Methodology for Investigation of Inappropriate Pollutant Entries into Storm Drainage Systems

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A summary is presented of the user's guide that was the result of a series of research projects sponsored by the Environmental Protection Agency to develop a procedure to investigate non-stormwater entries into storm drainage systems. Previous projects have found that dry-weather flows discharging from storm drainage systems can contribute significant pollutant loadings to receiving waters. If only wet-weather stormwater runoff is considered, little improvement in the conditions of receiving water may occur with many stormwater control programs. These dry-weather flows may originate from many sources; the most important sources are sanitary wastewater from separate sanitary collection systems or failing septic tank systems and industrial or commercial pollutant entries from vehicle maintenance facilities and the like. After the outfalls affected by polluted dry-weather flows are identified, additional survey activities are needed to locate and correct the non-stormwater entries into the storm drainage systems. The user's guide contains information on conducting local investigations to identify the types and estimate the magnitudes of these non-stormwater entries.

Urban stormwater runoff is the portion of precipitation that drains from urban surfaces such as roofs, streets, parking lots, and garages. Current interest in illicit or inappropriate connections to storm drainage systems is an outgrowth of investigations into the larger problem of determining the role of urban stormwater runoff as a contributor to problems with the quality of receiving water. An urban stormwater drainage system also conveys waters and wastes from many other sources. For example, Montoya found that slightly less than half the water discharged from Sacramento's stormwater drainage system was not directly attributable to precipitation (*1*). Sources of some of this water can be identified and accounted for by examining current permit records from the National Pollutant Discharge Elimination System (NPDES) for permitted industrial wastewaters that can be discharged to the storm drainage system. However, most of the water comes from other sources, including illicit and inappropriate entries to the storm drainage system. These entries can account for a notable amount of the pollutants discharged from storm drainage systems (*2*).

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The Storm and Combined Sewer Pollution Control Program of the Office of Research and Development, Environmental Protection Agency (EPA), and the NPDES Program Branch have supported the development of a user's guide (*3*) for the investigation of inappropriate entries to storm drainage systems. The user's guide is designed to provide information and guidance to local agencies by meeting the following objectives: (a) identify and describe the most common potential sources of inappropriate pollutant entries into storm drainage systems, and (b) describe a procedure that will allow a user to determine whether significant inappropriate pollutant entries are present in a storm drainage system and, if any, to identify the type of source, as an aid to finding the ultimate location of the source.

The user's guide (*3*) was prepared in conjunction with a background study by Pitt and Lalor (*4*) that examined three categories of non-stormwater outfall discharges:

1. Pathogenic and toxic pollutants,
2. Nuisances and threats to aquatic life, and
3. Clean water.

The most important category is that of outfall discharges containing pathogenic or toxic pollutants. The most likely sources for this category are sanitary or industrial wastewaters. The outfall analysis procedure described in the user's guide has a high probability of identifying all of the outfalls in this most critical category. High probabilities of detection of other contaminated outfalls are also likely when using the procedures. After identification of the contaminated outfalls, their associated drainage areas can be subjected to a detailed source identification investigation. The identified pollutant sources can then be corrected.

ROLE OF DRY-WEATHER FLOWS IN URBAN STORMWATER RUNOFF ANALYSES

EPA's Nationwide Urban Runoff Program (NURP) highlighted the significance of pollutants from inappropriate entries into urban storm drainage (*4*). Such entries may be evidenced by flow from storm drain outfalls following and during 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 (*4*) or of indirect connections (e.g., leaky sanitary sewerage contributions through infiltration). Many of these dry-weather flows are continuous and would therefore also occur during rain-induced runoff periods. Pollutant contributions from the dry-weather flows in some storm drains have been shown to be high enough to degrade water quality significantly because of their substantial contributions to the annual mass pollutant loadings to receiving waters.

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 stormwater and baseflows (*2*). The Toronto project involved intensive monitoring in two test areas (a mixed residential and commercial area and an industrial area) during warm and cold weather and during wet and dry weather. The annual mass discharges of many pollutants were found to be dominated by dry-weather processes.

