Bureau of Environmental Services • City of Portland

2008 Stormwater Management Facility Monitoring Report SUMMARY

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Sustainable Stormwater Management Program

▪

December 2008

ENVIRONMENTAL SERVICES
CITY OF PORTLAND
working for clean rivers

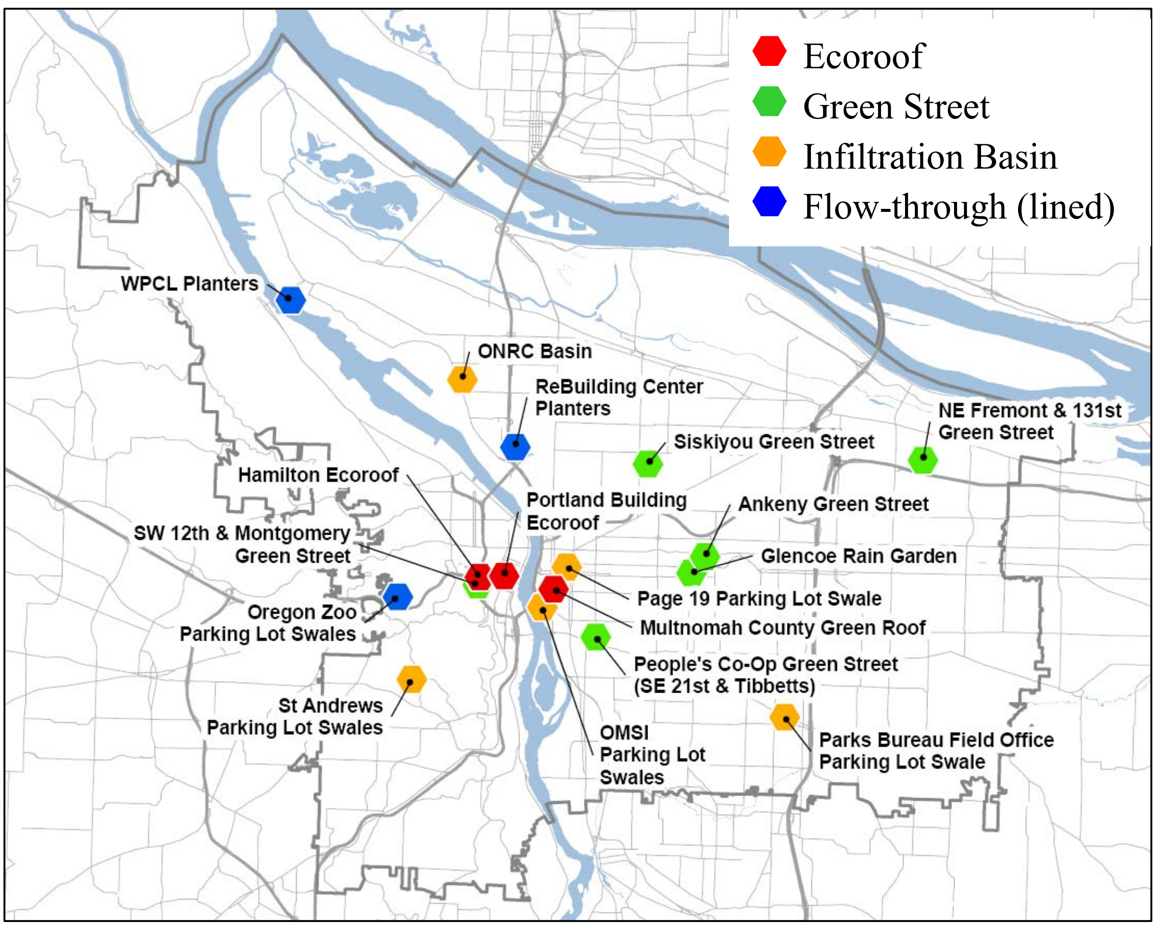
Dan Saltzman, Commissioner • Dean Marriott, Director

Introduction

Stormwater management facilities handle runoff from impervious areas and alleviate potentially negative impacts to the combined and storm sewer systems, and to watershed health. In particular, they can be used to reduce peak flows, reduce runoff volume, and improve water quality. Vegetated facilities are ideal because they reduce impervious area, improve aesthetics, provide a natural biological system that maintains infiltration pathways, and filters out many typical stormwater pollutants.

Information on how well facilities perform is critical to quantify their benefits, lower maintenance costs, ensure public safety, and improve overall design and function. In particular, information was desired on how well the facilities could reduce peak flows and total flow volume, which have implications for watershed health and regulatory compliance in the combined sewer system. Water quality monitoring is limited but will be increased in the future as budget allows. Sampling of facility soils has also begun to determine if there are any long-term issues with pollutant accumulation within the facilities.

