Illicit Discharge Detection and Elimination

A Guidance Manual for Program Development and Technical Assessments

by the
Center for
Watershed Protection

and
Robert Pitt
University of Alabama

October 2004

Notice

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under cooperative agreement X-82907801-0. Although it has been subjected to the Agency's peer and administrative review, it does not necessarily reflect the views of the Agency, and no official endorsement should be inferred. Also, the mention of trade names or commercial products does not imply endorsement by the United States government, the Center for Watershed Protection, or the University of Alabama.

ILLICIT DISCHARGE DETECTION AND ELIMINATION: A GUIDANCE MANUAL FOR PROGRAM DEVELOPMENT AND TECHNICAL ASSESSMENTS

by

Edward Brown and Deb Caraco
Center for Watershed Protection
Ellicott City, Maryland 21043

and

Robert Pitt
University of Alabama
Tuscaloosa, Alabama 35487

EPA Cooperative Agreement
X-82907801-0

Project Officer

Bryan Rittenhouse
Water Permits Division
Office of Water and Wastewater
U.S. Environmental Protection Agency
Washington, D.C.

October 2004

Photo Acknowledgments

Figure Number	***Source***
3	Regional Water Quality Control Board
4	Fort Worth Department of Environmental Management (DEM)
5	Fort Worth DEM
7	South Florida Water Management District (website)
8	Robert Pitt, University of Alabama
14	Robert Pitt
28 (fire hydrant)	Fort Worth DEM
34 (Chromium spill)	Fort Worth DEM
34 (highly turbid discharge)	Rachel Calabro, Massachussets Department of Environmental Protection
34 (industrial discharge)	Robert Pitt
34 (paint)	Robert Pitt
34 (Toronto industrial spill)	Robert Pitt
34 (blood)	Fort Worth DEM
34 (failing septic)	Snohomish County, WA
34 (construction site)	Don Green, Franklin, TN
34 (discharge of rinse water)	Rachel Calabro
35 (natural foam)	Snohomish County, WA
35 (high severity suds)	Fort Worth DEM
35 (moderate severity oil)	R. Frymire
35 (high severity oil)	Kelly Dinsmore, City of Newark, DE
38 (bright red bacteria)	R. Frymire
38 (Sporalitis filamentous)	Robert Ressl, City of Arlington, TX
38 (extreme algal growth)	Mark Sommerfield, Montgomery Co., Maryland
38 (brownish algae)	R. Frymire
39 (*all* but 'brownish stain')	R. Frymire
41 (*all*)	R. Frymire
42	Galveston, TX
48	Fort Worth DEM
49	Dr. Robert Pitt
52-53	Jewell, 2001
58-59	Jewell, 2001
60	Sargent and Castonguay, 1998
63	NEIWPCC, 2003
65-67	www.darrscleaning.com
68	www.usabluebook.com
69	www.superiorsignal.com
70-71	www.darrscleaning.com
72 (a)	Anish Jantrania
72 (b)	Snohomish County, WA
72 (c)	King County, WA
73	www.delmarva-homeinspector.com
74	Mecklenburg, NC Water Quality Program
75	U.S. EPA, 1999

Foreword

A number of past projects have found that dry-weather flows discharging from storm drainage systems can contribute significant pollutant loadings to receiving waters. If these loadings are ignored (by only considering wet-weather stormwater runoff, for example), little improvement in receiving water conditions may occur. Illicit dry-weather flows originate from many sources. The most important sources typically include sanitary wastewater or industrial and commercial pollutant entries, failing septic tank systems, and vehicle maintenance activities.

Provisions of the Clean Water Act (1987) require National Pollutant Discharge Elimination System (NPDES) permits for storm water discharges. Section 402 (p)(3)(B)(ii) requires that permits for municipal separate storm sewers shall include a requirement to effectively prohibit problematic non-storm water discharges into storm sewers. Emphasis is placed on the elimination of inappropriate connections to urban storm drains. This requires affected agencies to identify and locate sources of non-storm water discharges into storm drains so they may institute appropriate actions for their elimination.

This Manual is intended to provide support and guidance, primarily to Phase II NPDES MS4 communities, for the establishment of Illicit Discharge Detection and Elimination (IDDE) programs and the design and procedures of local investigations of non-storm water entries into storm drainage systems. It also has application for Phase I communities looking to modify existing programs and community groups such as watershed organizations that are interested in providing reconnaissance and public awareness services to communities as part of watershed restoration activities.

This Manual was submitted in partial fulfillment of cooperative agreement X-82907801-0 under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from July 2001 to July 2004 and was prepared by the Center for Watershed Protection, Ellicott City, MD in cooperation with Robert Pitt of the University of Alabama.

Some references in the document pertain to work conducted during this project. This internal support information was developed as work tasks were completed and research findings were developed. In some cases, memoranda or technical support documents were prepared. Most of these documents are in “draft” form and have not been published. As a result, they should be considered supplemental and preliminary information that is not intended for widespread citation or distribution. In the References section, these documents are identified as “IDDE project support material” at the end of each citation. Interested readers can access these documents through the website link to the project archive and support information.

Acknowledgments

This Guidance Manual could not have been completed had it not been for the contributions of many individuals. Much of the field survey and laboratory analysis guidance in this manual reflects an update to information presented in Pitt *et. al.* (1993). Bob Pitt and his students and researchers have been instrumental in furthering the science to develop and identify safe, quick, accurate and cost effective methods to collect and analyze dry weather flow samples. Team members from the University of Alabama that contributed to this manual include: Bob Pitt, Soumya Chaturvedula, Sanju Jacob, Veera Karri, Uday Khambhammettu, Alex Maestre, Renee Morquecho, Yukio Nara, and Sumandeep Shergill. Team members from the Center for Watershed Protection include Jessica Brooks, Ted Brown, Karen Cappiella, Deb Caraco, Tom Schueler, Stephanie Sprinkle, Paul Sturm, Chris Swann, Tiffany Wright, and Jennifer Zielinski.

Support from EPA has been constant and valuable. We would like to thank Wendy Bell and Jack Faulk of the Office of Wastewater, and in particular, project officer, Bryan Rittenhouse.

We are grateful to the many communities that agreed to fill out our extensive surveys and questionnaires including:

- Erica Anderson Maguire, Ada County Highway District, ID
- Charles Caruso, City of Albuquerque, NM
- Bill Hicks, City of Alexandria, VA
- Jason Papacosma, Arlington County, VA
- Roger Glick and Roxanne Jackson, City of Austin, TX
- Bill Stack, Baltimore City, MD
- Amy Schofield, Boston Water and Sewer Commission, MA
- John Nardone and James Wilcox, City of Cambridge, MA
- Andrew Swanson, Clackamas County, OR
- Michele Jones, City of Dayton, OH
- John H. Cox, City of Durham, NC
- Moe Wadda, City of Falls Church, VA
- Angela Morales, Howard County, MD
- David Hagerman and Bob Jones, City of Knoxville, TN
- Alan Searcy, City of Lakewood, CO
- Meosotis Curtis and David Rotolone, Montgomery County, MD
- Michael Loffa, City of Phoenix, AZ
- Ali Dirks, City of Portland, OR
- Mark Senior, City of Raleigh, NC
- Beth Schmoyer, City of Seattle, WA
- Todd Wagner, City of Springfield, MO
- Arne Erik Anselm, City of Thousand Oaks, CA
- Dean Tuomari, Wayne County, MI
- David Harris, City of Worcester, MA

Others that provided useful insight into their community programs include Michael Hunt, City of Nashville, TN; Mecklenburg County, NC; and Steve Jadlocki, City of Charlotte, NC.

The communities of Baltimore City, MD; Baltimore County, MD; Boston Water and Sewer Commission, MA; Cambridge, MA, Dayton, OH; Fort Worth, TX; Raleigh, NC; Tuscaloosa, AL; and Wayne County, MI were extremely generous in hosting project team members and sharing the details of their programs. A special thanks goes to Baltimore City, MD and Baltimore County, MD for providing access to laboratory and field equipment, and allowing protocols to be tested in their subwatersheds. Baltimore City staff members we would like to recognize include: Bill Stack, Dr. Freddie Alonzo, Ted

Eucare, Shelly Jesatko, Hector Manzano, Umoja Muleyyar, Van Sturtevant, and Joan White. Baltimore County staff we would like to recognize include Steve Stewart and Steve Adamski.

Many of the outstanding graphics in the Manual were provided by outside sources. While sources are noted on the back of the title page, we would like to especially thank the following:

- Rachel Calabro, MA DEP
- Kelly Dinsmore, City of Newark, DE
- Donette Dunaway, California RWQCB Region 3
- Fort Worth Department of Environmental Management
- Roger Frymire
- Dave Graves, New York DOT
- Don Green, Franklin, TN
- Hillsborough County Public Works Department, Stormwater Management Section
- Rusty Rozzelle, Mecklenburg County, NC
- Mark Sommerfield, Montgomery County, MD
- Greg Stockton, Stockton Infrared Thermographic Services, Inc.
- Barry Tonning, Tetra Tech

Table of Contents

List of Tables

List of Figures

Introduction

An up-to-date and comprehensive manual on techniques to detect and correct discharges in municipal storm drains has been unavailable until now. This has been a major obstacle for both Phase I and Phase II National Pollutant Discharge Elimination System (NPDES) municipal separate storm sewer system (MS4) communities that must have programs in place that detect, eliminate, and prevent illicit discharges to the storm drain system. Smaller Phase II communities, in particular, need simple but effective program guidance to comply with permits issued by the Environmental Protection Agency (EPA) and states. This manual provides communities with guidance on establishing and implementing an effective Illicit Discharge Detection and Elimination (IDDE) program.

Studies have shown that dry weather flows from the storm drain system may contribute a larger annual discharge mass for some pollutants than wet weather storm water flows (EPA, 1983 and Duke, 1997). Detecting and eliminating these illicit discharges involves complex detective work, which makes it hard to establish a rigid prescription to "hunt down" and correct all illicit connections. Frequently, there is no single approach to take, but rather a variety of ways to get from detection to elimination. Local knowledge and available resources can play significant roles in determining which path to take. At the very least, communities need to systematically understand and characterize their stream, conveyance, and storm sewer infrastructure systems. When illicit discharges are identified, they need to be removed. The process is ongoing and the effectiveness of a program should improve with time. In fact, well-coordinated IDDE programs can benefit from and contribute to other community-wide water resources-based programs, such as public education, storm water management, stream restoration, and pollution prevention.

This manual incorporates the experience of more than 20 Phase I communities that were surveyed about their practices, levels of program effort, and lessons learned (CWP, 2002). These communities took many different approaches to solve the IDDE problem, and provided great insights on common obstacles, setting realistic expectations and getting a hard job done right. Many of the IDDE methods presented in this manual were first developed and tested in many Phase I communities. Specific techniques applied in a community should be adapted to local conditions, such as dominant discharge types, land use, and generating sites.

Designed with a broad audience in mind, including agency heads, program managers, field technicians and water quality analysts, this manual is primarily focused on providing the thousands of Phase II communities that are now in the process of developing IDDE programs with guidance for the development and implementation of their own programs. The manual has been organized to address the broad range of administrative and technical considerations involved with setting up an effective IDDE program. The first 10 chapters of the Manual focus on "big picture" considerations needed to successfully get an IDDE program off the ground. The final four chapters provide detailed technical information on the methods to screen, characterize and remove illicit discharges in MS4 communities. These chapters present the state-of-the-practice on specific monitoring techniques and protocols.

In general, the content of this manual gets progressively more complex and technical toward the end. The basic organization of the manual is outlined below. The information is provided to help:

- Define important terminology and understand key illicit discharge concepts
- Conduct an audit to understand community needs and capabilities
- Establish adequate legal authority
- Develop a tracking system to map outfalls and document reported illicit discharges
- Conduct desktop analyses to prioritize targets for illicit discharge control
- Conduct rapid reconnaissance of the stream corridor to find problem outfalls
- Apply new analytical and field methods to find and fix illicit discharges
- Educate municipal employees and the public to prevent discharges
- Estimate costs to run a program and conduct specific investigations

Chapter 1. The Basics of Illicit Discharges - The many different sources and generating sites that can produce illicit discharges are described in Chapter 1. The chapter also outlines key concepts and terminology needed to understand illicit discharges, why they cause water quality problems and the regulatory context for managing them.

Chapter 2. Components of an Effective Illicit Discharge Program – This chapter presents an overall framework to build an IDDE program, by outlining eight key components of good programs. Each of the following eight chapters is dedicated to a key program component. The first page of the program component chapters is notated with a puzzle icon labeled with the applicable program component number.

Chapter 3. Audit Existing Resources and Programs – This chapter provides guidance on evaluating existing resources, regulations, and ongoing activities in your community to better address illicit discharges.

Chapter 4. Establish Responsibility, Authority and Tracking – This chapter presents guidance on how to identify the local agency who will be responsible for administering the IDDE program, and how to establish the legal authority to control illicit discharges by adapting an existing ordinance or adopting a new one. The chapter also describes how to set up a program tracking system needed to document discharges and local actions to respond to them.

Chapter 5. Desktop Assessment of Illicit Discharge Potential – The fifth chapter describes desktop analyses to process available mapping data to quickly characterize and screen illicit discharge problems at the community and subwatershed scale. Key factors include water quality, land use, development age, sewer infrastructure and outfall density. Rapid screening techniques are presented to define where to begin searching for illicit discharge problems in your community.

Chapter 6. Developing Program Goals and Implementation Strategies – Communities are required to establish and track measurable goals for their IDDE program under the NPDES MS4 permit program. This chapter recommends a series of potential program goals that can guide local efforts, as well as guidance on how to measure and track progress toward their achievement.

Chapter 7. Searching for Illicit Discharge Problems in the Field – This chapter briefly summarizes the major monitoring techniques to find illicit discharges, and discusses how to select the right combination of monitoring methods to incorporate into your local program.

Chapter 8. Isolating and Fixing Individual Illicit Discharges – The methods used to find and remove illicit discharges are briefly described in this chapter and include citizen hotlines and techniques to trace, locate and remove illicit discharge sources.

Chapter 9. Preventing Illicit Discharges – Prevention is a cost effective way to reduce pollution from illicit discharge. This chapter highlights a series of carrot and stick strategies to prevent illicit discharges.

Chapter 10. IDDE Program Evaluation – IDDE programs must continually evolve to changing local conditions. This chapter describes how to review and revisit program goals to determine if they are being met and to make any needed adjustments.

Chapter 11. The Outfall Reconnaissance Inventory (ORI) – The chapter presents detailed protocols to conduct rapid field screening of problem outfalls. The chapter also outlines the staff and equipment costs needed to conduct an ORI, and presents methods to organize, manage and interpret the data you collect.

Chapter 12. Chemical Monitoring – This chapter presents detailed guidance on the wide range of chemical monitoring options that can be used to identify the composition of illicit discharge flows. The chapter begins by describing different chemical indicators that have been used to identify illicit discharges, and presents guidance on how to collect samples for analysis. The chapter recommends a flow chart approach that utilizes four chemical indicators to distinguish the flow type. The chapter provides specific information on other analytical methods that can be used, as well as proper safety, handling, and disposal procedures. Simple and more sophisticated methods for interpreting monitoring data are discussed, along with comparative cost information.

Chapter 13. Tracking Discharges to Their Source – This chapter describes how to investigate storm drain systems to narrow and remove individual illicit discharges. These techniques include "trunk" investigations (e.g., video surveillance, damming, and infiltration and inflow studies) and on-site investigations (e.g., dye tests, smoke tests, and pollution prevention surveys). The pros and cons of each investigation technique are discussed, and comparative cost estimates are given.

Chapter 14. Techniques to Fix Discharges – This chapter provides tips on the best methods to repair or eliminate discharges. Specific advice is presented on how to identify responsible parties, develop pre-approved subcontractor lists, and estimate unit costs for typical repairs.

Appendices – Eleven technical appendices are provided at the end of the manual.

Chapter 1: The Basics of Illicit Discharges

An understanding of the nature of illicit discharges in urban watersheds is essential to find, fix and prevent them. This chapter begins by defining the terms used to describe illicit discharges, and then reviews the water quality problems they cause. Next, the chapter presents the regulatory context for controlling illicit discharges, and reviews the experience local communities have gained in detecting and eliminating them.

1.1 Important Terminology and Key Concepts

This Manual uses several important terms throughout the text that merit upfront explanation. This section defines the terminology to help program managers perform important illicit discharge detective work in their communities. Key concepts are presented to classify illicit discharges, generating sites and control techniques.

Illicit Discharge

The term "illicit discharge" has many meanings in regulation[1] and practice, but we use a four-part definition in this manual.

1. Illicit discharges are defined as a storm drain that has measurable flow during dry weather containing pollutants and/or pathogens. A storm drain with measurable flow but containing no pollutants is simply considered a discharge.

2. Each illicit discharge has a unique frequency, composition and mode of entry in the storm drain system.

3. Illicit discharges are frequently caused when the sewage disposal system interacts with the storm drain system. A variety of monitoring techniques is used to locate and eliminate illegal sewage connections. These techniques trace sewage flows from the stream or outfall, and go back up the pipes or conveyances to reach the problem connection.

4. Illicit discharges of other pollutants are produced from specific source areas and operations known as "generating sites." Knowledge about these generating sites can be helpful to locate and prevent non-sewage illicit discharges. Depending on the regulatory status of specific "generating sites," education, enforcement and other pollution prevention techniques can be used to manage this class of illicit discharges.

Communities need to define illicit discharges as part of an illicit discharge ordinance. Some non-storm water discharges to the MS4 may be allowable, such as discharges resulting from fire fighting activities and air conditioning condensate. Chapter 4 provides more detail on ordinance development.

[1] 40 CFR 122.26(b)(2) defines an illicit discharge as any discharge to an MS4 that is not composed entirely of storm water, except allowable discharges pursuant to an NPDES permit, including those resulting from fire fighting activities.

Storm Drain

A **storm drain** can be either an *enclosed pipe* or an *open channel*. From a regulatory standpoint, **major** storm drains are defined as enclosed storm drain pipes with a diameter of 36 inches, or greater or open channels that drain more than 50 acres. For industrial land uses, major drains are defined as enclosed storm drain pipes 12 inches or greater in diameter and open channels that drain more than two acres. **Minor** storm drains are smaller than these thresholds. Both major and minor storm drains can be a source of illicit discharges, and both merit investigation.

Some "pipes" found in urban areas may look like storm drains but actually serve other purposes. Examples include foundation drains, weep holes, culverts, etc. These pipes are generally not considered storm drains from a regulatory or practical standpoint. Small diameter "straight pipes," however, are a common source of illicit discharges in many communities and should be investigated to determine if they are a pollutant source.

Not all dry weather storm drain flow contains pollutants or pathogens. Indeed, many communities find that storm drains with dry weather flow are, in fact, relatively clean. Flow in these drains may be derived from springs, groundwater seepage, or leaks from water distribution pipes. Consequently, field testing and/or water quality sampling are needed to confirm whether pollutants are actually present in dry weather flow, in order to classify them as an illicit discharge.

Discharge Frequency

The **frequency** of dry weather discharges in storm drains is important, and can be classified as *continuous, intermittent or transitory.*

Continuous discharges occur most or all of the time, are usually easier to detect, and typically produce the greatest pollutant load. **Intermittent** discharges occur over a shorter period of time (e.g., a few hours per day or a few days per year). Because they are infrequent, intermittent discharges are hard to detect, but can still represent a serious water quality problem, depending on their flow type. **Transitory** discharges occur rarely, usually in response to a singular event such as an industrial spill, ruptured tank, sewer break, transport accident or illegal dumping episode. These discharges are extremely hard to detect with routine monitoring, but under the right conditions, can exert severe water quality problems on downstream receiving waters.

Discharge Flow Types

Dry weather discharges are composed of one or more possible **flow types**:

- *Sewage and septage* flows are produced from sewer pipes and septic systems.

- *Washwater* flows are generated from a wide variety of activities and operations. Examples include discharges of gray water (laundry) from homes, commercial carwash wastewater, fleet washing, commercial laundry wastewater, and floor washing to shop drains.

- *Liquid wastes* refers to a wide variety of flows, such as oil, paint, and process water (radiator flushing water, plating bath wastewater, etc.) that enter the storm drain system.

- *Tap water* flows are derived from leaks and losses that occur during the distribution of drinking water in the water supply system. Tap water discharges in the storm drain system may be more prevalent in communities with high loss rates (i.e., greater than 15%) in their potable water distribution system. (source of 15% is from National Drinking Water Clearinghouse http://www.nesc.wvu.edu/ndwc/articles/OT/FA02/Economics_Water.html)

- *Landscape irrigation* flows occur when excess potable water used for residential or commercial irrigation ends up in the storm drain system.
- *Groundwater and spring water* flows occur when the local water table rises above the bottom elevation of the storm drain (known as the invert) and enters the storm drain either through cracks and joints, or where open channels or pipes associated with the MS4 may intercept seeps and springs.

Water quality testing is used to conclusively identify flow types found in storm drains. Testing can distinguish illicit flow types (sewage/septage, washwater and liquid wastes) from cleaner discharges (tap water, landscape irrigation and ground water).

Each flow type has a distinct chemical fingerprint. Table 1 compares the pollutant fingerprint for different flow types in Alabama. The chemical fingerprint for each flow type can differ regionally, so it is a good idea to develop your own "fingerprint" library by sampling each local flow type.

In practice, many storm drain discharges represent a blend of several flow types, particularly at larger outfalls that drain larger catchments. For example, groundwater flows often dilute sewage thereby masking its presence. Chapter 12 presents several techniques to help isolate illicit discharges that are blended with cleaner discharges. Illicit discharges are also masked by high volumes of storm water runoff making it difficult and frequently impossible to detect them during wet weather periods.

Mode of Entry

Illicit discharges can be further classified based on how they enter the storm drain system. The **mode of entry** can either be **direct** or **indirect. Direct entry** means that the discharge is directly connected to the storm drain pipe through a sewage pipe, shop drain, or other kind of pipe. Direct entry usually produces discharges that are continuous or intermittent. Direct entry usually occurs when two different kinds of "plumbing" are improperly connected. The three main situations where this occurs are:

<u>Sewage cross-connections</u>: A sewer pipe that is improperly connected to the storm drain system produces a continuous discharge of raw sewage to the pipe (Figure 1). Sewage cross-connections can occur in catchments where combined sewers or septic systems are converted to a separate sewer system, and a few pipes get "crossed."

<u>Straight pipe</u>: This term refers to relatively small diameter pipes that intentionally bypass the sanitary connection or septic drain fields, producing a direct discharge into open channels or streams as shown in Figure 2.

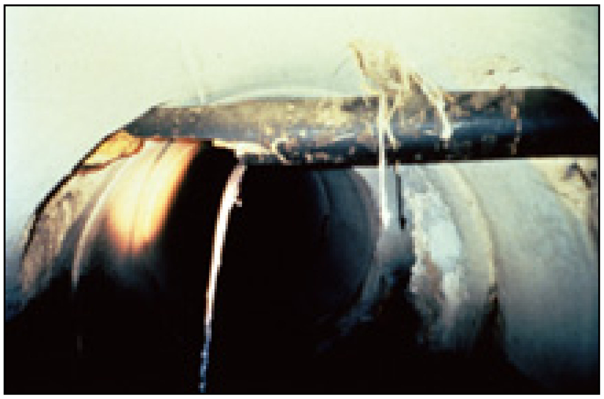


Figure 1: Sewer Pipe Discharging to the Storm Drain System

Table 1: Comparative "Fingerprint" (Mean Values) of Flow Types						
Flow Type	**Hardness (mg/L as CaCO3)**	**NH_3 (mg/L)**	**Potassium (mg/L)**	**Conductivity (µS/cm)**	**Fluoride (mg/L)**	**Detergents (mg/L)**
Sewage	50 (0.26)*	25 (0.53)*	12 (0.21)*	1215 (0.45)*	0.7 (0.1)*	9.7 (0.17)*
Septage**	57(0.36)	87 (0.4)	19 (0.42)	502 (0.42)	0.93 (0.39)	3.3 (1.33)
Laundry Washwater	45 (0.33)	3.2 (0.89)	6.5 (0.78)	463.5 (0.88)	0.85 (0.4)	758 (0.27)
Car Washwater	71 (0.27)	0.9 (1.4)	3.6 (0.67)	274 (0.45)	1.2 (1.56)	140 (0.2)
Plating Bath (Liquid Industrial Waste**)	1430 (0.32)	66 (0.66)	1009 (1.24)	10352 (0.45)	5.1 (0.47)	6.8 (0.68)
Radiator Flushing (Liquid Industrial Waste**)	5.6 (1.88)	26 (0.89)	2801 (0.13)	3280 (0.21)	149 (0.16)	15 (0.11)
Tap Water	52 (0.27)	<0.06 (0.55)	1.3 (0.37)	140 (0.07)	0.94 (0.07)	0 (NA)
Groundwater	38 (0.19)	0.06 (1.35)	3.1 (0.55)	149 (0.24)	0.13 (0.93)	0 (NA)
Landscape Irrigation	53 (0.13)	1.3 (1.12)	5.6 (0.5)	180 (0.1)	0.61 (0.35)	0 (NA)

** The number in parentheses after each concentration is the Coefficient of Variation; NA = Not Applicable*
*** All values are from Tuscaloosa, AL monitoring except liquid wastes and septage, which are from Birmingham, AL.*
Sources: Pitt (project support material) and Pitt et al. (1993)

Figure 2: Direct Discharge from a Straight Pipe

Sewage has the greatest potential to produce *direct* illicit discharges within any urban subwatershed, regardless of the diverse land uses that it comprises. The most commonly reported sewage-related direct discharges are broken sanitary sewer lines (81% of survey respondents), cross-connections (71% of survey respondents), and straight pipe discharges (38% of survey respondents). (CWP, 2002).

Industrial and commercial cross-connections*:* These occur when a drain pipe is improperly connected to the storm drain system producing a discharge of wash water, process water or other inappropriate flows into the storm drain pipe. A floor shop drain that is illicitly connected to the storm drain system is illustrated in Figure 3. Older industrial areas tend to have a higher potential for illicit cross-connections.

Indirect entry means that flows generated outside the storm drain system enter through storm drain inlets or by infiltrating through the joints of the pipe. Generally, indirect modes of entry produce intermittent or transitory discharges, with the exception of groundwater seepage. The five main modes of indirect entry for discharges include:

Groundwater seepage into the storm drain pipe*:* Seepage frequently occurs in storm drains after long periods of above average rainfall. Seepage discharges can be either continuous or intermittent, depending on the depth of the water table and the season. Groundwater seepage usually consists of relatively clean water that is not an illicit discharge by itself, but can mask other illicit discharges. If storm drains are located close to sanitary sewers, groundwater seepage may intermingle with diluted sewage.

Spills that enter the storm drain system at an inlet: These transitory discharges occur when a spill travels across an impervious surface and enters a storm drain inlet. Spills can occur at many industrial, commercial and transport-related sites. A very common example is an oil or gas spill from an accident that then travels across the road and into the storm drain system (Figure 4).

Dumping a liquid into a storm drain inlet*:* This type of transitory discharge is created when liquid wastes such as oil, grease, paint, solvents, and various automotive fluids are dumped into the storm drain (Figure 5). Liquid dumping occurs intermittently at sites that improperly dispose of rinse water and wash water during maintenance and cleanup operations. A common example is cleaning deep fryers in the parking lot of fast food operations.

Outdoor washing activities that create flow to a storm drain inlet: Outdoor washing may or may not be an illicit discharge, depending on the nature of the generating site that produces the wash water. For example, hosing off individual sidewalks and driveways may not generate significant flows or pollutant loads. On the other hand, routine washing of fueling areas, outdoor storage areas, and parking lots (power washing), and construction equipment cleanouts may result in unacceptable pollutant loads (Figure 6).

Non-target irrigation from landscaping or lawns that reaches the storm drain system: Irrigation can produce intermittent discharges from over-watering or misdirected sprinklers that send tap water over impervious areas (Figure 7). In some instances, non-target irrigation can produce unacceptable loads of nutrients, organic matter or pesticides. The most common example is a discharge from commercial landscaping areas adjacent to parking lots connected to the storm drain system.

Figure 3: A common industrial cross connection is a floor drain that is illicitly connected to a storm drain

Figure 4: Accident spills are significant sources of illicit discharges to the storm drain system

Figure 5: Dumping at a storm drain inlet

Figure 6: Routine outdoor washing and rinsing can cause illicit discharges

Figure 7: Non-target landscaping irrigation water

Land Use and Potential Generating Sites

Land use can predict the potential for indirect discharges, which are often intermittent or transitory. Many indirect discharges can be identified and prevented using the concept of "generating sites," which are sites where common operations can generate indirect discharges in a community. Both research and program experience indicate that a small subset of generating sites within a broader land use category can produce most of the indirect discharges. Consequently, the density of potential generating sites within a subwatershed may be a good indicator of the severity of local illicit discharge problems. Some common generating sites within major land use categories are listed in Table 2, and described below.

Residential Generating Sites: Failing septic systems were the most common residential discharge reported in 33% of IDDE programs surveyed (CWP, 2002). In addition, indirect residential discharges were also frequently detected in 20% of the IDDE programs surveyed, which consisted of oil dumping, irrigation overflows, swimming pool discharges, and car washing. Many indirect discharges are caused by common residential behaviors and may not be classified as "illicit" even though they can contribute to water quality problems. With the exception of failing septic systems and oil dumping, most communities have chosen education rather than enforcement as the primary tool to prevent illicit discharges from residential areas.

Commercial Generating Sites: Illicit discharges from commercial sites were reported as frequent in almost 20% of local IDDE programs surveyed (CWP, 2002). Typical commercial discharge generators included operations such as outdoor washing; disposal of food wastes; car fueling, repair, and washing; parking lot power washing; and poor dumpster management. Recreational areas, such as marinas and campgrounds, were also reported to be a notable source of sewage discharges. It is important to note that not all businesses within a generating category actually produce illicit discharges; generally only a relatively small fraction do. Consequently, on-site inspections of individual businesses are needed to confirm whether a property is actually a generating site.

Sewage can also be linked to significant *indirect* illicit discharges in the form of sanitary sewer overflows (52% of survey respondents), sewage infiltration/inflow (48% of survey respondents), and sewage dumping from recreational vehicles (33% of survey respondents) (CWP, 2002).

Table 2: Land Uses, Generating Sites and Activities That Produce Indirect Discharges		
Land Use	**Generating Site**	**Activity that Produces Discharge**
Residential	• Apartments • Multi-family • Single Family Detached	• Car Washing • Driveway Cleaning • Dumping/Spills (e.g., leaf litter and RV/boat holding tank effluent) • Equipment Washdowns • Lawn/Landscape Watering • Septic System Maintenance • Swimming Pool Discharges
Commercial	• Campgrounds/RV parks • Car Dealers/Rental Car Companies • Car Washes • Commercial Laundry/Dry Cleaning • Gas Stations/Auto Repair Shops • Marinas • Nurseries and Garden Centers • Oil Change Shops • Restaurants • Swimming Pools	• Building Maintenance (power washing) • Dumping/Spills • Landscaping/Grounds Care (irrigation) • Outdoor Fluid Storage • Parking Lot Maintenance (power washing) • Vehicle Fueling • Vehicle Maintenance/Repair • Vehicle Washing • Washdown of greasy equipment and grease traps
Industrial	• Auto recyclers • Beverages and brewing • Construction vehicle washouts • Distribution centers • Food processing • Garbage truck washouts • Marinas, boat building and repair • Metal plating operations • Paper and wood products • Petroleum storage and refining • Printing	• All commercial activities • Industrial process water or rinse water • Loading and un-loading area washdowns • Outdoor material storage (fluids)
Institutional	• Cemeteries • Churches • Corporate Campuses • Hospitals • Schools and Universities	• Building Maintenance (e.g., power washing) • Dumping/Spills • Landscaping/Grounds Care (irrigation) • Parking Lot Maintenance (power washing) • Vehicle Washing
Municipal	• Airports • Landfills • Maintenance Depots • Municipal Fleet Storage Areas • Ports • Public Works Yards • Streets and Highways	• Building Maintenance (power washing) • Dumping/Spills • Landscaping/Grounds Care (irrigation) • Outdoor Fluid Storage • Parking Lot Maintenance (power washing) • Road Maintenance • Spill Prevention/Response • Vehicle Fueling • Vehicle Maintenance/Repair • Vehicle Washing

Industrial Generating Sites: Industrial sites produce a wide range of flows that can cause illicit discharges. The most common continuous discharges are operations involving the disposal of rinse water, process water, wash water and contaminated, non-contact cooling water. Spills and leaks, ruptured pipes, and leaking underground storage tanks are also a source of indirect discharges. Illicit discharges from industry were detected in nearly 25% of the local IDDE programs surveyed (CWP, 2002).

Industries are classified according to hundreds of different Standard Industrial Classification (SIC) codes. The SIC coding system also includes commercial, institutional and municipal operations[2]. Many industries are required to have storm water pollution prevention and spill response plans under EPA's Industrial Storm Water NPDES Permit Program. A complete list of the industries covered by the Storm Water NPDES Permit Program can be found in Appendix A. The appendix also rates each industrial category based on its potential to produce illicit discharges, based on analysis by Pitt (2001).

Institutional Generating Sites*:* Institutions such as hospitals, corporate campuses, colleges, churches, and cemeteries can be generating sites if routine maintenance practices/operations create discharges from parking lots and other areas. Many large institutional sites have their own areas for fleet maintenance, fueling, outdoor storage, and loading/unloading that can produce indirect discharges.

Municipal Generating Sites*:* Municipal generating sites include operations that handle solid waste, water, wastewater, street and storm drain maintenance, fleet washing, and yard waste disposal. Transport-related areas such as streets and highways, airports, rail yards, and ports can also generate indirect discharges from spills, accidents and dumping.

Finding, Fixing, and Preventing Illicit Discharges

The purpose of an IDDE program is to find, fix and prevent illicit discharges, and a series of techniques exist to meet these objectives. The remainder of the manual describes the major tools used to build a local IDDE program, but they are briefly introduced below:

Finding Illicit Discharges

The highest priority in most programs is to find any continuous and intermittent sewage discharges to the storm drain system. A range of monitoring techniques can be used to find sewage discharges. In general, monitoring techniques are used to find problem areas and then trace the problem back up the stream or pipe to identify the ultimate generating site or connection. Monitoring can sometimes pick up other types of illicit discharge that occur on a continuous or intermittent basis (e.g., wash water and liquid wastes). Monitoring techniques are classified into three major groups:

- Outfall Reconnaissance Inventory
- Indicator Monitoring at Storm Water Outfalls and In-stream
- Tracking Discharges to their Source

[2] More recently, federal agencies including EPA, have adopted the North American Industry Classification System (NAICS, pronounced "Nakes") as the industry classification system. For more information on the NAICS and how it correlates with SIC, visit http://www.census.gov/epcd/www/naics.html.

!!! Caution !!!

Using land use as an indicator for certain flow types such as sewage is often less reliable than other factors in predicting the potential severity of sewage discharges. More useful assessment factors for illicit sewage discharges include the age of the sewer system, which helps define the physical integrity and capacity of the pipe network, as well as age of development, which reveals the plumbing codes and practices that existed when individual connections were made over time. Two particular critical phases in the sewer history of a subwatershed are when sanitary sewers were extended to replace existing septic systems, or when a combined sewer was separated. The large number of new connections and/or disconnections during these phases increases the probability of bad plumbing.

Fixing Illicit Discharges

Once sewage discharges or other connections are discovered, they can be fixed, repaired or eliminated through several different mechanisms. Communities should establish targeted education programs along with legal authority to promote timely corrections. A combination of carrots and sticks should be available to deal with the diversity of potential dischargers.

Preventing Illicit Discharges

The old adage "an ounce of prevention is worth a pound of cure" certainly applies to illicit discharges. Transitory discharges from generating sites can be minimized through pollution prevention practices and well-executed spill management and response plans. These plans should be frequently practiced by local emergency response agencies and/or trained workers at generating sites. Other pollution prevention practices are described in Chapter 9 and explored in greater detail in Manual 8 of the Urban Subwatershed Restoration Manual Series (Schueler *et al.*, 2004).

National Urban Runoff Project

EPA's National Urban Runoff Project (NURP) studies highlighted the significance of pollutants from illicit entries into urban storm sewerage (EPA, 1983). Such entries may be evidenced by flow from storm sewer outfalls following substantial dry periods. Such flow, frequently referred to as "baseflow" or "dry weather flow", could be the result of direct "illicit connections" as mentioned in the NURP final report (EPA, 1983), or could result from indirect connections (such as leaky sanitary sewer contributions through infiltration). Many of these dry weather flows are continuous and would therefore occur during rain induced runoff periods. Pollutant contributions from dry weather flows in some storm drains have been shown to be high enough to significantly degrade water quality because of their substantial contributions to the annual mass pollutant loadings to receiving waters (project research).

1.2 The Importance of Illicit Discharges in Urban Water Quality

Dry and wet weather flows have been monitored during several urban runoff studies. These studies have found that discharges observed at outfalls during dry weather were significantly different from wet weather discharges. Data collected during the 1984 Toronto Area Watershed Management Strategy Study monitored and characterized both storm water flows and baseflows (Pitt and McLean, 1986). This project involved intensive monitoring in two test areas (a mixed residential/commercial area and an industrial area) during warm, cold, wet, and dry weather. The annual mass discharges of many pollutants were found to be greater in dry weather flows than in wet weather flows.

A California urban discharge study identified commercial and residential discharges of oil and other automobile-related fluids as a common problem based on visual observations (Montoya, 1987). In another study, visual inspection of storm water pipes discharging to the Rideau River in Ontario found leakage from sanitary sewer joints or broken pipes to be a major source of storm drain contamination (Pitt, 1983).

Several urban communities conducted studies to identify and correct illicit connections to their storm drain systems during the mid-1980s. These studies were usually taken in response to receiving water quality problems or as part of individual NURP research projects. The studies indicated the magnitude and extent of cross-connection problems in many urban watersheds. For example, Washtenaw County, Michigan tested businesses to locate direct illicit connections to the county storm drain system. Of the 160 businesses tested, 38% were found to have illicit storm drain connections (Schmidt and Spencer, 1986). An investigation of the separate storm sewer system in Toronto, Ontario revealed 59% of outfalls had dry weather flows, while 14% of the total outfalls were characterized as "grossly polluted," based on a battery of chemical tests (GLA, 1983). An inspection of the 90 urban storm water outfalls draining into Grays Harbor in Washington showed that 32% had dry weather flows (Pelletier and Determan, 1988). An additional 19 outfalls were considered suspect, based on visual observation and/or elevated pollutant levels compared to typical urban storm water runoff.

The Huron River Pollution Abatement Program ranks as one of the most thorough and systematic early investigations of illicit discharges (Washtenaw County, 1988). More than a thousand businesses, homes and other buildings located in the watershed were dye tested. Illicit connections were found at 60% of the automobile-related businesses tested, which included service stations, automobile dealerships, car washes, and auto body and repair shops. All plating shops inspected were found to have illicit storm drain connections. Additionally, 67% of the manufacturers, 20% of the private service agencies and 88% of the wholesale/retail establishments tested were found to have illicit storm sewer connections. Of the 319 homes dye tested, 19 were found to have direct sanitary connections to storm drains. The direct discharge of rug-cleaning wastes into storm drains by carpet cleaners was also noted as a common problem.

Eliminating illicit discharges is a critical component to restoring urban watersheds. When bodies of water cannot meet designated uses for drinking water, fishing, or recreation, tourism and waterfront home values may fall; fishing and shellfish harvesting can be restricted or halted; and illicit discharges can close beaches, primarily as a result of bacteria contamination. In addition to the public health and economic impacts associated with illicit discharges, significant impacts to aquatic life and wildlife are realized. Numerous fish kills and other aquatic life losses have occurred in watersheds as a result of illicit or accidental dumping and spills that have resulted in lethal pollutant concentrations in receiving waters.

1.3 Regulatory Background For Illicit Discharges

The history of illicit discharge regulations is long and convoluted, reflecting an ongoing debate as to whether they should be classified as a point or nonpoint source of pollution. The Clean Water Act amendments of 1987 contained the first provisions to specifically regulate discharges from storm drainage systems. Section 402(p)(3)(B) provides that "permits for such discharges:

(i) May be issued on a system or jurisdiction-wide basis

(ii) Shall include a requirement to effectively prohibit non-storm water discharges into the storm sewers; and

(iii) Shall require controls to reduce the discharge of pollutants to the maximum extent practical including management practices, control techniques and system design and engineering methods, and such provisions as the Administrator or the State determines appropriate for the control of such pollutants."

In the last 15 years, NPDES permits have gradually been applied to a greater range of communities. In 1990, EPA issued a final rule, known as Phase I to implement section 402(p) of the Clean Water Act through the NPDES permit system. The EPA effort expanded in December 1999, when the Phase II final rule was issued. A summary of how both rules pertain to MS4s and illicit discharge control is provided below.

Summary of NPDES Phase I Requirements

The NPDES Phase I permit program regulates municipal separate storm sewer systems (MS4s) meeting the following criteria:

- Storm sewer systems located in an incorporated area with a population of 100,000 or more
- Storm sewer systems located in 47 counties identified by EPA as having populations over 100,000 that were unincorporated but considered urbanized areas
- Other storm sewer systems that are specially designated based on the location of storm water discharges with respect to waters of the United States, the size of the discharge, the quantity and nature of the pollutants discharged, and the interrelationship to other regulated storm sewer systems, among other factors

An MS4 is defined as any conveyance or system of conveyances that is owned or operated by a state or local government entity designed for collecting and conveying storm water, which is not part of a Publicly Owned Treatment Works. The total number of permitted MS4s in the Phase I program is 1,059.

PHASE I HIGHLIGHTS	
Who must meet the requirements?	MS4s with population ≥100,000 
How many Phase I communities exist nationally?	1,059
What are the requirements related to illicit discharges?	Develop programs to prevent, detect and remove illicit discharges

Phase I MS4s were required to submit a two-part application. The first part required information regarding existing programs and the capacity of the municipality to control pollutants. Part 1 also required identification of known "major" outfalls[3] discharging to waters of the United States, and a field screening analysis of representative major outfalls to detect illicit connections. Part 2 of the application required identification of additional major outfalls, limited monitoring, and a proposed storm water management plan (EPA, 1996).

Phase I communities were required to develop programs to detect and remove illicit discharges, and to control and prevent improper disposal into the MS4 of materials such as used oil or seepage from municipal sanitary sewers. The illicit discharge programs were required to include the following elements:

- Implementation and enforcement of an ordinance, orders or similar means to prevent illicit discharges to the MS4
- Procedures to conduct ongoing field screening activities during the life of the permit
- Procedures to be followed to investigate portions of the separate storm sewer system that, based on the results of the field screening required in Part 2 of the application, indicate a reasonable potential for containing illicit discharges or other sources of non-storm water
- Procedures to prevent, contain, and respond to spills that may discharge into the MS4
- A program to promote, publicize, and facilitate public reporting of the presence of illicit discharges or water quality impacts associated with discharges from the MS4
- Educational activities, public information activities, and other appropriate activities to facilitate the proper management and disposal of used oil and toxic materials
- Controls to limit infiltration of seepage from municipal sanitary sewers to the MS4

[3] A "major" outfall is defined as an MS4 outfall that discharges from a single pipe with an inside diameter of at least 36 inches, or discharges from a single conveyance other than a circular pipe serving a drainage area of more than 50 acres. An MS4 outfall with a contributing industrial land use that discharges from a single pipe with an inside diameter of 12 inches or more or discharges from a single conveyance other than a circular pipe serving a drainage area of more than two acres.

Summary of NPDES Phase II Requirements

The Phase II Final Rule, published in the Federal Register regulates MS4s that meet both of the following criteria:

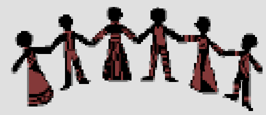
- Storm sewer systems that are not a medium or large MS4 covered by Phase I of the NPDES Program
- Storm sewer systems that are located in an Urbanized Area (UA) as defined by the Bureau of the Census, or storm sewer systems located outside of a UA that are designated by NPDES permitting authorities because of one of the following reasons:
  - The MS4's discharges cause, or have the potential to cause, an adverse impact on water quality
  - The MS4 contributes substantially to the pollutant loadings of a physically interconnected MS4 regulated by the NPDES storm water program

MS4s that meet the above criteria are referred to as regulated small MS4s. Each regulated small MS4 must satisfy six minimum control measures:

1. Public education and outreach
2. Public participation/involvement
3. Illicit discharge detection and elimination
4. Construction site runoff control
5. Post-construction runoff control
6. Pollution prevention/Good housekeeping

Under the third minimum measure, an illicit discharge is defined as any discharge to an MS4 that is not composed entirely of storm water, except allowable discharges pursuant to an NPDES permit, including those resulting from fire fighting activities (40 CFR 122.26(b)(2)). To satisfy this minimum measure, the regulated small MS4 must include the following five components:

- Develop a storm sewer system map that shows the location of all outfalls and the names and locations of all waters of the United States that receive discharges from those outfalls
- Prohibit, through ordinance or other regulatory mechanism, non-storm water discharges into the storm sewer system and implement appropriate enforcement procedures and actions
- Develop and implement a plan to detect and address illicit discharges to the MS4
- Educate public employees, businesses, and the general public of hazards associated with illicit discharges and improper disposal of waste
- Identify the appropriate best management practices and measurable goals for this minimum measure

PHASE II HIGHLIGHTS	
Who must meet the requirements?	Selected small MS4s 
How many Phase I communities exist nationally?	EPA estimates are 5,000-6,000
What are the requirements related to illicit discharges?	Develop programs to prevent, detect and remove illicit discharges
What is the deadline for meeting these requirements?	Permits issued by March 10, 2003. Programs must be fully implemented by the end of first permit term (5 years)

In the regulation, EPA recommends that the plan to detect and address illicit discharges include procedures for:

- Locating priority areas likely to have illicit discharges (which may include visually screening outfalls during dry weather and conducting field tests of selected pollutants)
- Tracing the source of an illicit discharge
- Removing the source of the discharge
- Program evaluation and assessment

1.4 Experience Gained in Phase I

The Center for Watershed Protection conducted a series of surveys and interviews with Phase I communities to determine the current state of the practices utilized in local IDDE programs, and to identify the most practical, low-cost, and effective techniques to find, fix and prevent discharges. The detailed survey included 24 communities from various geographic and climatic regions in the United States. Some of the key findings of the survey are presented below (CWP, 2002)[4].

- Lack of staff significantly hindered implementation of a successful IDDE program. Phase I communities rely heavily on the expertise of their field staff – practical expertise that has been acquired over many years as programs gradually developed. Methods or approaches recommended for Phase II communities should be less dependent on professional judgment.

[4] Survey results are based on responses from 24 jurisdictions from 16 states. Surveys were supplemented by on-site interviews of staff of eight IDDE programs: Baltimore City, MD; Baltimore County, MD; Boston Water and Sewer Commission (BWSC), MA; Cambridge, MA; Dayton, OH; Raleigh, NC; Wayne County, MI; and Fort Worth, TX. Jurisdictions selected for the survey and interviews represent a variety of geographic and climatic regions. The EPA storm water coordinators for each region of the country were contacted for recommendations on jurisdictions to include in the survey. Also, a variety of jurisdiction sizes in terms of population, IDDE program service area, and land use was targeted.

- Clear and effective ordinance language should be adopted by Phase II communities to ensure that all potential sources of illicit discharges are prohibited, and that the community has sufficient legal authority to inspect private properties and enforce corrections.

- Many communities lacked up-to-date mapping resources, and found that mapping layers such as storm sewers, open drainage channels, waters of the U.S., outfalls, and land use were particularly useful to conduct and prioritize effective field investigations.

- Outfall screening required the greatest staff and equipment resources, and did not always find problem outfalls. Communities recommended a fast and efficient sampling approach that utilizes a limited number of indicator parameters at each outfall to find problem outfalls.

- When purchasing equipment, Phase II programs should communicate with other jurisdictions to consider sharing field equipment and laboratory costs.

