# WSDOT NPDES Municipal Stormwater Permit Compost-Amended Bioswale Monitoring Status Report Water Year 2018

October 2019

Prepared by

Stormwater Monitoring Program
Environmental Services Office
Washington State Department of Transportation

Washington State Department of Transportation

## Author and Contact Information

Washington State Department of Transportation
Stormwater Branch
P.O. Box 47332
Olympia, WA 98504-7332

*Any use of product or firm names in this publication is for descriptive purposes only and does not imply endorsement by the author or the Departments of Transportation.*

*Materials can be provided in alternative formats by calling the ADA Compliance Manager at 360-705-7097.*

*Persons who are deaf or hard of hearing may contact the above number via the Washington Relay Service at 7-1-1.*

## Stormwater Monitoring Report

# Compost-Amended Bioswale Effectiveness Evaluation
# Water Years 2017-2018

**Approved by:**

I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to ensure qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for willful violations.

Signature: _____ Date: _____

Jana Crawford, Stormwater Branch Manager
WSDOT Environmental Services Office

Signatures are not available on the Internet version.
WSDOT = Washington State Department of Transportation

# Contents


1 Introduction ..... 1
1.1 Permit Overview ..... 1
1.2 Monitoring Requirements ..... 1
2 Monitoring Program Implementation ..... 2
2.1 Site Selection Strategy ..... 2
2.1.1 Personnel Safety ..... 2
2.1.4 Site Accessibility ..... 3
2.1.5 Equipment Security ..... 3
2.1.6 Discharge and Precipitation Measurement Capability ..... 3
2.1.7 Site Design Limitations ..... 3
2.2 Resource and Logistical Constraints ..... 4
2.3 Bioswale Effectiveness Monitoring Sites ..... 4
2.4 Preliminary Assessments of the Maintenance Facilities ..... 6
2.5 Mottman Compost-Amended Biofiltration Swale Description ..... 6
2.5.1 Mottman CABS Basic Design Features ..... 8
2.6 Lakeview Compost-Amended Biofiltration Swale Description ..... 10
2.6.1 Lakeview CABS Basic Design Features ..... 11
2.7 Geiger Compost-Amended Biofiltration Swale Description ..... 13
3 Sampling and Monitoring Procedures ..... 15
3.1 Monitoring Stations ..... 15
3.1.1 Precipitation Measurement ..... 15
3.1.2 Temperature Measurement ..... 15
3.2 Weather Tracking ..... 16
3.3 Sampling Parameters ..... 17
3.4 Sampling Methods ..... 17
3.5 Station Maintenance ..... 18
3.6 Equipment Decontamination ..... 18
3.7 Staff Roles and Responsibilities ..... 18
4 Quality Assurance and Quality Control ..... 19
5 Monitoring Results ..... 21
5.1 CABS BMP Monitoring ..... 21
5.1.1 Mottman ..... 21
5.1.2 Lakeview ..... 21
5.1.3 Geiger ..... 21
5.2 Sampling Logistics and Challenges ..... 22
5.3 Lessons Learned ..... 22
Glossary ..... 23

Literature Cited ..... 24
Acronyms and Abbreviations ..... 26
Acronyms and Abbreviations ..... 26

# List of Tables

Table 1. CABS effectiveness monitoring sites. ..... 5
Table 2. Maintenance facility monitoring locations and materials/activities matrix. ..... 6
Table 3. Storm event criteria for CABS monitoring. ..... 16
Table 4. Sampling water quality parameters. ..... 17
Table 5. Sampling methods overview. ..... 17

# List of Figures

Figure 1. WSDOT Bioswale study sites. ..... 4
Figure 2. Mottman CABS monitoring points and associated drainage area. ..... 7
Figure 3. Mottman biofiltration swale monitoring design and equipment placement. ..... 9
Figure 4. Lakeview biofiltration swale and associated drainage area. ..... 10
Figure 5. Lakeview biofiltration swale monitoring design and equipment placement. ..... 12
Figure 6. Geiger surveyed catchment area. ..... 14

# 1 Introduction

## 1.1 Permit Overview

On March 6, 2014, the Washington State Department of Ecology (Ecology) reissued a *National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge Municipal Stormwater General Permit* (Ecology 2014) to the Washington State Department of Transportation (WSDOT). Under Special Condition S7 of the permit, WSDOT developed and implemented a monitoring program to evaluate the effectiveness of stormwater treatment and hydrologic management best management practices (BMPs) at WSDOT facility sites. This work has continued under Section S7.B of the 2019 Municipal Stormwater Permit (Ecology 2019), reissued to WSDOT by Ecology on March 6, 2019.

Under Special Conditions S8 of the 2019 Municipal Stormwater Permit, WSDOT must submit annual reports that include monitoring information collected at the department's stormwater facility BMP monitoring sites. The following report helps satisfy these annual reporting requirements and provides a summary of monitoring activities completed at WSDOT maintenance facilities under S7.B from October 1, 2016, through September 30, 2018 (water years 2017-2018).

## 1.2 Monitoring Requirements

In accordance with the 2014 and 2019 Municipal Stormwater Permits, WSDOT must evaluate stormwater BMPs selected to address concerns identified during runoff characterization monitoring of WSDOT facilities. An additional requirement is to evaluate BMPs at two facilities in western Washington and one facility in eastern Washington. WSDOT chose to monitor compost-amended biofiltration swales (CABS) for treatment of stormwater runoff at three maintenance facilities.

WSDOT will continue monitoring until meeting statistical goals in the *Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol – Ecology (TAPE)* (Ecology 2018). If the data does not meet statistical goals in TAPE, the 2019 Municipal Stormwater Permit requires a maximum sampling effort of 35 sampling events.

# 2 Monitoring Program Implementation

## 2.1 Site Selection Strategy

WSDOT had conducted a runoff characterization monitoring study of several maintenance facilities, rest areas, and ferry terminals to meet requirements in the 2009 Municipal Stormwater Permit. Stormwater monitoring program staff reviewed baseline-monitoring data from this study and identified areas of concern at several maintenance facilities. Areas of concern include analytical results with comparatively high concentrations of metals, total petroleum hydrocarbons, and chlorides. Staff weighed these baseline results against complicating site factors such as safety concerns and ease of site retrofit during site selection.

Monitoring staff used the following evaluation criteria to select maintenance facility sites for monitoring.

- Personal safety.
- Site accessibility.
- Equipment security.
- Discharge and precipitation measurement capability.
- Site design limitations.

### *2.1.1 Personnel Safety*

For any WSDOT project, staff safety is a high priority. Staff avoided or minimized, whenever possible, hazards from maintenance yard traffic, explosive or toxic gases, poor footing on slopes, slippery conditions, and poor visibility due to adverse weather or night work.

The following site attributes expose monitoring field teams to potentially unsafe conditions:

- Sites located near heavy maintenance vehicle traffic.
- Sites with poor access.
- Slopes that encourage slips, trips, and falls.

To minimize the effects of these hazards, staff had to be capable of performing all tasks required for sample collection and be familiar with WSDOT's *Safety Procedures and Guidelines Manual* (WSDOT 2015 and 2018). Staff also developed site-specific Health and Safety Plans for each monitoring site to minimize the effect of these hazards.

### 2.1.4 Site Accessibility

WSDOT selected monitoring sites to provide safe and feasible access. To make sure personnel could quickly locate and access monitoring sites, staff developed site-specific Health and Safety Plans to include a description of parking and work zone safety procedures. Information in the Health and Safety Plans included lists of physical and biological hazards, standard emergency procedures, site maps, and directions.