Monitoring data collected through June 2008 is included in this report. Evaluated facilities are located throughout the city and represent an effort to include a variety of facility types, configurations, ages, and land uses. General facility types are: Ecoroofs, Green Streets, Vegetated Infiltration Basins, and Flow-through (lined) Planters and Swales.



Facilities Evaluated through June 2008

Ecoroofs

Multnomah County Green Roof

Hamilton Apartment Ecoroof

Portland Building Ecoroof

Ecoroofs, also called Green Roofs, consist of soil media and plants installed above traditional roofing materials. The soil media retains rainfall, which can then be sent back into the atmosphere through evapotranspiration.

Results from three ecoroofs are included: the Hamilton Apartments Ecoroof, Multnomah County Building Green Roof, and the Portland Building Ecoroof. All were continuously monitored for runoff and rainfall data was collected in gages located on each roof. The Hamilton Ecoroof has two different roof types – a thinner, lighter soil media (east side) and a thicker, heavier soil media (west side). The west side has shown the better performance and is summarized here (east side performance information is available in the full report).

All roof configurations do an excellent job of reducing peak flows, with reductions for the most intense rain events between 88% and 96%. This reduction would help lower basement sewer backup risk in the combined sewer, and lower velocities in open channels.

Volume retention varied widely across the roof configurations, but an average annual retention of over 50% is achievable. Retention is higher in the summer (low rainfall, high evapotranspiration rates) and lower during the winter months (high rainfall, low evapotranspiration rates). Higher retention in the summer is important because regulations for water quality and combined sewer overflows are most stringent between May and October. Retention for individual storm events varies substantially depending upon rainfall intensity, duration, and pattern.

Ecoroof Performance Summary

Facility	Monitoring Period	Size (sq ft)	Peak Flow Reduction	Volume Retention			
				Annual	Summer	Winter	CSO[1]
Hamilton Apts, West Side (Hamilton West)	6½ years Jan 2002 – Jun 2008	3,655	96%	54%	83%	47%	65%
Multnomah County Green Roof	3 years Jul 2004 – Jun 2007	7,000	88%	-10%[2]	-71%[2]	11%	11%
Portland Building Ecoroof	1½ years Mar 2007 – Jun 2008	5,250	93%	67%	81%	63%	N/A[3]

[1] For storms most similar to the Combined Sewer Overflow (CSO) Design Storms.
[2] Negative value is the result of daily irrigation runoff from late spring through early fall.
[3] No similar storms during monitoring period.

The Portland Building Ecoroof has the highest annual and winter retentions. However, with only 15 months of data, performance will need to be verified in the coming years. Hamilton West has performed consistently well during six-and-a-half years of monitoring, suggesting that it's reasonable to expect long-term stormwater retention of over 50%. The Multnomah County Green Roof is heavily irrigated during the summer. This has resulted in daily runoff when no rain is falling. This irrigation runoff accumulates during the summer months to erase any annual stormwater benefit. It is hoped that irrigation modifications and soil maturity will improve performance in the future.

While there are many potential variables that will impact volume retention (like the drainage design, exposure to sun and wind, amount and timing of irrigation, etc.), it appears the major differences between the ecoroofs are the soil media used and the irrigation applied – two issues that may be linked. Both Hamilton West and the Portland Building soils contain a fraction of sandy loam. A soil mix with fine particles is better at holding water against gravity – allowing more time for evapotranspiration to occur and for ingredients like digested paper fiber and organics to absorb water. It is also possible that the finer soil particles partially clog the filter fabric that separates the soil from the drainage layer. This would produce the same effect – water would be held against gravity and kept out of the drainage system. Better moisture retention in the soil could result in reduced irrigation needs.

Ecoroof Soil Media Comparison

Facility	Soil Thickness (in)	Soil Type
Hamilton Apts, West Side	5	sandy loam, perlite, digested paper fiber, coconut coir, compost
Multnomah County Green Roof	6	perlite, pumice, paper pulp, digested paper fiber
Portland Building Ecoroof	3	sandy loam, pumice, compost, and Stockosorb polymer

The Multnomah County Green Roof uses a lightweight and highly porous soil media with few fines. This type of soil media is often used to ensure that saturated soil weight does not exceed the structural capacity of the roof. However, it is possible for the media to be too porous and allow water to drain through too rapidly. Though the Multnomah County Green Roof is the thickest at 6 inches, it retains the least volume. This is due to the substantial irrigation applied to keep the roof green during the summer. The irrigation combined with a porous soil media leads to substantial daily irrigation runoff which greatly reduces overall retention.

