Stormwater Best Management Practices Maintenance Conditions Evaluation

SAM Study

Final White Paper

By
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Prepared for
City of Bellevue and
Water Quality Program at
Washington State Department of Ecology

On behalf of the **Stormwater Work Group**

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Related Information

- Stormwater Action Monitoring projects aim to improve stormwater management. Learn about current and past studies at the SAM website[1].
- The Stormwater Work Group (SWG) oversees the SAM Program. Visit the SWG website.[2] to learn more.

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[1] www.ecology.wa.gov/sam

[2] https://ecology.wa.gov/about-us/accountability-transparency/partnerships-committees/stormwater-work-group

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Executive Summary

This white paper summarizes the results of a Stormwater Action Monitoring (SAM) Study that evaluated the maintenance standards of selected stormwater best management practices (BMPs). The Study focused on operations and maintenance (O&M) of stormwater BMPs in relation to the maintenance standards in the Stormwater Management Manual for Western Washington (SWMMWW, Ecology 2019a and 2024). The Study addresses a priority topic for stormwater BMP O&M per the "Round 3" request for SAM study proposals (Ecology 2020), which is to evaluate maintenance thresholds to help permittees keep BMPs working while maintaining water quality benefits. This study explored how permittees could evaluate their BMP maintenance data relative to the maintenance standards, and we identified BMP types and maintenance needs that drive efforts (and, therefore, cost) that could be reviewed to consider revising maintenance efforts.

The maintenance standards evaluated in this Study are those in the BMP Maintenance Tables (Ecology 2019b) of the SWMMWW, and three general types of BMPs— ponds, trenches, and vaults— were evaluated that are in widespread use and cover most of the 23 BMP types in the Tables. For purposes of this Study, trenches include swales, and vaults include tanks. The BMP Maintenance Tables are provided by Ecology as guidance, and the municipal stormwater permits (Ecology 2019c and 2019d) allow permittees to adjust the frequency of BMP maintenance and the conditions that trigger maintenance based on demonstrated BMP performance and permittee experience.

The Study was implemented by the City of Bellevue (City) with Herrera Environmental Consultants (Herrera) and Aspect Consulting (Aspect). The SAM studies are administered by the Washington State Department of Ecology (Ecology), overseen cooperatively by the multi-agency Stormwater Work Group (SWG), and funded cooperatively by municipal stormwater permittees of the National Pollutant Discharge Elimination System (NPDES) in western Washington State.

Four technical tasks were implemented to achieve the Study objectives, which included a survey, a literature review, discussions with Ecology about the sources of the maintenance standards, and a pilot data analysis. These tasks built off one another and helped provide a broad and deep understanding of the origins of the maintenance standards, how maintenance standards vary across the region, and which ones may need updating.

The stormwater BMP maintenance standards in use today in western Washington are derived from the 2001 Ecology stormwater manual (SWMMWW, Ecology 2019a), which were significantly expanded and tabulated based on a few maintenance guidelines in the 1992 Stormwater Management Manual for the Puget Sound Basin (Ecology 1992). The 1990 King County Surface Water Design Manual was the first instance of codified maintenance standards for stormwater BMPs. While the current SWMMWW has an extensive bibliography, the BMP Maintenance Tables have relatively few references. Only newer BMPs have specific references and citations, such as low impact development (LID) BMPs.

In addition to the maintenance standards in the Ecology SWMMWW, the standards from four other leading regional stormwater manuals were reviewed and compared in this Study. This included the maintenance standards from King County, the City of Seattle, the City of Tacoma, and the Washington

State Department of Transportation. Among the 24 maintenance components and 48 maintenance elements reviewed, the great majority are the same among the stormwater manuals. However, seven standards showed notable variability, including some standards that aren't present in all manuals, some with significantly more or less detail, and some with differing numeric criteria. These include maintenance standards for:

- Grass cover height
- Pond liner integrity
- Sediment accumulation in ponds and in pipes
- Amount of standing water in wet ponds
- Blockage in pipes, air vents, treatment media, and filters
- The size of cracks or potential structural issues in vaults and tanks
- Sludge (settled material) versus oil accumulation (floating) for oil/water separators

A pilot data analysis was also done on stormwater BMP inspection and maintenance data collected by three municipal stormwater permittees to compare it to the BMP maintenance standards they use. As a pilot level effort, data from one Phase I and two Phase IIs permittees was used (who were also members of the Study technical advisory committee). The data represented inspection and maintenance data for stormwater BMPs from 2019 to 2023, which aligns with the 2019 SWMMWW and the previous reissuance of the 5-year municipal stormwater permits.

The data analysis was done by assessing the frequency of BMP visits for inspection and/or maintenance and by what types of BMP maintenance issues were recorded and their frequency of occurrence. The frequency analysis was limited to data from two of the three pilot cities, which represented multiple years of data. The third city's data represented just one year, and no repeat visits to BMPs were represented in that city's single year of data. Of the two pilot cities with multiple years of data, greater than 90 percent of visits for inspection or maintenance to all BMP types evaluated occurred yearly in alignment with NPDES permit requirements. But other notable frequencies stood out for all BMPs in one pilot city and for ponds in another pilot city with visits at approximately 100 days and between 250 and 300 days after the previous visit to a given BMP. These non-yearly BMP visits highlight opportunities for adjusting BMP visit frequencies based on the type of BMP and the maintenance issues that occur. The NPDES municipal stormwater permits allow adjusting of BMP maintenance frequencies based on data of at least as long as the proposed change and based on permittee experience.

The comparison of BMP maintenance data to the maintenance standards was limited by the relatively few instances of maintenance needs documented and the overall limited detail about inspection outcomes available in the data. However, the presence of maintenance needs associated with maintenance standards was documented and was related to the maintenance standards the pilot cities use. But specific and quantitative observations from BMP inspections were lacking in the data available, thus limiting the comparison of specific BMP inspections or maintenance activities to quantitative maintenance standards.

Results from the pilot data analysis indicate the most common maintenance needs were vegetation management and sediment or trash removal. The next most common maintenance activities were related to noxious weeds, blockage of inlets/outlets, and access issues. Rare or non-existent BMP maintenance issues in the data were structural issues, slope erosion, overflow/spillway concerns, or damage to a pond liner. The BMP maintenance issues recorded indicate that relatively few issues drive most of the routine maintenance activities.

Recommendations based on the study outcomes are provided for municipal stormwater permittees and for Ecology. Recommendations include what BMP maintenance standards could be updated (by Ecology) and approaches for permittees for how maintenance frequencies could be adjusted considering the maintenance needs.

