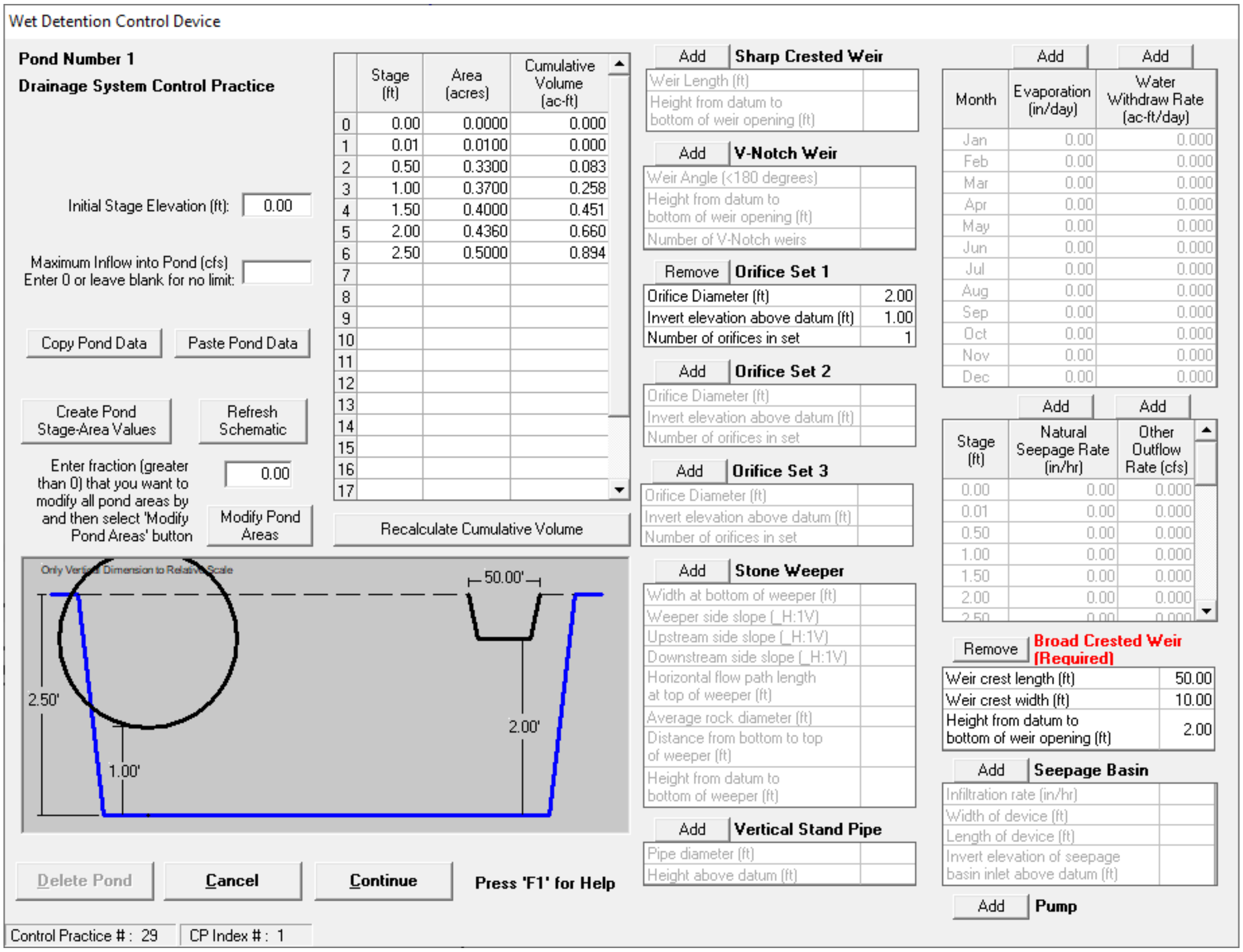


Figure 46: ENC-1 Spring Lake Park City Pond

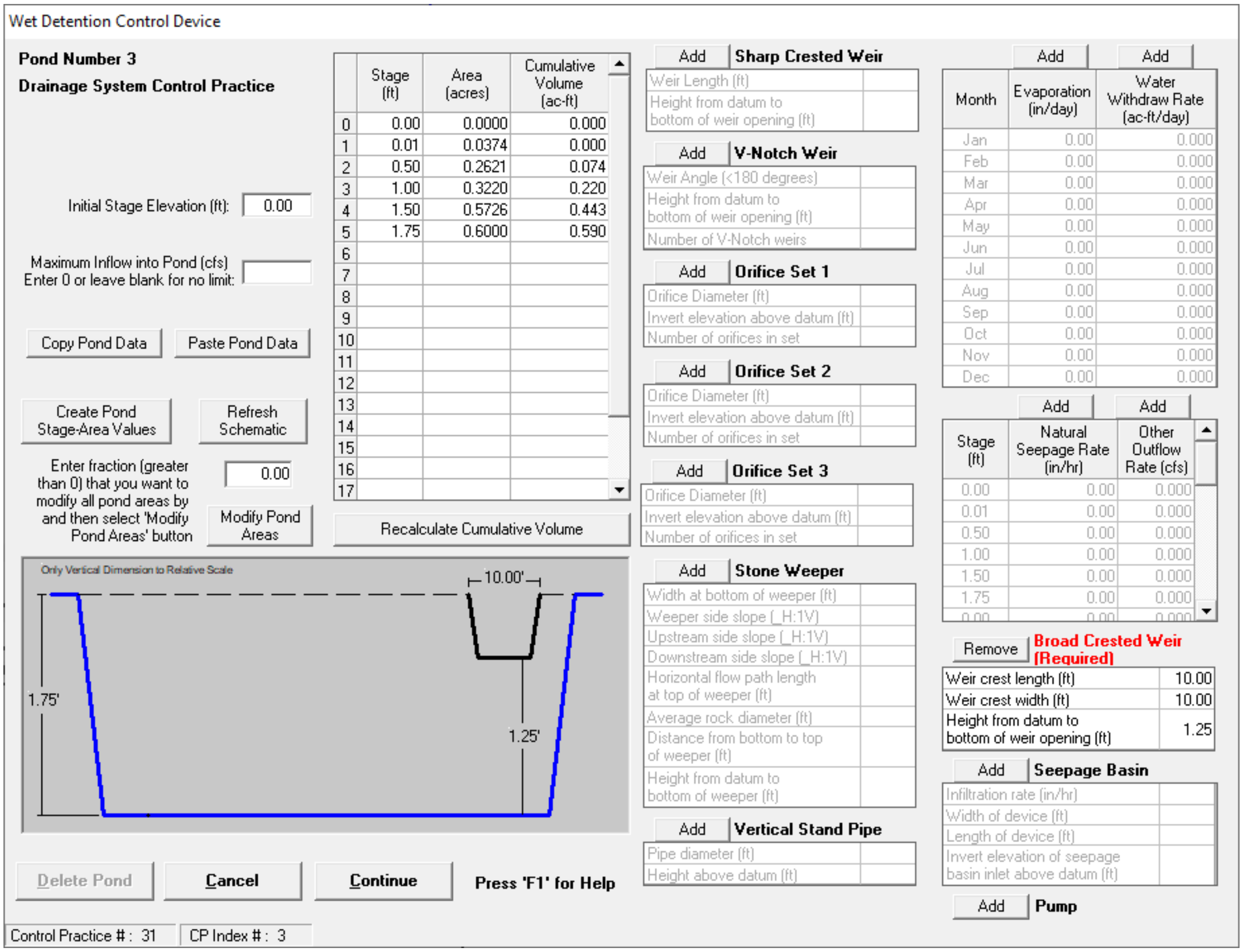
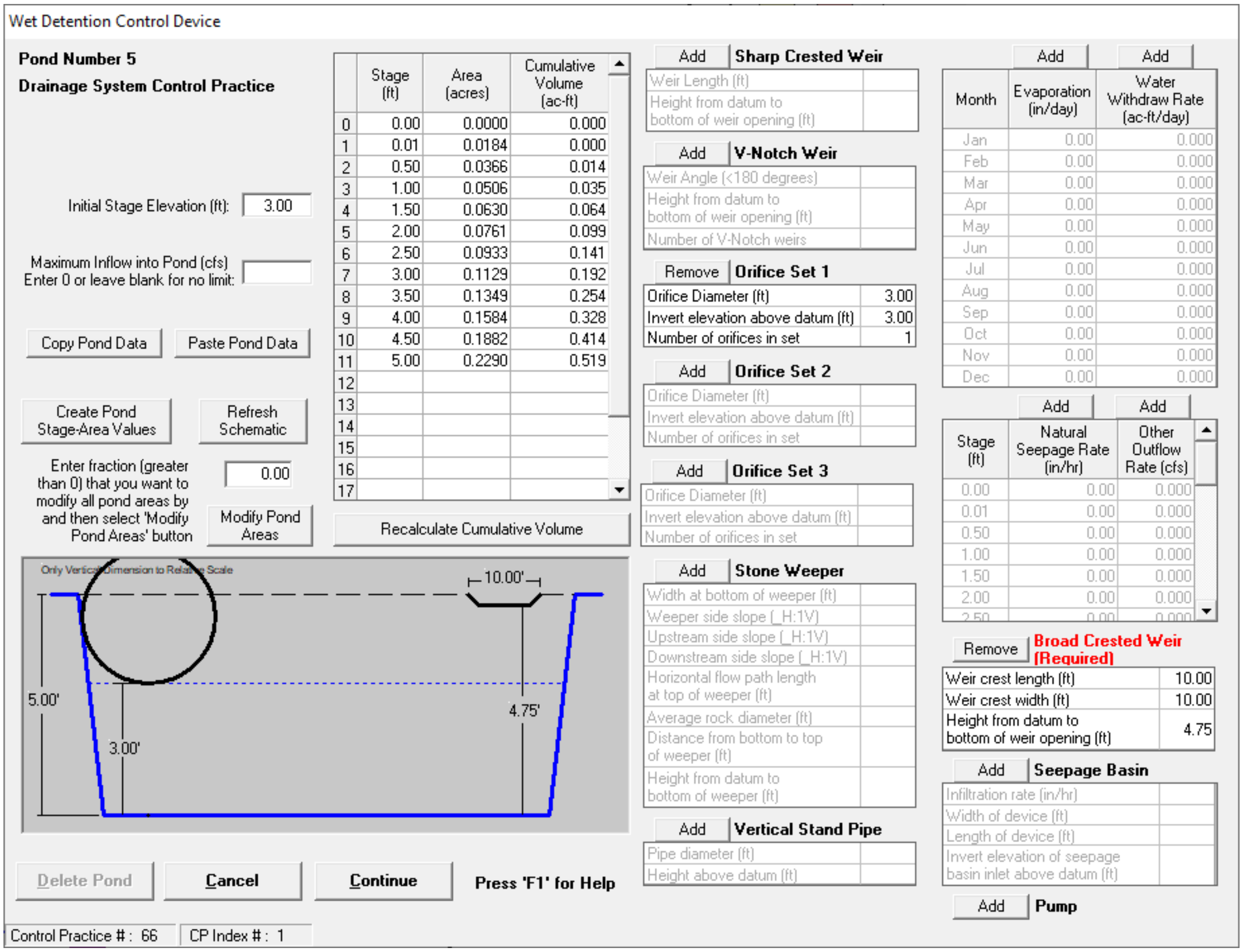


Figure 47: ENC-1 Substance Church Pond



Wet Detention Control Device

Pond Number 5

Drainage System Control Practice

Initial Stage Elevation (ft): 3.00

Maximum Inflow into Pond (cfs)
Enter 0 or leave blank for no limit:

Copy Pond Data | Paste Pond Data

Create Pond Stage-Area Values | Refresh Schematic

Enter fraction (greater than 0) that you want to modify all pond areas by and then select 'Modify Pond Areas' button: 0.00 | Modify Pond Areas

	Stage (ft)	Area (acres)	Cumulative Volume (ac-ft)
0	0.00	0.0000	0.000
1	0.01	0.0184	0.000
2	0.50	0.0366	0.014
3	1.00	0.0506	0.035
4	1.50	0.0630	0.064
5	2.00	0.0761	0.099
6	2.50	0.0933	0.141
7	3.00	0.1129	0.192
8	3.50	0.1349	0.254
9	4.00	0.1584	0.328
10	4.50	0.1882	0.414
11	5.00	0.2290	0.519
12			
13			
14			
15			
16			
17			

Recalculate Cumulative Volume

Add **Sharp Crested Weir**
Weir Length (ft)
Height from datum to bottom of weir opening (ft)

Add **V-Notch Weir**
Weir Angle (<180 degrees)
Height from datum to bottom of weir opening (ft)
Number of V-Notch weirs

Remove **Orifice Set 1**

Orifice Diameter (ft)	3.00
Invert elevation above datum (ft)	3.00
Number of orifices in set	1

Add **Orifice Set 2**
Orifice Diameter (ft)
Invert elevation above datum (ft)
Number of orifices in set

Add **Orifice Set 3**
Orifice Diameter (ft)
Invert elevation above datum (ft)
Number of orifices in set

Add **Stone Weeper**
Width at bottom of weeper (ft)
Weeper side slope (_H:1V)
Upstream side slope (_H:1V)
Downstream side slope (_H:1V)
Horizontal flow path length at top of weeper (ft)
Average rock diameter (ft)
Distance from bottom to top of weeper (ft)
Height from datum to bottom of weeper (ft)

Add **Vertical Stand Pipe**
Pipe diameter (ft)
Height above datum (ft)

Add | Add

Month	Evaporation (in/day)	Water Withdraw Rate (ac-ft/day)
Jan	0.00	0.000
Feb	0.00	0.000
Mar	0.00	0.000
Apr	0.00	0.000
May	0.00	0.000
Jun	0.00	0.000
Jul	0.00	0.000
Aug	0.00	0.000
Sep	0.00	0.000
Oct	0.00	0.000
Nov	0.00	0.000
Dec	0.00	0.000

Add | Add

Stage (ft)	Natural Seepage Rate (in/hr)	Other Outflow Rate (cfs)
0.00	0.00	0.000
0.01	0.00	0.000
0.50	0.00	0.000
1.00	0.00	0.000
1.50	0.00	0.000
2.00	0.00	0.000
2.50	0.00	0.000

Remove **Broad Crested Weir (Required)**

Weir crest length (ft)	10.00
Weir crest width (ft)	10.00
Height from datum to bottom of weir opening (ft)	4.75

Add **Seepage Basin**
Infiltration rate (in/hr)
Width of device (ft)
Length of device (ft)
Invert elevation of seepage basin inlet above datum (ft)

Add **Pump**

Delete Pond | Cancel | Continue | **Press 'F1' for Help**

Control Practice # : 66 | CP Index # : 1

Figure 48: ENC-2 82nd Ave. Pond

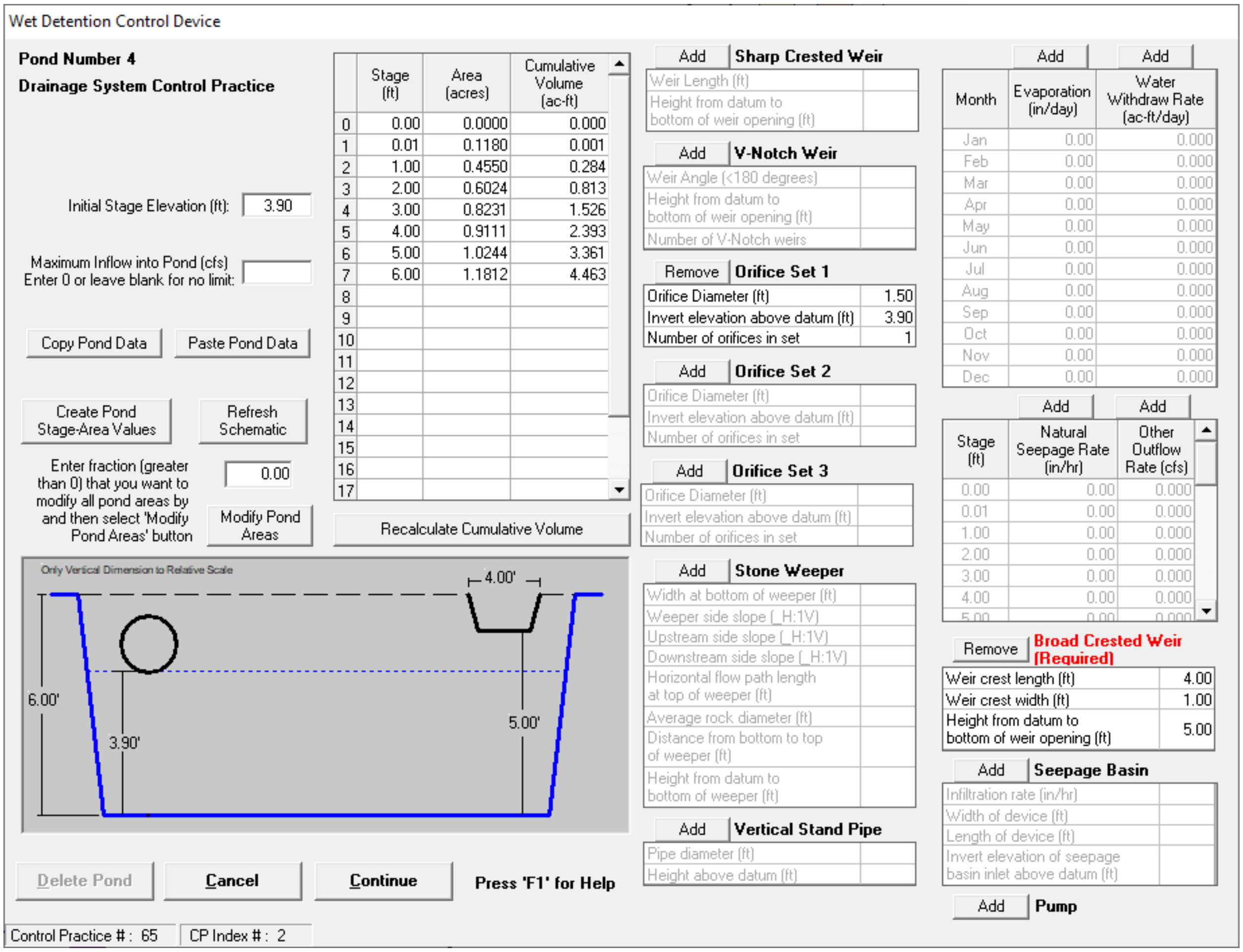


Figure 49: ENC-2 Spring Lake Estates Pond #1

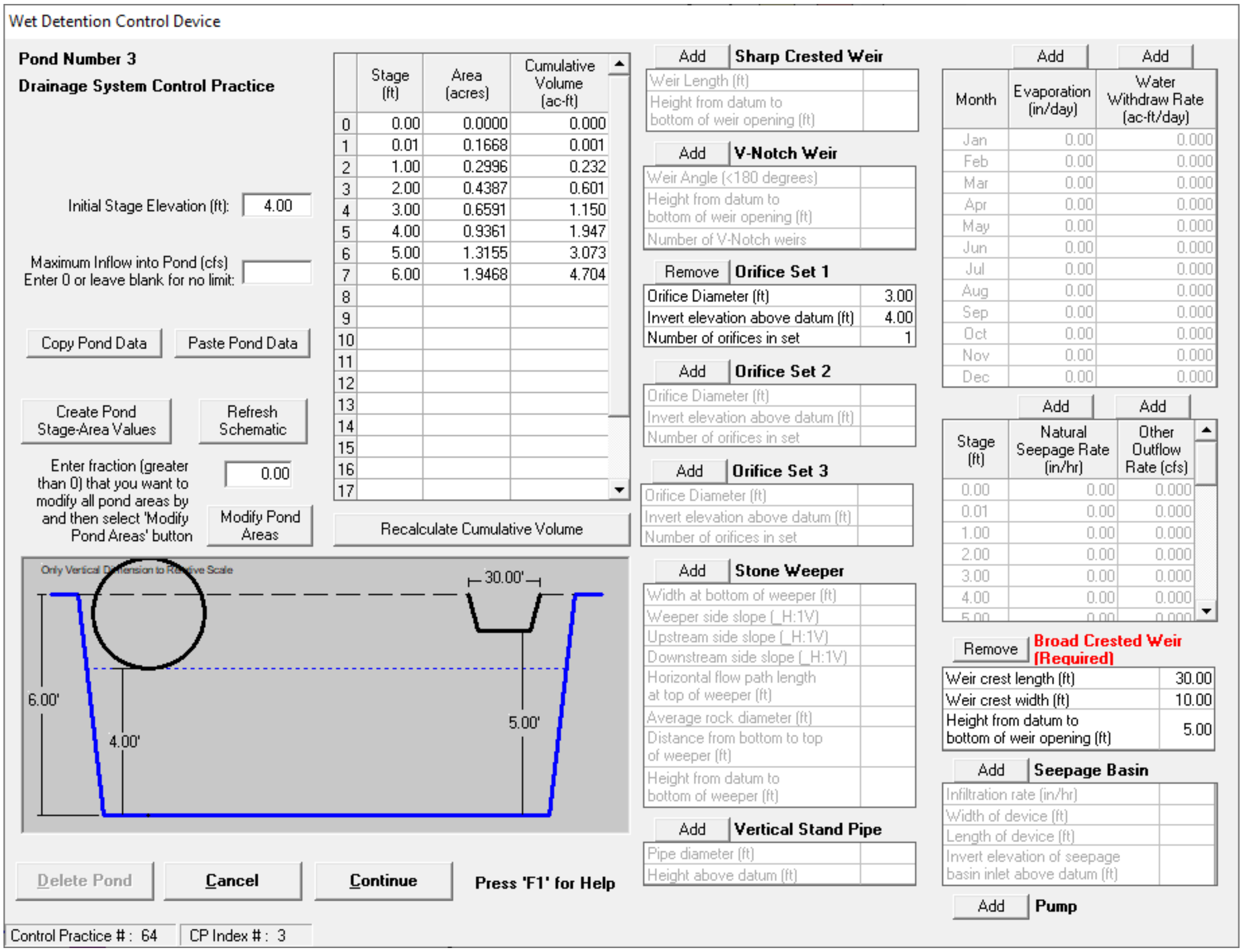


Figure 50: ENC-2 Spring Lake Estates Pond #2

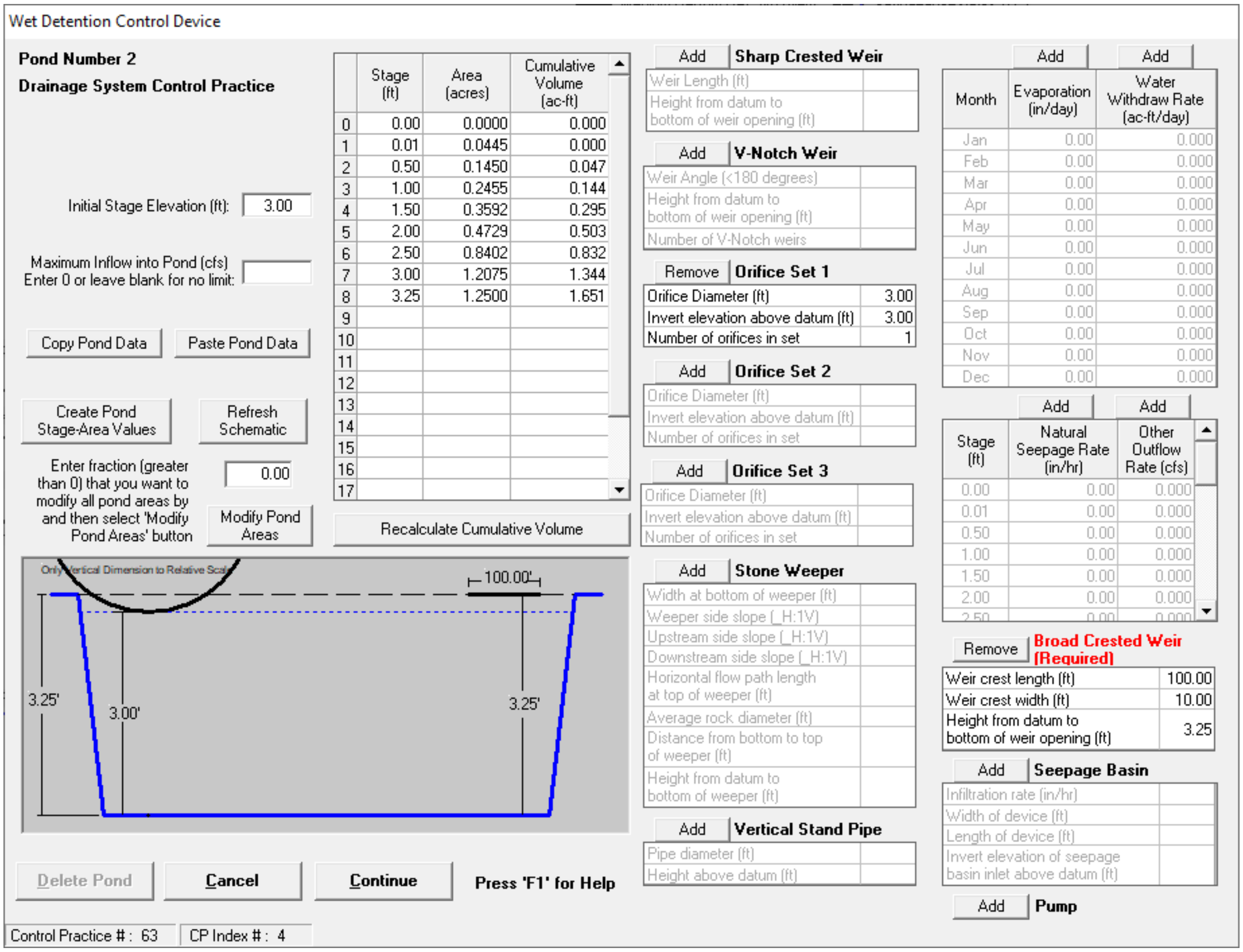


Figure 51: ENC-2 Spring Lake Estates Pond #3

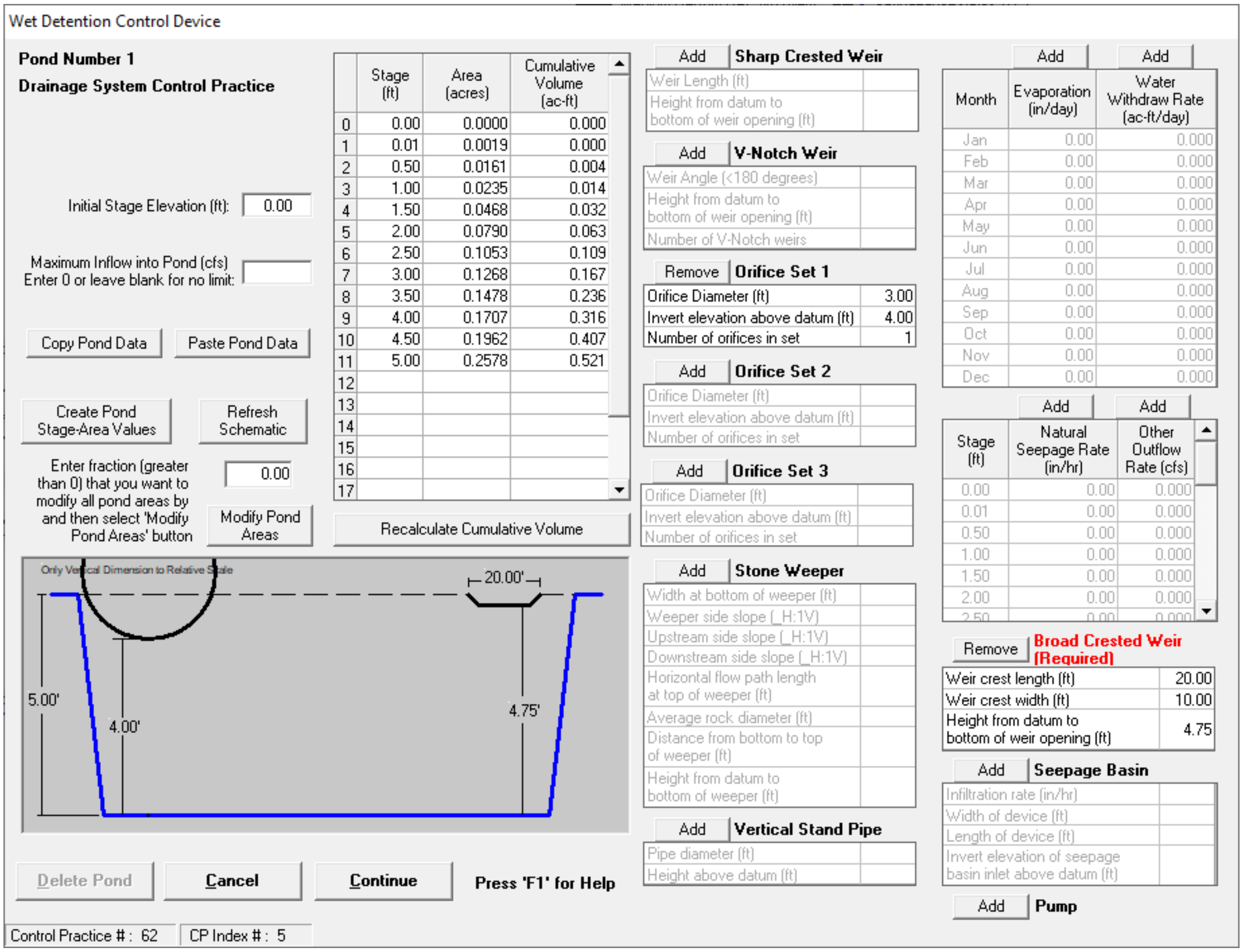


Figure 52: ENC-2 Water Tower Pond

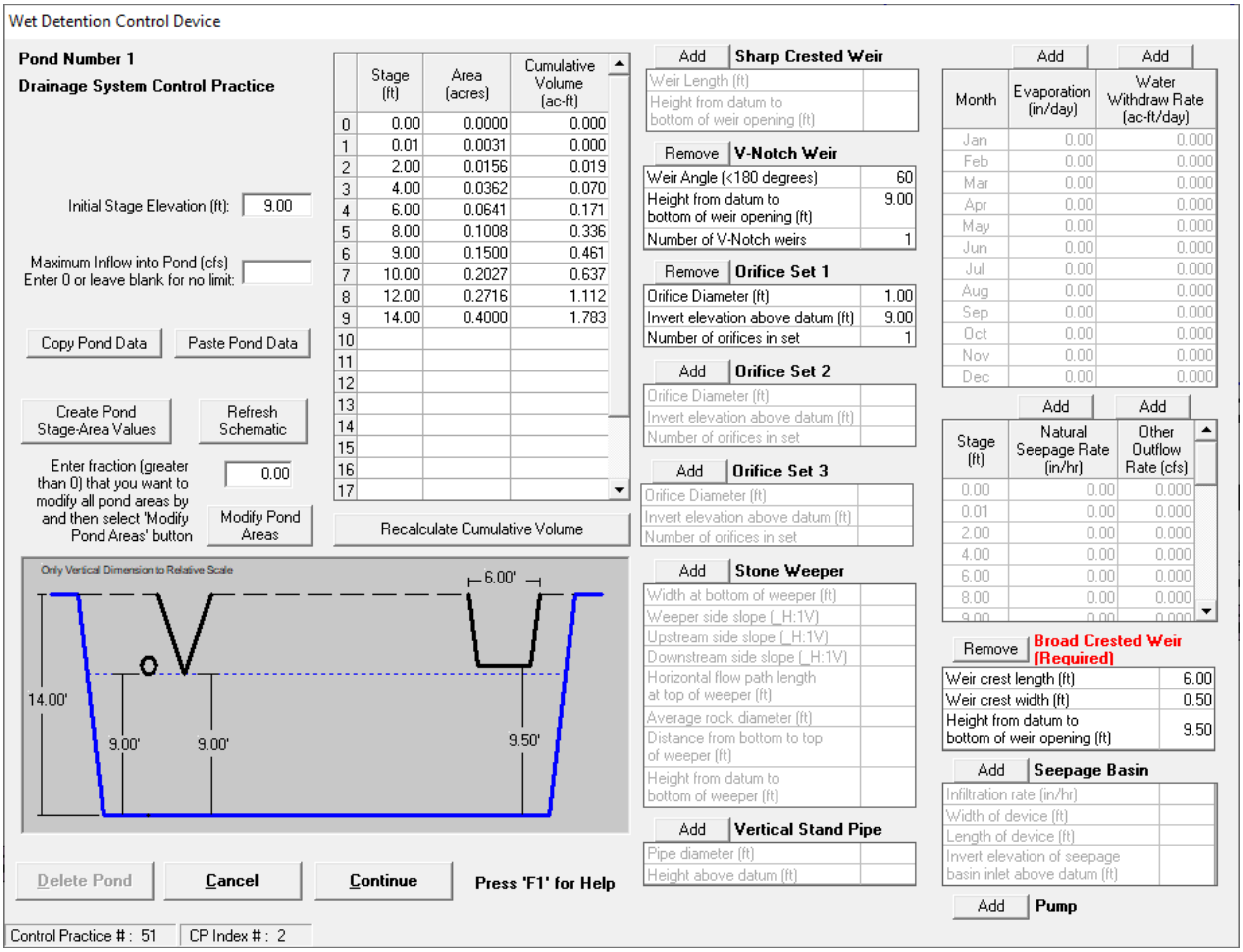
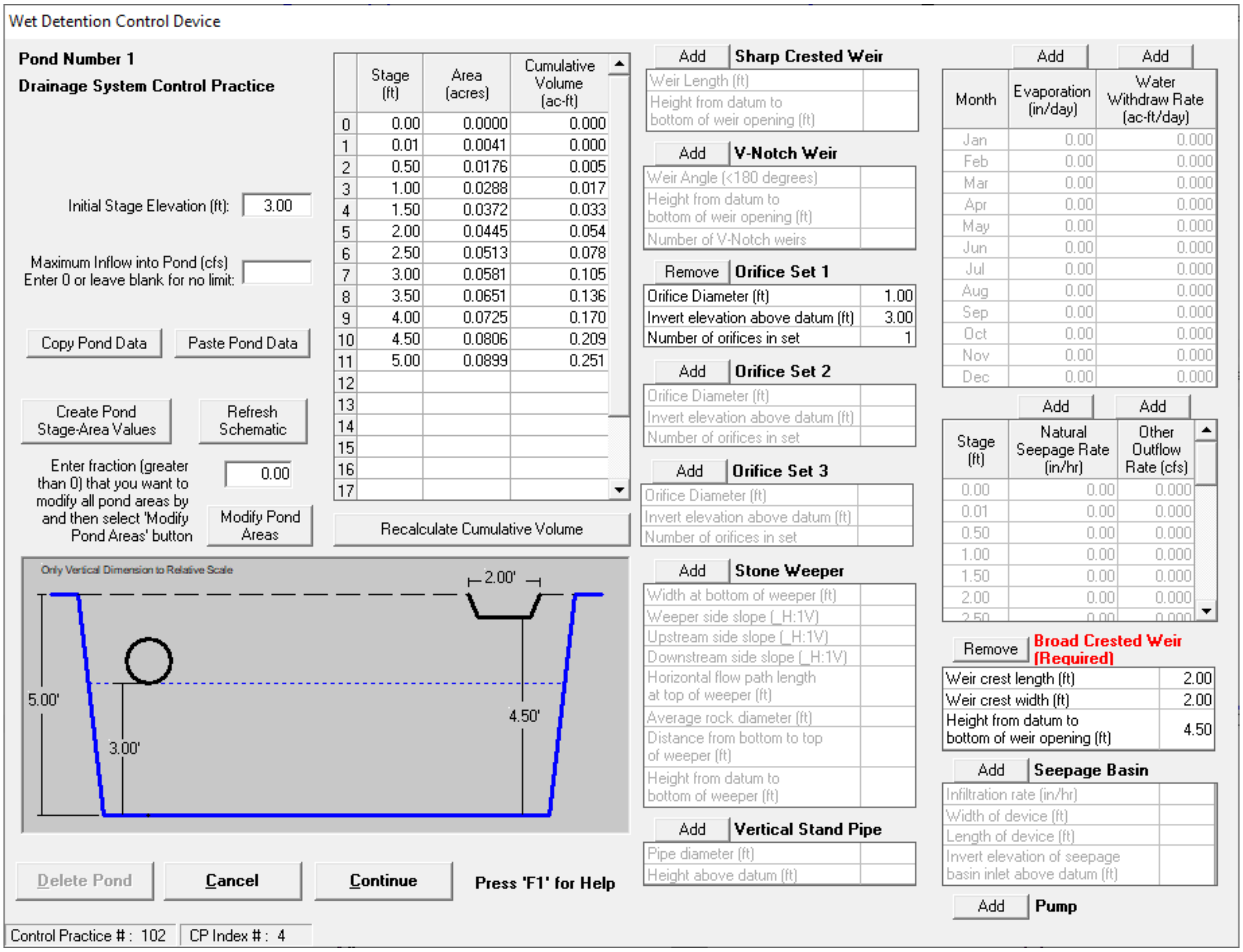