### 2.1.5 Equipment Security

Selected sites had to provide adequate level area for monitoring station installation in locations with sufficient space for monitoring equipment. Additionally, the western Washington sites were located within the perimeter fence of the maintenance facility. Staff installed data collection equipment in locked metal enclosures on level ground or concrete platforms to reduce the risk of tampering. Locked metal enclosures provide a secure location as well as protection from wind, rain, and snowfall.

### 2.1.6 Discharge and Precipitation Measurement Capability

Staff selected monitoring sites in locations that allow for discharge measurement and automatic sample collection. In order to monitor runoff from WSDOT facilities, field personnel constructed conveyance systems to collect, direct, and measure sheet flow moving through the bioswales.

Staff installed monitoring sites in locations that allowed for accurate precipitation monitoring. Requirements for accurate precipitation monitoring included adequate distance from biasing factors, such as trees, and the ability to mount rain gages high enough above the ground to avoid rain splashing from maintenance vehicle traffic.

### 2.1.7 Site Design Limitations

WSDOT established monitoring stations to collect water quality and quantity data from influent and effluent sampling locations. Personnel considered the following site design limitations when establishing monitoring stations for effectiveness evaluation:

- The physical space needed for monitoring infrastructure and data collection platform establishment.
- A monitoring site design that would provide easy access for influent and effluent sampling.
- Monitoring equipment and site infrastructure that enabled accurate flow measurements and reduced required maintenance.

## 2.2 Resource and Logistical Constraints

Staff identified two western Washington sampling locations within 30 miles of the monitoring program headquarters. These site locations reduce staff travel time, providing quick access to sites for station maintenance and sampling. For the eastern Washington location, WSDOT utilizes a member of a region office to perform sampling duties, though headquarters monitoring staff still visit the site for station maintenance.

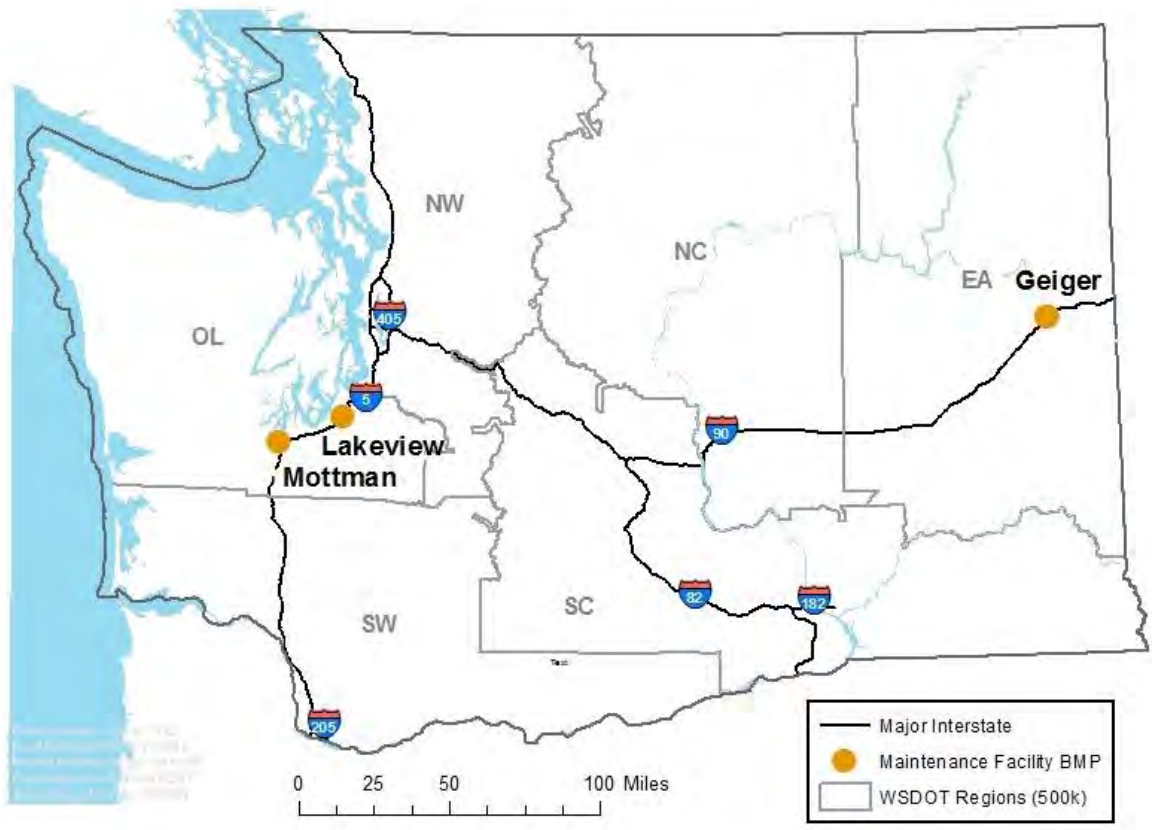


**Figure 1. WSDOT Bioswale study sites.**

## 2.3 Bioswale Effectiveness Monitoring Sites

Staff evaluated several maintenance facilities, identified during the initial runoff characterization study, as potential monitoring locations. WSDOT reviewed data collected during the baseline study and identified two facilities with comparatively high concentrations of water quality pollutants. Staff identified a third site following a review of maintenance activities occurring at that site. Table 1 lists the three representative maintenance facilities chosen for BMP effectiveness monitoring.

**Table 1. CABS effectiveness monitoring sites.**

| Facility Name | Facility Location | BMP Type | Sample Location Code | Sample Location Description |
|---|---|---|---|---|
| Mottman Maintenance Facility | Western WA, City of Tumwater | Modified CABS (Flow Length Reduction) | MOT-01 | Influent sump |
| | | | MOT-02 | Post sump trough at 30’ |
| | | | MOT-03 | Post sump trough at 73’ |
| | | | MOT-04 | Post sump basin at 123’ |
| | | Modified CABS (Oyster Shell amendment) | MOT-01 | Influent sump |
| | | | MOT-02 | Post sump trough at 30’ |
| | | | MOT-03 | Post sump trough at 73’ |
| | | | MOT-04 | Pre sump basin at 120’ |
| | | | MOT-05 | Post sump basin at 123’ |
| Lakeview Maintenance Facility | Western WA, City of Lakewood | Modified CABS (Flow Length Reduction) | LAK-01 | Influent sump |
| | | | LAK-02 | Post sump trough at 81’ |
| | | | LAK-03 | Post sump trough at 95’ |
| | | Modified CABS (Oyster Shell amendment) | LAK-01 | Influent sump |
| | | | LAK-02 | Post sump trough at 81’ |
| | | | LAK-03 | Post sump trough at 95’ |
| Geiger Maintenance Facility | Eastern WA, City of Spokane | CABS (Flow Length Reduction) | GEI-01 | Influent sump |
| | | | GEI-02 | Subsurface tee at 25’ |
| | | | GEI-03 | Surface trough at 27.5’ |
| | | | GEI-04 | Effluent at 100’ |

Data from the Lakeview facility showed relatively high concentrations for dissolved zinc that were likely an effect of uncovered galvanized metal storage on site. Monitoring results from the Geiger facility showed comparatively high concentrations for total petroleum hydrocarbons, copper, and total suspended solids. Although the Mottman facility was not part of the original runoff characterization study, the site had many of the same issues as other maintenance facilities (see Table 2). WSDOT collected several samples at Mottman that showed relatively high results for total petroleum hydrocarbons, total and dissolved metals, and total suspended solids.

