Bureau of Environmental Services • City of Portland

2010 Stormwater Management Facility Monitoring Report SUMMARY

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Sustainable Stormwater Management Program

▪

December 2010

ENVIRONMENTAL SERVICES
CITY OF PORTLAND
working for clean rivers

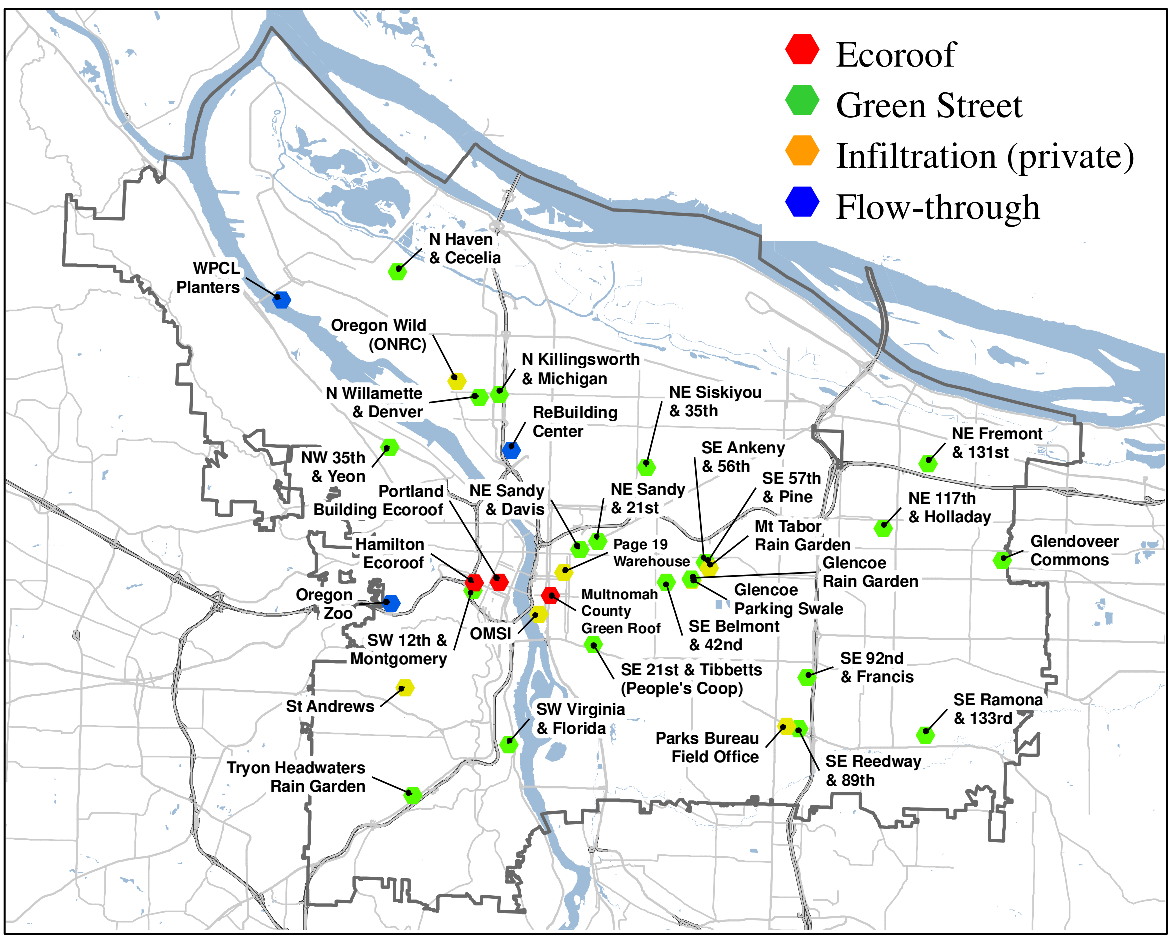
Dan Saltzman, Commissioner • Dean Marriott, Director

Introduction

Stormwater management facilities handle runoff from impervious areas and alleviate potentially negative impacts to our 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 on how well the facilities could reduce peak flows and total flow volume has been gathered to understand 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 is also ongoing to determine if there are any long-term issues with pollutant accumulation within the facilities.

Monitoring data collected through June 2010 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, Infiltration facilities (called Green Streets when managing the public right-of-way), and Flow-through (lined) facilities.



Facilities Evaluated through June 2010

Ecoroofs

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.

Multnomah County Green Roof

Results from three ecoroofs are included: the Hamilton Apartments Ecoroof, Multnomah County Building Green Roof, and the Portland Building Ecoroof. All have been 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).

Hamilton Apartment Ecoroof

All roof configurations do an excellent job of reducing peak flows, with reductions for the most intense rain events between 85% and 100%. 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 three roof configurations, but an average annual retention of over 50% appears 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.

Portland Building Ecoroof

Ecoroof Flow Performance Summary

Facility	Monitoring Period	Peak Flow Reduction	Volume Retention			
			Annual	Summer	Winter	CSO[1]
Hamilton Apts West	8½ years Jan 2002 – Jun 2010	**97%**	**49%**	82%	40%	53%
Multnomah County	3 years Jul 2004 – Jun 2007	**88%**	**-10%**[2]	-71%[2]	11%	11%
Portland Building	3+ years Mar 2007 – Jun 2010	**93%**	**67%**	80%	63%	43%[3]

[1] For storms most similar to the Combined Sewer Overflow (CSO) Design Storms (1.4 in / 24 hrs and 2.2 in / 35 hrs).
[2] Negative value is the result of daily irrigation runoff from late spring through early fall.
[3] Only two similar storms during monitoring period.

