STORMWATER ACTION MONITORING

Studies Completed During the 2019-2024 Municipal Stormwater Permit Term

SAM
Stormwater Action Monitoring

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Dear fellow stormwater professionals and interested stakeholders,

We are pleased to share the Stormwater Action Monitoring (SAM) study findings from the 2019-2024 municipal stormwater permit term. SAM began in 2014 and has funded 34 studies to date. This booklet compiles fact sheets from 15 completed studies and 4 interim reports on long-term studies. It provides a single source for the scientists' collective findings and explains how the Washington State Department of Ecology (Ecology) has applied this new information.

SAM provides a framework for partnership and collaboration in its monitoring of stormwater management effectiveness and impacts at a regional scale. 97 Western Washington permittees chose to meet permit monitoring requirements by funding SAM directly. State and federal agencies, businesses, and volunteers have provided funds or services to collaborate with SAM and leverage our work. By learning together, we can achieve far more than by funding studies individually, and we all benefit by answering regionally relevant questions. Our understanding, and our responses to improve and manage stormwater, are coming faster and more efficiently than before SAM.

We've arranged this booklet according to the three SAM focus areas:

Studies to measure the effectiveness of stormwater management approaches

Projects to identify and address the most common sources of stormwater pollution

Studies to measure stormwater impacts and trends over time in small streams and nearshore areas

SAM's successes are due to sustained commitment by jurisdictions' stormwater staff to committee work that keeps SAM focused on topics most relevant to stormwater management actions and activities. We want to extend our gratitude to the Stormwater Work Group (SWG) for continuing to shape and support SAM, and to the Pooled Resources Oversight Committee (PRO-C) for their supervision of the administration of this collaborative monitoring program. Lastly, we want to acknowledge our past SAM staff at Ecology: Karen Dinicola, Keunyea Song, and Brandi Lubliner. Their creativity and vision have made a lasting impact. We look forward to completing the studies currently underway and launching projects to address new topics during the 2024-2029 permit term.

Enjoy!

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Water Quality Program | Washington State Department of Ecology

ABOUT SAM

Stormwater Action Monitoring

Stormwater Action Monitoring (SAM) is a collaborative, regional stormwater monitoring program that is funded by more than 90 Western Washington cities and counties, the ports of Seattle and Tacoma, and the Washington State Department of Transportation. SAM's goal is to improve stormwater management to reduce pollution, improve water quality, and reduce flooding. We do this by measuring stormwater impacts on the environment and evaluating the effectiveness of stormwater management actions. *Note: the Regional Stormwater Monitoring Program (RSMP) changed its name to Stormwater Action Monitoring (SAM) in 2017 in recognition of SAM's broader role – using the results of monitoring and studies to inform policy decisions and identify the most effective management actions.*

Why SAM is important

Stormwater pollution is one of the biggest threats to western Washington streams, lakes, and Puget Sound. Stormwater runoff from developed areas drains to local water bodies, where it releases pollutants, causes flooding, erodes streams, harms salmon, and closes shellfish beds.

SAM identifies effective actions and tracks regional progress reducing pollution and flooding associated with stormwater. SAM projects are developed in an open and coordinated way. The goal is to capture a regional understanding of how management actions can lead to results. Stormwater managers, field practitioners, and policy makers can use SAM findings to improve management practices and to set project and funding priorities. The pooling of funds allows jurisdictions – large and small – throughout the region to benefit from SAM projects that are designed to produce transferable findings. Any jurisdiction with science staff, expertise, and interest can participate in SAM studies. Those without science staff, particularly smaller jurisdictions with limited capacity and resources to conduct monitoring, can benefit from these collective efforts. Jurisdictions may also leverage SAM funds to answer relevant local questions. All permittees implement SAM findings to protect lakes, rivers, local streams, and Puget Sound.

How SAM works

Collectively, municipal stormwater permittees in western Washington spend an estimated $250 million per year to manage stormwater and they invest about one percent of these expenditures into a pooled fund.
SAM efforts produce actionable findings in three focus areas.

How well are required or innovative stormwater management practices working? Our **effectiveness studies** answer why or why not, and under what conditions, various management approaches work or fail.

What are the most common types of pollution in stormwater? Our **source identification** projects identify the most common problems and propose regional actions.

How do we know if water quality is getting better or worse? Our **receiving waters** projects evaluate conditions in the water bodies that we are trying to protect. This approach is unique since no other monitoring in the state is designed to give feedback on permitted areas.

The long view

SAM's unique design provides flexibility to accomplish long-term results. Our projects are not limited by grant program timelines or permit expiration dates. SAM projects deliver concrete interim and final products, and provide useful information throughout the duration of each individual project.

Our partners

The Stormwater Work Group (SWG), a formal stakeholder group, defines SAM activities. The Pooled Resources Oversight Committee (PRO-Committee), a subgroup of the SWG, oversees transparency, efficiency, and accountability of SAM expenditures. The Washington State Department of Ecology serves as the administrative entity that manages SAM funds and executes SAM contracts. State and federal agencies provide in-kind leadership and support on projects.

What is NPDES?

NPDES stands for National Pollutant Discharge Elimination System. It is the federal Clean Water Act's permitting approach to reduce the impacts of stormwater by requiring local governments, ports, the state department of transportation, and other large public landowners to implement specific practices. In Washington, the State Department of Ecology writes and issues these permits as the U.S. Environmental Protection Agency's delegated authority. The permits require:

- Public education, involvement, and participation;
- Active management of stormwater runoff from construction projects and developed areas;
- Operation and maintenance (like sweeping and other cleaning) of roads, ponds, parking lots, catch basins, and other parts of the storm sewer system; and
- Efforts to prevent spills and remove illegal sources of pollution in stormwater.

Effectiveness Study

Bioretention capture efficacy of PCBs from stormwater

Plant and fungi amendments to bioretention for pollutant reduction over time

Bioretention hydrologic performance study – focus on current designs

Redmond paired watershed study – interim findings

Oyster shell retrofits in catch basins for dissolved metals treatment

Effects of mulch on stormwater treatment and maintenance effort in bioretention systems

Measuring individual tree water-use in mature native species in the PNW

Designing and evaluating behavior change marketing campaigns

Evaluation of hydraulic control approaches for bioretention systems

Bioretention hydrologic performance study – facilities ten years or older

Selecting the right plants for roadside ditches

Stormwater Action Monitoring

Bioretention capture efficacy of PCBs from stormwater

Effectiveness Study

Lead Entity: King County

Partner: Washington State University, United States Fish and Wildlife Service

For More Information: Go to Ecology.wa.gov/SAM and search for 'bioretention reduction of PCBs'

Study goals

Bioretention is a widely applicable and flexible best management practice (BMP) in western Washington and the fate of organic pollutants such as polychlorinated biphenyls (PCBs) in bioretention facilities has not been studied much historically. The goal of this study was to improve our understanding of the fate and transport of PCBs in the most commonly used bioretention BMP soil mixture (60% sand and 40% compost; the 60:40 mix). The study examined:

1) Does the bioretention soil mix effectively sequester PCBs from stormwater?

2) Are PCBs lost from the bioretention soil mix in the dry season?

3) Do PCBs accumulate in the bioretention soil mix?

Stormwater management problem

PCBs have caused impairments and fish consumption advisories in Washington State's freshwaters and in Puget Sound. Many PCB sources contribute to widespread distribution through urban air deposition and wash off of impervious surfaces. Despite their intentional manufacture being banned decades ago, PCBs continue to be created as byproducts of other manufacturing processes and are inadvertently used in the urban landscape. Reducing ongoing loads of PCBs is important to reduce and prevent adverse impacts on waterbodies. The potential for successful treatment and removal of PCBs from stormwater runoff by bioretention was largely unknown prior to this study.

Project findings

This two-year monitoring project installed six experimental bioretention soil mesocosms in 55-gallon drums in a Seattle neighborhood and applied stormwater gathered from 30 acres of the Interstate-5 highway and associated grassy medians and rights-of-way. Influent, effluent, and the bioretention soil mix were sampled quarterly.

We found over the course of the study that:

1) On average, effluent concentrations of PCBs were approximately 90% lower than the stormwater influents when filtered through the 60:40 bioretention soil mix. Including plantings in the mesocosms did not significantly change capture effectiveness compared to those with no plantings.

2) There was no seasonal pattern detected in PCB concentrations in bioretention soils.

3) PCBs did not accumulate in bioretention soils. No special soil management practices need be considered in the short term (years) with regard to accumulated PCBs. Overall, PCB concentrations in the bioretention soil went down slightly over the two-year period.

4) Loadings from stormwater to soil were modest in this study and bioretention soils are biologically active. Thus, PCBs are probably degrading at a rate comparable to their input, but this requires confirmation.

Figure 1. Six experimental bioretention soil mesocosms in 55-gallon drums received stormwater collected from Interstate-5 highway.

Recommendations

The long-term efficacy of bioretention for removing PCBs remains unknown. Establishing an annual or semi-annual bioretention monitoring program which includes persistent organic compounds including PCBs would be a valuable contribution. Conducting bench-scale studies of labelled PCBs in bioretention soil mix would help conclusively determine their fate.

Why does this study matter?

Bioretention soils are highly effective at removing PCBs from stormwater. Widespread application of BMPs incorporating bioretention could make significant progress towards reducing the impacts of PCBs on receiving waters and related fish consumption advisories.

There were no direct or known sources of PCBs to the study site and the concentrations were relatively low, presumably typical to stormwater from atmospheric deposition and low-level dispersed sources. The lack of buildup in the bioretention soils provides some assurances for stormwater managers that bioretention facilities in typical residential and roadway settings will not accumulate PCBs in the 60:40 soil mix.

What should we do with this information?

Stormwater managers should continue to utilize bioretention based BMPs with the 60:40 soil mix wherever practicable. Typical urban watersheds with high concentrations of PCBs in stormwater will benefit the most from bioretention retrofits to reduce PCB discharges to receiving waters. However, more study is needed to understand the fate and transport of PCBs in bioretention facilities in areas with the highest concentrations of PCBs.

What will Ecology do with this information?

Ecology will continue to encourage, support, and fund installation of bioretention facilities using the 60:40 mix to treat stormwater across the state. This study provides much needed information about the successful treatment and removal of PCBs in stormwater. Finding no buildup of PCBs in the soil matrix is promising. Ecology would welcome continued study to determine an upper treatment threshold of organic contaminants by established bioretention facilities and alternative bioretention soil mixes.

Plant and fungi amendments to bioretention for pollutant reduction over time

Stormwater Action Monitoring

Effectiveness Study

Lead Entity: U.S. Fish and Wildlife Service

Partner: Washington State University, Auburn Univeristy, King County Department of Natural Resources

For More Information: Go to Ecology.wa.gov/SAM and search for 'bioretention amendment with fungi'

Study goals

To evaluate the role of plants and fungal amendments in the bioretention best management practice (BMP) on hydraulic performance, stormwater treatment, and toxicity to zebrafish.

Stormwater management problem

Ecology specifies design criteria for bioretention with a layer of engineered bioretention soil mix (BSM) of 60% sand and 40% compost by volume (60:40) between a surface layer of mulch and a bottom layer of drainage gravel. The biological elements of bioretention, such as plants and fungi growing in the mulch layer, may provide water quality treatment and other benefits. However, these biological benefits have not been quantified in standard bioretention systems.

Project findings

This two-year field-scale evaluation gathers new information about how local plants and mulch inoculated with *S. rugosoannulata* affect water quality and other bioretention performance parameters. Runoff from 32 acres of urban residential and Interstate 5 (I-5) surfaces was collected in an underground vault and used to dose 12 underdrain bioretention mesocosms at a realistic loading rate for two years. (See Table 1 for mesocosm components.) Bare-root Pacific ninebark plants (deciduous shrubs) were used in half of the bioretention cells. Unfortunately, despite supplemental watering the summer 2017 drought killed some plants. By the end of the study, treatments with plants had reduced export of nitrogen and increased hydraulic conductivity. However, the failed establishment of the original plantings during half of the study period limited meaningful conclusions about plant impacts to water quality overall. Fungi decomposed nearly all of the alderwood mulch mass over the two years. By mid-study, fungi were observed to be growing in all of the treatments, including the control; however, the fungi were far more abundant in the inoculated treatments.

Differences in mulch mass between BSM treatments diminished by the end of the second year; these findings suggest that routine mulch resupply is likely needed for bioretention facilities. Whereas plants increased hydraulic conductivity, fungi decreased it by the end of the study. Control and treatment with both plants and fungi showed no change in hydraulic conductivity, implying that these biological elements of bioretention offset their individual impacts on hydraulic conductivity. Fungi retained soil moisture needed for plants and microorganisms to thrive.

Table 1. Bioretention treatments used in study; n = 3 for all treatments

Treatment label	Explanation
BSM (Control)	Bioretention soil medium with mulch
BSM + F	Bioretention soil medium with fungi-amended mulch
BSM + P	Bioretention soil medium with mulch and plants
BSM + F + P	Bioretention soil medium with fungi-amended mulch and plants

Water quality benefits of BSM, plants, and fungi
Bioretention systems, regardless of fungal and/or plant amendments, significantly improved water quality by removing metals, bacteria, solids, and organic compounds from urban runoff. Similar to previous study findings, nutrients and some metals were initially released from all bioretention systems. However, the export rate of orthophosphorus decreased over 70% during the two-year study period compared to the control. Bioretention was most effective for removing fecal coliform (including *E. coli*), lead, zinc, and total suspended solids. No contaminants in the BSM reached ecologically concerning levels.

The stormwater influent was inconsistently toxic to zebrafish, making it difficult to interpret the treatment effects. Neurotoxicity risk to fish was reduced in effluent waters from all treatments as a result of significant decreases in dissolved metal concentration. Toxicity reduction was more common during Year 2 than Year 1.

Fungi provided multiple water quality benefits to the systems including reduced phosphorus leaching from the BSM and improved removal of some metals, especially during the initial peak leaching stage.

Recommendations

For stormwater managers
To optimize water quality treatment, mulch should be renewed on a regular basis as a substrate for fungi. Plants roots maintain hydraulic conductivity, and plant selection should include evergreen varieties with tolerance to summer drought.

For future study
Future toxicity research should use more sensitive endpoints than zebrafish when stormwater with low suspended solids is the influent source for treatment effectiveness studies.

