FINAL

WHITE PAPER for Stormwater Management Program Effectiveness Literature Review

Source Control

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Prepared for:
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EXECUTIVE SUMMARY

Source control best management practices (BMPs) can effectively contribute to the reduction in the generation of stormwater pollutants. This white paper summarizes literature on source control and other BMPs used at construction sites, at private stormwater facilities, with illicit discharge detection and elimination (IDDE) programs, and in the context of inspections at businesses. The intended audience for this white paper is local government stormwater management program staff in Washington State, especially in the western Washington. Literature reviewed was from a preselected database of publication titles, and a series of ranked questions provided the organizing principle for this white paper. Key findings are as follows:

Construction Source Control and BMPs

- Effective use of construction site TESC BMPs depends on the BMP type and operation and maintenance as well as the site and soil conditions. Based on the literature reviewed, compost blankets and filter socks, permeable check dams, and polyacrylamide (PAM) treatment of other BMPs have the best performance characteristics for controlling sediments and treating erosion at the source.
- A combination of source control BMPs, runoff BMPs, and chemical treatment BMPs are usually required to reduce construction site runoff down to permit benchmark levels (25 NTU) to meet water quality standard levels for turbidity.
- As a widely used TESC BMP, literature indicates that sediment ponds have relatively low performance for containing sediments. This could be improved by a review of sediment pond sizing and design standards.

Source Control at Private Stormwater Facilities

- Site visits and inspections of private stormwater facilities can have positive effects on the management of stormwater. As a non-structural BMP, site visits to private facilities can be enhanced by building good relationships between agency personnel and facility operators.
- The optimum frequency of site visits to private stormwater facilities depends on the type of facility. Few publications addresses site visit frequency; however, a bacterial pollution study in Kitsap county found improved results when switching from site visits every other year to yearly.

Illicit Discharge Detection and Elimination

- Foreknowledge of the nature of the potential illicit discharges is a key step in deciding which IDDE methods to use.
- Several methods for detecting illicit connections and discharges work well. Information from local western Washington NPDES permittees indicates that an IDDE hotline, inspections of manholes/catch basins, and inspections of outfalls have had the greatest effectiveness for their IDDE efforts.

- Two forthcoming resources that can help agencies decide which IDDE methods to use are Ecology's Source Identification Information Repository and an IDDE field screening manual being prepared by King County.

Business Inspections as Source Control

- In-person inspections at businesses can help encourage the proper operation and maintenance of BMPs. Regular follow-up inspections can help improve long-term compliance.
- Knowledgeable staff is required to inspect the range of source control BMPs in use at businesses and identify proper usage, recommend corrections, and determine compliance.
- The frequency of site visits needed to affect lasting changes in behavior related to stormwater pollution prevention is a topic better addressed in a public education and outreach context.

Although many of the ranked questions that drove this white paper were not directly addressed in the effectiveness literature database, outside literature was identified and reviewed as much as possible within the constraints of the scope of work for writing this paper. In addition, professional experience by this author performing source control in various settings was used to inform the results and recommendations, especially for site visits to private stormwater facilities and business inspections. Recommendations for effectiveness studies and additional information are as follows:

1. Expand the literature database to include more studies on the range of construction TESC BMPs offered in the SWMMWW.
2. Study the effects of PAM on Puget Sound area soils as well as the typical combinations of TESC BMPs in use at construction sites in western Washington.
3. Review the sizing and design specifications for TESC sedimentation ponds in the SWMMWW. Use the Revised Universal Soil Loss Equation or another appropriate model to estimate sediment loading to ponds to adjust their size and design for maximum sediment retention, not just peak flow attenuation.
4. Investigate what combinations of education, inspection, and enforcement work best for improving compliance with stormwater BMPs and other source control activities in use at private stormwater facilities and at businesses. Ecology's Local Source Control Partnership is a valuable resource with recent and current data and experience of performing business and private facility inspections of stormwater BMPs.
5. Establish a regional chemical indicators database for local agencies to compare water quality profiles of discharge from various distinct areas to help inform which IDDE methods work best.
6. Investigate which combination of IDDE methods work best for wet weather screening and for specific land uses and business types.

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ABBREVIATIONS AND ACRONYMS

Al	Aluminum
AKART	all known and reasonable methods of prevention, control, and treatment
BMP	best management practice
Ca	Calcium
CCTV	closed circuit television
CESCL	certified erosion and sedimentation control lead
CTAPE	Chemical Technology Assessment Protocol - Ecology
CFS	cubic feet per second
CWA	clean water act of 1972
CWP	Center for Watershed Protection
Ecology	Washington State Department of Ecology
ESARRMP	Endangered Species Act Regional Road Maintenance Program
Fe	Iron
$kg\ ha^{-1}$	kilograms per hectare
$lb\ ac^{-1}$	Pounds per acre
LID	low impact development
LSC	local source control
Mg	Magnesium
$mg\ L^{-1}$	milligrams per liter
MS4	municipal separate storm sewer system
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity unit
P	Phosphorus
PAM	polyacrylamide
POTW	publically owned treatment works
RUSLE	revised universal soil loss equation
SIIR	source identification information repository
SWG	stormwater work group
SWMMWW	stormwater management manual for western Washington
SWMP	stormwater management program
SWPPP	stormwater pollution prevention plan

TESC	temporary erosion and sedimentation control
TSS	total suspended solids
USEPA	United States Environmental Protection Agency
UW	University of Washington
WAC	Washington Administrative Code

1.0 INTRODUCTION AND PROBLEM STATEMENT

This white paper presents a review of literature from a database of selected publication titles and abstracts (Ecology 2011a). The aim of the literature review and white paper is to identify and summarize available publications to support a decision process to prioritize stormwater effectiveness studies in western Washington. The topics of literature for the database were organized by the Washington State Department of Ecology (Ecology) Stormwater Work Group (SWG). The effectiveness literature topics were identified by input from local governments, permittees of Ecology's National Pollutant Discharge Elimination System (NPDES) Western Washington Phase II Municipal Stormwater Permit (Ecology 2012a), and other interested parties. The intent of identifying potential effectiveness studies is to provide information to Puget Sound governments and other western Washington NPDES Phase II permittees to assist them with implementation of the NPDES requirements. In addition, the activities of the SWG contribute to the stormwater component of a comprehensive regional ecosystem monitoring program in Puget Sound being organized by Ecology and Puget Sound Partnership. Funding for this white paper was provided by Ecology.

1.1 SCOPE OF THIS WHITE PAPER

The topic of this white paper is source control as related to stormwater management. The scope of the investigation into source control was guided by a series of ranked questions developed by the SWG Effectiveness subgroup. The scope and context for the literature summarized in this white paper is related to erosion and sediment management at construction sites, site visits and inspections of private stormwater facilities, illicit discharge detection and elimination, and source control inspections at businesses. These topics come directly from the western Washington Phase II Municipal Stormwater Permit (Ecology 2012a). Because the ranked questions and the Phase II permit guided this effort, the topics covered in this white paper include more than what is conventionally defined as source control.

The basic concept of source control in a stormwater context refers to the idea of preventing pollutants from entering stormwater runoff. Stormwater runoff refers to surface water flow that is created by rainfall coming in contact with any surface that sheds water that eventually flows into receiving waters. Ideally, source control is achieved by a variety of practices, techniques, and activities referred to as best management practices (BMPs) that serve to prevent the generation of potential pollutants or manage and treat them at the source once generated.

1.2 REGULATORY CONTEXT

The NPDES rules and regulations have been promulgated by the United States Environmental Protection Agency (USEPA) since 1972 as part of the Clean Water Act (CWA). The NPDES program is intended to prevent unwanted discharges into natural waters and was originally focused on point sources, such as publically owned treatment works (POTW) and businesses with a high risk of pollution-generating activities. In 1987, Congress expanded the scope of the CWA via the Water Quality Act (USEPA 1987) and included stormwater as a “nonpoint” source of potential pollution. The application of the NPDES program was then expanded to include many urban areas, small and medium industrial dischargers, and all municipalities.