WSDOT selected to construct compost-amended biofiltration swales (CABS) at each facility to treat the pollutants of concern. The selected test variations in stormwater treatment and flow control designs of a standard CABS, such as increasing hydraulic residence time with compost amendment, flow length reduction, and incorporation of oyster shells for phosphorous removal.

WSDOT is currently monitoring the CABS at the Mottman and Lakeview facilities to assess effectiveness. Staff will review chemistry and hydrology data as the study progresses to evaluate any adaptive management strategies deemed necessary. If the sites appear to be underperforming or there are site design issues, staff will make changes, as appropriate.

Detailed discussion of the CABS and issues WSDOT has had at the Geiger facility is included in Section 2.7.

## 2.4 Preliminary Assessments of the Maintenance Facilities

Prior to construction of the BMPs, staff conducted visits to each maintenance facility to verify the layout, stormwater drainage areas, catchment basins, and possible pollutant-source activities.

The activities and structures that may generate polluted stormwater vary from location to location, but in general, there exists consistent representation among the sites. Table 2 lists the identified maintenance facility activities that occurred within the drainage area of the selected monitoring sites. WSDOT identified these activities as possible pollutant-generating sources when exposed to rainfall or stormwater runoff.

**Table 2. Maintenance facility monitoring locations and materials/activities matrix.**

| Region | Facility | Activities | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Galvanized Metals | Treated Lumber | Prewash Pad | Sand | Salt | Deicer | Highway Sweepings Storage | Landscaping | Truck Parking | Storage Buildings | Maintenance Buildings | Transportation Equipment Fund Shop | Offices | Fuel Island | Herbicide/Fertilizer |
| Olympic | Lakeview | X | X | x | | | x | | x | x | X | x | x | x | x | x |
| Olympic | Mottman | X | | x | x | X | | X | | x | X | x | | x | | |
| Eastern | Geiger | | x | x | x | | | | | x | X | x | x | x | x | x |

The Mottman and Lakeview sites had existing swales or ditches to treat stormwater runoff. WSDOT retrofitted these features to address the study goals. WSDOT constructed the CABS at Geiger to address the study goals and site concerns related to on-site flooding.

## 2.5 Mottman Compost-Amended Biofiltration Swale Description

The Mottman Maintenance Facility (Mottman) is located at 2120 R.W. Johnson Boulevard Southwest in Tumwater. The Mottman CABS is a retrofit of an existing swale located at the facility. The previous swale did not meet WSDOT CABS standards (WSDOT 2014).

The Mottman CABS is east of the site's primary maintenance activities, and receives runoff from a 1.23-acre drainage area highlighted in Figure 2. Site observations during multiple storm events confirmed the delineated drainage area. Since stormwater flows to multiple discharge points, the CABS does not receive all of the runoff from the maintenance facility. This report only addresses pollutants generated in the drainage area that discharges to the CABS.

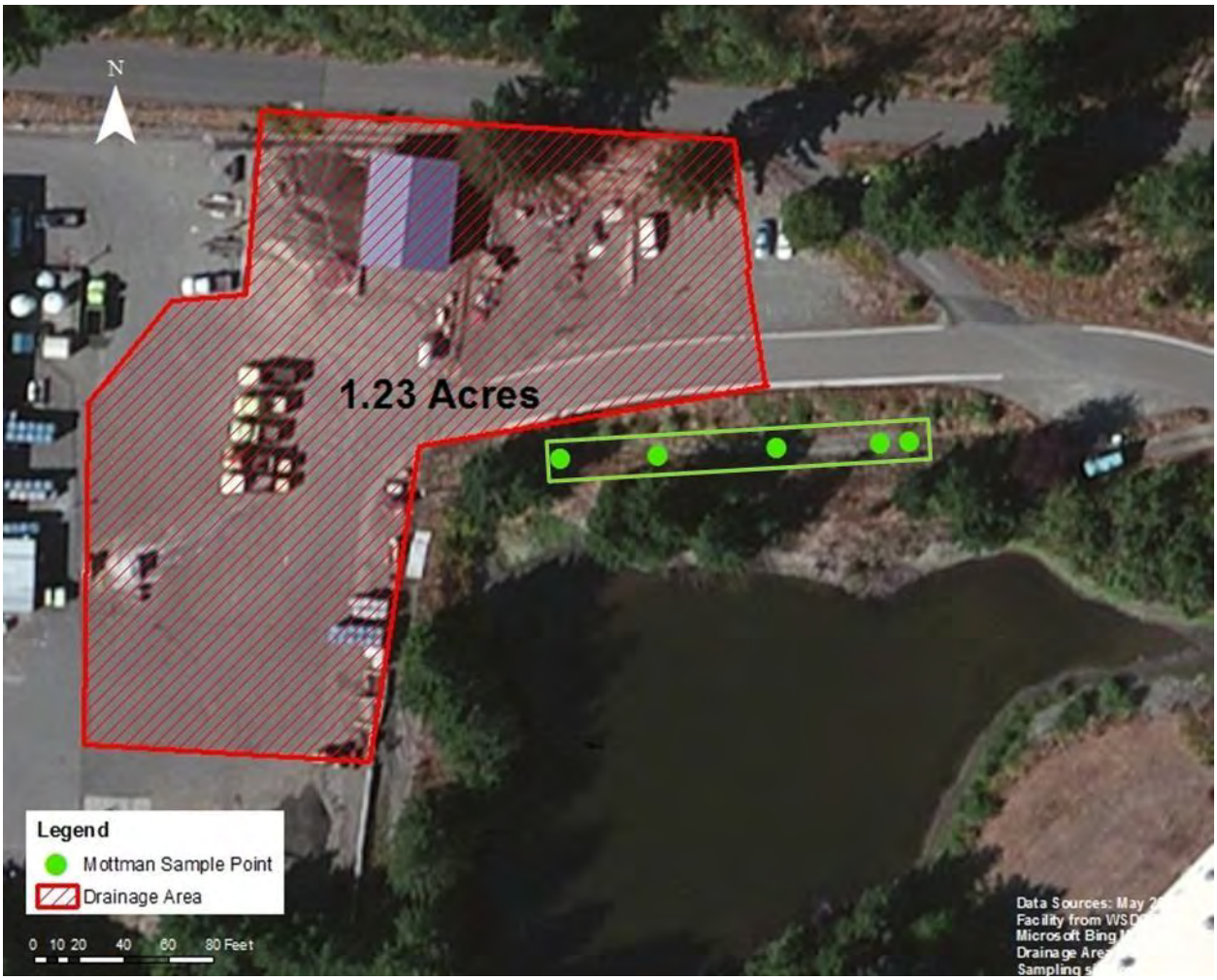


**Figure 2. Mottman CABS monitoring points and associated drainage area.**

Potential pollutant sources in the drainage area include trucks and heavy equipment parking, uncovered galvanized metal, a large sand pile, and a salt shed.

WSDOT designed the Mottman CABS to address three primary stormwater treatment goals:

- Assessing the effectiveness of using a 3-inch compost blanket to increase hydraulic residence time and reduce pollutants in the stormwater.
- Evaluating whether water treatment goals can be accomplished in a shorter length (i.e., shorter than the 100-foot minimum currently required for biofiltration swales) (WSDOT 2014).

- Evaluating whether the addition of crushed oyster shells will reduce, primarily via adsorption, exports of phosphorus from the compost blanket.

The construction of the Mottman CABS required retrofitting the existing swale and existing soils to the standards outlined in the *Highway Runoff Manual* (WSDOT 2014), as well as incorporating design features to facilitate the stated treatment goals.