The recommendations for permittees include:

- Collect information about BMP inspection and maintenance that is tied directly to the maintenance standards. This is key information that can help with assessing the efficacy of maintenance efforts in relation to the maintenance standards.
- For recordkeeping with a pass/fail approach, additional information could be recorded without significant effort that would provide a more complete picture of the BMP status.
- Use comments and notes sparingly in BMP inspection and maintenance notes. Instead, capture details in data fields that are searchable, have drop-down menu selections, and can be represented in reportable/exportable data.
- Note if the inspection or maintenance activity occurred as a spot check following a big storm event. Spot checks are sometimes also done for sites with known risk of issues after big storms, such as flooding or erosion.
- While some variation in the frequency of BMP visits is to be expected, the analysis of visit frequencies can be useful for highlighting common BMP maintenance needs and changes over time. That information can support the permittee experience to justify the adjustment of maintenance frequencies.
- BMPs with visit frequencies other than one year highlight opportunities to examine the reasons for longer or short visit frequencies. Those BMPs could be investigated to determine the cause of the visits and the conditions of the BMP after variable amounts of time between inspections. This could be achieved by reviewing the outcomes of those visits, especially in context of the relevant maintenance standards.
- A preventative approach for common issues, such as routinely cleaning out sediment and trash accumulation in BMPs, can be effective, even though it may not be an activity done in response to a maintenance standard being exceeded.

The recommendations for Ecology for updating maintenance standards include:

- Add reference citations to specific standards in the BMP Maintenance Tables. This is especially the case for standards for conventional BMPs, such as detention ponds, detention vaults, and infiltration trenches.
- Check or confirm the references in the bibliography of the current Ecology SWMMWW, as some appear to be decades old from bibliographies in historical stormwater manuals.
- Specific maintenance standards that would benefit from a review and update include:
    - Sediment accumulation in pipes, vaults, ponds, filter media, and other storage and conveyance features.
        - Several sediment criteria exist in the SWMMWW and include varying sediment depth criteria depending on the BMP.
    - Vegetation growth, especially tall grasses and trees.
        - Area of vegetation coverage and growth height are closely linked with habitat, and updated standards for these elements could take into consideration habitat benefits, which may increase the allowable vegetation growth and tree canopy.
    - Water ponding and associated storage area.
        - This affects all BMPs considered in this analysis and can be associated with sediment deposition, liner integrity, and vegetation coverage for varying acceptable fluctuations in stormwater BMP storage capacity.

Introduction

This white paper summarizes the results of a Stormwater Action Monitoring (SAM) Study that evaluated the maintenance conditions of selected stormwater best management practices (BMPs). The SAM Study focused on operations and maintenance (O&M) of stormwater BMPs and was implemented by the City of Bellevue (City), Herrera Environmental Consultants (Herrera), and Aspect Consulting (Aspect). The SAM studies are administered by the Washington State Department of Ecology (Ecology) and funded cooperatively by municipal permittees of the National Pollutant Discharge Elimination System (NPDES) in Washington State.

Study Goals and Objectives

The overall goal of the Study was to evaluate the maintenance standards, also referred to as maintenance criteria or thresholds, for selected stormwater BMPs in the current Stormwater Management Manual for Western Washington (SWMMWW, Ecology 2024). This Study topic was identified as a priority related to stormwater BMPs by the SAM Effectiveness Subgroup and the Stormwater Work Group (SWG), both administered by Ecology.

The SWMMWW referenced for this study is the 2019 update (Ecology 2019a) along with the 2019 version of the BMP Maintenance Tables (Ecology 2019b) since those were in effect for most of the Study period. The SWMMWW was updated during the study, and the BMP Maintenance Tables are effectively the same in the 2019 SWMMWW as in the current version (Ecology 2024).

For this Study, three general types of BMPs were evaluated that are in widespread use and cover most of the BMPs in the Ecology BMP Maintenance Tables (Ecology, 2019b)— ponds, trenches, and vaults. For purposes of this Study, trenches includes swales, and vaults include tanks. The BMP Maintenance Tables are provided by Ecology as guidance, and permittees are allowed to adjust the frequency of BMP maintenance and the conditions that trigger maintenance based on demonstrated BMP performance and permittee experience.

The objectives for the Study are represented by the four technical tasks that compose the evaluation and are summarized in the sections below. The technical tasks are:

Task 2 Survey of Municipal Stormwater O&M Programs

Task 3 Literature Review of Stormwater BMP Maintenance Standards

Task 4 Interviews with Ecology Staff

Task 5 Pilot O&M Data Analysis

Technical Advisory Committee

A technical advisory committee (TAC) helped guide the Study and reviewed the technical deliverables. The TAC was originally composed of members from five jurisdictions that are municipal stormwater permittees, including both Phase I and Phase II permittees.

City of Bellevue, Phase II permittee

City of Des Moines, Phase II permittee

City of Redmond, Phase II permittee

City of Sumner, Phase II permittee

City of Tacoma, Phase I permittee

City of Woodinville, Phase II permittee

The deliverables for the technical tasks of the Study were reviewed by the TAC members along with some deliverables also reviewed by the Ecology SAM coordinator. The TAC membership changed during the Study, including the representatives from Sumner and Tacoma changing jobs and leaving the TAC, and the representative from Des Moines participated just during the first quarter of the Study in 2022. No replacements or other jurisdictions joined the TAC, and the cities of Bellevue, Redmond, and Woodinville remained on the TAC for the entirety of the Study. `

Over the course of the Study, five TAC meetings were convened, and the agendas and minutes from the TAC meetings are posted on the Ecology SAM webpage.[3] The TAC meetings occurred on:

1. June 9, 2022
2. November 15, 2022
3. August 1, 2023
4. November 4, 2024
5. February 7, 2025

Permit Requirements and Maintenance Standards

The requirements for stormwater O&M for municipal stormwater permittees in western Washington are provided in section S5.C.7 of the current NPDES permits (Ecology, 2019c). The minimum performance measures cover stormwater facilities that are regulated, owned, and/or operated by the permittee, and the need for maintenance standards is indicated in the first minimum performance measure of the section:

a. *Each Permittee shall implement maintenance standards that are as protective, or more protective, of facility function than those specified in the Stormwater Management Manual for Western Washington or a Phase I program approved by Ecology. For facilities which do not have maintenance standards, the Permittee shall develop a maintenance standard.*

The permits note that a permittee can develop their own maintenance standards or implement Ecology's or those of a Phase I permittee. Many Phase I permittees in western Washington have developed their

[3] https://ecology.wa.gov/regulations-permits/reporting-requirements/stormwater-monitoring/stormwater-action-monitoring/sam-effectiveness-studies/bmp-maintenance-conditions

own standards, and nearly all Phase II permittees have adopted standards from Ecology or a Phase I permittee.

Ecology provides the maintenance standards in BMP Maintenance Tables in Appendix V-A of the SWMMWW (Ecology, 2024). Standards are provided for runoff treatment, flow control, and low impact development (LID) BMPs. The BMP Maintenance Tables cover 23 types of BMPs and define the minimum maintenance requirements for permittees to follow. The SWMMWW BMP Maintenance Tables are included in Appendix A of this memorandum for reference.

