RE-EVALUATED: A REGIONAL DATA EVALUATION OF ILLICIT DISCHARGE, DETECTION, AND ELIMINATION (IDDE) RECORDS IN WESTERN WASHINGTON.

by

Skyler Specht

A Thesis
Submitted in partial fulfillment
Of the requirements for the degree
Master of Environmental Studies
The Evergreen State College
August 2022

This Thesis for the Master of Environmental Studies Degree

by

Skyler Specht

has been approved for

The Evergreen State College

by

Ralph Murphy, Ph.D.

Member of Faculty

Date

ABSTRACT

Re-evaluated: A Regional Data Evaluation of Illicit Discharge, Detection, and Elimination (IDDE) Records in Western Washington.

Skyler Specht

In 2017, Stormwater Action Monitoring (SAM) published the Illicit Discharge Detection and Elimination (IDDE) Regional Data Evaluation for Western Washington, a regional monitoring study that evaluated IDDE records from the 2014 permit reports submitted from municipal stormwater permittees as part of their annual reporting requirements. Through the efforts of this study, a standardized reporting format was created to help facilitate the ease of data collection and analysis among permittees that began rollout starting in 2020. In this thesis, IDDE records submitted through the new standardized reporting format in the first year of its utilization in 2020 were collected to perform a similar type of analysis using methodology modified from the original regional data evaluation.

Table of Contents

List of Figures

List of Tables

Acronyms

BMPs	Best management practices
EPA	Environmental Protection Agency
ERTS	Environmental Response Tracking System
IDDE	Illicit Discharge Detection and Elimination
MS4	Municipal Separate Storm Sewer System
NEPA	National Environmental Policy Act
NPDES	National Pollution Discharge Elimination System
PARIS	Permit and Reporting Information System
PRO-C	Pooled Resources Oversight Committee
RSMP	Regional Stormwater Monitoring Program
SAM	Stormwater Action Monitoring
SWG	Stormwater Work Group
SWMP	Stormwater Management Program

Acknowledgements

I would like to express my sincere gratitude to my thesis reader and MES Faculty Ralph Murphy, who provided consistent support and a myriad of his time in guiding me through this research. I also want to thank MES Faculty Shawn Hazboun, who provided oversight to me during the beginning stages of my thesis research. Averi Azar, Assistant Director of MES, also deserves recognition for her assistance and guidance throughout the thesis process. The 2017 SAM Source ID study, the Illicit Discharge Detection and Elimination (IDDE) Regional Data Evaluation for Western Washington, must also be referenced as it is a foundational element of this analysis. I would also be remiss without mentioning my work colleagues for their comments and suggestions regarding my thesis research. Finally, I want to acknowledge my fiancé and my family for their unwavering support and belief in me. I would not have been able to complete this thesis without their encouragement throughout these past few years.

Positionality Statement

To provide transparency to my role as a researcher, I am a stormwater inspector for a Phase II municipal stormwater permittee in Western Washington doing thesis research independent of said organization to fulfill the requirements of this degree. My job duties primarily relate to the operation and maintenance of private stormwater facilities, however for this thesis I have decided to focus on the Illicit Discharge Detection and Elimination component of the municipal stormwater permit. As stormwater has been a part of my daily life for a better part of the last three years, I have built an understanding of the municipal stormwater permit and stormwater management in Washington State, however much of my knowledge and expertise relates to operations and maintenance of stormwater facilities, not necessarily on Illicit Discharge Detection and Elimination. To provide clarity to the reader, I rely on primary sources and not my first-hand experience throughout this analysis.

Introduction

To meet stormwater monitoring needs of municipal separate stormwater sewer systems (MS4s) for municipalities, a preliminary study was conducted to evaluate Illicit Discharge Detection and Elimination (IDDE) using records from municipalities in Western Washington from self-reported permit submissions in 2014 (SAM, 2017). This research seeks to further evaluate regional spill data using data from 2020 to look for new or existing trends in the spill data. Furthermore, it is an attempt to further the conversation that was started regarding regional IDDE Evaluation in Western Washington. This chapter will provide context to the origins of the initial study, its findings and significance, and the purpose and objective of continuing of this research.

Municipalities in urbanized areas in the United States are required under the National Pollutant Discharge Elimination System (NPDES) enacted under the Clean Water Act to obtain a municipal stormwater permit from the Department of Ecology. In Western Washington, there are 6 Phase I municipalities (cities and counties with a population over 100,000) and 88 Phase II permittees (urbanized growth areas with a population less than 100,000). The permit requires the establishment of a Stormwater Management Program (SWMP) which requires, among many components, an Illicit Discharge Detection and Elimination (IDDE) program designed to deter pollutants from entering stormwater and surface waters, and to detect and eliminate illicit connections to the MS4. An illicit connection is an unpermitted or undesired connection to the MS4 such as a sewer pipe, floor drain, or other pipe inlet or outlet. An illicit discharge is any discharge to the MS4 that is not entirely stormwater, or allowable non-stormwater discharges as allowed by the permit (Herrera Environmental Consultants & Aspect Consulting, 2020) As part of this program to eliminate illicit connections and track and reduce illicit discharges, permittees must submit their IDDE records annually to the Department of Ecology (Washington State Department of Ecology, 2019d, 2019c). Each IDDE record represents a specific discharge event that was discovered by or reported to the municipality, whether it be an illicit connection to the MS4 or a spill of any kind of pollutant that may discharge to the MS4.

In 2017, Stormwater Action Monitoring (SAM), a permittee-funded regional monitoring program in Western Washington, funded and published the Illicit Discharge Detection and Elimination (IDDE) Regional Data Evaluation for Western Washington (Aspect Consulting, 2017). This study evaluated IDDE records submitted in 2014 from 78 total municipalities in Western Washington as part of the annual reporting requirements of the municipal stormwater permit. This first SAM Source Identification (Source ID) project helped further the goal of the subgroup to provide information on successful illicit discharge detection and elimination methods and strategies to reduce the discharge of pollutants to stormwater. The report indicated a wide variety of reporting formats and the obvious necessity for a standardized reporting format due to the of preliminary task the team overtook in transcribing the data to fit within a common schema (Aspect Consulting, 2017). In addition, the study identified the most common pollutants, source tracing methods, methods of reporting, correction and elimination methods, and incident response times. Directly following this study, the Source ID subgroup worked with the Department of Ecology to come up with a standardized data reporting format that is now required to be used in the most recent iteration of the permit, starting 2020 (Washington State Department of Ecology, 2019a).

With the first Source ID data evaluation complete and a new data schema in place to facilitate standardization of IDDE reporting, 2020 would be the first year that permittees would use the new reporting format that would utilize Ecology’s Water Quality Permitting and

Reporting Information System (PARIS). The standardized reporting format would allow for direct comparison between individual IDDE records between permittees without the previously required coding element to compare between the various reporting formats that were previously accepted. This also enabled Ecology to compile IDDE records from municipal stormwater permittees into an online database that enabled a much more feasible method of data collection, as the previous method required the collection of each individual permittee's IDDE report via Ecology's "Document Search" database.

The purpose of this thesis is to perform a regional data evaluation of the 2020 IDDE report data, the first year of available annual IDDE reporting data collected using the new standardized reporting format via Ecology's online PARIS IDDE Report database. This extends the research of the previous regional data evaluation which performed analysis on 2014 data prior to the establishment of the standardized reporting format. To set up the foundation for this research, the literature review will first review stormwater regulation and specifically municipal stormwater regulation in the United States and more locally in Washington State. The next section will focus on the IDDE element of the municipal stormwater permit including regional monitoring efforts and groups associated with such efforts including SAM, and then review the Illicit Discharge Detection and Elimination (IDDE) Regional Data Evaluation for Western Washington which provides the foundation for this analysis.

Chapter 1. Literature Review

Introduction

To establish context to this study, it is necessary to review key background information regarding the establishment of stormwater regulation in the United States and highlight the previous study which is foundational to this research. This chapter will start with a review of the origins of federal water quality regulation, then cover the growing environmental movement in the 1960's and 1970's. This will lead to the 1972 introduction of the Clean Water Act and focus on point source pollution, and the subsequent addition of the Municipal National Pollutant Discharge Elimination System (NPDES) Program focused on reducing non-point source pollution. The next section will move more locally to Western Washington to review municipal NPDES stormwater regulation in Washington State and stormwater work groups associated with said regulation that are relevant to this research. The last elements of this chapter will focus on the Illicit Discharge Detection and Elimination (IDDE) component of the municipal stormwater permit and the Illicit Discharge Detection and Elimination (IDDE) Regional Data Evaluation for Western Washington (2017) that serves as the basis for this research.

Federal Stormwater Regulation and its Origins

Federal Water Pollution Control Act of 1948

Much of the federal stormwater regulation within the United States receives its origin from a federal statute commonly referred to as the Clean Water Act, originally known as the Federal Water Pollution Control Act of 1948 prior to sweeping amendments made in 1972. The 1948 law was the first major law passed by Congress regarding the federal regulation of water pollution in the United States, as previous regulation had largely focused on water transportation and quantity, not quality (Hunter & Waterman, 1996). The Rivers and Harbors Appropriation

Act of 1899 was technically the first federal law regarding water quality as it established federal oversight of navigable waters within the United States and controlled river and harbor improvements (EPA, n.d.-b). The 1948 law was a good first attempt to establish widespread regulation, but the enforcement mechanisms established were flawed in that it was very difficult to establish a link between an impaired waterway to a particular discharger. In addition, direct federal involvement in enforcement was limited to interstate matters, so much of the oversight authority was delegated to the states (Copeland, 2014). Because many states did not have the financial capacity or lacked the commitment to implement the programs outlined in the act, implementation was scattered and ineffective (Hunter & Waterman, 1996). By the 1960's, the overall perception of water quality regulation in the United States was poor, as frustration loomed over the slow response to cleaning up impaired waterways, in addition to the time-consuming nature of the enforcement process of the current legislation (Copeland, 2016).

Environmental Awareness in the 1960's and 1970's

By the late 1960's, public attention for the health of the nation's waterways was at an all-time high. In January 1969, a massive oil spill off the coast of Santa Barbara killed an indescribable amount of fish, seabirds and other aquatic life, and impacted nearly eight hundred miles of beaches (Clarke & Hemphill, 2002). In their 2002 retrospective of the oil spill events, Clarke and Hemphill describe the damage as so extensive that people of all age groups and political affiliations immediately came together to help begin cleanup, and a grassroots movement began that would quickly pick up steam. In June of 1969 when the Cuyahoga River caught fire in Cleveland, public attention turned to public outroar. The river had just caught on fire for the 10th time since 1868 and for the first time since 1952, when public sentiment towards industrial pollution was mostly indifferent: the river had been used for industrial discharge of a wide variety of solvents, oils, and industrial pollutants for generations (Blakemore, 2019). Beyond Cleveland, where the complacent belief at the time was that the fires were simply , the nation would become outraged at the events that would unfold on their TV screens and in their newsprint media: it was simply becoming too much (Blakemore, 2019). In 1971, Ralph Nader formed a task force that would subsequently release *Water Wasteland,* a report providing anecdotal evidence of the horrific state of U.S. waterways. This report documented findings of multiple studies, including mercury-contaminated drinking water, DDT levels in fish nearly ten times the legal limit, unsafe swimming areas due to bacterial contamination, and multiple record fish kills including the single largest fish kill event to date – 26.5 million fish due to discharges from food processing plants in Lake Thonotosassa, Florida (Adler et al., 1993; Zwick et al., 1971). The report, confirmed by governmental sources to be legitimate, pushed the issue of water pollution even further into the limelight of media attention (Adler et al., 1993).

The nation could no longer wait for water pollution regulation. This was the generation of Rachel Carson's *Silent Spring,* whose book inspired millions of Americans to open their eyes to the impact of DDT and other contaminants in nature and is often associated as a piece of foundational media leading up to the implementation of the CWA. Carson's book was just one small example of the growing movement of environmentally focused media, from books, articles, scientific literature, to nature shows and songs heard on the radio (Stradling, 2013). But there were other pressing social and political concerns at hand at the same time in the United States. Author David Stradling in his book *The Environmental Movement,* describes the social context of concentrated urban poverty, racism, and the callousness of the Vietnam War and how it created a situation where "civilization itself appeared to be threatened" (2013, p. 6). Stradling

(2013) proceeds to address the anxiety much of the nation felt by referencing Allan Temko's 1963 *New York Times* article which perfectly captures the sentiment of the era:

> Confronted by an environmental crisis of now almost incredible gravity, as traditional urban civilization disintegrates without a coherent order of technological civilization to take its place, our supposedly affluent and inventive society finds itself strangely powerless to establish rational patterns of growth (p. 6).

With public awareness of environmental problems and water quality issues at an all-time high during the late 1960's, the pathway was paved for change in the 1970s. In Robert Adler's 1993 book *The Clean Water Act 20 Years Later*, he portrays the Clean Water Act as an example of the "new social regulation of the seventies", describing its origin as the product of swift action from Congress due in response to demands from "newly empowered mass movements and interest groups" (Adler et al., 1993, p. 198). Adler also suggests that such activism and environmental values helped establish a political climate that encouraged politicians to "push the limits on such legislation" (pg. 198). It was clear by the 1970's that the nation was ready for water quality regulations at a federal level. Early on in his presidency, Richard Nixon declared that the 1970's must be an era reclaiming the purity of the nation's waterways, air, and environment, and to own up to the mistakes of the past. On January 1, 1970, Nixon signed the National Environmental Policy Act (NEPA), the first major environmental law in the United States requiring federal agencies to assess the environmental implications of their proposed actions prior to making any decisions. (EPA, n.d.-d; Nepa.gov, n.d.) This would eventually lead to the establishment of the Environmental Protection Agency later that year (Clarke & Hemphill, 2002). In April of 1970, the first Earth Day took place, which clearly demonstrated the nation's concern for the environment through public education and action (Stradling, 2013).

In the late 1960's and early 1970's, politicians were playing catch-up with this newly emerging national concern for the environment. In December of 1970, President Richard Nixon signed an executive order creating the Environmental Protection Agency (EPA), which combined several pollution programs into one agency. The EPA was the first and only regulatory agency in the United States that does not sit within the legislative government and is overseen by an administrator whose term runs concurrent with the president. This allows for the president to select an administrator of the EPA, although the selection must be confirmed by the Senate (Hunter & Waterman, 1996). Later in 1970, the Clean Air Act was signed, aimed at reducing air pollution and controlling air quality throughout the nation. The foundation was set for Congress to make big changes to the Federal Water Pollution Control Act, and it would come in the form of the Clean Water Act of 1972.

Clean Water Act of 1972

Between 1948 and 1972, five amendments to the Federal Water Pollution Control Act were made (see Table 1) (Copeland, 2014). The Water Pollution Control Act of 1956 strengthened enforcement provisions (EPA, n.d.-b); the 1961 Federal Water Pollution Control Act Amendments extended federal oversight to all navigable waters and coastal waters in the United States (Cohen & Sonosky, 1962); the Water Quality Act of 1965 established water quality standards for surface waters (EPA, n.d.-b); the Clean Water Restoration Act of 1966 which gave provisions to help guide the 1965 law (United States Senate, n.d.); and the Water Quality Improvement Act of 1970 which again expanded federal oversight of marine polluters (EPA, 2016). However, despite the many improvements since the introductory legislation in 1948 law, the resulting framework was a combination of ineffective water quality acts and change was needed to be able to effectively administrate and enforce water quality standards (EPA, n.d.-b).