Annual and seasonal retention for Hamilton West, the roof with the longest monitoring record, has been variable. Differences in yearly rainfall totals and patterns make year-to-year comparisons difficult. For instance, 2004 and 2005 had very high annual retentions (62% and 63%) but 2004 was a very low rainfall year and both years had large amounts of summer rainfall (when high evapotranspiration rates lead to quick recharge of storage capacity). 2006 on the other hand, was very wet with most rainfall occurring during the fall and winter months. As a result, annul retention dropped significantly (47%). Other variables like daily temperatures and wind speed also impact performance.

Annual runoff retention by year for the Hamilton Ecoroof

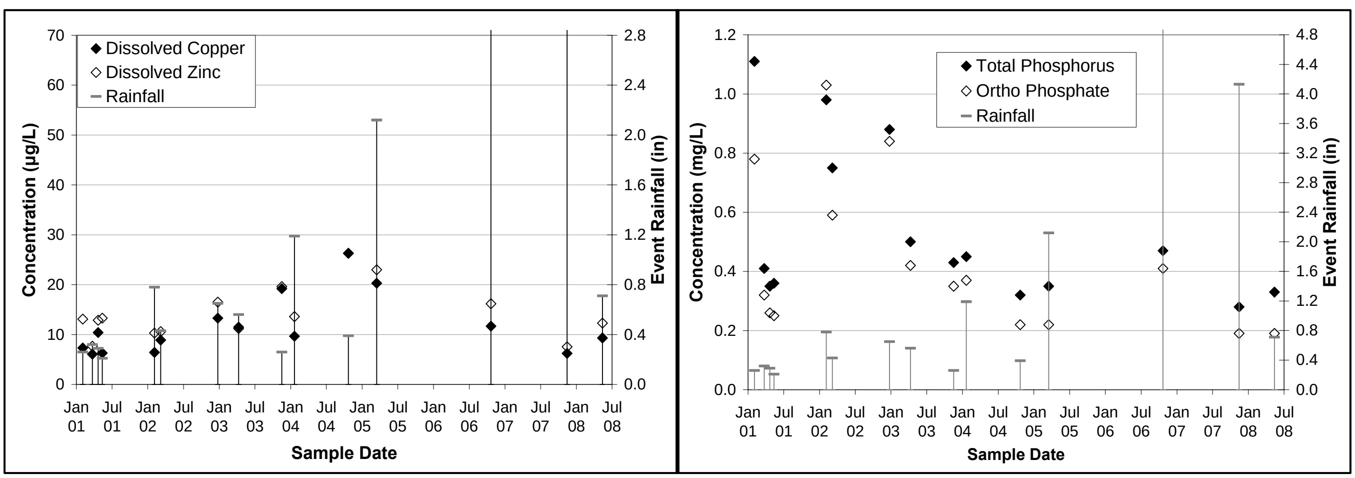
	2002	2003	2004	2005	2006	2007
Rainfall (in)	21.6[1]	37.1	26.0	36.1	47.2	34.8
Retention	**41%**	**54%**	**62%**	**63%**	**47%**	**51%**

[1] Excluding December when the runoff meter was down.

The potential export of metals and nutrients in ecoroof runoff is of interest because of regulatory requirements and watershed health objectives. Runoff samples from both sides of the Hamilton Ecoroof have been collected – a total of fifteen storm events over the last six years. The last two events included conventional roof samples for another portion of the roof for comparison.

Zinc and copper levels in the runoff are highly variable. All events had concentrations well below human health guidelines, but even low levels (down to 3 μg/L) of dissolved copper may adversely impact salmonids and other aquatic life [Hecht et al, 2007]. Potential metal sources include the soil media, corrosion of roofing materials – flashing, railings, etc. – and metals present in rainfall [Sullivan, 2005]. Ecoroof zinc levels were substantially lower than conventional roof runoff samples collected from the building penthouse (7.6 – 26.3 μg/L ecoroof versus 141 – 239 μg/L conventional), but ecoroof copper levels were notably higher (6.1 – 26.3 μg/L ecoroof versus 0.6 – 3.4 μg/L conventional). This would suggest the ecoroof can capture zinc from conventional roof sources like galvanized metals, but that copper in the ecoroof soil media can leach out and raise effluent levels. Efforts to reduce copper export should be investigated in the future.

Phosphorus concentrations appear to be decreasing over time but are still high when compared to benchmarks established in some Portland watersheds (0.13-0.16 mg/L). There was little or no phosphorus or nitrogen found in conventional roof runoff at the site.



