INVER GROVE HEIGHTS
Northwest Area

Chapter 9

Modeling Methodology and Example Design Procedure

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Modeling Methodology and Example Design Procedure

Chapter 9

this chapter of the manual is intended to serve as a guide for satisfying the stormwater management requirements of the Northwest Area (NWA) of Inver Grove Heights. To accomplish this task, a hypothetical development site has been created to demonstrate the steps that will need to be taken to meet these stormwater requirements

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I. Description of Generic Development Site

The example development site, which will be referred to as Inver Grove Heights Meadows, is a 241-acre development that is broken into the following land uses:

Table 9.1 Land-Use Distribution for Inver Grove Heights Meadows		
Land-Use	**Acres**	**%**
Commercial	41.2	17.1
High Density Residential	55.7	23.1
Institutional	3.7	1.5
Low Density Residential	49.12	19.1
Natural Areas	59.3	24.5
Roads	35.5	14.6
Total	**241.3**	**100.0**

The layout of Inver Grove Heights Meadows has been developed to cover most, if not all of the design implications that could be encountered on a development site in the NWA. The development site contains a variety of land uses, it contains landlocked basins and wetlands of various management classifications, and it incorporates most of the BSD techniques and BMPs recommended in the manual.

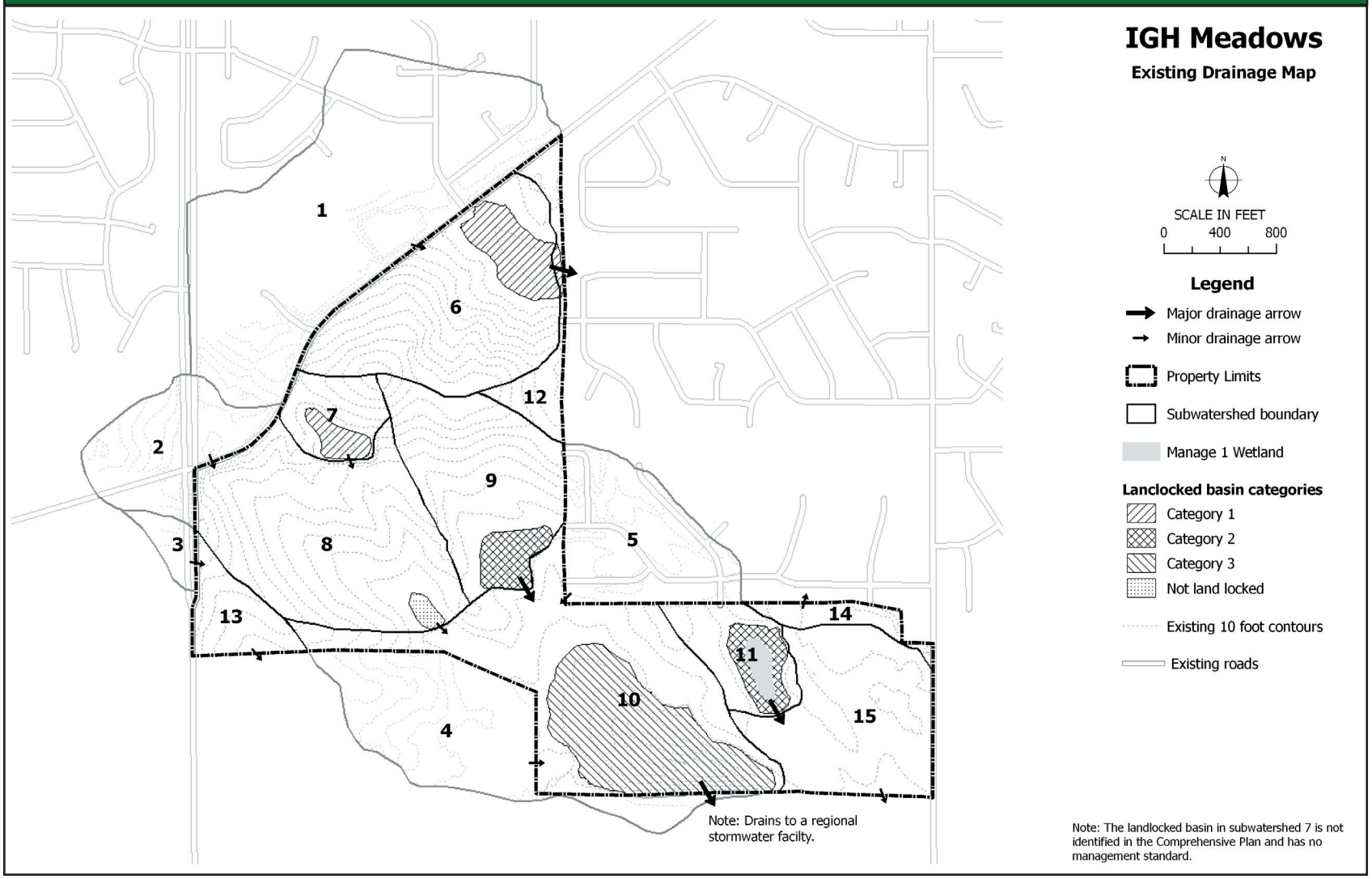
II. Summary of Stormwater Management Requirements

The example design procedure presented in this chapter, illustrates how a permit applicant in the NWA should perform stormwater calculations to meet the following stormwater management requirements:

Table 9.2 Summary of Stormwater Regulatory Requirements for the NWA	
Regulatory Requirements	**Regulatory Document**
Volume Control Standard - No increase in runoff volume from the site for the 5-year 24-hour rainfall event	NWA Planned Unit Development Overlay District
Pre-Treatment Standard	MPCA General Stormwater Permit for Construction Activity
Rate Control Standard - Rate control for the 2- and 10-year 24-hour rainfall events	Section 430 Inver Grove Heights Code
Minimum Building Low Floor Elevation Category 1 = Max. of HWL + 2 ft or NOF + 1 ft Category 2 - HWL + 6 ft Category 3 - HWL + 10 ft	Low Impact Development (LID): Overflow Contingencies and Cost Analysis
Wetland Bounce Standard – No increase in bounce for the 100-year 24-hour rainfall event for Manage 1 Wetlands and up to a half a foot of bounce for the 100-year 24-hour rainfall event for Manage 2 Wetlands.	Inver Grove Heights Natural Resource Inventory and NWA Planned Unit Development Overlay District

Figure 9.1 Inver Grove Heights Meadows Existing Conditions Drainage Map
Under existing conditions there are 15 subwatershed boundaries for Inver Grove Heights Meadows (see Figure 9.1). As the drainage arrows indicate, five of the subwatersheds contribute stormwater runoff from off-site areas, four of the subwatersheds drain to an off-site regional facility, and six of the subwatersheds are fully contained on-site.

SUBMITTAL REQUIREMENT: Provide map with existing conditions topography, drainage boundaries, and drainage arrows/ overflow points.



III. Format of Chapter 9

As mentioned previously, this chapter is meant to guide the design engineer through the steps required to meet the stormwater management requirements of the NWA. Given that most of the standards require matching pre-development or existing conditions for a given rainfall event, the general order of these calculations are as follows:

- Pre-Development Analysis
- Better Site Design Analysis
- Post-Development Analysis

For each of these analyses, the steps required to perform the analysis will be presented first, followed by the application to *Inver Grove Heights Meadows* (dark green callout box). Throughout the chapter, the design engineer will be notified of the City's submittal requirements (dark green callout box).

IV. Pre-Development Analysis

Step 1. Determine subwatershed boundaries and develop existing conditions drainage map.

Identify the subwatershed boundaries on an existing land use map based on the City's 2-foot topography (if still representative) or survey of the site. In some cases, subwatershed boundaries may extend off of the proposed development site. In these cases, this off-site stormwater contribution must be accounted for and included in the stormwater management plan and drainage calculations. In the event that a portion of the proposed development site is in a subwatershed that drains to an off-site regional stormwater management facility, the volume control standard will still need to be met locally.

Step 2. Develop surface water model to determine peak flow rate and runoff volumes for existing conditions.

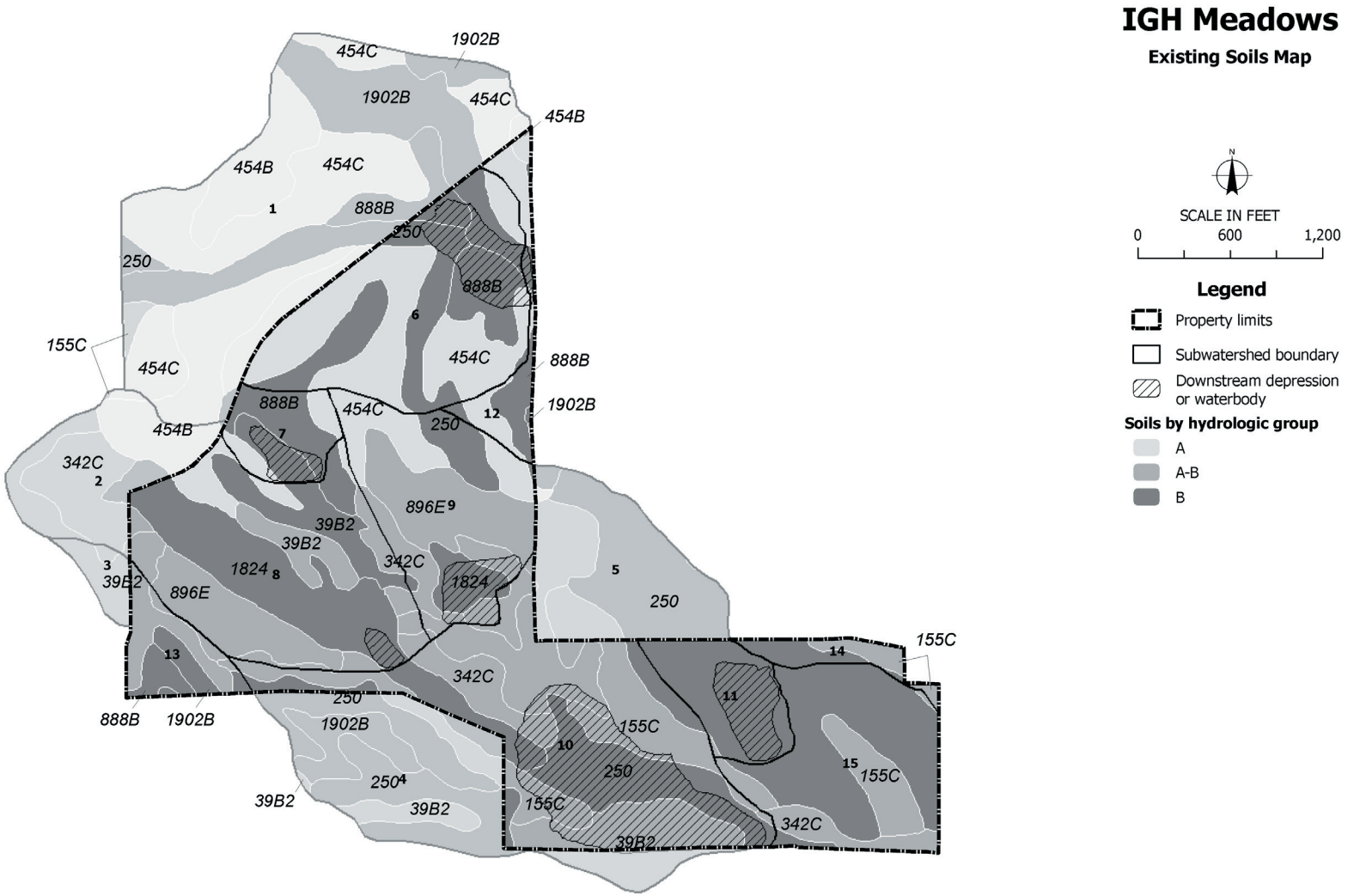
Stormwater calculations can be conducted using a TR-20 or Green-Ampt/Horton based hydrologic model (e.g. HydroCAD or SWMM). An electronic copy of the hydrologic model as well as the model report and design methodologies used for the determination of runoff and analysis of stormwater management practices shall be submitted to the City. The following steps provide guidance on the development of a TR-20 based hydrologic model.

A. Identify the soils located on site using the Dakota County Soil Survey. Given the map symbol for the soils, determine the corresponding Hydrologic Soil Group (HSG) for Inver Grove Heights using Table 9.3. Note that some soils have been assigned here an A-B classification since they have characteristics that are between A and B soils. On-site soil borings and classifications are good additional information that can be used and provided to modify the Dakota Soil Survey designations.

Table 9.3 NWA Soil Classification (HSG)		
Map Symbol	Soil Name	NWA HSG
177A,B,C	Gotham	A
283D	Plainfield	A
454B,C,E	Mahtomedi	A
611E	Hawick	A
7C,D	Hubbard	A-B
39B2	Wadena	A-B
129	Cylinder	A-B
155B,C,E	Chetek	A-B
342B,C,E,F	Kingsley	A-B
411A	Waukegan	A-B
415B,C	Kanaranzi	A-B
857A	Waukegan	A-B
858C	Chetek	A-B
889B,C,D	Wadena	A-B
	Hawick	A-B
896E,F	Kingsley	A-B
	Mahtomedi	A-B
49B	Antigo	B
94C	Terril	B
98	Colo	B
150B	Spencer	B
189	Auburndale	B
208	Kato	B
250	Kenebec	B
279B,C	Otterholt	B
313	Spillville	B
344	Quam	B
449B	Crystal Lake	B
539	Palms	B
861C	Kingsley	B
888B	Kingsley	B
895B,C	Kingsley	B
	Mahtomedi	B
	Spencer	B
1027	Udorthents	B
1029	Pits	B
1816	Kennebec Variant	B
1824	Quam	B
1902B	Jewett	B

Figure 9.2 Inver Grove Heights Meadows Existing Soils Map

SUBMITTAL REQUIREMENT: Provide map of existing condition soils, clearly labeling the NWA HSG for each map symbol (see Figure 9.2 for an example).



B. Determine the type of land cover that is present on the site based on the Natural Resource Inventory, recent aerial photographs and a site information. Land cover shall be classified as one of the following seven types: meadow; woods; woods & meadow; agricultural; urban open space (lawns and parks); wetland; and impervious surfaces (ponds, parking lots, roads, houses, etc.). Land cover shall be classified according to the definitions provided in Table 9.4.

Table 9.4 Land Cover Classification

Land Cover	Definition
Meadow	Greater than 85% of site vegetation consists of grasses
Woods	Greater than 85% of site vegetation consists of trees
Woods & Meadow	Combination of woods and meadow land cover with dominant cover consisting of less than 85% of total
Agricultural	Actively farmed land tilled for crop production
Urban Open Space	Lawns, parks, golf courses, etc. consisting primarily of turf grass
Wetland	Wetland as delineated by qualified professional
Impervious Surfaces	Paved surfaces, rooftops, open water, etc. where no infiltration of rainfall occurs

C. Assign curve numbers to each subwatershed given the soil type and existing land-use. Generally, the "Undisturbed" column of Table 9.5 should be used for pre-development modeling efforts and the "Graded" column should be used for post-development modeling efforts. Impervious surfaces (roads, houses, driveways, etc.) should be assigned a curve number of 98 while open water (ponds, lakes, etc.) should be assigned a curve number of 100. For more detailed information on how the curve numbers in Table 9.5 were established for the NWA see Appendix E.

D. Calculate composite curve numbers for each subwatershed. Open water surfaces may not be composited with the other areas. These surfaces will always be modeled as a separate subwatershed with a CN of 100.