In Washington State, the NPDES program is administered by Ecology who issues permits for all aspects of the NPDES program, including the Construction Stormwater General Permit

(Ecology 2010a), the Industrial Stormwater General Permit (Ecology 2009a), the Sand and Gravel General Permit (Ecology 2010b), the Municipal Stormwater Permit (Ecology 2012a, Ecology 2012b, and Ecology 2012c), and the Washington State Department of Transportation Municipal Permit (Ecology 2009b). The Municipal Stormwater Permit is divided into three sections for Washington state entities – the Phase I Municipal Permit (Ecology 2012b), the Phase II Municipal Permit for Western Washington (Ecology 2012a), and the Phase II Permit for Eastern Washington (Ecology 2012c). Phase I and Phase II permits refer to which entities are covered, with Phase I intended for larger entities and municipalities such as the cities of Seattle and Tacoma, and Phase II intended for smaller entities. Current permits extend to 2018 and cover a range of activities. Each permit has source control requirements for sediments and illicit discharges to the municipal separate storm sewers (MS4).

The current Phase II Municipal Stormwater Permit for western Washington (2013-2018) has significant changes from the previous permit (2007-2012, Ecology 2007). Two of the most significant changes are the increased requirements for a stormwater management program (SWMP) and the expanded monitoring requirements. The SWMP requirements in both permits include source control as part of section S5.C.4 *Controlling Runoff from New Development, Redevelopment and Construction Sites*. However, source control is indirectly relevant to other permit sections, especially *Illicit Discharge Detection and Elimination* (IDDE) and *Public Education and Outreach.* Both of these topics are related to source control: the goal of IDDE is to find and eliminate the sources of illicit connections and discharges; and the goal of education and outreach is behavior change that includes preventing the generation of pollutants at their source, including stormwater. Thus, this paper covers topics related both directly and indirectly to source control from the Washington state NPDES permits.

When developing or redeveloping a property, NPDES permittees are required to follow the Ecology Stormwater Management Manual (SWMM, Ecology 2012d) or an equivalent approved manual. Ecology has developed stormwater management manuals for western Washington and eastern Washington with specific guidelines on a variety of BMPs that are intended to be applied at a project level, including those for the purpose of source control. The manual defines BMPs as "schedules of activities, prohibitions of practices, maintenance procedures, and structural and/or managerial practices, that when used singly or in combination, prevent or reduce the release of pollutants and other adverse impacts to waters of Washington State." In addition to source control BMPs, the SWMM categorizes two other general types of BMPs – treatment BMPs and flow control BMPs – since source control BMPs are not intended to prevent all impacts, a combination of BMPs are required in practice. Furthermore, the methods used with some source control BMPs overlap into treatment BMPs and flow control BMPs.

The selection, design, implementation, and maintenance of source control BMPs are all important steps for their successful use. Each NPDES permittee is required to develop a stormwater pollution prevention plan (SWPPP) in which the specific BMPs and procedures for their implementation are identified. A successful source control program relies on both structural and operational BMPs, and the SWMM provides guidance and a menu of options for including both of these types of BMPs in SWPPPs. Structural BMPs are "physical, structural, or mechanical devices or facilities" intended to prevent pollution from entering stormwater while operational BMPs are non-structural practices (Ecology 2012d). An example of a structural source control BMP is to cover a potential pollution source, such as exposed soil, to prevent erosion, and an example of an operational source control BMP is good-housekeeping practices to prevent spills. Volume I of the SWMM (Minimum Technical Requirements and Site Planning) contains instructions on preparing SWPPPs and the minimum requirements for stormwater pollution prevention, and Volumes II (Construction Stormwater Pollution Prevention) and IV (Source Control BMPs) contain specific BMPs related to source control used in a wide range of industries.

Ecology periodically updates and revises the SWMM, the most recent of which was in 2012 seven years after the previous edition. The timing of this revision intentionally coincided with the current NPDES permit period (2013-2018) and is intended to provide current information about BMPs for NPDES permittees. While the SWMM incorporates information about new BMPs and their performance, its prescriptive use of BMPs is provided in the context of AKART - all known and reasonable methods of prevention, control, and treatment. The AKART approach is a presumptive one in which if the appropriate BMPs are selected and used then "compliance with water quality standards is presumed" (Ecology 2012d). An alternative approach is allowed by the SWMM, which is the demonstrative approach in which alternative selection, design, construction, implementation, operation and maintenance of BMPs is allowed but requires an individualized review process by Ecology. The demonstrative approach can sometimes be more cost effective than the presumptive approach for large projects; however, the burden of proof that the alternative approach will work falls to the permittee and the review process by Ecology can be very time consuming (Ecology 2012d). For these reasons, the presumptive approach is usually followed.

1.3 PROBLEM STATEMENT

Numerous studies indicate that although source control and other BMPs can reduce the generation of pollutants and their transport into stormwater runoff, their efficacy varies widely depending on the design and implementation of the BMP as well as local site, soil, and climate conditions. Furthermore, non-structural BMPs tend to have less tangible performance characteristics than structural BMPs due to the qualitative nature of actions like certain types of public outreach. These factors present a complexity to BMP selection, usage, and performance. Furthermore, the presumptive AKART approach does not make a direct connection to the ultimate goal, which is to prevent unwanted discharges into receiving waters that cause violations of state water quality standards. This white paper seeks to address specific null hypotheses and questions developed by the Ecology SWG that probe the performance and usefulness of selected BMPs and related practices as they are relevant to the Phase II permit.

2.0 LITERATURE SUMMARY AND TALKING POINTS

This section presents the summary of source control literature. First, the methods and results of the literature selection are described. Then the guiding questions and null hypotheses are provided for reference followed by a summary of key regulatory and BMP guidance information to which the questions make reference. Following that is the summary of the source control literature with talking points about each of the four main source control topics. Talking points for each main topic are provided at the end of each source control topic subsection.

2.1 LITERATURE SELECTION

The publications reviewed for this white paper came from a database of effectiveness study literature (Ecology 2011a). The literature database is composed of 336 titles from a variety of sources, including journals/primary literature, books, technical guidance manuals, marketing and public information flyers, and internally published agency reports. Key fields by which the database could be sorted include NPDES Permit Area, Specific BMP, and Study Location.

Source control publications were identified by sorting the literature database and by keyword searches. The database was sorted by each of the six NPDES Permit Areas then by each Specific BMP topic. Publications were chosen based on the title, review of the summary/abstract, and if there was relevance to the source control topics in the ranked questions.

Source control literature was present in all six NPDES Permit Areas, in 12 Specific BMP categories, and in over a dozen geographic areas including western Washington and Puget Sound cities. Location was often not specified in the literature database, so the most meaningful summary of source control literature found in the database was by Permit Area and BMP type. Tables 1 and 2 show the distribution of source control literature among these two fields.

Table 1 Publications by NPDES Permit Area

NPDES Permit Area	No. Publications	No. Source Control-related Publications
controlling runoff	267	18
monitoring	8	1
Multiple	4	2
pollution prevention & municipal operations	50	21
public education and outreach	10	5
other	2	1
Total	341[1]	48

Notes
1 Includes overlap of NPDES Permit Areas discussed among 336 discrete articles in the database.

Table 2 Publications by BMP Type

Specific BMP	No. Publications	No. Source Control-related Publications
biofilter	46	1
Catch basin cleaning	9	
detention basin	34	1
education	8	5
infiltration	21	1
LID	47	1
maintenance practice	8	
manufactured device	28	
media filter	34	
multiple	5	2
oil water separator	5	
other	35	4
porous pavement	48	1
rain garden	84	
retention pond	33	1
source control	33	18
street sweeping	25	12
wetland/wetlands	42	
(blank)	2	1
Total	547[1]	48

Notes
1 Includes overlap of BMPs discussed among 336 discrete articles in the database.

Keyword searches in the database were also used to identify source control publications. Keyword searches were best suited to searching among the publication titles and abstract/literature summaries. The keyword searches performed were: source control (12 hits), construction (12 hits), inspection (four hits), business or businesses (one hit), temporary erosion and sedimentation control or TESC (no hits), compliance (two hits), private (one hits), education or outreach (five hits), and illicit or IDDE (no hits). In total, 48 publications were identified by sorting and by keyword searches that addressed one or more aspect of the source control questions posed.