Trends for copper, zinc, and phosphorus from Hamilton West runoff samples

Water quality sampling also began on the Portland Building Ecoroof in 2007. This will provide another source of information once sufficient data points have been gathered. In addition, more work will be done to compare ecoroof runoff concentrations with those found in rainfall and conventional roof runoff, and to identify sources – soil media, roofing materials, rainfall, etc. While questions remain, current data does indicate that selection of a soil medium should include an evaluation of potential water quality impacts.

Ecoroofs – Monitoring Summary

- All configurations were effective at reducing peak flows (88% to 96%).

- Volume retention is highly dependent on the soil media and irrigation.
    - Soil media with some smaller particles have provided the best volume retentions. Long-term annual retention (6½ years) at the Hamilton Apartments Ecoroof is 54%.
    - Ecoroof design should minimize the need for summer irrigation to maintain storage capacity in the soil media and to prevent irrigation runoff.

- Metal (copper, zinc) and nutrient (phosphorus) concentrations in ecoroof runoff have been found at levels that could potentially adversely impact watershed health. While more information is needed to determine sources and what effluent concentrations are safe, it would be ideal to include minimizing metal and nutrient export as a consideration when choosing an ecoroof soil media.

Green Streets

Green Streets are vegetated facilities, typically within the public right-of-way, that manage street runoff. Facilities can be in a variety of configurations – including swales, curb extensions, planters, and infiltration basins. Design variables are flexible, but facilities are typically linear and pond 6 to 9 inches deep. All the facilities presented here are infiltration facilities with no underlying rock galleries, filter fabric, or underdrains. Facilities are generally sized between 4% and 6% of their drainage areas.

Glencoe Rain Garden

An evaluation of both flow tests and actual storm events indicate a strong ability to limit peak flows. During flow tests of the most intense design storm (the 25-yr, 6-hr), the lowest peak flow reduction was 80%. This would greatly lower or eliminate basement sewer backup risk in the combined sewer area under most circumstances, and velocities in open channel systems would be greatly reduced.

Peak Flow Reduction and Volume Retention of Green Street projects

Facility	Monitoring Period	Drainage Area (ft^2)	25-Yr Peak Flow Reduction	Annual Runoff Retention	CSO Flow Volume Retention
12th & Montgomery	4 flow tests Sep 2005 – Jun 2008	7,000	80%+	N/A	75%
Fremont & 131st	1 flow test Aug 2006	4,500	94%	N/A	95%
Glencoe Rain Garden	4½ years Jan 2004 – Jun 2008	34,800	80%+	87%	56% +
21st & Tibbetts	1 flow test Aug 2007	5,500	100%	N/A	70%
Siskiyou & 35th	3 flow tests Jan 2004 – Dec 2005	9,300	82%	N/A	61% - 83%

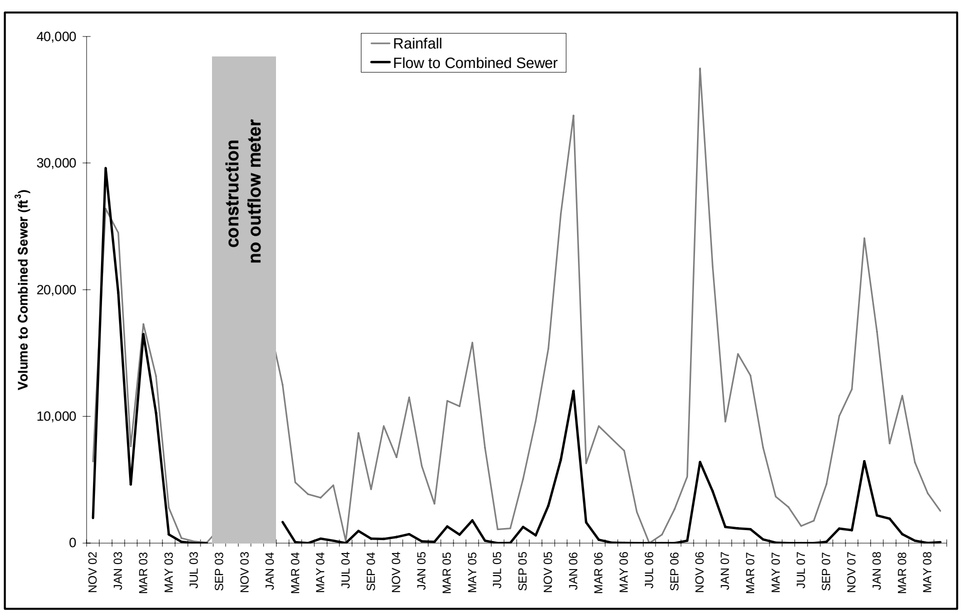
The Green Street facilities also provide a notable reduction in the flow volume entering the combined sewer. For one facility, annual runoff over a four-and-a-half year period has been reduced by over 85%. Flow tests simulating CSO design storms (modified by time compression to be 2.2 inches in 6 hours) at other facilities have shown conservative retentions as high as 80%.

