# WATERSHED INVESTIGATION FOR THE IDENTIFICATION OF SOURCES OF INAPPROPRIATE DISCHARGES TO THE CRIBBS MILL CREEK.

by

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A THESIS

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# ABSTRACT

Inappropriate discharges are a component of urban stormwater runoff which includes discharges from many anthropogenic activities/sources, which find their way into storm drainage systems. The importance of inappropriate discharges into storm drain systems stems from their retarding impacts on receiving water quality.

The Center for Watershed Protection (CWP) and the University of Alabama are currently conducting a technical assessment of techniques and methods for identifying and correcting inappropriate discharges geared towards NPDES Phase II Communities.

Investigation of non-stormwater discharges into storm drainage proceeds along a hierarchy of procedures. Exploratory techniques involve an extensive mapping effort to identify the locations of all outfalls for sampling. This is followed by the screening analyses at the outfalls which include sampling at repeated intervals at the outfalls, to measure chemical tracers which would identify the general categories of non-stormwater flows. Using a Flow chart method (developed by Pitt and Lalor 1993) and a source quantification modeling package (Chemical Mass Balance Model, Karri 2004), the most probable source of inappropriate discharge into the storm drain system can be identified. The final verification process entails the identification of problem outfalls and field investigation of these problem outfalls by surveying the contributing watershed.

The above methodology has been employed at Tuscaloosa, Alabama, to study the sources of illicit discharges into the Cribbs Mill Creek. Initially a local library of pure source samples was collected and analyzed for characteristic tracer concentrations. The

Cribbs Mill Creek was surveyed and the outfalls mapped and sampled to give tracer concentrations of the dry weather flows. Using the flow chart method and the CMBM model, the most likely sources of contamination have been identified. After the identification of problem outfalls, field verification studies were conducted. Flow chart analysis of the tracer concentrations from the field verification indicated sources of contamination consistent with sources seen at the outfalls. In some instances it was possible to physically locate the contaminant source from the field studies. A GIS project of the study area was created and the flow chart methodology was built in to automate the identification of the potential sources of contamination.

# CHAPTER 1

# INTRODUCTION

## 1.1 Inappropriate Discharges

Federal regulations define an inappropriate discharge as "...any discharge to a municipal separate storm sewer system (MS4) that is not composed entirely of storm water..." with some exceptions. These exceptions include discharges from National Pollutant Discharge Elimination System (NPDES)-permitted industrial sources and discharges from fire-fighting activities. Inappropriate discharges are prohibited because MS4s are not designed to accept, process, or safely discharge such non-storm water wastes.

Previous research that investigated inappropriate discharges identified three categories of non-stormwater outfall discharges: pathogenic/toxicant (such as sanitary wastes; toxic chemicals from households; and chemicals, oils and greases from automobile repair operations) nuisance and aquatic life threatening (such as washwaters from laundromats; carwash runoff; and fertilizer/insecticide laden irrigation runoff) and clean water (including flowing natural springs or leaking clean water mains) (Pitt et al.1993).

Inappropriate discharges are an issue not only because they are a nuisance and are aesthetically unpleasant, but more importantly, because they are a component of non-point pollutant discharges to receiving waters and can significantly contribute to water use degradation. The requirements prohibiting inappropriate discharges are especially appropriate because they can be identified and controlled using relatively simple and cost-effective strategies.

*1.1.1 Governing Regulations:* The Clean Water Act (CWA) amendments of 1987 were the first federal regulations that specifically addressed storm drain discharges. Under Section 402(p) (3) (b), the CWA requires that permits be issued for such discharges and to regulate and minimize non-stormwater, polluting discharges into the storm sewer systems.

In 1990, the EPA issued the Phase I rule to implement Section 402(p) through the NPDES permit system. As authorized by the Clean Water Act, the NPDES permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. MS4s are regulated under the Phase I rule. The Phase I rules required the communities to identify the major outfalls within their jurisdiction according to prescribed guidelines, and prepare a stormwater management plan to detect and contain inappropriate discharges to the MS4 systems. Approximately 850 entities participated in the Phase I Municipal Stormwater Permit Program. The Phase II Final Rule included storm sewer systems not addressed by Phase I regulations and also specified minimum control measures to identify and eliminate inappropriate discharges.

## 1.2. Detection and Elimination of Inappropriate Discharges

*1.2.1. Developing Identification Procedures:* Identification of storm drains carrying dry-weather flows (problem outfalls) is the key to identifying inappropriate discharges. Identification of these drains is a result of field studies and repeated dry-weather sampling of these outfalls. Once the contributing outfalls (storm drains) are identified, the sources of these discharges need to be tracked, identified and then eliminated by using appropriate technical, regulatory and educational methods

The Center for Watershed Protection (CWP) and the University of Alabama are currently being funded by EPA to complete a technical assessment of techniques and methods for identifying and correcting illicit and inappropriate discharges geared towards NPDES Phase II communities. Initially, we collected data from Phase I communities to identify the success of prevalent methods of identifying inappropriate discharges. The most cost effective and efficient techniques were identified and integrated with our prior methods and emerging techniques previously recommended. During the major project phase (mostly described in this thesis), the project team conducted field and laboratory demonstration studies. The last project phase includes the development of draft guidance on methods and techniques to identify and correct illicit connections, and conduct training and dissemination.

The basic monitoring procedures followed in this study were first recommended by Pitt, et al. (1993), and our first year project report submitted to the EPA in 2001 detailed the examination of new and promising methods. The prescribed methodlogy involves extensive mapping of the selected watershed and outfalls and noting the basic characteristics of all the outfalls. Periodic sampling efforts and subsequent quantification of the inappropriate discharges based on the selected tracer parameters indicate the problem outfalls and the most probable sources of contamination. These results are used to mark the problem outfalls and detailed micro-watershed investigation areas pertaining to the identified problem outfalls. This would result in pin-pointing the source(s) of contamination in order to check the outfall predictions.

This methodology was verified by conducting detailed investigations in the Cribbs Mill Creek watershed area in Tuscaloosa, AL. This watershed was selected for its representative nature in terms of land uses of interest, presence of a considerable urban/commercial/residential/ open space and new development area in the watershed, a well defined drainage system, presence of dry-weather storm drain flows and accessibility to the creek. Initially, the entire length of the creek was surveyed and all the outfalls were marked and mapped using a Geographic Positioning System (GPS) unit. The process of surveying the creek was repeated twice to identify the outfalls with dry-weather flows. Samples for analyses were also collected during these initial surveys. The inaccessible areas of the creek and the portion of the creek with no dry-weather flows were not selected as part of the sampling effort. A total of five rounds of creek walking and sampling of the outfalls, and subsequent sample analyses, generated tracer concentrations for all the outfalls. Gross physical indicators of contamination were noted and a simple check list was used to identify the most significant sources. The most likely sources of discharge were broadly classified into clean water sources (spring water, tap water and irrigation runoff) and wastewater sources (washwaters (carwash and laundry) and sanitary wastewater). A 'Library' of these sources was created by sampling these waters repeatedly. This library included springs, irrigation runoff, tap water, carwashes, wastewater treatment plants and laundromats in the study area. This sampling effort generated typical concentrations of the tracer parameters for these sources of contamination. The tracer parameters were selected based on earlier research conducted by Pitt, et al (1993) and more recent evaluations (such as Pitt, et al. 1998). The primary tracers used were: pH, temperature, color, turbidity, hardness, detergents, boron, potassium, ammonia, Enterococci and *Escherichia Coli* (E Coli).

With the data obtained for tracer concentrations for all the outfalls and the library sample concentrations, it was possible to quantify the contribution of the candidate sources to the outflows in the various outfalls. A flowchart method originally developed by Pitt et. al. (1993) and Lalor (1993) was revised and used to identify the possible sources of contamination. The original flowchart was modified using the concentrations observed for Tuscaloosa, AL, conditions. The process used to define the concentrations in the flowchart is described later in this document. The entire watershed and the elements of concern were mapped in ArcMap using ArcGIS software. The chemical analysis results are part of the attributes of the GIS project and the flowchart methodology was programmed in ArcMap to generate the most probable source of contamination. This project is described later in the document.

## 1.3. Objective of the Thesis

The objective of this project is to verify the prescribed methodology of identifying and verifying the sources of inappropriate discharges. This was accomplished by identifying the problem outfalls and carrying out detailed site investigations as a part of the verification process and physically verifying the sources of contamination identified by tools such as the flow chart and the Chemical Mass Balance Model (CMBM). A flowchart outlining this process is depicted in Figure 1.1.

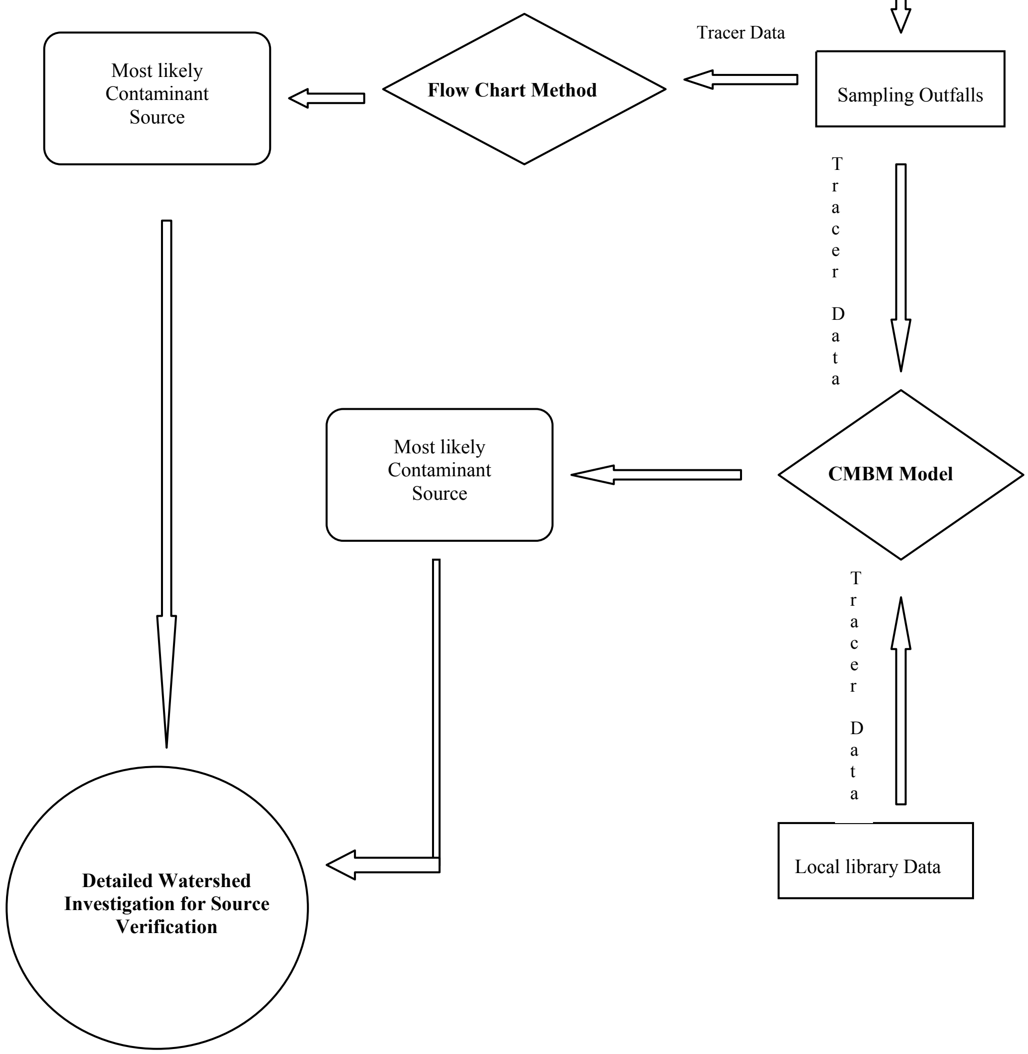


Figure 1.1. Flow chart showing the process of identifying and verifying the source of inappropriate discharges.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1. Background

In the early 1980s, the EPA's National Urban Runoff Project (NURP) conducted 28 projects across the nation to provide information regarding urban runoff mechanisms: quantifying the characteristics of urban runoff, assessing water quality effects of urban runoff discharges on receiving waters and examining the effectiveness of control practices in removing pollutants found in urban runoff. The significance of pollutants from illicit entries into urban storm sewerage was highlighted by these studies (EPA 1983). Such dry-weather flows were shown to be a result of 'illicit connections' or indirect connections through infiltration or cross connections between sanitary sewer systems and storm drain systems. Pollutant concentrations from dry-weather flows in some storm drains have been shown to result in high annual mass pollutant loadings in the receiving waters, to be able to significantly degrade the water quality (Pitt, 2001). Early studies conducted across the country, including ones conducted in Washtenaw County, Michigan (1984-1986), Sacramento, California (1985), Huron river Watershed as part of the Huron River pollution Abatement Program (1987), identified more than 60% commercial as well as residential dry-weather discharges in their storm drainage systems. In 1993, the EPA published the first ever user guide for the identification of inappropriate pollutant entries into storm drainage systems (Pitt, *et al*. 1993)..The current project is largely based on the methodology described therein, but examined newly emerging methods and examined procedures used by Phase 1 cities during the early years of the stormwater NPDES program.

## 2.2. Sources of Inappropriate Discharges to Storm Drain Systems

The sources of inappropriate discharges to urban water systems range from infiltration and seepage from ground water and underground storage tanks to toxic chemicals from households and automobile maintenance operations and seepage of sewage into the storm drain system through cross connections between sanitary lines and storm drains. The EPA estimated that 267 million gallons of used oil, including 135 million gallons from non-professional automobile oil changes are annually disposed improperly (EPA, 1989). Russell and Meiorin (1985) surveyed toxic material disposal practices into storm drains/streets by households and concluded that 3% of households disposed paints and thinners, 83% of household s flushed automobile radiators for used radiator fluid, and 11% households dumped used motor oil. Landscaped areas showed elevated concentrations of Total Dissolved Solids, COD, phosphates and nitrogen compounds (Pitt, 1983) (Pitt, Bozeman, Dec. 1982). Verbanck found that ammonia accounts for 80% of total nitrogen in Brussels' sewer waters and would therefore be the most prevalent member of the nitrogen group for which to test. Verbanck's work also suggested that potassium levels might be useful in distinguishing between sanitary wastewaters and commercial wash waters. It would also identify sanitary wastes with more ease and reliability than tests involving fecal bacteria (Verbanck, et al. Jan. 1990).

In a study by Le Fevre and Lewis (2003), stream and stormwater contributed the greatest numbers of Enterococci and, consequently, high numbers of Enterococci were found in both water and sediments surrounding discharge points for these sources. In an investigation on particle-associated microorganisms in stormwater runoff and the impact of these microorganisms on the analysis of microbial water quality, it was found that measured concentrations of these organisms, except for *E. coli*, increased after blending samples to detach/de-clump these particle-associated microorganisms (Borst and Selvakumar, 2003).

## 2.3. Selection of Tracer Parameters

Using the potential sources of contamination as a guide, the typical characteristics of such source waters were studied by Pitt (2001). The ideal tracer should have significant differences in concentrations between possible sources of contamination, low variations within source categories, conservative behavior with respect to in-situ biological and chemical processes, and ease of measurement with suitable detection limits and repeatability of results. From the observed characteristics of the source waters as defined by various researchers, 13 parameters listed here were selected as potential tracers by Pitt et al. (1993). Conductivity and temperature, Fluoride, Hardness, Detergents, Fluorescence, Potassium, Ammonia, Color, Toxicity, pH, Total Chlorine, total Copper and total Phenols. Due to the absence of industrial areas within our watersheds the toxicity, total phenols and total copper were omitted from our list of analyses. Chlorine is not a robust tracer since chlorine concentrations of water flowing on soil deplete rapidly (Pitt et al., 1993).

## 2.4. Creek Walk Methodology

The Creek walk methodology followed in this study was first described by Pitt, et al. (1993) in their report to the EPA. From other studies identifying and eliminating illicit discharges, it is noted that the methods followed elsewhere are on the same broad guidelines, but studies differ in the detailed procedures adopted. The Rouge River Project in Wayne County followed a methodology where a combination of methods involving identification of 'hot spots' using outfall observations, review of water quality data and complaint response followed by the tracking of illicit connections using intensive sampling, dye tracer studies, television monitoring and other case specific techniques (Tuomari, Thompson, No date).

In a study conducted at Birmingham, AL in the Village Creek watershed it was observed that in order to identify all the problem outfalls in the creek it was necessary to conduct multiple sampling runs. Even though the outfalls were visited for sample collection 8 or 9 times over a 30-month period during the demonstration project, flows were not consistently found during each visit at each outfall. For an outfall that never flowed or flowed 100% of the time, few visits were needed to identify a problem. But for outfalls with intermittent flows, a larger number of sampling runs were required. At least 4 outfall visits are likely needed for many intermittent conditions. If the outfall has a problem most of the time (say at least 60% of the time), four visits should result in less than a 25% error in identifying this problem. In contrast, if the outfall has a problem infrequently (such as 20% of the time), the possible error could be much larger. In most cases, more than 5 observations seldom resulted in additional useful information (Lalor, Brown, 1993).

## 2.5. Verification of Inappropriate Discharges

The Verification procedures followed in this project were initially developed by Pitt et al. (1993). In addition to the methods used in this project, the following techniques were followed in studies conducted in other MS4 communities and were described by Johnson and Tuomari (No date). In order to inspect connections in question to determine whether they are connected to the storm drain system or to the sanitary sewer the following methods of identification can be used:

- *Dye Testing*. Pouring fluorescent dye into suspicious downspouts can be useful to identify illicit connections. Once the dye has been introduced into the storm system via the connection in question, the water in the collection system is monitored to determine whether an illicit connection is present.
- *Visual Inspection.* Remotely guiding television cameras through sewer lines is another way to identify physical connections.
- *Smoke Testing.* Smoke testing is another method used to discover illicit connections. Zinc chloride smoke is injected into the sewer line and emerges via vents on connected buildings or through cracks or leaks in the sewer line. Monitoring and recording where the smoke emerges, crews can identify all connections, legal and illegal, to the sewer system.
- *Flow Monitoring.* Monitoring increases in storm sewer flows during dry periods can also lead investigators to sources of infiltration due to improper connections.
- *Infrared, Aerial, and Thermal Photography.* Researchers are experimenting with the use of aerial, infrared, and thermal photography to locate dischargers by studying

the temperature of the stream water in areas where algae might be concentrated and in soils. It also examines land surface moisture and vegetative growth, since an area with excessive flows would be warmer, and the vegetation would grow faster than in the surrounding area.

## 2.6. GIS

Geographic Information Systems are computer-based tools that can be used to store display and analyze geographical information. GIS can be used by municipalities when mapping their storm sewer systems for the purpose of documenting inappropriate discharge connections. As a pre-processor, GIS is also seen as a database to store information about inappropriate discharge connections, field screening, outfall analyses, water quality information and watershed characteristics. As post-processor, GIS may be used to map tracer concentrations, derive spatial statistics of data and also function as a data source for watershed models. Historically, GIS has been used in conjunction with models like SWMM and SLAMM. [The linking of GIS and several hydrologic process models is examined by Charnock et al (1996).

In the context of identifying inappropriate discharges GIS has largely been used as a database which aids in performing relevant analyses of the data. Examples of typical GIS applications to detect inappropriate discharges are:

- The City of Livonia, Michigan is using Geographic Information Systems (GIS) technology to enhance the implementation of its illicit discharge elimination program. The database system was designed to record investigation data and to provide ease in reporting investigation activities. (Rohrer et al., No date).

- The Oakland County Illicit Discharge Elimination Program (IDEP) uses a GIS database based on the existing County base map to track the entire outfall inventory program. Information that is gathered in the field is accessible by location on the base map. This database is updated as information is gathered from various outlets. The information documents not only the current conditions, but also tracks problems and the resolution of illicit connections.

Attempts are also being made to develop commercial customized applications based on GIS, which would function along the guidelines suggested by Pitt et al. (1993) and which can be used by the MS4 communities to track inappropriate discharges.

# CHAPTER 3

# DESCRIPTION OF THE CREEK WALK PROCESS AND ANALYSIS

## 3.1. Initial Mapping and Screening Effort

Initially, aerial maps, detailed street and topographic maps of the Cribbs Mill Creek area in Tuscaloosa, AL, were obtained and the study area was outlined on the maps. The Cribbs Mill Creek watershed area was then manually surveyed by walking the length of the creek in the study area and a total of about 75 outfalls were identified and initially numbered using spray paint. Out of these 75 outfalls, about 36 were found to have intermittent or continuous dry-weather flows during the course of the project. These outfalls were examined over a period of two years, and at least five rounds of sampling were conducted representing all seasons. The field trips were scheduled such that there was no interference from rains. All the sampling runs were scheduled such that there was no rain for at least 3 days prior to sampling. During the field surveys, gross indicators of contamination were noted for each outfall. These indicators included: odor, (sewage, sulfur, oil, gas, rancid-sour), color (clear, yellow, brown, green, gray, etc), turbidity (clear, cloudy, opaque), floatables (none, oil sheen, sewage, etc), deposits/stains (sediment or oily), vegetation conditions (excessive growth, inhibited growth) and damage to outfall structures (concrete cracking, concrete spalling, metal corrosion, etc.). These gross indicators can be used to identify obvious problem outfalls needing remediation efforts.

Once the samples were collected, it was important to preserve them in coolers having ice packs until they could be transferred to refrigerators in the laboratory. There is a maximum allowed holding time (and other preservation methods needed) for most of the chemical analyses, before which the analyses needed to be performed, as stated in *Standard Methods for the Examination of Water and Wastewater* (1992).

It is essential to bring the appropriate field equipment during the sample collection creek walks. The field equipment included the following:

- 1 liter 'Nalgene' sampling bottles,
- 100 ml. IDEXX sample bottles (with sodium thiosulfate) for bacterial sampling
- GPS unit
- Spray paint
- Marker pens
- Labels for the bottles
- Long handled dipper sampler
- Thermometer
- Field notebook with street maps and field evaluation sheets
- Stop watch
- Tape measure
- Hand operated vacuum pump sampler for shallow flow
- Snake-proof waders and walking stick
- Two-way radio (or cell phone) for communication between field crew and driver
- Digital camera

- First-aid kit
- Liter bottle of tap water and soap

In addition, coolers and ice packs, along with extra sample bottles, were kept in the vehicle.

Eight creek walks, as described on Table 3-1, were completed during this study, including the three verification rounds. Additional outfalls were found during the subsequent walks, but no new ones were found after the third walk. From these observations and from the previous studies conducted by Pitt, *et al.* (1993), it is suggested that in order to identify all the outfalls in an area, four rounds of sampling should be conducted. A later section will discuss the frequency of the sampling efforts in order to identify intermittent discharges.

Table 3.1. *Summary of creek walk schedule*

| **Creek walk** | **Start Date** | **End Date** | **Days** | **Notes** |
|---|---|---|---|---|
| 1st | 4/17/2002 | 5/10/2002 | 7 | Exploration of the watershed (76 outfalls found) |
| 2nd | 5/31/2002 | 7/2/2002 | 11 | Found 12 extra samples (total of 88 outfalls) |
| 3rd | 10/3/2002 | 10/18/2002 | 7 | Found one extra sample (total of 89 outfalls) |
| 4th | 2/18/2003 | 3/5/2003 | 5 | After three creek walks, some branches of the creek were eliminated from further study due to redundancy and time problems |
| 5th | 3/31/2003 | 4/18/2003 | 5 | Final round of complete creek walk |
| 6th | 12/20/2004 | 12/23/2004 | 4 | First round of verification evaluations. Examined 8 of 10 areas. Two areas not examined due to onset of bad weather |
| 7th | 1/20/2004 | 2/1/2004 | 12 | Second round of verification, sampled additional locations in the watershed |
| 8th | 3/27/2004 | 3/28/2004 | 2 | Completed sampling with this final verification round. |

## 3.2 Chemical Analyses

The following paragraphs describe the basic analysis procedures that were used during the laboratory and field tests. In all cases, blanks (zero concentration water) and standard solutions were also included in all sets of analyses, as appropriate.

- **Conductivity:** A ‘Cardy’- pocket-sized conductivity meter model B-173 made by Horiba, along with conductivity standards that are supplied with the meter, were used to measure the specific conductivity of the samples. Before any measurements were performed, the instrument was first calibrated. The meter should hold its calibration for an extended period (several weeks), but it is best to check the calibration before each sample batch. The duration of the test for each sample is about one minute. This test is simple and fast to perform and can be used in the field, if desired.
- **pH:** A ‘Cardy’- pocket-sized pH meter model B-213 made by Horiba, and the supplied pH standards, were used to measure the pH of the samples. The meter should be calibrated before each batch use and the meter should hold its calibration for an extended period (several days). Calibration takes around 3 minutes and testing of each sample only takes about 30 seconds. This test is simple and fast and can be used in the field, if desired.
- **Potassium**: A ‘Cardy’- potassium compact meter (an ion-specific electrode meter) by Horiba model C-131 and accessories that come with the meter were used. Calibration takes around 5 minutes and testing of each sample is only 30 seconds. This procedure, while rapid and inexpensive, unfortunately only has a detection limit of 1 mg/L, and reads in increments of 1 mg/L. While this is not a problem for moderately contaminated samples (when the results are most useful), it is frustrating when used for cleaner water

samples. Since we use a ratio of ammonia to potassium to distinguish between washwaters and sanitary wastewaters, <1, or coarsely incremented K values, can be a problem for relatively clean waters. However, this method works well for the more polluted waters of most interest. If still a problem, and if more sensitive K values are needed, the only real option is to use traditional laboratory methods (either ICP or atomic absorption). Other simple field procedures (such as the method supplied by HACH), rely on a photometric measurement of a floc and are not very repeatable for these types of samples.

- **Enterococci**: The IDEXX Enterolert test kit was used to measure the MPN (Most Probable Number) of Enterococci in the samples. The Enterolert reagent is dissolved in the sample collected in the IDEXX 100mL vessels and the solution is poured into the Quanti-Trays and the trays are sealed using the sealer. The samples in the Quanti-Tray are incubated at $41^{o}\pm5^{o}$ C for 24 hours and the quantitrays are read under the UV light to count the fluorescent wells. The MPN value is read from the IDEXX MPN table. Once the Quanti-Tray sealer is warm (10 min), it takes approximately 5 minutes per sample to mix, label, seal and place the Quanti-Tray in the incubator. After 24hours, it takes 1-2 minutes to read the sample results under the UV lamp. It is not a difficult procedure to learn, is sensitive and very repeatable. Knowledge of proper handling of bacterial specimens is necessary, especially when using the QA/QC material, and in the proper disposal of the used Quanti-Trays. This test cannot be performed in the field.

- ***E. coli*:** The IDEXX Colilert test kit is used to measure the MPN (Most Probable Number) of Total Coliforms and *E. coli* in the samples. The IDEXX Colilert reagent is dissolved in the sample collected in the IDEXX 100ml vessels and the solution is poured into the Quanti-Trays and is sealed using the sealer. The samples are incubated at 35±0.5$^{o}$ C for 24 hours. The IDEXX trays are compared to the comparator (provided by the manufacturer) and the cells which are more yellow than the comparator are counted as positive. The MPN is calculated using the MPN table to obtain a value for the Total Coliforms. The Quanti-Trays are then read under the UV light to count the fluorescent wells and the MPN is obtained using the IDEXX MPN table for *E. coli* values. Once the Quanti-Tray sealer is warm (10 min), it takes approximately 5 minutes per sample to label, seal and place the Quanti-Tray in the incubator. After the 24 hour incubation period, it takes 1-2 minutes to read the sample results under the UV lamp. Used Quanti-Trays must be disposed of in a biohazard bag and handled by an appropriate biohazard disposal facility, using similar practices as for alternative bacteria analysis methods.

- **Boron (low range 0 to 1.50 mg/L as B):** A Hach bench top or portable spectrophotometer or colorimeter was used to analyze boron. The boron test kit provided by Hach was used to analyze the samples. In this procedure, Azomethine-H, a Schiff base, is formed by the condensation of an aminonaphthol with an aldehyde by the catalytic action of boron. The boron concentration in the sample is proportional to the developed color which is measured by the colorimeter. Each batch of six samples takes approximately 20 minutes to analyze.
- **Fluoride (0 to 2.00 mg/L $F^-$):** A Hach bench top or portable spectrophotometer or colorimeter, AccuVac Vial Adaptor (for older spectrophotometers) and SPADNS Fluoride Reagent AccuVac Ampoules were used to measure fluoride in the samples. This procedure involves the reaction of fluoride with a red zirconium-dye solution. The fluoride combines with part of the zirconium to form a colorless complex, thus bleaching

the red color in an amount proportional to the fluoride concentration. Each sample takes an average of 3 minutes to test. The SPANDS reagent is a hazardous solution. The used AccuVac should be placed back in the Styrofoam shipping container for storage and then disposed properly through a hazardous waste disposal company. The procedure is relatively easy and fast and can be performed in the field using a portable spectrophotometer or colorimeter. However, as for all tests, it is recommended that the analyses be conducted in a laboratory, or at least in a work room having good lighting and water.

- **Total Hardness (10 – 4000 mg/L as $CaCO_3$):** This test was performed using the Hach digital titrator, total hardness titration cartridge, ManVer 2 hardness indicator, and hardness 1 buffer solution. This procedure involves buffering the sample first to pH 10.1, adding of the ManVer 2 Hardness Indicator, which forms a red complex with a portion of the calcium and magnesium in the sample, and then titrating with EDTA. The EDTA titrant reacts first with the free calcium and magnesium ions, then with those bound to the indicator, causing it to change to a blue color at the end point. It takes approximately 5 minutes per sample. The waste mixture of sample, buffer solution, hardness indicator, and EDTA must be stored properly in a labeled container until disposal by a hazardous waste disposal facility. While possible, it is not recommended to perform this procedure in the field.

- **Detergents (0-3ppm):** Detergents were analyzed using the Detergents (anionic surfactants) kit from CHEMetrics. The Detergents CHEMets® test employs the methylene blue extraction method. Anionic detergents react with methylene blue to form a blue complex that is extracted into an immiscible organic solvent. The intensity of the blue color is directly related to the concentration of "methylene blue active substances (MBAS)" in the sample. Anionic detergents are one of the most prominent methylene blue active substances. Test results are expressed in mg/L linear alkylbenzene sulfonate. It takes approximately 7 minutes per sample. This method uses a small amount of chloroform and extra precautions are therefore necessary during the test and when disposing of this hazardous material.

- **Ammonia (0 to 0.50 mg/L $NH_3$-N):** A Hach bench top, or portable spectrophotometer or colorimeter, ammonia nitrogen reagent set for 25-mL samples, and ammonia nitrogen standard solution were used for this test. In this method, ammonia compounds combine with chlorine to form monochloramine. Monochloramine reacts with salicylate to form 5-aminosalicylate. The 5-aminosalicylate is oxidized in the presence of sodium nitroprusside catalyst to form a blue-colored compound. The blue color is masked by the yellow color from the excess reagent present to give a final green-colored solution. Because of the duration of this test, it is best to run samples in batches of about 6. From start to finish, each batch of 6 samples takes about 25 minutes, including the time taken to clean the sample cells and reset the instrument between each batch. According to good laboratory practice, the contents of each sample cell, after the analysis, should be poured into another properly-labeled container for proper disposal. This procedure is time-consuming and should be performed indoors.
- **Color (0 – 100 APHA Platinum Cobalt Units)**: Color is measured using a Hach color test kit (Model CO-1), which measures color using a color disc for comparison. The sample is compared to a clean water tube and using the comparator, a match to the color of the sample is made. The readings on the comparator disc give the measurement of

color in APHA Platinum Cobalt Units. It takes about one minute to read a sample. This procedure is easy and fast and can be performed outside of the laboratory, if desired.

- **Turbidity (NTU):** A bench-top or portable turbidimeter is used to analyze turbidity. However, the portable turbidimeter has a much narrower analytical range compared to the laboratory instrument. The range of readings in NTU will depend upon the instrument. The instrument must be calibrated using the secondary standards supplied with the instrument. These secondary standards (very stable) need to be periodically checked against primary turbidity standards (which are unstable after dilution). Samples are normally stored under refrigeration prior to analysis. Before analyzing for turbidity, the samples must first be brought back to room temperature to prevent the formation of condensation on the outside of the glass sample cells used in the turbidity measurement. After wiping, the sample cell containing the sample is placed into the turbidimeter and the reading is noted. It takes approximately one minute to take a sample reading. It is a relatively simple test and may be performed outside the laboratory using a portable turbidimeter.

- **Optical Brighteners (mg/L as Tide):** A test for optical brighteners developed by Don Waye and used in his research in Northern Virginia, was also tested as a possible substitute for the detergents or fluorescence test. In this test, cotton pads enclosed in a steel grid covered with a plastic mesh are placed in the outfalls for at least 24 hours and are then brought back to the laboratory and dried. These pads are then viewed under the UV lamp to check for fluorescence. Standards of these cotton pads with pure samples of different concentrations of Tide detergent were prepared and the cotton pads from the outfalls are compared to these standards to estimate the concentration of detergent in the flows. The fluorescence of these pads was affected by deposits of silt and dirt onto the cotton pads. The method was also found to be very insensitive. However, if a clean pad was placed in an outfall, sheltered by the pipe, and it was later found to be fouled, that is a good indicator of the presence of intermittent dry-weather flows.

- **Fluorescence (mg/L as Tide)**: Fluorescence is the property of the whiteners in detergents that cause treated fabrics to fluoresce in the presence of ultraviolet rays, giving laundered materials an impression of extra cleanliness. These are also referred to as bluing, brighteners or optical brighteners and have been an important ingredient of most laundry detergents for many years. The effectiveness of the brighteners varies by the concentration of the detergents in the wash water. The detection of optical brighteners has been used as an indicator for the presence of laundry wastewater, and municipal sewage, in urban waters. The GFL-1 Portable Field Fluorometer by Opti-Sciences was used to measure fluorescence. The instrument was calibrated initially using known standards of the detergent *Tide* by *Procter and Gamble* and the calibration tables were saved in the instrument for future analyses. For each round of analysis, the calibration table is recalled and a blank sample is measured before analyzing the field samples. The samples to be analyzed are placed in the sample cells which are inserted into the sample chamber. Fluorescence is measured both in terms of signal strength and in mg/L. The values reported for this study are in mg/L. It is important to hold the samples till they are at room temperature in order to minimize interference due to condensation on the outside of the sample cells.

3.3 Development of the Flowchart Methodology

The flowchart methodology was initially described by Pitt, et al. (1993). Following a hierarchy of prescribed limits of tracers, the use of the flowchart makes it possible to identify the most probable source of contamination.

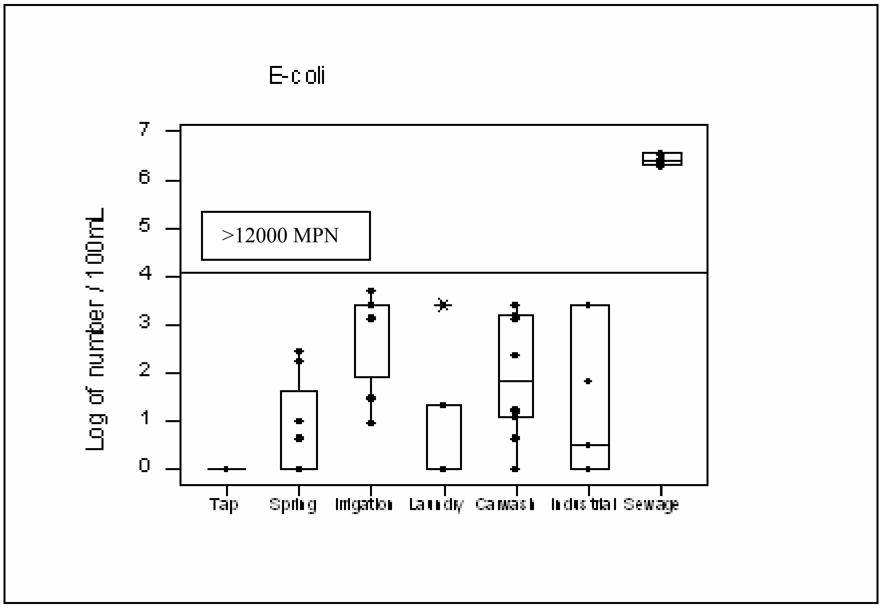


*Figure 3.1.* E.coli as a tracer to differentiate sanitary wastewaters from all other sources.

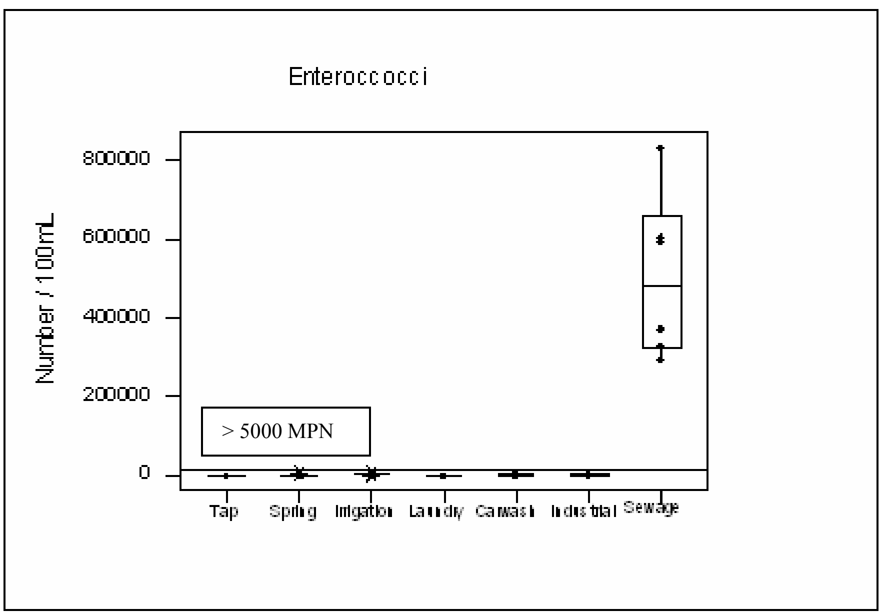


*Figure 3.2.* Enterococci as a tracer to differentiate sanitary wastewaters from all other sources.