Figure 53: ENC-5-3 Carriage Oaks Pond



Wet Detention Control Device

Pond Number 1

Drainage System Control Practice

Initial Stage Elevation (ft): 3.00

Maximum Inflow into Pond (cfs)
Enter 0 or leave blank for no limit:

Copy Pond Data | Paste Pond Data

Create Pond Stage-Area Values | Refresh Schematic

Enter fraction (greater than 0) that you want to modify all pond areas by and then select 'Modify Pond Areas' button: 0.00 | Modify Pond Areas

	Stage (ft)	Area (acres)	Cumulative Volume (ac-ft)
0	0.00	0.0000	0.000
1	0.01	0.0041	0.000
2	0.50	0.0176	0.005
3	1.00	0.0288	0.017
4	1.50	0.0372	0.033
5	2.00	0.0445	0.054
6	2.50	0.0513	0.078
7	3.00	0.0581	0.105
8	3.50	0.0651	0.136
9	4.00	0.0725	0.170
10	4.50	0.0806	0.209
11	5.00	0.0899	0.251
12			
13			
14			
15			
16			
17			

Recalculate Cumulative Volume

Add **Sharp Crested Weir**: Weir Length (ft); Height from datum to bottom of weir opening (ft)

Add **V-Notch Weir**: Weir Angle (<180 degrees); Height from datum to bottom of weir opening (ft); Number of V-Notch weirs

Remove **Orifice Set 1**

Orifice Diameter (ft)	1.00
Invert elevation above datum (ft)	3.00
Number of orifices in set	1

Add **Orifice Set 2**: Orifice Diameter (ft); Invert elevation above datum (ft); Number of orifices in set

Add **Orifice Set 3**: Orifice Diameter (ft); Invert elevation above datum (ft); Number of orifices in set

Add **Stone Weeper**: Width at bottom of weeper (ft); Weeper side slope (_H:1V); Upstream side slope (_H:1V); Downstream side slope (_H:1V); Horizontal flow path length at top of weeper (ft); Average rock diameter (ft); Distance from bottom to top of weeper (ft); Height from datum to bottom of weeper (ft)

Add **Vertical Stand Pipe**: Pipe diameter (ft); Height above datum (ft)

Month	Evaporation (in/day)	Water Withdraw Rate (ac-ft/day)
Jan	0.00	0.000
Feb	0.00	0.000
Mar	0.00	0.000
Apr	0.00	0.000
May	0.00	0.000
Jun	0.00	0.000
Jul	0.00	0.000
Aug	0.00	0.000
Sep	0.00	0.000
Oct	0.00	0.000
Nov	0.00	0.000
Dec	0.00	0.000

Stage (ft)	Natural Seepage Rate (in/hr)	Other Outflow Rate (cfs)
0.00	0.00	0.000
0.01	0.00	0.000
0.50	0.00	0.000
1.00	0.00	0.000
1.50	0.00	0.000
2.00	0.00	0.000
2.50	0.00	0.000

Remove **Broad Crested Weir (Required)**

Weir crest length (ft)	2.00
Weir crest width (ft)	2.00
Height from datum to bottom of weir opening (ft)	4.50

Add **Seepage Basin**: Infiltration rate (in/hr); Width of device (ft); Length of device (ft); Invert elevation of seepage basin inlet above datum (ft)

Add **Pump**

Delete Pond | Cancel | Continue | **Press 'F1' for Help**

Control Practice # : 102 | CP Index # : 4

Figure 54: NC-1 Sam's Auto Pond

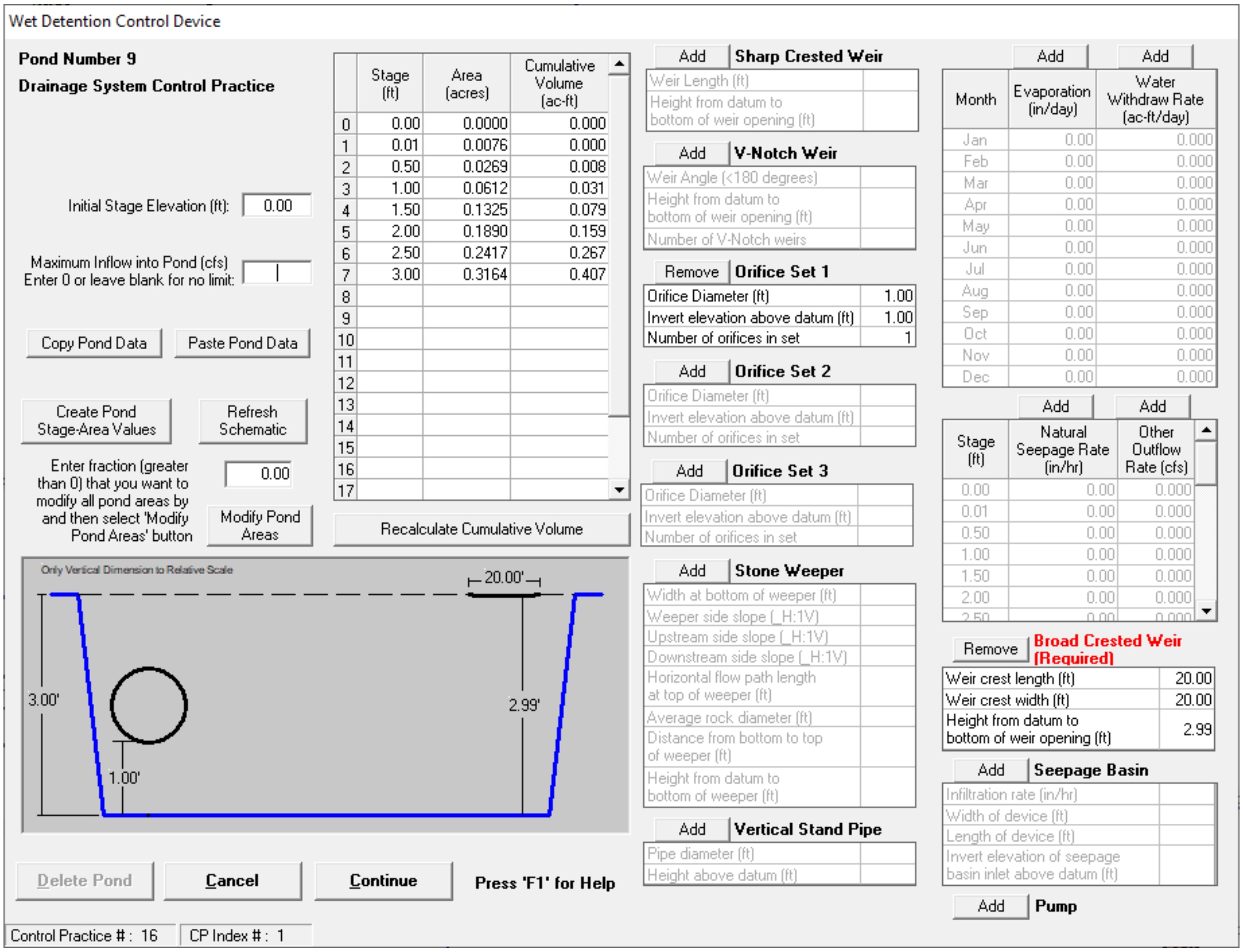
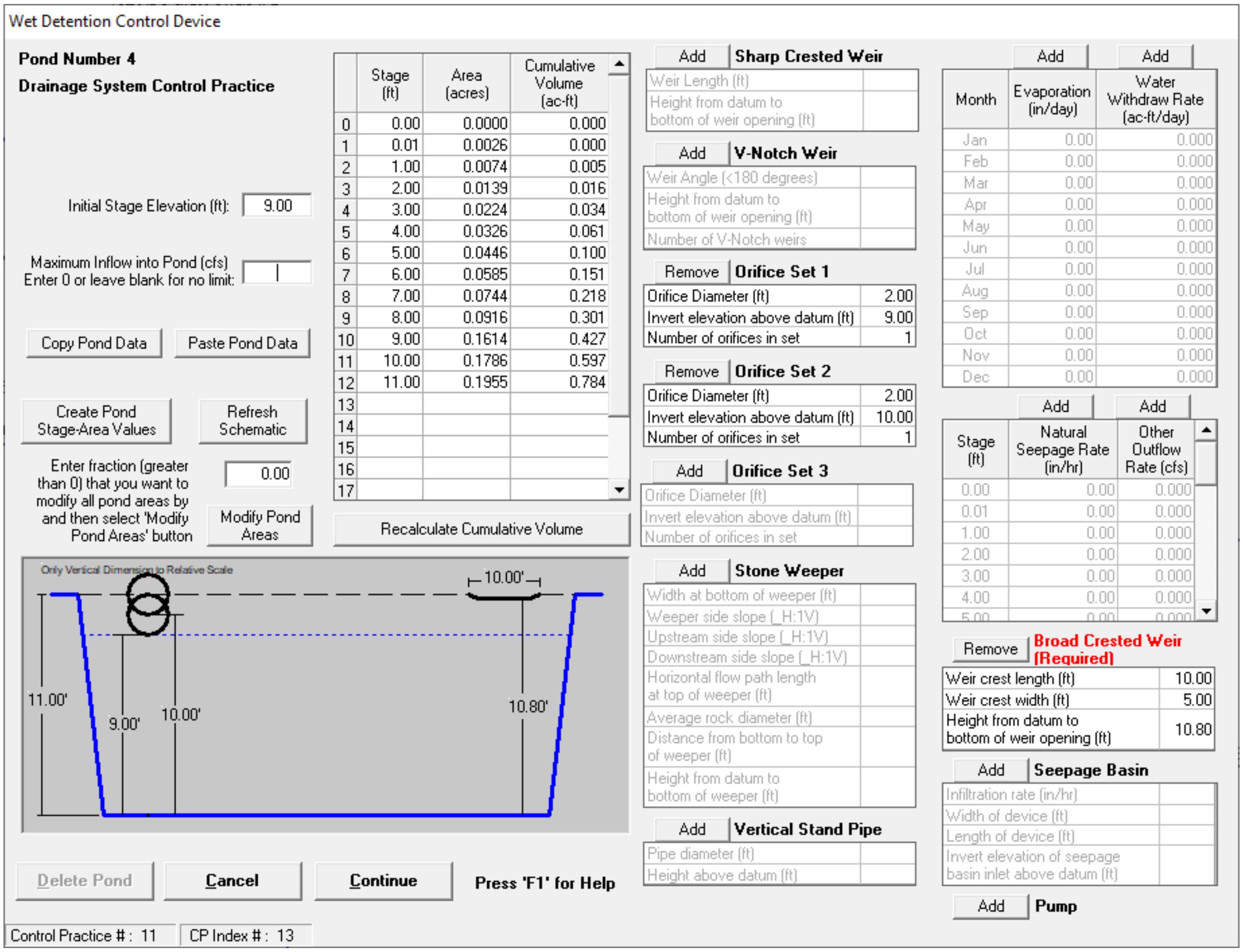


Figure 55: WNC-1 Central Ave. Pond


Wet Detention Control Device

Pond Number 4

Drainage System Control Practice

Initial Stage Elevation (ft): 9.00

Maximum Inflow into Pond (cfs) Enter 0 or leave blank for no limit:

Copy Pond Data | Paste Pond Data

Create Pond Stage-Area Values | Refresh Schematic

Enter fraction (greater than 0) that you want to modify all pond areas by and then select 'Modify Pond Areas' button: 0.00 | Modify Pond Areas

	Stage (ft)	Area (acres)	Cumulative Volume (ac-ft)
0	0.00	0.0000	0.000
1	0.01	0.0026	0.000
2	1.00	0.0074	0.005
3	2.00	0.0139	0.016
4	3.00	0.0224	0.034
5	4.00	0.0326	0.061
6	5.00	0.0446	0.100
7	6.00	0.0585	0.151
8	7.00	0.0744	0.218
9	8.00	0.0916	0.301
10	9.00	0.1614	0.427
11	10.00	0.1786	0.597
12	11.00	0.1955	0.784
13			
14			
15			
16			
17			

Recalculate Cumulative Volume

Delete Pond | Cancel | Continue | Press 'F1' for Help

Add **Sharp Crested Weir**

Weir Length (ft)	
Height from datum to bottom of weir opening (ft)	

Add **V-Notch Weir**

Weir Angle (<180 degrees)	
Height from datum to bottom of weir opening (ft)	
Number of V-Notch weirs	

Remove **Orifice Set 1**

Orifice Diameter (ft)	2.00
Invert elevation above datum (ft)	9.00
Number of orifices in set	1

Remove **Orifice Set 2**

Orifice Diameter (ft)	2.00
Invert elevation above datum (ft)	10.00
Number of orifices in set	1

Add **Orifice Set 3**

Orifice Diameter (ft)	
Invert elevation above datum (ft)	
Number of orifices in set	

Add **Stone Weeper**

Width at bottom of weeper (ft)	
Weeper side slope (_H:1V)	
Upstream side slope (_H:1V)	
Downstream side slope (_H:1V)	
Horizontal flow path length at top of weeper (ft)	
Average rock diameter (ft)	
Distance from bottom to top of weeper (ft)	
Height from datum to bottom of weeper (ft)	

Add **Vertical Stand Pipe**

Pipe diameter (ft)	
Height above datum (ft)	

Add | Add

Month	Evaporation (in/day)	Water Withdraw Rate (ac-ft/day)
Jan	0.00	0.000
Feb	0.00	0.000
Mar	0.00	0.000
Apr	0.00	0.000
May	0.00	0.000
Jun	0.00	0.000
Jul	0.00	0.000
Aug	0.00	0.000
Sep	0.00	0.000
Oct	0.00	0.000
Nov	0.00	0.000
Dec	0.00	0.000

Add | Add

Stage (ft)	Natural Seepage Rate (in/hr)	Other Outflow Rate (cfs)
0.00	0.00	0.000
0.01	0.00	0.000
1.00	0.00	0.000
2.00	0.00	0.000
3.00	0.00	0.000
4.00	0.00	0.000
5.00	0.00	0.000

Remove **Broad Crested Weir (Required)**

Weir crest length (ft)	10.00
Weir crest width (ft)	5.00
Height from datum to bottom of weir opening (ft)	10.80

Add **Seepage Basin**

Infiltration rate (in/hr)	
Width of device (ft)	
Length of device (ft)	
Invert elevation of seepage basin inlet above datum (ft)	

Add **Pump**

Control Practice # : 11 | CP Index # : 13

Figure 56: WNC-1 Hy-Vee East Pond

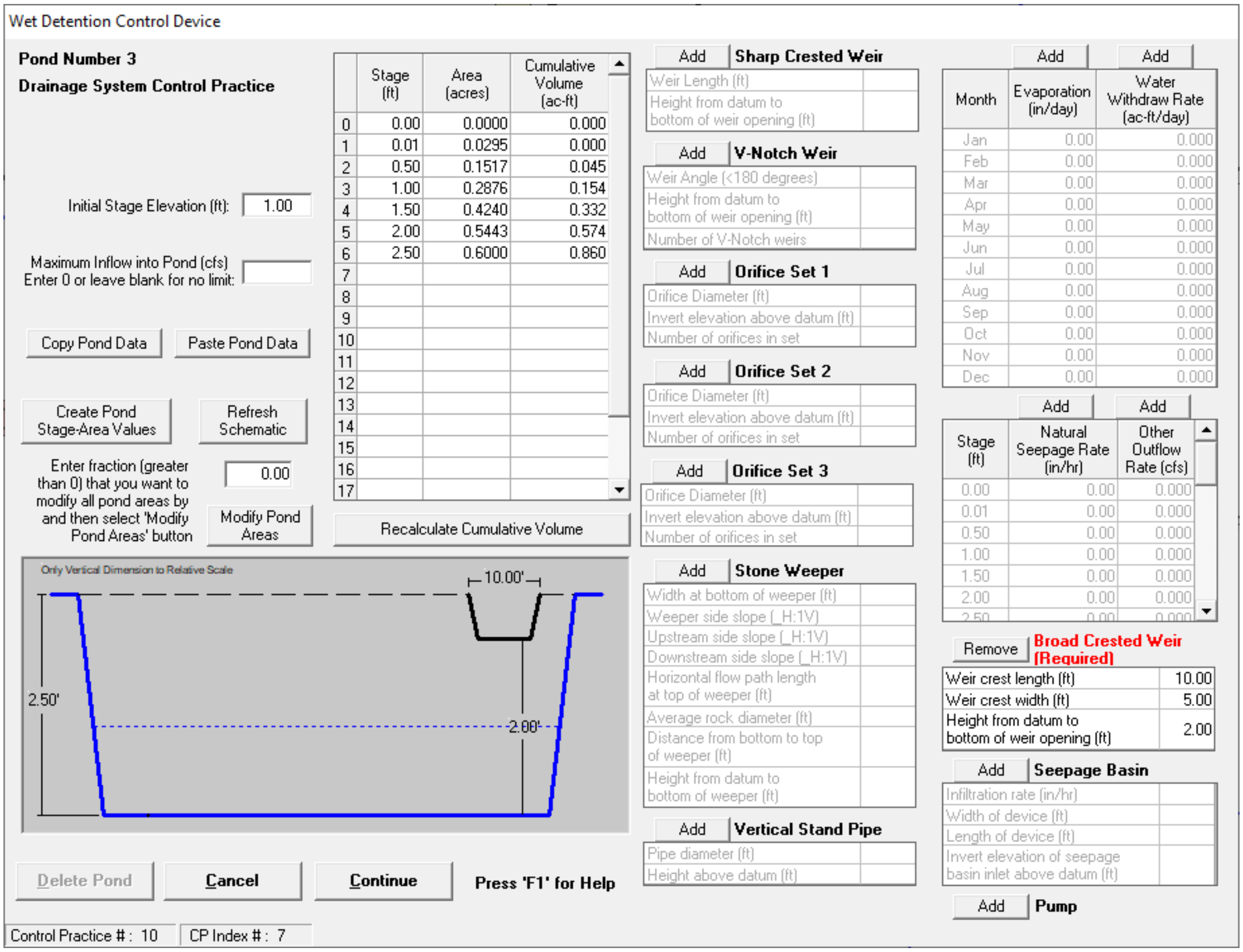


Figure 57: WNC-1 Hy-Vee North Wetland

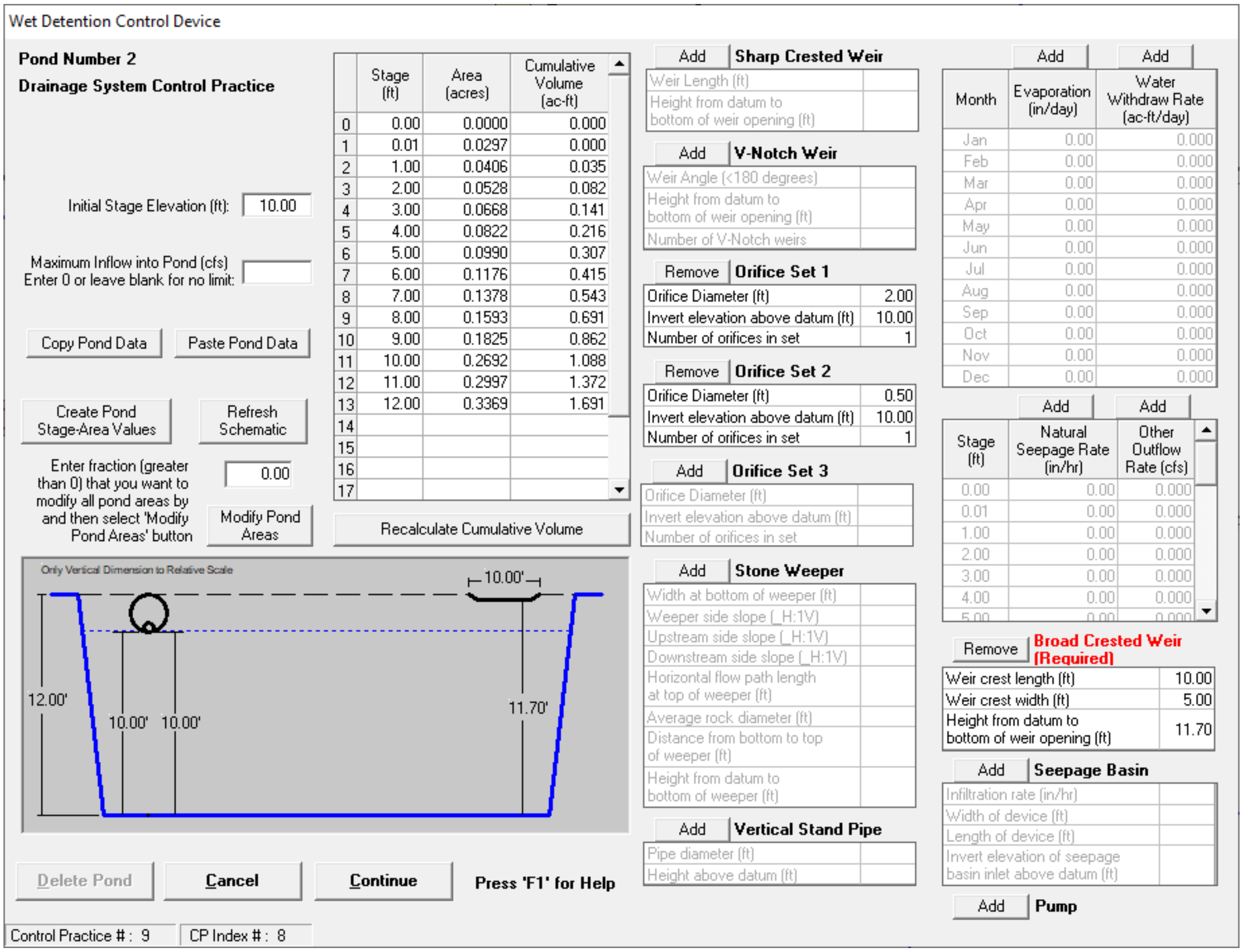
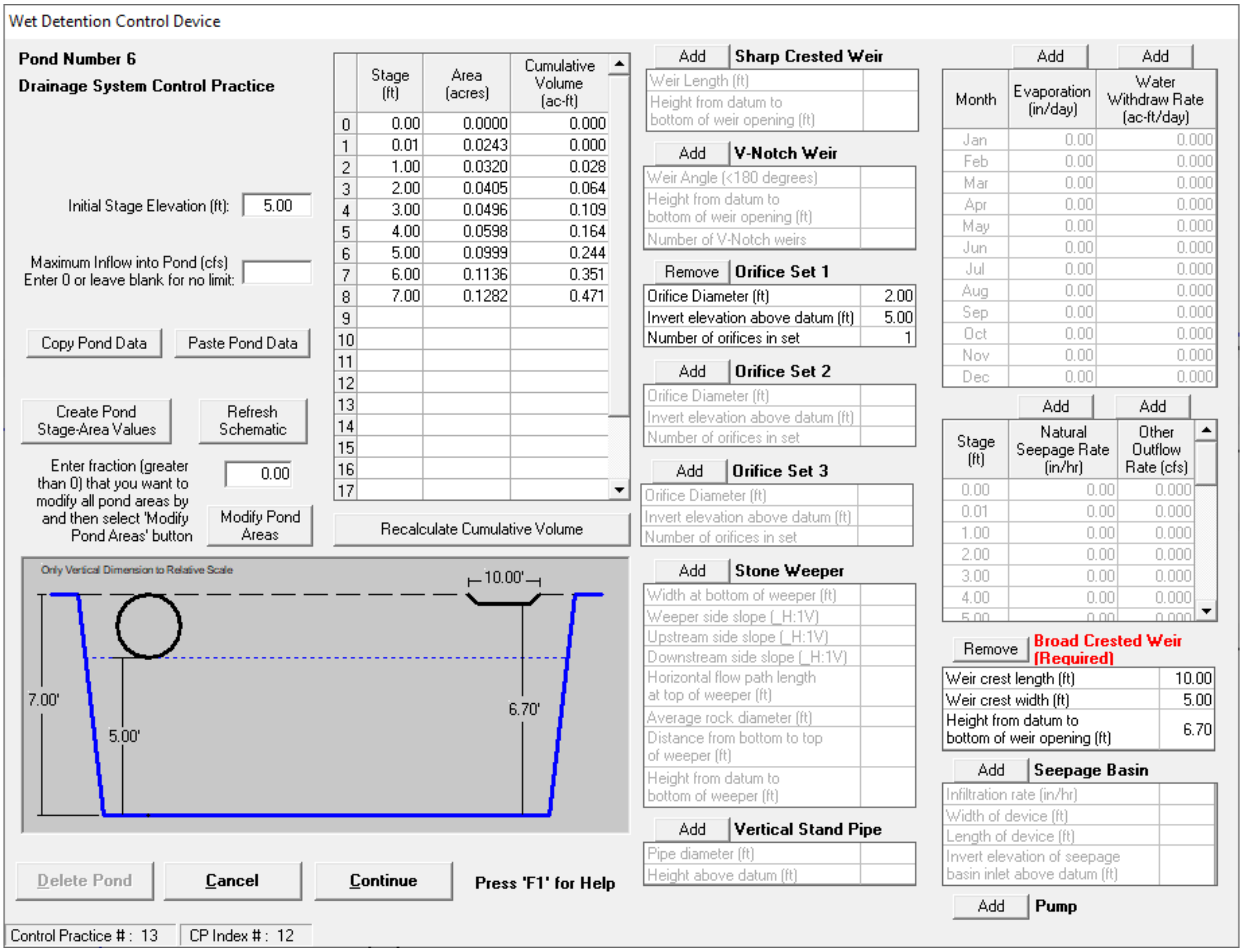


Figure 58: WNC-1 Hy-Vee North Pond



	Stage (ft)	Area (acres)	Cumulative Volume (ac-ft)
0	0.00	0.0000	0.000
1	0.01	0.0243	0.000
2	1.00	0.0320	0.028
3	2.00	0.0405	0.064
4	3.00	0.0496	0.109
5	4.00	0.0598	0.164
6	5.00	0.0999	0.244
7	6.00	0.1136	0.351
8	7.00	0.1282	0.471
9			
10			
11			
12			
13			
14			
15			
16			
17			

Month	Evaporation (in/day)	Water Withdraw Rate (ac-ft/day)
Jan	0.00	0.000
Feb	0.00	0.000
Mar	0.00	0.000
Apr	0.00	0.000
May	0.00	0.000
Jun	0.00	0.000
Jul	0.00	0.000
Aug	0.00	0.000
Sep	0.00	0.000
Oct	0.00	0.000
Nov	0.00	0.000
Dec	0.00	0.000

Stage (ft)	Natural Seepage Rate (in/hr)	Other Outflow Rate (cfs)
0.00	0.00	0.000
0.01	0.00	0.000
1.00	0.00	0.000
2.00	0.00	0.000
3.00	0.00	0.000
4.00	0.00	0.000
5.00	0.00	0.000

Figure 59: WNC-1 Hy-Vee South Pond

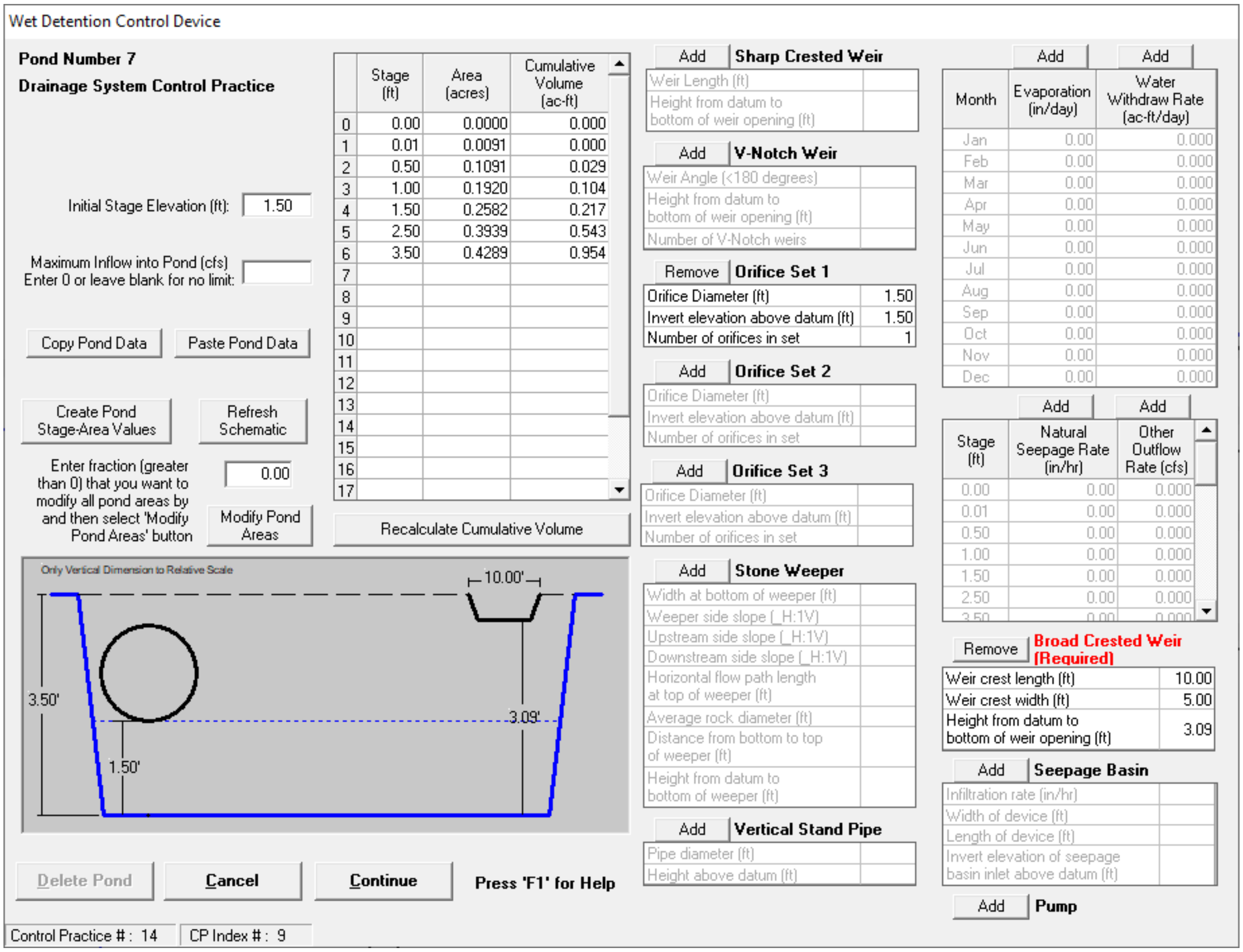
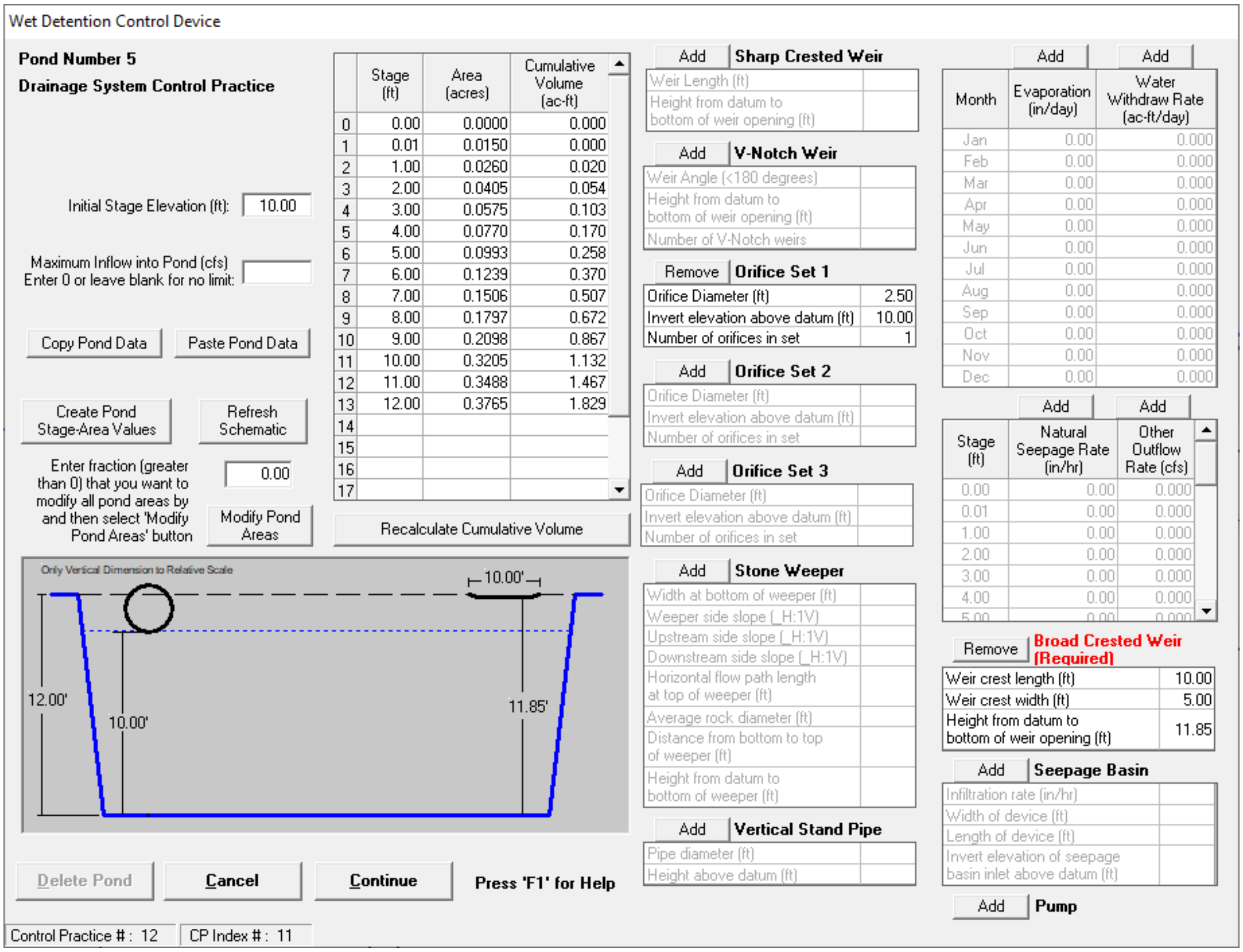


Figure 60: WNC-1 Hy-Vee Southeast Wetland



Wet Detention Control Device

Pond Number 5

Drainage System Control Practice

Initial Stage Elevation (ft): 10.00

Maximum Inflow into Pond (cfs) Enter 0 or leave blank for no limit:

Copy Pond Data | Paste Pond Data

Create Pond Stage-Area Values | Refresh Schematic

Enter fraction (greater than 0) that you want to modify all pond areas by and then select 'Modify Pond Areas' button: 0.00 | Modify Pond Areas

	Stage (ft)	Area (acres)	Cumulative Volume (ac-ft)
0	0.00	0.0000	0.000
1	0.01	0.0150	0.000
2	1.00	0.0260	0.020
3	2.00	0.0405	0.054
4	3.00	0.0575	0.103
5	4.00	0.0770	0.170
6	5.00	0.0993	0.258
7	6.00	0.1239	0.370
8	7.00	0.1506	0.507
9	8.00	0.1797	0.672
10	9.00	0.2098	0.867
11	10.00	0.3205	1.132
12	11.00	0.3488	1.467
13	12.00	0.3765	1.829
14			
15			
16			
17			

Recalculate Cumulative Volume

Add **Sharp Crested Weir**

Weir Length (ft)	
Height from datum to bottom of weir opening (ft)	

Add **V-Notch Weir**

Weir Angle (<180 degrees)	
Height from datum to bottom of weir opening (ft)	
Number of V-Notch weirs	

Remove **Orifice Set 1**

Orifice Diameter (ft)	2.50
Invert elevation above datum (ft)	10.00
Number of orifices in set	1

Add **Orifice Set 2**

Orifice Diameter (ft)	
Invert elevation above datum (ft)	
Number of orifices in set	

Add **Orifice Set 3**

Orifice Diameter (ft)	
Invert elevation above datum (ft)	
Number of orifices in set	

Add **Stone Weeper**

Width at bottom of weeper (ft)	
Weeper side slope (_H:1V)	
Upstream side slope (_H:1V)	
Downstream side slope (_H:1V)	
Horizontal flow path length at top of weeper (ft)	
Average rock diameter (ft)	
Distance from bottom to top of weeper (ft)	
Height from datum to bottom of weeper (ft)	

Add **Vertical Stand Pipe**

Pipe diameter (ft)	
Height above datum (ft)	

Month	Evaporation (in/day)	Water Withdraw Rate (ac-ft/day)
Jan	0.00	0.000
Feb	0.00	0.000
Mar	0.00	0.000
Apr	0.00	0.000
May	0.00	0.000
Jun	0.00	0.000
Jul	0.00	0.000
Aug	0.00	0.000
Sep	0.00	0.000
Oct	0.00	0.000
Nov	0.00	0.000
Dec	0.00	0.000