Table 9.5 NWA Curve Numbers

Soil Type	Meadow		Woods		Woods & Meadow		Agricultural	Urban Open Space		Wetland
	Undisturbed	Graded	Undisturbed	Graded	Undisturbed	Graded	Cultivated	Undisturbed	Graded	N/A
A	33	35	34	36	30	32	48	39	50	75
A-B*	35	45	36	48	32	45	51	50	61	76
B	45	56	48	60	45	58	59	61	74	78
C	56	70	60	73	58	72	67	74	80	83
D	70	77	73	79	72	79	76	80	80	85

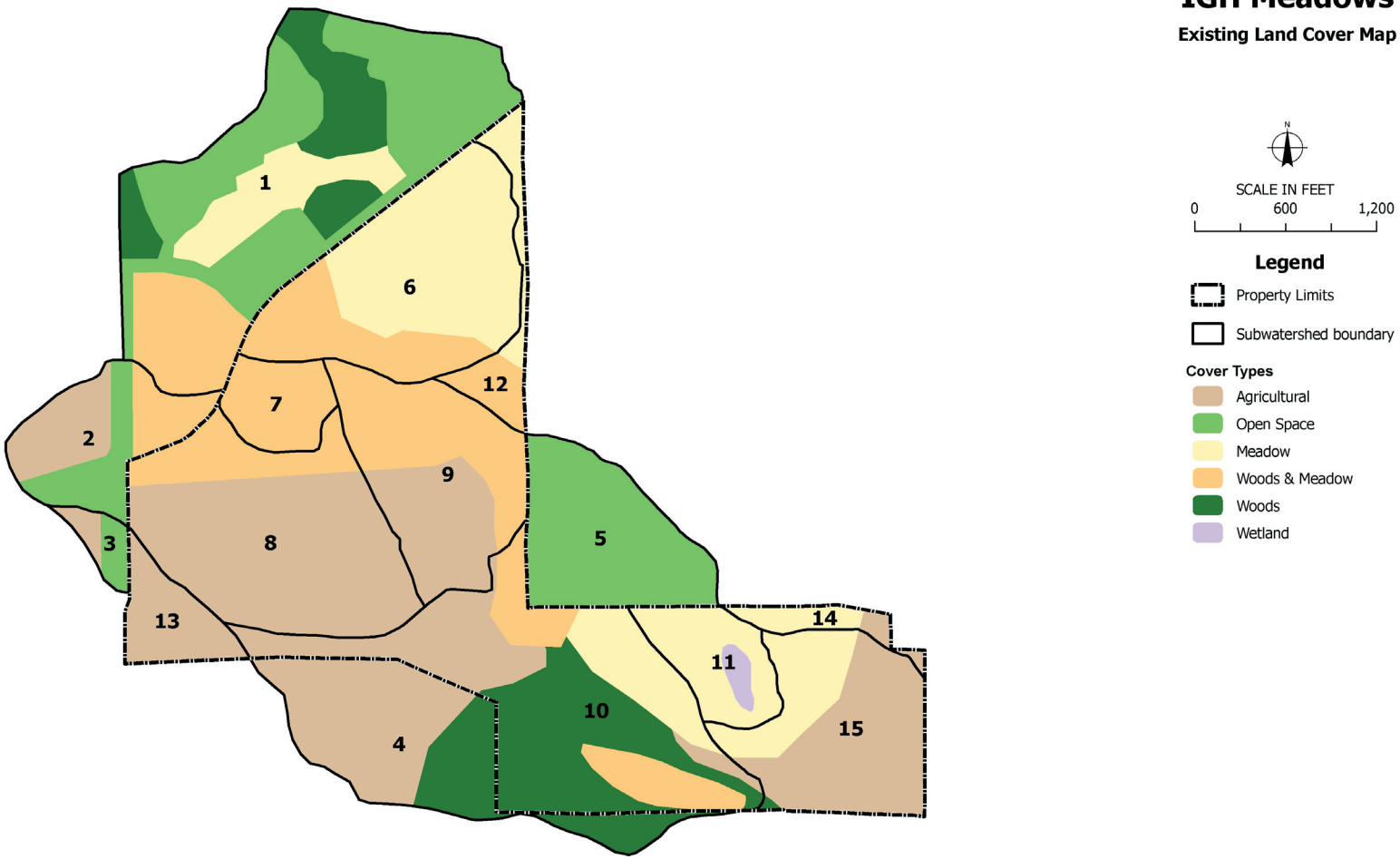
*Calculated average of A & B type soils, not found in MN Hydrology Guide

SUBMITTAL REQUIREMENT: Provide clear documentation of how curve numbers have been assigned.

E. Determine the Time of Concentration (T_c) for each subwatershed. The steps used to determine the T_c and the figures used to obtain the flow velocity based on slope and flow condition are provided in the Hydrology Guide for Minnesota (U.S. Department of Agriculture Soil Conservation Service St. Paul, Minnesota).

Figure 9.3 Inver Grove Heights Meadows Existing Land Cover
Under existing conditions, the development site for Inver Grove Heights Meadows consists of three primary land covers: agricultural, meadow, and woods & meadow. These land covers were classified using the definitions provided in Table 9.4. In addition, a wetland specialist identified and delineated one wetland on a site visit.

SUBMITTAL REQUIREMENT: Provide documentation of methods and sources used to determine site land cover.



F. Calculate existing peak flow for the 2-, 5-, 10-, and 100-year 24-hour rainfall events and total runoff volume for the 5-year rainfall event. Under pre-development conditions it is important to model or account for any natural ponding or depressions that may affect the amount and rate of runoff being flowed from the site. The rainfall depth in inches for the 2-, 5-, 10-, and 100-year 24-hour rainfall events for Inver Grove Heights are provided in Table 9.6:

Table 9.6 Rainfall Depths for the NWA

Recurrence Interval	Depth of Rainfall [inches]	Application of Analysis
2-year 24-hour	2.8	Rate Control
5-year 24-hour	3.6	Volume Control
10-year 24-hour	4.2	Rate Control
100-year 24-hour	6.0	Flood, Bounce & Duration Rate

Step 3. Evaluate basin interconnectivity and emergency overflow (EOF) requirements for each of the subwatersheds delineated in Step 1.

Identify the type of depression or water body located in each of the subwatersheds impacted by the proposed development site and determine the corresponding management standards. The depressions and water bodies in the NWA have been grouped into three categories based on the elevation difference between the outlet of the depression or water body and the existing conditions critical high water level of that depression or water body. The classification of each depression or water body critical event HWL can be found in the Comprehensive Plan Amendment.

As the *Technical Memorandum to the Inver Grove Heights Low Impact Development (LID) Stormwater Plan: Overflow Contingencies & Cost Analysis* describes, a downstream depression or water body will fall under one of the categories outlined in Table 9.7.

Table 9.7 NWA Landlocked Basin Management Categories

Management Category	Definition*	Description
Category 1	NOF-HWL is between 0 – 6 feet	No additional infrastructure to be provided. Preserve existing natural overflow.
Category 2	NOF-HWL is between 6 – 18 feet	To ensure limitation of property damages in the event of extreme flooding, an emergency back-up outlet will be constructed for basins in this category.
Category 3	NOF-HWL is greater than 18 feet	A contingency overflow and location must be identified and an easement must be provided along the potential drainageway.

*NOF = natural overflow (elevation at which a landlocked basin would overflow)
HWL = high water level (as provided by City or updated by applicant's modeling)

Table 9.8 Inver Grove Heights Meadows Landlocked Basin Categories				
Subwatershed Basin No.	Critical Event HWL	Outlet Elevation	Management Category	Outlet Management Standard
6	945.4’	951.0’	1	No change
7	1,023.7’	1,027.0’	1	N/A*
8	952.2’	951.0’	Not Landlocked	N/A*
9	954.6’	961.0’	2	Overflow drop structure at the HWL + 4 feet.
10	919.9’	939.0’	3	No change
11	938.9’	945.0’	2	Overflow drop structure at the HWL + 4 feet.

*NOTE: These two basins are not identified in the Comprehensive Plan. Check with City Engineering Division for management standards.

SUBMITTAL REQUIREMENT: Provide a map and table that identify all landlocked basins and clearly identify the Management Category (Table 9.7) for each basin. See Figure 9.1 for an example of how the landlocked basins can be identified on the existing conditions drainage map.

Step 4: Identify on-site and downstream wetlands by management classification.

The City of Inver Grove Heights has prioritized the protection of wetlands located within the City. The wetlands are classified into four categories, Manage 1, 2, 3, and 4 (NRI, October 2003). The classification of any wetland is provided in Chapter 2, Figure 2.10.

As mentioned previously, a wetland delineation identified one wetland on the development site. Using Figure 2.10 it is apparent that the wetland is a Manage 1 wetland. As figure 9.1 illustrates, this wetland is located at the bottom of landlocked basin 11. The management requirement for this water body will be to maintain the 100-year 24-hour HWL at or below existing or pre-development conditions.

Table 9.9 Wetland Management Requirements	
Wetland Classification	Management Requirements [100-year rainfall event]
Manage 1	Maintain HWL and duration at or below existing conditions
Manage 2	Maintain HWL and duration at or below existing conditions plus 0.5 feet
Manage 3	No requirement
Manage 4	No requirement

SUBMITTAL REQUIREMENT: Provide a map that identifies the management requirements of all wetlands located on site and those that are downstream (off-site) receiving water bodies. See Figure 9.1 for an example of how the wetland management classification can be identified on the existing conditions drainage map.

Step 5. Summarize the results of the pre-development analysis.

Develop a table with the following information to be used in a comparison with post-development conditions: subwatershed identification, area (acres), composite curve number, time of concentration (minutes), peak flow rates for the 2-, 5-, 10-, and 100-year 24-hour events and runoff volumes for the 5- and 100-year 24-hour events. The HWL for Manage 1 or 2 wetlands should also be shown.

Table 9.10 Inver Grove Heights Meadows Pre-Development Results

Sub-Watershed I.D.	Area [ac]	CN	Tc [min]	Peak Flow Rate 2-yr event [cfs]	Peak Flow Rate 5-yr event [cfs]	Peak Flow Rate 10-yr event [cfs]	Peak Flow Rate 100-yr event [cfs]	Runoff Volume 5-yr event [AF]	HWL 100-yr event [ft]
1	76.4	43	10-12	6.8	21.9	37.5	97.6	3.30	-
2	18.6	46	24-35	0.0	0.5	1.1	9.1	0.19	-
3	3.2	50	24-35	0.0	0.2	0.5	2.5	0.06	-
4	31.2	52	24-35	0.4	2.9	7.1	28.4	0.73	-
5	23.7	57	24-35	2.2	8.1	14.3	38.5	1.07	-
6	40.4	38	24-35	0.0	0.0	0.0	0.0	0.02	-
7	8.8	42	24-35	0.0	0.0	0.0	0.0	0.04	-
8	45.7	52	24-35	0.0	0.4	1.4	13.7	1.07	-
9	29.8	42	24-35	0.0	0.0	0.0	0.0	0.12	-
10	55.9	43	24-35	0.0	0.0	0.0	0.0	0.29	-
11	11.5	49	24-35	0.0	0.0	0.0	0.0	0.19	934.1
12	7.5	38	24-35	0.0	0.0	0.0	0.8	0.01	-
13	8.6	55	24-35	0.3	1.5	3.0	9.8	0.27	-
14	4.2	45	24-35	0.0	0.1	0.2	1.8	0.04	-
15	29.2	52	24-35	0.3	2.8	6.8	27.1	0.70	
TOTAL	394.5	-	-	-	-	-	-	-	-

SUBMITTAL REQUIREMENT: Show pre-development results including at a minimum all the results shown in the table above.

V. Better Site Design (BSD) Analysis

During the early stages of the concept plan development, the design engineer should incorporate all of the Better Site Design (BSD) techniques required in the Northwest Area Planned Unit Development Overlay District (PUD) as well as any others that may reduce the volume of stormwater runoff generated under post-development conditions.

This section of the Example Design Procedure identifies the BSD techniques that an applicant is required to incorporate on the development site. This section also makes recommendations for including additional BSD techniques that will reduce the volume of stormwater runoff generated on site thereby reducing the volume requiring mitigation. For a more detailed explanation of all of the BSD techniques and their application see Chapter 4 of this Manual.

Step 1. Determine how to incorporate the REQUIRED Better Site Design (BSD) techniques on the proposed development site.

The following BSD techniques are required in the PUD (note that these requirements are grouped in the same manner they are presented in Chapter 4 of the Manual).

In general, these BSD techniques result in a reduction in the amount of imperviousness on site and a corresponding reduction in the stormwater runoff volume requiring mitigation. For most of these BSD techniques, the SUBMITTAL REQUIREMENT will be to appropriately identify the BSD technique(s) in the construction plans and specifications. For those techniques that require additional information, the specific SUBMITTAL REQUIREMENTS will be provided in a call-out box.

Preserving Natural Areas

► **At least 20% of the buildable development area within the PUD shall be preserved as additional natural area/open space**, which may include greenways as shown in the City of Inver Grove Heights Natural Resources Inventory and Management Plan (BRAA, 2003). Natural area/open space shall be designated in the following priority order (identify these areas in relation to the proposed project site):

i. Protect steep slopes in those subwatersheds that have a significant portion of their drainage area covered in slopes of 25% or greater (see the steep slope map located in Chapter 2, Figure 2.9);

ii. Incorporate public trails or public open space designated in the Comprehensive Plan. This would be in addition to any land that would be used to satisfy the public park dedication requirement found in the City's Subdivision Ordinance (Section 510);

iii. Protect natural features such as slopes of 25% or greater, and environmentally sensitive areas and scenic features of the site identified as Manage 1 or 2 resources or priority sites in the City of Inver Grove Heights Natural Resource Inventory and Management Plan for the Northwest Expansion Area (BRAA, 2004);

iv. Create natural area/open spaces in and around neighborhoods. This priority is satisfied by providing continuity of adjacent natural area/open space corridors or parkways; network of interconnected natural area/open space corridors; or buffers between incompatible or conflicting land uses."

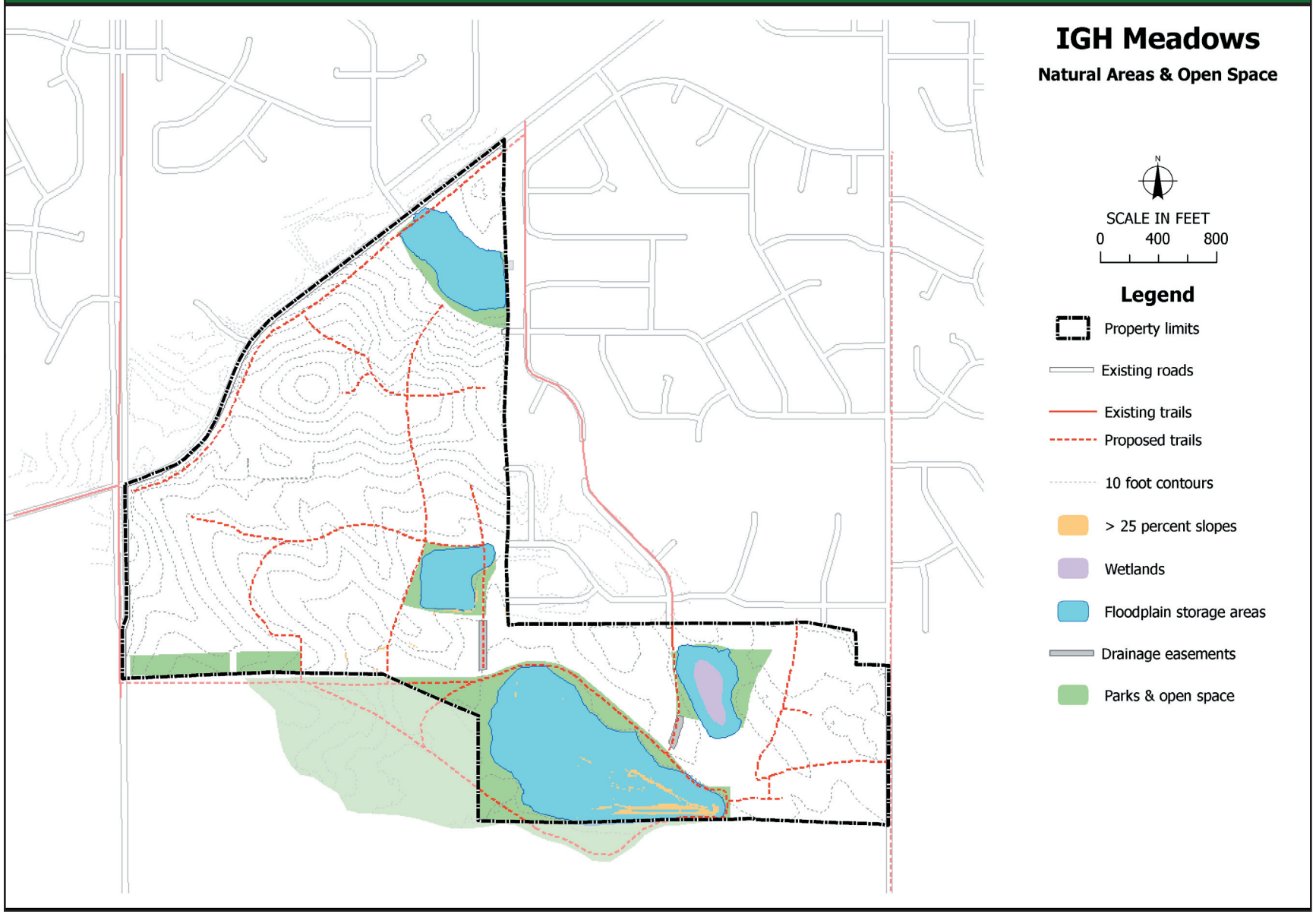
At least 75% of the natural area/open space shall be contiguous with no portion less than 100 feet wide, unless otherwise approved by the City Council.