The original flowchart was modified to reflect the current analytical methods and some changes in the tracers. The library tracer concentrations were used as a basis to find tracers which show unique values for different sources of contamination. A hierarchy of tracer concentrations was then derived, which would ultimately pin-point the source of contamination. From the basic flowchart depicted below, it can be seen that boron or detergents can be used to differentiate between the clean water sources and the wastewater sources. Fluoride concentrations can be used to distinguish between the natural water sources and the tap water sources. The ammonia to potassium ratio can help distinguish between sanitary wastewater sources and other wash waters. In the process of developing this flowchart it was also seen that bacteria values can also be used to distinguish between sanitary wastewaters and all other sources, but is not included in this basic flowchart as the cost of bacterial analysis and the time to conduct the analysis may be deterrents. The ammonia and potassium tests, on the other hand, are relatively easy to perform and are cheaper analyses. The additional bacteria analyses would be useful to verify the presence of sanitary wastewater, if present in high enough levels.

Fluorescence was also found to be effective in distinguishing between tap water and irrigation water. It has not been included in the main flowchart (Figure 3.3) used for the identification of contaminant sources in this project. But, in cases where a greater degree of differentiation between the tap water and irrigation waters is desired an alternate version of the flowchart can be used (Figure 3.4).

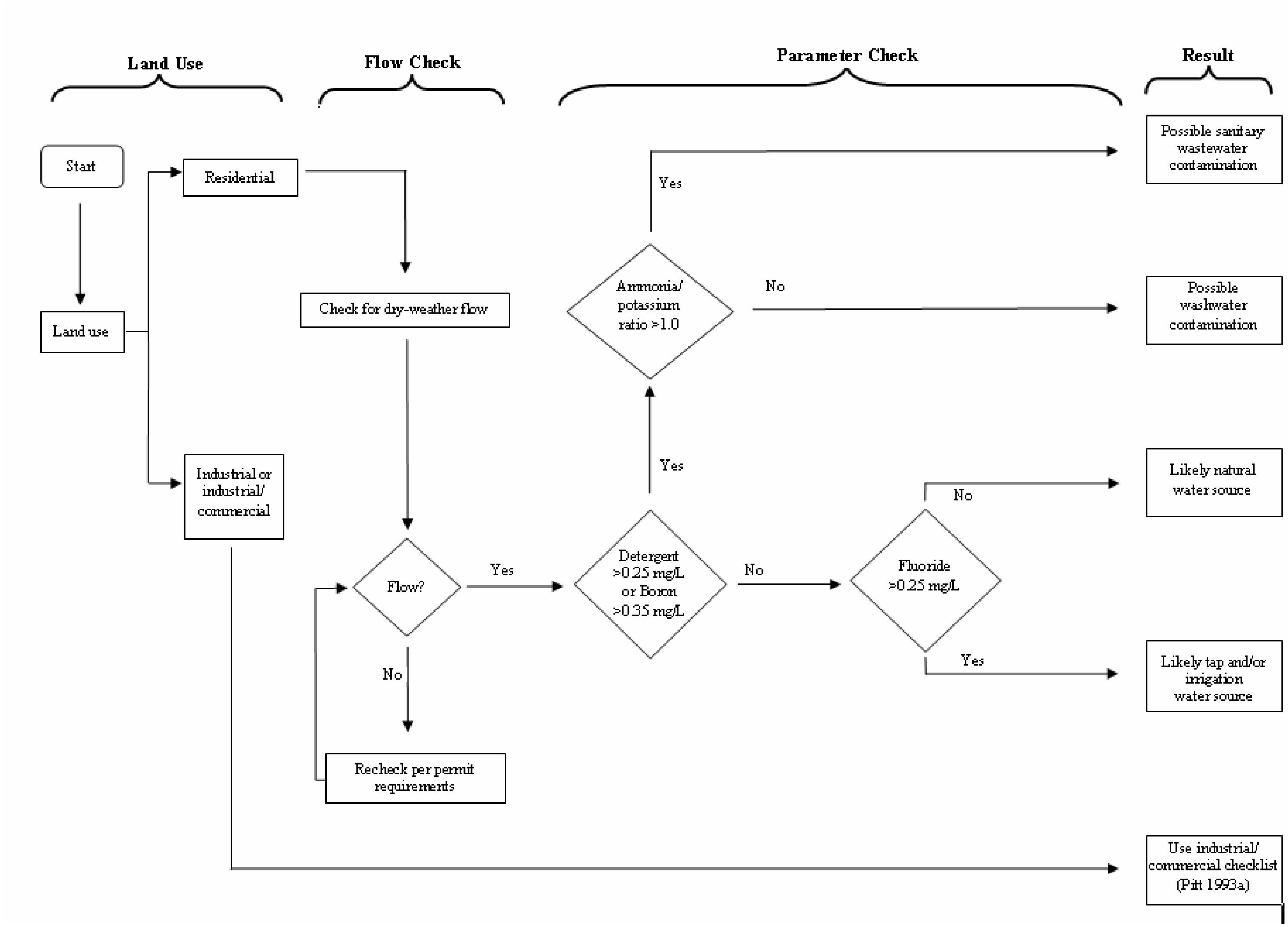


Figure3.3. Flowchart Methodology

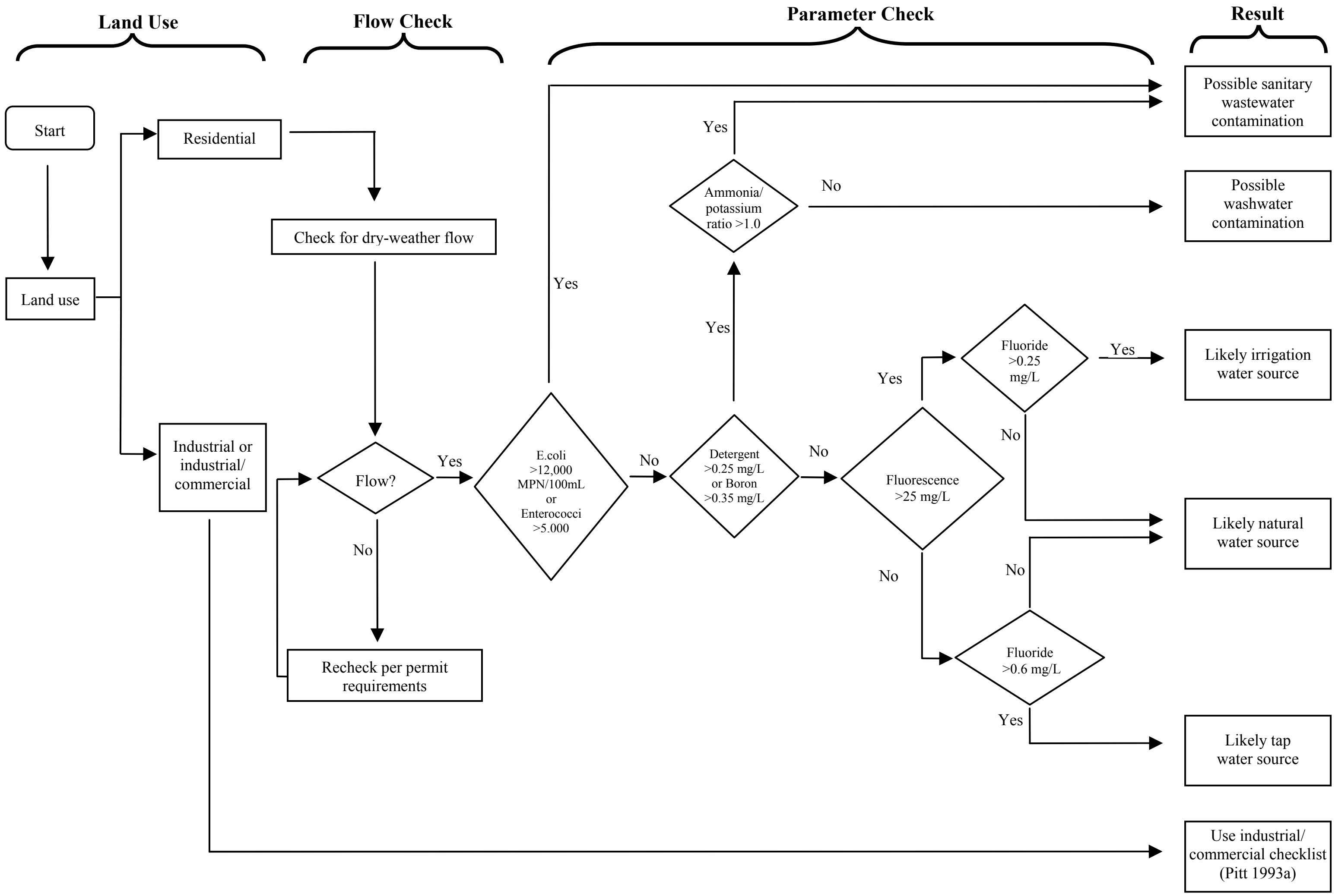


Figure 3.4. Flowchart Methodology (with differentiation between clean water sources)

The defining values in the flowchart were derived from the values observed during development of the local library of the tracer concentrations. The following table depicts the ranges of tracer concentrations for the various source categories as noted from the library samples collected in Tuscaloosa over a period from September 2002 to June 2003.

Table 3.2. Ranges of chemical tracers in the library data

| | **Tap water** | **Spring water** | **Irrigation Runoff** | **Laundry Washwater** | **Carwash water** | **Sanitary wastewater (Dry-weather)** | **Sanitary wastewater (Wet weather)** | **Industrial wastewater** |
|---|---|---|---|---|---|---|---|---|
| **pH** | 7.38-8.46 | 5.63-6.82 | 6.91-7.91 | 6.22-9.63 | 6.62-9.34 | 6.42-7.1 | 6.8-7.0 | 6.22-7.3 |
| **Temperature (F)** | N/A | 30-72 | 70-89 | 26-110 | 26-71 | N/A | N/A | N/A |
| **Conductivity (µS/cm)** | 125-156 | 112-230 | 148-200 | 152-1690 | 120-570 | 540-2100 | 440-1250 | 37-960 |
| **Turbidity (NTU)** | 0.433-1.15 | 0.591-67 | 4.03-826 | 25-398 | 1-383 | 53.6-306 | 113-270 | 10-309 |
| **Color (APHA Platinum Cobalt Units)** | 0 | 0-27 | 0-56 | 20-45 | 0->100 | 70-100 | 57->100 | 10->100 |
| **Hardness (mg/L as CaCO3 in 100 ml)** | 28-72.8 | 24.6-48 | 40-66 | 13-60 | 15-84 | 36-68 | 44-54 | 23-38 |
| **Boron (mg/l)** | 0.04-0.27 | 0.04-0.16 | 0.13-0.5 | 0.36-10.8 | 0.09-1.74 | 0.97 | 0.78-1.38 | N/A |
| **Detergents (mg/L)** | 0 | 0 | 0 | 420-1020 | 80-200 | 8-12.5 | 6.0-8.0 | 0.25-12.5 |
| **Fluorescence (mg/L)** | 0.21-4.88 | 0.46-47.97 | 32.16-92.55 | 302.92-2805.3 | 31.62-162.22 | 142.44-267.79 | 244.12-298.45 | 101.62-722.26 |
| **Fluoride (mg/l)** | 0.82-1.04 | 0.01-0.39 | 0.23-0.91 | 0.05-1.27 | 0.04- 6.45 | 0.64-0.82 | 0.14-0.25 | 0.01-0.89 |
| **Potassium (mg/L)** | 1.0-2.0 | 1.0-8.0 | 2.0-10.0 | 2.0-15.0 | 2.0-10.0 | 9.0-15.0 | 10.0-14.0 | 8.0-92 |
| **Ammonia (mg/L)** | 0.01-0.07 | 0.01-0.29 | 0.08-4.5 | 0.5-9.0 | 0.03-4.5 | 11.0-45.0 | 22.5-36.0 | 0.4-12.0 |
| **Ammonia-Potassium Ratio** | 0.005-0.07 | 0.001-0.145 | 0.016-1.75 | 0.035-3 | 0.02-1.5 | 1-4.091 | 1.875-3.273 | 0.0043-1.25 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Total Coliform (MPN/100mL)** | <1-21.6 | 4.1->2419.2 | >2419.2->4838.4 | <1->2419.2 | <1->2419.2 | >2419.2->24192000 | >24192000 | 204.6->2419.2 |
| ***E. Coli*** **(MPN/100mL)** | <1 | <1-290.9 | 8.3->4838.4 | <1->2419.2 | <1->2419.2 | >2419.2-12033000 | 1785000-3654000 | <1->2419.2 |
| **Enterococci (MPN/100mL)** | <1 | <1-412 | 2->4838.4 | <1 | <1->2419.2 | 43.6-613000 | 292000-833000 | 0->2419.2 |

The industrial water sources were differentiated into two categories- *Cintas* data and all other industrial sources (mostly food processing). The *Cintas* data is from a uniform manufacturing industry, which showed very unique tracer concentrations. All the other industries have been organized into one category. Only the tracer ranges in the common group of industries is mentioned here. It should also be noted that the industrial sources were not considered in our study as the watershed itself did not contain any of these industries.

From Table 3.2, it is seen that boron and/or detergents is used to distinguish the clean waters from the dirty waters. Within the dirty waters, the ammonia/potassium ratio is used to distinguish between the sanitary wastewaters and the washwaters. Among the twelve laundry samples taken, two samples showed an ammonia/potassium ratio value of greater than 1, but all of the sanitary wastewaters showed an ammonia/potassium ratio greater than 1. Hence, an ammonia potassium ratio greater than 1.5 is a robust value to differentiate between sanitary wastewaters and other dirty waters. From other analyses of sewage dilution, this has been found to be a robust tracer to differentiate between these dirty water categories.

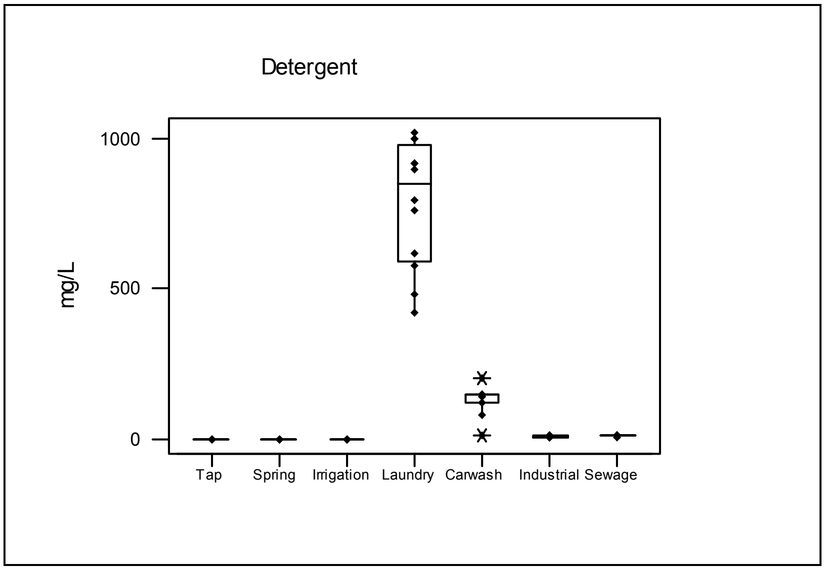


Figure 3.5. Detergents as a tracer to differentiate clean and dirty waters

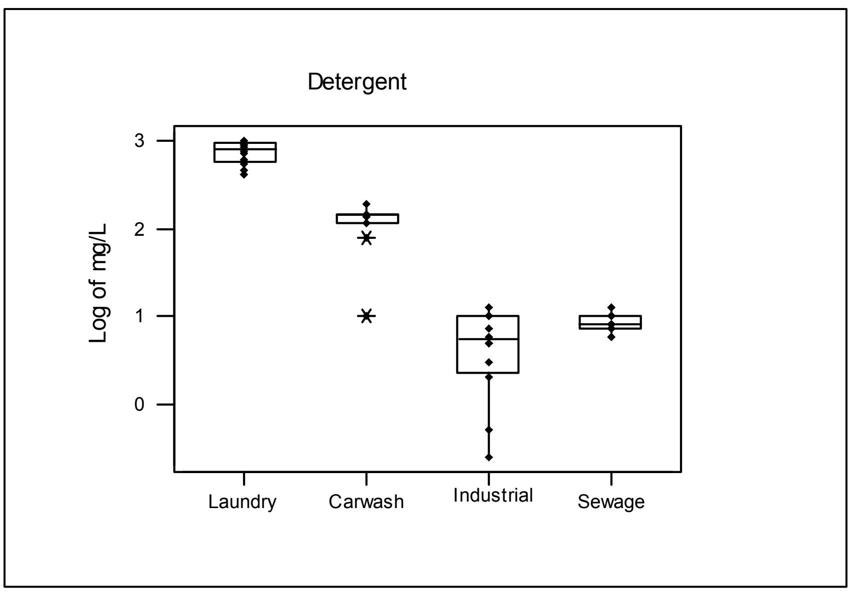


Figure 3.6. Detergent concentrations in dirty waters

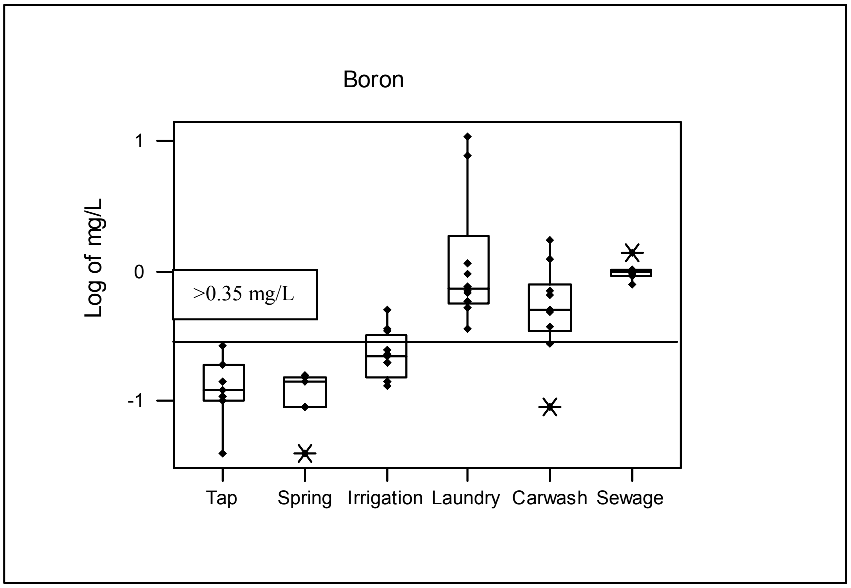


Figure 3.7. Boron as a tracer to differentiate clean and dirty water

From the box plots for boron shown in Figure 3.7, it can be seen that there is a marked difference between the boron concentrations for clean waters (spring tap and irrigation waters) and the dirty waters (laundry, carwash sanitary wastewaters). However, there is an overlap between the values for laundry and irrigation waters. The minimum boron values for laundry waters overlap the maximum boron values for irrigation waters. In this scenario, the differentiating value of 0.35 mg/L for boron needs to be further examined.

Table 3.3. Boron values in library samples

| ID | Tap Water | Spring Water | Irrigation | Laundry | Carwash | Sewage | |
|---|---|---|---|---|---|---|---|
| | | | | | | Dry | Wet |
| | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L |
| NO.1 | NA | NA | 0.14 | NA | NA | NA | 1.38 |
| NO.2 | NA | NA | 0.20 | NA | NA | NA | 0.98 |
| NO.3 | NA | NA | 0.25 | 0.53 | 0.50 | NA | 0.93 |
| NO.4 | NA | NA | 0.13 | 0.36 | 0.65 | NA | 1.05 |
| NO.5 | NA | NA | 0.2 | 0.67 | 1.23 | NA | 1.01 |
| NO.6 | 0.19 | 0.15 | 0.36 | 0.75 | 1.74 | 0.97 | 0.78 |
| NO.7 | 0.1 | 0.15 | 0.5 | 0.58 | 0.37 | | |
| NO.8 | 0.12 | 0.14 | 0.22 | 7.90 | 0.48 | | |
| NO.9 | 0.04 | 0.09 | 0.14 | 0.97 | 0.70 | | |
| NO.10 | 0.14 | 0.16 | 0.23 | 10.80 | 0.50 | | |
| NO.11 | 0.27 | 0.09 | 0.25 | 1.16 | 0.09 | | |
| NO.12 | 0.11 | 0.04 | 0.35 | 0.70 | 0.28 | | |
| Sample size | 7 | 7 | 12 | 10 | 10 | 1 | 6 |
| Mean | 0.14 | 0.12 | 0.25 | 2.44 | 0.65 | 0.97 | 1.02 |
| Median | 0.12 | 0.14 | 0.225 | 0.725 | 0.5 | 0.97 | 0.995 |
| Std. deviation | 0.07 | 0.04 | 0.11 | 3.71 | 0.49 | - | 0.20 |
| Variance | 0.01 | 0.00 | 0.01 | 13.77 | 0.24 | - | 0.04 |
| Skewness | 0.805 | -0.887 | 1.218 | 1.910 | 1.454 | - | 1.184 |
| Coef. of Variation | 0.529 | 0.381 | 0.438 | 1.520 | 0.744 | - | 0.195 |
| Anderson-Darling P- value (Normal) | 1.663 | 1.864 | 1.366 | 3.419 | 1.678 | - | 1.984 |
| Anderson-Darling P- value (Log-Normal) | 1.685 | 2.04 | 1.094 | 2.106 | 1.34 | - | 1.906 |

Table 3.3 lists the boron values for the library samples collected to define the values on the flowchart. From this table, it can be noted that the lowest differentiating value without an overlap is 0.53 mg/L. Hence, the difference in the number of problem outfalls

when using a value of 0.35 mg/L and 0.5 mg/L is studied. Figure 3.8 shows the percentage detection values using the various combinations of tracers. The graph shows that the use of two different concentrations of boron (0.35 mg/L and 0.50 mg/L) along with detergents (≥ 0.25 PPM) to identify problem outfalls yields different results. A higher concentration of boron results in a lower detection by almost 20% in three of the outfalls when compared to the current differentiating concentration of 0.35 mg/L. Since the detection of false negatives is more of a concern than false positives, the flowchart method would yield better results if a 0.35mg/L concentration of boron is used instead of a 0.50 mg/L value of boron.

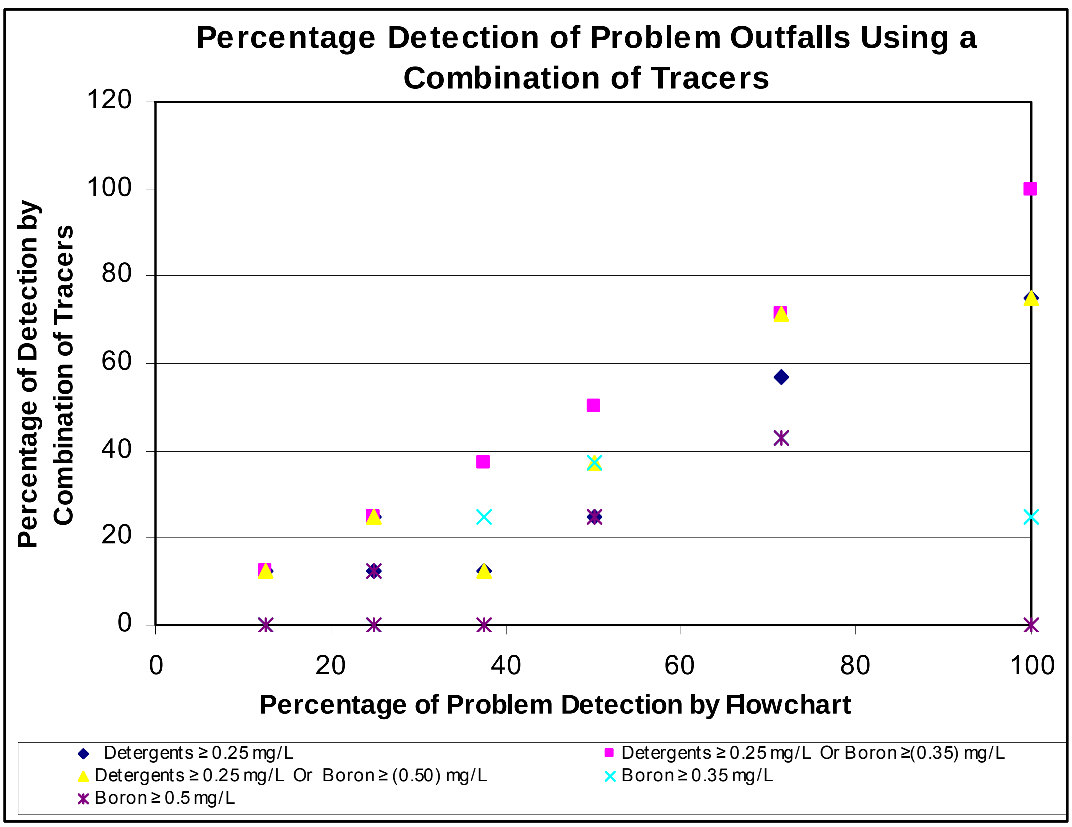


*Figure 3.8.* Percentage detection of problem outfalls by using a combination of tracers.

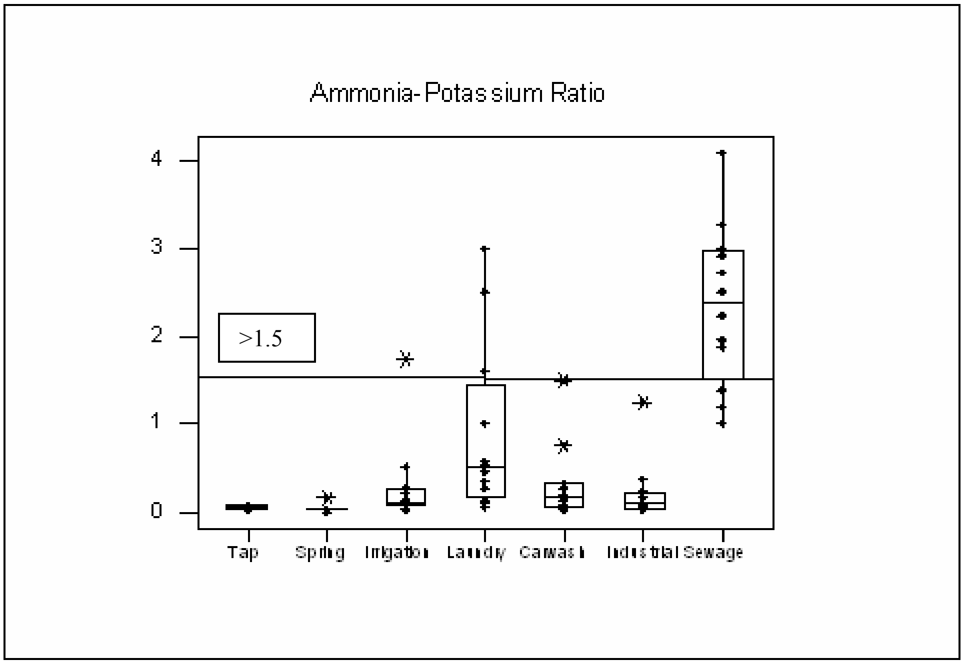


Figure 3.9. Ammonia-Potassium ratio to differentiate sanitary wastewater from washwater

Fluoride concentrations can be used to distinguish between the clean waters. Tap water and irrigation water (since it originates from tap water) can be differentiated from spring water by using fluoride as a tracer as fluoride is added to tap water in concentrations required by local regulations. Spring water, on the other hand will not have anthropogenic concentrations of fluoride in many areas, making it a dependable tracer.

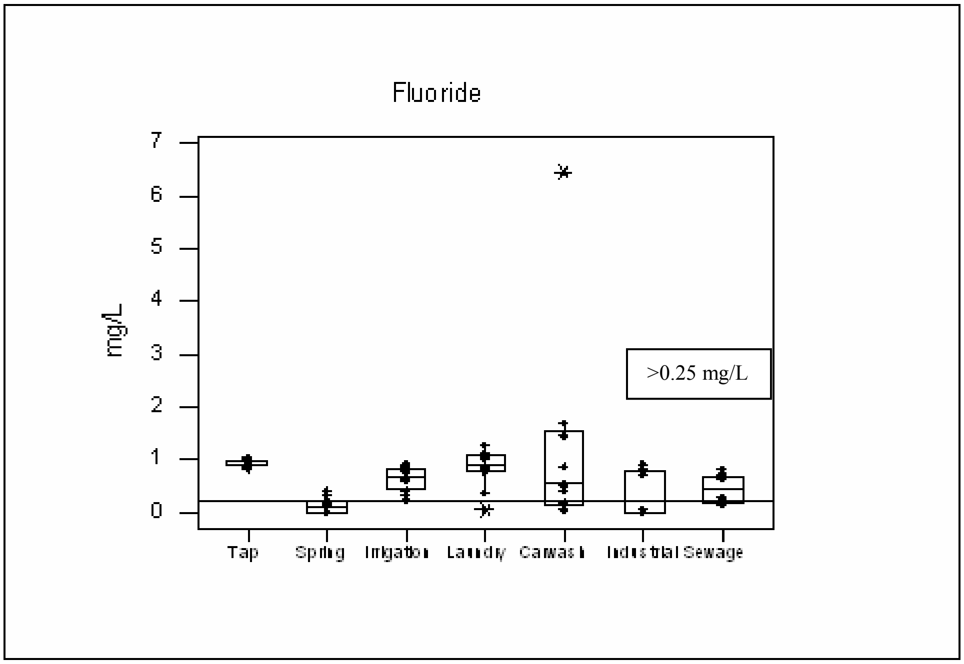


Figure 3.10. Fluoride as a tracer to differentiate natural water from tap/irrigation water.

Further differentiation between tap water and irrigation runoff is not specified by this flowchart, since this difference is not very significant, considering that the focus of this study is on finding methods to identify polluted waters. However, large tap water leaks can be identified and corrective action. If desired, turbidity can be used to differentiate between irrigation water and tap water, with tap water having extremely low turbidity values. Although, if tap water flows through a storm drain pipe for some distance, it will obviously become contaminated and will show higher turbidity values.

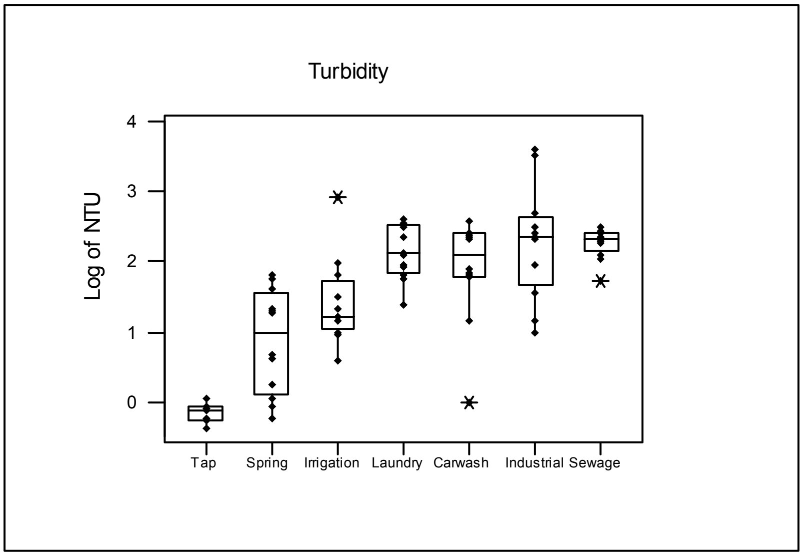


Figure 3.11. Turbidity as a tracer to differentiate tap water from irrigation Water

The methodology described above was used to define the flowchart arrangement and to identify the important values that can be used to identify the most likely cause of contamination in the dry-weather flow samples collected at all the outfalls in the Cribbs Mill Creek.

## 3.4 Chemical Mass Balance Model (CMBM)

This process can also be complemented by a method which can quantify the extent of contribution of each of the sources to the outfall flows. A Chemical Mass Balance Model (CMBM) using Monte Carlo simulation, which can calculate the chemical mass fractions of the various sources, was created by Veerabhadra Rao Karri, at the University of Alabama, Tuscaloosa, as part of his Masters thesis (2004). This program was used to identify the problem outfalls based on the contributions of the various sources. The following briefly describes this program. A more detailed description, including code and user manual, is presented in Karri (2004).

Identification of problem outfalls using only visual observations may result in many incorrect determinations, or false negatives. For regulatory applications, false negatives can be a serious problem. Therefore, for all regulatory applications, a quantifiable estimate (with uncertainties) is recommended. Hence, this method when used in conjunction with the flow chart methodology, would give greater confidence when determining the sources of contaminants than relying solely on visual observations.
The library tracer data was evaluated for normal, or log-normal distribution fits using the Anderson Darling (AD) test. As an example, the data distribution for boron in the laundry samples is shown in figures 3.12 and 3.13. Observing these plots, it is clear that the data fits the log-normal distribution (AD P-value: 2.108) better than the normal distribution (AD P-value: 3.419). However, Figure 3.13 shows 2 likely separate distributions for boron, one for lower and another for higher concentrations. Both the samples are collected from washing machines after the first wash cycle, much like the other samples, but both these samples have ‘Tide’ as the detergent. There is another sample among the 12 which is with ‘Tide’ detergent, but shows a lower boron concentration of about 0.7 mg/l. (Appendix E)

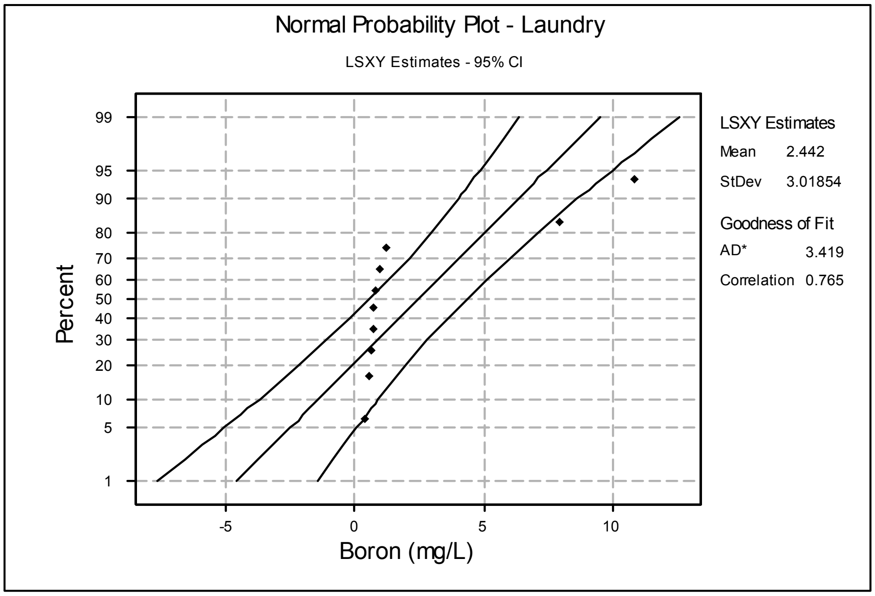


Figure 3.12. Normal probability plot of boron tracer data for laundry samples

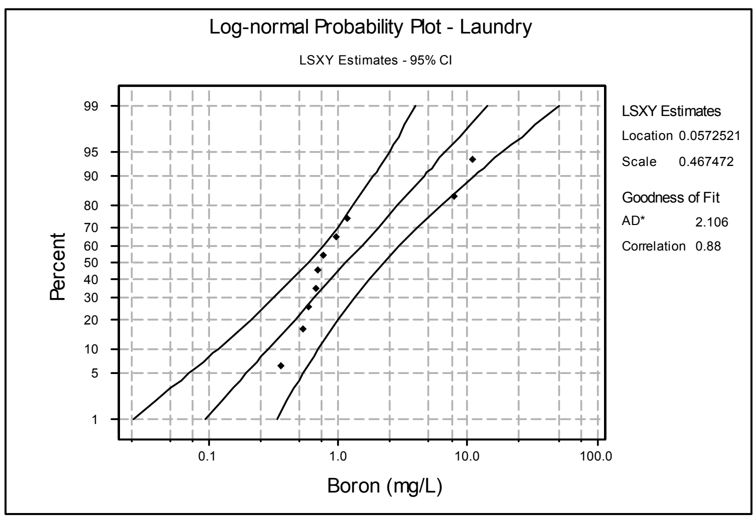


Figure 3.13. Log-normal probability plot of boron tracer data for laundry samples

The model uses the input values of the sources and tracers to be evaluated from the existing library data file, according to selections of the model user (the number of tracers used must equal the number of possible sources being examined). The mass fractions of the sources contributing to the outfall are then calculated using matrix algebra. The matrix algebra method used in this model involves solving a set of simultaneous chemical mass balance equations for the mass fraction values at the outfall. The model compares the tracer concentrations of outfall samples against local chemical tracer concentrations of pure source samples and from the ensuing mass balance equations returns the most probable source of contamination.

Since there is variability within the library data for each tracer, these equations have to be solved using a number of values of concentrations within the appropriate data distributions (log or log-normal) of these concentration values. Monte Carlo simulation is used to accomplish this task. Once the probability of correctness in the prediction of the source water is quantified, one can make a decision as to the most likely inappropriate source(s) contributing to the outfall discharge. If such a quantitative assessment of uncertainty was not conducted, insufficient water quality improvements and misallocation of other resources could result.