White Paper Organization

Descriptions and summaries of the four technical tasks are provided in sections 2 through 5 below. Each section begins with a summary of the task purpose and then a summary of the outcomes or findings. The details of each task's activities are then described. This 'summary first' approach is to provide key takeaways up front in each section for reading ease in a technical document. The reader can then, if desired, read further in each section about the detailed activities and findings of each task and the associated deliverables.

The document contains just a few tables and no figures. As a white paper, the findings from the Study are described and synthesized, and bulleted list are utilized to highlight key points. Rather than republish some figures here from the technical task reports, those reports and the associated detailed data analysis can be found appended to this report (Aspect 2022b, 2023b, and Herrera 2024b).

Section 6 has conclusions and the key findings and uses of the Study results. Recommendations are also provided based on the Study outcomes about stormwater BMP maintenance for municipal stormwater permittees and Ecology.

Study Deliverables

The deliverables from the Study are listed below in Table 1 for reference. Technical task reports can be found in Appendices B-D of this report.

Table 1. Deliverables of the Study

Task	Deliverable	Name	Completed
1	1A	TAC meeting agendas and minutes	June 2022, November 2022, August 2023, November 2024, February 2025
	1B	Quarterly progress reports	Quarterly from March 2022 to February 2025 (contract end)
2	2A	Final Survey of municipal O&M programs (Aspect 2022a)	June 2022
	2B	Technical Memorandum of Survey results (Aspect 2022b)	September 2022
3	3A	Draft Technical Memorandum of Literature Review (Aspect 2023a)	August 2023

	3B	Final Technical Memorandum of Literature Review (Aspect 2023b)	December 2023
4	4A	Ecology staff interview questions (Aspect 2022c)	December 2022
	4B	Draft report of Ecology staff interviews	(deliverable cancelled)
	4C	Final report of Ecology staff interviews	(deliverable cancelled)
5	5A	Data Request Memorandum to 3 TAC permittees (Aspect 2024)	January 2024
	5B	Draft Technical Memorandum of Pilot Data Analysis (Herrera 2024a)	December 2024
	5C	Final Technical Memorandum of Pilot Data Analysis (Herrera 2024b)	December 2024
6	6A	Draft White Paper	January 2025
	6B	Final White Paper	February 2025
7	7A	Project schedule	May 2022 and updated June 2023
	7B	Presentation to Stormwater Workgroup	planned for May 2025
	7C	Content for a 2-pg fact sheet	February 2025
	7D	Presentation to a local stormwater group	February 2025

Task 2: Survey of Municipal Stormwater Operations and Maintenance Programs

The first technical task of the Study was a survey of municipal stormwater O&M programs. The survey included 17 questions in total with the goal of learning about and evaluating municipal O&M of stormwater BMPs in support of the overall Study goals. Toward that end, the survey questions inquired about program staffing and budget, BMPs in use, maintenance standards and priorities, and data collection and recordkeeping. The technical memorandum of the full survey results (Aspect 2022b) is available in Appendix B.

Summary of Survey Findings

Survey findings were determined by assessing and interpreting the frequency of the response options for each survey question. Many findings from the survey were helpful to this Study with information about what BMPs are in use, what maintenance actions occur in relation to maintenance standards, and what information and data are collected about O&M activities. Key findings include:

- Three of the four BMP types being studied here (ponds, trenches, and tanks) are in wide use, with ponds representing the greatest usage.
- The most common maintenance activities were the same for ponds and trenches: vegetation management and sediment or trash removal.

- For tanks, the most common maintenance issues were related to trash removal and tank testing. Structural and erosion issues-related maintenance ranked low.
- Respondents noted that most maintenance occurs after 25 percent or less of BMP inspections, however some indicated maintenance occurs after nearly all inspections.
- Recordkeeping, especially of costs for O&M programs, is widely practiced but with varying methods.
- A few types of information regarding BMP effectiveness are collected only by a few jurisdictions, including data related to water quality, habitat, and facility or BMP operation.

In addition, some findings illuminated how permittees organize and run their O&M programs and comply with permit requirements. Ecology may consider using these findings to inform updates to the maintenance standards and future permits. These include:

- Maintenance for ponds and vaults occurs similarly in frequency among Phase I and Phase II permittees; maintenance frequency on trenches, however, varies more among permittees for maintenance measures related to complaints, erosion issues, and flooding.
- The maintenance standards used by jurisdictions includes many reference documents. The Ecology SWMMWW is the most widely used, but also site-specific plans and field data and observations are used for guidance on BMP performance standards and maintenance thresholds.
- The number and mix of BMPs in use and the reasons for BMP maintenance can reflect the permittee type, size, and geography. For example, the individual permittee (WSDOT) indicated a high number of trenches, which is logical given the linear geography of roads.

Survey Results

The results from the survey are summarized in the following sections. The 17 survey questions are summarized together in four groups.

- Respondents, Staffing, and Budget for survey questions 1-4
- BMPs In Use and Maintenance Issues for survey questions 5-14
- Maintenance Frequency and Maintenance Standards for survey questions 14-15
- Recordkeeping for survey questions 16-17

Respondents, Staffing, and Budget

In total, survey responses were submitted by 57 municipal NPDES permittees, including 10 Phase I permittees, 45 Phase II permittees, and one individual permittee. Among these, 5 secondary permittees also responded to the survey, and this mix of Phase Is, Phase IIs, and secondary permittees represents a good cross-section (44 percent) of municipal stormwater permittees in western Washington.

Regarding staffing, most jurisdictions indicated a range of 1.25-5 full-time equivalent (FTE) staff and no consultants or vendors. The second highest staffing level was 10.25-20 FTEs, of which two permittees also used consultants or vendors. The smallest number of staff (0.1-1 FTE) was represented by just Phase II

permittees. Notably, one Phase II permittee indicated no internal FTEs but rather just one consultant or vendor for O&M.

Regarding budgets for all stormwater-related O&M activities, answer options were ranges of round values from less than $0.1 million to more than $5 million annually. Most permittees indicated annual O&M budgets in the $1-$2.5 million range followed by the same number of permittees who indicated budgets in the $0.25-$0.5 million range and the $2.5-$5 million range. Notably, several respondents indicated annual budgets of more than $5 million, including some Phase I, Phase II, and individual permittees.

BMPs In Use and Maintenance Issues

Survey questions indicate that respondents use all types of BMPs asked about, including four types of ponds, two types of tanks, four types of trenches, and four types of tanks. Table 2 summarizes the BMPs with the most, moderate, and least use that corresponds, respectively, to greater than 40 permittees, 20-40 permittees, and less than 20 permittees.