Table 1

Clean Water Act Amendments

Year	Act
1948	Federal Water Pollution Control Act
1956	Water Pollution Control Act of 1956
1961	Federal Water Pollution Control Act Amendments
1965	Water Quality Act of 1965
1966	Clean Water Restoration Act
1970	Water Quality Improvement Act of 1970
1972	Federal Water Pollution Control Act Amendments
1977	Clean Water Act of 1977
1987	Water Quality Act of 1987

Note. This table includes the major amendments of the Clean Water Act. Modified from Copeland, 2014 for this study.

Congress began to draft the 1972 amendments to the Federal Water Pollution Control Act of 1948, completely rewriting the bill and shifting the focus from maintaining ambient water quality to increasing attention on individual dischargers (Hunter & Waterman, 1996). These sweeping amendments would be commonly referred to as the Clean Water Act. These amendments established a framework for regulating pollutant discharge from industrial point sources, mandated protection of the nation's surface waters, and delegated the Environmental Protection Agency the authority to delegate the provisions of the CWA. The act would set ambitious goals: the elimination of all pollution discharges into navigable waters of the United

States by 1985, and another goal to restore water quality to provide "…'fishable' and 'swimmable' waters…" to all navigable waters by 1983 (Copeland, 2014, p. 30).

With the establishment of the CWA, anyone who would discharge pollutants through a point source into a water of the United States would be required to obtain a National Pollutant Discharge Elimination System (NPDES) permit. The permit included constraints on what could be discharged, monitoring requirements, and other provisions to ensure the protection of United States waterways (EPA, n.d.-c). In addition, many technology-driven statutes were included to enforce industries to enforce best practicable control technology (BPT) to clean up industrial pollution (Copeland, 2014).

Federal Municipal NPDES Program

In 1977, the Clean Water Act was signed to provide initial fine-tuning to the 1972 amendments and further clarification of the legislature (Hall, 1978). The Water Quality Act of 1987 established the NPDES program for municipalities, requiring municipalities to develop nonpoint pollution control programs (Copeland, 2014). Prior to the amendments in 1987, regulation was directed towards point source pollution coming from discrete, identifiable industrial and municipal sources and had little focus on non-point pollution that comes from stormwater runoff picking up pollutants as it conveys to a waterway (Copeland, 2014). The EPA established the first phase of these requirements in 1990, requiring municipalities with a population of 100,000 or more (based on the 1990 census) to implement a Stormwater Management Program (SWMP) that would address outlined stormwater control components in the permit.

Now that the Clean Water Act and general water quality requirements have been introduced, this next section will focus specifically on non-point stormwater pollution and NPDES implementation in Washington State.

Washington State Stormwater Regulations and Monitoring Efforts

Washington State Municipal NPDES Program

The EPA allows states and tribes to oversee the implementation of NPDES programs and in Washington State, the Washington State Department of Ecology (Ecology) is the delegated authority that writes the permit and oversees its operation. Ecology published the first five-year cycle of the Phase I Municipal Stormwater Permit in 1990 (to begin in 1995) for cities and counties with a population greater than 100,000 based on the 1990 census. By 1999, the Phase II of the permit was published (to begin in 2003) for cities and counties with a population less than 100,000 in census-defined urban areas. In Washington State there are two Phase II permits based on region: the Phase II Municipal Stormwater Permit for Western Washington covers 80 cities and five counties; the Phase II Municipal Stormwater Permit for Eastern Washington covers 19 cities and portions of six counties (Washington State Department of Ecology, 2019b, 2019d). The five-year permit cycle process is designed to be adaptive so that the permit can evolve as our understanding of various pollutants and the methods and technology we use to eliminate them develop. Throughout each permit cycle, Ecology maintains a timeline for rollout of the next five-year cycle of the permit that includes several opportunities for permittees to provide comments to Ecology on existing and upcoming elements of the permit. With each iteration of the permit cycle, new permit elements for the permittees to establish are along with a specified timeline for rollout, along with any modifications of the existing sections of the permit based on feedback from municipal stormwater permittees.

Phase I and Phase II municipalities are required to submit an annual report that outlines each element of the permit in a questionnaire format that the permittee can fill out and submit online. The questions are designed to indicate whether the permittee has completed the outlined elements of each permit section and ask specified information regarding each permittee's SWMP and the actions they have taken to implement the components of the permit. The data from this analysis comes from a portion of this annual report that permittees are required to submit regarding spill records that the municipality has logged throughout the year. This will be explained in greater detail in the next section.

Illicit Discharge Detection, and Elimination (IDDE)

Now that an overview has been provided of the origins of federal municipal stormwater regulation and how federal regulation is implemented in Washington State, the component of the Municipal Stormwater Permit that pertains most to the topic of this analysis can be explored. As previously described Phase I and Phase II municipalities are required to implement a Stormwater Management Program (SWMP) that has outlined components that each permittee much include. In the current cycle of the Phase I Municipal Stormwater Permit, there are 11 SWMP components, including: Legal Authority; MS4 Mapping and Documentation; Coordination; Public Involvement and Participation; Controlling Runoff from New Development; Redevelopment and Construction Sites; Stormwater Planning; Structural Stormwater Controls; Source Control Program for Existing Development; Illicit Connections and Illicit Discharges Detection and Elimination; Operation and Maintenance Program; Education and Outreach Program. In the current cycle for both Phase II Municipal Stormwater Permits, there are 9 SWMP components, including: Stormwater Planning; Public Education and Outreach; Public Involvement and Participation; MS4 Mapping and Documentation; Illicit Discharge Detection and Elimination; Controlling Runoff from New Development, Redevelopment and Construction Sites, Operations and Maintenance, Source Control Program for Existing Development.

The analysis in this study focuses on the Illicit Connections and Illicit Discharges Detection and Elimination component of the Phase I and Phase II municipal stormwater permit. For this component of the SWMP, permittees must implement a program that includes multiple elements: eliminate non-stormwater discharges and illicit connections to the municipal separate stormwater system (MS4); implement an ordinance that prohibits non-stormwater discharges into the permittee's MS4; list a public hotline for public reporting of spills and other discharges; train staff responsible for responding to illicit discharges and illicit connections; and track and maintain records of all activities under this section. For the annual reporting requirements of this section of the permit, permittees are required to submit data for the illicit discharges, spills, and illicit connections that the permittee found, investigated, or were reported to. This analysis evaluates spill data that was submitted by municipal stormwater permittees for this permit obligation in 2020 for permittees in Western Washington. It is a continuation of previous regionally funded monitoring efforts in Western Washington which analyzed spill data for the 2014 calendar year.

The next section will review the Stormwater Work Group (SWG) and Stormwater Action Monitoring (SAM), two regional stormwater groups that are associated with the implementing monitoring associated with the municipal stormwater permit. SWG is responsible for oversight and implementation of SAM projects related to stormwater monitoring, which will be discussed in further detail.

Stormwater Work Group (SWG)

As Ecology describes on their Stormwater Work Group (SWG) webpage, most NPDES permits require some form of compliance monitoring. This presents a unique challenge for the municipal stormwater permit which applies to both point sources and non-point sources. As referenced earlier in this literature review, point sources are discernable conveyances including pipes, ditches, or other channels that are designed to convey specific discharges (EPA, n.d.-a). Non-point sources largely involve pollution coming from stormwater runoff as it picks up pollutants that exist over a broad landscape. These pollutants include fertilizers, oils and greases, sediment, bacteria, and other products from a variety of commercial, industrial, and residential sources (EPA, n.d.-a). The largest pollution concern comes from non-point pollution sources that are not a discrete, controlled source like the end of a pipe as they are difficult to track over a continuous landscape. Due to this, permittees came to Ecology to request an alternative to the traditional compliance monitoring that would be difficult, if not impossible to obtain (Washington State Department of Ecology, n.d.-e). Thus, in 2008, the Stormwater Work Group (SWG) formed to help guide a regional effort in understanding stormwater pollution and how to better manage it (Stormwater Work Group, n.d.-a). Participating stakeholders in the group include representatives of local, state, and federal governments, public ports, environmental and business organizations, and other various stormwater stakeholders in Puget Sound. In the first few years of the work group, hundreds of participants came together to develop a regional monitoring program for Western Washington (Washington State Department of Ecology, n.d.-e).

Within SWG, there are multiple subgroups that are designed to tackle specific issues within stormwater management, including the Effectiveness Studies Subgroup, The Source Identification Subgroup which we will discuss later in this section, and the most recently formed

6PPD Subgroup. This new subgroup formed to discuss and tackle 6PPD-quinone, a contaminant found in tire wear particles, that was recently linked to a widely documented phenomenon known as coho pre-spawn mortality in Puget Sound streams by researchers at UW Tacoma (Tian et al., 2022). Though it is not the core focus of this analysis, coho pre-spawn mortality rests within the core of stormwater literature in Puget Sound and must be referenced in the discussion of regional monitoring efforts. Recurrent die-offs of coho salmon returning to spawn in urban streams in the Seattle area were first documented in 1999 and 2000 during early monitoring efforts of newly accessible urban stream segments after a series of stream restoration projects in the 1990s (Scholz et al., 2011). This discovery led to a series of studies linking this phenomenon to toxic contaminants in stormwater from urbanized watersheds through spatial analyses of land use and coho mortality (Feist et al., 2011) and laboratory studies exposing coho salmon to untreated stormwater runoff (Scholz et al., 2011). Later studies provided evidence that simple biofiltration techniques are sufficient to eliminate the toxic effects of stormwater runoff to coho salmon (McIntyre et al., 2014, 2015, 2016), leading to a push to understand how biofiltration stormwater management techniques may mitigate against pre-spawn coho mortality.

Of the various subgroups within SWG, the Source Identification (Source ID) subgroup is most relevant subgroup to this study as it is responsible for the oversight and implementation of the Stormwater Action Monitoring (SAM) Source Identification projects. This includes oversight of the key study that will be covered in the next section, the Illicit Discharge Detection and Elimination (IDDE) Regional Data Evaluation for Western Washington. The Source ID subgroup formed in 2011 to help build tools to guide permittees in implementing the illicit discharge, detection, and elimination component of their SWMP (Stormwater Work Group, n.d.-

a). It will be discussed further in the next section when SAM Source Identification projects are covered.

Stormwater Action Monitoring (SAM)

Beginning with the launch of the 2014 permit cycle, Stormwater Action Monitoring (SAM) formed as a regional stormwater monitoring program funded by more than 90 municipal stormwater permittees in Western Washington. The overall goal of the group is to “improve stormwater management, reduce pollution, improve water quality, and reduce flooding” (Washington State Department of Ecology, n.d.-d) through targeted, collaborative studies. This program is the only example in the state where permit-driven monitoring efforts are defined and funded by the permittees themselves, allowing for the permittees to guide much of the overall process.

To explain how the relationship between this program and SWG, Washington State Department of Ecology (Ecology) serves as the administrator of SAM, overseeing the collection of the funds for the group and executing contracts for the projects. As a formal stakeholder group of SAM, SWG provides leadership, expertise, and general oversight of SAM projects. The Pooled Resources Oversight Committee (PRO-C) of SWG, the formal committee which oversees the pooled resources funding account, is responsible for overseeing Ecology’s implementation of SAM and the administration of SAM’s pooled resources (Stormwater Work Group, n.d.-b). The SAM coordinator works with PRO-C to review general administrative functions and discuss current projects. PRO-C provides consent for the SAM coordinator to execute contracts, gives general oversight, and reports back to SWG to discuss any issues that may need to be discussed further in subgroups, technical advisory committees, or with other various stakeholders (Stormwater Work Group, n.d.-c).

SAM studies focus on three broad categories related to stormwater management: effectiveness studies, status and trends studies, and source identification projects, the latter of which will be described in detail. SAM has published 14 effectiveness studies which focus on evaluating the viability of required or innovative stormwater management practices (Washington State Department of Ecology, n.d.-a). The status and trends studies focus on monitoring of Washington streams and nearshore waters in relation to stormwater management (Washington State Department of Ecology, n.d.-c). SAM's Source Identification studies are the most relevant to this thesis. These projects focus on discovering the best methods of preventing and eliminating illicit discharges, and detecting and reducing pollutants to stormwater (Washington State Department of Ecology, n.d.-b). The Source Identification subgroup of SWG oversees the implementation of SAM Source Identification projects. To date, three SAM source identification studies have been completed: the Regional Spill Hotline Feasibility Study, the Illicit Connection and Illicit Discharge Field Screening Manual, and the Illicit Discharge, Detection, and Elimination (IDDE) Regional Data Evaluation for Western Washington (Washington State Department of Ecology, n.d.-b). This next section will cover the regional data evaluation in detail as it serves as a foundation for the thesis.

SAM Source Identification Study: Regional Data Evaluation

In 2017, SAM completed the first Source Identification study, the Illicit Discharge Detection and Elimination (IDDE) Regional Data Evaluation for Western Washington. This study compiled IDDE incidents from the 2014 calendar year submitted by Western Washington municipal stormwater permittees as part of their annual permit reporting requirements. The identified goal of the study was to "…provide information on source identification and elimination methods and identify opportunities for regional solutions to common stormwater pollution problems related to illicit discharges and illicit connections" (Aspect Consulting, 2017, pg. 4).

In total 2,913 data records were compiled from 78 jurisdictions, including seven Phase I and 71 Phase II Permittees. At the time of the study, Ecology had an online submittal option with a standardized set of data fields available for permittee usage, however only 7 of the 78 reporting jurisdictions used this method as it was not part of the 2014 annual permittee submission requirements. Most of the records were thus obtained via Ecology's Permit and Reporting Information System (PARIS) designed for permittees to submit annual permit reporting data. The next step of the compilation phase required the team to organize the data records into a standardized database so that records could be compared. Because of this requirement, the authors included a set of recommendations in the study to "…reduce time-constraining data entry for future IDDE data collection…" (Aspect Consulting, 2017, pg. 11). As this analysis seeks to extend the research of this initial IDDE data evaluation, it serves as a representation of what the authors reference here and will be expanded on later in detail.

The standardized database included fields representing the type of incident (whether it was an allowable or illicit discharge), pollutant type, pollutant source, correction and elimination methods, how the incident was reported, and additional explanatory fields including the location, date, and the amount of time it took to resolve the incident. After the records were compiled into a standardized database, the records were evaluated by comparing counts of record types and incident characteristics primarily using graphical analysis. Statistical analysis was also performed to compare the records and to test for logical associations, (i.e., sediment pollution comes from a logical source such as a construction site, where sediment-exposing activity typically occurs).

In the discussion of this study, the authors reference five discussion topics relevant to the Source ID component of SAM, including the distribution of data among permittees, pollutants and their sources, source tracing and indicator testing methods, notification methods and response times, and correction and elimination methods. A modified version of these five discussion topics will be used in the discussion section to review the results. Thus, it is necessary to review the key findings from this study as the thesis will explore similar topics and trends. These findings are presented in the format of the five discussion topics below.

Distribution of Data. A total of 1,269 Phase I records and 1,644 Phase II records were obtained from 2014 annual IDDE permit submission reports. Data was weighted towards two cities in particular: one Phase I municipality contributed two thirds (59%) of the total IDDE records, and one Phase II contributed one fifth (19%) of the total IDDE records. The authors highlight that a low number of records from some jurisdictions, especially some of the larger Phase I entities with robust stormwater management programs, could represent room for improvement in terms of fulfilling the IDDE reporting requirements. However, as the authors indicate, this presumes that a high number of IDDE records represents a “good” implementation of the IDDE component (pg. 45). This is a valid critique as the number of records a municipality submits may be some indication of the level of effort the municipality places in tracking and recording IDDE incidents. Nevertheless, the number of records by itself is not a direct reflection of the quality of a municipality’s stormwater management program, as the quality of each record entry is also important.