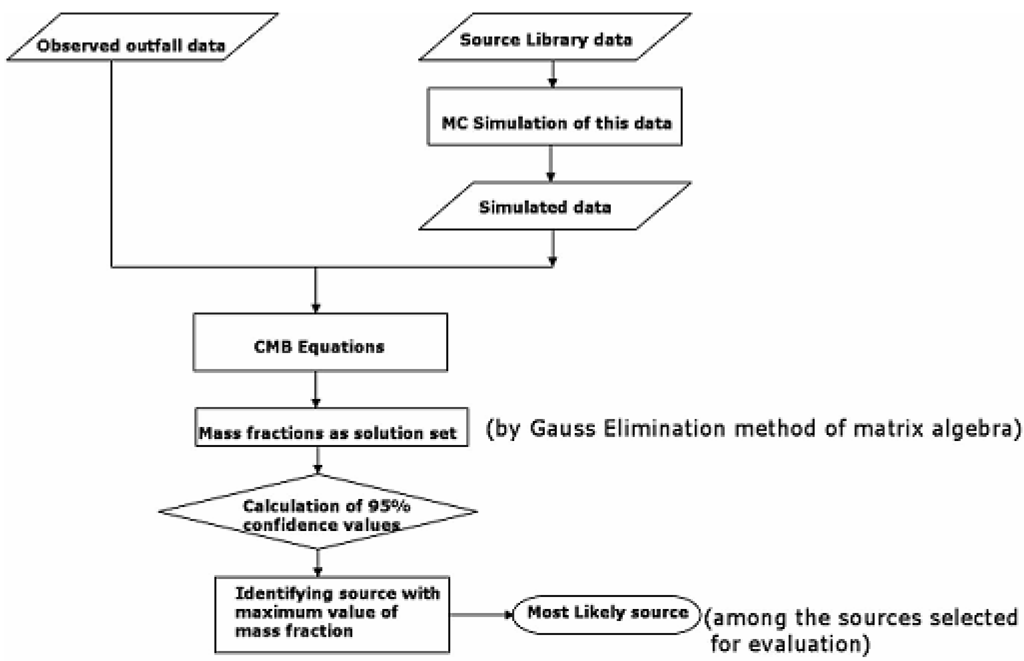


Figure 3.14. Chemical Mass Balance Model methodology (Adapted from Karri, 2004)

Summary Table

| | Tap Water | Spring Water | Carwash Wa | Laundry Wa | Sewage Was | Irrigation Wa | Mu |
|---|---|---|---|---|---|---|---|
| 2.5th %tile | -20.25 | -27.23 | -4.96 | -0.73 | -1.81 | -12.81 | -19.21 |
| 97.5th %tile | 19.56 | 24.53 | 4.18 | 0.74 | 2.8 | 9.25 | 19.76 |
| 50th %tile | 1.095 | -0.18 | -0.15 | 0.03 | 0.27 | -0.155 | -0.06 |

Figure 3.15. Example CMBM summary table (Adapted from Karri, 2004)

Figure 3.15 shows the summary table obtained as an output by the model during the analysis of outfall # 10a, collected on June 6th, 2002. As can be seen in the values listed for 50th percentile (the most likely mass fraction of the contributing sources as a result of the Monte Carlo simulation), there are two mass fraction values which are considerably higher than those for other sources (tap water and sewage wastewater). This indicates that tap water is the most common source, with some potential sanitary sewage contamination likely. The wide range for spring water indicates that there would be great uncertainty in eliminating this source as a potential contributor. This conclusion could only be made by using a quantifiable estimate such as this model. The flow chart method can identify only one of these sources as the critical source, and with no measure of uncertainty. This may result in a likely false negative determination for the most important source, sewage contamination. Remedial actions based on the less quantifiable methods could thus lead to insufficient water quality improvements. The calculated value of Mu shown on the summary table should be close to zero (as in this example). If it is large, the selection of possible sources being investigated, or tracers being used, should probably be changed.

The CMBM model is subject not only to the inherent random nature of the data as reflected in the Monte Carlo simulation and the subsequent difference in the results for the same tracer concentrations over various runs, but is also very sensitive to the tracer parameters that were selected for the possible sources of contamination. It follows that there is a ‘best’ combination of tracers for each area that can be used which would result in the most robust and accurate result. After repeated test runs, supported by statistical analyses, it was found that for any of the sources in the local Tuscaloosa area, a combination of the following tracers would work ‘best’: fluoride, hardness, conductivity, detergents or boron or fluorescence, potassium or ammonia, Enterococci or *E.coli,* and at times, turbidity.

The library data used in the model represents pure concentrations of the sources, but in reality, the dry-weather flows at the outfall would be a mixture of sources, with the dirty water sources diluted in concentration. Hence, the results generated by the model may not return the dirty water source as the most likely source of contamination. Hence, it is important to pay attention to the dirty water sources represented in the most likely sources (for example: The top three sources of contamination). Relatively small amounts of sanitary sewage are highly undesirable, for example.

# CHAPTER 4

# PROBLEM OUTFALLS VERIFICATION PROCESS

## 4.1. Overview of Outfall Verification Results

Out of all of the outfalls sampled, ten were selected for detailed analyses as they represented a range of potential problems, according to the flowchart methodology. All the analysis results for the five rounds of sampling were assessed. Out of the ten outfalls selected as problem outfalls, only nine were found to be flowing in all the verification creek walks. Hence Outfall 49 was eliminated from the verification process and from the results discussed below. The nine outfalls selected for these detailed tests are listed in Table 4.1 and the results presented are a summary of the results obtained by using the flowchart method and the CMBM for all the samples.

Where ever possible, tThe best tracer combination (indicated by a minimum $\mu$ value), as indicated in Table 4.1, was consistently used for each outfall. In instances where the reported value was below the detection limit or was not reported at all, a substitute tracer was selected, while still minimizing the $\mu$ value.

Table 4.1. *Summary table of most likely sources of contamination*

| **Outfall #** | **Most likely contaminated source by Flow chart method** | **Most likely source by CMBM** | **Tracers selected for model run** |
|---|---|---|---|
| 3 | Natural water (9/13), Possible Washwater (4/13) | Spring Water (13/13) | Fluoride, Hardness, Detergents, Fluorescence, Potassium, Enterococci |
| 4 | Natural Water (19/20), Tap/Irrigation Water (1/20) | Spring Water (20/20) | Conductivity, Fluoride, Hardness, Detergents, Boron, Enterococci |
| 27 | Natural Water (4/9), Tap/Irrigation Water (5/9) | Spring Water (7/9), Tap Water (2/9) | Conductivity, Hardness, Ammonia, Turbidity, E-Coli, Enterococci |
| 31 | Tap/Irrigation Water (9/13), Natural Water (2/13), Possible Washwater (2/13) , | Tap Water (9/13), Spring water (4/13) | Fluoride, Detergents, Fluorescence, Potassium, Ammonia, Boron |
| 36 | Natural Water (5/7), Possible Washwater (2/7) | Tap Water (1/8), Irrigation Water (1/8), Spring Water (3/8), Carwash Water (3/8) | Conductivity, Fluoride, Fluorescence, Potassium, Boron, Enterococci |
| 39 | Natural Water (14/14) | Tap Water (4/14) Spring Water (9/14), Carwash Water (1/14) | Fluoride, Hardness, Potassium, Turbidity, Boron, Enterococci |
| 45 | Possible Washwater (8/12), Natural Water (2/12), Tap/Irrigation Water (2/12) | Tap Water, Spring Water, Carwash Water | Conductivity, Fluoride, Hardness, Detergents, Boron, Enterococci |
| 53 | Natural Water (13/15), /Possible Washwater (2/15) | Tap (3/16), Spring Water (13/16) | Conductivity, Fluoride, Hardness, Detergents, Potassium, Enterococci |
| 55 | Possible Sanitary Wastewater (3/8), Possible Washwater (1/8), Natural Water, Tap (4/8) | Spring Water (6/9), Sanitary Wastewater (2/9), Tap Water (1/9) | Conductivity, Fluoride, Hardness, Ammonia, Boron, Enterococci |

Note: The flowchart results for outfalls 36, 53 and 55 indicate one sample less than the total number seen in the CMBM results. This resulted from missing data for certain key tracer concentrations. Appendix-A lists tracer concentrations for all the samples collected and analyzed.

The verification procedure entails mapping the watershed for each of the outfalls and tracing a path of the contaminant stream through the storm sewer network within the watershed and ultimately pin-pointing the source. Typically, the verification process included taking samples at the designated problem outfalls, investigating further on into the watershed by finding the associated storm drain network and taking samples at each manhole as we went upstream into the watershed till a point is reached where there was no sign of dry-weather flows. The source was then determined to be near the most upstream manhole in the watershed where dry-weather flows was last noticed. Most of the manholes in the network were associated with storm drain inlets at the curbs.

In the case of continuous dry-weather flows in an open channel flowing to the creek (such as for Outfall 3), the flows are sampled from the outfall to the boundary of the watershed or to the source of flow. The drainage system is roughly divided into thirds, and samples are obtained at these divisions. Differences in the tracer concentrations, or flows, between these sampling locations can be used to identify the area where the flows originate in the drainage system. Examining the residences and commercial establishments in the identified area where the flows or inappropriate discharges occur, including possibly investigating floor drains or discharges originating from these locations may be necessary. This information coupled with the predicted source of flows from the source characterization studies (the flow chart and/or the Monte Carlo mixing model) can narrow the likely source down to a few potential candidates.

This process was followed for the verification of the predicted sources of flows in the ten outfalls selected for detailed investigations, based on the flowchart methodology and visual observations. Outfalls 4, 27 and 39 were designated as potential problem outfalls based on visual observations. These outfalls always showed visible indications of contamination in terms of floatables, color, sediment, or high flows. Outfall 27, in particular, had flows with a strong unpleasant odor, characteristic of sewage. Outfall 39 was characterized by continuous large flows; hence it needed to be investigated.

## 4.2. Outfall Verification Results for Individual Outfalls

The process and results of verification for each of the outfalls is detailed below. This discussion imparts an understanding of the various facets involved in such a process, which are not restricted just to the collection and analysis of samples.

*4.2.1.Outfall 3:* Outfall 3 is located in a residential area, off 15th Street East in Tuscaloosa, AL. The banks of the creek are characterized by dense vegetation. This outfall is about 2 ft. in width, and is in the form of a stream flowing into the main creek. This outfall is located in the backyard of a quarter acre residence. There has been no indication of inappropriate flows originating from the residence itself. The single stream feeding this outfall was followed till it came to a point where it had two head streams. These head streams are again located in the backyards of residences. The area where the streams flow is characterized by dense fallen foliage and shrubs. Both the streams were followed to the source. Stream A (Figure 4.1) seems to have a very short run before it joins the main stream, and it seems to originate below all the dense foliage, making it inaccessible to verify the source. Stream B was also followed to its source and it also seems to be upwelling from the ground, but very close to a residence (Figure 4.4). Since both these streams showed wash waters at one time or another, it seems logical to conclude that there could be pipes originating from these residences which are covered by the dense foliage, which carry the laundry waters from these houses to the streams. There is also a likelihood of the presence of springs in this area, which contributes to the flow.

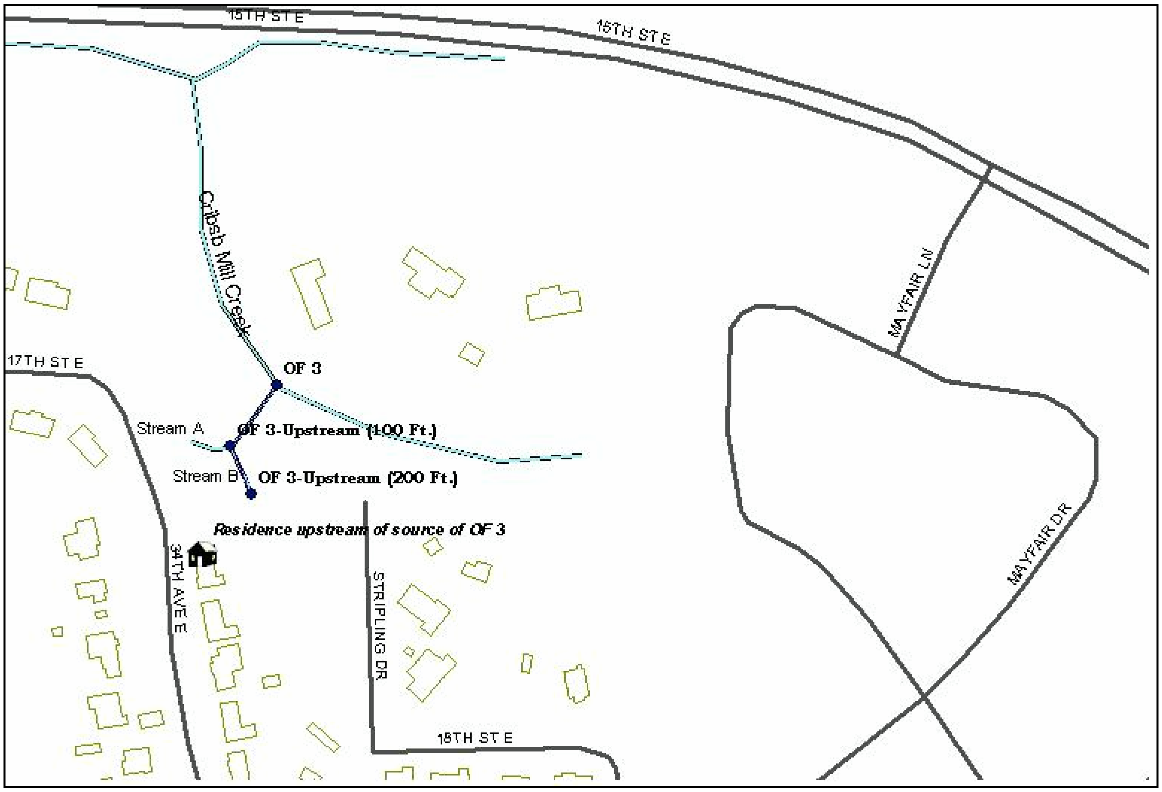


Figure 4.1. Location map of outfall 3

Figure 4.2. Outfall 3

The Stream A is located 100 ft. from the outfall and the point of origin of Stream B is located 200 ft. from the outfall. Hence, these two points were sampled along with the outfall. In order to get an appropriate sample for the shallow flows, a large suction sampler (a “turkey baster”) was used. Cotton pads, used to identify the presence of optical brighteners were placed at all the locations from where samples were collected and were picked up the next day in both cases. The pads showed a lack of fluorescence .

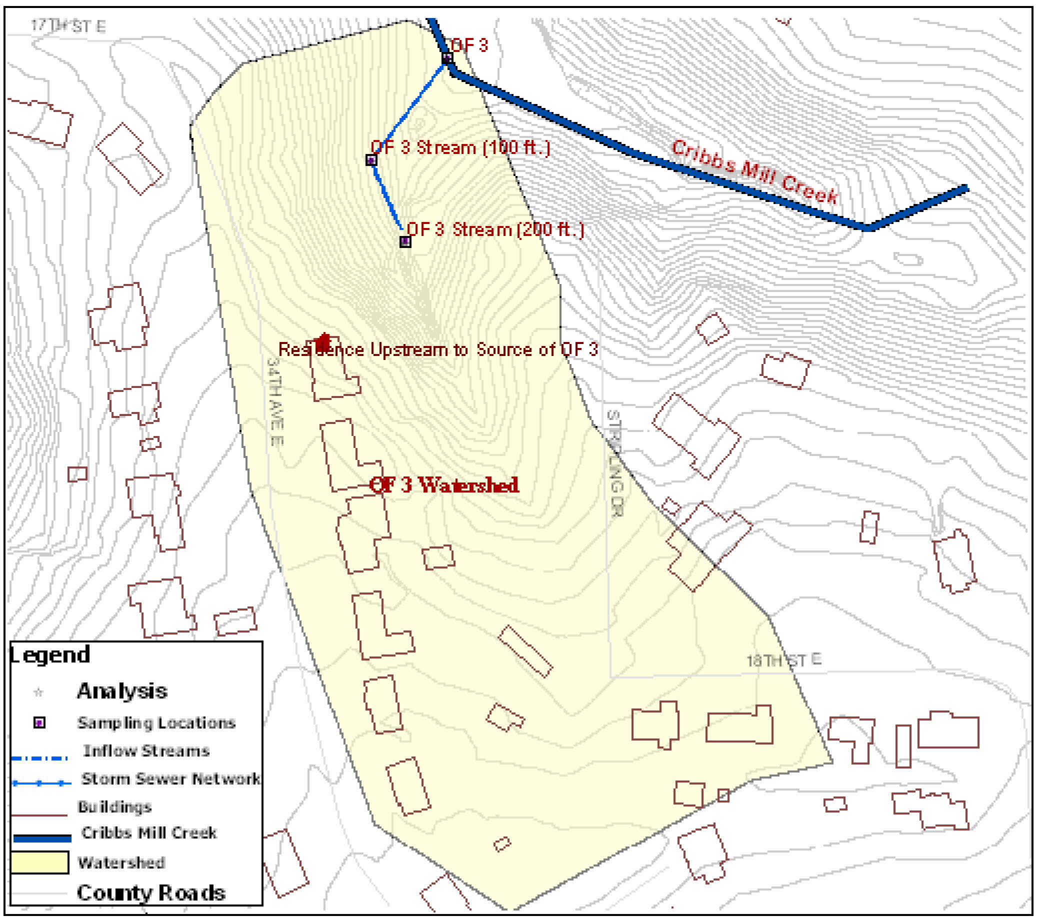


Figure 4.3. Watershed delineation for outfall 3

In the first round of verification testing, only the source of the stream (at 200 ft. from the outfall) was sampled (Figure 4.3). Since the samples showed the presence of washwater, it became more important to sample the stream at regular intervals. Hence, samples were taken every one third of the distance from the outfall to the source. The results obtained from the analysis of the watershed and the samples are shown in Table 4.2. The most likely source by model lists the top three contributing sources.

Figure 4.4. Residence upstream to head of outfall 3 stream

Table 4.2. *Summary of most likely sources of contamination for outfall 3*

| **Sample ID** | **Date of collection** | **Most likely source by CMBM (Top three sources)** | **Problem indicated by physical observations** | **Detergents contamination yes if ≥ 0.25 mg/l or Yes if boron ≥ 0.35** | **Most likely contaminated source by Flow chart method** |
|---|---|---|---|---|---|
| Outfall 3 | 4/17/2002 | Spring water, Laundry washwater | No | No | Natural Water Source |
| | 5/31/2002 | Spring water, Sanitary wastewater, Laundry washwater | No | No | Natural Water Source |
| | 10/9/2002 | Spring water, Tap water, Laundry washwater | Yes (floatables, color, turbidity) | Yes | Washwater Source |
| | 2/18/2003 | Spring water, Sanitary wastewater, Carwash water | Yes (floatables, color) | No | Washwater Source |
| | 3/31/2003 | Spring water, Laundry washwater | Yes (floatables, color) | No | Natural Water Source |
| | 12/20/2003 | Spring water, Laundry washwater | Yes (floatables, color) | No | Natural Water Source |
| | 1/20/2004 | Spring water, Tap water, Laundry washwater | No | No | Natural Water Source |
| | 3/27/2004 | Spring water, Laundry washwater, Tap water | No | No | Natural Water Source |
| OF 3-Upstream Ditch (200 Ft.) | 12/20/2003 | Spring water, Laundry washwater | No | No | Washwater Source |
| OF 3-Upstream Ditch (100 Ft.) | 1/20/2004 | Spring water, Laundry washwater | No | No | Washwater Source |
| OF 3-Upstream Ditch (100 Ft.) | 3/27/2004 | Spring water, Laundry washwater | No | No | Natural Water Source |
| OF 3-Upstream Ditch (200 Ft.) | 1/20/2004 | Spring water, Tap water | No | No | Natural Water Source |
| OF 3-Upstream Ditch (200 Ft.) | 3/27/2004 | Spring water, Laundry washwater, Sanitary wastewater | No | No | Natural Water Source |

From the above tables it can be discerned that the feeder streams might periodically have washwater contributions, but the outfall showed varying results, with mostly natural water contributions likely. This could be the effect of dilution by spring water present in this vicinity. If the watershed verification procedure was not carried out it would not be possible to verify the sources of contamination from the outfall samples alone.

*4.2.2 Outfall 4:* Outfall 4 is also located off 15th Street East, along the main road (Figure 4.5). This outfall can be accessed from the sidewalk off 15th Street East. The manholes up system from this outfall lie along the main road and are storm water inlets. The network of sewer pipes was traced back by manhole inspection, noting the direction of incoming pipes and following them to the next manhole, until we came to a point where the storm drain pipes seem to be coming from a residential area, which was characterized by multiple residences in a row, with only driveways extending from the main road up toward the residences with no side streets. Hence, it was difficult to trace the storm sewer network further above these manholes.

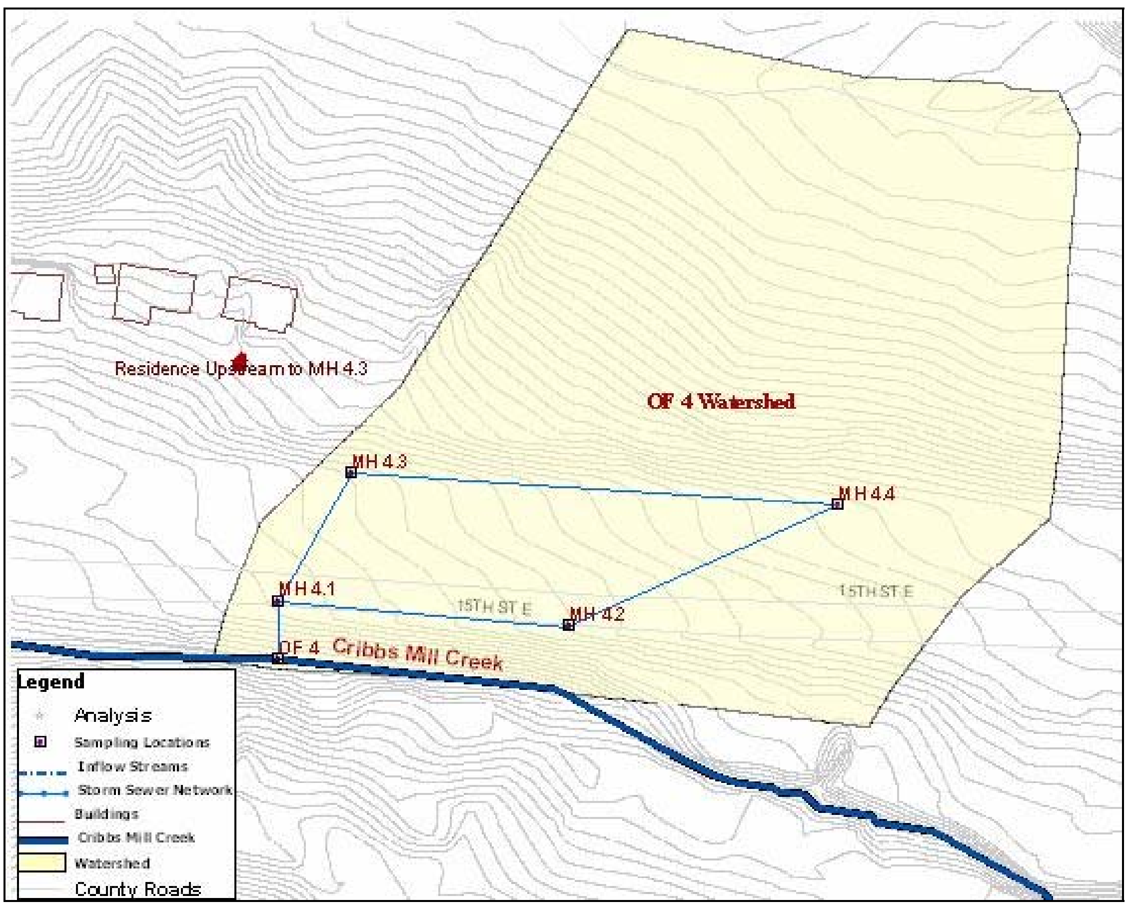


Figure 4.5. Watershed delineation for outfall 4

*Figure 4.6.* Outfall 4

Outfall 4 (Figure 4.6) showed continuous flows and was characterized by the presence of sediment all the time. During the three verification creek walks, all the connecting manholes were sampled and samples were taken separately at each of the incoming pipes, hence if a pipe is coming into a manhole from across the 15th Street, it is so labeled. The layout of the manholes is shown in Figure 4.5. The storm sewer drain flowing into the creek and the manholes were typically 2 ft. in diameter and the incoming sewer pipes were 2 ft. and 9 inch pipes. Typically, there were four inflow pipes, two large and two small at varying heights. The invert elevation ranged from 7.2 to 9.4 ft. The origin of the incoming storm sewer pipe, directed along the main road and emptying pouring into manhole 4.2 was not clear, since the manhole upstream one of 4.2, was flowing directly into the creek, with no sewer pipe pointing toward manhole 4.2. Hence, it was possible to locate only the storm sewer pipes coming from across the road to this manhole. The origin of the storm sewer pipes opening into manholes 4.3 and 4.4 could not be traced. Manhole 4.3 had two incoming pipes, both 9 inches in diameter, one coming from the upstream residential area, perpendicular to the road, and the second pipe coming in along the road from manhole 4.4. Only the pipe coming in from the side of the residential area was flowing at all times. There was minimal flow in manhole 4.4, however it was found to be damp in the first two rounds of verification. The samples from the manholes were collected using a long -handled dipper sampler. The samples at the outfall were collected using a suction baster. Cotton pads for the detection of optical brighteners were placed at the outfall and in the three manholes during the second and third rounds of verification testing. Again, the lack of fluorescence on the pads did not indicate any washwater flows. The results obtained for all these samples are listed in Table 4.3.

Table 4.3. Summary of most likely sources of contamination for outfall 4

| **Sample ID** | **Date of collection** | **Most likely source by CMBM (Top three sources)** | **Problem indicated by physical observations** | **Detergents contamination yes if ≥ 0.25 mg/l or Yes if boron ≥ 0.35** | **Most likely contaminated source by Flow chart method** |
|---|---|---|---|---|---|
| Outfall 4 | 4/22/2002 | Spring water, Laundry washwater | Yes (sediment) | No | Natural water source |
| | 6/4/2002 | Spring water, Laundry washwater | Yes (sediment) | No | Natural water source |
| | 10/9/2002 | Spring water, Laundry washwater | Yes (sediment) | No | Natural water source |
| | 2/19/2003 | Spring water, Carwash water, Tap water | Yes (sediment) | No | Natural water source |
| | 4/1/2003 | Spring water, Laundry washwater | Yes (sediment) | No | Natural water source |
| | 12/20/2003 | Spring water, Laundry washwater, Tap water | Yes (sediment) | No | Natural water source |
| | 1/24/2004 | Spring water, Laundry washwater | Yes (sediment) | No | Natural water source |
| | 3/27/2004 | Spring water, Tap water, Laundry washwater | Yes (sediment) | No | Tap/irrigation water source |

| | | | | | |
|---|---|---|---|---|---|
| MH 4.1-Along road | 12/20/2003 | Spring water, Tap water, Laundry washwater | No | No | Natural water source |
| MH 4.1-Along road | 1/24/2004 | Spring water, Laundry washwater, Sanitary wastewater | No | No | Natural water source |
| MH 4.1-Along road | 3/27/2004 | Spring water, Laundry washwater | No | No | Natural water source |
| MH 4.1-Across Road | 12/20/2003 | Spring water, Laundry washwater | No | No | Natural water source |
| MH 4.1-Across Road | 1/24/2004 | Spring water, Laundry washwater | No | No | Natural water source |
| MH 4.1-Across Road | 3/27/2004 | Spring water, Laundry washwater | No | No | Natural water source |
| MH 4.2- Along Road | 1/24/2004 | Spring water, Laundry washwater | No | No | Natural water source |
| MH 4.2- Along Road | 3/27/2004 | Spring water, Laundry washwater | No | No | Natural water source |
| MH 4.2-Across Road | 12/20/2003 | Spring water, Laundry washwater | No | No | Natural water source |
| MH 4.2-Across Road | 1/24/2004 | Spring water, Sanitary wastewater, Laundry washwater | No | No | Natural water source |
| MH 4.2-Across Road | 3/27/2004 | Spring water, Laundry washwater, Irrigation water | No | No | Natural water source |
| MH 4.3-Across Road | 12/22/2003 | Spring water, Laundry washwater | No | No | Natural water source |
| MH 4.3-Across Road | 1/24/2004 | Spring water, Laundry washwater | No | No | Natural water source |
| MH 4.3-Across Road | 3/27/2004 | Spring water, Laundry washwater | No | No | Natural water source |

As can be seen from the results, there was no indication of the presence of wash waters, and it is likely that the streams are a result of the upwelling of springs from the ground into the storm sewer pipes. The presence of sediments at the outfall could be caused by soil erosion occurring nearby.

*4.2.3.Outfall 27:* Outfall 27 is located off 25$^{th}$ Way East, opposite 20$^{th}$ St. East (Figure 4.7). The outfall is 2 ft. in diameter (Figure 4.8)

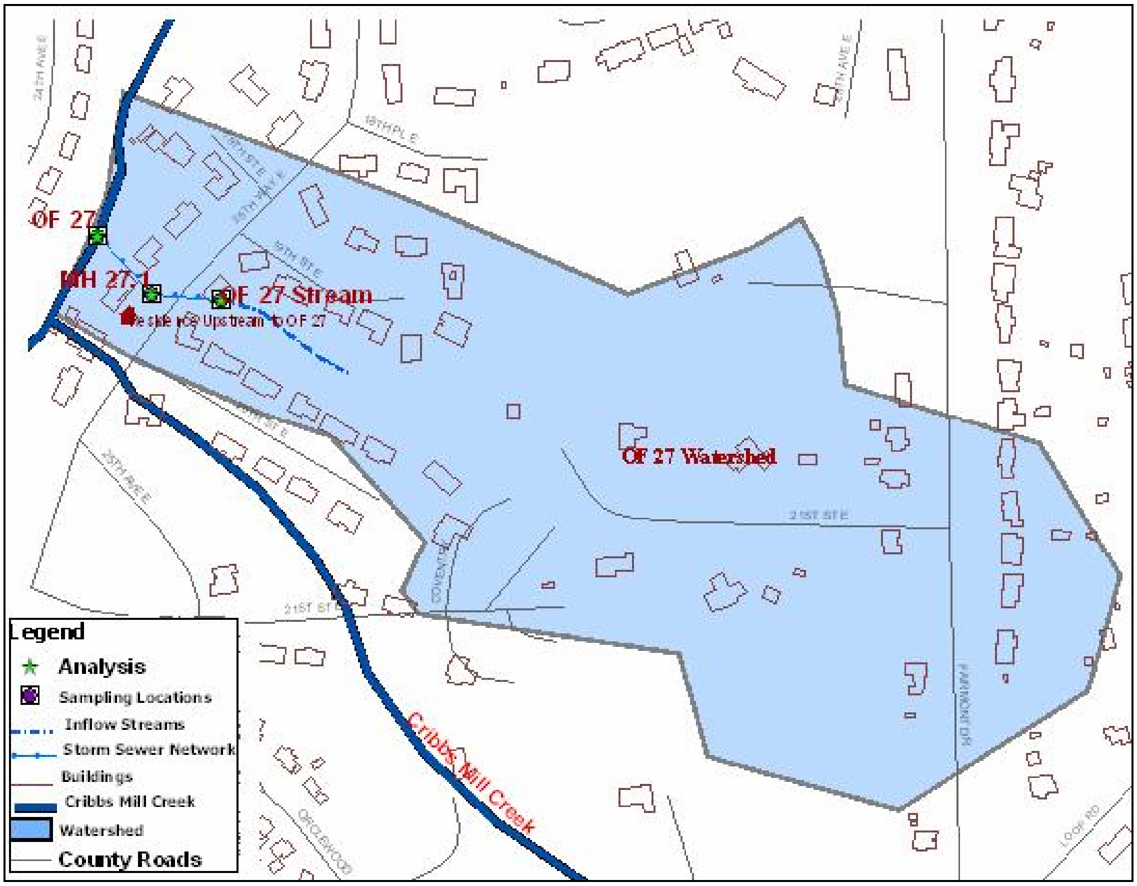


Figure 4.7. Watershed Delineation for outfall 27

This outfall and drainage area was investigated during the second and third rounds of the verification creek walk. This outfall was always characterized by foul odor (similar to sanitary flows) and continuous flows. Upstream to the outfall, the storm sewer pipes connect to a curb and gutter manhole, which seems to be receiving flows from stream upstream (Figure 4.9). It was difficult to track the stream to its course since that entailed venturing onto private property. However, the stream and the manhole were sampled, and indicated results similar to the outfall.

Figure 4.8. Outfall 27

Figure 4.9. Stream Flowing into MH 27.1

The notable factor in this verification process was that the upstream flow dried up in the summer and so did the flows in the manhole (03/27/04), but the outfall was still flowing. This indicated that flows other than the spring water were flowing into the outfall and there was potential contamination by anthropogenic sources. The verification analysis results are presented in Table 4.4.

Table 4.4. *Summary of most likely sources of contamination for outfall 27*

| **Sample ID** | **Date of collection** | **Most likely source by CMBM (Top three sources)** | **Problem indicated by physical observations** | **Detergents contamination yes if ≥ 0.25 mg/l or Yes if boron ≥ 0.35** | **Most likely contaminated source by Flow chart method** |
|---|---|---|---|---|---|
| OF 27 | 4/26/2002 | Spring water, Laundry washwater | YES (sediment) | No | Natural water source |
| | 6/11/2002 | Spring water, Laundry washwater | No | No | Tap/irrigation water source |
| | 10/14/2002 | Spring water, Sanitary wastewater | No | No | Tap/irrigation water source |
| | 2/24/2003 | Tap water, Spring water, Carwash water | YES (sediment) | No | Natural water source |
| | 4/17/2003 | Spring water, Sanitary wastewater | YES (sediment) | No | Natural water source |
| | 1/24/2004 | Spring water, Tap water, Sanitary wastewater | YES (color, odor) | No | Tap/irrigation water source |
| | 3/27/2004 | Tap water, Spring water, Carwash water | YES (color, odor) | No | Tap/irrigation water source |
| MH 27.1 | 1/24/2004 | Spring water, Tap water, Carwash water | No | No | Natural water source |
| OF 27 Stream | 1/24/2004 | Spring water | No | No | Tap/irrigation water source |

The presence of residences just above the outfall could explain the dry-weather flows. Basement sump pump connections pumping infiltrating spring water to the storm sewers could be the cause for these dry-weather flows.

*4.2.4. Outfall 31: Outfall 31 is located near 22nd Street east, and is in a residential area (Figure 4.10).*

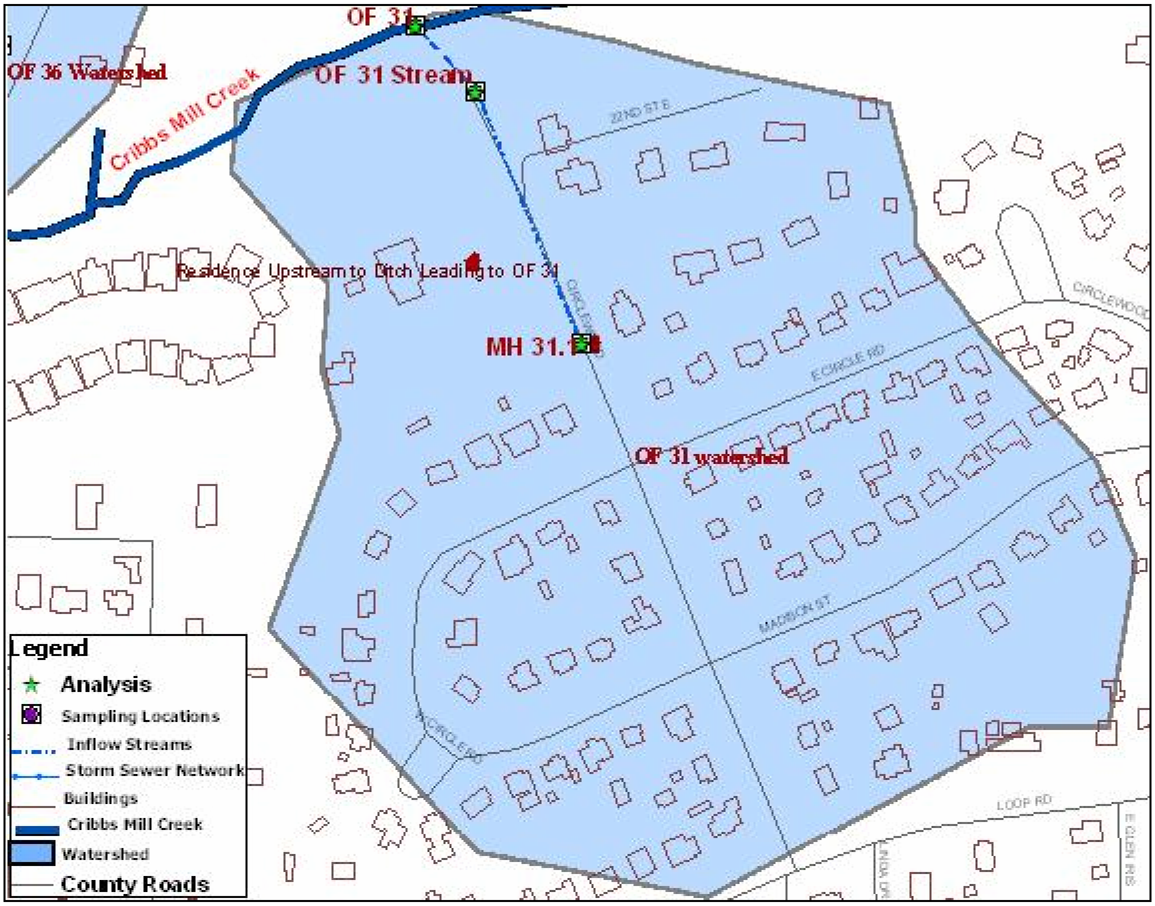


*Figure 4.10.* Watershed delineation for outfall 31

The outfall is in the form of an open drainage ditch (Figure 4.11), which was traced back to flows from a manhole MH 31.1 in Figure 4.10. The open drainage ditch is 1.5 ft. across, where it flows into the creek. The invert of MH 31.1 was damaged and was connected to the drainage ditch. The drainage ditch (marked as OF 31 stream in Figure 4.10.) flows through private property for a distance of 200 ft. A 9” pipe can be seen pouring into this drainage ditch from the residence (Figure 4.12). A smaller drainage ditch was observed to join the main drainage ditch which leads to the outfall. It was assumed that there could be a pipe upstream of this smaller ditch carrying water from one of the residences, but the flow was never sufficient to take a sample, hence it is not shown on the map in Figure 4.10.

