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Downspout Disconnection Suitability and Incentives Analysis for the City of Gresham, Oregon

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Abstract

The City of Gresham is developing a Downspout Disconnection Program, which encourages homeowners to disconnect their roof downspouts from the storm sewer system and divert the stormwater onto their lawn or rain garden. Downspout disconnection is being evaluated for its effectiveness to help the city meet stormwater discharge requirements in their NPDES-MS4 permit from Oregon DEQ. This study reviewed current Natural Resources Conservation Service (NRCS) soil data and developed a suitability map showing High, Medium and Low suitability zones for on-site stormwater management. To validate the map, 55 soil textural classes and 11 infiltration rates were determined at residences throughout Gresham. When the results were compared with the published NRCS data, 73% of the soil textural classes and 100% of the infiltration rates were in agreement. A survey was mailed to 500 residents in the High suitability zone to determine homeowners' willingness to disconnect and to identify incentives which would help persuade them to disconnect their downspouts. Ninety-four (19%) surveys were returned. The three most popular incentives were 1) a $2.32/mo. stormwater utility fee discount (35%), 2) free materials (20%) and 3) a "how-to" guide (18%). By extrapolating the responses to the full proportion of residences in the High suitability zone, a $2.32 discount would cost the city $47,700 dollars per year in reduced stormwater fees (as well as additional resources needed to verify that each site qualifies) and is expected to divert approximately 33.6 million gallons (100 acre feet) of stormwater each year from the storm sewer system over the long-term.

Introduction

The City of Gresham, Oregon is in the early stages of developing a Downspout Disconnection Program. The program will encourage residents to disconnect their downspouts from the separate storm sewer system and divert the roof runoff to a lawn or rain garden on the property. Currently, stormwater in Gresham that does not infiltrate into the ground (stormwater from most roofs, driveways, parking lots and roads) enters the storm sewer system.

Gresham has separate systems for handling stormwater and wastewater. As a result, stormwater does not go to a wastewater treatment facility; rather, it discharges directly or indirectly to local streams. Direct discharges are primarily in the form of outfall pipes, while indirect discharges can come from surface and subsurface (e.g. drywells) infiltration facilities. Direct discharges cause receiving streams to experience more frequent and higher peak flows, increased erosion, stream bank scouring and loss of stream bank habitat, reduced groundwater recharge and reduced stream baseflows (Keller, 1996, p. 76; Ward and Trimble, 2004, p. 340-342). Maintaining groundwater-fed baseflows are particularly important in late summer when a reliable supply of cool water is most needed for aquatic life (Schilling, 2001).

Since 1999, the city has created code requiring new development to build water quality treatment facilities (City of Gresham, 2003; City of Gresham, 2007; Gresham Development Code, 2009b). Since a significant portion of the city was already developed prior to current requirements, retrofitting these areas has been a challenge. In the past, the city has spent millions of dollars building regional facilities to detain and treat stormwater from some outfalls that were discharging directly to streams. However, end-of-pipe[1] treatments for volume reduction and water quality are costly and often not feasible due to space constraints in developed areas. Therefore, the city is examining ways to address stormwater management closer to the source, such as disconnecting downspouts and building rain gardens as a retrofit. A rain garden is a natural or landscaped basin that captures and soaks up water from roofs, driveways, walkways or other hard areas (Metro, 2009). The soil amendments and vegetation in rain gardens can increase infiltration at some locations that otherwise might not be suitable for simple downspout disconnection (City of Gresham, 2007; City of Gresham, 2009a). Gresham also began a pilot project in 2008, where the suitability and effectiveness of downspout disconnection is being monitored with a flow gage at the area's outfall pipe.

Gresham receives approximately 42 inches of rainwater per year, resulting in the average 1,500 ft^2 home shedding roughly 40,000 gallons of water in an average rainfall year (City of Gresham, 2009b; T. Lindbo, City of Gresham, personal communication). The five main drainage basins in Gresham are the Columbia River to the north, Columbia Slough to the northwest, Fairview Creek in the middle (flows to the Columbia River), Johnson Creek to the south (flows to the Willamette River), and Kelly and Beaver Creeks to the southeast (flows to the Sandy River) (Appendix I). There are approximately 2,700 acres in west Gresham, including large portions of the Columbia Slough and Fairview Creek watersheds, where stormwater drains to drywells rather than to surface water (Appendix II, T. Lindbo, personal communication, February 23, 2009). In the southern portion of the Johnson Creek basin is a group of volcanic buttes with steep slopes, which contribute to low infiltration and rapid runoff (Lee and Snyder, 2009).

[1] End-of-pipe refers to the point where stormwater daylights out of the storm sewer system.

Purpose and Need

This paper describes a suitability and incentives analysis undertaken to assist the City of Gresham in identifying suitable areas for on-site stormwater management, as well as estimating budget and resource needs to implement a Downspout Disconnection Program. Prior to this study, the City of Gresham had not conducted an exhaustive city-wide review of published soils data, nor was there a target area for a Downspout Disconnection Program.

When implemented, the Downspout Disconnection Program will help the City of Gresham comply with the National Pollutant Discharge Elimination System - Municipal Separate Storm Sewer System (NPDES-MS4) permit from the Oregon Department of Environmental Quality. One of the major aspects of the MS4 permit is to demonstrate how the city's Stormwater Management Program makes progress towards reducing pollutant loads for Total Maximum Daily Load (TMDL) constituents.

The TMDL parameters of interest in Gresham's stormwater runoff are bacteria, phosphorus, pH, dissolved oxygen, dioxin, DDT, DDE, dieldrin, lead, mercury, PAHs and PCBs (Kennedy, 2007). While these pollutants may largely originate from road runoff, roof runoff can contain detectable concentrations of some of these pollutants including bacteria (Chang, McBroom and Beasley, 2004), PAHs (Forster, 1999) and lead (Polkowska, 2004; Afshar *et al.*, 2009). These pollutants can originate in roof materials themselves or be deposited on roofs from the atmosphere, which are then flushed off during a rain event—concentrations and constituents will depend on nearby traffic volumes, types of local industries, wind direction, roof type, aspect and surface area (Chang and Crowley, 1993; Gobel *et al.*, 2007). Thus, diverting roof runoff out of the storm sewer system will help the city meet its NPDES-MS4 permit requirements for at least some of the TMDL parameters of interest. Further, reducing stormwater volumes will also improve the annual flow regime in local streams (T. Lindbo, personal communication, February 23, 2009).

Incentives Survey

To be successful, a Downspout Disconnection Program requires the participation of private property owners, with the ultimate goal of getting roof runoff back into the ground near the source. Some property owners will be reluctant to participate in the program due to the possibility of flooding their yard or basement, material and labor costs, and/or a lack of technical skills. For these reasons, it is expected that many property owners will likely not disconnect their downspouts without some form of incentive. Therefore, it is vital to know which incentives are needed to help entice property owners to take that step and to enable the city to estimate levels of resources and operational budget needed over years to reach a projected pollutant reduction goal. A homeowner survey also provides an estimate of volume of stormwater that could be removed from the storm sewer system if the proportion of willing property owners were to actually disconnect their downspouts.

Similar Efforts

The cities of Portland, OR and Seattle, WA currently have downspout disconnection programs. To date, the City of Portland has successfully disconnected over 50,000 downspouts, removing over 1.2 billion gallons of stormwater from the combined storm sewer system each year (Portland Bureau of Environmental Services, 2009). Portland provides free materials and city labor *or* a $53 reimbursement per downspout as well as a discount on the homeowner’s stormwater utility fee (up to 100% of the on-site management fee, which equates to $6.93/quarterly bill) (Portland Bureau of Environmental Services, 2009a). Portland also offers “how to” guides and regular workshops.

The point of discharge of a disconnected downspout in Portland must be at least 2 ft from slabs/crawlspaces, 6 ft from basements, 5 ft from a neighbor's property line and 3 ft from a public sidewalk (Portland BES, 2009). The same setbacks apply for a rain garden but must also be at least 100 ft from slopes of 10% with an additional 5 ft for each percent slope up to 30% (Portland BES, 2009). Slopes are an important consideration because they increase the likelihood of runoff, and soil saturation on a slope may cause a landslide (Keller, 1996, p. 146). Lastly, areas receiving stormwater must be sized to be at least 10% of a residence’s contributing impervious area (at least 9% for a rain garden) (Portland BES, 2009; City of Gresham, 2009a).

The City of Seattle asks its residents three basic questions: 1) Does the water have a place to go (lawn or rain garden)? 2) Can it get there (splash block, pipe or swale conveyance)? 3) What happens in a big storm (can it safely overflow to the street and not into a neighbor's property)? For Seattle, the point of discharge must be at least 5 ft from a crawlspace, 10 ft from a basement, 5 feet from a property line and 10 ft from neighboring buildings (Seattle Public Utilities, 2009). The City of Seattle advises to not disconnect on slopes over 15%, within 500 ft of a steep slope or landslide prone area, or send more than ½ of a roof (~700 sq.ft.) to any one discharge point. Seattle does not offer any incentives, but does provide free brochures on disconnecting downspouts, building rain gardens and several other “water wise” practices at www.seattle.gov/util/rainwise.

Soils Background

The soil data used in this report came from the United States Department of Agriculture Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS). The NRCS data were obtained from both a physical copy of the Soil Survey of Multnomah County (SCS, 1977) and from the online Web Soil Survey (www.websoilsurvey.nrcs.usda.gov). Soils with similar characteristics and similar arrangement of layers were grouped together into a "soil series." Map units were then drawn on aerial photographs to delineate areas where one soil series is dominant. Soil information in the Soil Survey was obtained by field and lab analyses conducted by SCS.

The Soil Survey further subdivides each soil series by phases (A,B,C,D,E or F) as well. Different phases within a soil series differ in slope or other appreciable features. Typically, slope differences between the phases are as follows: A = 0-3%, B = 3-8%, C = 8-15%, D = 15-30%, E = 30-60% and F > 60%. Most map units contain small patches of other soils that can have substantially different properties than the dominant soil type (NRCS, 2009). Complexes are map units with two or more dominant, but intermixed soils. For example, many parts of Gresham consist of an intermixed complex of native soil and urban land. The soil series in Gresham are listed in Table 1 and the map unit distributions are shown in Figure 1.

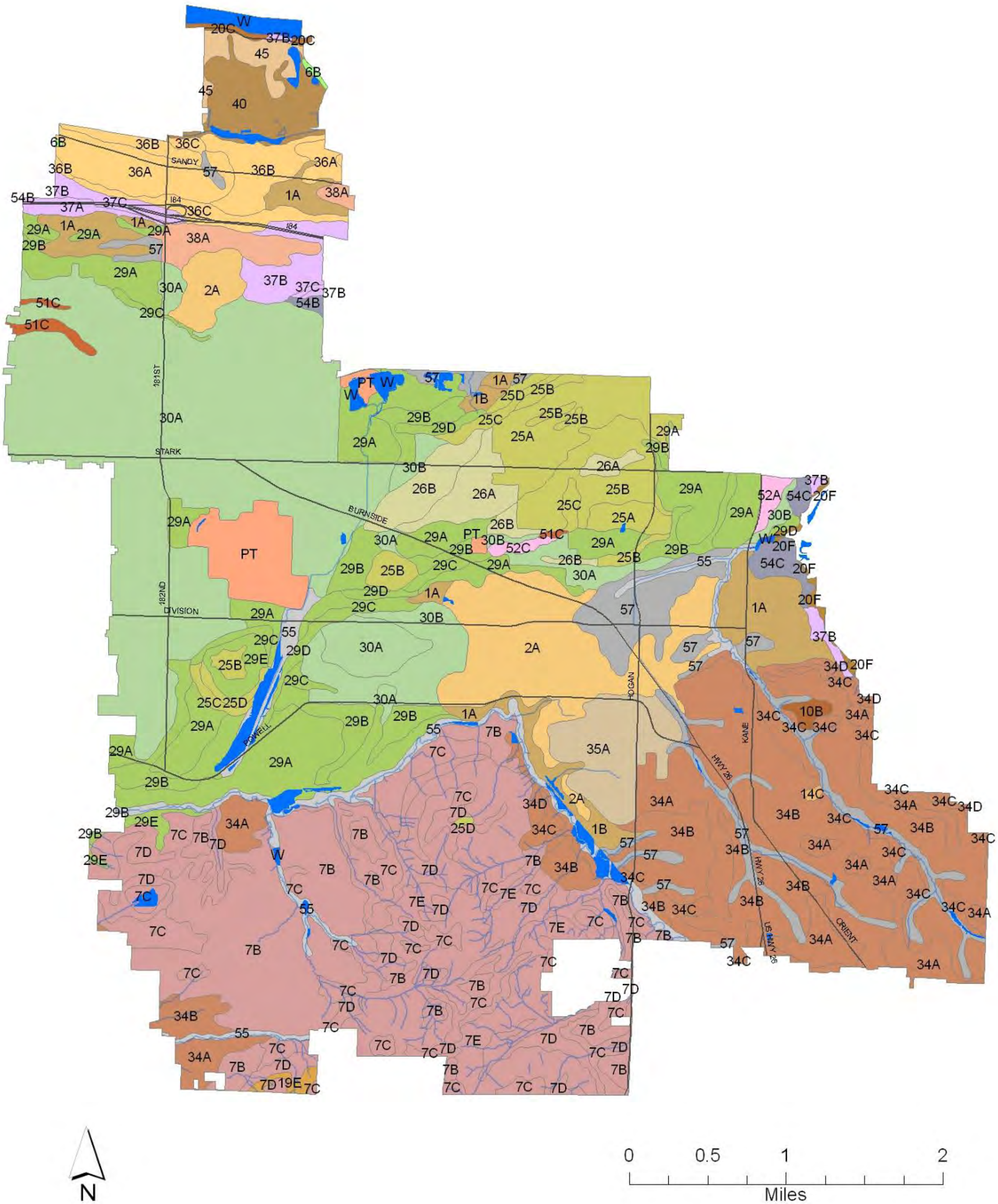


Figure 1. Soil series map units in Gresham (NRCS, 2009).

