

Tools for Tracking Human Fecal Pollution in Urban Storm Drains, Creeks, and Beaches



- *Sources*
- *Tools*
- *Strategies*

Dye entering Mission Creek (Santa Barbara, CA) after being flushed down toilets in nearby businesses. A private sewer lateral serving six businesses was found to be leaking into a storm drain.

City of Santa Barbara, Creeks Division

In partnership with:

University of California, Santa Barbara

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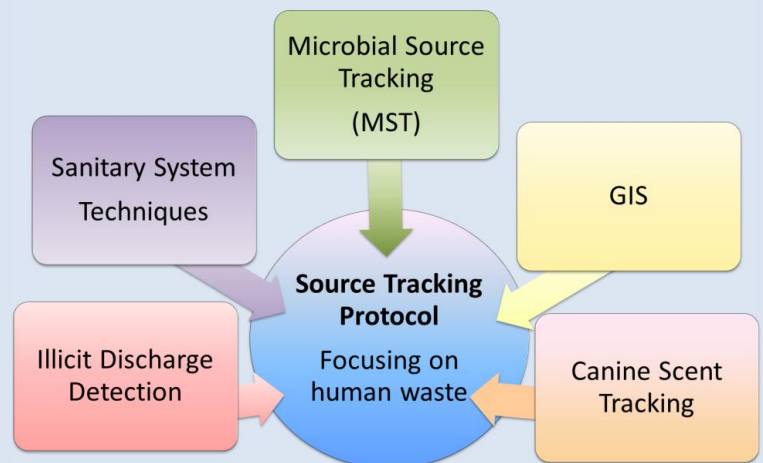
BACKGROUND

The motivation for this guide came as a result of the City of Santa Barbara's efforts to tackle the problem of frequent beach warnings for fecal indicator bacteria at Arroyo Burro Beach and East Beach at Mission Creek. Both sites have been listed as "Beach Bummers" in the past in Heal the Bay's Annual Beach Report Card (brc.healthebay.org). **The purpose of this guide is to present a brief overview of tools and provide examples where they have been used successfully to track "nonpoint source" human fecal pollution to its source.** Sections reference more specific guidance where appropriate.

The City has taken an aggressive approach to eliminating fecal indicator bacteria by installing capital projects such as low-flow storm drain diversions and a storm drain UV disinfection project. Concurrent with the capital program, the City partnered with Dr. Patricia Holden at the University of California, Santa Barbara (UCSB), whose research group recruited and tested cutting edge microbial markers, and developed other approaches, to investigate sources of indicator bacteria. Results from this research showed that some storm drain outfalls in Santa Barbara discharged water with consistent DNA-based signals of human waste. The City of Santa Barbara, with support of its Creeks Restoration and Water Quality Improvement Program Citizen Advisory Committee, decided to prioritize the goal of locating and eliminating human waste contributions to fecal indicator bacteria loads due to the potential associated health risks. However, despite substantial effort, tracking human-waste specific signals up storm drain networks to the points of input remained impossible for several years.

The tools described in this guide are the result of the City and UCSB's goal to develop and test tools for tracking signals of human waste in creeks, beaches, and storm drains to their sources. The following tools are described briefly in this report:

- Human-specific waste markers
- Microbial community fingerprinting , e.g. Phylochip MicroArray
- Flow gauges and autosamplers
- Non human-specific chemistry
- Canine scent tracking
- Storm drain televising
- Basic dye test
- Smoke test in storm drains
- Dye with rhodamine wastewater tracer probe
- Geographic Information System (GIS) modeling



The end pages of this report present broad guidance on strategies and a matrix of the tools suggesting where they are most appropriate.

During the course of this work, four sites with persistently leaking sewage were identified and repaired immediately. A set of potentially high-risk locations for sewage leaking into storm drains has also been slated for preventative rehabilitation. The project was mainly funded by the State Water Resources Control Board's Prop 50 Clean Beaches Initiative Grant Program, with partial funding provided by the City of Santa Barbara's Measure B, and the Water Environment Research Foundation.

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The work presented here is described in depth in the 2011 UCSB report "Source Tracking Protocol Development Project" ([UCSB Project Report](http://www.santabarbaraca.gov/Resident/Community/Creeks/Reports_and_Studies.htm)), as well as in several peer-reviewed publications from Dr. Holden's research group available on http://www.santabarbaraca.gov/Resident/Community/Creeks/Reports_and_Studies.htm. Links to specific sections of the report and publications are provided in the footnotes of the following pages. The [Final Report](#) for the Prop 50 Clean Beaches Initiative Grant will be available on the site as well.

WHY FOCUS ON HUMAN FECAL POLLUTION?



Dorsal Stream, CC BY-NC 2.0

TOP TEN BEACH BUMMERS	
BEACH/COUNTY	GRADE
1. Cowell Beach at the Wharf Santa Cruz County	
2. Avalon Harbor Beach, Catalina Island Los Angeles County	F
3. Cabrillo Beach, harborside at restrooms Los Angeles County	F
4. Topanga State Beach Los Angeles County	F
5. Poche Beach Orange County	F
6. North Beach Doheny Orange County	F
7. Arroyo Burro Beach Santa Barbara County	F
8. Baker Beach at Lobos Creek San Francisco County	F
9. Colorado Lagoon, Long Beach Los Angeles County	F
10. Capitola Beach Santa Cruz County	F

Grades of Heal the Bay,
Source: Malibu Times

Beach warnings in California are based on levels of **fecal indicator bacteria**, as mandated by the USEPA and State Assembly Bill AB411.

At many locations, total maximum daily load (TMDL) criteria have been developed for fecal indicator bacteria in order to lower their levels, but in most cases the implementation plans do not distinguish among sources of indicator bacteria. While eliminating all fecal indicator bacteria may lead to fewer beach warnings, it can be an impractical or impossible task in many locations.