*Figure 4.11*. Outfall 31

Figure 4.12. Pipe opening into ditch upstream to outfall 31

Manhole 31.1 has two incoming 2 ft. pipes, one pipe from along Circlewood road, the other entering from across the road. The pipe coming in from along the road never indicated any dry-weather flows. However, the pipe coming into MH 31.1 from across the road showed continuous dry-weather flows. The connecting manhole across the road had a concrete slab cover which could not be removed. But, it was observed that a pipe was coming into this manhole from the direction of the house lying above it, and it emanated a foul smell the first two times it was investigated. Hence, it was thought that the residence upstream could be discharging wastewater into the manhole. Ironically, storm sewer Manhole MH 31.1 had a sanitary sewer manhole cover! There is a 3 ft. pipe from MH 31.1, opening into the main ditch mentioned above and the invert of the manhole was also damaged in the side, resulting in direct flows from the manhole into the stream. The results obtained during the verification investigations are shown in Table 4.5.

Table 4.5. *Summary of most likely sources of contamination for outfall 31*

| **Sample ID** | **Date of collection** | **Most likely source by CMBM (Top three sources)** | **Problem indicated by physical observations** | **Detergents contamination yes if ≥ 0.25 mg/l or Yes if boron ≥ 0.35** | **Most likely contaminated source by Flow chart method** |
|---|---|---|---|---|---|
| Outfall 31 | 4/26/2002 | Tap water, Spring water, Irrigation water | YES (sediment) | YES | Washwater source |
| | 6/17/2002 | Spring water, Laundry washwater | No | No | Tap/irrigation water source |
| | 10/14/2002 | Spring water, Tap water, Laundry washwater | YES (sediment) | No | Natural water source |
| | 3/4/2003 | Tap water, Spring water, Laundry washwater | YES (color, turbidity, floatables) | No | Tap/irrigation water source |
| | 4/17/2003 | Tap water, Spring water, Laundry washwater | YES (color, turbidity, floatables) | No | Tap/irrigation water source |
| | 12/22/2003 | Spring water, Tap water, Laundry washwater | YES (odor) | No | Natural water source |
| | 1/24/2004 | Tap water, Spring water, Laundry washwater | YES (odor) | YES | Washwater source |
| Outfall 31 | 3/27/2004 | Tap water, Irrigation water | No | No | Tap/irrigation water source |
| Upstream (100 ft) to OF 31 | 1/24/2004 | Tap water, Irrigation water, Laundry washwater | No | No | Tap/irrigation water source |
| Upstream (100 ft) to OF 31 | 3/27/2004 | Tap water, Sanitary Wastewater, Laundry washwater | No | No | Tap/irrigation water source |
| MH 31.1 | 12/22/2003 | Tap water, Irrigation water | No | No | Tap/irrigation water source |
| MH 31.1 | 1/24/2004 | Spring water, Tap water | No | No | Tap/irrigation water source |
| MH 31.1 | 3/27/2004 | Tap water, Irrigation water, Carwash water | No | No | Tap/irrigation water source |

Manhole 31.1 was sampled during all three verification periods, but the sampling location in the drainage ditch, about 100 ft. upstream from the outfall, was sampled only during the second and third sampling periods. The outfall only indicated washwater

during the first round of verification, there was no corresponding indication of washwater at the two upstream locations. This could be caused by the continuous flows from the drainage ditch which could not be sampled due to low flows. Cotton pads placed at the outfall for the purpose of detecting optical brighteners, showed positive fluorescence under the UV light and was similar to the standard value of 35 mg/L of Tide. All other sampling runs predicted tap/irrigation water, indicating that these flows could arise from any of the residences.

*4.2.5. Outfall 36:* Outfall 36 is located near Kicker Bridge, off 19th Avenue East (Figure 4.13). This is one of the largest outfalls in the study area, measuring 5 ft. in diameter. The first connecting manhole is about 100 ft.upstream of the outfall. This manhole has two incoming pipes, 1.5 ft. and 5 ft. in diameter. These pipes are seen coming from manholes across the road to this manhole. Manhole 36.1 was always found to be damp, but the upstream manholes, were always dry. This is in contrast to the outfall which was always found to be flowing, sometimes in copious quantities, but sometimes just a trickle. Outfall 36 and associated manholes were sampled during all three verification periods. Since flows were seen at the outfall during all three periods with no corresponding flows in any of the upstream manholes, it was concluded that the residence upstream of the outfall but before Manhole 36.1 could be responsible for these dry-weather flows.

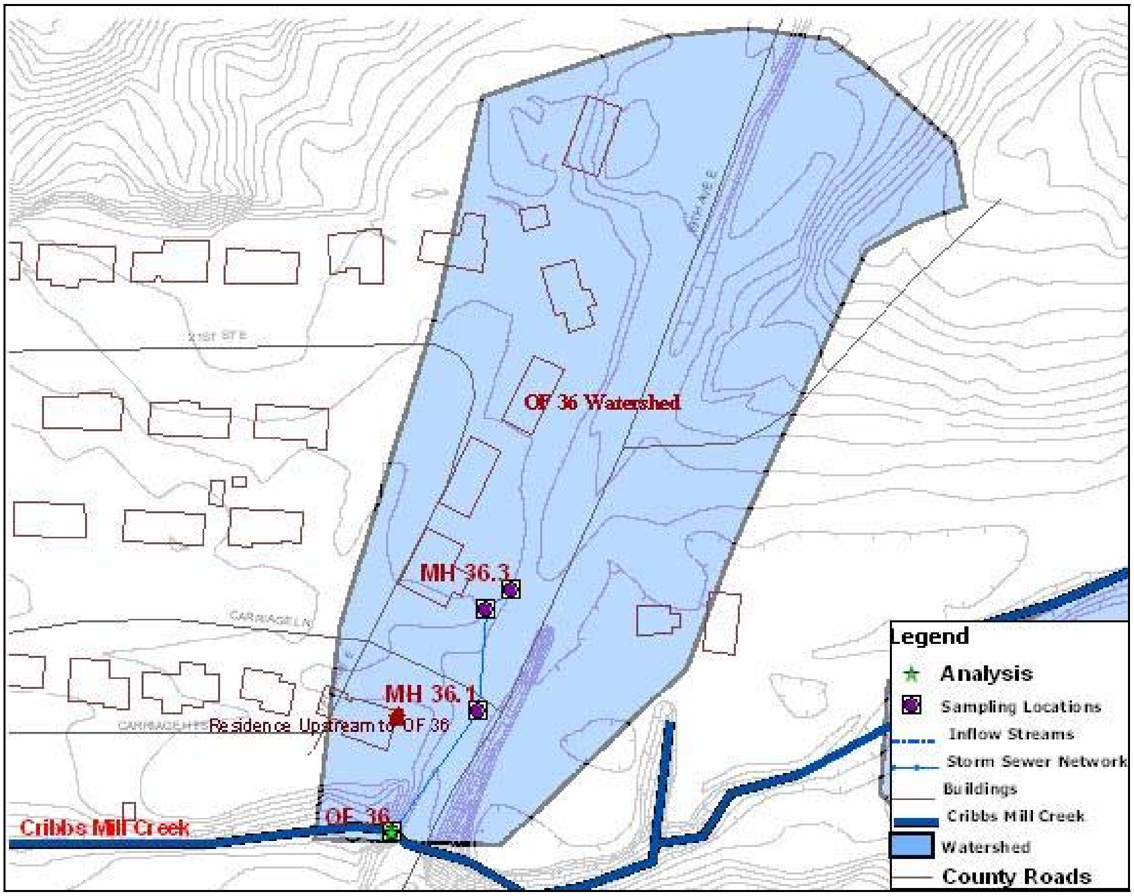


Figure 4.13. Watershed delineation for outfall 36


*Figure 4.14.* Outfall 36

The results of verification sampling are presented in Table 4.6

Table 4.6. *Summary of most likely sources of contamination for outfall 36*

| **Sample ID** | **Date of collection** | **Most likely source by model** | **Problem indicated by physical observations** | **Detergents contamination yes if ≥ 0.25 mg/l or Yes if boron ≥ 0.35** | **Flow chart method, most likely source** |
|---|---|---|---|---|---|
| Outfall 36 | 4/26/2002 | Irrigation water, Tap water, Carwash water | NO | No | Natural water source |
| | 6/19/2002 | Tap water, Irrigation water, Carwash water | YES (sediment) | Yes | Missing data |
| | 10/17/2002 | Spring water, Irrigation water, Carwash water | YES (sediment) | No | Natural water source |
| | 3/5/2003 | Spring water, Tap water, Irrigation water | YES (color, turbidity, floatables) | No | Natural water source |
| | 4/17/2003 | Spring water, Tap water, Laundry washwater | YES (sediment) | No | Natural water source |
| | 12/22/2003 | Carwash water, Sanitary wastewater, Spring water | NO | Yes | Washwater source |
| | 1/24/2004 | Carwash water, Tap water, Spring water | NO | Yes | Washwater source |
| | 3/27/2004 | Carwash water, Tap water, Spring water | NO | No | Natural water source |

The results in Table 4.6 show that washwater was predicted at Outfall 36 on three different occasions, flows during other times were predicted to be from a natural water source. The first sample collected  showed a detergent concentration of 0.25 mg/L while the other two washwaters showed high boron concentrations (0.49 and 0.38 mg/L respectively). This supports our theory that the residence just upstream from the outfall could be responsible for these flows. The natural water source indicates the presence of underground springs in this vicinity which could be infiltrating into the storm sewer pipe.

4.2.6. Outfall 39: Outfall 39 is located off Hargrove Road East on 12th Avenue East (Figure 4.15). It measures about 4.5 ft. in diameter and has always been found have flows during dry-weather.

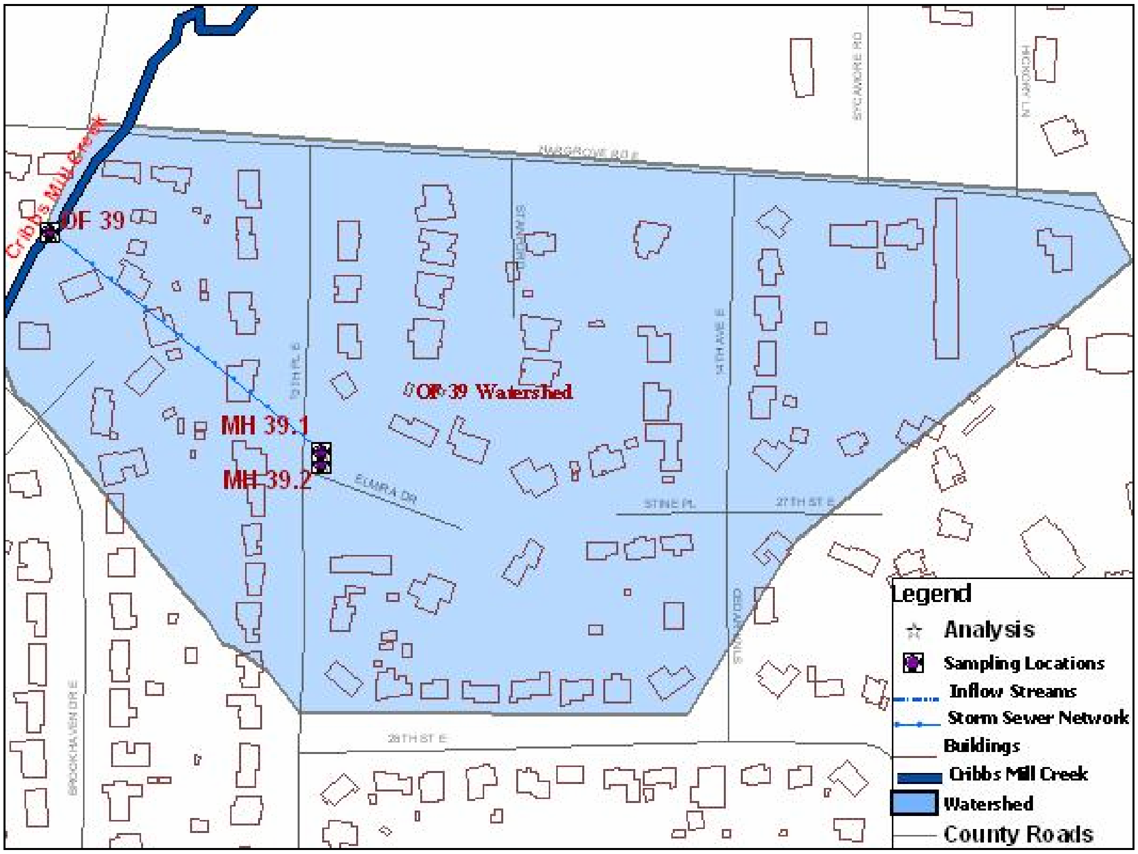


*Figure 4.15.* Watershed delineation for outfall 39

This outfall was difficult to trace upstream since it passes through the backyards of residences for a considerable distance before we could come across the first upstream manholes. The main point of identification that these manholes lead to the outfall was the size of the storm sewer pipe, their general direction, and the depth of the storm sewer pipes. Manholes (MH 39.1 and MH 39.2 seen in Figure 4.15  were located on the 12th Avenue East in a grass swale. The pipes opening into these manholes were traced back to a road drain (grating) in 14th Avenue East, two streets upstream to the 12th Avenue. The road grating could not be opened to take samples. However, there was also no considerable flow observed in this road drain. The incoming pipes into this road grating could not be traced as upstream to this point due to the presence of private property and residences.

*Figure 4.16.* Outfall 39

A resident of this locality, Mr. Simmons, who video-taped the on-going work on the storm drain system in this area, informed us that these drains could be originating upstream half a mile from this location in a residential complex called the Yorktown Commons. Manhole 39.1 is connected to a manhole in this resident's backyard. This outfall was sampled, with Mr. Simmons' permission, during the second verification sampling period.

*Figure 4.17.* Residences Upstream to MH 39.1 and MH 39.2

Table 4.7. *Summary of most likely sources of contamination for outfall 39*

| Sample ID | Date of collection | Most likely source by CMBM (Top three sources) | Problem indicated by physical observations | Detergents contamination yes if ≥ 0.25 mg/l or Yes if boron ≥ 0.35 | Most likely contaminated source by Flow chart method |
|---|---|---|---|---|---|
| Outfall 39 | 4/29/2002 | Tap water, Irrigation water, carwash water | No | No | Natural water source |
| | 6/24/2002 | Spring water, Irrigation water, carwash water | No | No | Natural water source |
| | 10/17/2002 | Spring water, Tap water, Irrigation water | No | No | Natural water source |
| | 3/5/2003 | Spring water, Tap water, Laundry washwater | No | No | Natural water source |
| | 4/17/2003 | Spring water, Tap water, Irrigation water | No | No | Natural water source |
| | 12/22/2003 | Tap water, Spring water | No | No | Natural water source |
| | 1/30/2004 | Carwash water, Tap water | No | No | Natural water source |
| Outfall 39 | 3/27/2004 | Spring water, Tap water, sanitary wastewater | No | No | Natural water source |
| MH 39.2 | 12/22/2003 | Spring water, Tap water, Carwash water | No | No | Natural water source |
| MH 39.2 | 1/30/2004 | Spring water, Tap water, Laundry Washwater | No | No | Natural water source |

| | | | | | |
|---|---|---|---|---|---|
| MH 39.2 | 3/27/2004 | Tap water, Spring water | No | No | Natural water source |
| MH 39.1 | 1/30/2004 | Spring water , Tap water, Irrigation water | No | No | Natural water source |
| MH 39.1 | 3/27/2004 | Tap water, Spring water, Sanitary Wastewater | No | No | Natural water source |
| MH 39.3 | 3/27/2004 | Spring water, Tap water, Sanitary Wastewater | No | No | Natural water source |

From the above results, it can be seen that all the water flowing through this system is very likely natural spring water. This analysis was corroborated by the residents' view that numerous springs were tapped into the storm drainage when the storm drainage system was being installed. The cotton pads laid out for optical brighteners analysis did not yield any positive results.

*4.2.7. Outfall 45:* Outfall 45 is located immediately off McFarland Blvd as shown in Figure 4.18. This outfall (Figure 4.19) can be accessed from the parking lot in front of the Willow Trace Ct. Apartments.

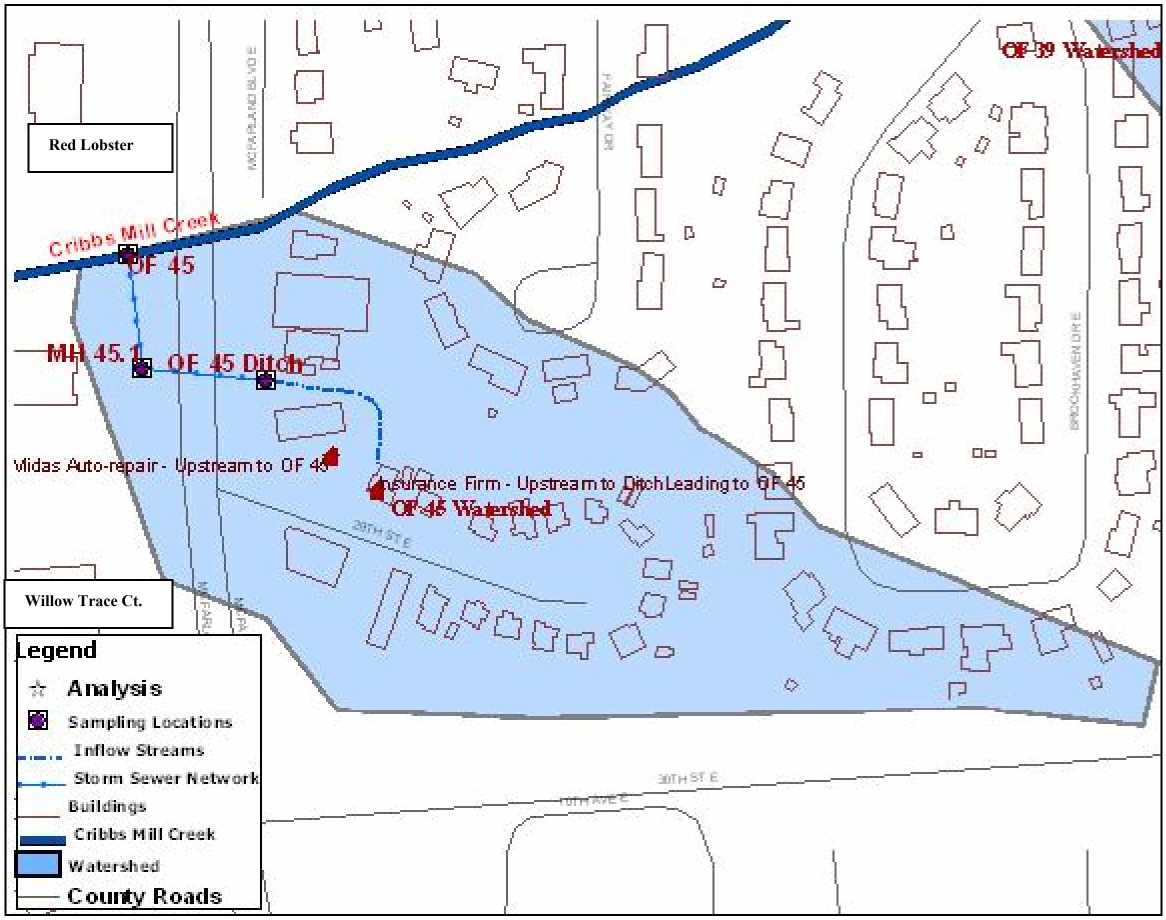


*Figure 4.18.* Watershed Delineation for Outfall 45

*Figure 4.19.* Outfall 45

Outfall 45 is 4 ft. in diameter and is connected to an upstream manhole, which seems to be connected to a drain upstream, on the other side of McFarland Blvd. The upstream manhole , MH 45.1 has two inflow pipes, one from an open drainage ditch on the other side of the Blvd. and one coming in from upstream, along the Blvd. The pipe coming from across the Blvd. was always found to be flowing, but the pipe coming in from along the road was showing a trickling flow only in the last verification sampling period. The flow coming into MH 45.1 seems to be originating from behind a local insurance office. There is about a 18" pipe found discharging into the drainage ditch. This pipe could be the source of the washwater predicted at the outfall. No pipes were found originating from the Midas automobile repair shop, located along the upstream ditch.

*Figure 4.20.* Pipe from Insurance Firm Opening into Ditch Flowing into MH 45.1

Table 4.8. *Summary of most likely sources of contamination for outfall 45*

| **Sample ID** | **Date of collection** | **Most likely source by CMBM (Top three sources)** | **Problem indicated by physical observations** | **Detergents contamination yes if ≥ 0.25 mg/l or Yes if boron ≥ 0.35** | **Most likely contaminated source by Flow chart method** |
|---|---|---|---|---|---|
| Outfall# 45 | 5/8/2002 | Tap water, Spring water, Carwash water | No | Yes | Washwater source |
| | 6/24/2002 | Tap water, Spring water, Carwash water | No | Yes | Washwater source |
| | 10/18/2002 | Tap water, Irrigation water, Carwash water | No | No | Tap/Irrigation water source |
| | 3/5/2003 | Spring water, Tap water, Laundry Washwater | No | Yes | Washwater source |
| | 4/17/2003 | Spring water, Tap water, Irrigation water | No | Yes | Washwater source |
| | 12/22/2003 | Tap water, Carwash water, Sanitary Wastewater | No | Yes | Washwater source |
| | 1/30/2004 | Tap water, Spring water, Sanitary Wastewater | No | Yes | Washwater source |
| | 3/28/2004 | Carwash water, Tap water | No | No | Natural water source |
| OF 45 Ditch | 1/30/2004 | Spring water, Tap water, Sanitary Wastewater | No | No | Natural water source |
| OF 45 Ditch | 3/28/2004 | Carwash water, Tap water, Spring water | No | No | Tap/irrigation water source |
| MH 45.1 | 2/1/2004 | Spring water, Tapwater, Sanitary Wastewater | No | Yes | Washwater source |
| MH 45.1 | 3/28/2004 | Tap water, Sanitary Wastewater, Laundry Washwater | No | Yes | Washwater source |

The results show that there is potential washwater contamination at this outfall. In all cases, except the last two, the detergent concentrations were high, but the last two showed high boron concentrations. In the third round of verification investigations, foaming could be seen at the outfall. It was also observed that while the connecting manhole, MH 45.1 likely had a washwater source, neither the outfall nor the upstream stream indicated detergent contamination at the outfall. This could be an effect of dilution with natural spring water. The upstream stream showed a moderate boron concentration of 0.27 mg/L, thus indicating irrigation/tap water but not washwater. Hence, it seems possible that water flowing into the manhole from the pipe along the road could be carrying washwater. However, it was not clear where this pipe was originating. None of the manholes upstream to this manhole had pipes pointing in the direction of this manhole. Therefore, it was especially important to examine the analytical results, in order to understand and verify the sources of contamination.

*4.2.8. Outfall 53:* Outfall 53 is located on the edge of the Willow Trace Court Apartments property, as shown in Figure 4.21. This outfall is about 3 ft. in diameter and is characterized by copious continuous flows (Figure 4.22).

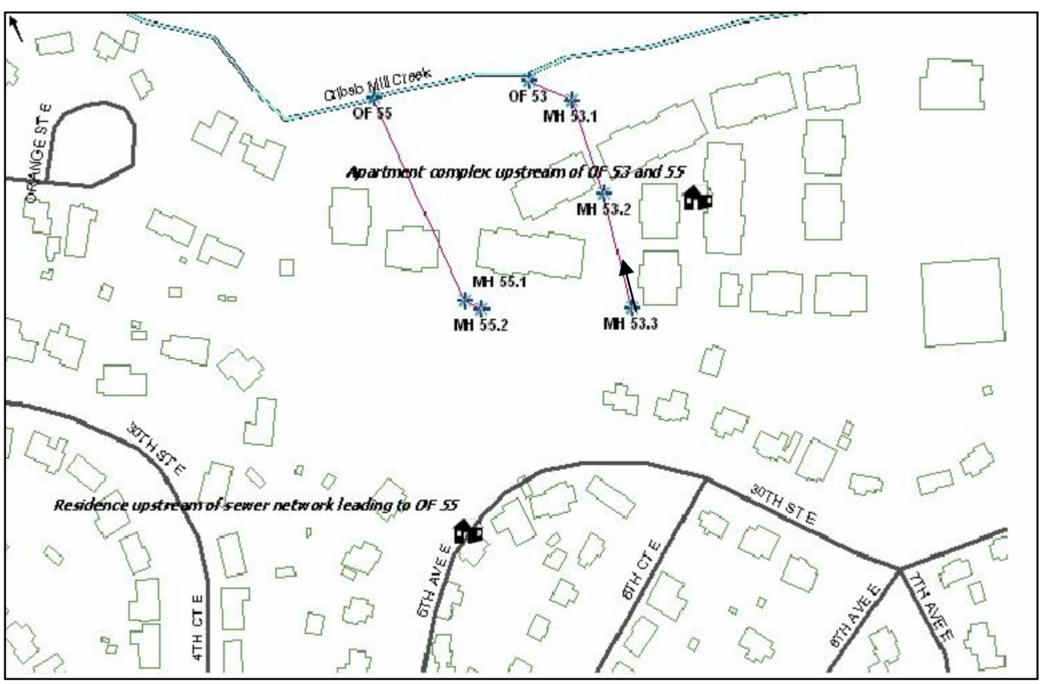


*Figure 4.21.* Layout Map for Outfall 53


*Figure 4.22.* Outfall 53

The drainage network above outfall 53 could be tracked to the far side of the apartment complex and three intermediate manholes were found and sampled. However, it was not possible to find the storm drainage network connecting to manhole 53.3, as it was outside the boundary of this apartment and we could not remove the manhole covers on the storm drain inlets on the other side of the boundary as they were sealed with concrete.

Table 4.9. Summary of most likely sources of contamination for outfall 53

| **Sample ID** | **Date of collection** | **Most likely source by CMBM (Top three sources)** | **Problem indicated by physical observations** | **Detergents contamination yes if ≥ 0.25 mg/l or Yes if boron ≥ 0.35** | **Most likely contaminated source by Flow chart method** |
|---|---|---|---|---|---|
| Outfall 53 | 5/8/2002 | Tap water, Spring water, Irrigation water | YES (sediment) | No | Natural water source |
| | 6/24/2002 | Tap water, Irrigation water, Carwash water | YES (sediment) | No | Natural water source |
| | 10/18/2002 | Spring water, Tap water, Laundry Washwater | YES (sediment) | Yes | Washwater source |
| | 3/5/2003 | Spring water, Tap water | No | No | Natural water source |
| Outfall 53 | 4/18/2003 | Spring water, Tap water, Sanitary Wastewater | No | No | Missing data |
| | 12/22/2003 | Spring water, Tap water, Laundry Washwater | No | No | Natural water source |
| | 2/1/2004 | Spring water, Tap water | No | No | Natural water source |
| | 3/28/2004 | Spring water, Laundry Washwater | No | No | Natural water source |
| MH 53.1 | 12/23/2003 | Spring water, Laundry Washwater | No | No | Natural water source |
| MH 53.1 | 2/1/2004 | Spring water, Irrigation water | No | No | Natural water source |
| MH 53.1 | 3/28/2004 | Spring water, Laundry Washwater | No | No | Natural water source |
| MH 53.2 | 12/23/2003 | Spring water, Laundry Washwater | No | No | Natural water source |
| MH 53.2 | 2/1/2004 | Tap water, Irrigation water, Carwash water | No | No | Natural water source |
| MH 53.2 | 3/28/2004 | Spring water, Tap water, Carwash water | No | Yes | Washwater source |
| MH 53.3 | 12/23/2003 | Spring water, Tap water | No | No | Natural water source |
| MH 53.3 | 3/28/2004 | Spring water, Tap water, Laundry Washwater | No | No | Natural water source |

From the results in Table 4.9, it is observed that washwater (due to the high boron > 0.35 mg/L) was seen only once at manhole 53.2 and never at the outfall. Again, this could be an effect of dilution with natural water. The sample containing boron was taken on a Sunday. From our observations in the field, the flow on this day was higher than usual and, because of the washwater indications; residents may more commonly be washing cars or doing laundry. This effect is also seen clearly in the analysis done for outfall 55.

*4.2.9. Outfall 55:* Outfall 55 is located a short distance from outfall 53 (Figure 4.23) and their watersheds are adjacent. Outfall 55 is also 3 ft. in diameter (Figure 4.24) and was always characterized by sediment, floatables and an unpleasant odor, characteristic of sanitary wastewater flows. This outfall was connected to manholes on the far end of the Willow Trace Court Apartments, which had drains coming in from outside the boundary of the property. Investigation further into the watershed revealed that the flows were coming in from a storm drain inlet located on 5$^{th}$ Avenue East.

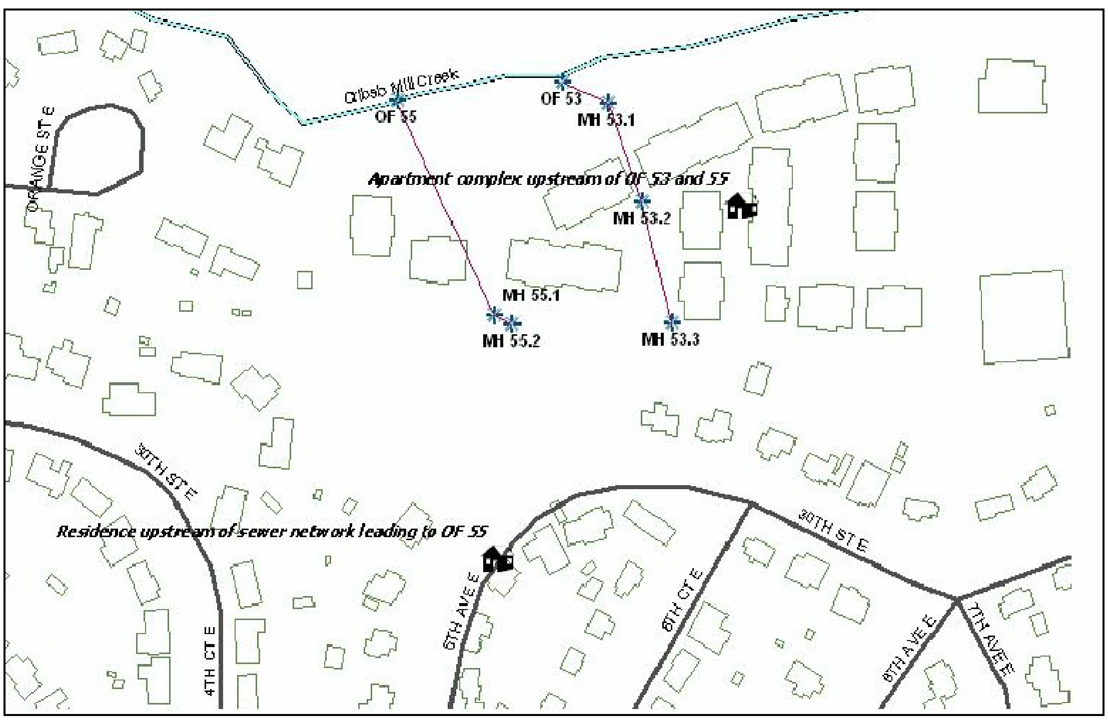


*Figure 4.23.* Map Layout of Outfall 55


*Figure 4.24.* Outfall 55

Outfall 55 and the watershed were investigated only in the second and third rounds of verification testing. The manholes were seen flowing only in the second round of sampling and the waters had a strong smell of bleach and laundry detergent. The storm drain inlet on 5th Avenue East (Figure 4.26) also smelled strongly of bleach and later on revealed washwater characteristics. This sample was taken in the morning. The next round of verification tests was also on a Sunday, but the samples were collected toward late evening. The manholes were damp, but not flowing. However the outfall was still flowing. The strong odor of detergent and bleach was apparent and the manhole was damp on another Sunday (May 30th) when we were out there to verify GPS coordinates. Hence, there seems to be a strong relation between the activities of folks in residences here and dry-weather flows in this storm drain network.

*Figure 4.25.* Resident washing automobile beside storm drain in area upstream to outfall 55

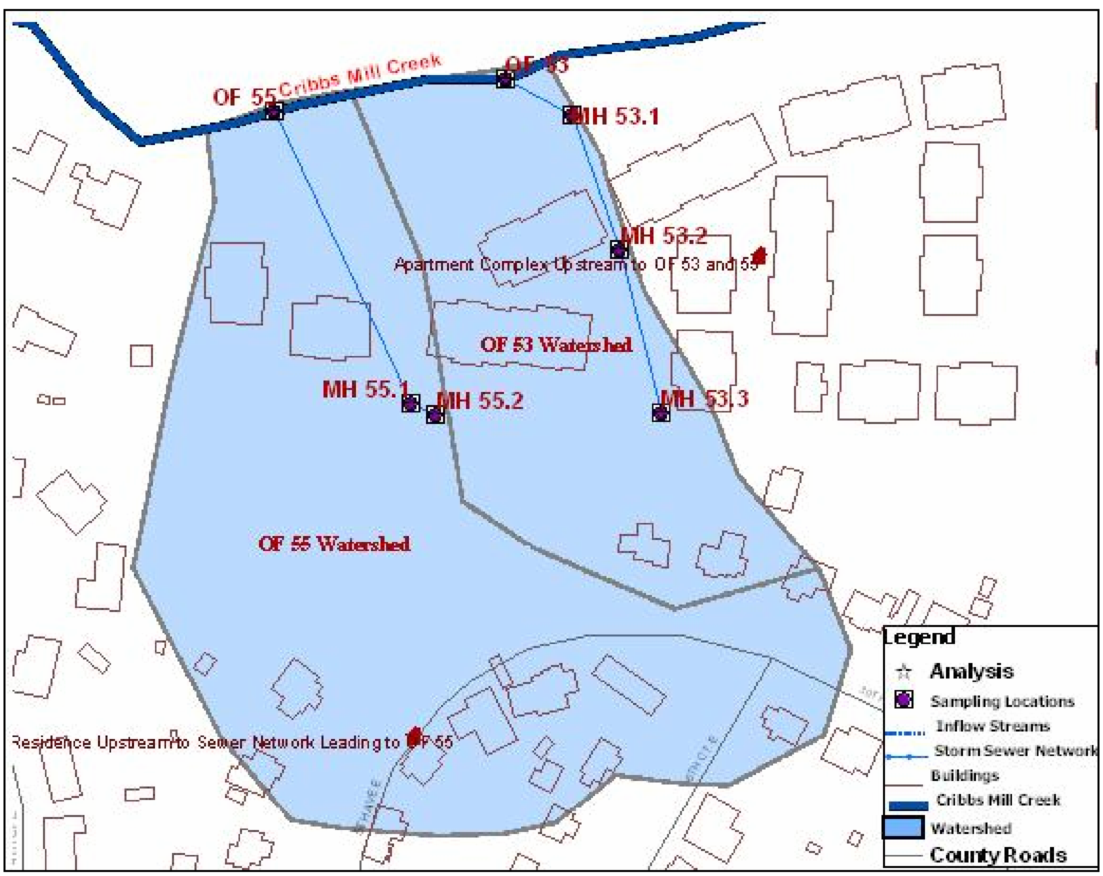


*Figure 4.26.* Watershed Delineation of Outfalls 53 and 55

The analytical results observed for outfall 55 are presented in Table 4.10.

Table 4.10. *Summary of most likely sources of contamination for outfall 55*

| **Sample ID** | **Date of collection** | **Most likely source by model** | **Problem indicated by physical observations** | **Detergents contamination yes if ≥ 0.25 mg/l or Yes if boron ≥ 0.35 mg/l** | **Flow chart method, most likely source** |
|---|---|---|---|---|---|
| Outfall# 55 | 5/8/2002 | Spring water, Irrigation water, Carwash water | Yes (sediment) | No | Natural water source |
| | 6/24/2002 | Spring water, Irrigation water, Tap water | Yes (sediment) | Yes | Missing data |
| | 10/18/2002 | Spring water, Tap water, Sanitary wastewater | Yes (sediment) | No | Natural water source |
| | 3/5/2003 | Spring water, Tap water, Sanitary wastewater | Yes (floatables) | No | Natural water source |
| | 4/18/2003 | Spring water, Tap water, Sanitary wastewater | Yes (floatables) | No | Washwater source |
| | 2/1/2004 | Sanitary wastewater, Tap water, Spring water | Yes (sediment, odor) | Yes | Sanitary wastewater |
| | 3/28/2004 | Spring water, Tap water, Laundry washwater | Yes (sediment, odor) | No | Natural water source |
| MH 55.1 | 2/1/2004 | Sanitary wastewater, Irrigation water, Tap water | No | Yes | Sanitary wastewater |
| MH 55.2 | 2/1/2004 | Tap water, Sanitary wastewater, Carwash water | No | Yes | Sanitary wastewater |

This is the only outfall in the study area which showed flows having potential sanitary wastewater components. The cotton detergent pads placed for detection of detergents also showed positive fluorescence under the UV lamp. Outfall 55 showed fluorescence corresponding to 500 mg/L as Tide, while MH 55.1 and MH 55.2 showed strengths equivalent to 300 mg/L as Tide. It is also noticed that other than the wastewater flows, there is a likelihood of springs in the vicinity which discharge into this storm drainage network.

# CHAPTER 5

# GIS APPLIED TO VERIFY SOURCES OF INAPPROPRIATE DISCHARGES

## 5.1. Applying GIS to the Identification and Verification of Inappropriate Discharges

GIS (Geographic Information Systems) is being used widely by public and private enterprise to store and manipulate data about specific locations in a defined area. Simply put, it is a digital mapping system which also stores associated attribute data, which can be queried to generate meaningful analyses.

GIS has been found to be an appropriate tool to aid the process of detecting inappropriate discharges within a defined watershed. The Cribbs Mill Creek Watershed has been described using ArcMap and numerous elements have been added to the project, which when queried according to the desired analysis would yield the physical location of the probable sources of contamination and also the most probable source of contamination according to the flowchart.

The first step in developing a GIS project for an application of this nature is to obtain the required base maps. Maps outlining the County of Tuscaloosa, the City of Tuscaloosa, road maps for the county, a map layer of the buildings and driveways in the City of Tuscaloosa and topographic maps with 2 ft. contour intervals for the desired area have been obtained from the Tuscaloosa Department of Transportation. Additionally, maps of the sanitary sewer network have also been obtained from the Stormwater

Engineering Department. These maps formed the background layers for the project to produce layers of the watershed, including the layout of the creek and the stormwater boundary. The stormwater boundary for the entire creek has been digitized using a rectified aerial image of the creek with the watersheds drawn in, which is based largely on the stormwater boundary layout defined by the planning document provided by the City's Stormwater Department.