Pollutants and Pollutant Sources. A total of 53 pollutants and 58 pollutant sources were grouped into eight pollutant categories and 7 pollutant sources categories during the data standardization process. Pollutant sources had to be manually interpreted through record notes.

The most common pollutants found were petroleum hydrocarbons from accidents and auto activities, sediment from construction sites, chemicals from industrial activities, and sewage from illicit connections. Statistical analysis confirmed logical association of pollutants to pollutant sources that expose said type of pollutant. These included sediment from construction sites, chemicals from industrial activities, and hydrocarbons from spills and dumping.

Source Tracing and Indicator Testing. To distinguish between the two, source tracing methods are the specific methods used to track a discharge. Indicator testing is a broad range of a visual, chemical, or odorous indicators that can be documented when tracing a spill. Source tracing methods were grouped into three categories from 10 reported methods during the data standardization process. These categories include in-pipe testing (i.e., dye testing, pressure testing, smoke testing, video testing), visual and empirical methods (i.e., visual reconnaissance, mapping), and an "other" category including methods such as canine detection. Visual and empirical methods were the most common source tracing methods, with the next-most frequent category including records that were left blank. Four categories of indicator testing methods were created from 18 reported methods during the data standardization process. These categories include chemical testing indicators, odor/pH/fecals, visual indicators such as turbidity (cloudiness of a liquid), and an "other" category for all other indicator tracing methods. Visual indicators were the most common category, suggesting that visual methods are most used for both source tracing and indicator testing. Statistical analysis confirmed the logical association of indicator types to pollutant types associated with said indicator. These included including chemical testing methods associated with in-pipe source tracing.

Notification Methods and Response Times. During the data standardization process, 19 reported notification methods were transformed into three notification categories. These include hotline calls and other reports directly to the jurisdiction, inspection or observation by staff, or referral from another agency. Hotline calls and other methods of direct reporting to staff were the most common methods of incident reporting, followed by inspections from field staff performing construction inspections, business inspections, or other field-related activities. Average response times ranged from within seven days for all incidents to within 21 days for illicit connections, with most responses occurring between one and three days.

Correction and Elimination Methods. From 13 reported correction and elimination methods, five categories were created during the data standardization process. These include enforcement, BMPs or cleanup, referral to another agency, no action needed, and an “other” category for all other methods. Discharges were corrected primarily with cleanup or implementation of Best Management Practices (BMPS). Enforcement was utilized to correct a discharge in a similar frequency for both Phase I and Phase II municipalities, although Phase I municipalities had a higher overall proportion of enforcement records.

Concluding Remarks. As referenced in the beginning of this section, the authors of this study indicated that the collection and standardization process was time-consuming in nature and could greatly benefit from a standardized data collection process. Due to these recommendations, the Source ID subgroup created an updated list of incident fields based on the optional data standardization schema from Ecology. Since then, the incident fields have gone through revisions and are now in a standardized schema that is required for usage by all municipal stormwater permittees as of 2021 (Washington State Department of Ecology, 2019a).

This regional data evaluation serves as key reference to how municipalities in Western Washington respond to illicit discharges and illicit connections. By examining common pollutants and their sources along with the common methods of correcting and eliminating said pollutants, municipal stormwater permittees can be better informed on how to guide their stormwater management programs in response. The authors indicate a myriad of uses these types of data evaluations can serve, including fostering inter-jurisdictional coordination, targeting public outreach efforts, tracking temporal and spatial trends, focusing municipal inspection efforts on common pollutants, among many others. Regional data evaluations are an effective tool to help guide municipal stormwater permittees in implementing the monitoring component of the permit and revisiting this type of data evaluation would be a practical exploration. Thus, analysis that follows serves as an extension of this original data evaluation which used annual reporting data from the 2014 calendar year. This analysis uses data collected from the 2020 calendar year and explores how changes to the IDDE reporting form have facilitated the collection of IDDE data since the implementation of the standardized reporting format.

Conclusion

This section started with an introduction to how water federal quality and stormwater regulation became established in the United States starting with the Federal Water Pollution Control Act of 1948. This first attempt of introducing federal water quality legislation proved ineffective, leading to a surge of environmental awareness and public engagement in the 1960's and 1970's surrounding numerous environmental catastrophes. With public support in full and after numerous attempts to amend the bill in its current state, Congress published sweeping amendments to the Federal Water Pollution Control Act of 1948 that would be commonly known as the Clean Water Act. This paved the way for the introduction of the Environmental Protection Agency (EPA) and the National Pollutant Discharge Elimination System (NPDES) permit including the municipal NPDES permit.

After covering the establishment of federal stormwater regulations, this literature review covered municipal stormwater regulations and current monitoring work performed specifically in Washington State. This started with an overview of the municipal NPDES permit in Washington State and the Illicit Discharge Detection and Elimination (IDDE) component of the permit. The regional stormwater groups and subgroups associated with monitoring efforts related to the municipal stormwater permit were next introduced as they are related to the first regional IDDE evaluation performed in Western Washington. Stormwater Work Group (SWG) and specifically the Source Identification subgroup led the oversight of the Stormwater Action Monitoring (SAM) Source Identification project, the Illicit Discharge Detection and Elimination (IDDE) Regional Data Evaluation for Western Washington. This study was covered in detail in the final part of the literature review. Key findings were outlined that will provide additional context to the findings presented in this analysis. In addition to these findings, this section referenced key discussion points raised by the authors, including the need for a standardized reporting format for municipal stormwater permittees to facilitate future regional data evaluations like the thesis that will now be presented. This next chapter will cover the methodology performed in this study, which evaluates IDDE submission data from the 2020 calendar year. This analysis serves to provide an extension of the research performed in the original SAM Source Identification regional data evaluation, which evaluated records from the 2014 calendar year prior to the implementation of the standardized data format.

Chapter 2. Methods

Introduction

This chapter describes the methods of data acquisition and data analysis. This includes both descriptive analysis in the form of graphical comparisons between data fields, and statistical analysis through chi-square contingency tests.

Data Acquisition

A total of 541 Phase I records and 1340 Phase II records were obtained from the Washington State Department of Ecology's (Ecology) Water Quality Permitting and Reporting Information System (PARIS) IDDE Report webpage. Using the fields on the PARIS webpage, records for filtered for the

I Municipal Stormwater Permit and Phase II Municipal Stormwater Permit for Western Washington for the 2020 annual report submission year. Since the focus of this study was Phase I and Phase II municipalities in Western Washington, data from the Phase II Municipal Stormwater Permit for Eastern Washington was excluded. The records contained in PARIS only contain records that were submitted by permittees through Ecology's WQWebIDE portal or through their own system that uses an XML IDDE schema provided by Ecology. As mentioned in the literature review, a new reporting schema was developed through the efforts of the SAM Source ID regional data evaluation. Permittees could begin using the new form and reporting method for the 2020 annual submission (Appendix 12) using either a zipped .xml file following the schema or another spreadsheet that follows the same schema (Washington State Department of Ecology, 2019a). By 2022, permittees are required to utilize the new standardized reporting using the zipped .xml format.

Each IDDE record contains the jurisdiction name and permit number; date the incident was discovered or reported date of beginning response; date of end of response; how the incident was discovered or reported; whether there was a discharge to the MS4; the incident location; pollutants identified; source or cause; source tracing approaches; correction/elimination methods; and a field for field notes, explanations, or other comments.

Descriptive Analysis

In the first phase of the analysis, a database was created to make frequency counts of six categories using a spreadsheet of the collected IDDE data, including: MS4 discharge; pollutant types; pollutant source; source tracing methods; correction and elimination methods; and discovery methods.

For the MS4 discharge analysis, MS4 discharge field responses were compared by phase type. For the five other categories besides MS4 discharge, the ten MS4 discharge field responses were combined to three categories: yes, no, and inconclusive for ease of analysis. “Yes” MS4 Discharge responses were combined from four responses: yes, allowable discharge; yes, no notice required; yes, notified Ecology; yes, notified Health. “No” MS4 Discharge responses were combined from the following responses: no, cleaned up; no, discharged to UIC (Underground Injection Control); no, none found. “Inconclusive” MS4 responses from the Phase II program were combined from three fields: other, unknown, and blank records (see Table 2).

Table 2

MS4 Discharge Fields and Combined Categories

Yes	No	Inconclusive
Yes, Allowable Discharge	No, Cleaned up	Other
Yes, No Notice Required	No, Discharged to UIC	Unknown
Yes, Notified Ecology	No, None found	Blank
Yes, Notified Health		

Note. The ten MS4 discharge fields and the three combined categories are described. This figure was derived from the analysis of this study.

Each of the five other categories (besides MS4 discharge) compared the respective category to MS4 discharge, using the combined MS4 discharge categories as described previously. This allowed for analysis of different spill incidents by the incident type, as will be explored in the results section. When performing the graphical analysis, separate spreadsheets and graphs were created to differentiate between Phase I and Phase II records.

Statistical analysis

Since the data in this study was largely categorical, chi-square analysis was performed to determine the relationship between individual variables and test for logical associations between the data. Chi-square analysis tests for differences between the observed and expected frequencies where the expected frequencies represent a random distribution of records. A statistically significant result indicates that the distribution of records is not random. As explained in the literature review, these tests can confirm logical associations such as sediment coming a construction site, or sewage from an illicit connection. This method was also used in the SAM Source Identification regional data evaluation using 2014 data.

This study performed analysis of the 2020 calendar year IDDE records from Phase I and Phase II permittees. Pollutant type categories were compared to five other category types: phase type categories, pollutant source categories, correction and elimination method categories, discovery method categories, and tracing method categories. Contingency tables were manually created using an excel spreadsheet for each test. For the statistical analysis portion of this study, chi-square analysis was performed using only IDDE records that had discharged to the MS4. This analysis included the four "yes" MS4 discharge responses record responses in the analysis (see Table 1). The reason for doing so was to perform analysis only on the data records that contributed a discharge to the permittee's MS4. Phase I and Phase II records were also combined for ease of analysis.

The two assumptions of the chi-square test are that no more than 20% of the cells can have an expected frequency of less than five, and no cell can have an expected frequency less than one. To meet these assumptions for each of the five statistical tests, categories were combined when necessary and where possible. In some circumstances, the assumptions could not be met without transforming the data substantially. In these situations, best judgement was used and if the assumptions were close to being met, the assumptions were deemed to have been met for the purposes of this study. Since the chi-square test is a relatively simple test that tests for associations between two or more categorical variables and is used primarily to test for logical associations and should be sufficient for this analysis.

A statistically significant result was determined by calculating a maximum likelihood chi-squared statistic for each of the tests and comparing to a critical value obtained using the chi-squared distribution the chi-squared with the associated significance level and degrees of freedom. A significance level of 0.05 (95 percent confidence level) and 0.001 (99.9 percent confidence level) were used to calculate the critical value that was then compared to the calculated maximum likelihood chi-squared statistics for each test.

When analyzing the contingency tables to examine for relationships between the data, if the residual (observed-expected) frequencies were greater than 10, an association between the two variables was assumed. If the residual was greater than 40, a high degree of association was assumed. The same could be said in the negative direction, with residual frequencies less than -10 considered an association, and residual frequencies less than -40 considered a high degree of association. These values were selected based on visual interpretation of the contingency tables. Since these contingency tables were manually calculated and statistical significance was only tested for the individual tests and not for these specific relationships, these associations are not confirmed to be statistically significant, but rather are to point out logical associations. However, a relatively high degree of confidence in the results was placed when with high (>50) or low (<-50) residuals. Using this type of analysis helps evaluate the relationship between the categorical variables.

Conclusion

This chapter described the data acquisition process of compiling IDDE records from the 2020 calendar year from municipal stormwater permittees. The process of how the descriptive analysis was performed was presented, demonstrating how the data was analyzed graphically by for each of the six IDDE field categories chosen to study in greater detail. Finally, the statistical analysis performed in this study was reviewed for the five chi-square categorical tests performed in this study. This next section will present the results of this analysis.

Chapter 3. Results

Introduction

This chapter covers the descriptive analysis and statistical analysis performed in this study. First, the descriptive analysis elements will be covered. This will start with a section highlighting the data represented, followed an in-depth analysis of the six IDDE field categories examined in the descriptive analysis phase. The following section will cover the statistical analysis portion of the study.

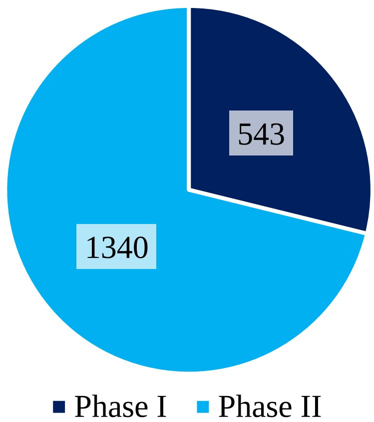
Descriptive Analysis

Data Represented

A total of 1340 Phase I and 543 Phase II records were submitted in a format that was compatible with Ecology's PARIS reporting system from 3 Phase I municipalities and 40 Phase II municipalities (see Figure 1 and Appendix B, Figure 18). City of Tacoma (396 records) and City of Seattle (136 records) contributed 98 percent of the total Phase I spill records, with Port of Seattle contributing 9 additional records. For Phase II municipalities, the top 5 contributing municipalities submit 100 or more IDDE records each, contributing nearly 60 percent of the total records (City of Kirkland, 266; City of Redmond, 156; City of Bothell, 127; City of Gig Harbor, 127; Kitsap County; 108).

Figure 1

Number of Records Submitted by Permittee Type



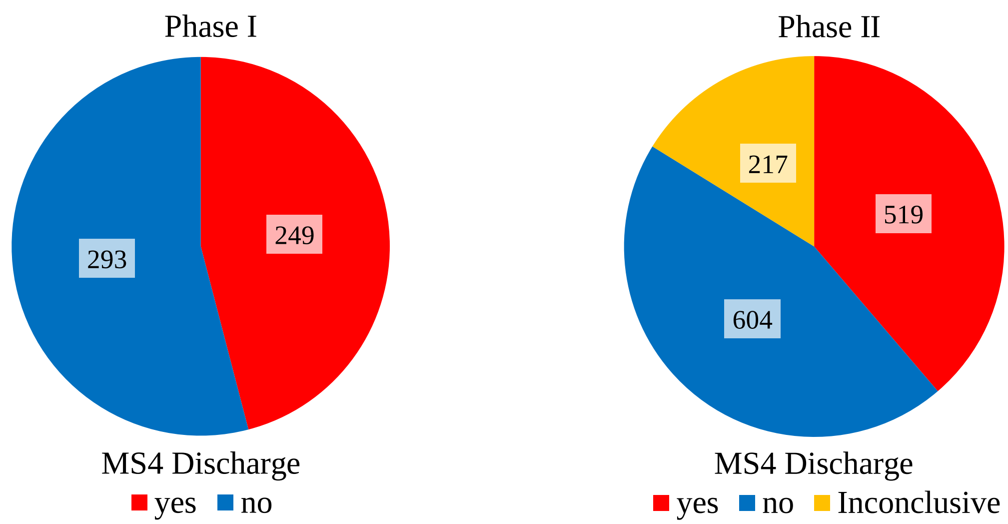
Note. This graph represents the total number of Phase I and Phase II permittees captured in this study. This figure was derived from the analysis of this study.

MS4 Discharge

Roughly half of the submitted IDDE records discharged to the permittee's municipal separate stormwater system (MS4), which constitutes an MS4 Discharge. For Phase I, 249 records were coded as yes and 293 as no. For Phase II, 519 records were coded as yes, 604 as no, and 217 as other, unknown, or blank (grouped as "inconclusive") (see Figure 2). A yes response indicates that the spill discharged to the permittee's MS4.