NE Siskiyou Green Street

Results have been generally consistent regardless of antecedent rainfall, and overflow only occurs during larger storms events.

It was assumed that the high variability in urban soils would lead to highly variable infiltration results. However, all facilities have been remarkably consistent despite differences in facility age, drainage area, geographic location, and antecedent moisture conditions. Though average infiltration rates have been variable, the minimum (or steady state) rates during flow tests have been consistently no lower than 1½ inches per hour.

The consistency of results may indicate a greater than expected uniformity in urban near-surface soils, or it could reflect a focus on soil preparation during construction designed to promote infiltration. In most facilities, the first 12 to 18 inches of soil is replaced with a specified mixture of topsoil, sand, and compost (a “three-way” mix). The boundary between imported and native soils is tilled to prevent a “hard” interface, and the imported soil is installed in lifts with no mechanical compaction. The Glencoe Rain Garden is an exception – it used native soils with no amendments. The only modification was using a tiller or “ditch-witch” to loosen the soil. Facilities with amended native soils will also be evaluated in the future. Tests will continue over time to determine changes in infiltration rates as the facilities age.



Inflow volumes to the combined sewer before and after construction of the Glencoe Rain Garden

Infiltration Test Summary for Green Street Projects

Facility	Location	Facility Area (ft^2)	# Tests	Minimum Infiltration Rate (in/hr)
12th & Montgomery	SW	270	4	3.2 – 5.5
Ankeny & 56th	SE	460	2	1.8 – 3.7
Fremont & 131st	NE	300	1	7.5
Glencoe Rain Garden	SE	1,975	3	1.5 – 3.0
21st & Tibbetts	SE	300	1	3.2
Siskiyou & 35th	NE	590	3	1.5 – 2.5

Several design issues have been identified that should be considered for future projects.

- when possible, facility overflow heights should be adjustable to provide flexible storage capacity
- facilities on flat streets (<1% longitudinal slope) require obstruction free entries to ensure water moves into the facility and does not bypass
- entries angled 90 degrees from the direction of flow must have substantial measures (e.g. small berms at the downstream end of the entry or substantially depressing the gutter in front of the entrance) taken to ensure curb flow enters the facility

Sediment accumulation has been significant in all facilities, and it is important to accommodate sediment removal. Accumulation varies depending upon site characteristics, but a removal frequency of at least twice a year seems appropriate. In general, removal is done by hand in vegetated forebays as opposed to mechanical removal in hardened forebays. Small concrete pads are often provided at the inlet, but their size is minimal in relation to the facility size.

SW 12th Green Street

As with any vegetation, some irrigation will be necessary during the first two years when plants and trees are establishing. After that, they are expected to survive on rainfall alone. Weeding is also important during the establishment period and needs to be done two to four times a year. As the plants mature and cover the facility, only minimal weeding should be necessary and that can be done in conjunction with sediment removal visits. Some plant species, Juncus patens in particular, have grown larger than expected and a smaller variety (Elk's Blue) is now planted. Ensuring the proper plant size and placement for the facility location is very important.

SE Ankeny Green Street

This initial set of data indicates that the monitored Green Street facilities have tremendous potential to manage stormwater flow rates and flow volumes. The City of Portland is actively pursuing a citywide program of green street implementation, having adopted a Green Street Policy in 2007 [COP, 2007]. Green street design details have also been incorporated into the 2008 Stormwater Management Manual which contains requirements for new development and re-development projects [BES, 2008].

Green Streets – Monitoring Summary

- All facilities are effective at reducing peak flows (> 80%).
- Facilities show good annual volume retention (> 80%), and the potential for volume retention during CSO compliance events appears high (>60%).
- Minimum (steady state) infiltration rates have been consistently 1½ inches per hour or higher.
- The facility overflow should be at the highest elevation possible to maximize the storage volume of the facility – especially for steep streets (>2%)
- Facilities on gently sloping (<1%) streets require designs that allow easy entry into the facility. The presence of check dams or substantial vegetation too close to the curb entry may create resistance to flow that encourages bypassing around the facility
- Facility entries angled at 90 degrees to the flow direction, require substantial design elements (berms, depressed gutters, etc) to prevent significant bypass during large events
- Weeding and sediment removal are the primary maintenance activities. Frequency will vary with the characteristics of each street, but basic maintenance should occur at least twice a year.