Fecal indicator bacteria can come from animal sources, including wildlife, decaying plant material, and even growth on gutters, storm drain pipes, and sand grains. Indicator bacteria growing in the environment are unlikely to pose health risks to humans, and the risk associated with recreational contact with animal fecal sources in water is unknown. The USEPA reports that there has never been a documented outbreak of animal-associated illness among swimmers at marine beaches. The vast majority of fecal indicator bacteria are not themselves pathogens (microbes that cause illness), and the majority of pathogens are not indicator bacteria.

Among types of fecal contamination at coastal urban beaches, **untreated human waste** has the greatest potential to sicken beach goers. Most illnesses would likely cause mild-to-moderate gastrointestinal (GI) problems, but untreated waste also has the potential to transmit more harmful pathogens.

Finding and eliminating sources of human waste entering California beaches reduces health risks to swimmers.

- 2 For detailed information about health risks and beach water quality, see Chapter 2 and Chapter 3 of the [UCSB Project Report](#). For additional information about animal sources of indicator bacteria, see the USEPA's 2011 report [Potential Human Health Risks from Exposure to Fecal Contamination from Avian and Other Wildlife Sources in Recreational Waters](#).

How *does* untreated human waste enter coastal creeks, beaches, and storm drains?

VISIBLE SOURCES:



Bucket latrine on creek bank.



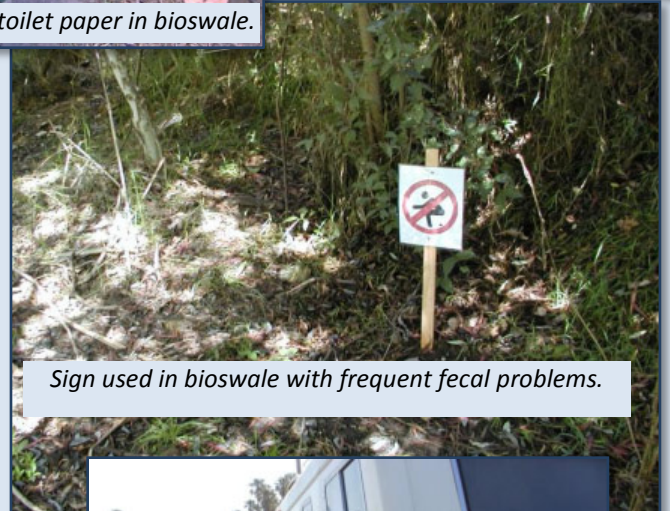
Feces and toilet paper in bioswale.



Feces wrapped in newspaper, then thrown from bridge into creek

- Use of creek banks and nearby swales as latrines at daytime gathering areas.
- Homeless encampments.
- Recreational vehicle dumping or leaking.
- Dumping of “chamber pots” into storm drains and creeks in crowded residential neighborhoods.
- Late-night use of parking lots, sidewalks, planters, and stairwells as latrines, that are later hosed into gutters and storm drains.
- Sanitary sewer overflows.

Visible sources can be located and removed. Repeated incidents can be addressed with outreach, contracted feces removal services, enforcement, providing restrooms, and installing barriers to creek access.



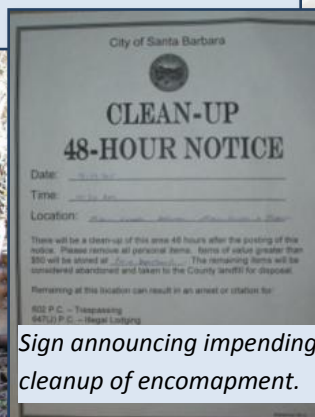
Sign used in bioswale with frequent fecal problems.



RV parked overnight in Santa Barbara, with leaking tank creating a puddle of fecal waste in parking lane.



Homeless encampment on creek bank.

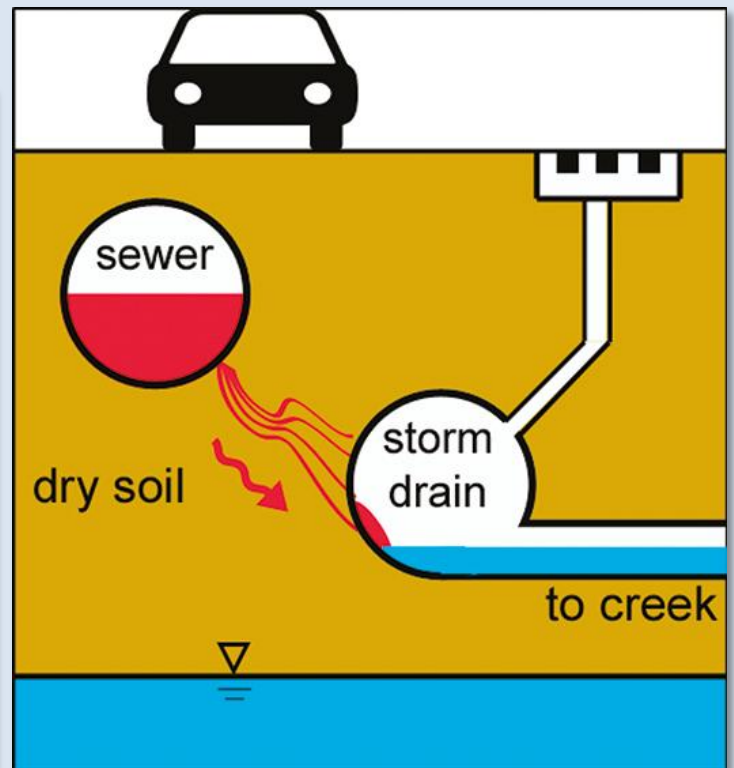


Sign announcing impending cleanup of encampment.