Table 1. Gresham's soil map units and soil series names (NRCS, 2009)

Map unit	Soil series	Map unit	Soil series	Map unit	Soil series
1 A,B	Aloha silt loam	26 A,B	Latourell-Urban land complex	40	Rafton silt loam, protected
2 A	Aloha-Urban land complex	29 A,B,C,D,E	Multnomah silt loam	45	Sauvie silt loam, protected
6 B	Burlington fine sandy loam	30 A,B	Multnomah-Urban land complex	51	Urban land-Latourell complex
7 B,C,D,E	Cascade silt loam	34 A,B,C,D	Powell	52 A,C	Urban land-Multnomah complex
10 B	Cornelius	35 A	Powell-Urban land complex	54 B,C	Urban land-Quatama complex
14 C	Delena	36 A,B,C	Quafeno loam	55	Wapato
20 F	Haplumbrepts	37 A,B	Quatama loam	57	Wollent silt loam
25 A,B,C,D	Latourell loam	38 A	Quatama-Urban land complex	W	Water

The soil properties explored in this report are those that affect water infiltration and are introduced here with a brief description—all of which came from the NRCS Soil Survey (either printed or online). Following the soil properties descriptions is Table 2, which shows the soil properties for each soil series in Gresham.

Hydrologic soil group*:* A grouping based on runoff potential (according to infiltration rate when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms).

Group A. Soils with a high infiltration rate (low runoff potential)
Group B. Soils with a moderate infiltration rate
Group C. Soils with a slow infiltration rate
Group D. Soils with a very slow infiltration rate (high runoff potential)

A complex may consist of two hydrologic soil group classes. For example, a Multnomah-Urban complex has a hydrological soil group A-D, where the "A" represents the soil type (low runoff potential) and the "D" represents the urban surfaces (high runoff potential).

Drainage class: The natural drainage of a soil, referring to the speed at which water drains out of the soil. There are seven classes of natural soil drainage: Excessively drained (very rapidly), Somewhat excessively drained (rapidly), Well drained (readily but not rapidly), Moderately well drained (somewhat slowly during some periods), Somewhat poorly drained (slowly enough that the soil is wet for significant periods), Poorly drained (so slowly that the soil is saturated or remains wet for long periods), and Very poorly drained (so slowly that free water remains at or on the surface).

Depth to restrictive feature: Vertical distance from the soil surface to the top of a nearly continuous layer with properties that significantly impede the movement of water, air or roots. A fragipan exists in some Gresham soils, which is a loamy, brittle subsurface horizon that is low in porosity, low or moderate in clay, but high in silt or very fine sand and appears cemented.

Ponding: Standing water in a closed depression. *Frequency* is an estimated likelihood for any given year: None (not probable); Rare (0-5% chance); Occasional (5-50% chance); and Frequent (greater than 50% chance). *Duration* is either Very brief (less than 2 days); Brief (2-7 days); Long (7-30 days); and Very long (more than 30 days).

Flooding: The temporary inundation of an area caused by overflowing streams and runoff from adjacent slopes. *Frequency* is similarly expressed for any given year: None (not probable); Very rare (<1% chance); Rare (1-5% chance); Occasional (5-50% chance); Frequent (more than 50% chance in a year, but less than 50% in all months); Very frequent (More than 50% chance in all months). *Duration* is either Extremely brief (0.1-4 hrs); Very brief (4 hrs-2 days); Brief (2-7 days), Long (7-30 days); and Very long (more than 30 days). Frequencies and durations are for normal weather conditions; therefore, unusually wet weather will increase the likelihood of ponding and flooding.

Table 2. Selected soil properties for each soil series in Gresham (NRCS, 2009).

Map Unit	Soil series	Slope (%)	Drainage class	Depth to restrictive feature	Frequency/ Duration of ponding (Jan-Feb)	Frequency/ Duration of flooding (Jan-Feb)
1A	Aloha silt loam	0-3	Somewhat poorly drained	NA	None	None
1B	Aloha silt loam	3-8	Somewhat poorly drained	NA	None	None
2A	Aloha-Urban land complex	0-3	Somewhat poorly drained	NA	None	None
6B	Burlington fine sandy loam	0-8	Somewhat excessively drained	NA	None	None
7B	Cascade silt loam	3-8	Somewhat poorly drained	20-30 to fragipan	None	None
7C	Cascade silt loam	8-15	Somewhat poorly drained	20-30 to fragipan	None	None
7D	Cascade silt loam	15-30	Somewhat poorly drained	20-30 to fragipan	None	None
7E	Cascade silt loam	30-60	Somewhat poorly drained	20-30 to fragipan	None	None
10B	Cornelius	3-8	Moderately well drained	30-40 to fragipan	None	None
14C	Delena	3-12	Poorly drained	20-30 to fragipan	Frequent/Brief	None
20C	Haplumbrepts (moderately steep)	3-25	Well drained	NA	None	None
20F	Haplumbrepts (very steep)	30-90	Well drained	NA	None	None
25A	Latourell loam	0-3	Well drained	NA	None	None
25B	Latourell loam	3-8	Well drained	NA	None	None
25C	Latourell loam,	8-15	Well drained	NA	None	None
25D	Latourell loam	15-30	Well drained	NA	None	None
26A	Latourell-Urban land complex	0-3	Well drained	NA	None	None
26B	Latourell-Urban land complex	3-8	Well drained	NA	None	None
29A	Multnomah silt loam	0-3	Well drained	NA	None	None
29B	Multnomah silt loam	3-8	Well drained	NA	None	None
29C	Multnomah silt loam	8-15	Well drained	NA	None	None
29D	Multnomah silt loam	15-30	Well drained	NA	None	None
29E	Multnomah silt loam	30-60	Well drained	NA	None	None
30A	Multnomah-Urban land complex	0-3	Well drained	NA	None	None
30B	Multnomah-Urban land complex	3-8	Well drained	NA	None	None
34A	Powell	0-3	Somewhat poorly drained	15-24 to fragipan	None	None
34B	Powell	3-8	Somewhat poorly drained	15-24 to fragipan	None	None
34C	Powell	8-15	Somewhat poorly drained	15-24 to fragipan	None	None
34D	Powell	15-30	Somewhat poorly drained	15-24 to fragipan	None	None
35A	Powell-Urban land complex	0-3	Somewhat poorly drained	15-24 to fragipan	None	None
36A	Quafeno loam	0-3	Moderately well drained	NA	None	None
36B	Quafeno loam	3-8	Moderately well drained	NA	None	None
36C	Quafeno loam	8-15	Moderately well drained	NA	None	None
37A	Quatama loam	0-3	Moderately well drained	NA	None	None
37B	Quatama loam	3-8	Moderately well drained	NA	None	None
37C	Quatama loam	8-15	Moderately well drained	NA	None	None
38A	Quatama-Urban land complex	0-3	Moderately well drained	NA	None	None
40	Rafton silt loam, protected	0-2	Very poorly drained	NA	Frequent/Long	Rare/Very brief
45	Sauvie silt loam, protected	0-2	Poorly drained	NA	None	Rare/Very brief
51C	Urban land-Latourell complex	8-15	Well drained	NA	None	None
52A	Urban land-Multnomah complex	0-3	Well drained	NA	None	None
52C	Urban land-Multnomah complex	8-15	Well drained	NA	None	None
54B	Urban land-Quatama complex	3-8	Moderately well drained	NA	None	None
54C	Urban land-Quatama complex	8-15	Moderately well drained	NA	None	None
55	Wapato	0-3	Poorly drained	NA	Frequent/Long	Frequent/Brief
57	Wollent silt loam	0-3	Poorly drained	NA	Frequent/Long	None
W	Water					

Particle Size Distributions

Soils are classified according to their particle sizes distributions. The NRCS uses the following diameter sizes to classify a particle as gravel, sand, silt or clay (gravel, sand and sometimes silt particles can be further differentiated, but not for this study):

Gravel:	> 2.0 mm
Sand:	2.0 mm – 0.05 mm
Silt:	0.05 mm – 0.002 mm
Clay:	< 0.002 mm

For this report, particle size distributions were determined using the hydrometer method (Ward and Trimble, 2004, p. 74). A hydrometer is a small glass bulb with cylindrical stem and enclosed ruler, weighted to float upright and calibrated to read zero in a column of pure water. When lowered into soil/water solution, the hydrometer will float higher (due to the increased density), causing the stem to extend out of the solution. Readings are taken from the protruding ruler where the meniscus touches the stem. Over time, as soil particles settle out of solution, the hydrometer sinks with the decreasing density and readings are taken at known intervals. Different sized particles sink and settle out of solution at different times—sands settle out between 30-60 seconds, silts settle out between 8-24 hours, with clays remaining in solution. The hydrometer method and calculations are based on Stoke's law, which relates settling velocities to the diameters of the particles.

This study used the hydrometer method to estimate the sand fraction, rather than the more common method of sieving. While the difference between these two methods may exceed 5% (Dane and Topp, 2002), it has been shown that hydrometer readings anywhere between 30-60 seconds can still reasonably estimate the sand fraction (Bohn and Gebhardt, 1989).

Different fractions of sand, silt and clay are used to define a soil's textural class (gravel is used only as a modifier; e.g. gravelly silt loam). In the U.S., 12 soil textural classes are defined by the USDA; ordered here by increasing proportion of fine particles:

- Sand
- Loamy sand
- Sandy Loam
- Loam
- Silt
- Silt loam
- Sandy clay loam
- Clay loam
- Silty clay loam
- Sandy clay
- Silty clay
- Clay

A soil horizon is a layer roughly parallel to the surface that can be distinguished from adjacent layers by a clear set of properties. This report mainly used color changes to differentiate between soil horizons. The O-horizon sits at the land surface and consists of slightly decomposed organic matter. A-horizons are near-surface soils of a black or dark grayish-brown color made of a mix of decomposed organic and mineral matter. B-horizons are deeper and tend to be more reddish-brown in color, due to an accumulation of iron-rich clays leached from the horizons above it (Keller, 1996, p. 60-61; Ward and Trimble, 2004, p. 65). In some soil profiles, there may be an E-horizon between the A- and B-horizons that is very leached of color and may appear almost white (Keller, 1996, p. 60).

Infiltration Background

Infiltration is the downward movement of water into a soil. Soil composition is the most important *natural* variable affecting infiltration, and in general, coarse-grained soils of sands and gravels will transmit water better than fine-grained soils of silts and clays (Keller, 1996, p. 67; Ward and Trimble, 2004, p. 62, 65) due to the number and size of large pore spaces (Dane and Topp, 2002, p. 802). The infiltration capacity of a soil is therefore strongly related to its particle size distribution (Dane and Topp, 2002, p. 797), particularly with regard to the percent sand and percent clay (A. Yeakley, personal communication, May 13, 2009).

Infiltration is also affected by many other factors, including compaction, surface crusting and sealing, vegetation, organic material, antecedent soil moisture, and soil fauna (e.g. earthworm holes) (Ward and Trimble, 2004, p. 66-68). Surface sealing effects have been found to be limiting factors for infiltration (Ward and Trimble, 2004, p. 73). A surface-sealing crust is caused by raindrop impact and is assumed to exist on bare soils (ASCE, 1996, p. 107).

Many methods and equations have been developed to model infiltration of water into unsaturated soil. Most are inadequate and no one model works well for all situations (Ward and Trimble, 2004, p. 72). One of the most common infiltration models in use is the Green-Ampt model, which assumes ponded conditions, a deep homogeneous soil, uniform soil moisture content, and vertical (piston) flow (ASCE, 1996, p. 106). The Green-Ampt equation used in this report to model infiltration is

$$f = K\,(1 + (\Phi - \theta_i)\,S_f / F)$$

where f is the infiltration rate (cm/hr), K is the effective hydraulic conductivity, Φ is the soil porosity (cm^3/cm^3), θ_i is the initial water content (cm^3/cm^3), S_f is the effective suction at the wetting front (cm), and F is the accumulated infiltration. The values for K, Φ, and S_f can be looked up from figures using the soil's textural class, or the percent sand and percent clay (ASCE, 1996, p. 109-111). Accumulated infiltration (F) values can be determined in the field using an infiltration test. Generally, the model is applied by incrementing F over time and solving for f. The infiltration rate asymptotically approaches the “field saturated” hydraulic conductivity (K_{fs}) of the soil. Field-saturated is often the assumed condition for the unsaturated zone due to entrapped air (Dane and Topp, 2002, p. 817)

Methods

This project was essentially conducted in three phases: I) Preliminary map of suitability zones was created by reviewing existing data; II) Map validation via ground-truthing the soils in each suitability zone; III) Homeowner “willingness to disconnect survey and incentives analysis.