Infiltration Basins

Vegetated infiltration basins are landscaped depressions designed to hold and infiltrate water. They are very similar to the Green Street facilities, but they have generally greater depths (typically 9 to 12 inches), a larger footprint, and are more frequently used to accept runoff from roofs and parking lots.

Infiltration testing is accomplished by filling the facility two or more times and then recording changes in water depths at regular time intervals. Tests will typically last for several hours.

Five facilities have been tested in different parts of the city. All performed well.

Infiltration Test Summary for Vegetated Infiltration Basins

Facility	Location	Facility Age (years)	Antecedent Conditions	Minimum Infiltration Rate (in/hr)
OMSI North Parking Lot	SE	16	Dry	**6.0**
ONRC Parking Lot	N	5½	Dry	**4.5**
Page 19 Parking Lot	SE	5½	very wet	**1.5**
Parks Eastside Field Office	SE	5½	Dry	**4.2**
St Andrews Parking Lot	SW	4½	Dry	**0.6**

OMSI North Parking Lot Swales

OMSI, ONRC, and the Parks Eastside Field Office have high rates, but they also overtop coarser soils that would be assumed to infiltrate well. Page 19 has a lower rate, but is located over urban fill that contains a large amount of silt. The rate at Page 19 is very similar to the rates found for the monitored Green Street facilities which sit in similar eastside, disturbed silt loams.

Despite being over 16 years old, the OMSI swales are still performing very well. A test was performed at the OMSI swales in 1995, and though a minimum infiltration rate was not mentioned for this test, the average rate was reported to be 8 inches per hour. The average rate for the test in 2005 was 13 inches per hour – indicating that infiltration capacity has been maintained and actually increased over time. This reinforces the idea that mature vegetation with woody root structures can open and maintain pathways within the soil and consequently improve infiltration.

The St Andrews Parking Lot infiltration rate is notably lower than the other facilities. However, this is expected because it is located in a west side area with finer silt soils than those present in east side locations.

Each vegetated infiltration basin will typically have a unique combination of subsurface soils, drainage area characteristics, and facility design variables that make results difficult to extrapolate to other locations. However, by accumulating infiltration data from a number of facilities, it is hoped that results can inform design and placement decisions. Any trends in the results may allow assumptions currently used in estimating the effectiveness of infiltration facilities to be refined.

Additional tests are planned for the future to track changes in infiltration over time, and to attempt to link infiltration performance to design variables and the type and frequency of maintenance activities.

Infiltration Basins – Monitoring Summary

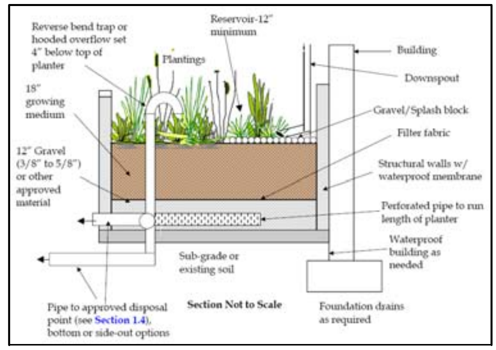
- Infiltration rates have met or exceeded expectations at all facilities.
- One older facility showed higher infiltration rates after 10 years, strengthening the concept that vegetated infiltration facilities can improve over time. Roots from vegetation – especially woody plants – have extensive root structures that counter siltation and can loosen soils compacted during construction.

Flow-through Facilities

Flow-through facilities contain soil and plants just like infiltration facilities, but are sealed off from the surrounding native soils. The sealing is most often done using an impervious liner or concrete. Water not captured in the soil is collected by an underdrain and connected to a disposal point like a sewer, sump, or surface drainage system.

Flow-through facilities are especially versatile because they can be used in areas with poorly draining soils or adjacent to building foundations. They provide peak flow reduction and water quality treatment, but because some flow volume passes through the underdrain system, they provide only partial volume retention.

Despite their heavy use for peak flow control and water quality improvement, it has been unclear how well flow-through planters will retain volume, and this is important information to determine long-term compliance with CSO regulations.



Flow-through Planter

Monitoring has been conducted on four facilities since 2005, and three of those facilities have produced results. The fourth, a retrofit of an existing landscape planter at George Middle School, did not produce usable information due to facility design, site layout, and a small drainage area that accentuated data errors.