Stage (ft)	Natural Seepage Rate (in/hr)	Other Outflow Rate (cfs)
0.00	0.00	0.000
0.01	0.00	0.000
1.00	0.00	0.000
2.00	0.00	0.000
3.00	0.00	0.000
4.00	0.00	0.000
5.00	0.00	0.000

Remove **Broad Crested Weir (Required)**

Weir crest length (ft)	10.00
Weir crest width (ft)	5.00
Height from datum to bottom of weir opening (ft)	11.85

Add **Seepage Basin**

Infiltration rate (in/hr)	
Width of device (ft)	
Length of device (ft)	
Invert elevation of seepage basin inlet above datum (ft)	

Add **Pump**

Delete Pond | Cancel | Continue | **Press 'F1' for Help**

Control Practice # : 12 | CP Index # : 11

Figure 61: WNC-1 Hy-Vee Southeast Pond

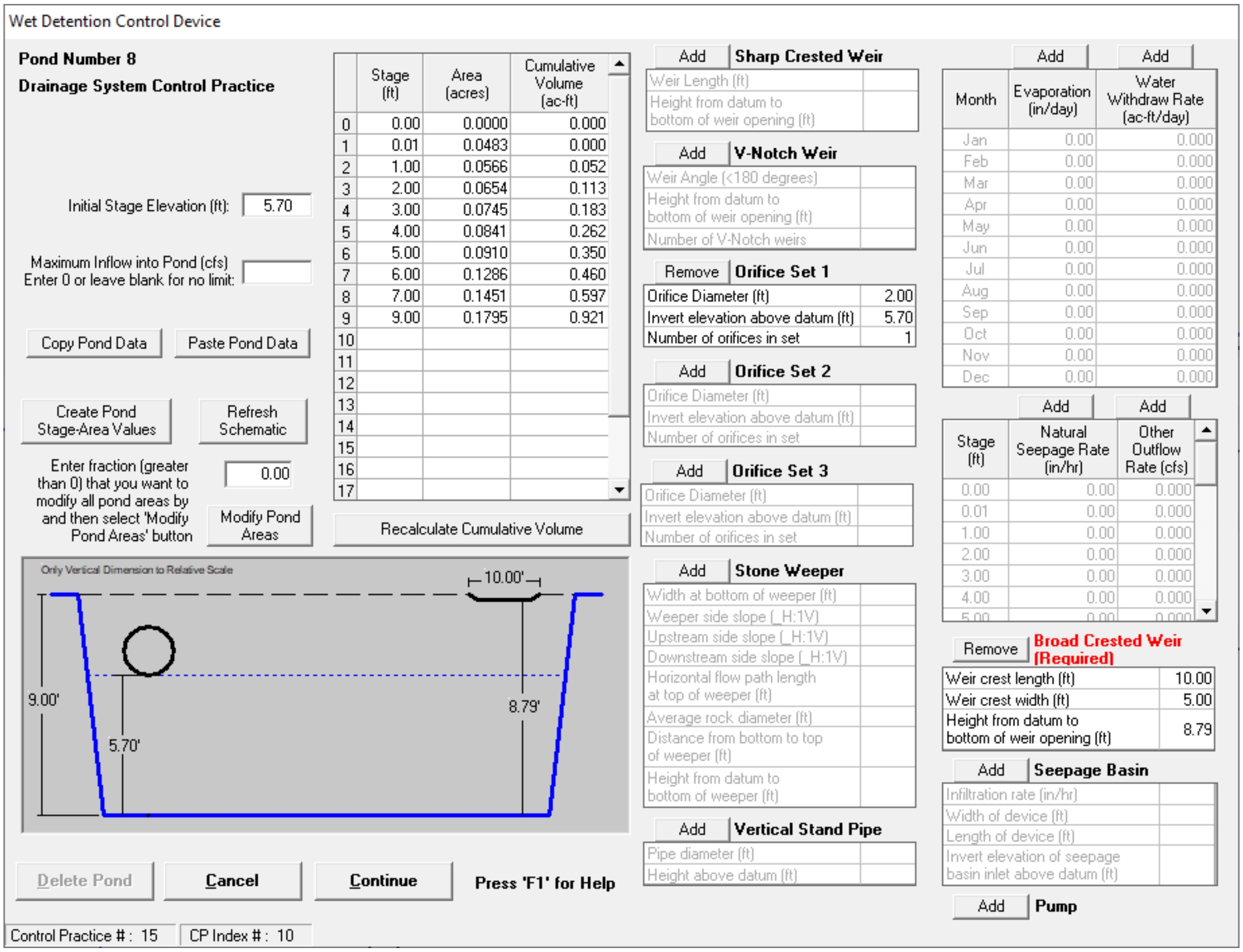


Figure 62: WNC-1 Hy-Vee Southwest Pond

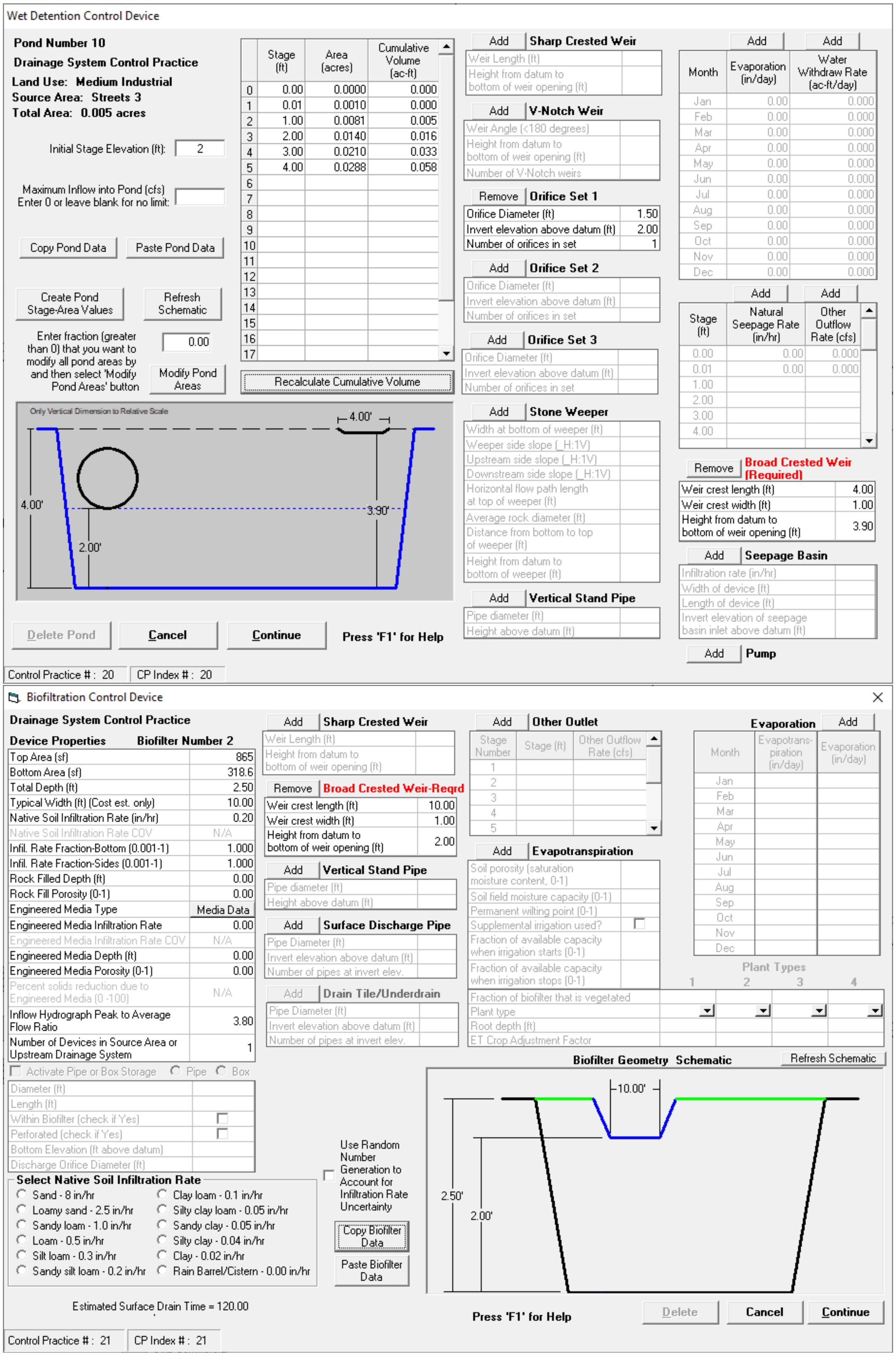


Figure 63: WNC-2 8097 office building wet pond and overflow infiltration basin

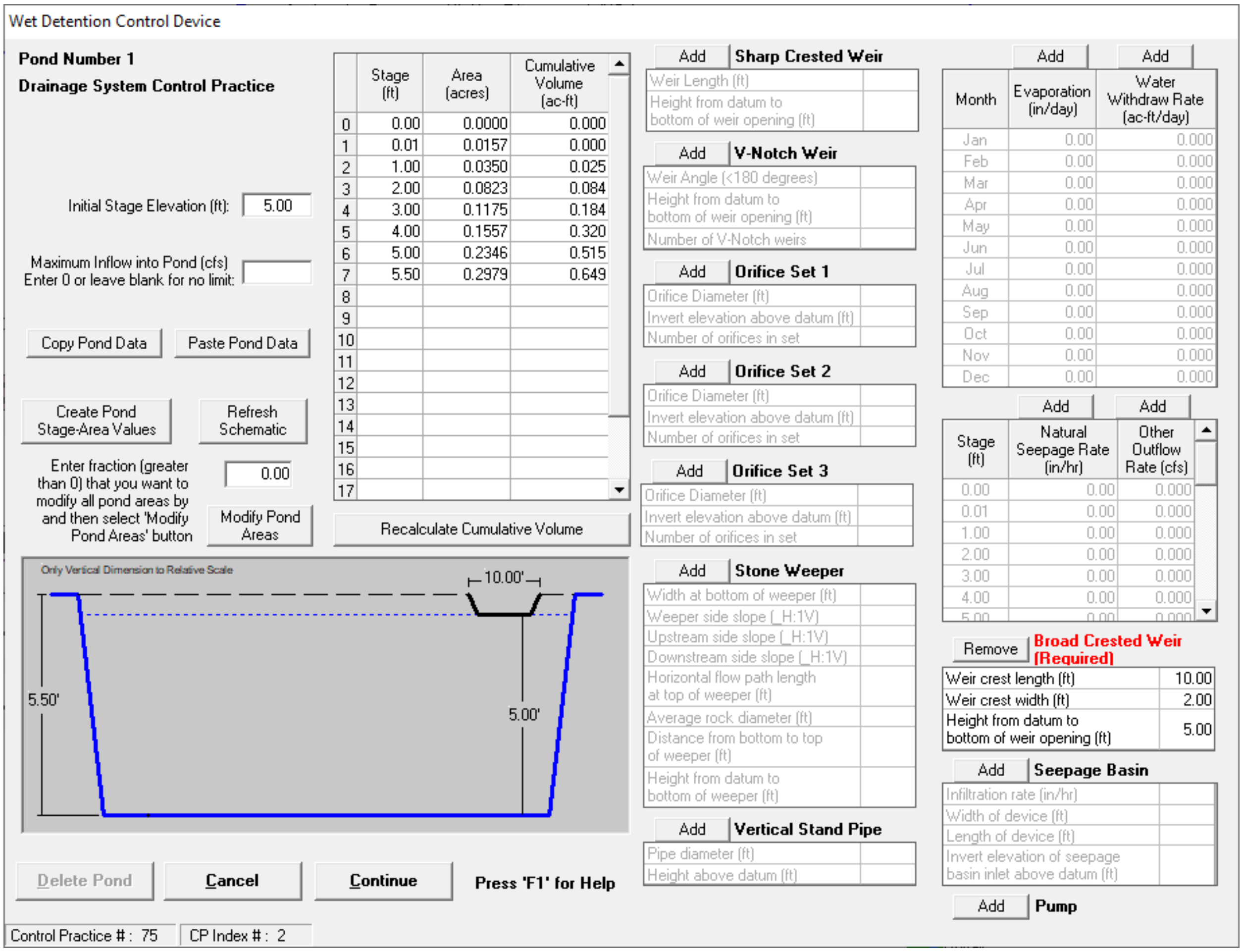
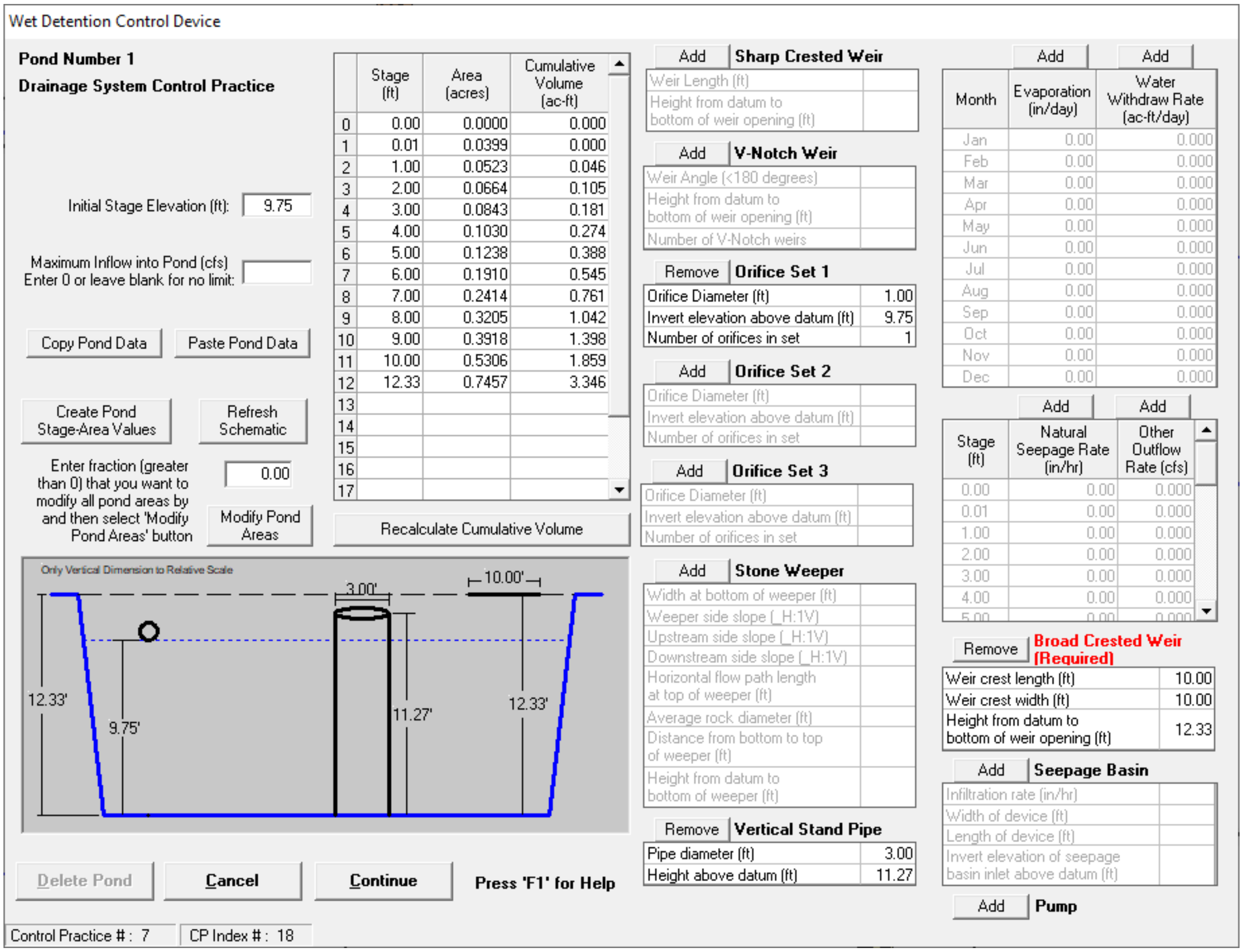


Figure 64: WNC-5 Spring Pines Townhomes Pond



Wet Detention Control Device

Pond Number 1

Drainage System Control Practice

Initial Stage Elevation (ft): 9.75

Maximum Inflow into Pond (cfs) Enter 0 or leave blank for no limit:

Copy Pond Data | Paste Pond Data

Create Pond Stage-Area Values | Refresh Schematic

Enter fraction (greater than 0) that you want to modify all pond areas by and then select 'Modify Pond Areas' button: 0.00 | Modify Pond Areas

	Stage (ft)	Area (acres)	Cumulative Volume (ac-ft)
0	0.00	0.0000	0.000
1	0.01	0.0399	0.000
2	1.00	0.0523	0.046
3	2.00	0.0664	0.105
4	3.00	0.0843	0.181
5	4.00	0.1030	0.274
6	5.00	0.1238	0.388
7	6.00	0.1910	0.545
8	7.00	0.2414	0.761
9	8.00	0.3205	1.042
10	9.00	0.3918	1.398
11	10.00	0.5306	1.859
12	12.33	0.7457	3.346
13			
14			
15			
16			
17			

Recalculate Cumulative Volume

Add **Sharp Crested Weir**

Weir Length (ft)	
Height from datum to bottom of weir opening (ft)	

Add **V-Notch Weir**

Weir Angle (<180 degrees)	
Height from datum to bottom of weir opening (ft)	
Number of V-Notch weirs	

Remove **Orifice Set 1**

Orifice Diameter (ft)	1.00
Invert elevation above datum (ft)	9.75
Number of orifices in set	1

Add **Orifice Set 2**

Orifice Diameter (ft)	
Invert elevation above datum (ft)	
Number of orifices in set	

Add **Orifice Set 3**

Orifice Diameter (ft)	
Invert elevation above datum (ft)	
Number of orifices in set	

Add **Stone Weeper**

Width at bottom of weeper (ft)	
Weeper side slope (_H:1V)	
Upstream side slope (_H:1V)	
Downstream side slope (_H:1V)	
Horizontal flow path length at top of weeper (ft)	
Average rock diameter (ft)	
Distance from bottom to top of weeper (ft)	
Height from datum to bottom of weeper (ft)	

Remove **Vertical Stand Pipe**

Pipe diameter (ft)	3.00
Height above datum (ft)	11.27

Add | Add

Month	Evaporation (in/day)	Water Withdraw Rate (ac-ft/day)
Jan	0.00	0.000
Feb	0.00	0.000
Mar	0.00	0.000
Apr	0.00	0.000
May	0.00	0.000
Jun	0.00	0.000
Jul	0.00	0.000
Aug	0.00	0.000
Sep	0.00	0.000
Oct	0.00	0.000
Nov	0.00	0.000
Dec	0.00	0.000

Add | Add

Stage (ft)	Natural Seepage Rate (in/hr)	Other Outflow Rate (cfs)
0.00	0.00	0.000
0.01	0.00	0.000
1.00	0.00	0.000
2.00	0.00	0.000
3.00	0.00	0.000
4.00	0.00	0.000
5.00	0.00	0.000

Remove **Broad Crested Weir (Required)**

Weir crest length (ft)	10.00
Weir crest width (ft)	10.00
Height from datum to bottom of weir opening (ft)	12.33

Add **Seepage Basin**

Infiltration rate (in/hr)	
Width of device (ft)	
Length of device (ft)	
Invert elevation of seepage basin inlet above datum (ft)	

