Fraser River
Action Plan

CANADA'S GREEN PLAN
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CSO & UR Investigative Assessment Guidelines

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CSO & UR
INVESTIGATIVE ASSESSMENT
GUIDELINES

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DISCLAIMER

This project was funded by Environment Canada under the Fraser River Action Plan through its Fraser Pollution Abatement Office. The ideas and views expressed herein do not necessarily state or reflect those of Environment Canada.

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EXECUTIVE SUMMARY

This document presents a methodology for investigative and detailed contaminant loading assessments of combined sewer overflow (CSO) and urban runoff (UR) wastewater discharges into the Fraser River. The overall purpose of the document is to provide agencies with procedural documentation to plan and implement monitoring programs for these two types of wastewater discharges.

The recommended approach is to first carry out an investigative assessment to determine whether specific contaminants of concern are present, or being discharged into the sewer system, and whether these key contaminants are also identifiable in receiving environment sediment and tissue samples collected within the vicinity of the discharge. The investigative assessment provides qualitative information which allows investigators to prioritize outfall discharges for detailed assessment. Depending on the findings of the investigative program, a detailed assessment program may be carried out to obtain information which will enable investigators to estimate the contaminant loading characteristics for each discharge. Finally a process assessment may be carried out to determine remedial measures to reduce contaminant discharges.

The document is presented in a three-ring binder format to allow extraction of specific sections, and to permit the document to be easily updated on a periodic basis as information changes (i.e. laboratory capabilities and equipment specifications). The methodology is presented in a step-by-step fashion, as the report is intended to serve as a guidance document for investigators and field sampling crews. The procedures are described in a matrix diagram presented at the beginning of Sections 3.0. The document also provides information on local laboratory capabilities, and safety procedures for use in field sampling.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

LIST OF FIGURES

LIST OF TABLES

Glossary of Abbreviations

AEMC	Average Event Mean Concentration
AET	Apparent Effects Threshold
As	Arsenic
BHC	Benzene Hexachloride
B/N	Base Neutral
BNA	Base Neutral Acid
BOD_5	Five Day Biochemical Oxygen Demand
Cd	Cadmium
CEPA	Canadian Environmental Protection Act
CI	Confidence Interval
COD	Chemical Oxygen Demand
Cr	Chromium
CSARS	Confined Space Airline Rescue System
CSO	Combined Sewer Overflow
CSO/UR	Combined Sewer Overflow and Urban Runoff
Cu	Copper
DOC	Dissolved Organic Carbon
DWF	Dry Weather Flow
EMC	Event Mean Concentration
EPA	Environmental Protection Agency
Fe	Iron
FF	First Flush
GC	Gas Chromatograph
GC/MS	Gas Chromatograph and Mass Spectrophotometer
Hg	Mercury
Mg	Magnesium
mg/L	milligrams per Litre
MISA	Municipal/Industrial Strategy for Abatement
Mn	Manganese
Mo	Molybdenum
MS	mass spectrophotometer
ng/L	nanograms per litre
NH_4	ammonia
Ni	Nickel
NOx	Nitrate and Nitrite forms of nitrogen
NO_2	Nitrite (Nitrogen)
NO_3	Nitrate (Nitrogen)
NPS	Non-Point Source
NURP	National Urban Runoff Program
PAH	Polynuclear Aromatic Hydrocarbons

Glossary of Abbreviations (Cont'd)

Pb	Lead
PCB	Polychlorinated biphenyl
pH	negative logarithm of the hydrogen ion concentration
QA/QC	Quality Assurance/Quality Control
STP	Sewage Treatment Plant
SWMM	Storm Water Management Model
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TSS	Total Suspended Solids
ug/L	micrograms per litre
um	micrometres
UK	United Kingdom
UR	Urban Runoff
VOC	Volatile Organic Carbon
VSS	Volatile Suspended Solids
WWTP	Wastewater Treatment Plant
Zn	Zinc

1.0 INTRODUCTION

1.1 Background

The Fraser River Action Plan (an initiative of the Federal Government) has a pollution abatement component directing that action be taken to identify and control contaminants entering the Fraser River Basin from point and non-point sources (Fraser River Action Plan, January 14, 1992). The Greater Vancouver Sewerage and Drainage District (GVS&DD) discharges some 700,000 m^3/yr of liquids comprised of 50 % urban stormwater runoff (UR), 41 % wastewater and 9 % combined sewer overflow (CSO) discharges (GVRD, 1988(a), 1988(b)). Although stormwater runoff and CSOs represent almost 60 percent of the discharge volume to the environment, very little is known of the wastewater contaminant characteristics or environmental impacts of either source on the Fraser River.

1.2 Report Purpose

This report describes a recommended approach, and associated protocols, for the purpose of characterizing both CSO and UR discharges in terms of their potential pollutant loading to the environment. The purpose of the report is to serve as a guidance document for the investigation and assessment of CSO and UR discharges within the Fraser River Basin. The document is intended for use by government agencies, including municipalities and regional districts, in characterizing such discharges.

1.3 Report Structure

The report has been bound in a manner to facilitate periodic updating of the document and to allow sections of the document to be extracted separately.

The report is structured into the following six sections:

- ***Section 1.0:*** presents background information and states the purpose of the report.
- ***Section 2.0:*** provides a general overview of contaminant sources in CSO and UR discharges and introduces the staged assessment approach adopted for this document.
- ***Section 3.0***: describes step-by-step investigative and detailed assessment methodologies for assessing contaminant loading from CSO and UR discharges.

- ***Section 4.0:*** provides information on local laboratories including analytical capabilities, contact information, and general analytical pricing for budgetary purposes.
- ***Section 5.0:*** provides safety guidelines, including confined space procedures, which must be followed in carrying out both UR and CSO sampling programs.
- ***Section 6.0:*** presents a brief conclusion statement.

2.0 ASSESSMENT APPROACH

2.1 General

It is important to identify the intended use and quality requirements of environmental data before a sampling program is initiated. The assessment methodology outlined in this document focuses on two key components. Firstly, on carrying out investigative sampling within a sewerage area (combined or storm) to determine what contaminants are present, and, if present, whether they are detectable in water, tissue or sediment samples collected from the immediate vicinity of the discharge. Secondly, on carrying out further detailed sampling to estimate the annual contaminant mass loadings to the environment.

A fully considered and well documented monitoring plan needs to be prepared prior to embarking upon any CSO or UR monitoring program. Monitoring plan elements that need to be considered include:

- Monitoring objectives
- Physical constraints
- Resource requirements
- Monitoring schedule

The first element of plan preparation is to clearly define the study objective(s). Examples of key questions that must be addressed in defining the objective(s) include:

- Is the program being carried out to identify problem discharges, or is the program intended to provide calibration data for a specific model?
- How much data should be collected to provide a representative estimate?
- What analytical or loading estimate accuracy is required, and over what time period should monitoring be carried out, to fulfill the overall objectives?

It must be kept in mind that the potential for error is, to a point, inversely proportional to the number of samples collected and the quality of the samples. It is neither possible to analyze all of the discharge, nor is it feasible to monitor every discharge event. The purpose of the sampling program is to collect representative samples in order to provide an acceptable *estimate* of the *average* discharge characteristics. The conclusions made as a result of the data collected during the program are based on the assumptions that:

1. The samples collected accurately represent the discharge conditions at the time of sampling;
2. The analyses accurately represent the characteristics of the samples collected.

Even if the sample collection and analyses are representative of the discharge conditions at the time of sampling, repeated sampling is required to establish an Event Mean Concentration (EMC) due to the inherent variability of CSO and UR discharges. Only by making a concerted effort to carefully collect, handle and analyze samples, and to repeat the process on several occasions, can we develop confidence that the data generated represents the discharge conditions. The greater the number of samples, the more precise the estimate of discharge characteristics.

Practical considerations, such as analytical and staffing budgets, and staff scheduling difficulties, often limit the number of samples which can be collected. Using high resolution, and expensive, analytical methods does not in itself ensure accurate or representative estimates of contaminant loading to the environment. For example, if the expected variation in a specific contaminant is plus or minus 50 percent, analytical resolutions of 0.05% of the measured concentration will not significantly contribute to the accuracy of a contaminant loading estimate. If the purpose is to screen for the presence of contaminants, low resolution, and lower cost, analytical techniques may be more appropriate.

Urban runoff and combined sewer overflows are diffuse sources of contaminants intermittently discharged into the receiving environment during wet events. Generally, it is impractical to consider monitoring all such discharges in estimating contaminant loading to the environment due to their large numbers and intermittent nature. Consequently, the common approach taken to estimate such loadings is to characterize the composition of runoff through field investigations of representative discharges, and to use this information in conjunction with modeling estimates of flow to obtain loading estimates. This approach was applied in a number of milestone urban runoff and combined sewer overflow contaminant loading assessment studies that have been carried out in North America in the past ten years including the U.S. EPA Nationwide Urban Runoff Program (NURP) (1983), the Environment Canada Great Lakes Basin Studies (Marsalek and Greck, 1984; Marsalek and Schroeter, 1984; Marsalek and Ng, 1987; Marsalek and Schroeter, 1988; Marsalek, 1991a), and the Ontario Ministry of Environment Metropolitan Toronto Waterfront study (Paul Theil Associates, 1992).

Runoff quality characteristics can be estimated from samples collected over a number of storm events. The greater the number of storm events sampled, the better the accuracy of the EMC but the greater the overall program cost. The cost of sample collection and analysis needs to be balanced against the intended use of the data and the level of desired accuracy. Monitoring programs typically set the number of samples to be collected to an acceptable minimum number. Work carried out by Marsalek and Ng (1987) in a long-term urban runoff study found that the concentration mean for the first 13 storm events (in

a series of 117 events monitored) was not statistically different from the mean for the entire data set for six out of eight chemical constituents. Accurate flow measurements were difficult to achieve and runoff volumes were estimated from hydraulic models and precipitation data. Despite the extensive statistical and analytical effort carried out, the loading estimates will only be as accurate as the hydraulic model used.

Three methods were considered by Environment Canada to assess urban runoff contaminant loading into the Great Lakes Basin: (1) direct field measurements; (2) detailed modeling; and (3) screening procedures (Marsalek, 1990a). Although field measurements provide the most accurate information, this approach was considered to be impractical because of the associated costs, time/labour requirements and the lack of predictive capability for future catchment conditions. Similarly, computer modeling was considered to be impractical due to the field measurements and calibration requirements for each watershed. The approach adopted by Environment Canada to assess contaminant loading for planning remediation measures was to use a screening procedure which uses a statistical approach to estimate runoff loads (Marsalek, 1990a, 1991a). Screening methods used in the Great Lakes Basin CSO and stormwater loading estimates included:

- Establish point source loads (treatment plants) by collecting 24-hour flow-proportioned samples for seven days during each of several (seasonal) sampling programs, and obtain available continuous discharge data.
- Establish non-point source (i.e. CSO/UR) annual loads using flow modeling, and constituent concentrations for a select number of days or events using the direct average method, the flow-weighted method, and the regression method.

2.2 Sources and Pathways of Toxic Contaminants

The contaminant sources most affecting CSO and UR quality are presented in Figure 2.1. Surface wash-off by rainfall (which may already be contaminated from atmospheric pollutants), or snowmelt, is the major transport mechanism. Particulate and soluble contaminants are carried from the catchment surface to the storm drains and into the storm or combined sewer system, and ultimately to the receiving water body. Land use activities influence the water quality and hydraulic characteristic of the surface runoff. Sources of land-use associated contaminants are numerous and complex, and include:

- Street refuse deposition (litter, street dirt, vegetation & organic residues) (Marsalek and Greck, 1984)
- Traffic emissions and debris (rust, paint, exhaust, brake lining, etc.);
- Industrial and commercial land use activities;
- Spills into sewer of storm drain systems;
- Urban erosion and land use;
- Road de-icing products;

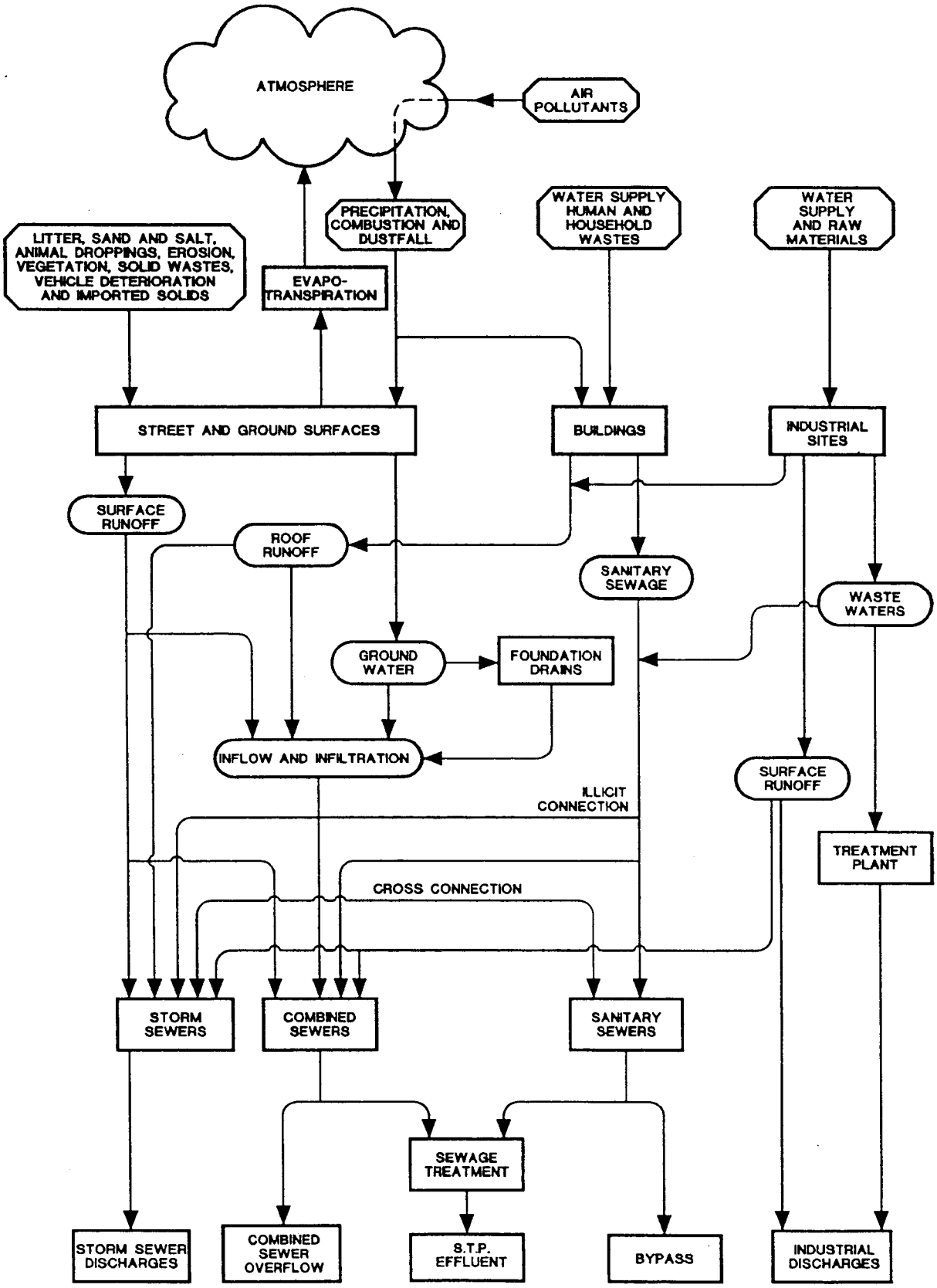


FIGURE 2.1
SOURCES AND PATHWAYS OF CONTAMINANTS

- Wet and dry atmospheric deposition (not as significant as other sources (Novotny et al. 1985)).

Although certain pollutants are highly soluble, and reside in the liquid phase, particulates in urban runoff often act as carriers for other pollutants. Marsalek and Greck (1984) found that of the total storm water toxic contaminant loading, the portion transported by solid phase exceeded the liquid phase fraction.

Contaminants typically associated with sediments include phosphorus, biodegradable organic matter, bacteria, pesticides, halogenated and non-halogenated hydrocarbons, metals and some organic toxic contaminants. The proportion of toxic contaminants associated with the sediment fraction depends on the contaminant chemical behavior (i.e. solubility and surface chemistry). Marsalek and Schroeter (1988) reported on 50 selected toxic chemicals that were monitored in urban runoff discharges from 12 urban centers within the study area. Approximately 90 percent of the PCB loading to the Great Lakes from urban runoff sources was contained in the sediment fraction, in comparison to only 3 and 6 percent for pesticides such as alpha-BHC and Lindane, respectively. Sediment associated inorganic toxicant loading fractions such as copper, lead and zinc were reported to be responsible for approximately 40, 29 and 10 percent, respectively, of the total loading to the Great Lakes Basin.

Having recognized the role of sediments in contaminant transport, it is important to obtain representative samples of runoff particulates during sampling programs. Sampling of particulate residues in catchment depositories, such as catch basins and pipes, and outfalls, can also give an indication of the presence of sediment associated contaminants.

The relationship between sediments and toxic contaminants can be of use in detecting the presence of such materials in the receiving environment.

2.3 Planning and Resource Considerations

At the planning stage, careful consideration must be given to the various factors which act as constraints in establishing monitoring programs. One of the most significant constraints are the physical limitations imposed by a particular site. Site reconnaissance is essential to the development of a viable monitoring program. The factors which need to be examined during the reconnaissance are discussed in more detail in the next subsection.

The program planning process must also address the optimum allocation of monitoring resources. Ideally, the process should be based on the intended use of the monitoring data, coupled with a realistic understanding of physical constraints impaired by the sampling location. Considerations as to the level of expertise of sampling crews must also be taken into consideration. The precision and accuracy of high resolution analytical techniques may be immaterial if the sampling crew is not familiar and experienced in the collection, handling and preservation of representative samples.

2.3.1 Resource Requirement Considerations

When evaluating program resource requirements the following factors should be taken into account:

- **Equipment requirements**. Necessary equipment may include not only samplers, flow meters or rain gauges but also protective and safety equipment, for field stuff field vehicles and an assortment of small tools and monitoring equipment spares.
- **Sampling and sample containers**. The cost of sample containers should also be considered in program planning, particularly where protocols require exhaustive cleaning and preparation of sample containers. Although sample containers are generally provided by the laboratory providing the analytical service, the cost of preparation will be reflected in the cost of analysis.
- **Setup, dismantling and calibration**. An allowance in scheduling and staff resources should always be made for monitoring equipment setup, and dismantling. An allowance should also be made at the initiation of monitoring to allow for calibrating equipment and establishing a smoothly functioning field crew routine.
- **Crew size**. For safety reasons, the crew must consist of at least two individuals. Depending on the need for traffic control, more personnel may be required. As a rule of thumb a single field crew should be able to service about 10 flow-monitoring locations with up to three locations requiring servicing of automated samplers. Beyond these limits additional field staff will be necessary. Clearly, where more complex process studies are undertaken, or where monitoring requires manual sampling at multiple sites, crew sizes will be dictated by the needs and resources of the program.
- **QA/QC**. Adequate resources need to be allocated to any QA/QC program supporting sampling or flow monitoring activities. In the case of flow measurements, QA/QC will include site calibration of flowmeters for Level 2 (Table 2.1) monitoring, and should also include frequent data review. Sampling QA/QC programs include many facets ranging from sampler and sample container preparation, to field and laboratory method checks, replicate samples (e.g. laboratory blind replicates), field transportation blanks, and field spikes (refer to Sections 3.3.5.9 and 4.3.5.9 for further details). A minimum 10 percent allowance should be provided for the extra analytical costs associated with the field QA/QC sample load.
- **Specialized studies**. Resource requirements for specialized studies such as column tests for particle size evaluation, or collimated beam UV dose response, are best based on previous experience. The requirements will vary in proportion to the number of sites and number of events to be sampled at a given site. At a minimum it is desirable to carry out surveys for at least 5 to 6 events at a site in order to obtain a reasonable representation of conditions.

2.3.2 Scheduling Considerations

A major element that needs to be considered in program planning is the scheduling of the monitoring activity. The schedule is dictated by a number of factors which include:

- The number of seasons required for data collection.
- The number of potential sites and time required for monitoring. The number of sites determines the actual time that can be allocated to monitoring requirements as well as the time required for setup and dismantling.
- The resources available in terms of staff, equipment, vehicles, etc.
- The experience of the monitoring staff, which affects the time required to calibrate equipment and time for crew training.
- Any specialized studies that must be undertaken.
- The complexity of equipment installations and the difficulty of site access.

It is important at the planning stage that a realistic schedule be adopted from the outset of the program, and preferably after some on-site investigation (or pilot work) has led to a reasonable appreciation of site physical and logistical constraints.

2.4 Investigative Approach

2.4.1 General

The overall approach to characterizing CSO and UR discharges, described in this report, is intended to meet the following two primary objectives:

1. To develop an appropriate database for the estimation of CSO or UR pollutant loadings.
2. To identify outfalls, or overflows, with elevated pollutant concentrations or proportionately large loadings.

The investigative approach described in this report is intended to provide the reader with a methodology to determine whether a discharge contains contaminants of concern to the environment, and a methodology to estimate the mass loading of a contaminant, once identified. The proposed approach is systematic in nature, and builds upon the information collected in successive study stages.

An overview of the proposed approach is presented in Figure 2.2. If little or no previous monitoring has been carried out, the overall program can consist of up to five phases

including: overall program planning, preliminary analysis and field inspection, outfall/overflow screening, detailed assessment, and process studies. Not every program planning phase will be needed in every study. For example, if there is reason to believe that a particular contaminant is likely present, due to factors such as industry type, a characterization study to estimate loading to the environment could be initiated at the detailed assessment phase. Alternatively, the study objective may be to identify potential problem outfalls for abatement or further monitoring, in which case the study would be terminated at the preliminary analysis phase. The program planning phase should be included in all programs. It is always important to have a clear understanding of the program objectives, and have identified any limitations imposed by budget or timetable constraints.

2.4.2 Levels of Assessment

In general, CSO and UR monitoring programs can be categorized into one of three levels of assessment, as described in Table 2.1:

1. Investigative Assessment
2. Detailed Assessment
3. Process Studies

First level investigative assessment monitoring activities are intended to provide preliminary data. When such data is coupled with planning level modeling tools the relative importance of specific outfalls can be examined, and detailed monitoring priorities can be developed for the second phase.