Table 2. BMPs in Use from Survey Results

BMP Category	Most Use (>40 permittees)	Moderate Use (20-40 permittees)	Least Use (less than 20 permittees)
Pond	Detention/wetpond Infiltration/bioretention pond	Other type of pond	
Tank	Below ground tank		Above ground tank Other type of tank
Trench	Biofiltration swale	Filter strip Infiltration trench	Sand vault Other type of trench
Vault	Wetvault Oil-water separator (OWS) Other media		Sand vault Other type of vault

The survey also inquired about what issues drive BMP maintenance. Fourteen answer options were provided of common BMP maintenance issues that may variable occur in ponds, trenches, or tanks, and respondents ranked the answer options from most to least common (Table 3). For ponds, the most common maintenance activity was vegetation management, which consistently ranked high (all answers from 1st to 4th rank). Second most common was sediment or trash removal, which also consistently ranked high (most answers from 1st to 4th rank). Maintenance activities with moderate rankings (most answers between 3rd and 7th ranks) included: cleaning, dredging, or replacing media; flooding; and repair or adjustment of the facility. Pond maintenance activities that ranked the lowest were issues due to animals (such as beaver dams), which always ranked moderate to low (most answers 5th to 10th rank), and similarly low rankings for issues related to spill response or vandalism.

Table 3. BMP Maintenance Issues from Survey Results			
Top Ranking of Occurrence: 1st most often, 10th least often			
Maintenance Topic	**Ponds**	**Trenches**	**Tanks**
Animal	10th	n/a	n/a
Cleaning (including replacement of media)	5th	6th	1st
Complaint	5th	13th	6th
Erosion	n/a	10th	n/a
Flooding	6th	4th	n/a
Habitat	7th	10th	n/a
Repair	3rd	3rd	4th/5th
Sediment or Trash	2nd	2nd	1st
Seepage	n/a	n/a	9th
Spill	9th	9th	8th
Testing	n/a	n/a	2nd
Vandalism	8th/9th	8th	7th
Vegetation	1st	1st	n/a
Ventilation	n/a	n/a	3rd

Regarding trench maintenance, the most common trench maintenance activity was vegetation management, which consistently ranked high (all answers 1st to 4th rank). Second most common was sediment or trash removal, which also consistently ranked high (most answers from 1st to 5th rank). Trench maintenance activities with moderate rankings (most answers between 3rd and 7th rank) included: cleaning, dredging, or replacing media; and flooding. Trench maintenance activities that ranked the lowest were issues due to complaints, vandalism, and spill response (most answers 5th to 10th rank).

For tank maintenance, the most common issue was sediment or trash management and cleaning of media, which consistently ranked very high (most answers 1st or 2nd rank). Second most common was maintenance for tank testing and ventilation with most responses from 2nd to 5th rank. Most tank maintenance activities were ranked moderately with most answers between 3rd and 8th ranks, including repair and complaint response. Tank maintenance activities that ranked the lowest were issues due to seepage, spills, or vandalism (most answers 7th to 10th rank). In addition, several maintenance topics were not applicable to tanks, including habitat, erosion, and vegetation.

Maintenance Frequency and Maintenance Standards

The frequency of BMP maintenance following inspection was asked about in the survey in ranges of approximate percent of time. Respondents could choose among ranges of the percent of time maintenance occurs following inspection: 1-10 percent, 11-25 percent, 26-50 percent, 51-75 percent, and 76-100 percent. The most common response was 11-25 percent of the time, followed by an equal number of responses (14 each) for less than 10 percent of the time and 26-50 percent of the time. The least common response was for maintenance occurring 76-100 percent of the time after BMP inspection.

Regarding what maintenance standards are used, the most common response was the Ecology SWMMWW with 41 responses (72 percent of respondents). The question was multiple choice, however,

and many respondents had multiple answers. and a high representation is also indicated for the use of four other stormwater manuals, guidance, or data.

1. Other non-Ecology (but Ecology-approved) stormwater manuals
2. Stormwater pollution prevention plans (SWPPPs) or other site-specific plans
3. Standard operating procedures
4. Field data

Other manuals and guidance mentioned in the survey responses include:

1. General O&M plans
2. Documentation of "practices, policies, and procedures" (per permit sections S5.C7.d for Phase IIs or S5.C10.e for Phase Is)
3. Maintenance procedures associated with Ecology's technology assessment protocol (TAPE) certification
4. WSDOT Highway Runoff Manual

Recordkeeping

Responses about qualitative recordkeeping methods and issues indicated that vegetation management was the most often documented (53 responses). Five other types of recorded or activities were also highly represented and had 46 to 49 responses each.

1. Observations associated with maintenance standards
2. Maintenance dates
3. Spot checks
4. Trash or debris presence
5. Photos or videos

Respondents were also asked about quantitative recordkeeping, which was intended to help inform what data may be available for the pilot data analysis in task 6. The most common quantitative information recorded was labor hours (45 responses) along with data about sediment or solids accumulation (42 responses) and equipment cost (37 responses). Second most collected was data regarding oil or floatables accumulation (30 responses), vendor costs (29 responses), and vegetation maintenance (21 responses). Third most collected quantitative data was the amount of material removed (17 responses) and water level or flow (12 responses). A few data types had low representation with five or fewer response each, including water quality data, habitat data, facility operation data, and other unspecified data.

Task 3: Literature Review of Stormwater BMP Maintenance Standards

Task 3 began as an effort to analyze published BMP maintenance data for the purpose of evaluating maintenance conditions in relation to maintenance standards. A significant effort was made to search for appropriate BMP maintenance data as described below, but ultimately efforts were not successful in finding relevant data for a meaningful data analysis.

Web searches turned up publications of maintenance standards, how to do BMP maintenance, and BMP performance evaluation. But none of the publications or online databases[4] that were reviewed had data of the maintenance activities. Without data that could be compared to the relevant maintenance standards, another approach was needed to evaluate the Ecology standards. The search was helpful with Task 5, however, in which a pilot data analysis was performed with local municipal stormwater permittee BMP inspection and maintenance data (see section 5 below).

The focus of Task 3 then turned to reviewing the maintenance standards that are in use in western Washington and comparing to Ecology's BMP Maintenance Tables. This was helpful to the Study by deepening the understanding of the sources, history, and variability of maintenance standards used by permittees in western Washington. A technical memorandum was prepared of the literature review (Aspect 2023) and is available in Appendix C with the other Study deliverables.

The sections below provide further details on the background and effort that was undertaken for this task. A brief history of the stormwater manuals is provided, and the key elements of similarity and difference in maintenance standards in western Washington are summarized.

Summary of Literature Review

The key outcomes from the literature review are summarized below.

- The review focused on three groups of BMPs: ponds (three types), trenches (two types), and vaults (three types).
- The maintenance standards in four regional stormwater manuals were compared to Ecology's.
- Among eight BMP types reviewed, 48 maintenance elements among 24 maintenance components were compared that compose the maintenance standards.
- Most maintenance standards are the same among the stormwater manuals reviewed.
- Seven types of maintenance standards showed variation among the manuals. This included some standards that aren't present in all manuals, some with more detail, and some with differing numeric criteria. Maintenance standards that varied include:

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[4] Searches included the International Stormwater BMP Database,, the National Pollutant Removal Performance Database (version 3, March 2016), and the National Stormwater Quality Database.