Add **Pump**

Delete Pond | Cancel | Continue | **Press 'F1' for Help**

Control Practice # : 7 | CP Index # : 18

Figure 65: WNC-6 Spring Lake Park Public Storage Pond

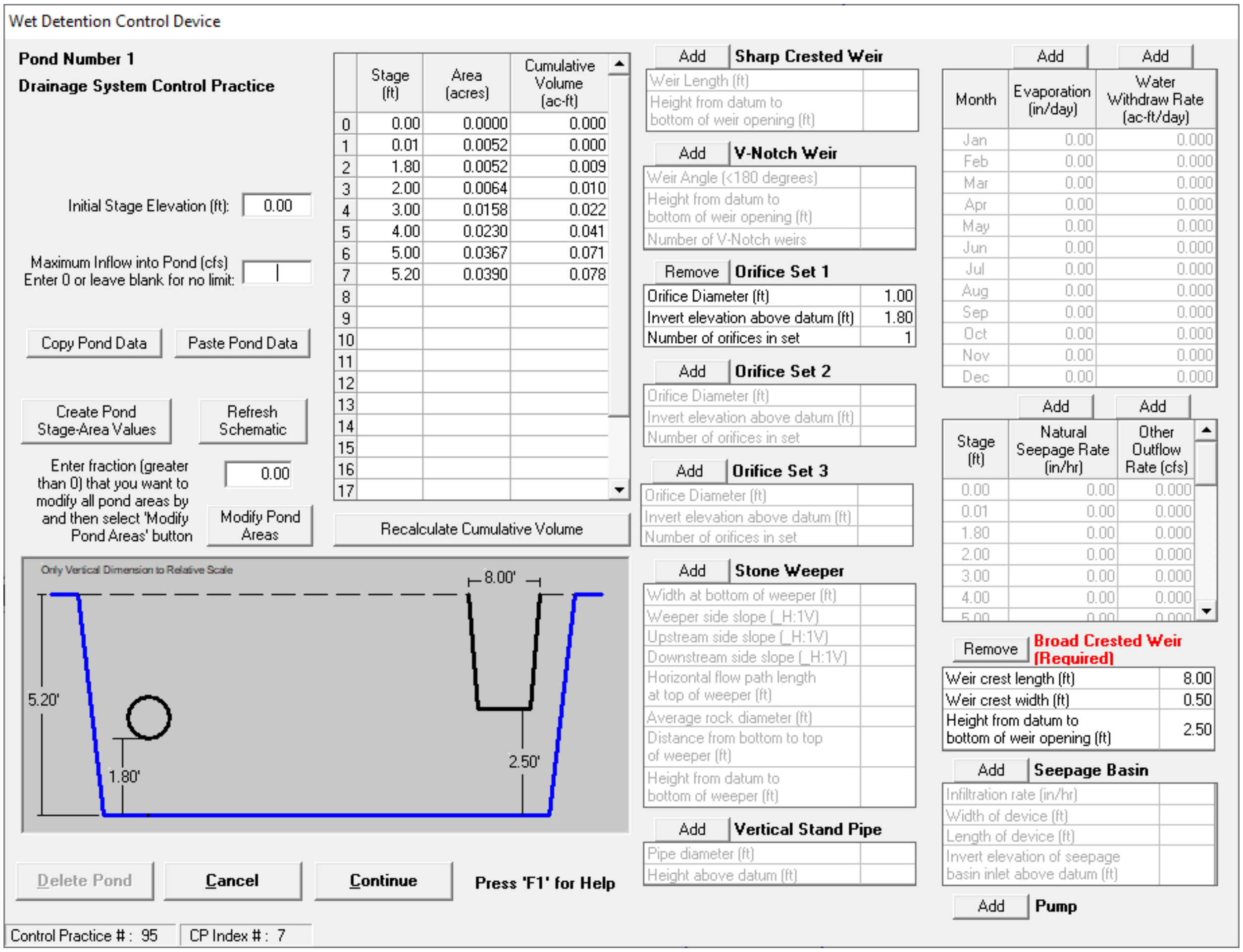


Figure 66: WNC-8 Aabco South Pond

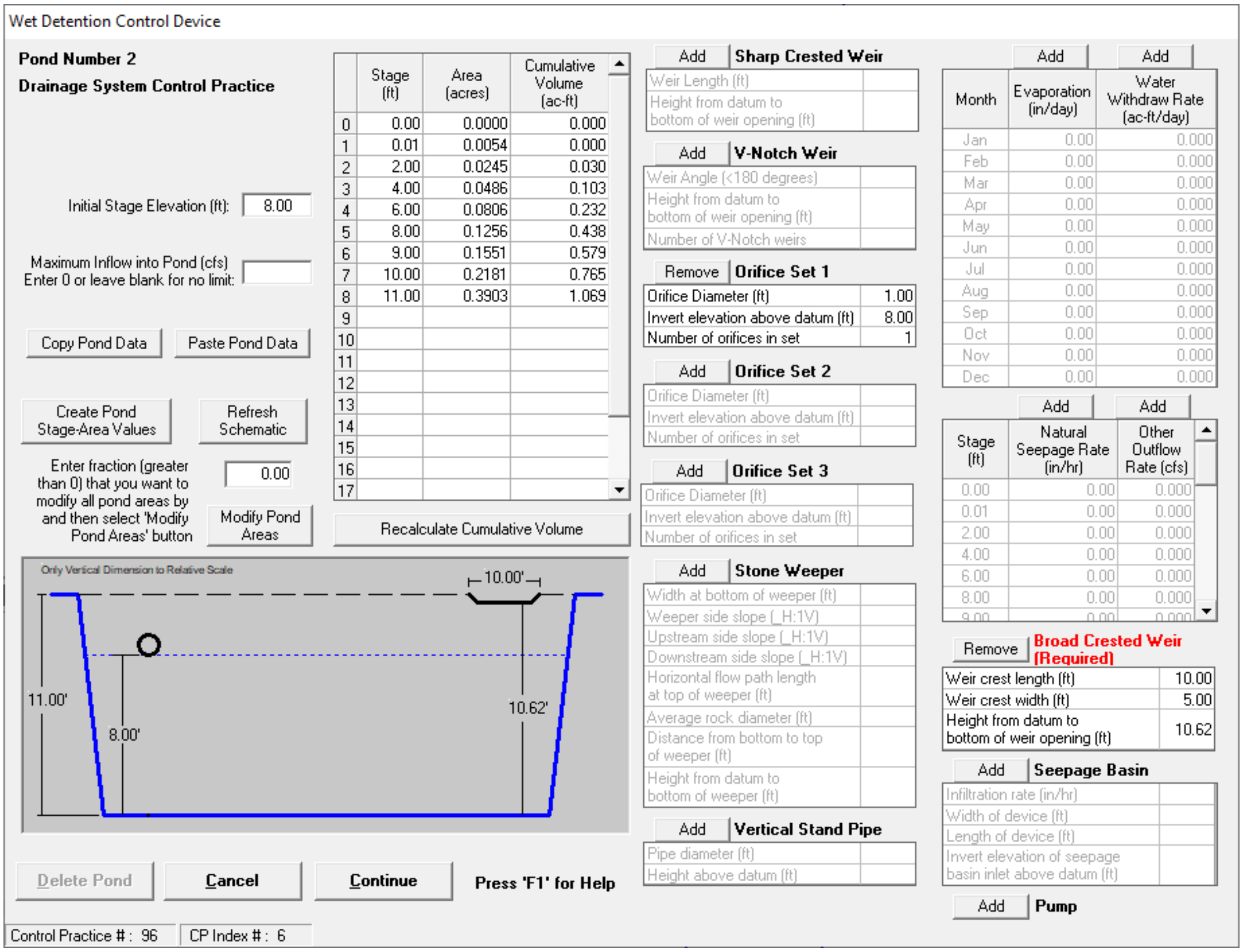


Figure 67: WNC-8 Aabco West Pond

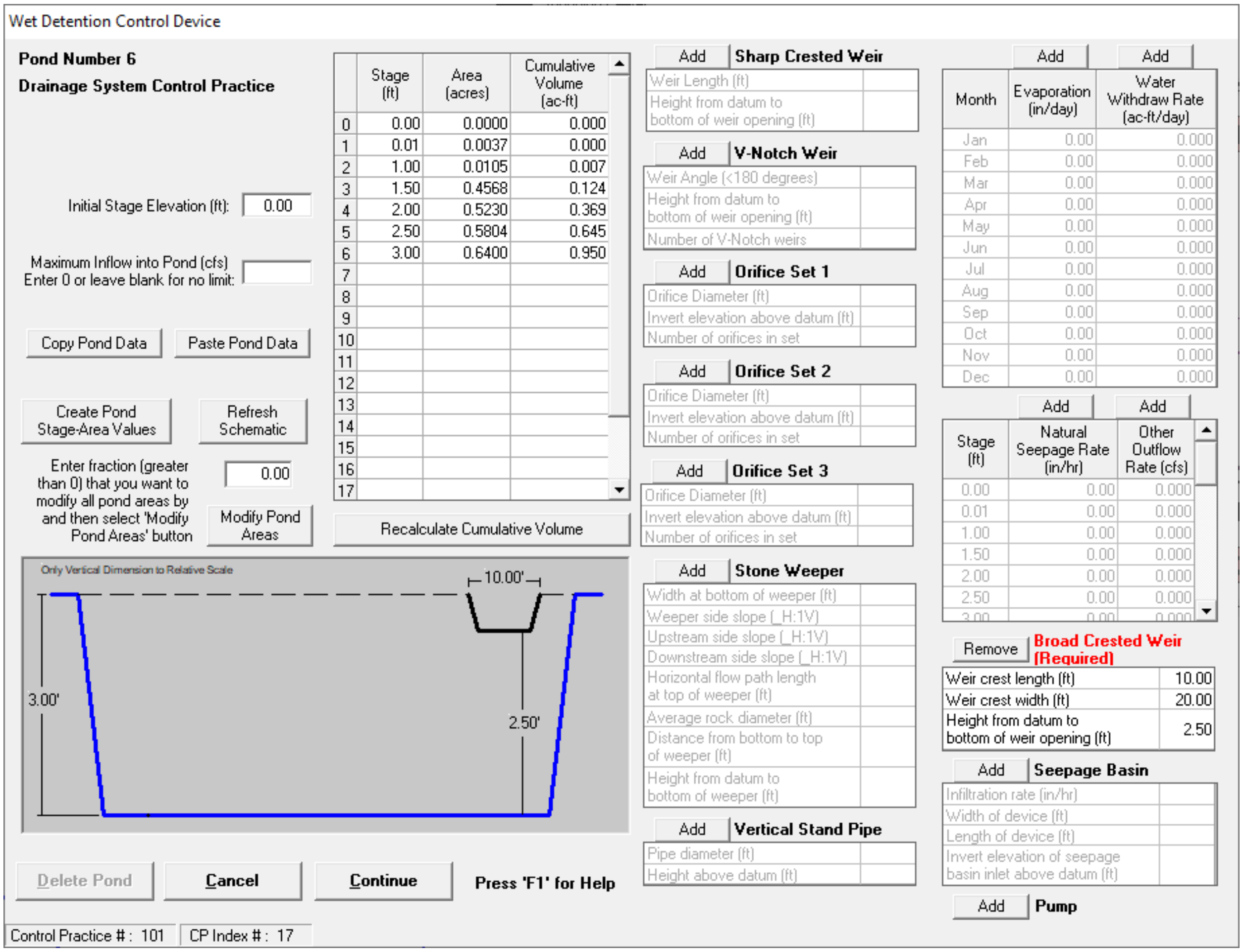


Figure 68: WNC-8 Brenk Brothers West Pond

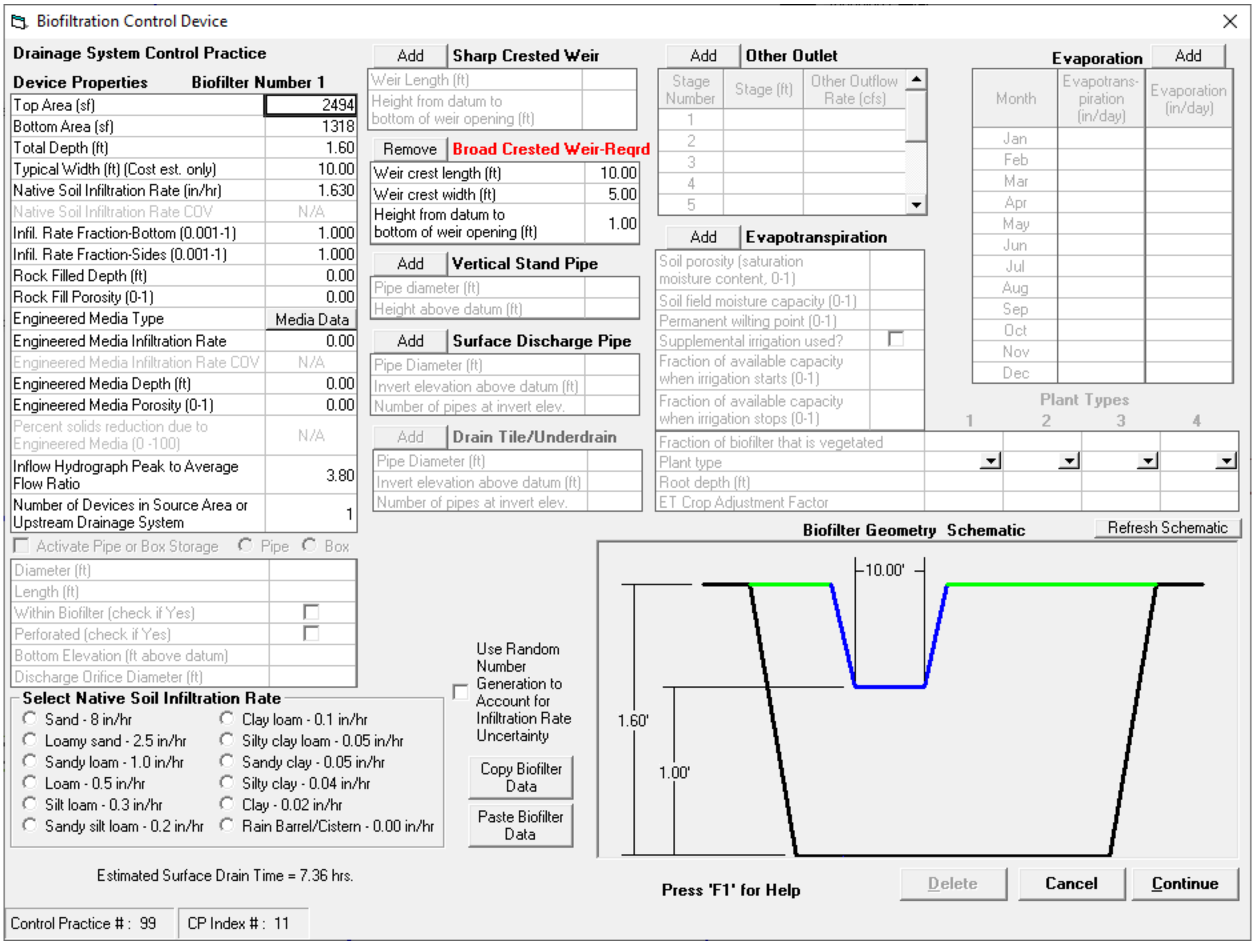


Figure 69: Pretreatment fore bay for WNC-8 Chevrolet Fireside Dr. South Pond

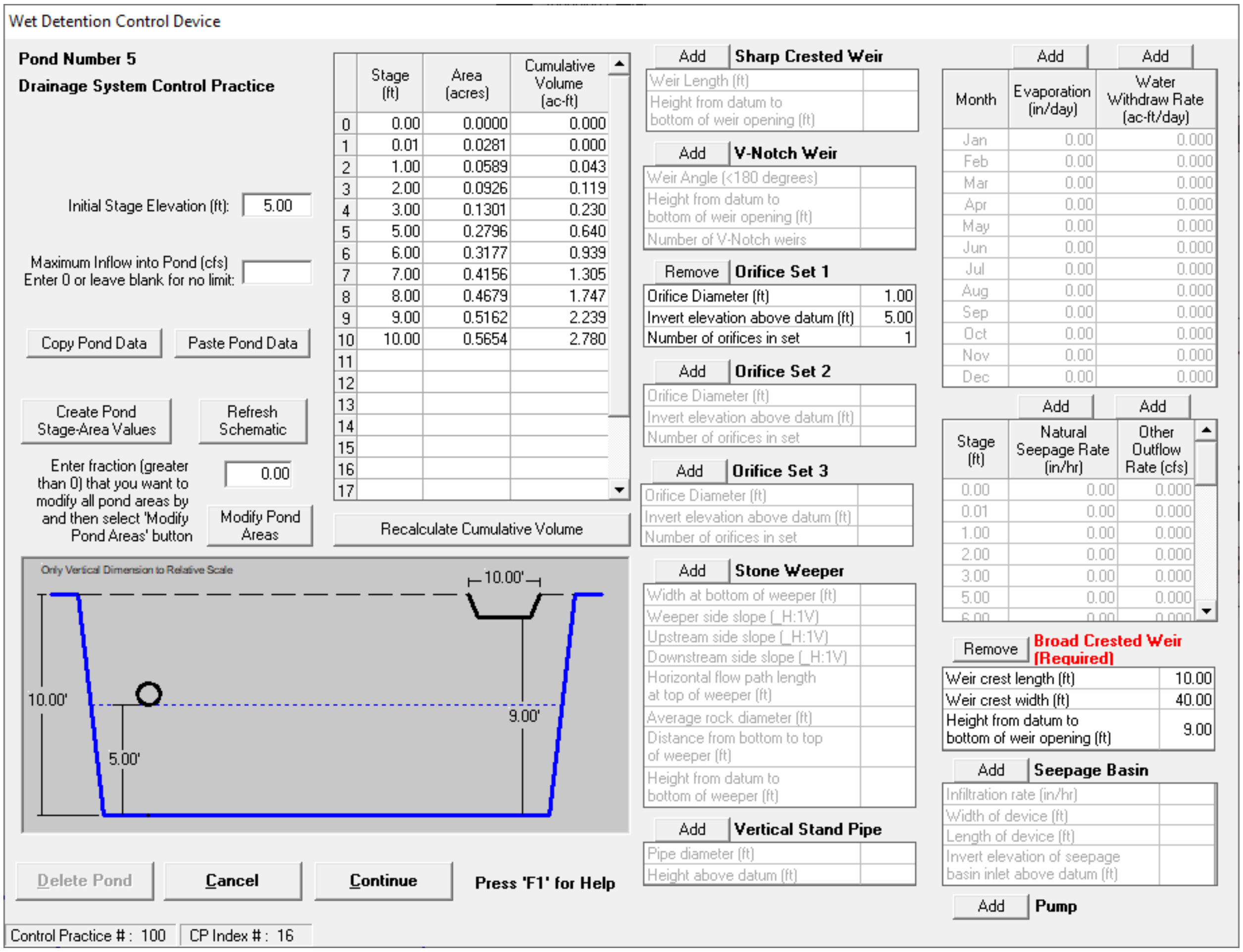


Figure 70: WNC-8 Chevrolet Fireside Dr. South Pond

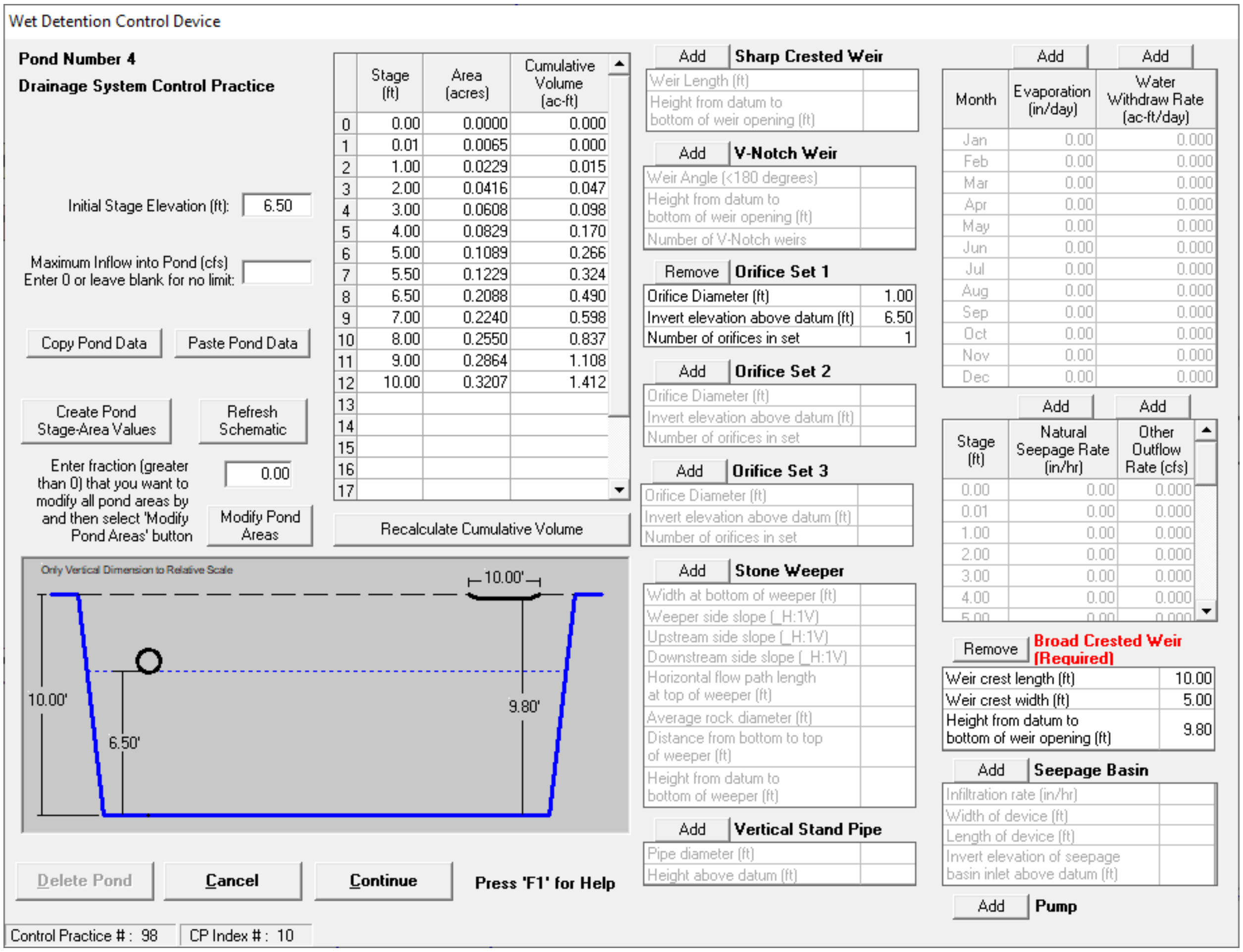


Figure 71: WNC-8 Creative Church South Pond

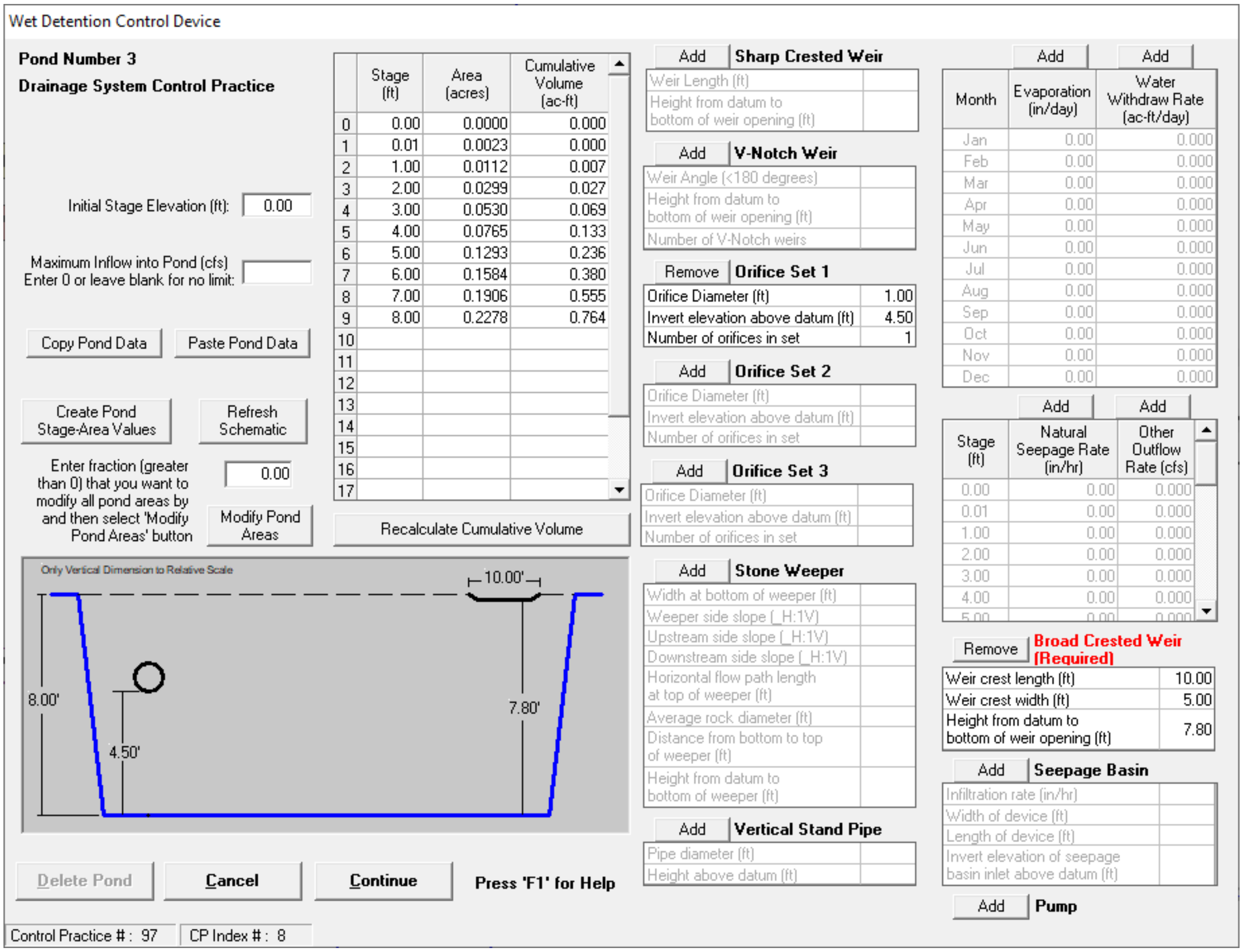
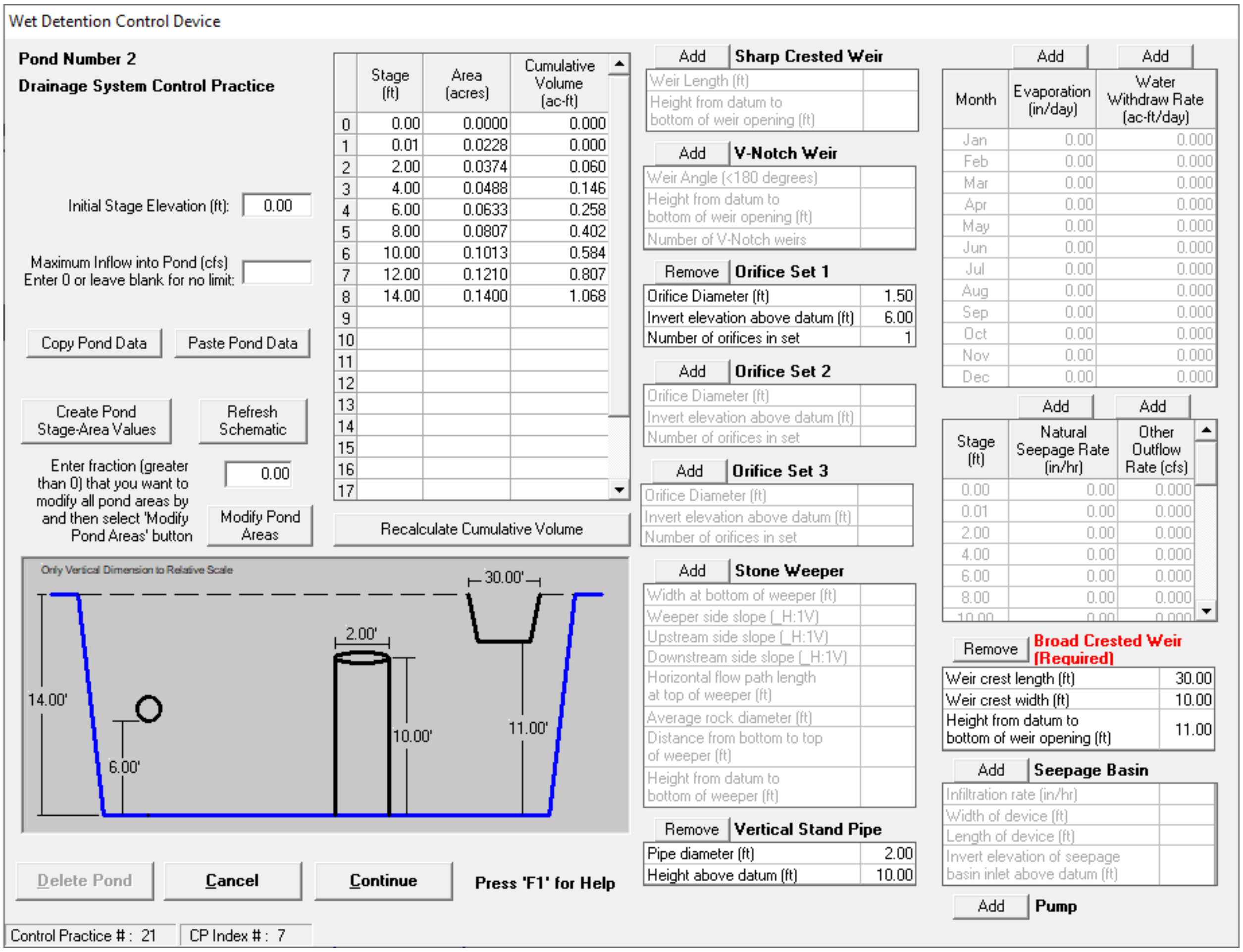


Figure 72: WNC-8 Creative Church West Pond



Wet Detention Control Device

Pond Number 2

Drainage System Control Practice

Initial Stage Elevation (ft): 0.00

Maximum Inflow into Pond (cfs)
Enter 0 or leave blank for no limit:

Copy Pond Data | Paste Pond Data

Create Pond Stage-Area Values | Refresh Schematic

Enter fraction (greater than 0) that you want to modify all pond areas by and then select 'Modify Pond Areas' button: 0.00 | Modify Pond Areas

	Stage (ft)	Area (acres)	Cumulative Volume (ac-ft)
0	0.00	0.0000	0.000
1	0.01	0.0228	0.000
2	2.00	0.0374	0.060
3	4.00	0.0488	0.146
4	6.00	0.0633	0.258
5	8.00	0.0807	0.402
6	10.00	0.1013	0.584
7	12.00	0.1210	0.807
8	14.00	0.1400	1.068
9			
10			
11			
12			
13			
14			
15			
16			
17			

Recalculate Cumulative Volume

Add **Sharp Crested Weir**

Weir Length (ft)	
Height from datum to bottom of weir opening (ft)	

Add **V-Notch Weir**

Weir Angle (<180 degrees)	
Height from datum to bottom of weir opening (ft)	
Number of V-Notch weirs	

Remove **Orifice Set 1**

Orifice Diameter (ft)	1.50
Invert elevation above datum (ft)	6.00
Number of orifices in set	1

Add **Orifice Set 2**

Orifice Diameter (ft)	
Invert elevation above datum (ft)	
Number of orifices in set	

Add **Orifice Set 3**

Orifice Diameter (ft)	
Invert elevation above datum (ft)	
Number of orifices in set	

Add **Stone Weeper**

Width at bottom of weeper (ft)	
Weeper side slope (_H:1V)	
Upstream side slope (_H:1V)	
Downstream side slope (_H:1V)	
Horizontal flow path length at top of weeper (ft)	
Average rock diameter (ft)	
Distance from bottom to top of weeper (ft)	
Height from datum to bottom of weeper (ft)	

Remove **Vertical Stand Pipe**

Pipe diameter (ft)	2.00
Height above datum (ft)	10.00

Month	Evaporation (in/day)	Water Withdraw Rate (ac-ft/day)
Jan	0.00	0.000
Feb	0.00	0.000
Mar	0.00	0.000
Apr	0.00	0.000
May	0.00	0.000
Jun	0.00	0.000
Jul	0.00	0.000
Aug	0.00	0.000
Sep	0.00	0.000
Oct	0.00	0.000
Nov	0.00	0.000
Dec	0.00	0.000

Stage (ft)	Natural Seepage Rate (in/hr)	Other Outflow Rate (cfs)
0.00	0.00	0.000
0.01	0.00	0.000
2.00	0.00	0.000
4.00	0.00	0.000
6.00	0.00	0.000
8.00	0.00	0.000
10.00	0.00	0.000

Remove **Broad Crested Weir (Required)**

Weir crest length (ft)	30.00
Weir crest width (ft)	10.00
Height from datum to bottom of weir opening (ft)	11.00

Add **Seepage Basin**

Infiltration rate (in/hr)	
Width of device (ft)	
Length of device (ft)	
Invert elevation of seepage basin inlet above datum (ft)	