At least 50% of the 20% of the natural area/open space shall be maintained in a natural, undisturbed condition with natural plant materials and shall not be graded or improved with any building, structure or other impervious surface except: 1) public utilities; 2) limited access in the form of a paved walking or hiker/biker path, the total impervious area of which shall not be more than 2% of the total natural area/open space; and 3) unless otherwise approved by the City Council.

The remaining 50% of designated natural area/open space may be used for passive or active recreation or the location of stormwater management features. If used for active recreation, impervious cover shall not exceed 5% of the remaining area.

Figure 9.4 Inver Grove Heights Meadows Natural Area Requirement Map

SUBMITTAL REQUIREMENT: Provide a map that clearly identifies the areas that meet the 20% natural area/open space designation and the classification of the natural area (see Figure 9.5 for an example).



The allocation of natural area/open space for Inver Grove Heights Meadows is illustrated in the following table:

Table 9.11 Natural Area/Open Space Requirement Allocation	
Natural Area Priority	**Total Percentage of Land**
i. – Subwatershed Steep Slopes	0.5%
ii. – Public Trails	6%
iii. – Natural Feature Protection	21%
iv. – Open Spaces	Not required (20% already attained)

Disconnecting and Distributing Runoff

- **Parking lot curbs shall either be flat or have breaks at regular intervals** to convey runoff into the stormwater system. The use of flat curbs or curbs with regular breaks can be used with filter strips to meet the pretreatment requirements identified in Chapter 6 of this Manual.

- Surface **parking lots in excess of 100 spaces shall provide landscaped islands** between double loaded rows of parking. Such landscaped islands shall also serve as a stormwater cell (see Stormwater Landscaping section of Chapter 4). The stormwater cell can act as a pretreatment measure or as a BMP. If it is to be used as a BMP, the appropriate length of filter strip must be provided as described in Chapter 6 of this Manual.

- Residential **downspouts and sump pumps shall flow to cisterns and/or permeable surfaces** (non-residential downspouts shall do the same when feasible). If a downspout is used, the flow may be pretreated by the vegetated surfaces. If cisterns are used for watering gardens and regularly drained, they can be used to meet the pretreatment requirement and as a direct runoff volume reduction (assume cistern is empty for stormwater calculations).

SUBMITTAL REQUIREMENT: For applications larger than a residential rain barrel, applicant must submit a plan for water usage and demonstrate adequate storage volume.

Reducing Impervious Cover in Site Design

- **Local public streets shall have a 28 foot paved width** in addition to a sidewalk or trail on one side of the street. This street dimension shall restrict parking to only one side of the street. See Chapter 4 for a proposed street cross-section.

- **Cul-de-sacs** shall be designed with a turn-around having an **outside roadway radius of 35 feet and a street property line (ROW) radius of 50 feet**. Cul-de-sacs can be designed with larger diameters provided a landscaped island is included and designed for stormwater storage.

- **Driveway widths for single-family detached residential dwellings, two family and twin home dwellings shall be no more than 20 feet**. In all other cases it shall be no more than 32 feet.

- 50% of total parking required for Multi-Family and Mixed Use development shall be **underground parking, tuck-under parking or structured parking** within or under the principal structure.

- **Pervious paving materials** shall be used for that portion of parking over the minimum required off-street parking spaces. For more information on pervious surfaces, see Chapter 9 of this Manual. In general, the losses resulting from the use of pervious systems should be modeled using information provided by the manufacturer or retailer of the product. If the system is sufficiently pervious, it should be modeled as a dry pond with the void ratio of the fill material.

- Where additional hard surface is desired such as an additional parking space near the garage or where a turn around/guest parking space is desired it must be of **permanent pervious surface**. See comments regarding the application of pervious systems in previous bullet.

Step 2. Evaluate the feasibility of incorporating additional RECOMMENDED BSD techniques to further reduce the volume of stormwater runoff generated under post-development conditions

The following BSD techniques are recommended to reduce the volume of stormwater generated on site, requiring mitigation (note that these requirements are grouped in the same manner they are presented in Chapter 4 of the Manual).

In general, these BSD techniques result in a reduction in the amount of imperviousness on site and a corresponding reduction in the stormwater runoff volume requiring mitigation. For most of these BSD techniques, the SUBMITTAL REQUIREMENT will be to appropriately identify the BSD technique(s) in the construction plans and specifications. For those techniques that require additional information, the specific SUBMITTAL REQUIREMENTS will be provided in a call-out box.

SUBMITTAL REQUIREMENT: For site reforestation or prairie restoration, the applicant will be required to submit a landscaping and vegetation management plan that at a minimum identifies responsible parties, duration of management, and acceptable maintenance activities.

Preserving Natural Areas

- Site Layout to avoid sandier soils (A, A-B) and wooded and/or meadow areas.

- Site Reforestation or Prairie Restoration (see Chapter 4 for a more detailed explanation of this BSD technique). The application of this technique will reduce runoff volumes due to the application of lower curve numbers applied to woods or meadow land cover (see Table 9.5).

SUBMITTAL REQUIREMENT: To apply this technique, the application will be required to submit a compost amendment of tilling plan that contains the following information: site plan identifying areas where soil treatment will be applies and any stockpiling or staging areas; brief written description of which soil treatment options will be used on site; compost and topsoil calculations demonstrating the amount of compost and/or topsoil to be imported.

Disconnecting and Distributing Runoff

- Soil compost amendments or tilling (see Chapter 4 for more detail on the application of this technique). The stormwater benefit of applying soil amendments or tilling is that the volume of runoff generated on site is reduced. To reflect this reduction in the stormwater calculations, the applicant will be allowed to select a CN value from Table 9.5 that reflects "undisturbed" conditions versus the "graded" conditions CN.

Reducing Impervious Cover

- Shared driveways (see Chapter 4 for more detail on the application of this technique).

- Single-family residential driveways constructed of pervious materials such as pavers, pervious concrete or pervious asphalt. For more information on pervious surfaces, see Chapter 9 of this Manual. In general, the losses resulting from the use of pervious systems should be modeled using information provided by the manufacturer or retailer of the product. If the system is sufficiently pervious, it should be modeled as a dry pond with the void ratio of the fill material.

VI. Post-Development Analysis

This section walks the applicant through the post-development analysis. At this point, the pre-development rates and volumes entering the downstream water bodies/landlocked basins have been determined and Better Site Design (BSD) techniques aimed at reducing stormwater runoff volume have been incorporated in proposed (post-development) site layout.

As the post-development drainage map (Figure 9.5) illustrates, there are a number of additional subwatersheds under the post-development scenario: 25 versus 15 under pre-development conditions. In order to illustrate the design approach recommended to meet the City's stormwater management standards, five subwatersheds have been selected for this example calculation. These examples have been selected to illustrate the application of most of the BSD techniques and BMPs recommended in this Manual. These examples, which can be found at the end of the Post-Development Analysis, re-iterate the design steps described below.

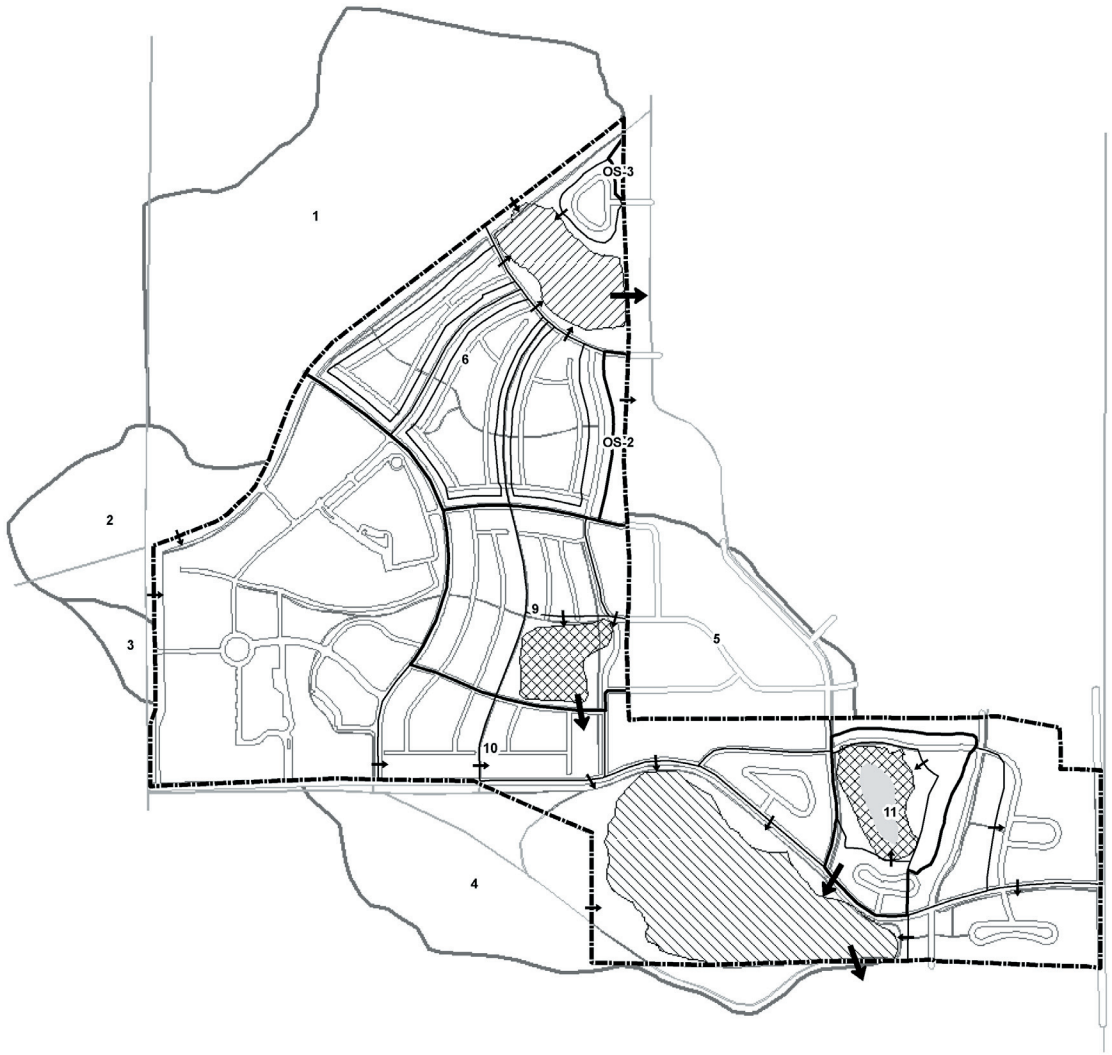
Step 1. Determine subwatershed boundaries and develop post-development conditions drainage map.

Identify the subwatershed boundaries on the proposed conditions (post-development) grading plan. In some cases, subwatershed boundaries may extend off of the proposed development site. In these cases, this off-site stormwater contribution must be accounted for and included in the stormwater management plan and drainage calculations. In the event that a portion of the proposed development site is in a subwatershed that drains to an off-site regional stormwater management facility, the volume control standard will still need to be met locally.

In general, development in the NWA should maintain existing hydrologic boundaries and flow to landlocked basins. In the event that the existing hydrologic boundary is modified under proposed (post-development) conditions, the applicant will be required to review the potential impacts of this change with the City early in the planning process. Alterations in the hydrologic boundary may impact the HWL for the critical event (the 100-year 10-day snowmelt event).

Figure 9.5 Post-Development Drainage Map
Under proposed conditions there are 25 subwatersheds versus 15 subwatersheds under pre-development conditions. The existing hydrologic boundaries are maintained and all stormwater flow points remain the same.

SUBMITTAL REQUIREMENT: Provide map with post-development conditions drainage boundaries and contour lines.



IGH Meadows

Proposed Conditions Drainage Map

N

SCALE IN FEET

0 600 1,200

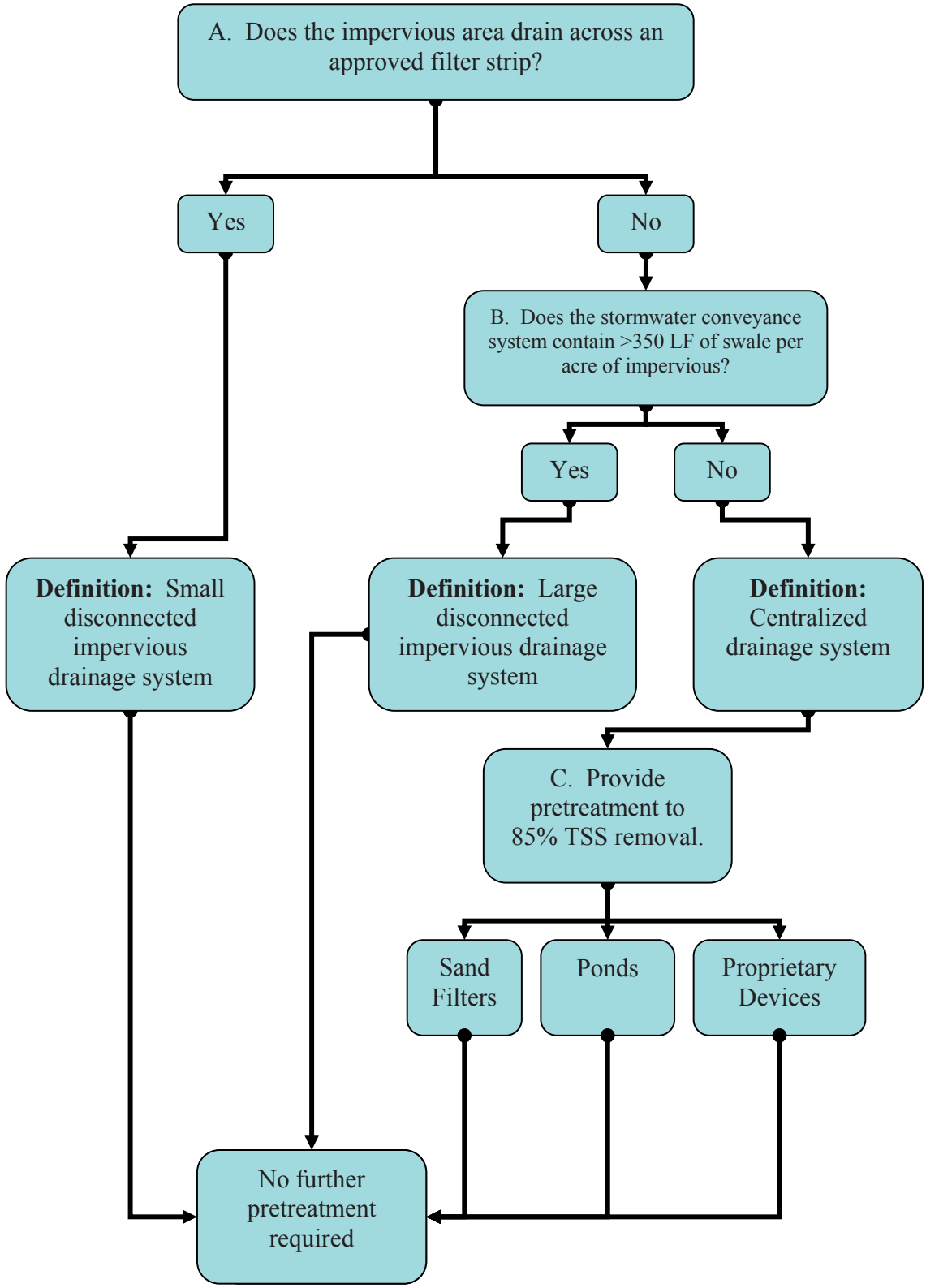
Legend

- Major drainage arrow
- Minor drainage arrow
- Property limits
- Major subwatershed boundary
- Minor subwatershed boundary
- Manage 1 Wetland

Lanclocked basin categories

- Category 1
- Category 2
- Category 3
- Proposed roads & trails

Figure 9.6 NWA Pretreatment Flow Chart



Step 2. Determine pretreatment requirements and design pretreatment measures.