During the mid-1980s, several individual municipalities and urban counties initiated studies to identify and correct illicit connections to their storm drain systems. This action was usually taken in response to problems with receiving water quality or information noted during individual NURP projects. Data from these studies indicate the magnitude of the cross-connection problem in many urban areas. From 1984 to 1986, Washtenaw County, Michigan, dye-tested 160 businesses in an effort to locate direct illicit connections to the county stormwater drainage. Of the businesses tested, 61 (38 percent) were found to have improper storm drain connections (*5*). In 1987 the Huron River Pollution Abatement Program dye-tested 1,067 commercial, industrial, and tax-exempt businesses and buildings, and 154 (14 percent) were found to have improper connections to storm drainage (*6*). Commercial car washes and other automobile-related businesses were responsible for most of the illicit connections in both studies. Discharges from commercial laundries were also noted.

An investigation of outfalls from the separate storm drain systems in Toronto, Canada, revealed 59 percent with dry-weather flows. Of these, 84 (14 percent of the total outfalls) were identified as grossly polluted, on the basis of the results of a battery of chemical tests (*7*). In 1987 an inspection of the 90 urban stormwater outfalls draining into Inner Grays Harbor in Washington revealed 29 (32 percent) flowing during dry weather (*8*). A total of 19 outfalls (21 percent) were described as suspect on the basis of visual observation or anomalous pollutant levels as compared with those expected in typical urban stormwater runoff characterized by the EPA 1983 NURP report.

CURRENT LEGISLATION

The Clean Water Act of 1987 contained provisions specifically addressing 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-stormwater discharges into the storm drains, and
> iii. Shall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants.

In response to these provisions, EPA issued a final rule to begin implementation of Section 402(p) of the Clean Water Act on November 16, 1990 (*9*). A screening approach that includes chemical testing of outfalls or storm drainage with dry-weather flow (defined by a 72-hr antecedent dry period) was adopted. The parameters to be tested are a combination of several pollutants of concern and tracers that may be used to help identify contaminated outfalls and predict the source of illicit discharges.

Section 122.26(d)(1)(iv)(D) of the rule applies specifically to the user's guide (*3*). EPA requires an initial screening program to provide a means of detecting high levels of pollutants in storm sewerage. Minimum requirements are

> a narrative description . . . of visual observations made during dry weather periods. If any flow is observed, two grab samples shall be collected during a 24 hour period with a minimum period of four hours between samples. For all such samples, a narrative description of the color, odor, turbidity, the presence of an oil sheen or surface scum as well as any other relevant observations regarding the potential presence of non-stormwater discharges or illegal dumping shall be provided. In addition, a narrative description of the results of a field analysis using suitable methods to estimate Ph, total chlorine, total copper, total phenol, and detergents (or surfactants) shall be provided along with a description of the flow rate. Where the field analysis does not involve analytical methods approved under 40 CFR Part 136, the applicant shall provide a description of the method used including the name of the manufacturer of the test method along with the range and accuracy of the test.

The protocol of the user's guide seeks to determine whether non-stormwater flows are causing problems (e.g. pathogenic, toxic, threat to aquatic life, nuisance) and to provide additional detail with respect to the source. It accomplishes this by outlining an effective screening methodology to identify storm drainage system outfalls contaminated by illicit or inappropriate discharges and to determine specifically how the likely sources can be identified. This protocol is supported by a research report containing the results of a demonstration project using these procedures and much more detailed information.

POTENTIAL DRY-WEATHER DISCHARGE SOURCES

The user's guide is directed to the identification and location of non-stormwater entries into storm drainage systems. It is important to note that for any effective investigation of pollution within a stormwater system, all pollutant sources must be included. Prior research has shown that for many pollutants, stormwater may contribute the smaller portion of the total pollutant mass discharged from a storm drainage system. Significant pollutant sources may include dry-weather entries occurring during both warm and cold months and snowmelt runoff, in addition to conventional stormwater associated with rainfall. Consequently, much less benefit in reducing pollution will occur if only stormwater is considered in a control plan for controlling storm drainage discharges. The user's guide contains a protocol to identify sources of inappropriate entries to storm drainage systems. The investigations presented in the user's guide may also identify illicit point source outfalls that do not carry stormwater. Obviously, these outfalls also need to be controlled and permitted.