INVISIBLE SOURCES: ILLICIT DISCHARGES TO STORM DRAINS



DIRECT CONNECTIONS refer to intentional or accidental connections to the storm drain network. This picture shows the confusing array of underground pipe layouts in urban settings. A plumbing contractor called in for repairs would not likely have the benefit of a large excavation and may mistake a storm drain for a sanitary sewer pipe. Most direct connections containing human waste are first identified by observing toilet paper in manholes, gutters, or storm drain outlets to creeks. See page 8 for case studies. Image source: Mccauley, Underground.



INDIRECT CONNECTIONS refer to leaking sewer lines – laterals and mainlines -- that cause untreated wastewater to reach storm drains. This process is also called exfiltration from sewer lines or infiltration to storm drain lines. The USEPA estimates that up to 10% of wastewater flow can be lost to exfiltration where older pipes are located above groundwater levels. Locating indirect connections was a primary goal of this project. Image source: Sercu et al., 2011. *Environ. Science Tech.* 45(17):7151-57.

TOOLS: WATER TESTING

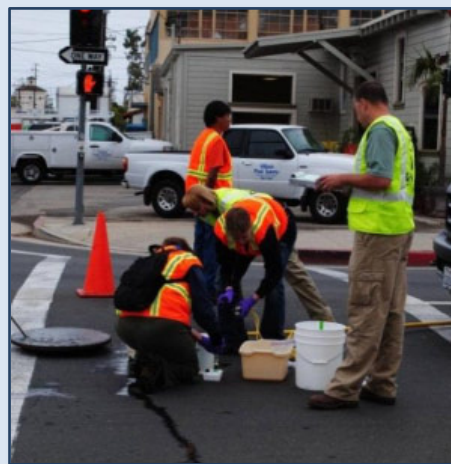
Illicit discharge, detection, and elimination programs have typically used indicators such as ammonia, surfactants, and fecal indicator bacteria to indicate the presence of wastewater.

Fecal indicator bacteria tests are cheap and readily available. However, several caveats are involved with their use in source tracking:

- They are not human or sewage specific
- They grow in the environment (see figure at right)
- Results do not always correlate with illness rates in epidemiological studies, particularly at urban-runoff impacted beaches.
- Results are often above or below certain thresholds, e.g. <10 or >24,192 MPN/100 ml, causing difficulties in data interpretation and statistical analyses.

When sewage input *is* suspected, indicator bacteria tests should be conducted at very high dilutions so that concentrations close to those found in wastewater influent can be obtained (millions to billions of MPN/100 ml, using 10,000 dilution).

Researchers interested in beach monitoring and understanding health risks associated with wastewater discharge to recreational areas have developed **human-specific DNA-based molecular tools** to identify the hosts of fecal indicator

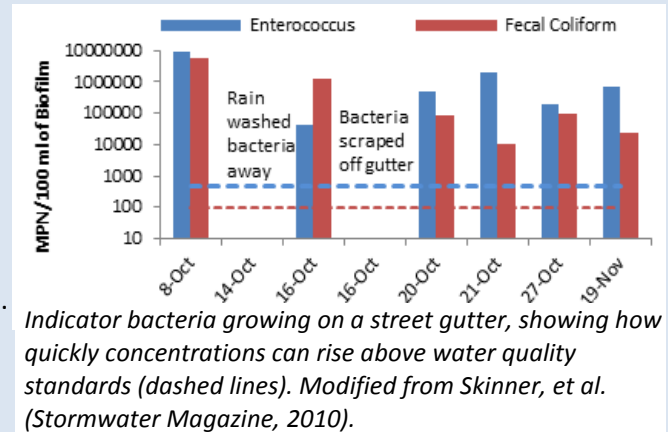


bacteria, particularly human hosts. These tools measure the DNA in bacterial species that are unique to the human intestine (they do not measure human DNA). Other tools for tracking microbial inputs use a bacterial community approach, trying to identify patterns, rather than specific species, that signify human waste input. The quantitative human-specific method used in the City/UCSB partnership is HF183 qPCR, a human-specific *Bacteroidales* marker. This marker has been shown to be sensitive and specific for human waste, with negligible false negatives when tested with dilute human waste, and few false positives when tested with other animal waste sources (cat, dog, and raccoon). Mnif, a second marker, is used to signal presence/absence of human waste. The community indicator in this work used a microarray technique called Phylochip analysis.

In addition, new molecular tools for measuring **human-waste specific chemical wastewater indicators**, such as caffeine (also dumped directly in gutters and drains) and cotinine (metabolite of nicotine), have brought down the costs of these tests and they can be used to corroborate DNA-based methods.

At the current time, most of the emerging molecular tools are available only when partnering with a research laboratory. One commercial laboratory that offers *Bacteroidales* tests at this time is Source Molecular (Miami, FL). The Phylochip microarray test can be obtained commercially through Second Genome, Inc. (San Bruno, CA).

Non-human specific chemistry such as surfactants, nutrients, and ions such as fluoride, boron, and potassium were tested alongside human-specific markers. While useful for investigating general potential illicit connections, the methods were not as useful for tracking human waste specifically.



Indicator bacteria growing on a street gutter, showing how quickly concentrations can rise above water quality standards (dashed lines). Modified from Skinner, et al. (Stormwater Magazine, 2010).

- For technical information on microbial and chemical methods, see Chapter 4 of the [UCSB Project Report](#).
- For tests of the specificity of the human-specific HF183 *Bacteroidales* marker, see Chapter 5 and [Van De Werfhorst et al. \(Appl. Environ. Micro., 2011\)](#).
- For information on the Phylochip method, see Chapter VI and [Wu et al, 2010 \(PlosOne\)](#)

TOOLS: FLOW-PACED SAMPLING



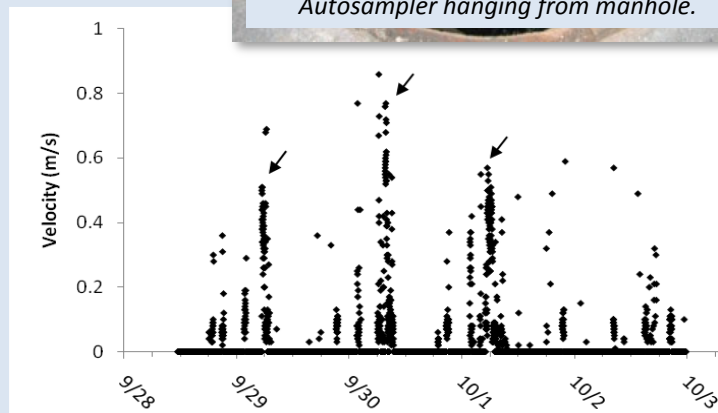
Flow gauge installed in bottom of storm drain.