Add **Pump**

Delete Pond | Cancel | Continue | **Press 'F1' for Help**

Control Practice # : 21 | CP Index # : 7

Figure 73: WNC-9 Medtronic Pond

Swales

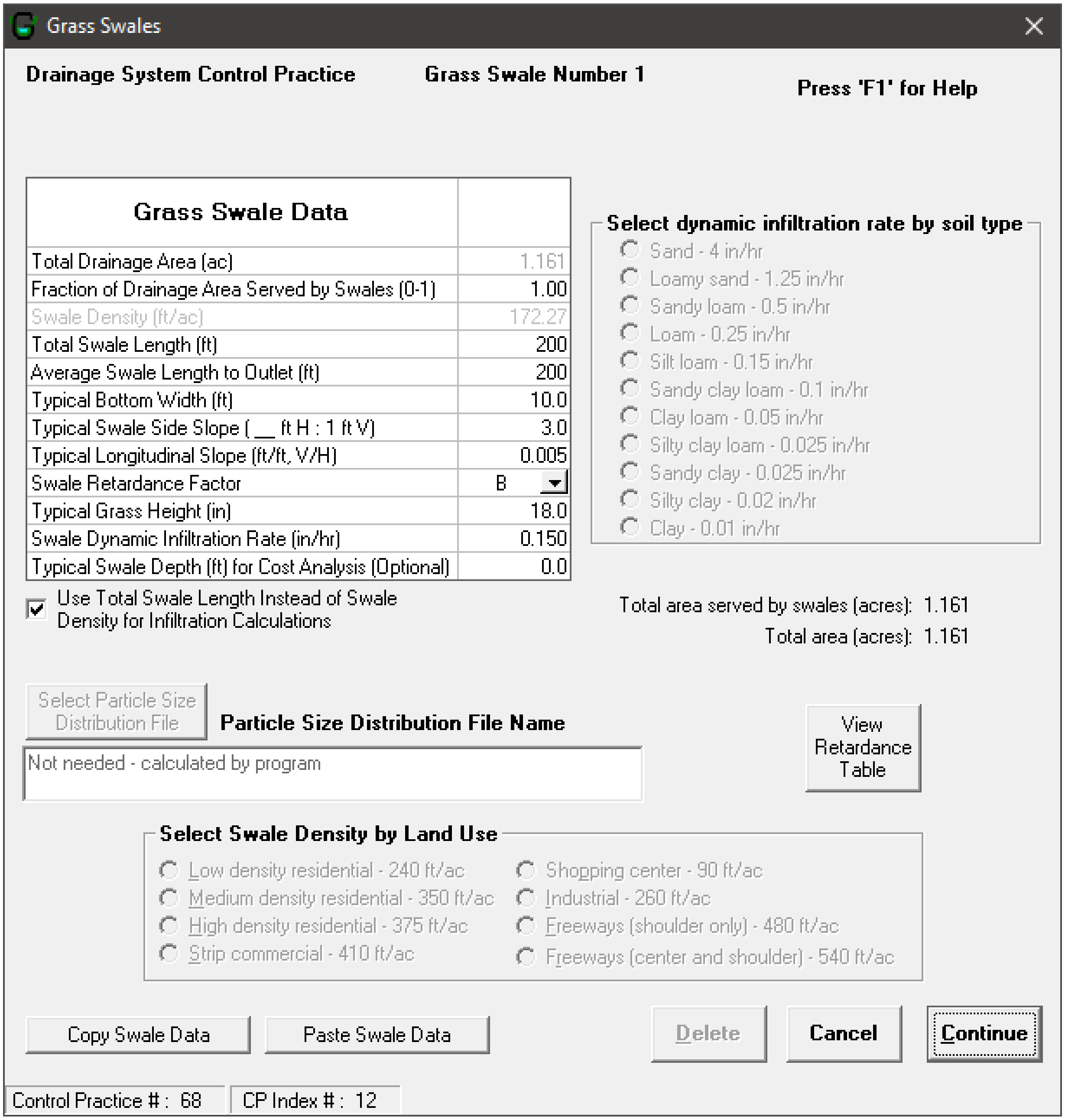


Figure 74: LRC-5-2 Banquets of Minnesota swale

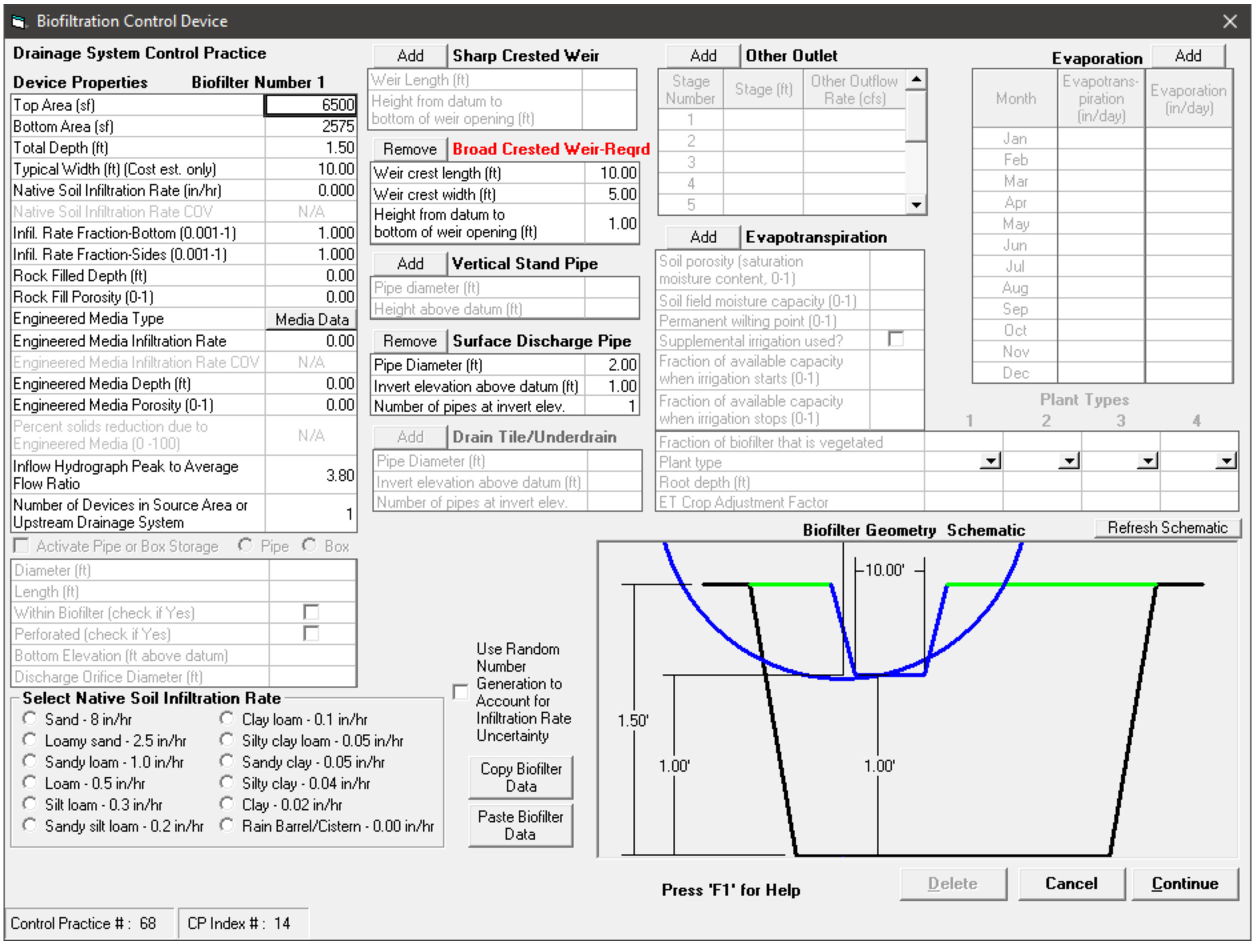


Figure 75: LRC-5-2 St. Philip's Lutheran Church ditch ponding area

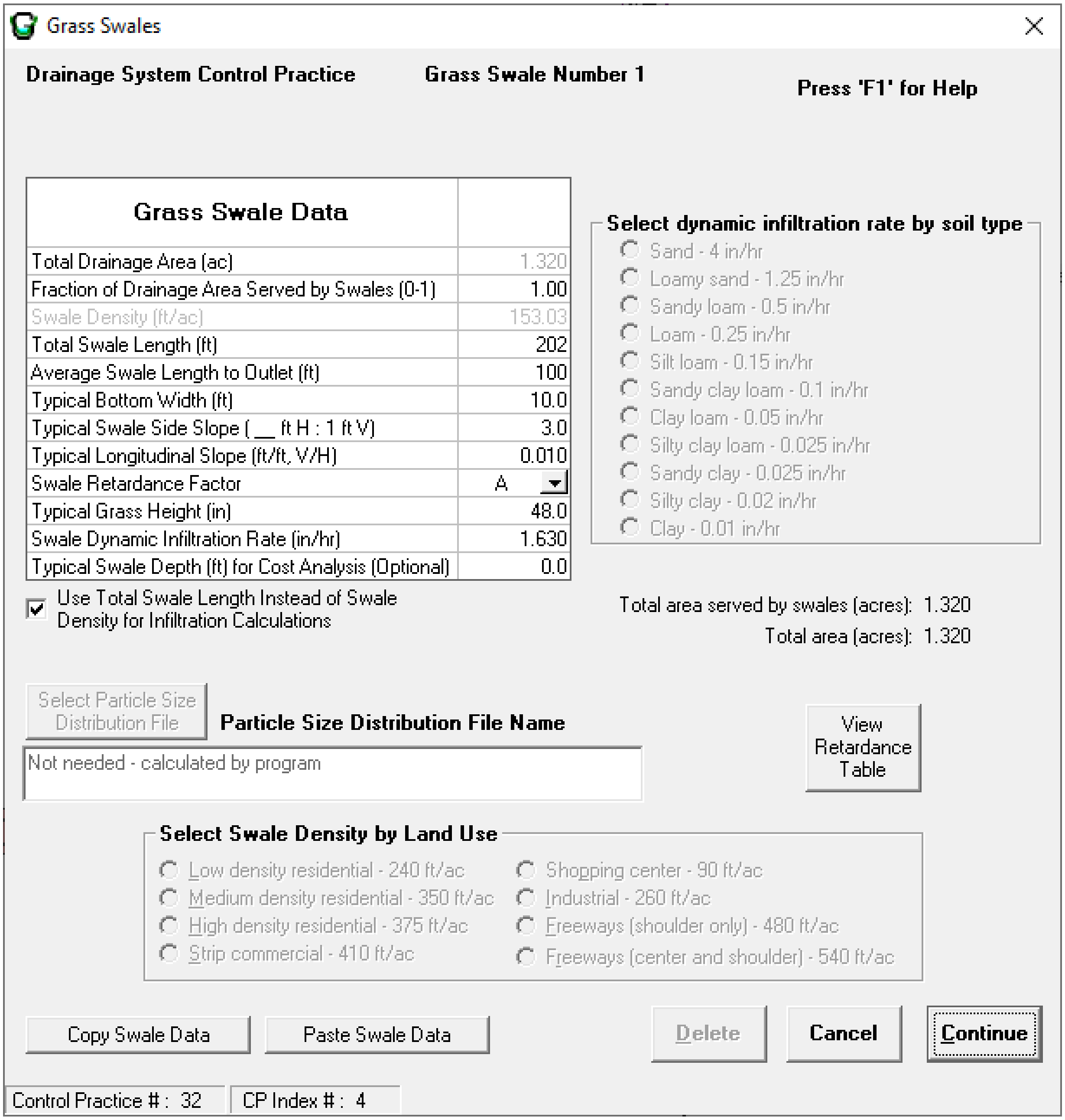


Figure 76: ENC-1 Water Doctors swale

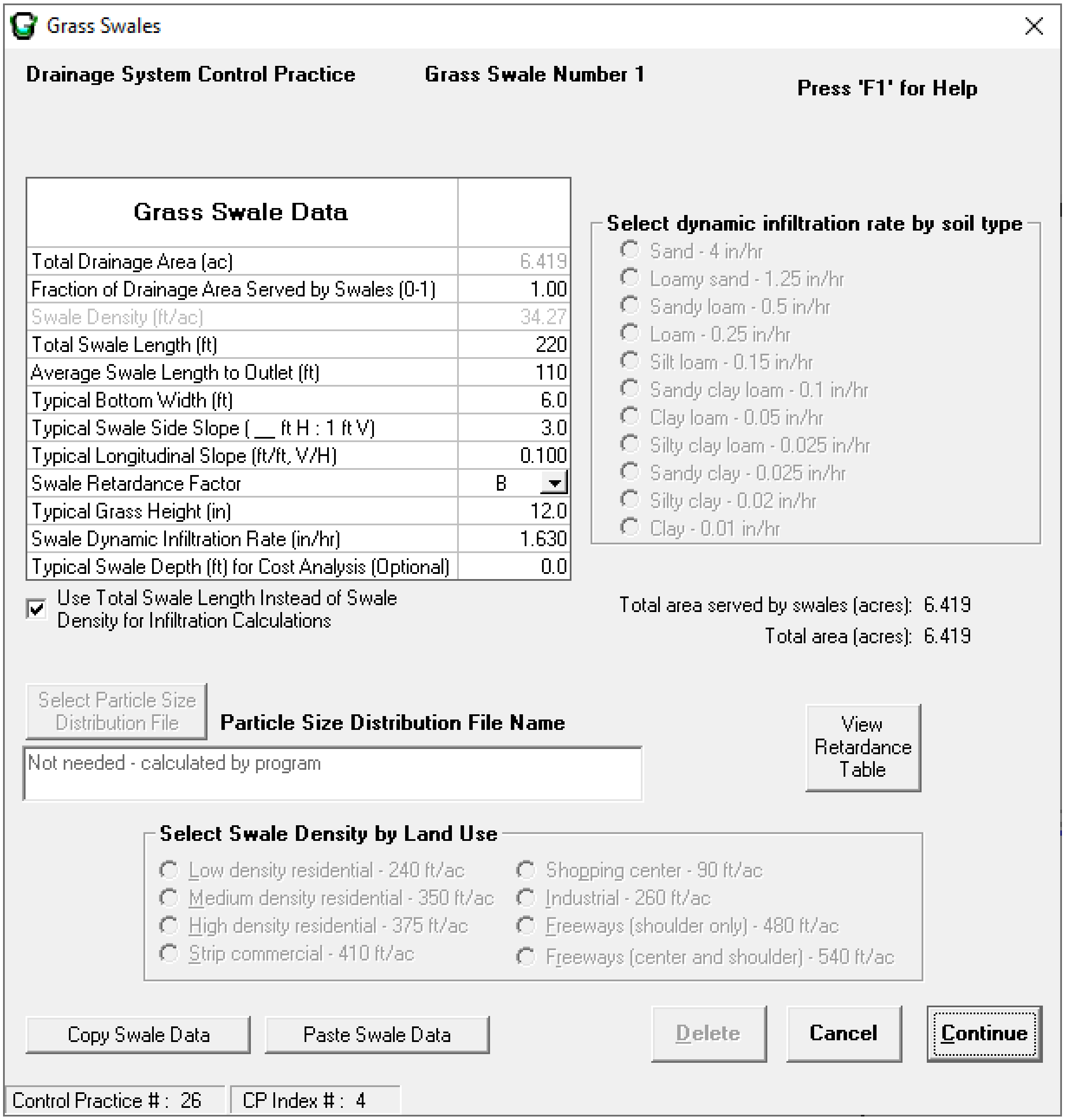


Figure 77: ENC-8 Cummins swale

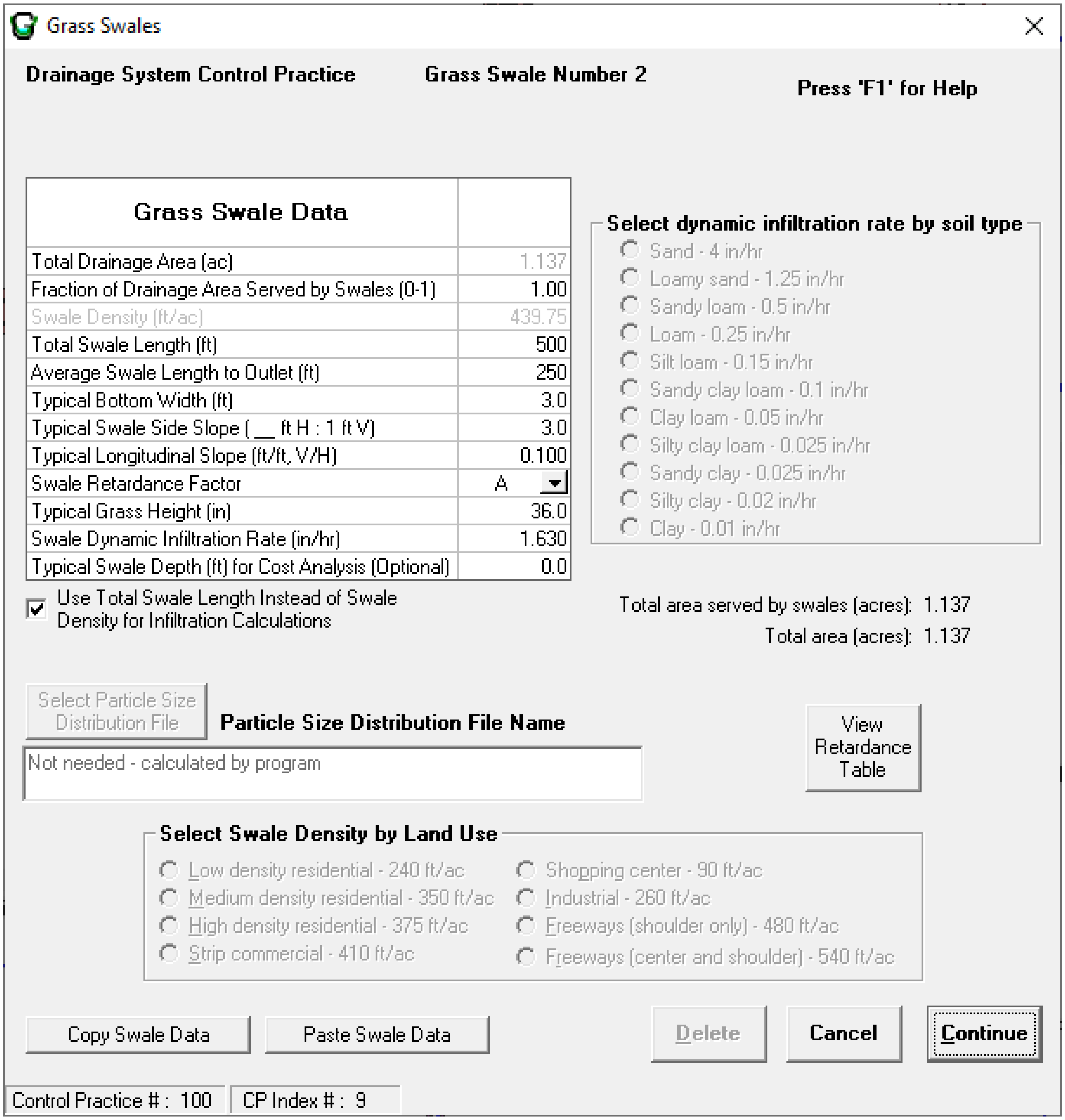


Figure 78: NC-2 Hwy 65 Frontage swale #1

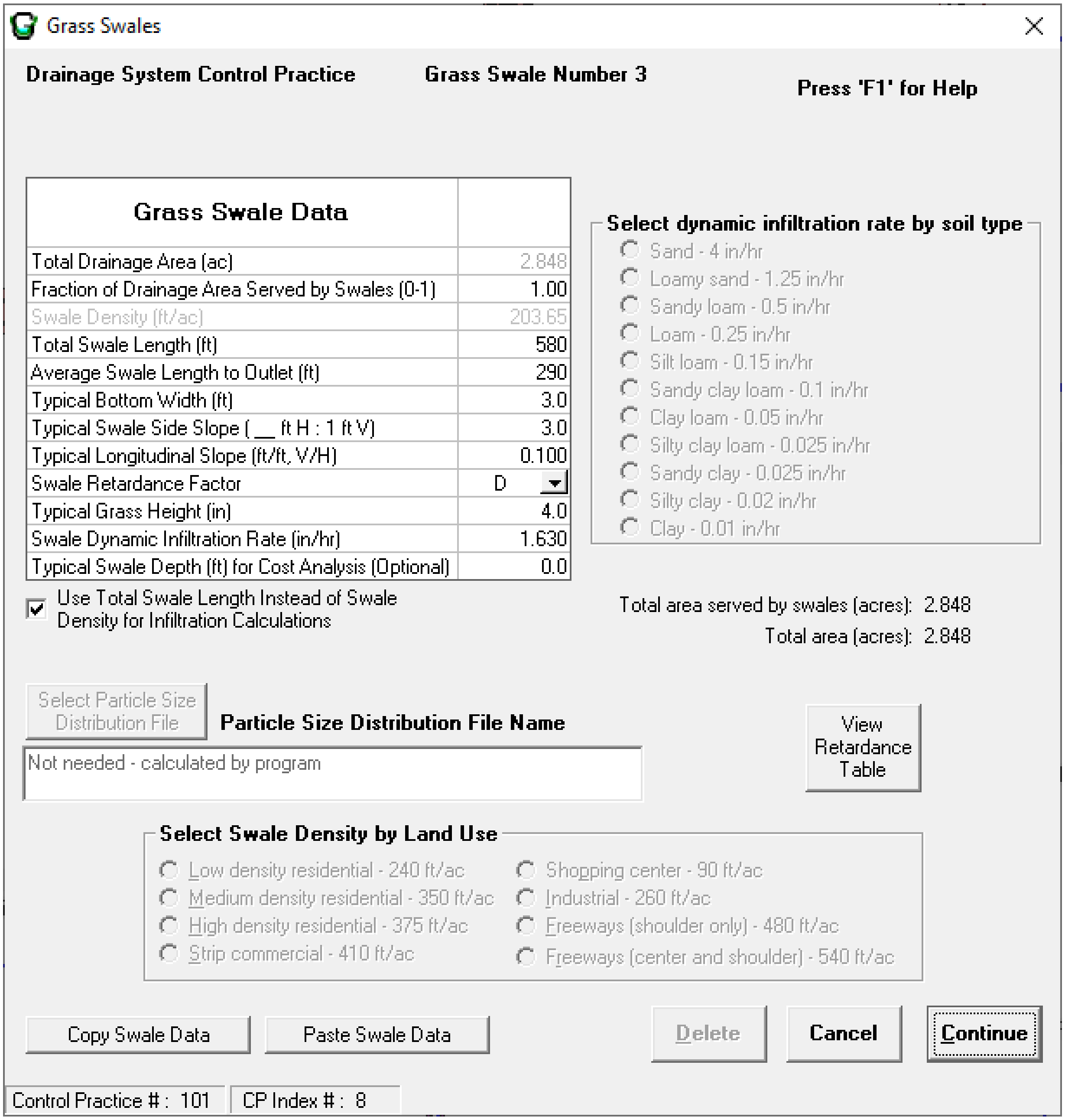


Figure 79: NC-2 Hwy 65 Frontage swale #2

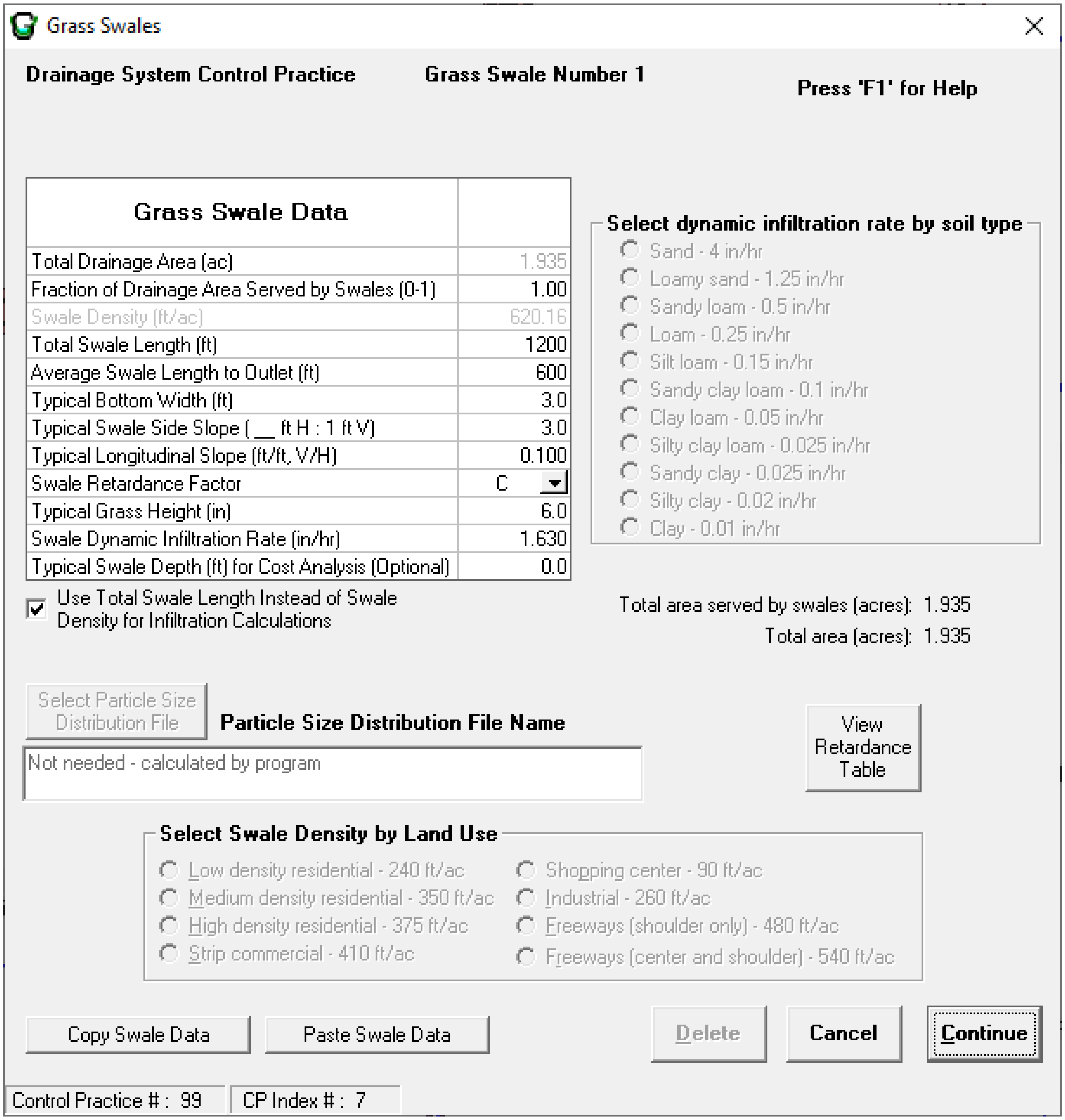


Figure 80: NC-2 Hwy 65 median swale

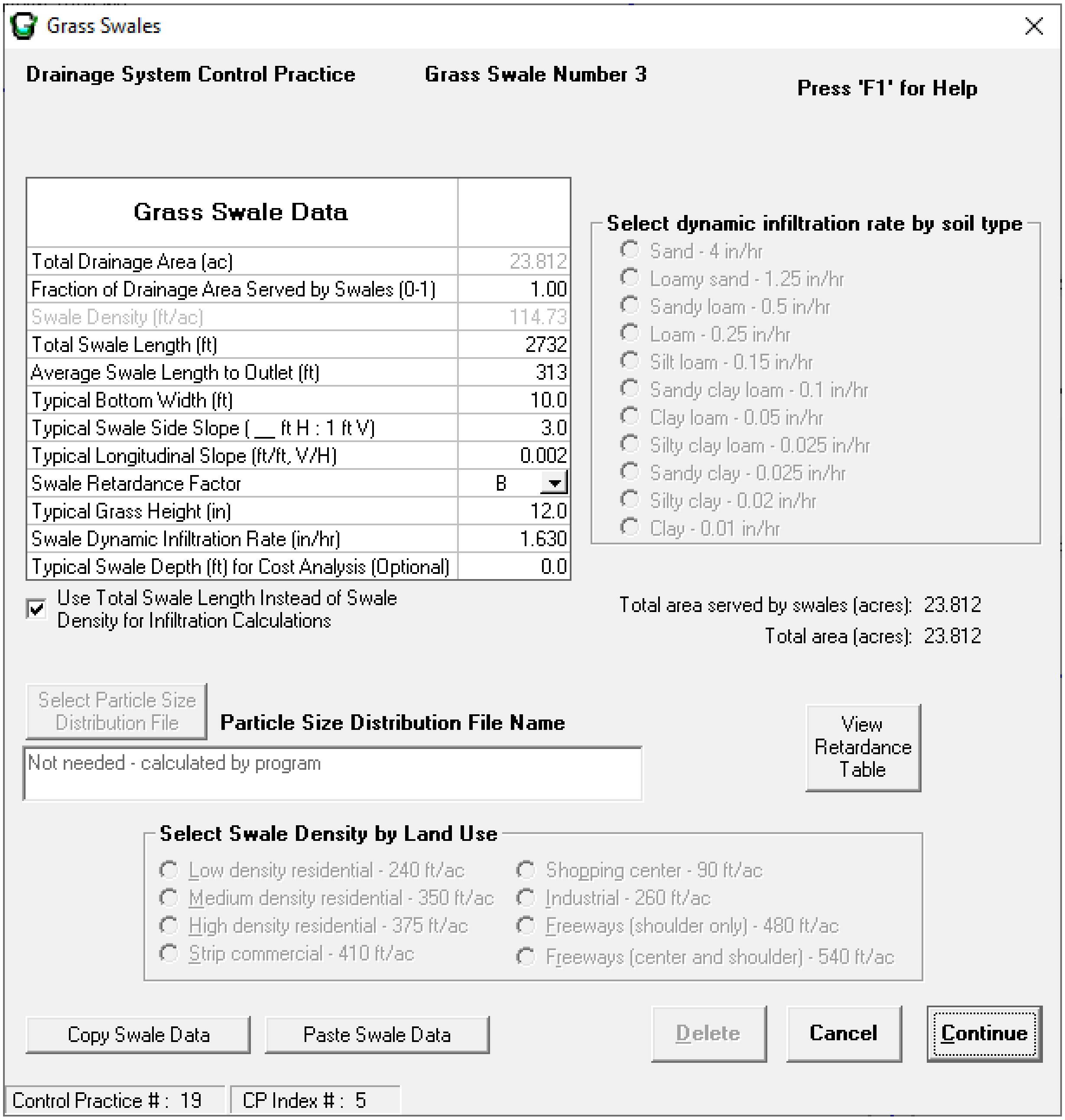


Figure 81: WNC-1 Hwy 65 frontage swale

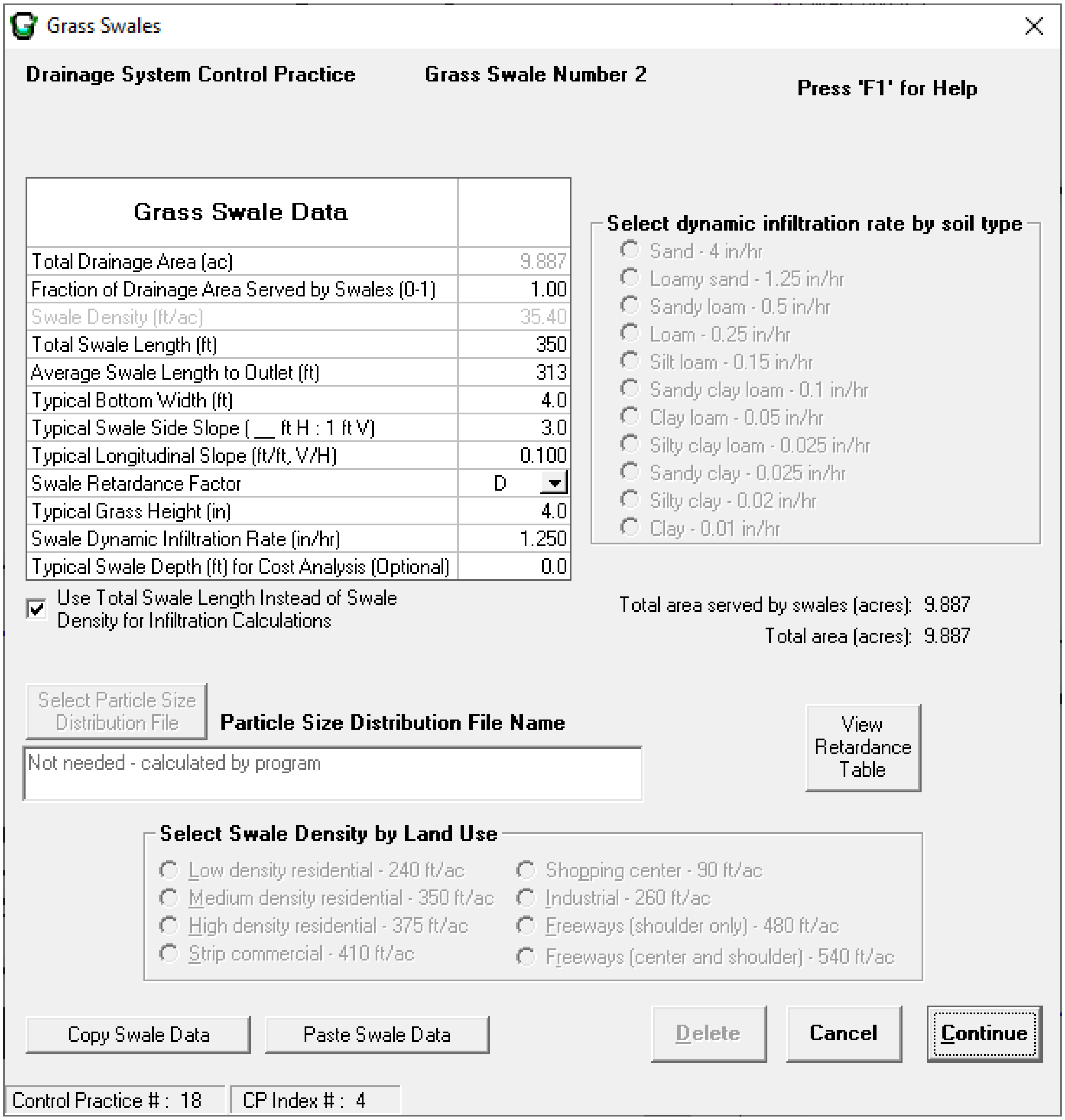


Figure 82: WNC-1 Central Ave. swale

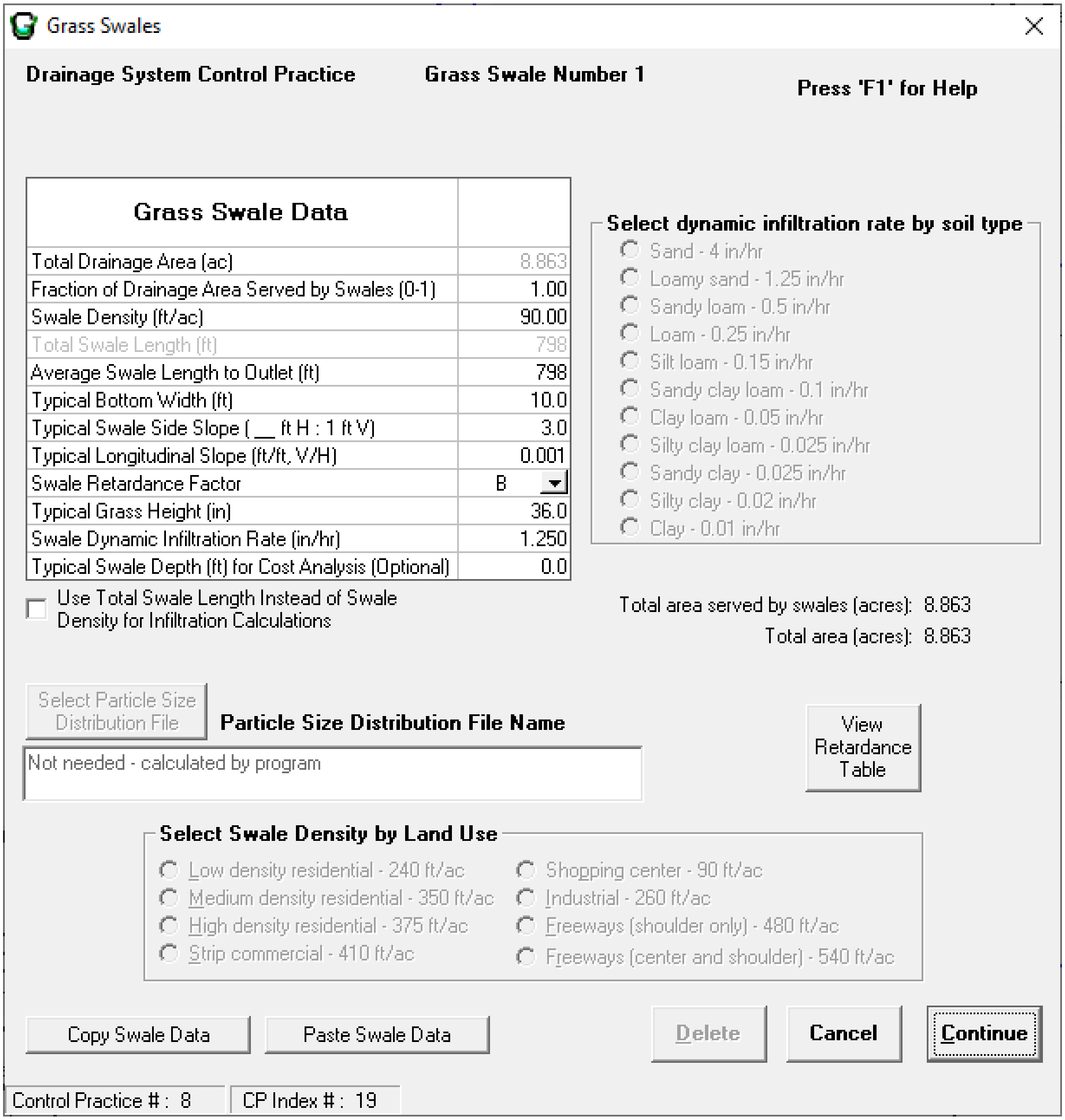


Figure 83: WNC-2 Hwy 65 frontage swale

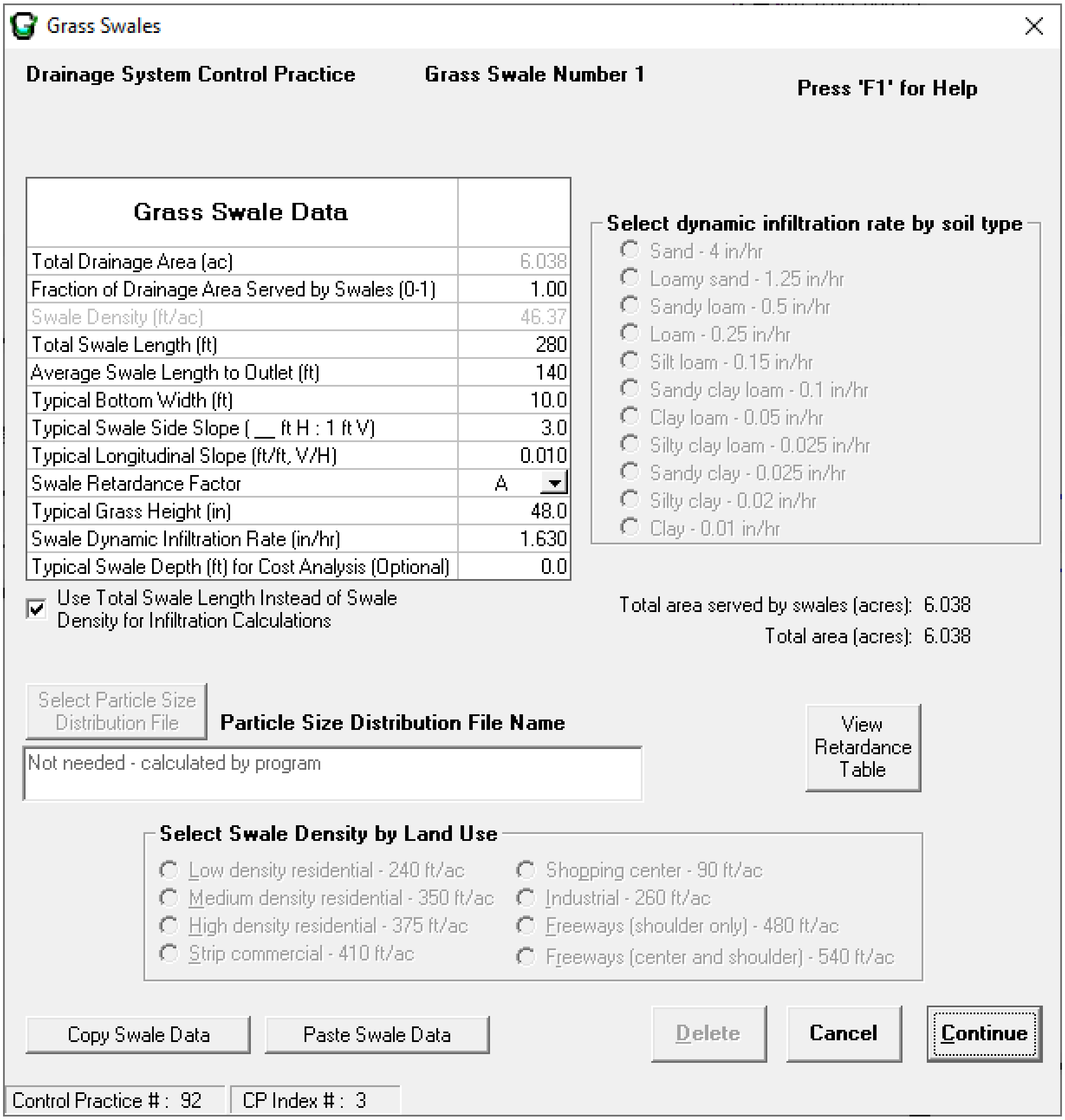


Figure 84: WNC-8 Hwy 65 frontage swale #1

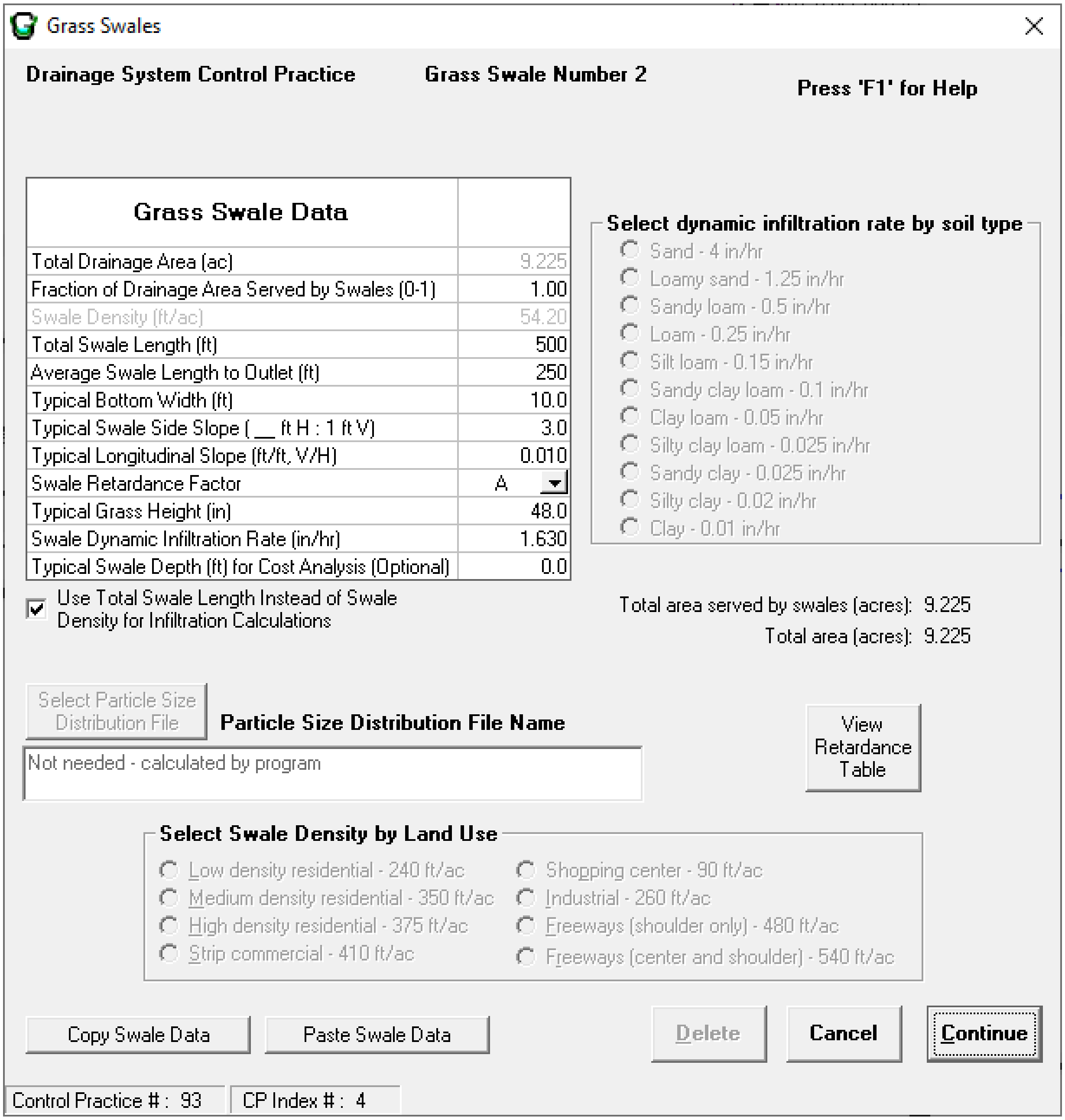


Figure 85: WNC-8 Hwy 65 frontage swale #2

Proposed Conditions

Curb-Cut Rain Garden

Curb-cut rain gardens were modeled as drainage area control practices within WinSLAMM. Bioinfiltration basins were modeled without an underdrain and given ponding depths based on available soil information. In sandy areas, a 12-inch ponding depth was applied. In silty areas, a 9" ponding depth was applied to facilitate drainage of the basin within 48 hours of a storm event. Biofiltration basins were modeled in areas with silty soil where an underdrain could be linked to a nearby catch basin with 12-inch ponding depths. All standard bioinfiltration and biofiltration basins were modeled with a 250 sq.-ft. top footprint.

High-Performance Modular Bioretention Systems were modeled with underdrains linking to subsurface storm sewer. These basins were modeled with a 100 sq.-ft. top footprint and 12-inch ponding depths.

Bioretention Basins

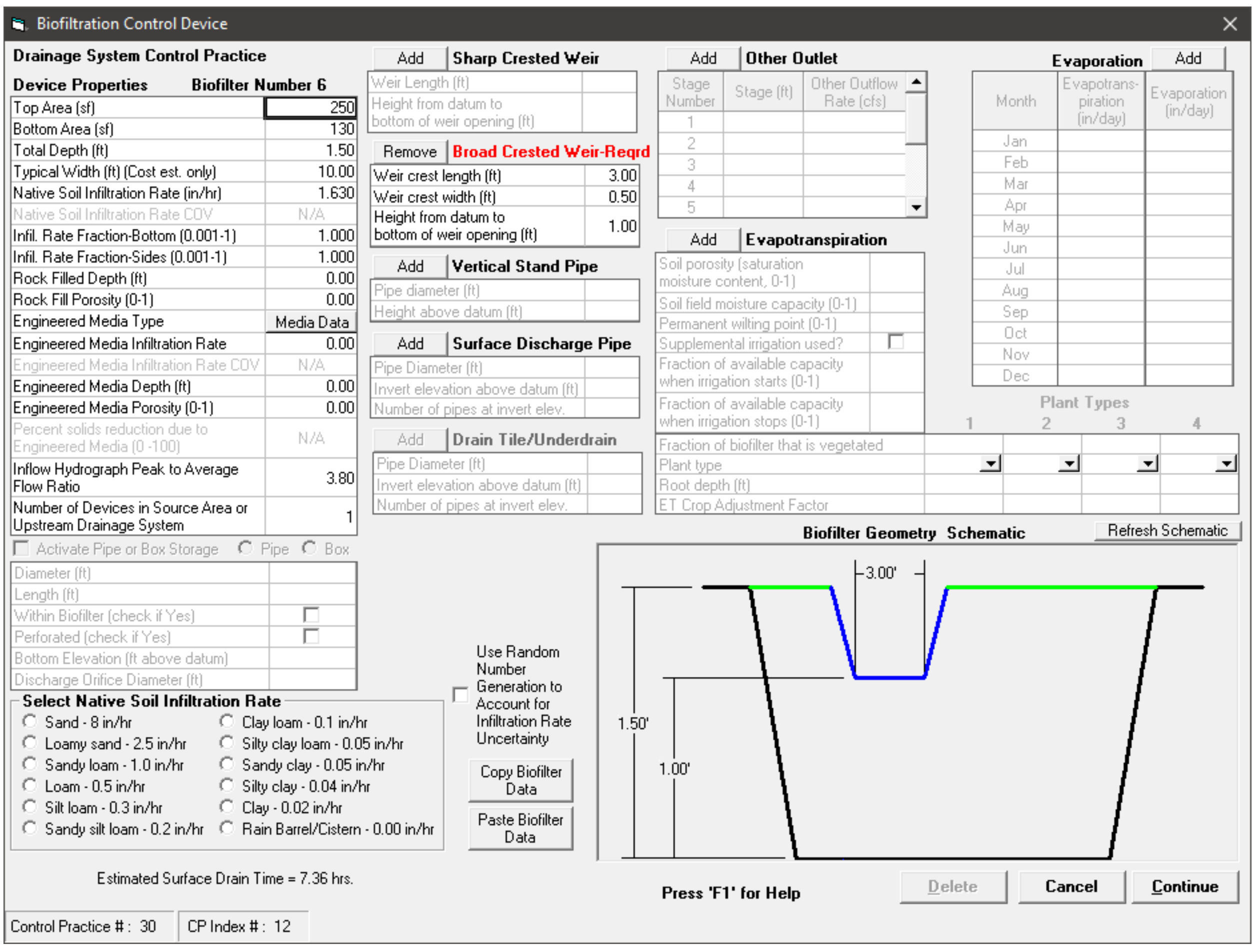


Figure 86: Sand infiltration basin – 12" ponding depth.

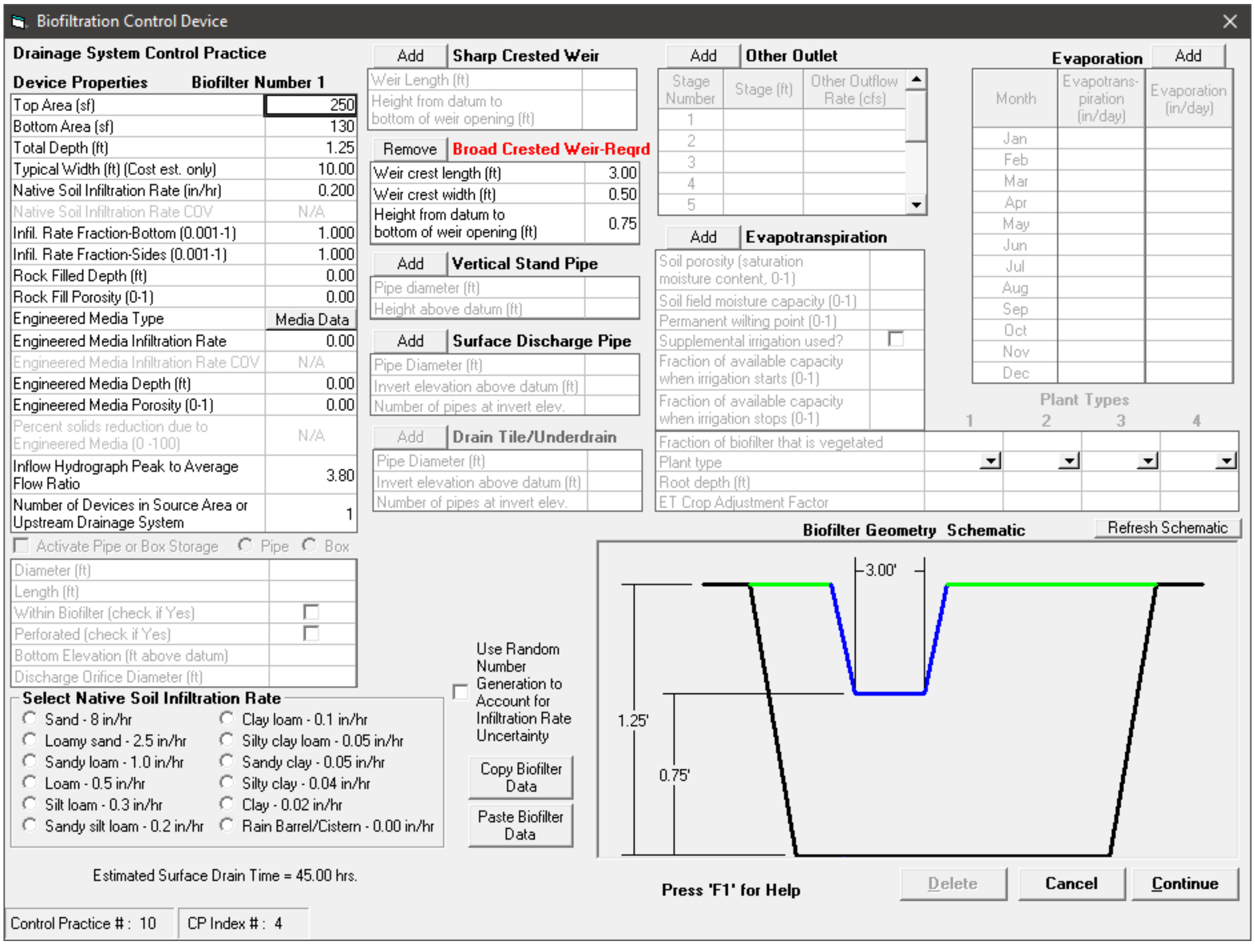


Figure 87: Silt infiltration basin – 9” ponding depth.

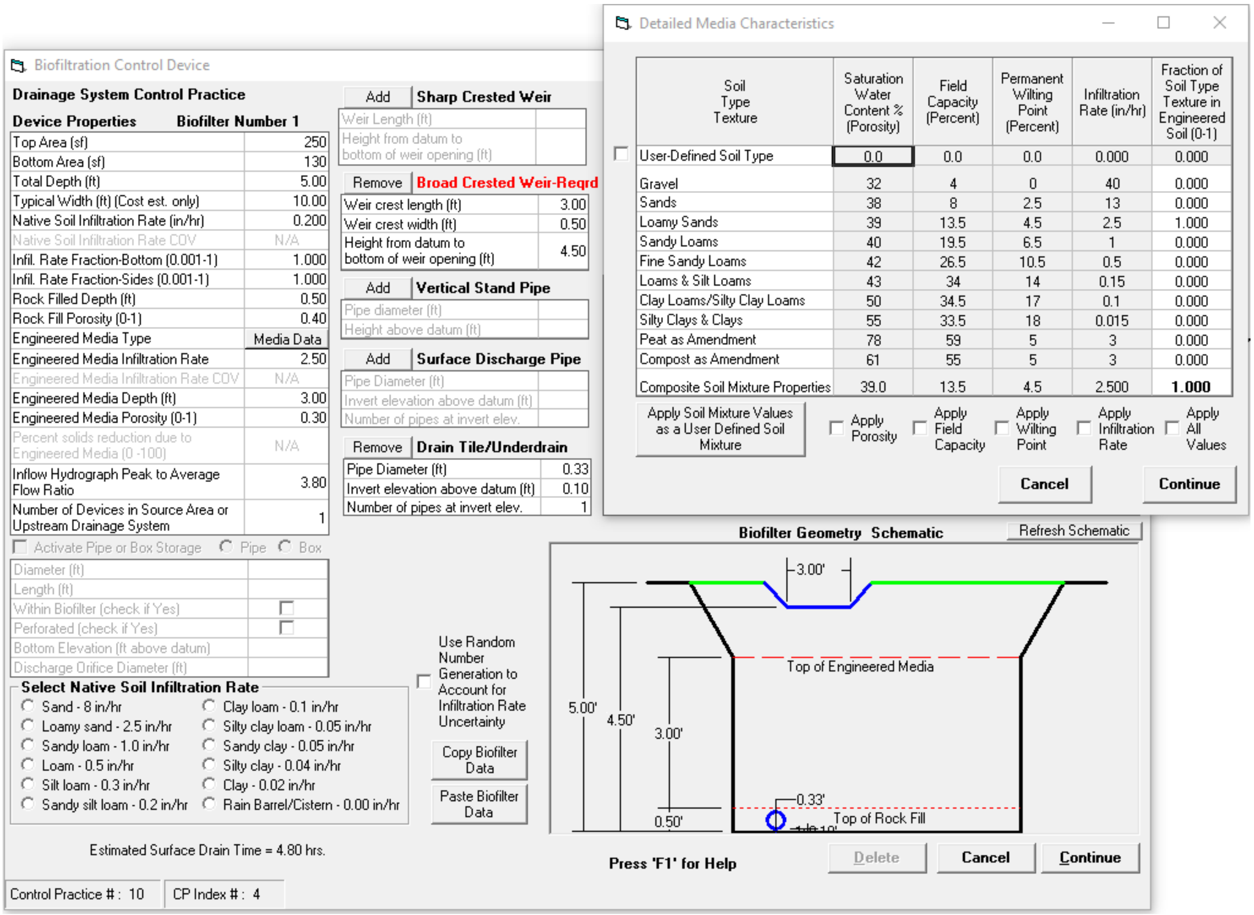


Figure 88: Silt filtration basin – 12" ponding depth.