To date, the Portland Building Ecoroof has the highest annual and winter retentions with only a three inch soil media depth. It is likely that the roof's insulation system (three-inch foam sheets on top of the membrane) is helping to slow and retain rainfall on the roof. Hamilton West has been consistent over more than eight years of monitoring, demonstrating that ecoroof systems can provide long-term annual stormwater retention of around 50%. The Multnomah County Green Roof was heavily irrigated during the summers of the three year monitoring period. This resulted in daily runoff when no rain was falling, and was sufficient enough to erase any annual stormwater benefit. Irrigation modifications and soil / plant complex maturity may improve performance in the future.

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 Sockosorb polymer

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.), for these three ecoroofs it appears the major performance differences are due to 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 filter fabrics that separate 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.

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 at least partially 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 mildly variable with an annual retention range of 38% to 63%. 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). In 2006, it was very wet with most rainfall occurring during the fall and winter months. As a result, annual retention was significantly lower (47%). Rainfall patterns are also very important. Ecoroofs manage smaller rainfall events much better than larger ones. Five inches of rainfall spread amongst ten ½-inch events would produce little or no runoff, while a single five inch event occurring over several days would produce significant runoff. Other variables like daily temperatures and wind speed also impact performance.

Annual runoff retention by year for the Hamilton Ecoroof

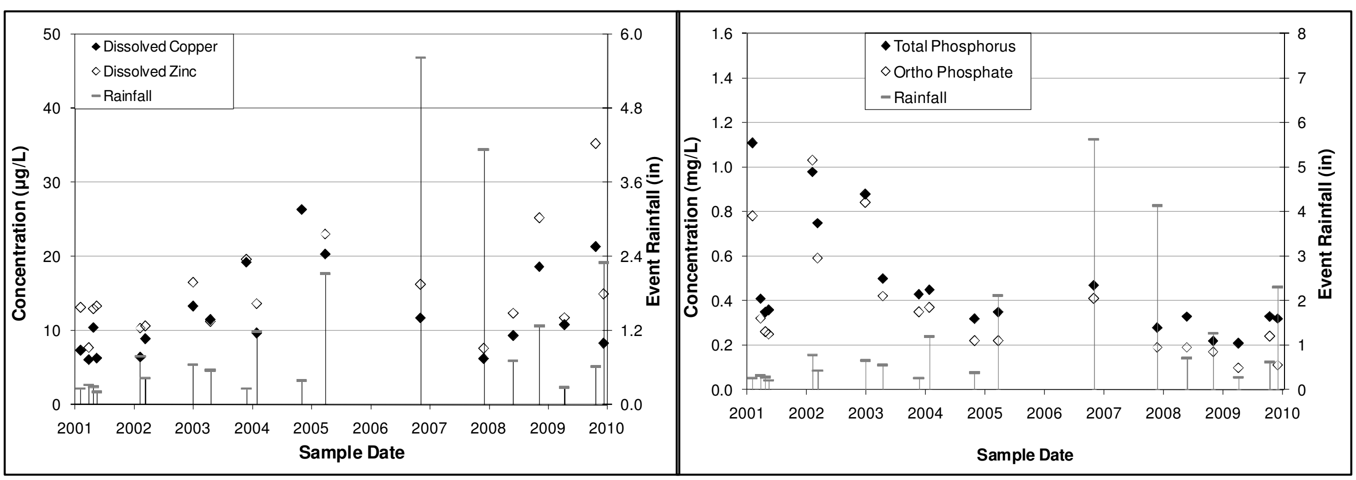
	2002	2003	2004	2005	2006	2007	2008	2009
Rainfall (in)	21.6[1]	37.1	26.0	36.1	47.2	34.8	28.2	31.5
Retention	**41%**	**54%**	**62%**	**63%**	**47%**	**40%**	**38%**	**42%**

[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 19 storm events over the last eight years. The last six events included conventional roof samples from another portion of the building roof for comparison.

Zinc and copper levels in the runoff are highly variable. 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 (8.9 – 39.3 µg/L ecoroof versus 67.2 – 239 µg/L conventional), but ecoroof copper levels were notably higher (6.8 – 20.6 µg/L ecoroof versus 0.61 – 3.9 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. 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]. 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 in water benchmarks (0.13-0.16 mg/L) established in some Portland watersheds. 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 –SUMMARY

- ***Peak Flow*** – all configurations were effective at reducing peak flows (76% to 100%).
- ***Flow Volume*** – long-term annual runoff retention has been shown to be as high 49%, but retention is highly dependent on the soil media and irrigation.
  - Soil media containing smaller soil particles (like sandy loam) have provided the best volume retentions.
  - Ecoroof design should minimize the need for summer irrigation to maintain storage capacity in the soil media and to prevent irrigation runoff.
- ***Water Quality*** – copper and phosphorus concentrations appear elevated in ecoroof runoff at Hamilton and the Portland Building, and are significantly higher than concentrations in conventional roof runoff at Hamilton. On the other hand, zinc concentrations are much lower for the ecoroof on Hamilton, which appears to buffer washoff from the galvanized metals on the roof. While more information is needed to determine specific sources and how effluent concentrations will impact in-stream watershed health benchmarks, minimizing metal and nutrient export should be a consideration when choosing an ecoroof soil media and building materials.

Infiltration Facilities

Infiltration facilities can be in a variety of configurations – including swales, curb extensions, planters, and infiltration basins. They are used to manage both public and private impervious area runoff, and typically pond six to nine inches deep. Sizing depends on their intended purpose but typically range from 2% for water quality only, up to 9% or more for complete infiltration of the 10-yr design storm. Some facilities have rock galleries beneath the soil to better manage large event volumes, but the majority do not.