Autosampler hanging from manhole.



Confined space entry used to install flow gauge.



Daily peaks in discharge from an urban storm drain to Arroyo Burro Creek in Santa Barbara. Arrows show where sample was collected automatically, based on flow programming.

In several locations in Santa Barbara, anecdotal observations suggested that sporadic pulses of dry weather runoff were discharged from storm drains to creeks. At one location, calls to the City's Illicit Discharge Enforcement line suggested that discharges of "dirty" water occurred only in predawn hours. In order to capture these pulses for water testing, flow gauges and autosamplers can be set up in storm drains. Autosamplers can be programmed to collect runoff based on flow conditions (absolute flow rate or percent change in flow rate) or based on time (e.g., hourly). One challenge is selecting equipment that works on low flows typically found during dry weather. Flow results have shown several locations where regular discharges occur to the storm drain network. In most cases, these were found to be from sump pumps in basements or underground utility vaults.

SAFETY FIRST

- ✓ Plan for **expenses** related to safety.
- ✓ Coordinate **traffic control** according to regulations and permit requirements.
- ✓ Be alert for **distracted drivers**.
- ✓ Do not enter storm drains without **confined space entry** training and personal projection equipment. Sewer gases can build up below grade, causing asphyxiation.
- ✓ Alternatively, hire a qualified plumber to install flow gauges.
- ✓ Use gloves and consider vaccinations.
- ✓ Require subcontractors to follow safety procedures.

TOOLS: SANITARY SYSTEM TECHNIQUES IN STORM DRAINS

Wastewater organizations are experienced in testing pipes for illicit connections, leaking joints, and infiltration. Sanitary system techniques can often be modified for use in storm drains to **confirm, or rule out, direct illicit connections**.

Basic Dye Testing

Basic dye testing is used in wastewater to confirm that laterals or specific plumbing fixtures are connected to sanitary sewer pipes. Dye is poured into a sewer cleanout (or toilet/sink), and the next manhole downstream is observed for dye. Water is flushed or poured down the pipe with the dye in order to speed transport.

Basic dye testing can be used in storm drains to confirm suspected connections. Challenges involve the length of time it can take for dye to move down a storm drain to the next manhole, and difficulty seeing the dye in manholes that have sediment and gravel in the bottom. Flushing with hoses or fire hydrants can speed up the process, but it is hard to rule *out* a suspected connection in this manner. Dye testing can also be used in combination with televising. See page 8 for a more complex dye technique used to test for indirect connections.

Televising

Closed circuit televising (CCTV) of storm drains is an important tool for locating direct and indirect connections – ***it is easier to see a sewage leak into the top or side of a dry storm drain than it is to see a leak out of the bottom of a wet sewer pipe***. Smaller “push” cameras, where the camera is attached to a rigid cable, can be used on short sections of small diameter pipe. The viewing screen is usually small and video recording may not be possible. In contrast, cameras can be mounted on remote control tractors and travel hundreds of feet down large-diameter pipes. These cameras can usually pan, tilt, and raise up on a scissor jack, and provide high resolution footage to a large monitor located inside a nearby trailer or vehicle.



Smoke Testing

Smoke testing is used in wastewater for determining where roof and yard drains are illicitly connected to sewer lines, allowing rain to enter the treatment plant. When used in storm drains, smoke is blown into pipes while catch basins, drop inlets, and downstream pipes are plugged or blocked. Nearby roof vents and sewer cleanouts are observed for smoke, which would indicate a connection of a sewer lateral to the storm drain.

Smoke testing is difficult in dense urban areas due to noticing requirements for residents. In addition, large pipe sizes require high smoke pressure, but this can also damage weak or smaller pipes.



TOOLS: SANITARY SYSTEM TECHNIQUES IN STORM DRAINS



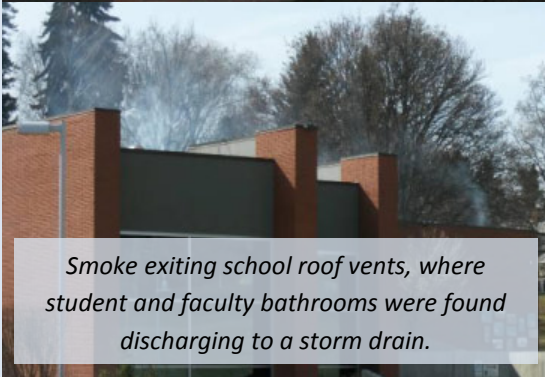
Smoke blown into storm drain manhole.



Smoke exiting catch basins, as it should.



Smoke exiting a residential roof vent, indicating illicit connection of plumbing fixture(s).



Smoke exiting school roof vents, where student and faculty bathrooms were found discharging to a storm drain.

Photos courtesy City of Yakima.