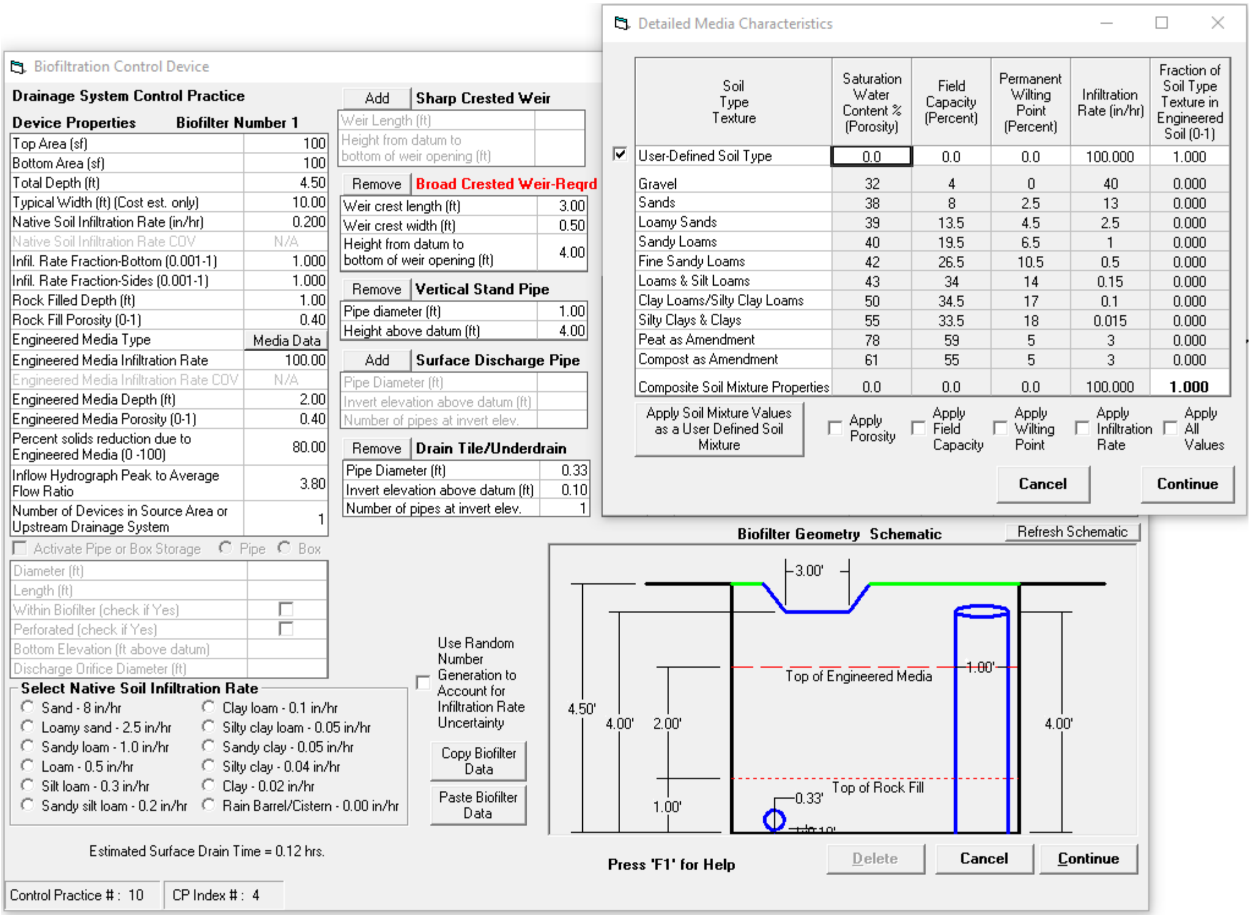


Figure 89: HPMBS basin – 12” ponding depth.

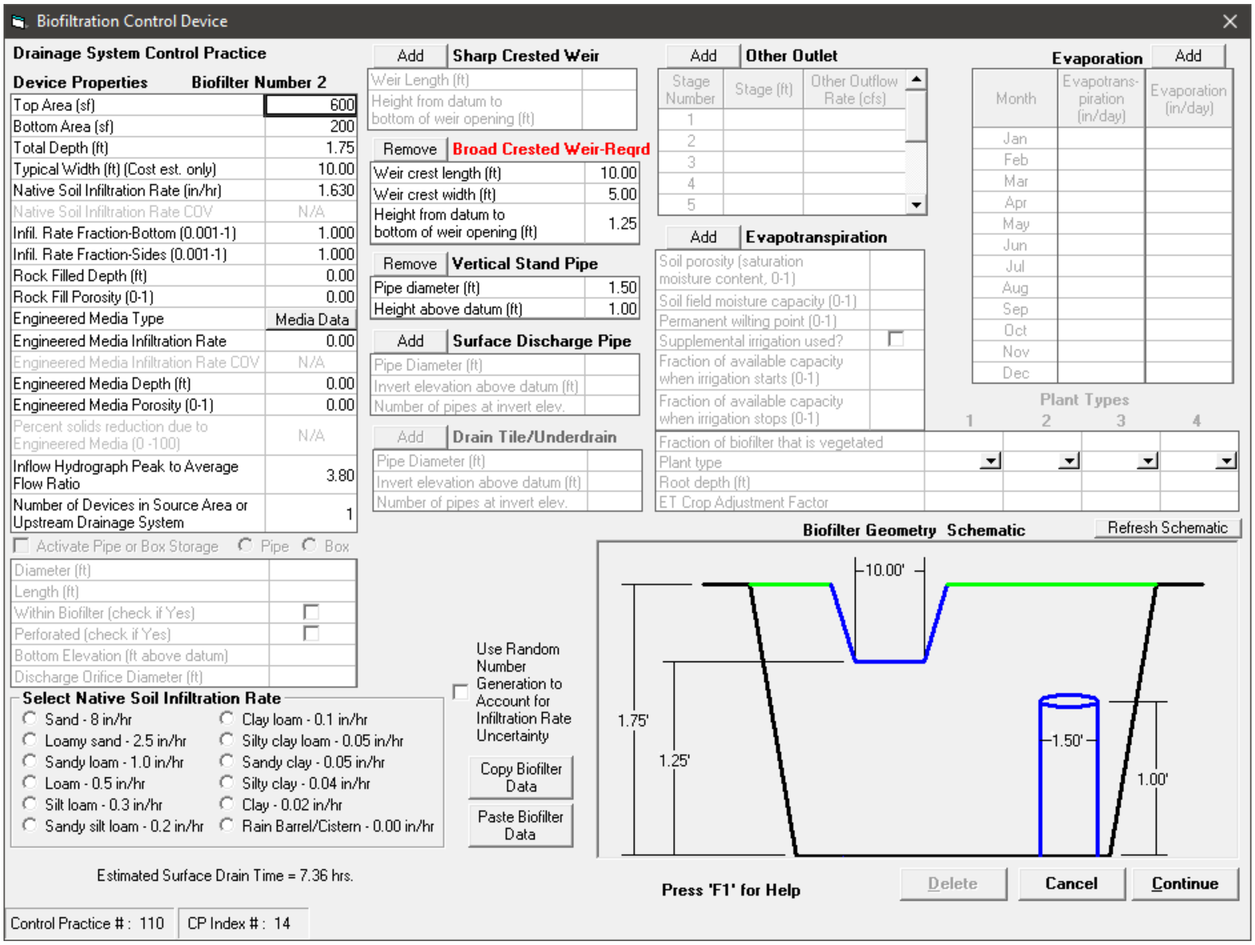


Figure 90: LRC 2-1 Wells Fargo infiltration basin - sand.

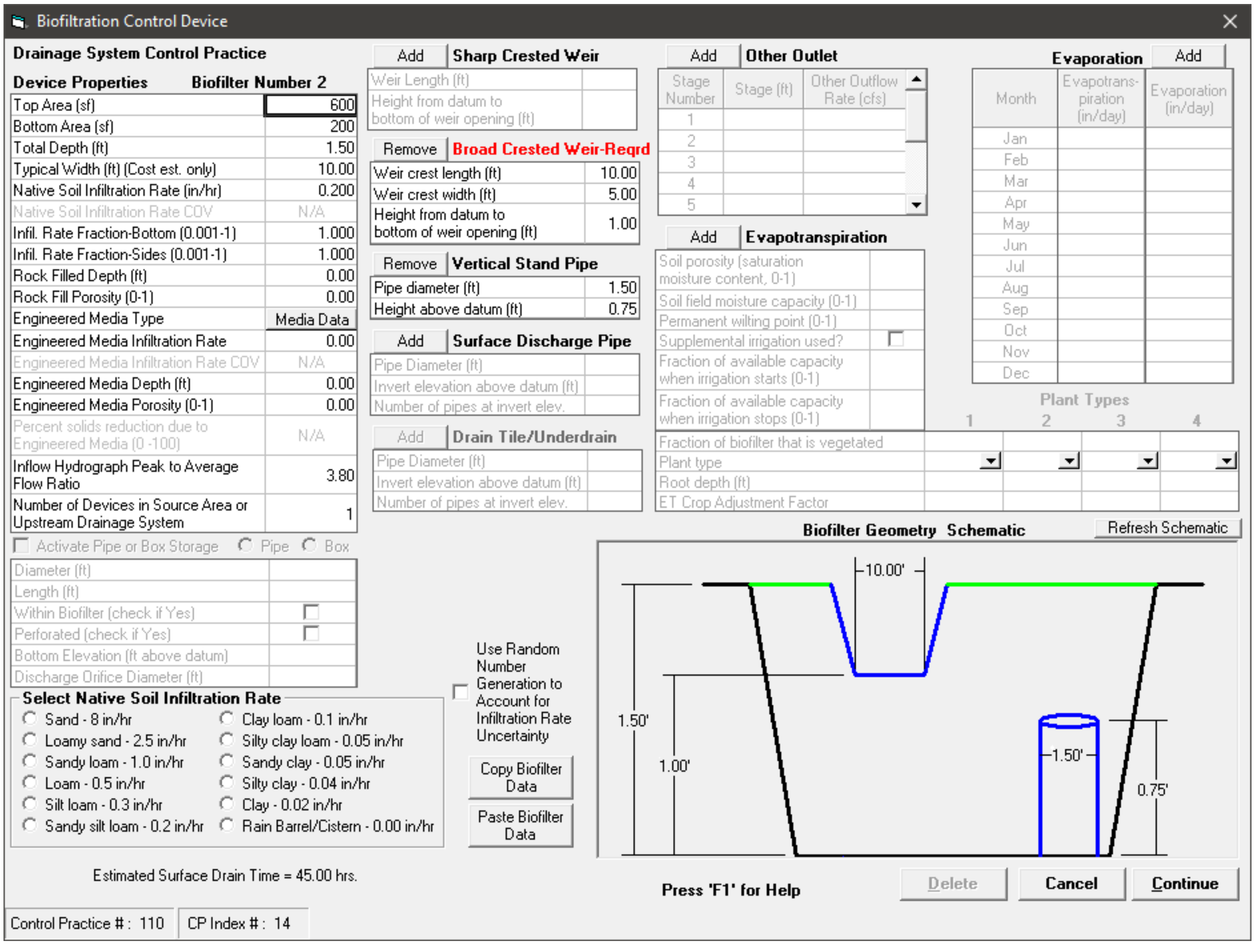


Figure 91: LRC 2-1 Wells Fargo infiltration basin - silt.

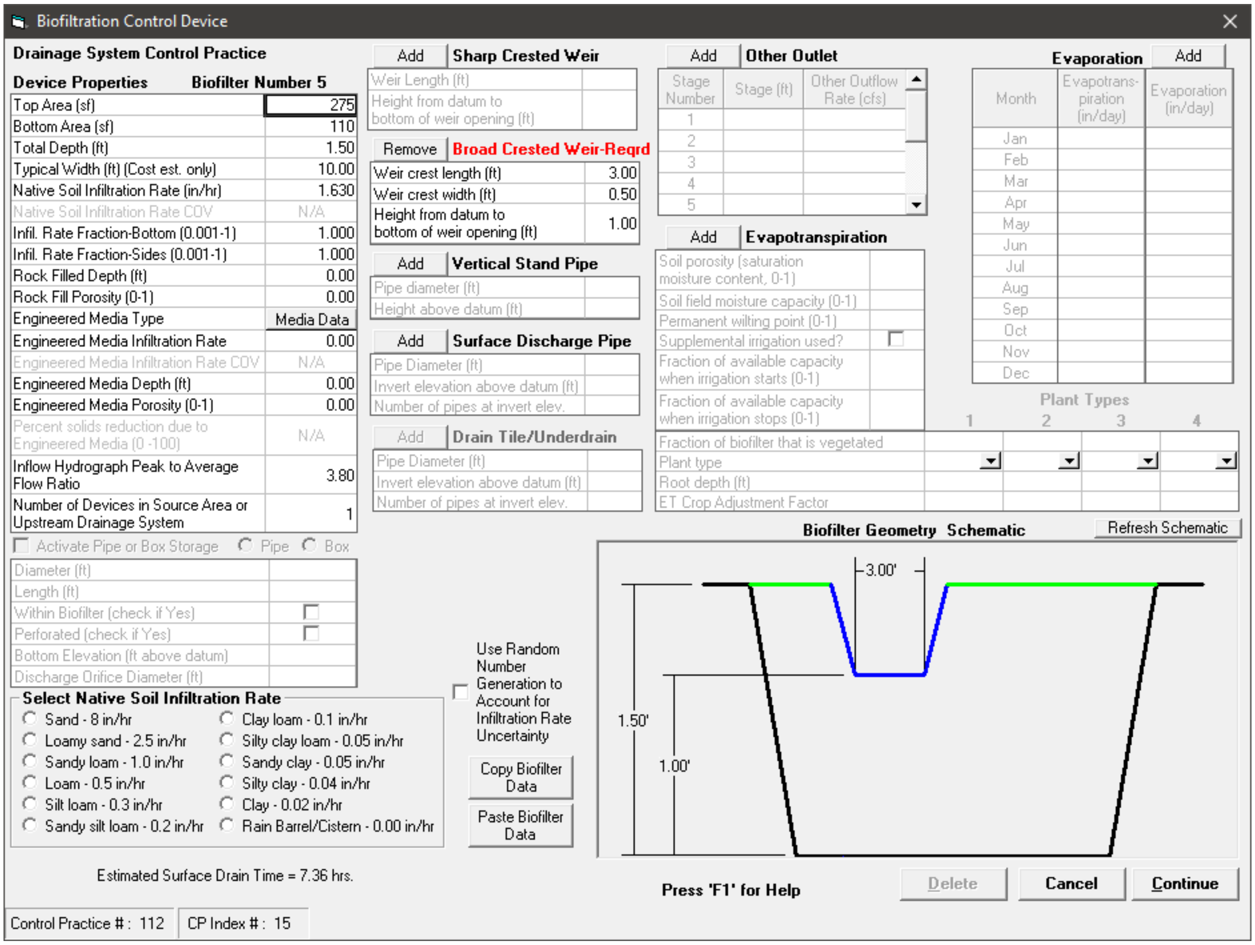


Figure 92: LRC 2-2 infiltration basin - sand.

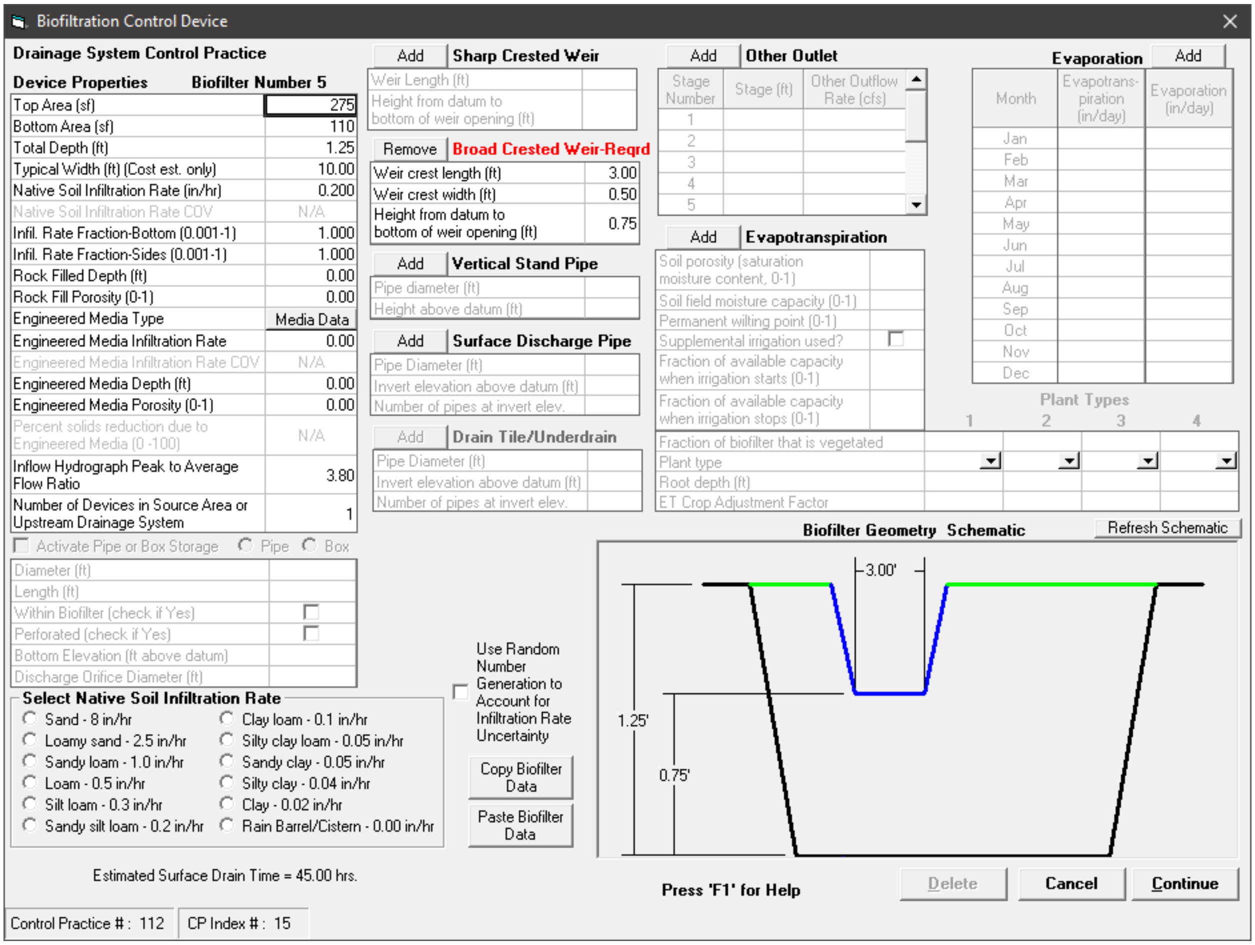


Figure 93: LRC 2-2 infiltration basin - silt.

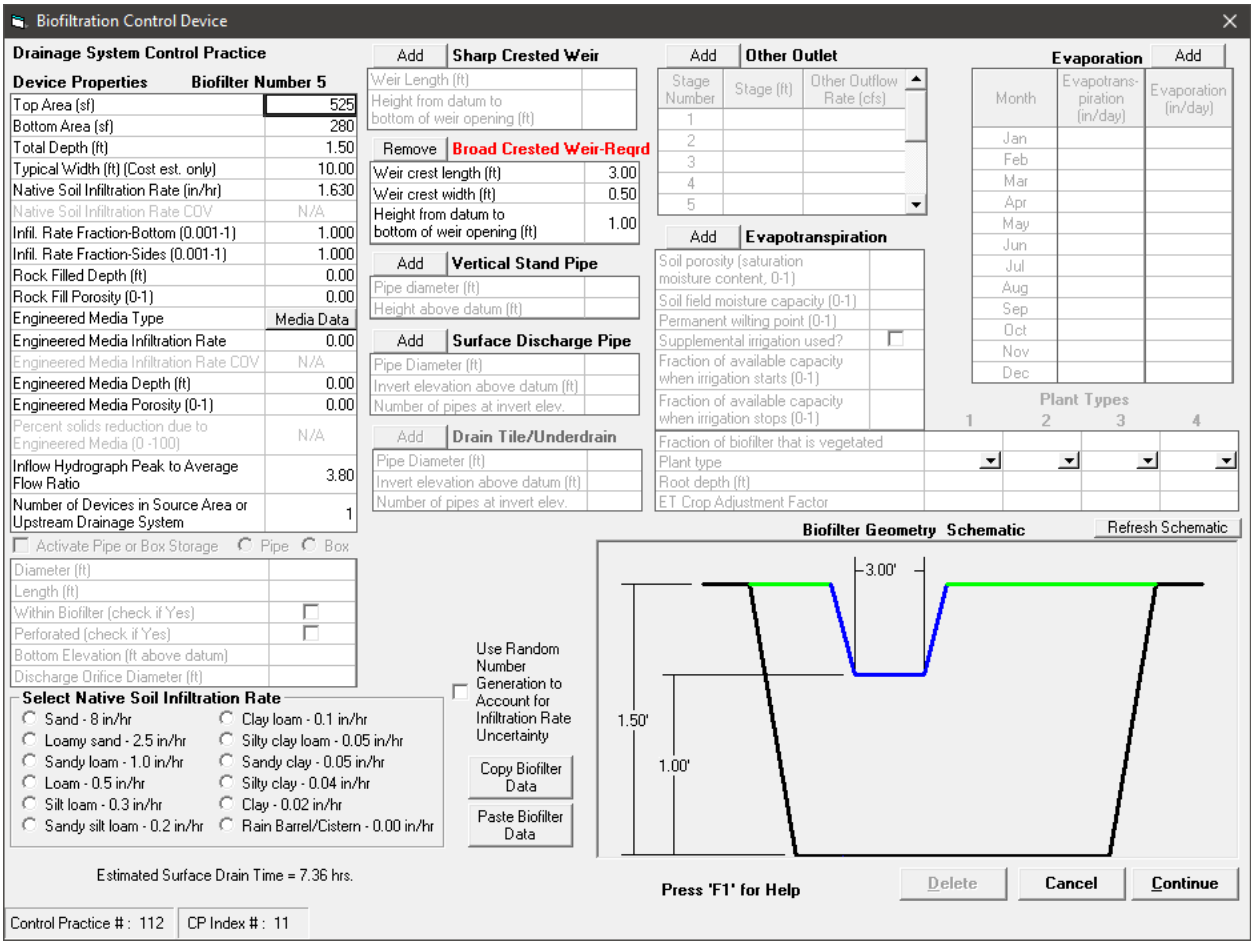


Figure 94: LRC 2-3 infiltration basin 1 - sand.

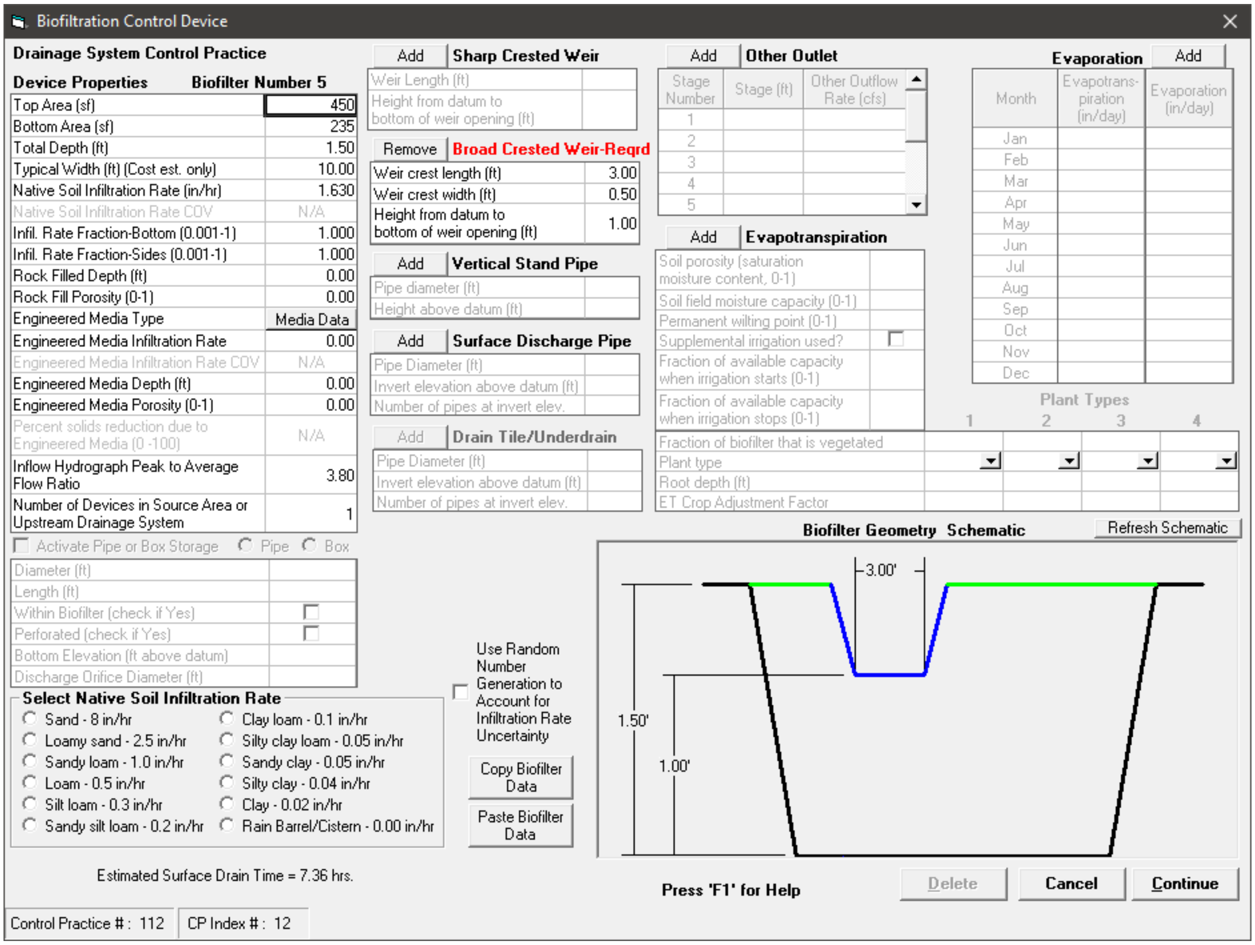


Figure 95: LRC 2-3 infiltration basin 2 - sand.

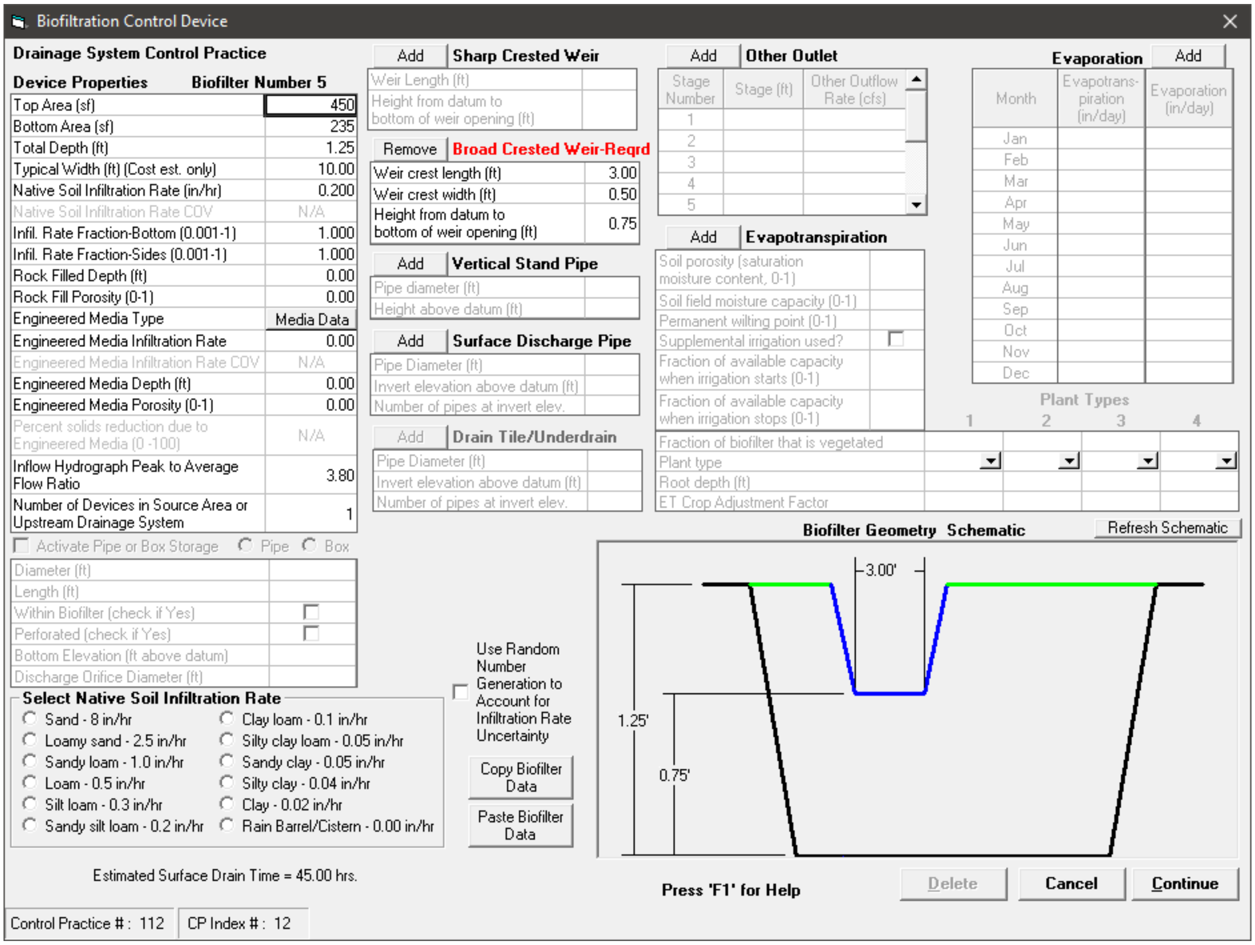


Figure 96: LRC 2-3 infiltration basin 2 - silt.

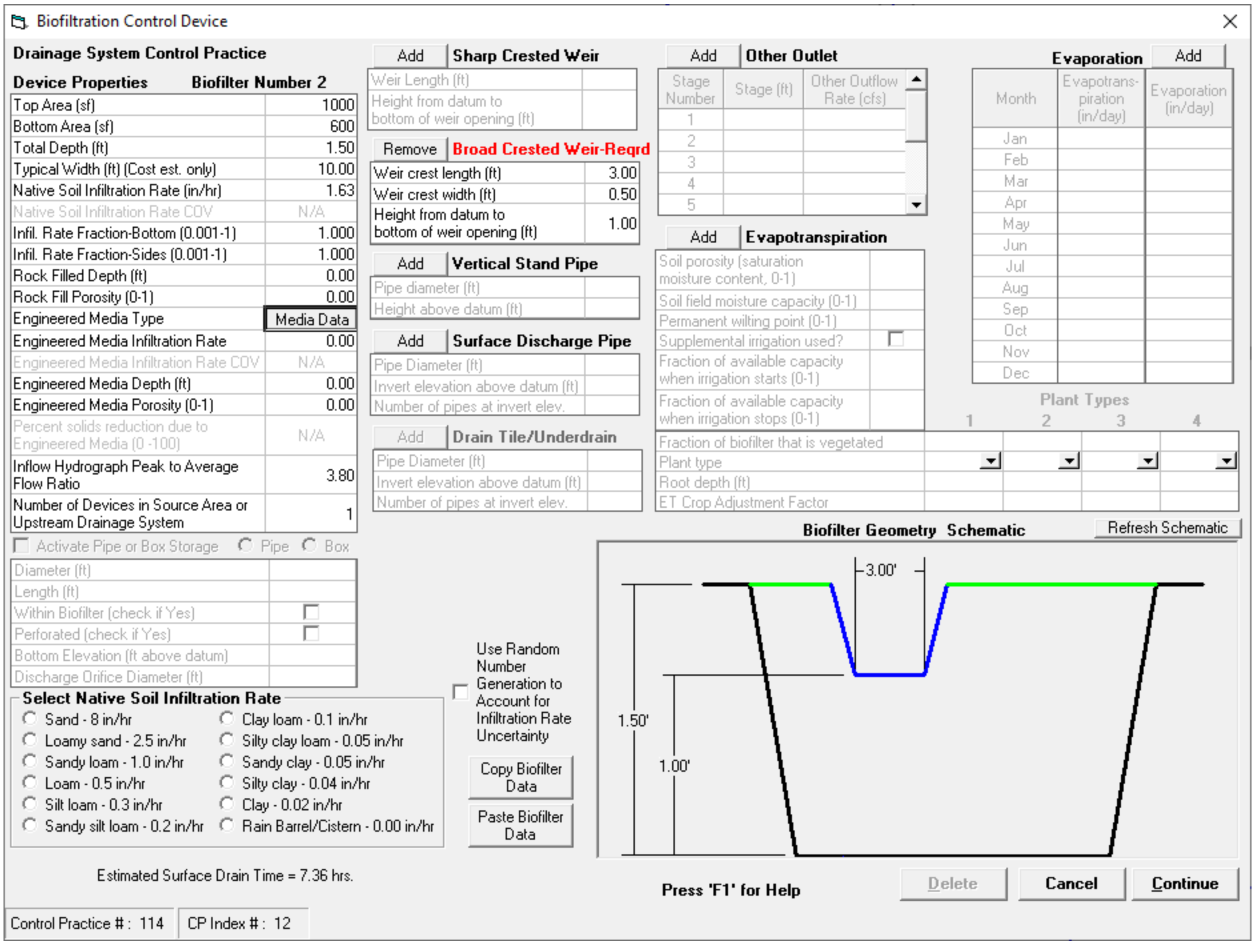


Figure 97: AC Medtronic IB – sand.

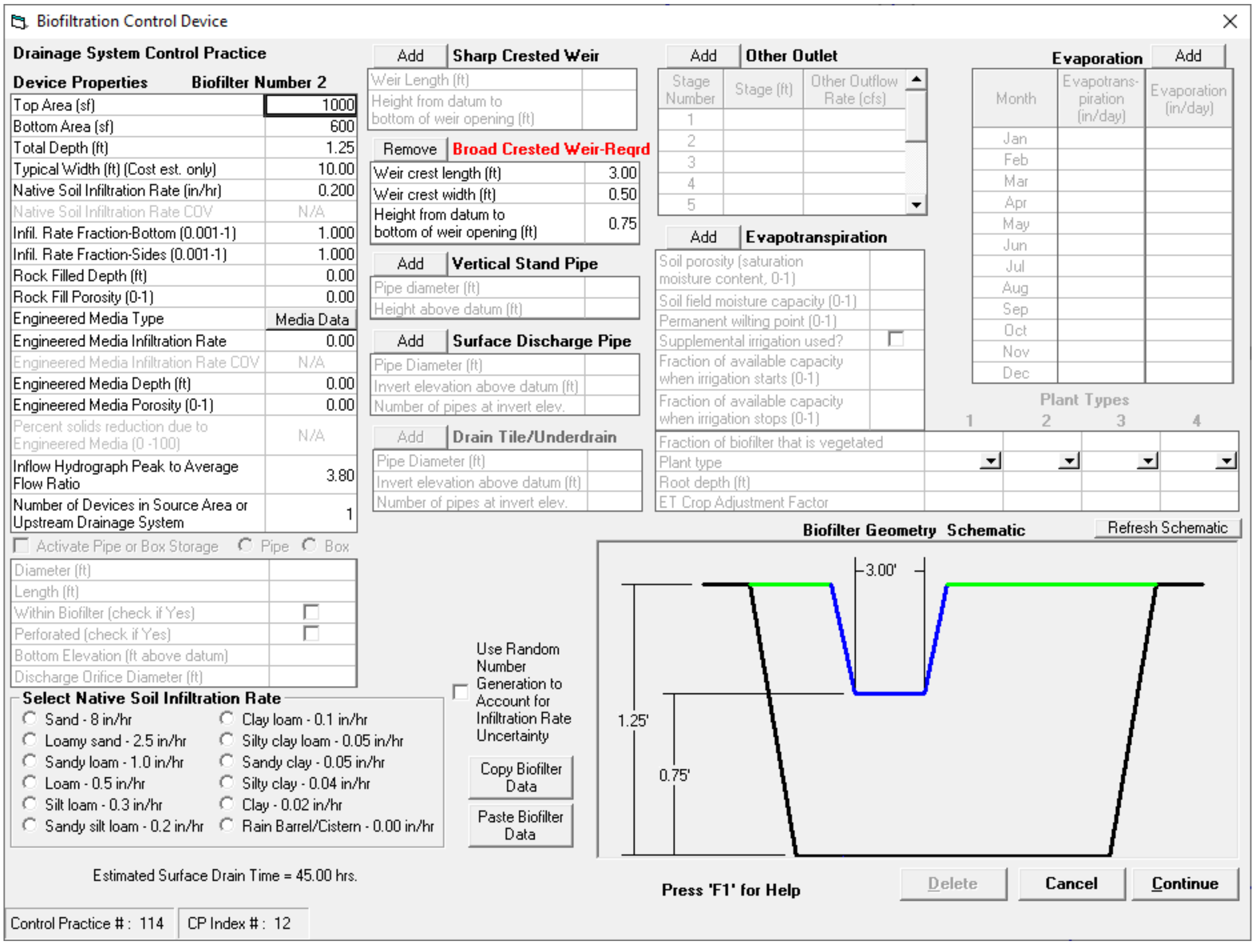


Figure 98: AC Medtronic IB – silt.