- Use of some discharge tracers has proven challenging and sometimes fruitless, because of false or ambiguous results and complex or hazardous analytical methods. Accurate, cost-effective, and safe monitoring methods are needed to effectively use tracers.

- Municipal IDDE programs worked best when they integrated illicit discharge control in the wider context of urban watershed restoration. Table 3 provides some examples of how greater interagency cooperation can be achieved by linking restoration program areas.

In summary, survey communities expressed a strong need for relatively simple guidance to perform illicit discharge investigations. To address this need, the Manual has been designed to make simple program and technical recommendations for Phase II communities to develop cost-effective IDDE programs.

Table 3: Linking Other Municipal Programs to IDDE Program Needs	
Watershed-Related Program	**How Program Relates to IDDE Program Needs**
Subwatershed Mapping and Analysis	• Mapping and aerial photography are critical tools needed for illicit connection detection surveys. GIS tax map layers are often useful to identify property ownership.
Rapid Assessment of Stream Corridors	• Observations from physical stream assessments are often useful in identifying problem areas, including dry weather flow outfalls, illegal dumping, and failing infrastructure locations.
Watershed Monitoring and Reporting	• Compiled water quality and other indicator data can be useful in targeting problem areas.
Stream Restoration Opportunities	• Stream restoration opportunities can often be coordinated with sewer infrastructure upgrades and maintenance.
Watershed Education	• Educating the public about unwanted discharges can save programs money by generating volunteer networks to report and locate problem areas. Better awareness by the public can also reduce the likelihood of unintentional cross-connections.
Pollution Prevention for Generating Sites	• Providing incentives to businesses to inspect and correct connections can save programs money.

Chapter 2: Components of an Effective IDDE Program

The prospect of developing and administering an IDDE program can be daunting, complex and challenging in many communities. This Chapter organizes and simplifies the basic tasks needed to build a program. In general, a community should consider eight basic program components, as follows:

1. Audit Existing Resources and Programs – The first program component reviews existing local resources, regulations, and responsibilities that bear on illicit discharge control in the community. A systematic audit defines local needs and capabilities, and provides the foundation for developing the initial IDDE program plan over the first permit cycle.

2. Establish Responsibility, Authority and Tracking – This component finds the right "home" for the IDDE program within existing local departments and agencies. It also establishes the local legal authority to regulate illicit discharges, either by amending an existing ordinance, or crafting a new illicit discharge ordinance. This program component also involves creation of a tracking system to report illicit discharges, suspect outfalls, and citizen complaints, and to document local management response and enforcement efforts.

3. Complete a Desktop Assessment of Illicit Discharge Potential – Illicit discharges are not uniformly distributed across a community, but tend to be clustered within certain land uses, subwatersheds, and sewage infrastructure eras. This program component helps narrow your search for the most severe illicit discharge problems, through rapid analysis of existing mapping and water quality monitoring data.

4. Develop Program Goals and Implementation Strategies – This program component integrates information developed from the first three program components to establish measurable goals for the overall IDDE program during the first permit cycle. Based on these goals, managers develop specific implementation strategies to improve water quality and measure program success.

5. Search for Illicit Discharge Problems in the Field – This component involves rapid outfall screening to find problem outfalls within priority subwatersheds. Results of outfall surveys are then used to design a more sophisticated outfall monitoring system to identify flow types and trace discharge sources. Many different monitoring options exist, depending on local needs and discharge conditions.

6. Isolate and Fix Individual Discharges – Once illicit discharge problems are found, the next step is to trace them back up the pipe to isolate the specific source or improper connection that generates them. Thus, this program component improves local capacity to locate specific discharges, make needed corrections, and take any enforcement actions.

7. Prevent Illicit Discharges – Many transitory and intermittent discharges are produced by careless practices at the home or workplace. This important program component uses a combination of education and enforcement to promote better pollution prevention practices. A series of carrots and sticks is used to reach out to targeted individuals to prevent illegal or unintentional illicit discharges.

8. Evaluate the Program – The last component addresses the ongoing management of the IDDE program. The measurable goals set for the IDDE program are periodically reviewed and revisited to determine if progress is being made, or implementation strategies need to be adjusted.

Within each program component, a community has many options to choose, based on its size, capability and the severity of its illicit discharge problems. Chapters 3 through 10 address each IDDE program component in more detail, and summarize its purpose, methods, desired product or outcome, and budget implications. The remainder of each chapter provides program managers with detailed guidance to choose the best options to implement the program component in their community.

Scheduling of the eight IDDE program components is not always sequential and may overlap in some cases. In general, the first four program components should be scheduled for completion within the first year of the permit cycle in order to develop an effective program for the remaining years of the permit. Table 4 summarizes the specific tasks and products associated with each IDDE program component. The scheduling, costs and expertise needed for each IDDE program component are compared in Table 5.

Table 4: Key Tasks and Products in IDDE Program Implementation

Program Component	Key Tasks	Products
1. Audit existing programs	• Infrastructure Profile • Existing Legal Authority • Available Mapping • Experienced Field Crews • Access to Lab Services • Education and Outreach Outlets • Discharge Removal Capability • Program Budget and Financing	• Agreement on Lead Agency • 5 year Program Development Plan • First Year Budget and Scope of Work
2. Establish responsibility and authority	• Review Existing Ordinances • Define “Illicit” • Provisions for Access/Inspections • Select Enforcement Tools • Design Tracking System	• Adopt or Amend Ordinance • Implement Tracking System
3. Desktop assessment of illicit discharge potential	• Delineate Subwatersheds • Compile Mapping Layers/Data • Define Discharge Screening Factors • Screen Subwatersheds for Illicit Discharge Potential • Generate Maps for Field Screening	• Prioritize Subwatersheds for Field Screening
4. Develop program goals and strategies	• Community Analysis of Illicit Discharge • Public Involvement	• Measurable Program Goals • Implementation Strategies

Table 4: Key Tasks and Products in IDDE Program Implementation		
Program Component	**Key Tasks**	**Products**
5. Search for illicit discharges problems in the field	• Outfall Reconnaissance Inventory (ORI) • Integrate ORI data in Tracking System • Follow-up Monitoring at Suspect Outfalls	• Initial Storm Drain Outfall Map • Develop Monitoring Strategy
6. Isolate and fix individual discharges	• Implement Pollution Hotline • Trunk and On-site Investigations • Corrections and Enforcement	• Maintain Tracking System
7. Prevent illicit discharges	• Select Key Discharge Behaviors • Prioritize Outreach Targets • Choose Effective Carrots and Sticks • Develop Budget and Delivery System	• Implement Residential, Commercial, Industrial or Municipal Pollution Prevention Programs
8. Program evaluation	• Analyze Tracking System • Characterize Illicit Discharges Detected • Update Goals and Strategies	• Annual Reports • Permit Renegotiation

Table 5: Comparison of IDDE Program Components					
IDDE Program Component	**When To Do It**	**Startup Costs**	**Annual Cost**	**Expertise Level**	**Type of Expertise**
1. Audit	Immediately	$	-0-	??	Planning/Permitting
2. Authority	Year 1	$$	$	??	Legal
3. Desktop Analysis	Year 1	$$	-0-	???	GIS
4. Goals/Strategies	Year 1	$	-0-	??	Stakeholder Management
5 Field Search/Monitoring	Year 2 to 5	$$	$$$$	???	Monitoring
6 Isolate and Fix	Year 2 to 5	$	$$	???	Pipe and Site Investigations
7. Prevention	Year 2 to 5	$$	$$$	??	Education
8. Evaluation/Tracking	Annually	-0-	$	?	Data Analysis
Key: $ = <$10,000 $$ = $10,000 - 25,000 $$$ = $25,000 - 50,000 $$$$ = > $50,000	? - Simple ?? - Moderately Difficult ??? - Complex				

2.1 Management Tips To Develop an Effective IDDE Program

Every community will develop a unique IDDE program that reflects its size, development history, land use, and infrastructure. Still, some common threads run through effective and well-managed local IDDE programs. Below are some tips on building an effective local.

1. Go after continuous sewage discharges first. Effective programs place a premium on keeping sewage out of the storm drain system. Continuous sewage discharges pose the greatest threat to water quality and public health, produce large pollutant loads, and can generally be permanently corrected when the offending connection is finally found. Intermittent or indirect discharges are harder to detect, and more difficult to fix.

2. Put together an interdisciplinary and interagency IDDE development team. A broad range of local expertise needs to be coordinated to develop the initial IDDE plan, as indicated in Table 5. Effective programs assemble an interagency program development team that possesses the diverse skills and knowledge needed for the program, ranging from legal analysis, GIS, monitoring, stakeholder management and pipe repairs.

3. Educate everybody about illicit discharges. Illicit discharge control is a new and somewhat confusing program to the public, elected officials, and many local agencies. Effective programs devote considerable resources to educate all three groups about the water quality impacts of illicit discharges.

4. Understand your infrastructure. Finding illicit discharges is like finding a needle in a haystack on a shoestring budget. Many indirect or transitory discharges are extremely difficult to catch through outfall screening. Therefore, effective programs seek to understand the history and condition of their storm water and sewer infrastructure to find the combinations that create the greatest risk for illicit discharge. Effective programs also screen land uses to locate generating sites within targeted subwatersheds. For example, knowing the proximity of the infrastructure to the groundwater table or knowing that the sewer collection system has a long transit time can influence the indicator parameters and associated thresholds that a community chooses to target.

5. Walk all of your streams in the first permit cycle. Perform a rapid Outfall Reconnaissance Inventory (ORI) on every mile of stream or channel in the community, starting with the subwatersheds deemed to have the greatest risk. The ORI allows you to rapidly develop an accurate outfall map and quantify the severity of your discharge problems. ORI data and field photos are extremely effective in documenting local problems. Stream walks and the ORI should be conducted regularly as part of an IDDE program. In many areas, it may require as many as three stream walks to identify all outfall locations.

6. Use GPS to create your outfall map. In most communities, the storm water system and sewer pipe networks are poorly mapped, and consist of a confusing blend of pipes and structures that were constructed in many different eras. Effective programs perform a field reconnaissance to ground truth the precise locations of all outfalls using GPS technologies. Effective programs have learned to quickly evaluate outfalls of all sizes, and not just major ones (>36 inches in diameter).

7. *Understand your discharges before developing a monitoring plan.* Monitoring is usually the most expensive component of any local IDDE program, so it is extremely important to understand your discharges before committing to a particular monitoring method or tracer. Compiling a simple discharge "fingerprint" library that characterizes the chemistry of major flow types in the community (e.g., sewage, septage, washwater, groundwater, tap water, or non-target irrigation water) is recommended. This library can distinguish flow types and adjust monitoring benchmarks.

8. Consider establishing an ambient (in-stream) chemical and/or biological monitoring program. Prioritizing outfall screening and investigation can save time in the field. An ambient chemical or biological monitoring program can provide supplemental information to help prioritize sites and can be used to document long-term success.

9. Utilize a simple outfall tracking system to organize all your IDDE program data. Illicit discharges are hard enough to find if an organized system to track individual outfalls is lacking. Effective programs develop a unified geospatial tracking system to locate each outfall, and store information on its address, characteristics, photos, complaints and monitoring data. The tracking system should be developed early in the permit cycle so that program managers can utilize it as an evaluation and reporting tool.

10. Outsource some IDDE functions to local watershed groups. Staffing is the greatest single line item expense associated with a local IDDE program, although staffing needs are often temporary or seasonal in nature. Some effective programs have addressed this staffing imbalance by contracting with watershed groups to screen outfalls, monitor stream quality, and handle storm water education. This strategy reduces overall program costs, and increases local watershed awareness and stewardship.

11. Utilize a hotline as an education and detection tool. Citizen hotlines are a low-cost strategy to engage the public in illicit discharge surveillance, and are probably the only effective way to pick up intermittent and transitory discharges that escape outfall screening. When advertised properly, hotlines are also an effective tool to increase awareness of illicit discharges and dumping. Effective programs typically respond to citizen reports within 24 hours, acknowledge their help, and send them storm water education materials. When citizens play a stronger role in reporting illicit discharge problems, local staff can focus their efforts on tracing the problem to its source and fixing it.

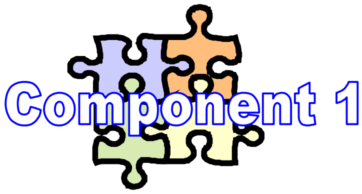
12. Cross-train all local inspectors to recognize discharges and report them for enforcement. Effective programs make sure that fire, building, plumbing, health, safety, erosion control and other local inspectors understand illicit discharges and know whom to contact locally for enforcement.

13. Target your precious storm water education dollars. Most programs never have enough resources to perform the amount of storm water education needed to reduce indirect and transitory discharges in their community. Consequently, effective programs target their discharges of concern, and spend their scarce dollars in the subwatersheds, neighborhoods or business sectors most likely to generate them.

14. Stress public health and safety benefits of sewage-free streams. Effective programs publicize the danger of sewage discharges, and notify the public and elected officials about the discharges that need to be prevented or corrected.

15. Calibrate your program resources to the magnitude of the illicit discharge problem. After a few years of analysis and surveys, communities get a good handle on the actual severity of their illicit discharge problems. In some communities, storm drains will be relatively clean, whereas others may have persistent problems. Effective programs are flexible and adaptive, and shift program resources to the management measure that will reduce the greatest amount of pollution.

16. Think of discharge prevention as a tool of watershed restoration. Discharge prevention is considered one of the seven primary practices used to restore urban watersheds (Schueler, 2004). Effective programs integrate illicit discharge control as a part of a comprehensive effort to restore local watersheds.



Chapter 3: Auditing Existing Resources and Programs

Purpose: This program component identifies the most capable local agency to staff and administer the IDDE program, analyzes staffing and resource gaps, and searches for all available local resources and expertise that can be applied to the IDDE program.

Method: The key method used for this program component is a local IDDE "audit," which consists of external research, agency interviews, and interagency meetings to determine existing resources and program gaps. The audit typically looks at eight major factors needed to build an IDDE program:

- Profile of existing storm water and sewer infrastructure, as well as historical plumbing codes
- Existing legal authority to regulate illicit discharges
- Available mapping data and GIS resources
- Field staff availability and expertise
- Lab/monitoring equipment and analytical capability
- Education and outreach resources and outlets
- Discharge removal capability and emergency response
- Program budgeting and financing

Desired Product or Outcome(s): The desired outcome is an initial five-year IDDE program development plan over the current permit cycle. This will usually consist of an internal agreement on the lead agency, an initial scope of work, the first year budget, and a budget forecast for the entire permit cycle.

Budget and/or Staff Resources Required: The cost to conduct an audit depends on the size of the community, the degree of interagency cooperation, and the local budget process. Plan for less than one staff month for smaller communities, and up to three staff months for larger ones.

Integration with Other Programs: The audit is the best time to integrate the other five minimum management measures required under NPDES Phase II permits, including public education and outreach, public involvement, construction site runoff control, post-construction runoff control, and pollution prevention/good housekeeping for municipal operations.

3.1 Audit Overview

A community should conduct a quick audit of existing and needed capacity when developing its IDDE program. The audit helps develop realistic program goals, implementation strategies, schedules, and budgets to comply with NPDES permit requirements and improve water quality. The audit consists of external research, agency interviews and interagency meetings to determine existing resources and program gaps. The audit examines the community's current capabilities in eight topic areas: infrastructure profile, legal authority, available mapping, field staff experience, access to monitoring labs, education and outreach resources, discharge removal capability, and program budgets and financing.

Existing expertise is likely divided among multiple agencies (see Table 6) that should be contacted during the audit. Some of these agencies can become important partners in the development and implementation of the IDDE program, and contribute resources, program efficiencies and overall cost savings. The first agencies to interview are local emergency responders that already deal with spills, accidents, hazardous materials and sewage leaks that occur. In addition, it is worth getting to know the local agency responsible for plumbing code inspection during construction.

Table 7 provides representative examples of questions that the audit should ask to determine the needs and capabilities of a community associated with each program element.

Table 6: Potential Local Agencies and Departments to Contact During an Audit

Audit Topic	Potential Agencies and Departments	
Infrastructure Profile	• Water and Sewer Authority	• Public Works
Existing Legal Authority	• Public Works • Planning Department • Parks and Recreation • Environmental Protection	• Local Health Department • Road Engineering Fire, Police or Rescue (Hazardous material responders)
Available Mapping	• Public Works • Local Streets/Utilities	• Planning and Zoning • Emergency Responders
Field Staff	• Public Works • Environmental Compliance • Development Review	• Watershed Groups • Fire, Building, Health and Code Inspectors
Access to Lab Services	• Public Works • Local College or University	• Drinking Water or Wastewater Treatment Plant • Private Contract Monitoring Laboratories • Health Department
Education and Outreach Resources	• Parks and Schools • Water and Sewer Utility	• Community Liaison Office • Civic and Watershed Groups
Discharge Removal Capability	• Fire, Rescue and Police • Public Works	• Water and Sewer Utilities • Private Plumbing Contractors
Program Budget and Financing	• Grants • Fines • Application fees	• Utility Fees • Department Operating Budget

Table 7: Potential IDDE Audit Questions	
Audit Topics	**Questions**
Infrastructure Profile	• How many miles of streams and storm drains exist in the MS4? • What is the area served by storm drains, sewers, and septics? • What is the general age and condition of the infrastructure?
Existing Legal Authority	• Does an illicit discharge ordinance already exist? • Does effective inter-departmental coordination and cooperation currently occur? • Is there an existing reporting and tracking system (e.g., hotline)? • Is the municipality involved with industrial storm water NPDES permit activities or pre-treatment programs?
Available Mapping Data	• Does current GIS data exist and does it include coverage of sanitary and storm sewer networks? • Is there a centralized location for the data? • Are digital and hardcopy versions of mapping data readily available?
Field Staff	• Are municipal staff available to walk stream miles and record information? • Do municipal staff have the training and expertise to lead a field team? • Are basic field supplies already owned by the municipality and available for use?
Access to Lab Services	• Does the municipality have access to an analytical laboratory? • Is there a local university or institution that might be a willing partner? • If yes, is the existing equipment and instrumentation considered to be safe, accurate and reliable? • Are experienced municipal staff available to conduct analytical analyses? • Does the lab and staff have the capability to conduct more sophisticated special studies?
Education and Outreach Resources	• Does the community already have an Internet website to post outreach materials? • Are there regular community events that can be used to spread the message? • Are good inter-agency communication mechanisms in place? • Do outreach materials on illicit discharges already exist?
Discharge Removal Capability	• Who currently responds to spills, overflows and hazardous material emergencies? • Are municipal staff properly equipped and trained to repair most common types of illicit connections? • Does the municipality have clear authority identifying responsible parties? • Is there a response time commitment to known and reported problems? • Is there a list of pre-approved contractors to perform corrections?
Program Budget and Financing	• Is there a dedicated annual budget line item planned for the IDDE program? • Are there cost-share arrangements/opportunities available with other departments? • Have grant awards been awarded to the municipality for special studies associated with watershed restoration in the past?

3.2 Develop Infrastructure Profile

The first part of the audit profiles current and historic storm water and sewer infrastructure in the community. The basic idea is to get a general sense of the magnitude of the task ahead, by looking at the size, age and condition of the storm drain system (and the sewers within the MS4 as well). Some useful planning statistics include:

- Number of storm drain outfalls
- Miles of storm drain pipe
- Total stream and channel miles
- Total area serviced by storm drains
- Total area serviced by sewers
- Total area serviced by septic systems

These statistics are extremely helpful in getting a handle on the total effort required to assess the overall system. Any data on the nature and age of storm drains and sewers can be useful (e.g., open vs. enclosed, young vs. old). The basic infrastructure statistics can be generated from a quick analysis of infrastructure and topographic maps. At this stage, ballpark estimates are fine; more detailed estimates can be developed later in the desktop analysis component.

It is also worth examining historic plumbing codes to determine what kinds of connections were allowed in the past. Often, interviews with "old-timers" who remember past building codes and practices can provide insights about historical construction as to where illicit connections may be a problem.

3.3 Establish Legal Authority

This part of the audit examines whether a community currently has adequate legal authority to regulate illicit discharges through the following actions:

- Evaluate and modify plumbing codes[5]
- Prohibit illicit discharges
- Investigate suspected illicit discharges
- Require elimination of illicit discharges
- Carry out enforcement actions

The audit of existing legal authority entails a search and review of all existing ordinances that could conceivably bear on illicit discharge control, and interviews with the agencies that administer them. Some common local ordinances that may address illicit discharges are outlined in Table 8. Many communities already have regulations prohibiting specific illicit discharges, such as hazardous chemicals, litter or sewage. Often, public health ordinances may prohibit certain sewage discharges. Local utilities may have plumbing codes and staff capability to track down and remove illicit connections on the system they operate.

[5] In some states such as NC, plumbing codes are established through a state process. In these cases, local governments typically need specific authority to adopt any local modifications, which can be difficult to obtain. In such states, it may be prudent for the storm water program managers of several local governments to organize as a single cooperative group to modify codes at the state level.

Table 8: Codes and Ordinances with Potential Links to IDDE	
• Fire codes • Hazardous wastes / spill controls • Health codes • Industrial storm water compliance • Litter control regulations • Nuisance ordinances • Plumbing codes	• Pollution prevention permitting requirements • Restaurant grease regulations • Septic system regulations • Sewer / drain ordinances • Storm water ordinance • Street / highway codes

To establish legal authority, communities will need to either develop a new IDDE ordinance or modify an existing ordinance that addresses illicit discharges. Language from existing ordinances that addresses illicit discharges should be incorporated or cross-referenced into any new IDDE ordinance to minimize conflicts and confusion. Furthermore, existing code ordinances may need to be amended or superceded to be consistent with the new IDDE ordinance.

In some instances, communities may want to consider collaborating with neighboring or nearby MS4s to develop ordinance language and legal authority, particularly if they share a common receiving water. Non-municipal permittees such as Departments of Transportation and special districts may also look to collaborate with municipal MS4s when considering ordinance language and legal responsibility.

3.4 Review Available Mapping

The third part of the audit looks at the coverage and quality of mapping resources available to support the IDDE program. Specifically, efforts should be made to see if a Geographic Information System (GIS) exists, and what digital mapping layers it contains. If a community does not possess a GIS, a community may choose to establish one (which can be quite expensive), or rely on available hardcopy maps. GIS and hardcopy maps are frequently available from the following local agencies: planning, tax assessment, public works, parks and recreation, emergency response, environmental, transportation, utilities, or health. If a watershed extends beyond the boundaries of a community, it may be necessary to acquire mapping data from adjacent communities.

Non-local sources of mapping data include state and federal agencies and commercial vendors. EPA and state environmental regulatory agencies maintain lists of NPDES dischargers; Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites; Resource Conservation and Recovery Act (RCRA) sites; and other industrial or hazardous material discharge sites. These sites are readily available as GIS layers[6]. Commercial vendors are good sources for low-altitude aerial photos of your community. These can be expensive but are often the best way to get a high-resolution recent ‘snapshot’ of the jurisdiction. Chapter 5 presents more detail on mapping layers needed for an IDDE program.

3.5 Availability of Field Staff

Field staff play a critical role in any IDDE program as they walk streams, assess outfalls, collect samples, respond to discharge complaints, and handle enforcement. This part of the audit evaluates

[6] Some readily available GIS layers provided by regulatory agencies can be incomplete and inaccurate (particularly with location information). Communities should use their IDDE program and the associated data collection efforts to update their local information associated with these databases.

the availability of local staff to perform these functions, and their training needs. Phase I communities report that experienced field staff are a major factor in IDDE program success.

Experienced staff can be supplemented with support staff such as interns and local watershed groups, if they are properly trained (CWP, 2002). As part of the audit, program managers should investigate whether existing staff can be used or whether new hires are anticipated, and explore intern opportunities with local universities and community colleges. Any local staff with experience in water quality sampling or development inspection should be identified. Fire, building, health, safety and erosion control inspectors are all potential field crew draftees.

An initial estimate of the staff time needed for field crews should be made at this time. Phase I IDDE programs allocated a median of 1.0 person-year for field investigations, with a range of 0.1 to 10 person-years each year (CWP, 2002). Several communities utilized interns to assist with field monitoring and office work. Since many IDDE surveys are short term and seasonal, several communities hired or transferred employees to serve on field crews on a temporary basis. Many Phase I programs found it hard to precisely quantify actual staff time dedicated to IDDE field work because staff were assigned from many departments, or performed other unrelated tasks (building inspections, erosion and sediment control inspections, etc.).

3.6 Access to Laboratory Analysis

This part of the audit identifies the best options for laboratory analysis of water quality samples collected in the field. Four basic options exist to get access to laboratory services, including:

1. Contract services from a private lab
2. Use existing lab facilities at local drinking water or wastewater treatment plants
3. Partner with a local water and sewer district, university or community college
4. Develop your own “in-house” monitoring and lab capability

The last three options may require purchasing special monitoring analysis equipment, depending on the water quality indicators ultimately selected. If a community is considering developing “in-house” monitoring capabilities, it will need to address quality control, training needs, safety, and hazardous waste disposal. At this point, a community simply wants to acquire data on costs, indicator parameters, quality control, and experience for each of the options being evaluated. Chapter 12 provides more detail on factors to consider when selecting lab analysis options.

3.7 Education and Outreach

The next part of the audit looks at existing educational and outreach resources in the community. To begin, look for other groups that are already involved in storm water or watershed education, including parks, schools, watershed groups, utilities and any other agencies performing this role. Next, look for the current tools the public can use to report water quality problems, such as complaint hotlines, websites or community liaison offices. When these exist, it may be possible to “piggy back” illicit discharge reporting at little additional cost. If reporting tools do not exist, program managers should look for opportunities to share start-up costs with other agencies that may stand to benefit from improved community interaction (e.g., erosion and sediment control, sanitary sewer overflows, abandoned cars, etc.).

The audit should also look at community-wide events and education outlets to spread the IDDE message, such as fairs, festivals, earth day events, school presentations, and homeowner association meetings. For a complete review of how to craft an effective outreach and education plan, consult Pollution Source Control Practices (Schueler *et al.*, 2004). Excellent education and outreach materials have already been developed by Phase I communities that are available at little or no cost (see Chapter 9). Program managers should consult these resources and modify them as needed to meet their local needs.

3.8 Discharge Removal Capability and Tracking

This part of the audit evaluates local capacity to locate specific discharges, make needed corrections or repairs, and take any enforcement actions. These responsibilities are frequently split among several local agencies. For example, spills are often handled by the fire department hazmat response team, whereas dumping may be enforced by public works. Communities should always coordinate their IDDE program with any experienced hazmat response teams that exist. Similarly, local water and sewer utilities or private contractors that are in the business of repairing pipes should always be consulted. Their experience in specialized techniques such as dye or video testing of pipe interiors is essential for many illicit discharge source investigations. Alternatively, communities can opt to contract out many of these services.

Illicit discharges often occur due to “bad plumbing" connections. Therefore, the audit should identify key building inspectors to determine what, if any, procedures are in place to prevent these deficiencies. Lastly, where corrections to plumbing are required, communities should maintain a list of "pre-approved" plumbing contractors that can promptly and professionally repair the problem.

To ensure coordination, an up-to-date tracking system should be shared among all agencies involved.

3.9 Program Funding

The last part of the audit explores how much the local IDDE program will cost, and how it will be funded. This section provides some general budgeting guidance on the costs to expect for the eight program components. Overall IDDE program costs vary depending on the severity of the illicit discharge problem, the size of the community (and storm drain systems), and the IDDE program choices you make.

Planning level budget estimates can be derived for the eight IDDE program components in three ways. The first way is to look at the cost of IDDE program compliance for Phase I NPDES communities. These costs were assessed in a CWP (2002) survey, and can be used to budget overall annual costs for an IDDE program. Table 9 summarizes median program costs for selected Phase I IDDE program activities. The second technique is to construct unit cost budgets for each program component, based on an assumed level of effort. The third technique relies on EPA’s overall average estimate of compliance costs for Phase II IDDE program of $1.30 per capita (with a staggering range $0.04 to $2.61/capita).

Phase I IDDE Program Costs

The bulk of the cost for most IDDE programs is related to staffing – typically, about 75% of the total budget. Equipment costs were fairly reasonable, with programs spending a median of $1,000 on office computers and software, and about $4,000 on field equipment. Many equipment costs can typically be shared across other community programs. Lab costs, for either the purchase of lab equipment or the cost associated with sending samples to labs, were as high as $87,000 annually, with a median of $8,000. Finally, most programs had additional budgets for "other" which included items such as education, training, travel, consultants, and contractors.

It is worth noting that program costs presented in Table 9 do not reflect expenditures associated with special investigations, which may be pursued by communities to isolate specific sources or test new methods or the direct costs to fix problem connections. However, five communities provided data on typical correction costs, with an average cost of $2,500 per correction (Table 10).

Estimated Phase II IDDE Program Unit Cost

Cost estimates for the eight IDDE program components are outlined in Table 11; more detailed guidance on budgeting for individual program components is provided in subsequent chapters. Under this presentation of cost, data, staff, equipment, and supply costs are combined and incorporated into a primary program element, such as conducting an outfall reconnaissance inventory. This approach assumes a hypothetical scenario of stream/MS4 miles and outfalls to investigate (see Table 11 notes).

Table 9: Summary of Annual Phase I IDDE Program Costs

Program Element	Median Annual Cost
Staff	$85,100
Office Equipment (Computer/Software)	$1,000
Field Equipment	$4,000
Lab Equipment/Testing	$8,000
Other	$10,000
Total	**$121,825**

Table 10: Average Correction Costs

Jurisdiction	Average Cost Per Correction
Cambridge, MA	$5,000
Boston, MA	$3,570
Knoxville, TN	$2,000
Raleigh, NC	$1,000
Springfield, MO	$1,000
Average	**$2,500**

Table 11: IDDE Program Costs					
IDDE Program Component		**Start Up Cost**		**Annual Cost**	
		Low	**High**	**Low**	**High**
Component 1:	a) Perform Audit	$3,000	$9,000	NA	NA
	b) Initial Program Plan	$1,000	$3,000	NA	NA
Component 2:	a) Adopt Ordinance	$1,000	$17,000	NA	NA
	b) Tracking System	$2,000	$15,000	$2,000	$2,000
Component 3:	a) Desktop Analysis	$1,000	$4,000	NA	NA
	b) Field Mapping	$500	$1,000	NA	NA
Component 4:	a) Develop Goals	$1,000	$3,000	NA	NA
	b) Field Monitoring Strategy	$1,000	$3,000	NA	NA
Component 5:	a) Outfall Reconnaissance Inventory (ORI)	NA	NA	$5,700	$12,800
	b) Establish Hotline	$1,300	$7,700	$1,500	$11,400
	c) Sample Analysis	$500	$15,500	$9,000	$21,200
	d) Outfall Map	NA	NA	$500	$1,000
Component 6:	a) Isolate	NA	NA	$2,000	$5,200
	b) Fix	NA	NA	$10,000	$30,000
Component 7:	a) Education	$1,000	$8,100	$1,300	$13,900
	b) Enforcement	NA	NA	$1,000	$14,000
Component 8:	a) Program Administration	$10,000	$15,000	$10,000	$15,000
TOTAL		**$23,300**	**$101,300**	**$43,000**	**$126,500**

Notes: NA = Not Applicable

Component 1 – Audit assumes $25/hr, 120 hours for low and 360 hrs for high. Program plan assumes 40 hrs for low and 120 hrs for high.

Component 2 – Ordinance low cost from Reese (2000), high cost from CWP (1998) adjusted and rounded for inflation (2002 $). Tracking system low cost assumes 40 hrs of development and $1K of equipment for start up. Annual cost for low assumes 40 hrs per year. High estimates are adapted from Reese (2000) and assume 200 hrs for development and $3k for equipment at start-up. High annual costs assume 100 hrs per year.

Component 3 – Desktop analysis assumes 1 week for low and 4 weeks for high. Mapping costs assume paper maps (CWP, 1998) under low and GIS under high (40 hrs)

Component 4 – Goals and strategies take 2 weeks for low and 6 weeks for high. Assume even split in time between two tasks.

Component 5 –

a) ORI costs are from Ch 11 and assume 10 miles with 2-person crew for low and 20 miles with 3-person crew for high. ORI costs assume work completed in one year, but not necessarily every year (permit cycle cost).

Low hotline costs are adapted from Reese (2000). High costs are from CWP research. Low annual costs assume an increased volume of calls due to advertisement and assume 50 hours per year dedicated to this plus annual training.

Sample analyses are from various sources and are presented in Chapter 12. Estimates based on 80 samples per year for both (shown as annual cost). Low start up costs are based on contract lab arrangements. High start up costs assume flow type library is developed for eight distinct flow types. Low annual costs assume in-house analysis for Flow Chart Method parameters. High annual costs assume contract lab analysis for 11 parameters.

Outfall map costs are same as the component 3 mapping task

Component 6 – Isolate and fix have no assumed start up costs and are both vary depending on the community conditions. Low annual isolation costs assume a one day investigation by a 2-person team per incident ($400) and four incidents per year plus $400 in equipment and supplies. High assumes one incident per month. Estimates include on-site inspections. Fix costs are from average costs from Phase I survey and assume same number of incidents as isolate. These costs can often be passed on to responsible parties.

Component 7 – Education estimate adapted from Reese (2000) and assumed to be 1/3 of total Phase I education budget. Some adjustments were made based on assumptions by CWP.

Component 8 – Low assumes 1/6 FTE, high assumes 1/4 FTE at an annual salary of $60K.

Financing an IDDE Program

Once the initial budget has been estimated, the next step is to investigate how to pay for it. A full discussion of how to finance local storm water management programs is beyond the scope of this manual, but it is worth consulting APWA (2001). The most common financing mechanisms include:

- Operating budgets
- Debt financing
- State grants and revolving loans
- Property assessments
- Local improvement districts
- Wastewater utility fees
- Storm water utility or district fees
- Connection fees
- Plan review/inspection fees
- Water utility revenues

Of these, storm water utilities or districts are generally considered one of the best dedicated financing mechanisms. Some useful resources to consult to finance your local storm water programs include the following:

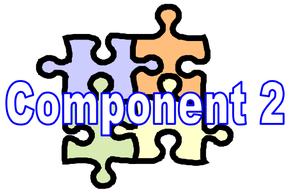
- An Internet Guide to Financing Storm Water Management. 2001 http://stormwaterfinance.urbancenter.iupui.edu
- Establishing a Storm Water Utility http://www.florida-stormwater.org/manual.html
- Florida Association of Storm Water Utilities. http://www.fasu.org
- How to Create a Storm Water Utility http://www.epa.gov/nps/urban.html
- The Storm Water Utility: Will It Work in Your Community? www.forester.net/sw_0011_utility.html

3.10 The Initial IDDE Program Plan

The local IDDE audit reveals resource gaps, and expertise and staffing needed to build an effective IDDE program. The next step is to organize how you plan to phase in the eight program components over the permit cycle. The process results in the development of an initial IDDE program plan that normally includes five elements:

- Overall schedule for plan implementation, with milestones
- Detailed work plan for the first year
- Budget for the first year
- Five-year budget forecast
- Process for gaining approval for first-year budget

Program managers should consult the next seven chapters for more guidance on planning and budgeting individual IDDE program components.



Chapter 4: Establishing Responsibility and Legal Authority

Purpose: This program component is where the legal and administrative authority is established to regulate, respond and enforce illicit discharges in the community. The component also reviews local plumbing codes to ensure that inappropriate connections are prohibited, and develops a tracking system to locate illicit discharges and track management response.

Method(s): Several methods are used to implement this program component, including development of a new or amended illicit discharge control ordinance and the creation of a relational computer database for internal and external tracking of illicit discharges.

Desired Product or Outcome(s):

a) Pass or amend a local ordinance that defines the lead regulatory agency, defines the range of illicit discharges to be covered, and specifies the range of enforcement mechanisms.

b) Establish an internal and external reporting and tracking system. The internal system is structured around the training/education of municipal staff to define and facilitate appropriated response and enforcement procedures. An external system or hotline links to the internal system and assists in response and enforcement by providing access to the public for reporting.

Budget and/or Staff Resources Required: Establishing responsibility, legal authority and an effective tracking system can take as little as a month of staff effort to complete if no major surprises or unforeseen costs are encountered in the process. However, the actual time-frame to adopt an ordinance or fund a response system, for example, is often much longer, given the crowded schedules of elected officials and timing of the local budget processes. Adoption of the ordinance and the actual budget authorization may require multiple votes over many months or years. Continuous engagement and education of key advisors, agency staff and elected officials are needed throughout the effort. Where hotlines exist (covering a range of municipal functions), significant staff and infrastructure savings should be realized. The primary hurdle in this instance will be employee training and education.

Integration with Other Programs: Public education to advertise the hotline and municipal training to educate employees across departments and agencies are the primary areas where this program component can be integrated with other community-wide initiatives. The hotline can be used to report other watershed and water quality problems (e.g., ESC, dumping, sanitary sewer overflows). Good coordination should occur between tracking repair costs and determining appropriate fine levels for enforcement purposes.

Three critical decisions are needed to implement this program component—what local agency will be responsible for administering the IDDE program, will it have adequate legal authority to do its job, and how will illicit discharges be tracked. Guidance is offered below to help program managers make these decisions.

4.1 Identify Responsible Department/Agency

For most communities, the IDDE program will be established under the same agency or department that oversees all other MS4 NPDES requirements (e.g., Department of Environmental Protection, Department of Public Works, Department of Health, etc.). For small communities, IDDE program administration and implementation may be wrapped into the broad duties of just a few staff. For larger communities, or where there are significant known problems associated with illicit discharges, a community may elect to have a dedicated department division with core staff. In either event, the agency and individuals responsible for the program should be well identified along with a clear understanding of program purpose, goals and actions.

Other local departments may already have authority over certain aspects of illicit discharges. Therefore, close coordination and communication with different departments is essential, and consideration should be given to consolidating responsibilities and authority. If consolidation is not pursued, regular inter-departmental briefings, training sessions, and data sharing will enhance program effectiveness and reduce the likelihood of significant lag times between discovery of a discharge and enforcement or correction due to split responsibilities between departments.

In some cases, communities may want to consider collaborating with adjacent or nearby permittees in order to form a regional approach to addressing illicit discharges. This might be appropriate in situations where municipalities share a common receiving water, and program implementation is conducted on a watershed management basis.

4.2 Develop Local Illicit Discharge Ordinance

A community must demonstrate that it has adequate legal authority to successfully implement and enforce its IDDE program. In fact, establishing legal authority is one of the required components identified in Phase II regulations, and can be identified as a measurable goal. Guidance is provided below on how to develop an IDDE ordinance to establish legal authority.

Reviewing What You Have

Communities with illicit discharge prohibitions in place have typically invoked legal authority using one or more of three mechanisms:

1. Storm water ordinance that prohibits illicit discharges to the drainage network
2. Plumbing code that prohibits illicit connections to the drainage network
3. Health code that regulates the discharge of harmful substances to the drainage network

A few concerns arise with the second and third mechanisms. One example is plumbing codes that only prohibit illicit connections fail to address other common discharges, such as indirect discharges, illegal dumping, or failing infrastructure. Similarly, exclusive reliance on health codes to regulate illicit discharges may not pick up discharges that are not harmful to human health, such as groundwater or potable water infiltration and residential irrigation return flows. With some revision and expansion, one or all of these existing mechanisms can meet the needs of the IDDE program. Alternatively, a new, stand-alone illicit discharge ordinance can be developed that supercedes all other related codes.

CASE STUDY

The City of Raleigh is an NPDES Phase I community. The Water Quality Group (WQG) within the Public Works Department oversees the City's illicit discharges program. The WQG was created in the early 1990s to be responsible for surface water quality across the City and to ensure compliance with the City's NPDES permits. Prior to that, various departments within city government handled water quality issues.

Raleigh's Illicit Discharge Ordinance was adopted in the second year of their original NPDES Phase I permit. The ordinance clearly defines and prohibits illicit discharges and illicit connections; requires containment and clean-up of spills/discharges to, or having the potential to be transported to, the storm drain system (it is also standard operating procedure that the City fire chief be notified of any spills immediately); allows for guaranteed right of entry for inspection of suspected discharges and connections; and outlines escalating enforcement measures, including civil penalties, injunctive relief, and criminal penalties.

Although the WQG runs the IDDE program, some functions are undertaken by the City's Public Utilities Department (e.g., fixing problems in the sanitary line, conducting dye and smoke testing, television inspection of the lines).

Raleigh began with a flat annual IDDE budget based on their past experience of what the program costs to run. More recently, the program began receiving additional funds from the City's storm water utility. A portion of the budget is allocated for testing. Cleaning and correction costs are funded through various budgets depending on the illicit discharge source. The WQG also budgets for two specialists: one is responsible for enforcement and dealing with citizen complaints and the other is responsible for monitoring and tracing the source of problems. The cost of television inspection and smoke testing is included in the Public Utilities Department budget.

Source: Senior (2002, 2004)

The length and complexity of an IDDE ordinance is largely a local community decision. Appendix B provides a model ordinance that may be adapted to meet the specific needs of local communities.

Some key components that should be addressed to ensure full authority to prevent and correct illicit discharges include the following:

- Prohibit illicit discharges
- Investigate suspected illicit discharges
- Require and enforce elimination of illicit discharges
- Address unique conditions or requirements

Defining What is Illicit

An IDDE ordinance should clearly define and/or identify illicit discharges and clearly state that these discharges are prohibited. Some communities may prefer to provide a short, concise definition of illicit discharges, while others may wish to list specific substances or practices that qualify as illicit discharges. However, if a detailed list is provided in the ordinance, a qualifying statement should follow in order to include polluting discharges not specifically listed.

Illicit connections should also be defined in the ordinance. These connections include pipes, drains, open channels, or other conveyances that have the potential to allow an illicit discharge to enter the storm drain system. The prohibition of illicit connections should be retroactive to include connections made in the past, whether or not the connection was permissible at the time. This is especially important if historic plumbing codes or standards of practice allowed for connection of laterals and drains (e.g., shop floor drains) to the MS4.

Lastly, the ordinance should identify categories of non-storm water discharges or other flows to the MS4 that are not considered illicit. For example, the Phase II rule exempts discharges resulting from fire fighting activities. Other activities that are commonly exempt include discharges from dye testing and non-storm water discharges permitted under an NPDES permit, provided that the discharger is in full compliance with the permit. The following categories of non-storm water discharges do not need to be addressed in the IDDE program unless the operator of the regulated small MS4 designates them as significant contributors of pollutants:

- Water line flushing
- Landscape irrigation
- Diverted stream flows
- Rising ground waters
- Uncontaminated ground water infiltration
- Uncontaminated pumped ground water
- Discharges from potable water sources
- Foundation and footing drain water
- Air conditioning condensation
- Irrigation water
- Springs
- Water from crawl space pumps
- Lawn watering
- Individual residential car washing
- Flows from riparian habitats and wetlands

In some cases, communities will need to assess unique local discharges of concern and ensure that they are properly addressed within the ordinance. Examples of unique conditions or requirements sometimes included in IDDE ordinances are septic system provisions, plumbing codes, point of sale dye testing, and pollution prevention plan requirements for certain generating sites.

Provisions for Access and Inspection

Although many communities report that most property owners cooperate when asked for access for illicit discharge investigations, this should never be taken for granted. Indeed, the right of access to private property for inspections is an essential provision of any IDDE ordinance. The ordinance should provide for guaranteed right of entry in case of an emergency or a suspected discharge or at any time for routine inspections, such as dye or smoke tests.

The ordinance should also clarify that right of entry applies to all land uses in the community, and that proof of discharge is not required to obtain entry. It should also state the responsibility of the property owner to disarm security systems and remove obstructions to safe and easy access. Enforcement actions should be established for property owners that refuse access, including the ability to obtain a search warrant through the court system.

Types of Enforcement Tools

An IDDE ordinance should define a range of enforcement tools so the responsible agency can effectively handle the wide range of illicit discharge violations it is likely to encounter. Potential enforcement tools can range from warnings to criminal prosecution. The choice of enforcement tools should be based on volume and type of discharge, its impact on water quality and whether it was intentional or accidental. In addition, it is helpful to spell out the specific activities that trigger progressively greater enforcement. Table 12 summarizes the range of enforcement tools that have been used by communities to respond to illicit discharges.

The ordinance should provide for escalating enforcement measures to notify operators of violations and to require corrective action. Voluntary compliance should be used for first-time, minor offenders, while more serious violations or continued non-compliance may warrant a more aggressive enforcement approach. Finally, the ordinance should include methods for appeal to provide owners with avenues for compliance.

Establish a Tracking and Reporting System

Communities need to develop tracking and reporting systems to support the entire IDDE program, including enforcement. A relational database with geospatial features provides the greatest flexibility to cover multiple program objectives. From a legal standpoint, tracking systems are important for historical documentation of problems and corrective actions. More details on designing and operating a tracking system are described in subsequent chapters.

Table 12: Summary of IDDE-Related Enforcement Tools	
Type of Enforcement Action	**Description**
Written Warning with Voluntary Compliance	• Applies to first time, minor violations (Field staff should have authority to do this)
Written Notice of Violation Ordering Compliance	• Should clearly state description of remedial measures necessary, time schedule, penalties assessed if it doesn't happen, and timeframe for appeal
Administrative Penalties	• Daily financial penalty imposed by a responsible department for each day violation remains unfixed
Civil Penalties	• Daily financial penalty imposed by judicial authority for each day violation remains unfixed
Compensatory Action	• In lieu of enforcement proceedings or penalties, impose alternative compensatory action, e.g., storm drain stenciling, etc.
Criminal Prosecution	• Applies to intentional and flagrant violations of ordinance • Each day discharge continues is typically a separate offense • Can result in fines and imprisonment
Cost of Abatement of the Violation / Property Liens	• Applies when jurisdiction remedies the discharge or conducts cleanup, but may also be used to recoup administrative costs • May constitute a property lien if not paid within certain timeframe
Emergency Cease and Desist Order	• Applies when ordinance continues to be violated • Requires immediate compliance with ordinance by halting operations/ terminating discharges • May be a written or verbal order to remove illicit discharge
Suspension of Water or Sewer Service	• Applied in emergency situations to immediately discontinue discharge to MS4 • May be applied as enforcement measure when property owner does not comply / fix the problem within timely manner
Stop Work Order	• Typically applies to discharges associated with construction activity • No further work can be done until compliance is achieved

Chapter 5: Desktop Assessment of Illicit Discharge Potential

Purpose: This program component uses mapping and other available data to determine the potential severity of illicit discharges within a community, and identifies which subwatersheds or generating land uses merit priority investigation.

Method(s): A simple desktop assessment method can rapidly determine the severity of illicit discharge problems in a community. If an MS4 has fewer than 20 stream miles, this component can be skipped and a community can proceed directly to an ORI. The desktop assessment method has five basic elements:

1) Delineate subwatersheds or other drainage units within your community
2) Compile available mapping and data for each drainage unit (e.g., land use, age, outfalls, infrastructure history)
3) Derive subwatershed discharge screening factors using GIS analysis
4) Screen and rank illicit discharge potential at the subwatershed and community level
5) Generate maps to support field investigations

Desired Product or Outcome(s): The desktop assessment is used to guide initial field screening, and support initial IDDE program decisions. Key outcomes include:

a) Screening problem catchments or subwatersheds
b) Creation of GIS or other database system to track outfalls
c) Gaining an overall assessment as to the severity of illicit discharge problems in the community
d) Generation of basic mapping for subsequent field work

Budget and/or Staff Resources Required: The initial desktop assessment of illicit discharge potential should not be a long or arduous process, and should generally take less than four staff weeks. The quality and accuracy of the desktop assessment, however, will vary depending on the extent of available mapping information and GIS data. If mapping information is poor, the desktop assessment should be skipped, and program managers should go directly to the field to inventory outfalls.

Integration with Other Programs: If the desktop assessment suggests few potential illicit discharge problems, program managers may want to combine outfall surveys with broader stream corridor assessment tools such as the Unified Stream Assessment (Kitchell and Schueler, 2004). The desktop assessment provides insight on how to narrow your illicit discharge search, and is helpful when designing a discharge tracking system to best suit your needs. Finally, the desktop assessment can identify subwatersheds, generating sites, and neighborhoods where storm water education should be targeted to address illicit discharge problems.