The first level investigative monitoring should be pilot in nature, not expend significant resources, and be carried out over a relatively compact time frame (e.g. 6 to 14 weeks). The primary purpose is to determine whether a particular contaminant is present in the discharge, and whether identified contaminants can be detected in tissue or sediment samples collected near the discharge. While it may be important to determine the presence of contaminants in the tisues of local biota, the sampling techniques and study design requirements are not within the scope of this report. The first level investigative monitoring is intended to determine whether further detailed assessment is needed.

The purpose of the second level monitoring is to obtain more detailed and exact measurements at sites which have been selected on a priority basis using the results of the investigative assessment monitoring. Detailed assessment monitoring is generally longer in duration than first level monitoring (several months to a year), and involves more flow meter calibration, automated/manual sampling, and local rainfall measurements. Detailed assessment monitoring should result in sufficient data to complete the problem definition (e.g. loading analysis, and receiving water impact analysis) portion of any project and provide at least a reasonable amount of information to develop a short list of possible control alternatives.

Process data may be required to further evaluate remedial control measures for both CSO and UR discharges. The scope for quantity, quality, and rainfall measurements taken during third level process study monitoring activities are similar to the second level detailed assessment program. However, additional large volume sampling is needed to provide adequate fluid for process testing purposes. Specialized sampling may also be initiated to characterize the time variation of quality during selected storm events.

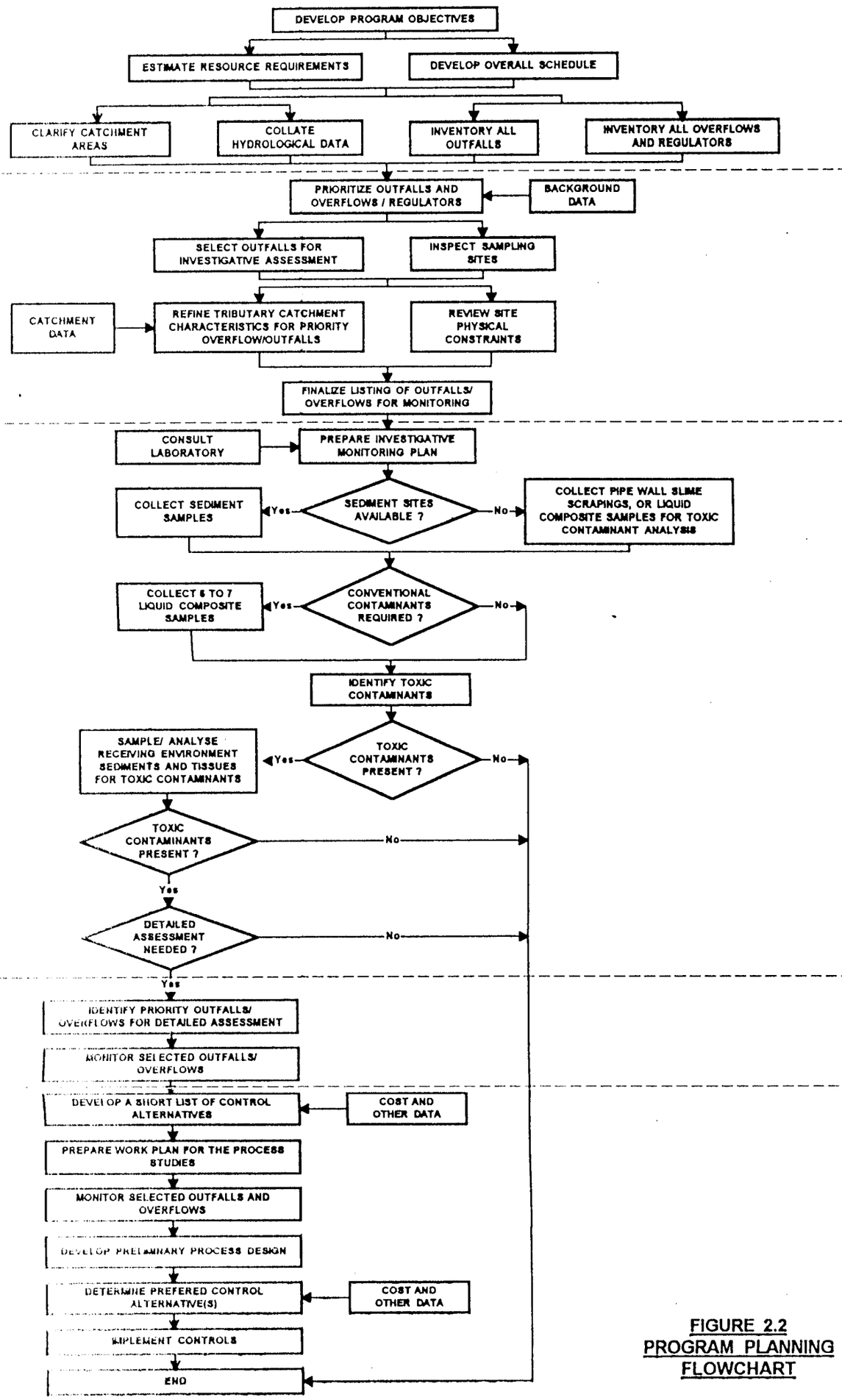


FIGURE 2.2
PROGRAM PLANNING FLOWCHART

Table 2.1 Levels of CSO and Urban Runoff Monitoring

STUDY LEVEL	ACTIVITY	DESCRIPTION	MONITORING
LEVEL 1	INVESTIGATIVE ASSESSMENT	During this phase of activity very little is known about the discharge behavior, or importance vis a vis loadings, presence of specific contaminants, overflow frequency (CSO), and accumulation in the receiving environment.	Monitoring activity at this level is investigative in nature, and aimed at evaluating overflows, outfalls, and the immediate receiving environment for subsequent more detailed investigation.
LEVEL 2	DETAILED ASSESSMENT	Priority outfalls have been identified at this point, and detailed studies are undertaken leading to characterization of individual outfalls or catchments. Studies include data collection for loading assessments, and hydraulic analysis of collection system operation (CSO).	Second level monitoring includes rainfall measurements, automated/manual sampling and calibrated flow monitors including the deployment of instruments and primary elements.
LEVEL 3	PROCESS STUDIES	In the final level of monitoring, more specialized studies are undertaken to develop process parameters for various control alternatives under consideration.	Depending on the nature of processes under consideration usually bench scale or small pilot scale studies are undertaken. Examples of typical studies include disinfection, dose-response experiments and particulate settling tests.

3.0 CSO/UR RUNOFF INVESTIGATION

3.1 CSO/UR Monitoring Matrix

Figure 3.1 presents a monitoring program decision matrix, with reference to the specific aspects of assessing contaminant loading from combined sewer overflows (CSOs) and urban runoff (UR) discharges. Because many of the investigative and detailed assessment procedures have common elements, the sub-section references indicated in Figure 3.1 are not necessarily sequential.

3.2 Contaminant Parameter List

The selection of analytical parameters depends on the potential for toxic contaminants to be present in significant quantities, and the sensitivity of the receiving environment. Storm water discharges have only been recognized as a significant source of environmental pollutants for about the past twenty years. Prior to that, runoff from urban areas was assumed to be essentially "clean water" (U.S. EPA, 1991(c)). Studies such as the Nationwide Urban Runoff Program (NURP), carried out by the U.S. Environmental Protection Agency (1983), and the Great Lakes Basin Study, carried out in part by Environment Canada, have illustrated that runoff from urban and industrial areas typically contains significant quantities of the same pollutants that are found in municipal and industrial wastewaters. Pollutants which have been identified in urban runoff include heavy metals, pesticides, herbicides and synthetic organic materials such as petrochemical compounds.

Combined sewer overflows (CSOs) have been widely recognized in terms of their potential for decreasing the dissolved oxygen concentration and raising the bacterial levels in receiving streams. Studies carried out by Environment Canada and the Ontario Ministry of Environment within the Great Lakes Basin, have illustrated that CSO discharges can also contain significant quantities of toxic contaminants including heavy metals, pesticides, herbicides and synthetic organic materials such as petrochemical compounds.

The large number of CSO and UR discharges into the Fraser River, and the large number of potential contaminants which could be present, make it economically impractical to carry out extensive characterization studies for every type of chemical contaminant on all discharges. Consequently, it is necessary to select a number of specific locations and contaminants for analysis which can be used to reflect the overall picture.

Presented in Table 3.1 is a suggested list of contaminants selected specifically for the Fraser River Basin. A list of conventional contaminants has been included as these

parameters are consistent with the Fraser River Action Plan objectives of reducing disruptive pollutants to satisfy Fisheries Act requirements. The list of toxic contaminants is based on the selected parameter list used by the B.C. Ministry of Environment Lands and Parks for the evaluation in sediments and biota samples collected within the Fraser Estuary (Swain and Walton, 1988). Phthalate esters, which are on the Ministry's list, are not included due to their ubiquitous presence in the environment and the common problems of analytical error for this parameter.

Table 3.1 Suggested Contaminants List

Conventional Contaminants (Liquid Samples)
• Biochemical Oxygen Demand (BOD_5)
• Chemical Oxygen Demand (COD)
• Total Suspended Solids
• Total Dissolved Solids
• pH
• Total Phosphorus
• Total Kjehldal Nitrogen
• Ammonia
• Bacteria (fecal coliform and *Escherichia* coliform)
Liquid and Solid Sample Toxic Contaminants (Swain and Walton, 1988*)
• 12 metals (total and dissolved As, Cd, Cu, Cr, Fe, Hg, Mg, Mn, Mo, Ni, Pb, Zn)
• Chlorinated phenols and Polychlorinated biphenyls (PCB's)
• Polynuclear aromatic hydrocarbons (PAH)
• Organochlorine pesticides

* Excluding phthalate esters.

This list of parameters may be modified depending on the receiving environment characteristics, and potential contaminant sources. For example, additional measures of wastewater strength can be used (i.e. total or dissolved organic carbon) in addition to other conventional parameters such as sediment organic content, alkalinity and conductivity. Generally, measurements such as pH are classified as field measurements, which can also include temperature, dissolved oxygen and residual chlorine. Similarly, the type and number of toxic contaminants could be modified to reflect specific expected wastewater characteristics, or parameters of concern to the receiving environment.

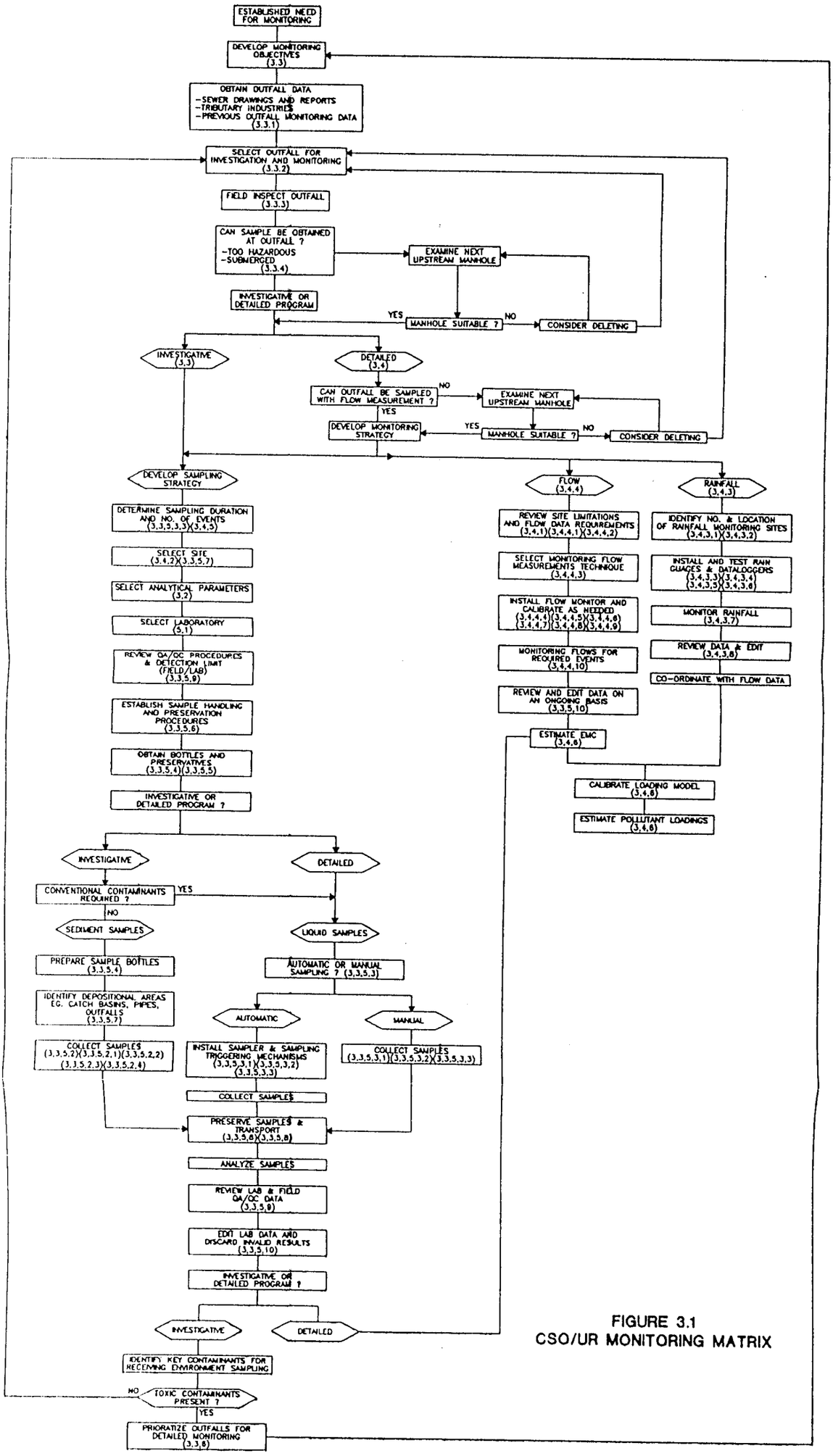


FIGURE 3.1
CSO/UR MONITORING MATRIX

3.3 Investigative Assessment

The primary objectives of the investigative phase are as follows:

- To inventory all outfalls and/or overflows within the study area.
- To systematically evaluate the outfalls and overflows using desktop analysis and field inspection procedures. The purpose of the evaluation is to identify priority outfalls and overflows requiring investigative level monitoring and/or a program of more detailed monitoring. The evaluation is also needed to identify outfalls or overflows which are characteristic of the study area and may be used for developing data useful for loading model calibration.
- To carry out an investigative monitoring program to identify key contaminants being discharged from selected overflows and outfalls.
- To evaluate whether contaminants identified in the collection system are present at significant levels in receiving environment water, sediment or tissue samples collected near the discharge.
- To analyze investigative level monitoring results to identify outfalls requiring abatement action or additional detailed monitoring.

3.3.1 Outfall and Overflow Inventory

The first step in developing a CSO or UR monitoring program is to develop the best inventory possible of all overflow and outfall structures. These structures are the outlets through which the contaminant loadings are discharged to the receiving water. Their number and specific location is important both from the perspective of assessing interactions with the receiving waters, and as a necessary input to any loading analysis models. Indeed the physical details of these structures are essential to any modeling activity.

Initially, the overflow/outfall inventory can be prepared from existing information. Subsequent field investigations will refine the details of the number of discharges, and their location and configuration. The following are sources of data useful for an inventory preparation:

- Sewer maps, atlases and detailed plans;
- Design reports;
- Previous investigative studies;
- Recent aerial photography and/or flood line mapping.

The inventory should be prepared as a database, recorded on a master sewer plan, and possibly on an aerial photograph mosaic or Geographic Information System (GIS). The database should be tailored to the ultimate purpose of the study. For example, if the intent is to ultimately estimate contaminant loadings using some type of model, then the database may contain provisions for catchment characteristics such as area, land-use, and degree of imperviousness.

3.3.2 Prioritization of Outfalls and Overflows

Based upon the data collected during the inventory preparation and upon the overall project objectives, the discharge structures can be prioritized initially for purposes of field inspection and subsequently for monitoring purposes. The factors considered in the prioritization will depend upon available data. As an example, priority settings could be based on the outfall sewer diameter (indicator of discharge volume) and land use (reflection of potential contaminant source) as follows:

1) **Storm Sewer Outfall Diameter**

Score	Size
1	Less than 900 mm
2	900 to 1500 mm
3	Greater than 1500 mm

2) **Land Use**

Score	Land Use
1	Residential (> 80%)
2	Mixed
3	Industrial (>80%)

A combined score rating of four or greater for storm sewer outfall diameter and land-use could be used to identify an outfall as a candidate for monitoring. Ideally a more comprehensive set of factors should be developed to identify priority monitoring sites. A list of factors that could be employed includes:

- Detailed land use breakdown
- Catchment Area
- Outfall Location
- Known Problems
- Source Control Best Management Practices

3.3.3 Field Inspection

Once an initial list of candidate overflows/outfalls have been identified, each proposed site should undergo a field inspection to ensure its suitability for monitoring. Information needs to be assembled on the physical characteristics sites which will assist in planning the monitoring program. Factors which should be examined include:

- **Physical description.** The inventory information should include pipe diameter, discharge depth, distance from shore, nearest access locations, and indications of water level variations or tidal influence. Photographs should be taken of potential sampling and monitoring sites, with particular emphasis on access safety and suitability for equipment installation.
- **Outfall submergence.** If the outfall is submerged or tidally influenced, it will be necessary to take samples at an upstream manhole location. In areas of low topography, this may mean that monitoring will actually take place a significant distance away from the outfall.
- **Tributary information.** Catchment area information should be assembled including land use, industrial and commercial discharge sources and outfall location relative to sensitive areas..
- **Manhole location.** In many instances manholes providing access to regulators and overflows are located in high traffic areas. In such cases, a decision needs to be made as to whether such monitoring locations should be relocated to another less busy site or whether equipment installation, sampling and maintenance should be scheduled during low traffic periods (e.g. late at night). If late night monitoring is not possible, traffic control will be needed which will increase costs.
- **Manhole depth.** Deep manholes create significant access and safety problems and should be avoided if at all possible. Where it is necessary to monitor a deep manhole, monitoring equipment should be of a type requiring minimum attention and ideally allowing remote data retrieval from a near surface position.
- **Flow depth and velocity.** High flow depths and high velocities can be a serious impediment to flow meter installation and maintenance. Other than avoiding locations with such conditions, attempts may be made to enter the sewer at low flow periods or draw down the sewer by pumping. High velocity flows in sewers or at outfalls may also impede the ability to collect either representative samples or adequate sample volumes.
- **Noxious atmosphere.** In-sewer monitoring at locations downstream of certain industries or in long reaches of forcemain may pose access hazards from the standpoint of a toxic, anoxic or corrosive atmosphere. These sites should be avoided if at all possible. Entry into all confined spaces must follow mandatory safety procedures as outlined in this document and may require specialized breathing equipment and manhole ventilators.
- **Hydraulic conditions.** The physical nature of in-sewer or outfall locations may preclude accurate, or for that matter, any flow measurements. For example, manhole sites with confluences of a number of inlet sewers are generally poor locations to implement most types of flow monitoring. Similarly not every site is ideal for locating a sampler intake. Areas of very low velocity can lead to stratification of particulates, and the low flow depth may make it difficult to obtain a representative sample.

- **Site security.** An often important constraint upon monitoring site location is the ability to ensure the security of the monitoring equipment against vandalism or theft. Sites with high potential for vandalism should be avoided or specialized housing will be required for any above ground facilities.

3.3.4 Finalization of Outfall Selection for Investigative Level Monitoring

The outfall selection for investigative level monitoring can be completed following the field inspection stage. The first step involves rationalizing the physical constraints identified during site inspections with the priorities previously identified. A specific investigative level monitoring plan can then be produced addressing objectives, methodologies, constraints, resources and scheduling. This plan forms the standard operating procedures (SOP) for the field crew(s) in executing the program.

3.3.5 Investigative Level Monitoring

3.3.5.1 General

The primary purpose of investigative level monitoring is to identify whether storm sewer outfalls, or discharges, contain specific contaminants of concern. It is generally recognized that many toxic contaminants have a high affinity for sediments (Allan, 1986; Marsalek and Greck, 1984, Marsalek and Schroeter 1988). Consequently, only sediment sampling programs are undertaken at this stage, if sediment sampling sites are available and analysis of conventional contaminants is not required. If sediment sampling sites are not available, samples can be scraped from the pipe wall (slime samples), or a limited number of liquid samples could be collected. If determination of conventional contaminants is required then sediment samples should be collected and analyzed for toxic contaminants, and liquid samples should be collected and analyzed for conventional parameters. As flow or rainfall equipment is unlikely to be available at the sampling site without considerable cost, any liquid composite samples required are usually collected on a time proportioned basis during the investigative phase.

Samples are either examined for extractable concentrations using unfiltered samples, or the samples are filtered, and the liquid and particulate fractions are analyzed separately. Sediment samples can be collected from areas of deposition within the sewer system, or directly off of road surfaces (Section 3.3.5.2.3).

Investigative level monitoring involves the collection of existing data including topographic maps for each catchment area, Atmospheric Environment Service's rain gauge information for the area, physical descriptions and locations of discharges, land use information, and wastewater discharge characterization data.

Generally, the large number of discharges within a urban area, and the high cost of analyses, make it impractical and prohibitively costly to carry out detailed contaminant loading assessments of all discharges. Depending on the number of discharges under consideration, one of two alternative investigative approaches are suggested:

1. Carryout investigative level sediment or suspended solids sampling of key (representative) discharges. This may include: collecting sediment samples from within the sewer during dry-weather periods; collecting suspended solids samples by filtering or centrifuging; or collecting street sediment samples by vacuum.
2. Collect grab, or short term (single event) liquid composite samples from key discharges during storm events, after a suitable period of dry-weather. The dry weather period can vary from 72 hours to several weeks. Typically, at least six representative events should be sampled.

Where practical, investigative assessment should focus on sediment or suspended solids sampling due to the potential of sediments to accumulate in the nearby receiving environment. Identification of key contaminants from liquid samples can be difficult due to dilution effects (i.e. experience suggests many contaminants will be found to be below or near the detection limits). Further, labour costs associated with collecting event samples are greater than for collecting sediment samples.

General principles of sampling urban runoff suggested by Marsalek and Greck (1984) (which also have application to CSO monitoring) include:

- Sediment and liquid samples should be collected in areas with various land uses (industrial, commercial, residential).
- Sediment samples should be collected both in wet and dry periods.
- Liquid samples should be collected as flow-proportioned composite samples where possible.