In addition, some publications listed in the database were available only via paid subscription or purchase of a book. We primarily used the University of Washington (UW) libraries to obtain journal articles, and while many publications in the effectiveness database were available, articles from two journals were not consistently available: Water Science & Technology and the Water Quality Research Journal of Canada. Between these two journals and other book references, seven publications in the database were not obtained that appeared relevant based on the title and/or abstract. The scope of this white paper was to review publications listed in the effectiveness literature database; however, due to the absence of literature for some of the topics covered in this paper, outside literature was identified and summarized as possible within the constraints of the project scope, budget, and schedule.

2.2 NULL HYPOTHESES AND RANKED QUESTIONS

The organizing principle for this white paper is the ranked questions (Ecology 2011b) posed by the SWG about source control. Those questions guided the literature review and summary and are provided in Table 3 for reference.

Table 3 Ranked Effectiveness Questions for Source Control (Ecology 2011b)

Rank[1]	Null Hypothesis	Questions	Source Control Topic
1	Construction site inspections are not effective at controlling sediments and turbidity from permitted construction sites.	• Are the temporary erosion and sediment control (TESC) BMPs required during development or redevelopment adequate to control erosion and sediment from construction sites? • Are the TESC BMPs used at construction sites effective at reducing turbidity/TSS for compliance with water quality standards? • What frequency of construction erosion and sediment control inspections are most effective for achieving compliance with codes/ordinance requirements at new development and redevelopment project sites?	• Construction Source Control and BMPs.
2	Education and inspection of private stormwater facilities does not affect water quality.	• Do more frequent site visits and contact with private facility owners improve compliance with operation and maintenance (O&M) requirements? • What is the optimum frequency of inspections to maintain the functionality of private stormwater facilities?	• Source Control at Private Stormwater Facilities
4	IDDE program components are not effective at reducing pollutants.	• Which combination of methods work best for detection of illicit connections: smoke testing, dye testing, CCTV, flow monitoring and outfall screening (wet and dry season)? • How effective is wet weather screening as a tool to detect illicit connections? • Which parameters should be measured during dry weather screening to improve the ability to detect illicit connections?	• Illicit Discharge Detection and Elimination
8	Business inspections and outreach are not effective source control techniques.	• Are businesses that receive an in-person visit/inspection more likely to implement source control BMPs? • What frequency of business inspections is most effective for implementing and maintaining source control requirements/BMPs at businesses?	• Business Inspections As Source Control.

Notes
1 Rank assigned by the SWG.

2.2.1 Regulations and Guidelines for Source Control

Some of the ranked questions refer to water quality standards. The water quality standards refer to section of 173-201A of the Washington Administrative Code (WAC, Ecology 2011d) for surface waters of Washington state. For construction discharge water quality, the main pollutant of concern is suspended sediment, which is expressed in turbidity as a surrogate parameter. The turbidity standards are organized by fish usage and habitat available in fresh water or on the quality of the marine waters as applicable. Background turbidity is defined as the “biological, chemical, and physical conditions of a water body, outside the area of influence of the discharge under consideration" (Ecology2011d). Thus, background turbidity at a construction site would be determined immediately upstream and outside the area of influence of a construction discharge point. The water quality standards also allow for a mixing zone in the receiving water body under special circumstances, which is applicable only if identified in a site-specific NPDES permit (Ecology 2011d). For reference, the turbidity criteria from the water quality standards are summarized in Table 4.

Table 4 Turbidity Criteria from 173-201A WAC (Ecology 2011d).

Fresh Water Aquatic Life Use Categories	Maximum Allowed
Char Spawning and Rearing	5 NTU over background <50, or 10% increase over background >50
Core Summer Salmonid Habitat	5 NTU over background <50, or 10% increase over background >50
Salmonid Spawning, Rearing, and Migration	5 NTU over background <50, or 10% increase over background >50
Salmonid Rearing and Migration ONLY	10 NTU over background <50, or 20% increase over background >50
Non-anadromous Interior Redband Trout	5 NTU over background <50, or 10% increase over background >50
Indigenous Warm Water Species	10 NTU over background <50, or 20% increase over background >50
Marine Water Aquatic Life Use Categories	**1-day Max**
Extraordinary Quality	5 NTU over background <50, or 10% increase over background >50
Excellent Quality	5 NTU over background <50, or 10% increase over background >50
Good Quality	10 NTU over background <50, or 20% increase over background >50
Fair Quality	10 NTU over background <50, or 20% increase over background >50
Mixing Zone	**Maximum Flow**
Mixing zone allowed for in-water work	Max flow 10 cfs, mixing zone 100 ft
Mixing zone allowed for in-water work	Flow 10-100 cfs, mixing zone 200 ft
Mixing zone allowed for in-water work	Flow >100 cfs, mixing zone 300 ft
Lakes ponds, wetlands	Mixing zone radius of 150 ft

In addition to the surface water quality standards that apply to waters of the state, the Construction General Stormwater Permit (Ecology 2010a) lists a turbidity benchmark of 25 NTU for construction site discharge. At construction sites, both the state water quality standards and the turbidity benchmark values apply; however, construction permittees are required only to measure turbidity in construction site discharge and not in the receiving waters. Section S3 of the permit notes the AKART approach that "Ecology presumes that a Permittee complies with water quality standards unless discharge monitoring data or other site-specific information demonstrates…a violation of water quality standards."

The ranked effectiveness questions also make reference to the TESC BMPs required at construction sites. Requirements for construction erosion and sediment control are in the Construction Stormwater Permit (Ecology 2010a). Guidelines and design requirements exist for designing and implementing TESC BMPs at construction sites in western Washington; Volume II of the SWMMWW (Ecology 2012d) includes approved lists of the two main types of TESC BMPs applicable at construction sites: source control BMPs and runoff conveyance and treatment BMPs. For reference, Tables 5 and 6 lists the source control BMPs and runoff conveyance and treatment BMPs, respectively, from the SWMMWW along with the number of relevant publications from the effectiveness literature database and the SWPPP element(s) that each BMP addresses.

Table 5 Source Control BMPs from the SWMMWW (Ecology 2012d).

Source Control BMPs	No. Relevant Publications in Database	SWPPP Elements that BMP Addresses
Preserving Natural Vegetation		Preserve Vegetation
Buffer Zones		Preserve Vegetation, Protect LID
High Visibility Plastic or Metal Fence		Preserve Vegetation, Protect LID
Stabilized Construction Entrance/Exit		Establish Construction Access
Wheel Wash		Establish Construction Access
Construction Road/Parking Area Stabilization		Establish Construction Access
Temporary and Permanent Seeding		Stabilize Soils, Protect Slopes
Mulching	2	Stabilize Soils, Protect Slopes
Nets and Blankets	3	Stabilize Soils, Protect Slopes, Stabilize Channels and Outlets
Plastic Covering		Stabilize Soils
Sodding		Stabilize Soils
Topsoiling/Composting	4	Stabilize Soils
Polyacrylamide for Soil Erosion Protection	4	Stabilize Soils
Surface Roughening		Stabilize Soils, Protect Slopes
Gradient Terraces		Stabilize Soils, Protect Slopes
Dust Control		Stabilize Soils
Materials on Hand		Maintain BMPs, Manage the Project
Concrete Handling		Control Pollutants
Sawcutting and Surfacing Pollution Prevention		Control Pollutants
Material Delivery, Storage, and Containment		Control Pollutants
Concrete Washout Area		Control Pollutants
Certified Erosion and Sediment Control Lead		Maintain BMPs, Manage the Project
Scheduling		Manage the Project

As is evidenced in Tables 5 and 6, the literature selected for the effectiveness database does not directly address many of the BMPs listed in the Ecology SWMMWW. Publications included in Tables 5 and 6 are those that had effectiveness information. Other publications available in the database related to source control focused on design elements or source control in contexts not related to the questions posed by the SWG. The publications that focused on effectiveness in context of the ranked questions are summarized below along with some outside publications that were used to fill information gaps. One publication not in the effectiveness literature database but relevant to TESC BMPs used with road construction is the guidelines document from the Endangered Species Act Regional Road Maintenance Program (ESARRMP, WSDOT 2008). The ESARRMP guidance documents list over 50 BMPs with design details for use on road construction and maintenance projects with the additional purpose of meeting ESA requirements. It is recommended that road construction and maintenance projects refer to the ESARRMP guidance document, which has grown out of an adaptive management process with input from multiple state and federal agencies.