Why does this study matter?

As bioretention becomes more widely used, stormwater managers want to apply the most successful design options and maintenance requirements to local facilities. This study increases our understanding of the biological elements of bioretention.

What will Ecology do with this information?

The reduction of phosphorus export from the fungal-inoculated mulch layer is notable for the establishment year of a new bioretention BMP. Use of fungal-inoculated mulch to jump-start microbial activity and reduce phosphorus export during the installment year is allowed for new bioretention facilities. Ecology will maintain guidance limiting new bioretention facilities built with the 60:40 BSM within ¼ mile of phosphorus-sensitive waterbodies.

What should we do with this information?

Stormwater managers should continue to use bioretention-based BMPs with the 60:40 BSM wherever practicable.

Fungal colonization will occur naturally in any mulch layer over time. Because fungi improve soil moisture content and provide favorable conditions for plants, stormwater managers may consider fungal inoculation to the mulch layer in new bioretention installations. This may stimulate fungal community growth and lessen phosphorus export during the higher initial leaching period.

Annual resupply of the mulch layer will help maintain the benefits of fungal communities, retain soil moisture, and help with weed control.

Stormwater managers should remember that, with 60% sand in the default BSM, summer irrigation is needed for plant establishment and survival.

Bioretention hydrologic performance study – focus on current designs

Stormwater Action Monitoring

Effectiveness Study

Lead Entity:
City of Olympia Public Works--Water Resources

Partner:
City of Bellingham, City of Marysville, City of Renton, Monroe School District, Tacoma School District, Tumwater School District, Clear Creek Solutions, Taylor Aquatic Science, Associated Earth Sciences, Aspect Consulting, LLC, Raedeke Associates, Inc.

For More Information: Go to Ecology.wa.gov/SAM and search for 'bioretention hydrologic performance'

Study goals

This is the second phase of the Bioretention Hydrologic Performance (BHP) Study. Both study phases evaluated the hydrologic effectiveness of bioretention facilities—specifically, how well modeled expectations for stormwater flow control match observed and measured performance at actual installations across Western Washington. This study phase focused on bioretention facilities that were designed using the current software version of *Western Washington Hydrology Model* (WWHM 2012), which includes the bioretention design model as opposed to other models. For more background, see SAM Fact Sheet #12: Bioretention Hydrologic Performance Study, Phase 1.

Stormwater management problem

Many bioretention facilities are built in the region to control stormwater flows and provide water quality treatment. They are also increasingly installed as retrofits, built to fit into an already developed landscape, to add more stormwater control than previously existed. Local governments seek evidence that bioretention facilities are efficient and effective in treating stormwater and can help protect receiving waters from erosive flows. A multidisciplinary assessment verifies that facilities function as intended and supports more bioretention infrastructure.

Project findings

All ten bioretention sites were recently constructed (within two years). Conclusions from the first BHP study were reaffirmed in this second phase, and some new findings are specific to the retrofit facilities (five of ten sites) monitored in this phase.

Geotechnical and soil conditions: Bioretention soil texture was again coarser than Ecology's guidance, resulting in greater infiltration rates than designed. Evidence of foot traffic compaction was seen, especially near edges of smaller linear facilities. More infiltration appears to occur near inflow locations, potentially affecting vegetation survival and water quality treatment performance in underdrain facilities.

Site design and hydrology modelling: The WWHM 2012 model built from field measurements of each site adequately represented observations, verifying accuracy of the model's ability to predict performance. However, the design models were often not set up correctly for infiltration rates and safety factors. Top areas (at overflow elevation) for three constructed bioretention facilities (two of which were retrofits) were substantially smaller than indicated in the design report, resulting in less flow control than intended. Low-set overflow elevations in other cases allowed frequent overflows to occur. Field-measured infiltration rates were substantially higher in the field at five facilities, resulting in a greater degree of infiltration than predicted by the model.

Vegetation survival: Plantings reflected the original planting plans, but unfortunately the many water-loving plants were a mismatch with the well-drained soil conditions of bioretention facilities. Shrubs generally survive better than herbaceous plants.

Recommendations

There are still areas for improvement in design, review, and construction stages. Some newer facilities showed inconsistencies in constructed conditions compared to their designs, which affected their performance.

For jurisdictional designers/engineers/landscape architects:

- Maintain a ratio of 5% bioretention top area to drainage area for under drained facilities.
- Maintain a minimum 6-inch riser height above the bioretention mulch surface.
- Confirm the observed and model infiltration rates, safety factors, and associated parameters in the model using the technical information report and site plan.
- For jurisdictions that encourage infiltration with low native soil rates, consider encouraging a capped underdrain to allow variable drainage after installation.
- Sample bioretention soil mix prior to installation to ensure appropriate particle size distribution and use depths specified in the stormwater manual.
- Select plant species tolerant of a wide range of moisture conditions both vertically and laterally, recognizing greater moisture availability near the inflow, to increase plant survival and reseeding overtime.

For jurisdictions and Ecology:

- Develop a checklist for engineers and permit reviewers to verify correct entry of model parameters.
- Consider the use of a variable evapotranspiration rate in the model, rather than the existing default for all conditions.

Why does this study matter?

The BHP studies provide proof of performance from 20 existing facilities and guidance for future installations. The findings show that bioretention facilities work as intended for stormwater runoff flow control, providing stormwater managers with confidence in requiring their use. Trainings reached over 260 individuals, and a recorded training is available on the Washington Stormwater Center YouTube channel.

What will Ecology do with this information?

Ecology will reconsider the evapotranspiration rates in WWHM 2012. At this time, Ecology is not considering allowing flexibility for designer use site by site unless multiple local government reviewers request such flexibility. Ecology intentionally does not require retrofit facilities to meet the same design criteria as new and redeveloped facilities. Designers should use best professional judgment to maximize improvements in stormwater management with the available space.

Ecology will continue to encourage local reviewers to develop a simplified checklist and will consider guidance for construction phase inspections to ensure that facilities are installed to function as designed.

What should we do with this information?

Stormwater managers should be confident in the use of WWHM 2012 for bioretention installations. Performance expectation and predictable basin-wide stormwater management depend on accurate design, model, and construction of the bioretention facilities. Stormwater managers should discuss these findings with their staff to ensure appropriate designs, review, hydrologic performance, and maintenance.

Local staff conducting reviews are encouraged to develop a simple review checklist to verify future bioretention facilities and evaluate models, technical reports, and plan conditions for consistency. Planting plans should anticipate a wide range of dry and wet conditions and use a variety of plants likely to survive site-specific conditions.

Paired watershed retrofit and restoration study – interim findings

Stormwater Action Monitoring

Effectiveness Study

Lead Entity: City of Redmond

Partners: King County, Herrera Environmental Consultants, Inc.

For More Information: Go to Ecology.wa.gov/SAM and search for 'paired watershed retrofit'

Study goals

The goal of the Redmond Paired Watershed Study (RPWS) is to evaluate the effectiveness of the following rehabilitation efforts for improving receiving water conditions at the watershed scale:

- Stormwater management retrofits in upland areas that include installation of best management practices (BMPs) for onsite stormwater runoff treatment and flow control.
- Riparian and in-stream habitat improvements.
- Programmatic practices for stormwater management (e.g., more frequent street sweeping).

For more background on the RPWS, see SAM Fact Sheet #6: Redmond Paired Watershed Study – Status Update.

Stormwater management problem

In theory, if all developed land in a watershed were equipped with nonstructural and structural stormwater controls, the receiving water would be protected from hydrologic and water quality impacts caused by urbanization. While the effectiveness of nonstructural and structural controls has been well documented at the site and parcel scale, limited data exist on the effectiveness of these controls in aggregate at the watershed scale to stop degradation and improve conditions in receiving waters.

Redmond's 2014 Citywide Watershed Management Plan (WMP) coordinates stormwater management efforts under the Phase II Municipal Stormwater Permit, Section 303(d) of the Clean Water Act, and salmon recovery efforts to support a watershed approach to improving receiving water conditions. The WMP allows Redmond to focus BMPs in a subset of priority watersheds moderately impacted by urbanization and expected to respond more quickly to rehabilitation efforts. This approach provides a unique opportunity to study the effectiveness of stormwater BMPs for improving receiving water conditions on an accelerated time frame and at a watershed scale.

Project findings

The RPWS experimental design involves routine and continuous measurements of various hydrologic, chemical, physical habitat, and biological indicators of stream health over an extended time frame to quantify improvements in receiving water conditions in response to watershed rehabilitation efforts. Using a "paired watershed" experimental design, these measurements are collected in seven watersheds categorized as follows:

- Three "Application" watersheds with streams that are moderately impacted by urbanization and prioritized for rehabilitation efforts: Evans, Monticello, and Tosh watersheds.
- Two "Reference" watersheds with relatively pristine streams that do not require rehabilitation: Colin and Seidel watersheds.
- Two "Control" watersheds with streams that are significantly impacted by urbanization and not currently prioritized for rehabilitation: Country and Tyler's watersheds.

Monitoring for the study began in 2016 and is anticipated to continue for a 10-year timeframe. In study years 4, 6, 8, and 10, trend analyses reports will summarize analyses to detect potential improving trends in receiving water conditions related to the implementation of rehabilitation efforts. The first trend analysis report (for year 4) of RPWS implementation was recently completed. Major conclusions from annual monitoring and the trend report are as follows:

- Few consistent trends have been detected in the data for each indicator because rehabilitation efforts have been relatively modest in the Application watersheds thus far. Redmond will be constructing projects in the Application watersheds in 2021 that can now be assessed over multiple years of operation and varied climatic conditions relative to an extremely robust data set for baseline conditions.

- An interannual hydrologic trend was detected in the rainfall runoff response across most stations located in the Application, Reference, and Control watersheds. This trend was traced to climate- related changes over the four years. Specifically, progressively drier water years from 2017 to 2019 likely resulted in less saturation of the landscape, increased evapotranspiration, and reduced interflow and overland flow. This confounding trend from the first four years of this 10-year study will need to be accounted for in future analyses to reliably detect trends driven by hydrologic controls installed in the Application watersheds.
- Two detention vaults constructed in the Evans Creek watershed appeared to provide no measurable flow control benefit based on analyses of the rainfall runoff response in the creek before and after the vaults became operational. The likely explanation is that these two vaults are not treating a sufficient amount of the watershed area to have a detectable impact on flows.
- Total suspended solids (TSS) and total copper (Cu) concentrations consistently and significantly decreased in the Monticello Creek watershed, indicating that the increase in street sweeping frequency (from once to twice per month) on all public roads in the watershed benefitted water quality. These results are also consistent with a street sweeping study that was implemented by Seattle Public Utilities circa 2018.

Recommendations

The RPWS is less than halfway completed. These early findings suggest that to detect changes in receiving water peak flows in any given watershed, a meaningful threshold of flow control implementation is needed. This study aims to quantify these thresholds. Street sweeping should receive increased emphasis as an effective practice for improving receiving water quality.

Why does this study matter?

Ecological function in Puget Sound lowland streams is impaired to a large degree by outdated development practices and a lack of adequate post-construction controls for preventing adverse impacts from stormwater runoff. Information on the level of stormwater retrofit and stream rehabilitation required to restore ecological function in these areas is essential for guiding policies and programs on stormwater and receiving water management.

What will Ecology do with this information?

Ecology will continue to fund infrastructure improvements and maintenance activities, like street sweeping, for Washington's cities and counties to improve stormwater management and protect receiving water quality.

What should we do with this information?

Based on these early project findings, stormwater managers aiming to control TSS and Cu should consider increasing street sweeping. This study helps manage expectations of the public and elected officials at the planning stage by highlighting the time it takes for benefits of retrofits to become measurable. Stormwater managers may also need to identify additional indicators of project impacts or success.

Oyster shell retrofits in catch basins for dissolved metals treatment

Stormwater Action Monitoring

Effectiveness Study

Lead Entity: King County, DNRP

Partners: City of Mercer Island, Port of Seattle

For More Information: Go to Ecology.wa.gov/SAM and search for 'oyster shell retrofits'

Study goals

This study evaluated whether oyster shells retrofitted into stormwater catch basins can decrease dissolved metal and nutrient concentrations and increase hardness to help reduce runoff toxicity.

Stormwater management problem

Previous studies have shown that dissolved metals typically present in urban stormwater – particularly copper and zinc – can be toxic to fish and other aquatic life, even at relatively low concentrations. The toxicity of these metals increases when water hardness levels decrease, and hardness levels in stormwater are often very low. Because of this low hardness level, copper and zinc concentrations in stormwater are frequently above the acute and chronic Water Quality Standard (WQS) level. Stormwater managers are interested in low-cost retrofit opportunities to improve runoff quality and reduce harmful effects of runoff on aquatic organisms in streams and lakes that receive substantial stormwater inputs.

Previous studies showed success of oyster shell retrofits at the parking lot or individual building site scale. This study aimed to test the approach at a larger catch basin scale.

Figure 1. Bagged oyster shells were added to two catch basins.

Project findings

This study compared runoff from two catch basins each fitted with two cubic feet of oyster shells filtering stormwater to two catch basins that had no oyster shells. Stormwater was captured from four storms using time-weighted auto samplers and analyzed for metals, nutrients, hardness, and other conventional parameters. Dissolved copper, lead and zinc exceeded WQS in every sample from both treated and untreated catch basin. No apparent differences were found in any measured parameters between influent and effluent samples at either oyster shell-fitted catch basin or the catch basin. As it became apparent that the oyster shell-fitted catch basins were not significantly improving water quality, the study was halted.

The flow rates during the sampled storms in the four study catch basins ranged from 4.5 to 1180 gallons per minute (GPM) with an average flow of 25 GPM through the catch basin.

Previous studies that had reported successful use of oyster and mussel shells as stormwater treatment media were conducted with larger volumes of shells and a lower volumes of storm water. A previous study using oyster shells to treat metals in roof runoff found success treating 5 to 15 GPM flow through 4.8 cubic feet of oyster shells.

The results of this pilot study indicate that a much larger treatment media volume of oyster shells is necessary to adequately treat the amount of stormwater draining through the Mercer Island stormwater catch basins.