Sediment and wastewater samples should be collected at, or as near as practical to, the discharge point. Where there are reasons to believe that specific trunks may be significant contributors to contaminant loading, or where personnel safety may be compromised, sampling locations may be moved further into the sewer system. Where direct sampling from the discharge is not possible due to access or submergence difficulties, samples may have to be collected upstream of the discharge.

Ideally, investigative level sediment sampling should be carried out on at least two to three occasions to provide an adequate data base for evaluation purposes. If composite liquid samples are collected, a minimum of six sampling events is recommended.

3.3.5.2 Solids Sampling

The contaminant loading associated with suspended solids can be responsible for as much as 50 percent, or greater, of the total contaminant loading for urban runoff. Marsalek and Greck (1984) found that toxic contaminant loadings transported by solids exceeded those transported by the dissolved (liquid) fraction, particularly for trace elements (mostly metals). For other elements the loadings from the liquid and solid fraction were approximately the same. The mean concentration of toxics in water samples were several orders of magnitude lower than those in sediment.

Recognizing that many metals and organic contaminants tend to adsorb on sediments, analysis of sediments deposited within a collection system is important. Various techniques which can be used to determine what contaminants may be associated with suspended particulates contained within either a CSO or UR discharge include filtration, and centrifugation. Alternatively, the vacuuming of accumulated road sediments has been a successful particulate contaminant sampling technique

3.3.5.2.1 Sewer Sediment Sampling

The transport and deposition of sediments within sewer systems is currently an area of active international research (Ashley et al., 1992a, 1992b). Sewer sediments are characteristically cohesive in nature and highly resistant to erosion. Deposition occurs during periods of dry weather and after storm runoff flows recede. The most important factors affecting deposition are related to the geometry of the sewer system, the velocity range, and the extent of the dry-weather. The larger the design peak flow to dry weather flow, generally, the greater the dry weather deposition rate. The erosion of deposited sediments depends on such factors as the intensity of storm events, the sediment particle size distribution, the length of dry-weather preceding the storm, and the size of the catchment area. There is no simple formula to predict the movement of sediments. Ashley et al. (1992b) reported that in Dundee sewers, the trunk sewer deposits were coarser than those found in interceptor sewers, and had a lower organic fraction. The complexity and variety of the sewer systems made the prediction of the timing of sudden sediment erosion events extremely difficult and inconsistent. For example, the bed shear stress in the Dundee interceptor was observed to vary by up to an order of magnitude. It was near impossible to predict under what conditions a sediment flush will occur.

The association of heavy metal and toxic organic contaminants with particulates, and the deposition of such particulates within the sewer system, provides a method to screen for the presence of specific contaminants. Surficial sediment deposits can be sampled at various locations within the sewer system, and analyzed. While the sediment samples can be used to identify the presence of specific contaminants in the sewers, the results cannot be interpreted in terms of contaminant loading.

Starting at the discharge location, sewer access points should be examined for sediment accumulation. Locations with significant deposits should be identified and prioritized for sediment sampling. The following information should be recorded:

- Station location or identification;
- Depth of sediment present;
- Gross characteristics of the surficial sediment
  - Texture
  - Color
  - Presence of oily sheen
  - Odour (e.g., hydrogen sulfide, oil, creosote).

The sediment samples should be collected using a solvent cleaned flat shovel-like Teflon or stainless steel scoop to a depth of about 2 cm. A curved scoop is not recommended as it does not sample a uniform depth. Non-representative materials, such as pieces of wood and other large debris, should be removed in the field prior to collecting the sample.

Care must be taken to avoid contaminating the sediment sample during collection (use polyethylene disposable gloves), and to minimize the amount of liquid collected with the sample. Excess water should be carefully and slowly siphoned off with a clean Teflon hose. Decanting the sample or pouring the water out of the sample container is not recommended as fine grained sediment or organic matter may be lost.

If the samples are to be analyzed for heavy metals or organic contaminants, ideally all sampling equipment (i.e., siphon hoses, scoops, containers) should be made of Teflon or glass and should be cleaned appropriately before use. Samples should not be touched with ungloved fingers. In addition, areas where potential airborne contamination (e.g., stack gases, cigarette smoke) might occur during sampling should be avoided. This concern can be addressed through the use of travel blanks (Section 3.3.5.9).

Particle size analysis is used to characterize the physical characteristics of sediments. Because particle size influences chemical variables, particle size can be used to normalize chemical concentrations according to sediment characteristics. The most commonly recognized sediment particle size divisions are based on the percentages of gravel (grain size > 5, < 75 mm), sand (> 0.075, < 5 mm), silt (> 0.002, <0.075 mm), and clay (< 0.002 mm). Each of these size fractions can be further subdivided in terms of characteristics of the size distribution, such as mean diameter, skewness, kurtosis.

There are two key reasons for being interested in sediment particle size distributions:

1. Studies (Sartor and Boyd, 1972) have indicated that up to 85 % of pesticides, 95% of lead and 60% of other heavy metals are associated with sediment particles less than 0.84 mm in diameter. Ashley (et al., 1992(a)) found that particulates smaller than 0.25 mm comprise 75 % o the total solids and chemical pollutant load washed in from road surfaces.

2. The distribution of particle sizes affects the ability to transport and treat (remove) the sediments.

Particle size analysis can be carried out either separately, or in conjunction with, the chemical analyses (Section 3.3.5.6.1). The sample can be sieved into two particle size groups for chemical analyses. Xanthopoulos and Augustin (1992) found that settleable solids fall into two major particle groups: medium polluted settleable solids with particle size from 60 to 600 μm and highly polluted settleable solids with particle size from 6 to 60 μm. The 60 to 600 μm range approximately coincides with the size of particles which pass standard sieve size number 30 (US Bureau of Standards). Alternatively, the un-sieved whole sample can be analyzed, and a separate sample be subject to particle size analysis. Preservation requirements for sediment samples are presented in Table 3.3 (Section 3.3.5.6.1).

For the purpose of investigative sediment sampling in sewer systems, the particle size determinations should include the organic material. This results in an "apparent" (i.e. organic plus inorganic) particle size distribution, as the "true" distribution considers only the inorganic fraction. Caution should be exercised in comparing the results of different studies if the method of determining particle size (apparent versus true) is different.

3.3.5.2.2 Suspended Solids Filtration and Centrifugation

Suspended solids filtration and centrifugation are two methods which can be used to collect particulate material from discharges. Normal filtration (0.45 μm filter size) of large volumes of sample can be tedious and may present problems for specific discharges due to filter clogging depending on the characteristics and quantity of sediment present in the wastewater (Burrus et al., 1989). For example Marsalek and Schroeter (1988) found it necessary to use 5.0 μm filters instead of standard 0.45 μm due to the high concentration of solids in the sewage. This was rationalized in reference to Marsalek and Greck (1984) who found that there was a tendency for few solids to exist in the range 0.45-5 μm

Centrifugation has been successfully used in several receiving environmental assessment studies in river systems (Ongley and Blachford, 1982; Horowitz, 1986; Merriman, 1988, Horowitz et al., 1989; Burrus et al., 1989). Its main draw-back is the high capital cost for a centrifuge large enough to process the volumes of stormwater necessary to obtain a particulate sample. The use of centrifuges to collect sediment samples from CSO discharges may be difficult to accomplish, due to the high organic solids content.

A comparison of centrifugation, settling/centrifugation and backflush-filtration methods to concentrate suspended sediment from water for subsequent trace metal analysis was reported by Horowitz (1986). All three techniques are comparable, and can be carried out precisely and accurately. There is less potential for post-sampling alteration of suspended sediment-associated metal concentrations with the centrifugation process because sample stabilization is accomplished more rapidly than with settling/centrifugation.

Horowitz et al. (1989) also evaluated two continuous flow centrifuges and a tangential-flow filtration system for dewatering suspended sediments for subsequent trace metal analysis. Although recovery efficiencies differed, the results showed that any of the devices tested can be effectively and precisely used for dewatering and that they appear to concentrate and dewater suspended sediments equivalently to that obtained through in-line filtration. Continuous-flow centrifugation can process whole water at an influent feed rate of 4 litres per minute, however, when either the suspended solids concentrations are low (<30 mg/L) or when the grain size is very fine (<10 μm), influent feed rates of 2 litres per minute may be more efficient. Tangential flow filtration can be used to process samples at 1 litre per minute.

Environment Canada has prepared a document outlining centrifuge field operating procedures for the collection of river sediments for dioxin analyses (Mitchell, 1992) which should be applicable to urban runoff. While the document outlines procedures specifically for an Alpha-Laval Centrifuge, the following set-up and solids handling guidelines are presented which have general application to the sampling of sediments for toxic contaminant analysis using other centrifuges:

- Use clean Teflon tubing if the discharge water is to be analyzed for organics;
- Place the discharge hose downstream to avoid stirring up sediment near the intake pump;
- Position the generator away and down wind from the centrifuge to prevent possible contamination from the generator exhaust;
- Use Teflon spray lubricant for threaded components around the centrifuge bowl;
- Use a stainless steel wire mesh around the intake nozzle to prevent large debris from entering the pump impeller;
- Use heat treated foil to protect exposed components from contamination;
- Use clean polyethylene gloves to handle all centrifuge bowl components;
- Use detergent washing, deionized water and solvent rinse procedures to clean centrifuge bowl and other equipment components that may come in contact with sediments;

Solids collected by centrifuge for toxic contaminant analysis should be removed from the centrifuge bowl using a Teflon or stainless steel scraper, and, if necessary, the sediment-water slurry should then be pressure filtered through a 0.5 μm Teflon filter. The dewatered solids can then be removed from the filter and placed in a pre-cleaned glass jar and frozen until analyzed.

3.3.5.2.3 Street Sediment Sampling for UR Assessment

Sediment samples collected from road surfaces should be collected using a combination of:

1. **Hand sweeping:** for dry solids collection. The sweeping pattern should be from the center of street towards the gutter. The sample should be collected using a whisk broom and dustpan.
2. **Vacuuming:** removes smaller-sized particles. The pattern is the same as for hand sweeping. An industrial vacuum cleaner with a 5 cm (2 inch) to 7.5 cm (3 inch) diameter hose is recommended.
3. **Flushing with water:** the test area is first slightly wetted to soften attached sediment, and then flushed with a stream of water using a garden hose spray nozzle and the liquid sample is collected.

The sampling equipment required for collecting street sediment includes the following:

- Hard bristle broom, rake, shovel, and foxtail or paint brush
- Alternator power plant, 3500 watt
- Two wet and dry vacuum cleaners, 38 L, with sufficient filter bags. A new filter bag for each sampling (3 vacuum passes)
- Steel drum, 208 L with lid and rim lock, containing 151 - 189 L of water
- Rotary screw pump, 3.5 amperes
- Garden hose
- Galvanized garbage can with clamp fitting lid
- Dual motor shop wet and dry vacuum mounted of a 208 L steel drum
- Sand bags

The sampling procedure recommended by the U.S. EPA (Wullschleger et al., 1976) is summarized as follows:

1. Select a continuous roadway sampling site of 30 metres (100 feet) or more in length. The street surface and curbing should be in relatively good condition. Mark the limits of the sampling length selected.
2. Rake and/or brush along the curb for 3 to 4.5 metres (10 to 15 feet) from the limit markings ***away*** from the section to be sampled.
3. Knock the brush clean. Rake and/or brush from the highest elevation point. Shovel bulk litter plus swept dust and dirt into clean galvanized can

4. Vacuum along entire curb length of the roadway sampling site, out to a distance of 1.2 to 1.5 metres (4 to 5 feet) from the curb. Three vacuumings of the site should be carried out to collect the dust and dirt sample fractions. Two vacuum cleaners are used simultaneously to speed up the operation with particular attention at the litter pick up point.
5. Position several sand bags at the curb of the lower limit of the sampling area to impound the flush water.
6. Place the nozzle of the dual motor shop vacuum at the low point in front of the sand bags so as to suck water into the 208 L drum.
7. Place the intake hose from the rotary screw pump into the 208 L drum filled with water, and begin flushing the roadway using the garden hose.
8. Flush the entire roadway surface area toward the curb, and finish by flushing the gutter toward the sand bags.
9. Approximately 57 to 95 L of water are required to flush 56 to 93 m^2 of roadway. Generally, greater than 50 % of the flush water is recovered by the vacuum.
10. Collect the sample using vacuum-operated collector trap. The inlet hose of the collector trap has a pickup nozzle on the open end. The outlet hose of the collector trap is connected to the industrial shop vacuum.
11. Store the samples in a clean glass containers and cool to 4 ^{o}C.

In contrast to the above procedure, sampling by Marsalek and Greck (1984) and Butler et al. (1992) was carried out using only manual brushing followed by the vacuuming procedure. Butler et al. (1992) selected a Numatic hazardous dust cleaner of 8 litre capacity to collect street sediments because of its efficiency in retaining small dust particles (99.98 % > 0.5μm).

3.3.5.2.4 Receiving Environment Sediment Sampling

The receiving environment investigative sediment sampling program involves the collection and analysis of surface and subsurface sediments to define the horizontal and vertical distribution of contaminated sediments within the benthic environment. Receiving environment sediment sampling methods for investigative level monitoring include:

1. Surface grab sampling;
2. Sub-surface (core) sampling.

Surface Sampling Methods

Samples are commonly collected using an appropriately cleaned 25 by 25 cm Ponar grab or stainless Eckman grab, depending on site specific requirements. Sampling stations can be positioned using either a Loran fix or on a line-of-site basis to shoreline reference

points. Time, depth, and location notes must be taken. Once retrieved, the sample is emptied from the grab into an appropriately cleaned stainless steel tray. A subsample is taken from the center of the sediment sample to avoid contamination from the grab and placed in clean sample containers. All sampling is performed using stainless steel or Teflon instruments washed and prepared as described in Section 3.3.5.5. Generally two jars of sample should be collected. All samples should be preserved as described in Table 3.3.

Sub-Surface Sampling

Sediment cores can be collected by divers or by using a tethered apparatus such as a Phleger-type corer. Selected stations from the grab sampling program can be used for coring. Station locations can be confirmed by establishing a subsurface coordinate grid around a control reference position or by direct chainage from shore positions.

Sediment cores can be collected in a lined or unlined coring device by scuba divers using a slide hammer. Once on station, the slide hammer is lowered by rope to the bottom. The divers then descend with a core tube. Once on the bottom care is taken not to disturb the sediments. The tube is placed on the sediment surface and pushed gently into the sediment until refusal. The slide hammer is then placed on the tube and both divers operate the hammer. Once the core penetrates 1.2 m, or hits refusal, the hammer is removed and a cap is placed on top of the core. Total penetration of the core is noted. The core is rotated and gently removed using the clamp handles. As soon as the core is out of the sediment a cap is placed on the bottom of the core tube. The divers then ascend with the core. Once at the surface, water is decanted from the core, the recovery length measured, and the core tube is stored vertically on deck.

Sub-sampling of the cores can be done on the shore. Sediments are extruded from core tubes with a push rod. The sample is split open with washed stainless steel instruments, photographed and the sediment horizons noted. Each "zone" between sediment horizons is sampled. Samples are taken from the center of the core to avoid "smearing" along the edges of the core which results from the extrusion process.

Using of a Phleger-type corer from a vessel can be considered. However, there are limitations in harbour areas where considerable debris may occur, frustrating the sampling process. Penetration is unknown by this method and as a result the amount of sediment compression is not known. Sample handling of sediments from this type of system is much the same as in the diver obtained cores when they arrive at the surface.

3.3.5.3 Liquid Sampling

3.3.5.3.1 Manual Versus Automatic Sampling

Samples can be collected either manually or with an automatic sampler.

Manual Samples

Manual samples have the disadvantages of being inconvenient and labour intensive. However, the key advantage of manual sampling methods is in the potentially higher quality of sampling. The individual collecting the sample can adapt the sampling methodology to changing sampling conditions (e.g. varying stream levels), and can better ensure that the sample collected is as representative as possible.

Procedures that should be considered in carrying out a manual sampling program include the following:

- Pre-label sample containers before a sampling event;
- Take a cooler with ice to the sampling point;
- Take the sample from the horizontal and vertical center of the channel where turbulence is at maximum;
- Avoid stirring up the bottom sediments in the channel;
- Hold the container so the opening faces upstream;
- Avoid touching the inside of the container to prevent contamination;
- Keep the sample free from uncharacteristic floating debris;
- Transfer samples to proper containers (e.g. from bucket to sample container), however, fecal coliform and fecal streptococcus should remain in pre-sterilized original container and phenols and oil and grease should remain in original container;
- Wear disposable glows.

Automatic Sampling

Automatic samplers have the disadvantages of being capital intensive, and having a greater potential for sampling error (i.e. contaminated hoses, equipment failure, hose blockages, displaced intake, etc.). In addition, automatic samplers cannot be used for the collection of volatile organic compounds (VOC), and should not be used for fecal streptococcus, fecal coliform, chlorine, pH, temperature, oil and grease due to the potential for these parameters to change during compositing and before analysis. The key advantage to automatic samplers is convenience, and the ability to flow composite samples during collection using a flow meter output signal.

The cleaning of automatic equipment is generally requires more time than for manual sampling techniques. The equipment, and particularly the tubing, must be thoroughly and properly cleaned before each sampling event. Deionized water should be drawn through the sampler to remove pollutant residuals, and to verify the sampler is clean (Field Blank, Section 3.3.5.9), and the Teflon lined tubing should be periodically replaced.

For the purpose of collecting samples for toxic contaminant analysis, it is important that the wastewater sampler components consist of inert materials, usually stainless steel or Teflon. The most common type of automatic sampler used in toxic contaminant sampling programs are based on using peristaltic pumps. This is because samples collected using a peristaltic pump only come into contact with the sampling tube, generally composed of a Teflon inner lined hose, and a short length of surgical grade silicon tubing. As can be seen from the summary of automatic sampling devices, and local suppliers, presented in Appendix A, there are a number of vacuum based automatic samplers currently being sold for toxic contaminant sampling. However, such vacuum based samplers systems are generally considered inappropriate due to the potential for hydrocarbon (motor lubricant) contamination. If such samplers are used, it may be prudent to periodically run reagent-grade deionized water through the sampler to check for potential contamination.

Automatic samplers and flow measurement devices can be electronically sophisticated, requiring correspondingly skilled staff to ensure their maintenance and correct operation. Crews must thoroughly understand both the mechanical and strategic operating principles to be able to properly install and calibrate the equipment, and troubleshoot problems in the field. It is common to have crews checking equipment prior to an important sampling event, only to find the equipment inoperative and in need of adjustment or repair.

All samples should be collected at, or just past, areas within the sewer which provide good mixing characteristics. Sampling for volatile organic compounds should avoid areas which are aerated. Where such conditions are encountered, the samples should be collected upstream.

The field sampling program for CSO and UR sampling is designed to collect accurate hydrological information to quantify discharges, and to collect flow-weighted composite samples. If composite sampling is required as a part of the investigative program (i.e. conventional parameter information is needed), the samples should be collected using an automatic sampler and should be flow-porportional (assuming flow measurement is possible). In addition, the water depth (stage) is monitored continuously during each storm event.

In addition to the general location factors described in Section 3.3.3, the following should be taken into consideration in setting up a sampling station:

- The intake for the automatic sampler must be protected from damage from large objects which can be transported within the sewer system during stormwater runoff events. The intake end of the intake-hose should be placed in a cage

constructed of quarter inch stainless steel rod, the purpose of which is to deflect moderate sized objects around the intake and the flow meter pressure sensor. Coarse stainless-steel intake screens are used to reduce the likelihood of blockage within the sample tubing.

- The intake must be located in a well-mixed area which is not subject to burial or submergence. The intake should be oriented to the bottom and intake velocity maximized to minimize sampling error.
- The water velocity within the intake hose must be maximized to maintain particulate material in suspension. A minimum velocity of 0.45 metres per second (1.5 feet per second) should be maintained at all times to prevent solids separation within the sampling hose. Consequently, the sampler should be located as close as practical to the discharge liquid level to minimize the amount of lift required to collect a sample, thereby maximizing the sampling rate and flow.
- For toxic organic contaminants the equipment materials must be either glass, stainless steel, Teflon, or surgical grade silicone rubber. The intake hose should have a 9.5 mm (3/8-inch) inner diameter, and be constructed of polyethylene on the outside and Teflon on the inside. The polyethylene provides physical strength while the Teflon provides a suitable material for handling samples which would be analyzed for either metals or organic compounds. Polyethylene is suitable for conventional contaminants and metals. The bore diameter of the intake-hose is selected to maximize the velocity of the flow within the hose, in order to prevent separation and solids settling within the hose. The inner diameter of 9.5 mm (3/8 inch) is generally necessary to maintain velocities of 0.3 to 0.6 metres per second (1 to 2 feet per second) at head differences up to 6 metres (20 feet).
- Glass sample containers are usually used for toxic contaminant sampling, as the sample container material must be compatible with holding samples to be analyzed for both trace metals and organic compounds.
- Where a peristaltic pump is used for the automatic sampler, it must be capable of delivering consistent sample volumes, regardless of intake hose length and changes in head associated with the rise and fall of stage in the sewer being sampled.
- The automatic sampler should not exceed a head difference of 6 metres (20 feet) above the water in order to avoid low water velocities within the intake hose, and decreased precision in sample volumes.
- While there is no absolute rule for locating the sampler intake within the liquid stream, generally the intake should be placed from 5 to 10 cm (2 to 4 inches) above the bottom. This range is believed to be a reasonable compromise between avoidance of bedload transport and keeping the intake submerged.
- A stage discharge relationship should be developed at each station. Weirs and flumes should be used to measure flow when appropriate (e.g. approach velocities are small, good upstream conditions).In order to ensure the integrity of sample results, a number of cleanliness, security and preservation procedures should be carried out in the field.

- All of the field equipment coming into contact with the samples must be washed with methanol and rinsed with organic-free distilled water prior to sampling.
- Prior to sampling, the equipment should also be pre-rinsed with the sample stream before the first sample is taken.
- For security measures against breakage in transport, or at the laboratory and QA reasons, all samples should be collected in duplicate (not necessarily analyzed).

Section 3.3.5.6 and Tables 3.3 and 3.4 present the preservation methods for solid and liquid samples, respectively. In addition to the specific preservation methods illustrated in the tables, all bottles should be stored at 4 ^{o}C (ice with water) in the field, and during transport.

3.3.5.3.2 Grab Versus Composite Sampling

There are two primary methods of collecting storm related wastewater samples: (1) Grab; and (2) Composite.

Grab Samples

Grab samples are single samples collected at one point in time, and used for a number of reasons including:

- To assess time-varying wastewater characteristics (e.g. changes in concentrations during a storm event);
- To determine wastewater characteristics which may change during storage (i.e. bacterial levels, volatile compounds);
- To provide a single wastewater characteristic profile which requires minimal labour or equipment costs.