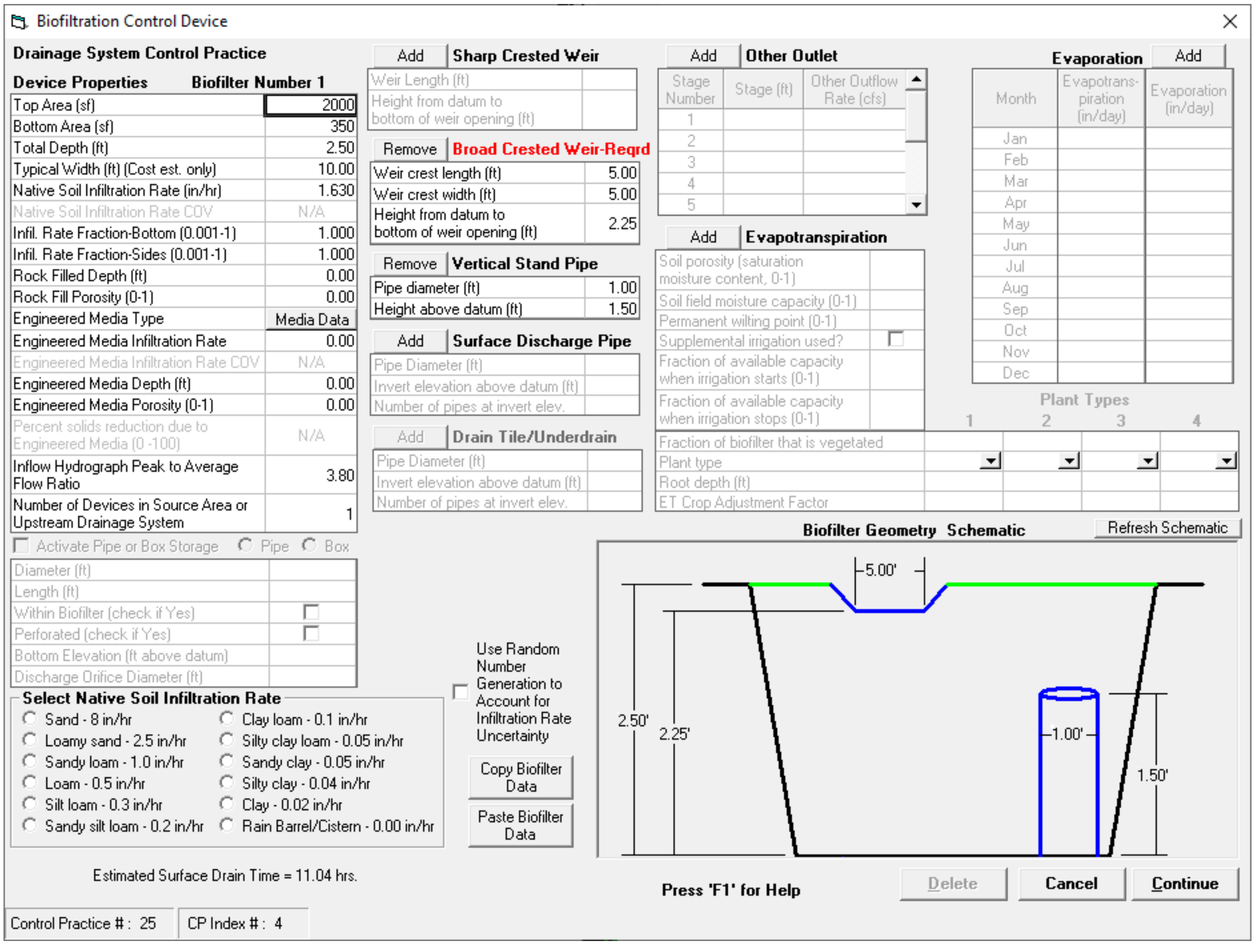


Figure 8: WNC-7 infiltration basin retrofit

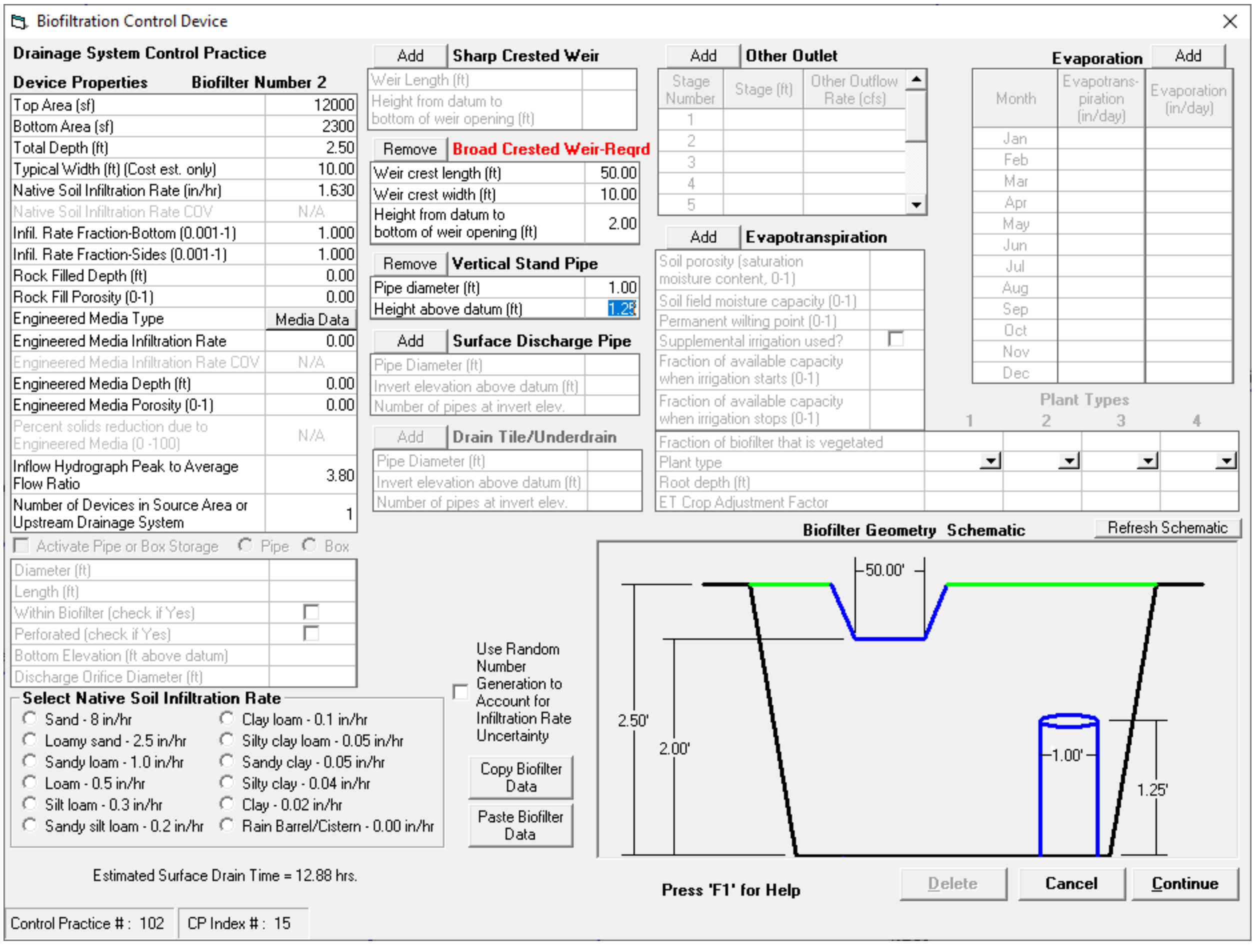


Figure 8: WNC-8 IB (Friendly Chevrolet Swale) Retrofit

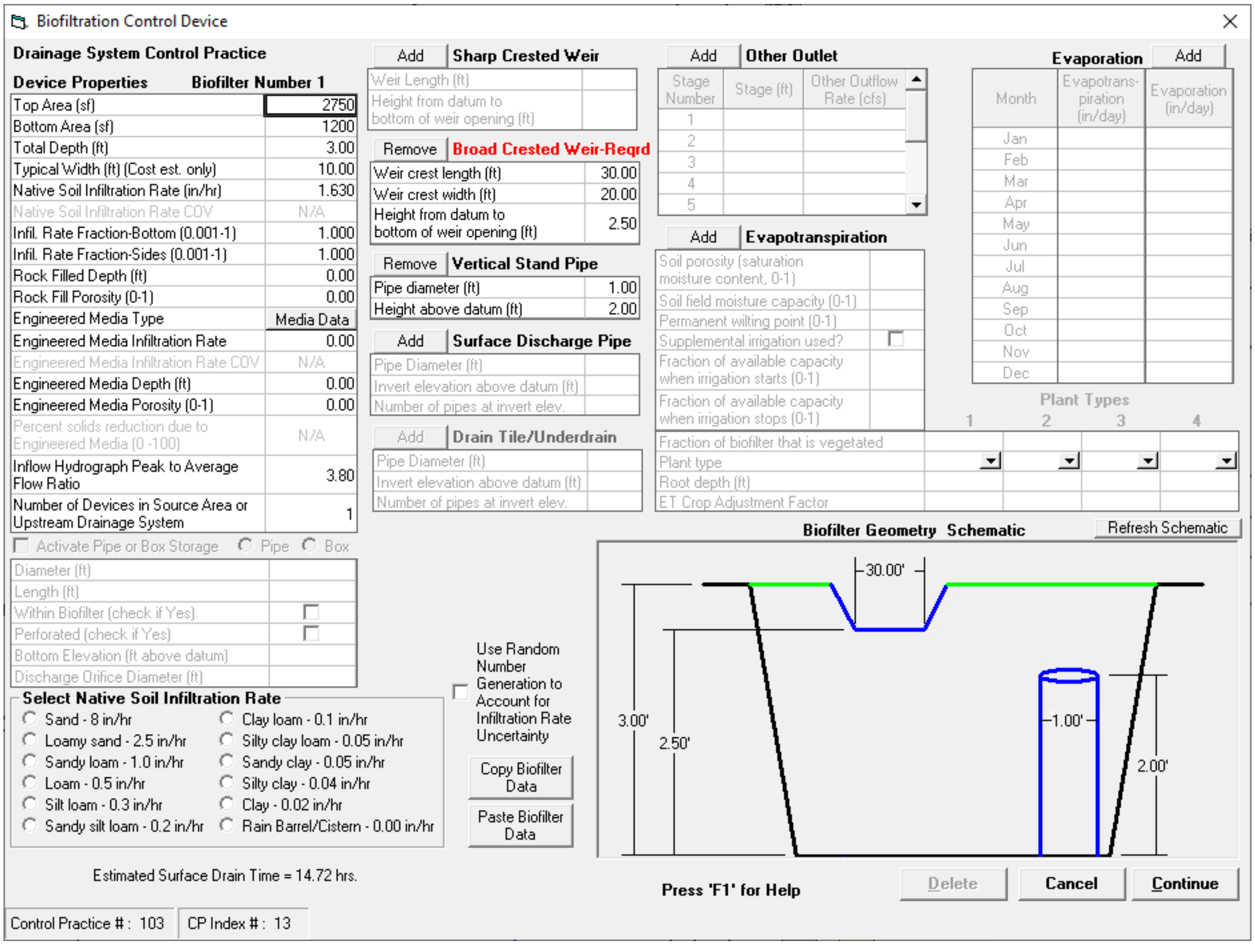


Figure 8: NC-2 72nd Ave. infiltration basin retrofit

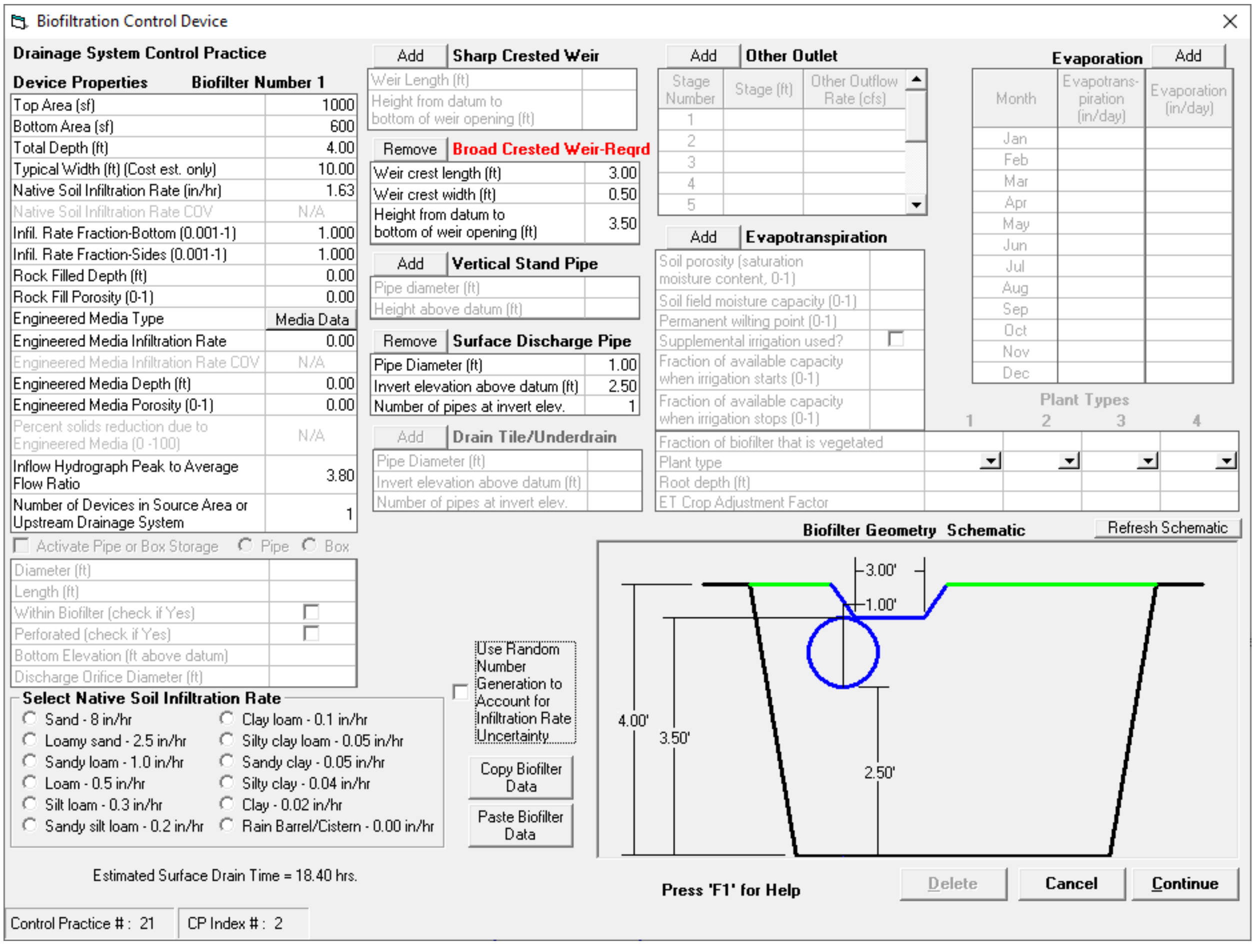


Figure 99: WNC-9 infiltration basin – sand.

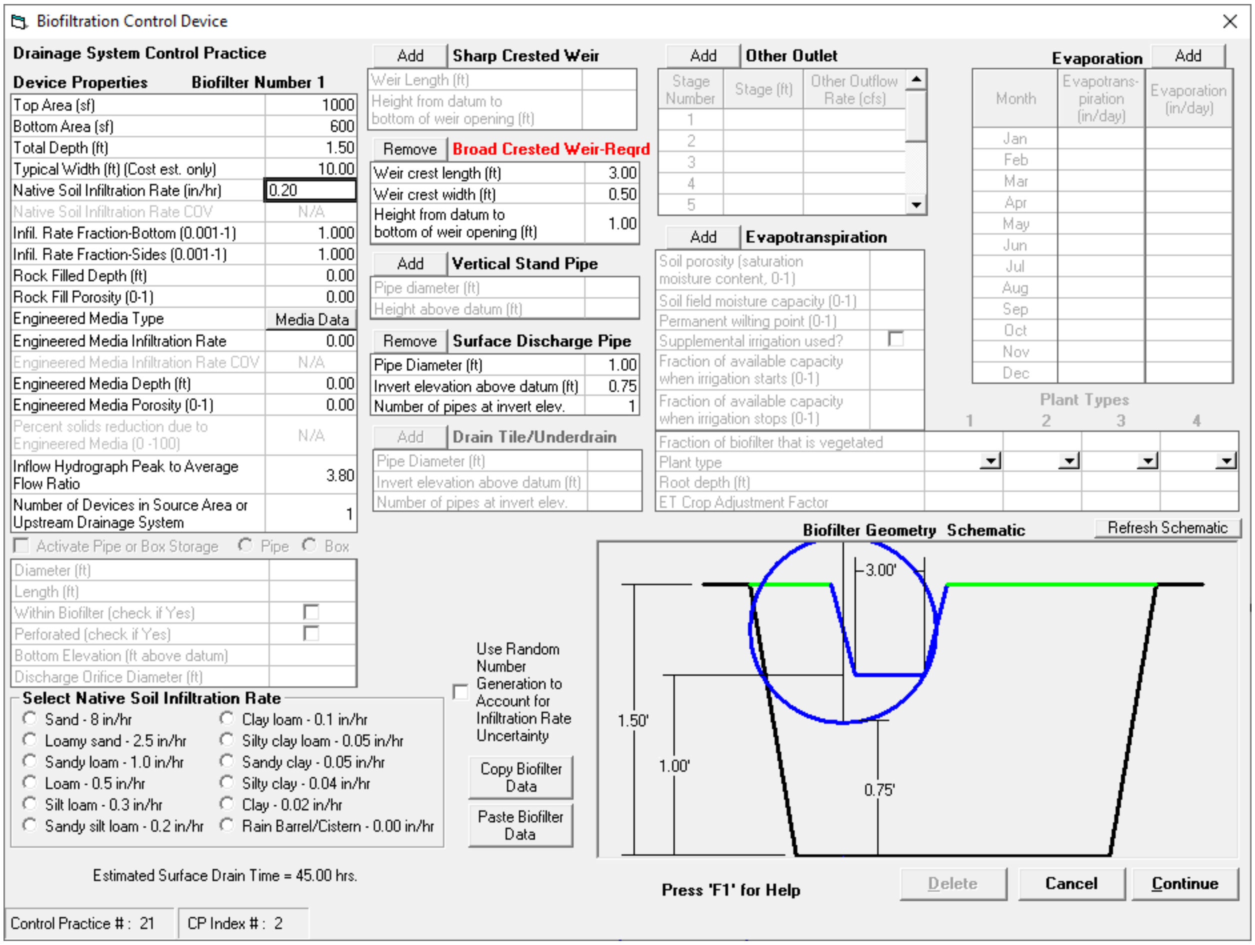


Figure 100: WNC-9 infiltration basin – silt.

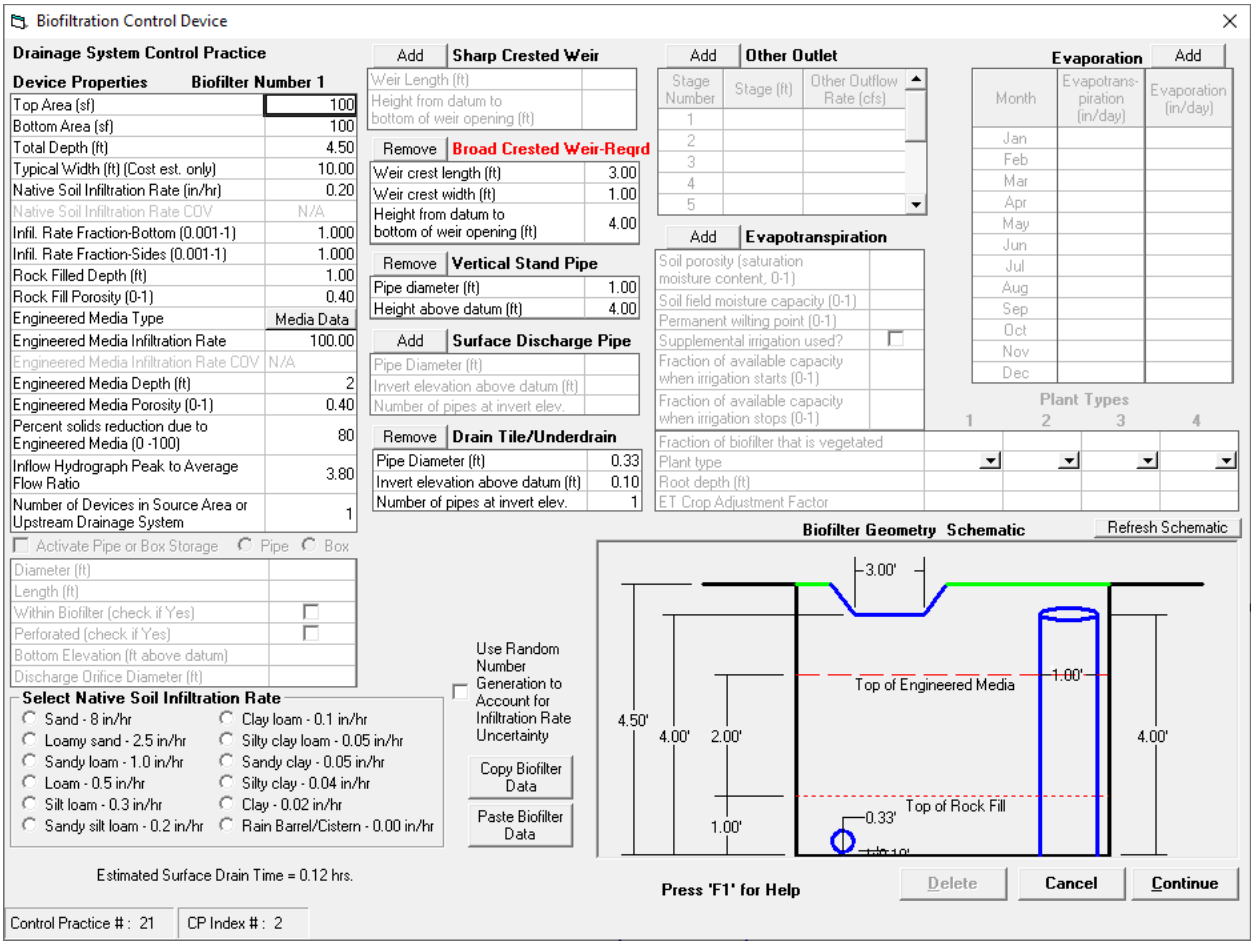


Figure 101: WNC-9 infiltration basin – HPMBS.

Hydrodynamic Devices

Table 12: 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

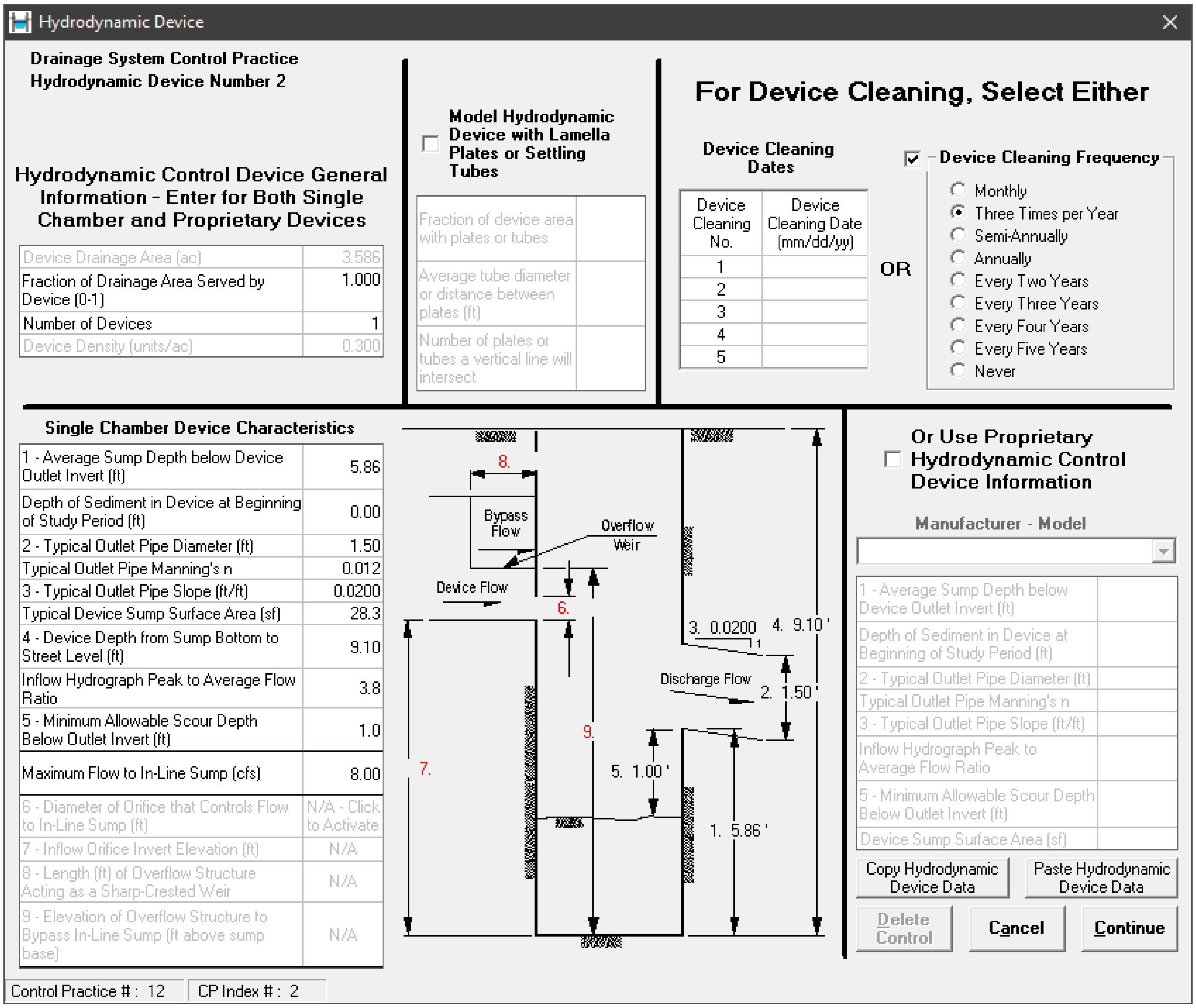


Figure 102: Hydrodynamic device – 6' diameter (WinSLAMM).

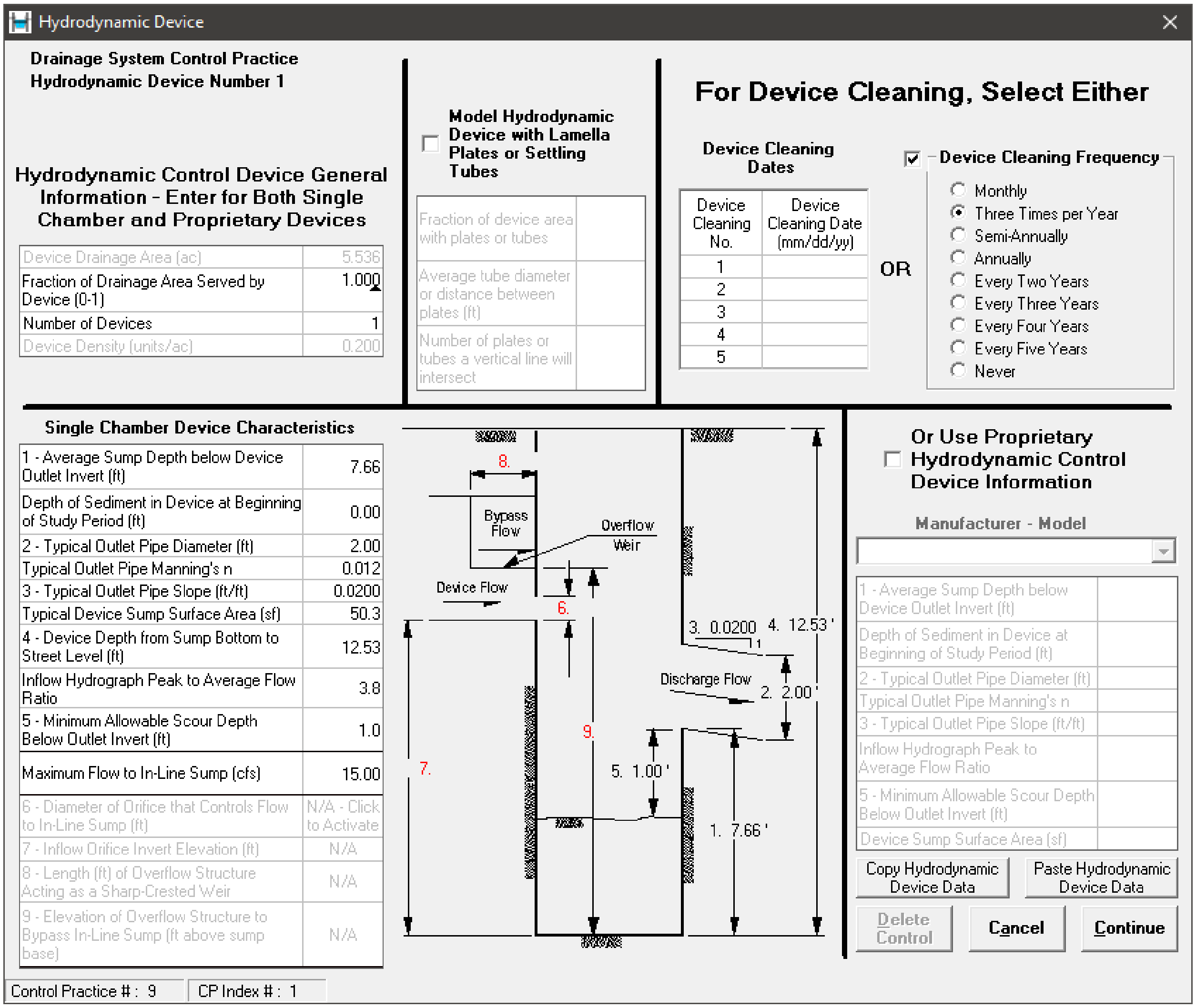


Figure 103: Hydrodynamic device – 8' diameter (WinSLAMM).

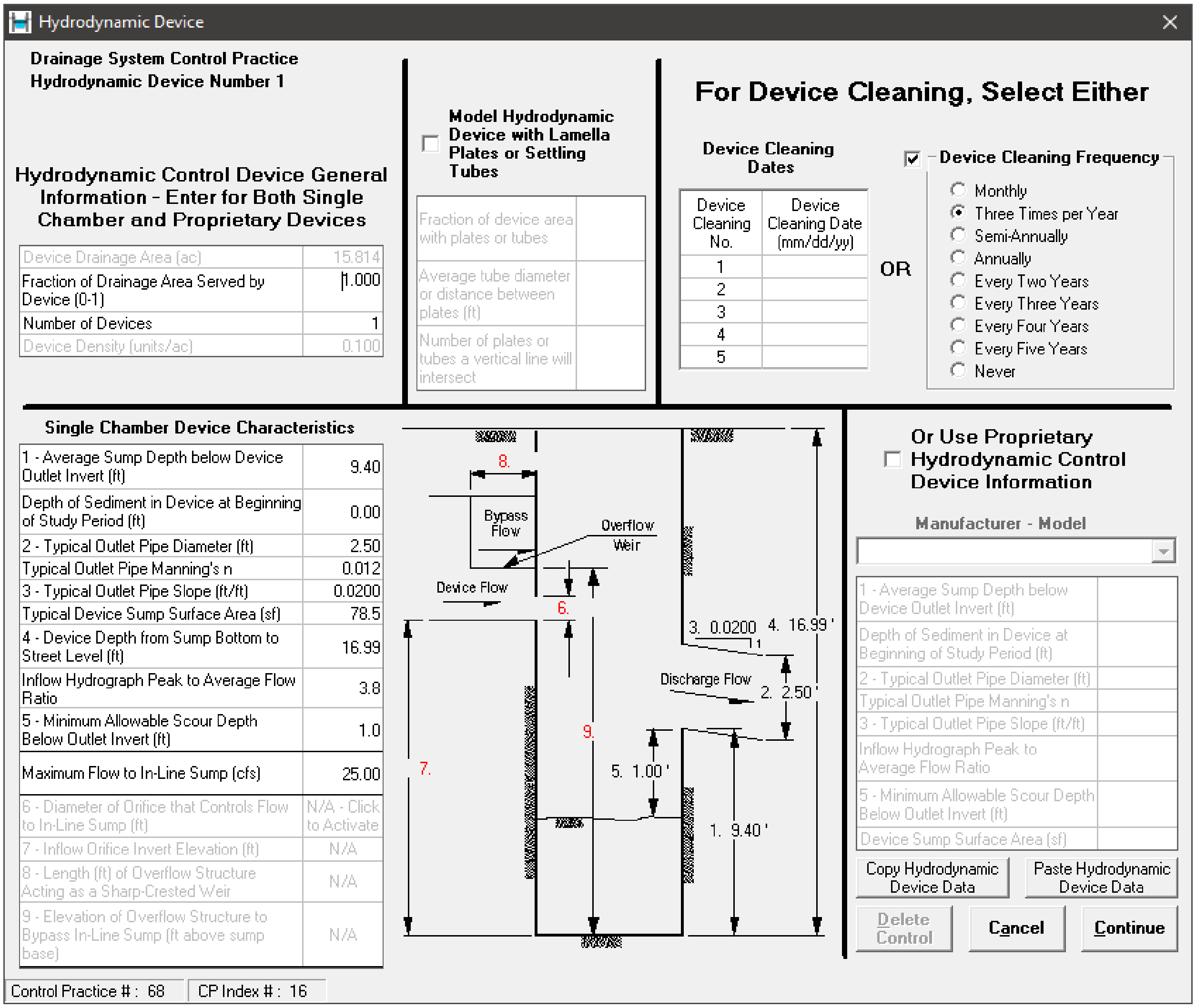


Figure 104: Hydrodynamic device – 10' diameter (WinSLAMM).

Ponds

Ponds were proposed in the landscape where sufficient drainage area could sustain a permanent pool of water. Ponds were proposed following guidance from the Minnesota Pollution Control Agency, in which depths are equal to or less than 8-10' to prohibit stratification and at least 1,800 cu-ft. of pond storage is available for each acre of drainage area where possible based on space limitations.