Phase I. Preliminary Data Review

Spatial and tabular soil data for Multnomah County were downloaded from the NRCS’s Web Soil Survey web site (http://websoilsurvey.nrcs.usda.gov/) and cropped to the Gresham city boundary. An initial review of the soil properties was conducted, which led to a preliminary set of soil suitability criteria (Table 3). Every soil type in Gresham was then initially placed into one of four suitability categories: High, Medium, Low, or Not Suitable based on the criteria in Table 3. The criteria in Table 3 were chosen partly because they were the soil properties used to identify suitability for Gresham’s Downspout Disconnection pilot project area, but the suitability zones are specific to this study. A soil series was demoted into a lower suitability zone if it met *any one* of the criteria in Table 3. For example, if a well-drained soil with no restrictive feature, no flooding or ponding, but had a slope of 60%, it was placed into the “Not suitable” zone.

Table 3. Soil properties and preliminary criteria for each suitability zone.

Suitability zone	Drainage class	Depth to restrictive feature	Frequency/ Duration of ponding (Jan-Feb)	Frequency/ Duration of flooding (Jan-Feb)	Slope
High	Moderately well drained or better	N/A	None	None	8% or less
Medium	Somewhat poorly drained or better	N/A	None	None	15% or less
Low	Poorly drained or better	20" to fragipan	None	None	30% or less
Not suitable	Very poorly drained or better	20" to fragipan	Frequent/Long or less	Rare/very brief or better	60% or less

Supplemental GIS layers, such as roads, streams and tax lots, were provided by City of Gresham staff. In addition, a depth-to-groundwater GRID[2] file was downloaded from the United States Geological Survey (USGS) website (Snyder D.T., 2008). All GIS datasets were brought into ArcMap 9.2 and cropped to the Gresham city boundary.

A slope layer was provided by Gresham staff and was included to ensure that very steep slopes were put into the “Not suitable” zone (which coincided extremely well with the steep slopes in the NRCS soil data). For the preliminary map, areas where the seasonally-high groundwater was 10 ft. or less were placed in the “Not suitable” zone due to possibility of flooding basements or yards.

All suitability zones were combined into a single GIS layer in ArcMap and overlayed with the Gresham tax lot layer to partition the tax lots according to suitability zone. Single-family residences were selected and exported to Microsoft Excel to generate a random selection of sites for ground-truthing in Phase II.

Figure 2 was developed from the suitability criteria in Table 3 and shows the spatial distribution of the preliminary soil suitabilities, steep slopes, and areas where the

[2] The GRID file is a raster-based GIS file format, which shows the average depth from the ground surface to the water table surface for any cell on the grid.

seasonally high depth-to-groundwater is 10 ft or less. A 50 ft buffer was added to provide a transition between two non-sequential zones—for example, a “High” zone that abutted a “Not suitable” zone received a 50 ft “Low” buffer *and* a 50 ft “Medium” buffer transition (these buffers, however, were ultimately removed from the final suitability zone map).

Phase II. Map Validation

Phase two involved ground-truthing to validate the preliminary suitability zone map. One hundred single-family residences were randomly selected from each of the High, Medium and Low suitability zones. A letter from the City of Gresham (Appendix III) was mailed to those three hundred residences asking permission for a Portland State University graduate student to extract two soil cores and perform an infiltration test on their property. Homeowners were asked to return a self-addressed, stamped postcard (Appendix III) to the city indicating their level of permission: Permission granted even if nobody is home; Permission granted only if someone is home; Permission not granted.

Materials used in the map validation phase were the following:

- Soil corer (one inch diameter, 36 inches long) from Portland State University
- Double-ring infiltrometer[3] from Oregon State University
- Two five-gallon buckets filled with water for the infiltration tests

[3] A double-ring infiltrometer consists of two thin metal cylinders, typically ~1’ and 2’ in diameter and ~8” deep. They are inserted 2-3” into the ground and filled with water to measure vertical flow infiltration rate.

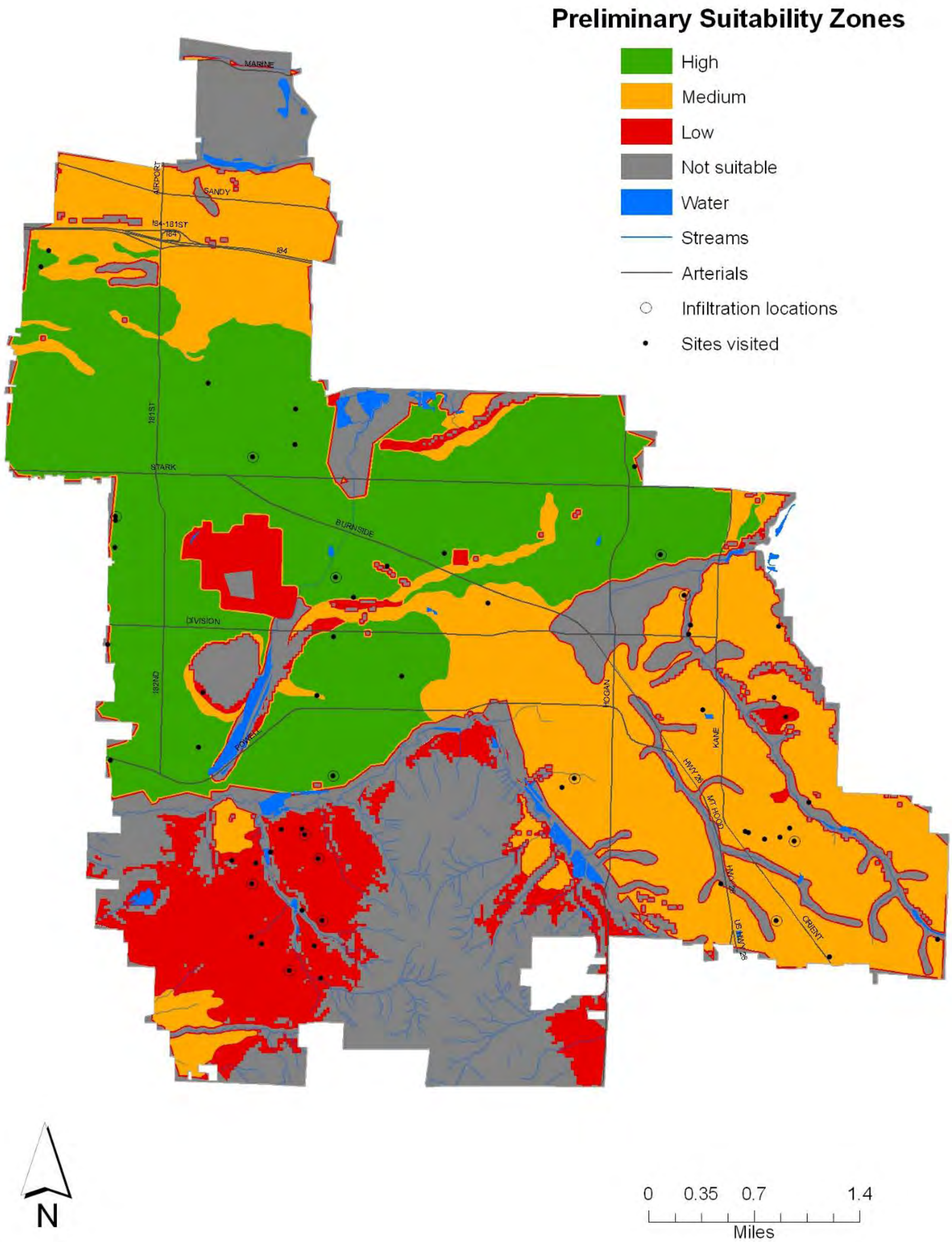


Figure 2. Preliminary suitability zones based on NRCS soil properties, steep slopes and depth-to-groundwater. Also shown are sites visited and locations of infiltration tests.

Sixty homes (20 per zone) were visited from 8 June through 3 July 2009 (Figure 2), which was the best available time window for field work. The first 45 homes visited were those in which unconditional permission was granted, and the additional homes visited (15) were chosen from those in which permission was granted as long as somebody was home up until the window of time was closed. The front door was always knocked on prior to sampling. When feasible, two soil cores were taken from left and right side of the residence (often near an existing downspout location). The core was inserted 8-12 inches at a time, retracted, visually inspected, and the soil separated at horizon breaks. Each soil horizon (A, B and C) was measured for depth and thickness and bagged separately. The same soil horizon from each of the two core samples were bagged together to get an aggregate, representative sample of each horizon at that residence.

Note, in this study, a "C" horizon is not necessarily a true C-horizon, but is instead a relative naming convention referring to the horizon that was deeper and distinctly different than the B-horizon. In some cases the C-horizon was thought to be a fragipan layer but may have been an E-horizon.

All soil samples were taken to Portland State University and analyzed for particle size distributions using the hydrometer method. The methodology closely followed lab guidelines from Portland State University's Geology department: Approximately 50g of soil from each horizon at each residence was ground in a coffee grinder and/or mortar and pestle, weighed, passed through a #10 sieve (2mm) to remove gravel, blended for several minutes with a solution of 50g/L sodium hexametaphosphate ($(NaPO_3)_6$) to disperse the particles and allowed to soak overnight in a 1.0L graduated cylinder. The cylinder was then filled to 1.0L, thoroughly mixed with a mixing rod and timed.

Hydrometer measurements were taken at 15s, 30s, 45s, 1min, 2min, 6min, 30min, 1hr, 3hr, 6hr and 24hr. Temperature and meniscus corrections were included in the final calculations. The resulting particle size distributions were used to determine soil textural classes and were compared to the published NRCS soil textural classes.

Statistical tests were performed on the particle size distribution results for each suitability zone in the A- and B-horizons. The Kruskal-Wallis *H* test (non-parametric analogue to a one-way ANOVA) and Mann-Whitney *U* test (non-parametric analogue to a Student's *t* test) were used to determine if there were significant differences ($p < 0.05$) between suitability zones using the program "R" for statistics.

In addition to soil sampling, infiltration tests were performed at 15 of the residences (five per zone, Figure 2) using a double-ring infiltrometer and the falling-head method (Selker, Keller and McCord, 1999, p. 97). The double-ring infiltrometer was pounded two to three inches into the ground and set up with a floating vertical ruler in the inner ring. Both rings were filled with water from 5-gallon buckets, outer ring first, and timed (during infiltration, the outer ring water confines the inner ring water to flow in the vertical direction only, which is measured). As the ruler dropped with the inner ring infiltrating water, measurements were taken (generally) every minute for 30 minutes, or until the infiltration rate became constant. An initial moisture sample was taken with the soil corer within a few feet from the infiltrometer, and a final moisture sample was taken within the center ring a few minutes after the test had concluded.

The accumulated infiltration data (F) were plotted in Microsoft Excel and input into the Green-Ampt equation ($f = K (1 + (\Phi - \theta_i) S_f / F)$. The unknown parameters of the equation (hydraulic conductivity (K), porosity (Φ), wetting front suction (S_f)) were obtained from figures in the Hydrology Handbook (ASCE, 1996, p. 109-111) using the percents of sand and clay determined from the soil analyses. Infiltration was then plotted as a function of time.

Phase III. Incentives Survey

A willingness and incentives survey (Appendix IV) was mailed to 500 randomly selected single-family residences in the "High" suitability zone in October 2009 (250 owner-occupied and 250 off-site owners). Residences located in the existing drywell area (Appendix II) were excluded, so the survey was only sent to those residences whose stormwater currently discharges to a surface water body. Homeowners were asked to select their level of willingness (1-5 scale) to disconnect their downspouts, what their concerns were, and what would be the *minimum* level of incentive at which they would choose to disconnect. This minimum level of incentive created a market-based "reverse auction" (Thurston *et al*., 2008) where the city could first serve those homeowners who stated they needed the least amount of assistance or incentive. The "bid" in the reverse auction is a homeowner's level of incentive, and the city could then offer its service to the lowest bidders. Using this approach, the city is able to disconnect downspouts at the lowest cost. The survey asked which of the following incentive(s) would be needed to persuade the homeowner to disconnect their downspouts:

- a "how to" installation guide
- a "how to" workshop
- a technical assistance site visit from city staff
- materials and/or installation (labor) provided
- a discount (~$2.00/mo.) on their stormwater utility fee
- a one-time payment that they specify

Similar questions were asked about homeowner's willingness to build a rain garden. The survey responses were returned within two weeks after they were sent and were compiled and logged by City of Gresham staff.

Results

Soil Sampling Results

Note: The following results reflect a change from the preliminary suitability zones. It was discovered during the data analysis phase that the preliminary suitability map was not correct, due to an incomplete soil report downloaded from the NRCS web soil survey. The discovery revealed that the Powell soils (34 A, B, C, D) in the southeast part of Gresham actually contain a shallow fragipan and should have been placed into the Low suitability zone (rather than Medium). The following results are based on this new change in suitability zones, shown in Figure 8.