This study also found that finely crushed oyster shells, approximately half-inch pieces, likely contributed to a clogging event that occurred in both catch basins fitted with oyster shells prior to sampling. These were replaced with mostly whole and some lightly broken oyster shells placed in mesh bags, which did not induce clogging during the remainder of the study.

Recommendations

Additional studies will help project proponents and stormwater managers understand how to scale up the previously successful ratio of approximately 1-3 GPM of runoff through each cubic foot of oyster shell treatment retrofit, and what is the upper recommended limit of area that can or should be treated with this approach. For this study, approximately 12.5 GMP through 1 cubic foot of shells was too much flow and not successful.

Retrofitting of existing stormwater infrastructure with oyster shells to improve stormwater quality may potentially still be successful with a greater treatment- media-volume to stormwater-flow ratio that provides sufficient treatment/contact time. The study results indicate that lightly crushed (i.e., larger pieces) oyster shells worked best to prevent clogging of stormwater catch basins during rain events. Hydraulic analysis of the stormwater infrastructure to be retrofitted will help better understand the treatment-media-volume to stormwater-flow ratio needed to be successful. The Port of Seattle has found success with retrofitted catch basins in a smaller drainage area (i.e., parking lot) and oyster shells in rain barrels treating roof runoff (see https://www.portseattle.org/sites/default/files/2023-04/2023-0307_Final_Oyster_Handout.pdf).

The study also aimed to determine whether this non-proprietary technology should be evaluated through the Technology Assessment Protocol – Ecology (TAPE) program dissolved metals treatment.

Figure 2. Turning stormwater science into a teaching moment.

Why does this study matter?

We want to increase opportunities for affordable retrofits that provide stormwater treatment benefits for local lakes, streams, and Puget Sound, especially from areas without existing stormwater treatment. This oyster shell retrofit design requires minimal construction and causes no impacts to above-ground areas. With the right treatment-media-volume to stormwater-flow ratio, this type of retrofit could provide a relatively inexpensive, low maintenance treatment for dissolved metals removal.

What will Ecology do with this information?

Ecology should continue to allow oyster shell retrofits to treat small areas. Ecology can use the findings from this study to design studies to help us further understand how to successfully design and implement oyster shell retrofits to improve stormwater quality. Such studies should result in provisional design and maintenance criteria for scaled-up application of oyster shell retrofits.

What should we do with this information?

Stormwater managers should allow oyster shell retrofits to treat runoff from a small parking lot or building roofs, particularly where land uses are likely to produce metals in the runoff. Shells should not be finely crushed, or clogging may result. Ensure that the project proponents choose a suitable site for installing oyster shell retrofits and an adequate treatment-media-volume to stormwater-flow ratio. These retrofits might be a key step in a treatment train.

Effects of mulch on stormwater treatment and maintenance effort in bioretention systems

Stormwater Action Monitoring

Effectiveness Study

Lead Entity: Washington Stormwater Center, Washington State University

Partners: Washington Stormwater Center, Washington State University, Boeing, Snohomish Conservation District

For More Information: Go to Ecology.wa.gov/SAM and search for 'mulch effectiveness for bioretention'

Highlights:

- Mulches preserve bioretention soil moisture to aid plant survival in the summer. Arborist chips and nugget mulches help retain the most water.
- Mulches cut weeding time by half and limit nitrogen export from soil.

Stormwater issues related to the study

Weeding, summer watering, and replacement of plants in bioretention systems can be costly. By design, stormwater that flows into bioretention facilities will contact a mulch layer first, before other biological components. Stormwater managers want to understand the role that mulch plays in reducing operation and maintenance (O&M) costs and limiting pollutant export, and how benefits differ among common mulch choices.

Study objectives

The study used 16 experimental bioretention cells located at Washington State University's Puyallup Extension campus. The cells were refurbished and four replicates each were topped with: three different types of mulch (arborist chips, medium bark mulch, and nugget mulch, see Figure 1) and no-mulch, for study control. The study objectives were to quantify, by mulch presence and type:

- difference in the necessary weeding time and effort;
- water retention in the bioretention cells;
- soil moisture content in the bioretention cells;
- pollutant reduction across the mulch types.

Project findings

All three mulches suppressed weed growth significantly over controls, and no single mulch type was significantly better over the two years of this study.

All bioretention cells reduced by half the water outflow *rates*. The cells topped with nugget mulch had significantly lower outflow *volumes* than the other mulches and no-mulch controls.

All three mulches preserved more soil moisture than the no-mulch controls. The cells with arborist chips maintained the highest soil moisture readings during the study, experiencing dry conditions (defined for this study as having soil moisture less than 25% water content by volume) only 22% of the study period, while no-mulch control cells experienced dry conditions nearly 83% of the time. Bioretention cells with medium bark and nugget mulch experienced dry conditions 38% and 33% of the time, respectively.

Figure 1: Three types of mulch were tested in bioretention systems

The arborist chips -- but not the other mulches -- were depleted, presumably due to soil microbe consumption, and were replenished during the study.

While all of the bioretention cells exported nitrogen and phosphorus, the nitrogen concentrations in bioretention effluent were significantly lower in the presence of mulch compared to the no-mulch controls.

While not an intentional component of the study design, sun exposure and shade had a significant impact in plant stress and survival. The plants in the cells that were partially shaded by a nearby building were more robust than the plants in full sun.

Recommendations

Add and maintain mulch at the recommended depth of 2 to 3 inches to help retain water and suppress weeds. The nugget mulch and medium bark mulch lasted for the duration of the study, and may need to be replenished after 2 or 3 years. Arborist chips needed annual replenishment in this study, increasing costs.

Use the plant "ninebark" sparingly in Washington bioretention cells and rain gardens because it spreads rapidly by putting out runners under the mulch, likely requiring added maintenance to prevent it from taking over the bioretention facility.

Figure 2: Mulch plays a critical role in maintaining soil moisture, and limiting weeds

Why does this study matter?

This study quantifies the benefits provided by a 2-3 inch layer of mulch in a bioretention facility for weed suppression, water retention, plant survival, and pollution reduction.

What should stormwater managers do with this information?

Add and maintain a mulch layer to help retain water and reduce plant loss in bioretention cells, particularly in full sun, and to limit the establishment of weeds. Stormwater maintenance programs utilizing mulches may see reduced O&M costs overall due to reducing watering needs in the summer, improved plant survival, and reduced weeding or the need for herbicides. Bioretention designers, landscape designers, horticulturists and others should limit use of water loving and easily spreading plants such as 'ninebark' to minimize maintenance needs in bioretention facilities and rain gardens.

What will Ecology do with this information?

Ecology will update the guidance for bioretention facility best management practices (BMPs) in the stormwater management manuals to recommend covering bioretention soil mix with a mulch covering. Ecology continues to support bioretention BMP projects and to prioritize these approaches and other low impact development (LID) or 'green infrastructure' treatment options for stormwater runoff management.

Measuring individual tree water-use in mature native species in the Pacific Northwest to determine their benefits for stormwater

Stormwater Action Monitoring

Effectiveness Study

Lead Entity:
Washington Stormwater Center, Washington State University

Partners:
Evergreen, Washington Department of Natural Resources

For More Information: Go to Ecology.wa.gov/SAM and search for 'tree water budgets'

Highlights:

- Evergreen and deciduous trees captured or slowed stormwater by intercepting and transpiring 44-65% of rainfall.
- Evergreen trees provide more hydrologic benefits for stormwater management than deciduous trees.

Study goals related to stormwater managment

Using existing trees to manage stormwater in urban areas, particularly rapidly growing communities in western Washington is of great local interest. Low Impact Development (LID) includes guidance to leave mature trees in place when developing properties to manage rainfall and runoff as well as providing other co-benefits such as green space and shade. Stormwater managers need information on the relative benefit provided by individual trees as stormwater best management practices (BMPs).

The purpose of this project was to quantify how much rain and runoff is captured by mature common native evergreen and deciduous trees based on actual climatic conditions of the Pacific Northwest.

Instruments were installed at 64 trees in two locations around the Olympia area to determine transpiration rates of four species: Douglas-fir, western red cedar, big leaf maple, and red alder. All 64 trees had instruments to measure sap flux, 36 measured canopy interception, and 24 measured stemflow.

Project findings

A total of 184 qualified storm events were monitored; 116 events occurred during leaf- off and 68 occurred during leaf-on seasons. The total tree hydrologic budget was calculated from the two years of data as the fraction of rainfall captured by transpiration and interception. Rainfall data was segmented into discrete storm events as defined by Ecology criteria.

Table 1. Water budgets: rainfall and median values for All four species intercepted and transpired over 40% of transpiration plus interception by tree species

Season	**Leaf-Off (Nov-April)**		**Leaf-On (May-Oct)**	
Qualifying Storm Totals (cm)	124.8		42.9	
	Median transpiration + interception of qualified storms by tree species			
Tree Species	%	cm	%	cm
Big leaf maple	27.6	34.4	126.5*	54.3
Red alder	30.6	38.2	76.2	32.7
Douglas-fir	57.2	71.4	73.1	31.3
Western red cedar	63.3	79.0	72.6	31.1

** The big leaf maples intercepted and transpired more than the total volume of water incident on their canopies (126.5%) during the leaf-on season. Extra water was likely drawn by the roots from the soil.*

All four species intercepted and transpired over 40% of the rainfall landing on their canopies on an annual basis, meaning this rainfall did not become runoff. Differences between trees were most evident in the leaf-off season (winter through spring) when the stormwater management needs are highest. During the leaf-off season the evergreen trees (which keep leaves year round) continue to transpire and intercept rainfall on their canopies, where as deciduous trees can only intercept on their branches, and are mostly dormant maple (not transpiring) for much of this timeframe. Overall these mature tree species managed 44-65% of annual rainfall through interception and evapotranspiration.

Recommendations

We recommend mature tree retention and tree planting in urban settings to the extent feasible, use of more evergreen trees when possible for the soil stormwater management in the wetter months.

Why does this study matter?

This study gathered high quality water budgets on individual mature native trees in Washington State. We compared these findings to the 'tree credits' offered in the Ecology Stormwater Management Manuals (SWMMs) under BMP T5.16 (WWA) and BMP F6.62 (EWA). Per BMP T5.16/F6.62, if trees are retained on site and meet certain requirements (e.g proximity to an impervious surface), the 'tree credits' allow the designer to reduce the amount of impervious surface entered into the model. This impervious surface reduction will mimic the reduced runoff flow that the retained tree(s) will cause, compared to runoff flow from the full amount of impervious surface(s) without nearby retained tree(s). Our comparison showed no changes are needed to the 'tree credits' under this BMP.

What should stormwater managers do with this information?

Stormwater designs may be able to reduce the size of Flow Control BMPs if they retain mature trees and apply 'tree credits' per SWMM BMP T5.16/F6.62. This LID strategy can be used to encourage preserving mature trees in areas for stormwater mitigation, which will also result in multiple co-benefits. Evergreen trees provide distinct advantages for winter and spring hydrology, but the most appropriate tree for the site should be planted.

What will Ecology do with this information?

We confirmed that the appropriate amount of 'tree credits' are allowed per BMP T5.16/F6.62. Ecology will add a reference to this study in BMP T5.16/F6.62, as supporting documentation for the BMP design guidance. Further, Ecology looks forward to the second phase of this study on the same species as new tree plantings.

Stormwater particle size distribution (PSD) & implications for BMP effectiveness

Stormwater Action Monitoring

Effectiveness Study

Lead Entity: Washington Department of Natural Resources

Partners: Evergreen Storm H2O

For More Information: Go to Ecology.wa.gov/SAM and search for 'stormwater particle-size distribution'

Highlights

- Fine particle sizes carry more bound pollutants to stormwater systems, yet many existing BMPs target this and other size ranges.

Study goals

The particle size distribution (PSD) of stormwater runoff can influence the types and amounts of pollutants that are present, as well as the way that pollutants are transported and interact with each other and the environment. BMP effectiveness in controlling the full range of particles in stormwater is typically not reported or even tested, which makes selecting a BMP more challenging. This literature review gathered the latest information on the size of particles in stormwater, the connection between particle size and stormwater chemistry, and the effectiveness of treatment approaches for particle sizes.

Findings

Methods for Measuring PSD

We identified common testing methods for PSD, and found that ASTM 3977-97 Method B with laser diffraction is most likely to have comparable results the TAPE method, The TAPE method ASTM D3977-97, is a modified version of ASTM 3977-97 Method B and Method C.

Sources of Particulates to Stormwater

Sources of particles to stormwater include automotive, local soil erosion products, and atmospheric deposition. The most transported sizes appear to be clay and silt sizes. There was not enough basin condition data in the literature to characterize particles and sources by land use or area.

BMP Effectiveness as a Function of PSD

To better understand pollutant transport, we identified what is known about the influence of PSD on stormwater chemistry. Literature reviewed focused on heavy metals, nutrients, and PAHs attached to particles, which suggests pollutant concentrations are generally higher for clay- and silt-sized particles. Targeting clay- and silt-sized particles may remove the highest amounts of metals, nutrients, and bacteria.

BMP studies with PSD influent and effluent data were located for 19 structural and 1 operational BMP. Most BMPs were highly effective at removing silt and fine sand sized particles (Table 1). These findings are based on only a few data points or a single study and there are many BMPs for which data were not located.

Recommendations for future research

Encourage researchers to report more basin conditions and pollutant data that is portioned to particle size ranges. This information can inform BMP selection and pollutant load estimates. Conduct BMP effectiveness testing for PSD on more structural, operational, and source control BMPs.