- Grass cover height (nonaquatic plants)
- Pond liner integrity
- Sediment accumulation in ponds and in pipes
- Amount of standing water in wet ponds
- Blockage in pipes, air vents, treatment media, and filters
- The size of cracks or potential structural issues in vaults and tanks
- Sludge (settled material) versus oil accumulation (floating) for oil/water separators

Other notable observations from the literature review included:

- The repetition of maintenance components varied among the literature reviewed, especially for common BMPs, which often share some of the same maintenance elements and components (e.g., trash/debris, rodents, presence of pollution, etc.).
- Like Ecology's maintenance standards, the other maintenance standards reviewed do not typically provide citations or references identifying where the standards are derived. The exception is for low impact development (LID) BMPs, which were added to stormwater manuals more recently and include a few key citations (e.g., LID Technical Guidance Manual for Puget Sound, [WSU and PSP, 2012]).

Literature Reviewed

The literature reviewed was a mix of sources chosen for their relevance to the origins of the Ecology maintenance standards (2019b) and the relative variability of the standards used by stormwater permittees in western Washington. Relatively newer BMPs—especially low impact development (LID) BMPs using infiltration, bioretention, and permeable pavement—generally have well-documented standards. But some common older and conventional BMPs—such as ponds, trenches, and vaults—have little or no documentation on the origin of the maintenance standards.

The literature reviewed included select city, county, and transportation agency stormwater manuals in western Washington.

- *King County Surface Water Design Manual* (King County, 2021)
  - Specifically, the maintenance standards in *Appendix A: Maintenance Requirements for Flow Control, Conveyance, and Water Quality Facilities*.
- *City of Seattle Stormwater Manual* July 2021 (City of Seattle, 2021)
  - Specifically, the maintenance standards in *Appendix G: Stormwater Control Operations and Maintenance Requirements*.
  - Also: *Green Stormwater Operations and Maintenance Manual*, August 2009 (Seattle Public Utilities, 2009).
- *City of Tacoma Stormwater Management Manual* (City of Tacoma, 2021)
  - Specifically, the maintenance standards in *Appendix C Operation and Maintenance*

- *Highway Runoff Manual (HRM), Washington State Department of Transportation* (WSDOT, 2019).
    - Specifically, the maintenance standards in *Management Practices Field Guide for ESA 4(d) Habitat Protection*, June 2018.

Additional literature and guidance documents were reviewed from a few other cities and regions in the country, including publications from the Center for Watershed Protection's Online Watershed Library (OWL) and the American Society of Civil Engineers. These sources turned up a few key documents that provided some helpful background and wider perspective on BMP maintenance standards.

- *Inspection and Maintenance of Stormwater Control Measures*, (ASCE, 2019).
- *Bioretention Illustrated: A Visual Guide for Constructing, Inspecting, Maintaining, and Verifying Bioretention Practices, version 2.0* (Chesapeake Stormwater Network, 2013).
- *Green City, Clean Waters: Green Infrastructure Maintenance Manual*, (Philadelphia Water Department, 2014).

A Brief History of Stormwater Manuals in the Puget Sound Region

The earliest stormwater manuals reviewed for the Puget Sound region were the King County Surface Water Design Manual (King County, 1990) and the Stormwater Management Manual for the Puget Sound Basin (Ecology, 1992). While earlier[5] stormwater manuals for the region exist, they were not reviewed as they are from prior to 1980 and under very different legal requirements than what spawned the BMP maintenance requirements that came about in the early 1990s.

The 1990 manual from King County sets the foundation for the current maintenance standards. It includes maintenance and operation as a core requirement for stormwater design. In addition, private facility maintenance requirements appear in Appendix A of the document for 12 types of BMPs, including ponds, energy dissipators, and closed detention systems (pipes/tanks). The layout and contents of the tables in the Ecology manuals from 1992 and 2001 are largely the same as the 1990 King County manual.

The maintenance requirements in the 1990 King County manual are a mix of engineering design details, hydraulic modeling, primary/academic research articles, textbook references, federal guidance publications from the EPA and USACE, and BMP performance observations from local studies. This is deduced based on the list of references provided for Volume V on Runoff Treatment BMPs in the 2001 Ecology SWMMWW, which appears to be the first instance of the comprehensive set of tables of maintenance standards similar to the current SWMMWW. However, the references for the maintenance standards from the 2001 SWMMWW appear to not be carried forward into subsequent versions of the SWMMWW.

The Ecology manual from 1992 has maintenance standards dispersed in the BMP sections of the document, and two tables of "maintenance requirements" are provided: for detention ponds and detention vaults/tanks. The tables in the 1992 Ecology manual have a similar format and content as the current BMP Maintenance Tables, and the tables include several components with standards for the

[5] See King County's Archived Surface Water Design Manuals

general site and for slopes, dikes, pond storage area, overflow spillway, and access. A few references are provided in the document, but as with subsequent versions of the Ecology manuals, no citations are provided for specific standards.

The maintenance standards are significantly expanded and tabulated in the 2001 Ecology manual. The 2001 manual does provide a list of references for Volume V where the BMP maintenance standards are provided. The list of references is extensive and sheds light on the likely origins of the BMP maintenance standards. However, no citations are noted in the BMP Maintenance Tables themselves making it difficult the trace the source and specific references to individual standards. The references include:

- Articles in academic journals, and local studies by University of Washington and Washington State University professors and students.
- Standard textbooks, such as *Open-Channel Hydraulics* (V.T. Chow, 1959).
- Government agency guidance, from local Puget Sound jurisdictions to the US Army Corps of Engineers (USACE) to the Environmental Protection Agency (EPA).
- Guidance and publications from non-governmental organizations, such as the Water Environment Federation, American Petroleum Institute, American Public Works Association, and the Center for Watershed Protection.
- Instructions and guidance for maintenance of proprietary BMPs.
- Performance observations of BMPs.

The current version of the maintenance standards in the Ecology SWMMWW has largely been adopted or customized by individual jurisdictions in western Washington. The maintenance tables in the other leading stormwater manuals in the region are formatted the same or similarly as in the Ecology manual. This highlights the common source of the standards and sets the stage for comparing what standards have changed over time or have been changed in individual jurisdictions' stormwater manuals.

Comparison of BMP Maintenance Standards Among Stormwater Manuals

The maintenance standards were compared among the four stormwater manuals reviewed for 24 maintenance elements among 24 maintenance components that compose the BMP maintenance standards. The BMPs were compared in three groups of BMP types: ponds, trenches, and vaults/tanks. The key takeaways of the findings are provided below about differences from the Ecology maintenance standards, and the full results are provided in the technical memorandum that was prepared for Task 3 (Aspect 2023a and 2023b).