5.1 Overview of Desktop Assessment of Illicit Discharge Potential

A community should understand the extent of water quality problems caused by illicit discharges. The desktop assessment should not be a time-consuming research effort, but should draw on existing background data and anecdotal information to initially characterize illicit discharge potential at the subwatershed level.

Subwatersheds are then screened based on their composite score, and are designated as having a low, medium or high risk:

- Low – no known illicit discharge problems in the subwatershed
- Medium– problems are confined to a few stream reaches, outfalls or specific generating sites in the subwatershed
- High – Problems are suspected to be severe throughout the subwatershed.

The desktop assessment also shapes the overall direction of a local IDDE program. For example, if the desktop assessment indicates that the risk of illicit discharges is low in the community, program managers may want to shift resources to other minimum management measures and integrate them into a broader watershed assessment and restoration effort. For example, IDDE programs may emphasize storm water education, public involvement and hotline setup. By contrast, if the desktop assessment reveals significant potential for severe discharges, program managers will need to allocate significant program resources to find and fix the discharge problems.

The recommended scale for desktop assessments is the subwatershed or sewershed, which typically range from two to 10 square miles in area. These small planning units are easily delineated on maps or a GIS system. Next, mapping, monitoring and other data are analyzed to identify subwatersheds with the greatest potential to contribute illicit discharges. The sophistication of the analysis varies depending on the data available, but can encompass up to 10 different screening factors. The desktop assessment consists of five basic steps:

Limited mapping or data should not hinder a desktop assessment. Most communities will have some gaps, but should make the most out of what they have. The desktop assessment is an office exercise to locate the most promising subwatersheds to find illicit discharge; subsequent outfall screening is needed to discover the problem outfalls in the field.

Step 1: Delineate subwatersheds

Step 2: Compile mapping layers and subwatershed data

Step 3: Compute discharge screening factors

Step 4: Screen for illicit discharge potential at the subwatershed and community level

Step 5: Generate maps to support field investigations

Step 1: Delineate Subwatersheds

Since hundreds of outfalls and many stream miles exist in most communities, the MS4 should be divided into smaller, more manageable planning units known as subwatersheds. If the community already does watershed planning, these subwatersheds may already be delineated, and should be used for subsequent characterization and screening. Working at the subwatershed scale is usually the most efficient way to conduct both desktop assessments and field surveys.

In small, heterogeneous or densely developed MS4s, conducting the assessment on a smaller scale may be more effective. In this case, sewersheds or catchments that are less than one square mile in area and have a common outfall or discharge point should be delineated. This finer level delineation allows for a refined characterization that can pinpoint probable sources of illicit discharges, but can obviously consume a lot of time. It should be noted that sewersheds do not always follow topographic delineations and therefore can provide a more accurate picture of the contributing areas to a particular outfall.

If subwatersheds are not yet defined, hydrologic, infrastructure and topographic map layers are needed to delineate the boundaries. Guidance on the techniques for accurately delineating subwatershed boundaries can be found at www.stormwatercenter.net (click "Slideshows," then scroll down to "Delineating Subwatershed Boundaries"). The use of digital elevation models (DEMs) and GIS can also make subwatershed delineation an easier and faster, automated process.

Some subwatersheds extend beyond the political boundaries of a community. Where possible, it is recommended that the entire subwatershed be delineated and assessed in conjunction with neighboring municipalities. This helps to ensure that all potential sources of illicit discharges are identified in the subwatershed, regardless of the community from which they originate.

Step 2: Compile Mapping Layers and Subwatershed Data

Once subwatersheds (or catchments) are delineated, a community can begin to acquire and compile existing data for each drainage area, preferably with a Geographic Information System (GIS). A GIS allows the user to analyze and manipulate spatial data, rapidly update data and create new data layers, associate data tables with each map layer, and create paper maps to display subwatershed information. A GIS can greatly speed up data compilation and provides greater accuracy in mapping specific locations. The mapping information facilitates the interpretation and understanding of the discharge screening factors (Step 3).

If a community does not currently have a GIS, developing a system from scratch may seem daunting, however, most GIS software can be installed on basic PCs, and free GIS data layers are often available online. The basic elements of a GIS program include a PC, Global Positioning System (GPS) units, a plotter, a digitizer, GIS software, data and staff training. As with many technologies, both low-end and high-end versions are available, as are many add-ons, extensions and tools. While a GIS is not necessary for the IDDE desktop assessment, it does make the process more efficient and accurate, which can save money in the long run. Moreover, other agencies within a community usually need or use GIS and may be willing to share hardware, software, support and development costs[7].

Acquiring data for each subwatershed is the next step in the desktop assessment process.

---

[7] If a community plans to defer using GIS, all databases it develops should have location information suitable for later use with GIS (i.e., using suitable georeferencing technology such as GPS).

The extent and quality of the data available for mapping directly influence subsequent analyses and field investigations. A list of recommended data layers to acquire for the desktop assessment is provided in Table 13.

Some mapping data may exist in GIS format, whereas others are only available in digital or hardcopy formats that need to be converted to GIS. Digital data with a geo-spatial reference such as latitude and longitude, parcel ID numbers or addresses can be directly entered into a GIS, if an existing road or parcel GIS layer can be associated to it. Hardcopy maps can also be digitized to create new GIS data layers. This can be a labor-intensive process, but will only need to be done once and can be easily updated. If GIS is not an option, hardcopy maps and data can be analyzed, with an emphasis on tax maps, topographic maps, historic aerial surveys, and storm drain and outfall maps.

Most data layers can be obtained from local sources, such as the city planning office, emergency response agency, or public works department. If a subwatershed extends beyond the boundaries of your community, you may need to acquire data from another local government. Some data layers may be available from state and federal agencies and commercial vendors. EPA and most state environmental agencies maintain databases of industrial NPDES, CERCLA, RCRA and other sites that handle or discharge pollutants or hazardous materials. These searchable permit databases are often available as GIS layers (see Appendix A). Commercial vendors are good sources for low-altitude aerial photos of your community. Aerial photos can be expensive but are often the best way to get a recent high-resolution ‘snapshot’ of subwatershed conditions.

Table 13: Useful Data for the Desktop Assessment

	Data	Likely Format
Recommended	Aerial photos or orthophotos	Digital map
	Subwatershed or catchment boundaries	Digital or hardcopy map
	Hydrology including piped streams	Digital or hardcopy map
	Land use or zoning	Digital or hardcopy map
	NPDES storm water permittees	Digital data or map
	Outfalls	Digital or hardcopy map
	Sewer system, 1” = 200’ scale or better	Digital or hardcopy map
	Standard Industrial Classification codes for all industries	Digital or hardcopy data
	Storm drain system, 1” = 200’ scale or better	Digital or hardcopy map
	Street map or equivalent GIS layers	Digital or hardcopy map
	Topography (5 foot contours or better)	Digital or hardcopy map
Optional	Age of development	Narrative data
	As-builts or construction drawings	Hardcopy map
	Condition of infrastructure	Narrative data
	Field inspection records	Hardcopy or digital data
	Depth to water table and groundwater quality	Digital data or maps
	Historical industrial uses or landfills	Narrative data or hardcopy map
	Known locations of illicit discharges (current and past)	Narrative data or digital map
	Outfall and stream monitoring data	Digital data
	Parcel boundaries	Digital or hardcopy map
	Pollution complaints	Narrative data
	Pre-development hydrology	Narrative data or hardcopy map
	Sanitary sewer Infiltration and Inflow (I/I) surveys	Hardcopy or digital data
	Septic tank locations or area served by septic systems	Hardcopy or digital map
	Sewer system evaluation surveys	Hardcopy or digital data

Alternatively, TerraServer (http://terraserver.microsoft.com/default.aspx) is a free mapping resource that most communities can use to get good quality aerial and other coverages (Figure 8 is an example). Higher quality photos may be desirable as more detailed investigations are pursued.

As GIS technology has become more affordable and easier to use, Phase II communities should harness their capabilities to develop the storm sewer system maps required by NPDES permits. GIS can become a powerful tool to track and manage the entire IDDE program, and demonstrate compliance in annual reports. In addition to being a powerful tool for analysis, GIS is also a great tool for communicating with the public. The images that can be created with GIS can summarize tables of data in a way that the public appreciates. If the recommended data layers are not available, a community may want to devote program resources to create or obtain them. Once data layers have been collected and digitized, they can be entered into the GIS to create a map of each subwatershed (Figure 8). Make sure all data layers are in the same coordinate system, and perform any conversions needed. Clip data layers to subwatersheds to enable calculation of factors such as land use, area, and outfall density. Summary data on subwatershed water quality and statistics on the age and condition of infrastructure should be entered into a database created for analysis in the next step.

Step 3: Compute Discharge Screening Factors

The third step of the desktop assessment defines and computes discharge factors to screen subwatersheds based on their illicit discharge potential (IDP). As many as 10 different discharge screening factors can be derived during the screening process, but not all may apply to every community. The potential screening factors are described in Table 14, along with how they are measured or defined. Keep in mind that these screening factors are a guide and not a guarantee. Each screening factor is described in detail in the following section.

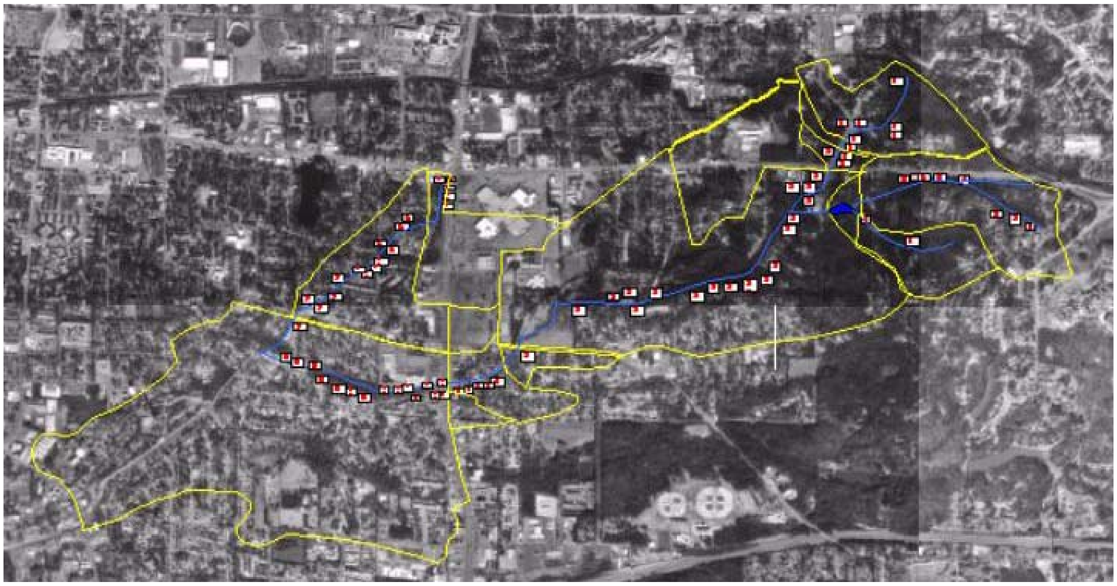


Figure 8: GIS Layers of Outfalls in a Subwatershed
Markings illustrate Tuscaloosa, AL outfalls and drainage areas surveyed as part of this project.

Table 14: Defining Discharge Screening Factors in a Community	
Discharge Screening Factors	**Defining and Deriving the Factor**
1. Past Discharge Complaints and Reports	Frequency of past discharge complaints, hotline reports, and spill responses per subwatershed. Any subwatershed with a history of discharge complaints should automatically be designated as having high IDP.
2. Poor Dry Weather Water Quality	Frequency that *individual* samples of dry weather water quality exceed benchmark values for bacteria, nutrients, conductivity or other predetermined indicators. High risk if two or more exceedances are found in any given year.
3. Density of Generating Sites or Industrial NPDES Storm Water Permits	Density of more than 10 generating sites or five industrial NPDES storm water sites per square mile indicates high IDP. Density determined by screening business or permit databases (Appendix A).
4. Storm Water Outfall Density	Density of mapped storm water outfalls in the subwatershed, expressed as the average number per stream or channel mile. A density of more than 20 outfalls per stream mile indicates high IDP.
5. Age of Subwatershed Development	Defined as the average age of the majority of development in a subwatershed. High IDP is often indicated for developments older than 50 years. Determined from tax maps and parcel data, or from other known information about neighborhoods.
6. Sewer Conversion	Subwatersheds that had septic systems but have been connected to the sanitary sewer system in the last 30 years have high IDP.
7. Historic Combined Sewer Systems	Subwatersheds that were once served by combined sewer system but were subsequently separated have a high IDP.
8. Presence of Older Industrial Operations	Subwatersheds with more than 5% of its area in industrial sites that are more than 40 years old are considered to have high IDP. Determined from historic zoning, tax maps, and "old-timers."
9. Aging or Failing Sewer Infrastructure	Defined as the age and condition of the subwatershed sewer network. High IDP is indicated when the sewer age exceeds design life of its construction materials (e.g., 50 years) or when clusters of pipe breaks, spills, overflows or I/I are reported by sewer authorities.
10. Density of Aging Septic Systems	Subwatersheds with a density of more than 100 older drain fields per square mile are considered to have high IDP. Determined from analysis of lot size outside of sewer service boundaries.

1. Past Discharge Complaints and Reports

Many communities already have some handle on where illicit discharges have occurred in the past, based on past complaints, reports and interviews with spill responders and public works repair crews. Pollution complaints made to the local environmental or health department are also worth analyzing. Each of these historical sources should be analyzed to determine if any patterns or clusters where illicit discharges have historically occurred can be found. Ideally, the number of past discharge complaints should be expressed on a subwatershed basis. Even if there is not enough data to quantify past discharges, it may be helpful to get a qualitative opinion from public works crews.

2. Poor Dry Weather Water Quality

If dry weather water quality monitoring data have been collected for local streams, it can be an extremely useful resource to screen subwatersheds for IDP. In particular, look for extreme concentrations of enterococci or *E. coli*, or high ammonia-nitrogen or conductivity. Remember to edit out any samples that were collected during or shortly after storm events, as they reflect the washoff of pollutants during storm water runoff. In general, most communities have more subwatersheds than baseflow monitoring stations, so complete coverage is usually lacking. The following benchmarks are recommended to flag streams with high IDP, based on individual samples of dry weather water quality that exceed:

- Fecal coliform or *E. coli* standards (e.g., typically 1,000 to 5,000 MPN/100 ml)
- Ammonia-nitrogen levels of 0.30 mg/l
- Total phosphorus of 0.40 mg/l
- Conductivity levels that exceed the 90^{th} percentile value for the pooled dataset.

Subwatersheds can be classified as having a moderate risk if stream water quality values exceed half the benchmark value. An alternative approach is to statistically analyze long-term dry weather water quality monitoring dataset to define breakpoints (e.g., 50^{th}, 75^{th}, and 90^{th} percentiles).

3. Density of Generating Sites or Industrial NPDES Storm Water Permits

The density of potential generating sites in a subwatershed can be a good screening factor, if land use and business databases are available. The basic database screening method used to locate commercial, industrial, institutional, municipal and transport-related generating sites is described in Chapter 1 and Appendix A. From the standpoint of discharge screening, the key variable to derive is the density of potential generating sites (e.g., sites/square mile). As a rule of thumb, more than 10 potential generating sites per square mile would indicate a high IDP, while subwatersheds with three to 10 generating sites per square mile might suggest a medium IDP.

Alternatively, communities may want to develop screening factors based on the density of industrial storm water permits in place within the subwatershed. State or federal regulatory agencies often have geospatial databases of industrial NPDES discharges that can be rapidly screened. Pretreatment programs are another valuable source of information on industrial and non-domestic discharges to the sanitary system.

4. Storm Water Outfall Density

The density of outfalls in a subwatershed is an effective discharge screening factor, and is expressed in terms of the number of outfalls per stream mile. Outfall density can be determined by analyzing storm drain maps, if they exist (although they often miss the smaller diameter outfalls that can also produce discharges). In general, subwatersheds that have more than 20 mapped outfalls per stream mile may indicate a higher risk for IDP. Alternatively, the breakpoints for outfall density can be statistically analyzed based on the frequency across all subwatersheds.

5. Age of Subwatershed Development

The average age of development in a subwatershed may predict the potential for illicit discharge problems. For example, a subwatershed where the average age of development is more than 100 years was probably constructed before sewer service was widely available, and many of the pipes and connections may have changed over the years as a result of modernization and redevelopment. Presumably, the risk of potential discharges would be higher in these older subwatersheds. By contrast, a recently developed subwatershed may have a lower discharge risk due to improved construction materials, codes and inspections. Therefore, high IDP may be indicated when subwatershed development is more than 50 years old, with medium IDP for 20 to 50 year old development, and low IDP if fewer than 20 years old. You should always check with local building and plumbing inspectors to confirm the building eras used in the screening analysis. The actual age of development can be estimated by checking tax maps and plats, or based on architecture, or common knowledge of neighborhoods.

6. Sewer Conversion

Subwatersheds that were once served by septic systems but were subsequently connected often have a high IDP. These subwatersheds are identified by reviewing past sewer construction projects to determine when and why sewer service was extended.

7. Historic Combined Sewer Systems

Subwatersheds that were once served by combined sewer systems but were subsequently separated often have a high IDP. They can be identified by reviewing past municipal separation projects.

8. Presence of Older Industrial Operations

Older industrial areas tend to have a high potential for illicit cross-connections for several reasons. First, sanitary sewers may not have been installed to handle wash water, process water and other discharge flows when the operation was originally constructed. In the past, storm drains were often used to handle non-sewage discharges at older industrial facilities. In addition, sanitary and storm drain lines built in different eras are poorly mapped, which increases the chance that someone gets the plumbing wrong during an expansion or change in operations at the facility. As a result, older industries may inadvertently discharge to floor drains or other storm drain connections thinking they are discharging pretreated water to the sanitary sewer. Finally, older industries that produce large volumes of process water may not have enough sanitary sewer capacity to handle the entire discharge stream, causing them to improperly discharge excess water through the storm drain system.

For these reasons, subwatersheds where older industry is present should be regarded as having a high IDP. For operational purposes, older industry is defined as sites that predate the Clean Water Act (e.g., 40 years old or more). They can be identified from historic zoning and land use maps, old parcel records or talking with old-timers.

9. Aging or Failing Sewer Infrastructure

Aging or failing sewer infrastructure often signals potential illicit discharges, and can be defined by the age and condition of the subwatershed sewer network. High IDP is indicated when the sewer age exceeds the design life of its construction materials (e.g., 50 years) or when clusters of pipe breaks, spills, overflows or infiltration and inflow (I&I) are reported by sewer authorities. Older and aging sewer infrastructure experience more leaks, cross-connections and broken pipes that can contribute sewage to the storm drain system. The key factor to determine is the approximate age of the sewer pipes and their construction materials, which can be gleaned from sewer maps I&I studies, or interviews with crews that regularly repair broken or leaking sewer pipes.

<u>10. Density of Aging Septic Systems</u>

Subwatersheds located outside of the sewer service area are presumably served by septic systems. Septic systems more than 30 years old are prone to failure, based on many site factors (Swann, 2001). In general, a high IDP is indicated if older septic tank density exceeds 100 per square mile. Sewer envelope boundaries or sewer network maps can be helpful to identify subwatersheds that are served by septic systems. Actual density is determined by counting or estimating the total number of septic households in the subwatershed. Tank density should be expressed as septic system units per square mile (average lot size can also be used as a surrogate estimator).

Step 4: Screen for Illicit Discharge Potential at the Subwatershed and Community Level

The process for screening IDP at the subwatershed level is fairly simple. The first step is to select the group of screening factors that apply most to your community, and assign them a relative weight. Next, points are assigned for each subwatershed based on defined scoring criteria for each screening factor. The total subwatershed score for all of the screening factors is then used to designate whether it has a low, medium or high risk to produce illicit discharges. Table 15 provides an example. Based on this comparison, high-risk subwatersheds are targeted for priority field screening. It is important for program managers to track and understand which screening factors contributed to identifying a watershed as "high-risk," as this may affect the type of investigatory strategy that is used for a particular watershed.

Table 15: Prioritizing Subwatersheds Using IDP Screening Factors

	Past Discharge Complaints/ Reports (total number logged)	**Poor dry weather water quality** (% of times bacteria standards are exceeded)	**Density of storm water outfalls** (# of outfalls per stream mile)	**Average age of development** (years)	**Raw IDP score**	**Normalized IDP score****
Subwatershed A	8 (2)*	30% (2)*	14 (2)*	40 (2)*	8	2
Subwatershed B	3 (1)	15% (1)	10 (2)	10 (1)	5	1.25
Subwatershed C	13 (3)	60% (3)	16 (2)	75 (3)	11	2.75
Subwatershed D	1 (1)	25% (1)	9 (1)	15 (2)	5	1.25
Subwatershed E	5 (1)	15% (1)	21 (3)	20 (1)	6	1.5

Notes:
* The number in parentheses is the IDP "score" (with 3 having a high IDP) earned for that subwatershed and screening factor. Basis for assigning scores (based on benchmarks) to assess IDP is as follows:
<u>Past discharge complaints/reports</u>: <5 = 1; 5-10 = 2; >10 = 3
<u>Dry weather water quality</u>: <25% = 1; 25-50% = 2; >50% = 3
<u>Storm water outfall density</u>: <10 = 1; 10-20 = 2; >20 = 3
<u>Average age of development</u>: <25 = 1; 25- 50 = 2; >50 = 3

** Normalizing the raw IDP scores (by dividing the raw score by the number of screening factors assessed) will produce scores that fall into the standard scale of 1 to 3 for low to high IDP, respectively.

The example provided in Table 15 uses four screening factors to assess five subwatersheds in a community. Data for each factor are compared against assigned benchmarks, as shown in the table. Each subwatershed receives a specific score for each individual screening factor. These scores are then totalled for each subwatershed, and the one with the highest score is given top priority screening. In this case, the screening priority would be given to Subwatershed C, then A, followed by E. Subwatersheds B and D, with the lowest potential for illicit discharges, have the lowest priority.

A similar screening process can be used to evaluate the IDP for the community as a whole. In this case, the entire population of subwatersheds in the community is analyzed to collectively determine the frequency of the three risk areas: high, medium, and low. Predefined criteria for classifying the community's IDP should be developed.

Table 16 and Figure 9 present an example system for classifying IDP as minimal, clustered or severe, based on the proportion of subwatersheds in each risk category. The community-wide assessment helps program managers define their initial IDDE program goals and implementation strategies, and target priority subwatersheds for field investigations.

Step 5: Generate Maps to Support Field Investigations

The last step in this program component involves generating the maps that field crews need to screen outfalls in priority subwatersheds. More detail on mapping requirements is provided in Chapter 11. The basic idea is to create relatively simple maps that show streams, channels, streets, landmarks, property boundaries and known outfall locations. The idea is to provide enough information so crews can find their way in the field without getting lost, but otherwise keep them uncluttered. Low altitude aerial photos are also a handy resource when available.

Table 16: Community-wide Rating of Illicit Discharge Potential

Rating	Indicators
Minimal (no known problems)	Majority of subwatersheds have a Low IDP risk, with the remainder having Medium IDP risk
Clustered (isolated problems)	More than 20% of subwatersheds with a Medium or High IDP risk that are in close proximity to each other
Severe (severe problems)	More than 50% of subwatersheds with a Medium or High IDP risk or more than 20% of subwatersheds with a High IDP risk

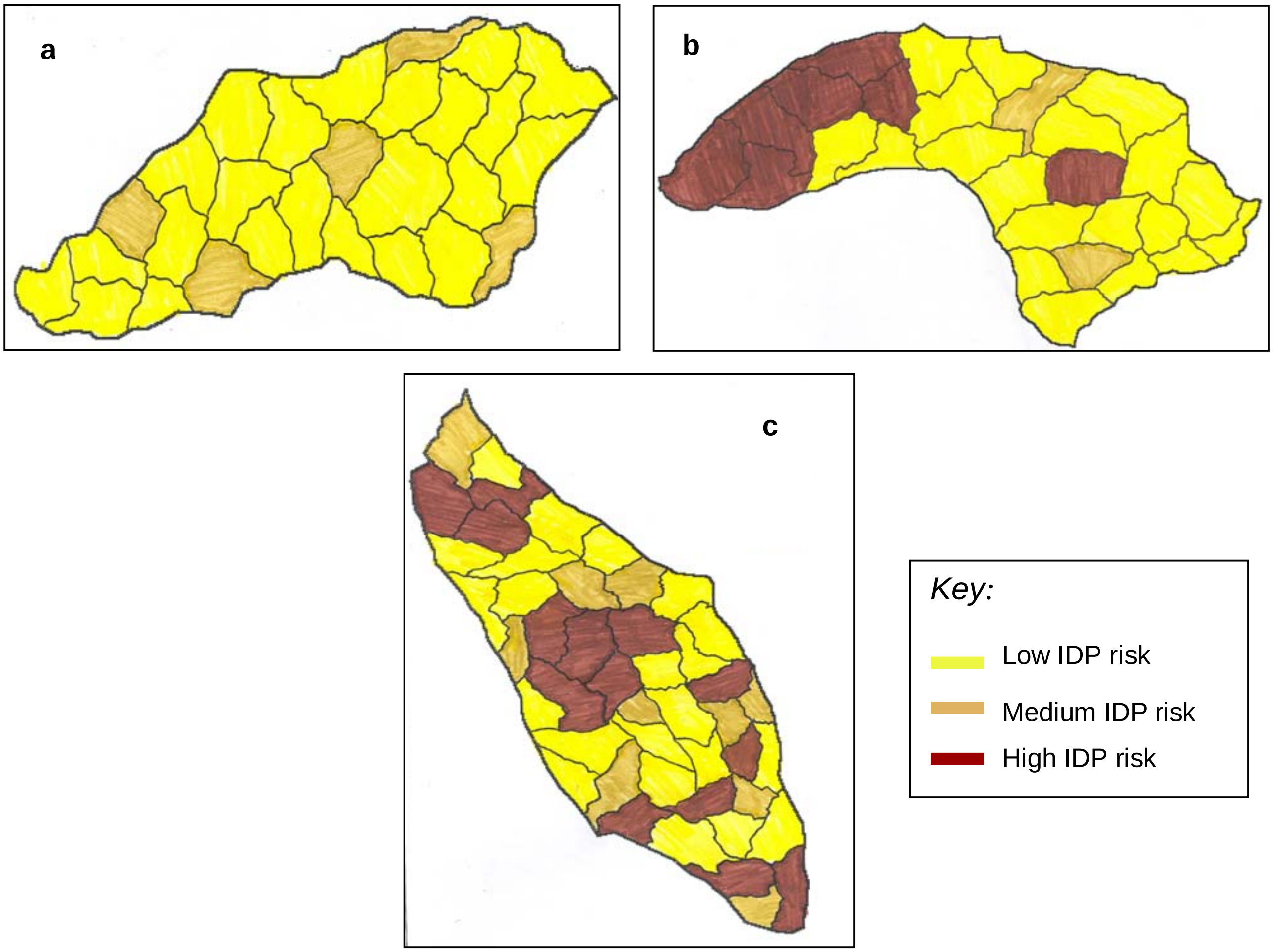
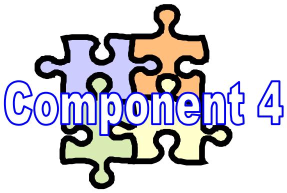


Figure 9: Communities with Minimal (a), Clustered (b), and Severe (c) Illicit Discharge Problems



Chapter 6: Developing Program Goals and Implementation Strategies

Purpose: This program component defines the goals and performance milestones to measure progress in IDDE program implementation during the first permit cycle, and selects the most appropriate and cost-effective strategies to find, fix and prevent illicit discharges. The goals and strategies ensure that scarce local resources are allocated to address the most severe illicit discharge problems that cause the greatest water quality problems in the community.

Method: The basic method is to analyze the results of the IDDE audit, desktop analysis and local water quality conditions to develop realistic, achievable and measurable goals for the program. The public and other stakeholders should be involved in the goal setting process. Once goals are selected, program managers need to select the appropriate implementation strategies and develop a timeline to make them happen. Both goals and strategies should closely align with the type and severity of water quality problems and local watershed management priorities. The probable contribution of illicit discharges to specific water quality problems should be estimated or modeled to determine the degree to which control efforts can meet local TMDLs, bacteria standards for water contact recreation, or other local water quality concerns.

Desired Product or Outcome(s): Agreement on program goals, measurable indicators and implementation strategies that address four key areas:

- Overall program administration
- Outfall assessment
- Finding and fixing illicit discharges
- Prevention of illicit discharges

Budget and/or Staff Resources Required: Staff effort to draft the goals and strategies, conduct needed meetings, respond to comments and finalize ranges from two to six weeks. Goals and strategies should be revisited and updated annually and at the end of each permit cycle. Staff and budget costs are not anticipated to be high unless a fundamental shift in program goals occurs.

Integration with Other Programs: Goal setting is always a good opportunity for public involvement, storm water education and watershed outreach. Effective implementation strategies often involve cost sharing with other departments and even other communities for monitoring equipment and lab facilities, hotlines, and education (e.g., public health/septic system programs).

6.1 Overview of Goals and Strategies Development

Communities can define program goals and implementation strategies once they understand the extent of their illicit discharge problem and how it influences local water quality. Initial program goals should be realistic and provide specific completion milestones to measure program compliance. Measurable goals enable a community to track and evaluate permit compliance over time, and to reassess and modify the program over time. The most basic measure of program effectiveness is to assess whether program goals are being met. So, if a program goal is to walk all stream miles and inventory all outfalls in the MS4 within the first permit cycle, this becomes a benchmark that determines program effectiveness. If a community finds that they only managed to walk and inventory 80% of stream miles, the program may need to be modified so that a full screening sweep is completed in a permit cycle, or they may need to adjust the goal or benchmark.

6.2 Develop Initial Program Goals

The NPDES Phase II MS4 permit regulations grant communities considerable flexibility to develop program goals, as long as they are defined in a measurable way to gauge permit compliance and program effectiveness. EPA (2000e) states that goals "should reflect the needs and characteristics of the operator and the area served by its small MS4. Furthermore, they should be chosen using an integrated approach that fully addresses the requirements and intent of the minimum control measure."

With this in mind, a series of representative goals that might be set for an IDDE program are presented in Table 17, along with proposed milestones. Four broad types of goals should be developed for every program:

1. Overall program administration
2. Outfall assessment
3. Preventing illicit discharges
4. Finding and fixing illicit discharge

The assumed timeframe is based on a five-year permit cycle. Some of the program goals outlined in Table 17 are considered essential while others are optional or recommended. Communities should feel free to adapt these suggested program goals to reflect their unique conditions and capabilities, or create new ones. The key point is that program goals should always have a timeframe to serve as a benchmark for whether the goal has been achieved.

Implementation strategies are designed to achieve program goals, and vary depending on the types and severity of illicit discharge problems in the community. These are outlined in more detail in the next section.

Table 17: Measurable Goals for an IDDE Program		
EXAMPLE MEASURABLE GOALS	**TIMEFRAME**	**PRIORITY**
Goals related to overall program administration		
Audit existing capabilities and identify needs	Immediately	●
Designate one program head and identify key support staff		●
Develop a complete list of ongoing activities related to IDDE		❍
Coordinate and communicate with other affected agencies	At program start up and continuously and regularly after that	●
Develop a projected 5-year budget		●
Secure funding to match 5-year goals		●
Draft and promulgate new or modified ordinance	Year 1	●
Establish a tracking and reporting system	Year 1	●
Goals related to outfall assessment		
Define and characterize drainage areas or sewer sheds	Year 1	●
Walk all stream miles	Begin in Year 1 and complete first screening by end of permit cycle. Repeat once per permit cycle	●
Develop a digital (e.g., GIS) map of all outfalls, land use, and other relevant infrastructure	Year 1 and continuously and regularly after that	●
Secure analytical laboratory services either internally or by arrangement with a private laboratory	Initiate in conjunction with field screening	●
Sample and trace the source of a percentage of flowing outfalls each year of permit cycle	Initiate during first permit cycle and expand and enhance where problems are observed	●
Conduct regular in-stream assessments		❍
Conduct investigations at a percentage of non-flowing outfalls with poor in-stream water quality to look for intermittent flows		❍
Integrate all collected stream data and citizen complaints into the GIS system	Initiate during first year and expand and enhance with time	❍
Goals related to preventing illicit discharges		
Distribute educational materials to citizens and industries	Initiate during first year and expand and enhance with time	❍
Conduct storm drain stenciling	Initiate during first permit cycle and expand and enhance where problems are observed	❍
Hold hazardous waste collection days at least annually		❍
Conduct upland subwatershed site reconnaissance surveys to better characterize generating site potential		❍
Goals related to finding and fixing illicit discharges		
Develop a spill response plan and coordinate emergency response with other agencies	Immediately	●
Remove all obvious illicit discharges	Ongoing in conjunction with field screening and in response to hotline reports	●

Table 17: Measurable Goals for an IDDE Program		
EXAMPLE MEASURABLE GOALS	**TIMEFRAME**	**PRIORITY**
Train staff on techniques to find the source of an illicit discharge	Initiate during first year and expand and enhance with time	●
Repair a fraction of the illicit discharges identified through field screening or citizen complaints	Initiate during first permit cycle and expand and enhance where problems are observed	●
Establish a hotline for public to call in and report incidents (consider establishing performance standards, such as guaranteed response time)	Initiate during first year and expand and enhance with time	❍
Inspect and dye-test all industrial facilities	Initiate during first permit cycle and expand and enhance where problems are observed	❍
Develop a system to track results of on-site inspections	Initiate during first year and expand and enhance with time	❍
Establish an Adopt-a-Stream program	Initiate during first permit cycle and expand and enhance where problems are observed	❍
Establish pre-approved list of plumbers and contractors to make corrections	Initiate during first year and expand and enhance with time	❍
Key: ● Essential ❍ Optional but Recommended		

Ultimately, IDDE program goals should be linked to water quality goals. Some common examples of water quality goals include:

- Keep raw or poorly-treated sewage out of streams
- Reduce pollutant loads during dry weather to help meet the TMDL for a water body
- Meet bacteria water quality standards for contact recreation during dry weather flows
- Reduce toxicant and other pollutant discharges to a stream to restore the abundance and diversity of aquatic insects or fish

A well-designed IDDE program may not guarantee that water quality goals will be always be achieved. Indeed, if program managers can document that illicit discharges do not contribute to poor water quality, they may want to shift resources to other pollution sources or practices that do. Burton and Pitt (2002) offer a complete discussion on designing and conducting a receiving water investigation.

6.3 Crafting Implementation Strategies

In order to meet program goals, managers must devise cost-effective implementation strategies that are most appropriate for the types of illicit discharge problems they actually have. The community-wide illicit discharge potential (IDP) developed during the desktop analysis can be quite helpful in choosing implementation strategies. Table 18 presents implementation strategies that are geared to the findings of the community-wide IDP. As the community acquires more program experience, they can refine the strategies to better address program goals or unique watershed conditions (Table 19).

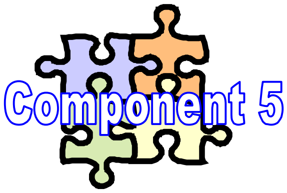
Perhaps the most important implementation strategy is targeting—screening, education and enforcement efforts should always be focused on subwatersheds, catchments or generating sites with the greatest IDP.

Adaptability after program startup is also an important strategy. Strategies developed from the desktop analysis should be constantly adjusted to reflect knowledge gained from field screening, hotline reports and other monitoring information.

Table 18: Linking Implementation Strategies to Community–wide IDP

Type	Examples of Implementation Strategy
Minimal IDP	• Conduct field screening of outfalls in the context of broader watershed assessment and restoration initiatives using the Unified Stream Assessment (CWP, 2004) or a comparable physical stream assessment approach that has broader focus and benefits. • Integrate IDDE program efforts into more comprehensive watershed assessment and restoration efforts where multiple objectives are being pursued (e.g., storm water education). • Target and coordinate with existing small watershed organizations as partners to accomplish inventory and data collection efforts. • Establish hotline to report suspicious discharges.
Clustered IDP	• Conduct limited sampling in the suspect areas. The most cost-effective approach will likely involve using outside laboratory services to avoid capital costs for special equipment (in some cases a municipal laboratory may be available for limited cost). • Select a small set of indicator parameters using the nature of historic problems and land use as a guide. • Target education program in problem areas. • Look for partnerships with local watershed groups to regularly monitor problem areas. • Establish a hotline to report suspicious discharges.
Severe IDP	• Establish a hotline to report suspicious discharges. • Conduct and repeat screening in all subwatersheds • Plan for more rigorous sampling approach to make establishment of internal laboratory set up more cost effective (i.e., plan for equipment expenditures for sample collection and analysis). Considerations include: expanding set of parameters to use as indicators, adopting a strategy for targeting intermittent discharges, and establishing in-stream stations to supplement screening effort. • Develop a community-specific chemical “fingerprint” of various flow sources to facilitate differentiation between likely flow sources. • Develop community-wide educational messages aimed at increasing public awareness and targeted education programs tailored to problem areas. • Look for partnerships with local watershed groups to be regular monitors of problem areas through an adopt-a-stream approach. • Emphasize cross-training of municipal employees to develop a broader reach of program efforts and lead by example by ensuring municipal facilities are not contributing to illicit discharge problem.

Table 19: Customizing Strategies for Unique Subwatershed Screening Factors		
Initial Problem Assessment	**Screening Factor** (from Table 14)	**Example Implementation Strategies**
Aging Sewer Infrastructure and/or Converted Combined System	• Complaints of sewage discharges • Poor dry weather quality • High outfall density • Septic to sewer conversion • Historic combined system • Aging sewers	• Institute a point of sale inspection and verification process. • Select a small set of indicator parameters that focuses on sewage connections. • Develop cost share program to assist property owners with connection correction.
Aging Septic Infrastructure and/or Converted Combined System	• Aging septic systems	• Develop targeted education program for septic system maintenance and institute a point of sale inspection and verification process. • Develop cost share capabilities to assist property owners with upgrade of system.
Discharges from Generating Sites	• Density of generating sites • Older industry • Past complaints and reports	• Link IDDE program to existing industrial NPDES discharge permits, and inspect storm water management pollution prevention plans. • Develop targeted training and technical assistance programs tailored to specific generating sites. • Aggressively enforce fines and other measures on chronic violators.
High Spill or Dumping Potential	• Past complaints and reports	• Establish a hotline and develop community-wide educational messages aimed at increasing public awareness. • Look for partnerships with local watershed groups to regularly monitor or adopt problem sites. • Increase number and frequency of used oil and hazardous waste recycling stations. • Post signs, with hotline reporting number at dumping sites.



Chapter 7: Searching for Illicit Discharge Problems in the Field

Purpose: This program component consists of detective work, and involves rapid field screening of outfalls in priority subwatersheds followed by indicator monitoring at suspect outfalls to characterize flow types and trace sources.

Method(s): The primary field screening tool is the Outfall Reconnaissance Inventory (ORI), which is used to find illicit discharge problems and develop a systematic outfall inventory and map of the MS4. The ORI is frequently supplemented with more intensive indicator monitoring methods to test suspect outfalls. A wide range of monitoring methods can be used; this chapter describes a framework for choosing the safest, most accurate and repeatable methods for a community.

Desired Product or Outcome(s): The search for illicit discharge problems yields several important management products, including:

- An updated map of the locations of all outfalls within the MS4
- Incorporation of ORI data into the outfall inventory/tracking system
- Design and implementation of an indicator monitoring strategy to test suspect outfalls
- Creation of a local chemical “fingerprint” library of pollutant concentrations for various discharge flow types
- Data reports that evaluate the significance and distribution of illicit discharge problems in the community

Budget and/or Staff Resources Required: Field screening and indicator monitoring can consume substantial staff and budget resources. Monitoring costs are closely related to the number of outfalls screened and the complexity of illicit discharge problems discovered. An MS4 that screens 10 stream miles and analyzes 80 indicator samples each year can expect to spend about $15,000 to $35,000. Consequently, choosing which indicator(s) to use in a community (and when and where to use them) ranks as one of the most important budget decisions for any project manager.

Integration with Other Programs: Program managers should explore two strategies to integrate field screening and indicator monitoring with other programs to achieve cost savings. The first strategy links outfall screening to broader stream corridor assessments that support local watershed restoration efforts. Often, watershed organizations and “stream waders” can be enlisted and trained to conduct outfall screening. The second strategy is to find a local agency partner to conduct laboratory analysis (such as a drinking water or wastewater treatment plant).

7.1 Overview of Searching for Illicit Discharge Problems in the Field

This chapter provides basic information about the field and laboratory strategies needed to detect illicit discharges, beginning with a field screening technique designed to gather basic information and identify highly suspect outfalls or obvious discharges. Next, it provides a basic framework for using the data from this screening to address obvious discharges, develop a chemical monitoring program, and make future program decisions. Finally, it summarizes the basic options for conducting an ongoing chemical monitoring program. The approaches outlined here are only summarized briefly, and primarily in the context of overall program management. Much more detailed and "hands-on" information is provided in Chapters 11 and 12 that provide specific methods and technical guidance for field crew and laboratory staff.

7.2 The Outfall Reconnaissance Inventory (ORI)

The field screening technique recommended for an IDDE program is the Outfall Reconnaissance Inventory or ORI. The ORI is a stream walk designed to inventory and measure storm drain outfalls, and find and correct continuous and intermittent discharges without in-depth laboratory analysis (Figure 10). The ORI should be completed for every stream mile or open channel within the community during the first permit cycle, starting with priority subwatersheds identified in the desktop analysis. Outfall screening requires relatively little expertise, and can be incorporated into other stream assessments such as the Unified Stream Assessment (Kitchell and Schueler, 2004).

The ORI can discover obvious discharges that are indicated by flowing outfalls with very high turbidity, strong odors and colors, or an "off the chart" value on a simple field test strip. When obvious discharges are found, field crews should immediately track down and remove the source (see Chapters 8 and 13). In other instances, ORI crews may encounter a transitory discharge, such as a liquid or oil spill that should be immediately referred to the appropriate agency for cleanup (Figure 11).

Figure 10: Measuring an outfall as part of the ORI

Figure 11: Some discharges are immediately obvious

The ORI is not meant to be a "one size fits all" method, and should be adapted to suit the unique needs of each community. Program managers should also modify the ORI over time to reflect field observations, crew experience, new or modified indicators, and any other innovations that make fieldwork easier or faster. Table 20 summarizes the four basic steps to conduct an ORI, and more detail on ORI protocols is provided in Chapter 11.

7.3 Interpreting ORI Data

Once the first few ORI surveys are conducted, data can be analyzed to confirm and update the desktop analysis originally used for targeting subwatersheds. The ORI data analysis follows four basic steps, which are described in Table 21. Ideally, ORI data should be stored within a continuously-updated geospatial tracking system.

Table 20: Field Screening for an IDDE Program

Step	Strategies
Step 1. Acquire necessary mapping, equipment and staff	• Use basic street maps or detailed maps from initial assessment • Minimal field equipment required; use a portable spectrophotometer if desired • Two staff per crew with basic field training required; more specialized staff or training is optional
Step 2. Determine when to conduct field screening	• During dry season and leaf off conditions • After a dry period of at least 48 hours • Low groundwater levels
Step 3. Identify where to conduct field screening (based on desktop assessment)	• Minimal: integrate field screening with broader watershed or stream assessments • Clustered: screen drainage areas ranking High and Medium first for illicit discharge potential • Severe: screen all outfalls systematically
Step 4. Conduct field screening	• Mark and photograph all outfalls • Record outfall characteristics • Simple monitoring at flowing outfalls • Take flow sample at outfalls with likely problems • Deal with major problems immediately

Table 21: Field Data Analysis for an IDDE Program	
Step	**Considerations**
Step 1. Compile data from the ORI	• Compile GPS data and photographs of outfall locations • Enter ORI data into database • Send any samples for lab analysis
Step 2. Develop ORI designation for outfalls	• Use ORI data to designate outfalls as having obvious, suspect, potential, or unlikely discharge potential
Step 3. Characterize the extent of illicit discharge problems	• Use data from initial assessment • Use outfall designation data • Update initial assessment of illicit discharge problems as minimal, clustered, severe
Step 4. Develop a monitoring strategy	• At a minimum, sample 10% of flowing outfalls per year • Repeat field screening in second permit cycle • Use various monitoring methods depending on outfall designation and subwatershed characteristics

7.4 Design and Implementation of an Indicator Monitoring Strategy

The next step is to design an indicator monitoring program to test suspect or problem outfalls to confirm whether they are actually an illicit discharge, and determine the type of flow. From a program management standpoint, six core issues need to be considered during the design of the monitoring strategy, as shown in Table 22.

The indicator monitoring strategy should be concentrated primarily on continuous and intermittent discharges, and can be adapted to isolate the specific flow type found in a discharge. Figure 12 presents an overall monitoring design framework that organizes some of the key indicators and monitoring techniques that may be needed. In general, different indicators and monitoring methods are used depending on whether flow is present at an outfall or not. The details of the discharge monitoring framework are described in Chapter 12. The basic framework should be adapted to reflect the unique discharge problems and analytical capabilities of individual communities.

Some of the recommended monitoring strategies are discussed below. The preferred method to test flowing outfalls is the **flow chart method** that uses a small set of indicator parameters to determine whether a discharge is clean or dirty, and predicts its or flow type (Pitt, 2004). The flow chart method is particularly suited to distinguish sewage and washwater flow types. Industrial sites may require special testing, and the **benchmark concentrations method** includes several supplemental indicators to distinguish industrial sources.

Table 22: Indicator Monitoring Considerations
• Use ORI data to prioritize problem outfalls or drainage areas • Select the type of indicators needed for your discharge problems • Decide whether to use in-house or contract lab analytical services • Consider the techniques to detect intermittent discharges • Develop a chemical library of concentrations for various flow types • Estimate staff time, and costs for equipment and disposable supplies

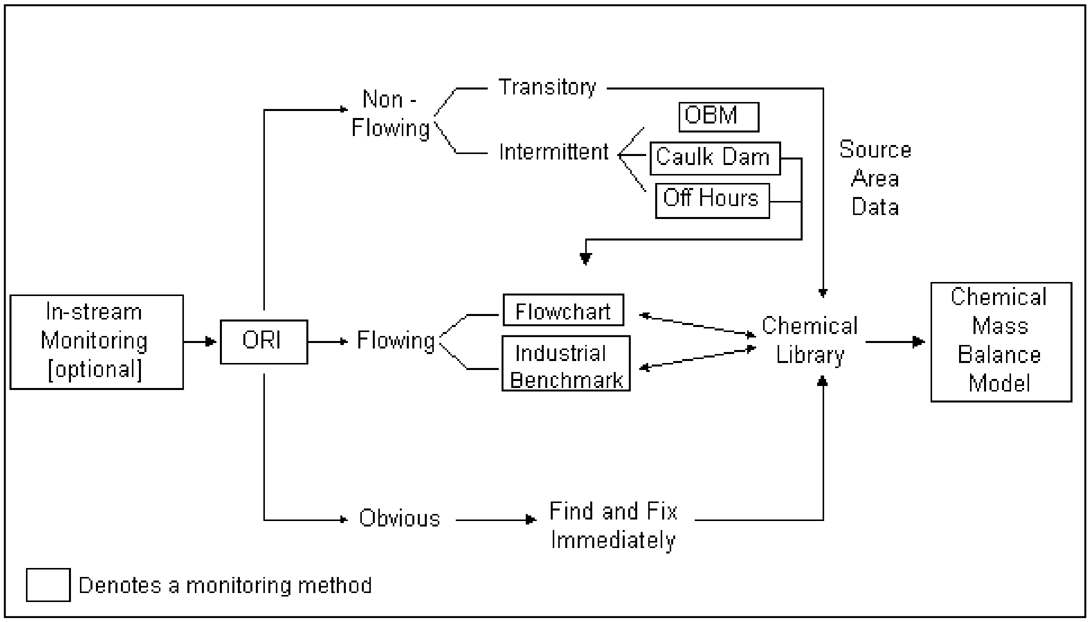


Figure 12: IDDE Monitoring Framework

Non-flowing outfalls are more challenging to diagnose. Intermittent flows can be diagnosed using specialized monitoring techniques such as:

- Off hours monitoring
- Caulk dams
- Optical brightener monitoring traps

When intermittent discharges are captured by these specialized techniques, samples are normally diagnosed using the flow chart method.