From the hydrometer analyses in Phase II, particle size distributions were determined for 55 of the 60 sites visited (20, 6, and 29 samples in the High, Medium and Low zones, respectively). Soil samples could not be collected at all 60 sites and in all horizons, mostly due to the limitations of the soil corer when encountering physical obstructions in the soil (rock/gravel or hardpan). Samples that could *not* be collected in each horizon are as follows: Of the 20 sites in the High suitability zone three A-horizons, 11 B-horizons, and 18 C-horizons were not observed or collected; Of the six sites in the Medium zone, two B-horizons and all six C-horizons were not observed or collected; Of the 29 sites in the Low zone, seven A-horizons, four B-horizons, and 16 C-horizons were not observed or collected (Table 4). Thus, while soil samples were analyzed for 55 sites, the numbers of samples processed (n) are different in all horizons. Table 4 shows the means and standard deviations of gravel, sand, silt and clay fractions for each suitability zone and soil horizon as well as the numbers of samples processed for each.

Table 4. Means (and standard deviations) of particle size distributions for each suitability zone and soil horizon. Also shown are the number of samples processed (n) in each zone and horizon. Samples for each horizon could not be collected at each site, explaining in the different samples processed (n) across horizons.

A - horizon	% Gravel	% Sand	% Silt	% Clay	
High	4.4 (2.8)	39.3 (5.0)	49.5 (4.8)	11.3 (3.3)	n=17
Medium	2.6 (2.8)	35.5 (1.3)	52.5 (2.6)	12.0 (2.6)	n=6
Low	1.4 (2.2)	32.6 (8.0)	54.1 (7.5)	13.4 (3.6)	n=22

B - horizon	% Gravel	% Sand	% Silt	% Clay	
High	2.3 (2.6)	40.8 (9.4)	45.8 (7.9)	13.4 (5.4)	n=9
Medium	1.7 (2.6)	34.9 (2.1)	52.3 (5.1)	12.8 (6.5)	n=4
Low	1.5 (2.4)	26.9 (5.6)	56.4 (4.2)	16.6 (4.6)	n=25

C - horizon	% Gravel	% Sand	% Silt	% Clay	
High	3.7 (5.2)	33.1 (3.0)	53.3 (7.0)	13.7 (4.0)	n=2
Medium	-	-	-	-	n=0
Low	0.3 (0.8)	25.3 (8.8)	56.4 (6.2)	18.3 (5.4)	n=13

Results from Table 4 show that the High suitability zone had more gravel and sand, and less silt and clay than the Medium and Low zones in all three horizons except for clay in the B-horizon. **Note**, the results should be treated with some caution due to the low numbers of samples processed, especially in the Medium suitability zone and the C-horizon. Statistical tests were not run on the C-horizon for this reason.

Statistical tests were run on the A- and B- horizons, and due to the small sample sizes, the non-parametric Kruskal-Wallis *H* test (analogue to a one-way ANOVA) and Mann-Whitney *U* test (analogue to a Student's *t* test) were performed. Non-parametric tests (and small sample sizes) have less statistical power than their parametric counterparts, but are still commonly used when certain test assumptions are not met. The null hypothesis (H_o) is that the High, Medium and Low suitability zones are identical with regard to sand, silt and clay content (gravel was not included due to the many samples that lacked any gravel). The Kruskal-Wallis *H* tests rejected the null hypothesis ($p < 0.05$) that the suitability zones are identical for sand and silt in both A- and B-horizons as well as clay in the A-horizon. The Mann-Whitney *U* tests confirm this, rejecting the null hypothesis ($p < 0.05$) in the following ways:

Compared to the Low zone, the High zone had:

- More sand in both A and B-horizons
- Less silt in both A and B-horizons
- Less clay in the A-horizon

Compared to the Low zone, the Medium zone had:

- More sand in the A- and B-horizons
- Less silt in the B-horizon

The tests failed to reject the null hypothesis between the High and Medium suitability zones. The results do suggest that the High zone is more suitable for water infiltration than the Low zone.

Figures 3, 4, and 5 are boxplots (box-and-whisker diagrams) showing the medians and spread of the particle size distributions. The box itself represents the middle 50% of the data and the line within the box is the median. The upper and lower whiskers are the upper and lower quartiles, respectively, and dots are outlier data points. The boxplots are particularly useful for quickly comparing the amounts of gravel, sand, silt and clay across all three suitability zones.

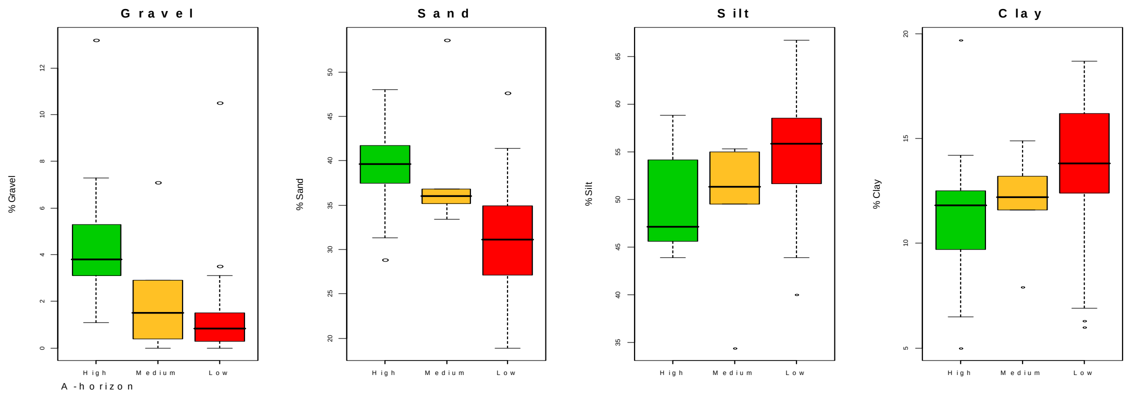


Figure 3. A-horizon boxplots showing the medians and spread of gravel, sand, silt and clay fractions. Numbers of samples: High=17, Medium=6, Low=22.

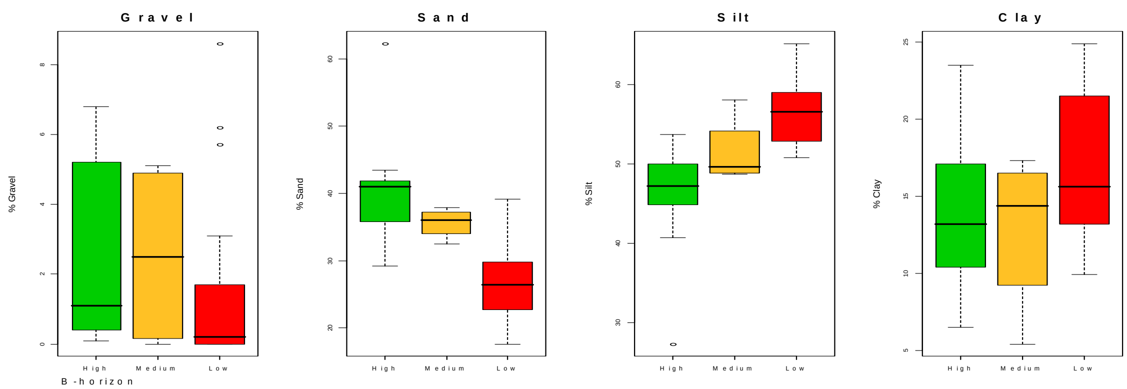


Figure 4. B-horizon boxplots showing the medians and spread of gravel, sand, silt and clay fractions. Numbers of samples: High=9, Medium=4, Low=25.

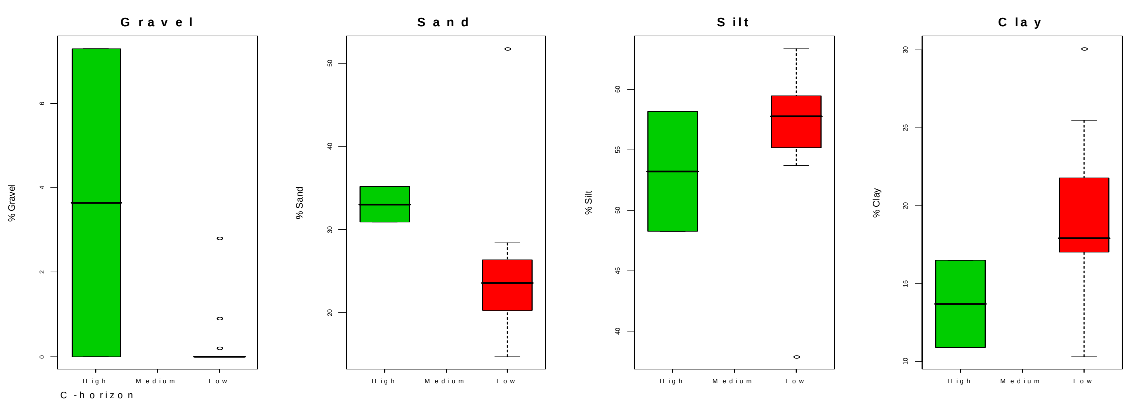


Figure 5. C-horizon boxplots showing the medians and spread of gravel, sand, silt and clay fractions. Numbers of samples: High=2, Medium=0, Low=13.

The medians in Figures 3, 4, and 5 follow the trends of Table 4, where the High zone shows more sand and gravel, but less silt and clay than both the Medium and Low zones (except for clay in the B-horizon). The means (Table 4) and medians of the A- and B-horizons (Figures 3 and 4) are also plotted on the standard USDA soil texture triangle, showing the general textural classes of each suitability zone (Figure 6). Note that Figure 6 does not show the full range of soil textures observed, just the central tendencies of each suitability zone.

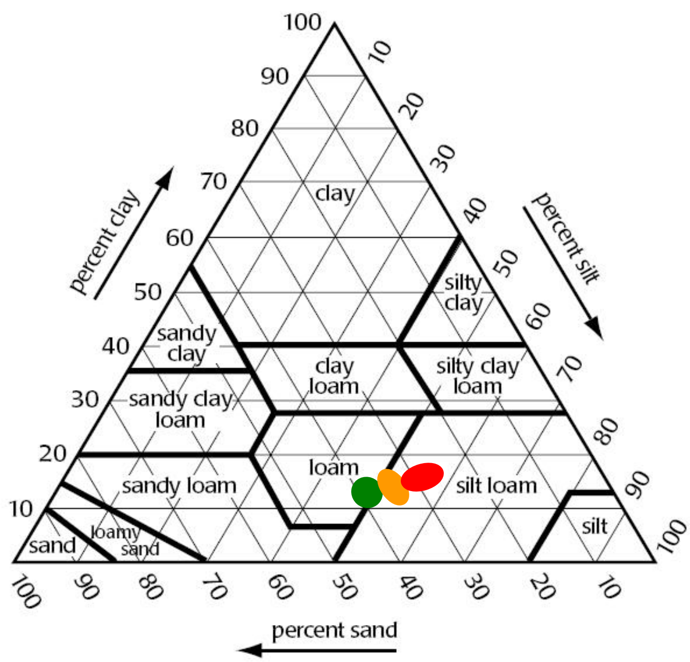


Figure 6. USDA soil texture triangle showing the general textures of soil samples in each suitability zone. Ovals capture the means and medians of both A-and B-horizons in the High (green), Medium (orange) and Low (red) suitability zones.

In the High suitability zone, the 17 A-horizon samples showed nine Loam (53%), seven Silt loam (41%), and one Sandy loam (6%); the nine B-horizon samples showed five Loam (56%), three Silt loam (33%), and one Sandy loam (11%); and the two C-horizon samples were Loam and Silt loam. In the Medium suitability zone, the six A-horizon samples showed four Silt loam (67%), one Loam and one Sandy loam (17% each); the four B-horizon samples showed two Loam and two Silt loam (50% each); there were no C-horizon samples collected in the Medium zone. In the Low suitability zone, the 22 A-horizon samples showed 19 Silt loam (86%) and three Loam (14%), all 25 B-horizon samples were Silt loam (100%), and the 13 C-horizon samples showed 11 Silt loam (84%), one Loam and one Silty clay loam (8% each). The textural class results are summarized in Table 5.

Table 5. Number (and percentage) of soil textural classes in the A, B, and C-horizons of collected soil samples (n), listed by suitability zone.

	A - horizon				
	Sandy loam	**Loam**	**Silt loam**	**Silty clay loam**	
High	**1** (6%)	**9** (53%)	**7** (41%)	-	**n=17**
Medium	**1** (17%)	**1** (17%)	**4** (67%)	-	**n=6**
Low	-	**3** (14%)	**19** (86%)	-	**n=22**
	B - horizon				
	Sandy loam	**Loam**	**Silt loam**	**Silty clay loam**	
High	**1** (11%)	**5** (56%)	**3** (33%)	-	**n=9**
Medium	-	**2** (50%)	**2** (50%)	-	**n=4**
Low	-	-	**25** (100%)	-	**n=25**
	C - horizon				
	Sandy loam	**Loam**	**Silt loam**	**Silty clay loam**	
High	-	**1** (50%)	**1** (50%)	-	**n=2**
Medium	-	-	-	-	**n=0**
Low	-	**1** (8%)	**11** (84%)	**1** (8%)	**n=13**

The soil textural classes determined from the particle size distributions matched 73% of the soil textural classes listed by the NRCS. This study found that 69% of all samples collected were Silt loam in either the A- or B-horizon, compared to 91% listed by the NRCS (2009). This high level of agreement generally confirms the published NRCS soil data. All soil samples collected in the High suitability zone were Multnomah silt loam or Multnomah-Urban land complex except for one sample in the Latourell series; Medium zone samples were Aloha and Aloha-Urban land complex; and the Low zone samples were mostly Cascade silt loam, Powell and Powell-Urban land complex (NRCS, 2009).