SUCCESS IN WASHINGTON STATE

- Washington State has included storm drain reconnaissance in permitting and grant programs, and communities have discovered multiple direct connections of sewage to storm drains ([WA DOE, 1/7/10](#) and [KUOW 1/15/10](#), includes audio.)
- In Wenatchee, toilet paper and sanitary waste were found in a storm drain manhole on a middle school property. Dye testing and video inspection confirmed that student and faculty bathrooms were connected to the storm water system, and not to the city's sewer ([Wenatchee World, 1/9/09](#)).
- City crews in Yakima used CCTV, smoke, and dye to locate several cross connections resulting in sewage discharge to storm drains, including wastewater from a hospital ([Yakima Herald, 1/20/10](#)). Photos at left.
- In a second study in Yakima, the City used dye and smoke testing, among other means, to trace the flow of water through city storm water pipes to a lake with high indicator bacteria levels. None of their tests revealed illicit discharges or contamination from sanitary sewers ([Yakima Herald, 9/20/2011](#)).
- In Vancouver, city workers using CCTV in a comprehensive survey of 300 miles of underground storm water pipes found a lateral for a large office building connected to a storm drain ([Seattle Times, 4/10/2009](#)).
- In Seattle, a relatively new development was found to have 22 laterals connected to storm drains, a discovery that was made after a broken sewer pipe came out of the storm drain outlet ([Rainier Valley Post 10/13/10](#)).

MORE CASE STUDIES

- In Milwaukee, microbial source tracking, camera, and dye tests were used to locate sporting arena bathrooms that were connected to the storm drain during construction ([Milwaukee Journal Sentinel, 3/14/07](#)). Additional dye, smoke, and CCTV work located more leaking pipes discharging sewage ([Milwaukee Journal Sentinel, 4/17/2007](#)). The Center for Watershed Protection (CWP) found many leaks into storm drains in Baltimore, MD ([Baltimore Sun, 10/10/2011](#)). Tools for locating illicit connections can be found on the [Center's website](#).

TOOLS: CANINE SCENT TRACKING

In summer 2010, the City of Santa Barbara and UCSB joined with Environmental Canine Services (www.ecks9.com) and the world's only sewage sniffing dogs, Logan and Sable, to test their effectiveness for use in urban storm drains. The work was funded by a grant from the Water Environment Research Foundation (WERF). The project sought to test the correlation of canine responses with human-specific waste markers and the use of canines for tracking up storm drain networks, routine watershed reconnaissance, and investigation of illegal dumping by recreational vehicle dwellers. The main advantages of the method are the low cost per sample, real-time results, and the large area that can be covered in one day. The highlight of the City's work was finding a force main leaking into a storm drain. The dogs were also very effective with community outreach events.



Logan, a rough collie rescue dog, "alerts" to the scent of sewage by sitting.



Sable, a rescue German Shepard, investigates a catch basin.



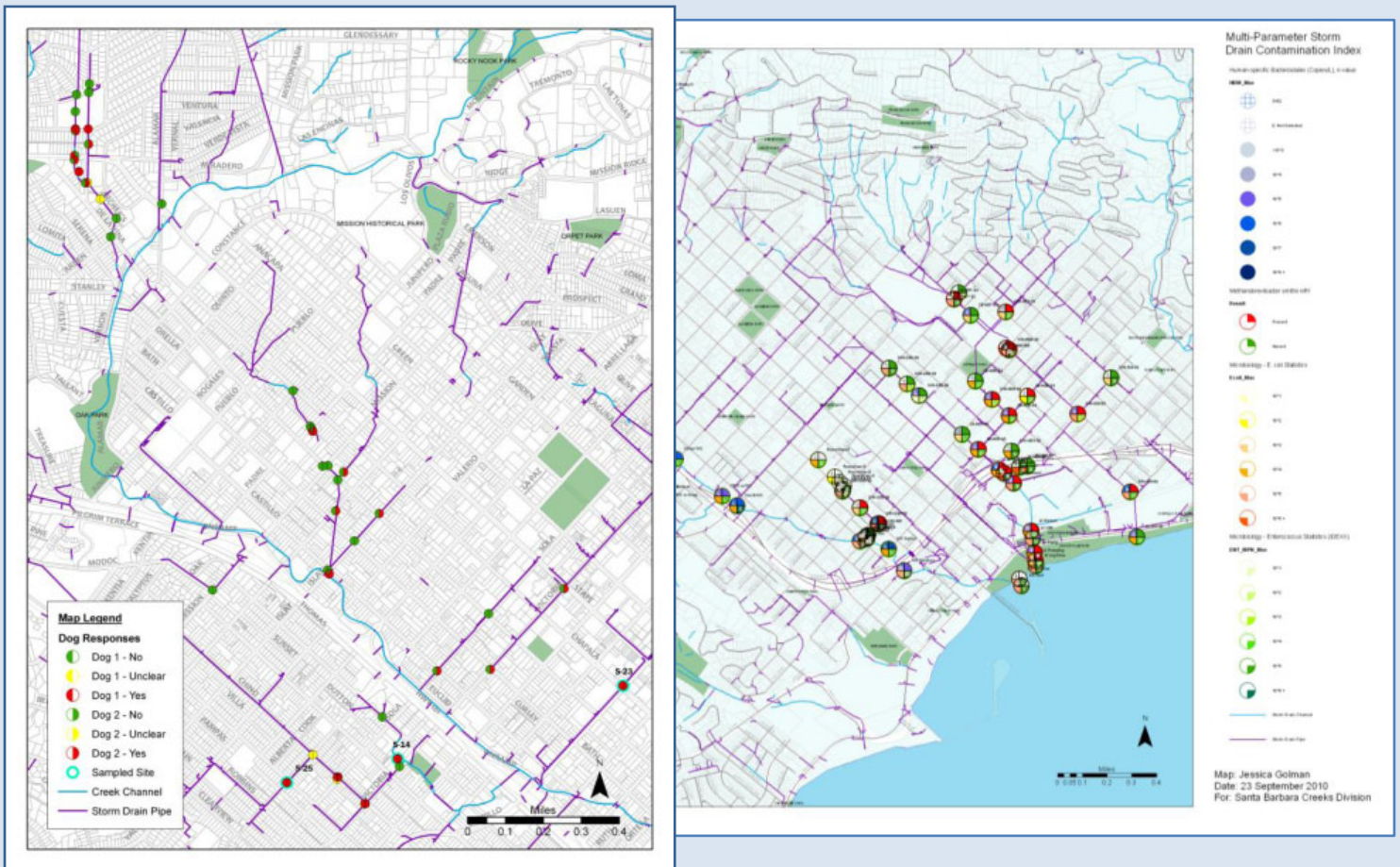
Based on canine responses, the crew uses storm drain maps to decide on the next testing location.