NE Siskiyou Green Street

The City of Portland requires the use of infiltration to manage stormwater when possible. The Stormwater Management Manual [BES, 2008] contains requirements for new development and re-development both on public and private property, and City Council has also adopted a Green Street Policy in 2007 [COP, 2007]. Data from the facilities monitored in this report reinforces those policies by showing that infiltration facilities have tremendous potential to manage stormwater flow rates and flow volumes.

An evaluation of flow tests and actual storm events indicate a strong ability to limit peak flows by all facilities. During flow tests of the most intense design storm (the 25-yr, 6-hr), the peak flow reductions ranged from 63% to 100%, with an average reduction of 90%. This would greatly reduce or eliminate basement sewer backup risk in the combined sewer area, and potentially erosive velocities in open channel systems would be greatly reduced.

Glencoe Rain Garden

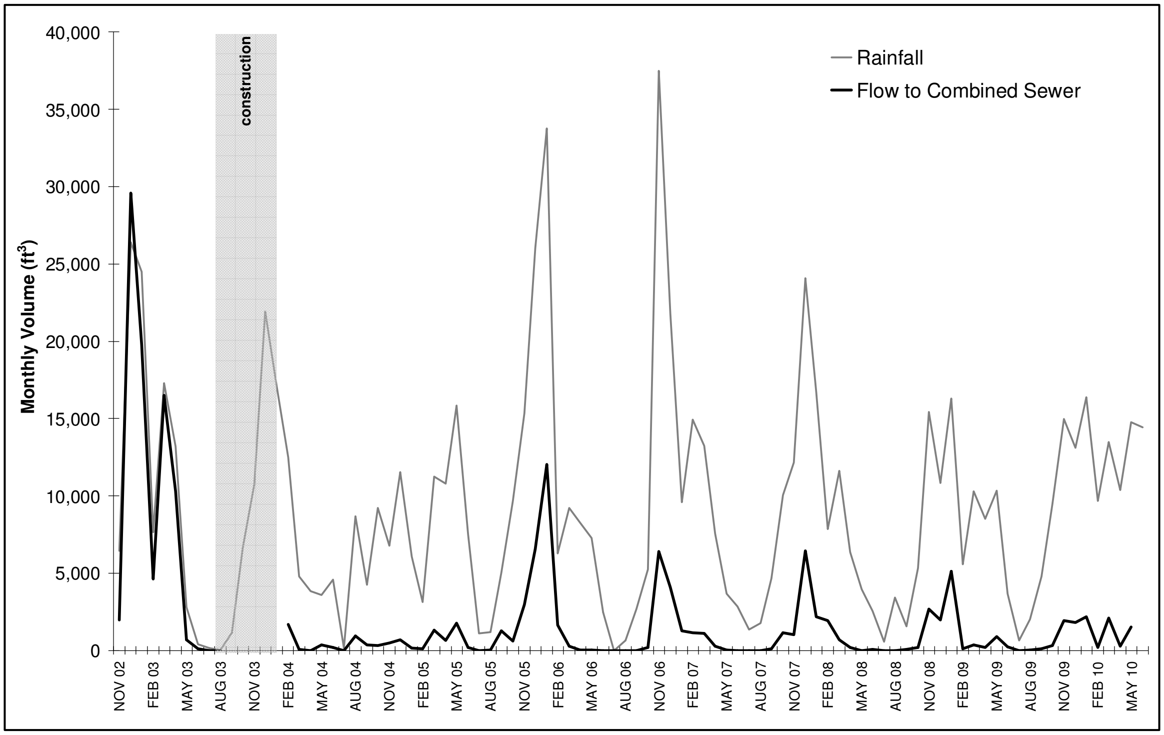
Infiltration facilities have also shown a sizeable reduction in the flow volume entering the city's drainage channels and sewer system. For one facility monitored continuously for six years, annual runoff has been reduced by 85%. Flow tests simulating CSO design storms have shown retentions ranging from 25% to 100%, with an average of 73%, while flow tests simulating the Water Quality Design Storm have shown retentions ranging from 61% to 100%, with an average of 93%.