The amount of pretreatment required depends upon the type of drainage system that is being used to convey stormwater runoff to the BMP. Figure 9.6 (introduced in chapter 6) should be used with the corresponding text to define the type of drainage system that is being used and decide where structural pretreatment devices are necessary. The three types of drainage systems are 1) "small disconnected drainage system", 2) "large disconnected drainage system" or 3) "centralized drainage system". Drainage systems 1 and 2 do not require any additional pretreatment devices because pretreatment is met through disconnection of impervious surfaces. Drainage system 3 requires the use of a BMP to accomplish the 85% TSS removal requirement.

A. Identify all impervious areas that flow over an approved filter strip.

There are two general situations that filter strips satisfy the pretreatment requirement. Areas that fall under this category do not need to provide additional pretreatment. Situations not covered here will require approval by city engineering staff.

► Impervious areas less than 0.25 acre that drain across grass filter strips with the dimensions shown in Table 9.12 (Introduced in chapter 6) or greater have already met the pretreatment requirement and require no further pretreatment. Use the Table 9.12 to find the necessary length of filter strip. The purpose of this drainage system distinction is to recognize pretreatment for disconnected impervious areas such as rooftops that drain through yards, or crowned driveways, patios, sheds and other small areas of imperviousness that drain over large pervious areas before entering the stormwater system.

Table 9.12 Filter Strip Sizing

Parameter	Impervious Parking Lots & Streets				Rooftops			
Inflow Approach Length [ft.]	0-35		>35		0-35		>35	
Filter Strip Slope	<2%	2-5%	<2%	2-5%	<2%	2-5%	<2%	2-5%
Filter Strip Minimum Length	10'	15'	20'	25'	10'	12'	15'	18'

► Filter strips may be used as pretreatment for lineal infiltration practices such as infiltration trenches along roadways. The roads, filter strip, and infiltration practices must be designed to allow sheet flow from the road through the filter strip before the runoff enters the infiltration practice. If water is to be concentrated and channelized then the drainage area is considered connected and additional pretreatment is necessary.

To establish that the impervious area falls into this category, it is helpful to examine the impervious/pervious interface. If more then 0.25 acres drains to the pervious area across any one point then the impervious surface is NOT a small disconnected impervious drainage system. The dimensions in Table 9.12 must also be met.

► Small disconnected impervious areas must be shown on the site plan and can be excluded from sizing of pretreatment facilities.

B. Identify all areas that are part of a large disconnected impervious drainage system

► If the drainage area to the infiltration BMP is conveyed through vegetated swales or buffers, the BMP is considered a large disconnected drainage system. Large disconnected impervious systems meet

the pretreatment requirement through filtering in vegetative channels but must contain at least 350 LF of channel per acre of impervious. Large disconnected impervious systems generally exist in areas developed with rural road cross-sections where stormwater is conveyed through grassed channels and/or swales.

► Large disconnected impervious areas must be shown on the site plan and can be excluded from sizing of pretreatment facilities.

C. Design Filter, Pond, or Proprietary device to remove 85% TSS for remaining impervious drainage area. The remaining impervious area is classified as a centralized drainage system.

► Identify the remaining impervious area on the site plan. This is the runoff area that you should use to size pretreatment facilities.

► Use the following sizing criteria for pretreatment facilities. Other practices may be allowed at the city engineer's discretion.

Sand Filters

An operation and maintenance plan must be made to ensure that sand filters are adequately maintained to provide pretreatment.

Recommendations:

► Use an 18-inch thick filter bed
► Use a sand media with a coefficient of permeability of 3.5 ft/day (1.75 in/hr)
► Set the maximum head on the filter to 6 feet
► Drain the filter bed within 72 hours, 48 hours if need to meet MPCA permit requirements

The filter area for a sand filter that has the recommended characteristics can be sized based on the following equation.

$$A_f = 0.0476 * V_{wq}$$

The filter area for a non-standard filtration system is sized using the following equation (based on Darcy's Law).

$$A_f = (V_{wq})\ (d_f)\ /\ [(k)\ (h_f + d_f)\ (t_f)]$$

Where:

A	=	Surface area of filter bed (ft^2)
V_{wq}	=	Water quality volume (ft^3)
df	=	Filter bed depth (ft)
k	=	Coefficient of permeability of filter media (ft/day)
h_f	=	Average height of water above filter bed (ft)
t_f	=	Design filter bed drain time (days)

SUBMITTAL REQUIREMENT: Provide a map that clearly distinguishes between impervious surfaces that satisfy the pretreatment requirement with filter strips (small disconnected drainage system) and those impervious surfaces that utilize other pretreatment methods (large disconnected or centralized drainage systems). Provide calculations that exhibit how the pretreatment standards are being met. Also identify all structural pretreatment features (swales, sand filters, proprietary devices, etc.) on the map and provide typical details for each pretreatment feature in the plan set.

Ponds

- Design to NURP standards
- Permanent Pool Volume =1800 CF/Acre of Drainage
- Permanent Pool Depth = 3' – 10'

Proprietary Devices

- Must meet a 85% TSS removal using standard particle size distribution
- Must have a means to remove floatables and grease
- Must have a maintenance plan for removing sediments

Step 3. Develop surface water model to determine peak flow rate and volume of runoff being generated for the 5-year, 24-hour rainfall event.

Develop the hydrologic model for the 5-year, 24-hour rainfall event to determine the stormwater runoff volume that the Best Management practices (BMPs) are being designed to handle. As the City's PUD states, there shall be no increase in runoff volume from the site for the 5-year 24-hour rainfall event. Stormwater calculations can be conducted using a TR-20 based hydrologic model (e.g. HydroCAD). An electronic copy of the hydrologic model as well as the model report and design methodologies used for the determination of runoff and analysis of stormwater management practices shall be submitted to the City. The following steps provide guidance on the development of a TR-20 based hydrologic model.

This hydrologic model will generate peak flow rates and volumes that will be compared to pre-development conditions. The rate and volume comparison will be made at the nearest landlocked basin or water body, or the point at which the runoff leaves the development site.

A. Identify the soils located on site using the Dakota County Soil Survey. See Figure 9.1 and Step 1A under the pre-development analysis for more detail.

B. Determine the type of land cover that is present on the site based on the Natural Resource Inventory, recent aerial photographs or a site survey. Land cover shall be classified as one of the following seven types: meadow; woods; woods & meadow; agricultural; urban open space (lawns and parks); wetland; and impervious surfaces (ponds, parking lots, roads, houses, etc.). Land cover shall be classified according to the definitions provided in Table 9.4.

SUBMITTAL REQUIREMENT: Provide clear documentation of how curve numbers have been assigned. If soil amendments or tilling are used the application will be required to submit a compost amendment of tilling plan that contains the following information: site plan identifying areas where soil treatment will be applies and any stockpiling or staging areas; brief written description of which soil treatment options will be used on site; compost and topsoil calculations demonstrating the amount of compost and/or topsoil to be imported.

C. Use Table 9.5 to assign curve numbers given the soil type and post-development condition land-use of the site (see highlighted columns in Table 9.5). If land has not been graded, or soil amendments have been utilized, use curve numbers provided in "Undisturbed" column. (See Chapter 8 for soil amendment details.) All impervious surfaces are to be assigned a curve number of 98. Ponds/open water are to be assigned a curve number of 100.

Figure 9.7 Inver Grove Heights Meadows Proposed Conditions (Post-Development) Soils Map

SUBMITTAL REQUIREMENT: Provide map of post-development condition soils, clearly labeling the NWA HSG for each map symbol.

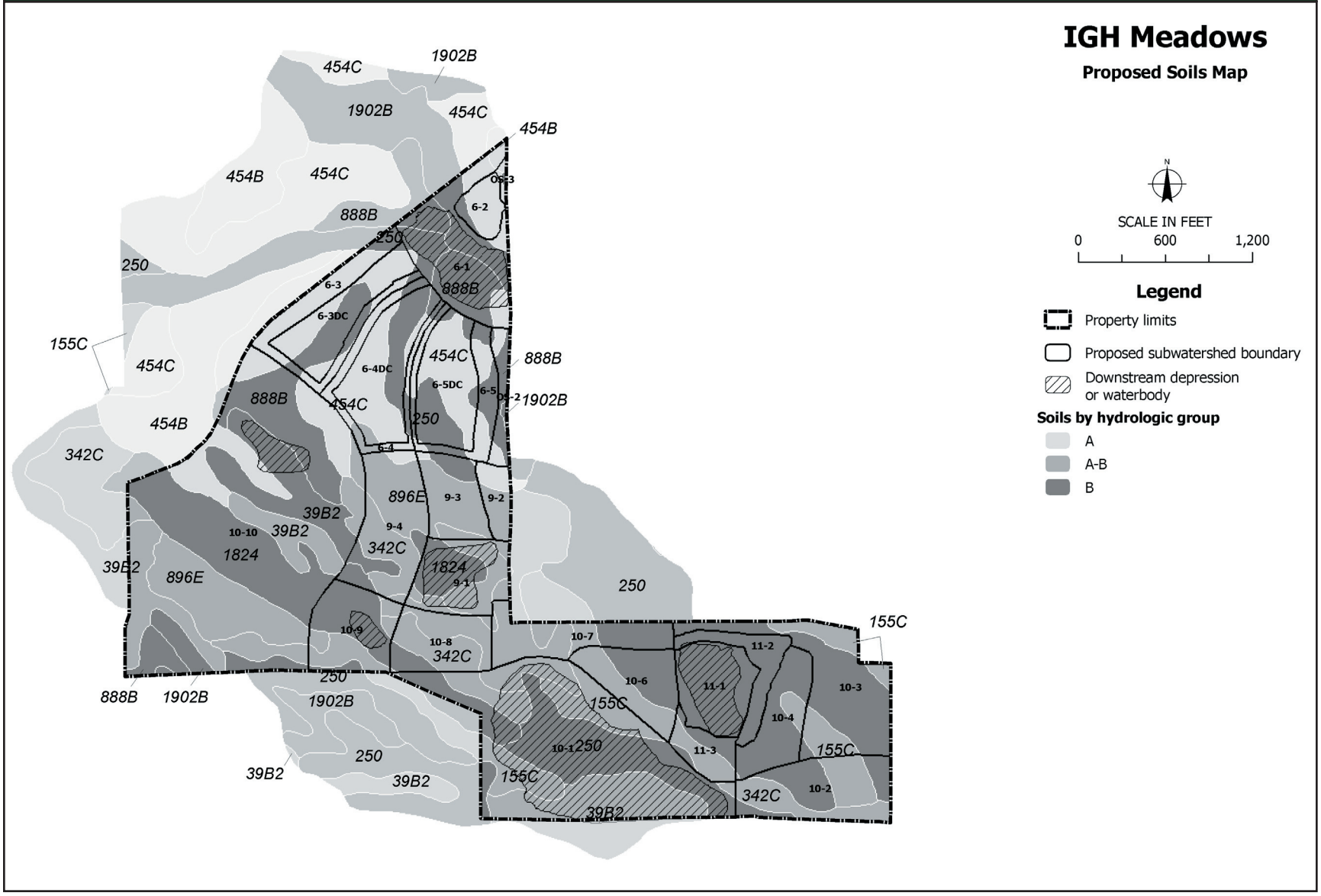


Figure 9.8 Inver Grove Heights Meadows Proposed Conditions (Post-Development) Land Cover
Under proposed conditions, the development site for Inver Grove Heights Meadows consists primarily of the following land uses: institutional, commercial, multi-family residential, single-family residential and open space.

SUBMITTAL REQUIREMENT: Provide documentation of methods and sources used to determine site land cover.

D. Calculate composite curve numbers for each subwatershed.

The pretreatment analysis conducted in Step 2 will be very useful in developing the model to calculate the peak flow rates and runoff volumes. The total impervious area for the site should be determined and divided into two categories: impervious area pretreated by filter strips (small disconnected drainage system); impervious area pretreated by other structural features (large disconnected or centralized drainage systems). These categories will be used to determine whether or not the impervious surface curve numbers may be composited with the pervious curve numbers or not.

Small Disconnected Impervious Drainage Systems – The pervious surfaces in the subwatershed should be composited with the impervious surface curve numbers (except for open water which must always be modeled separately).

Large Disconnected and Centralized Drainage Systems - The impervious surfaces that are pretreated by structural features other than filter strips should be modeled as a separate subwatershed with a curve number of 98 or greater (pond curve number = 100). Be sure to include all ponding areas as impervious surfaces for this calculation.

E. Determine the time of concentration for each subwatershed. The steps used to determine the T_c and the figures used to obtain the flow velocity based on slope and flow condition are provided in the Hydrology Guide for Minnesota (U.S. Department of Agriculture Soil Conservation Service St. Paul, Minnesota).

F. Calculate preliminary post-development peak flow and total runoff volume for the 5-year, 24-hour rainfall events and determine runoff volume for treatment. A comparison of the pre- and post-development volumes (post-development volume minus pre-development volume) will determine the volume of stormwater runoff that needs to be infiltrated on site. By meeting this requirements, other requirements established by agencies (e.g. Minnesota Pollution Control Agency) will be met or exceeded.

Step 4. Design Stormwater Best Management Practices (BMPs).

The specific design criteria for each of the BMPs that can be used to meet the City's volume control standard are provided in Chapter 8 of this Manual. These BMPs include:

- Bioretention
- Infiltration
- Green Roofs
- Pervious Surfaces
- Rainwater Harvesting
- Stormwater Ponds
- Stormwater Wetlands

While this detail of designing specific BMPs is provided in Chapter 8 of this Manual, the example calculations provided at the end of this section walk the applicant through the process for most of the BMPs. In general, the design of a stormwater BMP is an iterative process that involves performing the following steps:

A. Make a preliminary judgment as to whether site conditions are appropriate for the use of the BMP, and identify the function of the practice in the overall treatment system

- Consider basic issues for initial suitability screening including: site drainage area; site topography and slopes; soil infiltration capacity; regional or local depth to groundwater and bedrock; site location / minimum setbacks.

- ► Determine how the BMP will fit into the overall stormwater treatment system – will this be the only BMP employed or are there other BMPs addressing some of the treatment requirements and where on the site the bioretention practice is most likely to be located.

B. Perform field verification of site suitability

C. Select design variant based on Physical Suitability Evaluation

Given the runoff volume and the drainage area, select the appropriate BMP for the first iteration of the design process. Guidance on applicable BMPs given a certain drainage area is provided in Chapter 8 of this Manual.

Information collected during the site suitability evaluation should be used to explore the potential for multiple infiltration practices versus relying on a single infiltration facility. The use of smaller BMPs dispersed within a development is usually more sustainable than a single regional facility that is more likely to have maintenance and groundwater mounding problems (WDNR, 2004).