Grab samples are best suited to assess variable run-off characteristics caused by sewer flushing or surface wash-off during rainfall events, where the variation pattern is of interest, and the analytical costs are low (i.e. first-flush concentration variations in suspended solids and biochemical oxygen demand).

Grab samples are generally collected as a number of discrete samples of at least 100 mL, taken within a short period of time (less than 15 minutes) during the first 30 minutes of the discharge. Wastewater characteristics which cannot be assessed using composite sampling techniques, and hence must be grab sampled include:

a) pH;

b) Temperature;

c) Cyanide;

d) Total phenols;

e) Residual chlorine;

f) Volatiles;

g) Oil and grease;

h) Fecal coliform, E. coli, and fecal streptococcus.

Composite Samples

Composite samples are formed by combining a series of individual and discrete samples of specific volumes, at specified flow-weighted or time intervals, into a common container for analysis. Composite samples characterize wastewater quality over a longer period of time, in comparison to grab samples. Composite samples collected during a storm event must be collected throughout the first 3 hours of the discharge, or the entire discharge event (if it is less than 3 hours).

Composite samples are intended to reflect the "average" wastewater characteristics during the time of monitoring (i.e. a storm event). Composite samples provide a single integrated wastewater characteristic profile. Generally, composite samples provide a more representative wastewater characteristic profile than single grab samples, as they are collected over a longer period of time. This is particularly true where the wastewater characteristics vary with time. A single grab sample could be collected at either a time period of lower or higher than "average" concentration, and thereby bias the analytical interpretation.

In general, composite samples are more suitable than grab samples for assessing contaminant loading characteristics. There are several general advantages to estimating pollutant loading to the environment using composite sampling strategies including:

- Composites provide a practical summary of highly variable wastewater characteristics;
- Costs of analyses are substantially lower than for discrete sampling programs;
- More storm related discharge events can be sampled and analyzed due to the fewer number of analyses per discharge event.

The key disadvantages are that the approach does not provide any resolution as to the minimum or maximum concentration of any parameter during the discharge event, and that some parameters may not be detected due to dilution.

There are four basic types of composite samples:

1) ***constant time (Tc) - constant volume (Vc):*** simple composite
2) ***constant time (Tc) - volume proportional to flow rate (Vv)*** samples are taken at equal increments of time and composted proportional to the flow rate at the time each sample was taken
3) ***constant time(Tc) - volume proportional to flow rate since last sample (Vv)***:

4) ***constant volume (Vc) - time proportional to flow volume increment (Tv)*** where the number of uniform volume samples collected per unit time is varied proportional to flow

Table 3.2 illustrates the effect variations in concentration, and flow rate, with time, have on the four composite methods, in terms of the analytical results versus the actual "average" concentrations. There are two key conclusions that can be drawn from Table 3.2:

1. Most of the flow/concentration combinations have ratio values less than 1.0, indicating there is an overall tendency to underestimate the actual "average" concentration, regardless of the method of compositing.
2. There is little practical difference between the four methods of compositing for most of the concentration/flow relationships shown. Although the constant time (Tc) - volume proportional to flow rate (Vv) method is generally considered to be the most suitable compositing technique, any of the four methods will generally achieve acceptable results.

Typically, composite samples are collected using one of following three techniques:

1. Automatic sampler withdrawing one individual aliquot each hour. All of the aliquots can be manually composited on a flow proportioned basis at the end of the sampling event or after each 24 hour period.
2. Automatic sampler interfaced with flow measurement devices so that the flow weighted hourly aliquot volumes can be directly added to one composite container.
3. Hourly aliquots can be grab sampled and composited manually on a flow proportioned basis at the end of each 24-hour period.

For the purpose of investigative sampling, where accurate flow measurement devices are not typically available, time proportioned samples are generally adequate.

3.3.5.3.3 Sampling Events and Conditions

Dry Weather Monitoring

Although stormwater events are not generally associated with dry weather, dry weather periods can be important from a monitoring planning perspective. For example, field screening can provide a preliminary determination about the existence, extent and location of illicit connections with sanitary sewers and/or industrial discharges, illegal dumping activities, spills, leaking sanitary sewage systems, and infiltration of polluted ground water.

Table 3.2
RATIO OF COMPOSITE SAMPLE CONCENTRATIONS TO ACTUAL "AVERAGE" CONCENTRATIONS
(Shelley and Kirkpatrick, 1975)

CONC k ⇨ / FLOW Q ⇩	1 - t	1 - (t/2)	cos(πt/2)	e-t	sinπt
C	0.90 0.90 0.90 0.90	0.97 0.97 0.97 0.97	0.92 0.92 0.92 0.92	0.95 0.95 0.95 0.95	0.99 0.99 0.99 0.99
t	1.35 09.0 0.86 0.87	1.09 0.97 0.96 0.96	1.26 0.90 0.87 0.89	1.14 0.97 0.95 0.95	0.99 0.90 0.89 0.97
1 - t	0.68 0.95 0.92 0.92	0.87 0.98 0.97 0.97	0.72 0.98 0.95 0.93	0.82 0.96 0.95 0.95	0.99 1.12 1.09 0.97
sinπt	0.90 1.01 0.90 0.90	0.97 1.00 0.97 0.97	0.88 1.00 0.92 0.92	0.97 1.00 0.95 0.95	0.80 1.01 0.98 0.97

NOTES:

LINE 1. $T_C V_C$ - Simple composite

LINE 2 $T_C V_V$ - Volume proportional to flow rate (Q)

LINE 3 $T_C V_V$ - Volume proportional to flow rate (Q) since last sample

LINE 4. $T_V V_C$ - Time varied to give constant ΔQ

WHERE: T_C = Constant Time Interval V_C = Constant Volume

T_V = Variable Time Interval V_V = Variable Volume

Observations regarding the colour, odour, turbidity, and the presence of oil or surface scum should be noted, and grab samples can be obtained of any discharges noted. Ideally, 2 grab samples should be collected during a 24 hour period, with a minimum period of four hours between samples. Field estimates can also be made of such parameters as:

- Flow rate;
- pH;
- Total chlorine;
- Total copper;
- Total phenol;
- Detergents;
- Fecal coliforms.

First Flush

Pollutant transport during individual storms is not usually constant, but varies depending on such factors as the rainfall intensity, the degree of contaminant accumulation on the catchment surface, and the cohesiveness of sediments and particulate deposits within the catchment area. The accumulation and subsequent movement of particulates and soluble materials during a rainfall event can result in a "first-flush" phenomena. First-flush phenomena commonly exhibit the highest concentration of contaminants, particularly conventional parameters, in the runoff during the early portion of the runoff event which usually coincides with an increase in flow.

CSO discharges can also exhibit a first flush effect, often occurring during the initial stages of the CSO event identified when the biochemical oxygen demand (BOD_5) and the total suspended solids (TSS) concentrations rise above the dry weather concentration.. The presence of a first flush is evaluated by collecting discrete sewage samples on a timed interval bases during CSO events to establish a period of greatest concentration.

A CSO first-flush can contain high concentrations of soluble organic matter, with total suspended solids (TSS) and chemical oxygen demand (COD) levels reaching in the order of four times greater than the expected concentrations for dry-weather flow (Saul and Thornton, 1989). This phenomena is believed to be caused by a highly mobile fraction of in-sewer sediment deposits which accrue in the antecedent dry-weather periods. Research carried out in the UK have demonstrated the sewer sediments are cohesive in nature, and may not be re suspended until a critical hydraulic condition has been attained, complicating the prediction of sediment transport rates. Parameters such as the effect of concretion and the change with age of the physical, chemical and biological properties within the deposited sediments need to be taken into account (Saul and Thornton, 1989; Ashley et al., 1992). Consequently, it is extremely difficult to predict what hydraulic conditions are necessary to re suspend sediments deposited within the collection system.

Although first flush events are commonly associated with extended dry periods, followed by extensive precipitation (i.e. end of the summer or early fall), high contaminant concentrations can also occur as a result of snow-melt. Contaminants originated from rain or snow can be stored in snow packs, and transported, both hydraulically and by snow drifting and disposal (Marsalek, 1991). Pollutant deposition and accumulation increases during winter months due to such factors as combustion of heating fuels, less efficient vehicle combustion, increased road wear, and the application of de-icing material on the roads. Pollutants are initially stored within the snow packs and then are preferentially eluted as the packs melt, with soluble contaminants, such as acid depositions, being eluted first and hydrophobic contaminants last. For example, polynuclear aromatic hydrocarbons have been shown to remain within the snow pack until the last 5 to 10 percent of the snowpack remains (Schondorf and Herrman, 1987). Winter runoff and snowmelt have been shown to transport up to 60 percent of the annual runoff load of selected contaminants (Zariello, 1990).

With respect to investigative sampling of first flush events, grab samples can be collected. Where the run-off is from a relatively small catchment area, such as an industrial site, the grab sample should be collected during the first 30 minutes of the discharge. For larger catchment areas the sample should be collected at the beginning of the storm, but not necessarily within the first 30 minutes. Consequently, the scheduling and timing of first-flush events for small catchment areas is more critical than for larger catchment areas.

Storm Event Sampling

The sampling of storm events for investigative assessment purposes is less critical, in terms of timing and scheduling, than for first-flush events. Where possible, flow proportioned composite samples should be collected during the first three hours of a storm event discharge. The storm event should be proceeded by at least 72 hours of dry weather, and should have an accumulated precipitation (depth) greater than 2.5 cm (1 inch), and the rain depth and duration should not vary more than 50 % from the average depth and duration (where feasible) that may occur in a given year.

3.3.5.4 Sample Bottle Cleaning Procedure

Sample bottle cleaning is best left to the analytical laboratory, unless sampling crews are thoroughly trained in cleaning procedures. All of the laboratories described in Section 5.0 can provide sample bottles and collection preservation instructions for the samples to be collected. Preservation instructions usually involve shipping the bottles in coolers, with freezer packs and preservation chemicals, if/when appropriate. It is important that the laboratory be consulted well in advance of the actual sample program and provided with complete information on the parameters to be tested, including the detection limits required. This information is essential for the laboratory to determine the sample volumes and sample containers required for the specific project. It is recommended that the laboratory be contacted at least a week in advance for sample containers.

Cleaning Procedure for Conventional Contaminants

The following procedure is recommended for cleaning glass or plastic sampling containers or sample bottles where the containers are being used to collect or store samples for conventional contaminants analysis:

The volume of each rinse should be a minimum of 2 to 3 % of the container volume (Marsalek and Greck, 1984).

1. Wash containers with detergent and hot water;
2. Rinse 2 to 3 times with hot water;
3. Rinse 2 to 3 times with distilled water;
4. Air dry;
5. Cap the containers;
6. For re-used BOD and COD glassware, a chromic acid wash is recommended following the hot water rinse.

Cleaning Procedure for Toxic Organic Contaminants

The following procedure, established by the Inland Waters Directorate, Water Quality Branch, Ontario Region (Marsalek and Greck, 1984), is recommended for cleaning glass sampling containers, or sample bottles, where the containers are being used to collect or store samples for toxic organic contaminants analysis:

The volume of each rinse should be a minimum 2 to 3 % of the container volume (Marsalek and Greck, 1984).

1. Wash containers with detergent and hot water;
2. Rinse 2 to 3 times with hot water;
3. Rinse 2 to 3 times with distilled water;
4. After draining water, rinse 2 to 3 times with analytical grade acetone and petroleum ether;
5. Rinse 2 to 3 times with pesticide residue grade ethyl acetate;
6. Rinse with pesticide residue grade hexane;
7. Air dry;
8. Cap clean bottles with solvent washed aluminum foil.

The US EPA recommends rinsing with dichloromethane chloride instead of petroleum ether (step 4), since dichloromethane chloride is capable of dissolving a greater number of possible contaminants. Glassware used during laboratory analysis should be heat treated for 12 hours at 325 ^{o}C in an air forced circulated oven.

Cleaning Procedure for Heavy Metal Contaminants

Recommended cleaning procedures for glass and plastic containers used for heavy metal contaminant sampling includes the following:

1. Detergent and tap water wash;
2. Tap water rinse 2 to 3 times;
3. 10% HNO_3 rinse;
4. Rinse 2 to 3 times with distilled/deionized water;
5. Total air dry;
6. Cap the containers

The volume of each rinse should be a minimum 2 to 3 % of the container volume (Marsalek and Greck, 1984). A record should be kept of the staff performing the cleaning, and the date and time of cleaning

3.3.5.5 Automatic Sampler Cleaning Procedures

Automatic sampler should be cleaned both between sampling events and/or sampling sites. The following outlined procedures are applicable to both peristaltic and vacuum samplers.

Cleaning Procedure for Conventional Contaminants

The Teflon hose, sample collection chamber and stainless steel components should be cleaned according to the following procedure:

1. Rinse with approximately 3 L cleaning solution (e.g. FL-70 detergent and hot tap water);
2. Rinse with minimum 9 L of hot tap water;
3. Rinse with approximately 3 L of sample wastewater prior to composite sampling start.

Cleaning Procedure for Toxic Organic Contaminants

For toxic organic contaminants the Teflon hose, sample collection chamber and stainless steel components can be dismantled and should be cleaned according to the following procedure (Mitchell, 1992):

1. Flush with hot/warm tap water for at least one hour.
2. Pour approximately 1 litre of cleaning solution (e.g. FL-70 detergent and hot tap water) into the hose using a clean stainless steel funnel.
3. Using a small piece of heat-treated foil or dioxin-free cloth, rinse the soap solution back and forth through the hose at least three times, and drain.
4. Repeat step 3 using deionized water followed by three successive organic solvent rinses (acetone, hexane, and dichloromethane). The solvent rinsing must be done in a large well ventilated room with the hoses fully extended, and all personnel must wear appropriate safety gear.
5. After solvent rinsing, the ends of the hose should be covered with a double layer of heat-treated foil, and taped to the hose casing to prevent contamination.
6. The drained solvent should be immediately poured into a waste solvent container to minimize atmospheric contamination of the room.

Cleaning Procedure for Heavy Metal Contaminants

The Teflon hose, sampling collection chamber and stainless steel components should be cleaned according to the following procedure for heavy metal contaminant sampling:

1. Rinse with approximately 3 L of cleaning solution (FL-70 detergent and hot tap water);
2. Rinse with minimum 9 L of hot tap water;
3. Rinse with 10 % HNO_3;
4. Rinse with deionized water;
5. Rinse with approximately 3 L of sample wastewater prior to composite sample start.

3.3.5.6 Sample Preservation and Storage Requirements

3.3.5.6.1 Solids Samples

Samples of 100 to 150 grams should be collected and stored in glass or Teflon containers. The length of time prior to analysis, preservation requirements and storage conditions depend on the contaminants being analyzed for. General minimum sample volumes and preservation requirements are presented in Table 3.3. If large organic debris is present, the material should be removed and noted in the field log. If particle size analysis is to be carried out, the samples must not be frozen or dried prior to analysis, as either process may change the particle size distribution (Ashley et al., 1992(a)). Instead, the sediment samples for particle size distribution analysis should be stored (for a maximum of 6 months) in amber bottles at a temperature of 4 ^{o}C until analyzed.

3.3.5.6.2 Liquid Samples

Table 3.4 presents a summary of container and preservation requirements for various conventional and toxic contaminant parameters. Where glass bottles are required for sample storage, the bottles should be made of amber glass.

Sample collection for parameters such as oil and grease, volatiles, or bacterial analyses must be collected as a grab sample, as indicated in Table 3.4. The sample volumes indicated should be confirmed with the analytical laboratory before the sampling program is carried out. The minimum recommended sample volumes shown in Table 3.4 do not include toxicity bioassay volume requirements, which are specific to the test being conducted, and beyond the scope of this document.

Table 3.3
SEDIMENT SAMPLE COLLECTION AND PRESERVATION

ANALYSIS	SAMPLE VOLUME	PRESERVATION
Volatile Organics	250 mL	4°C (analyze immediately)
Base Neutral & Acid Extractable	250 mL	Freeze
Pesticides & Herbicides	250 mL	Freeze
Dioxins/Furans	250 mL	Freeze
ICAP, Mercury, Cyanide	500 mL	Freeze
Conventionals	250 mL	Freeze
Phenolics	250 mL	Freeze
Chlorinated phenols	250 mL	Freeze
Particle size	250 mL	4°C
Organic content	250 mL	4°C

Table 3.4

SUMMARY OF CONTAINER AND PRESERVATIVE SPECIFICATIONS

(Standard Methods for the Examination of Water and Wastewater, 1989)

PARAMETER	CONTAINER	MINIMUM SAMPLE SIZE (mL)	PRESERVATION**	MAXIMUM HOLDING TIME** (days)
Acidity	P, G(B)	100	4 °C	1
Alkalinity	P, G	200	4 °C	1
Bacterial*	P, G (sterilized)	100	4 °C	6 hours
BOD_5	P, G	1000	4 °C	6 hours
TOC, DOC	G	100	Add HCl to pH<2; 4 °C	7
COD	P, G	100	Add H_2SO_4 to pH<2; 4 °C	7
Colour	P, G	500	4 °C	2
Conductivity	P, G	500	4 °C	28
Cyanide	P, G	500	Add H_2SO_4 to pH<2; 4 °C; dark	1
Metals (elemental scan)	P(A), G(A)	-	Add HNO_3 to pH<2	180
Mercury	P(A), G(A)	500	Add HNO_3 to pH<2; 4 °C	28
Ammonia	P, G	500	Add H_2SO_4 to pH<2; 4 °C	7
$NO_2 + NO_3$	P, G	200	Add H_2SO_4 to pH<2; 4 °C	none
NO_3	P, G	100	4 °C	2
NO_2	P, G	100	4 °C	none
TKN	P, G	500	Add H_2SO_4 to pH<2; 4 °C	7
Odour	G	500	4 °C	6 hours
Oil and Grease	G, wide-mouth calibrated	1000	Add H_2SO_4 to pH<2; 4 °C	28
Organics*	G, TFE-lined cap	3000	none	30
Pesticides	G(S), TFE-lined cap	-	1000 mg ascorbic acid/L if residual chlorine present; 4 °C	7 (40 after extraction)
Phenols	P, G	500	Add H_2SO_4 to pH<2; 4 °C	-
Purgables by purge and trap	G, TFE-lined cap	50	Add H_2SO_4 to pH<2; 4 °C	7
DO (electrode)	G, BOD bottle	300	-	0.5 hours
pH	P, G	-	-	0.5 hours
Phosphate	G(A)	100	4 °C	2
Solids	P, G	-	4 °C	7
Sulphate	P, G	-	4 °C	28
Sulphide	P, G	-	Add 4 drops of 2N ZnAc/100 mL; Add NaOH to pH>9; 4 °C	28
Volatiles*	G, TFE-lined cap	-	4 °C	14

* Reference: US Federal Register 40CFR 136

** Some variability may exist between commercial laboratories and given preservative specifications. The appropriate procedure should be clarified before samples are collected.

G(A), P(A) = rinsed with 1+1 HNO_3 G = glass

P = plastic (polyethylene or equivalent) G(S) = rinsed with solvents

G(B) = glass, borosilicate

Analytical parameters which warrant special attention, in terms of treatment or preservation, include the following:

A) Cyanide:

Any residual chlorine or sulfides must be eliminated prior to adjusting the pH of the sample to a pH greater than 12. The removal of residual chlorine and sulphides can be accomplished in the following manner:

a) Residual chlorine identification and removal:

1) Test sample using potassium iodide-starch test paper;
2) If residual chlorine is present, add ascorbic acid 0.6 g at a time until test is negative; add additional 0.6 g of ascorbic acid.

b) Sulfides identification and removal:

1) Test sample using lead acetate paper moistened with an acetic acid buffer solution;

2) If sulfide is present, add cadmium nitrate in a manner similar to the ascorbic acid addition;

B) Volatiles:

An amber glass vial with a Teflon-coated septum seal is required. The samples must be collected as grabs. Do not composite samples in the field. If desired, compositing can be: carried out either procedurally in the laboratory, or mathematically once the analyses are complete. Grab samples for volatile organic compound analyses should be collected three times per day at least two hours apart. The equal volume samples should then be .combined into daily composite samples at the analytical laboratory

The sample collection procedure includes the following steps:

a) Fill the vial until a reverse meniscus forms above the top of the vial;

b) Screw on the cap;

c) Invert the vial to check for the presence of air bubbles;

d) If air bubbles are observed, the vial should be opened, emptied, then completely refilled.

C) Organics and Pesticides

All samples for organic and pesticides analyses must be stored in amber glass containers. All residual chlorine must be eliminated prior to adjusting the pH to between 5 and 9. The residual chlorine can be removed from the sample in the following manner.

a) Residual chlorine identification and removal:

1) Test sample using colour indicator test;
2) If residual chlorine is present, add ascorbic acid 0.6 g at a time until test is negative; add 80 mL of 0.008 % $Na_2S_2O_3$ per 1L of sample until test is negative.

D) Oil and Grease:

Oil and grease samples should be collected as grab samples using a 1L glass container which has a Teflon insert in the container's lid. The sample should not be transferred to another container.

3.3.5.7 Sampling Site Selection

The selection of sampling sites is usually governed by a number of factors including:

1) Distribution of urban areas in the study area;
2) Local contaminant sources;
3) Land uses;
4) Accessibility to site.

The number of sampling sites is determined in the planning stage and is limited by the availability of:

1) Analytical support;
2) Budget;
3) Field equipment;
4) Personnel.

3.3.5.8 Sample Documentation and Labeling

Ideally, sample bottles should be labeled with a non-water soluble marker prior to going to the sampling site. This avoids potential confusion in mislabeling, or forgetting to label, samples in the field during the sampling program. Information which should be on the label includes the following:

- Sample type and number;
- Source of sample, including facility name, address and sampling location;
- Date and time of sample collection (start/end for composite samples) and date, time and documentation of sample shipment;
- Analysis required;

- Preservatives used;
- Comments including sampling personnel and flow rate (if available).

Information pertaining to the collected samples should be recorded in a field log, similar to that shown in Table 3.5. The samples should be carefully packaged in a shipping container, for delivery to the laboratory. Glass bottles should be wrapped in foam rubber, or other shock absorbent material, to prevent breakage. All container lids should be sealed with tape and the samples should be stored in ice. The ice should be wrapped in water-tight bags. The laboratory copy of the sampling log should be placed in a waterproof envelope and taped to the inside of the transportation case. Finally, the shipping case should be sealed and directly delivered to the laboratory.