Table 6 Runoff Conveyance and Treatment BMPs from the SWMMWW (Ecology 2012d).

Runoff Conveyance and Treatment BMPs	No. Relevant Publications in Database	SWPPP Elements that BMP Addresses
Interceptor Dike and Swale	1	Protect Slopes, Protect LID
Grass-Lined Channel		Protect Slopes, Protect LID
Channel Lining		Stabilize Channels and Outlets
Water Bars		Control Flow Rates, Protect Slopes, Control Dewatering
Pipe Slope Drains		Protect Slopes
Subsurface Drains		Protect Slopes
Level Spreader		Protect Slopes
Check Dams	1	Control Flow Rates, Protect Slopes, Stabilize Channels and Outlets, Protect LID
Triangular Slit Dike(Geotextile Encased Check Dam)	1	Protect Slopes, Protect LID
Outlet Protection		Control Flow Rates, Stabilize Channels and Outlets
Storm Drain Inlet Protection		Protect Drain Inlets
Brush Barrier	1	Install Sediment Controls, Protect LID
Gravel Filter Berm		Install Sediment Controls
Silt Fence	1	Preserve Vegetation, Install Sediment Controls, Protect LID
Vegetated Strip		Install Sediment Controls, Protect LID
Wattles	1	Control Flow Rates, Install Sediment Controls
Vegetative Filtration		Control Dewatering
Sediment Trap		Control Flow Rates, Install Sediment Controls
Temporary Sediment Pond	3	Control Flow Rates, Install Sediment Controls
Construction Stormwater Chemical Treatment		Install Sediment Controls, Control Pollutants
Construction Stormwater Filtration		Install Sediment Controls, Control Pollutants
High pH Neutralization Using CO_2		Control Pollutants
pH Control for High pH Water		Control Pollutants

2.3 SUMMARY OF LITERATURE: CONSTRUCTION SOURCE CONTROL

2.3.1 Question: Are the TESC BMPs required during development or redevelopment adequate to control erosion and sediment from construction sites?

To answer this question, literature from the effectiveness database was reviewed in light of the potential BMPs used at construction sites. Several BMPs were discussed among the publications that are available choices in the SWMMWW; however, most BMPs were either not discussed in the available literature or discussed in contexts outside of construction sites. The most prevalent construction BMPs in the literature database are polyacrylamide (PAM) treatment, compost treatment, temporary sediment ponds, and erosion control blankets with various combinations of mulch and compost.

In the context of erosion and sediment control, PAM refers to an anionic non-toxic powder that helps small soil particles bind together so they discourage separation and helps particles settle out more easily in soil-laden runoff (Daughton 1988). Treatment with PAM involves applying the powder or liquid prepared to a specified concentration to exposed soil or incorporating it into soil coverings. It is often used in agricultural settings to diminish top soil loss and promote infiltration of irrigation waters (NRCS 2011).

For PAM-related studies, data of interest is typically the application rate (mass of PAM applied per unit area) and the sediment and runoff characteristics, especially turbidity, sediment load, and runoff volume. PAM performance is affected by application rate, soil type, soil slope, and rainfall. Hayes et al. (2005) reported on a comparison of mulch to PAM applied directly to soil and in a seed mix sprayed on soil of various slopes in the North Carolina Piedmont and Coastal Plain region. They applied two PAM products at the manufacturers' recommended rates of 1.3 lb ac^{-1} and 9.3 lb ac^{-1} as well as half of the recommended rates. They found very little effect on reducing turbidity, runoff, or sediment load among the test sites and suggested that heavier application of PAM would be necessary, especially on steep slopes. For reference, PAM application rates allowed in western Washington construction sites is 0.66 lb ac^{-1} or 80 mg L^{-1} in solution applied over one acre (Ecology 2012d).

McLaughlin and Bartholomew (2007) also tested PAM on soils from North Carolina, however they tested a larger selection of PAM products (11) and performed only laboratory tests to measure the decrease in turbidity of soil samples. In general, they found that the higher the concentration of PAM, the greater reduction in turbidity. But soil clay type and content were found to influence the turbidity reduction. The greatest reduction in turbidity was from soils with high sand content and kaolinitic clays and mica, especially soils with greater than 14 percent clay. They also mentioned that soils with multivalent metal cations present (Fe, Ca, Mg, and Al) tended to have greater turbidity reduction. Given that PAM works via an electrochemical process by binding to positively charged soil particles, soils that are high in (negatively charged) clays and mineral cations understandably respond more readily to the flocculation and binding process that PAM promotes. Optimal doses of PAM were found to be one to two mg L^{-1} for the best reduction in turbidity, although the doses were not related to the mass or area of soil tested so it is not possible to relate PAM application rate to area of soil treated in this study.

Several studies of PAM applied to various soil cover or flow reduction BMPs were also present in the literature database. A paper by McLaughlin et al. (2009) tested PAM effects when it was impregnated into fiber check dams, which showed very effective results at reducing turbidity. Fiber check dams are small permeable dams placed across a swale or ditch in order to reduce the velocity of flow. For this study PAM was applied by adding 100 grams of granulated product to the lower and center portion of each check dam. Results showed significant reduction in turbidity due to PAM application, but not significant reduction in sediment loss from PAM.

McLaughlin and Brown (2006) applied PAM to common ground cover BMPs, including straw, straw blankets, wood fiber, and bonded fiber matrix on natural soils and soil test beds ranging from four to 20 percent slope. PAM was applied at 19 kg ha^{-1} (0.02 lb ac^{-1}). Results showed that ground covers significantly reduced turbidity, but reductions in turbidity due to PAM were inconsistent with only some storm events (natural and simulated) showing reduction. Faucette et al. (2007) compared soil cover blankets with wood mulch/compost mix to blankets with straw and PAM application. Two PAM products were tested individually and applied at the manufacturer's recommended rates of 34 and 370 kg ha^{-1} (0.03 and 0.30 lb ac^{-1}, respectively). Wood mulch blankets were found to have the greatest reduction in runoff and turbidity, which is likely due to lessened impact by rain drops compared to bare soil. Application of PAM to the blankets was found to significantly reduce turbidity but not runoff volume. Higher mulch content in the blankets resulted in greater turbidity reduction. The particle size profile of straw blankets was also found to be important with smaller particle sizes increasing the protection of soil. Babcock and McLaughlin (2011) compared the sediment removal performance of straw, straw plus PAM, and excelsior (natural fiber) blankets applied on steep slopes with a 2:1 ratio. As with other studies by McLaughlin, the PAM treatment showed the highest removal of total suspended solids (TSS) and the excelsior blankets had a higher removal than plain straw.

In addition to application rates, the Construction General Permit (Ecology 2010a) includes details on how and where PAM should be applied to avoid it entering a receiving water body. It is not intended as a cure-all solution to prevent erosion or remove sediment from water. Rather, it is intended to be used in combination with other BMPs with an emphasis on stabilizing soils and preventing erosion. Due to the restrictions of PAM from entering receiving waters and concern about potential toxicity, many jurisdictions in western Washington do not use PAM as a construction BMP (A. Moon, personal communication).

Another type of source control BMP discussed in the literature is the use of geotextile fabrics. Geotextile fabric can be used in conjunction with a wide variety of material to cover soil, form a low- or no-permeability barrier (silt fence), and make objects such as check dams, brush barriers, and filter berms when used as a wrap around soil, rock, straw, and other materials. One study in the database by Rickson (2006) investigated the performance characteristics of geotextiles and noted that several factors are important to their performance, including soil type being protected, water ponding ability, water-holding capacity, and roughness of the fabric texture.

Faucette et al. (2008) compared a silt fence to compost filter socks (a type of contained filter berm) for removal of TSS and phosphorus (P) and reduction in flow. Some treatments also included adding PAM to the compost mix to enhance removal. Results from this bench-top test were that the compost socks with added PAM had the best reduction in TSS and P, followed by compost socks without PAM, then the silt fence. Another study by Faucette et al. (2009) also compared compost filter socks to several other BMPs, including straw bales, mulch filter berms, and PAM-treated compost socks. They found that compost filter socks had the best sediment removal properties, but no difference was found between the plain compost filter sock and PAM-treated sock.