D. Size BMP

E. Size outlet structure and/or flow diversion structure, if needed

F. Perform groundwater mounding analysis (as necessary depending upon the type of BMP being evaluated)

Step 5. Summarize the results of the post-development analysis.

After the BMP sizing iterative process has been completed, analyze the 2-, 10-, and 100-year, 24-hour rainfall event for peak flow rates. Once calculated, develop a table comparing the following information to pre-development conditions: subwatershed identification, area (acres), composite curve number, time of concentration (minutes), peak flow rates for the 2-, 5-, 10-, and 100-year 24-hour events and runoff volumes for the 5-year, 24-hour event. The HWL for Manage 1 or 2 wetlands should also be shown. If any modifications are proposed to the hydrologic boundaries, the overflow elevations, the outlet elevations, or if grading occurs within the regional basins, a critical even analysis must be performed. This includes modeling the back-to-back 100-year, 24-hour rainfall event as well as the 100-year, 10-day snowmelt event.

As seen in Table 9.13 and Table 9.14, all applicable peak flow rates and volumes decrease or remain the same moving from existing to proposed conditions. Table 9.15 summarizes pre- vs. post-development conditions. Because hydrologic boundary sizes do not significantly change, the critical event analysis was not conducted.

Table 9.13 Inver Grove Heights Meadows Post-Development Results

I.D.	Area [ac]	CN	Tc [min]	Peak Flow Rate 2-yr event [cfs]	Peak Flow Rate 5-yr event [cfs]	Peak Flow Rate 10-yr event [cfs]	Peak Flow Rate 100-yr event [cfs]	Runoff Volume 5-yr event [AF]	HWL 100-yr event [ft]
6-2	2.35	70	14	0.0	0.0	0.1	2.9	0.0	-
6-3	12.24	*1	*1	0.0	0.0	0.8	3.9	0.0	-
10-10	79.07	*1	*1	0.0	1.1	5.9	23.2	0.63	-
11-1	7.2	52*2	30	0.1	0.5	1.6	6.5	0.17	934.0’

Table 9.13 Inver Grove Heights Meadows Post-Development Results									
I.D.	Area [ac]	CN	Tc [min]	Peak Flow Rate 2-yr event [cfs]	Peak Flow Rate 5-yr event [cfs]	Peak Flow Rate 10-yr event [cfs]	Peak Flow Rate 100-yr event [cfs]	Runoff Volume 5-yr event [AF]	HWL 100-yr event [ft]
11-2	3.13	*1	*1	0.0	0.0	0.0	0.3	0.0	-

*1 more than one subwatershed, therefore more than one CN and T_c
*2 composite CN of 52 not used for calculations, see 11-1 step 3C for details

Table 9.14 5-year Pre- to Post-Development Peak Flow Rate and Volume Comparison							
Landlocked Basin	Subwatershed	Peak Flow Rate into Regional Basin [cfs]	Total Proposed Peak Flow Rate [cfs]	Peak Flow Rate from Existing Conditions [cfs]	Volume to Basin [ac-ft]	Total Proposed Volume [ac-ft]	Volume from Existing Conditions [ac-ft]
6	1 (OS)	1.4	1.4	1.8	1.52	1.52	1.54
	2	0.0			0.00		
	3	0.0			0.00		
	4	0.0			0.00		
	5	0.0			0.00		
	6	0.0			0.00		
9	1	0.1	0.2	0.2	0.02	0.10	0.12
	2	0.0			0.00		
	3	0.0			0.02		
	4	0.1			0.06		
10	1	0.2	12.3	14.6	0.14	2.57	3.32
	2 (OS)	2.9			0.73		
	3 (OS)	8.1			1.07		
	4 (OS)	-			-		
	5	0.0			0.00		
	6	0.0			0.00		
	7	0.0			0.00		
	8	0.0			0.00		
	9	0.0			0.00		
	10	1.1			0.63		
11	1	0.5	0.5	0.5	0.17	0.17	0.19
	2	0.0			0.00		
Off-Site	1 (OS)	0.2	1.0	4.5	0.06	0.25	1.07
	2	0.3			0.04		
	3	0.5			0.15		

	Output from example shown
	Onto site from off-site (doesn't change)
	Output from model

NOTE: In existing conditions subwatersheds 1 and 6 drain to Basin 6, subwatersheds 2, 4, 5, 7, 8, 9, and 10 drain to Basin 10, while Basins 9 and 11 receive only subwatersheds 9 and 11, respectively. Subwatersheds 3, 12, 13, 14, and 15 drain off-site.

Figure 9.9 Inver Grove Heights Meadows Proposed Conditions Drainage Map

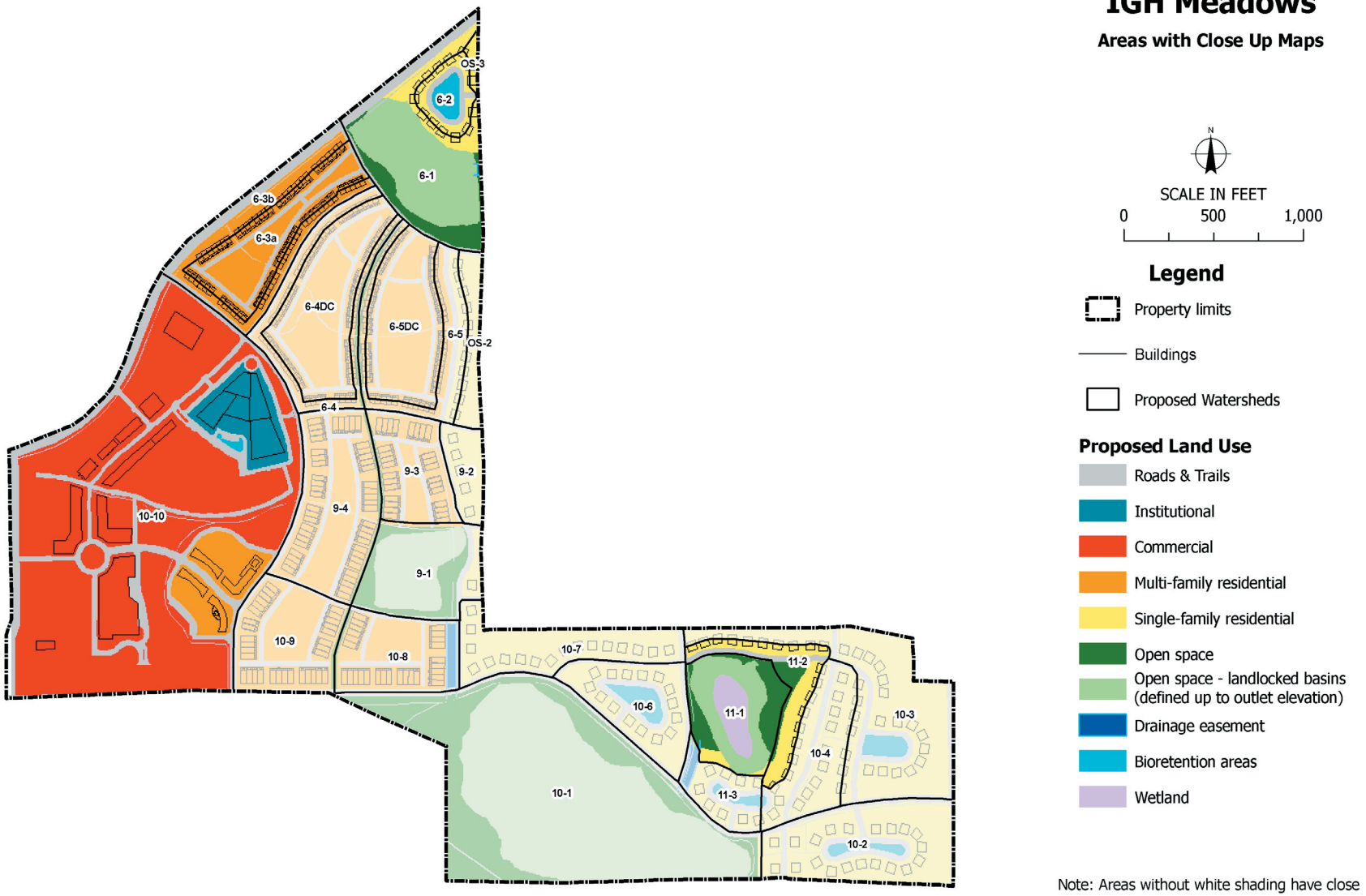


Figure 9.10 Example Calculation Summary for Subwatershed 6-2

Landuse(s): Low Density Residential
Pretreatment Feature(s): Filter Strips
BMP(s): Depressed Island and Soil Amendments

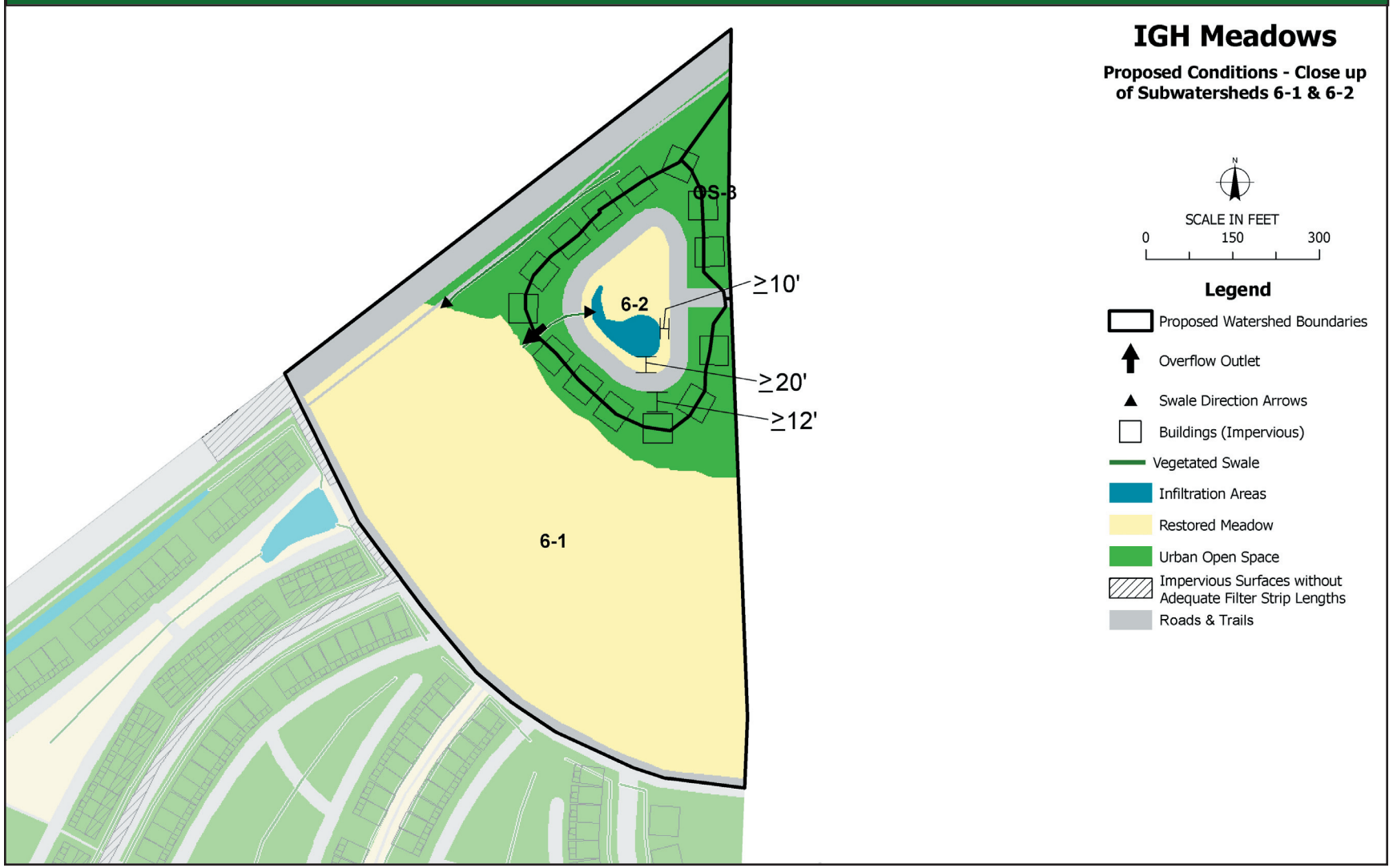


Table 9.15 Peak Flow Rate Comparison for Pre- to Post-Development Conditions								
Land-locked Basin	2-yr Peak Flow Rate [cfs]		10-yr Peak Flow Rate [cfs]		100-yr Peak Flow Rate [cfs]		100-yr HWL [ft]	
	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing
6	0.1	0.1	3.1	3.2	9.6	11.0	-	-
9	0.0	0.0	0.3	0.5	6.8	8.0	-	-
10	2.3	2.4	20.9	34.6	74.1	136.6	-	-
11	0.1	0.1	1.6	1.5	6.5	8.0	934.0’	934.1’
OS	0.2	0.6	9.2	9.4	35.5	41.8	-	-

SUBMITTAL REQUIREMENT: Post-development results including at a minimum all the results shown in Table 9.15. The post-development results must also be clearly compared to the pre-development results, showing that the 2-, 10-, and 100-year peak flow rates and 5-year runoff volumes into the landlocked basins do not increase.

VII. Example Design Procedure Analysis

The following analysis shows how Inver Grove Heights Meadows was designed to effectively meet all of the City’s stormwater requirements. As Figure 9.9 illustrates, the development site is comprised of institutional, commercial, multi-family residential, single family residential and open space. It also illustrates the final number of subwatersheds and drainage paths under post-development conditions.

Table 9.16 Subwatershed 6-2	
Step	**Action**
1	**Determine subwatershed boundaries and develop post-development conditions drainage map.**
	See Figure 9.8
2	**Determine pretreatment requirements and design pretreatment measures.**
A	**Identify on the site plan all impervious areas that flow over an approved filter strip.**
	All of the developed area in subwatershed 6-2 is graded to flow into the depressed BMP located in the center of the entrance road loop. Houses - Each house has its rooftop runoff directed over the front lawn which acts as a **filter strip** with at least 12 feet (3% slopes) of length before reaching the roadway, satisfying the pretreatment standard in Table 9.12. Roads - The roadway drains to the bioretention area. The roadway is 20 feet wide and runs off to a flat **filter strip** (1% slope), requiring a length of 10 feet. This is exceeded for the entire roadway. Driveways - The driveways are not crowned and flow directly onto the street and then to the bioretention area. The driveway length must be added to the roadway length for Table 9.12 calculations, resulting in a **filter strip** length requirement of at least 20 feet (1% slope). The filter strip was lengthened in order to meet this criteria and now satisfies the pretreatment requirement.
B	**Identify all areas that are part of a large disconnected impervious drainage system**
	No large disconnected impervious areas on site
C	**Design Filter, Pond, or Proprietary device to remove 85% TSS for impervious drainage areas not identified in steps A and B.**
	No centralized drainage systems on site
3	**Develop post-development surface water model.**
A	**Identify the soils on site.**
	See Figure 9.7
B	**Determine type of land cover on site.**
	See Figure 9.8
C	**Assign curve numbers based on Table 9.5 and calculate composite curve numbers for each subwatershed.**

Table 9.16 Subwatershed 6-2

Step	Action
	Filter strips were used to satisfy all of the pretreatment requirements. Therefore the impervious surface curve number (CN) may be composited with the CNs of the pervious surfaces. Therefore this site is modeled with one subwatershed with the CNs composited into one CN. All of the lawns have undergone a soil amendment following the procedure described in Chapter 8 allowing the use of the "urban open space, natural condition" CN found in Table 9.5. The area inside of the road loop will be a meadow buffer with soil amendments modeled using the CN in the column "meadow and woods, natural condition".