Investigating RV dumping. No deliberate dumping was found, but two leaking blackwater tanks were found.



TOOLS: GIS



A geographic information system (GIS) can be used to map storm drain and sewer infrastructure, as well as visualize spatial relationships of data collected. A challenge with visualizing water quality data is that multiple maps are generated for each parameter measured. Multiparameter displays can be developed to summarize the strength of a human-waste signal based on multiple tests. For human-waste specific markers, it is recommended that maximum concentrations be displayed, rather than averages or medians. In one storm drain in Santa Barbara, where raw sewage was found to make up all of the dry-weather flow (see page 14), the qPCR *Bacteroidales* HF183 marker came back positive on only one out of four dates, due to high volumes of wash water coming from a donut shop and a nail salon.

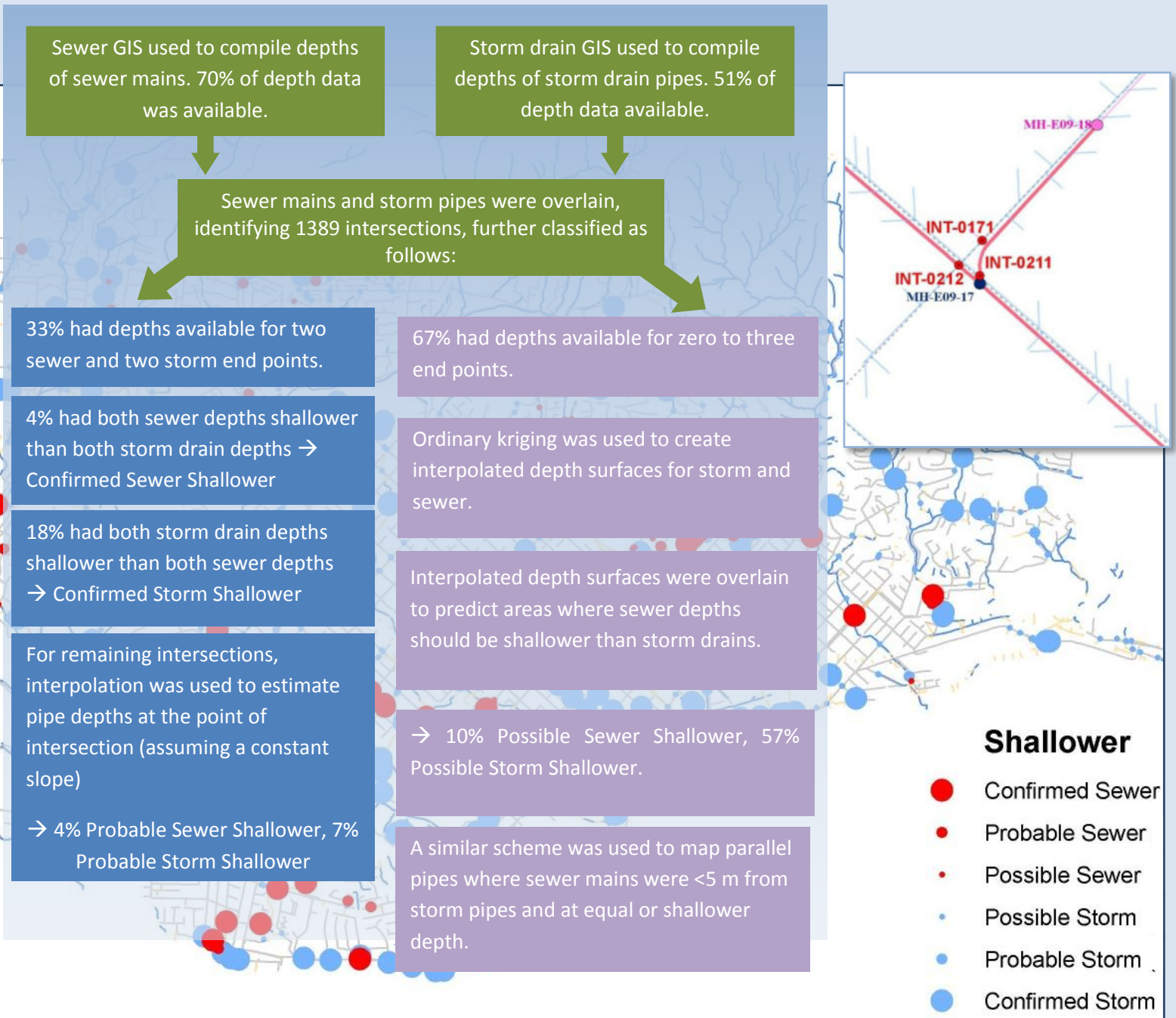
The ability to access multiple layers of infrastructure data in GIS while in the field can greatly help investigations, including camera, dye, and smoke testing.

Knowledge of groundwater depth can help target areas susceptible to sewage exfiltration. Leaks from sewers are not expected where sewer pipes are located below groundwater depth. In California, the State Water Resources Control Board's [GAMA Geotracker](#) tool has georeferenced depth-to-groundwater data that can be imported to GIS.