### 2.5.1 Mottman CABS Basic Design Features

The Mottman CABS is 135 feet long, with a flat bottom (10 feet wide) and trapezoidal sloping sides as presented in Figure 3. The CABS consists of one foot of tilled soil covered by a 3-inch compost blanket (WSDOT 2014) and hydroseeded with a seed mix that meets WSDOT erosion control specifications (WSDOT 2016b). Stormwater enters the CABS through a catch basin and drainage inlet draining to a 12-inch pipe. Stormwater flows from the pipe into a flume, and discharges onto a concrete flow spreader.

The flow spreader ends at a concrete sump that extends from one wall of the CABS to the other, capturing all the water coming into the BMP. Except for sample collection and flow monitoring points, stormwater flows the entire length of the CABS as sheet flow.

Monitoring and sampling points are located at the following locations:

- At the influent sump (sample point 1).
- At 30 feet from the influent sump, immediately after a sump/flow spreader that may contain oyster shell amendments during the next phase of the study (sample point 2).
- At 73 feet from the influent, immediately after a sump/flow spreader that may eventually contain oyster shell amendments (sample point 3).
- At the outflow, immediately before and after a sump/flow spreader that may contain oyster shell amendments during the next phase of the study (sample points 4 and 5).

WSDOT may add the oyster shell treatment to the sumps after testing stormwater treatment performance at different lengths of the CABS.

Each monitoring and sampling location consists of a flume, stage-measuring equipment, and an autosampler collection point. Immediately outside of the CABS is equipment for monitoring and sampling. Staff housed the equipment in enclosures with attached masts for rain gages and solar panels. Station equipment monitors precipitation and discharge. A data logger records and uses internal processes to direct flow-weighted sample collection from sample points within the CABS.

Figure 3 presents the Mottman CABS design, equipment, and location of all included elements.

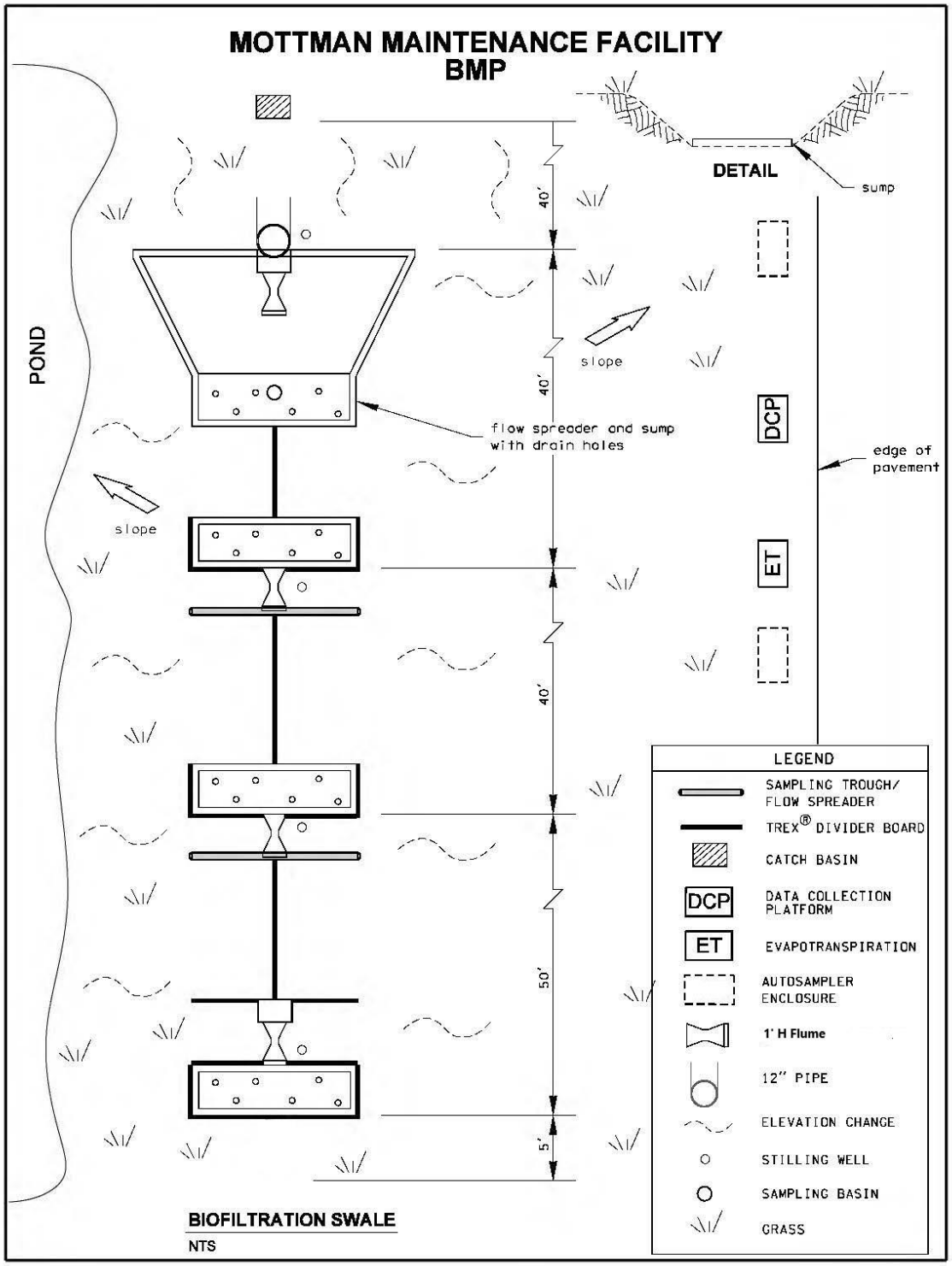


**Figure 3. Mottman CABS monitoring design and equipment placement.**

## 2.6 Lakeview Compost-Amended Biofiltration Swale Description

The Lakeview Maintenance Facility is located at 11211 41st Avenue Southwest in the City of Lakewood. Interstate 5 borders the facility to the east. Side streets and commercial properties surround the facility in all other directions.

Lakeview is maintenance facility with a stormwater system that collects runoff from nearly the entire facility into a large Type-2 catch basin with an integrated oil-water separator. This catch basin discharges to the Lakeview CABS. Figure 4 shows the drainage area of 2.56 acres.

Sources of potential pollutants in the drainage area include uncovered galvanized metal, treated lumber, a prewash pad, deicer tanks, landscaping equipment, truck parking, maintenance buildings, and herbicide and fertilizer storage.