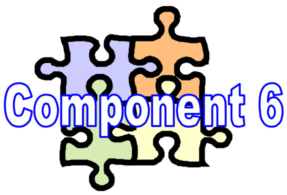
Transitory discharges are extremely difficult to detect with routine indicator monitoring, and are frequently identified from hotline reports. Transitory discharges are usually diagnosed by inspection, although water quality samples may be collected to support enforcement measures.

As communities acquire more monitoring data, they should consider creating a **chemical "fingerprint" library**, which is a database of the chemical make-up of the many different flow types in the community. Chemical libraries should include sewage, septage, washwater, and common industrial flows. Default values for the chemical library can initially be established based on existing research and literature values. Data are then updated based on local monitoring to develop more accurate decision points in the flow chart or benchmark methods. Clean water sources such as tap water, groundwater, spring water, and irrigation water are also important entries in the chemical library. The chemical library should also characterize the water quality of known or unknown transitory discharges sampled in the field. Over time, chemical library data should help a community better understand the potential pollutant loads delivered to receiving waters from various generating activities.

These library data can be used to support more advanced strategies such as the **Chemical Mass Balance Model** (CMBM) method. This method, developed by the University of Alabama as part of this project (Karri, 2004), is particularly useful in identifying flow types in blended discharges, where groundwater or tap water is diluted or commingled with sewage and other illicit discharges. The CMBM requires substantial upfront work to develop an accurate chemical library for local flow types. Specifically, the library requires 10-12 samples for each flow type (for industrial flow types, samples can be obtained in association with NPDES pre-treatment programs). A user's guide for the CMBM can be found in Appendix I.

Section 7.5 Field and Lab Safety Considerations

Program managers should take into account and fully plan for all necessary field and laboratory safety precautions. Most communities already have well established standard operating procedures they follow when conducting field and lab work, and these typically provide an excellent starting point for IDDE programs. Chapters 11, 12, and 13 along with Appendices F and G provide guidance on specific considerations associated with IDDE programs. Of particular note is that program managers may want to consider requiring/recommending field crews be vaccinated against Hepatitis B, particularly if the crews will be accessing waters known to be contaminated with illicit sewage discharges. Program managers should contact local health department officials to explore this issue in more detail prior to making a decision.



Chapter 8: Isolating and Fixing Individual Illicit Discharges

Purpose: This program component uses a variety of tools to trace illicit discharge problems back up the pipe to isolate the specific source or improper connection that generates the discharge. This often requires improved local capacity to locate specific discharges, make needed corrections and maintain an enforcement program to ensure repairs.

Method(s): Five basic tools exist to isolate and fix individual discharges, including:

- Pollution reporting hotline
- Drainage area investigations
- Trunk investigations
- On-site discharge investigations
- Correction and enforcement

Desired Product or Outcome(s): Finding and fixing illicit discharges is the core goal of any IDDE program. The process of finding and fixing discharges has several desirable outcomes, such as:

- Improved water quality
- Increased homeowner and business awareness about pollution prevention
- Maintenance of a tracking system to document repairs and identify repeat offenders.

Budget and/or Staff Resources Required: Budget and staff resources needed to find illicit discharges vary greatly. Some discharge sources will be immediately obvious, while others will require extensive investigations up the pipe until the source can be sufficiently narrowed. Fixing the problem once it is identified is more predictable and can often involve qualified contractors. Costs associated with repairs can also be fully incurred by the offending party or shared, depending on the nature and extent of the illicit discharge.

Integration with Other Programs: Two important aspects of this program component can be integrated with other NPDES minimum management measures and storm water permitting. First, the pollution hotline can be an important element of any local storm water education initiative. Second, on-site illicit discharge investigations should be closely coordinated with industrial NPDES storm water site inspections.

8.1 Overview of Isolating and Fixing Individual Illicit Discharges

The ultimate goal of every IDDE program is to find and fix illicit discharges, and a range of tools are available to meet this objective. The ensuing chapter discusses each of the tools in more detail. The choice of which tools are used depends on the nature of the local storm drain system, and the type and mode of entry of the discharges.

8.2 Isolating Illicit Discharges

Outfall screening and monitoring are excellent for finding illicit discharge problems, but they often cannot detect most intermittent or transient flows, nor can they always isolate the exact source, particularly when the outfall has a large contributing area and an extensive pipe network. This section provides guidance on four tools to find individual illicit discharges. The first tool is a pollution complaint hotline, which is particularly effective at finding obvious illicit discharges, such as transitory flows from generating sites and sewer overflows. Citizens provide free surveillance around the clock, and their reports should prompt rapid investigations and enforcement. The other three investigative tools involve drainage area, trunk, and on-site investigations.

Pollution Complaint Hotline

A complaint hotline is a dedicated phone number or website where citizens can easily report illicit discharge and pollution concerns. The hotline should always be supported by prompt investigations of each complaint by trained inspectors, usually within 24 hours. Many Phase I communities have utilized hotlines to track down intermittent and transitory discharges, and regard them as one of their most effective tools to isolate illicit discharges (CWP, 2002). Some of the benefits and challenges Phase I communities have encountered in administering an IDDE complaint hotline in summarized in Table 23.

Six basic steps are needed to establish and maintain a successful IDDE complaint hotline, which are outlined in Table 24. More detailed guidance on establishing a hotline is provided in Appendix C, along with a sample illicit discharge incident tracking form.

It is important to keep in mind that a successful hotline requires considerable advertising and outreach to keep the phone number fresh in the public's mind. Also, program managers should continuously monitor response times, inspection outcomes, and any enforcement taken. All complaints should be entered into the IDDE tracking system so that complaints can be analyzed.

Table 23: Benefits and Challenges of a Complaint Hotline

Benefits	Challenges
• Leads to early detection and correction of illicit discharges • Encourages active public stewardship • Can "piggyback" on other call response needs • Identifies suspected facilities for further investigation and education • Increases facilities' and municipalities' sense of accountability • Increases likelihood of discovering intermittent discharges	• Time and money to provide 24/7 service • Marketing the hotline number • Establishing inter- and intra-departmental process

Table 24: Steps to Creating and Maintaining Successful IDDE Hotline	
Steps	**Key Elements**
1. Define the scope	• Determine if a hotline is needed • Define the intent of the hotline • Define the extent of the hotline
2. Create a tracking and reporting system	• Design reporting method • Design response method
3. Train personnel	• The basics and importance of IDDE • The complaint hotline reporting, investigation and tracking process • How to provide good customer service • Expected responsibilities of each department/agency
4. Advertise	• Advertise hotline frequently through flyers, magnets, newspapers, displays, etc. • Publicize success stories
5. Respond to complaints	• Provide friendly, knowledgeable customer service • Send an investigator to respond to complaints in a timely manner • Submit incident reports to the hotline database system
6. Track incidents	• Identify recurring problems and suspected offenders • Measure program success • Comply with annual report requirements

The cost to establish and maintain a hotline varies, but savings can be realized if it can be piggy-backed on an existing community hotline or cost shared with other communities in the region. Also, hotline costs are related to the volume of calls and the staff effort needed for follow-up investigations. A budgeting framework for establish and maintaining a hotline from scratch is provided in Table 25.

Illicit Discharge Investigations

Once an illicit discharge is detected at an outfall or stream, one of four types of illicit discharge investigations is triggered to track down the individual source. These investigations are often time consuming and expensive, require special training and staff expertise, and may result in legal action. They include:

- Storm drain network investigations
- Drainage area investigations
- On-site investigations
- Septic system investigations

Each type of investigation handles a different type of discharge problem and has its advantages and disadvantages. More detail on these investigations is provided in Chapter 13.

Storm drain network investigations

Storm drain or "trunk" investigations narrow the source of a discharge problem to a single

<table>
<tr><th colspan="3">Table 25: IDDE Complaint Hotline Costs</th></tr>
<tr><th>Steps</th><th>Initial Cost</th><th>Annual Costs</th></tr>
<tr><td>Define the scope</td><td>$1,500</td><td>$0</td></tr>
<tr><td>Create a tracking and reporting system</td><td>$2,500</td><td>$2,440</td></tr>
<tr><td>Train personnel</td><td>$2,200</td><td>$1,000</td></tr>
<tr><td>Advertise</td><td>$1,500</td><td>$2,920</td></tr>
<tr><td>Respond to complaints</td><td rowspan="2">$0</td><td rowspan="2">$5,000</td></tr>
<tr><td>Track incidents</td></tr>
<tr><td>TOTAL</td><td>$7,700</td><td>$11,360</td></tr>
</table>

segment of a storm sewer. The investigation starts at the outfall, and the field crew must decide how it will explore the upstream pipe network. The three options include:

- Work progressively up the trunk from the outfall and test manholes along the way
- Split the trunk into equal segments and test manholes at strategic points of the storm drain system
- Work progressively down the trunk (i.e., from the headwaters of the storm drain network and move downstream)

The decision to move up, split, or move down the trunk depends on the nature of the drainage system and the surrounding land use. The three options also require different levels of advance preparation. Moving up the trunk can begin immediately when an illicit discharge is detected at an outfall, and only a map of the storm drain system is required. Splitting the trunk requires a little more preparation to examine the storm drain system and find the most strategic manholes to sample. Moving down the trunk requires even more advance preparation, since the most upstream segments of the storm drain network may be poorly understood.

Once crews choose one of these options, they need to select the most appropriate investigative methods to track down the source. Common methods include:

- Visual inspection at manholes
- Sandbagging or damming the trunk
- Dye testing
- Smoke testing
- Video testing

Drainage area investigations

Drainage area investigations are initially conducted in the office, but quickly move into the field. They involve a parcel by parcel analysis of potential generating sites within the drainage area of a problem outfall. They are most appropriate when the drainage area to the outfall is large or complex, and when the flow type in the discharge appears to be specific to a certain type of land use or generating site. These investigations may include the following techniques:

- Land use investigations
- SIC code review (see Appendix A)
- Permit review
- As-built review
- Aerial photography analysis
- Infrared aerial photography analysis
- Property ownership certification

On-site investigations

Once the illicit discharge has been isolated to a specific section of storm drain, an on-site investigation can be performed to find the specific source of the discharge. In some situations, such as subwatersheds dominated by industrial land uses or many generating sites, on-site investigations may be immediately pursued.

On-site investigations are typically performed by dye testing the plumbing systems of households and buildings. Where septic systems are prevalent, inspections of tanks and drain fields may be needed.

On-site investigations are excellent opportunities to combine IDDE efforts with industrial site inspections that target review and verification of proper Storm Water

Pollution Prevention Plans. Appendix A provides a list of industrial activities that typically require industrial NPDES discharge permits.

Septic system investigations

Communities with areas of on-site sewage disposal systems (i.e., septic systems) need to consider alternative investigatory methods to track illicit discharges that enter streams as indirect discharges, through surface breakouts of septic fields, or through straight pipe discharges from bypassed septic systems. Techniques can involve on-site investigations or imagery analysis (e.g., infrared aerials).

8.3 Fixing Illicit Discharges

Once the source of an illicit discharge has been identified, steps should be taken to fix or eliminate the discharge. Four questions should be answered for each individual illicit discharge to determine how to proceed; the answers will usually vary depending on the source of the discharge.

- Who is responsible?
- What methods will be used to repair?
- How long will the repair take?
- How will removal be confirmed?

Financial responsibility for source removal will typically fall on property owners, MS4 operators, or a combination of the two. Methods for removing illicit discharges usually involve a combination of education and enforcement. A process for addressing illicit discharges that focuses on identifying the responsible party and enforcement procedures is presented in Figure 13, while Table 26 presents various options for removing illicit discharges from various sources. Additional information on common removal actions and associated costs can be found in Chapter 14.

Program managers should use judgment in exercising the right mix of compliance assistance and enforcement. The authority and responsibility for correction and enforcement should be clearly defined in the local IDDE ordinance developed earlier in the program. An escalating enforcement approach is often warranted and is usually a reasonable process to follow. Voluntary compliance should be used for first-time, minor offenders. Often, property owners are not even aware of a problem, and are willing to fix it when educated. More serious violations or continued non-compliance may warrant a more aggressive, enforcement-oriented approach.

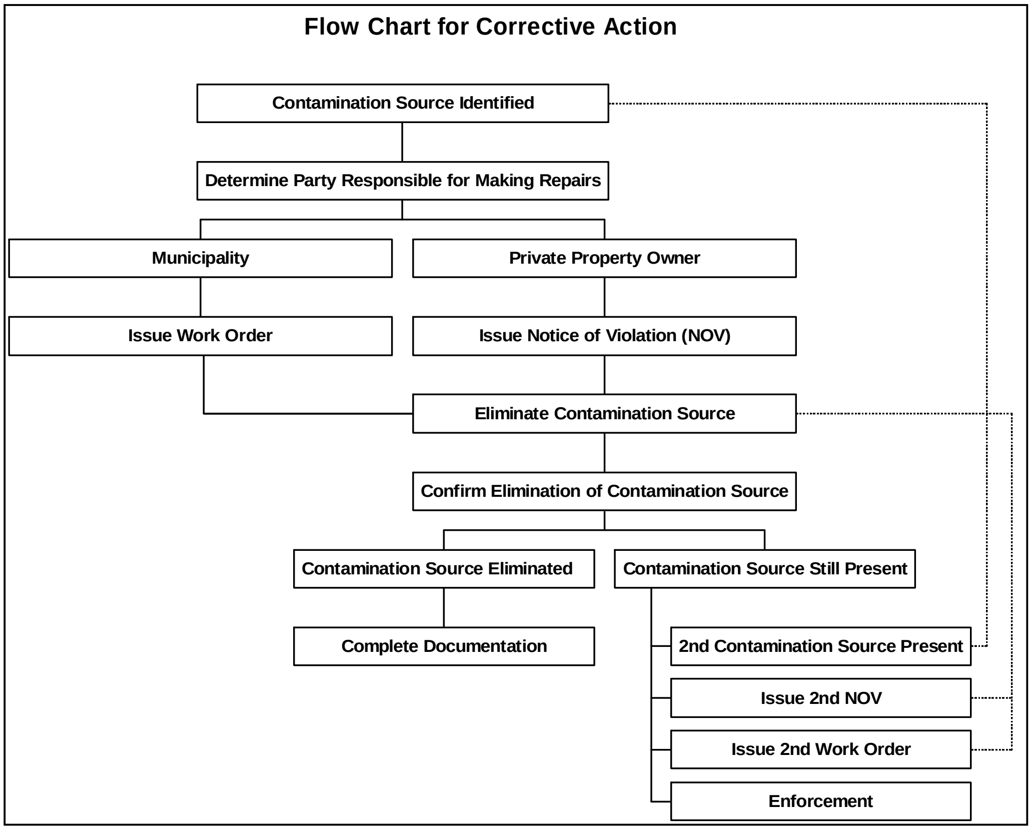
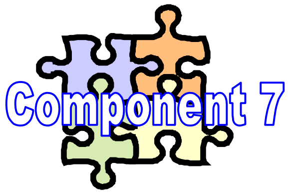


Figure 13: Process for Removing or Correcting an Illicit Discharge

Table 26: Methods to Fix Illicit Discharges

Type of Discharge	Source	Removal Action(s)
Sewage	Break in right-of-way	Repair by municipality
	Commercial or industrial direct connection	Enforcement
	Residential direct connection	Enforcement; Incentive or aid
	Infrequent discharge (e.g., RV dumping)	Enforcement; Spill response
	Straight pipes/septic	Enforcement; Incentive or aid
Wash water	Commercial or industrial direct connection	Enforcement; Incentive or aid
	Residential direct connection	Enforcement; Incentive or aid
	Power wash/car wash (commercial)	Enforcement
	Commercial wash down	Enforcement
	Residential car wash or household maintenance-related activities	Education
Liquid wastes	Professional oil change/car maintenance	Enforcement; Spill response
	Heating oil/solvent dumping	Enforcement; Spill response
	Homeowner oil change and other liquid waste disposal (e.g., paint)	Warning; Education; Fines
	Spill (trucking)	Spill response
	Other industrial wastes	Enforcement; Spill response



Chapter 9: Preventing Illicit Discharges

Purpose: This program component identifies key behaviors of neighborhoods, generating sites, and municipal operations that produce intermittent and transitory discharges. These key "discharge behaviors" are then targeted for improved pollution prevention practices that can prevent or reduce the risk of discharge. Communities then apply a wide range of education and enforcement tools to promote the desired pollution prevention practices.

Method(s): The Unified Subwatershed and Site Reconnaissance (USSR; Wright *et al.*, 2004) and the desktop analysis of potential generating sites (Chapter 5) are two methods used to identify the major behaviors that generate intermittent and transitory discharges. These methods, used alone or in combination, are extremely helpful to identify the specific discharge behaviors and generating sites that will be targeted for education and enforcement efforts. A Source Control Plan is then performed to select the right pollution prevention message, choose the appropriate combination of carrots and sticks to change behaviors, and develop a budget and delivery system to implement the prevention program. Refer to Schueler *et al.* (2004) for information on developing a Source Control Plan and the many carrots and sticks available to communities.

Desired Product or Outcome(s): The desired outcome is a mix of local prevention programs that target the most common intermittent and transitory discharges in the community. Program managers need to develop targeted pollution prevention programs for three sectors of the community:

- *Neighborhood Discharges*. The pollution prevention practices related to discharge prevention in residential neighborhoods include storm drain stenciling, lawn care, septic system maintenance, vehicle fluid changing, car washing, household hazardous waste disposal and swimming pool draining.
- *Generating Sites*. This group of pollution prevention practices can reduce spills and transitory discharges generated during common business operations. Practices include business outreach, spill prevention and response plans, employee training and site inspections.
- *Municipal Housekeeping*. This group of pollution prevention practices is performed during municipal operations, such as sewer and storm drain maintenance, plumbing code revision, and provision of household hazardous waste and used oil collection services.

Budget and/or Staff Resources Required: The budget and staff resources needed for prevention programs can be considerable, and should be coordinated with other storm water education, public involvement and municipal housekeeping initiatives required under NPDES Phase II MS4 permits. Special emphasis should be placed on cross-training staff, partnering with local watershed groups, and pooling educational resources with other communities.

Integration with Other Programs: Illicit discharge prevention is linked to three of the six NPDES Phase II minimum management measures, and should be closely integrated with local watershed restoration efforts.

9.1 Overview of Preventing Illicit Discharges

Intermittent and transitory discharges are difficult to detect through outfall screening or indicator monitoring. Indeed, the best way to manage these discharges is to promote pollution prevention practices in the community that prevent them from occurring. Effective IDDE programs develop education and outreach materials targeted toward neighborhoods, generating sites, and municipal operations. The discharge prevention message is normally integrated with other storm water education programs required under MS4 NPDES Phase II permits such as

- Public education and outreach
- Public participation/involvement
- Municipal pollution prevention/good housekeeping

9.2 Methods to Identify Opportunities for Illicit Discharge Prevention

The USSR and the desktop analysis of potential generating sites both help identify the major behaviors that generate intermittent and transitory discharges. These assessment methods are briefly described below:

The Unified Subwatershed and Site Reconnaissance (USSR)

The USSR is a field survey that rapidly evaluates potential pollution sources and restoration potential in urban subwatersheds. The survey quickly characterizes upland areas in order to inventory problem sites that may contribute pollutants and identifies pollution source controls and other restoration projects. For more information on how to conduct the USSR, consult Wright *et al.* (2004). The USSR has four major assessment components, three of which directly relate to illicit discharge prevention:

- *Neighborhood Source Assessment (NSA)*, which helps discover residential pollution source areas and potential restoration opportunities within the many neighborhoods found in urban subwatersheds
- *Hotspot Site Investigation (HSI)*, which ranks the potential severity of each commercial, industrial, institutional, municipal or transport-related hotspot site found within a subwatershed
- *Analysis of Streets and Storm Drains (SSD)*, which measures the average pollutant accumulation in the streets, curbs, and catch basins of a subwatershed

Desktop Analysis of Generating Sites

The desktop analysis method screens local business and permit databases to identify specific commercial, industrial, institutional, municipal, and transport-related sites that are known to have a higher risk of producing illicit discharges. Chapter 5 and Appendix A provide discussions of this analysis.

9.3 Preventing Illicit Discharges from Neighborhoods

Many common neighborhood behaviors can cause transitory discharges that are seldom defined or regulated as illicit discharges by most communities. Individually, these behaviors cause relatively small discharges, but collectively, they can produce significant pollutant loads. Most communities use outreach and education to promote pollution prevention practices, and some of the more effective practices to influence these behaviors are described in this section:

- Storm drain stenciling
- Septic system maintenance
- Vehicle fluid changing
- Car washing
- Household hazardous waste storage and disposal
- Swimming pool draining

Storm Drain Stenciling

Storm drain stenciling sends a clear message to keep trash and debris, leaf litter, and pollutants out of the storm drain system, and may deter illegal dumping and discharges (Figure 14). Stenciling may increase watershed awareness and neighborhood stewardship and can be used in any neighborhood with enclosed storm drains.

Stenciling is an excellent way to involve the public, and just a few trained volunteers can systematically stencil all the storm drains within a neighborhood in a short time. Volunteers can be recruited from scouting, community service, and watershed organizations, or from high schools and neighborhood associations. Program managers should designate a staff person to coordinate storm drain stenciling and be responsible for recruiting, training, managing, and supplying volunteers.

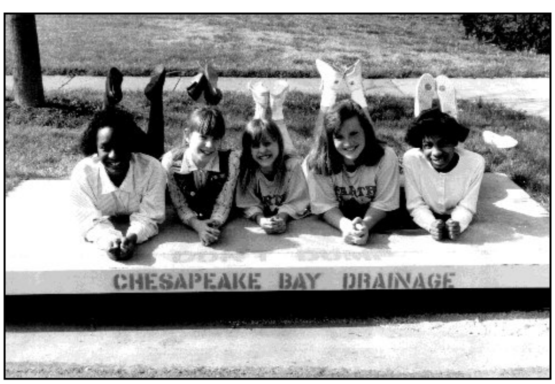


Figure 14: Storm drain stenciling may help reduce illicit discharges.

Storm drain stenciling programs are relatively inexpensive. Most communities use stencils, although some are now using permanent markers made of tile, clay, or metal. Stencils cost about 45 cents per linear inch and can be used for 25 to 500 drains, depending on whether paint is sprayed or applied with a brush or roller. Permanent signs are generally more costly; ceramic tiles cost $5 to $6 each and metal stencils can cost $100 or more. More guidance on designing a stenciling program can be found in Schueler *et al. (*2004).

Septic System Maintenance

Failing septic systems can be a major source of bacteria, nitrogen, and phosphorus, depending on the overall density of systems present in a subwatershed (Swann, 2001). Failure results in illicit surface or subsurface discharges to streams. According to U.S. EPA (2002), more than half of all existing septic systems are more than 30 years old, which is well past their design life. The same study estimates that about 10% of all septic systems are not functioning properly at any given time, with even higher failure rates in some regions and soil conditions.

Septic systems are a classic case of out of sight and out of mind. Many owners take their septic systems for granted, until they back up or break out on the surface of their lawn. Subsurface failures, which are the most common, go unnoticed. In addition, inspections, pump outs, and repairs can be costly, so many homeowners tend to put off the expense until there is a real problem. Lastly, many septic system owners are not aware of the link between septic systems

CASE STUDY

In 1997, Madison County, NC implemented a project to address straight piping problems. In 1999, a survey identified 205 households with black water straight-piping (toilet waste), 243 households with gray water straight-piping (sink, shower, washer waste), and 104 households with failing septic systems. The project facilitated more than 10 community meetings, and issued more than 20 educational articles on straight-piping and water quality in the local papers. In addition, the project leveraged $903,000 from the N.C. Clean Water Management Trust Fund to establish a Revolving Loan and Grant Program for low and moderate income county residents that need assistance installing a septic system or repairing a failing one. (Land of Sky Regional Council website, 2002).

and water quality. Communities can employ a range of tools to improve septic system maintenance. These include:

- Media campaigns and conventional outreach materials to increase awareness about septic system maintenance and water quality (e.g., billboards, radio, newspapers, brochures, bill inserts, and newsletters)
- Discount coupons for septic system maintenance
- Low interest loans for septic system repairs
- Mandatory inspections
- Performance certification upon property transfer
- Creation of septic management districts
- Certification and training of operation/maintenance professionals
- Termination of public services for failing systems

Vehicle Fluid Changing

Dumping of automotive fluids into storm drains can cause major water quality problems, since only a few quarts of oil or a few gallons of antifreeze can severely degrade a small stream. Dumping delivers hydrocarbons, oil and grease, metals, xylene and other pollutants to streams, which can be toxic during dry-weather conditions when existing flow cannot dilute these discharges. The major culprit has been the backyard mechanic who changes his or her own automotive fluids (Figure 15). Communities have a range of tools to prevent illegal dumping of car fluids, including:

- Outreach materials distributed at auto parts store and service stations
- Community oil recycling centers
- Directories of used oil collection stations
- Free or discounted oil disposal containers
- Pollution hotlines
- Fines and other enforcement actions

Figure 15: Home mechanic changing his automotive fluids

Car Washing

Car washing is a common neighborhood behavior that can produce transitory discharges of sediment, nutrients and other pollutants to the curb, and ultimately the storm drain. Communities have utilized many innovative outreach tools to promote environmentally safe car washing, including:

- Media campaigns
- Brochures promoting nozzles with shut off valves
- Storm drain plug and wet vac provisions for charity car wash events
- Water bill inserts promoting environmentally safe car washing products
- Discounted tickets for use at commercial car washes

Household Hazardous Waste Storage And Disposal

The average garage contains a lot of products that are classified as hazardous wastes, including paints, stains, solvents, used motor oil, pesticides and cleaning products. While some household hazardous waste (HHW) may be dumped into storm drains, most enters the storm drain system as a result of outdoor rinsing and cleanup. Improper disposal of HHW can result in acute toxicity to downstream aquatic life. The desired neighborhood behavior is to participate in HHW collection days, and to use appropriate pollution prevention techniques when conducting rinsing, cleaning and fueling operations (Figure 16).

Convenience and awareness appear to be the critical factors in getting residents to participate in household hazardous waste collection programs. Participation depends on the number of days each year collection events are held and is inversely related to both the distance homeowners must travel to recycle waste and the restrictions on what is accepted. Communities have used a variety of techniques to promote and expand HHW collection, including:

Figure 16: Household hazardous wastes should be properly contained to avoid indirect discharges

- Mass media campaigns to educate residents about proper outdoor cleaning/rinsing techniques
- Conventional outreach materials notifying residents about HHW and collection days
- More frequent HHW collection days
- Providing curbside disposal options for some HHW
- Establishing permanent collection facilities at solid waste facilities
- Providing mobile HHW pickup
- Waiving disposal fees at landfills

Swimming Pool Draining

Routine and end-of-season maintenance tasks for aboveground or in-ground pools can cause the discharge of chlorinated water or filter back flush water into the storm drain system or the stream (Figure 17). The ideal practice is to discharge chlorinated pool water into the sanitary sewer system, or hold it until chlorine and temperature levels are acceptable to permit spreading it over a suitable pervious surface.

Most pool owners understand that regular maintenance is essential to keep pools safe and clean, and they may be more receptive to changing discharge behaviors with proper education. Effective outreach methods include:

- Conventional outreach techniques on proper discharge (pamphlets, water bill inserts, posters)
- Educational kiosks at the retail outlets selling pool chemicals
- Changes in local plumbing codes to require discharge to sanitary sewer systems
- Local ordinances that allow for fines/enforcement for unsafe pool discharges

Figure 17: Swimming pools can be a source of illicit discharges.

9.4 Preventing Illicit Discharges from Generating Sites

Many indirect discharges can be identified and prevented using the concept of generating sites, which are a small subset of commercial, industrial, institutional, municipal and transport-related operations that have the greatest risk of generating indirect discharges. Program managers should become intimately familiar with the types of generating sites found in their community, particularly those regulated by industrial NPDES storm water permits. Some of the more common operations that generate spills and transitory discharges are profiled in Table 27.

Most communities consider nearly all non-storm water discharges from generating sites to be illicit, and take a more regulatory approach. Consequently, pollution prevention practices are more prescriptive, and are frequently incorporated into a pollution prevention plan for a facility or operation. Like anyone else, businesses respond better to carrots than sticks, but often need both. Communities possess four broad tools to promote effective pollution prevention practices at generating sites:

- Business outreach and education
- Spill prevention and response planning
- Employee training
- Site inspections

Table 27: Common Discharges Produced at Generating Sites	
Generating Site	**Activity Generating the Discharge**
Vehicle Operations (Maintenance, Repair, Fueling, Washing, Storage)	• Improper disposal of fluids down shop and storm drains • Spilled fuel, leaks and drips from wrecked vehicles • Hosing of outdoor work areas • Wash water from cleaning • Spills
Outdoor Materials (Loading/unloading, Outdoor storage)	• Liquid spills at loading areas • Hosing/washing of loading areas into shop or storm drains • Leaks and spills of liquids stored outside
Waste Management (Spill prevention and response, Dumpster management)	• Spills and leaks of liquids • Dumping into storm drains • Leaking dumpsters
Physical Plant Maintenance (Building Repair, Remodeling and maintenance, Parking lot maintenance)	• Discharges from power washing and steam cleaning • Rinse water and wash water discharges during cleanup • Runoff from degreasing and re-surfacing
Turf and Landscaping (Turf Management Landscaping/Grounds care)	• Non-target irrigation • Improper rinsing of fertilizer/pesticide applicators
Unique Hotspot Operations (Pools, Golf Courses, Marinas, Construction, Restaurants, Hobby farms)	• Discharge of chlorinated water from pools • Dumping of sewage and grease

Business Outreach and Education

Targeted distribution of educational materials to specific business sectors in the subwatershed is the most common method of promoting pollution prevention. Outreach materials are designed to educate owners and employees about polluting behaviors, recommend appropriate pollution prevention practices, and notify them of any local or state regulations. Useful outreach materials include brochures, training manuals, posters, directories of pollution prevention vendors, and signs. Passive business outreach works best when it is specially adapted and targeted to a specific business sector (e.g., vehicle repair, landscaping, restaurants) and is routinely and directly presented to local business groups and trade associations. Business outreach materials require employees to read or hear them, and then take active steps to change their behavior.

Communities can also provide direct technical assistance to develop a customized pollution prevention prescription for individual generating sites. In this case, local staff work closely with owners and operators to inspect the site and develop an effective pollution prevention plan. In other cases, pollution prevention workshops or model plans are offered to businesses and trade groups that represent specific groups of generating sites. In either case, the locality acts as a technical partner to provide ongoing consultation to individual businesses to support their pollution prevention efforts.

Spill Prevention and Response

A spill prevention and response plan is useful for any potential generating site, and is mandatory for any operation that uses, generates, produces, or transports hazardous materials, petroleum products or fertilizers. These operations are known as SARA 312 operators and are regulated by state environmental agencies. In addition, all industrial sites regulated by individual or group NPDES storm water permits must have an updated spill prevention and response plan on its premises. Spill containment and response plans should also be prepared for major highways that cross streams and other water bodies, since truck and tanker accidents often represent the greatest potential spill risk in most communities (Figure 18).

Spill prevention and response plans describe the operational procedures to reduce the risks of spills and accidental discharge and ensure that proper controls are in place in the event they do occur. Spill prevention plans standardize everyday procedures and rely on employee training to reduce potential liability, fines and costs associated with clean up. Planning begins with an analysis of how pollutants are handled at the site and how they interact with storm water. Spill prevention and response plans have five major components:

1. A site map and evaluation of past spills and leaks
2. An inventory of materials at the site
3. Identification of potential spill areas
4. A list of required spill response equipment
5. Employee training

When spills do occur, a good spill prevention and response plan will clearly:

- Identify potential spill sites and their drainage points
- Specify material handling procedures
- Describe spill response procedures
- Ensure that adequate spill clean-up equipment is available

Employee Training

Effective and repeated employee training is essential to maintain pollution prevention practices at generating sites. Indeed, continuous employee training is an essential component of any pollution prevention plan, particularly at generating sites where the work force turns over frequently. Many businesses perceive time devoted to pollution prevention training as reducing their bottom line, and may be hesitant to develop training materials or allocate time for training. In some cases, local agencies supply free or low cost videos, posters, shop signs, or training brochures (often in multilingual formats). In other cases, short training classes are offered for employees or supervisors that are scheduled for down times of the year (e.g., winter classes for landscaping companies or construction contractors) or coincide with regular employee safety meetings.

Figure 18: Spill response often involves portable booms and pumps

Program managers can refer to Schueler *et al.* (2004) for more guidance on developing effective pollution practices at generating sites and storm water hotspots. Employee training should be conducted at least annually to educate workers on the proper practices to avoid illicit discharges and respond to spills. Training can be reinforced with signs, and posters.

Site Inspections

Regular inspections of generating sites are a key tool to foster pollution prevention and reduce the risk of illicit discharges. Communities that possess an MS4 permit should ensure that they have the authority to inspect non-regulated sites that connect to the municipal storm drain system they operate. These inspections can be used to assess the site and educate owners/operators about recommended pollution prevention practices. Site inspections are staff intensive and therefore are best suited to high-risk generating sites.

An industrial NPDES storm water permit is an extremely important compliance tool at many generating sites. NPDES permits require operators to prepare a pollution prevention plan for the site and implement the practices specified in the plan. Significant penalties can be imposed for non-compliance.

To date, compliance with the industrial storm water permit program has been spotty, and a significant fraction of regulated industries has failed to file their required permits. According to Duke and Shaver (1999) and Pronold (2000), as many as 50% of industrial sites that are required to have a permit do not actually have one. These sites are termed "non-filers," and are often small businesses or operations that are unaware of the relatively new regulations. It is therefore quite likely that many hotspots in a subwatershed may not have a valid NPDES permit. These operations should be educated about the industrial permit program, and encouraged to apply for permit coverage. Non-filers should be referred to the NPDES permitting authority for details on how to obtain permit coverage.

Inspections are an important stick to improve compliance at generating sites subject to industrial NPDES permits. Inspectors should frequently observe site operations to ensure that the right mix of pollution prevention practices is routinely employed. Communities with MS4 permits have the authority to inspect storm water NPDES sites that discharge to their storm drain system, and refer any violations for subsequent state or federal enforcement.

Voluntary inspections of non-regulated generating sites are a good tool to educate owners/operators about recommended pollution prevention practices. When generating sites are inspected, existing fire, building or health inspectors should be considered since they are already acquainted with how to deal with small businesses.

9.5 Preventing Illicit Discharges from Municipal Operations

Many municipal operations and services have the potential to create or reduce illicit discharges. Program managers should review all municipal operations and services to make sure good housekeeping is practiced. In addition, program managers should examine:

- Routine sewer and storm drain maintenance
- Plumbing code revisions
- HHW collection services
- Used motor oil collection services

Routine Sewer And Storm Drain Maintenance

Failure to regularly inspect and maintain local sewer and storm water infrastructure can cause illicit discharges to receiving waters. Within the storm drain system, maintenance should focus on frequent cleaning to keep trash, debris and illegally dumped material from entering the storm drain system. In the sanitary sewer network, maintenance should focus on finding damaged infrastructure that allows sewage discharges from the sanitary sewer. In-stream monitoring, historical data reviews of past complaints, or aging sewer infrastructure can often be used to identify likely problem areas.[8]

Plumbing Code Revisions

Communities need to establish the legal authority to prohibit illicit connections to the storm drain system. When the illicit discharge ordinance is being prepared, communities should thoroughly review all of their plumbing codes to prevent any misinterpretation that might create cross connections to the storm drain system. Program managers should also specifically target licensed plumbers to educate them on any code changes.

Household Hazardous Waste Collection Services

Households generate a lot of hazardous wastes, and communities need to educate residents about proper household hazardous waster (HHW) handling and disposal, and provide convenient options for pick up and disposal. Communities have experimented with several innovative ways to deal with HHW including:

- A permanent facility that accepts HHW year-round and can serve as a central location for HHW exchange and recycling
- Mobile collection at temporary facilities. On designated special collection days, mobile units can move through communities accepting HHW and take the form of curbside pickup or central collection locations
- Some local businesses may act as drop off centers for certain products. Some local garages, for example, may accept used motor oil for recycling

Overall, the costs for implementing HHW collection programs can be high. Factors such as frequency of the collection, size of community, environmental awareness, level of staff training, and level of outreach all contribute to the overall cost. Participation in collection programs usually ranges from 1% to 5% of the population (HGAC, 2001), and the cost per participant can vary greatly (Table 28).

Used Motor Oil Collection Services

Used motor oil collection has been a common municipal service for many years, however, program managers may need to refine their programs to increase participation. Suggested outreach approaches include:

- Conventional outreach materials provided at points of sale (e.g., auto parts stores, service stations)
- Multilingual outreach materials
- Directories of used oil collection stations
- Free or discounted oil disposal containers

[8] Preliminary sewer system investigations are not discussed further in this manual. For more detail on how to conduct these investigations consult the EPA handbook, "Sewer System Infrastructure Analysis and Rehabilitation." (U.S. EPA, 1991)

CASE STUDY

The City of Denver operates a pilot, door-to-door collection program to assist residents in the proper disposal and recycling of HHW. To be eligible for collection, residents must currently be receiving trash collection service from City Solid Waste Management crews. Residents are permitted one HHW collection annually and are asked to have at least three different materials before calling for a pickup. Residents then receive a collection date and an HHW Kit that holds up to 75 pounds. Residents are instructed on what items can be placed inside the Kit, and can have additional items picked up for a small fee. The program also educates citizens on how to prevent the accumulation of chemicals in the home environment. The key element of this service is convenience for area residents. Customers can make a phone call, put their waste in a container, and schedule a pickup (City of Denver, 2003).

Table 28: Summary of Local Household Hazardous Waste Collection Programs

Location	Budget	Households Served	Participants	Cost per Participant	Program Description
Fort Worth TX (2002)	$937,740	26 cities	15,629	$60	Accept 3 days a week at permanent facility, plus approx 24 mobile units
Monmouth County, NJ (2002)	$900,000	620,000	6,200	$145.16	Permanent facility plus 2-3 remote days
Nashville, TN (2002)	$149,000	180,000	5,800	$26	361 day drop off at permanent facility
Putnam County, NY (1997)	$20,279	27,409	349	$58.10	One collection day per year
Town of East Hampton, NY (1997)	$36,495	4,878	452	$80	Three collection days per year

CASE STUDY

Municipal cross-training is a proven and effective tool for identifying illicit discharges. Wayne County, Michigan has a very active IDDE program that has included efforts to train all County “field” staff to identify and report suspicious discharges in the course of their duties. The Illicit Discharge Elimination Training Program includes presentations for general field staff that instructs them in the identification and reporting of suspicious discharges. To date, 734 people from various agencies and communities throughout Michigan have attended the training sessions (Tuomari and Thompson, 2002). The information these individuals gained from attending the training session helped identify 82 illicit discharges in the counties of Oakland, Washtenaw, and Wayne. Road division staff trained in recognizing illicit discharges discovered 12 septic systems in Wayne County that were failing or had direct discharges to surface water. Other counties found 70 illicit discharges during their investigations. The elimination of these illicit discharges will prevent an estimated 3.5 million gallons of polluted water from reaching Michigan surface waters each year (associated load reductions are estimated at 7,200 pounds/year of Biological Oxygen Demand and 25, 000 lbs/yr of Total Suspended Solids).

9.6 Budgeting and Scoping Pollution Prevention

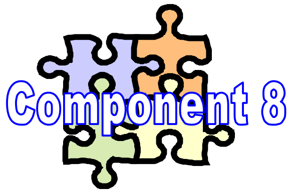
The cost of preventing illicit discharges is directly related to the scope of the education effort. Larger communities often employ education staff on a full-time basis, or at least have one staff member who spends much of their time doing outreach on issues such as illicit discharges. Smaller communities often spread the education effort out over several departments, and try to use already established programs such as cooperative extensions or citizen watershed groups. Table 29 provides some cost data for storm water education in one community.

In reality, program managers have to do a lot of homework to scope and budget their pollution prevention education program. Normally, these education efforts are integrated with other storm water education programs. One of the best tools to develop an overall education budget is the Source Control Plan, which is described in Schueler *et al.* (2004).

Table 29: Estimated Costs for Public Awareness Program Components
(Adapted from Wayne County, MI. 2001)

Education Component	Estimated Cost	Assumptions
Information Brochures	$100/hour for development $0.10-$0.20/pamphlet for black and white printing $0.30/pamphlet for mailing	160-320 hours
Technical Manuals	$100/hour for development $100.00/manual for printing	160-480 hours
Business Education	$50/hour for business/activity list $100/hour for development $50/hour for employee presentation	40-80 hours for compilation 80-160 hours for development. 8 hours for presentation, including prep time.
Program Planning and Administration	$10,000 per year	0.2 Full Time Equivalents (FTE) per year

Source: Wayne County, MI. 2001. Planning and Cost Estimating Criteria for Best Management Practices. *Rouge River Wet Weather Demonstration Project. TR-NPS25.00*



Chapter 10: IDDE Program Tracking and Evaluation

Purpose: This last program component addresses the ongoing management of the IDDE program and reviews progress made in meeting the measurable program goals established earlier in the permit cycle. Adaptive management is critical since most communities initially have a poor understanding of the scope and nature of their illicit discharge problem. Frequent program review can ensure that the most severe illicit discharges are eliminated in the most cost-effective way during the permit cycle. Program evaluation should also be directly tied to program goals (see Chapter 6 on Developing Program Goals and Implementation Strategy)

Method(s): The primary method is frequent maintenance and analysis of the IDDE tracking system developed as part of the program. The integrated tracking system contains geospatial data on ORI results, indicator monitoring, on-site investigations, dumping and spill sites and hotline calls. The tracking system is important from both an enforcement and program evaluation standpoint. Each of the eight program components should be reviewed annually and prior to new permit negotiation, using data collected, compiled, and assessed from the tracking system.

Desired Product or Outcome(s): Updated tracking database and annual report with summary of progress to date, findings, recommendations for program revisions, and work plan (including milestones and goals) for the upcoming year.

Budget and/or Staff Resources Required: Program assessment is an ongoing responsibility of the program manager. The staff effort to prepare an annual report is about three to four weeks. In general, the first annual report will require more effort than subsequent ones.

Integration with Other Programs: Program managers should always consider other programs and regulatory requirements when assessing program performance and revising goals. At a minimum, the annual report should be shared with other departments and agencies to head off duplication of efforts and to look for opportunities to pool resources.

10.1 Establish a Tracking and Reporting System

An accurate and user-friendly system to track, report and respond to illicit discharge problems is critical for program managers. Ideally, the tracking system should be designed and operational within the first year of the program. The tracking system enables managers to measure program indicators, and gives field crews a home to store the data they collect. The ideal tracking system consists of a relational database that is linked to a GIS system, which can be used to store and analyze data and produce maps.

The fundamental units to track are individual outfalls, along with any supporting information about their contributing drainage area. Some of the key information to include when tracking outfalls includes:

- Geospatial coordinates of each outfall location
- The subwatershed and watershed address
- Any supporting information about the contributing land use
- Diameter and physical characteristics of the outfall
- Outfall Reconnaissance Inventory (ORI) data, as it is collected
- Any accompanying digital photos
- Any follow-up monitoring at the outfall or further up the pipe
- Any hotline complaints logged for the outfall, along with the local response
- Status and disposition of any enforcement actions
- Maintenance and inspection data

10.2 Evaluate the Program

Since IDDE programs are a first time endeavor for many communities, program managers need to be extremely adaptable in how they allocate their resources. Effective IDDE programs are dynamic and flexible to respond to an ever-changing set of discharge problems, program obstacles, and emerging technologies. At a minimum, program managers should maintain and evaluate their IDDE tracking system annually, and modify program components as needed. Tracking systems should be designed so that progress toward measurable goals (see Chapter 6) can be easily reported. Communities that develop and maintain a comprehensive tracking system should realize program efficiencies. The tracking system should contain the following features at a minimum:

- Updated mapping to reflect outfalls located during the ORI
- Surveyed stream reaches with locations of obvious, suspect, and potential discharges, and locations of dumping sites
- Indicator sampling results for specific streams, outfalls and storm drains
- Frequency of hotline use and associated number of “hits” or confirmed illicit discharges
- Costs for each of the eight program components (e.g., office, field, lab, education, enforcement, etc.)
- Number of discharges corrected
- Status and disposition of enforcement actions

Regular analysis of the tracking system sheds light on program strengths and deficiencies, and improves targeting of limited program resources. For example, if hotline complaints are found to uncover the most severe illicit discharge problems, program managers may want to allocate more resources to increase public awareness about the hotline, and shift resources from outfall screening and indicator monitoring.

Chapter 11: The Outfall Reconnaissance Inventory

This chapter describes a simple field assessment known as the Outfall Reconnaissance Inventory (ORI). The ORI is designed to fix the geospatial location and record basic characteristics of individual storm drain outfalls, evaluate suspect outfalls, and assess the severity of illicit discharge problems in a community. Field crews should walk all natural and man-made streams channels with perennial and intermittent flow, even if they do not appear on available maps (Figure 19). The goal is to complete the ORI on every stream mile in the MS4 within the first permit cycle, starting with priority subwatersheds identified during the desktop analysis. The results of the ORI are then used to help guide future outfall monitoring and discharge prevention efforts.

11.1 Getting Started

The ORI requires modest mapping, field equipment, staffing and training resources. A complete list of the required and optional resources needed to perform an ORI is presented in Table 30. The ORI can be combined with other stream assessment tools, and may be supplemented by simple indicator monitoring. Ideally, a Phase II community should plan on surveying its entire drainage network at least once over the course of each five-year permit cycle. Experience suggests that it may take up to three stream walks to identify all outfalls.

Figure 19: Walk all streams and constructed open channels

Best Times to Start

Timing is important when scheduling ORI field work. In most regions of the country, spring and fall are the best seasons to perform the ORI. Other seasons typically have challenges such as over-grown vegetation or high groundwater that mask illicit discharges, or make ORI data hard to interpret[9].

Prolonged dry periods during the non-growing season with low groundwater levels are optimal conditions for performing an ORI. Table 31 summarizes some of the regional factors to consider when scheduling ORI surveys in your community. Daily weather patterns also determine whether ORI field work should proceed. In general, ORI field work should be conducted at least 48 hours after the last runoff-producing rain event.

Field Maps

The field maps needed for the ORI are normally generated during the desktop assessment phase of the IDDE program described in Chapter 5. This section provides guidance on the basic requirements for good

[9] Upon initial program start-up, the ORI should be conducted during periods of low groundwater to more easily identify likely illicit discharges. However, it should be noted that high water tables can increase sewage contamination in storm drain networks due to infiltration and inflow interactions. Therefore, in certain situations, seasonal ORI surveys may be useful at identifying these types of discharges. Diagnosis of this source of contamination, however, can be challenging.

Table 30: Resources Needed to Conduct the ORI		
Need Area	**Minimum Needed**	**Optional but Helpful**
Mapping	• Roads • Streams	• Known problem areas • Major land uses • Outfalls • Specific industries • Storm drain network • SIC-coded buildings • Septics
Field Equipment	• 5 one-liter sample bottles • Backpack • Camera (preferably digital) • Cell phones or hand-held radios • Clip boards and pencils • Field sheets • First aid kit • Flash light or head lamp • GPS unit • Spray paint (or other marker) • Surgical gloves • Tape measure • Temperature probe • Waders (snake proof where necessary) • Watch with a second hand	• Portable Spectrophotometer and reagents (can be shared among crews) • Insect repellant • Machete/clippers • Sanitary wipes or biodegradable soap • Wide-mouth container to measure flow • Test strips or probes (e.g., pH and ammonia)
Staff	• Basic training on field methodology • Minimum two staff per crew	• Ability to track discharges up the drainage system • Knowledge of drainage area, to identify probable sources. • Knowledge of basic chemistry and biology

Table 31: Preferred Climate/Weather Considerations for Conducting the ORI		
Preferred Condition	**Reason**	**Notes/Regional Factors**
Low groundwater (e.g., very few flowing outfalls)	High groundwater can confound results	In cold regions, do not conduct the ORI in the early spring, when the ground is saturated from snowmelt.
No runoff-producing rainfall within 48 hours	Reduces the confounding influence of storm water	The specific time frame may vary depending on the drainage system.
Dry Season	Allows for more days of field work	Applies in regions of the country with a "wet/dry seasonal pattern." This pattern is most pronounced in states bordering or slightly interior to the Gulf of Mexico or the Pacific Ocean.
Leaf Off	Dense vegetation makes finding outfalls difficult	Dense vegetation is most problematic in the southeastern United States. This criterion is helpful but not required.

field maps. First, ORI field maps do not need to be fancy. The scale and level of mapping detail will vary based on preferences and navigational skills of field crews. At a minimum, maps should have labeled streets and hydrologic features (USGS blue line streams, wetlands, and lakes), so field crews can orient themselves and record their findings spatially.