Subwatershed	Soil Type	Land Cover	Acres	CN
6-2	-	Impervious (FS)	1.19	98
6-2	A	Meadow	0.64	33
6-2	A	Urban Open Space	0.18	39
6-2	B	Urban Open Space	0.32	61
			2.35	**70**

For this subwatershed, there are 1.16 acres of pervious surfaces with a combination of A and B soils, and 1.19 acres of impervious surfaces with a curve number of 98. After compositing (see above table), the subwatershed runoff parameters were a CN of 70 for 2.35 acres.

D	**Determine the time of concentration for each subwatershed.**
	The time of concentration was calculated to be 14 minutes for this subwatershed.
E	**Calculate peak flow rates for applicable rainfall events.**
	See Table 9.15
4	**Design stormwater BMPs**
A	**Is site appropriate for BMPs and where will it function in the treatment train?**
	Yes, the site meets the criteria outlined in Step 4.A. Stormwater runoff receives pretreatment as described in Step 2 prior to flow to the BMP. The BMP will serve as the downstream feature in a landlocked system where the natural overflow is being preserved (Category 1).
B	**Perform field verification.**
	The soil borings performed on-site indicate that the soils are suitable for the design and construction of an infiltration practice. A soil boring representative of the soils found in the location of the proposed BMP indicates that the infiltration rates assumed in the stormwater calculations are appropriate (see Figure 9.11).
C	**Select design variant.**

Table 9.16 Subwatershed 6-2	
Step	**Action**
	The drainage area to the BMP is approximately 1 acre in size. Using the information presented in the following table, the depressed island (bioretention) appears to be the most suitable option for meeting the City's volume control requirements.

BMP Design Variant	Drainage Area (Acres)
Bioretention	0.5 - 2
Infiltration	
Infiltration Basin	5 - 50
Infiltration Trench	< 5
Dry Wells	< 1
Underground Infiltration Systems	< 10
Green Roofs	
Pervious Surfaces	
Rainwater Harvesting	
Stormwater Ponds	> 25
Stormwater Wetlands	> 25

D	**Size BMP.**

Figure 9.11 Example Soil Boring for Subwatershed 6-2

Boring 1

Inver Grove Heights Meadows — Black Street — Inver Grove Heights, MN

Project Number	321	Drill Rig	HSA-2
Geologist	J. Doe	Ground Elevation	897 Feet
Date Drilled	5-26-06	Total Depth of Borehole	25 Feet
Borehole Diameter	4 Inches	Depth to Water	N/A Feet

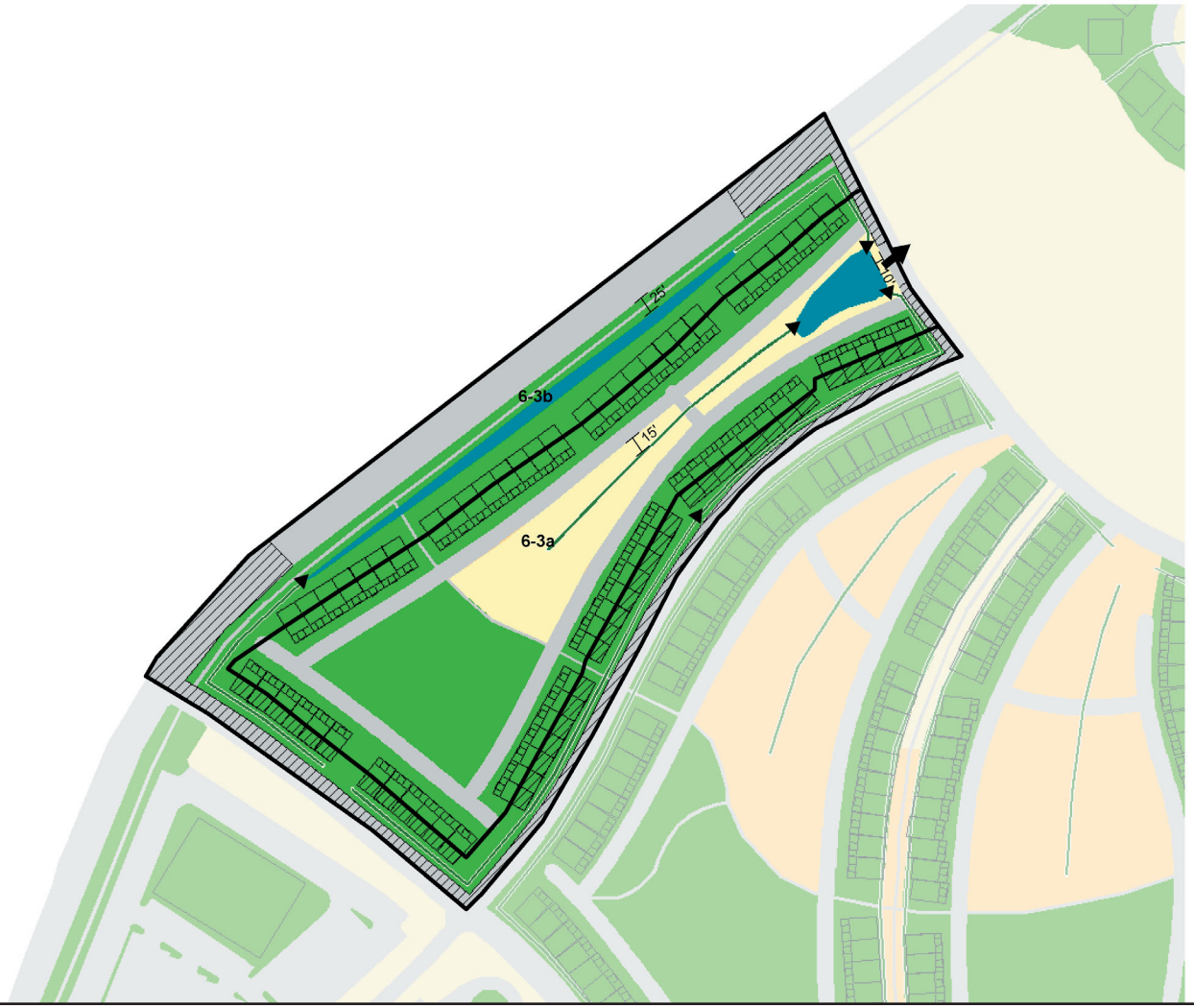
Graphic Log	Description	Depth	Sample	Elevation	Blow Counts	Completion
	Loam, with roots				4	
	Silt Loam, 10YR 3/4				7	
	Sand, 10YR 3/2, Mottled, Coarsening Downward				7	
					10	
		5			7	
					7	
		10			9	
					15	
					11	
		15				
					9	
		20				
					10	
					12	
		25				
		30				
		35				

Piedra Drilling Co. — Page 1

X:\Library\Geology and Groundwater\Programs and Models\Well Logger Software\GH sw manual.wl2

Figure 9.12 Example Calculation Summary for Subwatershed 6-3

Landuse(s): Medium Density Residential
Pretreatment Feature(s): Filter Strips and Vegetated Swales
BMP(s): Biofiltration and Soil Amendments



IGH Meadows

Proposed Conditions - Close up of Subwatersheds 6-3a & 6-3b

N

SCALE IN FEET
0 150 300

Legend

- Proposed Watershed Boundaries
- Overflow Outlet
- Swale Direction Arrows
- Buildings (Impervious)
- Vegetated Swale
- Infiltration Areas
- Restored Meadow
- Urban Open Space
- Impervious Surfaces without Adequate Filter Strip Lengths
- Roads & Trails

Table 9.16 Subwatershed 6-2	
Step	**Action**
	Compute runoff control volumes as explained in Step 3F. The existing conditions modeled five-year runoff volume into Basin 6 is 1.54 acre-feet with a rate of 1.8 cfs. 1.7 cfs and 1.52 acre-feet of this runoff comes from off-site directly into the basin. Therefore, essentially all of the volume for the surrounding area must be infiltrated before reaching the landlocked basin. This will be accomplished (see Step 6) by sizing the BMP appropriately so that no flow occurs during the 5-year rainfall event for all subwatersheds draining to Basin 6. The runoff control volume for 2.35 acres of land with a composite curve number of 70 is 0.210 acre-feet. To size the BMP perform the following steps as identified in Chapter 8 of this Manual: Depressed Island - For infiltration basins with slopes greater the 3:1 side slopes, use $A_i = V_w/D$ Where: A_i = effective infiltration area at half the volume of the practice* (ft^2) V_w = design volume (e.g. WQ_V) (ft^3) D = maximum depth of practice (feet) For this practice, the V_w is 0.210 acre feet (9,100 ft^3). The maximum depth for the A soil is 3.2 feet (0.8 in/hr x 48 hr*). From the above equation, the A_i is (9,100/3.2) 2,800 ft^2 or 0.07 acres. The actual depressed island has a 0.15-acre footprint, surrounded by a pretreatment buffer. Because the larger footprint was designed (aesthetic reasons), the outlet was moved to two feet above the basin bottom. The results of the 5-year rainfall event from the depressed island into Basin 6, modeled in HydroCAD, can be seen in Table 9.14. The HydroCAD results indicate that the depressed island does not outlet for this rainfall event *It is assumed for these calculations that the facility is being designed to meet the more stringent MPCA requirements for a drawdown within 48 hours instead of the IGH standard of 72 hours.
E	**Size outlet structure and/or flow diversion structure, if needed.**
	The depressed island will have an overflow pipe that collects all of the stormwater should the water level increase more than the designed depth of two feet. The overflow pipe will flow into Basin 6 for the large storm events.
F	**Perform groundwater mounding analysis.**
	The groundwater mounding analysis was not performed for the example site, but will be required for approval.
5	**Summarize the results of the post-development analysis**
	See Table 9.15

Table 9.17 Subwatershed 6-3	
Step	**Action**
1	**Determine subwatershed boundaries and develop post-development conditions drainage map.**
	See Figure 9.8
2	**Determine pretreatment requirements and design pretreatment measures.**
A	**Identify on the site plan all impervious areas that flow over an approved filter strip.**
	There are two primary drainage conveyance systems in subwatershed 6-3. Both systems are vegetated swales; one located in the center of the subwatershed (6-3a) and one located along the perimeter of the subwatershed (6-3b). Both swales direct water to the downstream BMP. Roads, Driveways, Townhomes - As Figure 9.12 shows, the majority of the impervious surfaces in the subwatershed are smaller than 0.25 acres and provide an adequate **filter strip** distance for pretreatment (see Table 9.12).
B	**Identify all areas that are part of a large disconnected impervious drainage system**
	The hatched areas in Figure 9.12 show the impervious surfaces where an adequately sized filter strip length could not be provided and therefore does not meet the small disconnected impervious drainage system requirements as determined using the flowchart, Figure 9.6. The drainage system that does not meet the filter strip length criteria is a **vegetated swale**, so the pretreatment flowchart indicates that the swale density must be 375 linear feet per acre of impervious surface. The amount of impervious surface requiring pretreatment is 1.99 acres and the length of swale serving this impervious area is 2,600 feet, therefore the pretreatment requirement is satisfied. (375 LF/AC) x (1.99 AC) = 746 LF $\leq$ 2,600 LF
C	**Design Filter, Pond, or Proprietary device to remove 85% TSS for impervious drainage areas not identified in steps A and B.**
	No centralized drainage systems on site
3	**Develop post-development surface water model.**
A	**Identify the soils on site.**
	See Figure 9.7
B	**Determine type of land cover on site.**
	See Figure 9.8
C	**Assign curve numbers based on Table 9.5 and calculate composite curve numbers for each subwatershed.**

Table 9.17 Subwatershed 6-3	
Step	**Action**

Subwatershed 6-3 drains into the bioretention basin located southwest of Basin 6. The private roads and back half of the town home roof areas drain into a vegetated swale located in the center of the buffer (subwatershed 6-3a). The public roads and town home front yards drain to a vegetated pretreatment swale which flows into the basin (subwatershed 6-3b). Figure 9.12 indicates the impervious surfaces that are pretreated by filter strips (FS) may be composited.

Subwatershed 6-3a			
Soil Type	**Land Cover**	**Acres**	**CN**
-	Impervious	**1.99**	**98**
-	Impervious (FS)	1.66	98
A	Urban Open Space	1.27	39
B	Urban Open Space	0.82	61
		3.75	70

Subwatershed 6-3b			
Soil Type	**Land Cover**	**Acres**	**CN**
-	Impervious (FS)	3.76	98
A	Urban Open Space	0.98	39
B	Urban Open Space	0.49	61
A	Meadow	0.55	33
B	Meadow	0.73	45
		6.50	75

D	**Determine the time of concentration for each subwatershed.**
	The T_c was calculated to be 18 minutes for subwatershed 6-3a and 10 minutes for 6-3b.
E	**Calculate peak flow rates for applicable rainfall events.**
	See Table 9.15
4	**Design stormwater BMPs**
A	**Is site appropriate for BMPs and where will it function in the treatment train?**
	Yes, the site meets the criteria outlined in Step 4.A. Stormwater runoff receives pretreatment as described in Step 2 prior to flow to the BMP. The BMP will serve as the downstream feature in a landlocked system where the natural overflow is being preserved (Category 1).
B	**Perform field verification.**

Table 9.17 Subwatershed 6-3

Step	Action
	The soil borings performed on-site indicate that the soils are suitable for the design and construction of an infiltration practice. A soil boring representative of the soils found in the location of the proposed BMP indicates that the infiltration rates assumed in the stormwater calculations are appropriate (see Figure 9.13).
C	**Select design variant.**
	The drainage area to the BMP is approximately 12 acres in size. Using the information presented in the following table, a small infiltration basin appears to be the most suitable option for meeting the City's volume control requirements.

BMP Design Variant	Drainage Area (Acres)
Bioretention	0.5 - 2
Infiltration	
Infiltration Basin	5 - 50
Infiltration Trench	< 5
Dry Wells	< 1
Underground Infiltration Systems	< 10
Green Roofs	
Pervious Surfaces	
Rainwater Harvesting	
Stormwater Ponds	> 25
Stormwater Wetlands	> 25

D	**Size BMP.**
	Compute runoff control volumes. The total volume running off of subwatershed 6-3 before utilizing bioretention is 1.636 acre-feet. For this subwatershed there are three smaller subwatersheds that need to be modeled.