Peak Flow Reduction and Volume Retention of Infiltration Facilities

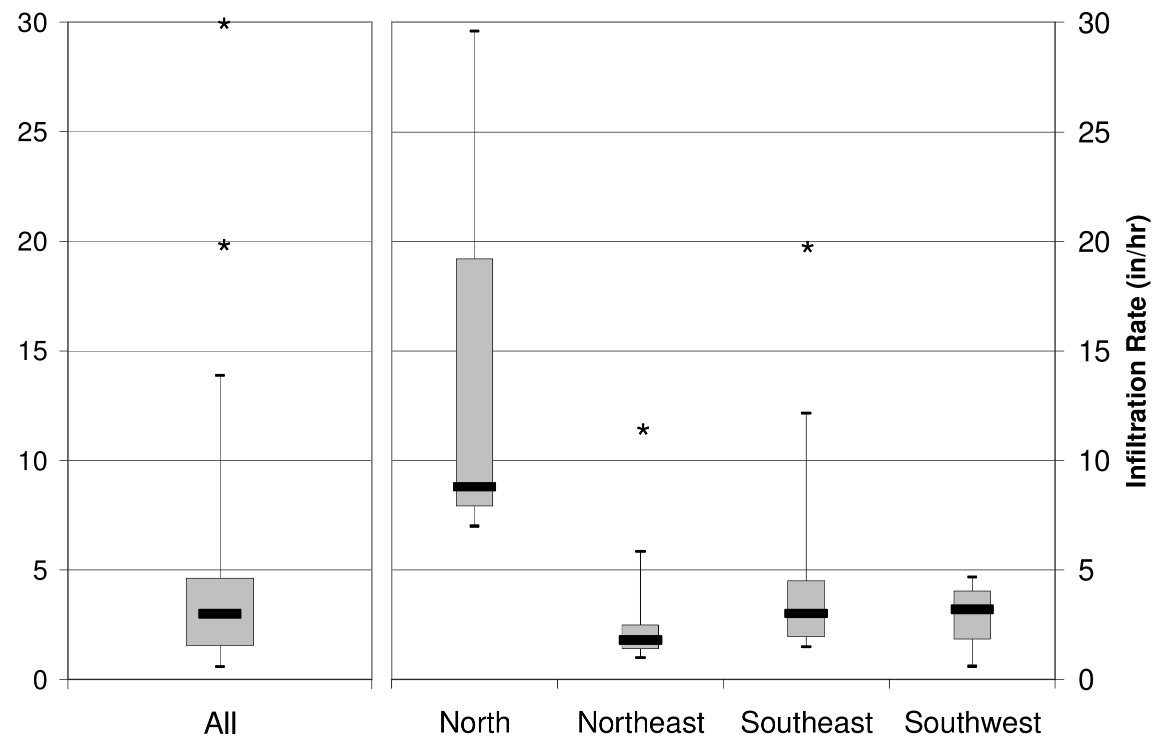
Facility	Monitoring Type	Green Street	Private	25-Yr Peak Flow Reduction	Annual Runoff Retention	CSO Flow Volume Retention	WQ Flow Volume Retention
12th & Montgomery	Flow Testing	✓		80%	N/A	74%	N/A
21st & Tibbetts	Flow Testing	✓		100%	N/A	70%	N/A
35th & Yeon	Flow Testing	✓		N/A	N/A	N/A	100%
56th & Ankeny	Flow Testing	✓		N/A	N/A	49%	N/A
92nd & Francis	Flow Testing	✓		N/A	N/A	N/A	61%
117th & Holladay	Flow Testing	✓		N/A	N/A	100%	100%*
Belmont & 42nd	Flow Testing	✓		96%	N/A	56%	N/A
Fremont & 131st	Flow Testing	✓		94%	N/A	95%	100%*
Glencoe Rain Garden	Continuous & Flow Testing	✓		80%	85%	56%	100%
Mt Tabor Rain Garden	Flow Testing		✓	N/A	N/A	68%	N/A
Reedway & 90th	Flow Testing	✓		N/A	N/A	N/A	100%
Sandy & 21st	Flow Testing	✓		100%	N/A	94%	100%*
Sandy & Davis	Flow Testing	✓		N/A	N/A	100%	100%*
Siskiyou & 35th	Flow Testing	✓		78%	N/A	75%	N/A
Virginia & Florida	Flow Testing	✓		N/A	N/A	N/A	100%
Tryon Headwaters	Flow Testing	✓		N/A	N/A	N/A	72%

* Not tested; assumed based on results of CSO design storm testing

While there is a range for the CSO design storm tests, results overall have been generally consistent, regardless of antecedent rainfall, with overflow occurring only during larger storms events. Variability in performance is usually attributable to design and local site variations. This is quite different than the



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



Infiltration Rates for All Facilities (left) and Facilities Separated by Region of the City (right)

(box plots: the thin vertical line represents the range of values, the grey box is the middle two quartiles, and the black bar is the median; * = statistical outliers. All n = 31, N n = 3, NE n = 10, SE n = 11, SW n = 7.

assumption before testing began – that a high degree of variability in urban disturbed soils would lead to highly variable performance.

SW 12th Green Street

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 infiltration facilities, the first 18 inches of soil is replaced with a specified mixture of topsoil, sand, and compost. The boundary between imported and native soils is tilled to prevent a "hard" interface, and the imported soil is installed in two lifts with no mechanical compaction (typically a landscape roller).

SE Ankeny Green Street

Infiltration rate data is either taken at the end of design storm testing or as a stand alone test. The stand alone test is accomplished by filling the facility two or more times and then recording changes in water depths at regular time intervals. In both cases, the facilities have been well wetted and represent wet soil conditions.

The median infiltration rate for all facilities tested was 3 inches per hour, and this median was similar in all parts of the city but the north which had noticeably higher rates. While the west side median rate is very similar to the median for all facilities tested, the range of values was lower – between 0.5 and 4.5 inches per hour. Rates on the east side typically ranged from 1 to 13 inches per hour. This is expected because the west side soils are typically finer grained and are more likely to have a confining layer of low permeability beneath them.

OMSI North Parking Lot Swales

It is interesting that one of the oldest facilities in Portland, the parking lot swales at OMSI, are still performing well. A test was performed in 1995, and though a minimum infiltration rate was not mentioned for this test, the average rate for the whole test was reported to be 8 inches per hour. The average rate for the test in 2005 was 13 inches per hour (with the rate at the end of the test dropping to 6 inches per hour). While there are likely differences between site conditions for the two tests, the results would indicate that infiltration capacity has at least been maintained and may have actually increased over time.

Because each infiltration facility will typically have a unique combination of subsurface soils, drainage area characteristics, and design variables, it is difficult to extrapolate results to other locations. However, by accumulating infiltration data from a large number of facilities in different parts of the city, it is hoped that results can be used to inform design and placement decisions, as well as refining performance assumptions used in planning and modeling.

There have been a few recent facilities that did not infiltrate well when construction was complete, but improved significantly in the months afterward. This reinforces the idea that growing root structures, worm tunnels, and other processes in a maturing soil / plant complex can open and maintain pathways within the soil and consequently improve infiltration.