Table 1 presents a summary of the potential sources of contaminated entries into storm drainage systems, along with their probable flow characteristics. The following subsections summarize these sources.

Residential and Commercial Sources

The most common potential non-stormwater entries, which have been identified by a review of documented case studies for commercial and residential areas, are

- Sanitary wastewater sources:
  - –Raw sanitary wastewater from improper sewerage connections, exfiltration, or leakage; and
  - –Effluent from improperly operating, designed, or nearby septic tanks.
- Automobile maintenance sources:
  - –Car-wash wastewaters,
  - –Radiator flushing wastewater,
  - –Engine degreasing wastes,
  - –Improper oil disposal, and
  - –Leaky underground storage tanks.
- Irrigation sources:
  - –Lawn runoff from overwatering, and
  - –Direct spraying of impervious surfaces.
- Clean sources:
  - –Infiltrating groundwater,
  - –Water routed from preexisting springs or streams, and
  - –Infiltrating potable water from leaking water mains.
- Other sources:
  - –Laundry wastewaters,
  - –Noncontact cooling water,
  - –Metal plating baths,
  - –Dewatering of construction sites,
  - –Washing of concrete ready-mix trucks,
  - –Sump-pump discharges,
  - –Improper disposal of household toxic substances, and
  - –Spills from roadway and other accidents.

From this list, sanitary wastewater is the most significant source of bacteria, and automobile maintenance and plating baths are the most significant sources of toxicants. Waste discharges associated with the improper disposal of oil and household toxicants tend to be intermittent and low in volume. These wastes may therefore not reach the stormwater outfalls unless carried by higher flows from another source or by stormwater during rains.

Industrial Sources

Industries can produce dry-weather entries to storm sewers in several ways. Common examples include the discharge of cooling water, rinse water, other process wastewater, and sanitary wastewater. Industrial pollutant sources tend to be related to the raw materials used, final product, and the waste or byproducts created. Guidance on typical discharge characteristics associated with common industries is given in Sections 3 and 4 of the user's guide.

There is also a high potential for unauthorized connections within older industries. One reason for this is that at the time of an industry's development, sanitary sewers may not have been in existence, since early storm drains preceded the development of many sanitary sewer systems. A lack of accurate maps of sanitary and storm drain lines may lead to confusion as to their proper identification. In addition, when the activ-

TABLE 1 Potential Inappropriate Entries into Storm Drainage Systems

	Storm Drain Entry		Flow Characteristic		Contamination Category		
Potential Source	Direct	Indirect	Continuous	Intermittent	Pathogenic/Toxic	Nuisance	Clear
Residential area							
Sanitary wastewater	X	x	X	x	X		
Septic tank effluent		X	X	x	X		
Household chemicals	x	X		X	X		
Laundry wastwater	X			X		X	
Excess landscaping watering		X		X	x	x	X
Leaking potable water pipes		X	X				X
Commercial area							
Gasoline filling station	X	x		X	X		
Vehicle maintenance/repair	X	x		X	X		
Laundry wastwater	X		X	x	x	X	
Construction site dewatering		X	X	x		X	
Sanitary wastewater	X	x	X		X		
Industrial area							
Leaking tanks and pipes	x	X	X	x	X		
Many process waters	X	x	X	x	X	x	x

NOTE: X: most likely condition
x: may occur
blank: not very likely

ities within an industry change or expand, there is a possibility for illicit or inadvertent connections (e.g., floor drains and other storm drain connections receiving industrial discharges that should be treated before disposal). Finally, industries that process large volumes of water may find the carrying capacity of sanitary sewer flow to be inadequate, leading them to remove the excess water improperly through the storm drain system.

Continuous processes (e.g., industrial manufacturing) are important potential sources because any waste streams produced are likely to be constantly flowing. Detection of dry-weather discharges from these sources is therefore made easier, because the continuous and probably undiluted nature of these discharges is more noticeable (e.g., odors produced will be stronger and colors more intense).