Ponds

Detention Ponds

- Detention Ponds are the basis for the maintenance standards for many other BMPs. This may be the case simply because detention ponds are listed first in the publications, but it is also likely due to the pond being one of the earliest and most widely used stormwater BMPs.
- The maintenance standards for detention ponds were the same among the publications reviewed and follow Ecology standards for most maintenance elements.
- A grass height standard is present in King County's, Seattle's, and Tacoma's manuals.
- The pond storage standard is different for King County and Seattle, and those manuals also have additional maintenance elements for sediment accumulation in pipes and pipe structural damage.

Infiltration Ponds

- All publications reviewed had differences in infiltration pond maintenance standards compared to Ecology's standards; none were completely the same as Ecology's.
- Some of the same key differences in infiltration ponds standards are the same for detention ponds, including grass height and the inclusion of pipe-based standards.
- King County and Seattle have additional maintenance elements for infiltration structures, pipes, access, and drain rock.
- The pond storage standard is different from Ecology's in all manuals, and the erosion standard is different in the WSDOT manual from other manuals.

Wetponds

- All publications reviewed had the same core general maintenance elements for Wetponds.
- Tacoma's and WSDOT's standards follow Ecology's almost identically.
- King County and Seattle have additional maintenance elements for Slopes and Berms/Dikes, Pond Area, Gravity Drain, and Pipes.
- King County also has a difference from other manuals in the standard for a change in water level for wetponds.

Trenches

Infiltration trenches

- The Ecology maintenance standards for infiltration trenches are minimal and cover just storage and structural elements.
- Additional maintenance elements in the non-Ecology manuals are present for pipe elements, structural elements, presettling areas, media liners, and emergency overflow.
- Many general maintenance standards for infiltration trenches (mowing, pests, trash, etc., which Ecology doesn't include), are the same as for other facilities, especially detention ponds, infiltration ponds, and wetponds.

- Seattle has unique standards for infiltration trenches for three maintenance elements (sediment depth in presettling chambers, sediment depth in media filter chambers, and water ponding).
- Tacoma includes two maintenance elements (presettling and ponding), and WSDOT includes three maintenance elements (presettling, ponding, and flow).

Dispersion Trenches

- Dispersion Trenches contain just a few maintenance elements, which are almost entirely the same among the manuals reviewed compared to Ecology's.
- King County and Tacoma have additional maintenance elements for preventative (trash) and pipes.
- King County and Tacoma include a standard for blockage in inlet pipes.
- King County and Seattle include a different standard (25%) than Ecology (50%) and others for perforated pipe blockage.

Vaults

Detention Vaults

- The maintenance standards were effectively the same for detention vaults and tanks among the manuals compared.
- King County, Seattle, and Tacoma have standards for site-related elements (trash, pests, grass, etc.) and pipe elements that Ecology and WSDOT do not include.

Wet Vaults

- The maintenance standards were mostly the same for wet vaults among the manuals compared with a couple of differences from Ecology in King County's, Seattle's, and Tacoma's standards.
- King County, Seattle, and Tacoma have standards for pipe elements and gravity drain valves, which Ecology does not include.
- The standard for the size of cracks in structures is different in the King County, Seattle, and Tacoma manuals (0.25 inches) compared to Ecology's (0.5 inches).
- WSDOT does not include wet vaults in their standards for vaults.

Oil/Water Separator Vaults

- The maintenance standards were mostly the same for Oil/Water Separator Vaults among the manuals compared.
- King County and Seattle have standards for pipe elements and gravity drain valves that Ecology and Tacoma do not include.
- King County, Seattle, and Tacoma include standards for water clarity.
- Tacoma includes standards for both floating oil and deposited sludge.
- WSDOT does not include oil/water separators in their standards.

Task 4: Department of Ecology Interviews

Task 4 was for obtaining more information from Ecology staff about the origins of the BMP maintenance standards. Interviews with Ecology staff were in the Study scope of work, and interview questions (Aspect 2022c) were prepared on topics related to the origins of the maintenance standards and inquiring about references for specific standards of the BMPs studied here (pond, trenches, and tanks/vaults).

Ecology permit managers, permit writers, engineers, and SAM staff reviewed the questions, and one stormwater engineer at Ecology provided answers to the extent possible. However, the answers were mostly that current Ecology staff is not aware of the specific origins of the BMP maintenance standards. The engineer's comments were helpful on the scope of the study and how some BMPs could be categorized. But the answers to the interview questions indicated just that current maintenance standards are derived from the 2001 version of the Ecology SWMMWW and no specific answers were able to be provided due to the reasons noted above.

With these succinct and limited answers, no interviews with Ecology staff were needed, and the Study team discussed the next steps with the SAM coordinator to brainstorm other sources of information about the origins of the maintenance standards. Long-time staff at King County were also consulted, and this pointed to the need to trace the standards back through previous stormwater manuals. Thus, the deliverable of a technical memorandum on the Ecology interviews (Task 4) was cancelled, and instead, the literature review in Task 3 was expanded to shed light on the history of the BMP maintenance standards.

Task 5: Pilot Data Analysis

Task 5 was for a pilot data analysis to evaluate stormwater BMP inspection and maintenance data collected by permittees and compare it to the maintenance standards. As a pilot level effort, data from three western Washington municipal stormwater NPDES permittees (who were also TAC members) was obtained and analyzed. The data represented inspection and maintenance data for stormwater BMPs from 2019 to 2023, which aligns with the previous reissuance of the 5-year municipal stormwater permits.

A summary of the outcomes from the pilot data analysis is provided below followed by detail about the data sources, the data request, and the data review and standardization process. The full technical memorandum of the pilot data analysis (Herrera 2024a and 2024b) contains additional details and recommendations.

Summary of Pilot Data Analysis Outcomes

As a pilot level effort, data from three cities was analyzed, including two Phase II permittees and one Phase I permittee. The data was requested in a memorandum (Aspect 2024) that sought information on the outcomes of BMP inspection and maintenance. Approximately 4,400 records were provided, though each city's data had limitations with varying levels of completeness (as described below).

The data analysis was done by assessing the frequency of BMP visits for inspection and/or maintenance, and by what types of BMP maintenance issues were recorded and their frequency of occurrence. Most

visit for inspection or maintenance to all types of stormwater BMPs evaluated occurred yearly in alignment with permit requirements. But other notable frequencies stood out within 100 days and between 250 and 300 days. These non-yearly BMP visits highlight opportunities for adjusting BMP visit frequencies based on the type of BMP and the maintenance issues that occur.

The comparison of BMP maintenance records to the maintenance standards was limited by the relatively few instances of maintenance needs documented and the overall limited detail about inspection outcomes available in the data. However, the presence of maintenance needs associated with maintenance standards was documented and ties to the maintenance standards generally speaking. But specific and quantitative observations from BMP inspections were lacking in the data available, thus limiting the comparison to specific maintenance standards.