Table 1 BMP Effectiveness Summary by BMP and Particle Size

BMP	# of Studies	# of Data Points	% Removal				
			<4 µm	4-62 µm	62-250 µm	250-500 µm	>500 µm
Biofiltration Swale	1	1	-65%	74%	100%	-233%	-40%
Bioinfiltration Swale	1	27	51%	100%	97%	37%	41%
Bioinfiltration Pond	1	34	75%	96%	96%	37%	49%
Vegetated Filter Strip	0	0	-	-	-	-	-
Bioretention	1	1	74%	92%	-	15%	22%
Bioretention Plus Jellyfish	0	0	-	-	-	-	-
Dry Detention Basin	0	0	-	-	-	-	-
Extended Detention Basin	2	1	-	60%	-	34%	18%
Filterra	1	4	-17%	100%	95%	61%	-
High Rate Media Filtration	1	1	11%	83%	90%	-	100%
Media Filter Drain	1	48	-	-	-	-	-
Oil/Grit Separator	3	1	36%	46%	0%	51%	41%
Porous Pavement – Modular Blocks	1	1	-	-	-	-	-
Sand Filter	1	4	-	-22%	58%	72%	-
Wet Vault	1	30	52%	92%	0%	51%	56%
MWS-Linear Modular Wetland	1	27	23%	33%	25%	35%	-
The BioPod BioFilter	1	17	-72%	-8%	22%	-	62%
StormGarden Biofilter System	1	17	83%	89%	77%	83%	85%
The Kraken	1	14	86%	88%	88%	93%	97%
Mechanical Street Sweeper	2	-	-	56.5%	52.9%	44.4%	61%
Vacuum Street Sweeper	2	-	-	65.0%	69.9%	85.9%	87.7%
Regenerative Air Street Sweeper	3	-	-133%	-73.5%	41.8%	80.0%	79.0%

Why does this study matter?

This summary of recent literature on PSD (from clay to coarse sand sizes) in stormwater runoff and the effectiveness of BMPs is needed to understand pollutant transport and select suitable BMPs to protect downstream receiving waters.

What should stormwater managers do with this information?

Continue to target silt-sized and smaller particles (less than 62.5 µm) when selecting BMPs. While PSD effectiveness data for all size ranges is not typically reported, the BMPs in Ecology's Stormwater Manuals that meet 'basic' treatment goals capture much of finer particles benefitting downstream water bodies.

What will Ecology do with this information?

The relationship between particle size and pollutant transport is complex and not fully understood. However, the literature review confirms our assumption that finer particles (clay and silt-sized particles less than 62.5 µm) is of concern, as these particles can carry high concentrations of pollutants longer distances in stormwater runoff. Therefore, we will continue to recommend testing for clay and silt-sized particles when consulted on BMP effectiveness testing. Ecology will discuss with the TAPE program the added benefits of gathering more basin information for future TAPE studies.

Designing and evaluating behavior change marketing campaigns

Stormwater Action Monitoring

Effectiveness Study

Lead Entity:
Washington Stormwater Center, Washington State University

Partner:
Evergreen Storm H2O

For More Information: Go to Ecology.wa.gov/SAM and search for 'designing behavior change programs'

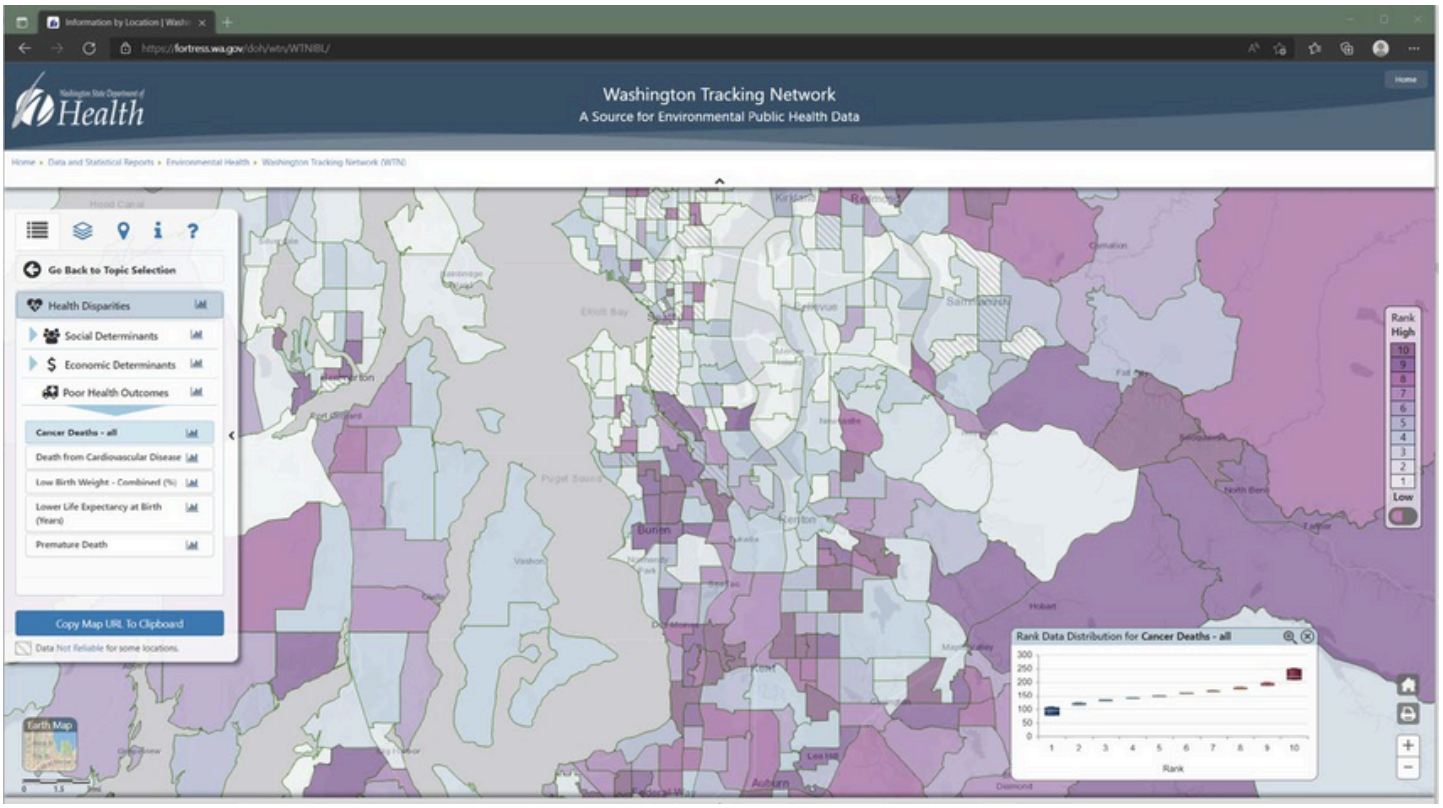


Figure 1: An interactive mapping tool that ranks the cumulative risk from environmental factors faced by Washington neighborhoods. https://fortress.wa.gov/doh/wtn/WTNIBL/

Study goals

The overall goal of this study was to provide jurisdictions with tools to identify and select which stormwater problems and behaviors to focus on as well as guidance for conducting and reporting effectiveness evaluations. These evaluations can then inform and improve future education and outreach (E&O) efforts in a positive feedback loop of doing and learning.

Study objectives & project findings

1. What types of stormwater problems are amenable to, and best addressed, by behavior change efforts?

The annotated bibliography provides an overview of stormwater pollutant prioritization by summarizing several critical, peer-reviewed studies from the last 15 years. One of the summarized projects is the cumulative environmental factors study by the Washington Department of Health.

Other key findings from literature, interviews and surveys are that a) most campaigns focus on pet waste and yard care; b) there is a desire for additional training on social marketing and program evaluation; c) staff feel that campaigns are often under-resourced; and d) additional high-quality evaluations of behavior change campaigns are needed.

2. Evaluate effective behavior changes tools in the literature and create a compilation tool organized by stormwater issue for jurisdictions to use.
A systematic review of behavior change campaigns was conducted which included evaluating the research quality on nine criteria. We rated 25% of studies as "fair", 66% of studies as "good", and 9% as "exemplary". Most studies identified well-targeted audiences and behaviors, and the majority collected pre-intervention data. However, three-quarters relied on self-reported data, and only 13% measured behavior in a comparison group. We created **www.waterbehaviorchange.org** to help jurisdictions search for information on evaluations of existing campaigns around the country. It also provides jurisdictions with guidance on choosing their own campaigns (as a downloadable spreadsheet).

3. Jurisdictions can now use the report template to report on behavior change evaluations.
Western Washington Permittees can use a template developed in this project to meet their stormwater Permit E&O requirements (Phase I S5.C.11.a.vi-vii and WWA Phase II S5.C.2.a.ii.(e)-(f)). The template streamlines report writing by identifying what information is required by the Permit, providing suggestions for content, and highlighting the basic information Ecology would like included in Permittees' final report.

4. Guidance manual helps jurisdictions evaluate the effectiveness of their behavior change campaigns.
Permittees can use the Evaluation Guidance Manual developed as part of this project to assess understanding and adoption of targeted behaviors of their implemented behavior change campaign. The manual content includes information about social marketing and community-based social marketing resources, sample size selection, common evaluation instruments (e.g., surveys, observational data checklist), data types, and analysis methods.

Why does this study matter?

This study synthesizes and evaluates effective behavior change campaigns for local jurisdictions to use to improve stormwater management success. It provides behavior change professionals with information and guidance they can apply to their own permit-required programs.

What should stormwater managers do with this information?

Cities and counties cannot fully control all the stormwater draining from the urban environment. Aspects of their stormwater management programs which aim to change behaviors of households, businesses, and others are critical tools in improving stormwater quality and protecting our natural resources. Managers can use information from the website, literature review, and evaluation guidance manual to help select suitable behavior change campaigns and then evaluate those efforts using valid approaches. Those evaluations can inform their decisions on management needs and future campaigns. Permittees may also use the report template to meet their permit reporting requirements.

What will Ecology do with this information?

Ecology considers social marketing to be a Best Management Practice (BMP) used to achieve behavior change that will reduce impacts of stormwater discharges to the environment. The permit requirement on behavior change requires significant time and resources to create and implement behavior change campaigns for the target audiences. Ecology will reference this project's products in our guidance as resources for local programs implementing and reporting on the effectiveness of the education and outreach programs. The literature review of pollutants, online decision tool, the reporting templates, and evaluation guidance can be used to inform new campaigns or evaluation of existing efforts. The template and guidance are written for use on large and complex campaigns or small and simple ones.

Stormwater Action Monitoring

Evaluation of hydraulic control approaches for bioretention systems

Effectiveness Study

Lead Entity:
Washington Stormwater Center, Washington State University

Partners:
Geosyntec Consultants

For More Information: Go to Ecology.wa.gov/SAM and search for 'outlet control for bioretention'

Highlights

- Outlet control has little additional effect on water quality of bioretention discharges for the traditional stormwater pollutants over media control.
- Outlet control has the potential to provide substantial value where project design goals call for:
  - increased residence time for pollutant removal
  - increased contact with complete bioretention media bed
  - predictable flow characteristics for flow control design goals.

Stormwater study background

Under the Stormwater Management Manual for Western Washington (SWMMWW), bioretention systems are commonly used to provide on-site stormwater management, runoff treatment, and flow control. Sites with poorly infiltrating soil often require underdrains to keep the water moving through the bioretention system. For bioretention systems that are under-drained, there can be two different hydraulic control approaches to control flow rate through the system. Bioretention systems can be designed to rely on the permeability of filtration media to restrict flow rates (i.e., "media control") or incorporate flow-restricting devices (valves or orifices) on the underdrain outlets to throttle flow rates through the system (i.e., "outlet control"). The hydraulic control approach used in bioretention systems has the potential to change the operations and performance of these systems. This research compares outlet-controlled and media-controlled designs.

Figure 1: Mesocosm Testing Facility at WSU-Puyallup

Study goals

- Compare performance between outlet-controlled and media-controlled configurations for: water quality treatment, plant vigor, and hydraulic fluctuation (flow rate, stage, and discharge volumes)
- Compare hydraulic performances of bioretention relationships over time for each configuration and to model predictions.

Project findings

When effluent stormwater pollutant concentration is of primary concern, an outlet control approach provides limited benefit. This approach moderately improved treatment performance for some pollutants but may increase the risk of leaching nutrients and dissolved copper from bioretention media, particularly for compost- based media that already have the potential to leach. An outlet control approach could be beneficial for applications where (1) more predictable and longer residence times are desired to target specific analytes, or (2) there is concern about short-circuiting through a portion of the media bed and exhausting the treatment capacity along the short-circulate pathway, and the selected bioretention media has limited risks for nutrient and dissolved copper leaching, and/or (3) accurate predictions of flow control performance are desired to meet bioretention performance goals. Outlet control effectively slows the water down, increases residence time, and saturates the full media bed more often. This study shows no impact on O&M or plant health associated with this outlet control bioretention designs.

Figure 2: Orifice control on underdrain outlet

Recommendations

An outlet control approach would provide the most benefit, where greater flow control predictability and precision are desired to meet bioretention performance goals. This research has shown that hydraulic conductivity through the media alone (media control) is variable. Flow control via an orifice on the underdrains reduces the variability and is more accurately simulated via the Western Washington Hydrology Model. This approach using an orifice is already allowed in Ecology's Stormwater Management Manuals for Washington State.

Why does this study matter?

Bioretention soil media is designated to filter stormwater at a relatively fast rate. This study evaluated the impacts to water quality and flow rate change when that flow-through rate was slowed down using an orifice on the underdrain.

What should stormwater managers do with this information?

When designing bioretention facilities, the choice between media control and outlet control bioretention should be based on the project goals. For facilities built solely to achieve effluent pollutant concentration reduction, outlet control design does not provide additional benefit compared to media control. However, outlet control designs provide more consistent, predictable, and significant flow control benefit and should be considered if these benefits are relevant to meeting project goals.

What will Ecology do with this information?

Ecology continues to allow outlet controls in bioretention designs to further control discharge rates and residence times.

Bioretention hydrologic performance study: assessment of facilities ten years or older

Stormwater Action Monitoring

Effectiveness Study

Lead Entity:
City of Olympia

Partners:
Raedeke Associates, Inc., Associated Earth Sciences, Clear Creek Solutions

For More Information: Go to Ecology.wa.gov/SAM and search for 'bioretention hydrologic performance'

Highlights

- Infiltration rates overall remained high with no indication of clogging or sediment accumulation except areas near the inflow

Stormwater study background

While the use of bioretention facilities in new and re-development is increasing rapidly, there has been little formal scientific assessment of the hydrologic performance of locally-constructed facilities. Local governments want to know the possibility of clogging and soil compaction in bioretention facilities over time, both of which can result in an overall reduction in permeability. Slow draining facilities increase the risk of hydrologic failure and can also create stagnant water, aesthetic problems, and vegetation failures.