Figure 2

MS4 Discharge by Permittee Phase Type



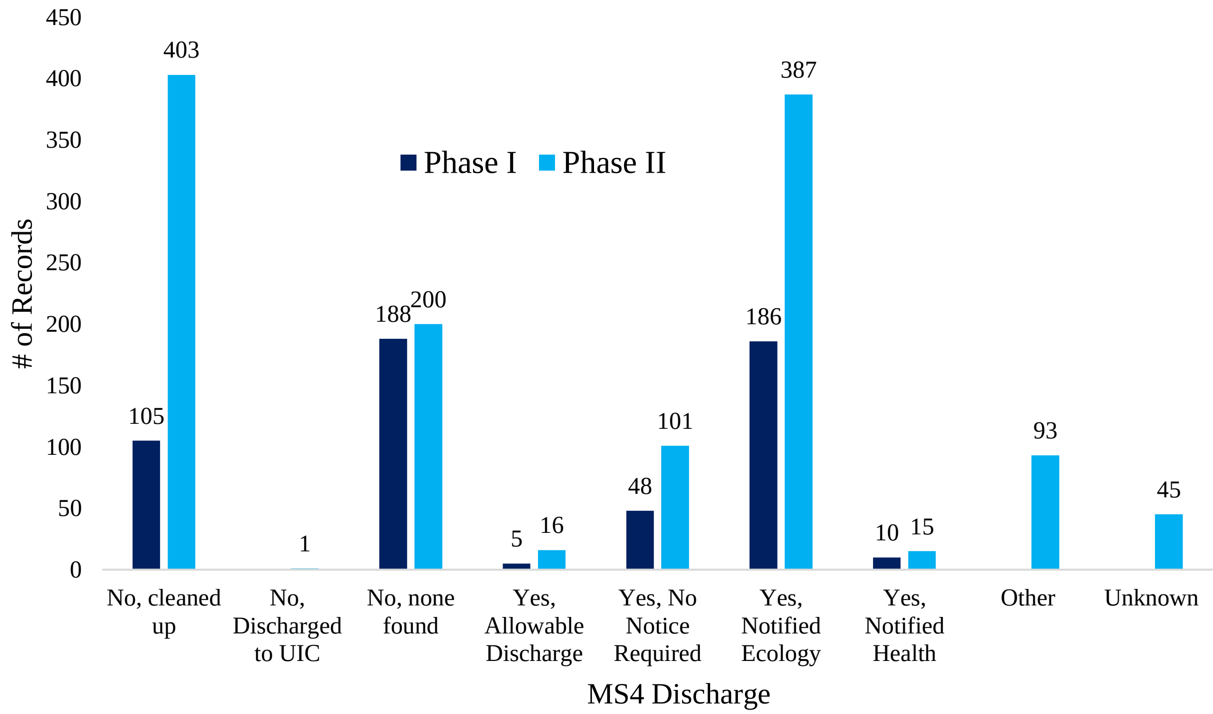
Note. These graphs demonstrate the frequency of records that discharged to the MS4 (municipal separate storm sewer system) for Phase I and Phase II jurisdictions. This figure was derived from the analysis of this study.

The other, unknown and blank MS4 discharge records constituted just over 16 percent of the total Phase II records. Of these records, 93 were reported as "other" where the permittee could write in a text response to provide further clarification to the impact of the spill to the MS4 (see Figure 3). Some of the responses referenced that the spill was outside of the permittee's jurisdiction, a non-stormwater issue, dried on the surface, or referenced an Environmental Report Tracking System (ERTS) number that is provided when a spill is reported via Ecology's statewide environmental incident report form. City of Sammamish records often contained responses such as "other: Republic notified" to indicate that the report was referred to their waste disposal agency Republic Services. Within the field notes and comments section, the permittee included additional notes regarding where spill occurred including the impact to the MS4.

Forty-five records were reported as having unknown MS4 Discharge by Phase II permittees (see Figure 3). Of these records, many of the responses within the field notes and comments field indicated that the permittee had performed some type of response and could not determine if there was a discharge to the MS4 or the report was referred the report to another agency. Of the 79 Phase II records with the MS4 discharge field left blank, 76 records came from the City of Kirkland. Within the field notes and comments field for these records, most of the responses either were left blank, indicated there was no IDDE found, or included a short response to the nature of the report.

Figure 3

MS4 Discharge by Permittee Phase Type, Expanded



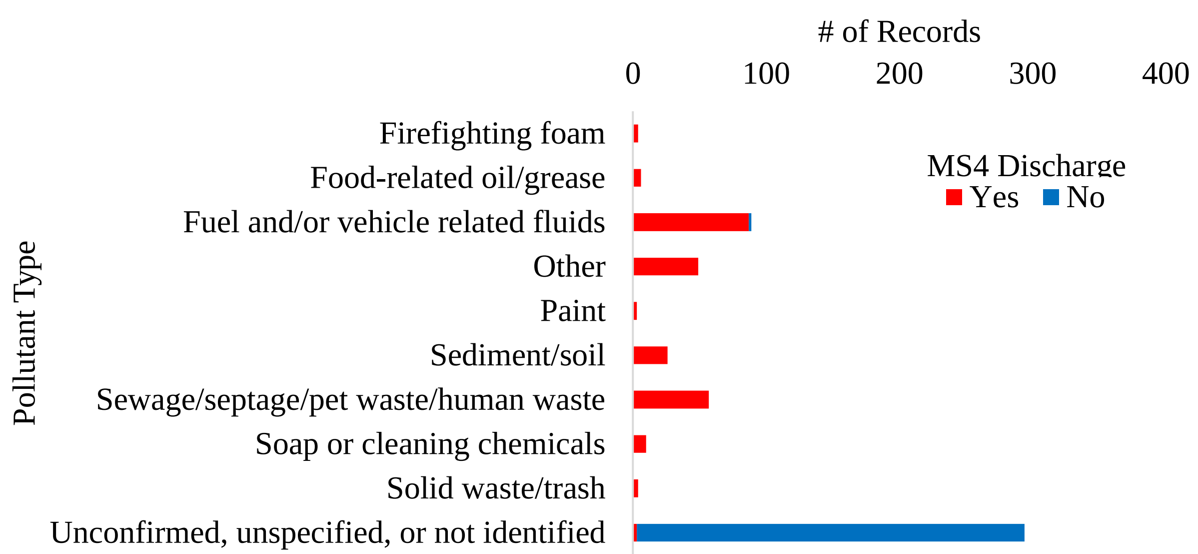
Note. MS4 Discharge types are shown for Phase I and Phase II permittee types showing all possible field responses. This figure was derived from the analysis of this study.

Pollutant Types

Phase I. For Phase I permittees, the pollutant category was skewed by whether there was a discharge to the MS4, likely because Ecology does not require permittees to answer all the questions for an individual IDDE record if the discharge does not occur to the MS4 For records that did not discharge to the MS4 (Washington State Department of Ecology, 2019a). 291 of 293 of the records reported the pollutants identified as “unconfirmed, unspecified, or not identified” (see Figure 4). All but one of these records were from the City of Tacoma, and upon examining the spill records from City of Tacoma that did discharge to the MS4, all the records included the specific pollutant type. This indicates that the City of Tacoma does not indicate the pollutant type when the spill does not contribute a discharge to the permittee’s MS4.

Figure 4

Phase I Pollutants

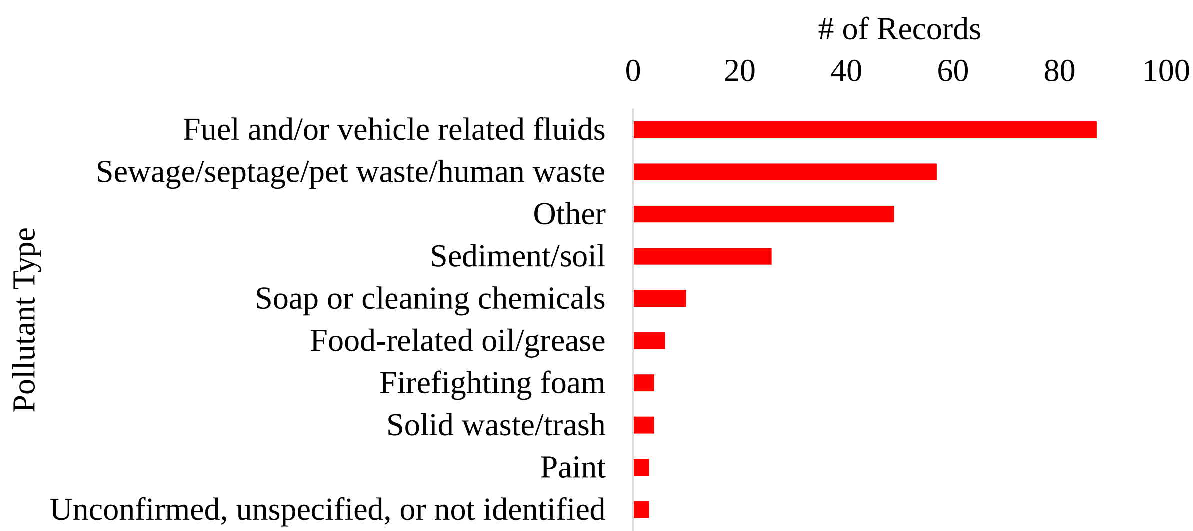


Note. The Phase I pollutants are portrayed in this stacked bar graph which distinguishes the records by MS4 Discharge. This figure was derived from the analysis of this study.

When only examining Phase I records that have discharged to the permittee's MS4, the top three contributing pollutant categories were fuel and/or vehicle related fluids, sewage/septage/pet waste/human waste, and the "other" write in category, contributing to 78 percent of the total records (see Figure 5). The next three top contributing pollutant categories, sediment/soil, soap or cleaning chemicals, and food-related oil/grease contributed 17 percent of the overall records. The least observed pollutants categories that discharged to the MS4 for Phase I permittees were food-related oil/grease, firefighting foam, solid waste/trash, paint, and unconfirmed, unspecified, or not identified.

Figure 5

Phase I Pollutants with MS4 Discharge, Ranked by Frequency

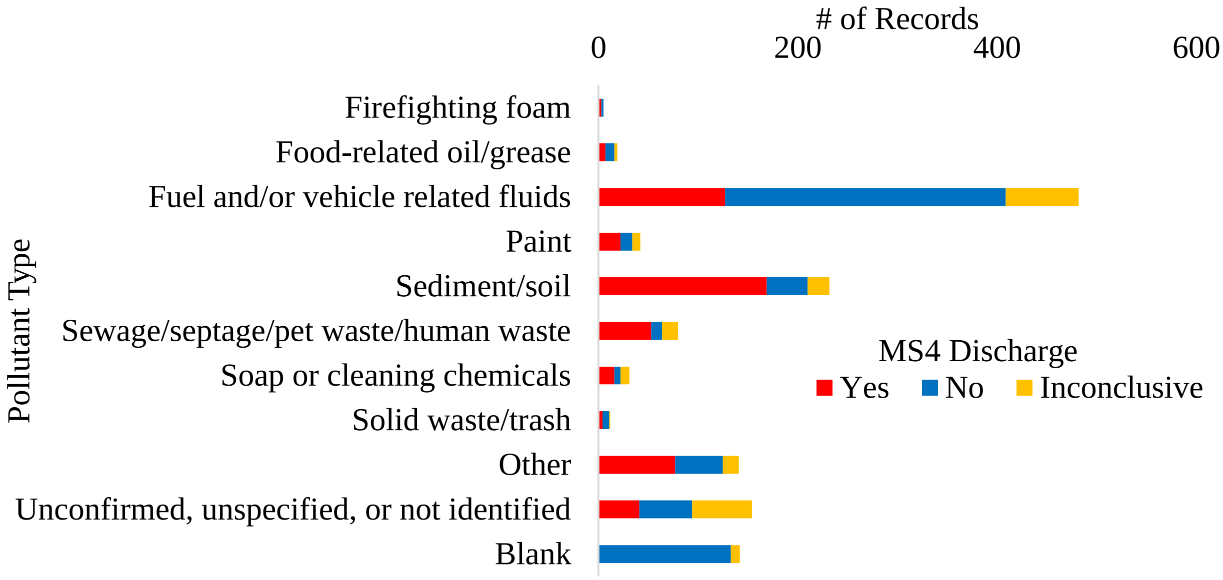


Note. This figure ranks the most common Phase I pollutants that have discharged to the MS4. This figure was derived from the analysis of this study.

Phase II. When examining the Phase II pollutant types for all discharge types, it appears that even records that were coded as “no” and “inconslusive” for MS4 discharge still had a pollutant type associated, even though a full record is not required for IDDE records that do not constitute a discharge to the permittee’s MS4 (see Figure 6). The top three contributing pollutant categories without distinguishing between MS4 discharge were fuel and/or vehicle related fluids, sediment/soil, and unconfirmed, unspecified, or not identified. The fuel and/or vehicle related fluids category constituted 36 percent of the overall records, with sediment/soil and unconfirmed, unspecified, or not identified at 17 percent and 10 percent, respectively.

Figure 6

Phase II Pollutants

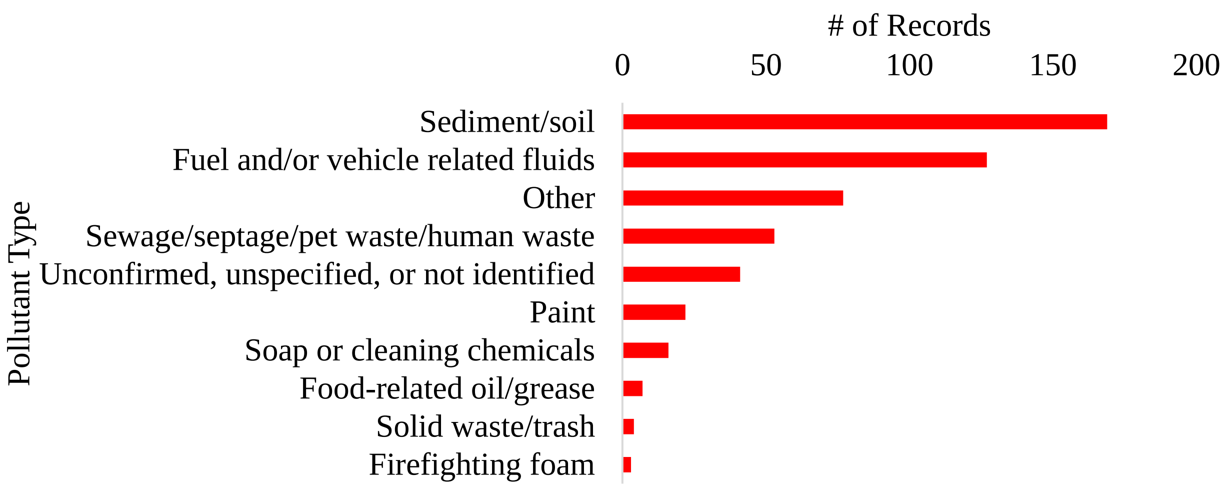


Note. The Phase II pollutants are portrayed in this stacked bar graph which distinguishes the records by MS4 Discharge. This figure was derived from the analysis of this study.

However, when distinguishing between records that have only discharged to the permittee's MS4, the top three pollutant categories were sediment/soil, fuel and/or vehicle related fluids, and the "other" write in category, contributing to 33 percent, 24 percent, and 15 percent of the overall records, respectively (see Figure 7). The next three contributing pollutant categories were sewage/septage/pet waste/human waste, unconfirmed, unspecified, or not identified, and paint, contributing to 22 percent of the overall records combined. The four least-contributing pollutant categories that discharged to the MS4 for Phase II permittees were soap or cleaning chemicals, food-related oil/grease, solid waste/trash, and firefighting foam, contributing to just 6 percent of the overall records.