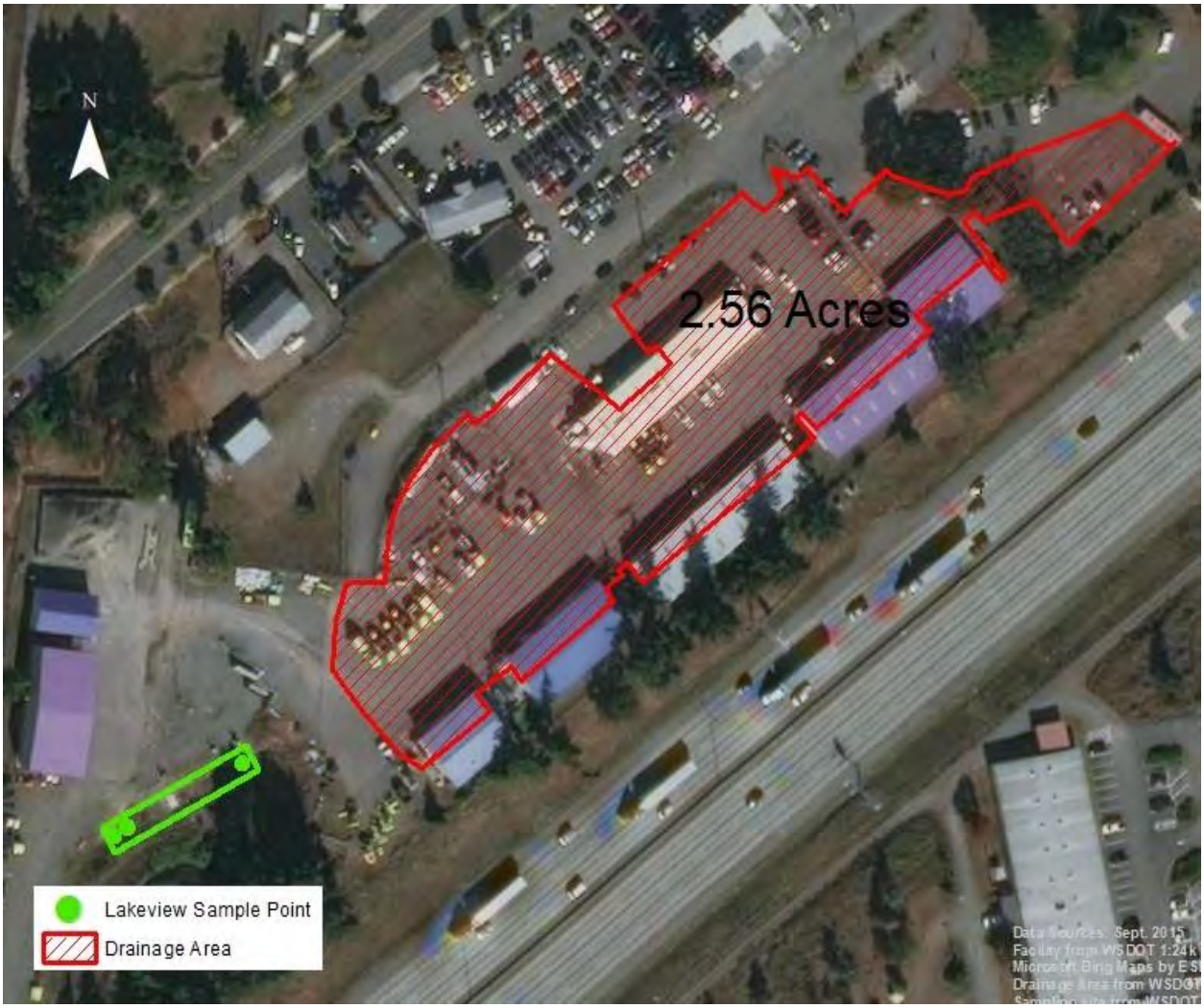


**Figure 4. Lakeview CABS and associated drainage area.**

WSDOT designed the Lakeview CABS to address three primary stormwater treatment goals:

- Assessing the effectiveness of using a 3-inch compost blanket to increase hydraulic residence time and reduce stormwater pollutants.
- Assessing whether a shorter length CABS can achieve stormwater treatment goals.
- Evaluating whether the addition of crushed oyster shells will reduce, primarily via adsorption, exports of phosphorus from the compost blanket.

The Lakeview CABS is a retrofit of an existing swale located at the facility. The previous swale performed the functions of a standard swale, receiving and treating stormwater runoff, before eventually discharging water to a wet pond at the facility.

### 2.6.1 Lakeview CABS Basic Design Features

The CABS is 95 feet long, with a flat bottom (12 feet wide) and trapezoidal sloping sides as presented in Figure 5. The CABS consists of one foot of tilled existing soil covered by a 3-inch compost blanket (WSDOT 2014), hydroseeded with seed that meets the WSDOT Erosion Control Specifications (WSDOT 2016b). Stormwater enters the CABS through a 4-inch pipe. During high stormwater flow events, a 12-inch pipe delivers additional water from a catch basin. Events during which the 12-inch pipe delivers water are rare, as the pipe functions as a catch basin overflow protection feature. A composite board directs the stormwater from the pipes over a concrete pad into a concrete sump where influent samples are collected. The flume receives water from the concrete sump for flow measurement.

Except for flow monitoring and sample-collection stage monitoring points, stormwater flows the entire length of the CABS as sheet flow.

Staff attached all the flumes at the monitoring locations to stilling wells, and utilized pressure transducers in the wells to monitor stage through the flumes. WSDOT established monitoring and sampling points at the following locations:

- At the inflow flume, using the post-flume container for sample collection (sample point 1).
- At 81 feet down the length of the CABS, using composite boards to concentrate stormwater to a flume, with a post-flume basin for sample collection (sample point 2). From this monitoring point, stormwater flows to a sump containing crushed oyster shells.
- At the effluent (95 feet down the length) and immediately following the sump holding oyster shells (sample point 3). Water from the sump flows to a flume that discharges to a sampling basin that functions as the final discharge point.

Figure 5 presents the Lakewood CABS monitoring design, equipment, and relative location of all included elements.