Field maps should delineate the contributing drainage area to major outfalls, but only if they are readily available. Urban landmarks such as land use, property boundaries, and storm drain infrastructure are also quite useful in the field. ORI field maps should be used to check the accuracy and quality of pre-existing mapping information, such as the location of outfalls and stream origins.

Basic street maps offer the advantage of simplicity, availability, and well-labeled road networks and urban landmarks. Supplemental maps such as a 1": 2000' scale USGS Quad sheet or finer scale aerial photograph are also recommended for the field. USGS Quad sheets are readily available and display major transportation networks and landmarks, “blue line” streams, wetlands, and topography. Quad maps may be adequate for less developed subwatersheds, but are not always accurate in more urban subwatersheds.

Recent aerial photographs may provide the best opportunity to navigate the subwatershed and assess existing land cover. Aerial photos, however, may lack topography and road names, can be costly, and are hard to record field notes on due to their darkness. GIS-ready aerial photos and USGS Quad sheets can be downloaded from the internet or obtained from local planning, parks, or public works agencies.

Field Sheets

ORI field sheets are used to record descriptive and quantitative information about each outfall inventoried in the field. Data from the field sheets represent the building blocks of an outfall tracking system allowing program managers to improve IDDE monitoring and management. A copy of the ORI field sheet is provided in Appendix D, and is also available as a Microsoft Word™ document. Program managers should modify the field sheet to meet the specific needs and unique conditions in their community.

Field crews should also carry an authorization letter and a list of emergency phone numbers to report any emergency leaks, spills, obvious illicit discharges or other water quality problems to the appropriate local authorities directly from the field. Local law enforcement agencies may also need to be made aware of the field work. Figure 20 shows an example of a water pollution emergency contact list developed by Montgomery County, MD.

Equipment

Basic field equipment needed for the ORI includes waders, a measuring tape, watch, camera, GPS unit, and surgical gloves (see Table 30). GPS units and digital cameras are usually the most expensive equipment items; however, some local agencies may already have them for other applications. Adequate ranging, water-resistant, downloadable GPS units can be purchased for less than $150. Digital cameras are preferred and can cost between $200 and $400, however, conventional or disposable cameras can also work, as long as they have flashes. Hand-held data recorders and customized software can be used to record text, photos, and GPS coordinates electronically in the field. While these technologies can eliminate field sheets and data entry procedures, they can be quite expensive. Field crews should always carry basic safety items, such as cell phones, surgical gloves, and first aid kits.

Staffing

The ORI requires at least a two-person crew, for safety and logistics. Three person crews provide greater safety and flexibility, which helps divide tasks, allows one person to assess adjacent land uses, and facilitates tracing outfalls to their source. All crew members should be trained on how to complete the ORI and should have a basic understanding of illicit discharges and their water quality impact. ORI crews can be staffed by trained volunteers, watershed groups and college interns. Experienced crews can normally expect to cover two to three stream miles per day, depending on stream access and outfall density.

11.2 Desktop Analysis to Support the ORI

Two tasks need to be done in the office before heading out to the field. The major ORI preparation tasks include estimating the total stream and channel mileage in the subwatershed and generating field maps. The total mileage helps program managers scope out how long the ORI will take and how much it will cost. As discussed before, field maps are an indispensable navigational aid for field crews working in the subwatershed.

Delineating Survey Reaches

ORI field maps should contain a preliminary delineation of **survey reaches**. The stream network within your subwatershed should be delineated into discrete segments of relatively uniform character. Delineating

Department of Environmental Protection

WATER POLLUTION PHONE NUMBERS TO CALL WHEN A WATER QUALITY PROBLEM IS OBSERVED or TO OBTAIN FURTHER INFORMATION ABOUT WATER QUALITY ISSUES
Spring 2001

COUNTY AGENCIES

DEP: Department of Environmental Protection
- DEPC: Division of Environmental Policy & Compliance
- WMD: Watershed Management Division

DPS: Department of Permitting Services
- LDS: Land Development Services
- SWM: Stormwater Management
- WS: Wells & Septic

INTER-COUNTY AGENCIES

MNCPPC: Maryland-National Capital Park & Planning Commission

WSSC: Washington Suburban Sanitary Commission

DHCD: Department of Housing & Community Development

DPWT: Department of Public Works & Transportation

PROBLEM/QUESTION	AGENCY & TELEPHONE NUMBER	
ILLEGAL DUMPING HOTLINE	**DEPC:**	**240-777-7700** Daytime hours ←
	→ Nighttime hours	**240/777-DUMP (3867) or 240-777-7788**
Blocked storm drain, inlet or pipe or erosion from public storm drain	DPWT:	240/777-ROAD (7623) Highway Maintenance)
Discolored public drinking water, odor to drinking water		301/206-4002
Erosion, flooding, drainage problems between private properties	DHCD:	240/777-3600 (Code Enforcement)
Erosion - stream banks on park land	MNCPPC:	301/495-2535
Fire & Rescue Services (emergencies: 911)	(Non-Emergencies):	240/777-0744
Recycling Programs/Special pick up services	DPWT:	240/777-6400 or 6466
Sanitary sewer problems	WSSC:	301/206-4002
Sediment (mud) from construction site entering streams	LDS:	240/777-6366
Septic Leaks/ Septic Tanks	WS:	240/777-6300
Stormwater Management, pond safety and maintenance	DEPC:	240/777-7744
Stormwater Management and Sediment Control Plan Review issues	SWM:	240/777-6320
Stream Clean-ups	WMD:	240/777-7712
Swimming Pool Discharges	DEPC:	240/777-7770
Trash and debris in parks and streams	MNCPPC:	301/495-2535
Water main break	WSSC:	301/206-4002
Water pollution	DEPC:	240/777-7770
(discharging, dumping, chemical spills into streams or storm drains)	LDS:	240/777-6260
Water quality monitoring programs for schools (Stream Teams)	WMD:	240/777-7714
Wells and Well Inspections	WS:	240/777-6300

askDEP.com

Figure 20: Example of a comprehensive emergency contact list for Montgomery County, MD

survey reaches provides good stopping and starting points for field crews, which is useful from a data management and logistics standpoint. Each survey reach should have its own unique identifying number to facilitate ORI data analysis and interpretation. Figure 21 illustrates some tips for delineating survey reaches, and additional guidance is offered below:

- Survey reaches should be established above the confluence of streams and between road crossings that serve as a convenient access point.
- Survey reaches should be defined at the transition between major changes in land use in the stream corridor (e.g. forested land to commercial area).
- Survey reaches should generally be limited to a quarter mile or less in length. Survey reaches in lightly developed subwatersheds can be longer than those in more developed subwatersheds, particularly if uniform stream corridor conditions are expected throughout the survey reach.
- Access through private or public property should be considered when delineating survey reaches as permission may be required.

It should be noted that initial field maps are not always accurate, and changes may need to be made in the field to adjust survey reaches to account for conditions such as underground streams, missing streams or long culverts. Nevertheless, upfront time invested in delineating survey reaches makes it easier for field crews to perform the ORI.

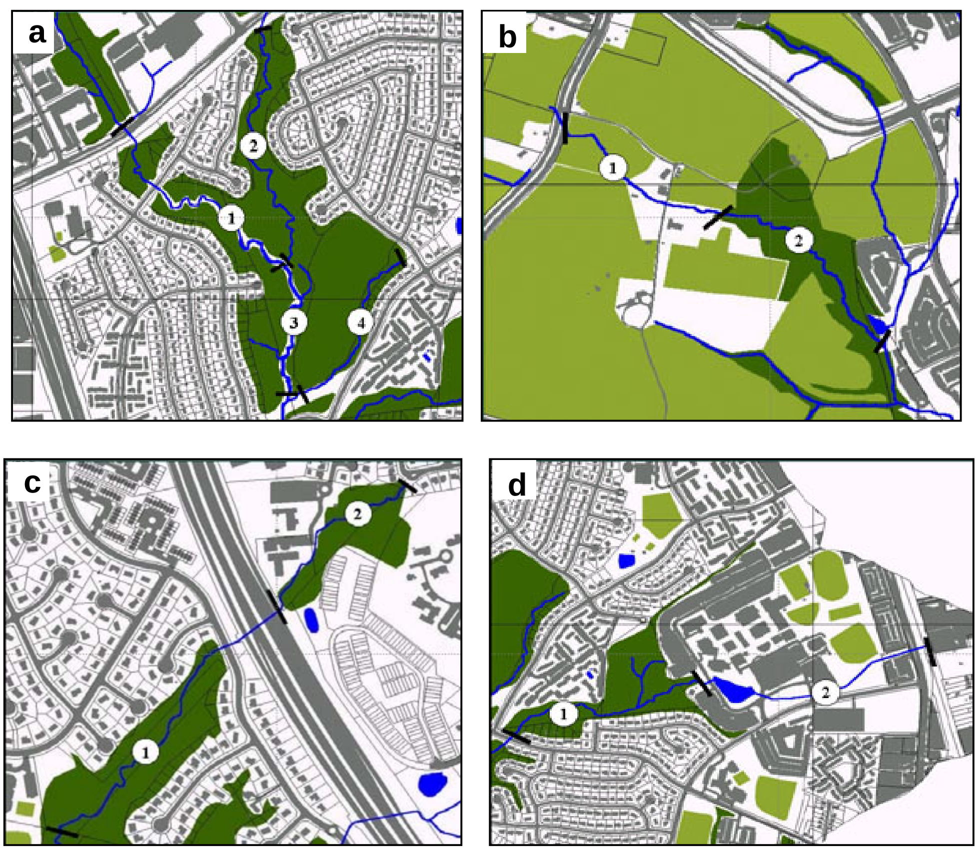


Figure 21: Various physical factors control how survey reaches are delineated. (a) Survey reaches based on the confluence of stream tributaries. (b) A long tributary split into ¼ mile survey reaches. (c) Based on a major road crossing (include the culvert in the downstream reach). (d) Based on significant changes in land use (significant changes in stream features often occur at road crossings, and these crossings often define the breakpoints between survey reaches).

11.3 Completing the ORI

Field crews conduct an ORI by walking all streams and channels to find outfalls, record their location spatially with a GPS unit and physically mark them with spray paint or other permanent marker. Crews also photograph each outfall and characterize its dimensions, shape, and component material, and record observations on basic sensory and physical indicators. If dry weather flow occurs at the outfall, additional flow and water quality data are collected. Field crews may also use field probes or test strips to measure indicators such as temperature, pH, and ammonia at flowing outfalls.

The ORI field sheet is divided into eight sections that address both flowing and non-flowing outfalls (Appendix D). Guidance on completing each section of the ORI field sheet is presented below.

Outfalls to Survey

The ORI applies to **all** outfalls encountered during the stream walk, regardless of diameter, with a few exceptions noted in Table 32. Common outfall conditions seen in communities are illustrated in Figure 22 As a rule, crews should only omit an outfall if they can definitively conclude it has no potential to contribute to a transitory illicit discharge. While EPA's Phase I guidance only targeted major outfalls (diameter of 36 inches or greater), documenting all outfalls is recommended, since smaller pipes make up the majority of all outfalls and frequently have illicit discharges (Pitt *et al.*, 1993 and Lalor, 1994). A separate ORI field sheet should be completed for each outfall.

Table 32: Outfalls to Include in the Screening

Outfalls to Record	Outfalls to Skip
• Both large and small diameter pipes that appear to be part of the storm drain infrastructure • Outfalls that appear to be piped headwater streams • Field connections to culverts • Submerged or partially submerged outfalls • Outfalls that are blocked with debris or sediment deposits • Pipes that appear to be outfalls from storm water treatment practices • Small diameter ductile iron pipes • Pipes that appear to only drain roof downspouts but that are subsurface, preventing definitive confirmation	• Drop inlets from roads in culverts (unless evidence of illegal dumping, dumpster leaks, etc.) • Cross-drainage culverts in transportation right-of-way (i.e., can see daylight at other end) • Weep holes • Flexible HDPE pipes that are known to serve as slope drains • Pipes that are clearly connected to roof downspouts via above-ground connections

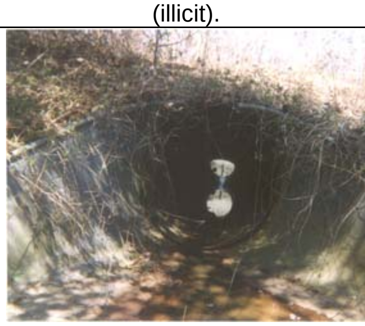
 Ductile iron round pipe	 4-6" HDPE; Check if roof leader connection (legal)	 Field connection to inside of culvert; Always mark and record.
 Small diameter (<2") HDPE; Often a sump pump (legal), or may be used to discharge laundry water (illicit).	 Elliptical RCP; Measure both horizontal and vertical diameters.	 Double RCP round pipes; Mark as separate outfalls unless known to connect immediately up-pipe
 Culvert (can see to other side); Don't mark as an outfall.	 Open channel "chute" from commercial parking lot; Very unlikely illicit discharge. Mark, but do not return to sample (unless there is an obvious problem).	 Small diameter PVC pipe; Mark, and look up-pipe to find the origin.
 CMP outfall; Crews should also note upstream sewer crossing.	 Box shaped outfall	 CMP round pipe with two weep holes at bridge crossing. (Don't mark weep holes)

Figure 22: Typical Outfall Types Found in the Field

Obvious Discharges

Field crews may occasionally encounter an obvious illicit discharge of sewage or other pollutants, typified by high turbidity, odors, floatables and unusual colors. When obvious discharges are encountered, field crews should STOP the ORI survey, track down the source of the discharge and immediately contact the appropriate water pollution agency for enforcement. Crews should photo-document the discharge, estimate its flow volume and collect a sample for water quality analysis (if this can be done safely). All three kinds of evidence are extremely helpful to support subsequent enforcement. Chapter 13 provides details on techniques to track down individual discharges.

11.4 ORI Section 1 - Background Data

The first section of the ORI field sheet is used to record basic data about the survey, including time of day, GPS coordinates for the outfall, field crew members, and current and past weather conditions (Figure 23). Much of the information in this section is self-explanatory, and is used to create an accurate record of when, where, and under what conditions ORI data were collected. Every outfall should be photographed and marked by directly writing a unique identifying number on each outfall that serves as its subwatershed "address" (Figure 24). Crews can use spray paint or another temporary marker to mark outfalls, but may decide to replace temporary markings with permanent ones if the ORI is repeated later. Markings help crews confirm outfall locations during future investigations, and gives citizens a better way to report the location of spills or discharges when calling a water pollution hotline. Crews should mark the spatial location of all outfalls they encounter directly on field maps, and record the coordinates with a GPS unit that is accurate to within 10 feet. Crews should take a digital photo of each outfall, and record photo numbers in Section 1 of the field sheet.

Section 1: Background Data

Subwatershed:		Outfall ID:	
Today's date:		Time (Military):	
Investigators:		Form completed by:	
Temperature (°F):	Rainfall (in.): Last 24 hours:	Last 48 hours:	
Latitutde:	Longitude:	GPS Unit:	GPS LMK #:
Camera:		Photo #s:	
Land Use in Drainage Area (Check all that apply):			
☐ Industrial		☐ Open Space	
☐ Ultra-Urban Residential		☐ Institutional	
☐ Suburban Residential		Other: ______	
☐ Commercial		Known Industries: ______	
Notes (e.g.., origin of outfall, if known):			

Figure 23: Section 1 of the ORI Field Sheet

Figure 24: Labeling an Outfall (a variety of outfall naming conventions can be used)

The land use of the drainage area contributing to the outfall should also be recorded. This may not always be easy to characterize at large diameter outfalls that drain dozens or even hundreds of acres (unless you have aerial photographs). On the other hand, land use can be easily observed at smaller diameter outfalls, and in some cases, the specific origin can be found (e.g., a roof leader or a parking lot; Figure 25). The specific origin should be recorded in the "notes" portion of Section 1 on the field sheet.

11.5 ORI Section 2 - Outfall Description

This part of the ORI field sheet is where basic outfall characteristics are noted (Figure 26). These include material, and presence of flow at the outfall, as well as the pipe's dimensions (Figure 27). These measurements are used to confirm and supplement existing storm drain maps (if they are available). Many communities only map storm drain outfalls that exceed a given pipe diameter, and may not contain data on the material and condition of the pipe.

Figure 25: The origin of this corrugated plastic pipe was determined to be a roof leader from the house up the hill.

Section 2 of the field sheet also asks if the outfall is submerged in water or obstructed by sediment and the amount of flow, if present. Figure 28 provides some photos that illustrate how to characterize relative submergence, deposition and flow at outfalls. If no flow is observed at the outfall, you can skip the next two sections of the ORI field sheet and continue with Section 5.

Section 2: Outfall Description

LOCATION	MATERIAL		SHAPE		DIMENSIONS (IN.)	SUBMERGED
☐ Closed Pipe	☐ RCP ☐ PVC ☐ Steel ☐ Other: ________	☐ CMP ☐ HDPE	☐ Circular ☐ Eliptical ☐ Box ☐ Other: _____	☐ Single ☐ Double ☐ Triple ☐ Other: _____	Diameter/Dimensions: ____________________	In Water: ☐ No ☐ Partially ☐ Fully With Sediment: ☐ No ☐ Partially ☐ Fully
☐ Open drainage	☐ Concrete ☐ Earthen ☐ rip-rap ☐ Other: _____		☐ Trapezoid ☐ Parabolic ☐ Other: _____		Depth: _____ Top Width: _____ Bottom Width: _____	
☐ In-Stream	(applicable when collecting samples)					
Flow Present?	☐ Yes	☐ No	*If No, Skip to Section 5*			
Flow Description (If present)	☐ Trickle	☐ Moderate	☐ Substantial			

Figure 26: Section 2 of the ORI Field Sheet

Figure 27: Measuring Outfall Diameter


Submerged: More than ½ below water


Partially submerged: Bottom is below water


Fully submerged: Can't see outfall


Outfall fully submerged by debris


Fully submerged from downstream trees trapping debris


Partially submerged by leaf debris "back water"


Trickle Flow: Very narrow stream of water


Moderate Flow: Steady stream, but very shallow depth


Significant flow
(Source is a fire hydrant discharge)

Figure 28: Characterizing Submersion and Flow

11.6 ORI Section 3 - Quantitative Characterization for Flowing Outfalls

This section of the ORI records direct measurements of **flowing outfalls**, such as flow, temperature, pH and ammonia (Figure 29). If desired, additional water quality parameters can be added to this section. Chapter 12 discusses the range of water quality parameters that can be used
.

Section 3: Quantitative Characterization

FIELD DATA FOR FLOWING OUTFALLS				
PARAMETER		**RESULT**	**UNIT**	**EQUIPMENT**
☐Flow #1	Volume		Liter	Bottle
	Time to fill		Sec	
☐Flow #2	Flow depth		In	Tape measure
	Flow width	’ ”	Ft, In	Tape measure
	Measured length	’ ”	Ft, In	Tape measure
	Time of travel		S	Stop watch
Temperature			°F	Thermometer
pH			pH Units	Test strip/Probe
Ammonia			mg/L	Test strip

Figure 29: Section 3 of the ORI

Field crews measure the rate of flow using one of two techniques. The first technique simply records the time it takes to fill a container of a known volume, such as a one liter sample bottle. In the second technique, the crew measures the velocity of flow, and multiplies it by the estimated cross sectional area of the flow.

To use the flow volume technique, it may be necessary to use a “homemade” container to capture flow, such as a cut out plastic milk container that is marked to show a one liter volume. The shape and flexibility of plastic containers allows crews to capture relatively flat and shallow flow (Figure 30). The flow volume is determined as the volume of flow captured in the container per unit time.
The second technique measures flow rate based on velocity and cross sectional area, and is preferred for larger discharges where containers are too small to effectively capture the flow (Figure 31). The crew measures and marks off a fixed flow length (usually about five feet), crumbles leaves or other light material, and drops them into the discharge (crews can also carry peanuts or ping pong balls to use). The crew then measures the time it takes the marker to travel across the length. The velocity of flow is computed as the length of the flow path (in feet) divided by the travel time (in seconds). Next, the cross-sectional flow area is measured by taking multiple readings of the depth and width of flow. Lastly, cross-sectional area (in square feet) is multiplied by flow velocity (feet/second) to calculate the flow rate (in cubic feet/second).

Crews may also want to measure the quality of the discharge using relatively inexpensive probes and test strips (e.g., water temperature, pH, and ammonia). The choice of which indicator parameters to measure is usually governed by the overall IDDE monitoring framework developed by the community. Some communities have used probes or test strips to measure additional indicators such as conductivity, chlorine, and hardness. Research by Pitt (for this project) suggests that probes by Horiba for pH and conductivity are the most reliable and accurate, and that test strips have limited value.

Figure 30: Measuring flow as volume per time

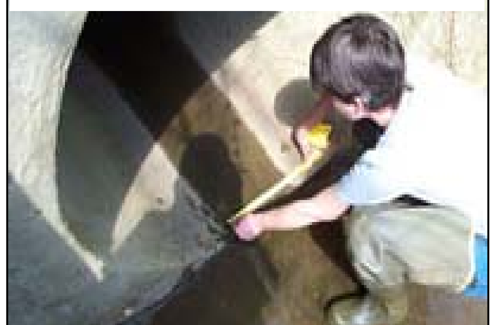
When probes or test strips are used, measurements should be made from a sample bottle that contains flow captured from the outfall. The exact measurement recorded by the field probe should be recorded in Section 3 of the field sheet. Some interpolation may be required for test strips, but do not interpolate further than the mid-range between two color points.

11.7 ORI Section 4 – Physical Indicators for Flowing Outfalls Only

This section of the ORI field sheet records data about four sensory indicators associated with **flowing outfalls --** odor, color, turbidity and floatables (Figure 32). Sensory indicators can be detected by smell or sight, and require no measurement equipment. Sensory indicators do not always reliably predict illicit discharge, since the senses can be fooled, and may result in a "false negative" (i.e., sensory indicators fail to detect an illicit discharge when one is actually present). Sensory indicators are important, however, in detecting the most severe or obvious discharges. Section 4 of the field sheet asks whether the sensory indicator is present, and if so, what is its severity, on a scale of one to three.

Step 1: Measure flow depth

Step 2: Measure flow width



Step 3: Time the travel of a light object (e.g., leaves) along a known distance to calculate velocity

Figure 31: Measuring flow (as velocity times cross-sectional area)

Section 4: Physical Indicators for Flowing Outfalls Only
Are Any Physical Indicators Present in the flow? ☐ Yes ☐ No *(If No, Skip to Section 5)*

INDICATOR	CHECK if Present	DESCRIPTION	RELATIVE SEVERITY INDEX (1-3)		
Odor	☐	☐ Sewage ☐ Rancid/sour ☐ Petroleum/gas ☐ Sulfide ☐ Other:	☐ 1 – Faint	☐ 2 – Easily detected	☐ 3 – Noticeable from a distance
Color	☐	☐ Clear ☐ Brown ☐ Gray ☐ Yellow ☐ Green ☐ Orange ☐ Red ☐Other:	☐ 1 – Faint colors in sample bottle	☐ 2 – Clearly visible in sample bottle	☐ 3 – Clearly visible in outfall flow
Turbidity	☐	See severity	☐ 1 – Slight cloudiness	☐ 2 – Cloudy	☐ 3 – Opaque
Floatables -Does Not Include Trash!!	☐	☐ Sewage (Toilet Paper, etc.) ☐ Suds ☐ Petroleum (oil sheen) ☐ Other:	☐ 1 – Few/slight; origin not obvious	☐ 2 – Some; indications of origin (e.g., possible suds or oil sheen)	☐ 3 - Some; origin clear (e.g., obvious oil sheen, suds, or floating sanitary materials)

Figure 32: Section 4 of the ORI Field Sheet

Odor

Section 4 asks for a description of any odors that emanate from the outfall and an associated severity score. Since noses have different sensitivities, the entire field crew should reach consensus about whether an odor is present and how severe it is. A severity score of one means that the odor is faint or the crew cannot agree on its presence or origin. A score of two indicates a moderate odor within the pipe. A score of three is assigned if the odor is so strong that the crew smells it a considerable distance away from the outfall.

TIP

Make sure the origin of the odor is the outfall. Sometimes shrubs, trash or carrion, or even the spray paint used to mark the outfall can confuse the noses of field crews.

Color

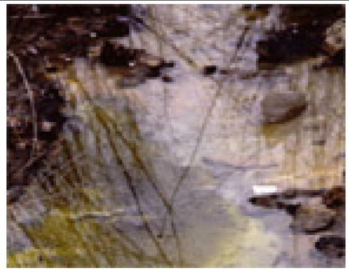
The color of the discharge, which can be clear, slightly tinted, or intense is recorded next. Color can be quantitatively analyzed in the lab, but the ORI only asks for a visual assessment of the discharge color and its intensity. The best way to measure color is to collect the discharge in a clear sample bottle and hold it up to the light (Figure 33). Field crews should also look for downstream plumes of color that appear to be associated with the outfall. Figure 34 illustrates the spectrum of colors that may be encountered during an ORI survey, and offers insight on how to rank the relative intensity or strength of discharge color. Color often helps identify industrial discharges; Appendix K provides guidance on colors often associated with specific industrial operations.

Turbidity

The ORI asks for a visual estimate of the turbidity of the discharge, which is a measure of the cloudiness of the water. Like color, turbidity is best observed in a clear sample bottle, and can be quantitatively measured using field probes. Crews should also look for turbidity in the plunge pool below the outfall, and note any downstream turbidity plumes that appear to be related to the outfall. Field crews can sometimes confuse turbidity with color, which are related but are not the same. Remember, turbidity is a measure of how easily light can penetrate through the sample bottle, whereas color is defined by the tint or intensity of the color observed. Figure 34 provides some examples of how to distinguish turbidity from color, and how to rank its relative severity.

Figure 33: Using a sample bottle to estimate color and turbidity

Color: Brown; Severity: 2
Turbidity Severity: 2



Chromium Spill
Color: Green; Severity: 3
Turbidity Severity: None

Highly Turbid Discharge
Color: Brown; Severity: 3
Turbidity Severity: 3

Sewage Discharge
Color: 3
Turbidity: 3

Paint
Color: White; Severity: 3
Turbidity: 3

Industrial Discharge
Color: Green; Severity: 3
Turbidity Severity: 3

Blood
Color: Red; Severity: 3
Turbidity Severity: None

Failing Septic System:
Turbidity Severity: 3

Turbidity in Downstream Plume
Turbidity Severity: 2
(also confirm with sample bottle)

High Turbidity in Pool
Turbidity Severity: 2
(Confirm with sample bottle)

Iron Floc
Color: Reddish Orange; Severity: 3
(Often associated with a natural source)

Slight Turbidity
Turbidity: 1
(Difficult to interpret this observation;
May be natural or an illicit discharge)

Construction Site
Discharge
Turbidity Severity: 3

Discharge of Rinse
from Floor Sanding
(Found during wet
weather)
Turbidity Severity: 3

Figure 34: Interpreting Color and Turbidity

Floatables

The last sensory indicator is the presence of any floatable materials in the discharge or the plunge pool below. Sewage, oil sheen, and suds are all examples of floatable indicators; trash and debris are generally not in the context of the ORI. The presence of floatable materials is determined visually, and some guidelines for ranking their severity are provided in Figure 35, and described below.

If you think the floatable is sewage, you should automatically assign it a severity score of three since no other source looks quite like it. Surface oil sheens are ranked based on their thickness and coverage. In some cases, surface sheens may not be related to oil discharges, but instead are created by in-stream processes, such as shown in Figure 36. A thick or swirling sheen associated with a petroleum-like odor may be diagnostic of an oil discharge.

Suds are rated based on their foaminess and staying power. A severity score of three is designated for thick foam that travels many feet before breaking up. Suds that break up quickly may simply reflect water turbulence, and do not necessarily have an illicit origin. Indeed, some streams have naturally occurring foams due to the decay of organic matter. On the other hand, suds that are accompanied by a strong organic or sewage-like odor may indicate a sanitary sewer leak or connection. If the suds have a fragrant odor, they may indicate the presence of laundry water or similar wash waters.

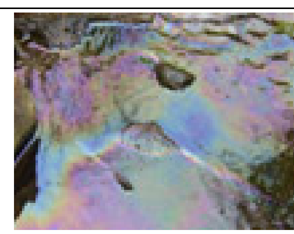
SUDS		
 Natural Foam Note: Suds only associated with high flows at the “drop off” Do not record.	 Low Severity Suds Rating: 1 Note: Suds do not appear to travel; very thin foam layer	 High severity suds Rating: 3 Sewage
OIL SHEENS		
 Low Severity Oil Sheen Rating: 1	 Moderate Severity Oil Sheen Rating: 2	 High Severity Oil Film Rating: 3

Figure 35: Determining the Severity of Floatables

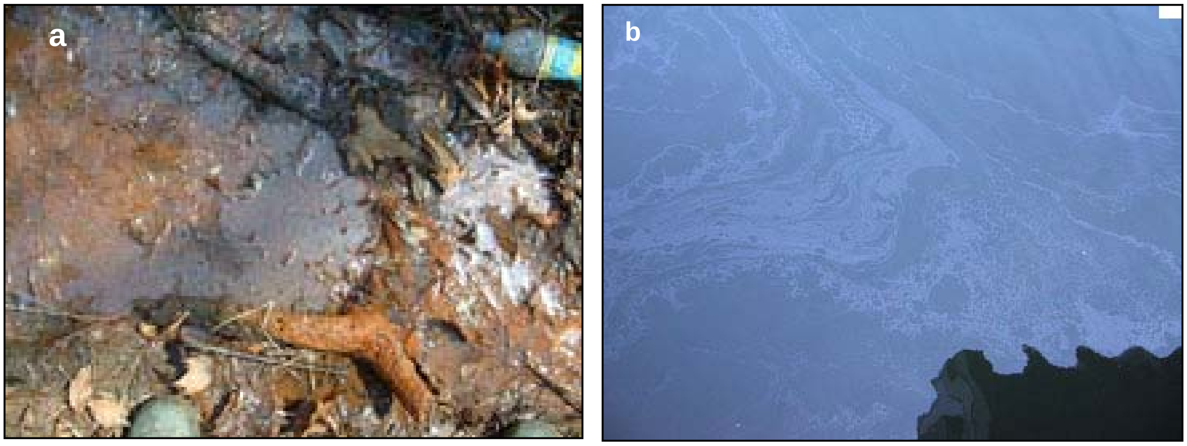


Figure 36: Synthetic versus Natural Sheen (a) Sheen from bacteria such as iron floc forms a sheet-like film that cracks if disturbed (b) Synthetic oil forms a swirling pattern

11.8 ORI Section 5 - Physical Indicators for Both Flowing and Non-Flowing Outfalls

Section 5 of the ORI field sheet examines physical indicators found at both **flowing and non-flowing** outfalls that can reveal the impact of past discharges (Figure 37). Physical indicators include outfall damage, outfall deposits or stains, abnormal vegetation growth, poor pool quality, and benthic growth on pipe surfaces. Common examples of physical indicators are portrayed in Figures 38 and 39. Many of these physical conditions can indicate that an intermittent or transitory discharge has occurred in the past, even if the pipe is not currently flowing. Physical indicators are not ranked according to their severity, because they are often subtle, difficult to interpret and could be caused by other sources. Still, physical indicators can provide strong clues about the discharge history of a storm water outfall, particularly if other discharge indicators accompany them.

Section 5: Physical Indicators for Both Flowing and Non-Flowing Outfalls
Are physical indicators that are not related to flow present? ☐ Yes ☐ No *(If No, Skip to Section 6)*

INDICATOR	CHECK if Present	DESCRIPTION	COMMENTS
Outfall Damage	☐	☐ Spalling, Cracking or Chipping ☐ Peeling Paint ☐ Corrosion	
Deposits/Stains	☐	☐ Oily ☐ Flow Line ☐ Paint ☐ Other:	
Abnormal Vegetation	☐	☐ Excessive ☐ Inhibited	
Poor pool quality	☐	☐ Odors ☐ Colors ☐ Floatables ☐ Oil Sheen ☐ Suds ☐ Excessive Algae ☐ Other:	
Pipe benthic growth	☐	☐ Brown ☐ Orange ☐ Green ☐ Other:	

Figure 37: Section 5 of the ORI Field Sheet

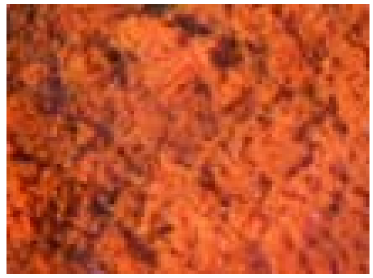
 Bacterial growth at this outfall indicates nutrient enrichment and a likely sewage source.	 This bright red bacterial growth often indicates high manganese and iron concentrations. Surprisingly, it is not typically associated with illicit discharges.	 *Sporalitis* filamentous bacteria, also known as "sewage fungus" can be used to track down sanitary sewer leaks.
 Algal mats on lakes indicate eutrophication. Several sources can cause this problem. Investigate potential illicit sources.	 Illicit discharges or excessive nutrient application can lead to extreme algal growth on stream beds.	 The drainage to this outfall most likely has a high nutrient concentration. The cause may be an illicit discharge, but may be excessive use of lawn chemicals.
	 This brownish algae indicates an elevated nutrient level.	

Figure 38: Interpreting Benthic and Other Biotic Indicators

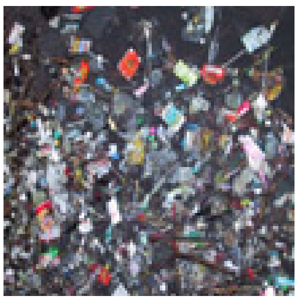
 Reddish staining on the rocks below this outfall indicate high iron concentrations.	 Toilet paper directly below the storm drain outlet.	 Watershed Protection??
 Trash is not an indicator of illicit discharges, but should be noted.	 Staining at the base of the outfall may indicate a persistent, intermittent discharge.	 Excessive vegetation may indicate enriched flows associated with sewage.
 Brownish stain of unclear origin. May be from degradation of the brick infrastructure.	 Cracked rock below the outfall may indicate an intermittent discharge.	 Poor pool quality. Consider sampling from the pool to determine origin.

Figure 39: Typical Findings at both Flowing and Non-Flowing Outfalls

11.9 ORI Sections 6-8 - Initial Outfall Designation and Actions

The last three sections of the ORI field sheet are where the crew designates the illicit discharge severity of the outfall and recommends appropriate management and monitoring actions (Figure 40). A discharge rating is designated as obvious, suspect, potential or unlikely, depending on the number and severity of discharge indicators checked in preceding sections.

It is important to understand that the ORI designation is only an initial determination of discharge potential. A more certain determination as to whether it actually is an illicit discharge is made using a more sophisticated indicator monitoring method. Nevertheless, the ORI outfall designation gives program managers a better understanding of the distribution and severity of illicit discharge problems within a subwatershed.

Section 7 of the ORI field sheet records whether indicator samples were collected for laboratory analysis, or whether an intermittent flow trap was installed (e.g., an optical brightener trap or caulk dam described in Chapter 13). Field crews should record whether the sample was taken from a pool or directly from the outfall, and the type of intermittent flow trap used, if any. This section can also be used to recommend follow-up sampling, if the crew does not carry sample bottles or traps during the survey.

The last section of the ORI field sheet is used to note any unusual conditions near the outfall such as dumping, pipe failure, bank erosion or maintenance needs. While these maintenance conditions are not directly related to illicit discharge detection, they often are of interest to other agencies and utilities that maintain infrastructure.

11.10 Customizing the ORI for a Community

The ORI method is meant to be adaptable, and should be modified to reflect local conditions and field experience. Some indicators can be dropped, added or modified in the ORI form. This section looks at four of the most common adaptations to the ORI:

- Open Channels
- Submerged/Tidally Influenced Outfalls
- Cold Climates
- Use of Biological Indicators

In each case, it may be desirable to revise the ORI field sheet to collect data reflecting these conditions.

Open Channels

Field crews face special challenges in more rural communities that have extensive open channel drainage. The ditches and channels serve as the primary storm water conveyance system, and may lack storm drain and sewer pipes. The open channel network is often very long with only a few obvious outfalls that are located far apart. While the network can have illicit discharges from septic systems, they can typically only be detected in the ORI if a straight pipe is found. Some adaptations for open channel systems are suggested in Table 33.

Section 6: Overall Outfall Characterization

☐ Unlikely	☐ Potential (presence of two or more indicators)	☐ Suspect (one or more indicators with a severity of 3)	☐ Obvious

Section 7: Data Collection

1. Sample For The Lab?	☐ Yes	☐ No		
2. If Yes, Collected From:	☐ Flow	☐ Pool		
3. Intermittent flow trap set?	☐ Yes	☐ No	If Yes, type: ☐ OBM	☐ Caulk dam

Section 8: Any Non-Illicit Discharge Concerns (e.g., trash or needed infrastructure repairs)?

Figure 40: Sections 6-8 of the ORI Field Sheet

Submerged/Tidally Influenced Outfalls

The ORI can be problematic in coastal communities where outfalls are located along the waterfront and may be submerged at high tide. The ORI methods need to be significantly changed to address these constraints. Often, outfalls are initially located from offshore using canoes or boats, and then traced landward to the first manhole that is not tidally influenced. Field crews then access the storm drain pipe at the manhole and measure whatever indicators they can observe in the confined and dimly lit space. Table 33 recommends strategies to sample outfalls in the challenging environment of coastal communities.

Winter and Ice

Ice can be used as a discharge indicator in northern regions when ice forms in streams and pipes during the winter months (Figure 41). Because ice lasts for many weeks, and most illicit discharges are warm, astute field crews can interpret outfall history from ice melting patterns along pipes and streams. For example, exaggerated melting at a frozen or flowing outfall may indicate warm water from sewage or industrial discharge. Be careful, because groundwater is warm enough to cause some melting at below freezing temperatures. Also, ice acts like an intermittent flow trap, and literally freezes these discharges. Crews should also look for these traps to find any discolored ice within the pipe or below the outfall.

A final winter indicator is “rime ice,” which forms when steam freezes. This beautiful ice formation is actually a good indicator of sewage or other relatively hot discharge that causes steam to form (Figure 41).

Biological Indicators

The diversity and pollution tolerance of various species of aquatic life are widely used as an indicator of overall stream health, and has sometimes been used to detect illicit discharges. One notable example is the presence of the red-eared slider turtle, which is used in Galveston, Texas to find sewage discharges, as they have a propensity for the nutrient rich waters associated with sewage (Figure 42).

Table 33: Special Considerations for Open Channels/Submerged Outfalls

OPEN CHANNELS	
Challenge	**Suggested Modification**
Too many miles of channel to walk	Stop walking at a given channel size or drainage area
Difficulty marking them	Mark on concrete or adjacent to earth channel
Interpreting physical indicators	For open channels with mild physical indicators, progress up the system to investigate further.
SUBMERGED/TIDALLY INFLUENCED OUTFALLS	
Challenge	**Suggested Modification**
Access for ORI – Tidal Influence	Access during low tide
Access for ORI – Always submerged	Access by boat or by shore walking
Interpreting physical indicators	For outfalls with mild physical indicators, also inspect from the nearest manhole that is not influenced by tides
Sampling (if necessary)	Sample “up pipe”

Figure 41: Cold climate indicators of illicit discharges

Figure 42: One biological indicator is this red-eared slider turtle

11.11 Interpreting ORI Data

The ORI generates a wealth of information that can provide managers with valuable insights about their illicit discharge problems, if the data are managed and analyzed effectively. The ORI can quickly define whether problems are clustered in a particular area or spread across the community. This section presents a series of methods to compile, organize and interpret ORI data, including:

1. Basic Data Management and Quality Control
2. Outfall Classification
3. Simple Suspect Outfall Counts
4. Mapping ORI Data
5. Subwatershed and Reach Screening
6. Characterizing IDDE Problems at the Community Level

The level of detail for each analysis method should be calibrated to local resources, program goals, and the actual discharge problems discovered in the stream corridor. In general, the most common conditions and problems will shape your initial monitoring strategy, which prioritizes the subwatersheds or reaches that will be targeted for more intensive investigations.

Program managers should analyze ORI data well before every stream mile is walked in the community, and use initial results to modify field methods. For example, if initial results reveal widespread potential problems, program managers may want to add more indicator monitoring to the ORI to track down individual discharge sources (see Chapter 12). Alternatively, if the same kind of discharge problem is repeatedly found, it may be wise to investigate whether there is a common source or activity generating it (e.g., high turbidity observed at many flowing outfalls as a result of equipment washing at active construction sites).

Basic Data Management and Quality Control

The ORI produces an enormous amount of raw data to characterize outfall conditions. It is not uncommon to compile dozens of individual ORI forms in a single subwatershed. The challenge is to devise a system to organize, process, and translate this data into simpler outputs and formats that can guide illicit discharge elimination efforts. The system starts with effective quality control procedures in the field.

Field sheets should be managed using either a three-ring binder or a clipboard. A small field binder offers the ability to quickly flip back and forth among the outfall forms. Authorization letters, emergency contact lists, and extra forms can also be tucked inside.

At the end of each day, field crews should regroup at a predetermined location to compare notes. The crew leader should confirm that all survey reaches and outfalls of interest have been surveyed, discuss initial findings, and deal with any logistical problems. This is also a good time to check whether field crews are measuring and recording outfall data in the same way, and are consistent in what they are (or are not) recording. Crew leaders should also use this time to review field forms for accuracy and thoroughness. Illegible handwriting should be neatened and details added to notes and any sketches. The crew leader should also organize the forms together into a single master binder or folder for future analysis.

Once crews return from the field, data should be entered into a spreadsheet or database. A Microsoft Access database is provided with this Manual as part of Appendix D (Figure 43), and is supplied on a compact disc with each hard copy. It can also be downloaded with Appendix D from http://www.stormwatercenter.net. Information stored in this database can easily be imported into a GIS for mapping purposes. The GIS can generate its own database table that allows the user to create subwatershed maps showing outfall characteristics and problem areas.

Once data entry is complete, be sure to check the quality of the data. This can be done quickly by randomly spot-checking 10% of the entered data. For example, if 50 field sheets were completed, check five of the spreadsheet or database entries. When transferring data into GIS, quality control maps that display labeled problem outfalls should be created. Each survey crew is responsible for reviewing the accuracy of these maps.

Outfall Classification

A simple outfall designation system has been developed to summarize the discharge potential for individual ORI field sheets. Table 34 presents the four outfall designations that can be made.

Table 34: Outfall Designation System Using ORI Data

Designation	Description
1: Obvious Discharge	Outfalls where there is an illicit discharge that doesn't even require sample collection for confirmation
2: Suspect Discharge	Flowing outfalls with high severity on one or more physical indicators
3: Potential Discharge	Flowing or non-flowing outfalls with presence of two or more physical indicators
4: Unlikely Discharge	Non-flowing outfalls with no physical indicators of an illicit discharge

Simple Suspect Outfall Counts

The first priority is to count the frequency of each outfall designation in the subwatershed or the community as a whole. This simple screening analysis counts the number of problem outfalls per stream mile (i.e., the sum of outfalls designated as having potential, suspected or obvious illicit discharge potential). The density of problem outfalls per stream mile is an important metric to target and screen subwatersheds.

Based on problem outfall counts, program managers may discover that a particular monitoring strategy may not apply to the community. For example, if few problem outfalls are found, an extensive follow-up monitoring program may not be needed, so that program resources can be shifted to pollution hotlines to report and control transitory discharges such as illegal dumping. The key point of this method is to avoid getting lost in the raw data, but look instead to find patterns that can shape a cost-effective IDDE program.

Mapping ORI Data

Maps are an excellent way to portray outfall data. If a GIS system is linked to the ORI database, maps that show the spatial distribution of problem outfalls, locations of dumping, and overall reach conditions can be easily generated. Moreover, GIS provides flexibility that allows for rapid updates to maps as new data are collected and compiled. The sophistication and detail of maps will depend on the initial findings, program goals, available software, and GIS capability.

Subwatershed maps are also an effective and important communication and education tool to engage stakeholders (e.g., public officials, businesses and community residents), as they can visually depict reach quality and the location of problem outfalls. The key point to remember is that maps are tools for understanding data. Try to map with a purpose in mind. A large number of cluttered maps may only confuse, while a smaller number with select data may stimulate ideas for the follow-up monitoring strategy.

Subwatershed and Survey Reach Screening

Problem outfall metrics are particularly valuable to screen or rank priority subwatersheds or survey reaches. The basic approach is simple: select the outfall metrics that are most important to IDDE program goals, and then see how individual subwatersheds or reaches rank in the process. This screening process can help determine which subwatersheds will be priorities for initial follow-up monitoring efforts. When feasible, the screening process should incorporate non-ORI data, such as existing dry weather water quality data, citizen complaints, permitted facilities, and habitat or biological stream indicators.

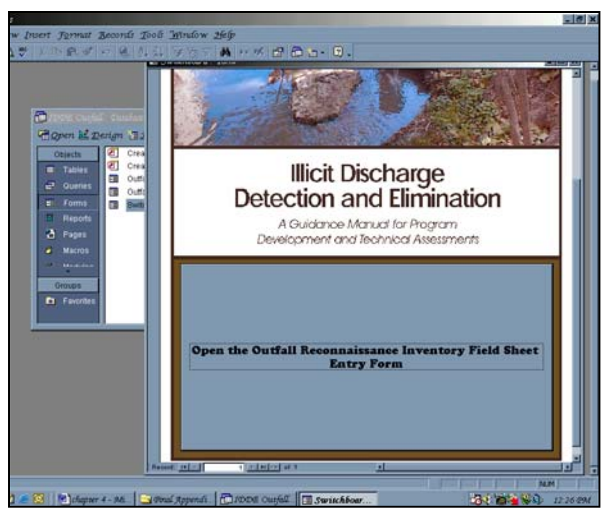


Figure 43: Sample screen from ORI Microsoft Access database

An example of how outfall metrics can screen subwatersheds is provided in Table 35. In this hypothetical example, four metrics were used to screen three subwatersheds within a community: number of suspect discharges, subwatershed population as a percent of the total community, number of industrial discharge permits, and number of outfalls per stream mile. Given these screening criteria, subwatershed C was selected for the next phase of detailed investigation.

Characterizing the IDDE Problem at the Community Level

ORI data should be used to continuously revisit and revise the IDDE program as more is learned about the nature and distribution of illicit discharge problems in the community. For example, ORI discharge designation should be compared against illicit discharge potential (IDP) predictions made during the original desktop analysis (Chapter 5) to refine discharge screening factors, and formulate new monitoring strategies.

In general, community illicit discharge problem can be characterized as minimal, clustered, or severe (Table 36). In the minimal scenario, very few and scattered problems exist; in the clustered scenario, problems are located in isolated subwatersheds; and in the severe scenario, problems are widespread.