Figure 7

Phase II Pollutants With MS4 Discharge, Ranked by Frequency



Note. This figure ranks the most common Phase II pollutants that have discharged to the MS4. This figure was derived from the analysis of this study.

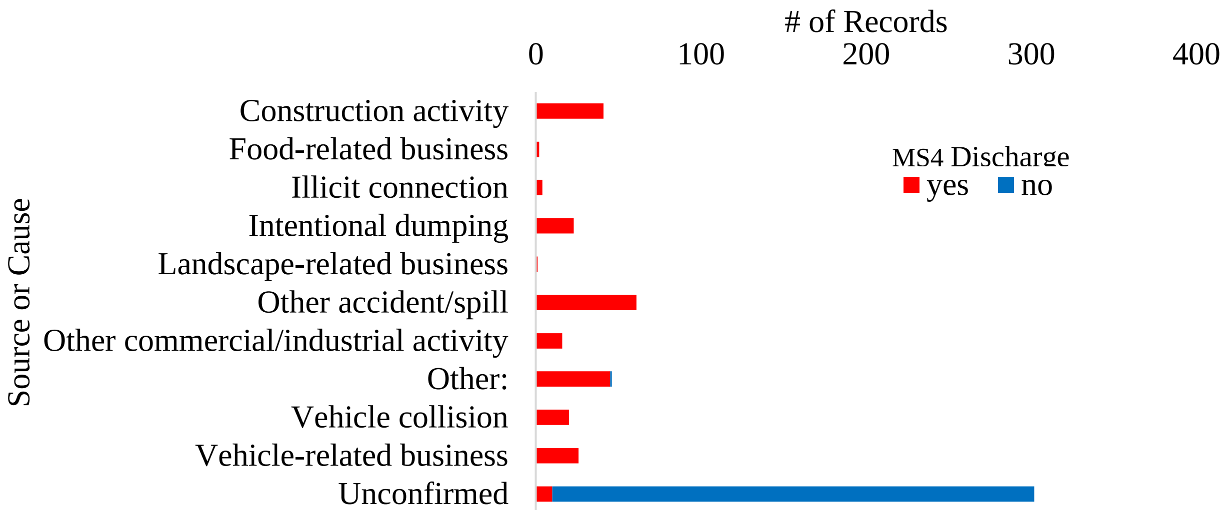
Pollutant Sources

Phase I. For Phase I permittees, the Pollutant Source category was often marked as "unconfirmed" when there was no discharge to the permittee's MS4, as again only a partial

IDDE record is required for discharges that do not reach the permittee's MS4 (see Figure 8). However, for 10 of these records, the pollutants were confirmed to have reached the permittee's MS4 and constituted a discharge, even though the spill source was not confirmed.

Figure 8

Phase I Pollutant Sources

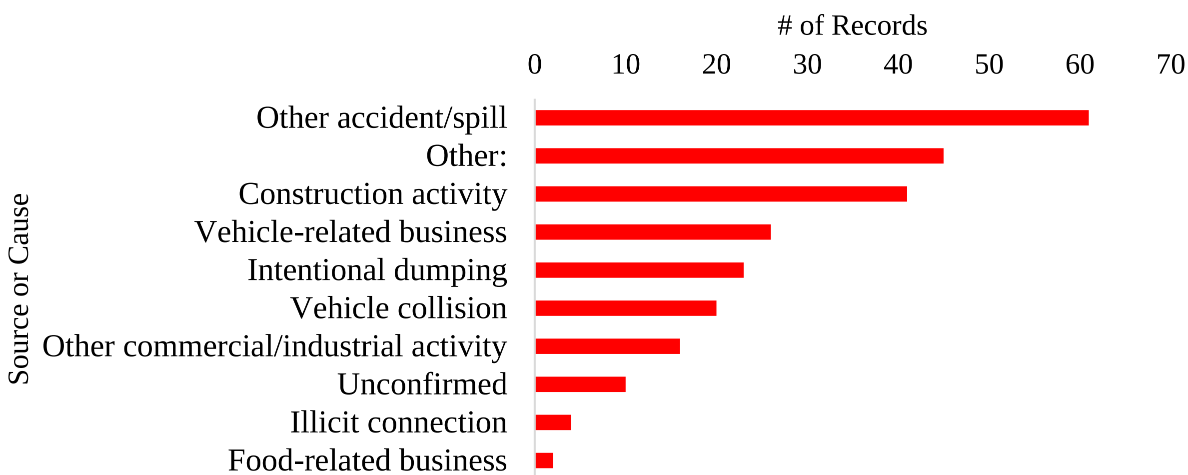


Note. Represented in this figure are the frequencies of pollutant sources found in Phase I municipal stormwater permit records, distinguished by MS4 discharge. This figure was derived from the analysis of this study.

For Phase I permittee MS4 discharge IDDE records, the top three pollutant source categories were other accident/spill, the "other" write-in category, and construction activity, contributing to 25 percent, 18 percent, and 16 percent of the overall records (figure 9). When examining the field notes and comments field of the other accident/spill records, comments ranged from vehicle-related incidents such as fuel, oil, antifreeze, and hydraulic fluid spills, to leaking grease traps, paint spills, turbid discharge, sewer overflows, and a sewer cross connection into the storm system. For the "other" category, permittees could write in their own description for a record that may not exactly fit within the description of any of the designated responses. Among these responses were reports of vehicle-related incidents such as fuel leaks and vehicle/RV fires requiring fire-fighter response, to broken water mains, pump failures, sanitary sewer failures, pollutant sheens and soapy water discharging into catch basins.

Figure 9

Phase I Pollutant Sources with MS4 Discharge, Ranked by Frequency

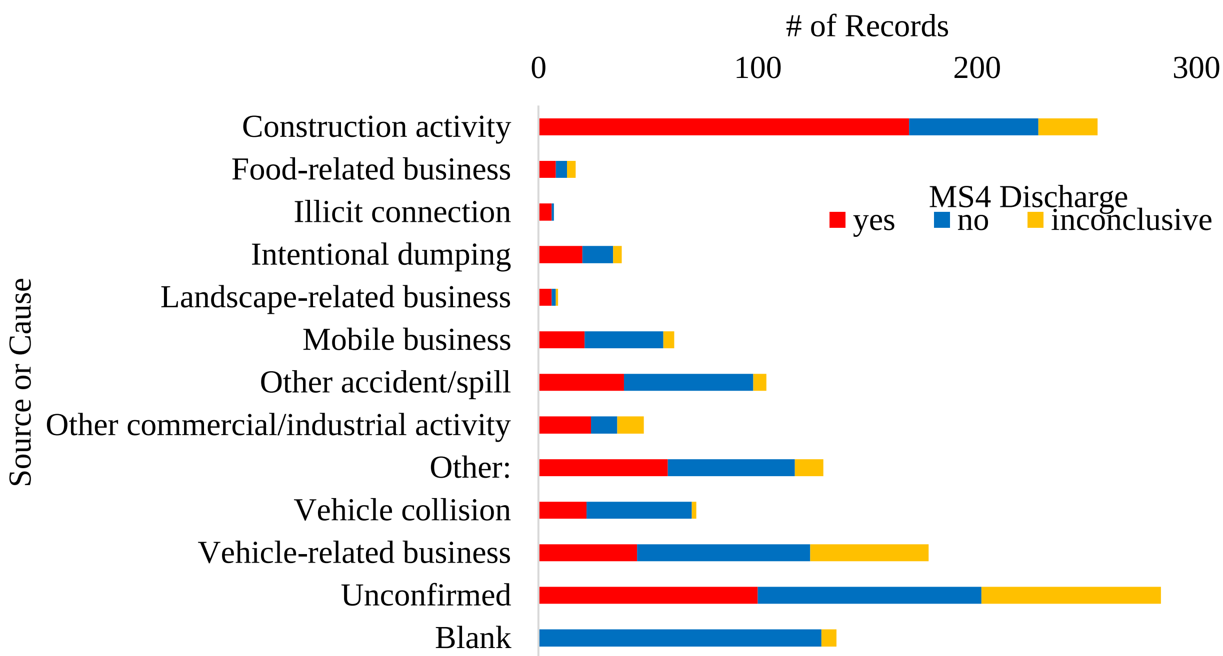


Note. This graph depicts the most common pollutant source types for Phase I permittees for incidents that have discharged to the MS4. This figure was derived from the analysis of this study.

Phase II. The unconfirmed pollutant source category contained the largest number of records for Phase II municipalities for all types of MS4 discharge, suggesting that although Phase II municipalities appeared to populate the pollutant type category, permittees were either unsure or did not desire to populate the pollutant source field (see Figure 10). In addition, there were over 100 blank records in for this category for the “no” MS4 discharge responses. For all types of MS4 discharge, the top contributing pollutant sources were the “unconfirmed” category followed by construction activity and vehicle-related business.

Figure 10

Phase II Pollutant Sources

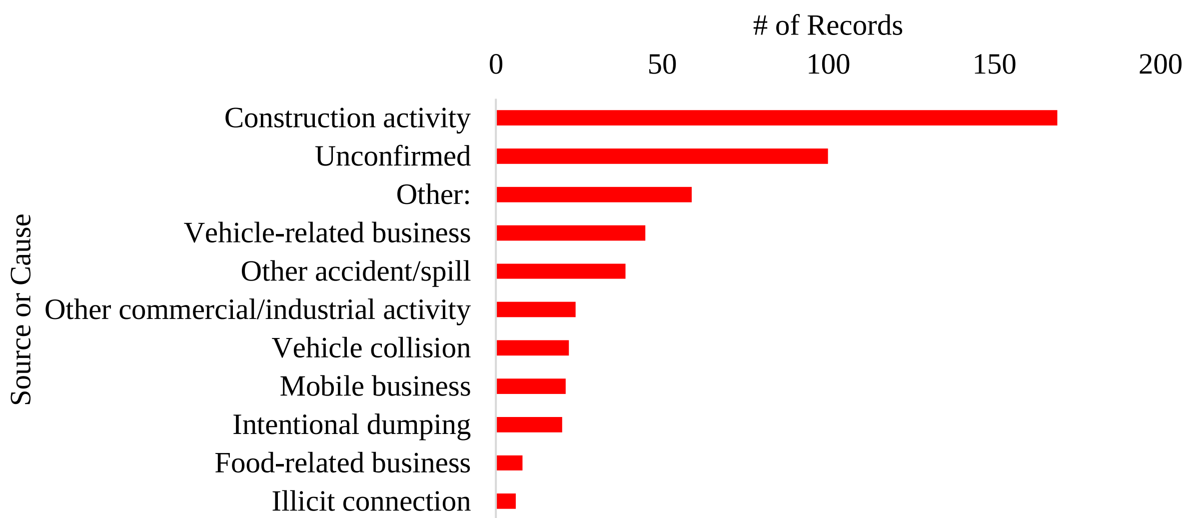


Note. Represented in this figure are the frequencies of pollutant sources found in Phase I municipal stormwater permit records, distinguished by MS4 discharge. This figure was derived from the analysis of this study.

When only examining the Phase II records that discharged to the MS4, construction activity, unconfirmed, and the “other” category were the top contributing pollutant source categories with 32 percent, 19 percent, and 11 percent of the overall records, respectively (see Figure 11). Of the unconfirmed records, most of all the records were cleaned up or education/technical assistance was provided. Some of the records contained field notes in comments field, with responses ranging from illegal or unconfirmed dumping of fluids, to reports of power washing fluid discharges, water main breaks, and cloudy water reports where the police were called in to assist the scene. For the "other" pollutant category where the permittee could write in their own response, some of the pollutant types included concrete washout, hydraulic fluid, potable water, and yard waste.

Figure 11

Phase II Pollutant Sources with MS4 Discharge, Ranked by Frequency



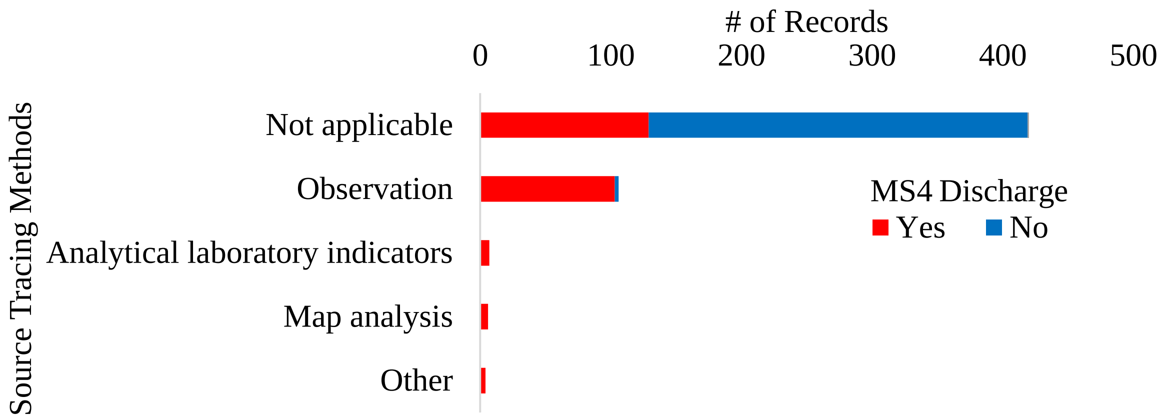
Note. This graph depicts the most common pollutant source types for Phase II permittees for IDDE incidents that have discharged to the MS4. This figure was derived from the analysis of this study.

Source Tracing Methods

As mentioned in the literature review, source tracing methods are the methods used to find the source of an illicit discharge or illicit connection. For Phase I permittees, the most common response for the source tracing method was not applicable, with 77 percent of the overall records. The next common response was the observation category, with 19 percent of the overall records. The analytical laboratory indicators, map analysis, and the “other” categories constituted just 3 percent of the overall records (see Figure 12).

Figure 12

Phase I Source Tracing Methods

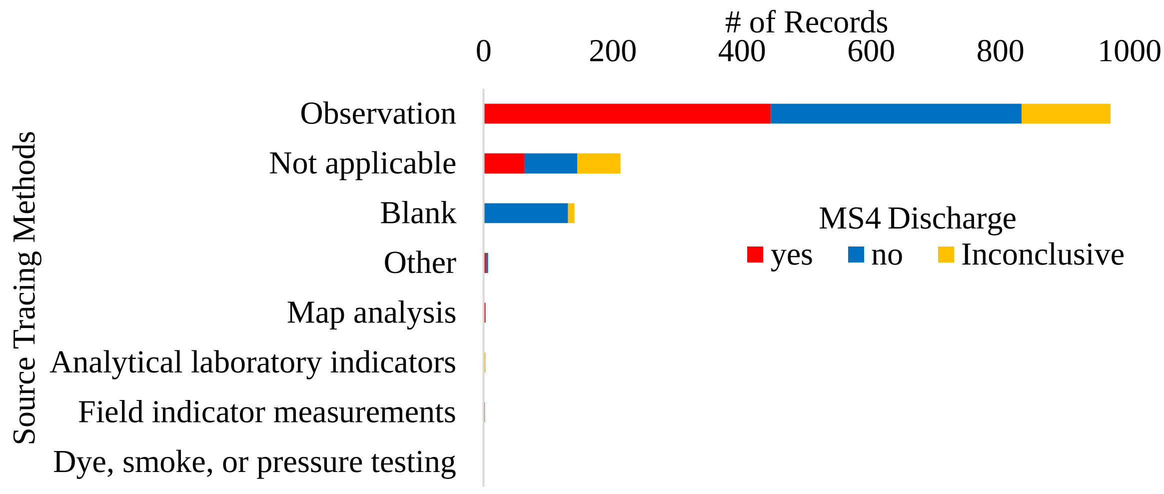


Note. Phase I source tracing methods are portrayed in this figure, ranked by frequency and distinguished by MS4 discharge. This figure was derived from the analysis of this study.