Table 3.5
Sampling Program Field Log Example

FIELD FORM FOR IN-SEWER SAMPLING	
event type;	
location;	
field sheet number;	
date/time of sampler activation;	
date and time of sample retrieval;	
volume collected;	
field sample number or code;	
sampling equipment check/clean verification;	
flow meter interrogation check verification;	
comments and observations;	
field blank sample number;	
other.	

Most laboratories have developed chain-of-custody (COC) procedures and documentation. The COC documents, if not completed in the field, must be completed on receipt at the laboratory. Any analyses contracted-out should also be tracked with COC forms for the samples shipped to another laboratory.

3.3.5.9 Quality Assurance/Quality Control Procedures

Ideally twenty to twenty-five percent of the total samples collected, and submitted to the laboratory for analysis, should be for Quality Assurance and Quality Control (QA/QC) purposes. From practical perspective (i.e. budgetary) typically only 5 percent are used for QA/QC purposes.

Field QA/QC procedures begin by ensuring that all instruments used in the field to measure a quantity, or which have an expected performance level, are calibrated prior to use. Calibration records should be maintained including:

- Type and brand of instrument;
- Date of calibration;
- Method of calibration;
- Instrument response;
- Name of individual/company.

The following field quality control samples should be considered for use in the sampling protocol:

a) ***Travel Blanks*** - used to assess potential sample contamination occurring during shipment, storage, lab handling and analysis. Travel blanks are important only for sampling programs involving the analysis of volatile organic compounds, which may migrate from one container to another. Travel blanks should be filled at the lab with reagent-grade deionized water, transported to the sampling site, and returned to the lab for analysis. A minimum of 5 % of the samples collected should be travel blanks, and should be provided for in the program budget.

b) ***Bottle Blanks*** - used to determine whether sample containers are sources of contamination. One bottle blank should be prepared for each box of sample containers. This is particularly important where the bottles are recycled from other programs and have been subject to cleaning procedures.

c) ***Field Blanks*** - used to assess potential sample contamination occurring during field collection, handling, shipment, storage and analysis. Field blanks should be filled with reagent-grade organic free distilled water in the field and handled with identical procedures as samples. The purpose of the field blank collected, and subsequent analyses, is to establish whether contamination is being introduced into the samples from the sampling equipment or preservation methods, transportation, and/or laboratory handling.

   A "grab" sample field blank is prepared by rinsing organic-free water in the grab sampling container prior to sampling. The rinse water is then placed in the sample

bottle and preserved using methods appropriate for the compounds to be analyzed (see Table 3.4).

If an automatic sampler is used for toxic organic analysis, an automatic sampler field blank should be prepared using organic-free distilled water, which is pumped through the sampler tubing prior to sampling. As above, the water is then bottled and preserved according to the prescribed methods (Table 3.4).

In order to determine the sources of contamination, if any, it is necessary to compare the field blank results with the laboratory method blank results. Ideally, a minimum of 5 % of the samples collected should be field blanks, and should be provided for in the program budget.

d) ***Field Replicates*** - used to assess natural sample variability, or variability attributable to field collection, sample handling, shipment, storage and analysis. Field replicates should be obtained by filling sample containers, at the same sampling location, at the same time. Ideally, a minimum of 5 % of the samples collected should be field replicates, and should be provided for in the program budget.

e) ***Surrogate Spikes in Field Samples:*** Surrogate spiked samples are used to estimate the recovery of organic compounds. The surrogate compound has similar physical and chemical characteristics to the compound of interest, and is a compound which is not expected to be in the sample. Surrogate compounds are the only means of checking method performance on a sample by sample basis. The amount of recovery of the surrogate spike is used to indicate the recovery of the target compound from the sample, and the variability of the compound recovery. The number of surrogate spikes required depends on the target compound, as follows (PTI Environmental Services, 1991):

- A minimum of five surrogate spikes (three neutral and two acid compounds) when analyzing for semi-volatile organic compounds;
- A minimum of three surrogate spikes when analyzing for volatile organic compounds;
- A minimum of one surrogate spike for each extracted sample as a check on the recovery of pesticides;
- A separate surrogate compound in each extracted sample to check the recovery of PCB mixtures.

All samples should be "randomly" marked in such a way that the laboratory is "blind" as to the sample identity, or location of sampling. The purpose of the random labeling is to avoid systematic analytical error, or bias, such as may be introduced by instrument calibration drift, from affecting sequential samples. This is particularly important for bacteriological samples, which are greatly affected by storage time. The laboratory should also be instructed to document the date and time of analysis.

In addition to the field QA/QC program, a number of laboratory QA/QC measures should be regularly used in the **laboratory** for quality assurance of the analytical results including the following:

f) ***Method Blanks:*** Method blanks are used to assess potential sample contamination attributable to lab analysis procedures. A method blank should be analyzed routinely along with each batch of samples to identify possible contamination contributed by glassware, reagents, other samples, etc. The method blank analyses are used for two main purposes.

1. Each day of analyses, method blank concentrations of each contaminant should be averaged for all of the blanks analyzed that day. The average value is used to correct the concentrations of the particular contaminant in the samples on a given day.
2. The method blank results for all of the analyses were used to determine if the background "noise" level is too high to use the data for a particular contaminant with confidence.

A method blank consists of an uncontaminated distilled water sample that undergoes identical preparation methods (e.g. extraction, purge and trap) and is analyzed with the field samples. A method blank should be analyzed each time the instrument is set up for a new batch of samples. Method blanks should be tested daily at the beginning of each analytical sequence and then one method blank per 10 samples per day.

g) ***Duplicates:*** Duplicate samples are defined as two aliquots taken from a single sample and carried through the same analytical process. The purpose of duplicate analyses is to provide a measure of analytical precision. This is carried out by comparing the differences of each set of duplicates, and determining if the differences are statistically significant.

h) ***Matrix Spikes in Distilled Water Samples:*** A known amount of standard mixture containing selected compounds to be analyzed in the sample is spiked into a reagent water sample, which subsequently undergoes the same preparation and analyses as the field samples. The percentage recovery is documented, and the following two results are the used to evaluate the applicability of the data for each batch of samples:

1. The recovery of the native compound from the distilled water blank analyzed for each batch of samples.
2. The recovery of the spiked compound from all of the distilled water blanks for the entire study.

The samples should be spiked prior to any extractions as a part of analysis. One matrix spiked sample should be analyzed for every set of 20 or less samples.

i) ***Duplicate matrix spiked samples*** - should be analyzed each time matrix spiked sample is analyzed. One duplicate matrix spiked sample should be analyzed per 10 samples per day.

The QA/QC data should be evaluated in the following manner:

1. ***Precision:*** is a measure of the variability of individual sample measurements. Assessed from analysis of replicate samples and from the use of duplicate matrix spiked samples. Measured as the percent difference in the duplicate measurements:

$$Pi = (Yi - Xi)/(0.5[Yi + Xi])*100$$

Where:

Pi - precision of duplicate pair i
Yi - concentration for primary sample i
Xi - concentration for duplicate sample i

2. ***Accuracy:*** is a measure of the system bias, or the difference between the mean of the true sample values, and the mean of the measured values. Accuracy is assessed using matrix spiked samples (the bias in lab procedures) in conjunction with travel blanks (bias introduced by sample handling, shipping and lab procedures), field blanks (bias introduced by contaminated sampling equipment, sample handling, shipping and lab procedures) and method blanks (bias introduced by lab procedures)

$$Ai = (Yi/Xi)*100$$

Where:

Ai - accuracy of compound i
Yi - measured spike concentration in sample i
Xi - known spike concentration of sample i

3.3.5.10 Evaluating Laboratory Data

As described in section 3.3.5.9, a quality assurance and quality control (QA/QC) program is an integral component of any monitoring program. The QA/QC component forms a significant component of the analytical costs. Many analyses require expensive instrumentation and stringent quality procedures to ensure accurate and reproducible results.

Although laboratories usually participate in inter-laboratory studies, for the comparison of a variety of analytical procedures, it should be noted that there is no registration mechanism in British Columbia for organic parameters (such as dioxins), as there is for

conventional parameters (i.e. BOD_5, TSS, nutrients, metals, etc.). All laboratories follow Quality Assurance/Quality Control (QA/QC) procedures for toxic contaminants including blanks, duplicates, standards, and matrix spikes. Where possible, field replicate samples, and spiked samples, should be included with field samples, with sample identification such that laboratory personnel are "blind" as to the sample identity, and sampling location. This will aid in carrying out an unbiased assessment of sampling and analytical error, essential to data interpretation.

There are four steps in evaluating laboratory data (PTI Environmental Services, 1991):

1) **Checking Data Completeness**

Once the data has been received from the laboratory it should be checked for completeness including verifying that all samples submitted are reported, the methodology is documented, the required QA/QC data is included, the precision of analytical methods and measurement bias, and a statement of sample holding times and conditions.

2) **Selecting a Data Validation Level**

Once the data has been determined to be complete, the data must be reviewed to determine if errors are present due to mis-identification, transcription of data or mis-calculation. The data is then compared with established criteria for acceptable performance in terms of analytical limits. The effort expended in data validation should be proportional to the intended use of the data and ranges from acceptance of the laboratory internal review to a detailed review of all sample data and laboratory quality control data. Higher validation levels may be applied only to a portion of the analyses which is considered to be more critical.

3) **Evaluating Data Quality**

The precision and accuracy are calculated as described in section 3.3.5.9. The following six factors are then reviewed to determine whether the data is acceptable:

a) Is the information complete?

b) Are the calibrations acceptable?

c) Are the blanks acceptable?

d) Is the Bias level acceptable?

e) Is the Precision Acceptable?

f) Are the detection limits acceptable?

Table 3.6 presents the Puget Sound Estuary Program warning, and action limits for calibration and quality control samples, for the analysis of organic compounds, as an example of criteria for evaluating data quality (PTI Environmental Services,

1991). The decision to accept or reject data must be based on such factors as how extensive are the limits exceeded, and the overall quality of the data. Some of the data may be rejected outright, or further documentation may be requested of the laboratory.

4) **Assigning Data Qualifiers**

Data qualification is usually performed by an QA/QC specialist. The data may be qualified in terms of outright rejection, or as a minimum or maximum estimate, depending on the extent and number of exceeded limits.

Table 3.6
PUGET SOUND ESTUARY PROGRAM WARNING, AND ACTION LIMITS FOR CALIBRATION AND QUALITY CONTROL SAMPLES (PTI ENVIRONMENTAL SERVICES , 1991)

ANALYSIS TYPE	RECOMMENDED WARNING LIMIT	RECOMMENDED ACTION LIMIT
Ongoing calibration	Project manager decision	> ±25 percent of the average response measured in the initial calibration
Surrogate spikes	< 50 percent recovery	Project manager decision
Method blanks	Exceeds the limit of detection	Exceeds the practical quantification limit
Reference materials	95 percent confidence interval, if certified	Project manager decision
Matrix Spikes	50 - 150 relative percent difference	Project manager decision
Spiked method blanks (check standards)	50-150 relative percent recovery	Project manager decision
Analytical replicates	35 percent coefficient of variation (standard deviation divided by the average)	> ±50 percent coefficient of variation (or a factor of 2 for duplicates)
Field replicates	Project manager decision	Project manager decision

3.3.6 Data Analysis and Identification of Priority Outfalls For Detailed Assessment

The results of monitoring are now combined with any previously collected data, and outfalls requiring detailed monitoring, or abatement, are identified. The investigative level sampling program may detect the presence of specific contaminants of concern which may warrant further investigation either by the fact of their presence alone, or by the concentrations observed in the liquid or sediment samples collected. As the monitoring program is investigative in nature, the results should be reviewed with regulatory agencies to determine whether detailed assessment is required. Factors which have to be taken into consideration include:

- Type of contaminants detected;
- The contaminant levels detected;
- The number of samples in which the contaminant was detected;
- Known sources of the contaminant within the collection system;
- Annual discharge volumes;
- The sensitivity of the receiving environment.

It is not possible to state specific criteria which would warrant carrying out a detailed assessment of contaminant loading from a given discharge. The decision to carry out a detailed assessment needs to be made in consultation with regulatory agencies, taking into consideration characteristics, such as that noted above. For example, a trace concentration of dioxin in a sediment sample may not, in itself, indicate that a problem exists. However, detailed assessment may be warranted if repeated samples consistently are positive for dioxins, potential sources of dioxin are known to exist within the collection system, and/or the catchment area is large.

Alternatively, toxic contaminant concentrations in liquid samples could be compared with receiving water quality objectives, allowing for an appropriate dilution factor. Assuming a nominal initial dilution factor of five to one, the criteria level for further investigation could be set at five times the maximum ambient water quality objective set by the B.C. Ministry of Environment Lands and Parks for the Fraser River (Swain and Holms, 1985).

3.4 Detailed Assessment

3.4.1 General

A work plan for a detailed assessment program can be established once the overflows/outfalls requiring detailed monitoring have been identified. The work plan should address the issues of objectives, physical constraints, resources, methodology and timetable.

The sampling strategy must be statistically based and not carried out in an unplanned manner. Sample collection methodology cannot be based solely on convenience factors if meaningful data are to be collected. For example, the depth of sample collection may be critical for representative solids assessment. Similarly the sampling of storm events is rarely convenient in terms of sampling conditions or the time of day during which rainfall events occur.

A minimum of six samples is required to obtain an adequate representation of the average annual pollutant concentration at a reasonable cost (U.S. EPA, 1983; Marsalek and Schroeter, 1984, Paul Theil Associates Ltd., 1992). Based on practical experiences reported in the literature, the number of failed attempts to collect a representative sample may equal the number of successful sampling events. Factors resulting in failed sampling attempts include insufficient storm duration resulting in inadequate sample volumes, and equipment malfunction resulting in a false sampling or no sample. A site visit is required after every event, regardless of the event size, to retrieve samples and/or ensure the equipment is ready for the next sampling event. Consequently, up to twelve sampling attempts may be required to successfully collect six representative samples.

3.4.2 Site Selection Considerations

Once a particular stormwater discharge has been identified for detailed sampling, the sewerage system information compiled during the investigative assessment phase must be reviewed to select a site or sites for detailed sampling and flow measurement. The following list presents a number of factors which must be taken into consideration in selecting a monitoring site:

- **Accessibility and safety:** avoid manholes on busy streets, sites with a history of surcharging/submergence and locations which tend to invite vandalism.
- **Ability to measure flow:** ideally the site should be suitable for flow measurement and automatic sampling.
- **Rain gauge location:** if a rain gauge is to be installed, consideration should be given to the location criteria presented in Section 3.3.2.

- **Distance from upstream discharges:** the sampling site should be far enough downstream from tributary inflow (to ensure mixing).
- **Straight length of sewer:** the straight length of sewer leading to the sampling site should be at least 6 sewer widths below bends.
- **Turbulence:** the sampling site should be located at a point of high turbulence to ensure a representative sample is collected.
- **Cost of installation:** the cost of installation should be minimized.

All sampling should follow the guidelines for wastewater sampling outlined in Section 3.3.5. The main difference between wastewater sampling for investigative versus detailed assessment purposes is the need for rainfall and flow measurement information to enable modeling and estimation of annual contaminant loads.

3.4.3 Rainfall Monitoring

3.4.3.1 Purpose

CSO and UR discharges primarily result from the surface runoff of rainfall. As the generation of stormwater flows in each catchment area varies depending on catchment characteristics, such as surface cover, size and slope, the collection of rainfall data is an essential element of a monitoring program. Rainfall data provides a means of verifying the accuracy of flow measurement, and predicting the impact of a given storm event on CSO/UR generation.

The basic information related to storm events which must be determined includes: total precipitation (mm/inches of precipitation per event); total duration of the sample event (hours); and time since the last measurable precipitation.

In some cases the installation of rainfall measurement stations by local agencies may be unnecessary. The Atmospheric Environment Service (AES) operates a network of rain gauge stations throughout Canada. If an AES gauge (or gauges) exists in a suitable location within a catchment in which UR is to be monitored, additional installations may not be required. The AES may also supply and install rain gauges and assist in the analysis of data provided that the data is of value to them, the local agency agrees to operate the gauge for a suitable period of time, and the equipment receives suitable exposure.

Developing a relation between rainfall and discharge is important as the relation can be used to derive probable discharge volumes on the basis of historical rainfall records available from long-established AES gauge stations. Often, a computer model is calibrated using rainfall and flow monitoring data. The calibrated computer model and rainfall data can then eliminate a costly flow monitoring program.

3.4.3.2 Site Selection Criteria

Improper siting of rain gauges can lead to considerable inaccuracies in the data collected. Gauges should be located at sites representative of the area for which the data is being gathered (i.e. sites influenced by small scale geographical or man-made features unique to the site should not be selected if they are not common to the area being monitored). Rainfall data representative of the average rainfall experienced in the catchment basin in which the UR monitoring is taking place is required. In relatively flat catchment basins, sites near the centre of the catchment are generally suitable. However, for example, if the catchment contains mountainous areas, the siting of the gauge will most likely have to be adjusted in order that a rainfall measurement representative of the average rainfall in the catchment is obtained.

Consideration should be given to the following four points in selecting rain gauge locations:

1. Site locations to be avoided include:
   - Tops of hills;
   - Hollows, bottoms of narrow valleys;
   - Locations in close proximity to hills, ridges or cliffs;
   - Near isolated ponds or streams;
   - Near roads where snow clearance operations or dust can affect site;
   - Areas of excessive human or animal traffic;
   - Areas where drifting snow accumulates;
   - Areas where heat is exhausted by vehicles, planes or buildings.
2. To prevent a rain shadow effect, rain gauges should be located at a distance from vertical obstructions at least four times the height of the obstruction; if the terrain rises abruptly (i.e. a steep cliff), it should be treated as an obstruction subject to the same minimum distances.
3. If the location is obstructed by trees, it is recommended that the distances be increased to allow for growth.
4. Distant trees and buildings are beneficial as they tend to break up wind currents; wind shields may be necessary in locations where high winds are expected to cause measurement errors.

A suitable rain gauge network density is required in order that resultant storm generated discharges may be predicted. The spatial variability of precipitation and the intended uses of the rainfall data are the primary factors in determining the gauge density necessary. For example, more extensive rain gauge networks are needed when modeling studies are to be conducted or rainfall in mountainous terrain is to be described. Also affecting the number

of gauges will be watershed size and prevailing storm patterns. No precise methods for determining the optimal density of rain gauge networks have yet been developed. However, recommendations regarding rain gauge densities may be found in the literature. Studies are also available which investigate adequate rain gauge densities for the characterization of precipitation patterns and watershed runoff through mathematical or empirical means (Eagleson and Shaake, 1966, Hendrick & Comer, 1970.; Osborn et al., 1972).

3.4.3.3 Equipment Selection

There are two basic types of rain gauges: (1) standard gauges; and (2) recording gauges. As a standard rain gauge simply collects rainfall, changes in rainfall intensity with respect to time cannot be noted without making frequent observations during a storm. Consequently, recording gauges are generally more appropriate as they provide a permanent record of the amount of rainfall accumulating over time. Three commonly used recording type gauges are the Tipping Bucket Gauge, the Weighing Type Gauge, and Float-recording Gauge.

A summary of select rain gauge equipment and local suppliers is presented in Appendix A.

Tipping Bucket Gauge

The tipping bucket gauge operates by funneling water into one compartment of a two-compartment bucket. After a known quantity of water fills the compartment, the bucket is overbalanced and empties into a reservoir, moving the second bucket into place beneath the funnel. The tipping of the bucket actuates an electric circuit which records the event. It should be noted that while the bucket is tipping, rainfall may still be collecting in the already filled compartment, thus potentially providing slightly erroneous results during heavy storm events. However, most commercial gauges are designed to compensate for this by measuring the total rainfall collected in the gauge reservoir independently of the bucket tips and prorating the difference through the period of excessive rainfall. This type of gauge is not suitable for measuring precipitation in regions receiving snowfall, because while the collector may be heated, deficient catches may result due to convective currents and increased evaporation.

Weighing Type Gauge

This gauge weighs the rain or snow falling into a bucket on the platform of a spring or lever balance. The increasing weight of the bucket and its contents is recorded, providing a record of the amount and intensity of precipitation. This type of gauge is suitable for both rainfall and snowfall measurement.

Float Recording Gauge

This type of rain gauge measures the rise of a float with the increasing catch of rainfall. The precipitation is emptied manually from some gauges, while others are self-siphoning. Heavy rainfall conditions may result in inaccurate measurements for self-siphoning devices, as rain will continue to enter the collection chamber during the time needed to siphon. This type of gauge is not recommended in areas where freezing conditions may be experienced, as floats may be damaged if the rainfall catch freezes.

3.4.3.4 Installation

For specific installation procedures, manufacturers guidelines should be adhered to. However, the following installation considerations generally apply:

- The rain gauge should be located on open, level ground;
- A primary fenced area at least 30m x 30m, covered with short grass, within a protected area (centred on the primary area) of 90m x 90m, should be provided;
- The top rim of the gauge must be level and not dented or chipped;
- The rain gauge should be mounted on a concrete base, unless the underlying surface is firm, hard-packed, clay soil.

3.4.3.5 Calibration

Rain gauges are typically calibrated at the factory and manufacturers generally suggest that re-calibration is unnecessary unless the gauge has been damaged in shipment or mishandled during installation. Regardless, it is wise to ensure correct calibration of the instrument after installation and at subsequent maintenance periods.

A rain gauge calibration check may be readily accomplished by transferring a known quantity of water into the gauge's collector and ensuring that the ensuing reading/action is in agreement. For example, to check the calibration of the Tipping Bucket Rain Gauge, a graduated cylinder can be used to measure out the quantity of water which is to cause the bucket to tip. If the bucket does not tip when this quantity passes into the compartment, the manufacturers instructions for re-calibration should be followed.

It should also be ensured that the clocking devices on the various rain gauges in operation are synchronized in order that data may be effectively correlated.

3.4.3.6 Maintenance

Ideally the rain gauge should be inspected prior to the onset of a storm to ensure it is in working order. A regular maintenance program should be followed which includes the following:

- Ensure no obstructions are shielding the gauge;
- Examine the collector for damage, i.e. dents or chips in the rim;
- Ensure the funnel is not obstructed with leaves, grass, dirt etc.;
- Ensure that the collector is level, particularly during the spring when heaving may occur as a result of frost;
- Check the accuracy of the time display;
- Grass should be no longer than approximately 5 cm within a distance of approximately 2 m of the gauge;
- Ensure an adequate power supply is available;
- Touch up any paint scratches on metal components;
- If a paper chart is being used to record data, replacement of chart and cleaning or replacement of pen may be necessary;
- Oil the pivot point of the Tipping Bucket Rain Gauge.