Table 35: An Example of ORI Data Being Used to Compare Across Subwatersheds

	# of suspect discharges	Population as % of total community	# of industrial discharge permits	# of outfalls per stream/ conveyance mile
Subwatershed A	2	30	4	6
Subwatershed B	1	10	0	3
Subwatershed C	8	60	2	12

Table 36: Using Stream and ORI Data to Categorize IDDE Problems

Extent	ORI Support Data
Minimal	• Less than 10% of total outfalls are flowing • Less than 20% of total outfalls with obvious, suspect or potential designation
Clustered	• Two thirds of the flowing outfalls are located within one third of the subwatersheds • More than 20% of the communities subwatersheds have greater than 20% of outfalls with obvious, suspect or potential designation
Severe	• More than 10% of total outfalls are flowing • More than 50% of total outfalls with obvious, suspect or potential designation • More than 20% of total outfalls with obvious or suspect designation

11.12 Budgeting and Scoping the ORI

Many different factors come into play when budgeting and scoping an ORI survey: equipment needs, crew size and the stream miles that must be covered. This section presents some simple rules of thumb for ORI budgeting.

Equipment costs for the ORI are relatively minor, with basic equipment to outfit one team of three people totaling about $800 (Table 37). This cost includes one-time expenses to acquire waders, a digital camera and a GPS unit, as well as disposable supplies.

The majority of the budget for an ORI is for staffing the desktop analysis, field crews and data analysis. Field crews can consist of two or three members, and cover about two to three miles of stream (or open channel) per day. Three staff-days should be allocated for pre- and post-field work for each day spent in the field.

Table 38 presents example costs for two hypothetical communities that conduct the ORI. Community A has 10 miles of open channel to investigate, while Community B has 20 miles. In addition, Community A has fewer staff resources available and therefore uses two-person field crews, while Community B uses three-person field crews. Total costs are presented as annual costs, assuming that each community is able to conduct the ORI for all miles in one year.

Table 37: Typical Field Equipment Costs for the ORI

Item	Cost
100 Latex Disposable Gloves	$ 25
5 Wide Mouth Sample Bottles (1 Liter)	$ 20
Large Cooler	$ 25
3 Pairs of Waders	$ 150
Digital Camera	$ 200
20 Cans of Spray Paint	$ 50
Test Kits or Probes	$ 100-$500
1 GPS Unit	$ 150
1 Measuring Tape	$ 10
1 First Aid Kit	$ 30
Flashlights, Batteries, Labeling tape, Clipboards	$ 25
Total	**$ 785-$1185**

Table 38: Example ORI Costs		
Item	**Community A**	**Community B**
Field Equipment[1]	$700	$785
Staff Field Time[2]	$2,000	$6,000
Staff Office Time[3]	$3,000	$6,000
Total	**$5,700**	**$12,785**

[1] From Table 44
[2] Assumes $25/hour salary (2 person teams in Community A and three- person teams in Community B) and two miles of stream per day.
[3] Assumes three staff days for each day in field.

Chapter 12: Indicator Monitoring

Indicator monitoring is used to confirm illicit discharges, and provide clues about their source or origin. In addition, indicator monitoring can measure improvements in water quality during dry weather flow as a result of the local IDDE program. This chapter reviews the suite of chemical indicator parameters that can identify illicit discharges, and provides guidance on how to collect, analyze and interpret each parameter.

Program managers have a wide range of indicator parameters and analytical methods to choose from when determining the presence and source of illicit discharges. The exact combination of indicator parameters and methods selected for a community is often unique. This chapter recommends some general approaches for communities that are just starting an indicator monitoring program or are looking for simple, cost-effective, and safe alternatives to their current program.

Organization of the Chapter

This chapter provides technical support to implement the basic IDDE monitoring framework shown in Figure 44, and is organized into eight sections as follows:

1. Review of indicator parameters
2. Sample collection considerations
3. Methods to analyze samples
4. Methods to distinguish flow types
5. Chemical library
6. Special monitoring methods for intermittent and transitory discharges
7. In-stream dry weather monitoring
8. Costs for indicator monitoring

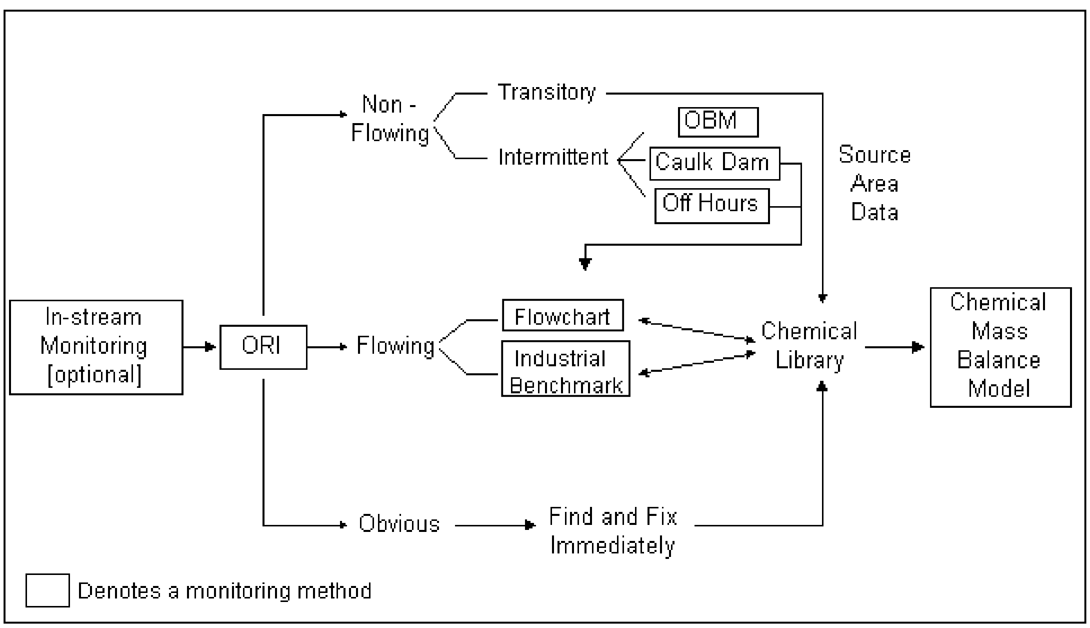


Figure 44: IDDE Monitoring Framework

Program managers developing an indicator monitoring program need a solid background in basic water chemistry, and field and laboratory methods. This chapter describes the major factors to consider when designing an indicator monitoring program for illicit discharges, and assumes some familiarity with water quality sampling and analysis protocols.

Indicator monitoring terminology can be confusing, so some of the basic terms are defined as they specifically relate to illicit discharge control. Some of the common terms introduced in this Chapter are defined below:

Chemical Library: A database and statistical summary of the chemical characteristics, or "fingerprint" of various discharge flow types in a community (e.g., sewage, wash water, shallow groundwater, tap water, irrigation water, and liquid wastes). The library is assembled by collecting and analyzing representative samples from the source of each major flow type in the community.

Chemical Mass Balance Model (CMBM): A computer model that uses flow characteristics from a chemical library file of flow types to estimate the most likely source components that contribute to dry weather flows.

Detergents: Commercial or retail products used to wash clothing. Presence of detergents in flow is usually measured as surfactants or fluorescence.

False Negative: An indicator sample that identifies a discharge as uncontaminated when it actually is contaminated.

False Positive: An indicator sample that identifies a discharge as contaminated when it is not.

Flow Chart Method: The use of four indicators (surfactants, ammonia, potassium, and fluoride) to identify illicit discharges.

Indicator Parameter: A water quality measurement that can be used to identify a specific discharge flow type, or discriminate between different flow types.

Monitoring: A strategy of sample collection and laboratory analysis to detect and characterize illicit discharges.

Optical Brightener Monitoring (OBM) Traps: Traps that use absorbent pads to capture dry weather flows, which can later be observed under a fluorescent light to determine if detergents using optical brighteners were present.

Reagent: A chemical added to a sample to create a reaction that enables the measurement of a target chemical parameter.

Sampling: Water sample collection from an outfall, pipe or stream, along with techniques to store and preserve them for subsequent laboratory analysis.

Surfactants: The main component of commercial detergents that detaches dirt from the clothing. The actual concentration of surfactants is much lower than the concentration of detergent, but analytical methods that measure surfactants are often referred to as "detergents." To avoid confusion, this chapter expresses the concentration of surfactants as "detergents as surfactants."

12.1 Indicator Parameters to Identify Illicit Discharges

At least fifteen different indicator parameters can confirm the presence or origin of an illicit discharge. These parameters are discussed in detail in Appendix F and include:

- Ammonia
- Boron
- Chlorine
- Color
- Conductivity
- Detergents
- *E. coli*, enterococi, and total coliform
- Fluorescence
- Fluoride
- Hardness
- pH
- Potassium
- Surface Tension
- Surfactants
- Turbidity

In most cases, however, only a small subset of indicator parameters (e.g., three to five) is required to adequately characterize an illicit discharge. This section summarizes the different indicator parameters that have been used.

An ideal indicator parameter should reliably distinguish illicit discharges from clean water and provide clues about its sources. In addition, they should have the following characteristics:

- Have a significantly different concentration for major flow or discharge types
- Exhibit relatively small variations in concentrations within the same flow or discharge type
- Be conservative (i.e., concentration will not change over time due to physical, chemical or biological processes)
- Be easily measured with acceptable detection limits, accuracy, safety and repeatability.

No single indicator parameter is perfect, and each community must choose the combination of indicators that works best for their local conditions and discharge types. Table 39 summarizes the parameters that meet most of the indicator criteria, compares their ability to detect different flow types, and reviews some of the challenges that may be encountered when measuring them. More details on indicator parameters are provided in Appendix F.

Data in Table 39 are based on research by Pitt (Appendix E) conducted in Alabama, and therefore, the percentages shown to distinguish "hits" for specific flow types should be viewed as representative and may shift for each community. Also, in some instances, indicator parameters were "downgraded" to account for regional variation or dilution effects. For example, both color and turbidity are excellent indicators of sewage based on discharge fingerprint data, but both can vary regionally depending on the composition of clean groundwater.

Table 39: Indicator Parameters Used to Detect Illicit Discharges

Parameter	Discharge Types it can Detect				Laboratory/Analytical Challenges
	Sewage	Washwater	Tap Water	Industrial or Commercial Liquid Wastes	
Ammonia	●	⦿	○	⦿	Can change into other nitrogen forms as the flow travels to the outfall
Boron	⦿	⦿	○	N/A	
Chlorine	○	○	○	⦿	High chlorine demand in natural waters limits utility to flows with very high chlorine concentrations
Color	⦿	⦿	○	⦿	
Conductivity	⦿	⦿	○	⦿	Ineffective in saline waters
Detergents – Surfactants	●	●	○	⦿	Reagent is a hazardous waste
E. coli Enterococci Total Coliform	⦿	○	○	○	24-hour wait for results Need to modify standard monitoring protocols to measure high bacteria concentrations
Fluoride*	○	○	●	⦿	Reagent is a hazardous waste Exception for communities that do not fluoridate their tap water
Hardness	⦿	⦿	⦿	⦿	
pH	○	⦿	○	⦿	
Potassium	⦿	○	○	●	May need to use two separate analytical techniques, depending on the concentration
Turbidity	⦿	⦿	○	⦿	

● Can almost always (>80% of samples) distinguish this discharge from clean flow types (e.g., tap water or natural water). For tap water, can distinguish from natural water.
⦿ Can sometimes (>50% of samples) distinguish this discharge from clean flow types depending on regional characteristics, or can be helpful in combination with another parameter
○ Poor indicator. Cannot reliably detect illicit discharges, or cannot detect tap water
N/A: Data are not available to assess the utility of this parameter for this purpose.
Data sources: Pitt (this study)
*Fluoride is a poor indicator when used as a single parameter, but when combined with additional parameters (such as detergents, ammonia and potassium), it can almost always distinguish between sewage and washwater.

12.2 Sample Collection Considerations

Sample collection is an important aspect of an IDDE program. Program managers need to be well informed about the key facets of sampling such as sample handling, QA/QC, and safety. The guidance in this section is limited to an overview of sample collection considerations including: equipment needed for collecting samples, elements of sampling protocols, and general tips. Several useful documents are available that detail accepted water quality sampling protocols such as the following:

- Burton and Pitt (2002) - Stormwater Effects Handbook: A Toolbox for Watershed Managers, Scientists, and Engineers

- USGS National Field Manual for the Collection of Water-Quality Data http://water.usgs.gov/owq/FieldManual/

- *Standard Methods for the Examination of Water and Wastewater* http://www.standardmethods.org/

- *EPA NPDES Stormwater Sampling Guidance Document* *http://cfpub.epa.gov/npdes* (Note: while this document is oriented towards wet weather sampling, there are still many sampling procedures that apply to dry weather sampling)

State environmental agencies are also a good resource to contact for recommended or required sampling protocols.

Equipment Needed for Field Sampling

The basic equipment needed to collect samples is presented in Table 40. Most sampling equipment is easily available for purchase from scientific supply companies and various retail stores.

Developing a Consistent Sample Collection Protocol

Samples should never be collected haphazardly. To get reliable, accurate, and defensible data, it is important to develop a consistent field sampling protocol to collect each indicator sample. A good field sampling protocol incorporates eight basic elements:

1. Where to collect samples
2. When to collect samples
3. Sample bottle preparation
4. Sample collection technique
5. Storage and preservation of samples
6. Sample labeling and chain of custody plan
7. Quality assurance/control samples
8. Safety considerations

Appendix G provides more detail on each monitoring element. Some communities already have established sampling protocols that are used for in-stream or wet weather sampling. In most cases these existing sampling protocols are sufficient to conduct illicit discharge sampling.

Tips for Collecting Illicit Discharge Samples

The following tips can improve the quality of your indicator monitoring program.

1. Remember to fill out an ORI field form at every outfall where samples are collected. The ORI form documents sample conditions, outfall characteristics and greatly aids in interpreting indicator monitoring data.

2. Most state water quality agencies have detailed guidance on sampling protocols. These resources should be consulted and the appropriate guidelines followed. Another useful guidance on developing a quality assurance plan is the “Volunteer Monitor’s Guide to Quality Assurance Project Plans” (EPA, 1996).

Table 40: Equipment Needed for Sample Collection
• A cooler (to be kept in the vehicle) • Ice or “blue ice” (to be kept in the vehicle) • Permanent marker (for labeling the samples) • Labeling tape or pre-printed labels • Several dozen one-liter polyethylene plastic sample bottles • A “dipper,” a measuring cup at the end of a long pole, to collect samples from outfalls that are hard to reach • Bacteria analysis sample bottles (if applicable), typically pre-cleaned 120mL sample bottles, to ensure against contamination

3. Sample in batches where feasible to cut down on field and mobilization time.

4. Avoid sampling lagged storm water flows by sampling at least 48 to 72 hours after runoff producing events.

5. It may be necessary to collect multiple samples at a single outfall if preservatives are going to be used. Preservatives are typically necessary when long hold times are required for samples before analysis occurs. Appendix G contains guidance on the required preservation and maximum allowable hold times for various parameters.

12.3 Methods to Analyze Indicator Samples

This section reviews methods to analyze indicator samples, and begins with a discussion of whether they should be analyzed in-house or sent to an independent contract lab. Next, recommended methods for analyzing indicator parameters are outlined, along with data on their comparative cost, safety, and accuracy. Lastly, tips are offered to improve an indicator monitoring program.

Analyzing Samples In-house vs. Contract Lab

Program managers need to decide whether to analyze samples in-house, or through an independent monitoring laboratory. The decision on which route to take is often based on the answers to the following questions:

- *What level of precision or accuracy is needed for the indicator parameter(s)?* Precise and accurate data are needed when indicator monitoring is used to legally document a violation or enforcement action. The lab setting is important, since the quality of the data may be challenged. Precise data are also needed for outfalls that have very large drainage areas. These discharges are often diluted by groundwater, so lab methods must be sensitive and have low detection limits to isolate illicit discharges that are masked or blended with other flow types. Accurate data are also needed for large outfalls since the cost and effort triggered by a false positive reading to track and isolate discharges in a large and complex drainage area is much greater.

- *How quickly are sampling results needed?* Fast results are essential if the community wants to respond instantly to problem outfalls. In this case, the capability to collect and analyze indicator samples in-house is desirable to provide quick response.

- *How much staff time and training is needed to support in-house analysis?* Local staff that perform lab analysis must be certified in laboratory safety, quality control and proper analytical procedures. Communities that do not expect to collect many indicator samples may want to utilize a contract lab to reduce staff training costs.

- *Does a safe environment exist to analyze samples and dispose of wastes?* A safe environment is needed for lab analysis including storage in a fireproof environment, eyewash stations, safety showers, fume hoods and ventilation. Lab workers should have standard safety equipment such as gloves, safety glasses and lab coats. Lastly, many of the recommended analytical methods create small quantities of hazardous wastes that need to be properly disposed. Program managers should carefully evaluate in-house work space to determine if a safe lab environment can be created.

- *What is the comparative cost for sample analysis in each option?* The initial up-front costs to use an independent laboratory are normally lower than those required to establish an in-house analysis capability. An in-house analysis capability normally becomes cost-effective when a community expects to analyze more than 100 indicator samples per year. Section 12.8 outlines some of the key budget factors to consider when making this decision, but program managers should always get bids from reputable and certified contract labs to determine analysis costs.

- *Are existing monitoring laboratories available in the community?* Cost savings are often realized if an existing wastewater treatment or drinking water lab can handle the sample analysis. These labs normally possess the equipment, instruments and trained staff to perform the water quality analyses for indicator parameters.

Considerations for In-house Analysis Capability

Three basic settings can be used to analyze indicator parameters in-house: direct field measurements, small office lab, and a more formal municipal lab. The choice of which in-house setting to use depends on the indicator parameters selected, the need for fast and accurate results and safety/disposal considerations.

In-Field Analysis – A few indicator parameters can be analyzed in the field with probes and other test equipment (Figure 45). While most field parameters can identify problem outfalls, they generally cannot distinguish the specific type of discharge. Some of the situations where in-field analysis[10] is best applied are:

- When a community elects to use one or two indicator parameters, such as ammonia and potassium, that can be measured fairly easily in the field

- When field crews measure indicator parameters to trace or isolate a discharge in a large storm drain pipe network, and need quick results to decide where to go next

Office Analysis – Many of the recommended indicator parameters can be analyzed in an informal “office” lab with the possible exception of surfactants and fluoride (Figure 46). The office analysis option makes sense in communities that have available and trained staff, and choose analytical methods that are safe and have few hazardous waste disposal issues. Another option is to use the office lab to conduct most indicator analyses, but send out fluoride and surfactant indicator samples to a contract lab.

TIP

The methodology for any bacteria analysis also has a waste disposal issue (e.g., biohazard). Check state guidance for appropriate disposal procedures.

[10] Some communities have had success with in-field analysis; however, it can be a challenging environment to conduct rapid and controlled chemical analysis. Therefore, it is generally recommended that the majority of analyses be conducted in a more controlled “lab” setting.

Formal Laboratory Setting – The ideal option in many communities is to use an existing municipal or university laboratory. Existing labs normally have systems in place to dispose of hazardous material, have room and facilities for storing samples, and are equipped with worker safety features. Be careful to craft a schedule that does not interfere with other lab activities.

When in-house analysis is used, program managers need to understand the basic analytical options, safety considerations, equipment needs and analysis costs for each analytical method used to measure indicator parameters. This understanding helps program managers choose what indicator parameters to collect and where they should be analyzed. Much of this information is detailed in Appendix F and summarized below.

Supplies and Equipment

The basic supplies needed to perform lab analysis are described in Table 41, and are available from several scientific equipment suppliers. In addition, reagents, disposable supplies and some specialized instruments may be needed, depending on the specific indicator parameters analyzed. For a partial list of suppliers, consult the Volunteer Stream Monitoring Manual (US EPA, 1997), which can be accessed at www.epa.gov/owow/monitoring/volunteer/stream/appendb.html. Table 42 summarizes the equipment needed for each analytical method.

Figure 45: Analyzing samples in the back of a truck.

Figure 46: Office/lab set up in Fort Worth, TX

Table 41: Basic Lab Supplies	
Disposable Supplies • Deionized water (start with about 10 gallons, unless a reverse osmosis machine is available) • Nitric acid for acid wash (one or two gallons to start) Safety • Lab or surgical gloves • Lab coats • Safety glasses	Glassware/Tools • About two dozen each of 100 and 200 mL beakers • Two or three 100 mL graduated cylinders • Two or three tweezers • Pipettes to transfer samples in small quantities

Table 42: Analytical Methods Supplies Needed				
Indicator Parameter	**Specific Glassware**	**Equipment**	**Reagents or Kits**	**Unique Suppliers**
Ammonia	Sample Cells	Spectrophotometer or Colorimeter	Hach reagents for method 8155	www.hach.com
Boron	None	Spectrophotometer or Colorimeter	Hach reagents for method 10061	www.hach.com
Chlorine	None	Spectrophotometer or Colorimeter	Hach reagents for method 8021	www.hach.com
Color	None	None	Color Kit	www.hach.com
Conductivity	None	Horiba probe	Standards	www.horiba.com
Detergents - Surfactants (MBAS)	None	None	Chemets Detergents Test	www.chemetrics.com
E. Coli	None	Sealer Black Light Comparator	Colilert Reagent Quanti-Tray Sheets	IDEXX Corporation www.idexx.com
Fluorescence	Cuvettes	Fluorometer	None	Several
Fluoride	None	Spectrophotometer or Colorimeter	Hach reagents for method 8029	www.hach.com
Hardness	Erlenmeyer Flask	Burette and Stand or Digital Titrator	EDTA Cartridges or Reagent and Buffer Solution	www.hach.com
pH	None	Horiba Probe	Standards	www.horiba.com
Potassium	None	Horiba Probe	Standards	www.horiba.com
Potassium (Colorimetric)	None	Spectrophotometer or Colorimeter	Hach Reagents for method 8012	www.hach.com

Cost

Table 43 compares the per sample cost to analyze indicator parameters. In general, the per sample cost is fairly similar for most parameters, with the exception of bacteria analyses for *E. coli*, total coliform, or Enterococci. Reagents typically cost less than $2.00 per sample, and equipment purchases seldom exceed $1,000. The typical analysis time averages less than 10 minutes per sample. More information on budgeting indicator monitoring programs can be found in Section 12.8.

Table 43: Chemical Analysis Costs					
Parameter	Analysis Cost				
	Per Sample Costs				Approximate Initial Equipment Cost (Item)
	Disposable supplies	Analysis Time (min/sample)	Staff Cost (@$25/hr)	Total Cost Per Sample	
Ammonia	$1.81	25[3]	$10.42	$12.23	$950[4] (Colorimeter)
Boron	$0.50	20[3]	$8.33	$8.83	$950[4] (Colorimeter)
Chlorine	$0.60	5	$2.08	$2.68	$950[4] (Colorimeter)
Color	$0.52	1	$0.42	$0.94	$0
Conductivity	$0.65[2]	4[3]	$1.67	$2.32	$275 (Probe)
Detergents – Surfactants[1]	$3.15	7	$2.92	$6.07	$0
Enterococci, *E. Coli* or Total Coliform[1]	$6.75	7 (24 hour waiting time)	$2.92	$9.67	$4,000 (Sealer and Incubator)
Fluoride[1]	$0.68	3	$1.25	$1.93	$950[4] (Colorimeter)
Hardness	$1.72	5	$2.08	$3.80	$125 (Digital Titrator)
pH	$0.65[2]	3.5[3]	$1.46	$2.11	$250 (Probe)
Potassium (High Range)	$0.50[2]	5.5[3]	$2.29	$2.79	$250 (Probe)
Potassium (Low Range)	$1.00	5	$2.08	$3.08	$950[4] (Colorimeter)
Turbidity	$0.50[2]	6[3]	$2.50	$3.00	$850 (Turbiditimeter)

[1] Potentially high waste disposal cost for these parameters.
[2] The disposable supplies estimates are based on the use of standards to calibrate a probe or meter.
[3] Analysts can achieve significant economies of scale by analyzing these parameters in batches.
[4] Represents the cost of a colorimeter. The price of a spectrophotometer, which measures a wider range of parameters, is more than $2,500. This one-time cost can be shared among chlorine, fluoride, boron, potassium and ammonia.

Additional Tips for In-house Laboratory Analysis

The following tips can help program managers with in-house laboratory analysis decisions:

- Program managers may want to use both in-house analysis and contract labs to measure the full range of indicator parameters needed in a safe and cost-effective manner. In this case, a split sample analysis strategy is used, where some samples are sent to the contract lab, while others are analyzed in house.

- Remember to order enough basic lab supplies, because they are relatively cheap and having to constantly re-order supplies and wash glassware can be time-consuming. In addition, some scientific supply companies have minimum order amounts, below which additional shipping and handling is charged.

- Be careful to craft a sample analysis schedule that doesn't interfere with other lab operations, particularly if it is a municipal lab. With appropriate preservation, many samples can be stored for several weeks.

Considerations for Choosing a Contract Lab

When a community elects to send samples to an independent contract lab for analysis, it should investigate seven key factors:

1. Make sure that the lab is EPA-certified for the indicator parameters you choose. A state-by-state list of EPA certified labs for drinking water can be found at: http://www.epa.gov/safewater/privatewells/labs.html. State environmental agencies are also good resources to contact for pre-approved laboratories.

2. Choose a lab with a short turn-around time. Some Phase I communities had problems administering their programs because of long turn-around times from local labs (CWP, 2002). As a rule, a lab should be able to produce results within 48 hours.

3. Clearly specify the indicator parameter and analysis method you want, using the guidance in this manual or advice from a water quality expert.

4. Ensure that the maximum hold time for each indicator parameter exceeds the time it takes to ship samples to the lab for analysis.

5. Carefully review and understand the shipping and preservation instructions provided by the contract lab.

6. Look for labs that offer electronic reporting of sample results, which can greatly increase turn-around time, make data analysis easier, and improve response times.

7. Periodically check the lab's QA/QC procedures, which should include lab spikes, lab blanks, and split samples. The procedures for cleaning equipment and calibrating instruments should also be evaluated. These QA/QC procedures are described below.

    - *Lab spikes* – Samples of known concentration are prepared in the laboratory to determine the accuracy of instrument readings.

    - *Lab blanks* – Deionized water samples that have a known zero concentration are used to test methods, or in some methods to "zero" the instruments.

    - *Split samples* – Samples are divided into two separate samples at the laboratory for a comparative analysis. Any difference between the two sample results suggests the analysis method may not be repeatable.

    - *Equipment cleaning and instrument maintenance protocols* – Each lab should have specific and routine procedures to maintain equipment and clean glassware and tubing. These procedures should be clearly labeled on each piece of equipment.

- *Instrument calibration* – Depending on the method, instruments may come with a standard calibration curve, or may require calibration at each use. Lab analysts should periodically test the default calibration curve.

Table 44 summarizes estimated costs associated with sample analyses at a contract lab.

12.4 Techniques to Interpret Indicator Data

Program managers need to decide on the best combination of indicator parameters that will be used to confirm discharges and identify flow types. This section presents guidance on four techniques to interpret indicator parameter data:

- Flow Chart Method (recommended)
- Single Parameter Screening
- Industrial Flow Benchmarks
- Chemical Mass Balance Model (CMBM)

Table 44: Typical Per Sample Contract Lab Costs

Parameter	Costs
Ammonia	\$12 - \$25
Boron	\$16 - \$20
Chlorine	\$6 - \$10
Color	\$7 - \$11
Conductivity	\$2 - \$6
Detergents – Surfactants	\$17- \$35
Enterococci, *E. Coli* or Total Coliform	\$17 - \$35
Fluoride	\$14 - \$25
Hardness	\$8 - \$16
pH	\$2 - \$7
Potassium	\$12 - \$14
Turbidity	\$9 - \$12

All four techniques rely on benchmark concentrations for indicator parameters in order to distinguish among different flow types. Program managers are encouraged to adapt each technique based on local discharge concentration data, and some simple statistical methods for doing so are provided throughout the section.

The Flow Chart Method

The Flow Chart Method is recommended for most Phase II communities, and was originally developed by Pitt *et al.* (1993) and Lalor (1994) and subsequently updated based on new research by Pitt during this project. The Flow Chart Method can distinguish four major discharge types found in residential watersheds, including sewage and wash water flows that are normally the most common illicit discharges. Much of the data supporting the method were collected in Alabama and other regions, and some local adjustment may be needed in some communities. The Flow Chart Method is recommended because it is a relatively simple technique that analyzes four or five indicator parameters that are safe, reliable and inexpensive to measure. The basic decision points involved in the Flow Chart Method are shown in Figure 47 and described below:

Step 1: Separate clean flows from contaminated flows using detergents

The first step evaluates whether the discharge is derived from sewage or washwater sources, based on the presence of detergents. Boron and/or surfactants are used as the primary detergent indicator, and values of boron or surfactants that exceed 0.35 mg/L and 0.25 mg/L, respectively, signal that the discharge is contaminated by sewage or washwater.

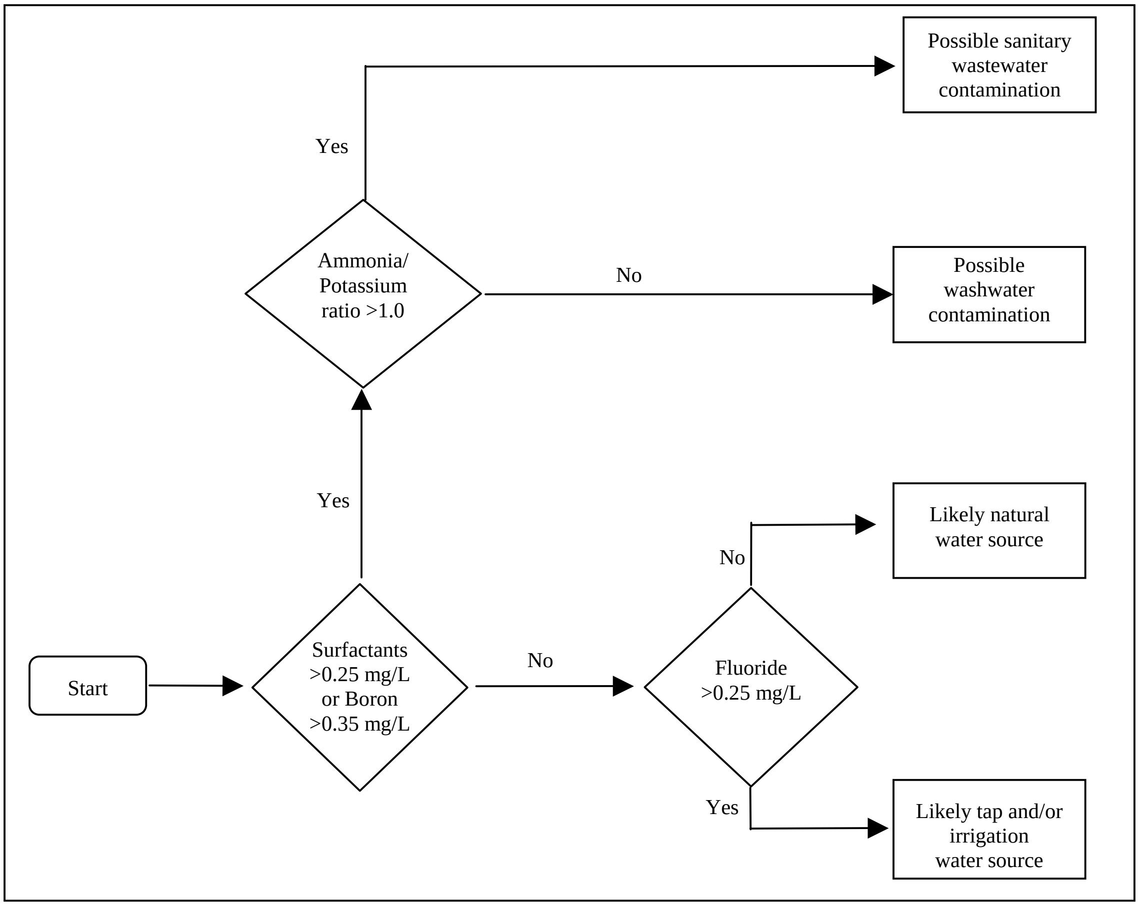


Figure 47: Flow Chart to Identify Illicit Discharges in Residential Watersheds

Step 2: Separate washwater from wastewater using the Ammonia/Potassium ratio

If the discharge contains detergents, the next step is to determine whether they are derived from sewage or washwater, using the ammonia to potassium ratios. A ratio greater than one suggests sewage contamination, whereas ratios less than one indicate washwater contamination. The benchmark ratio was developed by Pitt *et al.* (1993) and Lalor (1994) based on testing in urban Alabama watersheds.

Step 3: Separate tap water from natural water

If the sample is free of detergents, the next step is to determine if the flow is derived from spring/groundwater or comes from tap water. The benchmark indicator used in this step is fluoride, with concentrations exceeding 0.60 mg/L indicating that potable water is the source. Fluoride levels between 0.13 and 0.6 may indicate non-target irrigation water. The purpose of determining the source of a relatively "clean discharge" is that it can point to water line breaks, outdoor washing, non-target irrigation and other uses of municipal water that generate flows with pollutants.

Adapting the Flow Chart Method

The Flow Chart Method is a robust tool for identifying illicit discharge types, but may need to be locally adapted, since much of the supporting data was collected in one region of the country. Program managers should look at four potential modifications to the flow chart in their community.

1) Is boron or surfactants a superior local indicator of detergents?

Surfactants are almost always a more reliable indicator of detergents, except for rare cases where groundwater has been contaminated by sewage. The disadvantage of surfactants is that the recommended analytical method uses a hazardous chemical as the reagent. Boron uses a safer analytical method. However, if boron is used as a detergent indicator, program managers should sample boron levels in groundwater and tap water, since they can vary regionally. Also, not all detergent formulations incorporate boron at high levels, so it may not always be a strong indicator.

2) Is the ammonia/potassium ratio of one the best benchmark to distinguish sewage from washwater?

The ammonia/potassium ratio is a good way to distinguish sewage from washwater, although the exact ratio appears to vary in different regions of the country. The benchmark value for the ratio was derived from extensive testing in one Alabama city. In fact, data collected in another Alabama city indicated an ammonia/potassium ratio of 0.6 distinguished sewage from wash water. Clearly, program managers should evaluate the ratio in their own community, although the proposed ratio of 1.0 should still capture the majority of sewage discharges. The ratio can be refined over time using indicator monitoring at local outfalls, or through water quality sampling of sewage and washwater flow types for the chemical library.

3) Is fluoride a good indicator of tap water?

Usually. The two exceptions are communities that do not fluoridate their drinking water or have elevated fluoride concentrations in groundwater. In both cases, alternative indicator parameters such as hardness or chlorine may be preferable.

4) Can the flow chart be expanded?

The flow chart presented in Figure 47 is actually a simplified version of a more complex flow chart developed by Pitt for this project, which is presented in Appendix H. An expanded flow chart can provide more consistent and detailed identification of flow types, but obviously requires more analytical work and data analysis. Section 12.5 provides guidance on statistical techniques to customize the flow chart method based on your local discharge data.

Single Parameter Screening

Research by Lalor (1994) suggests that detergents is the best single parameter to detect the presence or absence of the most common illicit discharges (sewage and washwater). The recommended analytical method for detergents uses a hazardous reagent, so the analysis needs to be conducted in a controlled laboratory setting with proper safety equipment. This may limit the flexibility of a community if it is conducting analyses in the field or in a simple office lab.

Ammonia is another single parameter indicator that has been used by some communities with widespread or severe sewage contamination. An ammonia concentration greater than 1 mg/L is generally considered to be a positive indicator of sewage contamination. Ammonia can be analyzed in the field using a portable spectrophotometer, which allows for fairly rapid results and the ability to immediately track down sources and improper connections (see Chapter 13 for details on tracking down illicit discharges)[11]. Since ammonia can be measured in the field, crews can get fast results and immediately proceed to track down the source of the discharge using pipe testing methods (see Chapter 13 for details).

As a single parameter, ammonia has some limitations. First, ammonia by itself may not always be capable of identifying sewage discharges, particularly if they are diluted by "clean" flows. Second, while some washwaters and industrial discharges have relatively high ammonia concentrations, not all do, which increases the prospects of false negatives. Lastly, other dry weather discharges, such as non-target irrigation, can also have high ammonia concentrations that can occasionally exceed 1 mg/L. Supplementing ammonia with potassium and looking at the ammonia/potassium ratio is a simple adjustment to the single parameter approach that helps to further and more accurately characterize the discharge. Ratios greater than one indicate a sewage source, while ratios less than or equal to one indicate a washwater source. Potassium is easily analyzed using a probe (Horiba Cardy™ is the recommended probe).

Industrial Flow Benchmark

If a subwatershed has a high density of industrial generating sites, additional indicator parameters may be needed to detect and trace these unique discharges. They are often needed because industrial and commercial generating sites produce discharges that are often not composed of either sewage or washwater. Examples include industrial process water, or wash down water conveyed from a floor drain to the storm drain system.

This guidance identifies seven indicator parameters that serve as industrial flow benchmarks to help identify illicit discharges originating from industrial and other generating sites. The seven indicators (ammonia, color, conductivity, hardness, pH, potassium and turbidity) are used to identify liquid wastes and other industrial discharges that are not always picked up by the Flow Chart Method. Table 45 summarizes typical benchmark concentrations that can distinguish between unique industrial or commercial liquid wastes. Note that two of the seven indicator parameters, ammonia and potassium, are already incorporated into the flow chart method.

Table 46 illustrates how industrial benchmark parameters can be used independently or as a supplement to the flow chart method, based on data from Alabama (Appendix E). The best industrial benchmark parameters are identified in pink shading and can distinguish industrial sources from residential washwater in 80% of samples. Supplemental indicator parameters denoted by yellow shading, can distinguish industrial source from residential washwater in 50% of samples, or roughly one in two samples.

[11]In-field analysis may be appropriate when tracking down illicit flows, but it is typically associated with challenging and uncontrollable conditions. Therefore, it is generally recommended that analyses be conducted in a controlled lab setting.

Most industrial discharges can consistently be identified by extremely high potassium levels. However, these discharges would be misclassified as washwater when just the Flow Chart Method is used. Other benchmark parameters have value in identifying specific industrial types or operations. For example, metal plating bath waste discharges are often indicated by extremely high conductivity, hardness and potassium concentrations.

Adapting Industrial Flow Benchmark

By their very nature, industrial and other generating sites can produce a bewildering diversity of discharges that are hard to classify. Therefore, program managers will experience some difficulty in differentiating industrial sources. Over time, the composition of industrial discharges can be refined as chemical libraries for specific industrial flow types and sources are developed. This can entail a great deal of sampling, but can reduce the number of false positive or negative readings.

Table 45: Benchmark Concentrations to Identify Industrial Discharges

Indicator Parameter	Benchmark Concentration	Notes
Ammonia	≥50 mg/L	• Existing “Flow Chart” Parameter • Concentrations higher than the benchmark can identify a few industrial discharges.
Color	≥500 Units	• Supplemental parameter that identifies a few specific industrial discharges. Should be refined with local data.
Conductivity	≥2,000µS/cm	• Identifies a few industrial discharges • May be useful to distinguish between industrial sources.
Hardness	≤10 mg/L as $CaCO_3$ ≥2,000 mg/L as $CaCO_3$	• Identifies a few industrial discharges • May be useful to distinguish between industrial sources.
pH	≤5	• Only captures a few industrial discharges • High pH values may also indicate an industrial discharge but residential wash waters can have a high pH as well.
Potassium	≥20 mg/L	• Existing “Flow Chart” Parameter • Excellent indicator of a broad range of industrial discharges.
Turbidity	≥1,000 NTU	• Supplemental parameter that identifies a few specific industrial discharges. Should be refined with local data.

Table 46: Usefulness of Various Parameters to Identify Industrial Discharges

Industrial Benchmark Concentration	Detergents as Surfactants (mg/L)	Ammonia (mg/L)	Potassium (mg/L)	Initial "Flow Chart" Class	Color (Units)	Conductivity (μS/cm)[1]	Hardness (mg/L as $CaCO_3$)	pH	Turbidity (NTU)	Best Indicator Parameters to Identify This Flow Type	Additional Indicator Parameters to Identify This Flow Type
	--	≥50	≥20		≥500	≥2000	≤10 ≥2,000	≤5	≥1,000		
Concentrations in Industrial and Commercial Flow Types											
Automotive Manufacturer[1]	5	0.6	66	**Wash water**	15	220	30	6.7	118	Potassium	
Poultry Supplier[1]	5	4.2	41	**Wash water**	23	618	31	6.3	111	Potassium	
Roofing Product Manufacturing[1]	8	10.2	27	**Wash water**	>100[2]	242	32	7.1	229	None	Potassium Color
Uniform Manufacturing[1]	6	6.1	64	**Wash water**	>100[2]	798	35	10.4	2,631	Potassium	Color Turbidity
Radiator Flushing	15	(26.3)	(2,801)	**Wash water**	(3,000)	(3,278)	(5.6)	(7.0)	-	Potassium Conductivity Color	Hardness
Metal Plating Bath	7	(65.7)	(1,009)	**Wash water**	(104)	(10,352)	(1,429)	(4.9)	-	Ammonia Potassium Conductivity Hardness	pH
Commercial Car Wash	140	0.9; (0.2)	4; (43)	**Wash water**	>61; (222)	274; (485)	71; (157)	7.7; (6.7)	156		Potassium Turbidity
Commercial Laundry	(27)	(0.8)	3	**Wash water**	47	(563)	(36)	(9.1)	-		

Best Indicators, shaded in pink, distinguish this source from residential wash water in 80% of samples in both Tuscaloosa and Birmingham, AL.
Supplemental indicators, shaded in yellow, distinguish this source from residential wash water in 50% of samples, or in only one community.
(Data in parentheses are mean values from Birmingham); Data not in parentheses are from Tuscaloosa
[1] Fewer than 3 samples for these discharges.
[2] The color analytical technique used had a maximum value of 100, which was exceeded in all samples. Color may be a good indicator of these industrial discharges and the benchmark concentration may need adjustment downward for this specific community.

Chemical Mass Balance Model (CMBM) for Blended Flows

The Chemical Mass Balance Model (CMBM) is a sophisticated technique to identify flow types at outfalls with blended flows (i.e., dry weather discharges originating from multiple sources). The CMBM, developed by Karri (2004) as part of this project is best applied in complex sewersheds with large drainage areas, and relies heavily on the local chemical library discussed in the next section.

The CMBM can quantify the fraction of each flow type present in dry weather flow at an outfall (e.g., 20% spring water; 40% sewage; 20% wash water). The CMBM relies on a computer program that generates and solves algebraic mass balance equations, based on the statistical distribution of specific flow types derived from the chemical library. The CMBM is an excellent analysis tool, but requires significant advance preparation and sampling support. More detailed guidance on how to use and interpret CMBM data can be found in Appendix I.

The chemical library requires additional statistical analysis to support the CMBM. Specifically, indicator parameter data for each flow type need to be statistically analyzed to determine the **mean**, the **coefficient of variation**, and the **distribution type**. In its current version, the CMBM accepts two distribution types: normal or lognormal distributions. Various statistical methodologies can determine the distribution type of a set of data. Much of this analysis can be conducted using standard, readily-available statistical software, such as the Engineering Statistics Handbook which is available from the National Institute of Standards and Technology, and can be accessed at http://www.itl.nist.gov/div898/handbook/.

12.5 The Chemical Library

The chemical library is a summary of the chemical composition of the range of discharge types found in a community. The primary purpose of the library is to characterize distinct flow types that may be observed at outfalls, including both clean and contaminated discharges. A good library includes data on the composition of tap water, groundwater, sewage, septage, non-target irrigation water, industrial process waters, and washwaters (e.g., laundry, car wash, etc.). The chemical library helps program managers customize the flow chart method and industrial benchmarks, and creates the input data needed to drive the CMBM.

To develop the library, samples are collected directly from the discharge source (e.g., tap water, wastewater treatment influent, shallow wells, septic tanks, etc.). Table 47 provides guidance on how and where to sample each flow type in your community. As a general rule, about 10 samples are typically needed to characterize each flow type, although more samples may be needed if the flow type has a high coefficient of variation. The measure of error can be statistically defined by evaluating the coefficient of variation of the sample data (variability relative to the mean value), and the statistical distribution for the data (the probable spread in the data beyond the mean). For more guidance on statistical techniques for assessing sampling data, consult Burton and Pitt (2002) and US EPA (2002), which can be accessed at http://galton.uchicago.edu/~cises/resources/EPA-QA-Sampling-2003.pdf.

Chemical libraries should also be compared to databases that summarize indicator monitoring of dry weather flows at suspect outfalls. Outfall samples may not always be representative of individual flow types because of mixing of flows and dilution, but they can serve as a valuable check if the discharge source is actually confirmed. Program managers can also use both the chemical library and indicator database to refine flow chart or industrial benchmarks (see Appendix J for an example).

Over time, communities may want to add other flow types to the chemical library, such as transitory discharges that generate small volume flows such as "dumpster juice," power washing and residential car washing. Transitory discharges are hard to detect with outfall monitoring, but may cumulatively contribute significant dry weather loads. Understanding the chemical makeup of the transitory discharges can help program managers prioritize education and pollution prevention efforts.

<table>
<tr><th colspan="3">Table 47: Where and How to Sample for Chemical "Fingerprint" Library</th></tr>
<tr><th>Flow Type</th><th>Places to Collect the Data</th><th>Any Other Potential Sources?</th></tr>
<tr><td>Shallow Groundwater</td><td>• From road cuts or stream banks
• Samples from shallow wells
• USGS regional groundwater quality data
• Dry weather in-stream flows at headwaters with no illicit discharges</td><td>None. Locally distinct.</td></tr>
<tr><td>Spring Water</td><td>• Directly from springs</td><td>None. Locally distinct.</td></tr>
<tr><td>Tap water</td><td>• Individual taps throughout the community
• or analyze local drinking water monitoring reports or annual consumer confidence reports</td><td>None. Locally distinct</td></tr>
<tr><td>Irrigation</td><td>• Collect irrigation water from several different sites. May require a hand operated vacuum pump to collect these shallow flows (see Burton and Pitt, 2002)</td><td>None. Locally distinct.</td></tr>
<tr><td>Sewage</td><td>• Reported sewage treatment plant influent data provides a characterization of raw sewage and is usually available from discharge monitoring reports. Because the characteristics of sewage will vary within the collection system depending upon whether the area is serving residential or commercial uses, climate, residence time in the collection system, etc, it is often more accurate and valuable to collect "fingerprint" samples from within the system, rather than at the treatment plant.</td><td rowspan="2">Data in Appendix E can provide a starting point, but local data are preferred.</td></tr>
<tr><td>Septage</td><td>• Outflow of several individual septic tanks or leach fields</td></tr>
<tr><td>Most Industrial Discharges</td><td>• Direct effluent from the industrial process (Obtain samples as part of industrial pre-treatment program in local community)</td><td>Data in Appendix E characterize some specific industrial flows. Industrial NPDES permit monitoring can also be used.</td></tr>
<tr><td>Commercial Car Wash;
Commercial Laundry</td><td>• Sumps at these establishments</td><td>Data in Appendix E can provide a starting point, but local data are preferred.</td></tr>
</table>

Evaluating Interpretive Techniques Using Outfall Indicator Monitoring Data

Outfall sampling data for confirmed sources or flow types can be used to test the accuracy and reliability of all four interpretive techniques. The sampling record is used to determine the number of false positives or false negatives associated with a specific interpretive technique. A simple tabulation of false test readings can identify the types and levels of indicator parameters that are most useful.

Table 48 provides an example of how the Flow Chart Method was tested with outfall monitoring data from Birmingham, AL (Pitt *et al.*, 1993). In this case, the Flow Chart Method was applied without adaptation to local conditions, and the number of correctly (and incorrectly) identified discharges was tracked. Tests on 10 Birmingham outfalls were mostly favorable, with the flow chart method correctly identifying contaminated discharges in all cases (i.e., washwater or sewage waste water). At one outfall, the flow chart incorrectly identified sewage as washwater, based on an ammonia (NH_3)/ potassium (K) ratio of 0.9 that was very close to the breakpoint in the Flow Chart Method (ratio of one). Based on such tests, program managers may want to slightly adjust the breakpoints in the Flow Chart Method to minimize the occurrence of errors.