Study goals

This field study assessed 50 bioretention facilities in operation for more than 10 years by measuring infiltration rates, soil composition, vegetation, and comparing maintenance practices. The goal was to provide engineering guidance and recommendations for bioretention system design.

Project findings

Overall, findings from this study echoed findings from the previous two bioretention hydrologic performance studies, further strengthening those conclusions. For more background, see Fact Sheet #12: Bioretention Hydrologic Performance Study, Phase 1 and Fact Sheet #20: Bioretention Hydrologic Performance Study, Focus on Current Designs.

Of the 50 sites evaluated 28 were typical design bioretention facilities (i.e., infiltrating to native subgrade) and 22 were underdrained because subsoils drained extremely slowly. Infiltration rates overall remained high with no indication of clogging or sediment accumulation except localized areas near the point of inflow. Underdrained sites showed a generally higher range of infiltration rates than for typical sites.

Figure 1: Bioretention facilities in operation for more than 10 years

The plant species observed in the bioretention facilities shifted from mostly plants adapted to wetter conditions in the original plans to plants adapted to drier conditions currently. There was little correlation between the prevalence of wetland plants and site infiltration rates for both typical and underdrained facilities.

Surveys revealed that most facilities were maintained 1-4 times per year, while some received more frequent maintenance, with visits occurring 1-2 times per month. The most common activities included branch and line trimming, as well as debris and garbage removal. Facilities in public view were maintained more often than those in less visible locations.

Recommendations

For jurisdictional designers/engineers/landscape architects:

- Design to current recommendations: Follow current bioretention modeling recommendations in Ecology's Stormwater Management Manuals.
- Document site conditions before developing planting plan: Note things like drainage, shade, nearby vegetated areas, weather, irrigation, and groundwater to make sure the planting plan matches these conditions.
- Consider the plant list: Use more plants adapted to drier conditions instead of those that only thrive in wetlands.
- Confirm maintenance resources: Have site O&M and capital management staff review the site's management plan to ensure the planting plan fits with the available resources for long-term upkeep.
- Monitor sites: Particularly during large storm events, look for non-engineered outflows, leaking overflow structures and buildup near the overflow that allow bypass of flows before full infiltration. Monitor sites after large storm events to confirm ongoing sufficient infiltration.

For scientific agencies/Department of Ecology:

- Conduct sensitivity analyses using WWHM 2012 to determine the magnitude of effect of infiltration rate variability, contributing drainage area, and use of regional rainfall records on facility performance.

Why does this study matter?

This BHP study demonstrates the continued performance of 50 older bioretention facilities and provides guidance for future installations. The findings show that most bioretention facilities continue to infiltrate stormwater runoff as intended, providing stormwater managers with confidence in requiring their use.

What should stormwater managers do with this information?

Stormwater managers now have the evidence that early generation bioretention facilities generally perform as expected to control stormwater runoff. Permittees should inspect sites for short-circuited flow paths. When designing and building new bioretention facilities, designers should obtain site-specific information on infiltration rates and develop more drought tolerant planting plans.

What will Ecology do with this information?

Ecology will continue to encourage regional partners not to use wetland-obligate species when designing bioretention facilities.

Stormwater Action Monitoring

Selecting the right plants for roadside ditches

Effectiveness Study

Lead Entity: Washington State University

Partner: Washington Stormwater Center

For More Information: Go to Ecology.wa.gov/SAM and search for 'plant blends for roadside ditches'

Highlights

- The WSDOT blend (perennial ryegrass, creeping red fescue, and white clover) is recommended for fast establishment and widespread utility in roadside ditches.

Study goals

Ditches—their maintenance and vegetation choices—represent an opportunity to improve stormwater quality. This work aimed to identify plant blends with the following characteristics: Fast establishment, low-growing, competitive with invasives, and lower long-term maintenance efforts. Six plant blends were evaluated at three sites that covered a range in sun exposure, slope, temperature range, soil quality and composition, existing site vegetation, and stormwater inputs. Study goals for this project include:

- Quantify the percent establishment, quality ratings, and survival of plant blends.
- Identify plant blends for Washington ditches that establish quickly and outcompete invasives.

Stormwater management problems

Regraded roadside ditches present significant challenges for plant growth and establishment due to their harsh environmental conditions. Maintenance of these ditches is often prompted either by complaints from residents about invasive species or when jurisdictions determine that sediment buildup or excessive vegetation has compromised the ditch's ability to convey water effectively. Hundreds of miles of roadside ditches in Washington state provide an opportunity to gain efficiency of maintenance workloads if vegetation choices are optimized to limit invasive plants, prevent erosion, and maintain conveyance.

Project findings

Across all the replicated planting cells at both sites, the WSDOT blend performed with the most consistent success for the duration of the study. Of this mix, perennial ryegrass and creeping red fescue effectively colonized in full sun and at the more xeric, shady site. Clover struggled to establish and could be removed from the blend. WSU Blend 1 showed performance nearly identical to the WSDOT blend, with the only notable difference being a slightly higher establishment rate for the WSDOT blend at Fife. The WSDOT blend could serve as an alternative if Chewings fescue seed in WSU Blend 1 becomes scarce. PT-442 BES Grassy Swale Native Mix, a commercially available blend of native grasses, consistently underperformed. Soil quality was lacking at both sites, which seemed to be a factor in this blend. The study affirmed that blending is preferred--monoculture plantings are not recommended. Notably, certain species within the blends performed better during different phases of the growing season. WSU Blend 2 was slower to come out of winter dormancy but tolerated summer heat and drought stress well.

Specific grass species that performed well across the blends, site conditions, and growing season include fine fescues, bentgrass, and perennial ryegrass. Grass species that underperformed or struggled to establish included clover and yarrow. More research is necessary to develop blends that can successfully establish these species.

Recommendations

Managers should consider site-specific factors when selecting a blend.

Ditch condition	Blend recommendation	Performance details	Blend mix
Native site, little-to-no weed competition or soil disturbance	PT-442	Blend struggles to establish in sites lacking topsoil and large adjacent weed seed quantities	25% Meadow Barley 15% California Oatgrass 10% Blue Wildrye 10% California Brome 10% Roemer's Fescue 10% Tufted Hairgrass 10% Spike Bentgrass 5% Water Foxtail 5% Slender Hairgrass
Wide range of ditch conditions	WSDOT	Fast establishing utility blend. The combination of perennial rye grass and strong creeping red fescue is effective at colonizing in full sun and more xeric sites	50% Perennial Ryegrass 40% Creeping Red Fescue 10% White Clover
Wide range of ditch conditions	WSU Blend 1	Could be used interchangeably with WSDOT blend, good for shady sites	50% Creeping Red Fescue 40% Chewings Fescue 10% Highland Bentgrass
Wide range of ditch conditions	WSU Blend 6	Could be used interchangeably with WSDOT blend, good for shady sites	50% Molate Red Fescue 40% Chewings Fescue 10% Redtop Bentgrass
Sites that will allow for extended establishment	WSU Blend 2	Hard and sheep fescues have slower growth, but the blend works well for areas with shade and drought	50% Hard/Sheep Fescue 35% Strawberry Clover 15% Yarrow
Full sun, regenerative sites	WSU Blend 5	Useful blend for sites inundated with bentgrass. Not recommended for shady sites	50% Redtop Bentgrass 50% Highland Bentgrass

Why does this study matter?

Ditches and their maintenance and vegetation choices represent an opportunity to improve stormwater quality. Using plants that can quickly establish after maintenance or reconstruction will limit bank erosion and transport of sediments and associated pollutants. If those plants are also low-growing and outcompete invasive plants significantly, then less frequent ditch maintenance and mowing will be needed.

What should stormwater managers do with this information?

Jurisdictions should consider site-specific factors when selecting a plant blend for roadside ditches. Future studies should consider incorporating flowering plants for pollinators and developing aggressive native blends that quickly colonize disturbed areas, enhancing biodiversity and water quality.

What will Ecology do with this information?

Ecology will consider updating the guidance for roadside ditch maintenance in the stormwater management manuals to recommend the preferred blends.

Source Identification

2020 update to IC-ID field screening and source tracing guidance manual

Regional spill hotline feasibility study

Mobile business stormwater source control and coordination

2020 update to the illicit connection and illicit discharge (IC-ID) field screening and source tracing guidance manual

Stormwater Action Monitoring

Source Identification

Lead Entity:
King County Stormwater Services

Partners:
Aspect Consulting, LLC, Herrera Environmental Consultants, Inc.

For More Information: Go to Ecology.wa.gov/SAM and search for 'Updated IC-ID Field Screening Manual'

Study goals

The project:

1. Updated the Illicit Connection and Illicit Discharge (IC-ID) Field Screening and Source Tracing Guidance Manual (IC-ID Manual), originally published in 2013, with new and improved information on field methodologies and indicators for screening, identifying, and tracing the sources of stormwater pollution.
2. Provided eight trainings on the updated 2020 IC-ID Manual for municipal stormwater staff throughout Washington.
3. Updated and enhanced the training resources to support the updated IC-ID Manual.

Stormwater management problem

Municipal stormwater staff invest a substantial amount of time investigating and addressing potential illicit discharges to the municipal separate storm sewer system (MS4) for permit compliance. They encounter many different types of pollution that require quick, accurate, and inexpensive approaches to identify and find the source. This is especially challenging for diffuse sources of pollution.

The first IC-ID Manual in 2013 provided municipal illicit discharge detection and elimination (IDDE) programs with a comprehensive and useful resource for investigating stormwater pollution. The updated IC-ID Manual provides municipal stormwater professionals across the region with widely used information in an accessible format for screening, identifying, and tracing the sources of stormwater pollution. Trainings on the updated IC-ID Manual provided a refresher for existing personnel, and new additional training resources will help to train future personnel.

Project findings

The updated IC-ID Manual was published in May 2020 and is available via the SAM Source Identification webpage and the Washington Stormwater Center's IC-ID webpage. Updates were informed by feedback from municipal staff in two workshops, a literature review on updated and new methodologies and indicators, and a review of data from IDDE programs. The updates include:

- New *Index* and revised *Flow Charts* to quickly determine appropriate methods and tests to use
- Updated *Screening* and *Source Tracing* descriptions
- More *Indicator* tests
- Expanded *Bacteria* section to include four bacterial types and easy culturing test instructions
- Updated *Equipment Costs* and *Field Sheet* templates
- Reorganized and streamlined information

Eight training sessions in 2020 drew more than 200 attendees, mostly municipal staff from Western Washington. While the trainings were originally planned to be in-person, the COVID-19 pandemic provided an opportunity to reformat and present the trainings on a virtual platform more easily accessible to professionals across the region. The trainings included a small group exercise to find the sources of pollution, in a hypothetical scenario, along with live demonstrations and prerecorded videos of field equipment usage, indicator tests, and sampling techniques.

The original 2013 IC-ID Manual included 14 videos giving an overview of the manual and demonstrating specific indicator tests. The 2020 update created five short videos on indicator tests and a new, longer video presenting an overview of the updated IC-ID Manual, all posted on the Washington Stormwater Center's YouTube channel.

Recommendations

A comprehensive and up-to-date guidance manual and training materials are essential resources for conducting IDDE investigations. This 2020 IC-ID Manual and training resources should be used by municipal stormwater staff to support training and implementation of their programs on MS4 screening, source identification, and control. These materials are available online at no cost, providing access to all stormwater professionals and others working on pollutant source identification and control.

As stormwater pollution regulations adaptively improve in Washington, the knowledge and data available to evaluate best practices also improve. Ecology and permittees will benefit from more up-to-date efforts with National Pollutant Discharge Elimination System (NPDES) permit implementation in this updated IC-ID Manual. This will improve consistency, accuracy, and efficiency in how stormwater pollution is screened, identified, traced, and reported.

The project trainings on the updated IC-ID Manual were described as a valuable resource for ongoing stormwater management, helping train and refresh over 200 municipal stormwater staff on IC-ID field methodologies and indicators. Stormwater managers are encouraged to use these materials to train staff every two to five years on the updated IC-ID Manual.

Ecology and permittees are encouraged to consider supporting a future update to the IC-ID Manual and trainings in five to ten years.

Why does this study matter?

Stormwater carries numerous potential sources of pollution. Proven, accurate, and efficient methods to screen, identify, and trace the sources (which are often intermittent) are essential tools of stormwater management. Keeping municipal staff up to date and trained on how to spot and respond to illicit discharges is an essential requirement of the Municipal Stormwater Permits and a critical component of a local government's stormwater management program.

This project expanded educational and training materials for identifying and tracing stormwater pollution, which will help stormwater managers ensure their staff are efficient and knowledgeable on implementation of IDDE, source control, and MS4 screening.

What will Ecology do with this information?

Recognizing the need for and benefit of coordinated IC-ID practices and training materials, Ecology will continue to support regional efforts to develop consistent methods for pollution screening, identification, and tracing.

Ecology will share the updated IC-ID Manual with the Pollution Prevention Assistance program (formerly the Local Source Control program) and update websites to reference the updated manual and training materials.

What should we do with this information?

Permittees and stormwater managers should use the 2020 IC-ID Manual for IDDE investigations and the training resources and videos for ongoing staff training needs.

The Washington Stormwater Center should continue to host the material in an easy-to-find location on its Municipal Resources webpage, which provides a central source of permit tools.

Regional spill hotline feasibility study

Stormwater Action Monitoring

Source Identification

Lead Entity:
King County Department of Natural Resources and Parks

Partners:
Herrera Environmental Consultants, Inc., Hardwick Research

Other Participants:
Washington State Department of Ecology, Stormwater Work Group (SWG), Source ID Subgroup, Techincal Advisory Committee, Survey participants, Interview participants, cooperating vendors

For More Information: Go to Ecology.wa.gov/SAM and search for 'regional spill hotline feasibility'

Study goals

The goal of this study was to assess the feasibility of a regional or statewide "hotline" (reporting system) for citizens and municipal staff in Washington state to report spills and environmental incidents.
Key study questions included:

1. Is a regional spill reporting system technically feasible?
2. Is a regional spill reporting system preferred?

Stormwater management problem

The municipal stormwater permit requires jurisdictions to publicize a hotline or other telephone number for public reporting of spills and other illicit discharges. Permittees have expressed doubt about public awareness, confusion around numbers that vary widely by location, and concerns about potential delays and inefficiencies in spill response leading to lost opportunities to prevent environmental damages. Stormwater managers want to know what options are available to improve spill reporting and interjurisdictional cooperation, whether the options are recommended for regional-scale implementation, and what considerations individual jurisdictions should take into account.