GIS FOR TARGETING INDIRECT CONNECTIONS

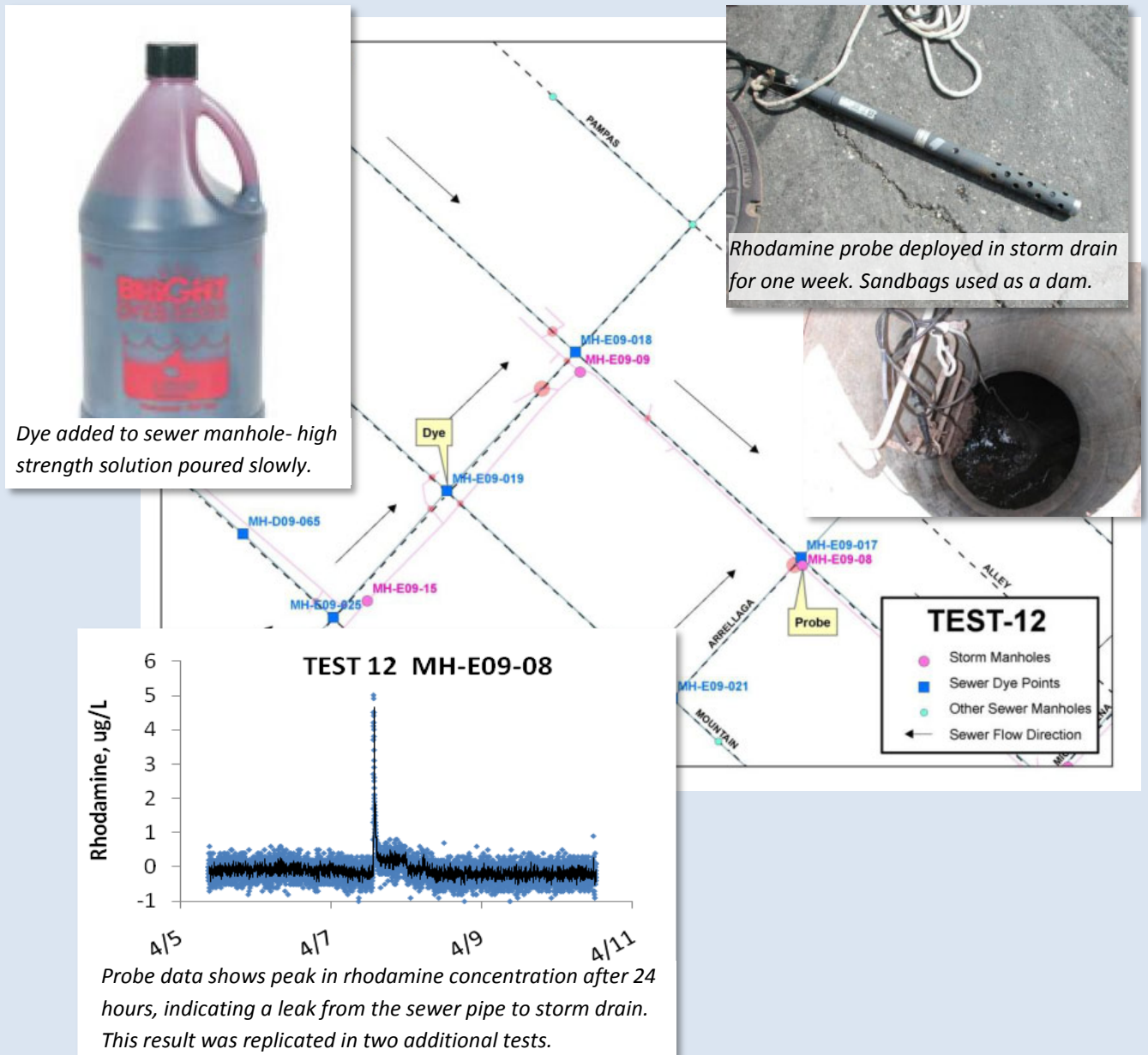
During this project, each location that was discovered and confirmed to allow the leaking of sewage to a storm drain was found where a sewer lateral or main crossed above a storm drain pipe. Based on this result, it was suspected that leaking “intersections” could be responsible for additional contamination in Santa Barbara. GIS was used to identify and model areas where aged sanitary sewer lines cross above storm drain lines or run parallel to storm drains at a distance <5m (and shallower). These areas were then targeted for follow-up dye studies and CCTV observation. An accurate and comprehensive GIS database of sewer and storm drain invert elevations, age, and pipe material is key for allowing an assessment of potential sewer to storm drain leakage transmission. The following flow chart provides an example of how target areas can be modeled from GIS infrastructure data.



DYE STUDIES FOR TARGETING INDIRECT CONNECTIONS

Dye studies can be conducted to investigate whether targeted “intersections” (locations where sanitary sewer lines cross above storm drain lines) and/or parallel lines are leaking to the storm drain.

Rhodamine Wastewater Tracer dye is added to sanitary sewer manholes, and field fluorometer (rhodamine probe) is placed in a storm drain for several days, recording fluorescence signals by a continuously operating optical probe. If there is no leakage between pipes, no signal should arise. If the sewer pipe is leaking and water is subsequently leaking into a storm drain, rhodamine may reach the storm drain and fluorescence is detected by the probe.



CASE STUDY – CARILLO DRAIN

During a routine survey of Mission Creek near Carrillo Street in June 2011, Creeks Division staff noticed what appeared to be degraded toilet paper and brown sludge in water flowing from the Carrillo Drain into a concrete section of the creek. The Carrillo Storm Drain had been tested several times in the past for wastewater indicators, but results were sporadic. It was later learned that fire hydrant flushing in the drainage likely forced gross solids out of the drain, making it more visible in the creek channel. Sampling conducted that afternoon and several times over the next week returned variable results for ammonia, ranging from <2 mg/L to 32 mg/L (it was later discovered that a drop inlet in a bus station parking lot upstream of the sewer leak received high inputs of ammonia from urine and cleaning agents). Indicator bacteria values were high for all groups tested. During several sampling events, corn kernels (“sewer corn”) were observed at the outfall.