This GIS application primarily addressed the verification outfalls. Using the 'Garmin GPS 12MAP' GPS unit, the sampling points of interest were mapped and the locations noted. 'Corpscon' was used to convert the coordinates collected in North American Datum-27 (NAD27) to NAD-83 ft. (West Alabama), in order to maintain consistency with the datum of existing map elements.. These X, Y coordinates of the sampling locations were added as a unique layer of sampling locations into the GIS project. The watershed for each outfall was then digitized using the existing contour layer.  From the flowchart results and subsequent detailed field studies, it was possible to identify the physical location of the most probable source of inappropriate flows. These locations (houses, commercial centers) were also collected using the GPS unit and were appropriately converted to generate a layer of the contaminant source location. From the trail of manholes identified, it was possible to map the storm sewer network for each of the outfalls. The chemical analysis data for each sampling location was added as a separate analysis layer. Figure 5.1 delineates the storm drain boundary for the study area.

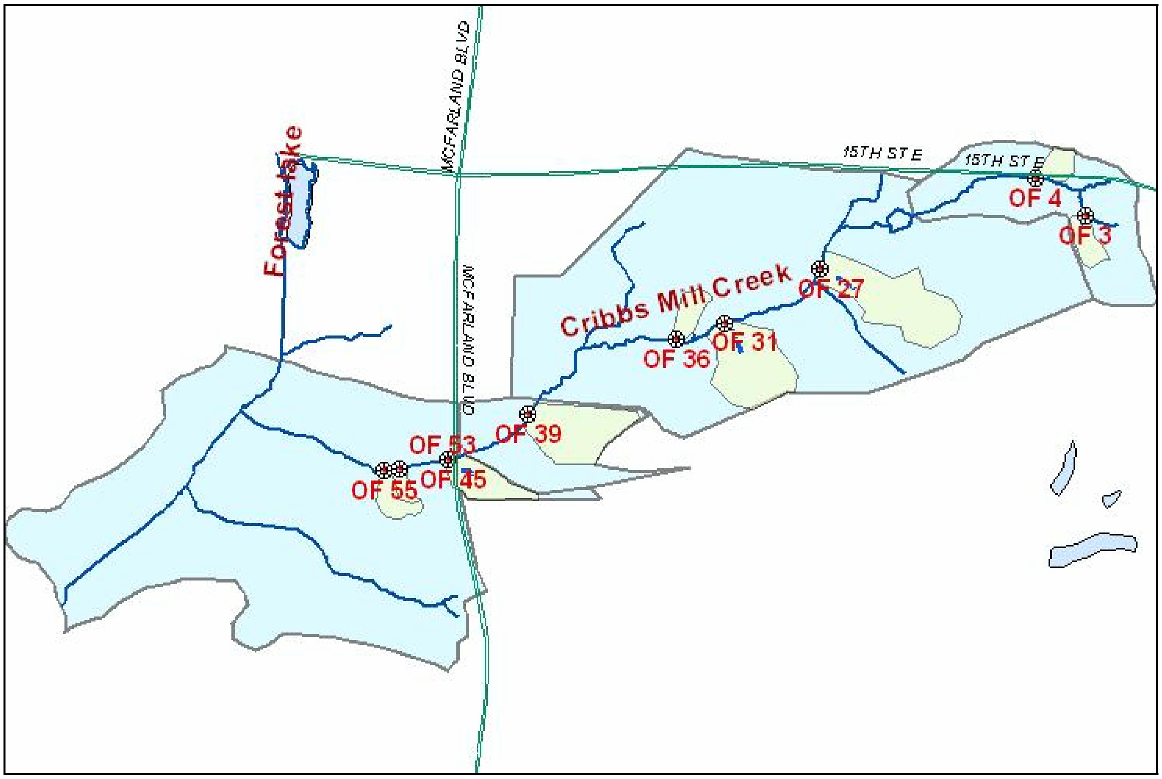


*Figure 5.1.* Storm drain boundary for the Cribbs Mill Creek, showing subwatershed areas for the verification studies

The layers of sampling locations, analysis, watersheds, stormwater boundary and contaminant source location are associated with relevant attribute data. The sampling locations layer has attribute data corresponding to the location ID and a description of the location, whether in a stream, manhole or at an outfall; and it has data regarding the frequency and nature of potential sources of contamination, outfall diameters and the material of the drain/ditch. The watershed layer has fields describing the outfall number of the watershed and its area and perimeter. The storm sewer network layer is associated with data regarding the upstream and downstream sampling locations. The inflow streams layer defines the head streams or ditches which flow into respective outfalls. The associated data describes upstream and downstream sampling locations. The analysis layer contains analysis results for the verification outfalls and also has a column which is programmed to generate the most probable source of contamination based on the flow chart methodology; it also has data regarding the outfall to which the sampling point relates to and the ID of the sampling point. The flowchart methodology was programmed into this attribute table using a short Visual Basic Program based on the logic defined in the flowchart. The program is shown in figure 5.2.

```
Dim ANSWER As String
If(([DETERGENTS] >= 0.25 And [DETERGENTS] < 1000) = True Or ([BORON] >=
0.35 And [BORON< 1000) = True) And ([AMM_POT] >= 1 And [AMM_POT] < 1000)
= True Then
ANSWER = "Possible Sanitary wastewater"
ElseIf(( [DETERGENTS] >= 0.25 And [DETERGENTS] < 1000) = True Or ([BORON]
>= 0.35 And [BORON] < 1000) = True) And ([AMM_POT] < 1) = True Then
ANSWER = "Possible Washwater"
ElseIf(([DETERGENTS] < 0.25 Or [BORON] < 0.35) = True) And ([FLOURIDE] <
0.20) = True Then
ANSWER = "Possible Natural Water"
ElseIf((ANSWER= "Possible Washwater") = False Or (ANSWER = "Possible Sanitary
wastewater" )= False Or (ANSWER = "Possible Natural Water")  = False)  AND  (
[DETERGENTS] < 0.25 Or [BORON] < 0.35) = True And (( [FLOURIDE] > 0.2 And
[FLOURIDE]<=1000) = True) Then
ANSWER = "Possible tap/Irrigation Water"
End If
```

*Figure 5.1. Visual Basic Code for Flow Chart Method*

While setting up the analysis table in ArcMap, it is important to code the right and left censored data (greater than and less than values) appropriately, in order to preclude errors in the flow chart analysis results. In this case, all the “less than” detection values for all the tracer data, excluding the bacterial analysis was coded by the number ‘1000’. This number would not interfere with any of the other analysis results. For the bacterial analysis results all the <1 results have been coded as ‘0’ and all the >2419.2 results have been coded as ‘2420’. The values which are not available are treated as null values, which do not interfere in the querying process.

For each outfall, it is possible to view in detail the watershed and all the relevant elements within the watershed, which could point to the location of generation of dry-weather flows. For example, at outfall 3, from the chemical analysis and the flowchart result generated by ArcMap, the sources of contamination are washwater and natural water. Hence, for the verification study, the focus would be on identifying buildings within the watershed which could be potential contributors. The buildings layer can be queried to identify those falling within the watershed boundary (Figure. 5.3). The selected buildings are highlighted with a thick black boundary. Subsequent field visits can be focused on trying to identify stormwater manholes with dry-weather flows which lie along the path from these buildings to the outfall. This would enhance the chance of finding a reliable contaminant source.

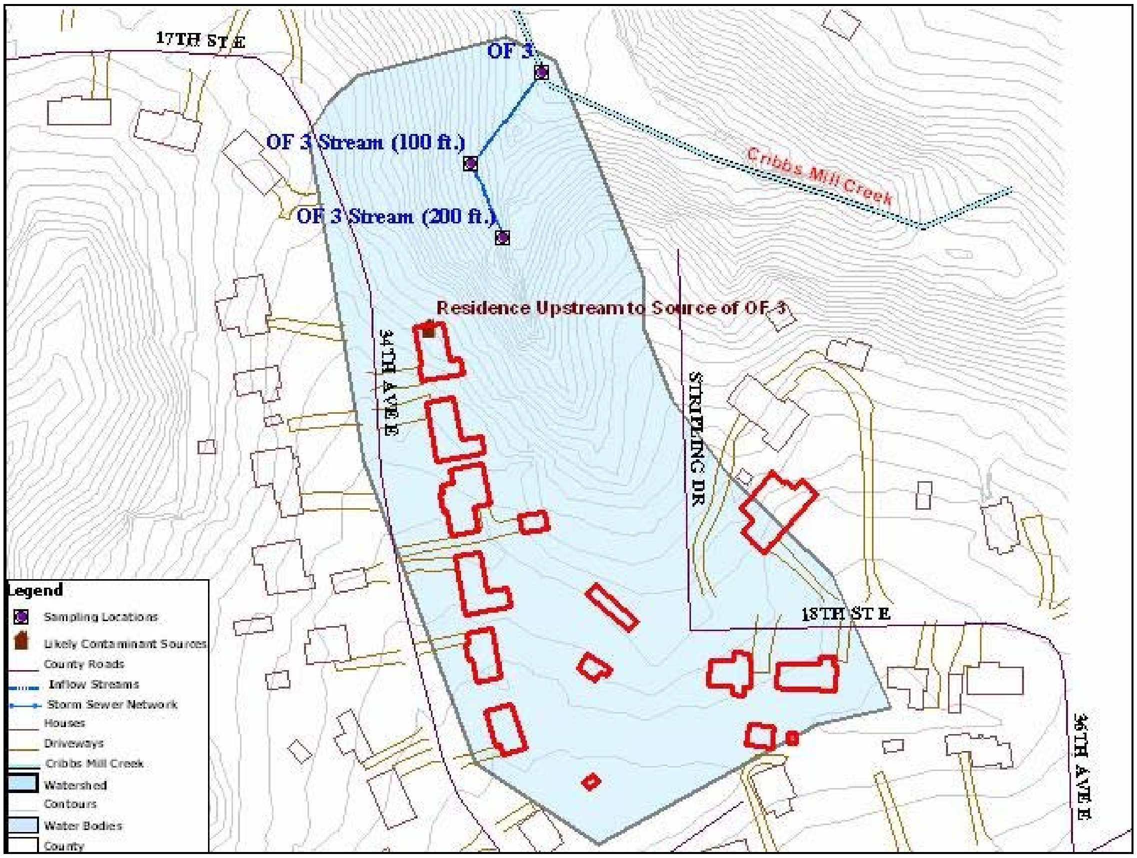


*Figure 5.3.* Spatial selection of buildings within watershed for outfall 3

In large study areas which span over huge watersheds within a jurisdiction, this technique would be very efficient, in that it helps the field crew focus their efforts in a relevant area of the watershed and already gives an indication of the potential contaminant sources even before going to the field. The programmed flowchart analysis would make it easier to handle vast number of samples. This would eliminate any possible errors in the detection of contaminant sources.

5.2. Example of possible analyses

By querying the flow chart result column in the analysis layer, it is possible to determine the number of problem outfalls and sources. The results for this study are shown in Table 5.1.

Table 5.1. *Summary table of outfalls with problem sources*

| **Corresponding outfall number** | **No. of contaminated samples among all observations related to each outfall** | **Percentage of Samples with problems** |
|---|---|---|
| 3 | 4 of 13 | 31 |
| 4 | 0 of 19 | 0 |
| 27 | 0 of 9 | 0 |
| 31 | 2 of 13 | 15 |
| 36 | 1 of 8 | 13 |
| 39 | 0 of 13 | 0 |
| 45 | 7 of 12 | 58 |
| 53 | 2 of 16 | 13 |
| 55 | 4 of 9 | 44 |

The acreage of individual watersheds can also be generated as a report from ArcMap.

Table 5.2 *Watershed area for individual outfalls*

| **Watershed No.** | **Area in sft.** | **Area in Acres** |
|---|---|---|
| OF 3 Watershed | 300206.24 | 6.90 |
| OF 4 Watershed | 251937.20 | 5.79 |
| OF 27 Watershed | 1761121.14 | 40.51 |
| OF 36 Watershed | 296324.82 | 6.82 |
| OF 31 watershed | 1419080.54 | 32.64 |
| OF 39 Watershed | 1248323.97 | 28.71 |
| OF 45 Watershed | 596912.61 | 13.73 |
| OF 55 Watershed | 292443.85 | 6.73 |
| OF 53 Watershed | 137367.79 | 3.16 |

From the summary of analysis results, we realize that there are no problem sources for outfall 4. But, during the on-site field verification studies, a residence upstream of manhole 4.3 appeared to be contributing to the flows seen in this manhole. This was indicated by the presence of a manhole, which was not a sanitary sewer manhole, within the premises of this residence, and hence this residence was marked as a potential location of the source using the GPS. From the outfall 4 layout obtained from the GIS project (Fig. 5.3), it is evident that this residence does not fall within the watershed boundary of outfall 4 (all buildings within this watershed would have been highlighted in red). Hence, it can be concluded with fair certainty that this house cannot be a potential source. Spatial querying of the associated layers would arrive at this conclusion. This detailed analysis is not possible without the capabilities provided by GIS. This is a fairly reliable way of identifying false positive and false negative source locations.

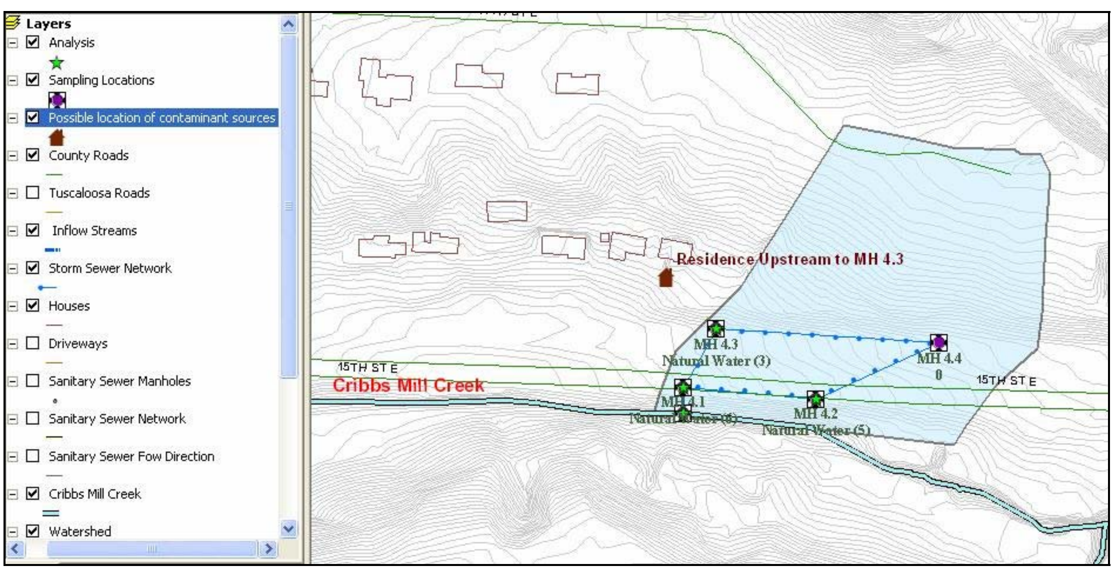


*Figure 5.3*. Selection of buildings within watershed for outfall 4: None

# CHAPTER 6

# CONCLUSIONS AND FUTURE RESEARCH

## 6.1 The Creek Walk Procedure

From the observation of the number of outfalls sampled in each round of the creek walk and from previous studies done by Pitt, et al. (1993) and Lalor (1994) , it is inferred that in order to be able to identify all the problem outfalls, it is important to conduct at least 4 rounds of sampling the creek, in order to be able to identify all the problem outfalls. It is also important to schedule the creek walks on days when we know that many residents would be at home as most of the problem outfalls were found on weekends and holidays when there is an increase in household activity.

It is also important to schedule sampling in all the seasons. In our case, where we found spring water most of the times at the outfalls, the samples collected in the summer months showed either reduced or no spring water flows (absence of head streams carrying clean water), but the outfalls still flowing indicated anthropogenic sources. Hence, the spatial and temporal distribution of sampling runs is reiterated.

## 6.2 Identification of Problem Outfalls

The methods used for identifying problem outfalls were based on physical indicators of contamination, presence or absence of detergents as indicated by the boron or detergent concentrations, and the flowchart method. Problem outfalls are identified as those having either washwater or sanitary wastewater contamination. Figure 6.1 shows that the detergents and the flowchart method return similar results, but the detection of problem outfalls based on physical indicators of contamination is not very consistent compared to the flow chart method.

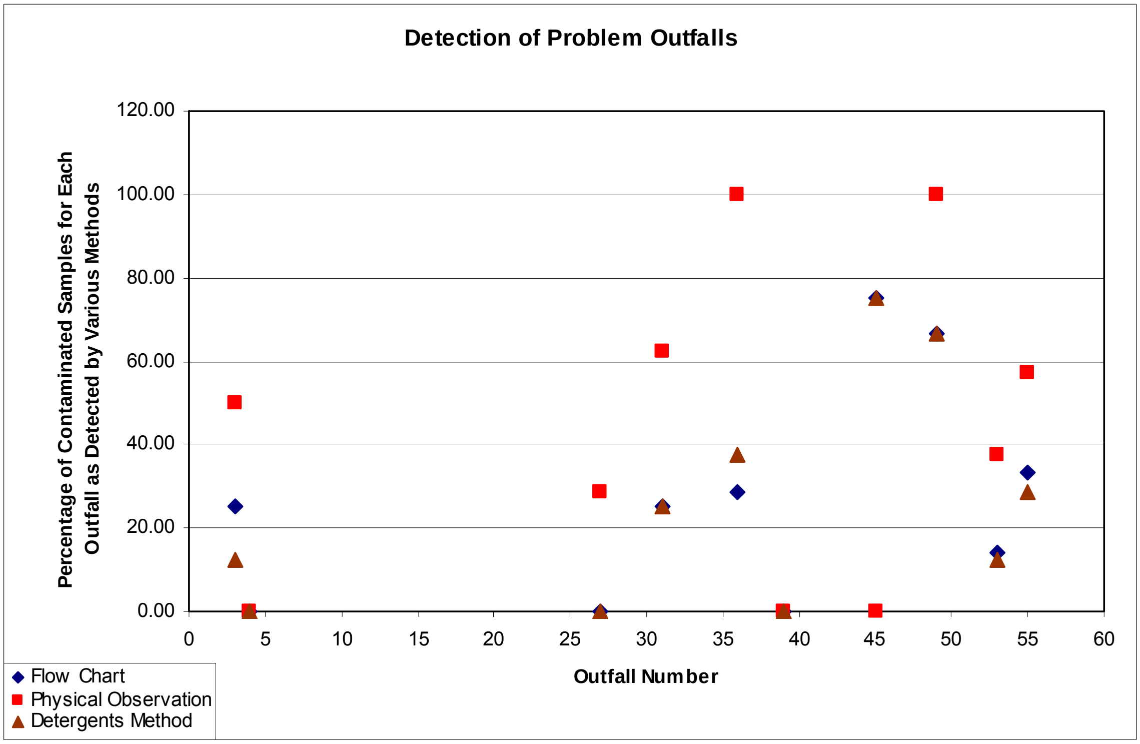


Figure 6.1. Relationship between percent detection of problems by individual methods for each outfall.

The flowchart method indicated that 24% of all the samples collected were problem waters. Using only the presence of detergents as an indicator, 21% of all the samples collected were classified as dirty waters and 14% of all samples collected were classified as dirty waters using the method of physical observation alone. In comparison to the flow chart method, an error of 36% is associated with the identification of problem outfalls using Physical Observation methods, and an error of 3% is associated with identifying problem outfalls using detergents as indicators, when these methods are compared to the flowchart method. The following table shows the percentages of errors calculated on an outfall basis.

Table 6.1. *Percentage of detection errors for each outfall in different methods in comparison to the flow chart method.*

| Outfall No. | Percentage of errors using Physical Observation | Percentage of Errors using Detergents Method |
|---|---|---|
| 3 | 25.00 | 12.50 |
| 4 | 0.00 | 0.00 |
| 27 | 28.57 | 0.00 |
| 31 | 62.50 | 0.00 |
| 36 | 71.43 | 0.00 |
| 39 | 0.00 | 0.00 |
| 45 | 75.00 | 0.00 |
| 49 | 33.33 | 0.00 |
| 53 | 28.57 | 0.00 |
| 55 | 33.33 | 16.67 |

The percentage of error is calculated by comparing the number of problem outfalls detected by the flowchart method to the number of outfalls detected based on either the concentration of detergents or physical observations.

## 6.3 Detailed Watershed Investigations

The detailed watershed investigations for the verification of the sources of inappropriate discharges into the Cribbs Mill Creek showed that six of the nine outfalls (outfall 49 not included because of no flows) carried dirty waters both at the outfall and in the storm sewer network leading to the outfall.

Table 6.2. *Summary of verification of problem sources per outfall*

| **Outfall #** | **Probable sources of contamination, identified as a result of detailed watershed analysis** |
|---|---|
| 3 | Residence upstream of stream/ditch leading to Outfall 3, contributing dirty water. |
| 4 | Springs within the watershed |
| 27 | Springs within the watershed and inflows from residence immediately upstream to the outfall, contributing irrigation runoff / washwater. |
| 31 | Positive evidence of residence contributing to dry-weather flows. |
| 36 | Flows from residence immediately upstream to outfall, contributing irrigation runoff/ washwaters |
| 39 | Springs within watershed |
| 45 | Positive evidence of upstream ditch carrying washwater/ sanitary wastewater from an insurance firm. |
| 53 | No positive physical identification of source. |
| 55 | Flows tracked to residential area upstream, no positive identification of individual residence. |

In most cases, it was possible to track the flows until a certain point upstream to a location where no flows were detected in the storm drain network. Depending on the layout of the residences in the area, it was possible to pinpoint a single residence in some cases, as in the case of outfall 31, where there was flow seen at the outfall but no flow in the manhole immediately above it and the characterization indicated that the flow consisted of either irrigation/tap runoff or washwater. In this case, the only source of the flows could be the house sitting right above the outfall. However, in most cases, the flows could be tracked to a cluster of residences, but it was not possible to pinpoint which one of them, as in the case of outfall 55 where washwater was repeatedly seen, but the residence responsible for these flows could not be pinpointed. Outfall 31 showed washwaters on three occasions. But only on one of these occasions was the detergent concentration high (0.25 mg/l), the other two occasions showed elevated boron concentrations of (0.49 and 0.38 mg/L), classifying them as washwaters according to the flowchart (values from Appendix A). This example illustrates that while in most cases, the observations are corroborated with multiple tracers and multiple methods showing similar results, there are some results, where an isolated tracer could indicate a problem. Such outfalls need to be sampled more extensively to identify a problem using a 'weight of evidence' using independent methods.

The verification process would have been more effective if local storm drain network maps were available. In such a case, it would have been most appropriate to sample the storm drain network from the outfall to the watershed boundary at every one third the distance and carry out intensive sampling in areas which indicate dry-weather flows.

## 6.4 Potential Improvements

The execution of this project and the results obtained indicate that there are avenues for further improvements in related areas. Potential improvements are listed below.

- It is important to dilute the bacterial samples before analysis in order to get a specific MPN value. In our study, many of the total coliform and Enterococci results are

>2419.2. Dilution and agitation of these samples prior to analysis is a must. However, it should be noted that total coliforms and Enterococci values are obtained from the same sample, and the MPN of Enterococci is much more important the total coliform results. It may be appropriate to use separate samples for the two tests, or to cover a wider range of dilutions.

- The use of the prescribed tracers and their accuracy can be enhanced if the sensitivity of the testing kits for potassium and detergents can be improved. From Appendix A, it is noted that potassium can be measured only in multiples of 1 and this does not provide us with the required resolution in many cases.
- The detergents kit is also limited in its application as it cannot read detergent values greater than 3 mg/L. It becomes necessary to dilute the samples, in almost all the cases where a presence of detergents is noted. The flow chart method would be more robust if a tracer that can better indicate the presence of detergents can be adopted (such as the work with boron and fluorescence).
- The verification studies indicate that this step should be followed by other intensive monitoring programs that would include dye studies, smoke tests and remote video inspections in the relatively small areas which have been identified as areas contributing to the contaminant sources.
- The methodology used in this project is appropriate for differentiating and identifying washwaters and sanitary wastewaters. However, while studying a watershed encompassing an industrial area; it becomes essential to supplement this method with other analytical methods used to identify industrial discharges, as described by Pitt, et al. (1993).

- The possibility of integrating the CMBM into the ArcMap framework can be explored, since both ArcMap and the CMBM are programmed in Visual Basic. One of the fields in the Analysis layer in the GIS project for this study can be programmed according to the CMBM model to generate the output of the model as a field in this layer.

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# APPENDIX A

## Analytical Results for Verification Outfalls

# Table A Analytical Results for Verification Outfalls

| OUTFALL # | | COLOR | FLOURIDE | HARDNESS | DETERGENTS | FLORESCENCE | Boron | POTASSIUM | TURBIDITY | AMMONIA | Bacteria | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date of collection | APHA Platinum Cobalt Units | mg/L | mg/L CaCO3 in100ml | PPM | PPM | mg/L | PPM | NTU | mg/L | Total Coliform(MPN) | E-Coli(MPN) | Enterrococci(MPN) |
| 3 | 4/17/2002 | 5 | 0.15 | 18.8 | 0 | 3.41 | N/A | 2 | 3.12 | 0.01 | N?A | N?A | N?A |
| | 5/31/2002 | 0 | 0.11 | 12.6 | 0 | 16.51 | N/A | 0 | 9 | 0.03 | N?A | N?A | N?A |
| | 10/9/2002 | 95 | 0.08 | 21.45 | 1.5 | 4.46 | 0.59 | 1 | 3.53 | 0.03 | >2419.2 | >2419.2 | 6 |
| | 2/18/2003 | 0 | 0 | 52 | 0 | 21.76 | 0.35 | 5 | 5.3 | 0 | 275.5 | 143.9 | 6.2 |
| | 3/31/2003 | 10 | 0.09 | 17 | 0 | 10.46 | 0.08 | 4 | 15.6 | 0.01 | 1413.6 | 325.5 | 48.3 |
| | 12/20/2003 | 50 | 0.08 | 16 | 0 | 18.87 | 0.17 | 1 | 9.9 | 0.01 | | 272.3 | 372.5 |
| | 1/20/2004 | 25 | 0.07 | 28 | 0 | 39.8 | 0.27 | 0 | 30.1 | 0.01 | 1732.87 | 461.1 | 172.5 |
| | 3/27/2004 | 20 | 0.22 | 17 | 0 | 14.55 | Under Range (-0.04) | 1 | 28.8 | 0.02 | >2419.2 | 1986.28 | 980.4 |
| OF 3-Upstream (200 Ft.) | 12/20/2003 | 450 | Under Range | 24 | 0 | 46.2 | 0.53 | 2 | 1.47 | 0.09 | | 524.7 | 287.7 |
| OF 3-Upstream (100 Ft.) | 1/20/2004 | 30 | Under Range | 16 | 0.25 | 65.09 | 0.25 | 1 | 0.05 | 0.05 | 1553.07 | 88 | |
| OF 3-Upstream (100 Ft.) | 3/27/2004 | 0 | 0.2 | 21 | 0 | 25.39 | 0.09 | 2 | 19.8 | Under Range (-0.02) | 770.1 | 96 | 18.3 |
| OF 3-Upstream (200 Ft.) | 1/20/2004 | 35 | Under Range | 22 | 0 | 31.22 | 0.26 | 0 | 53.2 | 0.08 | >2419.2 | 461.1 | |
| OF 3-Upstream (200 Ft.) | 3/27/2004 | 20 | 0.16 | 25 | 0 | 30.82 | 0.13 | 3 | 23.6 | 0.02 | 1119.85 | 35 | 15.8 |
| | 4/22/2002 | 0 | 0.09 | 14 | 0 | 1.95 | N/A | 0 | 0.507 | 0 | N?A | N?A | N?A |
| | 6/4/2002 | 4 | 0.1 | 12 | 0 | 1.35 | N/A | 0 | 10.3 | 0 | N?A | N?A | N?A |
| | 10/9/2002 | 0 | 0 | 12.25 | 0 | 3.73 | 0 | 1 | 0.5 | 0 | >2419.2 | 12.1 | 17.9 |
| | 2/19/2003 | 0 | 0.09 | 48 | 0 | 5.45 | 0.04 | 1 | 0.56 | 0 | 290.9 | 3 | 1 |
| | 4/1/2003 | 5 | 0.03 | 20 | 0 | 4.52 | 0.08 | 1 | 0.427 | 0.15 | 387.3 | 1 | 2 |
| | 12/20/2003 | 50 | 0.18 | 26 | 0 | 2.68 | 0.02 | <LD | 0.79 | 0.04 | | <1 | 105 |
| | 1/24/2004 | 5 | 0.14 | 24 | 0 | 5.88 | 0.15 | 0 | 5.29 | 0.01 | >2419.2 | >2419.2 | N/A |
| | 3/27/2004 | 0 | 0.5 | 31 | 0 | 3.93 | 0.07 | 0 | 2.59 | Under Range (-0.03) | >2419.2 | 6.2 | 7.3 |
| MH 4.1-Along road | 12/20/2003 | 25 | 0.22 | 27 | 0 | 4.9 | 0.09 | 1 | 136 | 0 | | <1 | 4.1 |
| MH 4.1-Along road | 1/24/2004 | 0 | 0.17 | 28 | 0 | 3.18 | 0.12 | 0 | 1.66 | 0.02 | 214.3 | 1 | |
| MH 4.1-Along road | 3/27/2004 | 0 | 0.18 | 21 | 0 | 1.27 | 0.21 | 0 | 1.65 | Under Range (-0.02) | 2419.7 | 2 | 4.1 |
| MH 4.1-Across Road | 12/20/2003 | 25 | 0.21 | 14 | 0 | 5.21 | 0.1 | <LD | 0.67 | under range | | <1 | 6.3 |

# Table A Continued

| OUTFALL # | | COLOR | FLOURIDE | HARDNESS | DETERGENTS | FLORESCENCE | Boron | POTASSIUM | TURBIDITY | AMMONIA | Bacteria | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date of collection | APHA Platinum Cobalt Units | mg/L | mg/L CaCO3 in100ml | PPM | PPM | mg/L | PPM | NTU | mg/L | Total Coliform(MPN) | E-Coli(MPN) | Enterrococci(MPN) |
| MH 4.1-Across Road | 1/24/2004 | 5 | 0.12 | 17 | 0 | 4.62 | 0.04 | 0 | 1.02 | 0 | 517.2 | <1 | |
| MH 4.1-Across Road | 3/27/2004 | 0 | 0.2 | 22 | 0 | 3.42 | Under range (-0.02) | 1 | 0.822 | Under Range (-0.03) | 2419.7 | <1 | 1 |
| MH 4.2- Along Road | 1/24/2004 | 5 | 0.15 | 25 | 0 | 2.2 | Under Range | 0 | 0.457 | 0 | <1 | <1 | |
| MH 4.2- Along Road | 3/27/2004 | 0 | 0.11 | 12 | 0 | 0.87 | 0.05 | 1 | 1.01 | 0 | 5.1 | <1 | <1 |
| MH 4.2-Across Road | 12/20/2003 | 25 | 0.1 | 24 | 0 | 3.72 | under range | 1 | 0.8 | under range | | 0 | 8.6 |
| MH 4.2-Across Road | 1/24/2004 | 5 | 0.12 | 29 | 0 | 3.25 | 0.05 | 0 | 0.988 | 0.04 | 461.1 | 4.1 | |
| MH 4.2-Across Road | 3/27/2004 | 0 | 0.1 | 18 | 0 | 0.98 | Under range (-0.01) | 0 | 0.578 | Under Range (-0.04) | 1299.65 | 1 | <1 |
| MH 4.3-Across Road | 12/22/2003 | 0 | 0.14 | 14 | 0 | 3.95 | under range | <LD | 4.8 | 0.04 | | 0 | 0 |
| MH 4.3-Across Road | 1/24/2004 | 0 | 0.13 | 12 | 0 | 3.27 | Under Range | 0 | 1.7 | under range | 60.1 | <1 | |
| MH 4.3-Across Road | 3/27/2004 | 0 | 0.15 | 17 | 0 | 3.43 | Under range (-0.14) | 0 | 1.66 | Under Range (-0.03) | 17.5 | <1 | <1 |
| 27 | 4/26/2002 | 0 | 0.18 | 27.2 | 0 | 10.37 | N/A | 1 | 3.39 | 0.18 | N?A | N?A | N?A |
| | 6/11/2002 | 12 | 0.34 | 2.4 | 0 | 15.97 | N/A | 1 | 2.36 | 0.31 | N?A | N?A | N?A |
| | 10/14/2002 | 0 | 0.66 | 22 | 0.125 | 35.57 | 0.04 | 2 | 4.65 | 0.1 | >2419.2 | 1203.3 | 100.8 |
| | 2/24/2003 | 0 | 0.18 | 56 | 0 | 34.47 | Under Range | 1 | 10.1 | 0.02 | 435.2 | 63.1 | 5.2 |
| | 4/17/2003 | 20 | 0.23 | 32 | 0 | 22.56 | 0.12 | 1 | 6.36 | 0.06 | >2419.2 | 410.6 | 3 |
| | 1/24/2004 | 5 | 0.26 | 46 | 0 | 18.44 | 0.14 | 1 | 3.75 | 0.19 | 920.8 | 19.5 | N/A |
| | 3/27/2004 | 25 | 0.2 | 55 | 0 | 20.36 | 0.15 | 3 | 9.45 | 0.31 | >2419.2 | 519 | 22.6 |
| MH 27.1 | 1/24/2004 | 30 | 0.11 | 42 | 0 | 36.33 | 0.27 | 1 | 36.3 | under range | >2419.2 | 285.1 | |
| OF 27 Stream | 1/24/2004 | 10 | 0.43 | 27 | 0 | 11.19 | 0.01 | 1 | 1.65 | 0.02 | 410.6 | 86.5 | |
| 31 | 4/26/2002 | 5 | 0.8 | 43.2 | 0.25 | 16.53 | N/A | 2 | 12.2 | 0.67 | N?A | N?A | N?A |
| | 6/17/2002 | 8 | 0.3 | 0 | 0 | 34.38 | N/A | 2 | 1.23 | 0.27 | N?A | N?A | N?A |
| | 10/14/2002 | 0 | 0.14 | 31.5 | 0.125 | 59.81 | 0.2 | 2 | 29 | 0.14 | >2419.2 | 125 | 10.7 |
| | 3/4/2003 | 15 | 0.61 | 54 | 0 | 76.45 | 0.09 | 1 | 10.5 | 0.04 | 488.4 | 68.3 | <1 |
| | 4/17/2003 | 30 | 0.72 | 20 | 0.125 | 57.85 | 0.13 | 1 | 22.1 | 0.02 | 770.1 | 33.6 | 9.2 |

# Table A Continued

| OUTFALL # | | COLOR | FLOURIDE | HARDNESS | DETERGENTS | FLORESCENCE | Boron | POTASSIUM | TURBIDITY | AMMONIA | Bacteria | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date of collection | APHA Platinum Cobalt Units | mg/L | mg/L CaCO3 in100ml | PPM | PPM | mg/L | PPM | NTU | mg/L | Total Coliform(MPN) | E-Coli(MPN) | Enterrococci(MPN) |
| | 12/22/2003 | 0 | 0.12 | 54 | 0 | 18.41 | 0.12 | 2 | 3.88 | 0.01 | N?A | 111.2 | 51.2 |
| 31 | 1/24/2004 | 5 | 0.76 | 70 | 0.25 | 24.08 | 0.21 | 1 | 6.38 | 0.44 | >2419.2 | >2419.2 | N/A |
| | 3/27/2004 | 10 | 0.66 | 64 | 0 | 30.13 | Under Range (-0.01) | 2 | 16.7 | 0.02 | >2419.2 | 356.4 | 1986.28 |
| MH 31.1 | 12/22/2003 | 25 | 1.07 | 57 | 0 | 2.75 | 0.17 | 1 | 1.09 | under range | | | 0 |
| MH 31.1 | 1/24/2004 | 5 | 1.08 | 53 | 0 | 3.93 | 0.12 | 1 | 1.23 | under range | 1 | <1 | |
| MH 31.1 | 3/27/2004 | 0 | 1.25 | 65 | 0 | 5.08 | 0.02 | 1 | 2.46 | Under Range (-0.04) | 5.2 | <1 | <1 |
| OF 31 Upstream (100 ft ) | 1/24/2004 | 5 | 1.04 | 62 | 0 | 17.67 | 0.13 | 1 | 4.39 | 0.18 | >2419.2 | >2419.2 | |
| OF 31 Upstream (100 ft ) | 3/27/2004 | 15 | 1.07 | 74 | 0 | 40.9 | 0.05 | 1 | 29 | 0.01 | 2419.17 | 920.8 | 48.8 |
| 36 | 4/26/2002 | 100 | 0.09 | 243.2 | 0.15 | 57.42 | N/A | 4 | 133 | 0.26 | 1 | N?A | N/A |
| | 6/19/2002 | 100 | 0.16 | 212.6 | 0.25 | 32.83 | N/A | 0 | 122.6 | 0.1 | N/A | N?A | N/A |
| | 10/17/2002 | 0 | 0.13 | 102.25 | 0 | 5.45 | 0.06 | 4 | 25 | 0 | >2419.2 | 61.3 | 3 |
| | 3/5/2003 | 10 | 0.08 | 185 | 0 | 49.92 | 0.11 | 2 | 1.08 | 0 | >2419.2 | 1 | 3.1 |
| | 4/17/2003 | 70 | 0.14 | 230 | 0.125 | 34.42 | 0.15 | 2 | 58.6 | 0.03 | >2419.2 | 22.8 | 25.3 |
| | 12/22/2003 | 350 | 0.06 | 156 | 0 | 66.01 | 0.49 | 2 | 120 | 0.04 | N/A | 5.2 | 47.1 |
| | 1/24/2004 | 10 | 0.22 | 191 | 0 | 20.84 | 0.38 | 2 | 5.73 | Under Range | 613.1 | 2 | N/A |
| | 3/27/2004 | 0 | 0.08 | 220 | 0 | 9.63 | 0.03 | 2 | 8.81 | Under Range (-0.04) | 2419.17 | 11 | 7.2 |
| | 4/29/2002 | 19 | 0.16 | 109.2 | 0 | 11.66 | N/A | 2 | 10.8 | 0.08 | N?A | N?A | N?A |
| | 6/24/2002 | 20 | 0.04 | 100.2 | 0 | 4.42 | N/A | 4 | 10.3 | 0 | N?A | N?A | N?A |
| | 10/17/2002 | 0 | 0.24 | 51 | 0 | 12.25 | 0.01 | 2 | 2.24 | 0.01 | >2419.2 | 178.9 | 112.4 |
| | 3/5/2003 | 5 | 0.09 | 120 | 0 | 27.24 | 0.11 | 2 | 0.413 | 0.01 | 178.9 | <1 | 1 |
| 39 | 4/17/2003 | 5 | 0.13 | 120 | 0 | 34.46 | 0.02 | 2 | 0.409 | 0 | >2419.2 | 38.6 | 12 |
| | 12/22/2003 | 25 | 0.12 | 104 | 0 | 3.61 | 0.14 | 1 | 0.9 | Under Range | N/A | N/A | 7.2 |
| | 1/30/2004 | 5 | 0.16 | 102 | 0 | 4.8 | 0.07 | 2 | 0.561 | Under Range | 1986.28 | 209.8 | NO |
| | 3/27/2004 | 10 | 0.16 | 203 | 0 | 7.43 | 0.02 | 3 | 5.73 | 0.04 | 1203.31 | 770.1 | 4 |