Eck et al. (2010) compared a manure compost/mulch blend to a wood-based hydromulch for containing sediments from a rock quarry in Texas. The treatments were spread directly on test plots of bare soil. The compost blend showed the best performance for containing soils due to the water-holding ability of the compost and the quicker establishment of vegetation than on hydromulch plots. Export of nutrients, especially dissolved phosphorus was noted as a drawback when using compost, and the authors recommended using a low-phosphorus compost blend.

Taleban et al. (2009) tested the performance of compost biofilter rolls/socks of varying sizes. They found that sediment removal increased with the number of socks placed in the path of runoff and that larger diameter socks provided better removal of TSS than smaller ones, with removal documented up to 95 percent. In addition, the TSS removal performance of the socks did not diminish with varying flow depths as long as the flow did not overtop the sock diameter.

The sedimentation pond is another type of BMP discussed in literature. Generally speaking a sedimentation pond is treatment BMP designed to capture sediment from runoff and includes BMPs variously referred to as temporary sediment ponds, detention basins, or wet ponds. Kalainesan et al. (2008) investigated four sediment ponds (called basins in this context) from highway construction sites in Pennsylvania and monitored for removal of sediment, a few particulate metals, and phosphorus. They found that sediment basins managed high flows well but were not very effective at capturing sediment with only 15 percent removal. Because the basins were designed following the specifications published by the Pennsylvania Department of Environmental Protection, Kalainesan recommends that an update to the design standards of sedimentation ponds in Pennsylvania is needed. Another publication by Kalainesan et al. (2009) provides a suggested methodology for sizing sediment basins based on a combination of local rainfall probability, the Revised Universal Soil Loss Equation (RUSLE), and setting low outflow rates to encourage particle settling in the pond. Their alternative design had better performance of sediment removal and peak flow attenuation than the traditional sediment pond design specified by the state of Pennsylvania. Their methodology has the potential to be an improvement to the sediment removal ability of temporary sediment ponds in Washington since it includes a step for estimating sediment delivery to the pond via the RUSLE.

Gharabaghi et al. (2006) compared two sediment pond designs following the Ontario (Canada) Ministry of the Environment Stormwater Management Planning and Design Manual (2003). They found that treatment of suspended solids was primarily influenced by the length-to-width ratio of the ponds. They cautioned against creating dead-zones of eddies in ponds that can decrease usable sediment accumulation area on the pond bottom.

In the James River basin that flows into the Chesapeake Bay, the CWP (2009) reported on field surveys of BMPs that included sedimentation ponds. The wet ponds, as they are referred to, have an overall performance score in the middle to lower range of the BMPs surveyed. The other BMPs included newer techniques like permeable pavement that emphasize infiltration, which generally performed better than more traditional techniques such as ponds, grass channels, and infiltration trenches. The report rated ponds by a variety of factors that includes shortest flow path through a pond, conditions upstream/downstream of the pond, maintenance, and detailed design information. However, information did not include pollutant treatment performance, especially for sediment, turbidity, and nutrients. The CWP does report on nutrient removal by ponds in their “Extreme Makeover BMP” (CWP 2008), with wet ponds showing similar ranges of nutrient removal as green roofs, permeable pavement, and bioretention (50 to 80 percent).

2.3.2 Question: Are the required TESC BMPs used at construction sites effective at reducing turbidity/TSS for compliance with water quality standards?

Of the studies noted above in addressing the previous question, many reported turbidity reduction from the BMP treatment. However, the presumptive approach in effect as stated in the Construction General Permit (Ecology 2010a) presumes that if the turbidity benchmark of 25 NTUs is met (and other permit requirements), then the water quality standards are not being violated. Several studies reported high BMP treatment levels, but the reduction was usually in comparison to bare soil, which had values as high as in the tens of thousands. The application of PAM to soil and other BMPs including compost, fiber check dams, and erosion control blankets and socks has the potential to reduce turbidity to less than the 25 NTU construction permit benchmark according to the literature reviewed (McLaughlin et al. 2009, Faucette et al.

2007); however, this was not the case across the board. Multiple factors affected the performance of PAM, especially in combination with other BMPs. These factors include PAM application concentration, time of exposure to sediment-laden runoff, soil characteristics, composition of the other BMP that PAM was added to (for example, compost mix), soil slope, and rainfall intensity. Other source control BMPs were noted to contribute to the reduction of turbidity at construction sites, such as temporary sediment ponds and the use of geotextile fabrics.

Treatment of construction site stormwater is intended to be done using a combination of TESC BMPs. The literature available in the effectiveness database was lacking in studies that focused on multiple BMPs used in series that would be common at a construction site. Specifically, no studies were available with BMP effectiveness results from construction sites in Washington. Instead, studies often focused on one or a few BMPs and their performance in reducing turbidity in a controlled situation, such as benchtop test, experimental plots, or customizable elevated soil beds.

Chemical treatment BMPs for treating stormwater from construction sites are an emerging technology, and Ecology added several chemical treatment BMPs to the latest version of the SWMMWW (Ecology 2012d). Chemical treatment BMPs were not discussed in the publications available in the effectiveness literature database. Some chemical treatment BMPs are very effective at reducing turbidity to low levels and include chitosan treatment and electrocoagulation (for example, see Sekine et al. 2006). Ecology has an evaluation program for certifying chemical treatment technologies for stormwater at construction sites (Chemical Technology Assessment Protocol-Ecology [CTAPE], Ecology 2003). The CTAPE program has a list of approved technologies that can be a useful reference for selecting chemical treatment BMPs for construction site stormwater.

2.3.3 Question: What frequency of construction erosion and sediment control inspections is most effective for achieving compliance with codes/ordinance requirements at new development and redevelopment project sites?

The frequency of inspecting erosion and sediment control BMPs at construction sites was not addressed in the literature available. Inspection of TESC BMPs would usually fall to the erosion and sedimentation control specialist at a construction site who is a Certified Erosion and Sediment Control Lead (CESCL). Per the SWMMWW (Ecology 2012d), the CESCL is responsible for ensuring compliance with erosion and sediment control and water quality requirements, and required inspection frequency ranges from weekly to twice per year depending the activities at the construction site (Ecology 2010a) with special inspections required immediately following storm events of 0.5 inches or more in 24 hours. While a thorough review of CESCL training information was outside the scope of this white paper, answering this question would benefit from such a review, including ensuring training materials cover emerging technologies.

2.3.4 Talking Points for Construction Source Control

Talking Point 1: TESC BMPs used at construction sites can control erosion and sediment. Effective use depends on BMP selection, operation and maintenance, and site conditions. Additional literature is needed to review the full range of TESC BMPs. A review of PAM performance in western Washington is warranted as is a review of sediment pond sizing and design.

The literature available in the effectiveness database discusses several TESC BMPs used on construction sites. However, many BMPs were not discussed in the available literature; more extensive literature search and review is needed to describe which BMPs work best of the options presented in the SWMMWW. Conclusions from available literature are that compost blankets and filter socks, permeable check dams, and polyacrylamide (PAM) treatment in combination with other BMPs have the best performance characteristics for controlling sediments and treating erosion at the source. Soil characteristics and site conditions can affect the effectiveness of BMPs with lower slope gradients and higher clay content in soil correlating to higher effectiveness for PAM treatment. Ecology has strict guidelines for the use of PAM to prevent it from entering receiving waters, and for this reason PAM is currently not widely used for construction erosion control in western Washington. In addition, a review of sediment pond design and sizing is warranted based on the literature. Specifically, the addition of a step to estimate sediment loading to a pond should be included to inform both the size and design of a pond as well as the potential maintenance schedule for dredging.

Talking Point 2: A combination of TESC BMPs is required to treat the full range of sediment in construction site runoff down to construction benchmark levels for turbidity. Additional literature or effectiveness studies are needed to describe the combinations of TESC BMPs typically in use in western Washington.

The literature available was insufficient to address the question about meeting water quality standards as most of it focused on controlled experiments of one or a few TESC BMPs. Much of the reported water quality treatment for sediment, nutrients, and other parameters was related in percent removal compared to bare soil. So, although several publications touted high removal of sediment (and reduction in turbidity), the effluent in some studies remained above construction permit benchmark levels of 25 NTU. In practice, reducing turbidity levels in construction site discharge to below benchmark levels for meeting water quality standards is done using a combination of TESC BMPs in series. Chemical treatment BMPs should be included to obtain low turbidity in construction site discharge.