Subwatershed	Acres	CN	Runoff
6-3a	6.5	75	0.744
6-3b Impervious	1.99	98	0.558
6-3b Composite	3.75	70	0.334

Figure 9.13 Example Soil Boring for Subwatershed 6-3

Boring 2

Inver Grove Heights Meadows — Red Street — Inver Grove Heights, MN

Project Number	321	Drill Rig	HSA-2
Geologist	J. Doe	Ground Elevation	904 Feet
Date Drilled	5-26-06	Total Depth of Borehole	25 Feet
Borehole Diameter	4 Inches	Depth to Water	N/A Feet

Graphic Log	Description	Depth	Sample	Elevation	Blow Counts	Completion
	Loam, with roots				4	
	Silt Loam, 10YR 3/4				7	
	Sand, 10YR 3/2, Mottled, Coarsening Downward				7	
					10	
		5			7	
					7	
		10			9	
					15	
		15			11	
	Sand, 10YR 3/2, Mottled, with intermittent gravel lense				21	
		20				
					26	
		25			19	
		30				
		35				

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Figure 9.14 Example Calculation Summary for Subwatershed 10-10

Landuse(s): Commercial, High Density Residential, Institutional
Pretreatment Features(s): Filter Strips, Ponds
BMP(s): Bioretention, Parking Lot Islands, Pervious Parking Areas

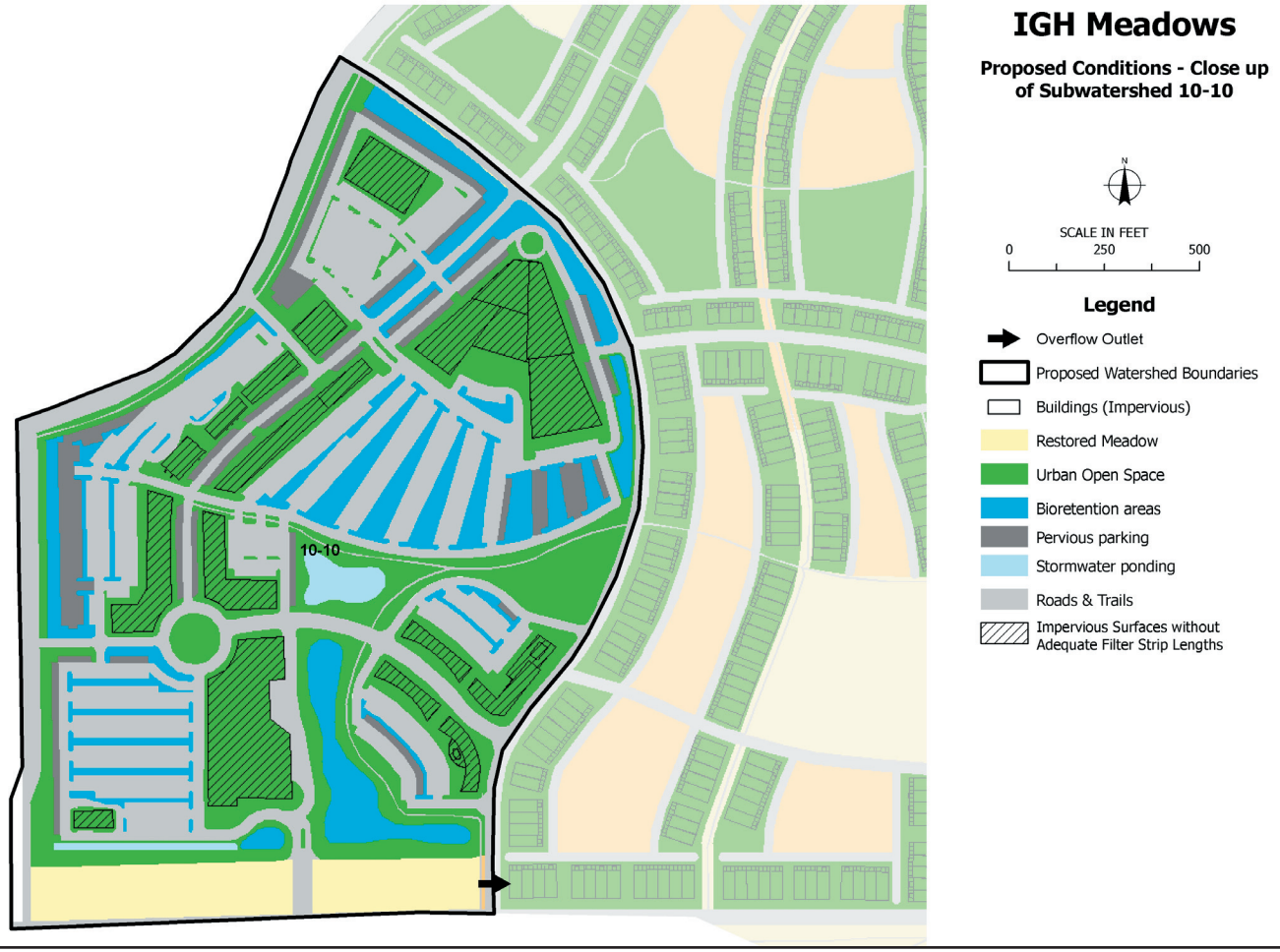

Table 9.17 Subwatershed 6-3	
Step	**Action**
	Because this subwatershed also drains to Basin 6, the bioretention practice must be designed to fully infiltrate the 5-year rainfall event volume. Therefore the water quality volume is 1.636 acre-feet. To size the BMP perform the following steps as identified in Chapter 8 of this Manual: A total of 1.636 acre-feet of runoff volume reaches the bioretention areas. Both bioretention areas are located in soil type 454C, an A type soil. An infiltration rate of 0.8 in/hr is used for design. The maximum depth possible is 3.2 feet (48 hr* x 0.8in/hr), so the required surface area was calculated to be 0.51 acres (1.636 acre-feet / 3.2 feet). The required area of bioretention provided by the roadside and central raingardens. (Note: It is assumed for these calculations that the facility is being designed to meet the more stringent MPCA requirements for a drawdown within 48 hours instead of the IGH standard of 72 hours.)
E	**Size outlet structure and/or flow diversion structure, if needed.**
	The small infiltration basin has a 24" RCP overflow culvert located two feet above the basin bottom. It drains north under the road and into Basin 6. The outlet is sized so that the road will not come within two feet of overtopping during the 100-year event.
F	**Perform groundwater mounding analysis.**
	The groundwater mounding analysis was not performed for the example site, but will be required for approval.
5	**Summarize the results of the post-development analysis**
	See Table 9.15

Table 9.18 Subwatershed 10-10	
Step	**Action**
1	**Determine subwatershed boundaries and develop post-development conditions drainage map.**
	See Figure 9.8
2	**Determine pretreatment requirements and design pretreatment measures.**
A	**Identify on the site plan all impervious areas that flow over an approved filter strip.**
	It is more difficult to show that the pretreatment has been satisfied for the high-density development areas. The higher percentage of impervious surfaces means longer flow routes and more concentrated flow. Pervious Parking Areas - No pretreatment is possible for the pervious parking areas because no routing of runoff occurs, the stormwater directly enters the underground storage. The "pretreatment" for this system will occur by the **sweeping or vacuuming** that is part of the operation and maintenance plan. If the pervious pavement was designed to receive runoff from the impervious parking areas, pretreatment would be required for the pervious parking. Traditional Parking Areas - Because of the large number of parking stalls required for this area (>100), the PUD requires landscaped islands be used between double loaded rows of parking. The **landscaped islands** were designed to meet the 0.25 acre drainage area minimum. This was done by limiting the drainage area to each curb cut inlet. The flow length into most of the islands is longer than 35 feet, requiring a filter strip length of 20 feet (1% slope). In many cases the islands will not be more than 20 feet wide. Therefore the filter strip will begin at the curb cut inlet and continue to the infiltration area. It is imperative that the filter strip length does not overlap with the infiltration area. The practice may not bounce to the elevation of the filter strip for the 3.6", 24-hour rainfall event or smaller. The infiltration islands were designed to meet this criterion.
B	**Identify all areas that are part of a large disconnected impervious drainage system**
	No large disconnected impervious areas on site
C	**Design Filter, Pond, or Proprietary device to remove 85% TSS for impervious drainage areas not identified in steps A and B.**
	Bioretention Areas/Infiltration Basins - There are many larger centralized bioretention areas located throughout the site. These can be seen in Figure 9.14. These areas collect runoff from the immediately adjacent area. The drainage area for each two of these bioretention features (located south and southeast of the big box store) is greater than 0.25 acres and is not vegetated; meaning another type of pretreatment is required. The drainage area for these bioretention areas is 30 acres, including 20 acres of impervious surfaces. Both of these features are pretreated using ponds. Ponds for this area (Type III Drainage System) require 1,800 ft^3 of dead storage per acre of impervious drainage area. The mean normal depth for each pond was constructed to be four feet deep. Therefore the total pond surface area is: [(20 impervious acres) x (1,800 ft^3 / acre) / (4 feet)] = 9,000 ft^2. Both ponds were placed just upstream of the large bioretention areas and satisfy the pretreatment requirements.
3	**Develop post-development surface water model.**

Table 9.18 Subwatershed 10-10	
Step	**Action**
A	**Identify the soils on site.**
	See Figure 9.7
B	**Determine type of land cover on site.**
	See Figure 9.8
C	**Assign curve numbers based on Table 9.5 and calculate composite curve numbers for each subwatershed.**

Subwatershed 10-10 is composed of commercial, institutional, and high-density residential (elderly living) land use. After delineating the subwatershed boundaries, the parking requirements were calculated according to City Ordinance 558 and the PUD. The following tables summarize the analysis

City of Inver Grove Heights Parking Requirements (City Ordinance 558)					
Land Use	**Specific Use**	**Area [ac]**	**Area [sq. ft.]**	**Maximum Parking Stalls**	**Minimum Parking Stalls**
Commercial Buildings	**Retail Stores**	4.551	198,242	**1,322**	**991**
	Auto Repair	0.235	10,237	**21**	**16**
Institutional Buildings	**Church**	2,187	1,900	**543**	**407**
Residential Buildings	**Single Family**	No parking beyond that provided by the garage is required			
	Medium Density	100	342	**171**	**128**
	Elderly Apartments	10	300	**450**	**338**
NOTE: Only the elderly apartments contain more than 100 spaces together and thus require pervious pavement.					

TOTAL STALLS:	**2335**	**1751**
	MAX	**MIN**

TOTAL PARKING STALLS CONSTRUCTED:	**2276**	**Parking Stalls**
PERVIOUS PAVEMENT REQUIRED FOR:	**525**	**Parking Stalls**

Table 9.18 Subwatershed 10-10	
Step	**Action**

Pervious Parking Area Requirement Calculation

Parking Area Supplied:	15,236	acres
Parking Stalls Designed:	2276	Parking Stalls
Parking per Stall:	292	sq. ft.
Impervious Parking Stalls:	1751	
Pervious Parking Stalls:	525	
Impervious Parking Area:	11.7	acres
Required Pervious Parking Area:	3.5	acres

This development has 2,276 parking stalls. The maximum number permitted under City Ordinance 558 is 2,335, and the minimum is 1,751. Shared parking was used on the site to minimize the number of parking stalls constructed. The number of pervious parking stalls required for the site is the difference between the minimum stalls and the constructed stalls. For this area, the number of parking stall required is 525 (2276-1751). The total parking area allotted is 15.2 acres, which indicates that one parking stall requires an average paved surface area of 292 ft^2 for this development. Therefore the amount of pervious pavement needed is 3.5 acres [(525 stalls x 292 ft^2/stall)/43,560 ft^2/acre]. This pervious pavement requirement is allocated in the overflow parking areas. All of the pervious pavement area is assigned a curve number of 100 and is modeled as an underground dry pond (more details in BMP design section). The curve number calculation (divided into the three subwatersheds) is shown below.

Soil Type	Land Cover	Acres	CN
-	Pervious Parking	**3.5**	**100**
-	Impervious including ponds	**12.10**	**98**
-	Impervious (FS)	20.00	98
A	Meadow	1.14	33
A-B	Meadow	5.31	35
B	Meadow	5.53	45
A	Graded Urban Open Space	2.55	50
A-B	Graded Urban Open Space	6.88	61
B	Graded Urban Open Space	3.52	74
		44.93	**72**

D	**Determine the time of concentration for each subwatershed.**
	The time of concentration was calculated to be 15 minutes for these subwatersheds.
E	**Calculate peak flow rates for applicable rainfall events.**
	See Table 9.15

Table 9.18 Subwatershed 10-10	
Step	**Action**
4	**Design stormwater BMPs**
A	**Is site appropriate for BMPs and where will it function in the treatment train?**
	Yes, the site meets the criteria outlined in Step 4.A. Stormwater runoff receives pretreatment as described in Step 2 prior to flow to the BMP. The BMP will serve as the downstream feature in a landlocked system where the natural overflow is being preserved (Category 1).
B	**Perform field verification.**
	The soil borings performed on-site indicate that the soils are suitable for the design and construction of an infiltration practice. A soil boring representative of the soils found in the location of the proposed BMP indicates that the infiltration rates assumed in the stormwater calculations are appropriate (see Figure 9.15).
C	**Select design variant.**
	The drainage area to the BMP is approximately 1 acre in size. Using the information presented in the following table, the depressed island (bioretention) appears to be the most suitable option for the stormwater management practice.

BMP Design Variant	Drainage Area (Acres)
Bioretention	0.5 - 2
Infiltration	
Infiltration Basin	5 - 50
Infiltration Trench	< 5
Dry Wells	< 1
Underground Infiltration Systems	< 10
Green Roofs	
Pervious Surfaces	
Rainwater Harvesting	
Stormwater Ponds	> 25
Stormwater Wetlands	> 25

D	**Size BMP.**

Table 9.18 Subwatershed 10-10	
Step	**Action**
	Compute runoff control volumes. Pervious Pavement – The pervious pavement was designed with an effective storage depth of two feet and a void ratio of 0.30. This 3.5-acre area is given a curve number of 100 and routed to a two-foot deep, 3.5-acre dry pond with 30% voids. The pond does not outlet for the 5-year event. Parking Lot Islands – The parking lot islands are a required better site design technique and were applied throughout the commercial parking lot area. They were designed with filter strips as pretreatment and to store and infiltrate at least the first 0.5 inches of runoff from the surrounding impervious surfaces. The islands were located on all three soil types and modeled appropriately for the surrounding soil type. The total runoff volume into the parking lot islands is 4.4 acre-feet coming from 44.3 acres with a CN of 72. Infiltration Basin – While the pervious pavement and parking lot islands were mandated by city ordinances, the large infiltration basin is added in order to meet site runoff volume control requirements. After modeling the pervious pavement and parking lot islands, 4.42 acre-feet of runoff was entering the infiltration basin. The volume entering Basin 10 according to the existing conditions model was 3.32 acre-feet, with 1.80 acre-feet coming from two off-site subwatersheds and 0.14 acre-feet from Basin 10 itself. Therefore the maximum volume allowed to Basin 10 from all of the developable area draining to Basin 10 is (3.32-1.80-0.14) 1.38 acre-feet. The commercial area is the most densely developed and inherently difficult to meet the volume standards. Therefore the development was designed so that the allowable 1.38 acre-feet of volume will be allowed to enter the basin from subwatershed 10-9. More stringent requirements allowing no runoff from the five-year event will be applied to all other basins draining to Basin 9. Before the infiltration basin is accounted for, the runoff volume is 4.42 acre-feet. The design water quality volume is then (4.42-1.38) 3.04 acre-feet. To size the BMP perform the following steps as identified in Chapter 8 of this Manual: Pervious Pavement – Designed per manufacturer's specifications. In this case it has an effective depth of 3.5 feet and a void ratio of 0.30. Parking lot islands – The parking lot islands were designed to have a depth of one foot before the drop structure became an effective outlet. They were planted with native species and sized to accommodate most of the 5-yr rainfall event. Infiltration Basin - For infiltration basins with slopes greater the 3:1 side slopes, use $A_i = V_w/D$ Where: A_i = effective infiltration area at half the volume of the practice* (ft^2) V_w = design volume (e.g. WQ_V) (ft^3) D = maximum depth of practice (feet) For this practice, the V_w is 3.04 acre feet (132,400 ft^3). The maximum depth for the AB soils is 2.4 feet (48 hr* x 0.5 in/hr). From the above equation, the A_i is (132,400/2.4) 55,000 ft^2 or 1.26 acres. *It is assumed for these calculations that the facility is being designed to meet the more stringent MPCA requirements for a drawdown within 48 hours instead of the IGH standard of 72 hours.
E	**Size outlet structure and/or flow diversion structure, if needed.**

Figure 9.15 Example Soil Boring for Subwatershed 10-10

Boring 2

Inver Grove Heights Meadows — Red Street — Inver Grove Heights, MN

Project Number	321	Drill Rig	HSA-2
Geologist	J. Doe	Ground Elevation	904 Feet
Date Drilled	5-26-06	Total Depth of Borehole	25 Feet
Borehole Diameter	4 Inches	Depth to Water	N/A Feet

Graphic Log	Description	Depth	Sample	Elevation	Blow Counts	Completion
	Loam, with roots				4	
	Silt Loam, 10YR 3/4				7	
	Sand, 10YR 3/2, Mottled, Coarsening Downward				7	
					10	
		5			7	
					7	
		10			9	
					15	
		15			11	
	Sand, 10YR 3/2, Mottled, with intermittent gravel lense				21	
		20				
					26	
		25			19	
		30				
		35				

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Figure 9.16 Example Calculation Summary for Subwatershed 11-1

Landuse(s): Natural Open Space and Manage 1 Wetland
Pretreatment Feature(s): None
BMP(s): None