# Table A Continued

| OUTFALL # | | COLOR | FLOURIDE | HARDNESS | DETERGENTS | FLORESCENCE | Boron | POTASSIUM | TURBIDITY | AMMONIA | Bacteria | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date of collection | APHA Platinum Cobalt Units | mg/L | mg/L CaCO3 in100ml | PPM | PPM | mg/L | PPM | NTU | mg/L | Total Coliform(MPN) | E-Coli(MPN) | Enterococci(MPN) |
| MH 39.1 | 12/22/2003 | 200 | 0.23 | 188 | 0 | 19.53 | 0.19 | 2 | 25.7 | 0.02 | | 21.8 | 53.4 |
| MH 39.2 | 1/30/2004 | 5 | 0.16 | 191 | 0.25 | 8.82 | Under Range | 3 | 1.05 | under range | 195.6 | 4.1 | |
| MH 39.2 | 3/27/2004 | 0 | 0.06 | 109 | 0 | 2.96 | Under range (-0.01) | 1 | 0.427 | 0.01 | >2419.2 | 461.1 | 15.6 |
| MH 39.1 | 1/30/2004 | 5 | 0.16 | 202 | 0 | 7.57 | 0 | 2 | 1.51 | under range | 152.9 | <1 | |
| MH 39.1 | 3/27/2004 | 0 | Under Range (-0.02) | 197 | 0 | 5.7 | 0.2 | 2 | 1.28 | 0.06 | 1732.87 | 488.4 | 3.1 |
| MH 39.3 | 3/27/2004 | 5 | 0.21 | 197 | 0 | 12.44 | 0.07 | 4 | 11.9 | 0.16 | >2419.2 | 1732.87 | 43.2 |
| 45 | 5/8/2002 | 15 | 0.34 | 51.2 | 12.5 | 8.96 | N/A | 2 | 42.2 | 0.01 | N?A | N?A | N?A |
| | 6/24/2002 | 15 | 0.19 | 44.8 | 10 | 6.86 | N/A | 2 | 40 | 0.02 | N/A | N/A | N/A |
| | 10/18/2002 | 20 | 2.17 | 44.5 | 0 | 13.65 | 0.29 | 2 | 29 | 0.33 | >2419.2 | 37.4 | 3.1 |
| | 3/5/2003 | 15 | 0.41 | 65 | 3 | 35.44 | 0.24 | 2 | 7.04 | 0.01 | >2419.2 | 74.4 | 14.6 |
| | | 10 | 0.09 | 51 | 2.5 | 42.32 | 0.04 | 2 | 6.11 | -0.02 | 980.4 | 8.6 | <1 |
| | 12/22/2003 | 50 | 1.06 | 66 | 0.25 | 24.05 | 0.08 | 1 | 4.46 | 0.02 | N/A | N/A | 791.5 |
| | 1/30/2004 | 5 | 2.73 | 80 | 1 | 61.35 | 0.19 | 1 | 13.9 | 0 | >2419.2 | >2419.2 | 3 |
| | 3/28/2004 | 0 | 0.21 | 84 | 0 | 7.9 | 0.01 | 1 | 4.21 | 0.02 | >2419.2 | 195.6 | 45.2 |
| OF 45 Ditch | 1/30/2004 | 60 | 0.08 | 82 | 0 | 43.43 | 0.26 | 1 | 28.6 | 0.07 | 2419.17 | 82 | |
| OF 45 Ditch | 3/28/2004 | 75 | 0.34 | 88 | 0 | 60.65 | 0.27 | 0 | 27.5 | 0.02 | >2419.2 | 21.6 | 19.1 |
| MH 45.1 | 2/1/2004 | 75 | Under Range | 39 | 0 | 41.18 | 0.38 | 2 | 60 | 0.05 | NA | NA | |
| MH 45.1 | 3/28/2004 | 95 | Under Range (-0.02) | 60 | 0 | 71.96 | 0.44 | 1 | 152 | 0.11 | >2419.2 | 27.2 | 250.7 |
| 53 | 5/8/2002 | 20 | 0.01 | 23.6 | 0 | 2.93 | N/A | 2 | 15 | 0.35 | N?A | N?A | N?A |
| | 6/24/2002 | 20 | 0.1 | 22.4 | 0 | 2.41 | N/A | 1 | 12.4 | 0.17 | N/A | N/A | N/A |
| | 10/18/2002 | 0 | 0.22 | 16.25 | 15 | 95.65 | 0.13 | 2 | 5.03 | 0.11 | >2419.2 | 16.6 | 18.7 |
| | 3/5/2003 | 5 | 0.1 | 39 | 0 | 9.44 | 0.15 | 2 | 0.5 | 0.1 | 488.4 | <1 | <1 |
| | 4/18/2003 | 10 | | 25 | 0 | 12.46 | 0.11 | 1 | 4.19 | 0.07 | 1413.6 | 1 | <1 |
| | 12/22/2003 | 75 | 0.21 | 28 | 0 | 13.18 | Under Range | 2 | 11.8 | 0.08 | N/A | N/A | 4.1 |

# Table A Continued

| OUTFALL # | | COLOR | FLOURIDE | HARDNESS | DETERGENTS | FLORESCENCE | Boron | POTASSIUM | TURBIDITY | AMMONIA | Bacteria | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date of collection | APHA Platinum Cobalt Units | mg/L | mg/L CaCO3 in100ml | PPM | PPM | mg/L | PPM | NTU | mg/L | Total Coliform(MPN) | E-Coli(MPN) | Enterococci(MPN) |
| | 2/1/2004 | 20 | 0.13 | 38 | 0 | 17.89 | 0.04 | 2 | 15 | 0.08 | 727 | 5.1 | N/A |
| | 3/28/2004 | 0 | 0.17 | 33 | 0 | 4.44 | Under Range (-0.12) | 1 | 2.82 | 0.08 | 325.5 | <1 | 1 |
| MH 53.1 | 12/23/2003 | 125 | 0.18 | 35 | 0 | 22.06 | 0.19 | 3 | 23.1 | 0.11 | | 0 | 2 |
| MH 53.1 | 2/1/2004 | 10 | 0.11 | 27 | 0 | 10.339 | 0.01 | 2 | 6.23 | 0.08 | 307.6 | <1 | |
| MH 53.1 | 3/28/2004 | 0 | 0.17 | 26 | 0 | | Under Range (-0.11) | 1 | | 0.09 | 1553.07 | 2 | 4.1 |
| MH 53.2 | 12/23/2003 | 25 | 0.06 | 33 | 0 | 11.28 | 0.18 | 4 | 7.74 | 0.05 | | 0 | 16.4 |
| MH 53.2 | 2/1/2004 | 10 | 0.07 | 64 | 0 | 10.78 | Under Range | 2 | 11.9 | 0.06 | NA | NA | |
| MH 53.2 | 3/28/2004 | 60 | 0.05 | 42 | 0 | 27.64 | 0.56 | 2 | 88 | 0.13 | >2419.2 | <1.0 | 28.6 |
| MH 53.3 | 12/23/2003 | 100 | 0.18 | 42 | 0 | 16.53 | 0.11 | 3 | 28.5 | 0.04 | | 0 | 226 |
| MH 53.3 | 3/28/2004 | 40 | 0.14 | 33 | 0 | 30.33 | 0.24 | 2 | 50.8 | 0.06 | >2419.2 | 6.3 | 40.8 |
| 55 | 5/8/2002 | 46 | 0.04 | 40.8 | 0 | 11.11 | N/A | 3 | 34.5 | 0.08 | N?A | N?A | N?A |
| | 6/24/2002 | 44 | 0.07 | 46.6 | 0.25 | 28.42 | N/A | 0 | 34.6 | 0.06 | N/A | N/A | N/A |
| | 10/18/2002 | 20 | 0.17 | 41 | 0 | 4.45 | 0.07 | 2 | 19.3 | 0.27 | >2419.2 | 2419.9 | 727 |
| | 3/5/2003 | 15 | 0.1 | 41 | 0 | 54.21 | 0.08 | 1 | 9.76 | 0.43 | >2419.3 | 1 | 12.2 |
| | 4/18/2003 | 260 | 0.95 | 38 | 0 | 18.76 | 0.85 | 1 | 3187 | 0.1 | >2419.2 | 307.6 | 10.5 |
| | 2/1/2004 | 10 | 0.32 | 47 | 1 | 68.38 | 0.14 | 5 | 31.6 | 13 | >2419.2 | >2419.2 | N/A |
| | 3/28/2004 | 90 | Under Range (-0.03) | 40 | 0 | 48 | Under Range (-0.06) | 2 | 126 | 0.37 | >2419.2 | 48.8 | 258.9 |
| MH 55.1 | 2/1/2004 | 25 | 0.58 | 71 | 5 | 165.92 | 0.69 | 8 | 45 | 19 | 2.38 | NA | NA |
| MH 55.2 | 2/1/2004 | 20 | 0.83 | 67 | 15 | 291.56 | 0.84 | 11 | 90.6 | 34 | 3.09 | >2419.2 | >2419.2 |

# APPENDIX B

## Analysis Results by All Methods for Problem Outfall Samples

## Table B. Analysis Results by All Methods for Problem Outfall Samples

| Outfall # | Date Of Collection | Vegetation | Damage To Outfalls | Problem Indicated (Besides Sediment) | Most Likely Source By Model | Problem Indicated By Physical Observations | Detergents Contamination Yes If ≥ 0.25 Mg/L Or Boron ≥ 0.35 Mg/L | Flow Chart Method, Most Likely Source |
|---|---|---|---|---|---|---|---|---|
| 3 | 4/17/2002 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Natural Water Source |
| | 5/31/2002 | Normal | No | No | Spring Water, Sanitary Wastewater, Laundry Washwater | No | No | Natural Water Source |
| | 10/9/2002 | Normal | No | Yes | Spring Water, Tap Water, Laundry Washwater | **Yes (Floatables,Color, Turbidity)** | **Yes** | **Washwater Source** |
| | 2/18/2003 | Normal | No | Yes | Spring Water, Sanitary Wastewater, Carwash Water | **Yes (Floatables,Color)** | No | **Washwater Source** |
| | 3/31/2003 | Normal | No | Yes | Spring Water, Laundry Washwater | **Yes (Floatasbles,Color)** | No | Natural Water Source |
| | 12/20/2003 | Normal | No | Yes | Spring Water, Laundry Washwater | **Yes (Floatables,Color)** | No | Natural Water Source |
| | 1/20/2004 | Normal | No | No | Spring Water, Tap Water, Laundry Washwater | No | No | Natural Water Source |
| | 3/27/2004 | Normal | No | No | Spring Water, Laundry Washwater, Tap Water | No | No | Natural Water Source |
| Of 3-Upstream (200 Ft.) | 12/20/2003 | Normal | No | No | Spring Water, Laundry Washwater | No | No | **Washwater Source** |
| Of 3-Upstream (100 Ft.) | 1/20/2004 | Normal | No | No | Spring Water, Laundry Washwater | No | No | **Washwater Source** |
| Of 3-Upstream (100 Ft.) | 3/27/2004 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Natural Water Source |
| Of 3-Upstream (200 Ft.) | 1/20/2004 | Normal | No | No | Spring Water, Tap Water | No | No | Natural Water Source |
| Of 3-Upstream (200 Ft.) | 3/27/2004 | Normal | No | No | Spring Water, Laundry Washwater, Sanitary Wastewater | No | No | Natural Water Source |
| 4 | 4/22/2002 | Normal | No | No | Spring Water, Laundry Washwater | **Yes (Sediment)** | No | Natural Water Source |
| | 6/4/2002 | Normal | No | No | Spring Water, Laundry Washwater | **Yes (Sediment)** | No | Natural Water Source |
| | 10/9/2002 | Normal | No | No | Spring Water, Laundry Washwater | **Yes (Sediment)** | No | Natural Water Source |
| | 2/19/2003 | Normal | No | No | Spring Water, Carwash Water, Tap Water | **Yes (Sediment)** | No | Natural Water Source |
| | 4/1/2003 | Normal | No | No | Spring Water, Laundry Washwater | **Yes (Sediment)** | No | Natural Water Source |
| | 12/20/2003 | Normal | No | No | Spring Water, Laundry Washwater, Tap Water | **Yes (Sediment)** | No | Natural Water Source |
| | 1/24/2004 | Normal | No | No | Spring Water, Laundry Washwater | **Yes (Sediment)** | No | Natural Water Source |
| | 3/27/2004 | Normal | No | No | Spring Water, Tap Water, Laundry Washwater | **Yes (Sediment)** | No | Tap/Irrigation Water Source |

# Table B Continued

| Outfall # | Date Of Collection | Vegetation | Damage To Outfalls | Problem Indicated (Besides Sediment) | Most Likely Source By Model | Problem Indicated By Physical Observations | Detergents Contamination Yes If ≥ 0.25 Mg/L Or Boron ≥ 0.35 Mg/L | Flow Chart Method, Most Likely Source |
|---|---|---|---|---|---|---|---|---|
| Mh 4.1-Along Road | 12/20/2003 | Normal | No | No | Spring Water, Tap Water, Laundry Washwater | No | No | Natural Water Source |
| Mh 4.1-Along Road | 1/24/2004 | Normal | No | No | Spring Water, Laundry Washwater, Sanitary Wastewater | No | No | Natural Water Source |
| Mh 4.1-Along Road | 3/27/2004 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Natural Water Source |
| Mh 4.1-Across Road | 12/20/2003 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Natural Water Source |
| Mh 4.1-Across Road | 1/24/2004 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Natural Water Source |
| Mh 4.1-Across Road | 3/27/2004 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Natural Water Source |
| Mh 4.2- Along Road | 1/24/2004 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Natural Water Source |
| Mh 4.2- Along Road | 3/27/2004 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Natural Water Source |
| Mh 4.2-Across Road | 12/20/2003 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Natural Water Source |
| Mh 4.2-Across Road | 1/24/2004 | Normal | No | No | Spring Water, Sanitary Wastewater, Laundry Washwater | No | No | Natural Water Source |
| Mh 4.2-Across Road | 3/27/2004 | Normal | No | No | Spring Water, Laundry Washwater, Irrigation Water | No | No | Natural Water Source |
| Mh 4.3-Across Road | 12/22/2003 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Natural Water Source |
| Mh 4.3-Across Road | 1/24/2004 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Natural Water Source |
| Mh 4.3-Across Road | 3/27/2004 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Natural Water Source |
| 27 | 4/26/2002 | Normal | No | No | Spring Water, Laundry Washwater | **Yes (Sediment)** | No | Natural Water Source |
| | 6/11/2002 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Tap/Irrigation Water Source |
| | 10/14/2002 | Normal | No | No | Spring Water, Sanitary Wastewater | No | No | Tap/Irrigation Water Source |
| | 2/24/2003 | Normal | No | No | Tap Water, Spring Water, Carwash Water | **Yes (Sediment)** | No | Natural Water Source |
| | 4/17/2003 | Normal | No | No | Spring Water, Sanitary Wastewater | **Yes (Sediment)** | No | Natural Water Source |
| | 1/24/2004 | Normal | No | Yes | Spring Water, Tap Water, Sanitary Wastewater | **Yes (Color, Odor)** | No | Tap/Irrigation Water Source |
| | 3/27/2004 | Normal | No | **Yes** | Tap Water, Spring Water, Carwash Water | **Yes (Color, Odor)** | No | Tap/Irrigation Water Source |
| Mh 27.1 | 1/24/2004 | Normal | No | No | Spring Water, Tap Water, Carwash Water | No | No | Natural Water Source |
| Of 27 Stream | 1/24/2004 | Normal | No | No | Spring Water | No | No | Tap/Irrigation Water Source |

# Table B Continued

| Outfall # | Date Of Collection | Vegetation | Damage To Outfalls | Problem Indicated (Besides Sediment) | Most Likely Source By Model | Problem Indicated By Physical Observations | Detergents Contamination Yes If ≥ 0.25 Mg/L Or Boron ≥ 0.35 Mg/L | Flow Chart Method, Most Likely Source |
|---|---|---|---|---|---|---|---|---|
| 31 | 4/26/2002 | Normal | No | No | Tap Water, Spring Water, Irrigation Water | **Yes (Sediment)** | **Yes** | **Washwater Source** |
| | 6/17/2002 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Tap/Irrigation Water Source |
| | 10/14/2002 | Normal | No | No | Spring Water, Tap Water, Laundry Washwater | **Yes (Sediment)** | No | Natural Water Source |
| | 3/4/2003 | Normal | No | Yes | Tap Water, Spring Water, Laundry Washwater | **Yes (Color, Turbidity, Floatables)** | No | Tap/Irrigation Water Source |
| | 4/17/2003 | Normal | No | Yes | Tap Water, Spring Water, Laundry Washwater | **Yes (Color, Turbidity, Floatables)** | No | Tap/Irrigation Water Source |
| | 12/22/2003 | Normal | No | Yes | Spring Water, Tap Water, Laundry Washwater | **Yes (Odor)** | No | Natural Water Source |
| | 1/24/2004 | Normal | No | Yes | Tap Water, Spring Water, Laundry Washwater | **Yes (Odor)** | **Yes** | **Washwater Source** |
| | 3/27/2004 | Normal | No | Yes | Tap Water, Irrigation Water | **Yes (Odor)** | No | Tap/Irrigation Water Source |
| Mh 31.1 | 12/22/2003 | Normal | No | No | Tap Water, Irrigation Water | No | No | Tap/Irrigation Water Source |
| Mh 31.1 | 1/24/2004 | Normal | No | No | Spring Water, Tap Water | No | No | Tap/Irrigation Water Source |
| Mh 31.1 | 3/27/2004 | Normal | No | No | Tap Water, Irrigation Water, Carwash Water | No | No | Tap/Irrigation Water Source |
| Of 31 Upstream (100 Ft) | 1/24/2004 | Normal | No | No | Tap Water, Irrigation Water, Laundry Washwater | No | No | Tap/Irrigation Water Source |
| Of 31 Upstream (100 Ft) | 3/27/2004 | Normal | No | No | Tap Water, Sanitary Wastewater, Laundry Washwater | No | No | Tap/Irrigation Water Source |
| 36 | 4/26/2002 | Normal | Concrete Spalling | Yes | Irrigation Water, Tap Water, Carwash Water | No | No | Natural Water Source |
| | 6/19/2002 | Normal | Concrete Spalling | Yes | Tap Water, Irrigation Water, Carwash Water | **Yes (Sediment)** | **Yes** | **Missing Data** |
| | 10/17/2002 | Normal | Concrete Spalling | Yes | Spring Water, Irrigation Water, Carwash Water | **Yes (Sediment)** | No | Natural Water Source |
| | 3/5/2003 | Normal | Concrete Spalling | Yes | Spring Water, Tap Water, Irrigayion Water | **Yes (Color, Turbidity, Floatables)** | No | Natural Water Source |
| | 4/17/2003 | Normal | Concrete Spalling | Yes | Spring Water, Tap Water, Laundry Washwater | **Yes (Sediment)** | No | Natural Water Source |
| | 12/22/2003 | Normal | Concrete Spalling | Yes | Carwash Water, Sanitary Wastewater, Spring Water | No | **Yes** | **Washwater Source** |
| | 1/24/2004 | Normal | Concrete Spalling | Yes | Carwash Water, Tap Water, Spring Water | No | **Yes** | **Washwater Source** |
| | 3/27/2004 | Normal | Concrete Spalling | Yes | Carwash Water, Tap Water, Spring Water | No | No | Natural Water Source |

# Table B Continued

| Outfall # | Date Of Collection | Vegetation | Damage To Outfalls | Problem Indicated (Besides Sediment) | Most Likely Source By Model | Problem Indicated By Physical Observations | Detergents Contamination Yes If ≥ 0.25 Mg/L Or Boron ≥ 0.35 Mg/L | Flow Chart Method, Most Likely Source |
|---|---|---|---|---|---|---|---|---|
| 39 | 4/29/2002 | Normal | No | No | Tap Water, Irrigation Water, Carwash Water | No | No | Natural Water Source |
| | 6/24/2002 | Normal | No | No | Spring Water, Irrigation Water, Carwash Water | No | No | Natural Water Source |
| | 10/17/2002 | Normal | No | No | Spring Water, Tap Water, Irrigation Water | No | No | Natural Water Source |
| | 3/5/2003 | Normal | No | No | Spring Water, Tap Water, Laundry Washwater | No | No | Natural Water Source |
| | 4/17/2003 | Normal | No | No | Spring Water, Tap Water, Irrigation Water | No | No | Natural Water Source |
| | 12/22/2003 | Normal | No | No | Tap Water, Spring Water | No | No | Natural Water Source |
| | 1/30/2004 | Normal | No | No | Carwash Water, Tap Water | No | No | Natural Water Source |
| | 3/27/2004 | Normal | No | No | Spring Water, Tap Water, Sanitary Wastewater | No | No | Natural Water Source |
| Mh 39.2 | 12/22/2003 | Normal | No | No | Spring Water, Tap Water, Carwash Water | No | No | Natural Water Source |
| Mh 39.2 | 1/30/2004 | Normal | No | No | Spring Water, Tap Water, Laundry Washwater | No | No | Natural Water Source |
| Mh 39.2 | 3/27/2004 | Normal | No | No | Tap Water, Spring Water | No | No | Natural Water Source |
| Mh 39.1 | 1/30/2004 | Normal | No | No | Springwater , Tap Water, Irrigation Water | No | No | Natural Water Source |
| Mh 39.1 | 3/27/2004 | Normal | No | No | Tap Water, Spring Water, Sanitary Wastewater | No | No | Natural Water Source |
| Mh 39.3 | 3/27/2004 | Normal | No | No | Spring Water, Tap Water, Sanitary Wastewater | No | No | Natural Water Source |
| 45 | 5/8/2002 | Normal | No | No | Tap Water, Spring Water, Carwash Water | No | **Yes** | **Washwater Source** |
| | 6/24/2002 | Normal | No | No | Tap Water, Spring Water, Carwash Water | No | **Yes** | **Washwater Source** |
| | 10/18/2002 | Normal | No | No | Tap Water, Irrigation Water, Carwash Water | No | No | Tap Water Source |
| | 3/5/2003 | | No | No | Spring Water, Tap Water, Laundry Washwater | No | **Yes** | **Washwater Source** |
| | | | No | No | Spring Water, Tap Water, Irrigation Water | No | **Yes** | **Washwater Source** |
| | 12/22/2003 | Normal | No | No | Tap Water, Carwash Water, Sanitary Wastewater | No | **Yes** | **Washwater Source** |
| | 1/30/2004 | Normal | No | No | Tap Water, Spring Water, Sanitary Wastewater | No | **Yes** | **Washwater Source** |
| | 3/28/2004 | Normal | No | No | Carwash Water, Tap Water | No | No | Natural Water Source |

# Table B Continued

| **Outfall #** | **Date Of Collection** | **Vegetation** | **Damage To Outfalls** | **Problem Indicated (Besides Sediment)** | **Most Likely Source By Model** | **Problem Indicated By Physical Observations** | **Detergents Contamination Yes If ≥ 0.25 Mg/L Or Boron ≥ 0.35 Mg/L** | **Flow Chart Method, Most Likely Source** |
|---|---|---|---|---|---|---|---|---|
| Of 45 Ditch | 1/30/2004 | Normal | No | No | Spring Water, Tap Water, Sanitary Wastewater | No | No | Natural Water Source |
| Of 45 Ditch | 3/28/2004 | Normal | No | No | Carwash Water, Tap Water, Spring Water | No | No | Tap/Irrigation Water Source |
| Mh 45.1 | 2/1/2004 | Normal | No | No | Spring Water, Tapwater, Sanitary Wastewater | No | **Yes** | **Washwater Source** |
| Mh 45.1 | 3/28/2004 | Normal | No | No | Tap Water, Sanitary Wastewater,Laundry Washwater | No | **Yes** | **Washwater Source** |
| | 5/8/2002 | Normal | Concrete Spalling | **Yes** | Tap Water, Spring Water, Irrigation Water | **Yes (Sediment)** | No | Natural Water Source |
| | 6/24/2002 | Normal | Concrete Spalling | **Yes** | Tap Water, Irrigation Water, Carwash Water | **Yes (Sediment)** | No | Natural Water Source |
| | 10/18/2002 | Normal | Concrete Spalling | **Yes** | Spring Water, Tap Water, Laundry Washwater | **Yes (Sediment)** | **Yes** | **Washwater Source** |
| 53 | 3/5/2003 | Normal | No | No | Spring Water, Tap Water | No | No | Natural Water Source |
| | 4/18/2003 | Normal | No | No | Spring Water, Tap Water, Sanitary Wastewater | No | No | Missing Data |
| | 12/22/2003 | Normal | No | No | Spring Water, Tap Water, Laundry Washwater | No | No | Natural Water Source |
| | 2/1/2004 | Normal | No | No | Spring Water, Tap Water | No | No | Natural Water Source |
| | 3/28/2004 | Normal | No | No | Spring Water, Laundry Washwater | No | | Natural Water Source |
| Mh 53.1 | 12/23/2003 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Natural Water Source |
| Mh 53.1 | 2/1/2004 | Normal | No | No | Spring Water, Irrigation Water | No | No | Natural Water Source |
| Mh 53.1 | 3/28/2004 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Natural Water Source |
| Mh 53.2 | 12/23/2003 | Normal | No | No | Spring Water, Laundry Washwater | No | No | Natural Water Source |
| Mh 53.2 | 2/1/2004 | Normal | No | No | Tap Water, Irrigation Water, Carwash Water | No | No | Natural Water Source |
| Mh 53.2 | 3/28/2004 | Normal | No | No | Spring Water, Tap Water, Carwash Water | No | **Yes** | **Washwater Source** |
| Mh 53.3 | 12/23/2003 | Normal | No | No | Spring Water, Tap Water | No | No | Natural Water Source |
| Mh 53.3 | 3/28/2004 | Normal | No | No | Spring Water, Tap Water, Laundry Washwater | No | No | Natural Water Source |
| 55 | 5/8/2002 | Normal | No | No | Spring Water, Irrigation Water, Carwash Water | **Yes (Sediment)** | No | Natural Water Source |
| | 6/24/2002 | Normal | No | No | Spring Water, Irrigation Water, Tap Water | **Yes (Sediment)** | **Yes** | **Missing Data** |

# Table B Continued

| Outfall # | Date Of Collection | Vegetation | Damage To Outfalls | Problem Indicated (Besides Sediment) | Most Likely Source By Model | Problem Indicated By Physical Observations | Detergents Contamination Yes If ≥ 0.25 Mg/L Or Boron ≥ 0.35 Mg/L | Flow Chart Method, Most Likely Source |
|---|---|---|---|---|---|---|---|---|
| 55 | 10/18/2002 | Normal | No | No | Spring Water, Tap Water, Sanitary Wastewater | **Yes (Sediment)** | No | Natural Water Source |
| | 3/5/2003 | Inhibited | No | **Yes** | Spring Water, Tap Water, Sanitary Wastewater | **Yes (Floatables)** | No | Natural Water Source |
| | 4/18/2003 | Inhibited | No | **Yes** | Spring Water, Tap Water, Sanitary Wastewater | **Yes (Floatables)** | No | **Washwater Source** |
| | 2/1/2004 | Normal | No | **Yes** | Sanitary Wastewater, Tap Water, Spring Water | **Yes (Sediment, Odor)** | **Yes** | **Sanitary Wastewater** |
| | 3/28/2004 | Normal | No | **Yes** | Spring Water, Tap Water, Laundry Washwater | **Yes (Sediment, Odor,Oily Deposits)** | No | Natural Water Source |
| Mh 55.1 | 2/1/2004 | Normal | No | | Sanitary Wastewater, Irrigation Water, Tap Water | No | **Yes** | **Sanitary Wastewater** |
| Mh 55.2 | 2/1/2004 | Normal | No | | Tap Water, Sanitary Wastewater, Carwash Water | No | **Yes** | **Sanitary Wastewater** |

# APPENDIX C

## Analysis Results for All Outfall Samples

## Table C. *Analysis Results for Outfall Samples*

| OUTFALL # | | pH | SPECIFIC CONDUCTIVITY | TEMPERATURE | COLOR | FLOURIDE | HARDNESS | DETERGENTS | FLORESCENCE | Boron | POTASSIUM | TURBIDITY | AMMONIA | Bacteria | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date of collection | | Micro S/cm | F | APHA Platinum Cobalt Units | mg/L | mg/L CaCO3 in100ml | ppm | ppm | mg/l | ppm | NTU | mg/L | Total Coliform(MPN) | E-Coli(MPN) | Enterrocci(MPN) |
| 1 | 4/17/2002 | 6.72 | 67 | N/A | 5 | 0.09 | 27.4 | 0 | 9.19 | | 1 | 0.797 | 0 | | | |
| | 2/18/2003 | 6.36 | 54 | 58 | 0 | 0.2 | 52 | 0 | 11.08 | 0.01 | 3 | 3.26 | 0.01 | 866.4 | 206.3 | 1 |
| | 3/31/2003 | 6.9 | 97 | | 5 | 0.21 | 19 | 0 | 9.24 | 0.06 | 1 | 2.41 | -0.01 | >2419.2 | >2419.2 | 8 |
| 3 | 4/17/2002 | 6.36 | 50 | N/A | 5 | 0.15 | 18.8 | 0 | 3.41 | | 2 | 3.12 | 0.01 | | | |
| | 5/31/2002 | 6.48 | 68 | 56 | 0 | 0.11 | 12.6 | 0 | 16.51 | | 0 | 9 | 0.03 | | | |
| | 10/9/2002 | 6.3 | 64 | 65 | 95 | 0.08 | 21.45 | 1.5 | 4.46 | 0.59 | 1 | 3.53 | 0.03 | >2419.2 | >2419.2 | 6 |
| | 2/18/2003 | 7.5 | 77 | 58 | 0 | 0 | 52 | 0 | 21.76 | 0.35 | 5 | 5.3 | 0 | 275.5 | 143.9 | 6.2 |
| | 3/31/2003 | 7.1 | 230 | | 10 | 0.09 | 17 | 0 | 10.46 | 0.08 | 4 | 15.6 | 0.01 | 1413.6 | 325.5 | 48.3 |
| 3a | 5/31/2002 | 7.02 | 134 | 58 | 0 | 0.02 | 18.6 | 0 | 7.37 | | 0 | 5.66 | 0.02 | | | |
| | 10/3/2002 | 6.65 | 160 | 65 | 0 | 0.57 | 32.75 | 0 | 9.61 | 0.03 | 2 | 2.62 | 0.04 | >2419.2 | 130.1 | 3 |
| | 2/18/2003 | 7.34 | 137 | 58 | 0 | 0.57 | 76 | 0 | 15.69 | 0.11 | 4 | 2.25 | 0.03 | >2419.2 | 166.4 | 28.5 |
| | 3/31/2003 | 7.79 | 138 | | 10 | 0.52 | 49 | 0 | 14.42 | 0.08 | 2 | 7.39 | 0.04 | >2419.2 | 29.2 | 36.3 |
| 3b | 5/31/2002 | 6.69 | 117 | 58 | 5 | 0.14 | 15.4 | 0 | 14.27 | | 1 | 4.56 | 0 | | | |
| | 10/3/2002 | 7.18 | 105 | 65 | 0 | 0.01 | 26 | 0 | 10.18 | 0.01 | 1 | 3.3 | 0.06 | >2419.2 | 5.2 | <1 |
| | 2/18/2003 | 7.25 | 111 | 56 | 0 | 0.11 | 52 | 0 | 22.97 | 0.14 | 3 | 5.25 | 0.02 | 139.6 | 18.5 | <1 |
| | 3/31/2003 | 7.29 | 128 | | 5 | -0.22 | 46 | 0 | 12.56 | 0.04 | 1 | 5.34 | 0.01 | 980.4 | 111.9 | 98.8 |
| 3c | 5/31/2002 | 5.62 | 51 | 58 | 6 | 0.07 | 22.8 | 0 | 0.98 | | 2 | 8.86 | 0 | | | |
| | 10/3/2002 | 6.03 | 48 | 65 | 0 | 0.02 | 6.25 | 0 | 0.68 | 0.02 | 0 | 0.35 | 0.01 | <1 | <1 | <1 |
| | 2/18/2003 | 6.55 | 58 | 56 | 0 | 0.23 | 52 | 0 | 2.63 | 0.06 | 2 | 0.52 | 0 | <1 | <1 | <1 |
| | 3/31/2003 | 6.42 | 56 | | 5 | 0.08 | 20 | 0 | 1.72 | 0.04 | 1 | 2.24 | -0.01 | <1 | <1 | <1 |

# Table C Continued

| OUTFALL # | | pH | SPECIFIC CONDUCTIVITY | TEMPERATURE | COLOR | FLOURIDE | HARDNESS | DETERGENTS | FLORESCENCE | Boron | POTASSIUM | TURBIDITY | AMMONIA | Bacteria | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date of collection | | Micro S/cm | F | APHA Platinum Cobalt Units | mg/L | mg/L CaCO3 in100ml | ppm | ppm | mg/l | ppm | NTU | mg/L | Total Coliform(MPN) | E-Coli(MPN) | Enterrocci(MPN) |
| | 6/4/2002 | 6.23 | 54 | 56 | 10 | 0.11 | 12 | 0 | 7.92 | | 1 | 3.36 | 0 | | | |
| | 10/9/2002 | 6.74 | 54 | 65 | 0 | 0 | 9.65 | 0 | 3.65 | 0.06 | 2 | 1.04 | 0.01 | >2419.2 | 272.3 | 142.3 |
| 3d | 2/19/2003 | 6.29 | 63 | 56 | 0 | 0.19 | 44 | 0 | 10.15 | 0.03 | 2 | 2.34 | 0.01 | 344.8 | 160.7 | 39.1 |
| | 6/4/2002 | 6.31 | 37 | 56 | 9 | 0.07 | 8 | 0 | 6.03 | | 0 | 1.22 | 0 | | | |
| | 2/19/2003 | 6.21 | 49 | 56 | 0 | 0.15 | 48 | 0 | 13.51 | 0.15 | 1 | 0.516 | 0 | 148.3 | 3.1 | <1 |
| 3e | 4/1/2003 | 7 | 53 | | 15 | 0.05 | 12 | 0 | 9.22 | 0.04 | 3 | 13.4 | 0.19 | 57.3 | 1 | <1 |
| | 4/22/2002 | 6.90 | 45 | N/A | 0 | 0.09 | 14 | 0 | 1.95 | | 0 | 0.507 | 0 | | | |
| | 6/4/2002 | 6.05 | 44 | 58 | 4 | 0.1 | 12 | 0 | 1.35 | | 0 | 10.3 | 0 | | | |
| | 10/9/2002 | 7.09 | 50 | 65 | 0 | 0 | 12.25 | 0 | 3.73 | 0 | 1 | 0.5 | 0 | >2419.2 | 12.1 | 17.9 |
| | 2/19/2003 | 7.16 | 80 | 58 | 0 | 0.09 | 48 | 0 | 5.45 | 0.04 | 1 | 0.56 | 0 | 290.9 | 3 | 1 |
| 4 | 4/1/2003 | 7.29 | 65 | | 5 | 0.03 | 20 | 0 | 4.52 | 0.08 | 1 | 0.427 | 0.15 | 387.3 | 1 | 2 |
| | 4/22/2002 | 7.10 | 140 | N/A | 6 | 0.07 | 62.8 | 0 | 4.89 | | 2 | 1.63 | 0.06 | | | |
| | 6/4/2002 | 7.26 | 190 | 56 | 2 | 0.09 | 80.8 | 0 | 6.18 | | 1 | 44.5 | 0 | | | |
| | 2/19/2003 | 6.98 | 143 | 60 | 0 | 0.13 | 60 | 0 | 15.01 | 0.05 | 2 | 3.47 | 0 | 344.8 | 12.1 | 10.8 |
| 5 | 4/1/2003 | 7.39 | 139 | | 10 | 0.01 | 51 | 0 | 7.88 | 0.06 | 1 | 7.19 | 0.03 | 1553.1 | 3.1 | 4.1 |
| 9 | 4/22/2002 | 7.20 | 123 | N/A | 4 | 0.85 | 38.4 | 0 | 4.62 | | 2 | 1.73 | 0 | | | |
| 10a | 6/6/2002 | 6.57 | 440 | 60 | 0 | 0.97 | 18.2 | 0.25 | 82.82 | | 2 | 2.36 | 8 | | | |
| | 4/25/2002 | 6.99 | 127 | N/A | 6 | 1 | 40 | 0 | 0.07 | | 2 | 1.02 | 0.01 | | | |
| 12 | 6/6/2002 | 6.83 | 128 | 60 | 0 | 0.94 | 12.4 | 0 | 0.99 | | 4 | 10.3 | 0.01 | | | |
| | 4/25/2002 | 6.53 | 112 | N/A | 5 | 0.08 | 1.7 | 0 | 13.68 | | 0 | 9.82 | 17 | | | |
| 23 | 6/10/2002 | 5.79 | 85 | 60 | 5 | 0.14 | 33.6 | 0 | 9.29 | | 0 | 23.3 | 14 | | | |