Infiltration Test Results

Due to the change in suitability zones (stated in the beginning of the results section), each zone did not receive the original goal of five infiltration tests. Three infiltration tests (in the Powell soil series) were transferred from the Medium to the Low suitability zone. Thus, the High, Medium, and Low suitability zones actually received five, two, and eight infiltration tests, respectively.

Eleven of the 15 infiltration tests yielded viable results and are shown in Table 6. One test in Medium zone and one test in the Low zone likely had water leak out of the infiltrometer, resulting in an unrealistically high infiltration rate. At one site in the Low zone, the infiltration rate was so slow (essentially zero) that the Green-Ampt model did not produce a viable result. Lastly, at another site in the Low zone, soil samples were either not collected or misplaced, so the Green-Ampt parameters could not be estimated from the sand and clay content. These four test results were omitted.

Table 6. Infiltration results for each suitability zone as determined by double-ring infiltration tests and the Green-Ampt model.

	High	Medium	Low
	3.30	1.49	1.52
	1.85	-	0.90
	1.50	-	0.71
	1.32	-	0.66
	1.30	-	0.59
mean	**1.9 in/hr**	**1.5 in/hr**	**0.9 in/hr**

The infiltration tests in the High suitability zone were all performed in the Multnomah soil series, with a published permeability ranging from 0.6 in/hr to 6.0 in/hr (and up to 20in/hr deeper than ~4 feet) (SCS, 1977). The Medium zone infiltration test was conducted in the Aloha soil series, with a published permeability ranging from 0.2 in/hr to 2.0 in/hr (SCS, 1977). The infiltration tests in the Low suitability zone were performed in the Cascade and Powell soil series, with published permeabilities ranging from 0.06 in/hr to 2.0 in/hr (SCS, 1977). Thus, all 11 viable infiltration tests (100%) fell within these permeability ranges, further confirming the NRCS soil data and supporting the validity of the suitability zones.

The infiltration test results should be treated with some caution for several reasons. The small number of tests run (High = 5, Medium = 1, Low = 5) cannot adequately represent infiltration throughout each suitability zone. Most of the infiltration tests were seemingly not run long enough to establish true steady state infiltration rate. For some soil types, several hours may be required, which is a limitation of this study. This is seen in Figure 7 where the Green-Ampt infiltration curve approaches an asymptote, but does not quite level off. It is not known how much further the infiltration rates would have decreased if given enough time, but the result is likely a slight overestimation of the infiltration rate into a field-saturated soil.

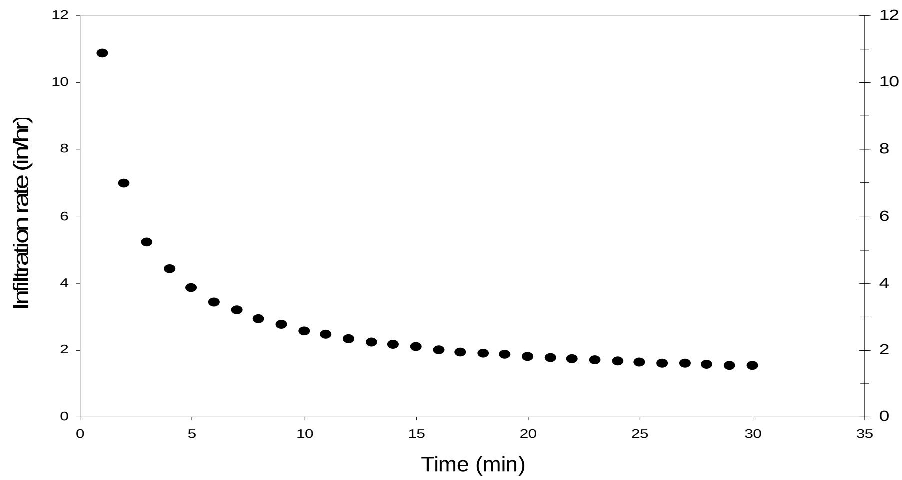


Figure 7. Infiltration rate over time as modeled by the Green-Ampt equation. In this example, the model determined a final infiltration rate of ~1.5 in/hr. Data were obtained from a double-ring infiltometer test.

The infiltration results were plotted as a function of gravel, sand, silt and clay of both A- and B-horizons as well as antecedent soil water content—the relationships were, at best, only weakly correlated ($R^2 \leq 0.33$).

Final Data Review

After the NRCS soil data in Gresham were ground-truthed, the Soil Survey was re-scrutinized and a final table of suitability criteria was created (Table 7). From these criteria, a final suitability zone map was created (Figure 8). Table 7 and Figure 8 include a new "Medium-high" zone, which include highly suitable Multnomah and Latourell soils but have slopes between 8-15%. Thus, some residences in the Medium-high zone may be somewhat less suitable than the High zone due to runoff or landslide potential, but more suitable than the Medium zone. For the "Pits" in Figure 8, no data were available in the Soil Survey—they are highly disturbed excavation pits.

Table 7. Suitability zone criteria used for the final suitability zone map.

Suitability zone	Drainage class	Depth to restrictive feature	Frequency/ Duration of ponding (Jan-Feb)	Frequency/ Duration of flooding (Jan-Feb)	Slope
High	Well drained	N/A	None	None	8% or less
Medium-high	Well drained	N/A	None	None	15% or less
Medium	Somewhat poorly drained or better	N/A	None	None	15% or less
Low	Poorly drained or better	≤ 40" to fragipan	None	None	15% or less
Not suitable	Very poorly drained or better	≤ 30" to fragipan	Frequent/Long or less	Rare/very brief or better	90% or less

The final suitability map differs from the preliminary map in several ways. First, the Powell soils in the southeast portion of Gresham changed from Medium to Low suitability because of an incomplete download from the NRCS Web Soil Survey. For reasons unknown, the data report downloaded from the website and used for the preliminary suitability map did not show any restrictive feature for the Powell series. However, a shallow fragipan (20-30 in.) *is*, in fact, listed in the Soil Survey for these soils, and that a perched water table exists in the wet season.

Second, all 50 ft. buffers were removed because they didn't reflect the actual soil conditions on the ground. For example, where a 50 ft. Low zone buffer was placed over a High suitability soil, the results aligned with the High zone soils much better than the Low zone. Thus, the suitability was actually high, not low.

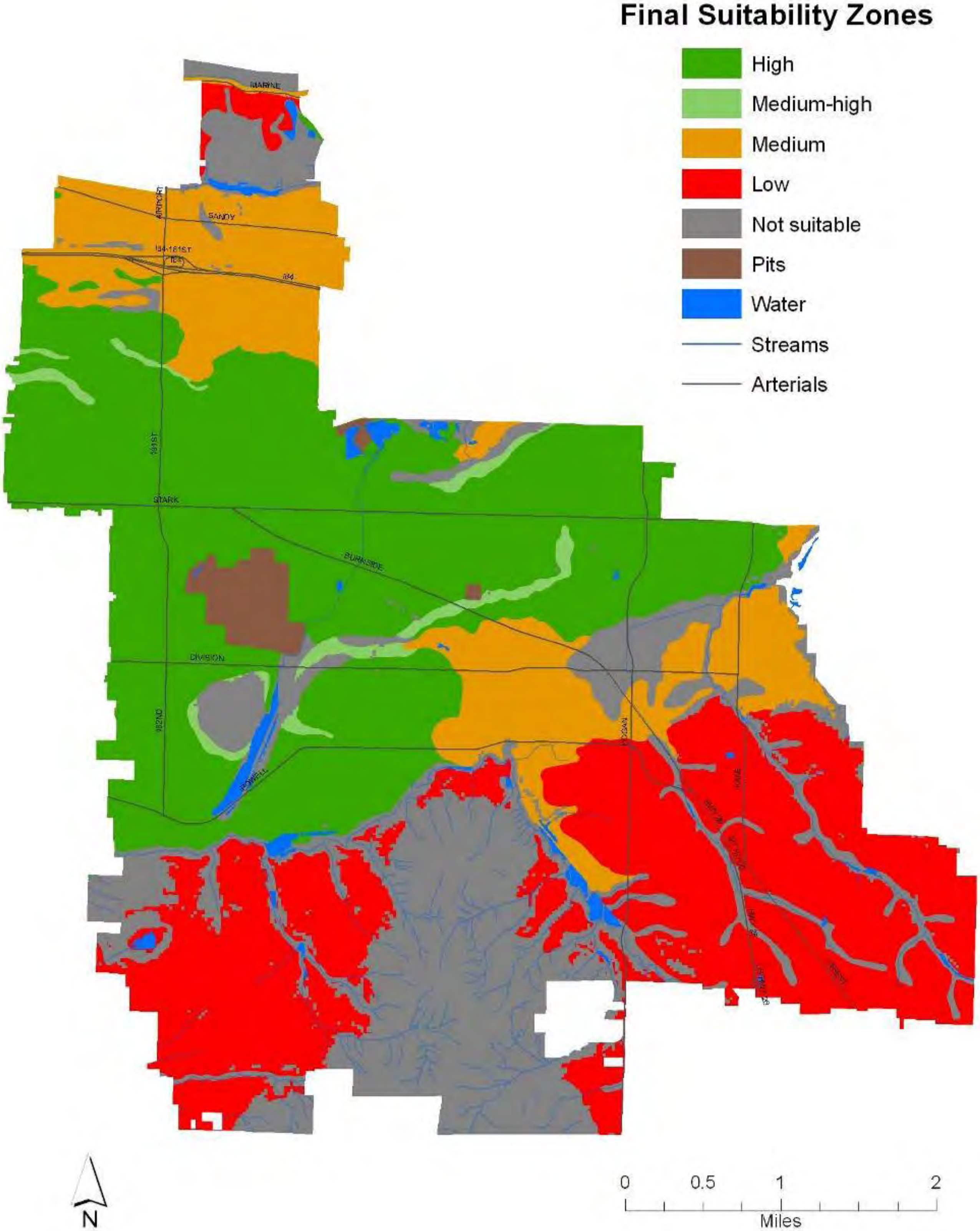


Figure 8. Final suitability zones for downspout disconnection based on NRCS soil data.

Third, the 10 ft. depth-to-groundwater was removed as a limiting factor, which revealed the soils at those locations. It was first thought that residents who live near a shallow water table should not disconnect their downspouts out of concern that they could flood their basements or yards. However, that individual water volume is likely to be negligible compared to the cumulative groundwater contributions of all of the disconnected downspouts located up-gradient. Further, this factor was somewhat redundant because areas where groundwater is high are already identified in the Soil Survey, as can be seen along most streams in Figure 8.

Small areas in the Columbia Slough and a long diagonal swath through the middle of the Fairvew Creek basin were promoted from Medium to Medium-high suitability due to an initial misunderstanding of the hydrologic soil group of an urban-soil complex. The hydrologic soil group "D" only defines the "urban land" portion of the soil complex, while the second rating classifies the soil portion of the complex (ultimately, though, hydrologic soil group was removed as a criterion, as it is mostly analogous to the drainage class criterion). Lastly, the Pits areas were not given a suitability rating due to the absence of any soil properties data.

Table 8 shows the complete list of soil series in Gresham by suitability zone, according to the soil properties criteria. Also included in Table 8 is a new column listing the permeability (inches/hour) of the most limiting layer of each soil series. While permeability of the most limiting layer was not used as a criterion, it could have been.

Table 8. NRCS soil series and selected soil properties in Gresham per suitability zone.