For Phase II source tracing methods, the observation category was the most common response with 72 percent of the overall records (see Figure 13). The next top categories were the not applicable category and records that were left blank.

Figure 13

Phase II Source Tracing Methods



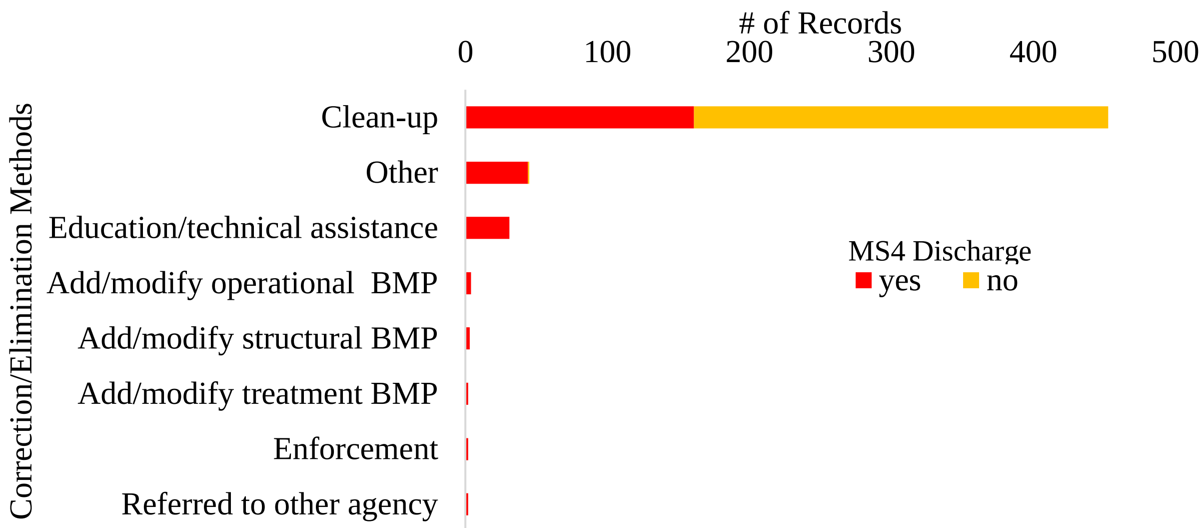
Note. Phase II source tracing methods are portrayed in this figure, ranked by frequency, and distinguished by MS4 discharge. This figure was derived from the analysis of this study.

Correction and Elimination Methods

Correction and elimination methods used to resolve a discharge ranged from cleanup, education and outreach, or the implementation of Best Management Practices (BMPs) including operational, structural, and treatment BMPs (although rare in usage for both Phase I and Phase II permittees). For Phase I permittees, cleanup was the most common correction and elimination method, followed by the "other" category and the education/technical assistance categories (see Figure 14). Cleanup was also the most prevalent method for Phase II permittees, followed by education/technical assistance and the category including blank records (see Figure 15).

Figure 14

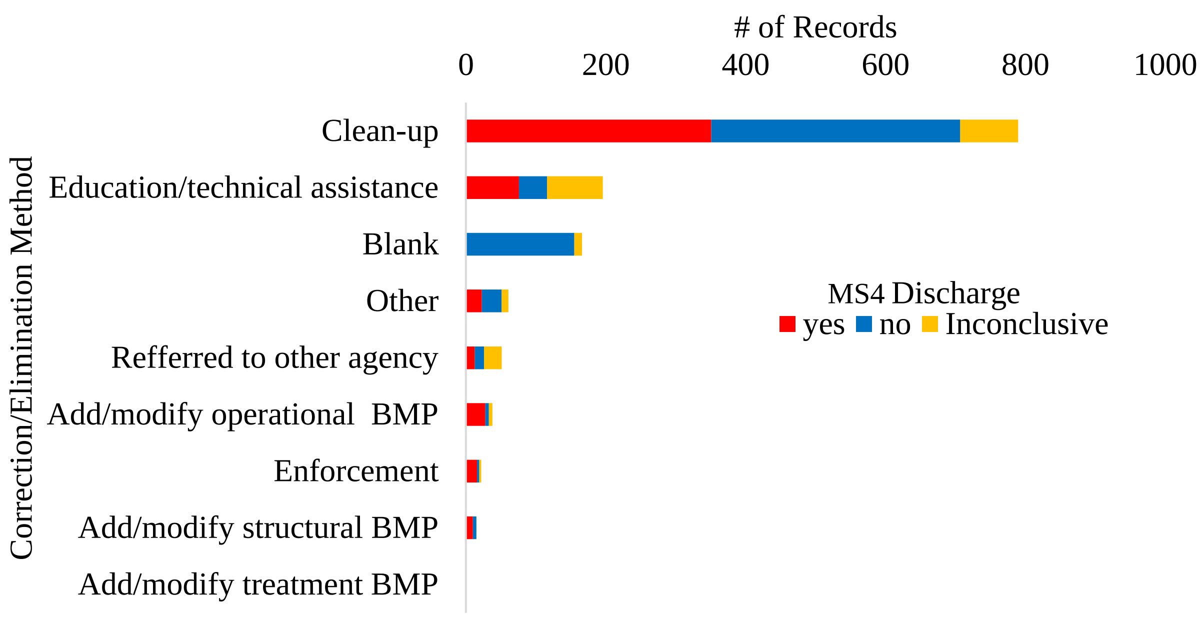
Phase I Correction and Elimination Methods



Note. Phase I correction and elimination methods are portrayed in this figure, ranked by frequency, and distinguished by MS4 discharge. This figure was derived from the analysis of this study.

Figure 15

Phase II Correction and Elimination Methods



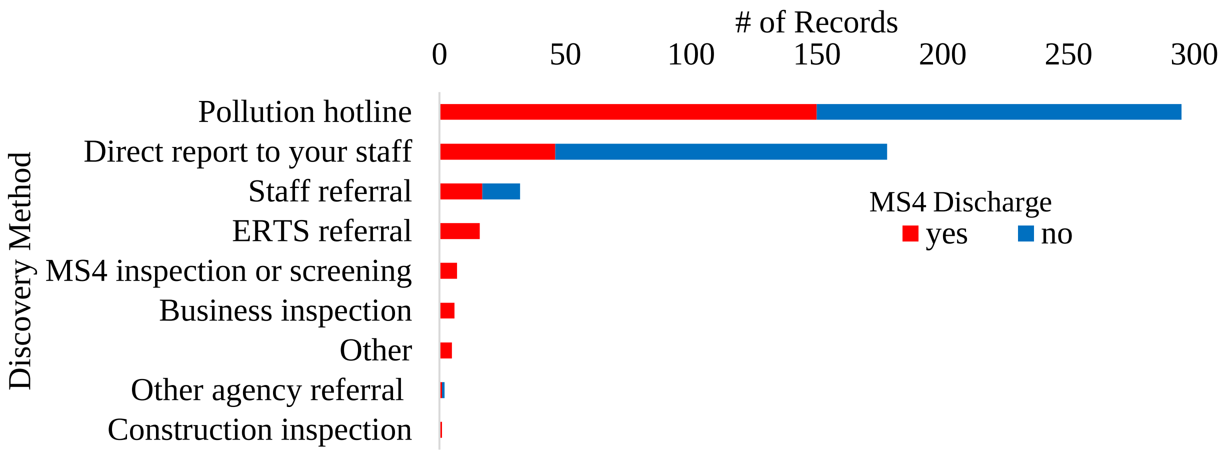
Note. Phase II correction and elimination methods are portrayed in this figure, ranked by frequency and distinguished by MS4 discharge. This figure was derived from the analysis of this study.

Discovery Methods

Discovery methods include the method the jurisdiction receives an IDDE report, ranging from the pollution hotline and staff referrals to ERTS (Environmental Report Tracking System) referrals through Department of Ecology's online portal, and field inspections. For both Phase I and Phase II jurisdictions, the pollution hotline was the most frequent discovery method for incidents. For Phase I jurisdictions, the next-most frequent discovery methods were direct reports to your staff, and staff referrals (see Figure 16). For Phase II jurisdictions, staff referrals and ERTS were the next-most common discovery methods (see Figure 17).

Figure 16

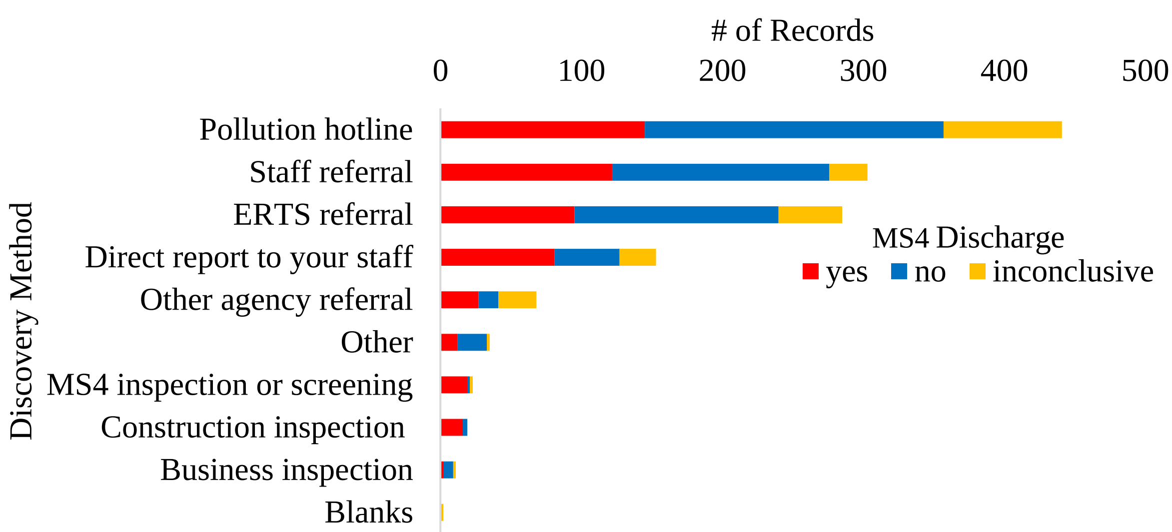
Phase I Discovery Methods



Note. Phase I discovery methods are portrayed in this figure, ranked by frequency, and distinguished by MS4 discharge. This figure was derived from the analysis of this study.

Figure 17

Phase II Discovery Methods



Note. Phase II discovery methods are portrayed in this figure, ranked by frequency, and distinguished by MS4 discharge. This figure was derived from the analysis of this study.

Statistical Analysis

Statistical analysis performed on each of the five chi-square contingency tests was statistically significant, indicating that the relationship between each of the categorical variables represented a distribution that was not random (see Appendix A). As referenced in the methods section, these tests compared pollutant type categories to: phase type categories, pollutant source categories, correction and elimination method categories, discovery method categories, and tracing method categories. By examining each of the contingency tests, relationships can be gleaned between the variables, and logical associations confirmed. This section will describe these results in detail.

Pollutant Type vs. Phase Type

When comparing pollutant type categories to phase type categories, Phase I jurisdictions had more fuel and/or vehicle related fluids and sewage/septage/pet waste/human waste records than expected compared to Phase II jurisdictions (see Appendix A, table 3). Phase I jurisdictions received less sediment/soil and unconfirmed, unspecified, or not identified pollutant records than expected compared to Phase II jurisdictions.

Phase II jurisdictions had more sediment/soil records than expected compared to Phase I jurisdictions. Phase II jurisdictions received less fuel and/or vehicle related fluids and sewage/septage/pet waste/human waste pollutant records than expected compared to Phase II jurisdictions.

Pollutant Type vs. Pollutant Source

When comparing pollutant type categories to pollutant source categories, several logical associations are confirmed by the observed counts compared to the residuals. Construction activity was highly associated with sediment/soil pollutants, and not highly associated with fuel and/or vehicle related fluids (see Appendix A, table 4). Construction activity was also not associate with sewage/septage/pet waste/human waste and the unconfirmed, unspecified, or not identified pollutant category. Illicit connections were associated with sewage/septage/pet waste/human waste and was not associated with sediment/soil pollutants. Other accidents were associated with fuel and/or related fluids and sewage/septage/pet waste/human waste, and not associated with sediment/soil pollutants. The unconfirmed pollutant source category was not associated with sediment/soil pollutants. Vehicle collisions were highly associated with fuel and/or vehicle related fluids, and not associated with sediment/soil and sewage/septage/pet waste/human waste.

Pollutant Type vs. Correction and Elimination Method

When comparing pollutant type categories to correction and elimination method categories, Best Management Practices (BMPs) were associated with sediment/soil pollutants and not associated with fuel and/or vehicle related fluids (see Appendix A, table 5). Cleanup was highly associated with fuel and/or vehicle related fluids, and highly not associated with sediment/soil. Education/technical assistance was associated with soap or cleaning chemicals and was not associated with fuel and/or vehicle related fluids.

Pollutant Type vs. Discovery Method

When comparing pollutant type categories to discovery method categories, inspection discovery methods were not associated with fuel and/or vehicle related fluids (see Appendix A, table 6). Hotline calls were associated with fuel and/or vehicle related fluids and the unconfirmed, unspecified, or not identified category, and were not associated with sediment/soil pollutants. Intra-or interagency referrals were associated with sediment/soil, and not associated with the unconfirmed, unspecified, or not identified pollutant category.

Pollutant Type vs. Tracing Method

When comparing pollutant type categories to tracing method categories, visual and empirical tracing methods were associated with sediment/soil pollutants (see Appendix A, table 7). The combined in-pipe testing/not applicable category was associated with fuel and/or vehicle related fluids and sewage/septage/pet waste/human waste, and not associated with sediment/soil.

Conclusion

This section presented the key findings from the descriptive and statistical analysis performed in this study. For the descriptive analysis section, six IDDE field categories chosen to study in greater detail were outlined. Of the 1340 records from 43 municipal stormwater permittees in Western Washington, the majority came from two Phase I jurisdictions and five phase II jurisdictions. Roughly half of the submitted records discharged to the permittee's MS4. Fuel and vehicle-related fluids spills were common among both Phase I and Phase II jurisdictions. When pollutant sources were reported, construction activity, accidents and spills, and the unconfirmed or other category were among the most commonly reported for both permittee phase types. Source tracing methods were primarily observation, and clean-up was by far the most common correction method. The pollution hotline was the most common reporting method followed by referrals through staff or agency referrals, including ERTS (Statewide Environmental Incident Report Form).

For the statistical analysis portion of the analysis, key findings from each of the five chi-square tests of the categorical comparisons were presented. This includes the confirmation of logical associations between pollutant type categories and pollutant source categories, correction and elimination methods, discovery methods, and tracing methods. For instance, the sediment pollutant category was associated with construction sites, best management practices, intra or inter-agency referrals, and visual tracing methods. In the discussion section, the implications of these findings will be explored in further detail.

Chapter 4. Discussion

Introduction

This chapter will discuss the key findings from the results of this study using a modified version of the five discussion topics used in the SAM Source Identification study. These include: distribution of data; pollutant types and pollutant sources; source tracing methods; discovery methods; correction and elimination methods. Next, several discussion topics will be presented, including reporting standardization, and a section outlining limitations as well as future recommendations.