Sediment accumulation has been significant in all facilities, though it is certainly more prevalent in some than others. It is important to accommodate sediment removal to maintain the design capacity of the facility so it can perform its intended function. Accumulation varies depending upon site characteristics, but a removal frequency of at least once a year seems necessary. In general, removal is done by hand in vegetated forebays as opposed to mechanical removal in hardened forebays. Small concrete pads (12 to 18 inches wide) are often used for facilities with higher expected sediment loads. When surrounded with plantings around the edge as a screen, much of the sediment is held on the pad which eases removal.

Some irrigation is 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 typically needs to be done two or more 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. Ensuring the proper plant size and placement for the facility location is very important.

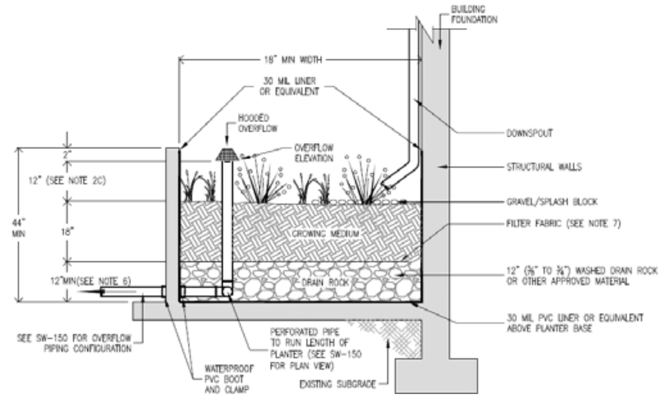
Testing will continue to track changes in infiltration over time, and to attempt to link infiltration performance to design variables and the type and frequency of maintenance activities.

Infiltration Facilities – SUMMARY

- ***Peak Flow*** – all facilities have been effective at reducing peak flows (average of 90% reduction with a range of 63% to 100%).
- ***Flow Volume*** – facilities have shown good annual volume retention (> 80%), and the potential for volume retention during CSO compliance events appears high (averaging 73%).
- ***Infiltration*** –
  - wet soil infiltration rates are typically between 1 and 5 inches per hour on the east side, while west side rates typically range between 0.5 and 3.0 inches per hour.
  - at least one older facility showed improved infiltration over a 10 year period (OMSI Parking Lot Swales).
  - a few facilities that have infiltrated poorly immediately after construction, have greatly improved after 3-6 months. This is likely attributable to vegetation roots, worm tunnels, and other soil processes occurring within a biologically active facility.
- ***Design*** –
  - facility overflows should be set to maximize the storage volume of the facility, but must be lower than any inlets to prevent an unintended overflow point.
  - elevations of weirs or check dams should be adjustable if possible, especially on gently sloping (<1%) streets where check dams or substantial vegetation close to entry may create resistance to flow that encourages bypassing around the facility.
  - straight-in inlets (requiring no change of flow direction) are preferred. Inlets at 90 degrees to the flow direction require substantial design elements (depressed gutters, diversion berms, etc) to prevent significant bypass during large events.
- ***Maintenance*** – sediment removal and weeding are the primary maintenance activities. Frequency will vary with the characteristics of each street, but basic maintenance should occur at least twice a year.

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 such as a sewer, sump, or surface drainage system.



Example Flow-through Planter Section

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 provide only partial volume reduction because some volume passes on through the underdrain system.

Though deemed successful for peak flow control and water quality improvement, it has been unclear how well flow-through planters will retain volume. This is important information when determining long-term compliance with CSO regulations.

Results from three lined facilities are reported: a lined swale in the Oregon Zoo parking lot, a lined planter taking roof runoff at the ReBuilding Center, and the test planters at the BES Water Pollution Control Lab (WPCL). The WPCL test planters were constructed to compare various planter design elements side-by-side. Four planters were constructed with the same surface area, but each bay is configured differently to compare three variables: 1) geometry (long and narrow versus short and wide); 2) soil mixture (sandy loam with varying amounts of amendments); and 3) underdrain clogging protection (filter fabric or a gravel blanket).

WPCL Test Planters

Peak Flow Reduction and Volume Retention of Flow-through Facilities

Facility	Monitoring Type	25-Yr Peak Flow Reduction	Annual Runoff Retention	CSO Flow Volume Retention
Oregon Zoo Parking Swales	Flow Testing	N/A	N/A	23%
ReBuilding Center Planters	Continuous & Flow Testing	62%	21%	29%
WPCL Test Planters	Flow Testing	91%[1]	N/A	26%[2]

[1] lowest reduction of the four planters; [2] average of all tests on all bays

Peak flow reduction was excellent for all configurations of the WPCL test planters, and was adequate at the ReBuilding Center planter. The range of peak flow reduction is similar to that found for infiltration facilities. This would suggest flow-through facilities are equivalent to infiltration facilities in reducing peak flow. However, it should be noted that because flow-through facilities have an underdrain, the choice of soil media is much more important. The use of freely draining soils, like those used at the ReBuilding Center Planters, result in quicker pass through of flow to the underdrain and less peak flow reduction.

Tests of the CSO design storms at all three facilities resulted in consistent volume retention results averaging 26%. The single tests at the Oregon Zoo and ReBuilding Center resulted in 23% and 29% retention, respectively. Results for the 14 tests run at the WPCL test planters ranged between 13% and 38% of inflow volume, with an average retention of 26% across all tests and all bays.