If the gauge is to be left outside during the winter, the accumulated snow and ice should be removed from inside and around the gauge after each snowfall.

A log should be kept of all maintenance activities. This record should confirm that all preventative maintenance work has been completed, and should describe the condition of the apparatus before and after any work was undertaken.

3.4.3.7 Monitoring and Recording

There are two forms in which the rainfall amount may be logged: (1) by time interval monitoring; or (2) by event monitoring. Time monitoring continuously records the amount of rainfall at specified time intervals, the choice of which will depend on the event detail desired and on the power and memory availability. Event monitoring notes the time of a specified event (i.e. the tipping of a bucket, or the achievement of a specified incremental increase in level). This method requires less memory capacity, and provides more detail on the intensity of a storm, than time monitoring.

Data may be recorded either by mechanically operated paper charts, or electronic data loggers. Paper charts are susceptible to numerous problems. Due to their mechanical nature, difficulties in connection with the drive mechanism or ink flow may arise.

Additionally, the paper charts require manual interpretation and digitizing, which can be both time consuming and subject to significant error. The cost of analog and digital data loggers has dropped considerably in the past few years. A lithium powered data logger, capable of storing 32,000 records, can be purchased for less than $1000 CDN.

3.4.3.8 Data Analysis

The rate and volume of discharge can be predicted using relationships derived from rain gauge network data, and accurate flow measurement information. Some rainfall data analysis may have already been conducted by the Atmospheric Environment Service (AES) for their installations. Depending on the duration of record, information regarding storm patterns (typical rainfall distributions), evapotranspiration, rainfall extremes, rainfall intensity/duration/frequency (IDF), seasonal variations and hourly time interval rainfall may be available. Data typically comes available on electronic media (i.e. diskette, tape or modem) approximately one year after the storm event. This time delay is required for data verification, adjustment and processing. However, unverified and unadjusted data, in recording chart form, may be obtained within a few days of a storm event. If a multiple of AES gauges exist within or near a catchment, single representative rainfall amounts may be derived by calculating an arithmetic mean or by using the Thiessen isoheytal methods (Linsley et al., 1982).

3.4.4 Flow Measurement

3.4.4.1 General

Flow measurement is required for collecting composite samples and for assessing mass loading. There are numerous techniques and types of flow measurement equipment which could be used to monitor UR flows. Similar to rain gauge equipment, flow measurement can be conducted manually or automatically. Manual systems would involve a person to record the data, such as water level, and calculate the flow based on this information. Automatic equipment can be used to record depth and, in some circumstances, velocity, with the data being recorded and converted to flow units automatically. The equipment cost generally ranges from $5000 to $7500. However, a high degree of skill and experience is often required to set up automatic flow measurement equipment so that the information gathered is meaningful. This is largely due to factors such as extremely unsteady flow conditions, channel obstructions and regulator characteristics.

Weirs and flumes are commonly used in measuring stormwater flows as they have a relatively simple relation between liquid depth and flow rate. There are a variety of weirs which are well suited to stormwater flow measurement and can give accurate results if properly installed. One of their advantages is cost as they can be either purchased prefabricated or fabricated at nominal cost. Their key disadvantage lies in the relatively restricted flow range.

3.4.4.2 Site Selection

CSO and UR discharges are characteristic of the area from which collection takes place. Factors which determine the discharge quality, such as land use, climate, and traffic intensity, should be taken into consideration in selecting representative locations for sampling (i.e. representative of industrial vs. agricultural, high vs. low rainfall etc.).

The CSO control structure often presents a suitable location for overflow measurement since, overflow regulation is typically achieved by a simple weir structure which can be relatively easily and economically adapted to measure overflow.

In general, the selection of sampling locations should consider the following:

- Avoid heavy traffic areas due to concerns for worker safety and potential equipment sensitivity to vibration.
- Avoid excessive turbulence at the sampling location. Sampling locations at confluence points, steep sections, changes in conduit slope and in close proximity to bends in the conduit are not recommended.
- Ideally, the sampling locations selected should be free, or relatively free, of surcharging, and backwater effects, as the occurrence of surcharging or backwater effects will place restrictions on the selection of equipment.
- Avoid sites in close proximity to electro-mechanical devices to prevent interferences.

3.4.4.3 Equipment Selection

Accurate flow measurement in combined and storm sewers is difficult as the flow measurement devices must perform accurately under adverse conditions with flow ranges of as high as 100:1. The following sections describe some of the more common methods of flow measurement and their suitability to the monitoring of flow under these circumstances: hydraulic structures, used in conjunction with level sensors; and velocity meters, which generally incorporate a level sensor. In addition, siting requirements for specific methods are given. While many flow meters can be adapted to various situations, the manufacturer's specifications and recommendations should be reviewed in conjunction with the particular monitoring locations, conditions and requirements for optimal results.

A summary of select flow measurement devices, and local suppliers, is presented in Appendix A.

3.4.4.4 Hydraulic Structures

A hydraulic structure, also known as a primary flow measurement device, is a control structure which creates a relationship between the depth of flow at a specific location, and the rate of flow, when placed in an open channel. Weirs and flumes, which are the most common primary devices, have been designed to provide a known, repeatable relationship between flow and depth. Tables for depth to flow relationship can be obtained from text and hand books on open channel flow, such as ISCO Open Channel Flow Measurement Handbook (1979).

Weirs

Weirs can be relatively easily constructed and inserted into flow streams, and are the least expensive type of primary device. Flow rate in the channel is determined using the equation associated with the type of weir being used (i.e. V-notch, rectangular) and knowledge of the head at a specified location upstream of the structure. Combined sewers generally use various types of weirs to direct low flows to the sewage treatment facility and high flows to a combined sewer overflow conduit. Therefore, CSOs can be best measured at the overflow weir structure.

Several limitations and siting constraints should be considered prior to the selection of a weir as a primary structure:

- The flow capacity of the channel may be reduced and backwater effects may be created upstream, which could potentially lead to upstream flooding of properties.
- A considerable amount of debris may be deposited behind the weir, thereby necessitating regular maintenance.
- The site location should allow the weir to be installed to prevent any "leakage" (especially "underflow" in ditches and natural watercourses).
- Weirs are generally considered more accurate than flumes; their accuracy however can be affected by variations in approach velocity.
- Overall accuracy figures are a combination of weir accuracy and the accuracy of the level measuring device; weir measurements are not highly accurate, particularly with excessive approach velocities and debris (+/- 10%)
- Sufficient space is required to locate the level sensing probe upstream of the weir, a minimum of four times the maximum weir head (the maximum weir head equals the distance between maximum and minimum water level flowing over the weir, e.g. distance from the bottom to the top of the "V" notch weir).
- The approach upstream from the weir should be straight for a distance at least 20x the maximum expected head of liquid and should have insignificant slope (baffles may however be installed to aid in achieving a uniform velocity distribution upstream).

- While, with certain provisions, a weir may still be effective under submerged conditions, it cannot be used under completely submerged (surcharge) conditions.

Figure 3.2 is an illustration of a rectangular weir installed at a sewer outfall. Of particular note is the presence of a stilling well connected well upstream of the weir. Rectangular weirs are subject to sedimentation on the upstream side of the weir, which can affect accuracy. Figure 3.3 illustrates two alternative weirs, the vertical slot weir and the modified trapezoidal weir, which are not affected by sedimentation.

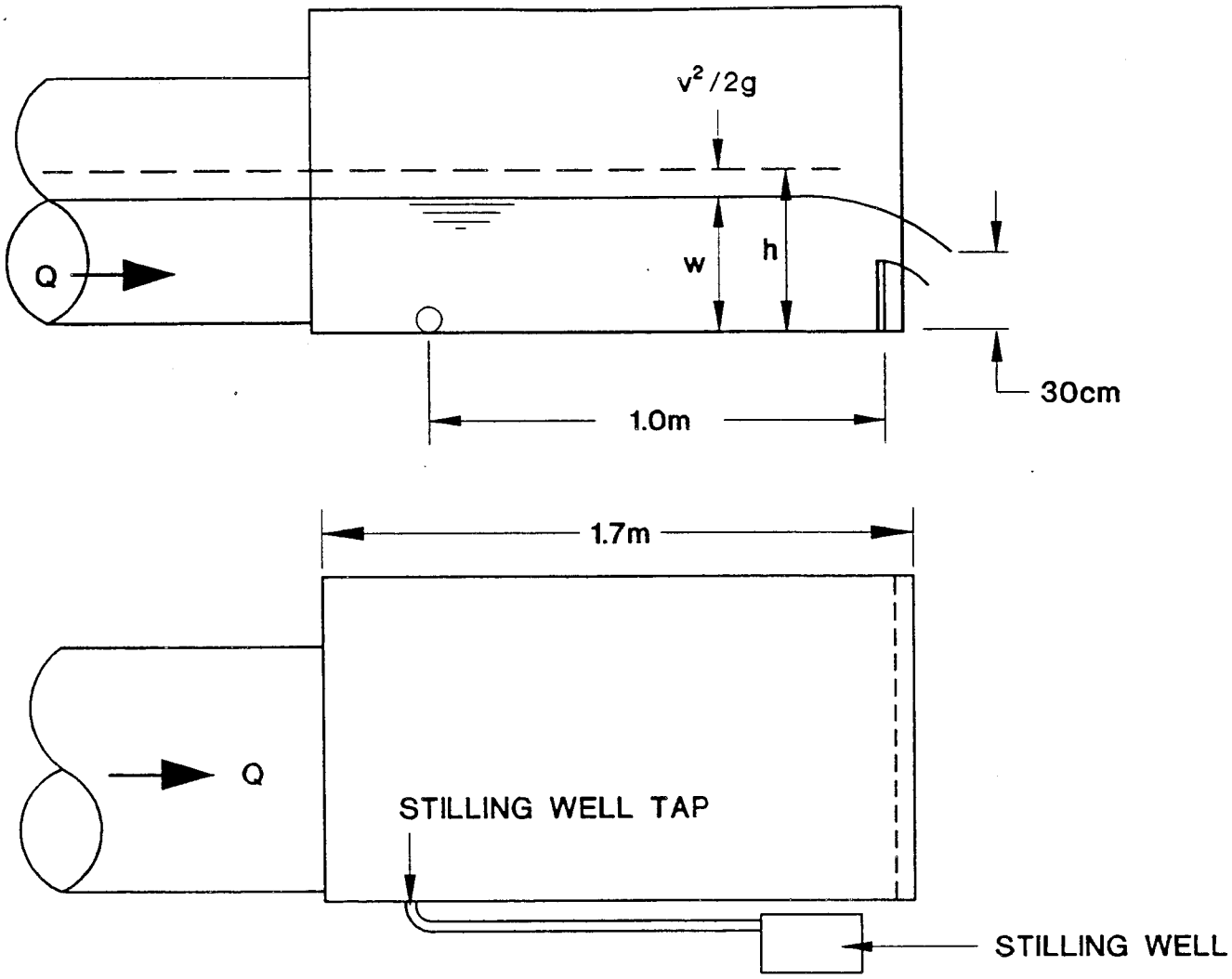
Flumes

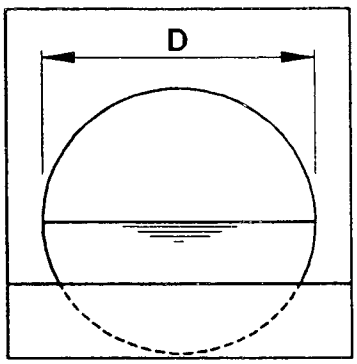
Flumes restrict the flow of liquid through a channel in such a manner that the freely moving flow through the constriction can be calculated from a measurement of upstream water level. The advantages offered by flumes in comparison to weirs include relatively low head losses (approximately 25% less in some cases), the ability to self-clean to a certain degree, and less of an effect on accuracy by approach velocity. Several types of flumes are available (Figure 3.4 to 3.6), although Parshall and Palmer-Bowlus flumes are the most commonly used in sewer systems.

Parshall flumes are available for most flow rates, and in some cases can allow a minimum to maximum flow range of 20:1. However, because the Parshall flume channel is rectangular and requires a head drop of at least 70 mm, it is difficult to install in sewers, and is primarily used for permanent installations. Palmer-Bowlus flumes are widely used in the sanitary field as they can be easily installed for temporary flow measurement in existing conduits. The useful range of flow rates is less than that of Parshall flumes, rarely exceeding 20:1.

The following points should be considered in the installation of flumes:

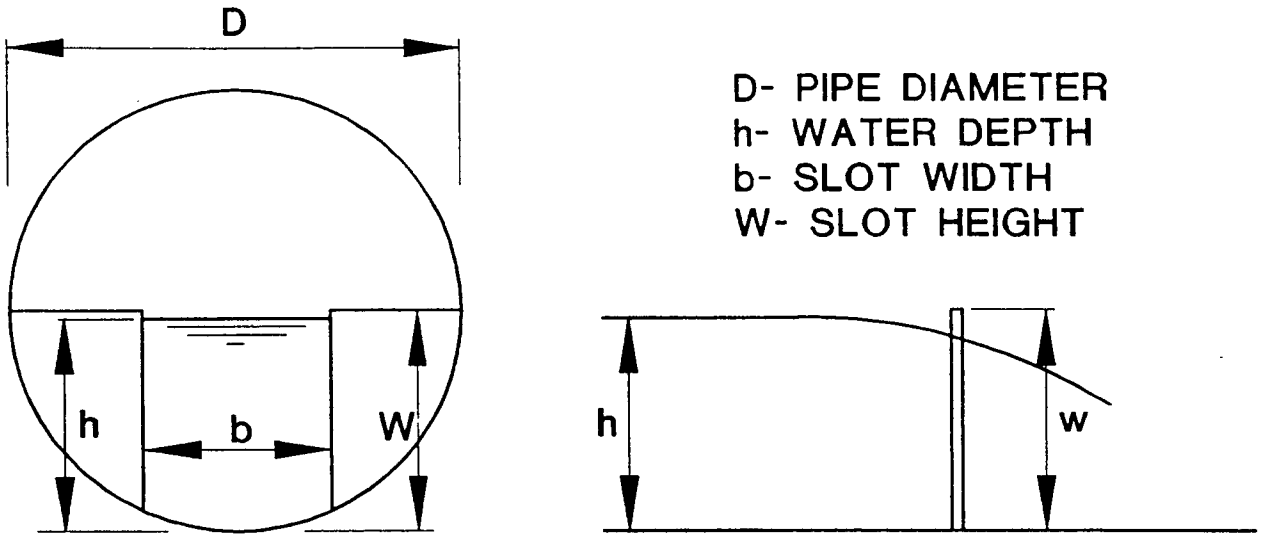
- Temporary flumes may not be available and installation may be cumbersome for large diameter channels.
- Approximately 10 channel widths of straight run should exist upstream of the flume inlet to create a symmetrical, uniform velocity distribution.
- Although ideally sites with high approach velocities should not be selected for flume installation, data accuracy may not be significantly affected if the water surface just upstream is smooth with no surface boils, waves or high velocity current concentration.
- Accurate results are difficult to obtain when flows fall below 10% of the rated capacity of the flume.
- Overall accuracy figures are a combination of flume accuracy and the accuracy of the level measuring device - flume measurements themselves are not highly accurate (+/-10%).



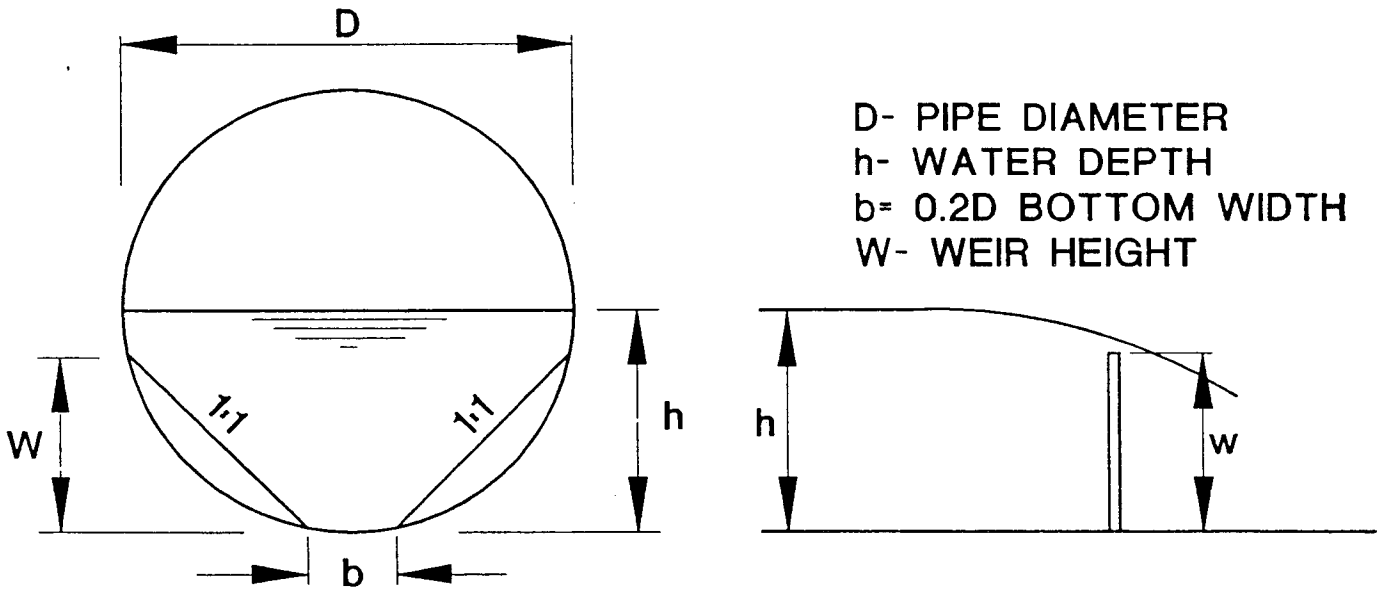


Q- FLOW RATE [m^3/s]
V- AVERAGE VELOCITY [m/s]
g- 9.81 [m/s^2] GRAVITY ACCELERATION
W- WATER DEPTH [m]
h= $W + \frac{V^2}{2g}$ WEIR HEAD
D- PIPE DIAMETER