# Table C Continued

| OUTFALL # | | pH | SPECIFIC CONDUCTIVITY | TEMPERATURE | COLOR | FLOURIDE | HARDNESS | DETERGENTS | FLORESCENCE | Boron | POTASSIUM | TURBIDITY | AMMONIA | Bacteria | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date of collection | | Micro S/cm | F | APHA Platinum Cobalt Units | mg/L | mg/L CaCO3 in100ml | ppm | ppm | mg/l | ppm | NTU | mg/L | Total Coliform(MPN) | E-Coli(MPN) | Enterrocci(MPN) |
| | 4/25/2002 | 7.38 | 91 | N/A | 5 | 0.04 | 0 | 0 | 25.19 | | 0 | 3.48 | 10.5 | | | |
| 24 | 6/10/2002 | 6.83 | 76 | 58 | 5 | 0.05 | 22.4 | 0 | 7.65 | | 0 | 20.5 | 9 | | | |
| | 6/11/2002 | 6.57 | 720 | 56 | 9 | 0.37 | 38.4 | 0.25 | 6.3 | | 1 | 25.33 | 0.08 | | | |
| 26a | 2/19/2003 | 7.69 | 83 | 60 | 42 | 0.15 | 48 | 0 | 51.54 | 0.1 | 2 | 7.4 | 0.01 | 1299.7 | 387.3 | 23.5 |
| | 4/26/2002 | 6.35 | 92 | N/A | 0 | 0.18 | 27.2 | 0 | 10.37 | | 1 | 3.39 | 0.18 | | | |
| | 6/11/2002 | 6.15 | 92 | 60 | 12 | 0.34 | 2.4 | 0 | 15.97 | | 1 | 2.36 | 0.31 | | | |
| | 10/14/2002 | 7.28 | 126 | 65 | 0 | 0.66 | 22 | 0.125 | 35.57 | 0.04 | 2 | 4.65 | 0.1 | >2419.2 | 1203.3 | 100.8 |
| | 2/24/2003 | 7.02 | 90 | 60 | 0 | 0.18 | 56 | 0 | 34.47 | LD | 1 | 10.1 | 0.02 | 435.2 | 63.1 | 5.2 |
| 27 | 4/17/2003 | 7.2 | 100 | | 20 | 0.23 | 32 | 0 | 22.56 | 0.12 | 1 | 6.36 | 0.06 | >2419.2 | 410.6 | 3 |
| | 10/14/2002 | 5.86 | 36 | 65 | 0 | 0.16 | 9.5 | 0 | 59.13 | 0.16 | 2 | 24.1 | 0.02 | >2419.2 | 172.3 | 11.6 |
| 27a | 4/17/2003 | 6.12 | 101 | | 25 | -0.02 | 15 | 0 | 32.24 | 0.19 | 1 | 51.1 | 0.01 | >2419.2 | 547.5 | 21.8 |
| 28 | 2/24/2003 | 7.25 | 67 | 56 | 10 | 0.16 | 48 | 0 | 37.71 | LD | 2 | 8.36 | 0 | 547.5 | 224.7 | 7.3 |
| | 10/14/2002 | 5.76 | 52 | 65 | 20 | 0.16 | 8.5 | 0 | 34.56 | 0.17 | 1 | 27.6 | 0.1 | >2419.2 | 2419.2 | 116 |
| 29a | 3/4/2003 | 6.08 | 67 | 56 | 20 | 0.04 | 28 | 0 | 40.22 | 0.2 | 1 | 13.8 | 0.04 | 140.1 | 12.2 | <1 |
| | 4/26/2002 | 6.53 | 137 | N/A | 5 | 0.8 | 43.2 | 0.25 | 16.53 | | 2 | 12.2 | 0.67 | | | |
| | 6/17/2002 | 6.31 | 133 | 60 | 8 | 0.3 | 0 | 0 | 34.38 | | 2 | 1.23 | 0.27 | | | |
| | 10/14/2002 | 6.56 | 151 | 65 | 0 | 0.14 | 31.5 | 0.125 | 59.81 | 0.2 | 2 | 29 | 0.14 | >2419.2 | 125 | 10.7 |
| | 3/4/2003 | 6.64 | 150 | 58 | 15 | 0.61 | 54 | 0 | 76.45 | 0.09 | 1 | 10.5 | 0.04 | 488.4 | 68.3 | <1 |
| 31 | 4/17/2003 | 6.11 | 70 | | 30 | 0.72 | 20 | 0.125 | 57.85 | 0.13 | 1 | 22.1 | 0.02 | 770.1 | 33.6 | 9.2 |
| 31a | 4/17/2003 | 6.9 | 230 | | 210 | -0.09 | 97 | 0 | 12.24 | 1.04 | 3 | 750 | 0.14 | >2419.2 | 60.5 | 33.2 |

# Table C Continued

| OUTFALL # | | pH | SPECIFIC CONDUCTIVITY | TEMPERATURE | COLOR | FLOURIDE | HARDNESS | DETERGENTS | FLORESCENCE | Boron | POTASSIUM | TURBIDITY | AMMONIA | Bacteria | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date of collection | | Micro S/cm | F | APHA Platinum Cobalt Units | mg/L | mg/L CaCO3 in100ml | ppm | ppm | mg/l | ppm | NTU | mg/L | Total Coliform(MPN) | E-Coli(MPN) | Enterrocci(MPN) |
| | 4/26/2002 | 5.98 | 56 | N/A | 9 | 0.09 | 16.8 | 0 | 8.9 | | 2 | 11.8 | 0.09 | | | |
| | 6/17/2002 | 6.39 | 60 | 60 | 10 | 0.37 | 20.2 | 0 | 68.35 | | 0 | 9.8 | 0.08 | 1 | | |
| | 3/4/2003 | 5.81 | 66 | 56 | 10 | 0.09 | 25 | 0 | 34.57 | 0.05 | 2 | 18.9 | 0.02 | 140.1 | 3 | 2 |
| 33 | 4/17/2003 | 9.46 | 131 | | 5 | 0.17 | 21 | 0 | 18.46 | 0.2 | 2 | 2.65 | 0.02 | >2419.2 | 5.2 | 21.3 |
| | 4/26/2002 | 7.19 | 450 | N/A | 100 | 0.09 | 243.2 | 0.15 | 57.42 | | 4 | 133 | 0.26 | 1 | | |
| | 6/19/2002 | 7.09 | 640 | 56 | 100 | 0.16 | 212.6 | 0.25 | 32.83 | | 0 | 122.6 | 0.1 | | | |
| | 10/17/2002 | 7.45 | 410 | 65 | 0 | 0.13 | 102.25 | 0 | 5.45 | 0.06 | 4 | 25 | 0 | >2419.2 | 61.3 | 3 |
| | 3/5/2003 | 7.45 | 430 | 58 | 10 | 0.08 | 185 | 0 | 49.92 | 0.11 | 2 | 1.08 | 0 | >2419.2 | 1 | 3.1 |
| 36 | 4/17/2003 | 7.59 | 430 | | 70 | 0.14 | 230 | 0.125 | 34.42 | 0.15 | 2 | 58.6 | 0.03 | >2419.2 | 22.8 | 25.3 |
| | 6/19/2002 | 7.43 | 260 | 56 | 100 | 0.1 | 21.8 | 0 | 7.37 | | 0 | 100.23 | 0.02 | | | |
| | 10/17/2002 | 7.90 | 360 | 65 | 0 | 0.21 | 72.25 | 0 | 3.36 | 0.06 | 3 | 2.47 | 0.09 | >2419.2 | 24.3 | 2 |
| | 3/5/2003 | 7.63 | 320 | 60 | 10 | 0.12 | 129 | 0 | 13.46 | 0.11 | 2 | 9.72 | 0.15 | 76.6 | 1 | 12 |
| 37a | 4/17/2003 | 7.79 | 370 | | 5 | 0.16 | 128 | 0 | 15.46 | 0.09 | 1 | 3.29 | 0.12 | 290.9 | 1 | 4.1 |
| | 4/29/2002 | 5.99 | 59 | N/A | 20 | 0.11 | 24.8 | 0 | 3.79 | | 2 | 5.32 | 0.01 | | | |
| | 6/24/2002 | 6.31 | 70 | 56 | 15 | 0.06 | 18.6 | 0 | 13.4 | | 1 | 5.44 | 0.08 | | | |
| 38 | 10/17/2002 | 6.74 | 122 | 65 | 0 | 0.18 | 26.25 | 0 | 24.55 | 0.15 | 2 | 9.86 | 0.06 | >2419.2 | 866.4 | >2419.2 |
| | 4/29/2002 | 6.63 | 220 | N/A | 19 | 0.16 | 109.2 | 0 | 11.66 | | 2 | 10.8 | 0.08 | | | |
| | 6/24/2002 | 6.66 | 200 | 58 | 20 | 0.04 | 100.2 | 0 | 4.42 | | 4 | 10.3 | 0 | | | |
| | 10/17/2002 | 7.28 | 230 | 65 | 0 | 0.24 | 51 | 0 | 12.25 | 0.01 | 2 | 2.24 | 0.01 | >2419.2 | 178.9 | 112.4 |
| | 3/5/2003 | 7.36 | 260 | 60 | 5 | 0.09 | 120 | 0 | 27.24 | 0.11 | 2 | 0.413 | 0.01 | 178.9 | <1 | 1 |
| 39 | 4/17/2003 | 7.39 | 250 | | 5 | 0.13 | 120 | 0 | 34.46 | 0.02 | 2 | 0.409 | 0 | >2419.2 | 38.6 | 12 |

# Table C Continued

| OUTF ALL # | | pH | SPECIFIC CONDUCTIVITY | TEMPERATURE | COLOR | FLOURIDE | HARDNESS | DETERGENTS | FLORESCENCE | Boron | POTASSIUM | TURBIDITY | AMMONIA | Bacteria | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date of collection | | Micro S/cm | F | APHA Platinum Cobalt Units | mg/L | mg/L CaCO3 in100ml | ppm | ppm | mg/l | ppm | NTU | mg/L | Total Coliform(MPN) | E-Coli(MPN) | Enterrococci(MPN) |
| | 5/8/2002 | 6.44 | 134 | N/A | 15 | 0.34 | 51.2 | 12.5 | 8.96 | | 2 | 42.2 | 0.01 | | | |
| | 6/24/2002 | 7.34 | 166 | 60 | 15 | 0.19 | 44.8 | 10 | 6.86 | | 2 | 40 | 0.02 | | | |
| | 10/18/2002 | 8.16 | 270 | 65 | 20 | 2.17 | 44.5 | 0 | 13.65 | 0.29 | 2 | 29 | 0.33 | >2419.2 | 37.4 | 3.1 |
| | 3/5/2003 | 6.99 | 165 | 60 | 15 | 0.41 | 65 | 3 | 35.44 | 0.24 | 2 | 7.04 | 0.01 | >2419.2 | 74.4 | 14.6 |
| 45 | | 7 | 153 | | 10 | 0.09 | 51 | 2.5 | 42.32 | 0.04 | 2 | 6.11 | -0.02 | 980.4 | 8.6 | <1 |
| | 5/8/2002 | 7.18 | 123 | N/A | 100 | 0.35 | 25.6 | 0.25 | 55.55 | | 1 | 29.3 | 5 | 1 | | |
| | 6/24/2002 | 7.08 | 36 | 60 | 100 | 0.48 | 20.4 | 0 | 14.02 | | 2 | 33.6 | 0.35 | | | |
| 49 | 4/18/2003 | 7.89 | 113 | | 15 | 0.13 | 28 | 0.25 | 35.06 | 0.15 | 0 | 6.83 | 6 | 325.5 | <1 | <1 |
| | 5/8/2002 | 6.07 | 74 | N/A | 20 | 0.01 | 23.6 | 0 | 2.93 | | 2 | 15 | 0.35 | | | |
| | 6/24/2002 | 6.14 | 72 | 58 | 20 | 0.1 | 22.4 | 0 | 2.41 | | 1 | 12.4 | 0.17 | | | |
| | 10/18/2002 | 6.92 | 94 | 65 | 0 | 0.22 | 16.25 | 15 | 95.65 | 0.13 | 2 | 5.03 | 0.11 | >2419.2 | 16.6 | 18.7 |
| | 3/5/2003 | 6.63 | 78 | 58 | 5 | 0.1 | 39 | 0 | 9.44 | 0.15 | 2 | 0.5 | 0.1 | 488.4 | <1 | <1 |
| 53 | 4/18/2003 | 6.7 | 82 | | 10 | -0.37 | 25 | 0 | 12.46 | 0.11 | 1 | 4.19 | 0.07 | 1413.6 | 1 | <1 |
| | 5/8/2002 | 5.99 | 101 | N/A | 46 | 0.04 | 40.8 | 0 | 11.11 | | 3 | 34.5 | 0.08 | | | |
| | 6/24/2002 | 6.48 | 112 | 58 | 44 | 0.07 | 46.6 | 0.25 | 28.42 | | 0 | 34.6 | 0.06 | | | |
| | 10/18/2002 | 7.19 | 98 | 65 | 20 | 0.17 | 41 | 0 | 4.45 | 0.07 | 2 | 19.3 | 0.27 | >2419.2 | 2419.9 | 727 |
| | 3/5/2003 | 6.63 | 128 | 56 | 15 | 0.1 | 41 | 0 | 54.21 | 0.08 | 1 | 9.76 | 0.43 | >2419.3 | 1 | 12.2 |
| 55 | 4/18/2003 | 6.8 | 105 | | 260 | 0.95 | 38 | 0 | 18.76 | 0.85 | 1 | 3187 | 0.1 | >2419.2 | 307.6 | 10.5 |

# Table C Continued

| OUTFALL # | Date of collection | pH | SPECIFIC CONDUCTIVITY Micro S/cm | TEMPERATURE F | COLOR APHA Platinum Cobalt Units | FLOURIDE mg/L | HARDNESS mg/L CaCO3 in100ml | DETERGENTS ppm | FLORESCENCE ppm | Boron mg/l | POTASSIUM ppm | TURBIDITY NTU | AMMONIA mg/L | Bacteria Total Coliform(MPN) | E-Coli(MPN) | Enterrococci(MPN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 61 | 10/18/2002 | 7.99 | 193 | 65 | 0 | 0.86 | 29.5 | 0 | 3.36 | 0.07 | 2 | 19 | 0.1 | >2419.2 | 124.6 | 228.2 |
| 65 | 10/18/2002 | 7.59 | 181 | 65 | 0 | 0.95 | 40 | 0 | 9.96 | 0.15 | 1 | 4.23 | 0.01 | >2419.2 | 307.6 | 172.3 |
| 66 | 5/10/2002 | 7.1 | 390 | N/A | 0 | 0.14 | 187.6 | 1 | 5.3 | | 2 | 2.86 | -0.2 | | | |
| | 5/10/2002 | 7.01 | 71 | N/A | 30 | 0.18 | 26.4 | 0.25 | 15.16 | | 1 | 21.7 | 0.11 | | | |
| 73 | 7/2/2002 | 6.05 | 72 | 58 | 30 | 0.13 | 29.8 | 0 | 21.37 | | 0 | 20.3 | 0.09 | | | |
| | | | | | | | | | | | | | | | | |
| Creek sample I | 10/14/2002 | 7.81 | 174 | 65 | 10 | 0.5 | 6 | 0 | 18.86 | 0.17 | 2 | 4.91 | 0.04 | >2419.2 | 410.6 | 4.1 |
| Creek Sample II | 10/18/2002 | 7.89 | 168 | 65 | 10 | 0.12 | 6.75 | 0 | 24.42 | 0.15 | 2 | 2.9 | 0.07 | >2419.2 | 686.7 | 517.2 |
| | 10/9/2002 | 7.46 | 145 | 65 | 0 | 0.52 | 3.5 | 0.125 | 32.08 | 0.13 | 2 | 1.49 | 0.02 | >2419.2 | 579.4 | 113.3 |
| | 2/19/2003 | 6.99 | 65 | 56 | 0 | 0.06 | 48 | 0 | 17.26 | 0.12 | 1 | 3.91 | 0.01 | 2 | <1 | <1 |
| Pond Entrance I | | 7.1 | 100 | | 30 | 0.49 | 33 | 0 | 18.42 | 0.16 | 2 | 35.3 | 0.01 | >2419.2 | 261.3 | 2 |
| | 10/14/2002 | 7.28 | 111 | 65 | 0 | 0.7 | 3 | 0 | 18.59 | 0.02 | 2 | 3.14 | 0.01 | 29.2 | 2 | 3 |
| Pond Entrance II | | 7.69 | 137 | | 35 | 0.14 | 39 | 0 | 12.76 | 0.1 | 2 | 0.9 | 0 | 2419.2 | 240 | 3.1 |
| | 10/14/2002 | 7.19 | 115 | 65 | 0 | 0.47 | 5 | 0 | 37.48 | 0.05 | 2 | 1.6 | 0.14 | 1986.3 | 47.5 | <1 |
| | 2/19/2003 | 7.34 | 84 | 56 | 30 | 0.07 | 48 | 0 | 76.44 | 0.12 | 2 | 22 | 0.03 | >2419.2 | 275.5 | 4.1 |
| Pond Outlet | | 7.4 | 127 | | 25 | 0.11 | 43 | 0 | 32.24 | 0.11 | 1 | 4.73 | 0.06 | 2419.2 | 21.8 | <1 |

# APPENDIX D

## CMBM Model Analysis Results for Problem Outfalls

# Table D. CMBM Model Analysis Results for Problem Outfalls

| OUTFALL # | Date of collection | Tap | Spring | Carwash | Laundry | Sewage | Irrigation | Mu | MOST LIKELY SOURCE by Model |
|---|---|---|---|---|---|---|---|---|---|
| | 4/17/2002 | -0.2 | 1.57 | -0.08 | 0.01 | -0.02 | -0.25 | 0.31 | Spring Water, Laundry Washwater |
| | 5/31/2002 | 0.03 | 1.77 | -0.18 | 0.03 | 0.06 | -0.605 | 0.415 | Spring Water, Sanitary Wastewater, Laundry Washwater |
| | 10/9/2002 | 0.195 | 1.305 | -0.24 | 0.05 | -0.12 | 0 | 0.05 | Spring Water, Tap Water, Laundry Washwater |
| | 2/18/2003 | 0.1 | 0.39 | 0.225 | -0.05 | 0.31 | -0.01 | -0.5 | Spring Water, Sanitary Wastewater, Carwash Water |
| | 3/31/2003 | -0.62 | 1.77 | -0.135 | 0.02 | -0.05 | 0 | 0.55 | Spring Water, Laundry Washwater |
| | 12/20/2003 | -0.14 | 1.65 | -0.3 | 0.06 | -0.2 | 0 | 0.26 | Spring Water, Laundry Washwater |
| | 1/20/2004 | 0.6 | 1.01 | -0.34 | 0.06 | -0.17 | 0 | -0.245 | Spring Water, Tap Water, Laundry Washwater |
| 3 | 3/27/2004 | 0.035 | 1.56 | -0.3 | 0.06 | -0.205 | 0.01 | 0.36 | Spring Water, Laundry Washwater, Tap Water |
| OF 3-Upstream (200 Ft.) | 12/20/2003 | -0.285 | 1.47 | -0.18 | 0.04 | -0.03 | 0 | -0.85 | Spring Water, Laundry Washwater |
| OF 3-Upstream (100 Ft.) | 1/20/2004 | -0.14 | 1.645 | -0.08 | 0.01 | -0.04 | -0.33 | 1.16 | Spring Water, Laundry Washwater |
| OF 3-Upstream (100 Ft.) | 3/27/2004 | -0.05 | 1.405 | -0.25 | 0.05 | -0.07 | 0 | 0.245 | Spring Water, Laundry Washwater |
| OF 3-Upstream (200 Ft.) | 1/20/2004 | 0.48 | 1.335 | -0.28 | 0.05 | -0.01 | -0.46 | 0.295 | Spring Water, Tap Water |
| OF 3-Upstream (200 Ft.) | 3/27/2004 | -0.145 | 1.3 | -0.17 | 0.03 | 0.02 | 0 | 0.22 | Spring Water, Laundry Washwater, Sanitary Wastewater |
| | 4/22/2002 | -0.665 | 1.95 | -0.09 | 0.02 | -0.065 | -0.14 | 0.595 | Spring Water, Laundry Washwater |
| | 6/4/2002 | -0.73 | 1.97 | -0.07 | 0.01 | -0.06 | -0.13 | 0.65 | Spring Water, Laundry Washwater |
| | 10/9/2002 | -0.205 | 1.58 | -0.49 | 0.08 | -0.06 | 0 | 0.06 | Spring Water, Laundry Washwater |
| | 2/19/2003 | 0.09 | 0.84 | 0.19 | -0.03 | -0.06 | 0 | -0.07 | Spring Water, Carwash Water, Tap Water |
| | 4/1/2003 | -0.17 | 1.425 | -0.31 | 0.05 | -0.05 | 0 | 0.1 | Spring Water, Laundry Washwater |
| | 12/20/2003 | 0.09 | 1.15 | -0.21 | 0.03 | -0.06 | 0 | 0.03 | Spring Water, Laundry Washwater, Tap Water |
| | 1/24/2004 | -0.1 | 1.345 | -0.09 | 0.02 | -0.08 | 0 | 0.17 | Spring Water, Laundry Washwater |
| 4 | 3/27/2004 | 0.42 | 0.83 | -0.19 | 0.03 | -0.06 | 0 | 0.06 | Spring Water, Tap Water, Laundry Washwater |
| MH 4.1-Along road | 12/20/2003 | 0.08 | 1.15 | -0.21 | 0.04 | -0.05 | 0 | 0.07 | Spring Water, Tap Water, Laundry Washwater |
| MH 4.1-Along road | 1/24/2004 | -0.48 | 1.59 | -0.37 | 0.05 | 0.02 | 0 | 0.78 | Spring Water, Laundry Washwater, Sanitary Wastewater |
| MH 4.1-Along road | 3/27/2004 | -0.14 | 1.42 | -0.27 | 0.04 | -0.08 | 0 | 0.23 | Spring Water, Laundry Washwater |

# Table D Continued

| OUTFALL # | Date of collection | Tap | Spring | Carwash | Laundry | Sewage | Irrigation | Mu | MOST LIKELY SOURCE by Model |
|---|---|---|---|---|---|---|---|---|---|
| MH 4.1-Across Road | 12/20/2003 | -0.06 | 1.54 | -0.5 | 0.09 | -0.06 | 0 | 0.16 | Spring Water, Laundry Washwater |
| MH 4.1-Across Road | 1/24/2004 | -0.03 | 1.54 | -0.12 | 0.02 | -0.09 | -0.23 | 0.09 | Spring Water, Laundry Washwater |
| MH 4.1-Across Road | 3/27/2004 | -0.41 | 1.515 | -0.06 | 0.01 | -0.08 | 0 | 0.47 | Spring Water, Laundry Washwater |
| MH 4.2- Along Road | 1/24/2004 | -1.985 | 2.93 | -0.26 | 0.04 | -0.06 | 0.165 | 2.11 | Spring Water, Laundry Washwater |
| MH 4.2- Along Road | 3/27/2004 | -0.095 | 1.62 | -0.12 | 0.02 | -0.07 | -0.305 | 0.14 | Spring Water, Laundry Washwater |
| MH 4.2-Across Road | 12/20/2003 | -0.32 | 1.43 | -0.08 | 0.01 | -0.07 | 0 | 0.28 | Spring Water, Laundry Washwater |
| MH 4.2-Across Road | 1/24/2004 | -0.235 | 1.36 | -0.36 | 0.055 | 0.01 | 0 | 0.47 | Spring Water, Sanitary Wastewater, Laundry Washwater |
| MH 4.2-Across Road | 3/27/2004 | -0.61 | 1.66 | -0.08 | 0.01 | -0.08 | 0.01 | 0.45 | Spring Water, Laundry Washwater, Irrigation Water |
| MH 4.3-Across Road | 12/22/2003 | -0.855 | 1.99 | -0.075 | 0.01 | -0.09 | 0 | 0.75 | Spring Water, Laundry Washwater |
| MH 4.3-Across Road | 1/24/2004 | -0.8 | 2.245 | -0.29 | 0.05 | 0.01 | -0.24 | 1.145 | Spring Water, Laundry Washwater |
| MH 4.3-Across Road | 3/27/2004 | -0.54 | 1.81 | -0.1 | 0.02 | -0.09 | -0.065 | 0.55 | Spring Water, Laundry Washwater |
| **MH 27.1** | 1/24/2004 | **0.13** | **0.69** | **0.12** | **0.02** | **-0.05** | **0.01** | **-0.26** | **Spring Water, Tap Water, Carwash Water** |
| **OF 27 Stream** | **1/24/2004** | **-0.14** | **1.27** | **-0.1** | **-0.01** | **-0.02** | **0** | **0.44** | **Spring Water** |
| | **4/26/2002** | **0.54** | **0.52** | **-0.04** | **0.01** | **0.01** | **0.02** | **0.255** | **Tap Water, Spring Water, Irrigation Water** |
| | **6/17/2002** | **-0.455** | **2.3** | **-0.33** | **0.06** | **-0.01** | **-0.5** | **1.035** | **Spring Water, Laundry Washwater** |
| | 10/14/2002 | **0.14** | **1.03** | **-0.18** | **0.04** | **0** | **0** | **0.06** | **Spring Water, Tap Water, Laundry Washwater** |
| | **3/4/2003** | **0.74** | **0.36** | **-0.25** | **0.05** | **0** | **0** | **-0.02** | **Tap Water, Spring Water, Laundry Washwater** |
| | 4/17/2003 | **0.85** | **0.25** | **-0.18** | **0.04** | **0** | **-0.01** | **-0.01** | **Tap Water, Spring Water, Laundry Washwater** |
| | **12/22/2003** | **0.065** | **0.98** | **-0.06** | **0.01** | **-0.03** | **0** | **0.02** | **Spring Water, Tap Water, Laundry Washwater** |
| **31** | **1/24/2004** | **0.82** | **0.32** | **-0.08** | **0.02** | **0.01** | **-0.1** | **0.07** | **Tap Water, Spring Water, Laundry Washwater** |

# Table D Continued

| OUTFALL # | Date of collection | Tap | Spring | Carwash | Laundry | Sewage | Irrigation | Mu | MOST LIKELY SOURCE by Model |
|---|---|---|---|---|---|---|---|---|---|
| OF 31 | 3/27/2004 | 0.845 | -0.38 | 0 | 0 | 0 | 0.46 | -0.39 | Tap Water, Irrigation Water |
| MH 31.1 | 12/22/2003 | 0.89 | -0.1 | 0 | 0 | -0.12 | 0.28 | 0.11 | Tap Water, Irrigation Water |
| MH 31.1 | 1/24/2004 | 0.445 | 0.735 | 0 | 0 | -0.12 | -0.235 | 0.89 | Spring Water, Tap Water |
| MH 31.1 | 3/27/2004 | 1.16 | -0.56 | 0.03 | 0 | -0.13 | 0.43 | -0.07 | Tap Water, Irrigation Water, Carwash Water |
| OF 31 Upstream (100 ft) | 1/24/2004 | 1.12 | -0.15 | -0.05 | 0.01 | 0 | 0.03 | -0.01 | Tap Water, Irrigation Water, Laundry Washwater |
| OF 31 Upstream (100 ft) | 3/27/2004 | 1.37 | -0.41 | -0.1 | 0.02 | 0.08 | 0 | -0.17 | Tap Water, Sanitary Wastewater, Laundry Washwater |
| | 4/26/2002 | 0.66 | -1.29 | 0.27 | -0.05 | 0.02 | 1.46 | -1.5 | Irrigation Water, Tap Water, Carwash Water |
| | 6/19/2002 | 2.405 | -3.125 | 0.27 | -0.05 | 0.07 | 1.27 | -2.84 | Tap Water, Irrigation Water, Carwash Water |
| | 10/17/2002 | -0.025 | 0.78 | 0.04 | -0.01 | 0 | 0.22 | -0.09 | Spring Water, Irrigation Water, Carwash Water |
| | 3/5/2003 | 0.17 | 0.97 | -0.15 | 0.03 | 0 | 0.05 | -0.03 | Spring Water, Tap Water, Irrigayion Water |
| | 4/17/2003 | 0.16 | 0.965 | -0.1 | 0.02 | 0 | -0.03 | 0.02 | Spring Water, Tap Water, Laundry Washwater |
| | 12/22/2003 | 0.06 | 0.12 | 0.79 | -0.01 | 0.15 | 0 | 0.04 | Carwash Water, Sanitary Wastewater, Spring Water |
| | 1/24/2004 | 0.31 | 0.2 | 0.54 | -0.03 | 0.16 | -0.02 | 0.03 | Carwash Water, Tap Water, Spring Water |
| 36 | 3/27/2004 | 0.37 | 0.17 | 0.41 | -0.04 | 0.15 | 0 | -0.31 | Carwash Water, Tap Water, Spring Water |
| | 4/29/2002 | 0.67 | 0.02 | 0.06 | -0.01 | 0.02 | 0.22 | -0.7 | Tap Water, Irrigation Water, Carwash Water |
| | 6/24/2002 | 0 | 0.795 | 0.07 | -0.01 | 0 | 0.25 | -0.24 | Spring Water, Irrigation Water, Carwash Water |
| | 10/17/2002 | 0.35 | 0.67 | -0.02 | 0 | 0 | 0.01 | -0.13 | Spring Water, Tap Water, Irrigation Water |
| | 3/5/2003 | 0.11 | 0.98 | -0.07 | 0.02 | 0 | 0 | -0.02 | Spring Water, Tap Water, Laundry Washwater |
| | 4/17/2003 | 0.27 | 0.775 | -0.09 | 0.02 | 0 | 0.05 | -0.11 | Spring Water, Tap Water, Irrigation Water |
| | 12/22/2003 | 1.1 | -0.6 | 0.815 | -0.08 | -0.065 | 0 | -0.5 | Tap Water, Spring Water |
| 39 | 1/30/2004 | 0.44 | -0.33 | 0.695 | -0.1 | -0.04 | -0.01 | -0.465 | Carwash Water, Tap Water |

## Table D Continued

| OUTFALL # | Date of collection | Tap | Spring | Carwash | Laundry | Sewage | Irrigation | Mu | MOST LIKELY SOURCE by Model |
|---|---|---|---|---|---|---|---|---|---|
| OF 39 | 3/27/2004 | 0.22 | 0.78 | -0.06 | 0.01 | 0.05 | 0 | -0.14 | Spring Water, Tap Water, Sanitary Wastewater |
| MH 39.2 | 12/22/2003 | 0.06 | 0.92 | 0.06 | -0.01 | -0.02 | 0 | 0.07 | Spring Water, Tap Water, Carwash Water |
| MH 39.2 | 1/30/2004 | 0.19 | 0.86 | -0.03 | 0.01 | -0.01 | 0 | -0.09 | Spring Water, Tap Water, Laundry Washwater |
| MH 39.2 | 3/27/2004 | 0.8 | 0.22 | 0 | 0 | 0 | 0 | -0.71 | Tap Water, Spring Water |
| MH 39.1 | 1/30/2004 | 0.25 | 0.79 | -0.025 | 0.01 | -0.04 | 0.04 | -0.11 | SpringWater , Tap Water, Irrigation Water |
| MH 39.1 | 3/27/2004 | 0.84 | 0.16 | -0.01 | 0 | 0.01 | 0 | 0.06 | Tap Water, Spring Water, Sanitary Wastewater |
| MH 39.3 | 3/27/2004 | 0.23 | 0.71 | -0.08 | 0.01 | 0.14 | 0 | -0.14 | Spring Water, Tap Water, Sanitary Wastewater |
| | 5/8/2002 | 0.57 | 0.36 | 0.09 | 0 | 0.01 | -0.01 | -0.32 | Tap Water, Spring Water, Carwash Water |
| | 6/24/2002 | 0.53 | 0.42 | 0.09 | 0 | 0.01 | -0.02 | -0.43 | Tap Water, Spring Water, Carwash Water |
| | 10/18/2002 | 1.96 | -1.51 | 0.03 | -0.01 | -0.01 | 0.45 | 0.11 | Tap Water, Irrigation Water, Carwash Water |
| | 3/5/2003 | 0.31 | 0.75 | -0.07 | 0.02 | -0.01 | 0.02 | 0.11 | Spring Water, Tap Water, Laundry Washwater |
| | 4/17/2003 | 0.2 | 0.835 | -0.09 | 0.02 | 0 | 0.05 | -0.11 | Spring Water, Tap Water, Irrigation Water |
| | 12/22/2003 | 1.12 | -0.33 | 0.32 | -0.05 | 0.05 | 0 | -0.14 | Tap Water, Carwash Water, Sanitary Wastewater |
| | 1/30/2004 | 2.61 | -1.9 | 0.53 | -0.09 | 0.19 | 0 | -0.09 | Tap Water, Spring Water, Sanitary Wastewater |
| 45 | 3/28/2004 | 0.41 | -0.03 | 0.93 | -0.15 | -0.03 | 0 | -0.325 | Carwash Water, Tap Water |
| OF 45 Ditch | 1/30/2004 | 0.12 | 1.22 | -0.11 | 0.02 | 0.07 | -0.305 | 0.1 | Spring Water, Tap Water, Sanitary Wastewater |
| OF 45 Ditch | 3/28/2004 | 0.12 | 0.085 | 1.05 | -0.16 | -0.05 | 0 | -0.035 | Carwash Water, Tap Water, Spring Water |
| MH 45.1 | 2/1/2004 | 0.275 | 0.82 | -0.045 | 0.01 | 0.175 | -0.2 | 0.21 | Spring Water, Tapwater, Sanitary Wastewater |
| MH 45.1 | 3/28/2004 | 1.37 | -0.275 | -0.19 | 0.04 | 0.08 | 0 | 0.22 | Tap Water, Sanitary Wastewater,Laundry Washwater |
| | 5/8/2002 | 0.645 | 0.16 | 0.07 | -0.01 | 0.03 | 0.11 | -0.75 | Tap Water, Spring Water, Irrigation Water |
| 53 | 6/24/2002 | 1.035 | -0.225 | 0.07 | -0.01 | 0.04 | 0.09 | -1 | Tap Water, Irrigation Water, Carwash Water |

# Table D Continued

| OUTFALL # | Date of collection | Tap | Spring | Carwash | Laundry | Sewage | Irrigation | Mu | MOST LIKELY SOURCE by Model |
|---|---|---|---|---|---|---|---|---|---|
| | 10/18/2002 | 0.27 | 0.76 | -0.17 | 0.06 | 0 | 0.04 | -0.04 | Spring Water, Tap Water, Laundry Washwater |
| | 3/5/2003 | 0.08 | 1.06 | -0.02 | 0 | 0 | -0.08 | 0.02 | Spring Water, Tap Water |
| | 4/18/2003 | 0.15 | 1.24 | -0.06 | 0.01 | 0.01 | -0.3 | -0.01 | Spring Water, Tap Water, Sanitary Wastewater |
| | 12/22/2003 | 0.305 | 0.91 | -0.25 | 0.04 | -0.03 | 0 | -0.05 | Spring Water, Tap Water, Laundry Washwater |
| | 2/1/2004 | 0.07 | 1.01 | -0.09 | -0.06 | 0 | 0 | 0.02 | Spring Water, Tap Water |
| 53 | 3/28/2004 | -0.06 | 1.16 | -0.1 | 0.02 | -0.05 | 0 | 0.16 | Spring Water, Laundry Washwater |
| MH 53.1 | 12/23/2003 | -0.04 | 1.06 | -0.06 | 0.01 | -0.04 | 0 | 0.155 | Spring Water, Laundry Washwater |
| MH 53.1 | 2/1/2004 | -0.1 | 1.2 | -0.14 | -0.03 | 0 | 0.09 | 0.03 | Spring Water, Irrigation Water |
| MH 53.1 | 3/28/2004 | -0.31 | 1.38 | -0.22 | 0.03 | -0.01 | 0 | 0.36 | Spring Water, Laundry Washwater |
| MH 53.2 | 12/23/2003 | -0.25 | 1.29 | -0.05 | 0.01 | -0.03 | 0 | 0.22 | Spring Water, Laundry Washwater |
| MH 53.2 | 2/1/2004 | 0.63 | -0.06 | 0.08 | -0.11 | 0 | 0.37 | -0.68 | Tap Water, Irrigation Water, Carwash Water |
| MH 53.2 | 3/28/2004 | 0.21 | 0.77 | 0.05 | -0.01 | -0.04 | 0 | -0.27 | Spring Water, Tap Water, Carwash Water |
| MH 53.3 | 12/23/2003 | 0.13 | 0.87 | 0 | -0.01 | 0 | 0 | -0.01 | Spring Water, Tap Water |
| MH 53.3 | 3/28/2004 | 0.27 | 0.86 | -0.14 | 0.02 | -0.03 | 0 | -0.17 | Spring Water, Tap Water, Laundry Washwater |
| | 5/8/2002 | -0.06 | 0.87 | 0.04 | -0.01 | -0.01 | 0.13 | -0.11 | Spring Water, Irrigation Water, Carwash Water |
| | 6/24/2002 | 0.095 | 0.65 | 0.05 | -0.01 | -0.01 | 0.21 | -0.245 | Spring Water, Irrigation Water, Tap Water |
| | 10/18/2002 | 0.09 | 0.94 | -0.04 | -0.04 | 0.01 | 0 | -0.01 | Spring Water, Tap Water, Sanitary Wastewater |
| | 3/5/2003 | 0.09 | 0.86 | -0.01 | 0.01 | 0.01 | 0 | -0.09 | Spring Water, Tap Water, Sanitary Wastewater |
| | 4/18/2003 | 0.125 | 0.88 | -0.04 | 0.01 | -0.02 | 0 | 0.74 | Spring Water, Tap Water, Sanitary Wastewater |
| 55 | 2/1/2004 | 0.36 | 0.15 | -0.12 | 0.02 | 0.45 | -0.04 | -0.36 | Sanitary Wastewater, Tap Water, Spring Water |

## Table D Continued

| OUTFALL # | Date of collection | Tap | Spring | Carwash | Laundry | Sewage | Irrigation | Mu | MOST LIKELY SOURCE by Model |
|---|---|---|---|---|---|---|---|---|---|
| 55 | 3/28/2004 | 0.5 | 0.72 | -0.19 | 0.03 | -0.06 | 0 | -0.31 | Spring Water, Tap Water, Laundry Washwater |
| MH 55.1 | 2/1/2004 | 0.38 | -0.46 | -0.12 | 0.02 | 0.63 | 0.4 | -0.22 | Sanitary Wastewater, Irrigation Water, Tap Water |
| MH 55.2 | 2/1/2004 | 1.64 | -0.57 | 0.09 | 0 | 0.36 | -0.58 | -0.57 | Tap Water, Sanitary Wastewater, Carwash Water |