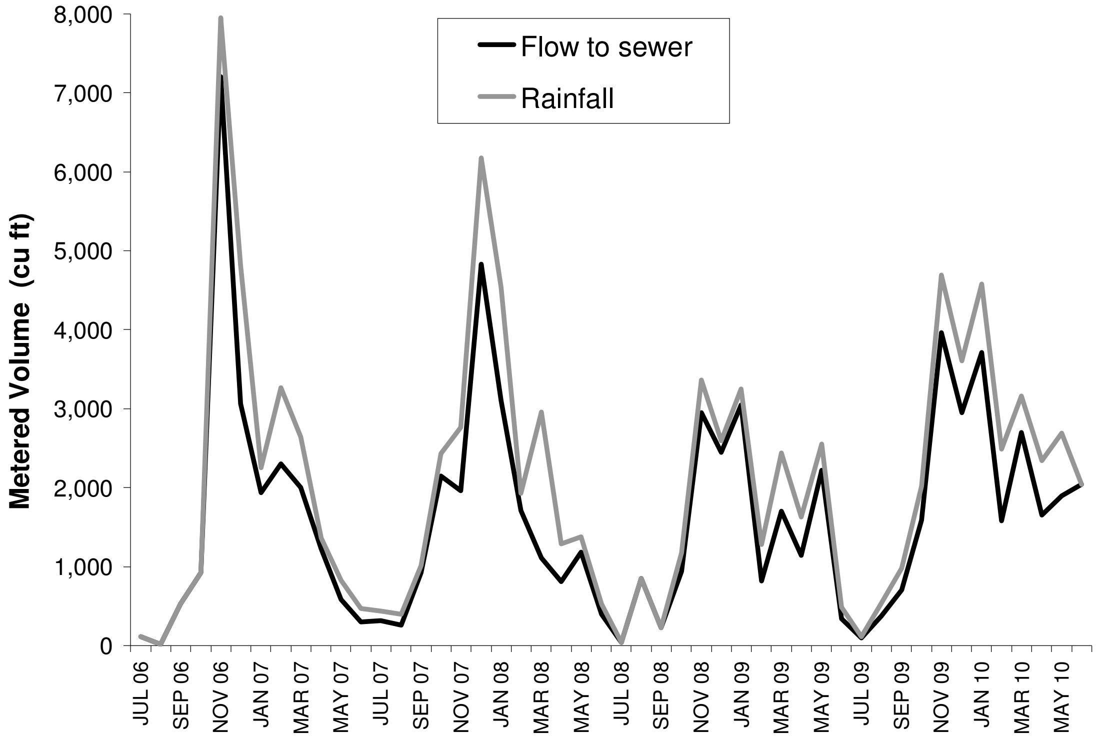
Regarding the design variables investigated at the WPCL planters, geometry appears to make a significant difference. The long, skinny planter [Bay 4] has an average retention 11% lower than the shorter, wider planter [Bay 1]. This is likely due to the greater wall length to surface area ratio. The greater wall length provides more opportunity for water to leak down the between the planter wall and soil, avoiding contact with 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). Differences in the two soils [Bay 1 versus Bay 2] were not significant. The soil / rock separator difference [Bay 1 (filter fabric) versus Bay 3 (gravel)] of 6% could be mildly significant, but the difference is only 3% for the last three tests. Filter fabric's greater resistance to the passage of water into the underdrain may increase volume retention. However, if filter fabric is used, it is important to ensure the soil and fabric are well matched to prevent clogging.

Estimated Volume Retention for WPCL Planter Tests

	Test	Bay 1	Bay 2	Bay 3	Bay 4
Apr 06 2006	Summer 6	**38%**			**24%**
Jul 16 2007	Summer 6	**34%**	**28%**	**28%**	**14%**
Aug 06 2007	ASFO	**30%**	**30%**	**28%**	**29%**
Jul 23 2008	Summer 6	**21%**	**27%**	**19%**	**13%**
Average		**31%**	**28%**	**25%**	**20%**

The ReBuilding Center Planters have been monitored continuously over the past four years, and have retained 21% of the total rainfall volume. Results are mildly conservative because during the largest rain events, the equipment becomes surcharged when the drywell overflow backs up. During such events, 0% retention is assumed.

An effort will be made to test more lined facilities in the future. It is expected that the number of lined facilities will increase in the future as facilities are needed in areas that are not suitable for infiltration.



Monthly Inflow and Outflow Volumes for the ReBuilding Center Planters

Flow-through Facilities – SUMMARY

- ***Peak Flow*** – Planters reduce peak flows of intense storm events well (> 62%).
- ***Flow Volume*** – CSO design storm retention has averaged 25% (with a range of 13% to 38%). Annual retention at one location has been 21%.
- ***Design*** –
  - freely draining soil mixes (> 2 inches per hour) can limit peak flow and flow volume reduction. If soils drain too quickly, there is little or no ponding because runoff infiltrates close to the inflow point and drops down into the underdrain while contacting only a small portion of the facility soil volume. A separate soil specification for flow-through systems may be warranted, along with some design modifications to prevent short-circuiting pathways to the underdrain.
  - shorter, wider planters seem to retain volume better than longer, skinnier planters. This is likely due to the fact that 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 underdrain.

Soil Sampling

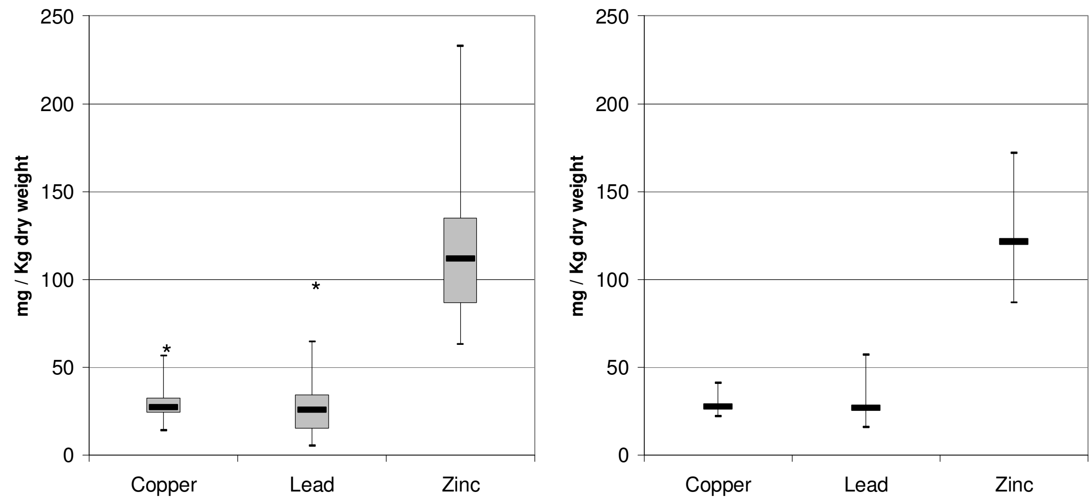
BES wants to ensure that surface stormwater management facilities do not create localized areas of high pollutant concentrations. A program of periodic soil sampling of selected facilities will be used to track changes in pollutant levels over time to determine if pollutant levels are changing over time.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