FIGURE 3.2
RECTANGULAR WEIR INSTALLED AT A SEWER OUTFALL

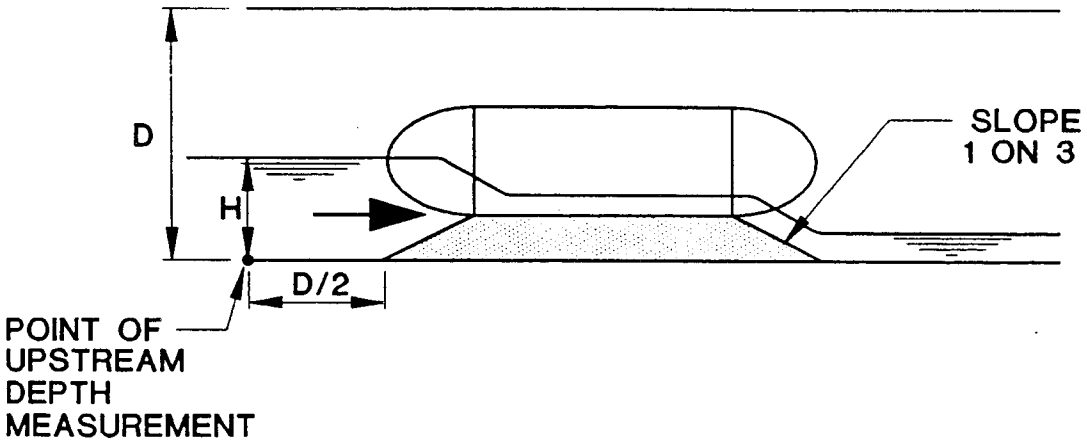


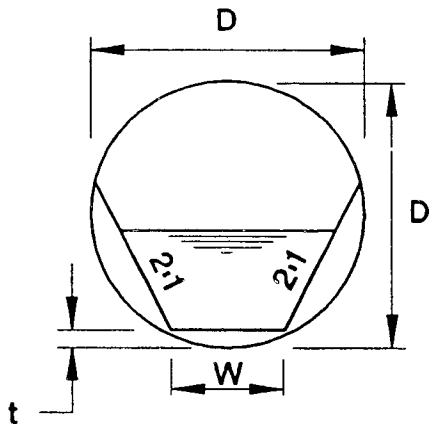
(A) VERTICAL
SLOT WEIR



(B) MODIFIED
TRAPEZOIDAL
WEIR

FIGURE 3.3
VERTICAL SLOT AND MODIFIED TRAPEZOIDAL WEIRS





D- PIPE DIAMETER

W- $\frac{5D}{12}$

t- $\frac{D}{12}$

H- WATER DEPTH

FIGURE 3.4
PALMER-BOWLUS FLOW MEASURING FLUME

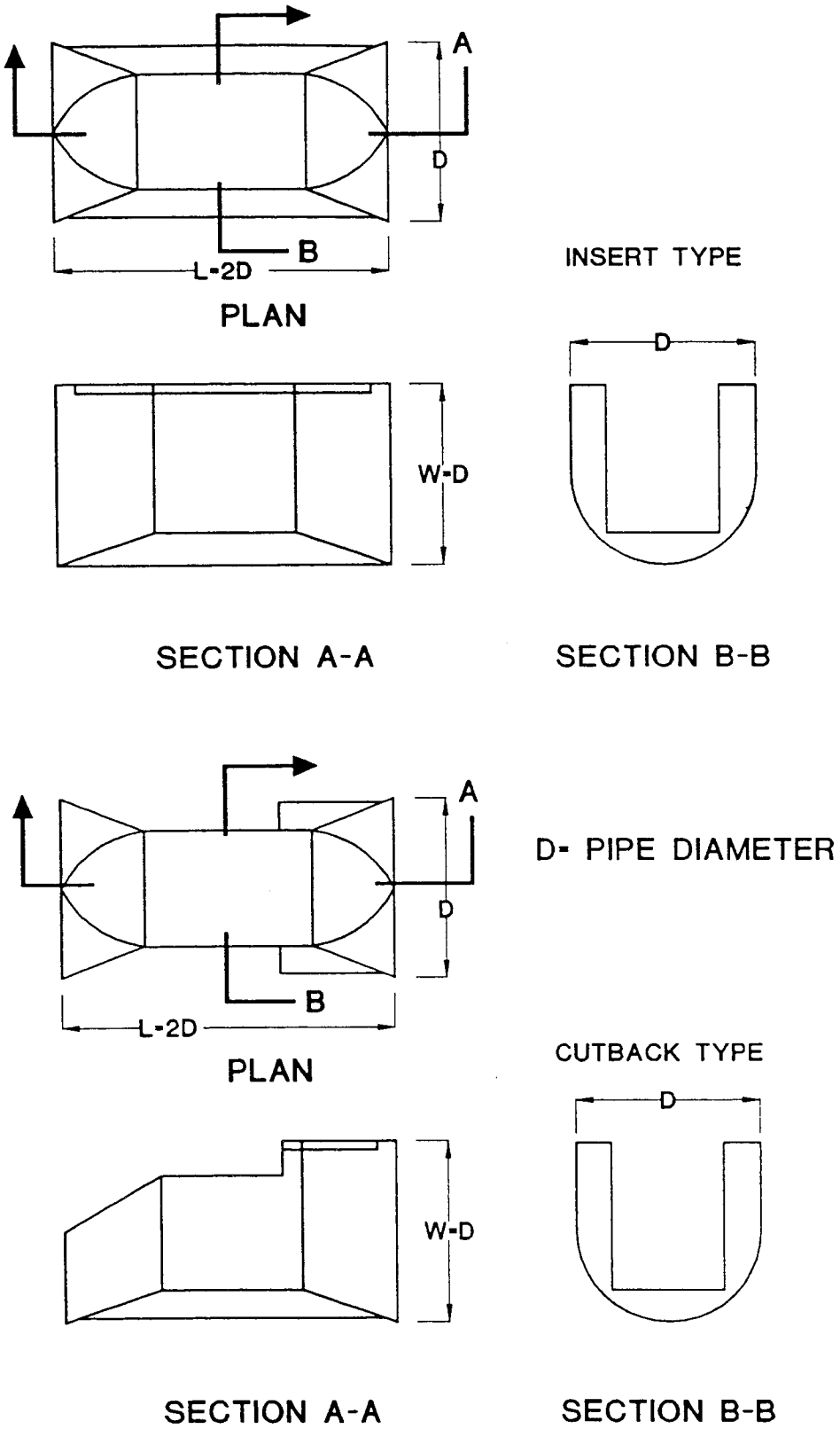
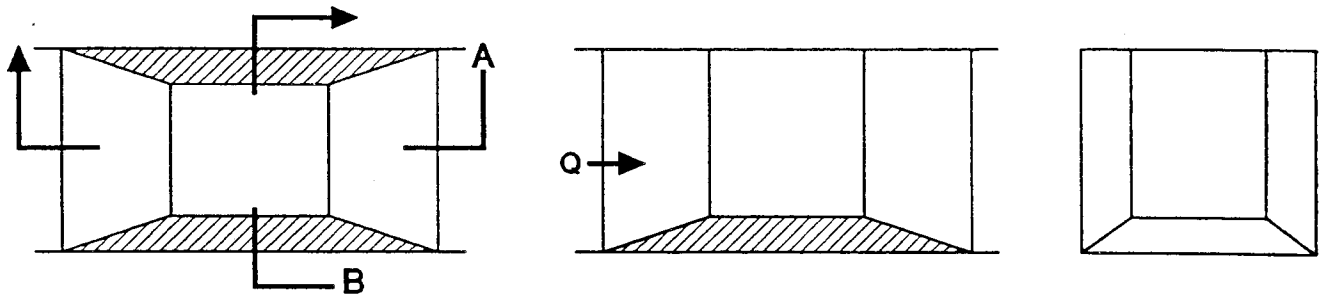


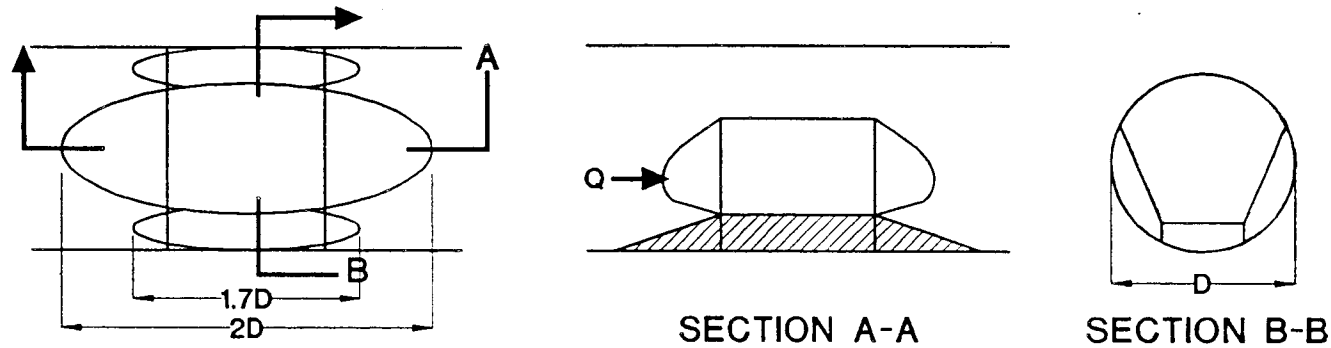
FIGURE 3.5
LEOPOLD-LAGCO FLOW MEASURING FLUME

A. RECTANGULAR FLUME



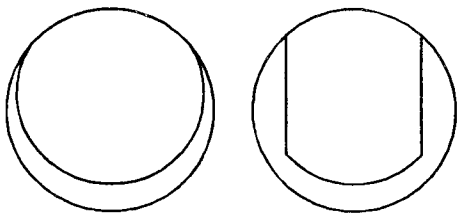
PLAN SECTION A-A SECTION B-B

B. TRAPEZOIDAL FLUME (Palmer-Bowlus)



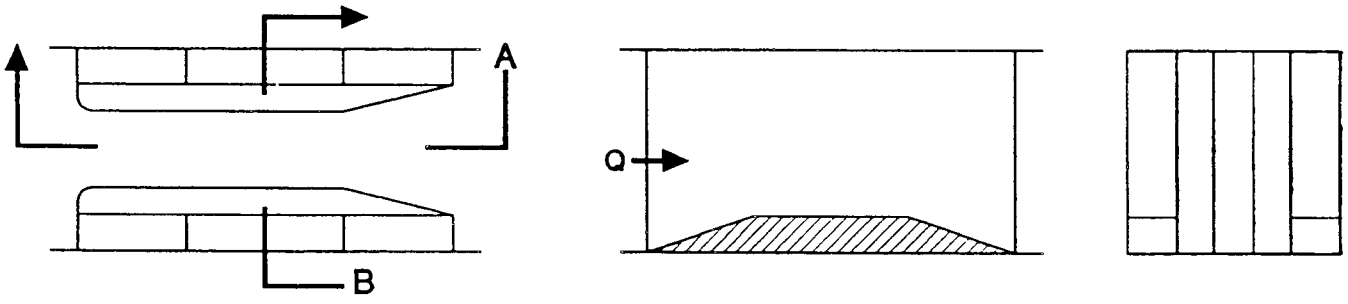
PLAN SECTION A-A SECTION B-B

C. SEMICIRCULAR FLUME



D. COMPOSITE FLUME

E. TWO STAGE COMPOUND FLUME



PLAN SECTION A-A SECTION B-B

D- PIPE DIAMETER

FIGURE 3.6
TYPES OF FLOW MEASURING FLUMES

- The height of the upstream channel should be sufficient to sustain the increased depth of flow caused by flume installation.

- While, with certain provisions, a flume may still be effective under submerged conditions, it cannot be used under completely submerged (surcharge) conditions.

Slope-Hydraulic Radius

This method makes use of the channel itself as a primary device assuming "steady uniform flow" conditions - a resistance equation, such as the Manning formula, can be used to determine the flow rate in a channel given that the channel slope, liquid depth, channel cross-section and surface roughness over a length of uniform section channel are known. However, given the uncertainty of the roughness coefficients of sewer pipes and the unsteady nature of CSO and flows, a high level of accuracy is not achievable. This method is occasionally used in sewers to obtain initial flow estimates, since it does not require the installation of additional structures in the flow stream. Table 3.7 presents Manning's equation and values of Manning coefficient for various materials.

A culvert installed in a ditch or a natural watercourse can be used as a primary device in a similar fashion.

3.4.4.5 Level Sensors

Level sensors (also known as secondary devices) are used in conjunction with hydraulic structures and velocity meters to determine the rate of flow in a channel. Common means of level measurement include bubblers, submerged pressure and ultrasonic transducers.

Bubbler

A bubbler consists of a tube, anchored in the flow stream at a fixed depth, through which pressurized air is passed. The pressure required to maintain a constant bubble rate from the tube is proportional to the liquid level in the channel. While bubblers can be used to accurately measure liquid levels, and may be used under dry conditions, the following should be considered:

- The air flow may promote biological growth within the air tube which can constrict the tube.
- The bubble tube may be fouled by debris, algae and bacteria; the automatic purge features of some bubblers may however alleviate the occurrence of blockages.
- Bubblers are highly velocity sensitive; readings may thus be greatly influenced by non-vertical installation of the tube or disturbance of the tube by floating debris.
- Periodic maintenance is required to regenerate the desiccant (which prevents moisture from being drawn into the flow meter) and to provide the constant supply

of compressed air/nitrogen. The mechanical nature of the air compressor may create additional maintenance problems.

Table 3.7
Manning Coefficient for Various Materials (ASCE Manuals and Reports on Engineering Practice No 60)

Manning equation:	$Q^* = AR^{2/3}S^{1/2}/n$
Conduit Material	**Manning n**
Asbestos-cement	0.011 - 0.015
Brick	0.013 - 0.017
Cast iron (cement lined & seal coated)	0.011 - 0.015
Concrete	0.011 - 0.015
Plastic	0.011 - 0.015
Corrugated metal	
- plain	0.022 - 0.026
- paved invert	0.018 - 0.022

* Q - Flow [m^3/s]
A - Cross sectional area [m^2]
R - Hydraulic radius [m]
S - Slope

Pressure Transducer

The hydrostatic pressure acting upon a submerged pressure transducer is proportional to the liquid level. The electronic nature of this sensor eliminates all moving parts and thus reduces maintenance and inaccuracy difficulties. However, while the transducers are not affected by air temperature and flow velocity, accuracy can be affected by large fluctuations in water temperature. In addition, submerged pressure transducers are not recommended for channels in which dry conditions may take place (i.e. storm drains).

Ultrasonic Transducer

An ultrasonic sensor determines liquid level from the time required for an acoustic pulse to travel from the transmitter to the liquid surface and back since ultrasonic level sensors are affixed above the flow stream, concerns regarding equipment damage from floating objects are removed. However, ultrasonic flow meters are susceptible to external interferences from temperature changes (air & water), radio and electromagnetic waves, shock waves, fog, rain, water turbulence, foam, condensation, floating debris and oil and grease on the water surface.

Capacitance Probe

A yardstick (or a capacitance probe) covered with special sensing metal plates at regular intervals (say 10 mm) is lowered vertically into the flow. Those plates which are submerged in water will have a different electrical capacitance from plates that stay above water. Such difference in capacitance will indicate the depth of flow which is then printed out onto a strip chart.

The open design of the problem sensors can be very easily fouled by suspended matters in the flow. In addition the sensor is subject to damage by floating debris in the sewer system, and is not suitable for long term installations.

3.4.4.6 Velocity Sensors

As mentioned earlier, CSO can be best measured by monitoring water levels at the overflow structure. However, measuring the velocity of flow has the advantage that, in the event of surcharge conditions in the conduit, accurate flow data may still be obtained. In addition, under conditions of surcharge, discharge to tidal basins or conduit blockage, channel flow may be reversed; some velocity meters will record a negative velocity to indicate the change in flow direction under such circumstances. Most flow meters measuring velocity also incorporate pressure transducers for simultaneous depth measurement to determine flow rate. For storm sewer and culvert applications, Doppler and electromagnetic flow meters are commonly used. Portable velocity meters can be used to establish a stage-discharge curve for an open channel. For combined sewer applications, Doppler and electromagnetic flow meters are commonly used.

Doppler Flow Meters

A Doppler flow meter operates by emitting ultrasonic waves of known frequency and duration from a transmitter located either on the channel invert or on the outside of the conduit in the 3 or 9 o'clock position. The reflected waves are sensed either directly by an opposing receiver or indirectly by a receiver adjacent to the transmitter. The flowing liquid causes a phase shift in the emitted waves which is proportional to the liquid velocity with a 1-5% accuracy. For the appropriate selection and installation of this type of flow meter the following points should be considered:

- Sonic reflectors (i.e. suspended solids) representative of fluid velocity should be present in the liquid.

- The pipe should be of uniform cross section without abrupt changes in direction for a minimum of 10 pipe diameters upstream and 5 diameters downstream.

- Ultrasonic sensors can be affected by vibration, temperature, AC motors or transformers, radio transmitters and antennas. Therefore, the manufacturers' minimum distance requirements/design ranges should be met.

- Pipe material should allow penetration of the ultrasonic signal if transducers are to be mounted on the outside - concrete is not suitable.

Electromagnetic Flow Meters

In situ electromagnetic flow meters are a less expensive alternative to closed conduit magnetic flow meters (magmeters) which become prohibitively costly when used for the large pipe diameters of sewerage and storm drainage collection systems. The magnetic probe of the in situ electromagnetic flow meter consists of wire coils that generate an electromagnetic field and electrodes to measure voltage. The wastewater passing through the electromagnetic field induces a voltage which is proportional to the velocity of the flow.

The following practices should be followed in the selection and installation of electromagnetic flowmeters:

- The installation should be downstream of pumps and upstream of control valves.
- The meters should not be installed after a double change in plane (i.e. 2 elbows, or a tee and an elbow).
- Piping elements and obstructions should be a minimum of 5 pipe diameters upstream and downstream of the meter.
- The meter and transmitter should be located a minimum of 6 m (20 ft) from EMI (Electro-Mechanical Interference) generating machinery (100 hp or larger).

3.4.4.7 Installation

The various flow monitoring methods have distinct advantages or disadvantages under different conditions and, therefore, specific installation requirements. While some of these were described previously, manufacturer's guidelines should be consulted for specific installation procedures. However, some common installation considerations do exist.

A field inspection is recommended prior to the installation of a flow measurement device to investigate hydraulic conditions in the conduit - flow direction, obstructions, benching, structural design, presence of debris and high water marks can all affect flow measurement. The conduit up and down stream of the proposed location should be inspected for potential problems such as slipped joints, dips in the conduits caused by settling or poor construction and breaks in service connections in the downstream section. These conditions, if of sufficient significance, can create unnecessary turbulence or surcharging, distorting depth and velocity readings.

Recommendations for the installation of measurement devices also include:

- The upstream sewer section, at least 15 diameters from the sensor, should be cleared of debris and sediments.
- Metering equipment should be installed in the sewer, upstream of the manhole.
- Cables should be secured to pipe and manhole walls to prevent catching by floating debris.
- Vibration mounts should be used if the site his subject to strong vibrations (i.e. heavy truck traffic).
- Desiccant should be placed inside the instrument enclosure to prevent moisture build-up.
- Where applicable, it should be ensured that sensors are installed centred and flat on the conduit bottom.
- If a velocity meter is being installed in conditions where fouling or high flow velocities (greater than 1.5 m/s) are anticipated, better results may be obtained by mounting the sensor facing the downstream direction, if possible.

When a level sensor is installed in an open channel, a stilling well should be constructed to protect the sensor. A perforated pipe can be used for this purpose. A recorder can be housed on top of the stilling well. A lock should be provided to protect the device from vandalism.

3.4.4.8 Calibration

Both level and velocity sensors are typically pre-calibrated at the factory or are calibrated by the distributor upon installation. The calibration of the level sensor may be simply checked by comparing the sensor reading with a tape measurement of the depth. The velocity meter calibration may be verified by a portable velocity meter. The accuracy of the flow monitoring system as a whole (i.e. weir plus level sensor or level plus velocity sensor) should also be examined to ensure accurate estimates of flow rate. Two methods commonly used for this task are:

1. Dilution;
2. Point velocity and depth measurement

The first method measures flow rate by determining the dilution of a tracer solution in the flow stream. Radioactive or fluorescent dye (i.e. Rhodamine WT) are commonly used tracers. Typically, the dye is continuously injected at a constant rate, at a distance sufficiently upstream that the dye is uniform in concentration throughout the cross section of wastewater at the point of sampling. The dye's change in concentration will be proportional to the change in flow rate. The accuracy of the results will be dependent on

the sensitivity and precision of the fluorometer or Geiger counter, the precision of the tracer preparation procedures and delivery system, and the extent of mixing (complete vertical and lateral mixing is required).

The second method requires the collection of depth and velocity measurements at specific points across the channel cross section to determine the flow (flow = mean velocity x cross-sectional area of flow). Generally, channel cross sections are partitioned into concentric regions, with the number of measurements taken throughout each region being proportional to the area of the region. The point velocities are then averaged by region and the total flow is calculated from the regional areas and the corresponding mean velocities. Alternatively, the mean velocity through a channel cross-section can be determined by numerous other documented methods, namely, the Two-Point Method, the Six-Tenths Depth Method, the Integration Method, the Subsurface Method etc. Depth measurements are normally taken manually with a staff gauge, while velocity measurements are made with a portable velocity meter.

If any measurement discrepancies are discovered, the manufacturer's instructions for re-calibration should be followed. The suitability of the measurement equipment to the flow conditions or the flow-level/velocity relationship may also require reexamination.

3.4.4.9 Maintenance

Regular site inspection and maintenance is recommended on a weekly or bi-weekly basis, and after every storm. It should include the following tasks:

- Clean the sensor and the instrument enclosure, particularly the gaskets.
- Check the desiccant for possible replacement.
- Remove sediment and debris from around the sensor and sensor cables.
- Check the accuracy of the time display.
- Compare the depth reading to a manual measurement of the depth, before and after clean-up; if the difference in depth is greater than two inches or 10% the meter should be removed for re calibration.
- Check the power availability.
- Note any irregularities.

For long-term installations, a thorough maintenance regime should be carried out every six months. This should include:

- Removal of sensor and cable for cleaning;
- Cleaning of the sewer at least 15 pipe diameters upstream of the sensor location;
- Re-calibration.

A log should be kept of all maintenance activities. This record should confirm that all preventative maintenance work has been completed and should describe the condition of the apparatus before and after any work was undertaken.

3.4.4.10 Monitoring and Recording

Time interval monitoring is typically used for the logging of both level and velocity measurements. The level or velocity is continuously recorded at specified time intervals, dependent on the battery life, memory capacity of the equipment, catchment size and flow detail desired. The frequency of flow recordings should change with the intended use of the data. If the data is required for calibrating computer models, a time interval as short as one minute may be required. If the data is required to estimate pollution loading, a time interval in the order of one hour may be sufficient. A five minute recording interval is generally sufficient for most flow conditions, unless there are flow disturbances of interest which occur for lower duration.

Similar to rain gauge recording devices, data may be recorded by mechanically operated paper charts or by electronic data loggers. However, paper charts, are susceptible to numerous problems. Being mechanical in nature, difficulties with the drive mechanism or ink flow may arise. Additionally, paper charts require manual interpretation and digitizing, which can be both time consuming and subject to significant error. In terms of electronic data logging, most instruments either generate an analog signal (usually 4 to 20 mA, or 1 to 5 volts DC), which is proportional to flow or level, or a digital signal (pulses) proportional to flow. A computer program within the flow measurement device is often available to convert the data to flow rates based on the hydraulic structure/level/velocity - flow relationship selected. Alternatively, the recorded signal can be converted to flow by downloading the analog data to a microcomputer, and converting the data.

3.4.5 Number of Sampling Events

The wastewater quality characteristics are estimated from mean values obtained from flow proportioned sample collections for a number of events. The greater the number of sampling events, the better the accuracy of the mean concentration values but the greater the cost. Considering the costs of sample collection and analysis, monitoring programs typically keep the number of samples to an acceptable minimum number reflective of the intended use of the information. For example, work carried out by Marsalek and Ng (1987) in a long-term urban runoff study found that concentration mean of the first 13 events in a series of 117 events monitored was not statistically different from the mean of the entire data set for six out of eight constituents.

The minimum number of samples required at each site depends on the sample variation. The number of samples must be sufficient such that the uncertainty in estimating the mean concentration is sufficiently low enough to permit relative comparisons of pollutant

sources. Unfortunately, it is not usually possible to determine sample variability until after the samples have been collected, and an estimate must be made prior to the first sampling event. Unless the data is actively reviewed, this may mean that the number of samples collected initially will be high. By actively reviewing the data as it is reported by the laboratory, a determination can be made when sufficient samples have been collected. Based on the Environment Canada Great Lakes Basin studies, from six to twelve samples may be required.

3.4.6 Estimating Contaminant Loads

The data should be subjected to a number of statistical analyses to determine representative concentrations including:

- Identify contaminant detection frequency to confirm contaminant occurrence and aid in statistical analyses selection.
- Determine the concentration frequency distribution for use in probability determinations.

- Evaluate the relationship between event volumes and composite concentrations, if no relationship appears to exist then the concentrations can be averaged, otherwise the relationship can be used in predictive manner.
- Compare the average concentrations observed between sites to determine if an aggregate database can be used to estimate discharge concentrations.

Since the total annual runoff can be determined with fair accuracy by either direct measurements or modeling, the main task in estimating annual loads is in determining the annual mean concentration (AMC). Conceptually, the (AMC) is determined by analyzing the event mean concentrations (EMCs) obtained through analysis of composite samples collected during the assessment program. However, there are a number of factors which complicate this determination, including:

1) Various contaminants, in particular toxic contaminants, may not be detectable in all samples.
2) EMCs may be affected by runoff volume.
3) The storm events sampled may not accurately represent the potential range of storms or conditions throughout the year.

There are three types of mean concentrations which are of interest in UR monitoring programs:

1. Single-event mean;
2. Multi-event means;
3. Multi-site means.

Single-event means are generally estimated using time or flow proportioned composite samples, and are useful in examining the variation in contaminant concentration and loading at a particular site. Multi-event means are estimated using single-event mean data, and are useful in comparing contaminant concentration and loading between sites. Finally, multi-site means are estimated using either single-event or multi-event mean data which have discharges with common characteristics (i.e. land-use, geographical location, etc.), and are useful for comparing contaminant loading between areas with different characteristics.

Environmental data sets are typically not normally distributed, and are often characterized by values below analytical detection limits (censored data) or skewed by high values. Consequently, urban runoff EMCs are often based on a log normal distribution (U.S. EPA, 1983; Di Torro, 1984; Marsalek 1990 (a)), the applicability of which should be statistically verified by standard statistical tests. In order to estimate the AMC, it is necessary to place some numerical value on the non-detectable results. The difficulty lies in deciding what the value should be.