# APPENDIX E

## Library Data Tables

| Sample number | Sampling Location | Date | pH | Specific conductivity (µS/cm) | Temperature (ºF) | Turbidity. (NTU) | Color (APHA Platinum Cobalt Units) | Fluoride (mg/L) | Hardness (mg/L $CaCO_3$ ) | Detergent (mg/L as MBAS) | Fluorescence (mg/L as "Tide") | Potassium( mg/L) | $NH_3$ (mg/L as N) | $NH_3$/K (ratio) | Boron (mg/L) | Total Coliforms (MPN/100 mL) | *E. coli* (MPN/100 mL) | Enterococci (MPN/100 mL) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | B.B.Commer Hall | 5/17/2002 | 8.19 | 132 | N/A | N/A | 0 | 0.97 | 63.6 | 0 | N/A | 1 | <LD | N/A | N/A | N/A | N/A | N/A |
| 2 | Rose Towers | 5/17/2002 | 7.92 | 145 | N/A | N/A | 0 | 0.97 | 68.4 | 0 | N/A | 1 | <LD | N/A | N/A | N/A | N/A | N/A |
| 3 | H.C.Commer Hall | 5/17/2002 | 8.46 | 125 | N/A | N/A | 0 | 0.96 | 60.8 | 0 | N/A | 1 | <LD | N/A | N/A | N/A | N/A | N/A |
| 4 | Rec Centre | 5/17/2002 | 8.11 | 130 | N/A | N/A | 0 | 0.92 | 64.8 | 0 | N/A | 1 | <LD | N/A | N/A | N/A | N/A | N/A |
| 5 | Coleman Coliseum | 5/17/2002 | 8.28 | 130 | N/A | N/A | 0 | 0.94 | 72.8 | 0 | N/A | 1 | <LD | N/A | N/A | N/A | N/A | N/A |
| 6 | Mib (UA) | 5/29/2003 | 7.81 | 146 | N/A | 1.15 | 0 | 1.04 | 28 | 0 | 4.88 | 2 | 0.01 | 0.005 | 0.19 | 1 | <1 | <1 |
| 7 | Alex Appt. | 5/30/2003 | 7.38 | 156 | N/A | 0.761 | 0 | 0.82 | 44 | 0 | 0.21 | 2 | <LD | N/A | 0.1 | <1 | <1 | <1 |
| 8 | Georgas Library (UA) | 6/3/2003 | 8.13 | 152 | N/A | 0.811 | 0 | | 42 | 0 | 2.9 | 1 | <LD | N/A | 0.12 | <1 | <1 | <1 |
| 9 | Rodgers Library | 6/8/2003 | 7.5 | 141 | N/A | 0.566 | 0 | 0.84 | 40 | 0 | 0.38 | 1 | <LD | N/A | 0.04 | 21.6 | <1 | <1 |
| 10 | Alexander Property Apt. | 6/8/2003 | 7.5 | 138 | N/A | 0.61 | 0 | 0.89 | 46 | 0 | 1.47 | 1 | 0.07 | 0.07 | 0.14 | <1 | <1 | <1 |
| 11 | Pslidea Court Apt. | 6/8/2003 | 7.68 | 139 | N/A | 0.433 | 0 | 1.00 | 44 | 0 | 1.3 | 2 | 0.07 | 0.035 | 0.27 | <1 | <1 | <1 |
| 12 | University Plaza Apt. | 6/8/2003 | 7.5 | 140 | N/A | 0.856 | 0 | 0.94 | 46 | 0 | 2.31 | 2 | 0.07 | 0.035 | 0.11 | <1 | <1 | <1 |
| Mean | | | 7.87 | 140 | - | 0.74 | 0 | 0.94 | 52 | 0 | 1.92 | 1.3 | <0.055 | 0.036 | 0.14 | <11 | <1 | <1 |
| Standard Deviation | | | 0.36 | 9.3 | - | 0.23 | 0 | 0.065 | 14 | 0 | 1.62 | 0.49 | 0.03 | 0.026 | 0.07 | 15 | - | - |
| COV | | | 0.05 | 0.07 | - | 0.32 | - | 0.07 | 0.27 | - | 0.84 | 0.37 | 0.55 | 0.73 | 0.53 | 1.3 | - | - |
| AD-P Value (Normal) | | | **1.138** | **1.004** | - | **1.57** | - | **1.144** | **1.331** | - | **1.601** | **3.809** | **3.199** | **2.539** | **1.663** | 4.103 | - | - |
| AD-P Value (Log-normal) | | | - | 0.998 | - | 1.543 | - | 1.185 | 1.307 | - | 1.639 | 3.809 | 3.199 | 2.703 | 1.685 | 4.103 | - | - |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |

**Table E 1.** ***Tap Water Reference ("Library") Sample***

| ample number | Sampling Location | Date | pH | Specific conductivity (µS/cm) | Temperature (°F) | Turbidity. (NTU) | Color (APHA Platinum Cobalt Units) | Fluoride (mg/L) | Hardness (mg/L $CaCO_3$ ) | Detergent (mg/L as MBAS) | Fluorescence (mg/L as “Tide”) | Potassium( mg/L) | $NH_3$ (mg/L as N) | $NH_3$/K (ratio) | Boron (mg/L) | Total Coliforms (MPN/100 mL) | *E. coli* (MPN/100 mL) | Enterococci (MPN/100 mL) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Marrs Spring | 9/30/2002 | 5.77 | 128 | 30 | 56 | 0 | 0.01 | 24.6 | 0 | 0.94 | 8 | 0.01 | 0.001 | N/A | 1203.3 | 4.1 | 4.1 |
| 2 | Jack Warner Pkwy | 10/11/2002 | 6.46 | 124 | 30 | 67 | 0 | 0.01 | 34.4 | 0 | 0.56 | 1 | 0.02 | 0.02 | N/A | 275.5 | 1 | 36.4 |
| 3 | Marrs Spring | 11/3/2002 | 6.21 | 166 | N/A | 0.85 | 0 | 0.01 | 40.2 | 0 | 4.84 | 3 | 0.04 | 0.013 | N/A | N/A | N/A | N/A |
| 4 | Jack Warner Pkwy | 11/3/2002 | 6.36 | 112 | N/A | 42 | 0 | 0.01 | 28.6 | 0 | 6.64 | 2 | 0.02 | 0.01 | N/A | N/A | N/A | N/A |
| 5 | Marrs Spring | 3/11/2003 | 6.64 | 230 | N/A | 0.591 | 0 | 0.08 | 38 | 0 | 0.46 | 3 | 0.08 | 0.026 | N/A | N/A | N/A | N/A |
| 6 | Jack Warner Pkwy | 5/16/2003 | 6.45 | 126 | N/A | 19.3 | 0 | 0.21 | 32 | 0 | 47.97 | 3 | 0.01 | 0.0033 | 0.15 | 116.2 | <1 | <1 |
| 7 | Jack Warner Pkwy | 5/17/2003 | 6.16 | 128 | N/A | 19.6 | 0 | 0.17 | 44 | 0 | 5.30 | 2 | 0.29 | 0.14 | 0.15 | >2419.2 | 290.9 | 412 |
| 8 | Marrs Spring | 5/18/2003 | 6.82 | 182 | N/A | 1.78 | 0 | 0.39 | 42 | 0 | 3.56 | 4 | 0.01 | 0.0025 | 0.14 | >2419.2 | 172.3 | 140.8 |
| 9 | Marrs Spring | 5/30/2003 | 6.43 | 143 | N/A | 1.12 | 5 | 0.31 | 40 | 0 | 2.61 | 3 | 0.05 | 0.016 | 0.09 | 111.2 | <1 | 3.1 |
| 10 | Marrs Spring | 6/3/2003 | 6.81 | 200 | N/A | 21.2 | 27 | 0.07 | 42 | 0 | 15.11 | 2 | 0.05 | 0.025 | 0.16 | >2419.2 | 9.7 | 65.7 |
| 11 | Jack Warner Pkwy | 6/3/2003 | 5.63 | 125 | 72 | 4.08 | 0 | 0.14 | 48 | 0 | 18.15 | 4 | 0.05 | 0.012 | 0.09 | 4.1 | 1 | <1 |
| 12 | Jack Warner Pkwy | 6/5/2003 | 6.04 | 130 | 68 | 4.89 | 0 | 0.24 | 48 | 0 | 12.35 | 3 | 0.05 | 0.016 | 0.04 | 7.2 | <1 | <1 |
| Mean | | | **6.3** | **149** | **50** | **19.8** | **2.6** | **0.13** | **38** | **0** | **9.8** | 3.1 | 0.057 | 0.024 | 0.117 | >286 | <80 | <110 |
| Standard Deviation | | | **0.37** | **36** | **23** | **23** | **7.7** | **0.12** | **7.3** | **0** | **13.3** | 1.7 | 0.077 | 0.039 | 0.045 | 460 | 123 | 156 |
| COV | | | **0.05** | **0.24** | **0.46** | **1.16** | **2.92** | **0.93** | **0.19** | **-** | **1.3** | 0.55 | 1.35 | 1.592 | 0.381 | 1.60 | 1.54 | 1.41 |
| AD-P Value (Normal) | | | **1.046** | **1.046** | **1.795** | **-** | **1.726** | **5.451** | **1.215** | **1.08** | **-** | 1.9 | 3.01 | 3.498 | **1.864** | 2.06 | 3.27 | 2.66 |
| AD-P Value (Log-normal) | | | **-** | **-** | **1.633** | **-** | **1.192** | **4.201** | **1.664** | **1.213** | **-** | **1.4** | **1.2** | **1.3** | 2.04 | 1.55 | 2.14 | 1.47 |

## Table E2. *Spring Water Reference ("Library") Samples*

| Sample number | Sampling Location | Date | pH | Specific conductivity (µS/cm) | Temperature (°F) | Turbidity. (NTU) | Color (APHA Platinum Cobalt Units) | Fluoride (mg/L) | Hardness (mg/L $CaCO_3$ ) | Detergent (mg/L as MBAS) | Fluorescence (mg/L as "Tide") | Potassium (mg/L) | $NH_3$ (mg/L as N) | $NH_3$/K (ratio) | Boron (mg/L) | Total Coliforms (MPN/100 mL) | *E. coli* (MPN/100 mL) | Enterococci (MPN/100 mL) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Gee's Car Wash-Self Service | 10/31/2002 | 6.62 | 320 | 26 | 263 | 100 | <LD | 56 | | 132 | 10 | 0.44 | 0.044 | N/A | >2419.2 | 1553.1 | >2419.2 |
| 2 | Texaco Gas Station - Automatic Carwash | 10/31/2002 | 6.90 | 300 | 28 | 232 | >100 | 0.04 | 15 | 150 | 130 | 2 | 0.65 | 0.33 | N/A | >2419.2 | 1413.60 | 6.20 |
| 3 | Chevey Gas Station - Automatic Carwash | 5/16/2003 | 7.00 | 260 | N/A | 383 | 80.00 | 6.45 | 68 | 120 | 106 | 2 | 0.37 | 0.19 | 0.50 | >2419.2 | 4.1 | 5.2 |
| 4 | Self service carwash-University Blvd. | 5/17/2003 | 9.04 | 380 | N/A | 81 | >100 | 1.70 | 76 | 150 | 44 | 5 | 0.28 | 0.06 | 0.65 | >2419.2 | 14.6 | 3.1 |
| 5 | Self service carwash-University Blvd. | 5/17/2003 | 7.37 | 390 | N/A | 239 | >100 | 0.56 | 78 | 140 | 55 | 2 | 0.03 | 0.02 | 1.23 | >2419.2 | >2419.2 | 1 |
| 6 | Chevey Gas Station - Automatic Carwash | 5/17/2003 | 9.34 | 570 | N/A | 264 | >100 | <LD | 82 | 80 | 90 | 3 | 4.50 | 1.50 | 1.74 | >2419.2 | 1413.6 | >2419.2 |
| 7 | Chevey Gas Station-McFarland - Automatic Carwash | 5/29/2003 | 7.79 | 210 | N/A | 62 | 77.00 | 1.47 | 83 | 200 | 95 | 3 | 0.75 | 0.25 | 0.37 | >2419.2 | 15.8 | <1 |
| 8 | Parade gas station (McFarland) - Automatic Carwash | 6/3/2003 | 8.57 | 200 | N/A | 207 | >100 | 0.05 | 84 | 150 | 125 | 2 | 0.25 | 0.13 | 0.48 | >2419.2 | 11.9 | 11.1 |
| 9 | Stop and go self service carwash-Skyland Blvd. | 6/3/2003 | 6.81 | 200 | 70 | 65 | 80.00 | 0.42 | 76 | 120 | 162 | 6 | 1 | 0.17 | 0.70 | >2419.2 | 235.9 | <1 |
| 10 | Parade gas station-(Skyland Blvd.) - Automatic Carwash | 6/3/2003 | 7.53 | 192 | 70 | 69 | 60.00 | 0.19 | 74 | 150 | 82 | 2 | 0.25 | 0.13 | 0.50 | >2419.2 | 15.5 | <1 |
| 11 | shell gas station (Skyland Blvd.) - Automatic Carwash | 6/3/2003 | 7.2 | 120 | 71 | 1 | 30.00 | 0.50 | 82 | 150 | 34 | 3 | 0.05 | 0.02 | 0.09 | >2419.2 | 1553.1 | 2419.2 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | parade gas station (Skyland Blvd.) - Automatic Carwash | 6/8/2003 | 7.89 | 154 | N/A | 14 | 0.00 | 0.87 | 80 | 140 | 31 | 3 | 2.25 | 0.75 | 0.28 | <1 | <1 | <1 |
| Mean | | | 7.67 | 274 | 53 | 156 | >61 | 1.22 | 71 | 140 | 90 | 3.6 | 0.90 | 0.29 | 0.65 | >2419.2 | >623 | >407 |
| Standard Deviation | | | 0.89 | 126 | 23 | 122 | 34 | 1.92 | 19 | 29 | 42 | 2.4 | 1.2 | 0.42 | 0.48 | - | 744 | 985 |
| COV | | | 0.11 | 0.45 | 0.44 | 0.77 | 0.56 | 1.56 | 0.27 | 0.20 | 0.46 | 0.667 | 1.4 | 1.4 | 0.74 | - | 1.1 | 2.4 |
| AD-P Value (Normal) | | | **1.22** | **1.27** | - | **1.33** | **1.96** | 2.66 | **1.72** | **1.87** | **1.029** | 2.313 | 2.6 | 2.58 | 1.678 | - | 2.158 | 4.467 |
| AD-P Value (Log-normal) | | | - | 1.02 | - | 1.79 | 2.18 | **1.20** | 1.81 | 3.12 | 1.254 | **1.71** | **1.103** | **0.999** | **1.34** | - | 1.626 | 2.372 |

## Table E 3. *Carwash Reference ("Library") Samples*

## Table E 4. *Laundry Reference ("Library") Samples*

| Sample number | Sampling Location | Date | pH | Specific conductivity (μS/cm) | Temperature (°F) | Turbidity. (NTU) | Color (APHA Platinum Cobalt Units) | Fluoride (mg/L) | Hardness (mg/L $CaCO_3$) | Detergent (mg/L as MBAS) | Fluorescence (mg/L as "Tide") | Potassium (mg/L) | $NH_3$ (mg/L as N) | $NH_3$/K (ratio) | Boron (mg/L) | Total Coliforms (MPN/100 mL) | *E. coli* (MPN/100 mL) | Enterococci (MPN/100 mL) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Renee's House (unknown) | 11/3/2002 | 6.52 | 220 | 26 | 90.40 | 20 | 1.27 | 13.00 | 1000.00 | 1231 | 2 | 1.10 | 0.55 | N/A | N/A | N/A | N/A |
| 2 | Renee's House (unknown) | 12/14/2002 | 6.22 | 180 | 26 | 66.20 | 30 | 0.98 | 18.00 | 920.00 | 1002 | 2 | 0.89 | 0.44 | N/A | N/A | N/A | N/A |
| 3 | Renee's House (unknown) | 5/11/2003 | 9.06 | 440 | N/A | 366.00 | 20 | 0.82 | 54 | 900 | 1490 | 7 | 2.50 | 0.35 | 0.53 | 290.9 | <1 | <1 |
| 4 | Renee's House (unknown) | 5/11/2003 | 7.73 | 1690 | N/A | 85.70 | 20 | 0.78 | 60 | 1020 | 1720 | 4 | 0.50 | 0.12 | 0.36 | <1 | <1 | <1 |
| 5 | Renee's House (unknown) | 5/11/2003 | 9.63 | 360 | N/A | 398.00 | 20 | 1.07 | 58 | 1000 | 302 | 15 | 0.53 | 0.03 | 0.67 | <1 | <1 | <1 |
| 6 | Yukio's apartment (Purex) | 5/30/2003 | 7.10 | 590 | N/A | 226.00 | 20 | 0.84 | 42 | 920 | 2049 | 15 | 1.50 | 0.1 | 0.75 | >2419.2 | >2419.2 | <1 |
| 7 | Yukio's apartment (Purex) | 5/31/2003 | 8.7 | 370 | 81 | 344 | 20 | 0.76 | 46 | 800 | 1402 | 9 | 5 | 0.55 | 0.58 | >2419.2 | 20.1 | <1 |
| 8 | Suman (Tide) | 5/30/2003 | 7.1 | 430 | 70 | 25 | >100 | 0.05 | 52 | 620 | 2805 | 5 | 8 | 1.6 | 7.90 | >2419.2 | <1 | <1 |
| 9 | Yukio's apartment (Purex) | 6/3/2003 | 8.2 | 470 | 84 | 128 | >100 | 0.38 | 50 | 760 | 1349 | 12 | 3 | 0.25 | 0.97 | >2419.2 | 19.7 | <1 |
| 10 | Soumya (Tide) | 6/3/2003 | 8.03 | 420 | 110 | 304 | >100 | 1.04 | 56 | 420 | 1722 | 2 | 5 | 2.5 | 10.80 | <1 | <1 | <1 |
| 11 | Veera (Gain) | 6/3/2003 | 9.45 | 240 | N/A | 135 | 45 | 1.12 | 54 | 580 | 430 | 2 | 2 | 1 | 1.16 | <1 | <1 | <1 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | Sanju (Tide) | 6/8/2003 | 7.2 | 152 | N/A | 59.1 | 40 | 1.09 | 44 | 480 | 601 | 3 | 9 | 3 | 0.70 | <1 | <1 | <1 |
| Mean | | | 7.91 | 220 | 26 | 185 | >26 | 0.85 | 45 | 785 | 1342 | 6.5 | 3.2 | 0.87 | 2.4 | >2419.2 | - | <1 |
| Standard Deviation | | | 1.12 | 180 | 26 | 134 | 9.93 | 0.34 | 15 | 212 | 709 | 5.0 | 2.8 | 0.98 | 3.7 | - | - | - |
| COV | | | 0.14 | 440 | N/A | 0.72 | 0.38 | 0.40 | 0.33 | 0.27 | 0.52 | 0.78 | 0.89 | 1.12 | 1.59 | - | - | - |
| AD-P Value (Normal) | | | **1.013** | 1690 | N/A | 1.401 | **2.578** | **1.42** | **1.841** | **1.28** | **1.035** | 1.568 | 1.468 | 1.871 | 3.419 | - | - | - |
| AD-P Value (Log-normal) | | | - | 360 | N/A | **1.132** | 2.587 | 2.71 | 2.583 | 1.435 | 1.32 | **1.294** | **0.982** | **0.99** | **2.106** | - | - | - |

## Table E 5. *Sewage (Dry Weather) Reference ("Library") Samples*

| Sample number | Sampling Location | Date | pH | Specific conductivity (μS/cm) | Temperature (°F) | Turbidity. (NTU) | Color (APHA Platinum Cobalt Units) | Fluoride (mg/L) | Hardness (mg/L $CaCO_3$ ) | Detergent (mg/L as MBAS) | Fluorescence (mg/L as "Tide") | Potassium(mg/L) | $NH_3$ (mg/L as N) | $NH_3$/K (ratio) | Boron (mg/L) | Total Coliforms (MPN/100 mL) | *E. coli* (MPN/100 mL) | Enterococci (MPN/100 mL) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Tuscaloosa WWTP (Dry Season) | 12/18/2002 | 6.44 | 780 | N/A | 192 | >100 | 0.64 | 36 | 10 | 260 | 11 | 11 | 1 | N/A | >2419.2 | >2419.2 | >2419.2 |
| 2 | Tuscaloosa WWTP (Dry Season) | 1/8/2003 | 6.56 | 2100 | N/A | 306 | >100 | 0.74 | 42 | 10 | 156 | 10 | 14 | 1.4 | N/A | N/A | N/A | N/A |
| 3 | Tuscaloosa WWTP (Dry Season) | 1/15/2003 | 6.42 | 1500 | N/A | 203 | >100 | 0.64 | 52 | 12.5 | 142 | 15 | 18 | 1.2 | N/A | >2419.2 | >2419.2 | >2419.2 |
| 4 | Tuscaloosa WWTP (Dry Season) | 3/11/2003 | 6.9 | 1280 | N/A | 53.6 | >100 | 0.68 | 68 | 10 | 189 | 11 | 45 | 4.0 | N/A | >2419.2 | 816.4 | 43.6 |
| 5 | Tuscaloosa WWTP (Dry Season) | 5/18/2003 | 7.1 | 540 | N/A | 230 | 70 | 0.65 | 65 | 8 | 264 | 15 | 37.5 | 2.5 | N/A | N/A | N/A | N/A |
| 6 | Tuscaloosa WWTP (Dry Season) | 5/29/2003 | 6.99 | 1090 | N/A | 128 | 100 | 0.82 | 42 | 8 | 267 | 9 | 27 | 3 | 0.97 | >24192000 | 12033000 | 613000 |
| Mean | | | 6.73 | 1215 | - | 185 | >100 | 0.695 | 50 | 9.7 | 213 | 11.8 | 25.4 | 2.19 | 0.97 | >2419.2 | 6000000 | 300000 |
| Standard Deviation | | | 0.29 | 553 | - | 86 | - | 0.072 | 13 | 1.66 | 57 | 2.5 | 13.6 | 1.21 | - | - | 8500000 | 430000 |
| COV | | | 0.04 | 0.45 | - | 0.46 | - | 0.104 | 0.260 | 0.171 | 0.27 | 0.21 | 0.53 | 0.55 | - | - | 1.41 | 1.41 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AD-P Value (Normal) | **1.878** | **1.96** | - | **1.77** | **-** | **1.992** | **1.874** | **2.012** | **2.042** | **2.026** | **1.77** | **1.81** | - | - | 3.066 | 3.065 |
| AD-P Value (Log-normal) | - | 1.913 | - | 1.996 | - | 1.96 | 1.846 | 2 | 2.025 | 1.955 | 1.737 | 1.785 | - | - | 2.846 | 2.672 |

# Table E 6. *Sewage (Wet Weather) Reference ("Library") Samples*

| Sample number | Sampling Location | Date | pH | Specific conductivity (µS/cm) | Temperature (°F) | Turbidity. (NTU) | Color (APHA Platinum Cobalt Units) | Fluoride (mg/L) | Hardness (mg/L $CaCO_3$) | Detergent (mg/L as MBAS) | Fluorescence (mg/L as "Tide") | Potassium (mg/L) | $NH_3$ (mg/L as N) | $NH_3$/K (ratio) | Boron (mg/L) | Total Coliforms (MPN/100 mL) | *E. coli* (MPN/100 mL) | Enterococci (MPN/100 mL) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Tuscaloosa WWTP (Wet Season) | 5/30/2003 | 6.8 | 1240 | N/A | 202 | >100 | 0.19 | 52 | 8 | 267 | 11 | 30 | 2.72 | 1.38 | >24192000 | 2851000 | 833000 |
| 2 | Tuscaloosa WWTP (Wet Season) | 6/2/2003 | 6.81 | 1250 | N/A | 270 | >100 | 0.22 | 48 | 7.5 | 292 | 12 | 35 | 2.91 | 0.98 | >24192000 | 3654000 | 598000 |
| 3 | Tuscaloosa WWTP (Wet Season) | 6/3/2003 | 6.99 | 440 | N/A | 255 | 100 | 0.25 | 44 | 6 | 251 | 12 | 22.5 | 1.87 | 0.93 | >24192000 | 2187000 | 292000 |
| 4 | Tuscaloosa WWTP (Wet Season) | 6/4/2003 | 6.92 | 440 | N/A | 231 | 100 | 0.14 | 52 | 8 | 298 | 10 | 22.5 | 2.25 | 1.05 | >24192000 | 1785000 | 328000 |
| 5 | Tuscaloosa WWTP (Wet Season) | 6/5/2003 | 7.00 | 550 | N/A | 113 | 57 | 0.20 | 54 | 7.5 | 252 | 11 | 36 | 3.27 | 1.01 | >24192000 | 3255000 | 369000 |
| 6 | Tuscaloosa WWTP (Wet Season) | 6/6/2003 | 7.00 | 850 | N/A | 259 | 60 | 0.17 | 47 | 7.5 | 244 | 14 | 27.5 | 1.96 | 0.78 | >24192000 | 2282000 | 609000 |
| Mean | | | 6.9 | 795 | - | 221 | >79 | 0.19 | 49 | 7.4 | 267 | 11.6 | 28.9 | 2.500 | 1.02 | >24192000 | 2669000 | 504833 |
| Standard Deviation | | | 0.09 | 379 | - | 58 | 24 | 0.03 | 3.78 | 0.73 | 22 | 1.3 | 5.8 | 0.55 | 0.19 | - | 708561 | 210828 |
| COV | | | 0.01 | 0.47 | - | 0.26 | 0.30 | 0.197 | 0.07 | 0.0996 | 0.086 | 0.11 | 0.203 | 0.22 | 0.195 | - | 0.265 | 0.418 |
| AD-P Value (Normal) | | | 2.097 | 1.722 | - | 2.097 | 2.72 | 1.708 | 1.83 | 2.357 | 1.911 | 1.891 | 1.809 | 1.751 | 1.984 | - | 1.744 | 1.854 |
| AD-P Value (Log-normal) | | | - | 1.725 | - | 2.3 | 2.706 | 1.734 | 1.838 | 2.43 | 1.898 | 1.858 | 1.825 | 1.761 | 1.906 | - | 1.747 | 1.833 |

# Table E 7. *Industrial Reference ("Library") Samples*

| Sample number | Sampling Location | Date | pH | Specific conductivity (µS/cm) | Temperature (ºF) | Turbidity (NTU) | Color (APHA Platinum Cobalt Units) | Fluoride (mg/L) | Hardness (mg/L $CaCO_3$) | Detergent (mg/L as MBAS) | Fluorescence (mg/L as "Tide") | Potassium (mg/L) | $NH_3$ (mg/L as N) | $NH_3$/K (ratio) | Boron (mg/L) | Total Coliforms (MPN/100 mL) | *E. coli* (MPN/100 mL) | Enterococci (MPN/100 mL) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | DELPHI (Automotive manufacture)(Water supply unknown) | 12/18/2002 | 6.72 | 240 | N/A | 91.6 | 20 | 0.04 | 23 | 7.5 | 722 | 24 | 0.55 | 0.02 | N/A | 920.8 | 66.3 | 0 |
| 2 | PECO FOODS (Poultry Supplier) (City water supply). | 12/18/2002 | 6.44 | 850 | N/A | 309 | 40 | 0.89 | 34 | 10 | 149 | 37 | 6 | 0.16 | N/A | >2419.2 | >2419.2 | >2419.2 |
| 3 | TAMKO (Roofing Products)(Water supply unknown) | 12/18/2002 | 7 | 380 | N/A | 251 | >100 | 0.02 | 32 | 12.5 | 309 | 8 | 10 | 1.25 | N/A | >2419.2 | 3 | >2419.2 |
| 4 | DELPHI (Automotive manufacture)(Water supply unknown) | 1/8/2003 | 6.88 | 340 | N/A | 225 | 10 | LD | 30 | 0.25 | 101 | 92 | 0.4 | 0.004 | N/A | N/A | N/A | N/A |
| 5 | PECO FOODS (Poultry Supplier)(City water supply). | 1/8/2003 | 6.22 | 960 | N/A | 14.8 | 10 | 0.72 | 32 | 0.5 | 130 | 42 | 4.5 | 0.10 | N/A | N/A | N/A | N/A |
| 6 | TAMKO (Roofing Products)(Water supply unknown) | 1/8/2003 | 6.9 | 310 | N/A | 210 | >100 | 0.01 | 38 | 2 | 410 | 32 | 12 | 0.37 | N/A | N/A | N/A | N/A |
| 7 | DELPHI (Automotive manufacture)(Water supply unknown) | 1/15/2003 | 6.42 | 81 | N/A | 37.4 | 15 | 0.01 | 36 | 6 | 599 | 81 | 0.9 | 0.01 | N/A | >2419.2 | <1 | <1 |
| 8 | PECO FOODS (Poultry Supplier)(City water supply). | 1/15/2003 | 6.36 | 45 | N/A | 10 | 20 | 0.81 | 28 | 5 | 150 | 45 | 2 | 0.04 | N/A | >2419.2 | >2419.2 | 866.4 |
| 9 | TAMKO (Roofing Products)(Water supply unknown) | 1/15/2003 | 7.3 | 37 | N/A | 226 | >100 | 0.01 | 26 | 10 | 375 | 37 | 8.5 | 0.22 | N/A | 204.6 | <1 | <1 |
| Mean | | | 6.6 | 360 | - | 152 | >19 | 0.31 | 31 | 5.9 | 327 | 44 | 4.9 | 0.24 | - | >562 | >34 | >433.2 |
| Standard Deviation | | | 0.35 | 335 | - | 114 | 11 | 0.41 | 4.7 | 4.4 | 221 | 26.5 | 4.3 | 0.39 | - | 506 | 44 | 612 |
| COV | | | 0.053 | 0.930 | - | 0.748 | 0.58 | 1.309 | 0.155 | 0.741 | 0.67 | 0.60 | 0.88 | 1.6 | - | 0.89 | 1.2 | 1.4 |
| AD-P Value (Normal) | | | **1.321** | 1.629 | - | **1.538** | 2.056 | 2.414 | **1.21** | **1.276** | **1.451** | **1.611** | **1.371** | 2.499 | - | 2.575 | 2.668 | 2.172 |
| AD-P Value (Log-normal) | | | - | **1.408** | - | 1.792 | **1.833** | **1.982** | 1.254 | 1.763 | 1.386 | 1.536 | 1.436 | 1.203 | - | 2.603 | 1.963 | 2.467 |

Table E 8. *Industrial (Cintas) Reference (“Library”) Samples*

| Sample number | Sampling Location | Date | pH | Specific conductivity (µS/cm) | Temperature (°F) | Turbidity (NTU) | Color (APHA Platinum Cobalt Units) | Fluoride (mg/L) | Hardness (mg/L $CaCO_3$) | Detergent (mg/L as MBAS) | Fluorescence (mg/L as “Tide”) | Potassium (mg/L) | $NH_3$ (mg/L as N) | $NH_3$/K (ratio) | Boron (mg/L) | Total Coliforms (MPN/100 mL) | *E. coli* (MPN/100 mL) | Enterococci (MPN/100 mL) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | CINTAS (Cooperate uniform mfg.)(City water supply). | 12/18/2002 | 11.44 | 1460 | N/A | 3388 | >100 | <LD | 35 | 5 | 29 | 53 | 7.5 | 0.14 | N/A | 0 | 0 | 0 |
| 2 | CINTAS (Cooperate uniform mfg.)(City water supply). | 1/8/2003 | 9.56 | 850 | N/A | 483 | >100 | <LD | 40 | 10 | 285 | 56 | 6 | 0.10 | N/A | N/A | N/A | N/A |
| 3 | CINTAS (Cooperate uniform mfg.)(City water supply). | 1/15/2003 | 10.22 | 85 | N/A | 4023 | >100 | 0.02 | 32 | 3 | 66 | 85 | 5 | **0.05** | N/A | 0 | <1 | 22.2 |
| Mean | | | 10.4 | 798 | - | 2631 | >100 | <0.02 | 35 | 6 | 35 | 64 | 6.1 | 0.10 | - | 0 | - | 11.1 |
| Standard Deviation | | | 0.95 | 688 | - | 1887 | - | - | 4.0 | 3.6 | 4.0 | 17 | 1.2 | 0.04 | - | 0 | - | 15.6 |
| COV | | | 0.091 | 0.86 | - | 0.71 | - | - | 0.11 | 0.6 | 0.11 | 0.27 | 0.20 | 0.40 | - | - | - | 1.4 |
| AD-P Value (Normal) | | | **3.067** | **3.072** | - | **3.21** | - | - | **3.063** | **3.084** | **3.063** | **3.182** | **3.06** | **3.079** | - | 4.201 | - | 4.201 |
| AD-P Value (Log-normal) | | | - | 3.201 | - | 3.298 | - | - | 3.06 | 3.059 | 3.06 | 3.167 | 3.059 | 3.118 | - | - | - | - |

# Table E 9. *Irrigation Reference ("Library") Samples*

| Sample number | Sampling Location | Date | pH | Specific conductivity (µS/cm) | Temperature (°F) | Turbidity (NTU) | Color (APHA Platinum Cobalt Units) | Fluoride (mg/L) | Hardness (mg/L $CaCO_3$ ) | Detergent (mg/L as MBAS) | Fluorescence (mg/L as "Tide") | Potassium (mg/L) | $NH_3$ (mg/L as N) | $NH_3$/K (ratio) | Boron (mg/L) | Total Coliforms (MPN/100 mL) | *E. coli* (MPN/100 mL) | Enterococci (MPN/100 mL) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Sampling Location | Date | 7.91 | 200 | N/A | 16.2 | 0 | 0.69 | 62 | 0 | 49 | 2 | <LD | N/A | 0.14 | >2419.2 | 27.8 | >2419.2 |
| 2 | Ferguson Parking (UA) - Run over concrete | 5/16/2003 | 7.38 | | N/A | 4.03 | 10 | 0.68 | 60 | 0 | 32 | 9 | 1.0 | 0.111 | 0.20 | >2419.2 | 8.3 | 2 |
| 3 | B.B. Commer (UA) - Run over concrete | 5/18/2003 | 7.46 | 200 | N/A | 64.6 | 0 | 0.76 | 55 | 0 | 92 | 5 | 0.08 | 0.016 | 0.25 | >2419.2 | >2419.2 | >2419.2 |
| 4 | Art Building (UA) - taken at a little puddle, NO concrete | 5/16/2003 | 7.18 | 163 | N/A | 9.95 | 20 | 0.83 | 58 | 0 | 44 | 3 | 0.21 | 0.07 | 0.13 | >2419.2 | >2419.2 | >2419.2 |
| 5 | MIB (UA) - Run over concrete | 5/19/2003 | 7.1 | 148 | 89 | 21.8 | 50 | 0.30 | 40 | 0 | 62 | 2 | 3.5 | 1.75 | 0.2 | >2419.2 | 31.8 | >2419.2 |
| 6 | MIB (UA) - Run over concrete | 5/30/2003 | 7.46 | 200 | 70 | 96.6 | 56 | 0.39 | 44 | 0 | 88 | 4 | 0.5 | 0.125 | 0.36 | >2419.2 | >2419.2 | 287.7 |
| 7 | Art Building (UA) - taken at a little puddle, NO concrete | 5/30/2003 | 6.99 | 181 | 70 | 826 | 54 | 0.23 | 52 | 0 | 53 | 5 | 1 | 0.2 | 0.5 | >2419.2 | >2419.2 | >2419.2 |
| 8 | Quad(UA) - taken at a little puddle, NO concrete | 5/30/2003 | 7.26 | 183 | 82 | 14.5 | 50 | 0.64 | 54 | 0 | 53 | 9 | 4.5 | 0.5 | 0.22 | >2419.2 | >2419.2 | >2419.2 |
| 9 | MIB (UA) - Run over concrete | 6/5/2003 | 7.16 | 182 | 78 | 16.5 | 30 | 0.91 | 52 | 0 | 41 | 8 | 0.5 | 0.06 | 0.14 | >2419.2 | >2419.2 | >2419.2 |
| 10 | MIB (UA) - Taken at a little puddle, NO concrete | 6/5/2003 | 6.91 | 156 | 72 | 32 | 27 | 0.57 | 48 | 0 | 55 | 4 | 1 | 0.25 | 0.23 | >2419.2 | 1299.7 | >2419.2 |
| 11 | Bevil (UA) - taken at a little puddle, NO concrete | 6/5/2003 | 7.4 | 183 | 78 | 9 | 40 | 0.84 | 66 | 0 | 53 | 7 | 0.5 | 0.07 | 0.25 | >4838.4 | >4838.4 | >4838.4 |
| 12 | MIB (UA) - Run over concrete | 6/9/2003 | 7.3 | 194 | 80 | 16.6 | 50 | 0.57 | 54 | 0 | 53 | 10 | 1 | 0.1 | 0.35 | >4838.4 | >4838.4 | >4838.4 |
| Mean | | | 7.2 | 180 | 77 | 93 | 32 | 0.61 | 53 | 0 | 56 | 5.6 | 1.25 | 0.29 | 0.24 | >2419.2 | >2419.2 | >2419.2 |
| Standard Deviation | | | 0.26 | 18 | 6.5 | 232 | 20 | 0.21 | 7.3 | 0 | 17 | 2.8 | 1.41 | 0.50 | 0.10 | - | - | - |
| COV | | | 0.03 | 0.10 | 0.08 | 2.46 | 0.64 | 0.35 | 0.13 | - | 0.31 | 0.50 | 1.12 | 1.69 | 0.43 | - | - | - |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AD-P Value (Normal) | **1.147** | **1.401** | | 5.099 | **1.296** | **1.103** | **1.002** | - | 1.718 | **1.144** | 2.471 | 3.343 | 1.366 | - | - | - |
| AD-P Value (Log-normal) | - | 1.457 | | **1.516** | 1.677 | 1.457 | 1.006 | - | **1.383** | 1.146 | **1.325** | **1.277** | **1.094** | - | - | - |