Project findings

This project documented industry knowledge, experience, and preferences and interviewed municipalities, Ecology, hotline owners, and vendors. The final report contains a brief overview of findings as well as two appendices containing interview summaries and an options matrix.
1. Based on the survey and interviews, the idea of implementing a regional spill reporting system is not broadly supported by most jurisdictions or state agencies.
2. Currently, municipalities interpret and use Ecology's Environmental Report Tracking System (ERTS) for regional spill reporting. Although Ecology did not initially intend for ERTS to function as a regional spill reporting system, it is used for that purpose to some extent.
3. Implementation of a multi-jurisdiction regional spill reporting system is technically feasible. Multiple vendors can provide accessible, cloud-based products with desired features including geodynamic routing, data standardization, and two-way communication with the public.
4. Implementation of a regional spill reporting system could streamline Municipal NPDES Permit annual reporting activities and promote regional analysis while allowing local spill response procedures to remain in place.

Recommendations

This study determined that implementing a regional spill reporting system is feasible and identified key benefits of a regional system that are not addressed by the current system of disparate local hotlines. The study identified overall low support from jurisdictions to implement a new regional system. However, these recommendations can apply at smaller scales for individual jurisdictions or several jurisdictions working together. The study recommends further discussions on this topic. See next section for specific recommendations.

Recommendations for implementing a regional spill reporting system:

- Incorporate the following core components for a centralized system:
  - Primary coordinating entity
  - Central call center (supplemental service)
  - Central web form
  - Central cloud-based data storage
  - Mobile application is not necessary
- To promote equity and accessibility:
  - Provide a central hotline number
  - Offer multiple language options for phone and web formats
  - Allow anonymous reporting when necessary

- For multi-jurisdiction regional spill reporting systems, establish a primary coordinating entity to:
  - House centralized data
  - Manage contracting and system maintenance
  - Lead a cohesive communication network
- Use vendors that prioritize features which support efficient response, streamlined reporting, regional analysis, and community engagement:
  - Map integration
  - Geodynamic routing
  - Workflow customization
  - Data standardization
  - Follow-up (two-way communication) with community members
- While possible, a hybrid system (integrating the local hotline with a regional hotline) is not the primary recommendation of this study due to added costs and workflow complexity.
- Further cost evaluation for regional implementation would require a preliminary structure (e.g., system components, participants, and hybrid features).

Recommendations for Ecology:

- Post clarifying language on the purpose, function, and limitations of ERTS on Ecology's website.
- Configure a regional spill reporting system, if implemented, for compatibility with ERTS and WQWebIDDE. Participate directly in the system to receive reports in a preferred format.

Recommendations for future study:

- Resurvey jurisdictions to determine whether opinions have changed based on vendor capabilities.
- Form a preliminary structure with centralized entity to begin interjurisdictional coordination and define most variables.
- If broad regional implementation is still not desired, consider local or subregional strategies and options identified in this study (Appendix 1 and 2 of final report).
- Gather community input on what would make spill reporting easier. Consider jurisdictions' needs formore public outreach support.

Why does this study matter?

There are over 90 municipal stormwater permittee hotlines for the public to report spills to the environment and stormwater system in Western Washington alone. Complex coordination among state and local programs can delay spill reporting and response. This study was funded to examine feasibility of a single regional hotline to complement local numbers. Interestingly, despite enough support to fund this feasibility study, surveys and interviews of stormwater permittees indicate a reluctance to support a modern regional hotline; many believe the role is filled by Ecology's ERTS.

What will Ecology do with this information?

The ERTS reporting system continues to rely on an imperfect process, and some delays in reporting are likely when ERTS reports are submitted outside of work hours. Though the Water Quality Program at Ecology has a limited role in the maintenance and enhancement of ERTS, we aim to improve reporting timeframes for jurisdictions. We will aim to streamline reporting requirements for the municipal stormwater permit where feasible and appropriate.

What should we do with this information?

Stormwater managers may consider subregional approaches working in cooperation with other jurisdictions. The concept is technically feasible, and potential advantages include improved response times to reported spills, mobilization efficiencies, data standardization, and better interjurisdictional communication.

Mobile business stormwater source control and coordination

Stormwater Action Monitoring

Source Identification

Lead Entity:
King County Stormwater Services

Partner:
Aspect Consulting, Herrera Environmental Consultants

For More Information: Go to Ecology.wa.gov/SAM and search for 'mobile business source control'

Highlights

- This study helps expand and deepen the source control resources and guidance available for Washington permittees and mobile businesses.
- Permittees can use the software tool to identify mobile businesses of interest to stormwater and use related outreach materials and best practices guidance for municipal source control efforts.

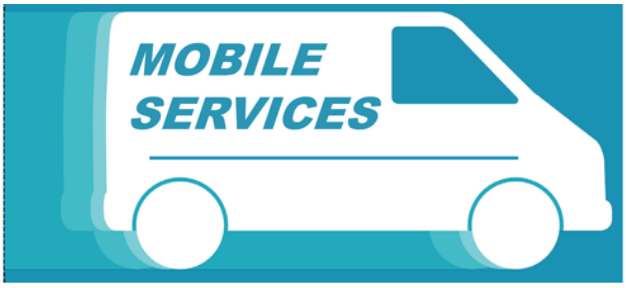
Stormwater management problem

Some businesses have unique stormwater and pollution prevention challenges due to their mobile nature and working at dispersed sites in multiple jurisdictions. For stormwater permittees who include mobile businesses in their mandated source control efforts, they are faced with how to engage with and inspect businesses that may operate at various locations both within and outside of the permittee's jurisdiction. Regardless of where a business may be legally registered, good stormwater management and source control addresses business activities where they occur.

Study goals

The overall goal of the study was to provide guidance and tools to help permittees identify, inspect, and coordinate mobile business engagement for municipal stormwater source control activities. Questions included:

- How can permittees identify mobile businesses of interest to stormwater management to include in their source control inventories?
- What are the unique challenges to mobile businesses for pollution prevention?
- What methods and recommended best practices can stormwater managers use to inspect mobile businesses for source control?



Project findings

The study developed several resources for stormwater permittees to use with mobile businesses in municipal source control programs. The resources were used and tested during the study in a pilot program in King County. The resources include:

- Software tool for searching keywords in business licenses lists and identifying likely mobile businesses of interest to stormwater.
- Best Practices Guidance for municipal source control efforts with mobile businesses.
- Compilation of 27 existing outreach materials for mobile business types and activities from cities in Washington and other states.
- Compilation of 26 best management practices (BMPs) for mobile business types and activities from leading stormwater management manuals in western Washington.
- New outreach brochures developed for three mobile business types: mobile automobile repair, commercial landscaping, and pressure washing.

In addition, the study outcomes included reports, technical memoranda, and presentation slides of task work.

- Survey of municipal source control programs in Washington state.
- Analysis of illicit discharge detection and elimination (IDDE) data, including for mobile business sources.
- Pilot Program in King County in which 18 permittee cities used and tested the resources developed for the Study and engaged with each other in cross-jurisdiction discussion about source control.
- Slides and recorded video presentation of findings and outcomes from the study.

Recommendations

For permittees:

- Use the keyword search software tool developed in the study. The tool searches for keywords in the business's own description of its services, and the keyword list can be customized by the user.
- Communicate, collaborate, and share information with neighboring jurisdictions about mobile business source control efforts. Consider doing a joint inspection with another jurisdiction of a mobile business that operates in both places.
- Support and encourage municipal staff to include mobile businesses in source control efforts and to work across jurisdictional boundaries.

For Ecology:

- Consider updating Appendix 8 of the municipal stormwater permits. The NAICS codes could be updated to better reflect commercial and industrial activities with risk of stormwater pollution, including mobile businesses.
- Continue to communicate with the Business Licensing Service of the Department of Revenue on how environmental pollution risk can be better captured in business licensing and how a business can indicate they are mobile.

Figure 1: Wash water from cleaning pavement may contain soaps, dirt, oil, grease, toxic chemicals, and heavy metals. Photo credit: Scott McQuary, City of Redmond

Why does this study matter?

Some mobile businesses have unique pollution prevention challenges due to their mobile nature. Stormwater permittees are faced with how to identify and inspect mobile businesses that may operate both within and outside of the permittee's jurisdiction. Good source control efforts address business activities where they occur, and this study helps expand and deepen the resources and guidance available for permittees and mobile businesses in Washington.

What should stormwater managers do with this information?

As a requirement in the municipal stormwater permits, source control programs for existing development are implemented across the state by over 130 municipal stormwater permittees. Thus, stormwater managers should find ways to support staff to include mobile businesses in source control efforts and to work across jurisdictional boundaries to coordinate source control efforts.

What will Ecology do with this information?

The next time the permit is revised, Ecology will review and consider changes to the NAICS codes in Appendix 8 Businesses and Activities that are Potential Sources of Pollutants. Ecology encourages permittees partnering with the Department of Revenue Business Licensing Service for business licensing to add a Mobile Vendor Business endorsement to their application so that mobile businesses can be more easily identified.

Receiving Waters

Puget Sound small stream study design

Puget Sound small streams monitoring – water year 2020

Puget Sound nearshore mussel monitoring – 2019/2020 survey

Puget Sound nearshore mussel monitoring – 2021/2022 survey

Lower Columbia urban streams monitoring – water years 2020-2023

Puget Sound small streams study design

Stormwater Action Monitoring

Receiving Waters

Lead Entity: Stormwater Action Monitoring Staff

Partners: U.S. Environmental Protection Agency, U.S. Geological Survey, Washington State Department of Ecology, Puget Sound Partnership, King County, Washington Department of Fish and Wildlife, Washington Department of Natural Resources

For More Information: Go to Ecology.wa.gov/SAM and search for 'Puget Sound small streams'

Project purpose

SAM is monitoring small stream conditions over time to see if they are getting better or worse in urban and urbanizing areas of Puget Sound. A group of scientists spent two years reviewing the previous stream monitoring study findings and other literature to recommend adjustments to the monitoring design.

The Puget Small Streams (PSS) design improves statistical robustness and monitoring efficiency and will capture year-to-year climate variations. This improved design can be conducted with the current level of funding from municipal stormwater permittees participating in SAM.

Stormwater management problem

We need to know what combinations of management approaches are working, or not working, to prevent stormwater from harming streams. While SAM effectiveness studies provide useful information about specific methods, regional-scale monitoring tells us whether collective stormwater management efforts in the region are meeting our goals to protect and recover water quality and biota in streams. Stormwater managers need information at multiple scales from site-specific to region-wide.

The new streams status and trend monitoring study design

The first SAM Puget Lowland Ecoregion Streams (2015 PLES) study planned to evaluate 100 sites once every five years, with half of the sites inside and half outside designated Urban Growth Area boundaries. Site candidacy was based on stream order.

The new PSS study design, starting in 2020, improves statistical robustness and trend detection power, better captures annual climate variability, and is less expensive to implement than the 2015 PLES design.

Sampling sites selected for the PSS study design represent the full range of urban and urbanizing conditions across the region using a probabilistic design approach. The Generalized Random Tessellation Stratified survey design tool selected 6,316 candidate sites spaced one kilometer apart in the updated National Hydrography Dataset (NHD Hi-resolution, 1:24K or higher). The candidate sites are stratified into four groups based on the percentage of total impervious cover (TIC) in the contributing watersheds to ensure annual sampling of sites in each development range: least developed areas (0-<10% TIC), and low (10-<20% TIC), medium (20-<40% TIC), and high (40-100% TIC) developed watersheds.

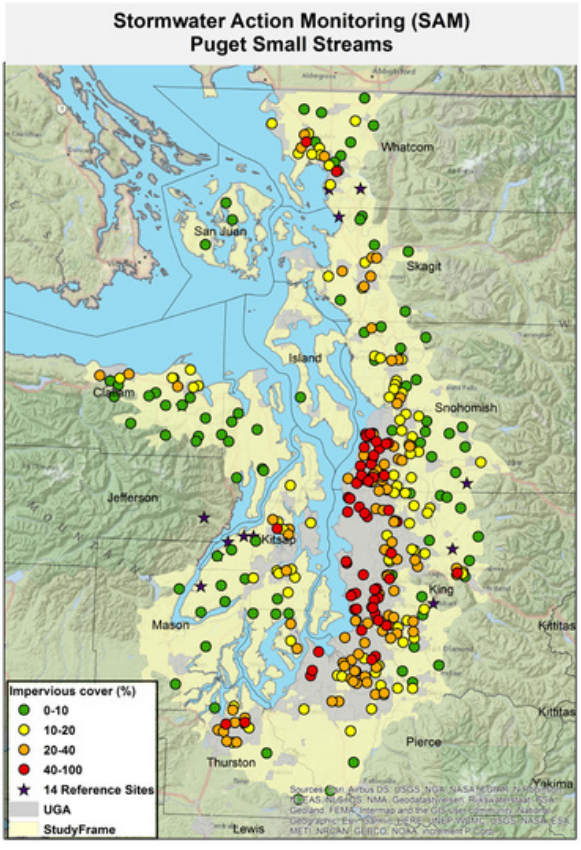


Figure. 1 Sampling sites in next 20 years grouped by category of total impervious cover (TIC) of the watershed area contributing to each site.

Each sampling site must be a perennial, wadeable stream segment with contributing watershed size between 0.5-70 km² (0.2-27 mi2). Starting in 2020, a total of 33 sites will be sampled every year.

Each year, nine sites will represent each category of least, low, and medium TIC watersheds and six sites will represent high TIC watersheds. All sites will be field evaluated and confirmed the year prior to sampling.

Trend detection power is increased by a 'revisit' approach introduced in the PSS design where each new site will be sampled three times at five-year intervals. Each year, some sites will be sampled for the first time while others will be sampled for the second or third time. Some 2015 PLES sites met the updated site selection criteria and will be sampled three more times in next 20 years.