Distribution of Data

Data evaluated from this study included records from a total of 43 Phase I and Phase II jurisdictions in Western Washington. Data from the Phase I jurisdictions came from three jurisdictions of the 15 total Phase I permittees and secondary permittees in Western Washington (two cities, four counties, nine secondary permittees total). These records came from the City of Seattle, City of Tacoma, and the Port of Seattle. Data was heavily weighted towards City of Seattle and City of Tacoma, which contributed all but 6 of the IDDE records as indicated in the results. Data from the Phase II jurisdictions came from 39 cities and one county, of the possible 118 Phase II permittees and secondary permittees in Western Washington (83 cities, five counties, 30 secondary permittees). The top five contributing municipalities representing over 60 percent of the total number of records.

Since 2020 was the first year the standardized reporting format was available for use to submit annual IDDE reporting data, the jurisdictions included in this study represent the first wave of municipal stormwater permittees that have migrated to the new reporting format. The benefit of this format is that little to no data standardization was needed to perform preliminary analysis of the IDDE records. The reporting standardization discussion topic later on in this chapter will explore this in detail.

Pollutant Types and Pollutant Sources

For Phase I municipalities, the most common pollutant types that contributed a discharge to the permittee's MS4 were fuel and vehicle related fluids and sewage/septage/pet waste/human waste pollutants, followed by the "other" pollutant category with write-in responses. The most common pollutant sources contributing a discharge to the MS4 were from the other accident/spill category and "other" pollutant source category with write-in responses, followed by construction activity.

For Phase II municipalities, the most common pollutant types that contributed a discharge to the permittee's MS4 were sediment/soil, and fuel and/or vehicle related fluids, followed by the "other" pollutant category with write-in responses. The most common spill sources that contributed a discharge to the permittee's were construction activity, the "unconfirmed" category, and the "other" pollutant source category with write-in responses.

For both Phase I and Phase II jurisdictions, fuel and vehicle related fluids, sediment, and sewage were all common spill types. Spill sources were commonly coded using the "unconfirmed" or "other" categories where permittees could write in their own responses, however common pollutant sources also included construction activity, other accidents/spills and vehicle related businesses.

Statistical analysis demonstrated logical associations between pollutant types and pollutant sources. Sediment and soil were associated with construction sites, illicit connections were associated with sewage and other waste, and vehicle collisions were associated with fuel or vehicle related fluids.

Source Tracing Methods

For Phase I and especially Phase II municipalities, it appears that if the source tracing method was not an observation, then it was likely either going to be left blank or checked as not applicable. Very rarely did any Phase I or Phase II permittee use any other source tracing method besides observation, suggesting that observation alone is the primary method of source tracing for both permittees for the majority of IDDE records. In some circumstances when fecal coliform or another type of human health hazard took place, analytical laboratory methods or map analysis were conducted, however the records also indicate that permittees may also refer the IDDE response to their Department of Health instead of performing analysis themselves.

Statistical analysis comparing pollutant type categories to source tracing categories revealed the association that visual and empirical tracing methods were associated with sediment/soil. This makes sense since turbidity, or the cloudiness of water due to soil contamination, is a common indicator for soil pollution. Statistical analysis also revealed the combined in/pipe testing/not applicable category was associated with fuel or vehicle related fluids and the encompassing sewage category. This also makes sense because in pipe testing is a logical source tracing method to trace illicit sewage connections, and specific source tracing methods are often not used or necessary for fuel or vehicle related fluids where the spill may be rather obvious. However, these interpretations can only be inferred since the category was combined, which was necessary to meet the assumptions of the chi-square test for this specific comparison (see page 27).

Discovery Methods

For both Phase I and Phase II municipalities, the pollution hotline was the most common way that a discharge was identified or reported to the permittee. Direct referrals to staff, from ERTS referrals, or from other agency referrals were also quite common. There were very few records from both Phase I and Phase II permittees with MS4 inspection, construction inspection, or business inspection as the indicated discovery method, suggesting inspections are typically not when a discharge occurs. However, this could also indicate that there are only a small number of MS4 inspections, construction inspections, or business inspections occurring. Regardless, it appears that the pollution hotline is being utilized as it is the primary discovery method. This result indicates that permittees should continue to utilize the use of their pollution hotlines and create ways to inform the public on how they can utilize such a hotline.

Statistical analysis confirmed logical assumptions between the data. Hotline calls were associated with fuel or vehicle related fluids, and the unspecified, unidentified, or not identified category. This makes sense because fuel, oil, or vehicle related fluids are an easy substance to spot, and spills and accidents are often called into the hotline. In addition, it would make sense that calls coming in through the hotline would be associated with an unspecified or unidentified pollutant category unless specific information regarding the spill was communicated through the hotline report. Intra- or interagency referrals were associated with sediment/soil, which also confirms logical assumptions because multiple agencies are often involved in sediment or construction-related pollution-generating activities.

Correction and Elimination Methods

Cleanup was by far the most common response category for both Phase I and Phase II permittees. There were only a few instances where an addition or a modification of a BMP were required, and very few instances of enforcement among both permittee types. This indicates that permittees may largely focus on the cleanup efforts of each IDDE record, but could also be the most common response because cleanup of a discharge is typically necessary and it may be an obligatory response from most permittees when populating an IDDE record.

Statistical analysis confirmed logical assumptions between correction and elimination methods and pollutant types. Best Management Practices (BMPs) were associated with sediment/soil pollutants, which makes sense because construction activities are often the source of sediment or soil discharge due to inadequate or improperly installed BMPs. Cleanup was highly associated with fuel or vehicle related fluids, which also makes sense because cleanup is typically necessary when correcting a discharge of pollutants from a vehicle accident or fuel spill.

Reporting standardization

Since the IDDE reporting data and format requirements were only recently implemented and permittees were not required to submit their data in the format compatible with the online database for the 2020 annual report, only a fraction of the total number of permittees and thus the number of IDDE records were captured in this study. Thus, the results of this study represent only a fraction of the total number of Phase I and Phase II municipal stormwater permittees in Western Washington whereas the previous study manually compiled the individual reports before standardizing the various reporting formats in a manner that would allow for comparison between the records. Though this study only represents a sample of the total population, this study proves that direct comparison between individual records is now possible with this new standardized reporting format. However, the format does come with some nuances.

Permittees may write in a response in the “other” field when the record would have fit just fine into one of the predetermined fields. For instance, hydraulic fluid was indicated in the write-in “other” category when technically the pollutant source should have been logged as fuel/and or vehicle related fluids. When combing through individual IDDE records, it becomes clear each permittee populates an IDDE record slightly differently from small nuances and variations in the way records are populated. Because of the recent rollout of the standardized reporting format, it would be a great time for there to be a guidance document or short training provided for permittees so that within the standardized reporting format, permittees themselves have a standardized approach to populating an IDDE form. Granted, each jurisdiction has their own management styles and techniques and regardless of any level of guidance documentation or training provided, everyone may have their own interpretation of what an IDDE record should look like. Thus, even with the standardized reporting format, some level of coding may be necessary when conducting future regional data evaluations to ensure that the records submitted truly capture the nature of each IDDE record.

Lastly, because the new IDDE reporting data has only recently been implemented and was only required starting with the 2021 annual permit report, the data from this study which evaluates 2020 annual permit reporting data is only a preliminary example of what a regional data evaluation could look like with this new standardized reporting format. Only a small fraction of permittees submitted data compatible with Ecology’s PARIS database for the 2020 permit reporting year. Hopefully in subsequent years all permittees are able to utilize the new standardized reporting format to capture a more encompassing data spread in subsequent regional data evaluations.

Limitations and Recommendations

If this study were to be replicated again, it would be recommended to distinguish between records that constitute an illicit discharge instead of focusing solely on records that have discharged to the MS4. To elaborate, the "yes, allowable discharge" MS4 discharge records technically do not constitute an illicit discharge to the permittee's MS4, as they are considered an allowable discharge. In the results, the distinction was made to indicate that the results are for all discharges to the permittees' MS4, not just the records that were considered illicit discharges, as was performed in the previous regional data evaluation. In future studies, the benefit between indicating what is considered an illicit discharge, rather than all discharges to the permittees' MS4 including allowable discharges.

Future studies should consider spending time performing some preliminary coding of the data specifically in the field notes portion the amount of information that could be gleaned specifically from the field notes field, and the "other" write-in category where municipalities write in their own responses. Significant amount of time could be spent combing through these records to see what typical responses are for this "other" category to try to come up with a schema that encompasses these records. Through further research and evaluation, it could be possible to amend the current schema to incorporate some of these records that are getting lost in this "other" category. The results from this study are inspiring in that a limited amount of coding was needed to be able to conduct a data evaluation and shows signs that the IDDE report standardization was well worth the efforts.

Conclusion

This section further explored the key findings from this study, reviewing the five modified discussion topics as was performed in the original SAM Source Identification regional data evaluation. The success of the data reporting standardization was also discussed, followed by a discussion of the limitations of this study including future recommendations. The final chapter will offer concluding remarks on what has been covered in this study.

Chapter 5. Conclusion

Stormwater regulation in the United States has come a long way since its beginnings in the 20th century. The nation has gone from an era of direct dumping into its waterways into the era of identifying discharges and eliminating them, where each spill deserves its own record. This thesis started by presenting how stormwater regulation was conducted in the early 20th century, leading up to a review of the current regulation federally and in Washington State, before diving into the Illicit Discharge, Detection, and Elimination (IDDE) portion of the municipal stormwater permit. Here, the regional stormwater groups associated with these efforts were discussed, including Stormwater Work Group (SWG) and Stormwater Action Monitoring (SAM), which both play a crucial role in stormwater monitoring in Western Washington. Next, the SAM Source Identification study, the Illicit Discharge Detection and Elimination (IDDE) Regional Data Evaluation for Western Washington was covered, which served as a foundational starting point for this study. Finally, the core of the thesis was explored. Descriptive and statistical analysis of 2020 annually submitted IDDE data was performed to present key findings regarding illicit discharge and illicit connection response by municipal stormwater permittees in Western Washington. This study represents a successful attempt to conduct a regional data evaluation using standardized data collected through search results on Ecology's PARIS webpage. This by itself speaks volumes, as the previous regional data evaluation required a time-consuming data standardization step that this thesis did not require. Future studies will benefit from this standardized data format and can be rest assured that this time-consuming step may no longer be required in future efforts.

To conclude, the following is a list of key findings from this study:

- Roughly half of the submitted IDDE records discharged to the permittee's municipal separate stormwater system (MS4)
- The top three contributing pollutant categories for Phase I permittees were fuel and/or vehicle related fluids, sewage/septage/pet waste/human waste, and the "other" write in category.
- The top three contributing pollutant categories for Phase II permittees were fuel and/or vehicle related fluids, sewage/septage/pet waste/human waste, and the "other" write in category.
- The top three pollutant source categories for Phase I permittees were other accident/spill, the "other" write-in category, and construction activity.
- The top three pollutant source categories for Phase II permittees were construction activity, unconfirmed, and the "other" category.
- For all jurisdictions, observation was by far the most common source tracing method.
- Clean-up was the most common method of correction or elimination of an IDDE record.
- The pollution hotline was the most common method of reporting among both Phase I and Phase II jurisdictions.
- Statistical analysis confirmed various logical associations that are seen in stormwater management as was seen in the previous regional data evaluation. Pollutants were linked to common spill sources and associated discovery methods, correction methods, and tracing methods.

References

Adler, R. W., Landman, J. C., & Cameron, D. M. (1993). *The Clean Water Act 20 Years Later*. Island Press.

Aspect Consulting, L. (2017). *Illicit Discharge Detection (IDDE) Regional Data Evaluation for Western Washington*. *160384*.

Blakemore, E. (2019). The Shocking River Fire That Fueled the Creation of the EPA. *History.Com*. https://www.history.com/news/epa-earth-day-cleveland-cuyahoga-river-fire-clean-water-act

Clarke, K. C., & Hemphill, J. J. (2002). The Santa Barbara Oil Spill: A Retrospective. *Yearbook of the Association of Pacific Coast Geographers*, *64*(1), 157–162. https://doi.org/10.1353/pcg.2002.0014

Cohen, W. J., & Sonosky, J. N. (1962). *Federal Water Pollution Control Act Amendments of 1961*. *77*(2), 107–113.

Copeland, C. (2014). Clean Water Act: A summary of the law. In *U.S. Wetlands: Background, Issues and Major Court Rulings* (pp. 93–108). www.crs.gov

EPA. (n.d.-a). *Basic Information about Nonpoint Source (NPS) Pollution*. Retrieved June 25, 2022, from https://www.epa.gov/nps/basic-information-about-nonpoint-source-nps-pollution

EPA. (n.d.-b). *Introduction to the Clean Water Act | Watershed Academy Web*. Retrieved June 26, 2022, from https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=2574

EPA. (n.d.-c). *NPDES Permit Basics*. Retrieved May 2, 2022, from https://www.epa.gov/npdes/npdes-permit-basics

EPA. (n.d.-d). *What is the National Environmental Policy Act?* Retrieved May 14, 2022, from https://www.epa.gov/nepa/what-national-environmental-policy-act

EPA. (2016). *EPA History: Water - The Challenge of the Environment: A Primer on EPA's Statutory Authority*. https://archive.epa.gov/epa/aboutepa/epa-history-water-challenge-environment-primer-epas-statutory-authority.html

Feist, B. E., Buhle, E. R., Arnold, P., Davis, J. W., & Scholz, N. L. (2011). Landscape ecotoxicology of coho salmon spawner mortality in urban streams. *PLoS ONE*, *6*(8). https://doi.org/10.1371/journal.pone.0023424

Hall, R. M. J. (1978). Clean water act of 1977. *Environmental Science and Technology*, *12*(3), 257–258. https://doi.org/10.1007/978-94-011-7373-5_33

Herrera Environmental Consultants, I., & Aspect Consulting, L. (2020). *ILLICIT CONNECTION AND ILLICIT DISCHARGE FIELD SCREENING AND SOURCE TRACING GUIDANCE MANUAL Prepared for Washington State Department of Ecology*.

Hunter, S., & Waterman, R. W. (1996). *Enforcing the Law: The Case of the Clean Water Acts*. M.E Sharpe.

McIntyre, J. K., Davis, J. W., Hinman, C., Macneale, K. H., Anulacion, B. F., Scholz, N. L., & Stark, J. D. (2015). Soil bioretention protects juvenile salmon and their prey from the toxic impacts of urban stormwater runoff. *Chemosphere*, *132*, 213–219. https://doi.org/10.1016/j.chemosphere.2014.12.052

McIntyre, J. K., Davis, J. W., Incardona, J. P., Stark, J. D., Anulacion, B. F., & Scholz, N. L. (2014). Zebrafish and clean water technology: Assessing soil bioretention as a protective treatment for toxic urban runoff. *Science of the Total Environment*, *500–501*, 173–180. https://doi.org/10.1016/j.scitotenv.2014.08.066

McIntyre, J. K., Edmunds, R. C., Redig, M. G., Mudrock, E. M., Davis, J. W., Incardona, J. P., Stark, J. D., & Scholz, N. L. (2016). Confirmation of Stormwater Bioretention Treatment Effectiveness Using Molecular Indicators of Cardiovascular Toxicity in Developing Fish. *Environmental Science and Technology*, *50*(3), 1561–1569. https://doi.org/10.1021/acs.est.5b04786

Nepa.gov. (n.d.). *NEPA | National Environmental Policy Act*. Retrieved May 14, 2022, from https://ceq.doe.gov/

Scholz, N. L., Myers, M. S., McCarthy, S. G., Labenia, J. S., McIntyre, J. K., Ylitalo, G. M., Rhodes, L. D., Laetz, C. A., Stehr, C. M., French, B. L., McMillan, B., Wilson, D., Reed, L., Lynch, K. D., Damm, S., Davis, J. W., & Collier, T. K. (2011). Recurrent die-offs of adult coho salmon returning to spawn in Puget Sound lowland urban streams. *PLoS ONE, 6*(12). https://doi.org/10.1371/journal.pone.0028013

Stormwater Work Group. (n.d.-a). *About SWG*. Retrieved May 3, 2022, from https://sites.google.com/site/pugetsoundstormwaterworkgroup/home/about-swg

Stormwater Work Group. (n.d.-b). *Pooled Resources Oversight*. Retrieved May 11, 2022, from https://sites.google.com/site/pugetsoundstormwaterworkgroup/home/pooled-resources-oversight

Stormwater Work Group. (n.d.-c). *SWG Work Plan*. Retrieved May 3, 2022, from https://sites.google.com/site/pugetsoundstormwaterworkgroup/home/source-identification-information-repository

Stradling, D. (2013). *The Environmental Moment, 1968-1972*. University of Washington Press.