Suitability zone	Map Unit	Soil series	% of zone	Slope (%)	Permeability of most limiting layer (in/hr)	Drainage class	Depth to restrictive feature	Frequency/ Duration of ponding (Jan-Feb)	Frequency/ Duration of flooding (Jan-Feb)
High (5,171 ac)	6B	Burlington fine sandy loam	0.1	0-8	2.0-6.0	Somewhat excessively drained	NA	None	None
	25A	Latourell loam	6.1	0-3	0.6-2.0	Well drained	NA	None	None
	25B	Latourell loam	5.6	3-8	0.6-2.0	Well drained	NA	None	None
	26A	Latourell-Urban land complex	2.6	0-3	0.6-2.0	Well drained	NA	None	None
	26B	Latourell-Urban land complex	2.7	3-8	0.6-2.0	Well drained	NA	None	None
	29A	Multnomah silt loam	20.6	0-3	0.6-2.0	Well drained	NA	None	None
	29B	Multnomah silt loam	7.9	3-8	0.6-2.0	Well drained	NA	None	None
	30A	Multnomah-Urban land complex	48.5	0-3	0.6-2.0	Well drained	NA	None	None
	30B	Multnomah-Urban land complex	5.3	3-8	0.6-2.0	Well drained	NA	None	None
	52A	Urban land-Multnomah complex	0.5	0-3	0.6-2.0	Well drained	NA	None	None
Medium-high (220 ac)	25C	Latourell loam,	31.1	8-15	0.6-2.0	Well drained	NA	None	None
	29C	Multnomah silt loam	45.5	8-15	0.6-2.0	Well drained	NA	None	None
	51C	Urban land-Latourell complex	15.9	8-15	0.6-2.0	Well drained	NA	None	None
	52C	Urban land-Multnomah complex	7.5	8-15	0.6-2.0	Well drained	NA	None	None
Medium (2,113 ac)	1A	Aloha silt loam	17.5	0-3	0.2-0.6	Somewhat poorly drained	NA	None	None
	1B	Aloha silt loam	4.6	3-8	0.2-0.6	Somewhat poorly drained	NA	None	None
	2A	Aloha-Urban land complex	34.8	0-3	0.2-0.6	Somewhat poorly drained	NA	None	None
	20C	Haplumbrepts (moderately steep)	0.7	3-25	0.2-2.0	Well drained	NA	None	None
	36A	Quafeno loam	10.3	0-3	0.2-0.6	Moderately well drained	NA	None	None
	36B	Quafeno loam	7.7	3-8	0.2-0.6	Moderately well drained	NA	None	None
	36C	Quafeno loam	4.2	8-15	0.2-0.6	Moderately well drained	NA	None	None
	37A	Quatama loam	1.8	0-3	0.2-0.6	Moderately well drained	NA	None	None
	37B	Quatama loam	6.6	3-8	0.2-0.6	Moderately well drained	NA	None	None
	37C	Quatama loam	2.3	8-15	0.2-0.6	Moderately well drained	NA	None	None
	38A	Quatama-Urban land complex	6.1	0-3	0.2-0.6	Moderately well drained	NA	None	None
	54B	Urban land-Quatama complex	0.5	3-8	0.2-0.6	Moderately well drained	NA	None	None
	54C	Urban land-Quatama complex	2.8	8-15	0.2-0.6	Moderately well drained	NA	None	None
Low (3,727 ac)	7B	Cascade silt loam	24.9	3-8	0.06-0.2	Somewhat poorly drained	20-30 to fragipan	None	None
	7C	Cascade silt loam	9.5	8-15	0.06-0.2	Somewhat poorly drained	20-30 to fragipan	None	None
	10B	Cornelius	0.6	3-8	0.06-0.2	Moderately well drained	30-40 to fragipan	None	None
	34A	Powell	14.0	0-3	0.06-0.2	Somewhat poorly drained	15-24 to fragipan	None	None
	34B	Powell	36.6	3-8	0.06-0.2	Somewhat poorly drained	15-24 to fragipan	None	None
	34C	Powell	5.1	8-15	0.06-0.2	Somewhat poorly drained	15-24 to fragipan	None	None
	35A	Powell-Urban land complex	7.3	0-3	0.06-0.2	Somewhat poorly drained	15-24 to fragipan	None	None
	45	Sauvie silt loam, protected	2.1	0-2	0.2-0.6	Poorly drained	NA	None	Rare/Very brief
Not suitable (3,537 ac)	7D	Cascade silt loam	22.7	15-30	0.06-0.2	Somewhat poorly drained	20-30 to fragipan	None	None
	7E	Cascade silt loam	26.5	30-60	0.06-0.2	Somewhat poorly drained	20-30 to fragipan	None	None
	14C	Delena	0.2	3-12	0.0-0.6	Poorly drained	20-30 to fragipan	Frequent/Brief	None
	20F	Haplumbrepts (very steep)	0.7	30-90	0.2-2.0	Well drained	NA	None	None
	25D	Latourell loam	1.4	15-30	0.6-2.0	Well drained	NA	None	None
	29D	Multnomah silt loam	2.7	15-30	0.6-2.0	Well drained	NA	None	None
	29E	Multnomah silt loam	2.9	30-60	0.6-2.0	Well drained	NA	None	None
	34D	Powell	2.0	15-30	0.06-0.2	Somewhat poorly drained	15-24 to fragipan	None	None
	40	Rafton silt loam, protected	7.6	0-2	0.2-2.0	Very poorly drained	NA	Frequent/Long	Rare/Very brief
	55	Wapato	11.5	0-3	0.2-0.6	Poorly drained	NA	Frequent/Long	Frequent/Brief
	57	Wollent silt loam	19.2	0-3	0.2-0.6	Poorly drained	NA	Frequent/Long	None
	W	Water	2.6						

Survey Results

Surveys were sent to 500 randomly selected single-family residences in the High suitability zone that discharge to surface water (i.e. not in Gresham's drywell area). Of the 500 surveys that were mailed out, 94 were returned (19%); 55 from on-site owners and 39 from off-site owners. Eighty-eight out of the 94 returned surveys had indicated some level of willingness or unwillingness to disconnect their downspouts: 31% of these were *not* willing and 22% were *very* willing to disconnect. Ten percent stated that their downspouts were already disconnected.

Unfortunately, 51% of all respondents did not select any incentive on the survey, and many selected several. Of the 19 respondents who said they were "very willing" to disconnect, two also indicated at least one incentive on the survey, suggesting that while they may be very willing, they probably need something to help compel them to take that step. Only 3% of all respondents said they were willing without any incentive to participate in the program. Table 9 lists each incentive included in the homeowner survey and the percentage of each that respondents indicated would help entice them to disconnect their downspouts.

Table 9. Percentage of incentives that survey respondents indicated would help entice them to disconnect their downspouts.

35%	(33/94)	Discount on stormwater utility fee
20%	(19/94)	Materials provided
18%	(17/94)	How-to guide
16%	(15/94)	Labor provided
14%	(13/94)	Technical assistance
9%	(8/94)	How-to workshop

As can be seen in Table 9, a discount on the stormwater utility fee (survey stated ~$2.00/mo) was clearly the most popular incentive to help entice homeowners to participate in a downspout disconnection program. (Note, the actual discount to a residence would be $2.32/mo., which is the on-site management portion (27%) of the stormwater fee.) The next most popular incentives were free materials, a how-to guide, free labor, technical assistance and a how-to workshop (Table 9). Three respondents wrote in that they would need, on average, $23.00 to persuade them to disconnect.

Similar questions in the survey were asked for building a rain garden with the results shown in Table 10. Again, the most popular incentive was a ~$2.00/mo. discount on the stormwater utility fee followed by a how-to guide, free materials, free labor and technical assistance, and a how-to workshop. Four respondents indicated that they would need, on average, $212.50 to persuade them to build a rain garden on their property, and 12% of respondents indicated that they don't have space to accommodate a rain garden.

Table 10. Percentage of incentives that survey respondents indicated would help entice them to build a rain garden.

30%	(28/94)	Discount on stormwater utility fee
29%	(27/94)	How-to guide
19%	(18/94)	Materials provided
16%	(15/94)	Labor provided
16%	(15/94)	Technical assistance
13%	(12/94)	How-to workshop

These survey responses were translated into potential water volumes that could be diverted from the stormwater sewer system as well as costs to the city. These costs and benefits will be distributed among Gresham's drainage basins as follows: Fairview Creek (44%), Johnson Creek (30%), Columbia Slough (24%), and Kelly Creek (3%). The following calculations are based on two assumptions: 1) The full proportion of Gresham's residences that requested a stormwater utility discount in the High suitability zone and not in the drywell area (4,894 residences) follow the trends of the survey responses; 2) The average 1,500 ft^2 home can safely disconnect half of their downspouts (= 750 ft^2). Given these assumptions, Gresham can potentially divert 33.6 million gallons (100 acre feet) of stormwater each year by providing a $2.32 discount on participating residents' stormwater utility fee[4], which equates to a cost of $47,700 annually in reduced fees to the city. Roughly two-thirds of these respondents also indicated at least one additional incentive to the stormwater fee reduction, so they may or may not disconnect with a fee reduction alone (e.g. may also need a "how-to" guide).

Another optimistic, yet reasonable estimate of potential stormwater diversions is based on the 24% of respondents that 1) stated they were either willing or very willing to disconnect; and 2) did not select more incentives than the stormwater fee discount and/or the how-to guide (and may not have indicated any incentive at all). Thus, if Gresham were to offer *both* of these incentives, it is optimistic, but reasonable to expect that these homeowners would participate. If the proportion of these homeowners in the High suitability zone (not in the drywell area) were to disconnect, Gresham could divert over 23 million gallons (71 acre feet) of stormwater from the storm sewer system at a cost of $32,700 in stormwater fee reductions, plus the cost of creating (on website and possibly printing) a how-to guide. It should also be expected that many of these residences will not qualify for downspout disconnection due to setback (space) requirements, resulting in lower potential flow reduction and lower costs to the city than those stated here. Additional costs will be incurred by dispatching city staff to verify safety requirements and confirm that each home has actually disconnected their downspouts.

Discussion

Based on a thorough review of existing soil data, particle size distributions, infiltration test results, field observations and homeowner accounts, there is reasonable

[4] Calculation = (4,894 residences) (750 ft^2/residence) (42 in/yr) (1 ft/12 in) (7.48 gallons/ft^3) (35%)

confidence that over 4,800 residences that currently discharge to surface water bodies in Gresham can safely disconnect their downspouts, particularly in the Fairview Creek and Columbia Slough basins (Appendix I). These residences are all in the High suitability zone and do not discharge to Gresham's drywell area. Soils in the High zone had, on average, higher amounts of gravel and sand and lower amounts of silt and clay than the Medium and Low zones, except for clay content in the B-horizon (Table 4, Figures 3-6).

The Latourell soils (25A, 25B, 26A, 26B) in the High suitability zone may not actually be highly suitable for infiltration, even though they fit all of the criteria. Dr. Scott Burns (Portland State University's leading soil scientist) suggested that the Medium-high or Medium suitability zone may be more appropriate for these soils. A portion of Gresham's drywell area (Appendix II) is in these Latourell soils, and can be a good source of information regarding their suitability for infiltration.

Results from the Medium suitability zone tended to fall in between the High and Low suitability zones with regard to their particle size distributions (less gravel and sand and more silt and clay than the High zone, and more gravel and sand and less silt and clay than the Low zone), except for the clay fraction in the B-horizon (Table 4, Figures 3-6). However, the very low number of samples processed makes it impossible to make any definitive statements about the Medium zone. There is some concern about the Aloha soils (1A, 1B, 2A) in the Medium zone because the Soil Survey (1977) states that the "lower part of the subsoil and the upper part of the substratum ranges from a slightly brittle layer to a fragipan that is very weak." Even though this fragipan layer may be brittle and very weak (and deeper than 80 in.), it could cause water to perch and flood basements or yards in some storm events. For this reason, the Aloha soils in the Medium zone warrant extra attention before extending the Downspout Disconnection Program there.

Several sites in the Low suitability zone exhibited interesting characteristics including light gray colors, redoximorphic features in the soil matrix and saturation. The light gray layer could be a fragipan below the B-horizon but could possibly be an E-horizon that has been leached of its color. Since this layer was always observed *below* the B-horizon, it is not thought to be an E-horizon (an E-horizon is typically located *above* the B-horizon). Some of these observations were corroborated by a few homeowner accounts (Appendix V).

Soil saturation and redox features could be caused by perched water sitting atop a shallow fragipan, which was listed in the NRCS Soil Survey and resulted in all of the Cascade silt loams south of Johnson Creek and the Powell series in the southeast to be classified as Low suitability (as well as much smaller areas of the Cornelius and Delena series). The fragipan in the Cascade series is listed as 20 to 30 in. deep and from 2 to more than 4 ft. thick (~4 to 6^+ ft. total depth); the fragipan in the Powell series is listed as 20 to 40 in. deep and from 2 to 4 ft. thick (SCS, 1977). It is not known what the true extent of this fragipan is, and the degree to which this layer may inhibit on-site stormwater management. There may be mitigation measures that could increase infiltration capacity (e.g. breaking through the pan, sandy soil amendments, and/or rain garden). Further study is therefore warranted before promoting downspout disconnection into the Low suitability zone.

The suitability zone map can be used as a reference to help the City of Gresham target their Downspout Disconnection Program and to highlight those areas where the city should proceed with caution. The map is a best estimate based on readily available

NRCS data, field observations and lab tests. The map can also be thought of as “Level of Confidence” zones that reflect the likelihood that treating stormwater on-site will safely infiltrate into the ground during *most* storm events. Large storm events may exceed the infiltration capacity of the soil and result in runoff, so planning for this possibility is advised (especially in the Medium and Low zones). Gresham may chose to follow the recommendations of Seattle and make sure any overflow from large storms goes to the street and not into a house’s foundation or a neighbor’s property. Regardless of whether a site can infiltrate all of its stormwater or not, any amount of infiltration will alleviate the burden to Gresham’s streams and will help the city meet its NPDES-MS4 water quality permit requirements.

The survey responses are a general indicator of the attitude and willingness of Gresham’s residents to disconnect their downspouts, but do not necessarily represent the actual actions that residents will take. For example, 22% of respondents indicated that they were “very willing” to disconnect, suggesting that little or no incentive is needed. However, this does not mean that they will actually disconnect on their own and some form of incentive will likely be needed to compel them to participate in the program.