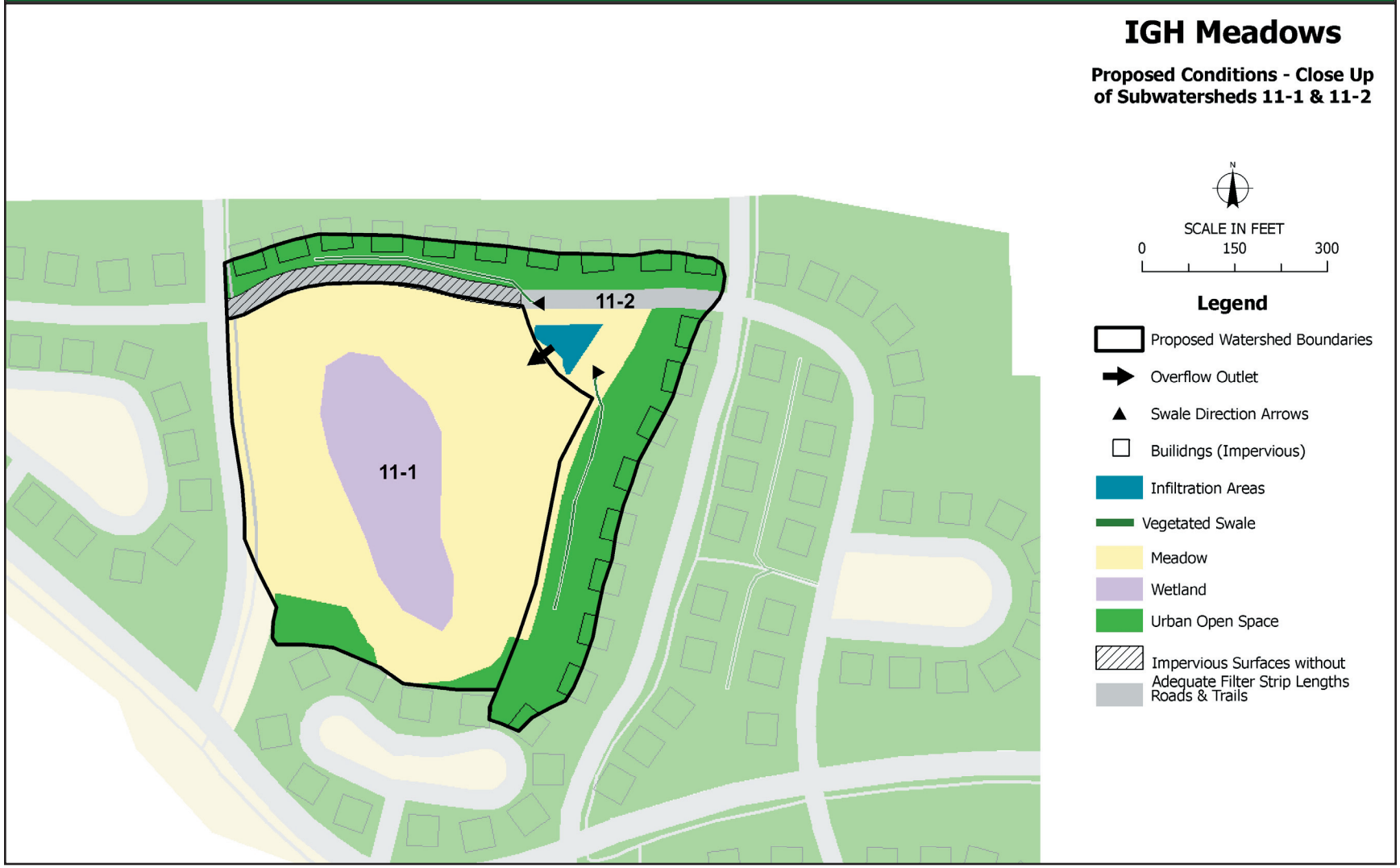

Table 9.18 Subwatershed 10-10	
Step	**Action**
	Pervious pavement: - The primary outlets are the appropriate number of drain tile outlets (varies by location) located two feet above the pond bottom. An emergency overflow is also utilized that allows the pavement to drain to the surrounding traditional pavement and into the parking lot islands. Parking lot islands – The outlet for the parking lot islands are drop structure outlets that connect to a small stormsewer system that drains into the large bioretention area. Infiltration basin – The primary outlet consists of a drop structure draining into a 1,500-foot long, 24-inch RC pipe outletting to Basin 9. It also has an emergency overflow that outlets into a roadside swale adjacent to the road, ultimately reaching Basin 9. The emergency overflow will only be utilized for rainfall events greater than the 100-year event.
F	**Perform groundwater mounding analysis.**
	The groundwater mounding analysis was not performed for the example site, but will be required for approval.
5	**Summarize the results of the post-development analysis**
	See Table 9.15

Table 9.19 Subwatershed 11-1	
Step	**Action**
1	**Determine subwatershed boundaries and develop post-development conditions drainage map.**
	See Figure 9.8
2	**Determine pretreatment requirements and design pretreatment measures.**
A	**Identify on the site plan all impervious areas that flow over an approved filter strip.**
	There is no pretreatment requirement because there are no BMPs or impervious surfaces in the subwatershed except for a trail made of pervious pavement. No small disconnected impervious areas on site
B	**Identify all areas that are part of a large disconnected impervious drainage system**
	No large disconnected impervious areas on site
C	**Design Filter, Pond, or Proprietary device to remove 85% TSS for impervious drainage areas not identified in steps A and B.**
	No centralized drainage areas on site
3	**Develop post-development surface water model.**
A	**Identify the soils on site.**
	See Figure 9.7
B	**Determine type of land cover on site.**
	See Figure 9.8
C	**Assign curve numbers based on Table 9.5 and calculate composite curve numbers for each subwatershed.**

Figure 9.17 Example Soil Boring for Subwatershed 11-1

Boring 3

Inver Grove Heights Meadows — Blue Street — Inver Grove Heights, MN

Project Number	321	Drill Rig	HSA-2
Geologist	J. Doe	Ground Elevation	888 Feet
Date Drilled	5-26-06	Total Depth of Borehole	25 Feet
Borehole Diameter	4 Inches	Depth to Water	N/A Feet

Graphic Log	Description	Depth	Sample	Elevation	Blow Counts	Completion
	Loam, with roots				4	
	Sandy Loam, 10YR 3/4				7	
	Silty Sand with coarse sand lenses, 10YR 5/3				7	
					10	
		5			7	
					7	
		10			9	
					15	
					11	
		15				
	Silty Sand - Silty Gravelly Sand, 10YR 5/4					
					21	
		20				
					26	
					19	
		25				
		30				
		35				

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Figure 9.18 Example Calculation Summary for Subwatershed 11-2

Landuse: Low Density Residential
Pretreatment Feature(s): Filter Strips and Vegetated Swales
BMP(s): Infiltration Trench and Soil Amendment

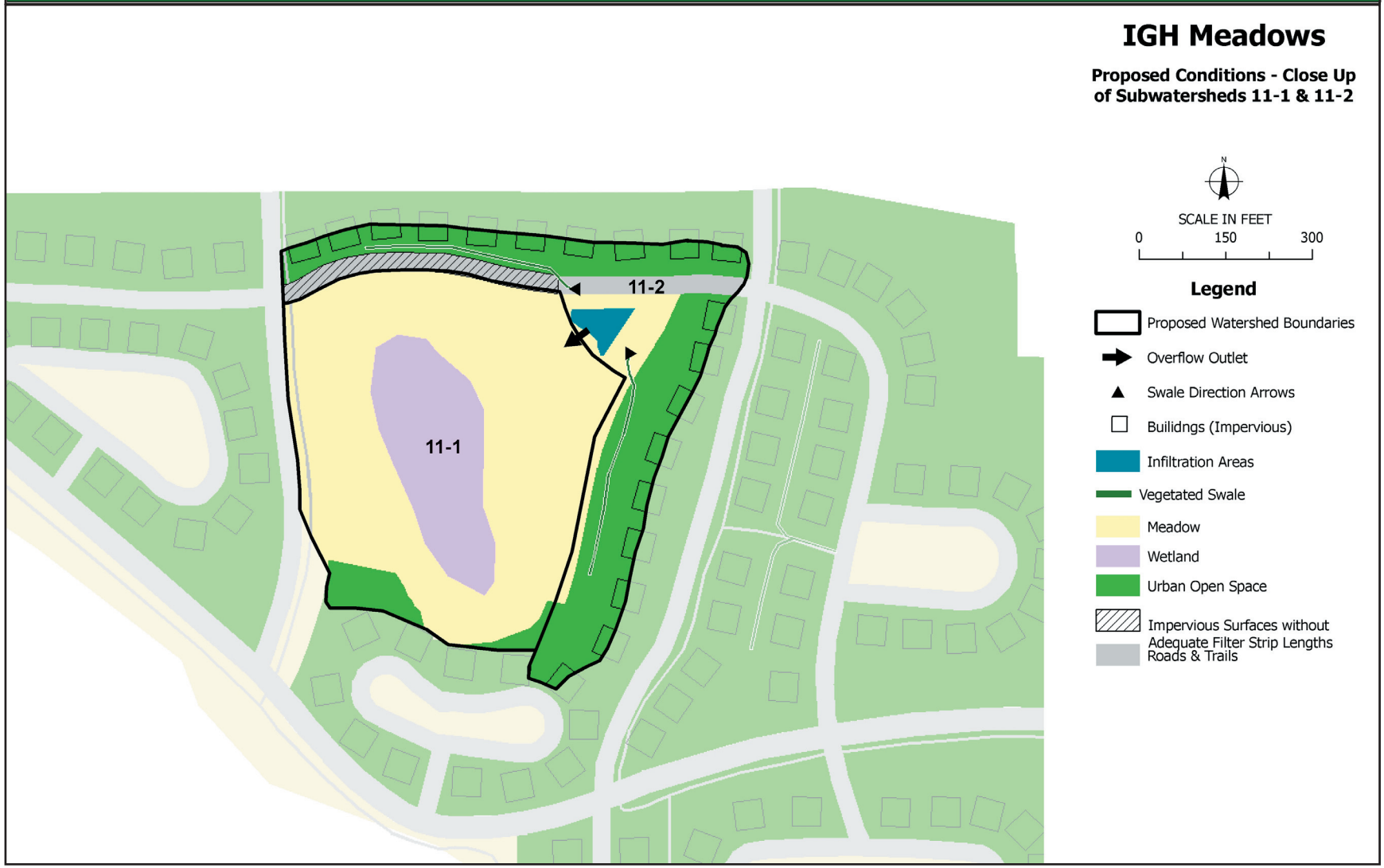

Table 9.19 Subwatershed 11-1

Step	Action
	Subwatershed 11-1 contains a Manage 1 wetland. The stormwater requirements for a Manage 1 wetland are more intense than for other features (no increase in HWL for 100-year event). There are no BMPs included in this area, instead it remains in its original, undisturbed natural state, meaning the volume cannot increase. The subwatershed boundaries were originally delineated to include the rear yards of some of the adjacent homes. However, the 5-year runoff volume increased from existing to proposed conditions. Then the drainage boundary was re-graded so that only the wetland and basin drainage were allowed to drain to the wetland. However, the high wetland curve number had such a strong effect on the subwatershed composite curve number that the runoff volume still increased using SCS methodology. This type of effect is rare, but can occur when there is a large separation in curve numbers. In this rare circumstance, the curve numbers should not be composited. This error is inherent with the use of curve numbers. Subwatershed 11-1 in proposed conditions and subwatershed 15 in existing conditions were modeled discretely without compositing the curve numbers. This methodology better reflected what was actually occurring in the drainage region and showed a decrease in runoff volume.

Soil Type	Land Cover	Acres	CN
B	Meadow	5.37	45
A-B	Urban Open Space	0.002	50
B	Urban Open Space	0.57	61
B	Wetland	1.39	78
		7.34	**53**
NOTE: Composite CN of 53 was not used in the calculation.			

D	**Determine the time of concentration for each subwatershed.**
	The time of concentration was calculated to be 30 minutes for this subwatershed.
E	**Calculate peak flow rates for applicable rainfall events.**
	See Table 9.15
4	**Design stormwater BMPs**
A	**Is site appropriate for BMPs and where will it function in the treatment train?**
	Yes, the site meets the criteria outlined in Step 4.A. Stormwater runoff receives pretreatment as described in Step 2 prior to flow to the BMP. The BMP will serve as the downstream feature in a landlocked system where the natural overflow is being preserved (Category 1).
B	**Perform field verification.**
	The soil borings performed on-site indicate that the soils are suitable for the design and construction of an infiltration practice. A soil boring representative of the soils found in the location of the proposed BMP indicates that the infiltration rates assumed in the stormwater calculations are appropriate (see Figure 9.17).
C	**Select design variant.**
	No BMP required as the natural drainage area was decreased for wetland protection purposes.

Table 9.19 Subwatershed 11-1	
Step	**Action**
D	**Size BMP.**
	Compute runoff control volumes. Because the subwatershed has a smaller area from existing to proposed conditions and all of the area is remaining undisturbed, the runoff volume decreases without requiring any control volume. To size the BMP perform the following steps as identified in Chapter 8 of this Manual: No BMPs are used.
E	**Size outlet structure and/or flow diversion structure, if needed.**
	See Step 6.
F	**Perform groundwater mounding analysis.**
	Not required since no BMPs designed for this subwatershed.
5	**Summarize the results of the post-development analysis**
	See Table 9.15 Because the subwatershed has a smaller area from existing to proposed conditions and all of the area is remaining undisturbed, the wetland will meet the Manage 1 HWL requirement.

Table 9.20 Subwatershed 11-2	
Step	**Action**
1	**Determine subwatershed boundaries and develop post-development conditions drainage map.**
	See Figure 9.8
2	**Determine pretreatment requirements and design pretreatment measures.**
A	**Identify on the site plan all impervious areas that flow over an approved filter strip.**
	Subwatershed 11-2 contains an infiltration trench for a BMP. A total of 1.06 acres of impervious surfaces exist in the subwatershed. 0.70 acres of impervious surfaces are pretreated by filter strips.
B	**Identify all areas that are part of a large disconnected impervious drainage system**
	0.36 acres of impervious are pretreated by two **vegetated swales**. These swales have a total length of 800 feet, thus providing adequate pretreatment for the impervious surfaces. (375 LF/AC) x (0.36 AC) = 135 LF ≤ 800
C	**Design Filter, Pond, or Proprietary device to remove 85% TSS for impervious drainage areas not identified in steps A and B.**
	No centralized drainage areas on site
3	**Develop post-development surface water model.**
A	**Identify the soils on site.**
	See Figure 9.7
B	**Determine type of land cover on site.**
	See Figure 9.8
C	**Assign curve numbers based on Table 9.5 and calculate composite curve numbers for each subwatershed.**

Subwatershed 11-2 is a 3.8-acre subwatershed draining into a Manage 1 wetland. The runoff is directed through a small vegetated swale and into an infiltration trench. Because all of the pretreatment requirements for this subwatershed are met by filter strips, the CNs were composited.

Soil Type	Land Cover	Acres	CN
-	Impervious	0.36	98
-	Impervious (FS)	0.70	98
B	Meadow	0.19	45
B	Urban Open Space	1.88	61
		7.34	**53**

Figure 9.19 Example Soil Boring for Subwatershed 11-2

Boring 4

Inver Grove Heights Meadows — Green Street — Inver Grove Heights, MN

Project Number	321	Drill Rig	HSA-2
Geologist	J. Doe	Ground Elevation	888 Feet
Date Drilled	5-26-06	Total Depth of Borehole	25 Feet
Borehole Diameter	4 Inches	Depth to Water	N/A Feet

Graphic Log	Description	Depth	Sample	Elevation	Blow Counts	Completion
	Loam, with roots				4	
	Sandy Loam, 10YR 3/4					
	Silt, 10 YR 3/5				7	
					10	
		5			7	
					7	
		10			9	
					15	
		15			11	
	Silt, 10 YR 4/4					
		20			21	
					26	
		25			19	
		30				
		35				

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