12.6 Special Monitoring Techniques for Intermittent or Transitory Discharges

The hardest discharges to detect and test are intermittent or transitory discharges to the storm drain system that often have an indirect mode of entry. With some ingenuity, luck, and specialized sampling techniques, however, it may be possible to catch these discharges. This section describes some specific monitoring techniques to track down intermittent discharges. Transitory discharges cannot be reliably detected using conventional outfall monitoring techniques, and are normally found as a result of hotline complaints or spill events. Nevertheless, when transitory discharges are encountered, they should be sampled if possible.

Techniques for Monitoring Intermittent Discharges

An outfall may be suspected of having intermittent discharges based on physical indicators (e.g., staining), poor in-stream dry weather water quality, or the density of generating sites in the contributing subwatershed. The only sure way to detect an intermittent discharge is to camp out at the outfall for a long period of time, which is obviously not very cost-effective or feasible. As an alternative, five special monitoring techniques can be used to help track these elusive problems:

- Odd hours monitoring
- Optical brightener monitoring traps
- Caulk dams
- Pool sampling
- Toxicity monitoring

Table 48: Evaluation of the Flow Chart Method Using Data from Birmingham, Alabama
(Adapted from Pitt et al., 1993)

Outfall ID	Outfall Concentrations (mg/L)					Predicted Flow Type	Confirmed Flow Type	Result
	Detergents-Surfactants (>0.25 is sanitary or wash water)	NH_3	K	NH_3/K (>1.0 is sanitary)	Fluoride (>0.25 is tap, if no detergents)			
14	0	0	0.69	0.0	0.04	Natural Water	Spring Water	Correct
20	0	0.03	1.98	0.0	0.61	Tap Water	Rinse Water (Tap) and Spring Water	Correct
21	20	0.11	5.08	0.0	2.80	Washwater	Washwater (Automotive)	Correct
26	0	0.01	0.72	0.0	0.07	Natural Water	Spring Water	Correct
28	0.25[1]	2.89	5.96	0.5	0.74	Washwater	Washwater (Restaurant)	Correct
31	0.95	0.21	3.01	0.1	1.00	Washwater	Laundry (Motel)	Correct
40z	0.25[1]	0.87	0.94	0.9	0.12	Washwater	Shallow Groundwater and Septage	Identifies Contaminated but Incorrect Flow Type
42	0	0	0.81	0.0	0.07	Natural Water	Spring Water	Correct
48	3.0	5.62	4.40	1.3	0.53	Sanitary Wastewater	Spring Water and Sewage	Correct
60a	0	0.31	2.99	0.1	0.61	Tap Water	Landscaping Irrigation Water	Correct

[1] These values were increased from reported values of 0.23 mg/L (outfall 28) and 0.2 mg/L (outfall 40z). The analytical technique used in Birmingham was more precise (but more hazardous) than the method used to develop the flow chart in Figure 47. It is assumed that these values would have been interpreted as 0.25 mg/L using the less precise method.

Odd Hours Monitoring

Many intermittent discharges actually occur on a regular schedule, but unfortunately not the same one used by field crews during the week. For example, some generating sites discharge over the weekend or during the evening hours. If an outfall is deemed suspicious, program managers may want to consider scheduling "odd hours" sampling at different times of the day or week. Some key times to visit suspicious outfalls include:

- Both morning and afternoon
- Weekday evenings
- Weekend mornings and evenings

Optical Brightener Monitoring Traps

Optical brightener monitoring (OBM) traps are another tool that crews can use to gain insight into the "history" of an outfall without being physically present. OBM traps can be fabricated and installed using a variety of techniques and materials. All configurations involve an absorbent, unbleached cotton pad or fabric swatch and a holding or anchoring device such as a wire mesh trap (Figure 48) or a section of small diameter (e.g., 2-inch) PVC pipe. Traps are anchored to the inside of outfalls at the invert using wire or monofilament that is secured to the pipe itself or rocks used as temporary weights.

Field crews retrieve the OBM traps after they have been deployed for several days of dry weather, and place them under a fluorescent light that will indicate if they have been exposed to detergents. OBM traps have been used with some success in Massachusetts (Sargent *et al*., 1998) and northern Virginia (Waye, 2000). Although each community used slightly different methods, the basic sampling concept is the same. For more detailed guidance on how to use OBM traps and interpret the results, consult the guidance manual found at: http://www.naturecompass.org/8tb/sampling/index.html and http://www.novaregion.org/obm.htm.

Although OBM traps appear useful in detecting some intermittent discharges, research during this project has found that OBM traps only pick up the most contaminated discharges, and the detergent level needed to produce a "hit" was roughly similar to pure washwater from a washing

Figure 48: OBM Equipment includes a black light and an OBM Trap that can be placed at an outfall
Source: R. Pitt

machine (see Appendix F for results). Consequently, OBM traps may be best suited as a simple indicator of presence or absence of intermittent flow or to detect the most concentrated flows. OBM traps need to be retrieved before runoff occurs from the outfalls, which will contaminate the trap or wash it away.

Caulk Dams

This technique uses caulk, plumber's putty, or similar substance to make a dam about two inches high within the bottom of the storm drain pipe to capture any dry weather flow that occurs between field observations. Any water that has pooled behind the dam is then sampled using a hand-pump sampler, and analyzed in the lab for appropriate indicator parameters.

Pool Sampling

In this technique, field crews collect indicator samples directly from the "plunge pool" below an outfall, if one is present. An upstream sample is also collected to characterize background stream or ditch water quality that is not influenced by the outfall. The pool water and stream sample are then analyzed for indicator parameters, and compared against each other. Pool sampling results can be constrained by stream dilution, deposition, storm water flows, and chemical reactions that occur within the pool.

Toxicity Monitoring

Another way to detect intermittent discharges is to monitor for toxicity in the pool below the outfall on a daily basis. Burton and Pitt (2002) outline several options to measure toxicity, some of which can be fairly expensive and complex. The Fort Worth Department of Environmental Management has developed a simple low-cost outfall toxicity testing technique known as the Stream Sentinel program. Stream sentinels place a bottle filled with minnows in the pool below suspected outfalls and measure the survival rate of the minnows as an indicator of the toxicity of the outfall [12] (see Figure 49).

One advantage of the sentinel program is that volunteer monitors can easily participate, by raising and caring for the minnows, placing bottles at outfalls, and visiting them everyday to record mortality. The long-term nature of sentinel monitoring can help pick up toxicity trends at a given outfall. For example, Fort Worth observed a trend of mass mortality on the second Tuesday of each month at some outfalls, which helped to pinpoint the industry responsible for the discharges, and improved sample scheduling (City of Fort Worth, 2003). More information about the Stream Sentinel program can be found at: www.fortworthgov.org/DEM/stream_sentinel.pdf.

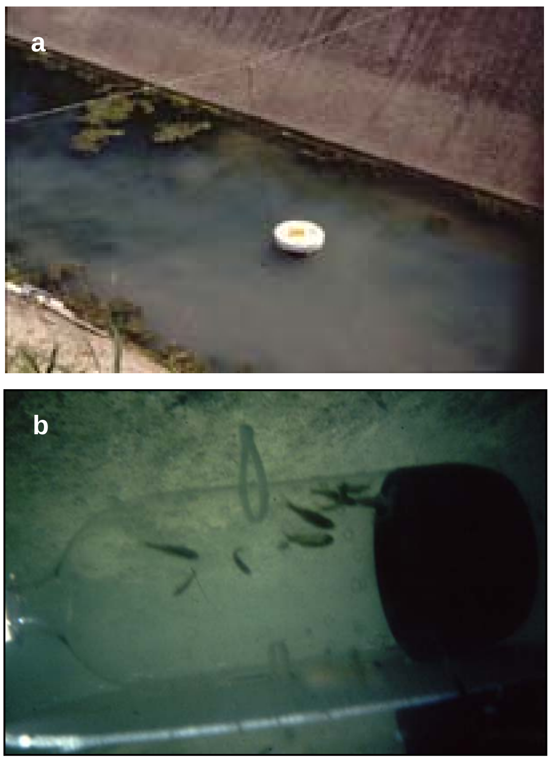


Figure 49: Float and wire system to suspend a bottle in a stream sentinel station deployed in Fort Worth, TX (a); Minnows in the perforated bottle below the water surface (b).

Due to the cost and difficulty of interpreting findings, toxicity testing is generally not recommended for communities unless they have prior experience and expertise with the method.

Techniques for Monitoring Transitory Discharges

Transitory discharges, such as spills and illegal dumping, are primarily sampled to assign legal responsibility for enforcement actions or to reinforce ongoing pollution prevention education efforts. In most cases, crews attempt to trace transitory discharges back up the pipe or drainage area using visual techniques (see Chapter 13). However, field crews should always collect a sample to document the event. Table 49 summarizes some follow-up monitoring strategies to document transitory discharges.

12.7 Monitoring of Stream Quality During Dry Weather

In-stream water quality monitoring can help detect sewage and other discharges in a community or larger watershed. Stream monitoring can identify the subwatersheds with the greatest illicit or sewage discharge potential that is then used to target outfall indicator monitoring. At the smaller reach scale, stream monitoring may sometimes detect major individual discharges to the stream.

[12] It may be necessary to obtain approval from the appropriate state of federal regulatory agency before conducting toxicity monitoring using vertebrates.

Table 49: Follow-Up Monitoring for Transitory Discharges	
Condition	**Response**
Oils or solvents	Special hydrocarbon analysis to characterize the source of the oil
Unknown but toxic material	Full suite of metals, pesticides, other toxic materials
Probable sewage	Monitor for parameters associated with the Flow Chart Technique (detergents, ammonia, potassium, fluoride) for residential drainage areas

Stream Monitoring to Identify Problem Reaches or Subwatersheds

Stream monitoring data can be used to locate areas in subwatersheds where illicit discharges may be present, and where human or aquatic health risks are higher. To provide this information, stream monitoring should be conducted regularly during dry weather conditions to track water quality (at least monthly) and to document changes in water quality over a period of time. Stream monitoring data are particularly effective when combined with ORI data. For example, a subwatershed with many ORI physical indicators of illicit discharges (e.g., a high number of flowing outfalls) that also has poor stream water quality would be an obvious target for intensive outfall monitoring.

Stream monitoring parameters should reflect local water quality goals and objectives, and frequently include bacteria and ammonia. Bacteria are useful since sewage discharges can contribute to violations of water contact standards set for recreation during dry weather conditions. Table 50 summarizes water quality standards for *E. coli* that EPA recommends for water contact recreation. It is important to note that individual states may use different action levels or bacteria indicators (e.g., Enterococci or fecal coliform) to regulate water contact recreation. For a review of the impacts bacteria exert on surface waters, consult CWP (2000).

An important caveat when interpreting stream monitoring data is that a violation of bacteria standards during dry weather flow does not always mean that an illicit discharge or sewage overflow is present. While raw sewage has bacteria concentrations that greatly exceed bacteria standards (approximately 12,000 MPN/100 mL) other bacteria sources, such as urban wildlife, can also cause a stream to violate standards. Consequently, stream monitoring data need to be interpreted in the context of other information, such as upstream land use, past complaints, age of infrastructure, and ORI surveys.

Ideally, stream monitoring stations should be strategically located with a minimum of one station per subwatershed, and additional stations at stream confluences and downstream of reaches with a high outfall density. Stations should also be located at beaches, shellfish harvesting and other areas where discharges represent a specific threat to public health. See Burton and Pitt (2002) for guidance on stream monitoring.

Stream Monitoring to Identify Specific Discharges

Stream monitoring data can help field crews locate individual discharges within a specific stream reach. Immediate results are needed for this kind of monitoring, so indicator parameters should be analyzed using simple field test kits or portable analytical instruments (e.g., spectrophotometer). Bacteria is not a good indicator parameter to use for this purpose because lab results cannot be received for at least one day (analytical method requires a "hold time" of 24 hours). Table 51 summarizes nutrient indicator parameters along with their "potential problem level" benchmarks. It is important to note that other factors, such as animal operations, can elevate stream nutrient concentrations, so data should always be interpreted in the context of surrounding land use. Stream monitoring benchmarks should be continuously refined as communities develop a better understanding of what dry weather baseline concentrations to expect.

If stream monitoring indicates that a potential problem level benchmark has been exceeded, field crews continue stream sampling to locate the discharge through a process of elimination. Crews walk upstream taking regular samples above and below stream confluences until the benchmark concentration declines. The crews then take samples at strategic points to narrow down the location of the discharge, using the in-pipe monitoring strategy described in Chapter 13.

Table 50: Typical "Full Body Contact Recreation" Standards for *E. coli*
(Source: EPA, 1986)[1]

Use	Criterion
Designated beach area	235 MPN /100 mL
Moderately-used full body contact recreation area	298 MPN /100 mL
Lightly-used full body contact recreation	406 MPN /100 mL
Infrequently-used full body contact recreation	576 MPN /100 mL

[1] *These concentrations represent standards for a single sampling event. In all waters, a geometric mean concentration of 126 MPN/100 mL cannot be exceeded for five samples taken within one month.*

Table 51: Example In-Stream Nutrient Indicators of Discharges
(Zielinski, 2003)

Parameter	Potential Problem Level*	Possible Cause of Water Quality Problem
Total Nitrogen (TN)	3.5 mg/l	High nutrients in ground water from agriculture, lawn practices, or sewage contamination from illicit connection, sanitary line break or failing septic system.
Total Phosphorus (TP)	0.4 mg/l	Contamination from lawn practices, agriculture, sewage or washwater.
Ammonia (NH_3)	0.3 mg/l	Sewage or washwater contamination from illicit connection, sanitary line break or failing septic system.

**Nutrient parameters are based on USGS NAWQA data with 85% of flow weighted samples being less than these values in urban watersheds (Note: data from Nevada were not used, due to climatic differences and for some parameters they were an order of magnitude higher). Communities can modify these benchmarks to reflect local data and experience.*

12.8 The Costs of Indicator Monitoring

This section provides general guidance on scoping and budgeting an indicator monitoring program. The required budget will ultimately be dictated by the monitoring decisions and local conditions within a community. The budgeting data presented in this section are based on the level of indicator sampling effort in two hypothetical communities, using different numbers of samples, indicator parameters, and analysis methods.

Budgets for Indicator Monitoring in a Hypothetical Community

Communities can develop annual budgets for indicator monitoring if the degree of sampling effort can be scoped. This is normally computed based on the expected number of samples to analyze and is a function of stream miles surveyed and outfall density. For example, if a community collects samples from 10 stream miles with eight outfalls per mile, it will have 80 samples to analyze. This number can be used to generate start-up and annual monitoring cost estimates that represent the expected level of sampling effort. Table 52 summarizes how indicator monitoring budgets were developed for two hypothetical communities, each with 80 outfalls to sample. Budgets are shown using both in-house and contract lab set-ups, and are split between initial start-up costs and annual costs.

Community A: Primarily Residential Land Use, Flow Chart Method

In this scenario, six indicator parameters were analyzed, several of which were used to support the Flow Chart Method. The community took no additional samples to create a chemical library, and instead relied on default values to identify illicit discharges. The community analyzed the samples in-house at a rate of one sample (includes analysis of all six parameters) per staff hour.

Community B: Mixed Land Use - Multiple Potential Sources, Complex Analysis

In the second scenario, the community analyzed 11 indicator parameters, including a bacteria indicator, and took samples of eight distinct flow types to create a chemical library, for a total of 88 samples. The community analyzed the samples in-house at a rate of one sample per 1.5 staff hours.

Some general rules of thumb that were used for this budget planning example include the following:

- $500 in initial sampling equipment (e.g., sample bottles, latex gloves, dipper, cooler, etc).
- Outfall samples are collected in batches of 10. Each batch of samples can be collected and transported to the lab in two staff days (two-person crew required to collect samples for safety purposes).
- Staff rate is $25/hr.
- Overall effort to collect samples for the chemical library and statistically analyze the data is approximately one staff day per source type.
- The staff time needed to prepare for field work and interpret lab results is roughly two times that required for conducting the field work (i.e., eight days of collecting samples requires 16 days of pre- and post-preparation).

Costs for Intermittent Discharge Analyses

Equipment costs for most specialized intermittent discharge techniques tend to be low (<$500), and are dwarfed by staff effort. As a rule of thumb, assume about four hours of staff time to deploy, retrieve and analyze samples collected from a single outfall using these techniques.

Table 52: Indicator Monitoring Costs: Two Scenarios				
	Community A: In-House	**Community A: Contract Lab**	**Community B: In-House**	**Community B: Contract Lab**
Initial Costs				
Initial Sampling Supplies and Lab Equipment [1]	$1,700	$500	$7,500	$500
Staff Cost: Library Development [2]	$0	$0	$4,600[3]	$2,000
Analysis Costs: Library Development (Reagents or Contract Lab Cost)	$0	$0	$1,400	$13,000[4]
Total Initial Costs	**$1,700**	**$500**	**$13,500**	**$15,500**
Annual Costs in Subsequent Years				
Staff Field Cost (Sample Collection) [2, 5, 6]	$3,200	$3,200	$3,200	$3,200
Staff Costs: Chemical Analysis [2]	$2,000	$200[7]	$3,000	$200
Staff Time to Enter/ Interpret Data [2, 6]	$3,200	$3,200	$4,800	$4,800
Analysis Costs: Annual Outfall Sampling (Reagents or Contract Lab Cost)	$600	$8,400[4]	$1,400	$13,000[4]
TOTAL ANNUAL COST	**$9,000**	**$15,000**	**$12,400**	**$21,200**

Notes:
[1] $500 in initial sampling equipment.
[2] Samples can be shipped to a contract lab using one staff hour.
[3] Overall effort to collect samples for the library and statistically analyze the data is approximately one staff day per source type.
[4] For contract lab analysis, assume a cost that is an average between the two extremes of the range in Table 43.
[5] Outfall samples are collected in batches of 10. Each batch of samples can be collected and transported to the lab in two staff days (two-person crew required to collect samples for safety purposes).
[6] Assume that the staff time needed to interpret lab results and prepare for field work is roughly 16 staff days. An additional eight days are required for the flow type pre- and post-preparation for Community 2.
[7] Staff rate is $25/hr.

Chapter 13: Tracking Discharges To A Source

Once an illicit discharge is found, a combination of methods is used to isolate its specific source. This chapter describes the four investigation options that are introduced below.

Storm Drain Network Investigation

Field crews strategically inspect manholes within the storm drain network system to measure chemical or physical indicators that can isolate discharges to a specific segment of the network. Once the pipe segment has been identified, on-site investigations are used to find the specific discharge or improper connection.

Drainage Area Investigation

This method relies on an analysis of land use or other characteristics of the drainage area that is producing the illicit discharge. The investigation can be as simple as a "windshield" survey of the drainage area or a more complex mapping analysis of the storm drain network and potential generating sites. Drainage area investigations work best when prior indicator monitoring reveals strong clues as to the likely generating site producing the discharge.

On-site Investigation

On-site methods are used to trace the source of an illicit discharge in a pipe segment, and may involve dye, video or smoke testing within isolated segments of the storm drain network.

Septic System Investigation

Low-density residential watersheds may require special investigation methods if they are not served by sanitary sewers and/or storm water is conveyed in ditches or swales. The major illicit discharges found in low-density development are failing septic systems and illegal dumping. Homeowner surveys, surface inspections and infrared photography have all been effectively used to find failing septic systems in low-density watersheds.

13.1 Storm Drain Network Investigations

This method involves progressive sampling at manholes in the storm drain network to narrow the discharge to an isolated pipe segment between two manholes. Field crews need to make two key decisions when conducting a storm drain network investigation—where to start sampling in the network and what indicators will be used to determine whether a manhole is considered clean or dirty.

Where to Sample in the Storm Drain Network

The field crew should decide how to attack the pipe network that contributes to a problem outfall. Three options can be used:

- Crews can work progressively up the trunk from the outfall and test manholes along the way.
- Crews can split the trunk into equal segments and test manholes at strategic junctions in the storm drain system.
- Crews can work progressively down from the upper parts of the storm drain network toward the problem outfall.

The decision to move up, split, or move down the trunk depends on the nature and land use of the contributing drainage area. Some guidance for making this decision is provided in Table 53. Each option requires different levels of advance preparation. Moving up the trunk can begin immediately when an illicit discharge is detected at the outfall, and only requires a map of the storm drain system. Splitting the trunk and moving down the system require a little more preparation to analyze the storm drain map to find the critical branches to strategically sample manholes. Accurate storm drain maps are needed for all three options. If good mapping is not available, dye tracing can help identify manholes, pipes and junctions, and establish a new map of the storm drain network.

Option 1: Move up the Trunk

Moving up the trunk of the storm drain network is effective for illicit discharge problems in relatively small drainage areas. Field crews start with the manhole closest to the outfall, and progressively move up the network, inspecting manholes until indicators reveal that the discharge is no longer present (Figure 50). The goal is to isolate the discharge between two storm drain manholes.

Table 53: Methods to Attack the Storm Drain Network

Method	Nature of Investigation	Drainage System	Advance Prep Required
Follow the discharge up	Narrow source of an individual discharge	Small diameter outfall (< 36”) Simple drainage network	No
Split into segments	Narrow source of a discharge identified at outfall	Large diameter outfall (> 36”), Complex drainage Logistical or traffic issues may make sampling difficult.	Yes
Move down the storm drain	Multiple types of pollution, many suspected problems – possibly due to old plumbing practices or number of NPDES permits	Very large drainage area (> one square mile).	Yes

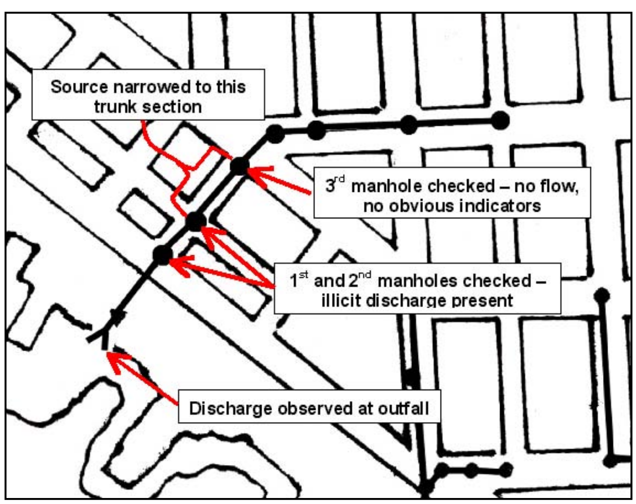


Figure 50: Example Investigation Following the Source up the Storm Drain System

Option 2: Split the storm drain network

When splitting the storm drain network, field crews select strategic manholes at junctions in the storm drain network to isolate discharges. This option is particularly suited in larger and more complex drainage areas since it can limit the total number of manholes to inspect, and it can avoid locations where access and traffic are problematic.

The method for splitting the trunk is as follows:

1. Review a map of the storm drain network leading to the suspect outfall.
2. Identify major contributing branches to the trunk. The trunk is defined as the largest diameter pipe in the storm drain network that leads directly to the outfall. The "branches" are networks of smaller pipes that contribute to the trunk.
3. Identify manholes to inspect at the farthest downstream node of each contributing branch and one immediately upstream (Figure 51).
4 Working up the network, investigate manholes on each contributing branch and trunk, until the source is narrowed to a specific section of the trunk or contributing branch.
5. Once the discharge is narrowed to a specific section of trunk, select the appropriate on-site investigation method to trace the exact source.
6. If narrowed to a contributing branch, move up or split the branch until a specific pipe segment is isolated, and commence the appropriate on-site investigation to determine the source.

Option 3: Move down the storm drain network

In this option, crews start by inspecting manholes at the "headwaters" of the storm drain network, and progressively move down pipe. This approach works best in very large drainage areas that have many potential continuous and/or intermittent discharges. The Boston Water and Sewer Commission has employed the headwater option to investigate intermittent discharges in complex drainage areas up to three square miles (Jewell, 2001). Field crews certify that each upstream branch of the storm drain network has no contributing discharges before moving down pipe to a "junction manhole" (Figure 52). If discharges are found, the crew performs dye testing to pinpoint the discharge. The crew then confirms that the discharge is removed before moving farther down the pipe network. Figure 53 presents a detailed flow chart that describes this option for analyzing the storm drain network.

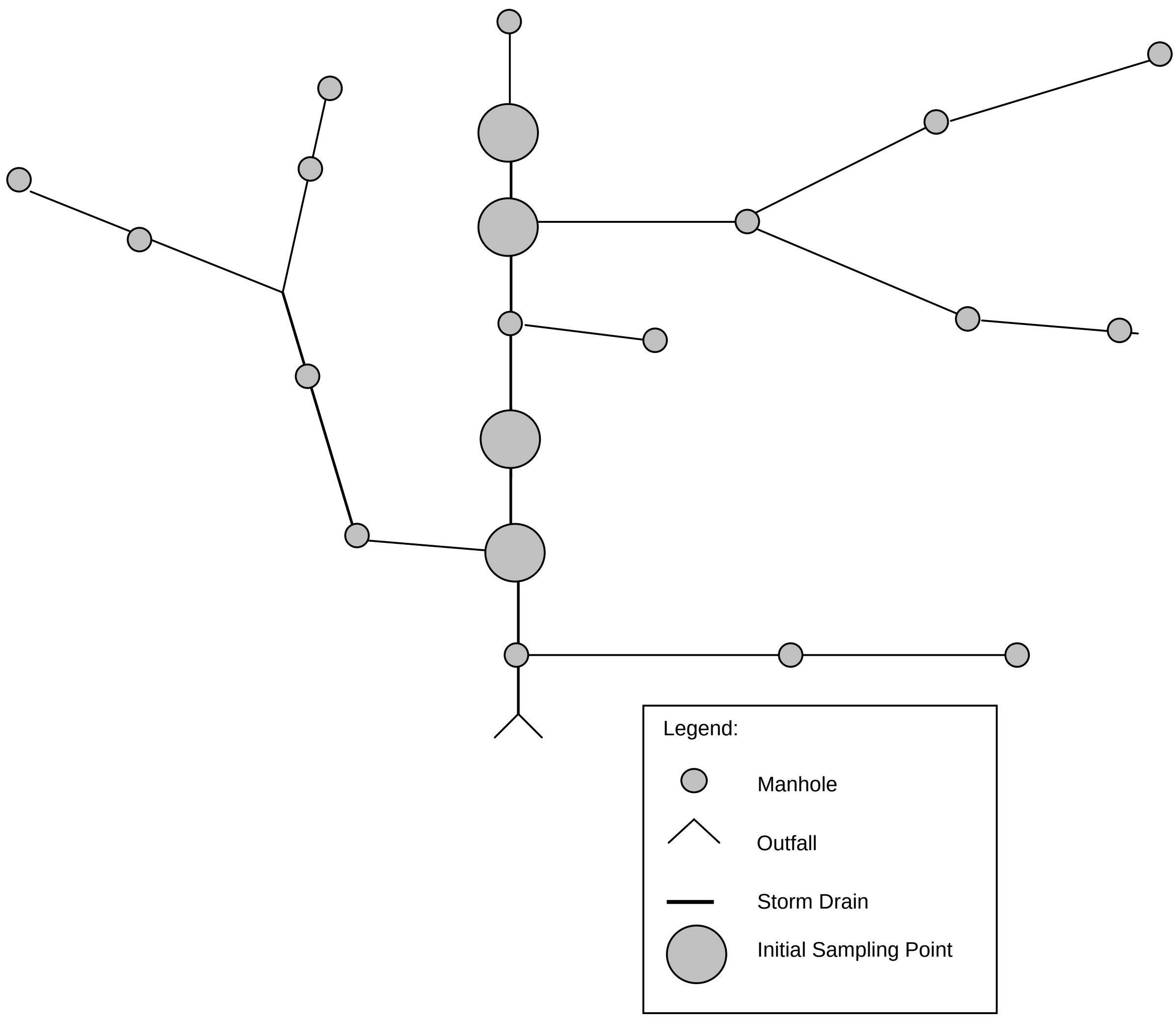


Figure 51: Key initial sampling points along the trunk of the storm drain

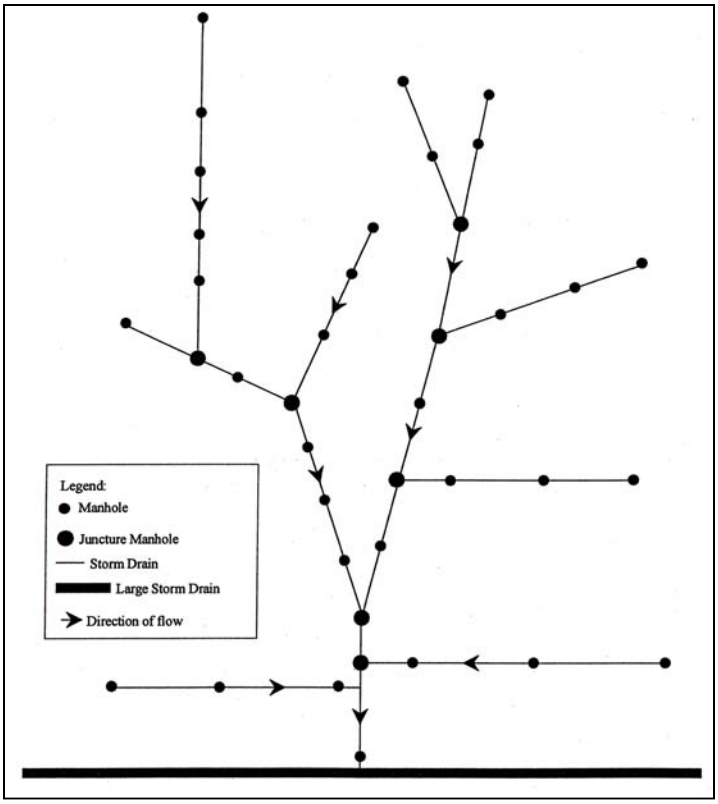


Figure 52: Storm Drain Schematic Identifying "Juncture Manholes" (Source: Jewell, 2001)

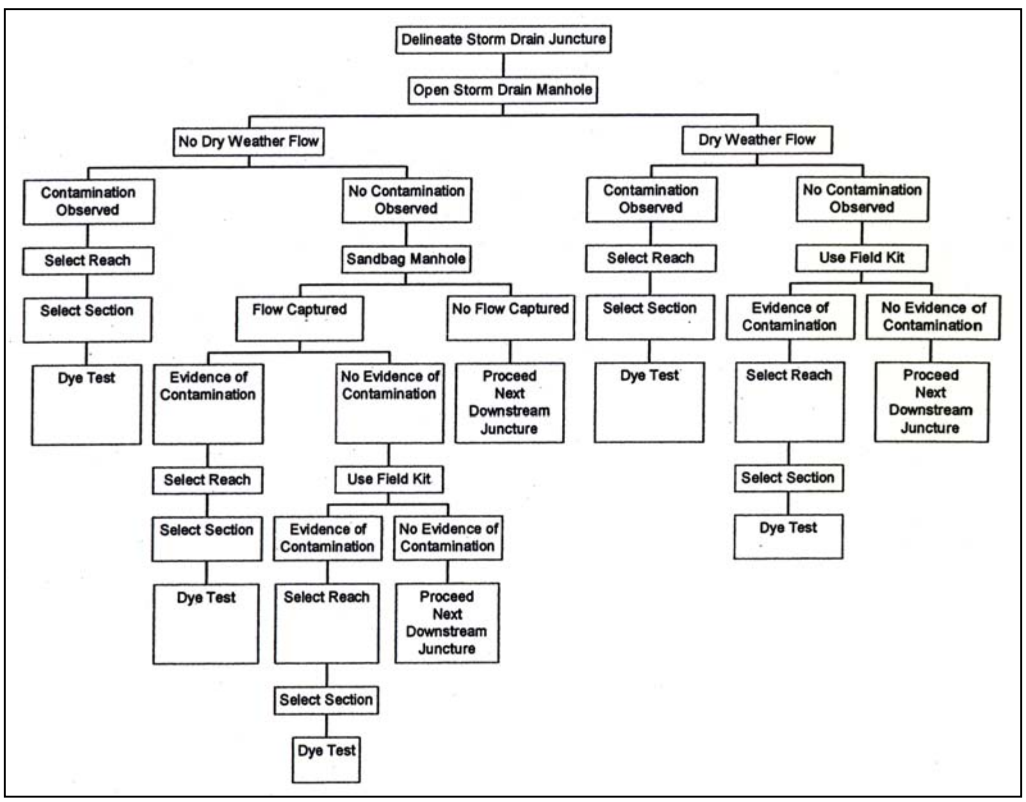


Figure 53: A Process for Following Discharges Down the Pipe (Source: Jewell, 2001)

Dye Testing to Create a Storm Drain Map

As noted earlier, storm drain network investigations are extremely difficult to perform if accurate storm drain maps are not available. In these situations, field crews may need to resort to dye testing to determine the flowpath within the storm drain network. Fluorescent dye is introduced into the storm drain network and suspected manholes are then inspected to trace the path of flow through the network (U.S. EPA, 1990). Two or three member crews are needed for dye testing. One person drops the dye into the trunk while the other(s) looks for evidence of the dye down pipe.

To conduct the investigation, a point of interest or down pipe "stopping point" is identified. Dye is then introduced into manholes upstream of the stopping point to determine if they are connected. The process continues in a systematic manner until an upstream manhole can no longer be determined, whereby a branch or trunk of the system can be defined, updated or corrected. More information on dye testing methods is provided in Section 13.3.

Manhole Inspection: Visual Observations and Indicator Sampling

Two primary methods are used to characterize discharges observed during manhole inspections—visual observations and indicator sampling. In both methods, field crews must first open the manhole to determine whether an illicit discharge is present. Manhole inspections require a crew of two and should be conducted during dry weather conditions.

Basic field equipment and safety procedures required for manhole inspections are outlined in Table 54. In particular, field crews need to be careful about how they will safely divert traffic (Figure 54). Other safety considerations include proper lifting of manhole covers to reduce the potential for back injuries, and testing whether any toxic or flammable fumes exist within the manhole before the cover is removed. Wayne County, MI has developed some useful operational procedures for inspecting manholes, which are summarized in Table 55.

Table 54: Basic Field Equipment Checklist	
• Camera and film or digital camera	• Storm drain, stream, and street maps
• Clipboards	• Reflective safety vests
• Field sheets	• Rubber / latex gloves
• Field vehicle	• Sledgehammer
• First aid kit	• Spray paint
• Flashlight or spotlight	• Tape measures
• Gas monitor and probe	• Traffic cones
• Manhole hook / crow bar	• Two-way radios
• Mirror	• Waterproof marker/pen
• Hand held global positioning satellite (GPS) system receiver (best resolution available within budget, at least 6' accuracy)	

Figure 54: Traffic cones divert traffic from manhole inspection area

Table 55: Field Procedure for Removal of Manhole Covers *(Adapted from: Pomeroy* et al.*, 1996)*
Field Procedures: 1. Locate the manhole cover to be removed. 2. Divert road and foot traffic away from the manhole using traffic cones. 3. Use the tip of a crowbar to lift the manhole cover up high enough to insert the gas monitor probe. Take care to avoid creating a spark that could ignite explosive gases that may have accumulated under the lid. Follow procedures outlined for the gas monitor to test for accumulated gases. 4. If the gas monitor alarm sounds, close the manhole immediately. Do not attempt to open the manhole until some time is allowed for gases to dissipate. 5. If the gas monitor indicates the area is clear of hazards, remove the monitor probe and position the manhole hook under the flange. Remove the crowbar. Pull the lid off with the hook. 6. When testing is completed and the manhole is no longer needed, use the manhole hook to pull the cover back in place. Make sure the lid is settled in the flange securely. 7. Check the area to ensure that all equipment is removed from the area prior to leaving.
Safety Considerations: 1. Do not lift the manhole cover with your back muscles. 2. Wear steel-toed boots or safety shoes to protect feet from possible crushing injuries that could occur while handling manhole covers. 3. Do not move manhole covers with hands or fingers. 4. Wear safety vests or reflective clothing so that the field crew will be visible to traffic. 5. Manholes may only be entered by properly trained and equipped personnel and when all OSHA and local rules are followed.

Visual Observations During Manhole Inspection

Visual observations are used to observe conditions in the manhole and look for any signs of sewage or dry weather flow. Visual observations work best for obvious illicit discharges that are not masked by groundwater or other "clean" discharges, as shown in Figure 55. Typically, crews progressively inspect manholes in the storm drain network to look for contaminated flows. Key visual observations that are made during manhole inspections include:

- Presence of flow
- Colors
- Odors
- Floatable materials
- Deposits or stains (intermittent flows)


Figure 55: Manhole observation (left) indicates a sewage discharge. Source is identified at an adjacent sewer manhole that overflowed into the storm drain system (right).

Indicator Sampling

If dry weather flow is observed in the manhole, the field crew can collect a sample by attaching a bucket or bottle to a tape measure/rope and lowering it into the manhole (Figure 56). The sample is then immediately analyzed in the field using probes or other tests to get fast results as to whether the flow is clean or dirty. The most common indicator parameter is ammonia, although other potential indicators are described in Chapter 12.

Manhole indicator data is analyzed by looking for "hits," which are individual samples that exceed a benchmark concentration. In addition, trends in indicator concentrations are also examined throughout the storm drain network.

Figure 56: Techniques to Sample from the Storm Drain

Figure 57 profiles a storm drain network investigation that used ammonia as the indicator parameter and a benchmark concentration of 1.0 mg/L. At both the outfall and the first manhole up the trunk, field crews recorded finding "hits" for ammonia of 2.2 mg/L and 2.3 mg/L, respectively. Subsequent manhole inspections further up the network revealed one manhole with no flow, and a second with a hit for ammonia (2.4 mg/L). The crew then tracked the discharge upstream of the second manhole, and found a third manhole with a low ammonia reading (0.05 mg/L) and a fourth with a much higher reading (4.3 mg/L). The crew then redirected its effort to sample above the fourth manhole with the 4.3 mg/L concentration, only to find another low reading. Based on this pattern, the crew concluded the discharge source was located between these two manholes, as nothing else could explain this sudden increase in concentration over this length of pipe.

The results of storm drain network investigations should be systematically documented to guide future discharge investigations, and describe any infrastructure maintenance problems encountered. An example of a sample manhole inspection field log is displayed in Figure 58.

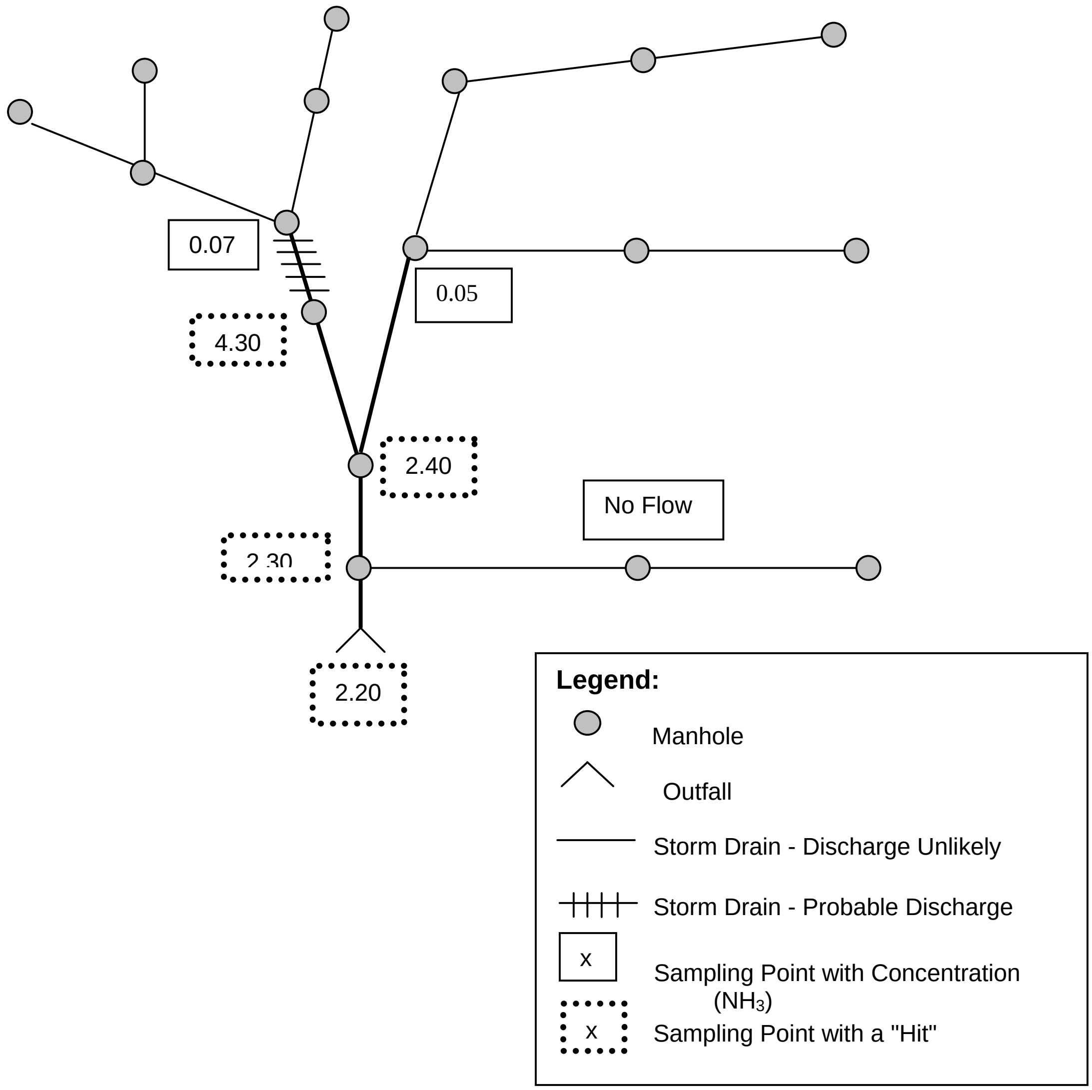


Figure 57: Use of Ammonia as a Trace Parameter to Identify an Illicit Discharge

BOSTON WATER AND SEWER COMMISSION
MANHOLE INSPECTION LOG

Manhole ID No. ____________

Inspection Date: ____________________ Tributary Area: ______________________________

Street: __________________________ Manhole Type:

Inspection: Not Found ___ Surface ___ Internal ___ Sanitary Sewer _____ Storm Drain _____

Follow Up Inspection _________ High Outlet _______ Lovejoy _______

Time Since Last Rain:

Inspector: __________________________ < 48 hours _____ 48 – 72 hours _____ > 72 hours _____

Observations:

Standing Water in Manhole: Yes ____ No ____ Color of Water: Clear ____ Cloudy ____ Other ____________

Flow in Manhole: Yes _____ No _____ Velocity: Slow _____ Medium _____ Fast _____ Depth of Flow: _____ in.

Color of Flow: No Flow: _____ Clear _____ Cloudy _____ Suspended Solids _____ Other ______________

Blockages: Yes _____ No _____ Sediment in Manhole: Yes ____ No____ If Yes: Percent of Pipe Filled: _____ %

Floatables: None _____ Sewage _____ Oily Sheen _____ Foam _____ Other ______________________

Odor: None _____ Sewage _____ Oil _____ Soap _____ Other ________________________________

Field Testing:

pH _____ Temp _____ Spec. Cond. _____ Surfactants: Yes _____ No __ Ammonia: Yes _____ No __

Contamination:

Found During Inspection Yes __ Check one: __Observation __Positive Test Kit Result

No __ Sandbagged Placed No __ Yes ____ Give Date _______

Sandbag Checked (Date): _______ Flow was ____ Captured ____ Not Captured:

Condition of Manhole:

Grade: At _____ Above_____ Below _____

Common Manholes:

High Outlet: Blocked Yes ___ No ___ NA ___

Lovejoy: Cover Plate in Place Yes ___ No ___ NA ___

	Good	Fair	Poor	Comments
Pavement	____	____	____	______________
Cover	____	____	____	______________
Frame	____	____	____	______________
Corbel	____	____	____	______________
Walls	____	____	____	______________
Floor	____	____	____	______________

Construction Material:

Brick	Precast	Other
___	___	______________
___	___	______________
___	___	______________

Comments: Manhole Correct as Mapped Yes _____ No _____

N↑

Plan of Manhole

Figure 58: Boston Water and Sewer Commission Manhole Inspection Log (Source: Jewell, 2001)

Methods to isolate intermittent discharges in the storm drain network

Intermittent discharges are often challenging to trace in the storm drain network, although four techniques have been used with some success.

Sandbags

This technique involves placement of sandbags or similar barriers within strategic manholes in the storm drain network to form a temporary dam that collects any intermittent flows that may occur. Any flow collected behind the sandbag is then assessed using visual observations or by indicator sampling. Sandbags are lowered on a rope through the manhole to form a dam along the bottom of the storm drain, taking care not to fully block the pipe (in case it rains before the sandbag is retrieved). Sandbags are typically installed at junctions in the network to eliminate contributing branches from further consideration (Figure 59). If no flow collects behind the sandbag, the upstream pipe network can be ruled out as a source of the intermittent discharge.

Sandbags are typically left in place for no more than 48 hours, and should only be installed when dry weather is forecast. Sandbags should not be left in place during a heavy rainstorm. They may cause a blockage in the storm drain, or, they may be washed downstream and lost. The biggest downside to sandbagging is that it requires at least two trips to each manhole.

Optical Brightener Monitoring (OBM) Traps

Optical brightener monitoring (OBM) traps, profiled in Chapter 12, can also be used to detect intermittent flows at manhole junctions. When these absorbent pads are anchored in the pipe to capture dry weather flows, they can be used to determine the presence of flow and/or detergents. These OBM traps are frequently installed by lowering them into an open-grate drop inlet or storm drain inlet, as shown in Figure 60.The pads are then retrieved after 48 hours and are observed under a fluorescent light (this method is most reliable for undiluted washwaters).

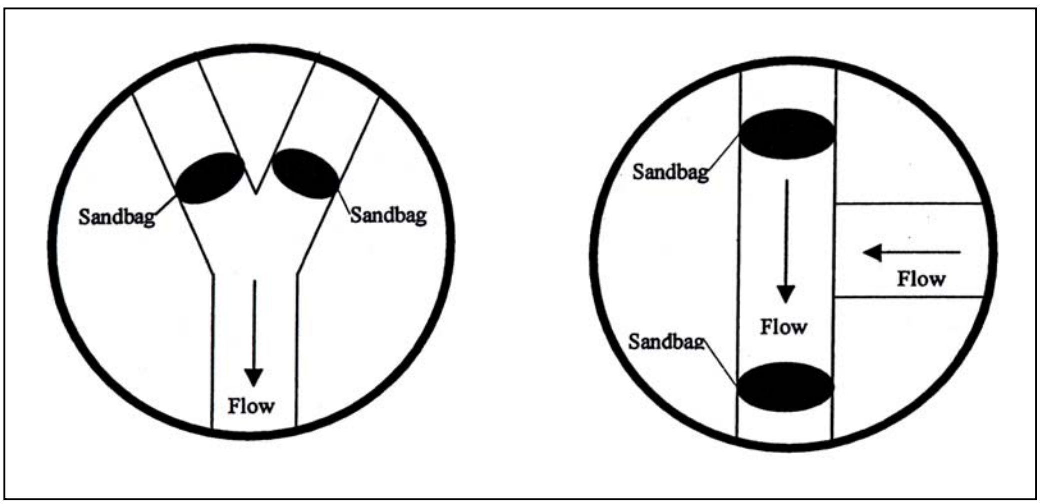


Figure 59: Example Sandbag Placement (Source: Jewell, 2001)

Figure 60: Optical Brightener Placement in the Storm Drain
(Source: Sargent and Castonguay, 1998)

Automatic Samplers

A few communities have installed automated samplers at strategic points within the storm drain network system that are triggered by small dry weather flows and collect water quality samples of intermittent discharges. Automated sampling can be extremely expensive, and is primarily used in very complex drainage areas that have severe intermittent discharge problems. Automated samplers can pinpoint the specific date and hours when discharges occur, and characterize its chemical composition, which can help crews fingerprint the generating source.

Observation of Deposits or Stains

Intermittent discharges often leave deposits or stains within the storm drain pipe or manhole after they have passed. Thus, crews should note whether any deposits or stains are present in the manhole, even if no dry weather flow is observed. In some cases, the origin of the discharge can be surmised by collecting indicator samples in the water ponded within the manhole sump. Stains and deposits, however, are not always a conclusive way to trace intermittent discharges in the storm drain network.