It will likely take many years before the city can expect to reach sizeable stormwater flow reductions; similarly, the costs to the city will be incurred gradually. There will also be additional costs (not accounted for in this report) to the city to verify that each residence safely qualifies for the program and that each residence has, in fact, disconnected their downspouts before the fee discount can be applied. Thus, the true cost for the city will be higher than $2.32/residence, as was calculated here. The city may be able to incur the costs more slowly by following the “reverse auction” concept laid out by Thurston *et al*. (2008).

Limitations

Samples for each horizon could not be collected at all sites due to gravel, rock, and/or a hardpan layer, which prevented the one-inch diameter soil corer from penetrating. Thus, at some sites, horizons were not accessible or observed. At other sites, insufficient amounts of soil were collected (< 30g) to run a reliable hydrometer analysis. Further, the soil corer could only reach a maximum depth of approximately 34 inches, limiting the scope of the soil analyses.

There were a few problems with the infiltration tests. Most tests were not run long enough to establish a true steady state infiltration rate (due to a lack of water on-hand). Some tests likely had leakage out of the rings resulting in an unrealistic overestimation of the infiltration rate. In addition, the measurement ruler would sometimes slip and stick against its support piece, causing inaccurate readings. Even if accurate infiltration rates were determined, it would seem imprudent to try to predict infiltration rates over broad urban areas due to site-specific differences (e.g. lack of vegetation, surface crusting and/or surface compaction, number of worm and root holes), which can greatly alter the infiltration properties of a soil (Ward and Trimble, 2004, p. 66-68, Dane and Topp 2002, p. 817). In short, urban soils are notoriously disturbed (A. Yeakley, personal communication, May 13, 2009), and can result in infiltration rates that vary widely compared to similar, undisturbed soils (S. Burns, personal communication, October 22, 2009).

Recommendations

The City of Gresham can begin implementing the Downspout Disconnection Program in the High and Medium-high suitability zones. While these areas should sufficiently allow water to infiltrate into the ground, every home may not qualify. Therefore, every participating home should be visited to check site-specific conditions such as slope, land use, overflow direction and space and setback requirements. A much less costly option for the city could be to simply advertise and widely distribute brochures (such as the City of Seattle) so homeowners have the necessary technical and safety information they need to assess their own site and disconnect downspouts themselves. This strategy, however, would make it very difficult to monitor the effectiveness of the program over time because without some incentive, many residents won't see a compelling reason to register with the city that they have actually disconnected.

More research is needed in the Medium and Low suitability zones, particularly with regard to the Powell and Cascade series (20-40 in. fragipan) as well as the Aloha series (possible fragipan more than 80 in.) soils. The presence of a shallow fragipan may impede infiltrating water, causing the water to perch and possibly flood yards or basements, especially during large storm events. Homeowners can be a source of invaluable information, so a homeowner survey is suggested as a relatively cost-effective way to learn more about the potential complications in these areas before extending the Downspout Disconnection Program there.

Special attention should also be given to those areas where there is a shallow depth-to-groundwater (usually near creeks) in all suitability zones. As the Downspout Disconnection Program expands over the years and increasing numbers of residences divert their stormwater back into the ground, an elevated water table may occur, especially in wet years. Flooding from high groundwater has been observed in the lower Johnson Creek watershed. The record rainfall years of 1996 and 1997 led to groundwater flooding of Crystal Springs Creek and Holgate Lake, which lasted for months to years (Lee and Snyder, 2009). To prepare for this possibility, the city should consider a groundwater monitoring plan to ascertain the long-term effects of disconnecting downspouts as well as encouraging homeowners to plant large trees on site, which are known to take up large amounts of groundwater in the growing season (Ward and Trimble, 2004, p. 87) and create flow paths along root channels (T. Lindbo, personal communication, November 13, 2009). For this very reason, the City of Portland offers a stormwater utility discount to homeowners with four or more large trees (>15 ft tall) on their property (City of Portland, 2009).

Due to all of the potential land-use differences in an urban area, infiltration rates can vary substantially. Thus, measuring infiltration in the discharge area is advisable if there is concern of site suitability (e.g. compaction, lack of vegetation, history of ponding, etc). If building a rain garden, it is recommended to measure infiltration at each rain garden location. However, performing double-ring infiltration tests and applying the data to the Green-Ampt model is impractical at this scale. An alternative could be a simpler test, such as a percolation test. In a percolation test designed for a rain garden, a small hole is dug (at least 12 in. deep) and filled with water two times, the second fill immediately after the first has soaked in. If the water of the second filling soaks in at a rate above 2 in/hr, the site is considered suitable (EMSWCD, 2009). It can be filled a third time to ensure the percolation rate remains constant. Having a direct measure of a site's infiltration rate will add confidence about the site's suitability and can help prevent flooding or runoff problems before they arise.

In order to achieve willing participation in a downspout disconnection program, it is recommended that the city advertise and offer the most popular incentive of a $2.32 stormwater fee reduction. It will likely entice many homeowners to actually take that step and disconnect their downspouts. Most homeowners will also need some technical assistance, so a thorough, easy-to-follow web page (and/or pamphlet) with how-to instructions and safety guidelines is also recommended. The city will also need to ensure that participating residences have actually disconnected their downspouts and met safety and setback requirements, so city staff will need to visit each site before registering a home as "disconnected." Many of these recommendations follow the City of Portland's well-established downspout disconnection and Clean River Rewards programs, which the City of Gresham can reference when designing its own program.

Acknowledgments

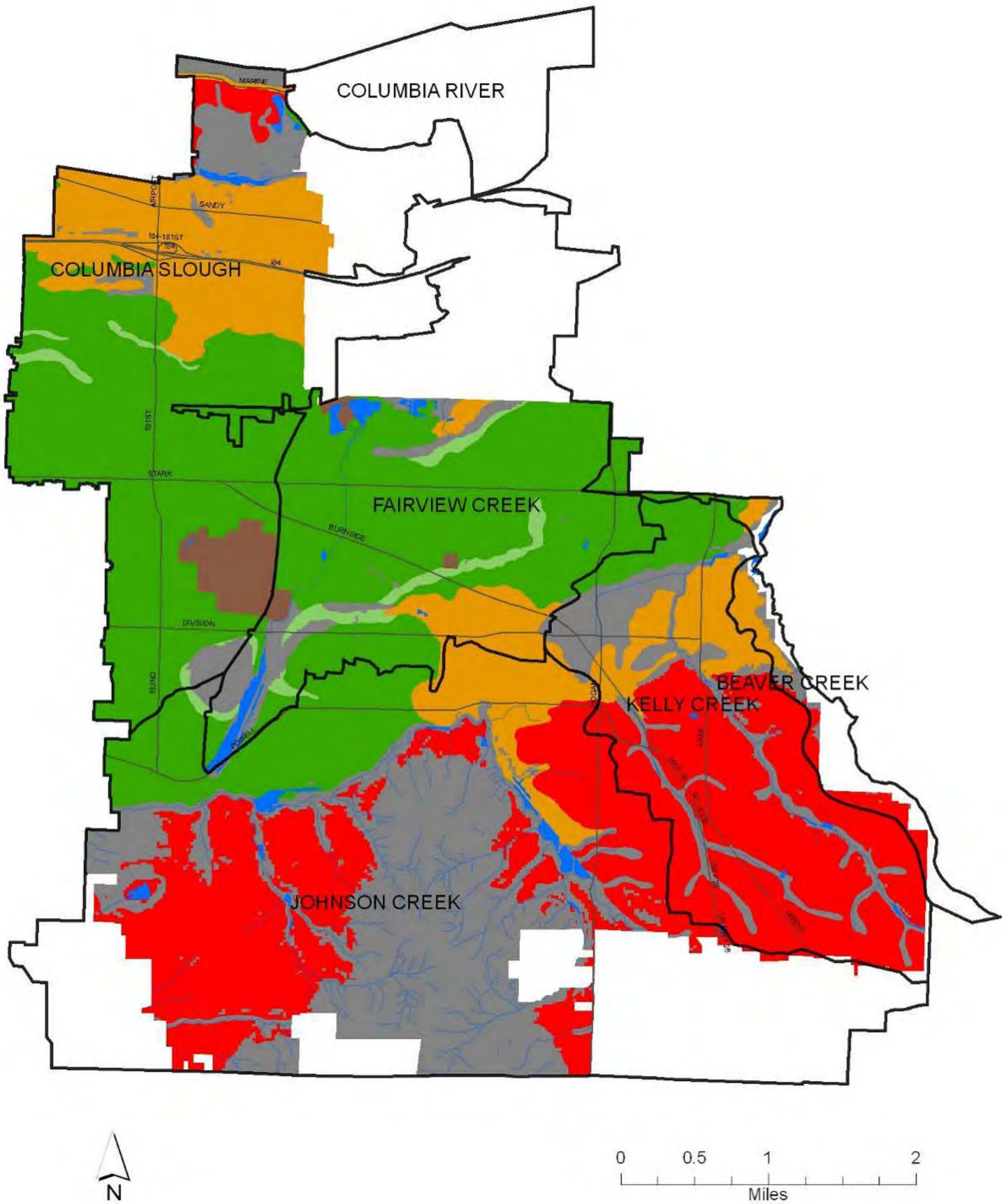
I would like to thank my committee: Dr. Joe Maser (Portland State University) for his guidance and encouragement; Torrey Lindbo (City of Gresham) for his thorough, helpful input every step of the way, and Keri Handaly (City of Gresham) for her knowledgeable insights and invaluable outreach help. I would also like to thank those who helped me along the way, including Portland State University's Dr. Josh Caplan, Dr. Alan Yeakley, Kate Norton and Dr. Scott Burns; The City of Gresham's Deanna Foster, Pam Nooyen, Gabrielle Fraley and Jamie Stamberger, Dr. Erick Burns (United States Geological Survey), Dr. John Selker (Oregon State University), as well as Portland State University students Angelique Hockett, Molly Swanson, Ashley Edwards and Whitney

Temple who volunteered their time to help me collect field data. Thanks also to all of the unnamed envelope stuffers who got the letters and surveys mailed out.

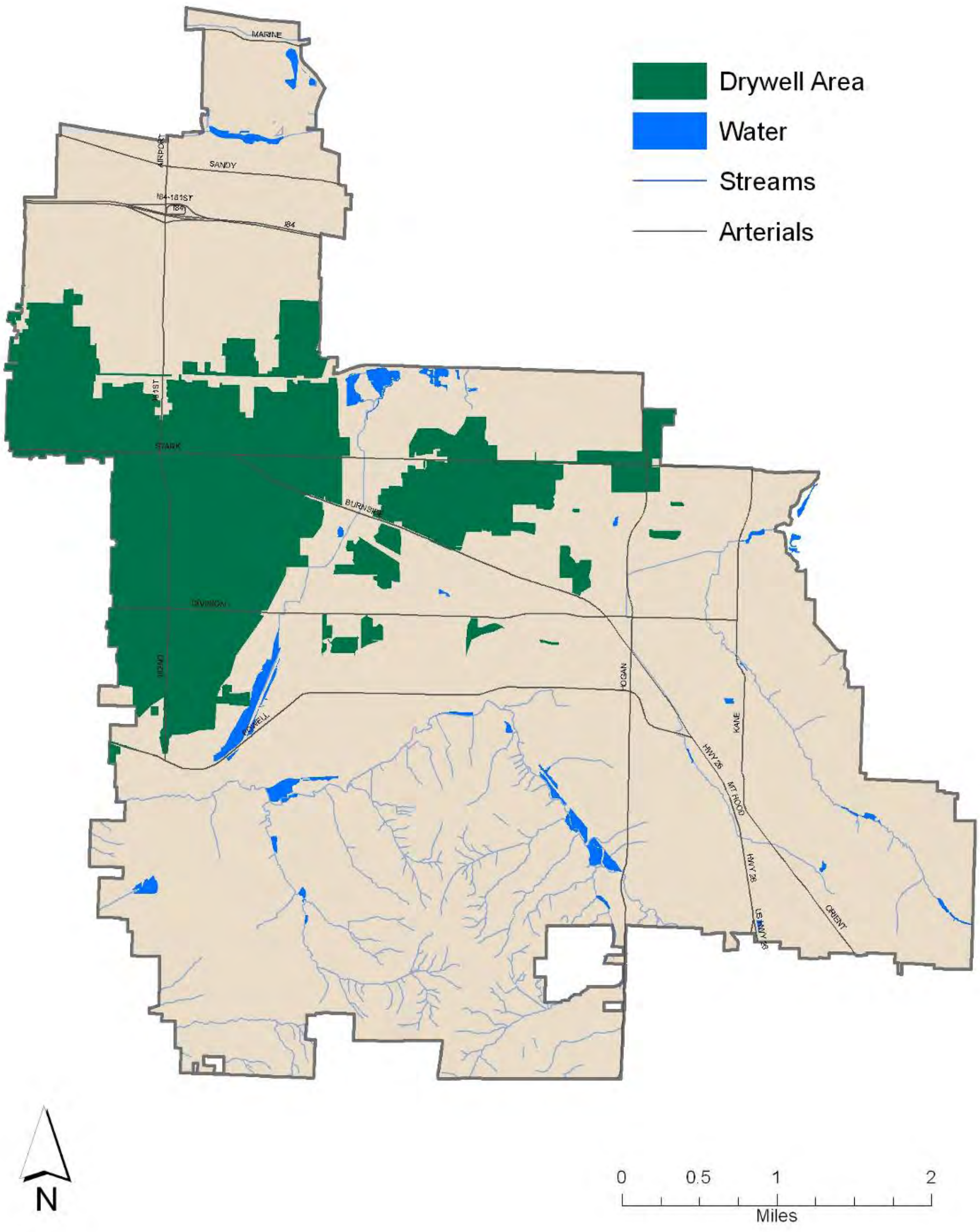
Personal Statement

My dealings with City of Gresham staff were wholly enjoyable. I was fully encouraged to pursue this project and was given freedom to execute it. Specifically, I cannot overstate my gratitude to Torrey Lindbo for all of his guidance and support from the very beginning. He provided the initial idea for the project, spearheaded a kick-off meeting that brought other Gresham staff on board, and always thoroughly reviewed and commented on the project as it progressed. Keri Handaly always provided valuable insight when needed and was instrumental in producing the homeowner letter of permission and the homeowner survey—both of which were integral to the project. Every other staff member I met offered and delivered help whenever I asked, particularly Pam Nooyen and Deanna Foster for supplying GIS data and providing large maps that were invaluable for the ground-truthing phase, Jamie Stamberger for generously providing the most current information on Gresham's Downspout Disconnection pilot program, and Gabrielle Fraley for her help and insights into soil sampling methods. Everyone I worked with at the City of Gresham was approachable, accessible, friendly and helpful.