Intermittent Sources

The presence of regular, but intermittent, flows will usually be a good indication of contaminated entries to the storm drains and can usually be distinguished from groundwater infiltration flows. However, as drainage areas increase in size, many intermittent flows will combine to create a continuous composite flow. Examples of situations or activities that can produce intermittent dry-weather flows are

- Wash-up operations at the end of a work shift or job activity,
- Wash-down following irregular accidents and spills,
- Disposal of process batches or rinse water baths,
- Overirrigation of lawns, and
- Car maintenance (e.g., automobile washing, radiator flushing, and engine degreasing).

Industries that operate on a seasonal basis, such as fruit canning and tourism, can also be a source of longer-duration intermittent discharges.

Direct Connections to Storm Drains

Direct connections refer to physical connections of sanitary, commercial, or industrial piping that carry untreated or partially treated wastewaters to a separate storm drainage system. These connections are usually unauthorized. They may be intentional or accidental, due to mistaken identification of sanitary sewer lines, and they represent the most common source of entries to storm drains by industry.

Direct connections can result in continual or intermittent dry-weather entries of contaminants into the storm drain. Some common situations are

- Sanitary sewer lines that tie into a storm drain;
- Foundation drains or residential sump-pump discharges that are frequently connected to storm drains—although this practice may be quite appropriate in many cases, it can be a source of contamination when the local groundwater is contaminated (e.g., by septic tank failures); and
- Commercial laundries and car-wash establishments that may route process wastewaters to storm drains rather than sanitary sewers.

Infiltration to Storm Drains

Infiltration into storm drains most commonly occurs through leaking pipe joints and poor connections to catch basins, but it can also be due to other causes, such as damaged pipes and subsidence.

Storm drains, as well as natural drainage channels, can therefore intercept and convey subsurface groundwater and percolating waters. In many cases, these waters will be uncontaminated and have variable flows due to fluctuations in the level of the water table and percolation from rainfall events.

Breaks of underground potable water mains are another potential clean source of releases to storm drains. Although such occurrences are not a direct pollution source, obviously they should be corrected.

Groundwater may be contaminated, either in localized areas or on a relatively widespread basis. In cases where infiltration into the storm drains occurs, it can be a source of excessive contaminant levels in the storm drains. Potential sources of groundwater contamination include, but are not limited to,

- Failing or nearby septic tank systems,
- Exfiltration from sanitary sewers in poor repair,
- Leaking underground storage tanks and pipes,
- Landfill seepage,
- Hazardous waste disposal sites, and
- Naturally occurring toxicants and pollutants due to the surrounding geological or natural environment.

Leaks from underground storage tanks and pipes are a common source of soil and groundwater pollution and may lead to continuously contaminated dry-weather entries. These situations are usually found in commercial operations such as gasoline service stations or industries involving the piped transfer of process liquids over long distances and the storage of large quantities of fuel (e.g., petroleum refineries).

INVESTIGATION METHODOLOGY

The methodology presented in the user's guide can determine if a storm drain outfall (and drainage system) is affected by pronounced non-stormwater entries. In many cases, the information to be collected following this methodology will also result in a description of the most likely sources of these discharges. Several aspects of the methodology were derived from the experience of many municipalities that have previously investigated inappropriate entries into storm drainage systems.

The methodology establishes priorities to identify the areas with the highest potential for causing problems. The investigative procedures then separate the storm drain outfalls into three general categories (with a known level of confidence) to identify which outfalls (and drainage areas) need further analyses and investigations. These categories are outfalls affected by non-stormwater entries from pathogenic or toxic pollutant sources, nuisance and aquatic life–threatening pollutant sources, and unpolluted water sources.

The pathogenic and toxic pollutant source category should be considered the most severe because it can cause illness upon water contact or consumption as well as significant water treatment problems for downstream consumers, especially if the pollutants are soluble metal and organic toxicants. These pollutants may originate from sanitary, commercial, and industrial wastewater non-stormwater entries. Other residential area sources (besides sanitary wastewater)—for example, inappropriate household toxicant disposal, automobile engine degreasing, and excessive use of fertilizers and pesticides—may also be considered in this most critical category.