Summary of Facilities Selected for Soil Sampling

Facility	Location	Drainage	Age (yrs)	Land Use	2005	2007	2008	2010
12th & Montgomery Green Street	SW	Street	5	COM	✓	✓		✓
Glencoe Parking Swale	SE	Parking	7	RES	✓	✓		
Glencoe Rain Garden	SE	Street	6	RES			✓	
New Seasons Green Street	SE	Street	5	COM	✓	✓		
OMSI, North Parking Lot	SE	Parking	17	IND	✓			✓
Oregon Zoo Parking Lot	SW	Parking	3	COM			✓	✓
Siskiyou Green Street	NE	Street	6	RES	✓	✓		
SW Community Center Parking Lot	SW	Parking	13	RES	✓			✓
Tryon Headwaters Rain Garden	SW	Street	3	COM			✓	
Walnut Park Precinct Parking Lot	NE	Parking + cruiser washing	13	COM	✓			
Willamette & Denver Green Street	N	Street	3	RES			✓	

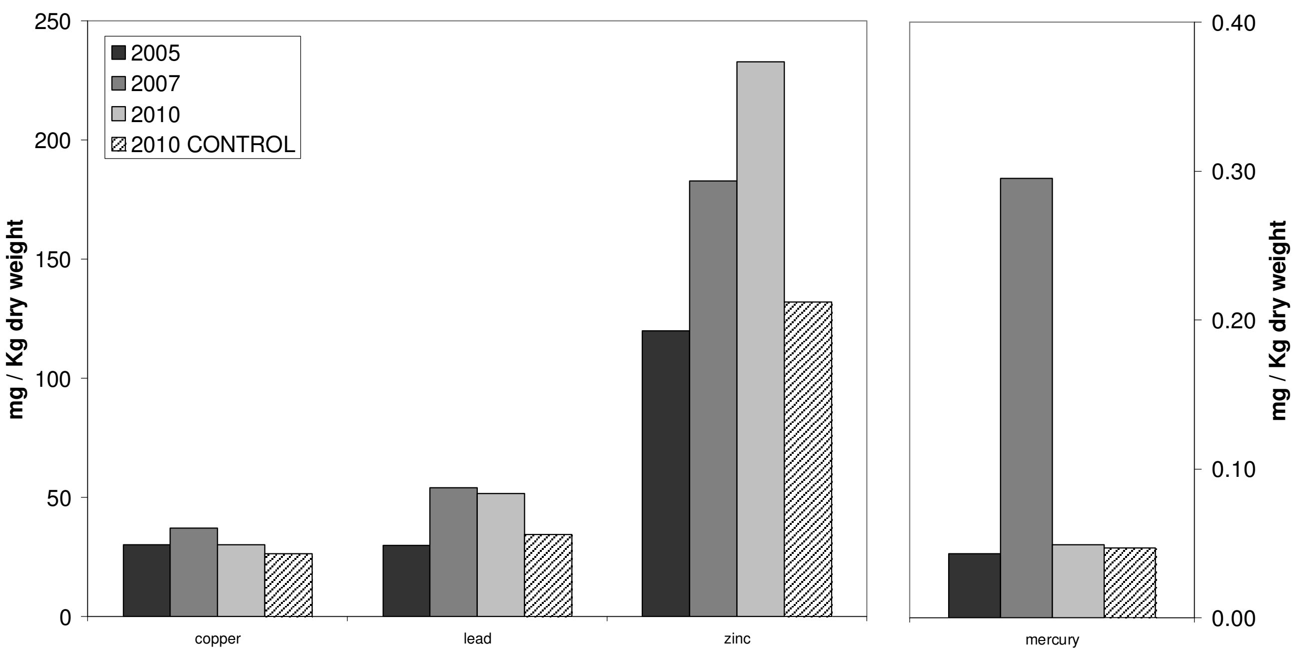
Samples are taken at three different 6 inch depth horizons: the surface (0 to 6 inches), the root zone (6 to 12 inches), and soil media / native soil interface (12 to 18 inches). Samples are tested for heavy oils, metals, pH, and polycyclic aromatic hydrocarbons (PAHs). Control samples are also taken from nearby landscape areas that are not within the stormwater facility and do not receive stormwater runoff.

There are no strong trends for metals, but one facility with three samples, 12th & Montgomery, has shown increasing zinc levels in the surface sample (0 to 6 inches), which are also elevated over control samples from outside the stormwater facility. Results may also be impacted by the level and frequency of maintenance, with greater attention to sediment removal likely resulting in lower concentration levels. The 12th & Montgomery facility was routinely maintained, but sediment did slowly accumulate in the facility. That accumulating sediment may be the source for the increasing zinc levels in the surface sample, though other metals did not increase.