Tian, Z., Zhao, H., Peter, K. T., Gonzalez, M., Wetzel, J., Wu, C., Hu, X., Prat, J., Mudrock, E., Hettinger, R., Cortina, A. E., Biswas, R. G., Kock, F. V. C., Soong, R., Jenne, A., Du, B., Hou, F., He, H., Lundeen, R., … Kolodziej, E. P. (2022). Erratum: A ubiquitous tire rubber-derived chemical induces acute mortality in coho salmon (Science DOI: 10.1126/science.abd6951). *Science, 375*(6582), 185–189. https://doi.org/10.1126/science.abo5785

United States Senate. (n.d.). *The Clean Waters Restoration Act Signed into Law*. Retrieved June 26, 2022, from https://www.senate.gov/artandhistory/history/minute/Clean_Waters_Restoration_Act.htm

Washington State Department of Ecology. (n.d.-a). *SAM effectiveness studies*. Retrieved June 25, 2022, from https://ecology.wa.gov/Regulations-Permits/Reporting-requirements/Stormwater-monitoring/Stormwater-Action-Monitoring/SAM-effectiveness-studies

Washington State Department of Ecology. (n.d.-b). *SAM source identification*. Retrieved June 25, 2022, from https://ecology.wa.gov/Regulations-Permits/Reporting-requirements/Stormwater-monitoring/Stormwater-Action-Monitoring/SAM-source-identification

Washington State Department of Ecology. (n.d.-c). *SAM status & trends*. Retrieved May 22, 2022, from https://ecology.wa.gov/Regulations-Permits/Reporting-requirements/Stormwater-monitoring/Stormwater-Action-Monitoring/SAM-status-and-trends

Washington State Department of Ecology. (n.d.-d). *Stormwater Action Monitoring - Washington State Department of Ecology*. Retrieved May 3, 2022, from https://ecology.wa.gov/Regulations-Permits/Reporting-requirements/Stormwater-monitoring/Stormwater-Action-Monitoring

Washington State Department of Ecology. (n.d.-e). *Stormwater Work Group*. Retrieved May 14, 2022, from https://ecology.wa.gov/About-us/Accountability-transparency/Partnerships-committees/Stormwater-Work-Group

Washington State Department of Ecology. (2019a). *APPENDIX 12 – IDDE Reporting Data and Format*. 1–25. https://apps.ecology.wa.gov/paris/DownloadDocument.aspx?id=279090

Washington State Department of Ecology. (2019b). *Eastern Washington Phase II Municipal Stormwater Permit*.

Washington State Department of Ecology. (2019c). *Phase I Municipal Stormwater Permit*.

Washington State Department of Ecology. (2019d). *Western Washington Phase II Municipal Stormwater Permit*.

Zwick, D., Benstock, M., & Nader, R. (1971). *Water wasteland; Ralph Nader's study group report on water pollution*.

Appendix A: Contingency Tables and Maximum Likelihood Chi-Squared Analysis

The appendix provides additional detail to the analysis in the results chapter. Appendix A contains tables portraying the chi-squared contingency analysis performed. Appendix B contains a figure of all permittees represented in this study.

Table 3

Observed Frequencies and Residuals for Pollutant Type by Phase Type

	Observed			Observed - Expected	
Factor	**Phase I**	**Phase II**	**Row Total**	**Phase I**	**Phase II**
Firefighting foam	4	3	7	2	-2
Food-related oil/grease	6	7	13	2	-2
Fuel and/or vehicle related fluids	87	127	214	13	-26
Other wastewater	7	10	17	1	-2
Paint	3	22	25	-6	4
Sediment/soil	26	169	195	-41	29
Sewage/septage/pet waste/human waste	57	53	110	19	-26
Soap or cleaning chemicals	10	16	26	1	-3
Solid waste/trash	4	4	8	1	-2
Unconfirmed, unspecified, or not identified	3	41	44	-12	9
Column Total	207	452	615		

Note. This table shows the observed frequencies and the residuals for the chi-square contingency table comparing pollutant types and phase types. This table was derived from the analysis of this study.

(Maximum Likelihood Chi-Square = 79, df = 9, $p<0.001$).

Table 4

Observed Frequencies and Residuals for Pollutant Type by Pollutant Source

	Observed									Observed - Expected							
Factor	1	2	3	4	5	6	7	8	Row Total	1	2	3	4	5	6	7	8
Firefighting foam	0	0	0	0	3	1	0	1	5	-1.54	-0.08	-0.39	-0.18	2.21	0.69	-0.87	0.17
Food-related oil/grease	0	7	1	0	2	1	1	0	12	-3.69	6.80	0.06	-0.44	0.09	0.26	-1.09	-1.99
Fuel and/or vehicle related fluids	10	0	6	8	42	10	36	87	199	-51.23	-3.33	-9.64	0.68	10.39	-2.31	1.39	54.06
Other wastewater	5	1	0	0	2	2	3	1	14	0.69	0.77	-1.10	-0.52	-0.22	1.13	0.57	-1.32
Paint	5	0	5	1	13	3	5	1	33	-5.15	-0.55	2.41	-0.21	7.76	0.96	-0.74	-4.46
Sediment/soil	148	0	2	5	5	4	17	3	184	91.38	-3.08	-12.46	-1.77	-24.23	-7.38	-15.00	-27.46
Sewage/septage/pet waste/human waste	14	0	26	0	27	5	5	1	78	-10.00	-1.30	19.87	-2.87	14.61	0.17	-8.57	-11.91
Soap or cleaning chemicals	0	1	2	1	1	6	8	4	23	-7.08	0.62	0.19	0.15	-2.65	4.58	4.00	0.19
Solid waste/trash	1	1	3	0	0	1	0	0	6	-0.85	0.90	2.53	-0.22	-0.95	0.63	-1.04	-0.99
Unconfirmed, unspecified, or not identified	1	0	2	7	0	4	29	1	44	-12.54	-0.74	-1.46	5.38	-6.99	1.28	21.35	-6.28
Column Total	184	10	47	22	95	37	104	99	598								

Note. This table shows the observed frequencies and the residuals for the chi-square contingency table comparing pollutant types and pollutant sources. This table was derived from the analysis of this study.

Factor key: 1 = construction activity; 2 =food-related business; 3 = Illicit connection and intentional dumping categories combined; 4 = landscape-related business; 5 = other accident/spill; 6 = other commercial/industrial activity; 7 = unconfirmed; 8 = vehicle collision.

(Maximum Likelihood Chi-Square = 904, df = 63, $p<0.0001$)

Table 5

Observed Frequencies and Residuals for Pollutant Type by Correction Method

	Observed					Observed-Expected			
Factor	**1**	**2**	**3**	**4**	**Row Total**	**1**	**2**	**3**	**4**
Firefighting foam	0	6	0	0	6	-0.40	1.50	-0.83	-0.27
Food-related oil/grease	1	7	0	3	11	0.26	-1.26	-1.51	2.51
Fuel and/or vehicle related fluids	1	200	5	0	206	-12.85	45.33	-23.37	-9.12
Other wastewater	1	8	6	1	16	-0.08	-4.01	3.80	0.29
Paint	0	20	3	1	24	-1.61	1.98	-0.30	-0.06
Sediment/soil	34	97	35	18	184	21.63	-41.15	9.66	9.86
Sewage/septage/pet waste/human waste	2	77	7	4	90	-4.05	9.43	-5.39	0.02
Soap or cleaning chemicals	1	10	14	0	25	-0.68	-8.77	10.56	-1.11
Solid waste/trash	0	7	0	0	7	-0.47	1.74	-0.96	-0.31
Unconfirmed, unspecified, or not identified	1	26	14	0	41	-1.76	-4.78	8.35	-1.81
Column Total	41	458	84	27	610				

Note. This table shows the observed frequencies and the residuals for the chi-square contingency table comparing pollutant types and correction methods. This table was derived from the analysis of this study.

Factor key: 1 = BMP; 2 = cleanup; 3 = education/technical assistance; 4 = enforcement and referral to another agency categories combined.

(Maximum Likelihood Chi-Square = 209, df = 27, p<0.0001)

Table 6

Observed Frequencies and Residuals for Pollutant Type by Discovery Method

	Observed				Observed-Expected		
Factor	**1**	**2**	**3**	**Row total**	**1**	**2**	**3**
Firefighting foam	2	3	4	9	1.35	-0.61	-0.74
Food-related oil/grease	2	3	7	12	1.13	-1.82	0.69
Fuel and/or vehicle related fluids	1	107	101	209	-14.11	23.08	-8.97
Other wastewater	1	4	11	16	-0.16	-2.42	2.58
Paint	2	10	12	24	0.26	0.36	-0.63
Sediment/soil	22	50	125	197	7.76	-29.10	21.35
Sewage/septage/pet waste/human waste	11	44	55	110	3.05	-0.17	-2.88
Soap or cleaning chemicals	2	9	10	21	0.48	0.57	-1.05
Solid waste/trash	2	2	4	8	1.42	-1.21	-0.21
Unconfirmed, unspecified, or not identified	2	29	13	44	-1.18	11.33	-10.15
Column Total	47	261	342	650			

Note. This table shows the observed frequencies and the residuals for the chi-square contingency table comparing pollutant types and discovery methods. This table was derived from the analysis of this study.

Factor key: 1 = inspection methods; 2 = pollution hotline; 3 = intra or interagency referral.

(Maximum Likelihood Chi-Square = 64, df = 18, $p<0.0001$).

Table 7

Observed Frequencies and Residuals for Pollutant Type by Tracing Method

	Observed			Observed-Expected	
Factor	**1**	**2**	**Row total**	**1**	**2**
Firefighting foam	2	5	7	0.33	-0.33
Food-related oil/grease	3	9	12	0.14	-0.14
Fuel and/or vehicle related fluids	61	152	213	10.29	-10.29
Other wastewater	3	14	17	-1.05	1.05
Paint	3	22	25	-2.95	2.95
Sediment/soil	23	169	192	-22.71	22.71
Sewage/septage/pet waste/human waste	39	69	108	13.29	-13.29
Soap or cleaning chemicals	10	16	26	3.81	-3.81
Solid waste/trash	3	4	7	1.33	-1.33
Unconfirmed, unspecified, or not identified	8	36	44	-2.48	2.48
Column total	155	496	651		

Note: This table shows the observed frequencies and the residuals for the chi-square contingency table comparing pollutant types and tracing methods. This table was derived from the analysis of this study.

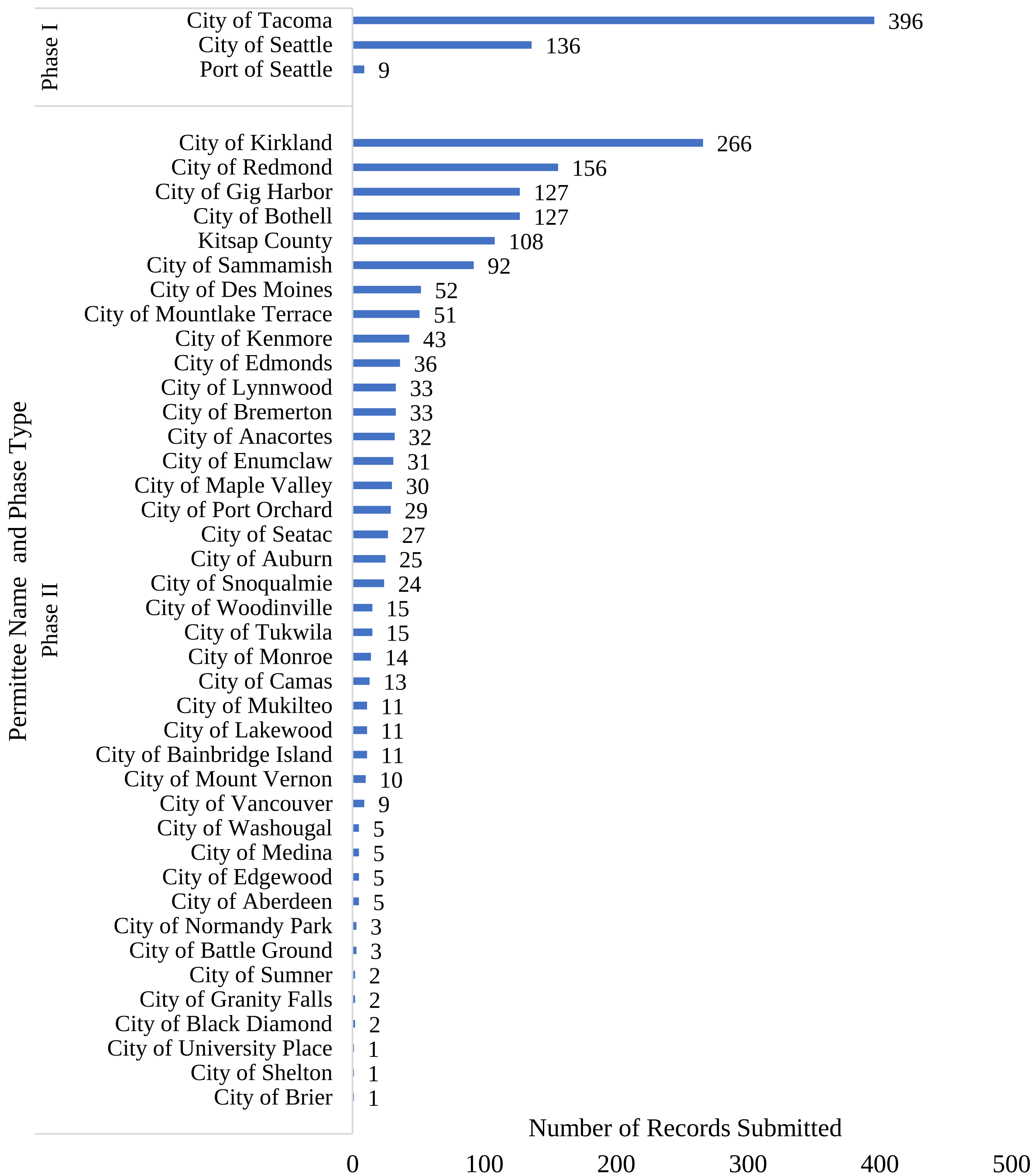
Factor key: 1 = in pipe testing and not applicable categories combined; 2 = visual and empirical methods

(Maximum Likelihood Chi Square = 34, df = 9, p<0.0001).

Appendix B: Permittees Represented

Figure 18

Permittee Names and Frequencies of Records Submitted



Note. This figure is a list of permittees derived from the analysis of this study.