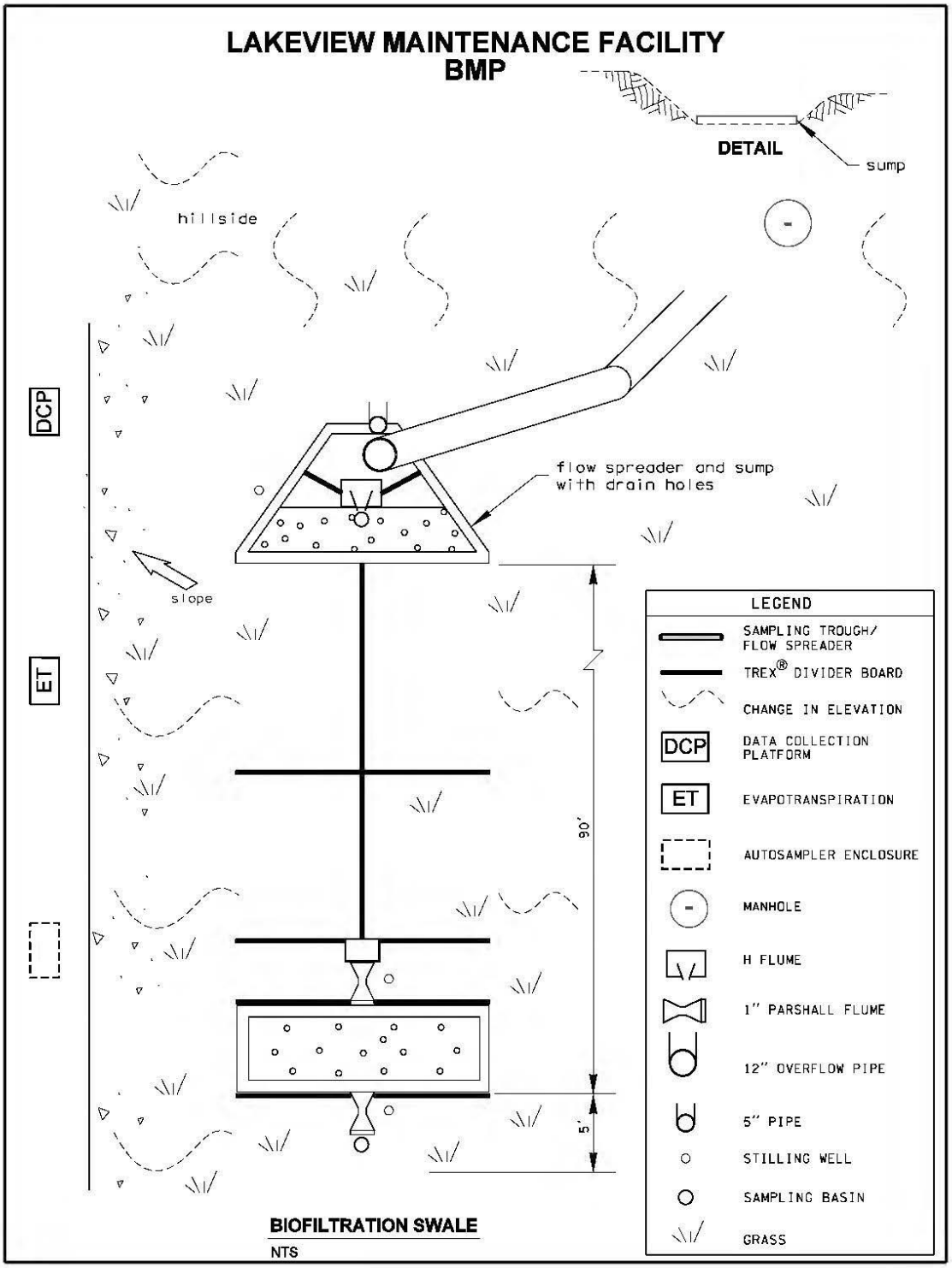


**Figure 5. Lakeview CABS monitoring design and equipment placement.**

## 2.7 Geiger Compost-Amended Biofiltration Swale Description

The Geiger Maintenance Facility is located west of Spokane near the Spokane International Airport at 7211 West Westbow Boulevard. Open areas border the site to the east and west, and county roads run along the north and south sides of the facility.

During a storm in May 2018, monitoring staff discovered that the depth of water moving through the CABS appeared to exceed the design limits for an eastern Washington CABS (WSDOT 2014). Staff suspected that the CABS might be undersized for the volume of runoff entering the BMP. In addition, a visual comparison of the total suspended solids load of the influent to effluent showed that treatment might not be occurring as expected.

WSDOT also discovered that the catchment area was determined to be too small, and that stormwater is running off a gravel parking lot adjacent to the originally delineated catchment area during larger storm events. WSDOT surveyed the maintenance facility to create a new estimate of the catchment area of 1.59 acres of paved area with an additional 0.3 acres of flat gravel area that likely adds flow during larger rain events. This information will be used to redesign the system. WSDOT design staff completed the site redesign in summer 2019 with construction slated for the fall.

Staff also determined that an underdrain system and liner placed along the first 25 feet of the CABS failed. The underdrain and liner are not part of a standard CABS design (WSDOT 2014). WSDOT installed the system to be able to evaluate treatment performance that occurs under the surface of the soil. The redesigned swale will not include an underdrain system.

Figure 6 shows the new drainage area. Potential pollutant sources observed in the drainage area include a fueling station, prewash pad, sand pile, vehicle parking spaces, and incidental runoff from materials storage areas.

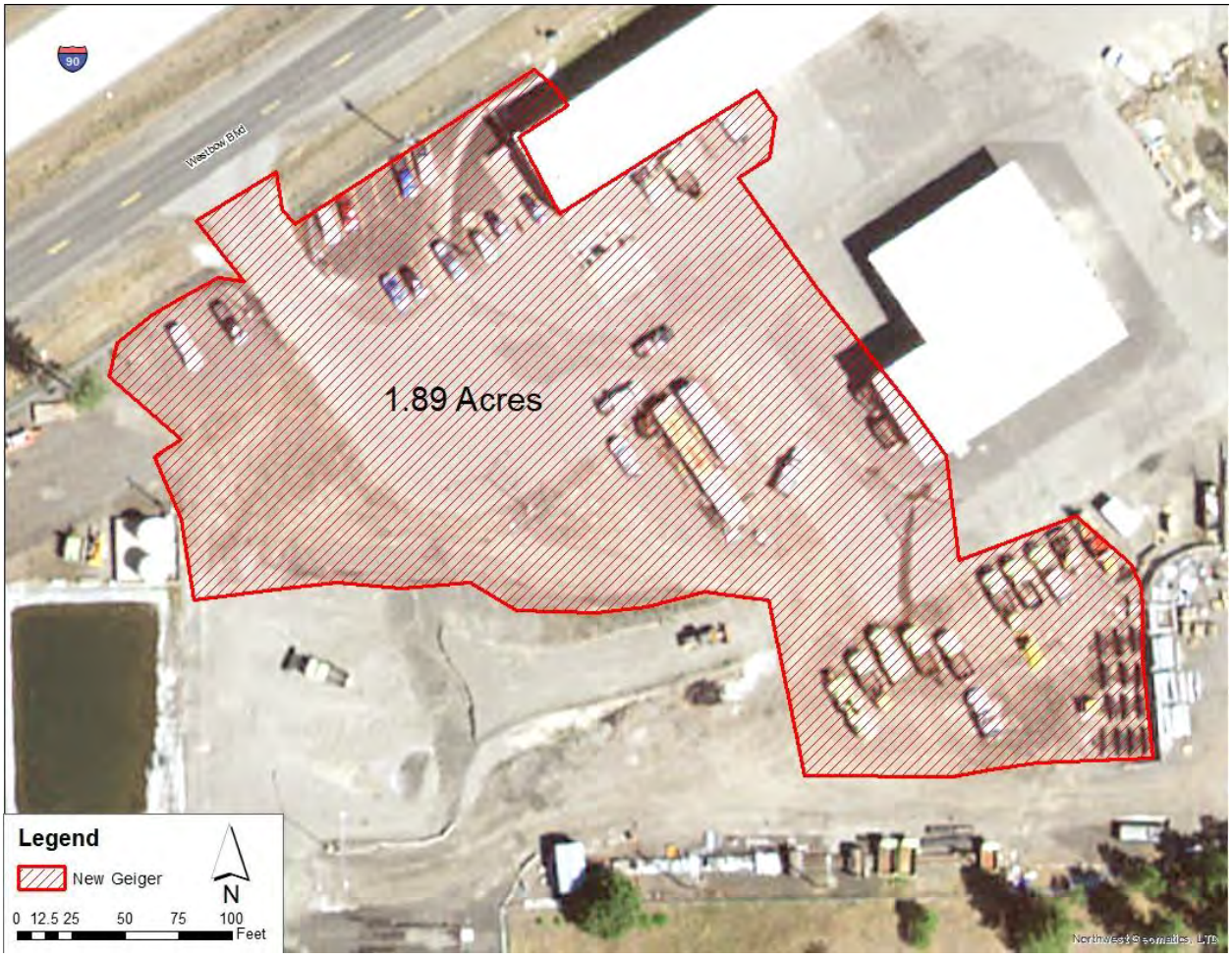


**Figure 6. Geiger surveyed catchment area.**

# 3 Sampling and Monitoring Procedures

## 3.1 Monitoring Stations

Monitoring stations at CABS effectiveness monitoring sites typically include an equipment enclosure with lock, Global Positioning System, antenna, solar panel, and rain gage. Staff mounted the antenna, solar panel, and rain gage on a mast attached to the side of the equipment enclosure.

The equipment enclosure houses a data logger, refrigerated automatic sampler, sample tubing, stage measuring devices, and a 12-volt battery. Sample tubing runs from the automatic sampler to the designated sampling point through protective conduit. The stage measuring equipment cables run through the conduit to a stilling well where pressure transducers record stage and temperature. The locked enclosure provides a secure location for equipment as well as protection from wind, rain, and snowfall.

### *3.1.1 Precipitation Measurement*

At each monitoring station, WSDOT installed a pole-mounted, tipping-bucket rain gage to measure rainfall. Using National Weather Service criteria as guidance (NWS 2010), WSDOT installed rain gages where no trees, buildings, overpasses, or other objects would obstruct or divert precipitation. Rain gages collect data every 15 minutes and store the data in the data logger's memory. WSDOT uses these data to track and record site-specific precipitation measurements.