13.2 Drainage Area Investigations

The source of some illicit discharges can be determined through a survey or analysis of the drainage area of the problem outfall. The simplest approach is a rapid windshield survey of the drainage area to find the potential discharger or generating sites. A more sophisticated approach relies on an analysis of available GIS data and permit databases to identify industrial or other generating sites. In both cases, drainage area investigations are only effective if the discharge observed at an outfall has distinct or unique characteristics that allow crews to quickly ascertain the probable operation or business that is generating it. Often, discharges with a unique color, smell, or off-the-chart indicator sample reading may point to a specific industrial or commercial source. Drainage area investigations are not helpful in tracing sewage discharges, since they are often not always related to specific land uses or generating sites.

Rapid Windshield Survey

A rapid drive-by survey works well in small drainage areas, particularly if field crews are already familiar with its business operations. Field crews try to match the characteristics of the discharge to the most likely type of generating site, and then inspect all of the sites of the same type within the drainage area until the culprit is found. For example, if fuel is observed at an outfall, crews might quickly check every business operation in the catchment that stores or dispenses fuel. Another example is illustrated in Figure 61 where extremely dense algal growth was observed in a small stream during the winter. Field crews were aware of a fertilizer storage site in the drainage area, and a quick inspection identified it as the culprit.

Figure 61: Symptom (left): Extreme algal growth; Diagnosis (right): Cracked fertilizer storage is the phosphorus source

A third example of the windshield survey approach is shown in Figure 62, where a very thick, sudsy and fragrant discharge was noted at a small outfall. The discharge appeared to consist of wash water, and the only commercial laundromat found upstream was confirmed to be the source. On-site testing may still be needed to identify the specific plumbing or connection generating the discharge.

Detailed Drainage Area Investigations

In larger or more complex drainage areas, GIS data can be analyzed to pinpoint the source of a discharge. If only general land use data exist, maps can at least highlight suspected industrial areas. If more detailed SIC code data are available digitally, the GIS can be used to pull up specific hotspot operations or generating sites that could be potential dischargers. Some of the key discharge indicators that are associated with hotspots and specific industries are reviewed in Appendix K.

13.3 On-site Investigations

On-site investigations are used to pinpoint the exact source or connection producing a discharge within the storm drain network. The three basic approaches are dye, video and smoke testing. While each approach can determine the actual source of a discharge, each needs to be applied under the right conditions and test limitations (see Table 56). It should be noted that on-site investigations are not particularly effective in finding *indirect* discharges to the storm drain network.

Figure 62: The sudsy, fragrant discharge (left) indicates that the laundromat is the more likely culprit than the florist (right).

Table 56: Techniques to Locate the Discharge		
Technique	**Best Applications**	**Limitations**
Dye Testing	• Discharge limited to a very small drainage area (<10 properties is ideal) • Discharge probably caused by a connection from an individual property • Commercial or industrial land use	• May be difficult to gain access to some properties
Video Testing	• Continuous discharges • Discharge limited to a single pipe segment • Communities who own equipment for other investigations	• Relatively expensive equipment • Cannot capture non-flowing discharges • Often cannot capture discharges from pipes submerged in the storm drain
Smoke Testing	• Cross-connection with the sanitary sewer • Identifying other underground sources (e.g., leaking storage techniques) caused by damage to the storm drain	• Poor notification to public can cause alarm • Cannot detect all illicit discharges

TIP

The Wayne County Department of the Environment provides excellent training materials on on-site investigations, as well as other illicit discharge techniques. More information about this training can be accessed from their website: Http://www.wcdoe.org/Watershed/Programs___Srvcs_/IDEP/idep.htm.

Figure 63: Dye Testing Plumbing (NIWPC, 2003)

Dye Testing

Dye testing is an excellent indicator of illicit connections and is conducted by introducing non-toxic dye into toilets, sinks, shop drains and other plumbing fixtures (see Figure 63). The discovery of dye in the storm drain, rather than the sanitary sewer, conclusively determines that the illicit connection exists.

Before commencing dye tests, crews should review storm drain and sewer maps to identify lateral sewer connections and how they can be accessed. In addition, property owners must be notified to obtain entry permission. For industrial or commercial properties, crews should carry a letter to document their legal authority to gain access to the property. If time permits, the letter can be sent in advance of the dye testing. For residential properties, communication can be more challenging. Unlike commercial properties, crews are not guaranteed access to homes, and should call ahead to ensure that the owner will be home on the day of testing.

Communication with other local agencies is also important since any dye released to the storm drain could be mistaken for a spill or pollution episode. To avoid a costly and embarrassing response to a false alarm, crews should contact key spill response agencies using a "quick fax" that describes when and where dye testing is occurring (Tuomari and Thomson, 2002). In addition, crews should carry a list of phone numbers to call spill response agencies in the event dye is released to a stream.

At least two staff are needed to conduct dye tests – one to flush dye down the plumbing fixtures and one to look for dye in the downstream manhole(s). In some cases, three staff may be preferred, with two staff entering the private residence or building for both safety and liability purposes.

The basic equipment to conduct dye tests is listed in Table 57 and is not highly specialized. Often, the key choice is the type of dye to use for testing. Several options are profiled in Table 58. In most cases, liquid dye is used, although solid dye tablets can also be placed in a mesh bag and lowered into the manhole on a rope (Figure 64).

Table 57: Key Field Equipment for Dye Testing
(Source: Wayne County, MI, 2000)

Maps, Documents
- Sewer and storm drain maps (sufficient detail to locate manholes)
- Site plan and building diagram
- Letter describing the investigation
- Identification (e.g., badge or ID card)
- Educational materials (to supplement pollution prevention efforts)
- List of agencies to contact if the dye discharges to a stream.
- Name of contact at the facility

Equipment to Find and Lift the Manhole Safely (small manhole often in a lawn)
- Probe
- Metal detector
- Crow bar
- Safety equipment (hard hats, eye protection, gloves, safety vests, steel-toed boots, traffic control equipment, protective clothing, gas monitor)

Equipment for Actual Dye Testing and Communications
- 2-way radio
- Dye (liquid or "test strips")
- High powered lamps or flashlights
- Water hoses
- Camera

Figure 64: Dye in a mesh bag is placed into an upstream manhole (left); Dye observed at a downstream manhole traces the path of the storm drain (right)

If a longer pipe network is being tested, and dye is not expected to appear for several hours, charcoal packets can be used to detect the dye (GCHD, 2002). Charcoal packets can be secured and left in place for a week or two, and then analyzed for the presence of dye. Instructions for using charcoal packets in dye testing can be accessed at the following website: http://bayinfo.tamug.tamu.edu/gbeppubs/ms4.pdf.

The basic drill for dye tests consists of three simple steps. First, flush or wash dye down the drain, fixture or manhole. Second, pop open downgradient sanitary sewer manholes and check to see if any dye appears. If none is detected in the sewer manhole after an hour or so, check downgradient storm drain manholes or outfalls for the presence of dye. Although dye testing is fairly straightforward, some tips to make testing go more smoothly are offered in Table 59.

Table 58: Dye Testing Options

Product	Applications
Dye Tablets	• Compressed powder, useful for releasing dye over time • Less messy than powder form • Easy to handle, no mess, quick dissolve • Flow mapping and tracing in storm and sewer drains • Plumbing system tracing • Septic system analysis • Leak detection
Liquid Concentrate	• Very concentrated, disperses quickly • Works well in all volumes of flow • Recommended when metering of input is required • Flow mapping and tracing in storm and sewer drains • Plumbing system tracing • Septic system analysis • Leak detection
Dye Strips	• Similar to liquid but less messy
Powder	• Can be very messy and must dissolve in liquid to reach full potential • Recommended for very small applications or for very large applications where liquid is undesirable • Leak detection
Dye Wax Cakes	• Recommended for moderate-sized bodies of water • Flow mapping and tracing in storm and sewer drains
Dye Wax Donuts	• Recommended for large sized bodies of water (lakes, rivers, ponds) • Flow mapping and tracing in storm and sewer drains • Leak detection

Table 59: Tips for Successful Dye Testing
(Adapted from Tuomari and Thompson, 2002)

Dye Selection

- Green and liquid dyes are the easiest to see.
- Dye test strips can be a good alternative for residential or some commercial applications. (Liquid can leave a permanent stain).
- Check the sanitary sewer before using dyes to get a "base color." In some cases, (e.g., a print shop with a permitted discharge to the sanitary sewer), the sewage may have an existing color that would mask a dye.
- Choose two dye colors, and alternate between them when testing multiple fixtures.

Selecting Fixtures to Test

- Check the plumbing plan for the site to isolate fixtures that are separately connected.
- For industrial facilities, check most floor drains (these are often misdirected).
- For plumbing fixtures, test a representative fixture (e.g., a bathroom sink).
- Test some locations separately (e.g., washing machines and floor drains), which may be misdirected.
- If conducting dye investigations on multiple floors, start from the basement and work your way up.
- At all fixtures, make sure to flush with plenty of water to ensure that the dye moves through the system.

Selecting a Sewer Manhole for Observations

- Pick the closest manhole possible to make observations (typically a sewer lateral).
- If this is not possible, choose the nearest downstream manhole.

Communications Between Crew Members

- The individual conducting the dye testing calls in to the field person to report the color dye used, and when it is dropped into the system.
- The field person then calls back when dye is observed in the manhole.
- If dye is not observed (e.g., after two separate flushes have occurred), dye testing is halted until the dye appears.

Locating Missing Dye

- The investigation is not complete until the dye is found. Some reasons for dye not appearing include:
- The building is actually hooked up to a septic system.
- The sewer line is clogged.
- There is a leak in the sewer line or lateral pipe.

Video Testing

Video testing works by guiding a mobile video camera through the storm drain pipe to locate the actual connection producing an illicit discharge. Video testing shows flows and leaks within the pipe that may indicate an illicit discharge, and can show cracks and other pipe damage that enable sewage or contaminated water to flow into the storm drain pipe.

Video testing is useful when access to properties is constrained, such as residential neighborhoods. Video testing can also be expensive, unless the community already owns and uses the equipment for sewer inspections. This technique will not detect all types of discharges, particularly when the illicit connection is not flowing at the time of the video survey.

Different types of video camera equipment are used, depending on the diameter and condition of the storm sewer being tested.

Field crews should review storm drain maps, and preferably visit the site before selecting the video equipment for the test. A field visit helps determine the camera size needed to fit into the pipe, and if the storm drain has standing water.

In addition to standard safety equipment required for all manhole inspections, video testing requires a Closed-Circuit Television (CCTV) and supporting items. Many commercially available camera systems are specifically adapted to televise storm sewers, ranging from large truck or van-mounted systems to much smaller portable cameras. Cameras can be self-propelled or towed. Some specifications to look for include:

- The camera should be capable of radial view for inspection of the top, bottom, and sides of the pipe and for looking up lateral connections.
- The camera should be color.
- Lighting should be supplied by a lamp on the camera that can light the entire periphery of the pipe.

When inspecting the storm sewer, the CCTV is oriented to keep the lens as close as possible to the center of the pipe. The camera can be self-propelled through the pipe using a tractor or crawler unit or it may be towed through on a skid unit (see Figures 65 and 66). If the storm drain has ponded water, the camera should be attached to a raft, which floats through the storm sewer from one manhole to the next. To see details of the sewer, the camera and lights should be able to swivel both horizontally and vertically. A video record of the inspection should be made for future reference and repairs (see Figure 67).

Smoke Testing

Smoke testing is another “bottom up” approach to isolate illicit discharges. It works by introducing smoke into the storm drain system and observing where the smoke surfaces. The use of smoke testing to detect illicit discharges is a relatively new application, although many communities have used it to check for infiltration and inflow into their sanitary sewer network. Smoke testing can find improper connections, or damage to the storm drain

Figure 66: Tractor-mounted Camera

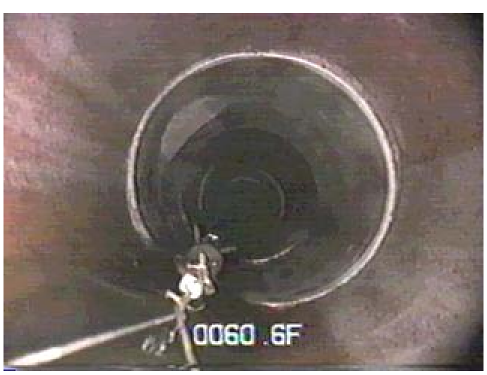


Figure 65: Camera being towed

Figure 67: Review of an Inspection Video

system (Figure 68). This technique works best when the discharge is confined to the upper reaches of the storm drain network, where pipe diameters are to small for video testing and gaining access to multiple properties renders dye testing infeasible.

Notifying the public about the date and purpose of smoke testing before starting is critical. The smoke used is non-toxic, but can cause respiratory irritation, which can be a problem for some residents. Residents should be notified at least two weeks prior to testing, and should be provided the following information (Hurco Technologies, Inc., 2003):

- Date testing will occur
- Reason for smoke testing
- Precautions they can take to prevent smoke from entering their homes or businesses
- What they need to do if smoke enters their home or business, and any health concerns associated with the smoke
- A number residents can call to relay any particular health concerns (e.g., chronic respiratory problems)

Program managers should also notify local media to get the word out if extensive smoke testing is planned (e.g., television, newspaper, and radio). On the actual day of testing, local fire, police departments and 911 call centers should be notified to handle any calls from the public (Hurco Technologies, Inc., 2003).

The basic equipment needed for smoke testing includes manhole safety equipment, a smoke source, smoke blower, and sewer plugs. Two smoke sources can be used for smoke testing. The first is a smoke "bomb," or "candle" that burns at a controlled rate and releases very white smoke visible at relatively low concentrations (Figure 69). Smoke bombs are suspended beneath a blower in a manhole. Candles are available in 30 second to three minute sizes. Once opened, smoke bombs should be kept in a dry location and should be used within one year.

The second smoke source is liquid smoke, which is a petroleum-based product that is injected into the hot exhaust of a blower where it is heated and vaporized (Figure 70). The length of smoke production can vary depending on the length of the pipe being tested. In general, liquid smoke is not as consistently visible and does not travel as far as smoke from bombs (USA Blue Book).

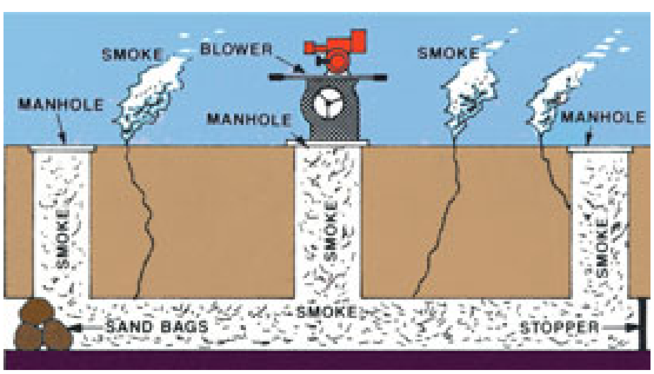


Figure 68: Smoke Testing System Schematic

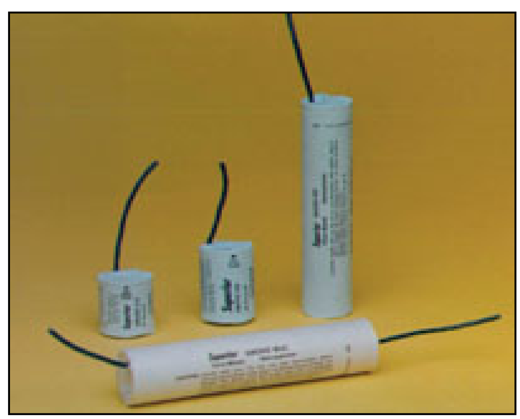


Figure 69: Smoke Candles

Figure 70: Smoke Blower

Smoke blowers provide a high volume of air that forces smoke through the storm drain pipe. Two types of blowers are commonly used: “squirrel cage” blowers and direct-drive propeller blowers. Squirrel cage blowers are large and may weigh more than 100 pounds, but allow the operator to generate more controlled smoke output. Direct-drive propeller blowers are considerably lighter and more compact, which allows for easier transport and positioning.

Three basic steps are involved in smoke testing. First, the storm drain is sealed off by plugging storm drain inlets. Next, the smoke is released and forced by the blower through the storm drain system. Lastly, the crew looks for any escape of smoke above-ground to find potential leaks.

One of three methods can be used to seal off the storm drain. Sandbags can be lowered into place with a rope from the street surface. Alternatively, beach balls that have a diameter slightly larger than the drain can be inserted into the pipe. The beach ball is then placed in a mesh bag with a rope attached to it so it can be secured and retrieved. If the beach ball gets stuck in the pipe, it can simply be punctured, deflated and removed. Finally, expandable plugs are available, and may be inserted from the ground surface.

Blowers should be set up next to the open manhole after the smoke is started. Only one manhole is tested at a time. If smoke candles are used, crews simply light the candle, place it in a bucket, and lower it in the manhole. The crew then watches to see where smoke escapes from the pipe. The two most common situations that indicate an illicit discharge are when smoke is seen rising from internal plumbing fixtures (typically reported by residents) or from sewer vents (Figure 71). Sewer vents extend upward from the sewer lateral to release gas buildup, and are not supposed to be connected to the storm drain system.

Figure 71: Smoke Rising from Sewer Vent

13.4 Septic System Investigations

The techniques for tracing illicit discharges are different in rural or low-density residential watersheds. Often, these watersheds lack sanitary sewer service and storm water is conveyed through ditches or swales, rather than enclosed pipes. Consequently, many illicit discharges enter the stream as indirect discharges, through surface breakouts of septic fields or through straight pipe discharges from bypassed septic systems.

The two broad techniques used to find individual septic systems -- on-site investigations and infrared imagery – are described in this section.

On-Site Septic Investigations

Three kinds of on-site investigations can be performed at individual properties to determine if the septic system is failing, including homeowner survey, surface condition analysis and a detailed system inspection. The first two investigations are rapid and relatively simple assessments typically conducted in targeted watershed areas. Detailed system inspections are a much more thorough investigation of the functioning of the septic system that is conducted by a certified professional. Detailed system inspections may occur at time of sale of a property, or be triggered by poor scores on the rapid homeowner survey or surface condition analysis.

Homeowner Survey

The homeowner survey consists of a brief interview with the property owner to determine the potential for current or future failure of the septic system, and is often done in conjunction with a surface condition analysis. Table 60 highlights some common questions to ask in the survey, which inquire about resident behaviors, system performance and maintenance activity.

Surface Condition Analysis

The surface condition analysis is a rapid site assessment where field crews look for obvious indicators that point to current or potential production of illicit discharges by the septic system (Figure 72). Some of the key surface conditions to analyze have been described by Andrews *et al*., (1997) and are described below:

- Foul odors in the yard
- Wet, spongy ground; lush plant growth; or burnt grass near the drain field
- Algal blooms or excessive weed growth in adjacent ditches, ponds and streams
- Shrubs or trees with root damage within 10 feet of the system
- Cars, boats, or other heavy objects located over the field that could crush lateral pipes
- Storm water flowing over the drain field
- Cave-ins or exposed system components
- Visible liquid on the surface of the drain field (e.g., surface breakouts)
- Obvious system bypasses (e.g., straight pipe discharges)

Table 60: Septic System Homeowner Survey Questions ***(Adapted from Andrews et al., 1997 and Holmes Inspection Services)***
• How many people live in the house?[1] • What is the septic tank capacity?[2] • Do drains in the house empty slowly or not at all? • When was the last time the system was inspected or maintained? • Does sewage back up into the house through drain lines? • Are there any wet, smelly spots in the yard? • Is the septic tank effluent piped so it drains to a road ditch, a storm sewer, a stream, or is it connected to a farm drain tile?
[1] Water usage ranges from 50 to 100 gallons per day per person. This information can be used to estimate the wastewater load from the house (Andrews *et. al*, 1997). [2] The septic tank should be large enough to hold two days' worth of wastewater (Andrews *et. al*, 1997).

Figure 72: (a) Wet, spongy ground. Grass may be bright green or burnt due to high nutrient loading. (b) Straight pipe discharge to nearby stream. (c) Algal bloom in a nearby pond.
(Sources: a- Anish Jantrania; b- Snohomish County, WA c- King County, WA)

Detailed System Inspection

The detailed system inspection is a much more thorough inspection of the performance and function of the septic system, and must be completed by a certified professional. The inspector certifies the structural integrity of all components of the system, and checks the depth of solids in the septic tank to determine if the system needs to be pumped out. The inspector also sketches the system, and estimates distance to groundwater, surface water, and drinking water sources. An example septic system inspection form from Massachusetts can be found at http://www.state.ma.us/dep/brp/wwm/soilsys.htm.

Although not always incorporated into the inspection, dye testing can sometimes point to leaks from broken pipes, or direct discharges through straight pipes that might be missed during routine inspection. Dye can be introduced into plumbing fixtures in the home, and flushed with sufficient running water. The inspector then watches the septic field, nearby ditches, watercourses and manholes for any signs of the dye (Figure 73). The dye may take several hours to appear, so crews may want to place charcoal packets in adjacent waters to capture dye until they can return later to retrieve them.

Figure 73: Dye surfacing in a septic field

Infrared Imagery

Infrared imagery is a special type of photography with gray or color scales that represent differences in temperature and emissivity of objects in the image (www.stocktoninfrared.com), and can be used to locate sewage discharges. Several different infrared imagery techniques can be used to identify illicit discharges. The following discussion highlights two of these: aerial infrared thermography[13] and color infrared aerial photography.

Infrared Thermography

Infrared thermography is increasingly being used to detect illicit discharges and failing septic systems. The technique uses the

[13] Infrared thermography is also being used by communities such as Mecklenburg County and the City of Charlotte in NC to detect illicit discharges at outfalls.

temperature difference of sewage as a marker to locate these illicit discharges. Figure 74 illustrates the thermal difference between an outfall discharge (with a higher temperature) and a stream.

The equipment needed to conduct aerial infrared thermography includes an aircraft (plane or helicopter); a high-resolution, large format, infrared camera with appropriate mount; a GPS unit; and digital recording equipment. If a plane is used, a higher resolution camera is required since it must operate at higher altitudes. Pilots should be experienced since flights take place at night, slowly, and at a low altitude. The camera may be handheld, but a mounted camera will provide significantly clearer results for a larger area. The GPS can be combined with a mobile mapping program and a video encoder-decoder that encodes and displays the coordinates, date, and time (Stockton, 2000). The infrared data are analyzed after the flight by trained analysts to locate suspected discharges, and field crews then inspect the ground-truthed sites to confirm the presence of a failing septic system.

Late fall, winter, and early spring are typically the best times of year to conduct these investigations in most regions of the country. This allows for a bigger difference between receiving water and discharge temperatures, and interference from vegetation is minimized (Stockton, 2004b). In addition, flights should take place at night to minimize reflected and direct daylight solar radiation that may adversely affect the imagery (Stockton, 2004b).

Figure 74: Aerial Thermography Showing Sewage Leak

Color Infrared Aerial Photography

Color infrared aerial photography looks for changes in plant growth, differences in soil moisture content, and the presence of standing water on the ground to primarily identify failing septic systems (Figure 75).

The Tennessee Valley Authority (TVA) uses color infrared aerial photography to detect failing septic systems in reservoir watersheds. Local health departments conduct follow-up ground-truthing surveys to determine if a system is actually failing (Sagona, 1986). Similar to thermography, it is recommended that flights take place at night, during leaf-off conditions, or when the water table is at a seasonal high (which is when most failures typically occur (U.S. EPA, 1999).

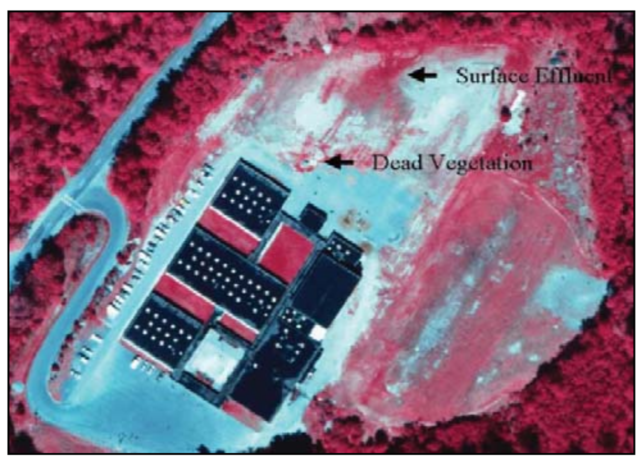


Figure 75: Dead vegetation and surface effluent are evidence of a septic system surface failure.
(Source: U.S. EPA, 1999)

13.5 The Cost to Trace Illicit Discharge Sources

Tracing illicit discharges to their source can be an elusive and complex process, and precise staffing and budget data are difficult to estimate. Experience of Phase I NPDES communities that have done these investigations in the past can shed some light on cost estimates. Some details on unit costs for common illicit discharge investigations are provided below.

Costs for Dye, Video, and Smoke Testing

The cost of smoke, dye, and video testing can be substantial and staff intensive, and often depend on investigation specific factors, such as the complexity of the drainage network, density and age of buildings, and complexity of land use. Wayne County, MI, has estimated the cost of dye testing at $900 per facility. Video testing costs range from $1.50 to $2.00 per foot, although this increases by $1.00 per foot if pipe cleaning is needed prior to testing.

Table 61 summarizes the costs of start-up equipment for basic manhole entry and inspection, which is needed regardless of which type of test is performed. Tables 62 through 64 provide specific equipment costs for dye, video and smoke testing, respectively.

Table 61: Common Field Equipment Needed for Dye, Video, and SmokeTesting

Item	Cost
1 Digital Camera	$200
Clipboards, Pens, Batteries	$25
1 Field vehicle	$15,000 - $35,000
1 First aid kit	$30
1 Spotlight	$40
1 Gas monitor and probe	$900 - $2,100
1 Hand-held GPS Unit	$150
2 Two-way radios	$250 - $750
1 Manhole hook	$80 - $130
1 Mirror	$70 - $130
2 Reflective safety vests	$40
Rubber/latex gloves (box of 100)	$25
1 Can of Spray Paint	$5
4 Traffic Cones	$50

Table 62: Equipment Costs for Dye Testing		
Product	**Water Volume**	**Cost**
Dye Strips	1 strip / 500 gallons	$75 - $94 per 100 strips
Dye Tablets	0 – 50,000 gallons	$40 per 200 tablets
Liquid Concentrate (Rhodamine WT)	0 – 50,000 gallons	$80 - $90 per gallon $15 - $20 per pint
Powder	50,000 + gallons	$77 per lb
Dye Wax Cakes	20,000 – 50,000 gallons	$12 per one 1.25 ounce cake
Dye Wax Donuts	50,000 + gallons	$104 - $132 per 42 oz. donut
Price Sources: *Aquatic Eco-Systems http://www.aquaticeco.com/* *Cole Parmer http:/www.coleparmer.com* *USA Blue Book http:/www.usabluebook.com*		

Table 63: Equipment Costs for Video Testing	
Equipment	**Cost**
GEN-EYE 2™ B&W Sewer Camera with VCR & 200' Push Cable	$5,800
100' Push Rod and Reel Camera for 2" – 10" Pipes	$5,300
200' Push Rod and Reel Camera for 8" – 24" Pipes	$5,800
Custom Saturn III Inspection System 500' cable for 6-16" Lines	$32,000 ($33,000 with 1000 foot cable)
OUTPOST • Box with build-out • Generator • Washdown system	$6,000 $2,000 $1,000
Video Inspection Trailer • 7'x10' trailer & build-out • Hardware and software package • Incidentals	$18,500 $15,000 $5,000
Sprinter Chassis Inspection Vehicle • Van (with build-out for inspecting 6" – 24" pipes) • Crawler (needed to inspect pipes >24") • Software upgrade (optional but helpful for extensive pipe systems)	$130,000 $18,000 $8,000
Sources: USA Blue Book and Envirotech	

Table 64: Equipment Costs for Smoke Testing	
Equipment	**Cost**
Smoke Blower	$1,000 to $2,000 each
Liquid Smoke	$38 to $45 per gallon
Smoke Candles, 30 second (4,000 cubic feet)	$27.50 per dozen
Smoke Candles, 60 Second (8,000 cubic feet)	$30.50 per dozen
Smoke Candles, 3 Minute (40,000 cubic feet)	$60.00 per dozen
Sources: Hurco Tech, 2003 and Cherne Industries, 2003	

Costs for Septic System Investigations

Most septic system investigations are relatively low cost, but factors such as private property access, notification, and the total number of sites investigated can increase costs. Unit costs for the three major septic system investigations are described below.

Homeowner Survey and Surface Condition Analysis

Both the homeowner survey and the surface condition analysis are relatively low cost investigation techniques. Assuming that a staff person can investigate one home per hour, the average cost per inspection is approximately $25. A substantial cost savings can be realized by using interns or volunteers to conduct these simple investigations.

Detailed System Inspection

Septic system inspections are more expensive, but a typical unit cost is about $250, and may also include an additional cost of pumping the system, at roughly $150, if pumping is required to complete the inspection (Wayne County, 2003). This cost is typically charged to the homeowner as part of a home inspection.

Aerial Infrared Thermography

The equipment needed to conduct aerial infrared thermography is expensive; cameras alone may range from $250,000 to $500,000 (Stockton, 2004a). However, private contractors provide this service. In general, the cost to contract an aerial infrared thermography investigation depends on the length of the flight (flights typically follow streams or rivers); how difficult it will be to fly the route; the number of heat anomalies expected to be encountered; the expected post-flight processing time (typically, four to five hours of analysis for every hour flown); and the distance of the site from the plane's "home" (Stockton, 2004a). The cost range is typically $150 to $400 per mile of stream or river flown, which includes the flight and post-flight analyses (Stockton, 2004a).

As an alternative, local police departments may already own an infrared imaging system that may be used. For instance, the Arkansas Department of Health used a state police helicopter with a Forward Looking Infrared (FLIR) imaging system, GPS, video equipment, and maps (Eddy, 2000). The disadvantage to this is that the equipment may not be available at optimal times to conduct the investigation. In addition, infrared imaging equipment used by police departments may not be sensitive enough to detect the narrow range of temperature difference (only a few degrees) often expected for sewage flows (Stockton, 2004a).

Chapter 14: Techniques to Fix Discharges

Quick and efficient correction of illicit discharges begins with having well defined legal authority and responsibilities coupled with strong enforcement and follow-up measures. Chapter 4 discussed important considerations with respect to legal authority and responsibility and Appendix B contains a model illicit discharge ordinance that provides language on violations, enforcement and penalties.

Most illicit discharge corrective actions involve some form of infrastructure modification or repair. These structural repairs are used to eliminate a wide variety of **direct discharges** such as sewage cross-connections, straight pipes, industrial cross-connections, and commercial cross-connections. Fixes range from simple plumbing projects to excavation and replacement of sewer lines. In some cases, structural repairs are necessary when **indirect** discharges, such as sewage from a sewer break or pump station failure enter the MS4 through an inlet, or flows directly into receiving waters. Most **transitory** discharges are corrected simply with spill containment and clean-up procedures. Section 8.3 previously discussed an overview of the correction process. The following section discusses more specific correction considerations.

14.1 Implementation Considerations

Once the source of an illicit discharge has been identified, steps should be taken to fix or eliminate the discharge. The following four questions should be answered for each individual illicit discharge to determine how to proceed:

- Who is responsible?
- What methods will be used to fix it?
- How long will it take?
- How will removal be confirmed?

The answer to each of these questions depends on the source of the discharge. Illicit discharges generally originate from one of the following sources:

- *An internal plumbing connection* (e.g., the discharge from a washing machine is directed to the building's storm lateral; the floor drain in a garage is connected to the building's storm lateral)
- *A service lateral cross-connection* (e.g., the sanitary lateral from a building is connected to the MS4)
- *An infrastructure failure within the sanitary sewer or MS4* (e.g., a collapsed sanitary line is discharging into the MS4)
- *An indirect transitory discharge resulting from leaks, spills, or overflows.*

Financial responsibility for source removal will typically fall on property owners, MS4 operators, or some combination of the two.

Who's responsible for fixing the problem?

Ultimate responsibility for removing the source of a discharge is generally that of either the property owner or the municipality/utility (e.g., primary owner/operator of the MS4).

Internal Plumbing Connection

The responsibility for correcting an internal plumbing connection is generally the responsibility of the building owner. Communities may wish to develop a list of certified contractors that property owners can hire for corrections.

Service Lateral

As with internal plumbing connections, the responsibility for correcting a problem within a service lateral is typically that of the property owner being served by the lateral. However, the cost of correcting a service lateral problem can be significantly higher than that of fixing an internal plumbing problem, so communities may want to consider alternative remedial approaches than those for internal plumbing corrections. For example, communities can have on-call contractors fix lateral connections allowing the problem to be fixed as soon as it is discovered. The community can then: 1) pay for correction costs through the capital budget, or state or federal funding options, or 2) share the cost with the owner, or 3) pass on the full cost to the property owner.

Infrastructure Failure Within the Sanitary Sewer or MS4

Illicit discharges related to some sort of infrastructure failure within the sanitary sewer or MS4 should be corrected by the jurisdiction, utility, or agency responsible for maintenance of the sewers and drains.

Transitory Discharge

Repair of transitory discharge sources will usually be the responsibility of the property owner where the discharge originates. Ordinances should clearly stipulate the time frame in which these discharges should be repaired.

What methods will be used to fix the problem?

The methods used to eliminate discharges will vary depending on the type of problem and the location of the problem. Internal plumbing corrections can often be performed using standard plumbing supplies for relatively little cost. For correction locations that occur outside of the building, such as service laterals or infrastructure in the right of way, costs tend to be significantly more due to specialized equipment needs. Certified contractors are recommended for these types of repairs. Table 65 provides a summary of a range of methods for fixing these more significant problems along with estimated costs. The last six techniques described in Table 68 are used for sanitary sewer line repair and rehabilitation. These activities are typically used when there is evidence of significant seepage from the sanitary system to the storm drain system.

How long should it take?

The timeframe for eliminating a connection or discharge should depend on the type of connection or discharge and how difficult elimination will be. A discharge that poses a significant threat to human or environmental health should be discontinued and eliminated immediately. Clear guidance should be provided in the local ordinance on the timeframe for removing discharges and connections. Typically, discharges should be stopped within seven days of notification by the municipality, and illicit connections should be repaired within 30 days of notification.

How is the removal or correction confirmed?

Removal and correction of a discharge or connection should be confirmed both at the source, to ensure that the correction has been made, and downstream, to ensure that it is the only local discharge present.

For discharges resulting from internal plumbing and lateral connections, dye testing can confirm the correction. Also, sandbagging should be done in the first accessible storm drain manhole downstream of the correction to verify that this was the only discharge present.

The correction of discharges resulting from some sort of infrastructure failure in the sanitary sewer or MS4 can be verified by dye testing or televising the line in conjunction with sandbagging and sampling at an accessible downstream manhole.

Table 65: Methods to Eliminate Discharges

Technique	Application	Description	Estimated Cost
1. Service Lateral Disconnection, Reconnection	Lateral is connected to the wrong line	Lateral is disconnected and reconnected to appropriate line	$2,500[1]
2. Cleaning	Line is blocked or capacity diminished	Flushing (sending a high pressure water jet through the line); pigging (dragging a large rubber plug through the lines); or rodding	$1 / linear foot[2]
3. Excavation and Replacement	Line is collapsed, severely blocked, significantly misaligned, or undersized	Existing pipe is removed, new pipe placed in same alignment; Existing pipe abandoned in place, replaced by new pipe in parallel alignment	For 14" line, $50-$100 / linear foot (higher number is associated with repaving or deeper excavations, if necessary)[2]
4. Manhole Repair	Decrease ponding; prevent flow of surface water into manhole; prevent groundwater infiltration	Raise frame and lid above grade; install lid inserts; grout, mortar or apply shortcrete inside the walls; install new precast manhole.	Vary widely, from $250 to raise a frame and cover to ~ $2,000 to replace manhole[2]
5. Corrosion Control Coating	Improve resistance to corrosion	Spray- or brush-on coating applied to interior of pipe.	< $10 / linear foot[2]
6. Grouting	Seal leaking joints and small cracks	Seals leaking joints and small cracks.	For a 12" line, ~ $36-$54 / linear foot[2]
7. Pipe Bursting	Line is collapsed, severely blocked, or undersized	Existing pipe used as guide for inserting expansion head; expansion head increases area available for new pipe by pushing existing pipe out radially until it cracks; bursting device pulls new pipeline behind it	For 8" pipe, $40-$80 / linear foot[4]
8. Slip Lining	Pipe has numerous cracks, leaking joints, but is continuous and not misaligned	Pulling of a new pipe through the old one.	For 12" pipe, $50-$75 / linear foot[2]
9. Fold and Formed Pipe	Pipe has numerous cracks, leaking joints	Similar to sliplining but is easier to install, uses existing manholes for insertion; a folded thermoplastic pipe is pulled into place and rounded to conform to internal diameter of existing pipe	For 8-12" pipe, $60-$78 / linear foot[3]

Table 65: Methods to Eliminate Discharges			
Technique	**Application**	**Description**	**Estimated Cost**
10. Inversion Lining	Pipe has numerous cracks, leaking joints; can be used where there are misalignments	Similar to sliplining but is easier to install, uses existing manholes for insertion; a soft resin impregnated felt tube is inserted into the pipe, inverted by filling it with air or water at one end, and cured in place.	\$75-\$125 / linear foot[2]
[1] CWP (2002) [2] 1991 costs from Brown (1995) [3] U.S. EPA (1991) [4] U.S. EPA (1999b)			

References

American Public Works Association (APWA). 2001. Designing and Implementing an Effective Storm Water Management Program: Storm Water NPDES Phase II Regulations. Kansas City, MO.

Andrews, E. 1997. *Home*A*Syst An Environmental Risk-Assessment Guide for the Home*. Northeast Regional Agricultural Engineering Service, Regents of the University of Wisconsin.

Brown, Ellen K. 1995. Investigation and Rehabilitation of Sewer Systems (Fact Sheet). Presented at: Navy Pollution Prevention Conference. June 6, 1995. Available online: (http://es.epa.gov/program/p2dept/defense/navy/navysewr.html (Accesssed 2004)

Burton, Jr., G.A. and R. Pitt. 2002. Stormwater Effects Handbook: A Tool Box for Watershed Managers, Scientists and Engineers. CRC/Lewis Publishers, Boca Raton, FL, 924 pp.

Center for Watershed Protection. 2002. Unpublished Task I Technical Memorandum: Phase I Community Surveys in Support of Illicit Discharge Detection and Elimination Guidance Manual. IDDE project support material.

Center for Watershed Protection. 1998. Rapid Watershed Planning Handbook: A Comprehensive Guide for Managing Urbanizing Watersheds. Center for Watershed Protection. Ellicott City, MD.

Cherne Industries. Website. http://www.cherneind.com. Accessed 2003.

City of Denver. Website. http://www.denvergov.org/recycle/hhw_collection.asp. Accessed 2004.

City of Fort Worth Department of Environmental Management. 1993. Stream Sentinel Operational Guide. Fort Worth, TX.

Duke, L.R. 1997. Evaluation of Non-Storm Water Discharges to California Storm Drains and Potential Policies for Effective Prohibition. California Regional Water Quality Control Board. Los Angeles, CA.

Duke, L. and K. Shaver. 1999. Widespread failure to comply with U.S. Stormwater Regulations for Industry: Parts I and II in *Environmental Engineering Science*. 16(4)

Eddy, N. 2000. “Arkansas Sanitarian Uses Infrared Technology to Track Down Sewage.” *Small Flows Quarterly* 1(2): 22-24. National Small Flows Clearinghouse, Morgantown, West Virginia.

Galveston County Health District Pollution Control Division (CGHD). 1990. A Guidance Manual for Identifying and Eliminating Illicit Connections to Municipal Separate Storm Sewer Systems (MS4).

Gartner Lee and Associates (GLA). 1983. Toronto Area Watershed Management Strategy Study - Humber River and Tributary Dry Weather Outfall Study. Technical Report #1. Ontario Ministry of the Environment. Toronto, Ontario.

Holmes Inspections Services. No Date. www.holmesinspection.com. Accessed 2004.

Houston-Galveston Area Council (HGAC). 2001. Household Hazardous Waste. Available online http://www.h-gac.com/HGAC/Programs/Solid+Waste/Recycling+Information/Household_Hazardous_Waste.htm. Accessed 2004.

Hurco Technologies. 2003. "Smoke Testing Our Sewer Systems" presentation from website. http://www.hurcotech.com.

Jewell, Charlie. 2001. A Systematic Methodology for the Identification and Remediation of Illegal Connections. Systems Odyssey: Combining Wet Weather and O&M Solutions.

Karri, V. 2004. *Monte Carlo Mixing Model to Identify Inappropriate Discharges to Storm Drainage Systems*. Masters thesis, Department of Civil and Environmental Engineering, the University of Alabama. Tuscaloosa, AL.

Kitchell, A. and T. Schueler. 2004. Unified Stream Assessment: A User's Manual. Center for Watershed Protection. Ellicott City, MD.

Lalor, M. 1994. *Assessment of Non-Stormater Dischargest to Storm Drainage Systems in Residential and Commercial Land Use Areas.* Ph.D. Thesis. Vanderbilt University Department of Environmental and Water Resources Engineering. Nashville, TN.

Land of Sky Regional Council. 2002. www.landofsky.org/.Accessed 2004

Montoya, B. L. 1987. Urban Runoff Discharges From Sacramento, California. Prepared for the California Regional Water Quality Control Board. Los Angeles, CA.

Pelletier, G.J. and T.A. Determan. Urban Storm Drain Inventory, Inner Grays Harbor. Prepared for Washington State Department of Ecology, Water Quality Investigations Section, Olympia, WA.

Pitt, R. 2004. Methods for Detection of Inappropriate Discharge to Storm Drain Systems. Internal Project Files. Tuscaloosa, AL.

Pitt, R. 2001. *Methods for Detection of Inappropriate Discharges to Storm Drainage Systems: Background Literature and Summary of Findings.* IDDE Project Support Material.

Pitt, R. and J. McLean. 1986. Humber River Pilot Watershed Project. Ontario Ministry of the Environment. Toronto, Ontario, Canada.

Pitt, R. *et al.* 1993. A User's Guide for the Assessment of Non-Stormwater Dischargers Into

Separate Storm Drainage Systems. EPA/600-R-92-238. Risk Reduction Engineering Laboratory, USEPA. Cincinnati, OH.

Pitt, R. 1983. Urban Bacteria Sources and Control in the Lower Rideau River Watershed, Ottawa, Ontario. Ontario Ministry of the Environment

Pomeroy, C., K. Cave, and D. Tuomari. 1996. Rouge River National Wet Weather Demonstration Project Technical Memorandum: Summary of Illicit Connection Detection Programs in Michigan. Wayne County, MI.

Pronold, M. 2001. Administering the NPDES Industrial Storm Water Program. In Proceedings: National Conference on Tools for Urban Water Resource Management and Protection. U.S. EPA Office of Research and Development. Cincinnati, OH. EPA/625/R-00/001

Reese, A. 2000. Funding Phase II Storm Water Programs. In Proceedings: National Conference on Tools for Urban Water Resource Management and Protection. U.S. EPA Office of Research and Development. Cincinnati, OH.

Sagona, F. 1986. "Monitoring and Planning for Onsite Wastewater Disposal Along TVA Reservoirs." in Lake and Reservoir Management: Volume II. North American Lake Management Society, Madison, WI.

Sargent, D. and W. Castonguay. 1998. An Optical Brightener Handbook. Prepared for: The Eight Towns and the Bay Committee. Ipswich, MA. Available at: http://www.naturecompass.org/8tb/sampling/index.html Accessed 2004

Schmidt, S. and D. Spencer. “The Magnitude of Improper Waste Discharges in an Urban Stormwater System.” in Journal Water Pollution Control Federation, July 1986.

Schueler, T. 2004. An Integrated Framework to Restore Small Urban Watersheds. Center for Watershed Protection, Ellicott City, MD.

Schueler, T., C. Swann, T. Wright, S. Sprinkle. 2004. Pollution Source Control Practices. Center for Watershed Protection. Ellicott City, MD.

Senior, M. 2002. Personal Communication. Senior Project Engineer, Water Quality Group, Public Works Department. City of Raleigh, NC.

Senior, M. 2004. Personal Communication. Senior Project Engineer, Water Quality Group, Public Works Department. City of Raleigh, NC.

Stockton, G. R. 2004a. Personal Communication. Phone conversation on January 7, 2004.

Stockton, G. R. 2004b. Advances in Applications and Methodology for Aerial Infrared Thermography. Proceedings: IR/INFO 2004.

Swann, C. 2001. "The Influence of Septic Systems at the Subwatershed Level." in Watershed Protection Techniques. 3(4): 821-834. Center for Watershed Protection. Ellicott City, MD.

Tuomari, D. and S. Thompson. 2003. "Sherlocks of Stormwater: Effective Investigation Techniques for Illicit Connection and Discharge Detection." in Proceedings of the National Conference on Urban Storm Water: Enhancing Programs at the Local Level. Chicago, IL. February 17-20, 2003.

United States Environmental Protection Agency (U.S. EPA). 2002. Guidance on Choosing a Sampling Plan for Environmental Data Collection. EPA /240/R-02/005. Office of Environmental Information. Washington, D.C.

U.S. EPA. 2000e. Stormwater Phase II Final Rule Fact Sheet 2.5: Illicit Discharge Detection and Elimination Minimum Measure (EPA-833-F-00-007). US EPA Office of Water. Washington, DC. January 2000.

U.S. EPA. 1999a. Aerial Photography Helps Assess Septic Systems. Available online http://www.epa.gov/nerlesd1/land-sci/epic/pdf/fs-septic.pdf. Accessed 2004.

U.S. EPA. 1999b. Collection Systems O&M Fact Sheet: Trenchless Sewer Rehabilitation. U.S. EPA Office of Water. EPA-832-F-99-032.

U.S. EPA. 1997. Volunteer Monitoring: A Methods Manual. EPA 841-B-97-003. Washington, D.C.

U.S. EPA. 1991. Sewer System Infrastructure Analysis and Rehabilitation. EPA/625/6-91/030.

U.S. EPA. 1990. Draft Manual of Practice Identification of Illicit Connections. U.S. EPA Permits Division (EN-336).

U.S. EPA. 1986. Quality Criteria for Water. EPA 440/5-86-001. USEPA Office of Water. Washington, D.C. Available online http://www.epa.gov/waterscience/criteria/goldbook.pdf. Accessed 2004.

U.S. EPA. 1983. Results of the Nationwide Urban Runoff Program. Water Planning Division, PB 84-185552, Washington, D.C.

USA Blue Book. No Date. "Smoke Testing Sewers" Fact Sheet. Available on website: www.usabluebook.com. Accessed 2004.

Washtenaw County Drain Commissioner. 1988. Huron River Pollution Abatement Project, Summary. Washtenaw County, MI.

Water Environment Federation. 2003. Smoke, Dye, and Television Ways and Reasons to Fix Sewer Defects on Private Property.

http://www.wef.org/publicinfo/factsheets/smokedye.jhtml Accessed 2004

Waye, D. 2003. A New Tool for Tracing Human Sewage in Waterbodies: Optical Brightener Monitoring. Northern Virginia Regional Commission. Annandale, VA. Available online http://www.novaregion.org/pdf/OBM_Abstract2.pdf. Accessed 2004.

Wayne County, Michigan. 2003. Personal Communication.

Wayne County. 2000. Illicit Connection/Discharge Elimination Training Program Manual. Department of Environment, Watershed Management Division. Wayne County, MI.

Wayne County, MI. 2001. Planning and Cost Estimating Criteria for Best Management Practices. Rouge River Wet Weather Demonstration Project. TR-NPS25.00

Wright, T., C. Swann, K. Cappiella, and T. Schueler. 2004. Unified Subwatershed and Site Reconnaissance: A User's Manual. Center for Watershed Protection. Ellicott City, MD

Zielinski, J. 2003. Draft Stream Watch Program Document. Center for Watershed Protection, Ellicott City, MD.