Frequencies of BMP Inspection and Maintenance

The analysis of inspection and maintenance frequencies indicated that most visits (greater than 90%) to most kinds of BMPs occur on a yearly cycle consistent with permit requirements. However, small but notable upticks in BMP visit frequencies were seen for all BMP types within 100 days of a previous visit, at the 250-300 day mark for trenches, and at approximately the two-year mark for ponds. The longer visit frequencies are presumed to be associated with capital construction projects per permit guidance (see section 1.3).

The shorter frequencies are presumed to be associated with urgent needs for maintenance, such as spot-checks after big storm events. For swale/trench BMPs in one Phase II city, the visit frequency curve is skewed right with the peak between 250 and 300 days. The reasons for the differences in visit intervals were not directly explored in this data analysis, but feedback from that city indicated the relatively more frequent visits for swales may be related to how visible they are being above ground.

BMP Maintenance Issues

The analysis of maintenance needs indicated that relatively few maintenance issues were recorded in the data records. The issues evaluated were those that aligned with 18 maintenance standard categories for issues related to, which capture the maintenance components and elements of the standards for the BMPs being evaluated. These include maintenance needs related to:

- Access
- Animals
- Berms
- Bollards
- Energy Dissipators
- Fence/Gate
- Filterbag Full
- Inlet/Outlet

- Liner or Structure
- Noxious Weeds
- Overflow Spillway
- Pollution
- Slope/Erosion
- Storage Capacity Reduction
- Trash Racks
- Trash/Debris/Sediment
- Trees
- Vegetation Blockage

When issues were recorded, it was mostly in notes and comments from the maintenance personnel, which required a time-consuming process to read through and extract relevant information for the pilot data analysis. The limited detail about BMP maintenance issues observed is partly due to the pilot cities' varying approaches to recordkeeping for BMP O&M, with one Phase II city focusing on items related to the maintenance standards, and the Phase I city and the other Phase II city focusing on pass/fail status to indicate if maintenance is needed or not. The most common maintenance need recorded was related to clearing trash, debris, and sediment, which is done as a routine preventative measure by Bellevue. Other maintenance needs highlighted by the data analysis include issues at the BMP inlet or outlet, noxious weeds, and reduction in stormwater storage capacity.

Data Sources and Data Request

The data needed for the pilot data analysis was identified in discussion with the participating cities about what data they collect and are available from their recordkeeping system. The search for published BMP maintenance data in Task 3 also informed the identification of the data desired for the pilot data analysis in Task 5. This culminated in a data request (Aspect 2024) to the pilot participants that included a spreadsheet template of the data fields desired.

The data available from the pilot cities, however, was limited in detail and covered varying time periods from one to four years. One Phase II city and the Phase I city provided four years of data each, but the other Phase II city provided just one year of data (the most recent, 2023), which reflects the limited digital records of BMP maintenance from that city.

Significant variability was also present in the pilot data about the detail of what maintenance needs were observed during BMP inspections. This was a result of several factors, especially the varying emphasis among the pilot cities for recording specific information about BMP status and maintenance versus pass/fail status. Despite these limitations, a pilot-level data analysis was possible that helps inform permittees and Ecology regarding stormwater BMP maintenance, maintenance standards, and recordkeeping.

Data Review and Standardization

In total, 4,397 relevant records were provided and analyzed. Most of the records were from one Phase II sity, which included catch basins in their data. Table 4 summarizes the number of records, the types of BMPs, and the years of data represented in the pilot data.

Table 4. BMP Inspection and Maintenance Records Provided for Pilot Data Analysis.

	Ponds	Trenches/Swales	Vaults/Tanks	TOTAL	Period
Phase II city	469	237	2,761	**3,467**	2019-2023
Phase II city	95	151	308	**554**	2023
Phase I city	105	107	164	**376**	2019-2023
TOTAL	**669**	**495**	**3,233**	**4,397**	

Before analyzing the data, the records were reviewed and standardized to be comparable among jurisdictions. The review and standardization included several steps to create a database. Steps included:

- Establishing common formats for text, dates, and numbers
- Assigning each record a BMP type using consistent descriptions based on variable BMP names, facility types, and categories
- Adding data fields for each maintenance element per the maintenance standards
- Interpreting notes, especially comments and abbreviations, to determine BMP issues or maintenance activities
- Mapping terminology of maintenance outcomes to terminology used in the maintenance standards, which included the Ecology SWMMWW used by both Phase II pilot cities and the jurisdiction-specific stormwater manual used by the Phase I pilot city.
- The data review and standardization process required a significant effort since all three pilot participants use different methods and software for tracking BMP inspection and maintenance.

Conclusions and Recommendations

The overall conclusions from this SAM Study are summarized below with the key outcomes of the Study's technical tasks. In addition, recommendations are provided for updating some BMP maintenance standards, for adjusting maintenance activities of some BMPs, and topics of potential further inquiry and research.

Conclusions

History of BMP Maintenance Standards in Western Washington

- The BMP maintenance standards in use today in western Washington are derived from the 2001 Ecology stormwater manual (SWMMWW, Ecology 2024). The standards in the 2001 manual were significantly expanded and tabulated based on the 1992 *Stormwater Management Manual for the Puget Sound Basin* (Ecology 1992).
- The 1990 King County *Surface Water Design Manual* was the first instance of codified maintenance standards for stormwater BMPs in western Washington.
- Current Ecology staff are not familiar with the specific basis for many of the BMP maintenance standards.
- Only newer BMPs (i.e., LIDs) have specific references and citations in the Ecology BMP Maintenance Tables in which the maintenance standards are tabulated.
- The maintenance standards used by local jurisdictions includes many reference documents in addition to the Ecology SWMMWW.
- The 2001 Ecology SWMMWW had a bibliography associated with the BMP Maintenance Tables, but that has not been carried forward into the current version.

Differences in Maintenance Standards in the Puget Sound Region

- Among the maintenance standards reviewed in four major stormwater manuals, seven standards showed notable variability. This included some standards that aren't present in all manuals, some with more detail, and some with differing numeric criteria, including:
    - Grass cover height
    - Pond liner integrity
    - Sediment accumulation in ponds and in pipes
    - Amount of standing water in wet ponds
    - Blockage in pipes, air vents, treatment media, and filters
    - The size of cracks or potential structural issues in vaults and tanks
    - Sludge (settled material) versus oil accumulation (floating) for oil/water separators

Stormwater BMPs in Use and Maintenance Issues

- The stormwater BMPs in use by municipal stormwater permittees in western Washington and the associated maintenance issues was evaluated in a survey at the beginning of the Study and in a Pilot Data Analysis at the end of the Study.
- The three types of BMPs evaluated here— ponds, trenches/swale, and vaults—are in wide use by municipal stormwater permittees, with ponds representing the greatest usage.