Appendix I. Gresham's Drainage Basins



Appendix II. Gresham's Drywell Area



Appendix III. Letter to Residents

CITY OF GRESHAM

Department of Environmental Services
1333 N.W. Eastman Parkway
Gresham, OR 97030-3813
(503) 618-2525
FAX (503) 661-5927
www.GreshamOregon.gov

David S. Rouse
Director

Transportation & Development Services
John Dorst
Deputy Director

Office of Community Relations
Tam Driscoll
Manager

Parks & Recreation Division
Randy Shannon
Interim Manager

Watershed Management Division
Steve Fancher
Manager

Wastewater Services Division
Brian Stahl
Interim Manager

Water Division
Brian Stahl
Manager

Recycling & Solid Waste Program
Dan Blue
Manager

May 18, 2009

Dear Resident,

The City of Gresham is partnering with Portland State University's (PSU) Environmental Science and Management Department to create an updated soil map of the city. This letter is to notify you that your neighborhood has been randomly selected for soil testing. If you agree, the tests will be conducted on the front lawn about 5-10 feet from your home's foundation. The test will not affect the appearance of your lawn. The data collected will not be associated with your personal address and will be kept confidential.

A postage paid response card is enclosed for your convenience. If you do not wish to participate, please let us know. Tests will not be conducted on your property without someone being at home, unless you indicate that it is okay on the postcard.

A graduate student from PSU will be visiting neighborhoods in June during daylight hours. Three soil cores about the size of a quarter will be taken back to PSU to determine the particle size distribution and other characteristics (e.g. moisture and texture). Infiltration testing may also be conducted by temporarily inserting two thin metal rings (~1 ft and 2 ft in diameter) approximately three inches into the soil. The rings will be filled with water and timed to see how long it takes to drain into the soil.

The new map will group areas of the city by soil type and infiltration ability. This research will assist the city in meeting future stormwater program planning goals as required by the city's permit from the Oregon Department of Environmental Quality (DEQ). The primary goal is to capture and infiltrate stormwater in the most cost effective manner possible.

The student, Brian Fletcher, will be issued a photo identification badge from the city for your reference. I hope that you will agree to participate in the random city-wide soil testing project to enable further advancement of our stormwater management and stream protection efforts in Gresham. Please do not hesitate to contact me if you have any questions about this project or other stormwater programs.

For a variety of stormwater resources for residents, please visit our web page at: http://greshamoregon.gov and type "watershed" in the search engine box at the top right hand portion of the home page.

Sincerely,

Keri M. Handaly, Community Watershed Steward
503-618-2657
Keri.handaly@ci.gresham.or.us
Brian C. Fletcher, Master of Environmental Management
bfletch@pdx.edu

Portland State UNIVERSITY

Appendix III cont'd. Letter to Residents - Return Postcard

City of Gresham Soil Survey—Map Update Project

☐ I give permission for the city's partner from Portland State University to conduct a soil infiltration test and remove two soil core samples on my front lawn, even if I am not at home.

☐ I wish to participate in the soil survey data collection effort, but request that tests and soil core samples only be taken when someone is at home.

☐ I do not wish to participate in the city's effort to update the soils map by allowing soil infiltration and soil core sampling on my property.

Name____
Address____

Appendix IV. Homeowner Letter and Incentives Survey

CITY OF GRESHAM

Department of Environmental Services
1333 N.W. Eastman Parkway
Gresham, OR 97030-3813
(503) 618-2525
FAX (503) 661-5927
www.GreshamOregon.gov

David S. Rouse
Director

Transportation & Development Services
John Dorst
Deputy Director

Office of Community Relations
Tam Driscoll
Manager

Watershed Management Division
Steve Fancher
Manager

Wastewater Services Division
Paul Eckley
Manager

Water Division
Brian Stahl
Manager

Recycling & Solid Waste Program
Dan Blue
Manager

October 15, 2009

Dear Gresham Homeowner:

The city is offering homeowners assistance to improve local streams. **Please return the enclosed short survey by Oct 30, 2009.**

Even if you do not wish to participate, your answers are important and will help ensure the efficient delivery of city services from your stormwater rates. The results will be kept confidential.

Your neighborhood has been identified as having soils that allow two of the most effective techniques for stormwater management: disconnecting downspouts and building rain gardens.

The survey results will be used to decide the order in which homes will receive assistance and to project future costs for the program. Homeowners requesting the <u>least</u> amount of resources (materials, labor, and money) will be served first. The goal is to use the existing budget to create the most cost-efficient program possible, while improving local stream conditions.

Frequently asked questions are provided on the back of this letter. If you have additional questions, please call (503) 618-2657.

Sincerely,

Keri Handaly
Community Watershed Steward

FREQUENTLY ASKED QUESTIONS

Why is the City doing this?
Gresham receives almost 40 inches of rain annually. This water runs off roofs, sidewalks and driveways and flows to our streams through a pipe system, carrying many pollutants with it. Therefore, our streams do not meet the State of Oregon's standards for water quality. Based on this, the Department of Environmental Quality (DEQ) has issued the city a stormwater permit that requires additional efforts to protect our local streams and rivers.

Is this mandatory?
At this time, our DEQ permit does not make this approach mandatory, but it is highly encouraged.

How can I help?
We hope that those who are able and willing to disconnect downspouts and/or build rain gardens will do so in order to protect our surface water and preserve our natural areas for future generations.

Why rain gardens and disconnected downspouts?
By filtering water into the ground rather than sending it to the streams, we'll improve stream quality and recharge the groundwater supply.

What is a rain garden?
Disconnected downspouts can be directed onto lawn, a landscaped area or into a rain garden in order to absorb the water from your roof. A rain garden is a landscaped area that has been excavated slightly and planted like a flower bed in order to maximize the amount of water that can be absorbed into the ground. Rain gardens may make disconnection of downspouts possible in areas that otherwise would not be suitable.

Are you sure the ground can infiltrate that much additional water if I disconnect my downspouts?
The City of Portland has disconnected almost 50,000 homes through its program with almost no issues. Gresham staff are using lessons learned from Portland's experience, plus soil maps updated in conjunction with Portland State University to identify suitable areas. In addition, all homes that participate in the program will receive free safety inspections to protect your property and that of your adjacent neighbors. Homeowners that are unhappy with the results may request that their downspouts be re-connected.

What if I want to help, but can't do it on my own?
The city recognizes that not everyone has the time or other resources needed to disconnect downspout or build rain gardens. Based on results from a pilot project that we are currently evaluating and the responses to this survey, the city will plan, design, and offer services over a period of years in order to effectively manage overall budget impacts. Fill out the survey, tell us your needs and preferences, and we'll try to meet as many needs and interests as we can.

Appendix IV cont'd. Homeowner Willingness and Incentives Survey

City of Gresham

In completing this survey, keep in mind that if your home is selected for inclusion in the program, you will receive a free safety inspection to determine which downspouts can be disconnected or where a rain garden may be installed. **Not all properties or downspouts qualify and safety is our first priority.**

1. Given the following:
    - The cost to disconnect your gutter is about $15 per downspout
    - The typical home can safely disconnect two downspouts
    - The parts are readily available at local hardware stores
    - It takes about an hour to disconnect two downspouts
    - The city will provide a free safety inspection

    How willing are you to disconnect your downspouts to protect Gresham streams?
    CIRCLE ONE:

NOT WILLING		NEUTRAL		VERY WILLING
1	**2**	**3**	**4**	**5**

2. If your response was not a "5", please tell us **why you are concerned** about disconnecting your downspouts**:**
    CIRCLE ALL THAT APPLY
    a. My downspouts are already disconnected
    b. Cost of tools and supplies
    c. No time to get parts and install
    d. My lawn/yard is soggy in the winter
    e. Might damage my home's foundation or basement
    f. May create runoff to neighbor's property
    g. I have pets/children that use yard (mud concerns)
    h. Other: ________________________________

3. If you did not indicate "5" (highly willing), what would be the **minimum** amount of assistance/incentive you need to participate in downspout disconnection?
    CIRCLE ALL THAT APPLY
    a. Not applicable; I am willing
    b. An easy to use "how to" guide for installation
    c. A "how to" workshop
    d. Technical assistance
    e. Materials (parts) provided
    f. Installation (labor) provided
    g. Discount on my stormwater utility fee (averages about $2/month)
    h. One time payment (write in amount here per downspout: $_________)
    i. Other____

Appendix IV cont'd. Homeowner Willingness and Incentives Survey

4. Given the following:

- Rain gardens can be designed to address concerns about your home, your neighbor's property, mud, and soggy lawns from disconnected downspouts
- The city will provide a free safety inspection
- The cost of building a rain garden, including plants and soil amendments, can be $100-$300
- Construction is about a day's worth of work for two people.
- The typical space needed varies from about 5'x5' to 10'x10' (25 to 100 sq ft respectively).

Indicate the **minimum** amount of assistance/incentive you need to install a rain garden in order to disconnect your downspouts.

CIRCLE ALL THAT APPLY

a. An easy to use "how to" guide for installation
b. A "how to" workshop
c. Technical assistance
d. Materials (plants, soil amendment, mulch)
e. Installation (labor)
f. Discount on my stormwater utility fee (averages about $2/month)
g. One time payment (write in amount here: $_________)
h. I don't have space to accommodate a rain garden
i. Other____

5. What didn't we ask you that you would like to communicate related to stream protection, downspout disconnections and rain gardens?_____________________________________

____

____

Please include your name and contact info so that we can follow up with you when we are offering these services.

Name: ____

Address: ____

Phone: ____

Email: ____

If you have questions, please contact Keri Handaly at (503) 618-2657 or
email: keri.handaly@greshamoregon.gov
Return to: City of Gresham, ATTN: K. Handaly, 1333 NW Eastman Parkway, 97030
Postage paid envelope enclosed for your convenience.

Appendix V. Selected Observations and Homeowner Accounts

Zone	Field Observations and Homeowner Accounts
High	Already disconnected; homeowner says never ponding; rocky & bouldery up to 10' down.
High	Homeowner says large,egg-shaped, head-sized boulders.
High	Lots of gravel under sod.
High	Already disconnected.
High	Rock 4-6" down at 2 other cores near core 1.
Medium	C=gravelly/gleyed layer.
Medium	Some erosion evidence; house on small hill/mound.
Low	Homeowner says ponding/sopping back yard in winter via groundwater; located at toe of slight hill.
Low	Homeowner says clayey w/ poor drainage & ponding; C=gleyed gray (2.5Y 4/2) w/ horizontal flaking/platelike.
Low	Homeowner suspected "clayey".
Low	C=gleyed w/ redox; abuts creek; ~85% of property has 10' depth-to-groundwater in winter.
Low	C=lots of iron oxides & gleyed color (2.5y 5/3).
Low	Gleyed layer at~1ft down, 1" thick (10YR 3/1.5).
Low	C=gleyed w/ ~40% redox.
Low	Hydric soil in C in front yard w/ metallic blue, yellows; homeowner waters 15 min/day in summer; back yard not hydric.
Low	Gravel/rock at 3" in 5/6 attempts. Erosion evidence; 10' drop between front & back yards & 30' drop beyond back fence.
Low	Already disconnected & homeowner says no ponding unless torrential downpour.
Low	Homeowner suspected clay; back lawn walking path of average use had extremely slow infiltration.
Low	Core 2=red to gleyed transition at 6.5".
Low	Dark & gleyed in B & C.
Low	Gravel prevented 2/3 of core attempts in A horizon.
Low	1.5" sod laid atop gravel; no viable sample possible; brand new neighborhood.

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