The new design includes the 2015 PLES indicators that were most frequently detected and showed more differences by urban development gradient. The PSS indicators are: sediment chemistry including metals (total arsenic, cadmium, chromium, copper, lead, and nc) and organics (polycyclic aromatic hydrocarbons, polybrominated diphenyl ethers, and phthalates); biotic indices (macroinvertebrates, periphyton, and physical habitat); and water quality including temperature, dissolved oxygen, total suspended solids, nutrients, metals (total and dissolved arsenic, cadmium, chromium, copper, lead, and zinc), chlorophyll-a, and bacteria (fecal coliform and E. coli). Continuous water level will be monitored at each site for a full water year to improve our understanding of stream hydrology.

Reporting will include annual assessment of the fractions of all stream miles in good, fair, and poor condition and the fractions of stream miles that are above and below benchmarks including water quality standards. In addition, trends analyses and risk assessments will be conducted every four years to identify the key stressors causing poor conditions in the region.

Why does this study matter?

Under Ecology's municipal stormwater permits, local governments are investing hundreds of millions of dollars each year managing stormwater. We need a way to know whether, why, and how well these investments are collectively working to protect and improve stream conditions.

What will Ecology do with this information?

Ecology will use this study to track progress in reducing stormwater impacts on streams and evaluate overall and long-term effectiveness of municipal stormwater permits.

What should we do with this information?

As we continue to track regional conditions and identify key stressors and pollutants impairing stream health, local officials and stormwater managers will be able to compare their stream conditions with others in the region and prioritize and focus their management practices. State and local agencies can use this information to develop regional protection and restoration strategies and evaluate the effectiveness of those programs.

Puget Sound small streams monitoring
Water Year 2020

SAM Stormwater Action Monitoring

Receiving Waters

Lead Entity:
United States Geologic Survey

Partner:
Washington State Department of Ecology

For More Information: Go to Ecology.wa.gov/SAM and search for 'Puget Sound small streams'

Project purpose

This study is monitoring how the health of small, wadable streams change over time in urban, and urbanizing areas of the Puget Lowlands. The aim of this study is to provide a better understanding of influential stressors contributing to impaired waters and overall stream health. This monitoring is designed to assess the current stream conditions and answer the question:

- Is the quality of receiving waters in the region improving with broad implementation of required stormwater management practices?

Stormwater management problem

Stormwater runoff from urban and urbanizing areas causes the majority of habitat and water quality degradation in small streams. Local jurisdictions throughout the Puget Sound are increasing their stormwater management efforts to reduce flow volumes and pollutants. This regional evaluation of stream health focuses on areas covered by municipal stormwater permits because stormwater managers and policymakers need a better understanding of the most influential stressors on biological health to identify the most promising solutions. Over time, we believe that permittees' collective stormwater management efforts will result in detectible stream quality improvements.

Project findings

This monitoring study samples up to 33 sites annually across varying levels of urbanization, categorized based on the percentage of impervious surface within their watersheds. The sites are randomly selected using a method that ensures spatially balanced sampling and enables regional extrapolation of biological, chemical, and physical indicators. Parameters such as water and sediment quality, habitat metrics, and biological indicators are measured during a single summer event, supplemented by continuous temperature and flow monitoring, to track trends and evaluate urbanization impacts on stream ecosystems.

Learn more about the design in our study design fact sheet.

Stream health conditions in this study were evaluated based on sampling sites grouped by the percentage of total impervious area (TIA%) within their respective basins. Monitoring data from water year 2020 revealed that while dissolved metal concentrations remained below water-quality criteria in all samples, they increased as TIA% rose. Nutrient levels similarly increased with higher TIA%, with the most urbanized sites (40–100 TIA%) often exhibiting poor conditions. Sediment metals and organic pollutants also showed increases corresponding to higher TIA%, though poor conditions were rarely observed in these metrics. Macroinvertebrate bioassessment scores declined as TIA% rose, with most sites classified as being in poor condition (Figure 2).

Figure. 1 Collecting samples in small wadeable streams.

Additionally, although not statistically significant, the 2020 data suggested a decrease in stream quality since 2015 in terms of bioassessment scores and sediment metals, with the largest declines observed in the most urbanized category (40–100 TIA%). For the full report on Water Year 2020 and future reports, visit the Puget Small Streams Monitoring webpage.

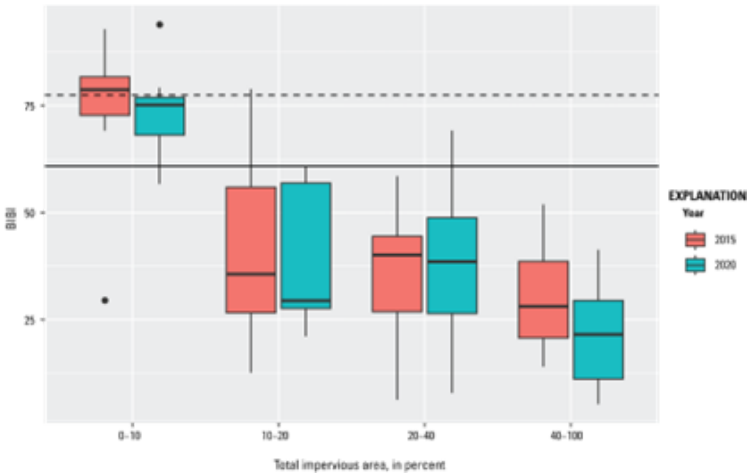


Figure. 2 Benthic Index of Biological Integrity (B-IBI) scores from 2015 and 2020 across watershed impervious surface category (TIA%). Values below solid line represent poor conditions, values above dashed line represent good conditions. A description of boxplot characteristics is available in the full report from the Puget Small Streams Monitoring webpage.

Looking ahead

Regional scale monitoring is a cost-effective way to evaluate unbiased status and trends in the ecoregion. SAM will continue to gather long-term status and trend data in the region. A detailed trend analysis is planned for after the initial 5-year data collection period is completed (after water year 2024). This analysis will help refine stormwater management strategies and improve outcomes for water quality and overall stream health.

Why does this study matter?

With this regional-scale monitoring program, we are improving our understanding of the effects of urbanization and influences of stormwater management efforts on stream health across Puget Sound. Over time, this stream monitoring will tell us whether our overall management strategies, including stormwater management, are improving stream health. More specific studies, in particular, effectiveness studies complementing this monitoring, will help inform how stormwater management contributes to overall improvements in stream health.

What will Ecology do with this information?

Ecology needs this objective regional information to evaluate whether or not the overall permitting program is slowing or reversing the decline in receiving water conditions caused by stormwater from existing and new development. Ecology can also use the study findings about conditions of streams in areas covered by the municipal stormwater permits to prioritize stormwater grant funding.

What should we do with this information?

Stormwater managers should consider the findings of this study and compare their local monitoring data to the regional data set. In the absence of local monitoring, the results for streams with similar watershed characteristics sampled in this study can provide useful information for targeting stormwater management actions. Permittees can use this knowledge, coupled with findings of effectiveness studies, to help prioritize and implement stormwater runoff management practices in their jurisdictions.

Puget Sound nearshore mussel monitoring
2019/2020 Survey Status

Stormwater Action Monitoring

Receiving Waters

Lead Entity:
Washington Department of Fish and Wildlife

Partners:
Bainbridge Beach Naturalists, City of Bellingham, Feiro Marine Life Center, Harbor WildWatch, Jamestown S'Klallam Tribe, Jefferson County Public Health, King County, Kitsap County Public Works, Makah Tribe, NOAA's Northwest Fisheries Science Center, NOAA NCCOS, Penn Cove Shellfish, Port Townsend Marine Science Center, Puget Sound Corps, Puget Sound Ecosystem Monitoring Program, Puget Soundkeeper Alliance, Rich Passage Estates HOA, Salish Sea Stewards, San Juan County Marine Resources Committee (MRC), Seattle Aquarium, Snohomish County MRC, Sound Water Stewards of Island County, South Puget Sound Salmon Enhancement, Stillaguamish Tribe, Suquamish Tribe, Tulalip Tribe, University of Puget Sound, University of Washington-Tacoma, Vashon Nature Center, Washington Conservation Corps, Washington Department of Ecology, Washington Department of Natural Resources Aquatic Reserves Program, Western Washington University, Whatcom County MRC, Washington State University

For More Information: Go to Ecology.wa.gov/SAM and search for 'Puget Sound nearshore mussels'

Highlights

- Mussels in the urban nearshore of Puget Sound accumulate organic contaminants (PAHs, PCBs, PBDEs, DDTs) at a greater rate than at the reference site.
- PAHs, PBDEs, and DDTs had significantly lower central tendency concentrations in mussels from this third survey (2019-20) than the prior two surveys.
- The spatial extent of the impacted urban nearshore remains unchanged in Puget Sound.

Stormwater goals related to the study

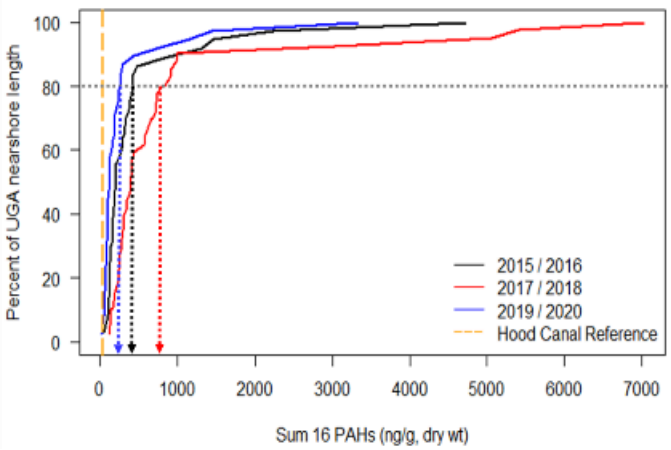
Stormwater delivers metals, organic contaminants, and other chemical pollutants into Puget Sound. These pollutants can accumulate in biota. The SAM Nearshore Mussel monitoring is conducted biannually using caged mussels (Mytilus sp.) as the primary indicator organism to assess the winter nearshore water quality, areas impacted by pollutants carried by stormwater. Randomly selected sites are located in Puget Sound nearshore along urban growth area shorelines –areas presumed to be most affected by stormwater runoff. Mussels, filter feeders, are a good tool to measure the extent of pollutants present in the nearshore. The objectives of the SAM Mussel Monitoring survey are to; 1) characterize the spatial extent of contamination to which nearshore biota residing inside the UGA sampling frame may be exposed, and 2) track changes in tissue contamination over time inside the UGA sampling frame.

Project findings

This winter 2019/2020 monitoring survey was the third survey under this 'UGA' study design and provides the first opportunity to evaluate changes in contamination of nearshore biota residing inside the urban growth areas (UGAs) of Puget Sound. The other two surveys were conducted in winters of 2015/2016 and 2017/2018, hereafter surveys are referred to as 2016, 2018, and 2020 respectively. We characterized mussel tissue contaminant concentrations at 40 sites in the Puget Sound UGA nearshore each survey and changes in the spatial extent of contamination. Results are compared to a reference site established in Hood Canal, a site with consistently low contaminant concentrations.

Most of the sampled UGA nearshore had sum total of 16 polycyclic aromatic hydrocarbons (∑16PAHs), total PCBs (TPCBs), sum total of 11 polybrominated diphenyl ethers (∑11PBDEs), and sum total of 6 dichlorodiphenyl- tricholoethanes (∑6DDTs) concentrations above the reference site concentration indicating mussels accumulated these contaminants at nearshore sites within the UGA.

The spatial extent of the measured organic contaminants in the UGA nearshore showed little to no decline over 4 years (Figure 1). The smooth slope of TPCBs CFD graph (Figure 1) suggest gradual accumulation of PCBs throughout the UGA shoreline. In contrast, the steep slope of PAHs CFD graph indicates relatively low level of PAHs in the study area with only few high contamination sites, possibly from another point source nearby.



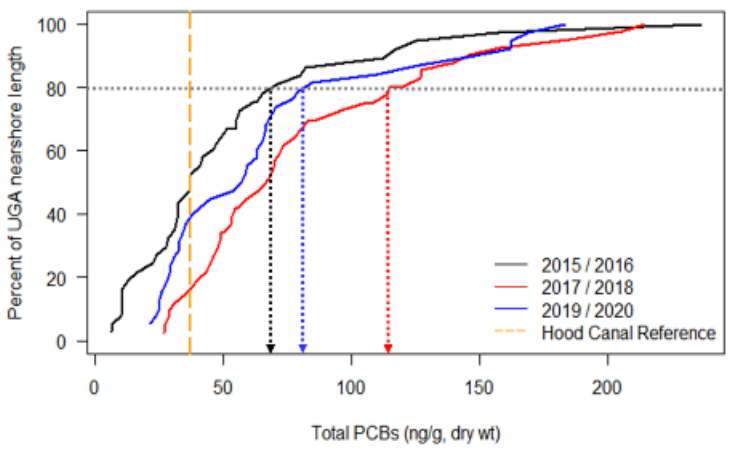


Figure 1. Cumulative frequency distribution (CFD) of Σ16PAH and TPCB concentrations in mussels by survey. CFD plots represent the concentrations by the total sampled length of nearshore in Puget Sound UGAs. The dashed yellow line is the reference site concentration. Dotted lines are guides to read the plot, pointing to the concentrations observed in each survey year at 80% of the total sampled UGA nearshore length.

PAHs, PBDEs, and DDTs had significantly lower central tendency concentrations in mussels from the 2020 survey than in the 2016 and/or 2018 survey. The declining PBDEs concentrations but stable PCBs concentrations were congruent with the temporal pattern in two other WDFW-TBiOS indicator species (English sole and Pacific herring) reported in the Toxics in Aquatic Life Vital Sign. The 2019-2020 SAM Puget Sound Nearshore Mussel Monitoring Survey report contains all findings.

This represents the final survey under the 'UGA design' and all future SAM mussel monitoring surveys will be done under the new design that expands the nearshore study frame to the entire Puget Sound lowlands. The 2021-22 survey will include a subset of the sites (15) sampled under this 'UGA design' to track changes in these locations. For more information on the revised design and study, see the SAM Marine Nearshore Mussel QAPP for 2021-2025.

Why does this study matter?

This long-term status and trends monitoring of the marine nearshore will evaluate whether and how stormwater discharge and the stormwater management actions implemented in the region are affecting or even detected in nearshore biota contaminants levels.

What should stormwater managers do with this information?