Peak Flow Reduction and Volume Retention of Green Street projects

Facility	Monitoring Period	Drainage Area (ft^2)	25-Yr Peak Flow Reduction	Annual Runoff Retention	CSO Flow Volume Retention
Oregon Zoo Parking Swales	1 flow test Sep 2007	9,450	N/A	N/A	23%
ReBuilding Center Planters	2 years Jun 2006 – Jun 2008	8,400	67%	21%	N/A
WPCL Test Planters	6 flow tests Apr 2005–Aug 2007	2,000 (4 configurations)	91%	N/A	22% - 38%

The Water Pollution Control Laboratory (WPCL) test planters were constructed to compare various planter design elements side-by-side. Four planters were constructed, each with 120 square feet of surface area (sized to manage up to 2,000 square feet of impervious area). Each bay is configured differently to compare: 1) geometry (long and narrow versus short and wide); 2) soil mixture (sandy loam with varying amounts of amendments); and 3) ways to protect the underdrain system from sedimentation (filter fabric or a gravel blanket).

WPCL Test Planters

All the WPCL planters have been able to reduce peak flow by at least 91%.

Planters tested for volume retention of the CSO design storm (time compressed, 2.2 inches in 6 hours) have retained between 14% and 47% of inflow volume. Geometry appears to make a significant difference. The long, skinny planter has an average retention 16% lower than the shorter, wider planter. This is likely due to the greater wall length to surface area ratio. The greater wall length provides a greater chance for water to leak down the side, avoiding most of the soil volume. This is accentuated in the summer when the soil dries and shrinks back from the walls (and when most testing has been done). This provides a gap along the wall for water to leak down.

The two soils have performed similarly well, indicating that their differences – proportions of sandy loam, digested paper fiber, and coconut coir – are not substantial.

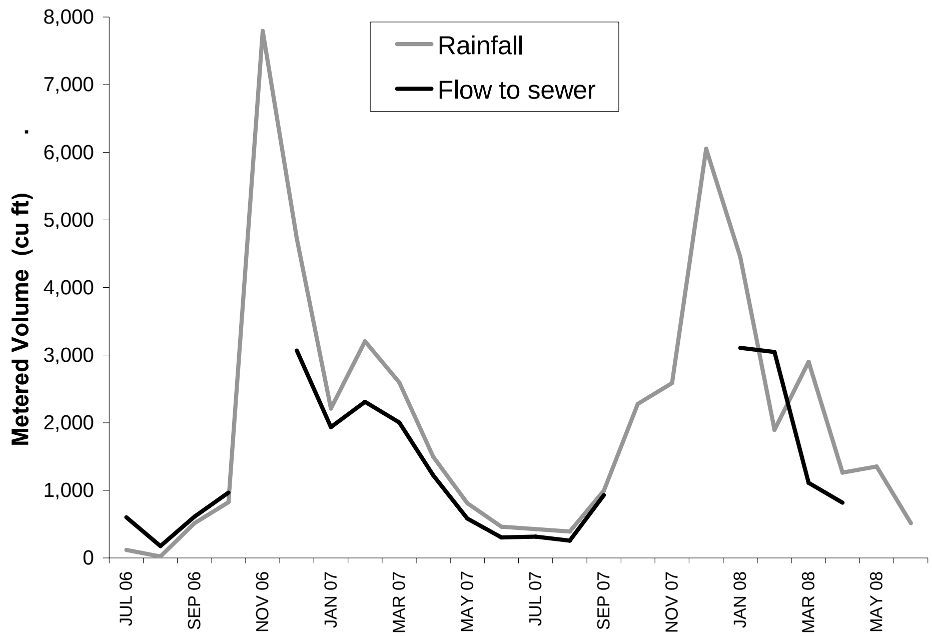
Filter fabric has shown a 10% greater retention when compared to the pea gravel separator lens, indicating that the filter fabric is more of a barrier to water movement and creates more retention. If filter fabric is used, it is important to ensure the facility soil will not clog the fabric.

Estimated volume retention for WPCL Planter tests

	Bay 1	Bay 2	Bay 3	Bay 4
Apr 06 2006	38%			24%
Apr 25 2006	43%	45%		
Jul 05 2006	43%	47%		
Sep 19 2006	41%	42%		
Jul 16 2007	34%	28%	28%	14%
Aug 06 2007	30%	30%	28%	29%
Average	38%	38%	28%	22%

The ReBuilding Center Planters were installed during a re-development project and manage runoff from 8,000 square feet of roof. Outflow from the planters has being continuously monitored for two years, and the planters have retained 21% of annual rainfall to date. During the largest (depth) rain events, the equipment can become surcharged which makes data unusable.