- Among the 18 categories of maintenance activities analyzed, the most common maintenance needs were vegetation management and sediment or trash removal. This confirmed the survey results in Task 2.
- The next most common maintenance activities were related to noxious weeds, blockage of inlets/outlets, and access issues.
- Rare or non-existent BMP maintenance issues in the data analyzed include the BMP structure, slope erosion, overflow/spillway concerns, and damage to a pond liner.
- The reasons for specific BMP visits were not analyzed due to data limitations. However, the BMP maintenance issues recorded were analyzed and indicate that relatively few issues (noted above) drive most of the routine maintenance activities.
- How BMP visit outcomes are tracked varied among the pilot cities. Two cities use a pass/fail approach to indicate overall if maintenance is needed or not, and one city tracks outcomes directly tied to the maintenance standards. This variability in the data limited the comparison of BMP visit outcomes among the pilot cities.
- Only two pilot cities' data (one Phase I permittee and one Phase II permittee) was useable for the frequency analysis of BMP visits for inspection or maintenance. The third city's data (Phase II permittee) represented just one year of data, which was useful for the maintenance needs assessment, but not useful for frequency analysis over time.
- Most BMPs are visited for inspection and/or maintenance about once per year consistent with permit requirements. However, pond and trench/swale BMPs also showed a small number of additional visits occur after 100 days, which may be related to spot-checks after big storms, and after approximately 250 to 300 days.

Recordkeeping of stormwater BMP O&M

- Recordkeeping of O&M activities is widely practiced but with varying methods and software used ranging from paper field notes to all digital records.
- Each pilot city's pilot data records and data formats were unique and created the need for custom procedures to evaluate each city's data.
- The use of notes and comments in O&M records is common, and understanding the maintenance needs of a BMP requires reading the notes, which can be a time-consuming task.
- Information in one Phase II city's records was directly tied to the maintenance standards. But information in the records of the other Phase II city and of the Phase I city was not directly comparable to the maintenance standards since they included just a pass/fail status overall about whether or not maintenance is needed.

Recommendations

Recommendations are provided below based on the outcomes of the Study. The recommendations are for municipal stormwater permittees on how maintenance frequencies could be adjusted and recordkeeping, and for Ecology on what stormwater BMP maintenance standards could be updated.

Adjusting Maintenance Practices and BMP Visit Frequencies

- Analysis of BMP O&M data can be useful for adjusting BMP maintenance frequencies. To support such an analysis, information would need to be collected about the reasons for a BMP visit related to the relevant maintenance standards. This can provide a basis for demonstrating BMP status in relation to the frequency of inspection or maintenance and making a case for alternate time intervals between BMP visits.
- Variation in the frequency of BMP visits is to be expected since they occur both routinely and in response to special events, such as large storms or capital construction. The variation in BMP visit frequency can be useful for highlighting common BMP maintenance needs and the status of BMPs after inspection or maintenance. As with documenting BMP conditions relative to maintenance standards, the analysis of non-routine BMP visits can also support the permittee experience for adjusting maintenance frequencies.
- BMPs with visit frequencies other than one year (as required by the NPDES permits for the BMPs evaluated here) highlight opportunities to examine the reasons for longer or short visit frequencies. Those BMPs could be investigated to determine the cause of the visits and the conditions of the BMP after variable amounts of time between inspections. This could be achieved by analyzing the outcomes (i.e. maintenance needs observed) of visits that occurred outside of the one-year interval, especially in context of the relevant maintenance standards for those BMPs.
- Routine assessment (e.g., every two to five years) of the frequency of visits can help to adaptively inform BMP inspection and maintenance efforts.
- A preventative approach for common issues, such as routinely cleaning out sediment and trash accumulation in BMPs, can be effective, even though it is not an activity done in response to a maintenance standard being exceeded.

Updating Maintenance Standards

- Adding references and citations to specific standards in the BMP Maintenance Tables would help permittees better understand the basis for the standards. This is especially the case for standards for conventional BMPs, such as detention ponds, wetvaults, and infiltration trenches.
- The bibliography in the current Ecology SWMMWW includes some references that appear to be decades old from bibliographies in historical stormwater manuals. The old references for any BMP maintenance standards could be checked and confirmed if they are still relevant.
- Field testing can be used to provide an updated and referenced basis for the BMP maintenance standards. Relying on literature alone, especially for BMPs that have been in use for long periods, is not sufficient with climate change upon us and changing precipitation patterns.
- Specific maintenance standards that would benefit from a review and update include:
    - Sediment accumulation in pipes, vaults, ponds, and other storage and conveyance features.
        - Several sediment criteria exist in the SWMMWW and include varying sediment depth criteria depending on the BMP.

- Vegetation growth, especially tall grasses and trees.
    - Area of vegetation coverage and growth height are closely linked with habitat, and updated standards for these elements could take into consideration habitat benefits, which may increase the allowable vegetation growth and tree canopy.
- Water ponding and associated storage area.
    - This affects all BMPs considered in this analysis and can be associated with sediment deposition and vegetation coverage for varying acceptable fluctuations in stormwater storage capacity.

Permittee Recordkeeping

- Collect information about BMP inspection and maintenance that is tied directly to the maintenance standards. This is key information that can help with assessing the efficacy of the standards.
- For recordkeeping with a pass/fail approach, additional information could be recorded without significant effort that would provide a more complete picture of the BMP status.
    - An example is for a fail observation of vegetation overgrowth requiring mowing. The inspection notes could also include observation of specific related maintenance standards, such as if stormwater storage capacity is diminished, if inlets/outlets are blocked or partially blocked, or if the vegetation affects habitat.
- Use comments and notes sparingly. Instead, capture details in data fields that are searchable and can be represented in reportable/exportable data.
    - For example, issues that occur frequently can be represented by a checkbox or pull-down list of preset options rather than noted or abbreviated in comments.
- Note if the inspection or maintenance activity occurred as a spot check following a big storm event. Spot checks are sometimes also done for sites with known risk of issues after big storms, such as flooding or erosion. Collecting and sharing this information among departments can help with tracking the effort associated with the permit requirement for performing spot checks following 10-year (or greater) storms.
- Use common terminology for BMPs, especially for trenches, swales, and cells used for infiltration or bioinfiltration, the terms for which are sometimes used interchangeably.

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Appendix A
Ecology BMP Maintenance Tables 2019 SWMMWW Appendix V-A

Please see the appendix linked below.

https://apps.ecology.wa.gov/publications/parts/2510034part1.pdf

Appendix B
Technical Memorandum: Survey of Municipal Stormwater Operations and Maintenance Programs

Please see the appendix linked below.

https://apps.ecology.wa.gov/publications/parts/2510034part2.pdf

Appendix C
Technical Memorandum: Literature Review of Stormwater BMP Maintenance Standards

Please see the appendix linked below.

https://apps.ecology.wa.gov/publications/parts/2510034part3.pdf

Appendix D
Technical Memorandum: Pilot Data Analysis of Stormwater BMP Inspection and Maintenance Data

Please see the appendix linked below.

https://apps.ecology.wa.gov/publications/parts/2510034part4.pdf