Comparison of Surface Soil Metal Content for Facilities (left) and Controls (right)

for box plots, the thin vertical line represents the range of values, the grey box is the middle two quartiles, and the black bar is the median; * = statistical outliers

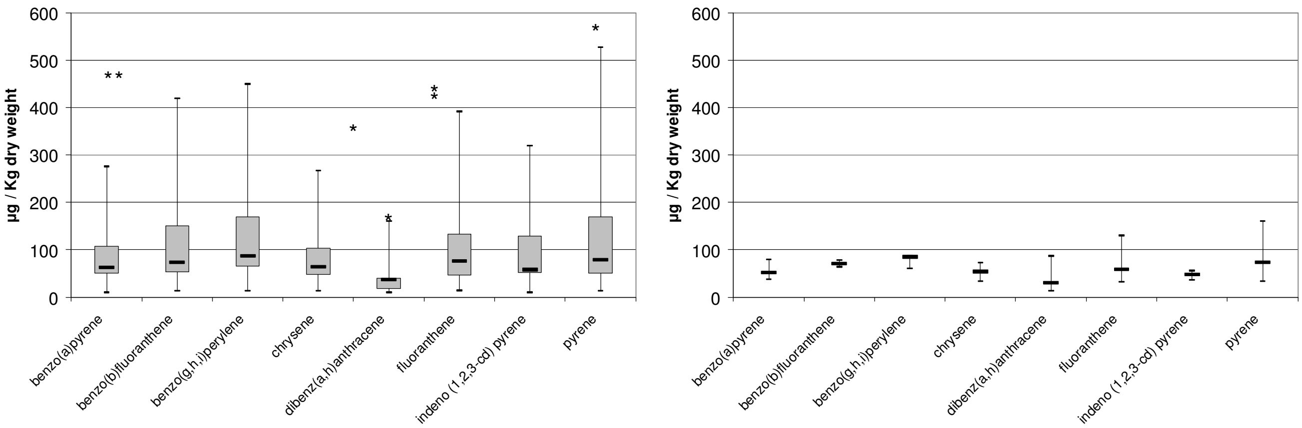


Surface Soil Metal Levels at SW 12th & Montgomery

The range of metal concentrations for the limited number of control samples (n=4), are generally similar to the concentration found in the facility samples (n=35). As more control samples become available, it will be possible to determine if this trend continues.

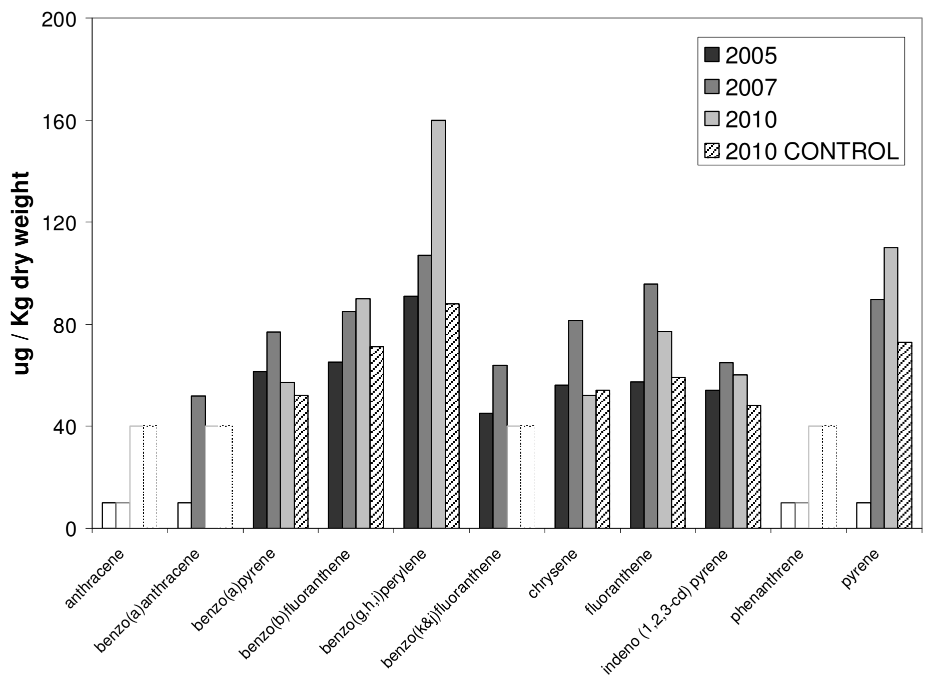
PAHs were found in all stormwater facilities, but typically at concentrations well below human health guidelines. More samples are needed to determine any potential trends in concentrations. There appears to be no strong correlation between PAH concentrations and surrounding land use or facility age.

Control samples were taken in 2010 outside the stormwater facilities for comparison. Control sample PAH levels were generally consistent with stormwater facility sample levels. This suggests that PAHs are prevalent in urban soils and not specifically associated with the soil in stormwater facilities. All PAH levels will be closely watched in the future to determine how levels are changing over time.



Comparison of Surface Soil PAH Content for Facilities (left) and Controls (right)

for box plots, the thin vertical line represents the range of values, the grey box is the middle two quartiles, and the black bar is the median; * = statistical outliers



Surface Soil PAH Levels at SW 12th & Montgomery

Soil Sampling – SUMMARY

- With only one to three samples available for each facility, more samples will be necessary to identify any trends that may exist. Each year, samples are taken at 3 to 4 facilities.
- PAHs levels found in stormwater facilities are generally similar to those found in control sites outside the stormwater facilities. Levels will continue to be tracked to determine if this continues in the future.
- PAHs levels found in stormwater facilities are generally similar to those found in control sites outside the stormwater facilities. Levels will continue to be tracked to determine if this continues in the future.

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