Nuisance and aquatic life–threatening pollutant sources can originate from residential areas and may include laundry wastewaters, lawn irrigation runoff, automobile washwaters, construction site dewatering, and washing of concrete ready-mix trucks. These pollutants can cause excessive algal growths, tastes and odors in downstream water supplies, offensive coarse solids and floatables, and noticeably colored, turbid, or odorous waters.

Clean water discharged through stormwater outfalls can originate from natural springs feeding urban creeks that have been converted to storm drains, infiltrating groundwater, infiltrating domestic water from waterline leaks, and such.

An outline of the major topics presented in the user's guide follows:

1. Initial mapping (Section 3).
   a. Identify receiving waters.
   b. Locate all outfalls.
   c. Compile area and land use data for each drainage area.
2. Design of initial field survey (Section 4).
   a. Select tracer parameters (visual and chemical).
   b. Develop local library of likely source flow characteristics.
3. Field screening sampling activities (Section 5).
   a. Select sample analysis procedures (detection limits, repeatability, etc.).
   b. Conduct field screening survey for both intermittent and continuous flows.
4. Data analysis (Section 6).
   a. Use simple procedures (negative indicators).
   b. Employ checklist for major flow components.
   c. Quantify major sources with flow-weighted procedures.
   d. Use matrix algebra procedures to quantify many flow components.
5. Locate inappropriate pollutant sources (Section 7).
   a. Conduct drainage surveys using tracer parameters in critical watersheds.
   b. Use flow mass balances, dye studies, and smoke tests in isolated drainage areas.
6. Correct inappropriate pollutant sources (Section 8).
   a. Use public education and zoning ordinances.
   b. Treat widespread sanitary sewerage failures possibly as a combined sewer overflow.
   c. Require regional solutions possibly for failing septic tanks.
   d. Prevent industrial and commercial area pollution.

Figure 1 is a simplified flow chart for the detailed methodology. The initial phase of the investigative protocol includes the initial mapping and field surveys. These activities require minimal effort and result in little chance of missing a seriously contaminated outfall. The initial activities are followed by more detailed watershed surveys to locate and correct the sources of the contamination in the identified problem areas. After corrective action has been taken, repeated outfall field surveys are required to ensure that the outfalls remain uncontaminated. Receiving water monitoring should also be conducted to analyze improvements in water quality. If expected improvements are not noted, then additional contaminant sources are probably present, and additional outfall and watershed surveys are needed.

RECOMMENDATIONS

The user's guide should be used as part of a comprehensive stormwater management plan that addresses all sources of stormwater pollution. The correction of pollutant entries identified only by the use of the user's guide is unlikely to achieve a significant improvement in the quality of stormwater discharges or receiving waters.

A municipality will need to plan its investigation of inappropriate entries to a storm drainage system to suit local conditions. The guide describes the issues in sufficient depth and provides examples only to enable the design of a local investigation.

The full use of all of the applicable procedures described in the user's guide is probably necessary to identify pollutant sources. Attempting to reduce costs—by, for example, examining only a certain class of outfalls or using inappropriate testing procedures—will greatly reduce the utility of the testing program and result in inaccurate data. Cursory data analysis is also likely to result in inaccurate conclusions.

Consideration should be given to any economic and practical advantages of designating the storm drainage system as a combined sewer and applying end-of-pipe treatment during investigations of non-stormwater entries to storm drainage systems.

It is also recommended that the methodology (appropriately modified) be applied to other types of sewer systems, such as combined and separate sanitary sewer systems, to locate inappropriate entries (e.g., untreated or toxic industrial wastewaters and wastes).

It is recommended that the user's guide be updated and refined by incorporating experience gained in its application. Incorporation of information from a wide variety of test locations (e.g., lake and large river receiving waters, tidal receiving waters, areas experiencing long dry periods, areas having short summers, areas having unusual groundwater characteristics, areas where the stormwater is pumped for discharge, etc.) will improve the testing and data analysis protocols described.