An alternative question to guide future effectiveness studies is which combinations of the TESC BMPs listed in the SWMMWW are the most effective at controlling erosion and sediment from construction sites in western Washington.

Talking Point 3: Inspection of source control BMPs for erosion and sedimentation control is most effective when done on a consistent schedule that includes special inspections after significant precipitation and runoff events. Additional literature or effectiveness studies are needed to identify the optimum frequency of construction BMP inspections.

The inspection frequency of TESC BMPs was not addressed in the literature available. The SWMMWW specifies various frequencies of inspections of construction site erosion control BMPs depending on the type of site and the activity. Weekly inspections are a minimum at active construction sites in addition to inspections immediately after storm events 0.5 inches or more rain in 24 hours. Additional literature is needed that addresses inspections of construction site erosion and sedimentation BMPs, and a review of CESCL training requirements is warranted to ensure erosion control leads and inspectors have latest information on maintenance practices for TESC BMPs, especially for emerging technologies.

2.4 SUMMARY OF LITERATURE: SOURCE CONTROL AT PRIVATE STORMWATER FACILITIES

2.4.1 Question: Do more frequent site visits and contact with private facility owners improve compliance with operation and maintenance (O&M) requirements?

Only a few publications were available in the effectiveness literature database that addressed site visits to private stormwater facilities. None of these, however, specifically addressed the frequency of site visits and contact with private facility owners. This question is related to public outreach and education as much or more than to source control. Fohn (2010) reported on Kitsap County's efforts to reduce bacterial pollution in Dyes Inlet in western Puget Sound that included private property inspections. Inspections of private stormwater systems in Kitsap County were not done prior to 2006 and for the bacterial pollution study, an inspection was done once in 2006 or 2007 and a second inspection was done in 2008 for properties with deficiencies. After the first year of the program, the deficiency in private stormwater facilities dropped from 41 to 8 percent of inspected properties. After initial corrections were made during the first inspections, compliance was noted to flatten out at 85 percent (M. Fohn, personal communication). In addition, water quality improved at two marine water quality monitoring stations influenced by runoff from the inspected areas (presumably because of factors that include more consistent and correct operation and maintenance of private stormwater facilities). Because of these positive results, Kitsap County increased their inspection frequency from once every two years to annually.

Taylor et al. (2007) reported results from an education campaign in commercial areas in Melbourne, Australia. The program did not include inspections of private facilities, rather it focused on education including community workshops, one-on-one visits with merchants, and observation of behaviors with the objective of reducing litter and increasing proper waste disposal. Their findings were that behaviors changed for a while, but knowledge of litter and waste management information did not significantly change. These results, while not from a stormwater study, do emphasize the difference between education and behavior. Their findings suggest that private facility owners can be more compliant when simply told what to do rather than attempts at education around waste issues.

Hillegass (undated) reported on an approach for measuring stormwater program effectiveness in NPDES Phase II communities in Chesapeake, Virginia. The report was a summary of SWMP goals, measurement parameters, and evaluation objectives for an indicator database that included inspection of private stormwater facilities. However, the frequency of inspections was not mentioned and no data were presented.

2.4.2 Question: What is the optimum frequency of inspections to maintain the functionality of private stormwater facilities?

This question is a focused version of the previous question. The literature available did not address inspection frequency of private stormwater facilities except as noted for the Kitsap county bacterial pollution study (Fohn 2010). To answer this question, the range and variety of private stormwater facilities needs to be identified and the inspection frequency may be different for different types of facilities. More literature or effectiveness studies are needed to address this question.

2.4.3 Talking Points for Private Stormwater Facilities

> *Talking Point 4*: Site visits and/or inspections of private stormwater facilities can have positive effects on the operation and maintenance of stormwater BMPs. Communications with private facilities need to be tailored to specific agency goals for building relationships with owners and managers of private stormwater facilities. Additional literature or effectiveness studies are needed to address how inspections of private stormwater facilities affect operations and maintenance of those facilities.

The nature, scope, and frequency of inspections of private stormwater facilities was addressed by only one publication available. That publication indicates that inspections of private stormwater facilities can generally contribute to overall benefits in water quality (Fohn 2010) and annual inspections were implemented as the norm to some facilities in Kitsap county following this study. However, the connection of inspections to the operation and maintenance of these facilities was not addressed and requires additional literature or effectiveness studies. Personal experience by this author with the Washington State Local Source Control Program (LSC) indicates that corrective actions to private stormwater facilities can be short-lived and regular site visits may be needed depending on the type of facility, the risk of pollution-generating activities, and the willingness of the facility owner or personnel.

Different jurisdictions have different approaches and resources available for building relationships with private stormwater facility owners and managers. A blanket approach in the message and tone of communications with private facilities may not work for every jurisdiction. For this reason, there should be some flexibility for jurisdictions to choose the types and frequencies of communications with private facility owners in order to build positive relationships that can help motivate compliant pollution prevention behaviors.

An alternative question to consider is what combination of education and inspection of private stormwater facilities is most effective for improving compliance with operations and maintenance requirements.

> *Talking Point 5*: The optimum frequency of site visits at private stormwater facilities depends on the types of facilities. Additional literature or effectiveness studies are needed to address what frequency of inspections is best to maintain private stormwater facilities.

As noted above, the frequency of inspecting private stormwater facilities was not addressed in the literature available. However, the frequency of inspecting private stormwater facilities depends partly on the type of facility. A recommendation to address this question is to find literature about or implement effectiveness studies that explore how inspection frequencies affect the maintenance of the range of private stormwater facilities.

2.5 SUMMARY OF LITERATURE: ILLICIT DISCHARGE DETECTION AND ELIMINATION

2.5.1 Question: Which combination of methods work best for detection of illicit connections: smoke testing, dye testing, CCTV, flow monitoring, or outfall screening (wet and dry season)?

IDDE was not specifically addressed in the literature in the effectiveness database. Outside publications were used, and include CWP and Pitt (2004) and Pitt (2001) who provide detailed resources for creating IDDE programs and source tracing of illicit discharges. Some methods, such as chemical monitoring, can work well for detecting a general presence or absence of illicit discharges and establishing a history of water body chemical profiles. Other methods can work well to detect the location of illicit connections, such as closed circuit television (CCTV), flow monitoring, and smoke or dye testing. The selection of which IDDE methods to use is greatly enhanced by some foreknowledge of what the illicit discharge may be. Such foreknowledge can be obtained by a desktop assessment of activities and conditions in an area to determine the potential for the presence and type of illicit discharges. Gaining this foreknowledge can provide significant time and cost savings compared to uninformed IDDE investigations. Additional literature or effectiveness studies are needed to determine which methods work best under which circumstances and what, if any, foreknowledge was used to help select IDDE methods.

A resource currently in progress that will help Washington state NDPES permittees choose IDDE methods is a field screening manual for Washington Phase I and Phase II permittees. The precursor to the manual, a draft report of IDDE survey results and literature review (King County 2012) is available that has summary information about which IDDE methods work best for this region. Methods were ranked low, medium, and high based on input from NPDES jurisdictions around the state. The most effective methods were having an IDDE hotline, inspections of manholes/catch basins, and inspections of outfalls. However, these were also some of the more expensive options. The report also provides the pros and cons of 14 IDDE methods, and this information should provide a useful toolbox of IDDE methods and approaches for SWMP staff to use in their IDDE efforts.

An additional resource currently under development that could help western Washington NPDES permittees in the selection of IDDE methods is a regional repository of information about IDDE findings. The Source Identification Information Repository (SIIR, Monsey et al. 2012) is a project of the SWG's Source Identification and Diagnostic Monitoring subgroup. The SIIR project is envisioned to be an information source that will address the Permit Fact Sheet guidance to "allow permittees to share source identification program information and provide a regional understanding of stormwater pollutant sources" (Ecology 2011e). Resources from SIIR will include a database of findings from IDDE-related activities around the region that can help jurisdictions compare results from IDDE efforts and help inform which IDDE methods work best under different conditions.