Stormwater managers know that effective and lasting improvements to infrastructure, best management practices, and changing behaviors of Puget Sound residents takes time. Monitoring long term in several key environments such as the marine nearshore will help us determine if conditions are getting better despite population growth as building codes and stormwater management improves in the areas adjacent to the nearshore.

What will Ecology do with this information?

Ecology will use this objective regional information to evaluate the efficacy of the municipal stormwater permitting program over time in slowing or reversing the decline in the marine nearshore. While there are many other potential dischargers beyond municipal stormwater impacting Puget Sound's water quality, the nearshore is the most likely environment for stormwater impacts to be measured and tracked, especially as the region expands existing and new development. Ecology supports SAM's receiving water studies under the municipal stormwater permits and will continue to coordinate findings with SAM's urban stream monitoring program in Puget Sound.

Puget Sound nearshore mussel monitoring
2021/2022 Survey Status

Stormwater Action Monitoring

Receiving Waters

Lead Entity:
Washington Department of Fish and Wildlife

Partners:
Bainbridge Beach Naturalists, City of Bellingham, Feiro Marine Life Center, Harbor WildWatch, Jamestown S'Klallam Tribe, Jefferson County Public Health, King County, Kitsap County Public Works, Makah Tribe, NOAA's Northwest Fisheries Science Center, NOAA NCCOS, Penn Cove Shellfish, Port Townsend Marine Science Center, Puget Sound Corps, Puget Sound Ecosystem Monitoring Program, Puget Soundkeeper Alliance, Rich Passage Estates HOA, Salish Sea Stewards, San Juan County Marine Resources Committee (MRC), Seattle Aquarium, Snohomish County MRC, Sound Water Stewards of Island County, South Puget Sound Salmon Enhancement, Stillaguamish Tribe, Suquamish Tribe, Tulalip Tribe, University of Puget Sound, University of Washington-Tacoma, Vashon Nature Center, Washington Conservation Corps, Washington Department of Ecology, Washington Department of Natural Resources Aquatic Reserves Program, Western Washington University, Whatcom County MRC, Washington State University

For More Information: Go to Ecology.wa.gov/SAM and search for 'Puget Sound nearshore mussels'

Goal & Background

The Stormwater Action Monitoring (SAM) Status and Trends in Receiving Waters program conducts monitoring in Puget Sound nearshore marine waters to provide a regional assessment of whether collective stormwater management actions are leading to improved receiving water conditions. The SAM Puget Sound Nearshore Mussel Monitoring study focuses on the bioaccumulation of pollutants in caged native bay mussels (Mytilus trossulus) to evaluate the current status and trends of nearshore conditions (Figure 1). The 2021/2022 survey was the first conducted under the new SAM study design, whereby the sampling area expanded to the entire nearshore of the Puget Lowland ecoregion and the study sites were stratified into four categories by estimates of average percentage of total impervious area of the contributing upland watersheds.

The primary goal for the survey was to determine the status of contamination in the marine nearshore during Winter 2021/2022. The status was mainly described by determining the detection frequency and distribution of contaminant concentration data, and the spatial extent of contamination in the Puget Sound Lowland ecoregion. Determining how contaminant concentration results from the survey compare against project-specific thresholds and how key findings in this survey are either in line with or contrast with previous surveys (conducted only within urban growth areas) were also objectives.

Survey Findings

Like prior survey years, the most abundant organic contaminants detected in mussels of the Puget Sound nearshore are:

- polycyclic aromatic hydrocarbons (as Σ16PAH)
- polychlorinated biphenyls (as total PCBs)
- polybrominated diphenyl ethers (as Σ11PBDEs)
- dichlorodiphenyltrichloroethane and its metabolites (as Σ6DDTs).

Though, the detection frequency for PBDEs noticeably reduced in this survey. At previous survey sites located within the urban growth areas, PBDEs were detected at a frequency greater than 80%, while detections at current sites across the entire Puget Sound are below 50%. All metals tested (arsenic, cadmium, copper, lead, mercury, zinc) continue to be frequently detected in mussels. The central tendency concentrations of most of the measured organic and metal contaminants in mussels at survey sites across the Puget Sound shoreline were similar or lower when compared to concentrations from prior surveys with sites within the urban growth areas only.

Figure. 1 Bagged bay mussels (Mytilus trossulus) in a predator exclusion cage at the Chimacum Creek Delta monitoring site.

Estimates of the spatial extent of mussel tissue contamination in the Puget Lowland ecoregion indicate that most of the Puget Sound nearshore length (approximately 50-90%) had low concentrations of Σ16PAHs, TPCBs, Σ11PBDEs, and Σ6DDTs based on project-specific thresholds, and less than approximately 5% of the nearshore length had high concentrations (Figure 2).

Similarly, for most of the metals (cadmium, copper, lead, mercury, zinc), a small proportion (approximately 0-10%) of the nearshore length had values exceeding the high concentration threshold. With the sampling area expanded to the entire Puget Lowland ecoregion in this survey, most of the organic and metal contaminant distribution patterns shifted toward lower concentrations across the nearshore. A higher proportion of the nearshore length had values below the low concentration threshold, and a lower proportion of the nearshore length had values above the high concentration threshold.

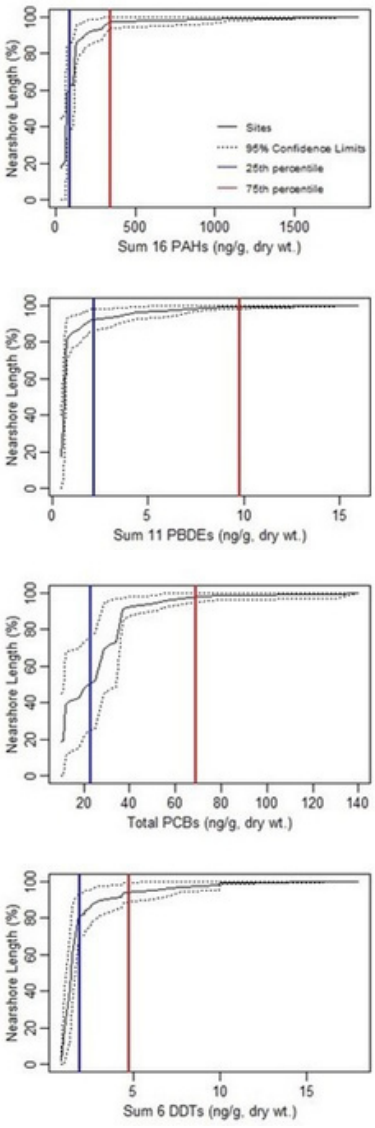


Figure 2. Cumulative distribution function (CDF) plot ofΣ16PAHs, TPCBs, Σ11PBDEs, and Σ6DDTs concentrations in mussels from the 2021/2022 SAM study sites. Values to the left of the blue line represent low concentrations, and values to the right of red line represent high concentrations based on project-specific threshold values determined using percentiles (25th and 75th).

Why does this study matter?

This long-term status and trends monitoring of the marine nearshore will evaluate whether and how stormwater discharge and the stormwater management actions implemented in the region are affecting nearshore biota contaminant levels.

What will Ecology do with this information?

Stormwater managers know that effective and lasting improvements to infrastructure, best management practices, and changing behaviors of Puget Sound residents takes time. Monitoring long term in several key environments such as the marine nearshore will help us determine if conditions are getting better despite population growth as building codes and stormwater management improves in the areas adjacent to the nearshore.

What should we do with this information?

Ecology will use this objective regional information to evaluate the efficacy of the municipal stormwater permitting program over time in slowing or reversing the decline in the marine nearshore. While there are many other potential dischargers beyond municipal stormwater impacting Puget Sound's water quality, the nearshore is the most likely environment for stormwater impacts to be measured and tracked, especially as the region expands existing and new development. Ecology supports SAM's receiving water studies under the municipal stormwater permits and will continue to coordinate findings with SAM's urban stream monitoring program in Puget Sound.

Lower Columbia urban streams monitoring
Water years 2020-2023

Stormwater Action Monitoring

Receiving Waters

Lead Entity: **Clark** County

Partner: Washington State Department of Ecology

For More Information: Go to Ecology.wa.gov/SAM and search for 'Lower Columbia urban streams'

Study goals

This study is monitoring how the health of small, wadable streams change over time in urban, and urbanizing areas of the Lower Columbia River region. The aim of this study is to provide a better understanding of influential stressors contributing to impaired waters and overall stream health. The monitoring objectives and questions were developed as part of the Lower Columbia Habitat Status and Trends Monitoring implementation plan, for the Urban-Area Water Quality and Quantity component.

Stormwater management problem

Stormwater runoff from urban and urbanizing areas causes the majority of habitat and water quality degradation in small streams. Local jurisdictions throughout the Lower Columbia River region are increasing their stormwater management efforts to reduce flow volumes and pollutants. This regional evaluation of stream health focuses on areas covered by municipal stormwater permits because stormwater managers and policymakers need a better understanding of the most influential stressors on biological health to identify the most promising solutions. Over time, we believe that permittees' collective stormwater management efforts will result in detectible stream quality improvements.

Findings

For this study, 22 sites have been selected; five sites that will be visited for annual monitoring throughout the study period and 17 sites that will be monitored for a single year within a five-year sampling cycle under a rotating panel design. The study evaluated stream health using biological measures, water and sediment chemistry, and a physical habitat conditions in streams and watersheds. A benthic invertebrate index of biotic integrity (B-IBI) is a comprehensive indicator of stream biological health.

Urban development, as measured by impervious surface and traffic density negatively impacted stream B-IBI scores. B-IBI scores decreased with increasing levels of impervious area (Figure 1). B-IBI scores were poor or very poor for all sites with traffic intensity greater than 20,000 vehicle trips per mile. No site met the aquatic life temperature criteria and most sites exceeded the criteria over 50% of the designated criteria period, suggesting that these streams are not supportive of salmonids.

The Lower Columbia Urban Streams (LCUS) monitoring program results for water years 2020–2022 highlight the profound impacts of urbanization on stream health. All monitored subwatersheds exhibited excessive impervious cover (14–50%), surpassing thresholds needed to support healthy salmonid and macroinvertebrate populations.

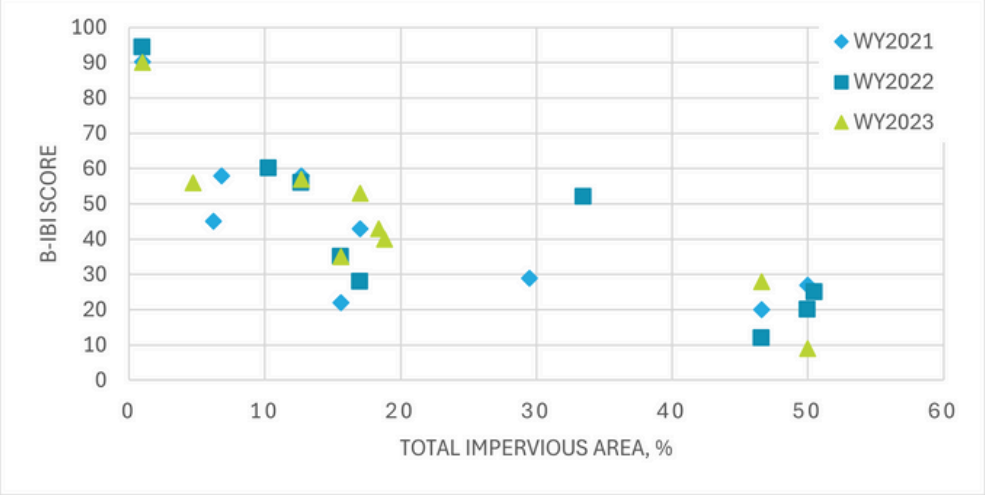


Figure 1 Benthic Macroinvertebrate Index (B-IBI) scores measured in the stream decrease with increased impervious surface in the watershed contributing area. Data presented for water years 2021, 2022, and 2023.

Recommendations

Stormwater managers should review Table 1, determine what combinations of the key stressors are present in their jurisdictions, and then consider adjusting their management programs to address these stressors.

Table 1 List of the most important stressors identified for B-IBI for each category of stream health indicators.

Stream Health Category	Important regional stressors to address to improve B-IBI scores
Watershed scale land cover	• Percent impervious surface • Traffic intensity • Riparian canopy cover
Water	• Water temperature
Sediment	• Substrate embeddedness

Regional scale monitoring is a cost-effective way to evaluate unbiased status and trends in the ecoregion. SAM will continue to gather long-term status and trend data in the region. In 2024, we added monitoring of least-disturbed reference conditions to establish reasonable expectations for good and poor biological conditions and help identify important stressors.

Why does this study matter?

With this regional-scale monitoring program, we are improving our understanding of the effects of urbanization and influences of stormwater management efforts on stream health across the Lower Columbia River Basin. Over time, this stream monitoring will tell us whether our overall management strategies, including stormwater management, are improving stream health. More specific studies, in particular, effectiveness studies complementing this monitoring, will help inform how stormwater management contributes to overall improvements in stream health.

What will Ecology do with this information?

Ecology needs this objective regional information to evaluate whether or not the overall permitting program is slowing or reversing the decline in receiving water conditions caused by stormwater from existing and new development. Ecology can also use the study findings about conditions of streams in areas covered by the municipal stormwater permits to prioritize stormwater grant funding.

What should we do with this information?

Stormwater managers should consider the findings of this study and compare their local monitoring data to the regional data set. In the absence of local monitoring, the results for streams with similar watershed characteristics sampled in this study can provide useful information for targeting stormwater management actions. Permittees can use this knowledge, coupled with findings of effectiveness studies, to help prioritize and implement stormwater runoff management practices in their jurisdictions.

SAM studies underway in 2025

Effectiveness studies & Source Identification projects

Evaluation of best management practices maintenance conditions

Longevity of biological protection using bioretention

Water budgets of individual local trees

Paired watershed retrofit & restoration study

Measuring street sweeping 6PPDQ whole environment load reductions

Characterization of stormwater transport of contaminants of emerging concern

Bioretention effectiveness for 6PPD and PFAS

Updated infiltration methods in the stormwater manuals

Receiving water monitoring

Puget Sound nearshore mussel contaminants

Puget Sound small streams

Lower Columbia urban streams

SAM

Stormwater Action Monitoring