### *3.1.2 Temperature Measurement*

WSDOT uses water temperature measurements at each of the CABS effectiveness monitoring sites to determine when to discontinue sampling in the event of freezing or near freezing conditions. The data logger records temperature sensor data every 15 minutes and transmits these records hourly to WSDOT's database.

## 3.2 Weather Tracking

WSDOT uses weather information—from satellite imagery, prediction models, the National Oceanic and Atmospheric Administration National Weather Service, and private forecasters—to forecast potentially qualifying storm events on a daily basis. As candidate storms approach, radar observations and hourly reports from land-based weather stations help track and evaluate storm potential. Staff use telemetered data transmitted from individual monitoring stations to track the progress of a storm event and the beginning of runoff. The stormwater monitoring team uses this information to direct field team deployments for sample collection.

To qualify, storms have to meet rainfall depth and antecedent dry period criteria. Table 3 lists storm event criteria in effect for BMP effectiveness monitoring sites through WY18.

**Table 3. Storm event criteria for CABS monitoring.**

| Criteria | BMP Effectiveness Monitoring |
|---|---|
| Monitoring Period | Year round |
| Rainfall Depth | 0.15” minimum; no fixed maximum |
| Rainfall Duration | 1-hour minimum; no fixed maximum |
| Antecedent Dry Period | < 0.04” rain in the previous 6 hours |
| Inter-event Dry Period | Not specified |
| Minimum Intensity | Range of rainfall intensity[1] |

[1] To assess performance on an annual average basis and performance at the peak design rate, Ecology suggests that samples are over a range of rainfall intensities (Ecology 2011, 2018).

## 3.3 Sampling Parameters

Sampling requirements listed in the Municipal Stormwater Permit and Ecology's TAPE (Ecology 2011 and 2018) specify parameters for BMP effectiveness monitoring. Table 4 lists these parameters in the priority order of analysis. If insufficient sample volume exists, WSDOT processes samples in order of priority taking into account volume requirements for laboratory analysis.

**Table 4. Sampling water quality parameters.**

| BMPs |
|---|
| Total suspended solids |
| Copper, zinc (total) |
| Copper, zinc (dissolved) |
| Particle size distribution |
| pH |
| total phosphorus |
| orthophosphate |
| hardness |

## 3.4 Sampling Methods

WSDOT established BMP effectiveness monitoring sites to measure stormwater quality and quantity. Table 5 lists parameter categories, sampling frequency, and methods.

**Table 5. Sampling methods overview.**

| Parameter Category | Sampling Frequency | Sampling Method | Telemetered Data? |
|---|---|---|---|
| Rainfall | Continuous, year round | Rain gage | yes |
| Stage (flow) | Continuous, year round | Stage measuring device | yes |
| Temperature | Continuous, year round | Stage measuring device | yes |
| Chemical | Discrete storm events | Autosampler | no |

For further information regarding fieldwork activities, sample processing details, and analytical requirements for BMP effectiveness evaluation, see the *Quality Assurance Project Plan for WSDOT Facility Stormwater Treatment Evaluation: Best Management Practices* (WSDOT 2016a).

## 3.5 Station Maintenance

WSDOT staff perform site maintenance on a three-week schedule. Monitoring staff perform a visual inspection of the monitoring site to identify possible damage to equipment and any new or unsafe conditions. Field teams check equipment enclosures for signs of tampering or forced entry. Staff inspect and clean outlet pipes, sampling basins, and the conveyance system to ensure the monitoring station is in good condition prior to a sampled storm event. Field staff follow this inspection and cleaning procedure to ensure representative data collected from the system is unaffected by accumulated debris and sensor drift.

Following the *Standard Operating Procedure for Monitoring Station Maintenance* (WSDOT 2019b), field staff conduct station checks that include inspections, testing, and replacement of worn or missing parts. Monitoring staff inspect internal wires and cables to evaluate wear and ensure cable connections to the data logger are in good condition. Staff check station antennae declinations and bearings, and clean solar panels to remove accumulated debris. When servicing or calibrating of scientific equipment at monitoring stations is required, staff follow manufacturers' specifications and conduct servicing and calibration of equipment on site or in a controlled environment, as appropriate.

## 3.6 Equipment Decontamination

Unless certified as precleaned from the equipment source, a contract lab decontaminates churners, sample containers, filters, or other materials that contact sampled stormwater prior to each use. The lab also cleans intake and pump head tubing prior to installation. WSDOT staff change tubing once each year or as necessary.

For detailed descriptions of decontaminated procedures, see the *Quality Assurance Project Plan for WSDOT Facility Stormwater Treatment Evaluation: Best Management Practices* (WSDOT 2016a).

## 3.7 Staff Roles and Responsibilities

WSDOT uses Stormwater Monitoring Program staff in its Headquarters Environmental Services Office and staff from the department's region offices to implement its monitoring program. Seven staff from the Headquarters Environmental Services Office played key roles in the stormwater monitoring strategy.

# 4 Quality Assurance and Quality Control

The *Quality Assurance Project Plan for WSDOT Facility Stormwater Treatment Evaluation: Best Management Practices* (WSDOT 2016a) includes a comprehensive description of quality assurance and quality control activities.

WSDOT implements quality control procedures through all phases of data collection and analyses. Quality control procedures include field collection and laboratory processing for all permit-required samples. Additionally, verification and validation of both field- and laboratory-generated data occur as part of data management activities. The quality of raw, unprocessed, and processed data is subject to review and management, including the following areas of work:

1. Field quality control
    - Implementation of standard operating procedures.
    - Field instrument inspection, calibration, and maintenance.
    - Site water conveyance systems inspection and maintenance.
    - Collection of field notes and maintenance documentation.
    - Collection of composite field duplicate samples.
    - Collection of field equipment blanks.
2. Laboratory quality control
    - Laboratory instrument maintenance and calibration.
    - Analysis of laboratory duplicate/split samples.
    - Analysis of laboratory matrix spike and matrix spike duplicate samples.
    - Analysis of laboratory blanks and standards.
3. Data management
    - Hydrology and precipitation data validation.
        - Checking for concurrence between adjacent pressure transducers.
        - Checking for consistency and similarity between site rain gage measurements.
        - Examining hydrology and precipitation data compared to historical and expected patterns at the site.
        - Verifying that no equipment malfunctions biased the data.
        - Verifying that conveyance systems operated accurately.
        - Checking field notes to ensure no outside factors biased the data.

    - Verifying that precipitation and runoff patterns make logical sense. For example, an extended delay in runoff at the highway edge, which normally takes little time, might be indicative of issues in the equipment or site performance.
- Field data verification.
- Correction of data gaps, anomalies, and use qualification for precipitation and hydrology data.
- Laboratory data verification and validation. This includes 2b level validation for 90% of the data and level 3+4 validation for 10% of the data (USEPA 2009).
- Self-assessment and review of project processes.

# 5 Monitoring Results

## 5.1 CABS BMP Monitoring

### 5.1.1 Mottman

No sample attempts were made at the Mottman site in WY18. The site underwent extensive reconstruction during the water year to correct issues with hydrological data collection.

### 5.1.2 Lakeview

The soils at the site exhibit such high rates of infiltration that runoff only reaches the end of the CABS during short bursts of high intensity rainfall. The influent receives regular flows during storms, while runoff may reach the effluent during 15-20% of storms. Runoff also reaches the effluent for only short periods during individual storm events.