2.5.2 Question: How effective is wet weather screening as a tool to detect illicit connections?

The effectiveness of wet weather screening to detect illicit discharges was not specifically addressed in the literature in the effectiveness database. Dilution during wet weather is the most significant challenge for detecting chemical indicators of illicit discharges. Dry season screening is the preferred method in general, but dry periods may not coincide with when illicit discharges occur, especially from seasonal or intermittent activities or when discharges are diluted by fluctuating baseflow and groundwater levels in a watershed. Observation of certain deposits and algal or biological growth at stormwater outfalls can indicate the presence of illicit discharges in areas that experience frequent wet weather. In addition, the CWP (2004) promotes the use of a chemical indicators database where the presence of ammonia, fluoride, potassium, and other parameters are used to establish "fingerprint" profiles of water chemistry. When established on a regional scale, jurisdictions can review chemical profiles in water bodies in the region as well as the IDDE efforts by others to help identify what methods work best during wet weather flows. A chemical indicators database uses the principle that the presence of combinations of certain chemicals can indicate the source of an illicit discharge. For example the presence of fluoride and potassium together can indicate industrial discharge. Chemical indicator monitoring is not meant to be stand-alone IDDE method and is not the least expensive method either. Rather, it is intended to be used selectively in combination with other IDDE methods and investigations. Additional literature or effectiveness studies are needed to provide a more thorough review of how a variety of IDDE methods can be used successfully during wet weather.

2.5.3 Question: Which parameters should be measured during dry weather screening to improve the ability to detect illicit connections?

The parameters to be measured during dry weather screening to improve the detection of illicit discharges were not specifically addressed in the literature in the effectiveness database. As with the selection of IDDE methods in general, detecting illicit discharges during dry weather is greatly enhanced by some foreknowledge of what the illicit discharge may be (CWP 2004). Several western Washington jurisdictions have already developed dry weather screening manuals or procedures as part of the IDDE requirement in the previous NPDES permit (Ecology 2007). These include the City of Seattle (Seattle 2010), Snohomish County (2009), and City of Bainbridge Island (2009), among others. Seattle recommends screening for 15 parameters during dry weather screening, ranging from flow to discharge odor to chemical screening. Snohomish County and Bainbridge Island recommend starting with a dry weather screening for parameters including presence, color, and odor of flow.

2.5.4 Talking points for IDDE

> *Talking Point 6*: Several methods and combinations of methods work well for detecting illicit connections. Foreknowledge of what potential illicit discharges may occur from an area is an important first step that can help inform what methods may work best.

The best method(s) to be used for detecting illicit discharges and connections to a storm sewer network depends on the nature of the potential illicit discharge. Smoke and dye testing can work well for detecting illicit connections, and outfall screening and monitoring of flow and indicator chemicals can work well for detecting illicit discharges. Foreknowledge of the activities and industry types can provide essential information to establish profiles of certain areas and prioritize IDDE methods. Information from a background survey and literature review of IDDE field screening (King County 2012) from NPDES permittees reports that an IDDE hotline, inspections of manholes/catch basins, and inspections of outfalls have the highest effectiveness. However, there are pros and cons of each screening method, which should be considered along with the cost of each method prior to commencing IDDE screening. A resource currently under development that could help Washington NPDES permittees select

IDDE methods is the Source Identification Information Repository (SIIR, Monsey et al. 2012). The SIIR is envisioned to be an information resource that will allow permittees to share information about IDDE efforts. Additional information is needed in the effectiveness literature database to more thoroughly address which IDDE methods and combinations of methods work best across a range of conditions. Grouping methods by cost level and level of detail of results would be a helpful addition to sorting the many IDDE methods available.

An alternative question to consider is what combination of IDDE methods is most appropriate for specific land uses and business types.

> *Talking Point 7*: Wet weather screening can be effective when implemented with foreknowledge of what illicit discharges may be present and as part of a comprehensive IDDE program. Additional literature or effectiveness studies are needed to more thoroughly address how wet weather screening is best used.

Even though wet weather flows can dilute illicit discharges, it is still possible to successfully screen for them. The information available in the effectiveness literature database does not address wet weather IDDE screening. However, the CWP (2004) suggests establishing a regional chemical indicators database to identify profiles of chemicals in stormwater that can point toward the presence of certain types of illicit discharges. Wet weather screening especially requires a combination of methods to overcome the challenge of dilution. Additional literature or effectiveness studies are needed to more thoroughly address how wet weather screening can be most effective and what combination of methods can help verify the findings of wet weather screening.

> *Talking Point 8*: Several western Washington jurisdictions have developed dry weather screening manuals. As with selecting IDDE methods in general, gaining some foreknowledge of what to expect in certain areas can be very useful for selecting parameters to measure during dry weather screening. Outfall screening has been shown to be an effective tool.

Although dry weather screening can be easier to target discrete pollutants due to the lack of dilution by wet weather runoff, knowing what to look for is still necessary. Thus, as with other IDDE methods, some foreknowledge via desktop assessment can be valuable to select dry weather screening parameters. Several western Washington jurisdictions have developed IDDE dry screening procedures and indicate that effective parameters to investigate include flow monitoring, visual inspection of outfalls for discharge odor and color, and presence of algal growth and deposition patterns. In addition, chemical screening of dry weather discharges can be informative but also more expensive depending on what chemical parameters are analyzed.

2.6 SUMMARY OF LITERATURE: BUSINESS INSPECTIONS AS SOURCE CONTROL

2.6.1 Question: Are businesses that receive an in-person visit/inspection more likely to implement source control BMPs?

Business inspections related to source control were not covered in the publications in the effectiveness database. Business inspection is more a public education and outreach topic than a strictly source control topic. The list of source control BMPs in volume IV of the SWMMWW includes many that are specific to the activity, industry, or setting. Therefore, in-person inspections should be performed by knowledgeable personnel who can identify proper use of BMPs and specify correction actions when needed.

Since 2008, Washington state has implemented the Local Source Control Partnership (LSCP) throughout Puget Sound and in the Spokane River watershed. The LSCP focuses on inspections of small-quantity generator businesses for pollution prevention. Experience by this author with the LSCP for two cities in western Washington has indicated that in-person visits can be an effective tool for implementing source control BMPs. However, the success of a lasting positive effect for stormwater source control at businesses is the result of a combination of education, inspection, and enforcement. Businesses should be prioritized by risk of pollution and personnel turnover rate to ensure new staff are informed about source control BMP operation. Additional literature or effectiveness studies are needed that addresses the connection of inspecting businesses and the successful long-term implementation of source control BMPs.

2.6.2 Question: What frequency of business inspections is most effective for implementing and maintaining source control requirements/BMPs at businesses?

As noted above, business inspections related to source control BMPs for stormwater were not covered in the publications in the effectiveness database. Personal experience by this author has shown that, as with inspections of private stormwater facilities, the frequency of inspections at businesses is affected by the type of BMPs present. As a form of non-structural BMPs themselves, inspections require regular contact to build relationships with owners, managers, and staff at businesses. Positive relationships can encourage businesses to comply with proper BMP usage, and follow-up visits can improve compliance rates even further. Conversely, strained relationships and bad attitudes by businesses toward government agencies can negatively impact proper BMP usage. To answer this question, additional literature or effectiveness studies are needed that explore the relationship between inspection frequency and source control BMPs.

2.6.3 Talking Points for Business Inspections as Source Control

> *Talking Point 9*: In-person visits to businesses can help encourage the implementation of source control BMPs. Knowledgeable staff is necessary to competently inspect the range of source control BMPs present at businesses. Additional literature or effectiveness studies are needed to address how in-person inspections affect the use of source control BMPs.

One publication in the effectiveness literature database included incidental reference to visits to businesses in Kitsap County for source tracing and source control of bacteria (Fohn 2010). They reported positive results from business inspections but related the results only generally to control of bacterial sources by businesses due to in-person site visits. There is a wide range of BMPs at businesses due to the variety of industries that are included under the general category of “business inspections.” Inspection staff knowledgeable of the range and proper usage of BMPs expected to be encountered is necessary. Experience by this author with the LSCP in Washington has shown that in-person visit can result in effective use of source control BMPs and that follow-up is important. However, more information is needed that addresses the relationships among in-person inspections, education, and enforcement of proper use of source control BMPs.