The Creeks Division hired a contractor to survey the interior of the storm drain using state-of-the-art robotics. The storm drain was very old, with a brick and mortar roof (it may have been an old sewer pipe). Suspicions of sewage input were confirmed when two locations were found where water was dripping into the storm drain (see screen shots below). Even though all evidence pointed to a sewer leak, it was hard to visualize how solids, such as toilet paper and baby wipes, could be forced through the small cracks.



The next day, Creeks Division and Wastewater Division staff flushed fluorescent green dye in the toilets of nearby businesses (USGS confirms that this dye can enter creeks without causing toxicity problems). Rhodamine (red dye) was used first, and was not observed by the camera in the storm drain or at the outfall. After a few flushes with bright green dye, the bright green stream was observed flowing out of the storm drain into Mission Creek (see photo below). With the camera in the storm drain, trained on the dye, the void then appeared large enough to allow solids to enter the drain.

A similar procedure was used to identify the second leak, and private property owners repaired the leaking sewer laterals within 24 hours of confirming the sources (see photo of one repair below). Following the repairs, the Creeks Division has observed no water at all coming from the Carrillo Drain into Mission Creek.



CREATING A STRATEGY

Locating sources of human fecal contamination in storm drains, creeks, and beaches can be challenging, time-consuming, and expensive, but strategies exist that communities can use. Careful planning with a wise allocation of resources is essential.

Throughout our work, the following themes arose:

- 1) Start with **specific questions and hypotheses**, rather than a shot-gun approach. Sample methods are too expensive, and the results too variable, to expect a broad-brush approach to help resolve contamination questions.
- 2) Do not expect a single method to provide all of the answers. A **toolbox approach** is necessary for tracking human waste contamination.
- 3) Try to sample in places and times that represent **“worst-case scenarios.”** This way, if results come back negative for human-specific waste markers, it is more likely that contamination problems truly do not exist.
- 4) **Consistent positive results for human waste markers**, even at low concentrations, likely signal a sustained input to the storm drain. Moving up a storm drain is best pursued with camera and/or dye studies. On the other hand, recognize that marker concentrations will vary, especially where additional water inputs arise and cause marker dilution.
- 5) Seek **grant funding** and **partnerships with university researchers**.
- 6) Expect “messy” results, and **be persistent**.

A detailed plan for getting started is presented in the UCSB Project Report. The exact order and the amount of time and effort spent on each step will depend on the quantity and quality of existing data at the onset of the project. The recommended steps for locating indirect connections (leaking sewers) to storm drains are:

- 1) Visual Survey: Identify storm drains that flow in dry weather, and where these flows initiate.
- 2) Identify Target Areas: Use GIS to identify where aging sewer lines are above and near flowing storm drains.
- 3) Tier 1 Testing: Use less expensive procedures to evaluate source of flows, including canine scent tracking, field probes, non-human specific chemistry and microbiology identified in (2).
- 4) Tier 2 Testing: Use human waste specific markers to confirm human fecal origin at sites identified in (3).
- 5) Upstream Tracking: Use canine scent tracking, CCTV and/or smoke testing, and rhodamine wastewater probe studies on areas narrowed in 1-4 to locate and confirm sanitary sewer to storm drain connections.
- 6) Repair and/or rehabilitate identified connections.

TOOL	BEST USE	CAVEATS and CHALLENGES	COSTS	AVAILABILITY
Visual Survey	Homeless encampments, sites with frequent daytime use, under bridges.	Feces often contained in newspaper or plastic bags.	\$	#
Human-specific waste markers	Best tool for quantifying inputs of human waste. Best for sampling in creeks, beaches, storm drain outfalls or major nodes in storm drain network.	Plan repeated sampling to account for variable results. Different results for urine-specific vs. fecal-specific waste markers may indicate different sources of input.	\$\$\$	###
Community approach, e.g. Phylochip	Best for sampling along a gradient of suspected inputs, e.g. to test if septage is entering a creek. May be advantageous in storm drains diluted with clean ground water, due to low detection thresholds.	At this point, results are not conducive to simple interpretation suitable for a nontechnical audience. Contact Second Genome, Inc. http://www.secondgenome.com/tag/phylochip/	\$\$\$\$	###
Flow gauges and autosamplers	Best for drains with evidence of higher flows (wet walls, signs of water shooting into creek channel). Excellent for estimating loads of fecal pollution.	Check specs carefully to find flow gauges suitable for dry weather flows. Requires confined space entry in most cases.	\$\$\$ (one time)	#
Non Human-Specific Chemistry	Finding illicit connections besides sewage leaks. Good for understanding nutrient inputs from any type of illicit connection.	Background signal of urban runoff can make fingerprinting sewage difficult.	\$\$	#
Canine Scent Tracking	Best for use when real time results are desired, such as working up storm drain networks with many branches. Also when broad spatial coverage is sought.	Canines may respond to non-human illicit connections, due to training with detergents. Contact Environmental Canine Services (http://www.ecsk9s.com/).	\$\$	###
CCTV	Best for use where sampling data suggests sustained input of sewage.	Most operators are trained for sanitary sewer pipe inspection, and may seek to clean the lines first. Plan to guide operators to slow down, look carefully at leaks, and do not clean the lines first (in order to see solids on bottom of storm drain).	\$\$	##
Basic Dye Test	Best for testing laterals or fixtures feeding a single illicit connection that has been observed in CCTV work.	Use bright green dye and a UV light to look for dye in storm drains.	\$	#
Smoke Test	Best for limited geographic areas with strong evidence for direct connections, e.g. visible toilet paper.	Difficult in large pipes and densely populated areas.	\$\$	#
Dye with Rhodamine Probe	Best for testing suspected sewage infiltration to storm drains, when persistent human-waste markers are found without observing solids such as toilet paper.	Difficult to know how long to leave probe in storm drain. Rain events may create a false positive signal.	\$\$	##
GIS	Essential for planning and analyzing data in relation to infrastructure.		\$\$	##

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Geosyntec: Brandon Steets, Ryan Smith

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City of SB Streets Division: Jeff Brent, Vidal Gonzalez

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