WSDOT and Ecology decided that pairing influent and effluent samples in this situation would not accurately represent treatment at the CABS as a parcel of water exiting the BMP does not represent a parcel concurrently entering the BMP. In January 2019, WSDOT made changes to the Lakeview monitoring protocol to switch the sampling strategy from matched pair sampling to the long detention time protocol per Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol – Ecology (TAPE), Appendix C (Ecology, 2018).

Two samples were collected during WY18. These samples were collected at the influent only so matched pair samples were not collected. Since WSDOT and Ecology agreed to no longer use a matched pair sampling strategy, the data collected is no longer applicable to the study and was therefore not included in this report, but is available upon request.

The long detention protocol calls for randomizing a number of sampling attempts according to the historic number of days with flows that would provide sufficient volumes for sampling. Staff then used this data to estimate the number of sampling events required to collect 15 samples during WY19-20. Water yeat 2020 is the first full year of attempting long detention sampling. If 15 samples are not collected by the end of WY20, either randomized sampling will be attempted for another water year or the sample design will be reconsidered.

### 5.1.3 Geiger

Staff will not sample at Geiger until the site has been reconstructed and vegetation has been established per agreement with Ecology. Site construction is planned for spring 2020.

## 5.2 Sampling Logistics and Challenges

WSDOT field staff used storm event criteria and guidelines detailed in WSDOT's Municipal Stormwater Permits (Ecology 2014) and Ecology's Technical Assessment Protocol (TAPE) (Ecology 2011 and 2018) to deploy resources for forecast qualifying storm events. Collecting CABS stormwater data was challenging due to the dynamic and unpredictable nature of storm forecasts and rainfall, as well as site-specific challenges.

WSDOT anticipates using field observations paired with consistent improvements in the understanding of site hydrology to improve sampling success and efficiency.

## 5.3 Lessons Learned

WSDOT found that developing the CABS BMP effectiveness-monitoring program was a complex endeavor. The following are lessons learned from implementing the monitoring program:

1. **Establishment of standard operating procedures:** Establishing Standard Operating Procedures (SOPs) helped clarify the fundamentals of various monitoring activities allowing for efficient and consistent collection of the most reliable and representative data possible (WSDOT 2019a, b, c, d). SOPs detail all steps in the monitoring process from sample collection in the field to data management and validation in the office.

2. **Cross training of staff:** Cross training staff proved to be an important factor for the program considering the limited number of staff. Having more team members able to respond to different aspects of the program was a key part of the program's approach.

3. **Conduct frequent site storm event observations:** WSDOT discovered several issues at the CABS BMPs when observing the sites during storm events. If staff had conducted site visits during storm events shortly after construction, they would have noticed design issues in a timelier manner.

4. **Include data analysis early in the study**: Including data analysis early in the study would have led to earlier improvements in methods and infrastructure. Staff spent a large part of WY18 correcting design and construction issues that were affecting flow measurements. WSDOT should have concentrated on analyzing flow data earlier so that data analysis could coincide with field observations.

# Glossary

**best management practices (BMPs)** – The structural devices, maintenance procedures, managerial practices, prohibitions of practices, and schedules of activities that are used singly or in combination to prevent or reduce the detrimental impacts of stormwater, such as pollution of water, degradation of channels, damage to structures, and flooding (WSDOT 2014).

**data collection platform** – A collection of instruments or sensors that operate and report to a central data logger. WSDOT houses data collection platforms in a central location or "platform" at the monitoring site.

**Global Positioning System** – A satellite navigation system used to determine ground position and velocity (location, speed, and direction).

**hydrograph** – A graph of flow versus time for a given point.

**National Pollutant Discharge and Elimination System (NPDES)** – The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Federal Clean Water Act, for the discharge of pollutants to surface waters of the state from point sources. The Washington State Department of Ecology administers these permits referred to as NPDES permits and, in Washington State.

**pH** – A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

**Quality Assurance Project Plan** – A document that describes the objectives of a monitoring project and the procedures necessary to ensure the quality and integrity of the collected data (Ecology 2004).

**representativeness** – The state or quality of being accurately representative of something. Expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at the sampling point, or an environmental condition (USEPA 2006).

**stormwater** – That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, pipes, and other features of a stormwater drainage system into a defined surface water body or a constructed infiltration facility (WSDOT 2014).

**stilling well** – A well or chamber that is connected to the main flow channel by a small inlet used to house a pressure transducer.

# Literature Cited


Ecology. 2004. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-030. Revised December 2016.

Ecology. 2011. Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol – Ecology (TAPE), 2011 revision. Washington State Department of Ecology, Olympia, WA. Publication No. 11-10-061.

Ecology. 2014. Washington State Department of Transportation National Pollutant Discharge and Elimination System and State Waste Discharge Municipal Stormwater General Permit. Washington State Department of Ecology, Olympia, WA. Permit No. WAR043000A. Issued March 6, 2014.

Ecology. 2018. Technology Assessment Protocol – Ecology (TAPE), Process Overview. Washington State Department of Ecology, Olympia, WA. Publication No. 18-10-039.

Ecology. 2019. Washington State Department of transportation National Pollutant Discharge Elimination System and State Waste Discharge Municipal Stormwater General Permit. Permit No. WAR043000A. Issued March 6, 2019.

NWS. 2010. National Weather Service Instruction. U. S. Department of Commerce, National Oceanic and Atmospheric Association, National Weather Service, Silver Spring, MD. NWSPD 10-13.

USEPA. 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process. EPA QA/G-4. EPA/240/B-06/001. February 2006.

USEPA. 2009. Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use. EPA 540-R-08-005.

WSDOT. 2014. Highway Runoff Manual. Washington State Department of Transportation, Environmental and Engineering Programs Design Office, Olympia, WA. Publication M 31-16.04. Supplement February 2016.

WSDOT. 2015. Safety Procedures and Guidelines Manual. Publication No. M 75-01.28. Washington State Department of Transportation, Olympia, WA.

WSDOT. 2016a. Quality Assurance Project Plan for WSDOT Facility Stormwater Treatment Evaluation: Best Management Practices. Washington State Department of Transportation, Environmental Services Office, Olympia, WA. Updated 2018.

WSDOT. 2016b. Standard specifications for Road, Bridge, and Municipal Construction. Washington State Department of Transportation, Headquarters Construction Office, Olympia, WA. Publication M 41-10.

WSDOT. 2018. Safety Procedures and Guidelines Manual. Publication No. M 75-01.34. Washington State Department of Transportation, Olympia, WA.

WSDOT. 2019a. Standard Operating Procedure for Forecasting and BMP Storm Targeting. Washington State Department of Transportation, Olympia, WA.

WSDOT. 2019b. Standard Operating Procedure for Monitoring Station Maintenance. Washington State Department of Transportation, Olympia, WA.

WSDOT. 2019c. Standard Operating Procedure for Pre-storming and Pressure Transducer Zeroing at Sampling Locations. Washington State Department of Transportation, Olympia, WA.

WSDOT. 2019d. Standard Operating Procedure for Stormwater Composite Sample Collection and Delivery to Laboratory. Washington State Department of Transportation, Olympia, WA.

# Acronyms and Abbreviations

## Acronyms and Abbreviations

| | |
|---|---|
| BMP | best management practice |
| CABS | compost-amended bioswale |
| Ecology | Washington State Department of Ecology |
| NPDES | National Pollutant Discharge Elimination System |
| NWS | National Weather Service |
| pH | measure of alkalinity or acidity |
| TAPE | Technology Assessment Protocol – Ecology (TAPE) |
| USEPA | United States Environmental Protection Agency |
| WSDOT | Washington State Department of Transportation |
| WY | water year |