> *Talking Point 10*: The optimum frequency of inspections at business depends on the type of BMP present and the relationship with businesses. Follow-up inspections can improve BMP compliance. Additional literature or effectiveness studies are needed to address how the frequency of in-person inspections affects the use of source control BMPs

The literature in the effectiveness database did not address frequency of business inspections. This topic fits better under public education and outreach since it relates to behavior change. The type of BMP and the nature of the relationship between agencies and businesses can affect the optimum inspection frequency. More literature or effectiveness studies are needed to identify what frequency of inspections at businesses produces the best results for source control.

3.0 CONCLUSIONS AND RECOMMENDATIONS

This review of stormwater source control best management practices has several key findings for each topic covered. The four topics are erosion and sediment management at construction sites, site visits of private stormwater facilities, illicit discharge detection and elimination, and source control inspections at businesses. The key findings and suggested effectiveness studies are as follows:

3.1 EROSION AND SEDIMENT MANAGEMENT AT CONSTRUCTION SITES

1. Temporary erosion and sedimentation control (TESC) BMPs used at construction sites can be effective at controlling erosion. Effective use depends on BMP selection, operation and maintenance, and site conditions.
2. Source control BMPs are a necessary component of erosion and sediment management at construction sites. The requirements for BMP use in western Washington are found in the NPDES stormwater permits and the details of the BMP options can be found in the SWMMWW (Ecology 2012d).
3. Construction TESC BMPs reviewed in the available literature indicate that polyacrylamide (PAM), compost and mulch mixes used in socks, rolls, and blankets, and geotextile-based BMPs show the best performance for preventing and controlling erosion. Effectiveness of PAM is highest in conjunction with another BMP, such as with compost filled blankets placed on slopes or straw filled check-dams wrapped in geotextile fabric placed in a channel directing discharge to a treatment pond or infiltration zone.
4. Application rates of PAM in the literature varied from 0.03 pounds of powder spread over one acre (lb ac^{-1}) up to 9.3 lb ac^{-1}. Washington state has strict guidelines about the use of PAM with allowable application rates of up to 0.66 lb ac^{-1}, or 80 mg L^{-1} in solution. Due to concerns about potential toxicity and the requirement that PAM not enter receiving waters, it is currently not a widely used construction BMP in western Washington.
5. Compost-based TESC BMPs have the added benefit of providing nutrients to encourage plant growth, which is a necessary component of long-term erosion management. However, compost has the drawback of the possibility of nutrient export, which can cause unwanted algal and plant growth in receiving waters.
6. Chemical treatment BMPs should be used in combination with other TESC BMPs at construction site to reduce turbidity to benchmark levels for compliance with water quality standards. Ecology's SWMMWW and C-TAPE program have lists of approved chemical treatment BMPs.
7. Sediment pond (detention basin) design and sizing can strongly influence the ability to effectively capture and contain suspended sediment. The design and sizing criteria for sedimentation ponds in western Washington could be improved by including an explicit estimation of anticipated sediment loading.

8. A review of CESCL training requirements in warranted to ensure TESC inspectors have the latest information about emerging technologies.

3.1.1 Recommendations for Additional Literature and Effectiveness Studies

1. Relatively few TESC BMPs were covered in the literature available in the effectiveness literature database. Additional literature is needed to review the full range of TESC BMPs.
2. A review of PAM performance in western Washington is warranted. Such a review should include potential toxicity of anionic PAM used for erosion control as well as PAM performance with the types of soils present in western Washington.
3. A review of sediment pond sizing and design is recommended based on literature reviewed. Current sizing in the SWMMWW is based on peak flows of anticipated stormwater runoff. Inclusion of a step to estimate sediment loading is recommended to improve sizing and design of sediment ponds for maximum sediment retention.
4. An alternative question to consider is which combinations of TESC BMPs listed in the SWMMWW are the most effective at controlling erosion and sediment from construction sites across the range of conditions in western Washington.

3.2 SITE VISITS OF PRIVATE STORMWATER FACILITIES

1. Site visits and inspections of private stormwater facilities can have positive effects on the operation and maintenance of stormwater BMPs. Effective use of stormwater facilities by private entities can be encouraged by establishing good relationships between agencies and private facility operators.
2. Positive relationships can be encouraged by tailoring communications to the specific agency goals for building relationships with owners and managers of private stormwater facilities.
3. The optimum frequency of site visits at private stormwater facilities depends partly on the types of facilities present.

3.2.1 Recommendations for Additional Literature and Effectiveness Studies

1. Inspections of private stormwater facilities in a bacterial pollution study in Kitsap county were shown to generally contribute to overall benefits in water quality. More literature or effectiveness studies are needed to verify this result and explore the connection between site visits to private stormwater facilities and downstream water quality benefits.
2. Additional literature or effectiveness studies are needed to address what frequency of inspections is best to maintain private stormwater facilities.
3. An alternative question to consider is what combination of inspection of private stormwater facilities and education of their owners and operators is most effective for improving compliance with operations and maintenance requirements.

3.3 ILLICIT DISCHARGE DETECTION AND ELIMINATION

1. Foreknowledge of what potential illicit discharges may occur from an area is an important first step that can help inform what IDDE methods may work best. A desktop assessment of activities and drainage network in an area of interest can provide this foreknowledge.
2. During wet weather screening, dilution of illicit discharges is the main challenge to overcome. Chemical indicator monitoring is recommended in the literature and should be used in combination with other IDDE methods for conclusive determination of illicit connections.
3. The forthcoming Source Identification Information Repository (a project of the SWG Source Identification and Diagnostic Monitoring subgroup, Monsey et al. 2012) will be a valuable resource for allowing local agencies to compare IDDE findings and help point toward effective IDDE methods for conditions in western Washington.
4. Several western Washington jurisdictions have developed IDDE dry weather screening manuals. Primary methods recommended in those manuals include flow monitoring and inspection of outfalls and storm catch basins for odorous or discolored discharge.
5. A forthcoming IDDE field screening manual (King County 2012) will have a useful toolbox of information for deciding which IDDE methods work best. Based on preliminary findings from a survey used to develop the manual, the most effective methods were establishing an IDDE hotline, outfall screening, and inspection of stormwater manholes and catch basins.

3.3.1 Recommendations for Additional Literature and Effectiveness Studies

1. Establish a regional chemical indicators database for local entities to compare results across the region of water quality profiles and IDDE efforts.
2. Additional literature or effectiveness studies are needed to more thoroughly address what combination of IDDE methods work best for wet weather screening.
3. An alternative question to consider is what combination of IDDE methods is most appropriate for specific land uses and business types.

3.4 INSPECTION OF SOURCE CONTROL BMPS AT BUSINESSES

1. In-person visits to businesses can help encourage the implementation of source control BMPs. Although inspections of businesses were not addressed in the literature, personal experience by this author indicates that the presence of inspectors can sometimes result in immediate correction to the proper usage of source control BMPs.
2. The optimum frequency of inspections at business depends on the type of BMPs present and the relationship with businesses. Regular follow-up inspections can improve long-term BMP compliance.
3. Knowledgeable staff is necessary to competently inspect the range of source control BMPs present at businesses.

4. The topic of business inspections for BMPs relates to human behavior and psychology as much or more so than to technical operation and maintenance of BMPs.

3.4.1 Recommendations for Additional Literature and Effectiveness Studies

1. Additional literature or effectiveness studies are needed to address how in-person inspections and the frequency of inspections affect the use of source control and other BMPs at businesses. Specifically, such literature or studies should explore the relationships among in-person inspections, education about BMPs, and enforcement for compliance.
2. A valuable resource for investigating recent and current business inspections in Washington is Ecology's Local Source Control Partnership being implemented throughout Puget Sound and in the Spokane River basin. It is recommended to confer with that program in designing an effectiveness study on business inspections.

Of the 336 publication titles in the effectiveness literature database, 48 were identified as relevant to the four main topics that served as the organizing principle for this white paper. However, only a subset of those 48 titles addressed the specific ranked questions posed by the SWG. In many ways, this white paper was an exercise in matching articles in the effectiveness literature database as best as possible to the questions posed. Results from this white paper recommend additional literature to fill gaps in knowledge for each of the four main topics. There are also recommendations of effectiveness studies that can be considered and implemented without further literature review. In this way, the conclusions of this white paper can be used to help prioritize effectiveness studies and also identify areas where additional knowledge is required.

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