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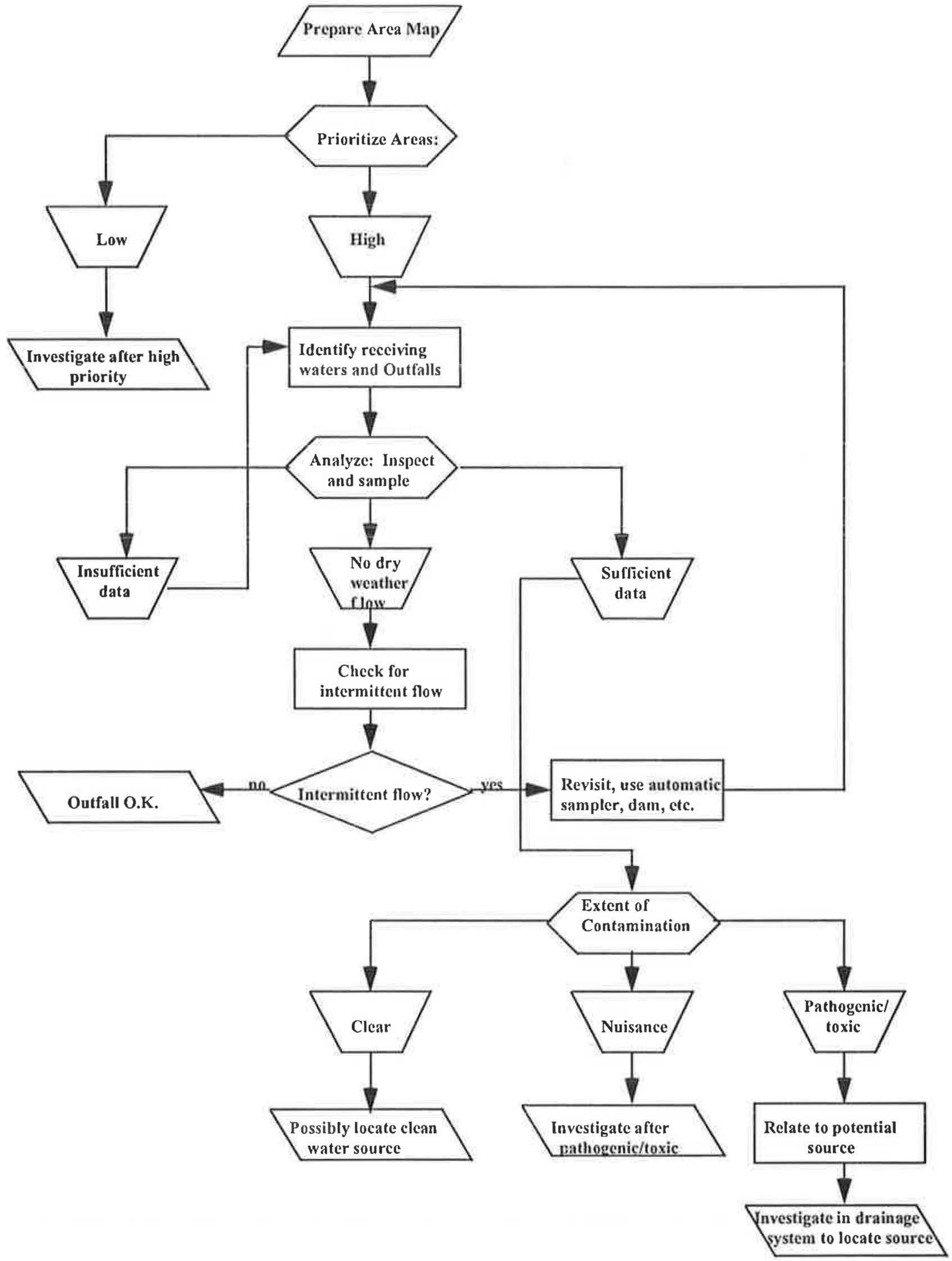

FIGURE 1 Flow chart for investigative procedures.

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