Trends have been consistent over the first two years of monitoring.



Inflow and outflow volumes for the ReBuilding Center Planters

A flow test was also performed at the Oregon Zoo Parking Swales. Two swales and a filter strip were installed to manage a portion of a highly used parking lot. Lined vegetated swales were installed because of portion of the site was in a landslide hazard area. Underdrains collect water not retained by the swales and send it to the storm sewer.

One swale (Row #7) was tested using a CSO design storm (time compressed, 2.2 inches in 6 hours). The swale retained 23% of the inflow volume.

Facilities tested to date suggest that flow-through facility volume retention is between 20% and 30%. More data needs to be gathered to determine what design elements may be most important in improving overall retention.

Flow-through Facilities – Monitoring Summary

- Planters reduce peak flows well (> 67%).
- Volume retention has averaged approximately 25%.
- Soil selection did not have a large impact at the WPCL test planters, but it is still an important variable. An ideal soil mix must be able to promote healthy vegetation, provide adequate water quality treatment, and retain water volume.
- Filter fabric seems to enhance retention when compared with a gravel lens. Care must be taken to use the proper soil to prevent clogging of the fabric.
- Shorter, wider planters seem to retain volume better than longer, skinnier planters. This may be because long, narrow planters have more wall length per surface area. Walls are potential locations for water to bypass soil and fabric and leak directly into the drain rock and underdrain.

Soil Sampling

BES wants to ensure that surface stormwater management facilities do not create localized areas of high pollutant concentrations. A program of periodic soil sampling of selected facilities will be used to track any changes in pollutant levels over time. Facilities were selected to provide a good sampling of facility types, age, and land uses.

Samples are taken at three different horizons at several locations within each facility. Horizons were 6 inches thick representing the surface (0 to 6 inches), root zone (6 to 12 inches), and native soil (12 to 18 inches). Samples are tested for heavy oils, metals, volatile organic compounds (VOCs), and polycyclic aromatic hydrocarbons (PAHs).

The first set of samples (2005) represents a baseline against which future samples will be compared to determine if concentrations are increasing, decreasing, or staying constant. BES intends to take samples every 2 to 3 years to identify trends.

Facilities Selected for Soil Sampling

Facility	Location	Drainage	Age (yrs)	Land Use
12th & Montgomery Green Street	SW	Street	3	COM
Glencoe Parking Swale	SE	Parking	6	RES
Glencoe Rain Garden	SE	Street	5	RES
New Seasons Green Street	SE	Street	4	COM
OMSI, North Parking Lot	SE	Parking	16	IND
Oregon Zoo Parking Swales	SW	Parking	2	COM
Siskiyou Green Street	NE	Street	5	RES
SW Community Center Parking Lot	SW	Parking	11	RES
Tryon Headwater Rain Garden	SW	Street / Parking	1	COM / RES
Walnut Park Precinct Parking Lot	NE	Parking (cruiser washing)	14	COM
Willamette & Denver Green Street	N	Street	2	RES

There appears to be no threat to human health from metals or VOCs in any of the tested facilities. However, at least one sample from each facility contained levels of zinc that may negatively impact plants and invertebrates. This conflicts with visual observations of these facilities, where the plants appear healthy and earthworms are frequently observed. Current levels are generally near the benchmark, so it may be that levels are not yet high enough to have a significant impact. It is not unusual for local soils to be high in zinc, so it may be that facility levels are not substantially higher. Also, some of the sample points with the highest readings may represent locally high concentrations that are not present throughout the facility.

Several facilities have levels of the PAH benzo(a)pyrene that exceed at least one screening level for human health exposure – the Environmental Protection Agency Region 6 Preliminary Remediation Goal (PRG) for Superfund residential soil cleanup. Stormwater facilities taking street and parking runoff are required to meet residential requirements, but benzo(a)pyrene levels will be closely watched in the future to determine how levels are changing over time. Of the facilities that exceed the screening level, there appears to be no strong correlation with land use or age.

In the future, more control testing outside of the stormwater facilities will be done to see how benzo(a)pyrene and other pollutants concentrations compare inside and outside of the facilities.

Soil Sampling – Monitoring Observations

- Only one or two samples exist for each facility. More samples will be necessary to identify any trends that may exist. Additional samples will be taken every 2 to 3 years.
- Benzo(a)pyrene was found in several facilities at levels above EPA Region 6 human health guidelines for cleanup of soils for residential use. Public right-of-way stormwater facilities are not required to meet this criterion, but levels will be watched in the future to determine if this, or other PAH levels, are increasing over time.

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