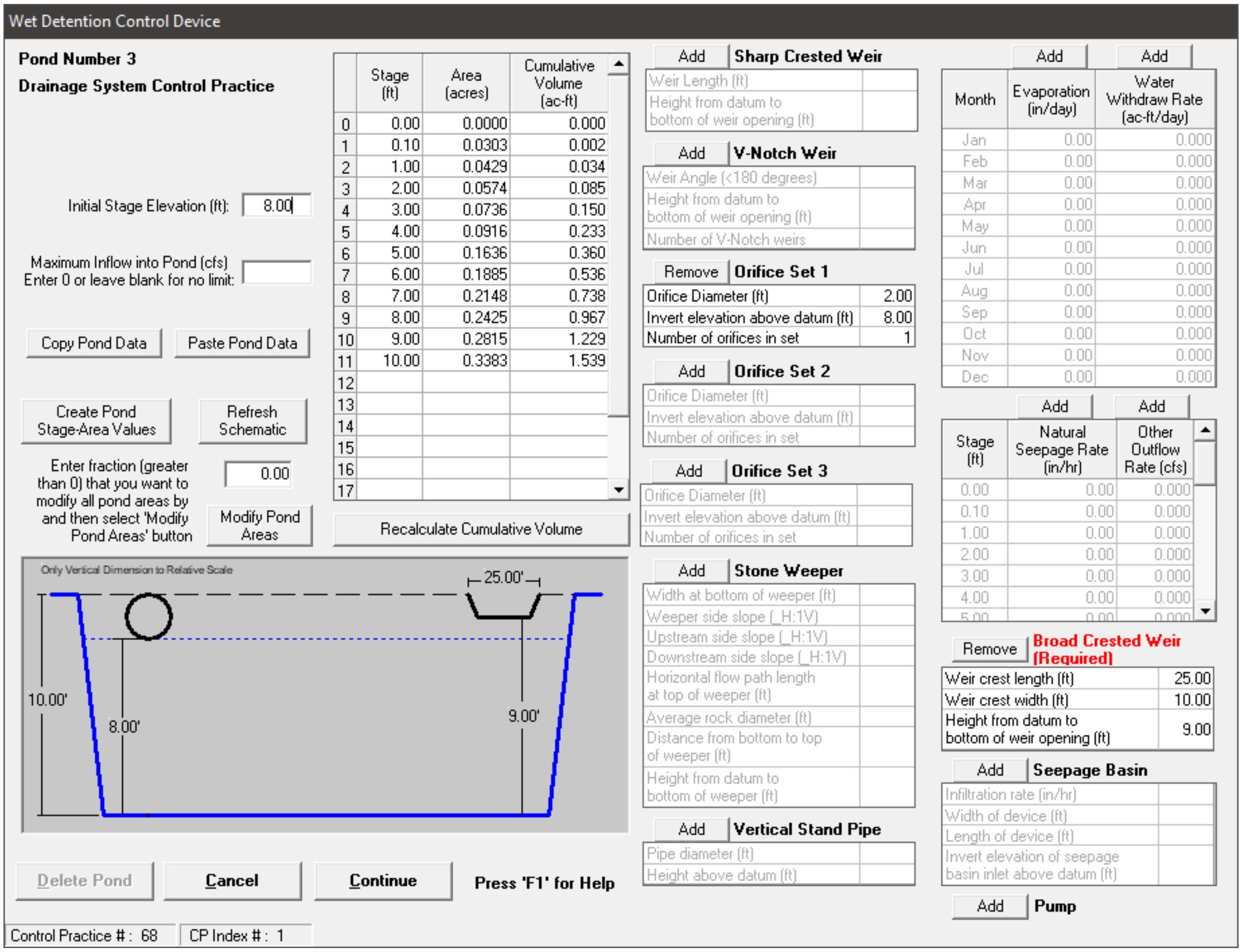


Figure 105: LRC-5 wet pond.

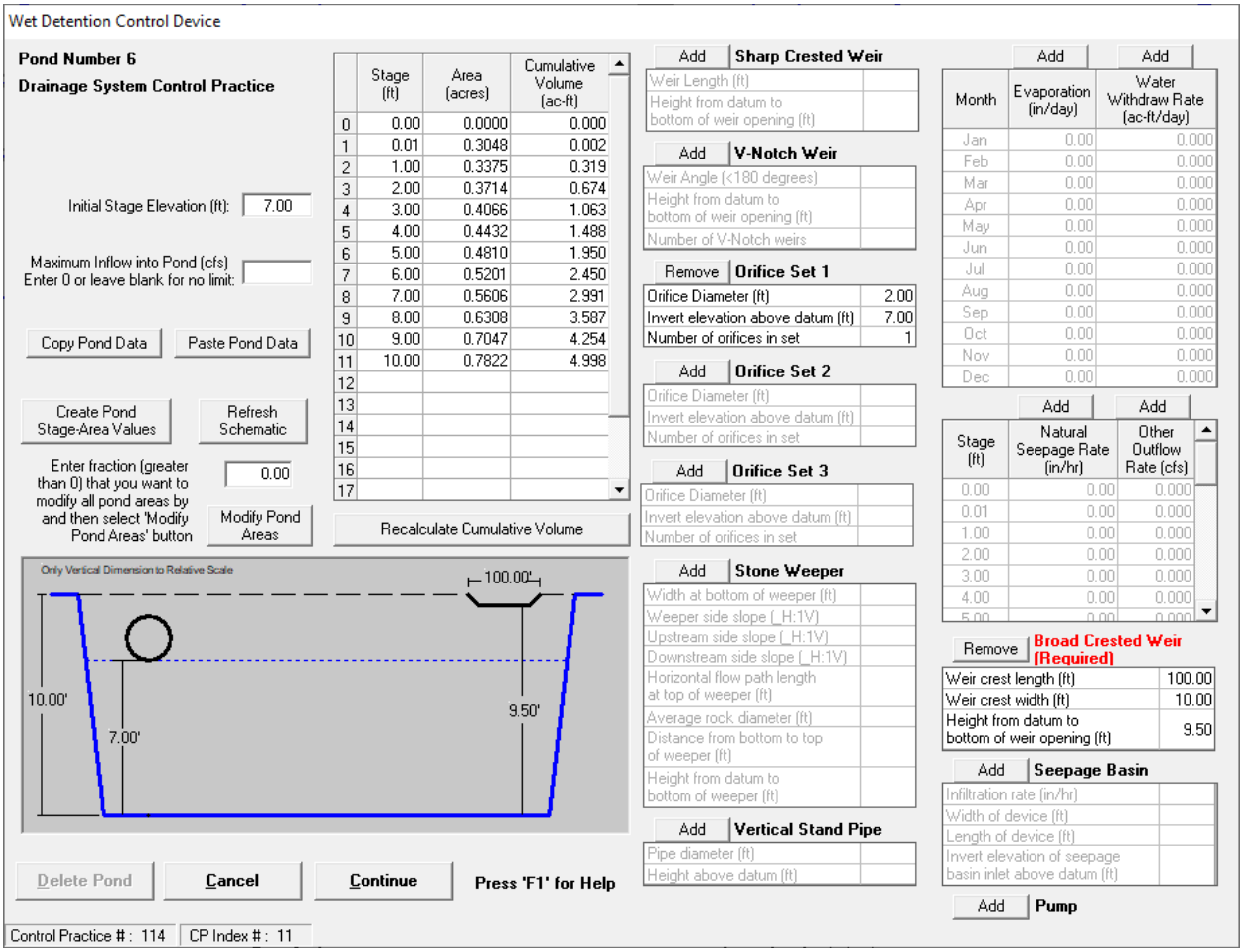


Figure 106: AC wet pond.

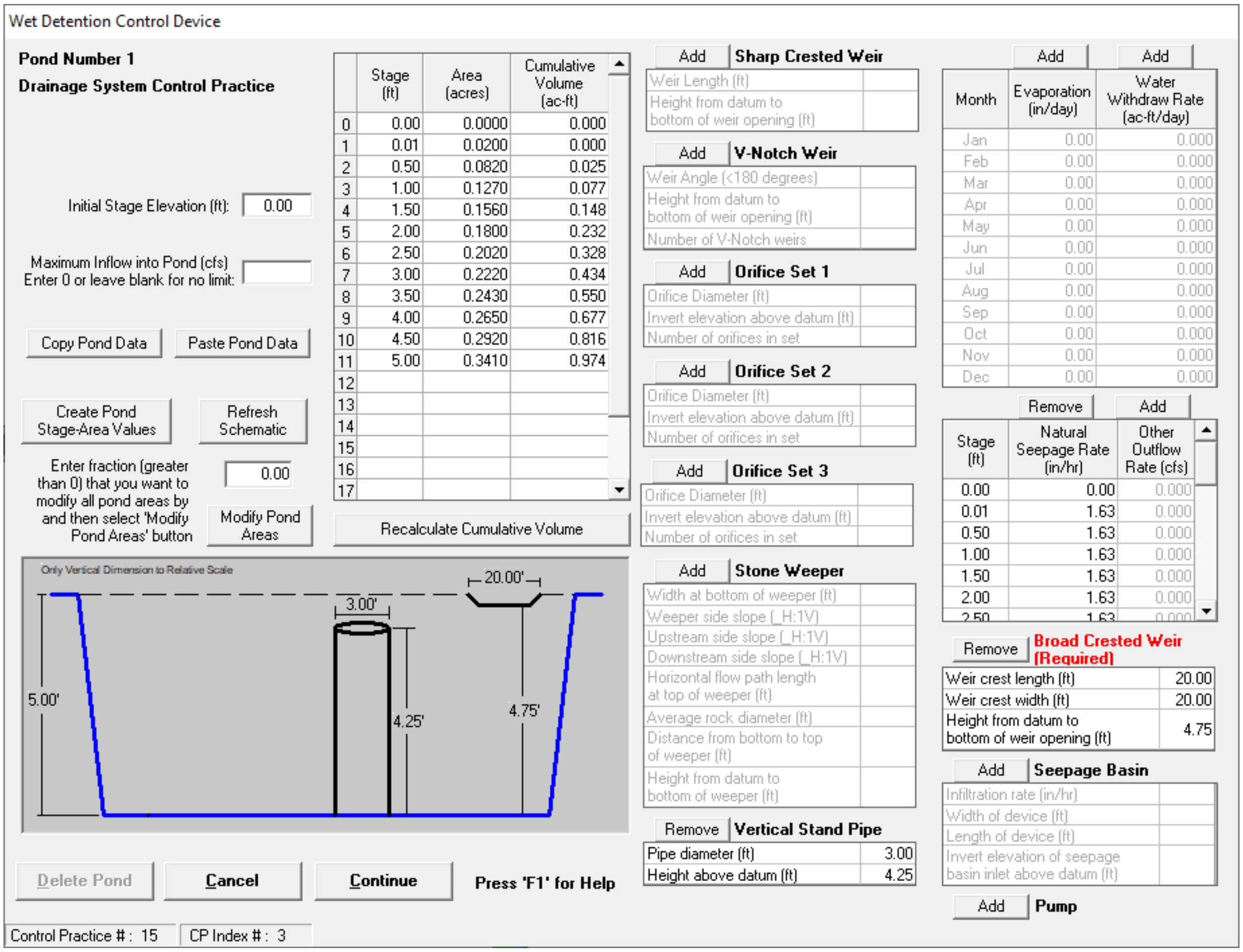


Figure 107: ENC-5-2 pond retrofit

Appendix B – Project Cost Estimates

Introduction

The 'Cost Estimates' section 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.

Ponds

Table 13: ENC-5-2 Pond Retrofit.

Activity	Units	Unit Price	Quantity	Unit Price
Design	Hours	$ 73	40	$ 2,920
Mobilization	Each	$ 2,500	1	$ 2,500
Excavation	cu-yards	$ 30	0	$ -
Curb-cut inlet, Pretreatment, rip rap	Each	$ 5,000	2	$ 10,000
		Total for project =		$ 15,420

Table 14: LRC-5 Stormwater Pond.

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 50,000	1	$ 50,000
Mobilization	Each	$ 30,000	1	$ 30,000
Excavation	cu-yards	$ 30	2,483	$ 74,488
Inlet/Outlet Storm Sewer Tie-in	Each	$ 15,000	2	$ 30,000
Site Restoration/Revegetation	Each	$ 10,000	1	$ 10,000
		Total for project =		$ 194,488

Table 15: AC Stormwater Pond.

Activity	Units	Unit Price	Quantity	Unit Price
Land Purchase	Each	$ 175,000	1	$ 175,000
Design	Each	$ 50,000	1	$ 50,000
Mobilization	Each	$ 30,000	1	$ 30,000
Excavation	cu-yards	$ 30	8,063	$ 241,903
Inlet/Outlet Storm Sewer Tie-in	Each	$ 15,000	2	$ 30,000
Site Restoration/Revegetation	Each	$ 10,000	1	$ 10,000
		Total for project =		$ 536,903

Infiltration Basins

Table 16: WNC-7 Infiltration Basin Retrofit.

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 73	40	$ 2,920
Mobilization	Each	$ 2,500	1	$ 2,500
12" Riser/Baffle	Each	$ 1,000	1	$ 1,000
Curb-cut inlets	Each	$ 2,500	0	$ -
Site Restoration/Revegetation	Each	$ 2,000	0	$ -
		Total for project =		$ 6,420

Table 17: WNC-8 Infiltration Basin Retrofit.

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 73	40	$ 2,920
Mobilization	Each	$ 2,500	1	$ 2,500
21" Riser/Baffle	Each	$ 1,000	1	$ 1,000
Curb-cut inlets	Each	$ 2,500	0	$ -
Site Restoration/Revegetation	Each	$ 2,000	0	$ -
		Total for project =		$ 6,420

Table 18: NC-2 Infiltration Basin Retrofit.

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 73	40	$ 2,920
Mobilization	Each	$ 2,500	1	$ 2,500
18" Riser/Baffle	Each	$ 1,000	1	$ 1,000
Curb-cut inlets	Each	$ 2,500	0	$ -
Site Restoration/Revegetation	Each	$ 2,000	0	$ -
		Total for project =		$ 6,420

Streambank Stabilization

Table 19: NC-2 Norton Creek Channel Stabilization.

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 50,000	1	$ 50,000
Mobilization	Each	$ 15,000	1	$ 15,000
Stabilization	Linear ft.	$ 100	1,000	$ 100,000
Check Dams	Each	$ 2,500	4	$ 10,000
		Total for project =		$ 175,000

Appendix C – Soil Information

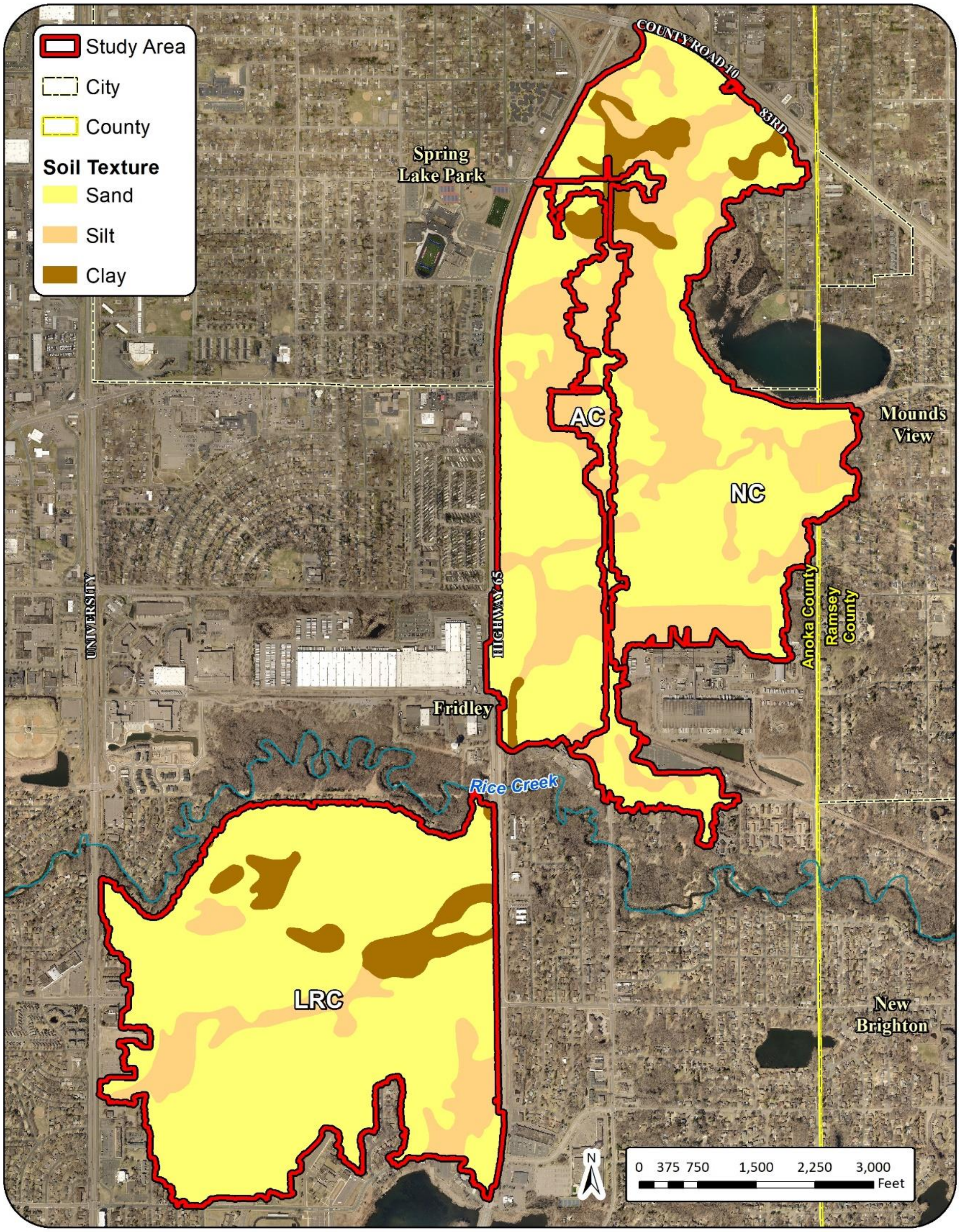


Figure 108: Soil texture used for WinSLAMM model.

Appendix D –Wellhead Protection Areas

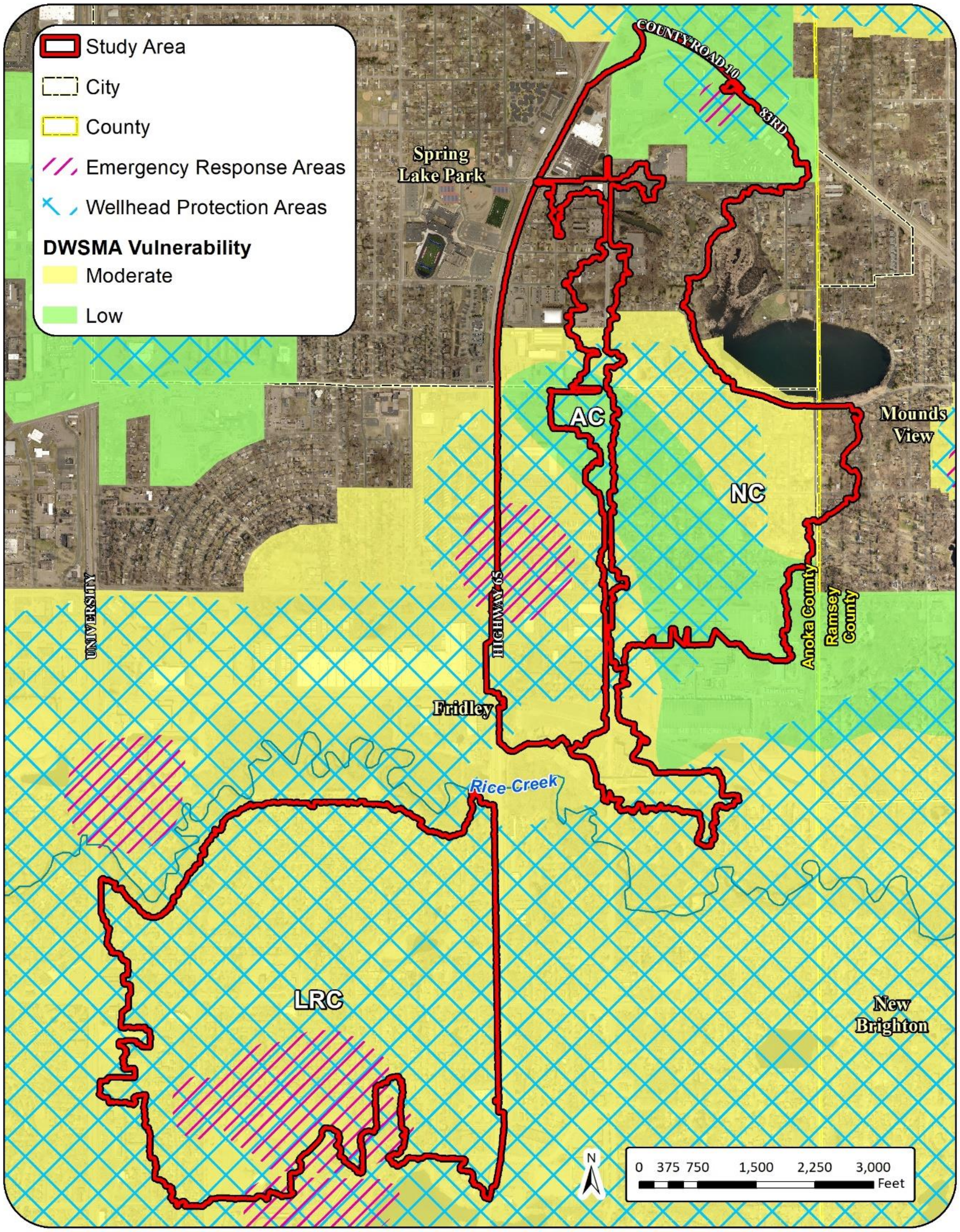


Figure 109: Wellhead protection areas and Drinking Water Supply Management Area (DWSMA) vulnerability.

Appendix E –High-Performance Modular Biofiltration System (HPMBS) Specification

SPECIFICATION
HIGH PERFORMANCE MODULAR BIOFILTRATION SYSTEM (HPMBS)
Material, Performance and Installation Specification

I. Summary

The following general specifications describe the components and installation requirements for a volume based High Performance Modular Biofiltration System (HPMBS) that utilizes physical, chemical and biological mechanisms of a soil, plant and microbe complex to remove pollutants typically found in urban storm water runoff. The modular treatment system in which the biologically active biofiltration media is used shall be a complete, integrated system designed to be placed in Square Foot or Linear Foot increments per the approved drawings to treat contaminated runoff from impervious surfaces.

The High Performance Modular Biofiltration System (HPMBS) is comprised of the following components:

A. Plant Component

1. Supplier shall provide a regionalized list of acceptable plants.
2. Plants, as specified in the approved drawings/supplier's plant list, shall be installed at the time the HPMBS is commissioned for use.
3. Plants and planting are typically included in landscape contract.

B. Biofilter Component

1. This component employs a high performance cross-section in which each element is highly dependent on the others to meet the performance specification for the complete system. It is important that this entire cross-section be provided as a complete system, and installed as such.

2. As indicated in the approved drawings, the elements of the Biofilter include:

   A. *A <u>mulch protective layer</u> (if specified).*

   B. *An advanced <u>high infiltration rate biofiltration planting media bed</u> which utilizes physical, chemical and biological mechanisms of the soil, plant, and microbe complex, to remove pollutants found in storm water runoff.*

   C. *A <u>separation layer which utilizes the concept of 'bridging'</u> to separate the biofiltration media from the underdrain without the use of geotextile fabrics.*

D. *A wide aperture mesh layer utilized to prevent bridging stone from entering the underdrain/storage element.*

E. *A modular, high infiltration rate 'flat pipe' style underdrain/storage system which is designed to directly infiltrate or exfiltrate water through its surface. The modular underdrain must provide a minimum of 95% void space.*

C. Energy Dissipation Component

1. An Energy Dissipation Component is typically specified to slow and spread out water as it enters the system. This component is dependent upon the design in the approved drawings, but typically consists of a rock gabion, rock filter dam or dense vegetation element, such as native grasses, either surrounding the Biofiltration Component or located immediately upstream of it.

D. Pretreatment Component

1. Pretreatment, when specified, is typically accomplished by locating the Biofiltration Component within a traditional vegetated BMP such as a vegetated swale, vegetated depression, traditional bioretention system, vegetated filter strip, sediment forebay, etc. These BMPs provide primary TSS removal when desirable.

E. Observation and Maintenance Component

1. An Observation and Maintenance Port shall be installed per the approved drawings to provide for easy inspection of the underdrain/storage element, and cleanout access if needed.

F. Extreme Event Overflow (by others)

1. An Extreme Event Overflow should be located external to, but near the Biofiltration element to provide bypass when needed. This may be an overland flow bypass structure, beehive overflow grate structure, or equivalent that serves the purpose. If a beehive overflow structure is utilized it should include a removable filter insert to provide for effective control of gross pollutants, trash and floatables.

II. Quality Assurance and Performance Specifications

The quality and composition of all system components and all other appurtenances and their assembly process shall be subject to inspection upon delivery of the system to the work site.

Installation is to be performed only by skilled work people with satisfactory record of performance on earthworks, pipe, chamber, or pond/landfill construction projects of comparable size and quality.

A. Plants

1. Plants must be compatible with the HPMBS media and the associated highly variable hydrologic regime. Plants are typically facultative with fibrous roots systems such a native grasses and shrubs.

2. Supplier shall provide a regionalized list of acceptable plants.

3. All plant material shall comply with the type and size required by the approved drawings and shall be alive and free of obvious signs of disease.

B. Mulch

1. Mulch, typically double shredded hardwood (non-floatable), shall comply with the type and size required by the approved drawings, and shall be screened to minimize fines.

C. Biofiltration Media

1. Biologically active biofiltration media shall be visually inspected to ensure appropriate volume, texture and consistency with the approved drawings, and must bear a batch number marking from the supplier which certifies performance testing of the batch to meet or exceed the required infiltration rate (100 in/hr). A third party laboratory test must be provided to certify the 100 in/hr rate.

2. Within 90 days after project completion, the infiltration rate shall be confirmed at the supplier's expense, by a wetted condition hydraulic conductivity test.

    a. *Failure to pass this test will result in removal and replacement of all media in the system at no cost to the project owner/operator.*

    b. *Test must utilize the equipment and follow the standard operating procedures found in the Harris County Texas manual entitled, Low Impact Development & Green Infrastructure Design Criteria for Storm Water Management (2011).*

    c. *Replacement media, if required, must be taken from a different batch than the original.*

3. Supplier shall provide, at no additional cost to the project owner/operator, maintenance of the biofiltration system for a period of one year.

4. Pollutant Removal performance, composition and characteristics of the Biofiltration Media must meet or exceed the following minimum standards as

demonstrated by testing acceptable to the project engineer:

Pollutant	**Removal Efficiency**
TSS	> 80%
Phosphorus	≥ 60%
Nitrogen	≥ 48%
Composition and Characteristics	
Sand - Fine	< 5%
Sand – Medium	10% - 15%
Sand – Coarse	15% - 25%
Sand – Very Coarse	40% - 45%
Gravel	10% - 20%
Infiltration Rate	>100 inches per hour
Peat Moss*	5% - 15%
*** Peat Moss Specification**	
Listed by Organic Materials Review Institute 100% natural peat (no composted, sludge, yard or leaf waste) Total Carbon >85% Carbon to Nitrogen Ratio 15:1 to 23:1 Lignin Content 49% to 52% Humic Acid >18% pH 6.0 to 7.0 Moisture Content 30% to 50% 95% to 100% passing 2.0mm sieve > 80% passing 1.0mm sieve	

D. Underdrain/Storage System

1. Underdrain/storage components shall be manufactured in an ISO certified facility and be manufactured from at least 90% post consumer recycled materials.

2. Underdrain/storage components shall meet or exceed the following characteristics:

Property	Value
Surface Void Area	≥ 85%
Unit Weight	3.25 lbs/cf
Service Temperature	-14° to 167°
Unconfined Crush Strength	32.48 psi
180 Day Creep Test	
Load Applied – Initial and Sustained	11.16 psi
• Creep Sustained – After 180 Days	0.20 inches
• Creep Sustained – After 180 Days	1.13 %
• Projected Creep – 40 years	1.72%

E. Separation Mesh

1. Separation Mesh shall be composed of high-tenacity monofilament polypropylene yarns that are woven together to produce an open mesh geotextile which shall be inert to biological degradation and resistant to naturally encountered chemicals, alkalis and acids. The mesh shall meet or exceed the following characteristics:

Properties	Test Method	Unit	Min Ave Roll Value	
			MD	CD
Tensile Strength	ASTM D4595	kN/m (lbs/ft)	21 (1440)	25.3 (1733)
Creep Reduced Strength	ASTM D5262	kN/m (lbs/ft)	6.9 (471)	8.3 (566)
Long Term Allowable Design Load	GRI GG-4	kN/m (lbs/ft)	5.9 (407)	7.2 (490)
UV Resistance (at 500 hours)	-	% strength retained	90	
Aperture Size (machine direction)	-	mm (in)	2 (0.08)	
Aperture Size (cross machine direction)	-	mm (in)	2 (0.08)	
Mass/Unit Area	ASTM D5261	g/m^2 (oz/yd^2)	197 (5.8)	

F. Bridging Stone

1. Bridging Stone shall be 3/8" pea gravel, or other diameter sized to prevent migration of filter media, as specified by supplier.

2. Stone must be washed and free from sediment, soil and contaminants.

III. Delivery, Storage and Handling

A. Protect all materials from damage during delivery and store UV sensitive materials under tarp to protect from sunlight including all plastics, when time from delivery to installation exceeds one week. Storage should occur on smooth surfaces, free from dirt, mud and debris.

B. Biofiltration media shall be segregated from any other aggregate materials and shall be protected against contamination, including contamination from any stormwater runoff from areas of the site which are not stabilized.

IV. Submittals

A. Product Data

1. Submit supplier's product data and approved Installation Manual as well as supplier's Operations and Maintenance Manual for the system. It will be the responsibility of the system owner/operator or their contractor to ensure the system is operated and maintained in accordance with the manual.

B. Certification

1. Supplier shall submit a letter of certification that the complete system meets or exceeds all technical and packaging requirements. Biofiltration media packaging must bear a batch number marking from the supplier which matches a letter from the supplier certifying performance testing of the batch to meet or exceed the required infiltration rate.

C. Drawings

1. Supplier shall provide dimensional drawings including details for construction, materials, specifications and pipe connections.

D. Warranty

1. Supplier shall provide a warranty for all components of the HPMBS for a period of one year provided the unit is installed, operated and maintained in accordance with the manual. Improper operation, maintenance or accidental or illegal activities (i.e. dumping of pollutants, vandalism, etc.) will void the warranty. Biofiltration media shall be warranted to pass the post-installation infiltration test described in this document.

E. Design Computations

1. The HPMBS must be sized using a volume based sizing criteria and demonstrate, using a SCS stormwater modeling software/spreadsheet calculator that the required water quality volume (defined by the Engineer of Record) passes through the HPMBS prior to activation of the overflow device (set no lower higher than six (6) inches above the top elevation of the HPMBS (typically defined as top of mulch)). Design computations must be provided as part of the submittal process. Sizing based solely on a filter surface area to drainage area ratio method will not be accepted.

F. Substitutions

1. Any proposed equal alternative product substitution to this specification must be submitted for review and approved prior to bid opening. Review package should include third party reviewed performance data of the biofiltration media that includes saturated conductivity measurements and pollutant removal efficiency. Pollutant removal data must follow specified protocols. All components must meet or exceed Quality Assurance and Performance Criteria indicated herein.

V. Project Conditions

A. Review supplier's recommended installation procedures and coordinate installation with other work affected, such as grading, excavation, utilities, construction access and erosion control to prevent all non- installation related construction traffic over the completed HPMBS.

B. Cold Weather

1. Do not use frozen materials or materials mixed or coated with ice or frost.

2. Do not build on frozen ground or wet, saturated or muddy subgrade.

3. Care must be taken when handling plastics when air temperature is at 40 degrees or below as plastic becomes brittle.

C. Protect partially completed installation against damage from other construction traffic when work is in progress and following completion of backfill by establishing a perimeter with highly visible construction tape, fencing, or other means until construction is complete.

D. Soil stabilization of the surrounding site must be complete before the Biofiltration System can be brought online. Soil stabilization occurs when 90% of the site has been paved or vegetated. Temporary erosion control and/or sedimentation prevention measures shall be implemented to reduce the possibility of sediments being transported into the Biofiltration System prior to full stabilization of the site. Significant sediment loads can damage the HPBMS and lead to failure if not prevented or remediated promptly.

VI. PRODUCTS

A. Acceptable HPBMS

FocalPoint High Performance Biofiltration System

B. Acceptable Beehive Overflow Grate Structure (Optional)

Beehive Overflow Grate Structure with removable StormSack

C. Acceptable System Supplier

Convergent Water Technologies, Inc.
(800) 711-5428
www.convergentwater.com

D. **Authorized Value Added Reseller**

ACF Environmental
2831 Cardwell Road
Richmond, VA 23234
(800 448-3636
www.acfenvironmental.com

VII. Packaging

A. HPMBS is assembled on site.

B. Modular underdrain/storage unit is shipped flat and modules are assembled prior to installation.

C. Biofiltration media is delivered in one ton super sacks each labeled with supplier's batch number and/or in bulk with accompanying supplier's certification.

D. Other components are delivered in bulk or super sacks

VIII. Execution

A. Excavation and Backfill

1. Base of excavation shall be smooth, level and free of lumps or debris, and compacted unless infiltration of storm water into subgrade is desired. A thin layer (3") of compacted base material is recommended to establish a level working platform (may not be needed in sandy soils). If the base of the excavation is pumping or appears excessively soft, a geotechnical engineer should be consulted for advice. In many cases, a stabilization geotextile and 6" of compactable material that drains well will be sufficient to amend the bearing capacity of the soil.

2. Most applications require 8 oz Non-Woven Geotextile or equivalent nonwoven geotextile with a nominal weight of 8 oz per square yard to line the excavation to separate in situ soils and the HPMBS. (Applications requiring water to infiltrate the in situ sub-soils should use a bridging stone rather than geotextile to provide a separation layer between the HPMBS and the in situ soils). Geotextile, when utilized, should be placed on the bottom and up the sides of the excavation. Absolutely no geotextiles should be used in the water column. If an impermeable liner is specified, it shall be installed according to supplier's instructions and recommendations.

3. Specified backfill material must be free from lumps, debris and any sharp objects that could penetrate the geotextile. Material is used for backfill along the sides of the system as indicated in engineering detail drawings.

B. Inspection

1. Examine prepared excavation for smoothness, compaction and level. Check for presence of high water table, which must be kept at levels below the bottom of the under drain structure at all times. If the base is pumping or appears excessively soft, a geotechnical engineer should be consulted for advice.

2. Installation commencement constitutes acceptance of existing conditions and responsibility for satisfactory performance. If existing conditions are found to be unsatisfactory, contact Project Manager or Engineer for resolution prior to installation.

IX. Cleanup and Protection during Ongoing Construction Activity

A. Perform cleaning during the installation and upon completion of the work.

B. Remove from site all excess materials, debris, and equipment. Repair any damage to adjacent materials and surfaces resulting from installation.

C. If surrounding drainage area is not fully stabilized, a protective covering of geotextile fabric should be securely placed to protect the Biofiltration Media.

D. Construction phase erosion and sedimentation controls shall be placed to protect the inlet(s) to the Biofiltration System. Excessive sedimentation, particularly prior to establishment of plants may damage the HPMBS.

E. Strictly follow supplier's guidelines with respect to protection of the HPMBS between Installation and Commissioning phases.

X. Commissioning

A. Commissioning should only be carried out once the contributing drainage area is fully stabilized. If Commissioning must be carried out sooner, it is imperative that appropriate erosion and sediment controls be placed to prevent the entry of excessive sediment/pollutant loads into the system.

B. Commissioning entails removing the protective covering from the Biofiltration Media, planting the plant material in accordance with the approved drawings, and placing mulch if specified.

1. Dig planting holes the depth of the root ball and two to three times as wide as the root ball. Wide holes encourage horizontal root growth that plants naturally produce.

2. With trees, you must ensure you are not planting too deep. Don't dig holes deeper than root balls. The media should be placed at the root collar, not above the root collar. Otherwise the stem will be vulnerable to disease.

3. Strictly follow supplier's planting guidance.

C. Cover the exposed root ball top with mulch. Mulch should not touch the plant base because it can hold too much moisture and invite disease and insects. Evenly place 3 inches of double-shredded hardwood mulch (if specified) on the surface of the media.

D. Plantings shall be watered-in at installation and temporary irrigations shall be provided, if specified.

XI. Using the HPMBS

A. Maintenance Requirements

1. Each correctly installed HPMBS is to be maintained by the supplier for a minimum period of one year. The cost of this service is to be included in the supplier's price of the system.

2. Annual maintenance consists of two (2) scheduled visits unless otherwise specified.

3. Each maintenance visit consists of the following:

   1. *Complete system inspection*
   2. *Removal of foreign debris, silt, plant material, trash and mulch (if needed)*
   3. *Evaluation of biofiltration media*
   4. *Evaluation of plant health*
   5. *Inspection of underdrain/storage system via Observation/Maintenance Port*
   6. *Properly dispose of all maintenance refuse items (trash, mulch, etc.)*
   7. *Take photographs documenting plant growth and general system health*
   8. *Update and store maintenance records*
   9. *To ensure long term performance of the HPMBS, continuing annual maintenance should be performed per the supplier's Operations and Maintenance Manual.*

4. If sediment accumulates beyond an acceptable level in the underdrain/storage system, it will be necessary to flush the underdrain. This can be done by pumping

water into the Observation/Maintenance Port or adjacent overflow structure, allowing the turbulent flows through the underdrain to re- suspend the fine sediments. If multiple Observation/Maintenance Ports have been installed, water should be pumped into each port to maximize flushing efficiency.

Sediment-laden water can be pumped out and either captured for disposal or filtered through a Dirtbag filter bag, if permitted by the locality.

XII. Measurement and Payment

Given the integrated nature of the HPMBS, measurement and payment will be based not on the individual component prices, but on the size of the Biofiltration Media bed. The external dimension as indicated in the approved plans and executed in the installation will be measured in Square Feet and payment will be made per HPMBS system.

Measurement and payment of beehive overflow grate structure with removable filter insert will be based on per unit price.