There are a number of methods which have been used to estimate mean parameter concentrations where a portion of the data set contains values less than the detection limit including:

1. Substitute the value of zero for all samples less than the detection limit;
2. Substitute half the detection limit concentration for values less than the detection limit;
3. Substitute the detection limit concentration for values less than the detection limit;
4. Estimate the sample distribution using probability plots for data above the detection limit, and use regression techniques to extrapolate the distribution for concentrations below the detection limit, and obtain the mean from the established probability plot (Travis and Land, 1990; Paul Theil Associates, 1992; Snodgrass and D'Andrea, 1992).

Although there is some evidence to suggest that Method 4 is a robust method of evaluating environmental data sets (Travis and Land, 1990), it is recommended that Method 2 be used, as it is easy to use, it is a compromise between Methods 1 and 3, and there is often insufficient data on which to base a regression for Method 4.

The average annual pollutant concentrations, comprised of pooled composite sample analyses may be independent of common land use types such as residential and commercial. If this can be statistically verified, then a case can be made to pool the sampling data, creating one event mean and annual mean concentration.

The annual mean concentration for each contaminant is then multiplied by the estimated discharge volume to obtain an annual mass loading estimate. The loading due to sediment transport can be estimated either by:

1) Calculate an average solids contaminant concentration (weight/weight) based on sediment sampling within the catchment area, and then multiply the suspended solids mass loading (annual mean concentration multiplied by the annual discharge volume) by the average sediment concentration (Marsalek and Schroeter, 1988);
2) Calculate a mean annual contaminant concentration (weight/weight) based on suspended solids filtration, or centrifugation, samples, and then multiply the suspended solids mass loading (annual mean concentration multiplied by the annual discharge volume) by the mean annual concentration;
3) Calculate a mean annual contaminant concentration associated with the suspended solids fraction by subtracting the total versus filtered wastewater analysis, and multiply the concentration by the estimated annual discharge volume.

3.5 Process Study Assessments

Process studies may be considered where remedial action is determined to be necessary. Although an extended description is beyond the scope of this document, process study assessment monitoring typically involves the collection of further characterization data (flow and quality), with particular emphasis on the proportion of contaminants associated with the sediment fraction of the discharge, the grain size and settleability characteristics of the suspended sediment, first flush analyses of conventional contaminants, and the potential for disinfection. Depending upon the severity of the loading problem identified during the detailed assessment program, this stage may also involve pilot scale work to evaluate remedial alternatives for full scale application.

The association between contaminants and sediments is a key element in developing treatment strategies to reduce contaminant loading to the environment from UR discharges. The range of particulate sizes and settling velocities can provide an indicator of the treatability of the runoff stream by settling, or other types of physical processes (e.g. vortex separators). Findings based upon data from selected US cities have shown that particulates greater than 43 microns (sand) make up the bulk of mass urban runoff, with only 10 to 25% in the silt/clay particle size range. The range of particulate sizes and settling velocities also provides an indicator of the treatability of the runoff stream by settling, or other types of physical processes (e.g. vortex separators).

Process assessment studies often involve establishing the settling velocity of settleable particles using a settling column. A large volume sample (in excess of 10 gallons) is initially poured through a #10 sieve to retain large materials (i.e. twigs, sticks, leaves, stones, etc.), and the amount retained is burned to determine the volatile content. The sample is then vigorously mixed and poured into a settling column, and samples are withdrawn at specific time intervals.

4.0 LOCAL LABORATORY CAPABILITIES

4.1 General

Due to the scope of the analytical requirements there are very few analytical laboratories located within the lower mainland area that can provide analysis for all chemical parameters of interest. Thus, as indicated in the table of laboratory capabilities presented in Appendix B, most laboratories have working arrangements with other laboratories to carry out the analytical procedures not in their repertoire.

The analytical services of laboratories located within the lower mainland and Vancouver Island are summarized in Appendix B, and include:

ASL Analytical Services Laboratories Ltd.	Vancouver
Axys Analytical Services Ltd.	Sidney
BC Research Corp.	Vancouver
CanTest Ltd.	Vancouver
Chemex Laboratories Ltd.	North Vancouver
Econotech Services Ltd.	New Westminster
Enviro-Test Laboratories	Burnaby
JB Laboratories Ltd.	Victoria
Norwest Labs	Langley
Quanta Trace Laboratories Inc.	Burnaby
Zenon Environmental Laboratories	Burnaby

The list of laboratories has been limited to those providing physical or chemical analytical services who responded to a request for information, and does not include those providing only bioassay or microbiological services. Laboratories are constantly bringing new analytical capabilities on-line. Consequently, the list of capabilities provided in Appendix B should be considered as an indication of analytical services offered within the lower mainland area, and should be updated and verified, as applicable, during the development of monitoring programs.

The parameter that is most commonly contracted out is dioxin/furan analysis. Local laboratories that provide analysis for dioxins/furans include Axys, BC Research, and Zenon. However, all other labs listed have working relationship with other laboratories to provide this service.

4.2 Laboratory Contacts

Initial contacts to a laboratory are typically directed through the laboratory receptionist to a laboratory manager, department supervisor, or project manager. Most laboratories have defined departments or sections in their organization. Depending on the parameters involved, either a department supervisor or, for multi-parameter analyses such as the CSO program, a project manager may be the initial contact for pricing information. Once all the analytical requirements are clarified, a project manager or coordinator may be defined. However, this may not happen until an analytical contract has been established with the lab. The project contact or coordinator will be identified once the analytical contract has been set up. All questions relating to technical details and the progress of the analysis and report should be directed to this individual.

4.3 Supplementary Data

For further investigation of trace organic parameters, more detailed inspection of chromatograms (GLC and GC/MS) may be valuable. Chromatograms are available from the laboratory but at extra cost.

There has been some concern expressed by laboratories with regards to providing this documentation for external review. It should be noted that further analysis of raw GC or GC/MS data must be done only by an experienced analyst who is familiar with the interpretation of such chromatograms.

4.4 Turn-Around Time

Analytical turn-around time includes the time from sample receipt at the laboratory to delivery of the report to the client. The time span can range from a few days to four to six weeks depending on such factors as the parameters involved, the number of samples delivered, the laboratory workload, staff availability (e.g. holidays), and maximum acceptable storage times. If time is critical, contact the laboratory well ahead of time and verify with them what an appropriate schedule would be to obtain the best turn-around time to meet with your schedule.

Some labs will, if requested, provide preliminary reports for partial data reporting if it is important to receive results for a few parameters before the others can be completed.

4.5 Computer Communications

A few companies have set up, or are in the process of setting up, direct computer access for electronic transfer of data. This involves contacting the lab for a user account for access via modem. Data can then be transferred at the convenience of the client directly into the report without the concern for the possibility of error inherent in the manual transfer of data.

4.6 Costs

Local laboratory analytical costs are given in Appendix B. For reasons of confidentiality, the costs are presented in terms of minimum, maximum, and representative values. The representative prices indicated in the appendix represent reasonable budgetary figures, and are not simply arithmetic averages of the quotations received from the laboratories. There are a number of factors which influence analytical costs, including:

- The number of samples received at one time;
- The number of analytical parameters required per sample;
- The amount of QA/QC and associated documentation required;
- Turn-around time required and analysis scheduling.

The representative prices are suggested for use in preparing analytical budgets. However, the laboratories should be contacted for exact analytical costing as each laboratory has volume discounts for multi-parameter/multi-sample batches, and also provides discount prices on a project specific basis. All laboratories stress that the laboratory should be contacted for firm prices for each project.

Additionally, it should be noted that many of the firms have working arrangement with other laboratories to carry out analyses which they would otherwise not have the capability to carry out in-house.

5.0 PROGRAM SAFETY

5.1 General

The most critical component of a sampling program is crew safety. Safety is of paramount importance as both storm water and CSO sampling can be extremely dangerous. The conditions are often wet, dark and confined adding to the dangers. There are well established safety procedures for entry into confined spaces which must be followed. The element of danger is accentuated if personnel are unfamiliar with their surroundings and/or procedures, consequently, staff must be properly trained in both safety and monitoring procedures, following a well throughout program.

Sampling locations are usually within sewer lines which require access through roadway areas. Special precautions are required to protect the crew from traffic and potential hazards of confined space entry problems. The Workers Compensation Board of B.C. have established general requirements for confined space entry (1992) titled "Confined Space Entry - A Manual of Standard Practices" which is provided in its entirety in Appendix D.

5.2 Confined Space Entry

A confined space is defined as a space which has any of the following characteristics:

- Limited openings (by size or location) for entry and exit. Although small openings may limit access, making it difficult for personnel and needed equipment to get in or out, large openings can also present access limitations, particularly where devices such as hoists, ladders or other devices are needed to escape such areas.
- Unfavorable natural ventilation. Such conditions may trap deadly gases or contain atmospheric conditions which can jeopardize worker safety. For sewer systems, the levels of oxygen, hydrogen sulfide, carbon monoxide and flammable gases can create hazardous working conditions.
- Spaces not designed for continuous worker occupancy. Many confined spaces are designed for maintenance/inspection activities.

The Workers Compensation Board of B.C. has prepared a document (also included in Appendix D) which describes the minimum confined space entry requirements for municipal operations (1990). The document references the B.C. Industrial Health and Safety Regulations, and provides a brief overview of key considerations in accessing confined space areas including:

- **Identification:** location and category inventory.
- **Air Testing:** maintenance use and interpretation. Testing must be done before entry and while the space is occupied.
- **Ventilation:** blowing versus extraction of air, exchange rates, and alarms. Note that ventilation must never be done with pure oxygen, as oxygen-enriched atmospheres (above 21 percent) will cause flammable materials to burn violently when ignited. Gases such as nitrogen, carbon monoxide, and carbon dioxide can displace oxygen as a result of work being done or chemical/biological action within the sewer.
- **Electrical, Pneumatic and Mechanical Safety:** isolation of electrical sources (disconnect), blanking or bleeding of pneumatic and hydraulic lines, disconnecting mechanical linkages and drives, and securing mechanical moving parts within confined spaces.
- **Traffic Control:** where access is within traveled areas of the road.
- **Emergency Procedures:** use of self contained breathing apparatus (SCBA) or fire department involvement in rescue plans. A standby person should be present whose sole duty is to remain outside the confined space, and be in constant contact with workers inside, to provide and obtain help if needed. Standby personnel should not enter a confined space until help arrives.
- **Training:** requirement for advanced training, and records of entry. All staff involved in confined space entry must have completed training in understanding the potential dangers present and emergency rescue procedures.
- **Miscellaneous Considerations:** odour, smoking, explosive gases, non-routine work.

Four categories of confined entry space hazards are described in the B.C. Industrial Health and Safety Regulations, specifically:

- **Category I:** with walk in access from grade, or with manhole access and no direct exposure to sewage or potentially hazardous substances; activities which will not generate air contaminants (i.e. meter reading, sampling and inspection); access time less than 20 minutes.
- **Category II:** includes Category I spaces but with access time in excess of 20 minutes, or where air contaminants will be generated but at levels which will not exceed specified levels.
- **Category III:** includes manhole or hatch access with direct exposure to sewage or potentially hazardous substances; where air contaminants will be generated above Category II levels, but not immediately dangerous to life or health (IDLH); or where compliance with Industrial Health and Safety Regulation 13.07 cannot be achieved.

- **Category IV:** where IDLH levels may be present or reached, and where ventilation is provided.

The category of confined space hazard will likely vary, depending on site conditions at each location and the potential for hazardous materials to be present in the collection system. However, it is suggested that all manhole, or hatch access, to CSO and UR monitoring sites be treated as a Category IV access, as IDLH conditions could be reached due to trapped gasses moving within the sewer system. Requirements for entry into Category IV confined spaces are presented in Table 5.1, with reference to the relevant Industrial Health and Safety Regulations, as presented in Appendix D.

For safety and practical reasons, the sampling crew will generally consist of at least two members, to install and maintain the equipment and prepare and submit the samples collected at each site. Depending upon weather and site conditions, a third person may be required to assist in traffic control and sample preparation. Ideally, the crew should be prepared to collect and process samples on a seven day per week basis.

For safety reasons, all confined space entries must be documented. An example of documentation information which should be included is presented in Table 5.2: A written work procedure for sewer entry must be followed whenever a sewer manhole or similar is to be entered. A copy of this must be available to everyone involved in sewer entry. For sewer entry special training, proper equipment including rescue equipment, along with the workers' physical capabilities must be required. A further description of confined space entry procedures is presented in Appendix E.

Typical safety equipment requirements includes the following:

- Portable gas detector with a hand aspirated system for oxygen, combustible gases, hydrogen sulfide and carbon monoxide;
- tripod hoist, safety harness and life-line;
- mechanical ventilation blower (B.C. WCB guidelines indicate capacity requirement for 20 air changes per hour, up to a maximum of about 1500 cubic feet per minute);
- confined space airline rescue system (CSARS) with a 60 minute air supply plus a 5 minute emergency egress air supply;
- two man fall arrest and retrieval system (rope, acceders, tripod, figure eight and body harness);
- first-aid kit
- lighting equipment;
- traffic control signs, barricades and street safety cones (as applicable);
- amber rotating vehicle light;

Table 5.1 WCB Category IV Requirements

Section	Description
(13.05)	Provision of written work and emergency procedures. Pre-entry gas testing for oxygen concentration, flammables, other harmful substances which may be present (i.e. hydrogen sulfide gas and carbon monoxide).
(13.07)	Ventilation required bring air within the confined space to within safe levels, if unsafe conditions detected, specifically: <u>Unsafe Conditions</u> • Oxygen Content (lower than 18% or higher than 23.5%) • Flammables greater than 20% of Lower Explosive Limit (LEL) • Hydrogen Sulfide (higher than 10 ppm) • Other harmful substances higher than levels indicated in Appendix A of the B.C. Industrial Safety and Health Regulations.
(13.09 a)	Where a safe atmosphere cannot be assured appropriate respiratory equipment shall be used, an effective respiratory protection program must be in place, and the program must meet CSA standards.
(13.09 b)	Compliance with atmospheric safety requirements must be ensured through repeated testing.
(13.09 c)	Where flammables or explosive gases or liquids are present, all sources of ignition must be eliminated or controlled.
(13.11 a)	Life-line and harness must be worn if the hazard inside the confined space is such that the workers inside cannot effect a self rescue.
(13.11 b)	The person stationed outside the confined space must be equipped for and capable of effecting rescue.
(13.13)	Entry access must be such to prevent life-lines from becoming entangled.
(13.15)	A continuous man watch is required, or the worker must be provided with continuous communication and a mancheck is provided at least every 30 minutes.
(13.17 a)	Continuous mechanical ventilation must be provided.
(13.17 b)	The atmosphere must be re-tested if either the confined space is vacated for more than 20 minutes or if conditions inside the confined space cannot be assured against any change.
(13.17 c)	Oxygen content and flammable levels inside the confined space should also be checked periodically.

Table 5.2
Example Confined Space Entry Documentation

PARAMETER	DESCRIPTION
Identification/Location:	
Site Description:	
Personnel in Attendance:	
Municipality:	
Date:	
Gas Test Results	
• O_2	
• H_2S	
• CO	
• Explosive Combined Gas	
Equipment Used for Entry Testing	
Person Responsible for Testing Entry Environment	
Time of entry	
Time of exit	
Nature of Work Carried Out	

- emergency communications device (radio or cellular phone);
- personal safety equipment (hard hats, safety boots, vests, goggles and gloves).

Where the program objectives permit, consideration should be given to restricting sample retrieval to daylight hours.

5.3 Gas Hazards

5.3.1 General

In addition to bacteria and viruses, gases are particularly dangerous in sewers because they have no warning properties. Gases are invisible, often odourless, toxic, explosive and deadly therefore procedures are imperative and no chances can be taken. Under certain

Table 5.3 Gas Hazards

NAME OF HAZARD	EXPLOSIVE?	ODOR?	LIGHTER OR HEAVIER THAN AIR	ACTION
Oxygen deficiency	NO	NO	N/A	asphyxiant
Hydrogen Sulfide H_2S	YES	YES (rotten eggs smell at low conc.)	heavier	nerve gas deadly poison
Carbon Monoxide	YES	NO	almost same as air	asphyxiant deadly poison
Methane	YES	NO	lighter	asphyxiant
Gasoline Vapours	YES	NO	heavier	asphyxiant

circumstances, harmful substances are released into the sewer system, such as by chemical action, decomposition , incomplete combustion, or accidentally, etc. The Table 5.3 notes four gas hazards and their characteristics.

5.3.2 Occupational Exposure Limits (OEL)and Lower Explosive Limits (LEL)

The OEL defines the maximum airborne concentrations of substances to which workers may be exposed to for specific lengths of time. The LEL defines the maximum concentration of explosive gases. Some examples of OEL and LEL values relevant to sewer systems are presented in Tables 5.4 and 5.5, respectively. For more specific information, refer to the CRC Handbook of Chemistry and Physics (CRC, 1991).

Table 5.4 OEL Limits

HAZARDOUS SUBSTANCE	8 HOUR OEL	15 MINUTE OEL	CEILING CONC.
Hydrogen Sulfide	10 ppm	15 ppm	20 ppm
Carbon Monoxide	50 ppm	400 ppm	
Gasoline Vapours	300 ppm	500 ppm	

Table 5.5 LEL Limits

EXPLOSIVE SUBSTANCE	LOWER EXPLOSIVE LIMIT (% by volume)
Methane	5.0
Carbon Monoxide	12.5
Hydrogen	4.0
Hydrogen Sulfide	4.3
Ammonia	15.5
Propane	2.12
Ethane	3.0

5.4 Disease and Immunization

Disease causing bacteria, viruses, and parasites are always present in sewers. They occur in both liquid sewage and the dry sludge which coats pipes, and other surfaces inside sewers. The serious threats are Hepatitis A (virus), Hepatitis B (virus), Tetanus (bacteria), Typhoid (bacteria) and Polio (virus). Hepatitis A is a major problem, and there is no vaccine for it. Proper hygiene is the only way to avoid it, as the virus is acquired by entering the mouth. Proper hygiene methods must be followed. Wash hands before eating or smoking. Protective clothing must be laundered and equipment kept clean. Workers should avoid touching their eyes to prevent any eye inflammation. Cuts and abrasions of the skin should be covered by bandages and the use of gloves to minimize chances of infection by sewer organisms.

Immunization prevents Hepatitis B, Typhoid, Tetanus, Diphtheria, and Polio. The typhoid vaccine is 2 shots, 3 to 4 weeks apart, with a 3 year booster. The hepatitis B serum is given in 3 shots over a 6 month period, the second given 1 month after the first, and the third shot given 5 months after the second. Boosters are not required at this time (according to health officials studying it, it is good for at least 7 years. Studies are ongoing to check the need for boosters). For the polio vaccine, primary immunization is needed only. Tetanus and Diphtheria vaccine are required once every 10 years.

6.0 CONCLUSIONS

This document presents a methodology for investigative and detailed contaminant loading assessments of urban runoff (UR) and combined sewer overflow (CSO) wastewater discharges into the Fraser River. The overall purpose of the document is to provide agencies with procedural documentation to plan and implement monitoring programs for these two types of wastewater discharges.

The recommended approach is to first carry out an investigative assessment to determine whether specific contaminants of concern are present, or being discharged into the sewer system, and whether these key contaminants are also identifiable in receiving environment sediment samples collected within the vicinity of the discharge. The investigative assessment provides information which allows investigators to prioritize outfall discharges for detailed assessment. Depending on the findings of the investigative program, a detailed assessment program may be carried out which obtains information to enable investigators to estimate the contaminant loading characteristics for each discharge. Finally a process assessment may be carried out to determine remedial measures to reduce contaminant discharges.

The document is presented in a three-ring binder format to allow extraction of specific sections, and to permit the document to be easily updated on a periodic basis as information changes (i.e. laboratory capabilities and equipment specifications). The methodology is presented in a step-by-step fashion, as the report is intended to serve as a guidance document for investigators and field sampling crews. Separate procedural sections are provided for both UR and CSO assessment programs; Sections 3.0 and 4.0, respectively, to allow those sections to be individually extracted from the document. The procedures are also described in a matrix diagram presented at the beginning of Sections 3.0 and 4.0. Information is also provided on local laboratory capabilities and safety procedures for use in field sampling.

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APPENDIX A

Equipment Listing

CSO/UR EQUIPMENT INFORMATION

H:\1043\13\WQ1\SAMPLER2.WQ1

PORTABLE SAMPLERS

#	NAME	METHOD	DISCRETE/ COMPOSITE	SAMPLE MODE	PRIORITY POLLUTANTS	MANUFACTURER	SUPPLIER	ADDRESS	PHONE #	CONTACT NAME
1	Model S-4900	Vacuum	D/C		Silicon Teflon/Glass	TEXAS NUCLEAR MANNING PRODUCTS	BG Controls	2460 Kingsway Port Coquitlam, B.C.	(604)942-0288	George Balder
2	EPIC 1011T	Vacuum/Pressure	D/C	FL/TM/E/M	Teflon/Glass Silicon/S Steel	EPIC PRODUCTS LTD.	B & D Engineering	2120 Van Dyke Place Richmond, BC V6V 1X9	(604)273-9481 Fax 273-3705	Ken Bottomly
3	ISCO WW Sampler Model # 3700	Peristaltic	D/C	FL/TM/E/M	Silicon Teflon/Glass	ISCO SAMPLERS	Nortech Control Equipment Inc.	401 - 11861 88th Ave Delta, B.C. V4C 3C6	(604)596-6510 Fax 596-6512	Jim Cornish
4	SIRCO Sampler Model PVS-C or PVS-D	Vacuum/Compressor	D/C	FL/TM/M	optional Teflon/Glass	SOUTHWELL CONTROLS LTD.	Sealand Sales Ltd.	316 West 6th Avenue, Vancouver, BC V5Y 1K9	(604)875-6599	Cameron Wonnick
5	Calypso Model GI	Peristaltic	D/C	FL/TM/E/M	Silicon Teflon/Glass	GENEQ INC.	Watt-Pearson Ltd.	836 West 15th Street North Vancouver, BC	(604)986-3457 Fax 986-3458	John Watt
6	American Sigma Model 800SL	Peristaltic	D/C	FL/TM/E/M	Silicon Teflon/Glass	AMERICAN SIGMA	Mackenzie & Feiman	7930 Vantage Way Delta, B.C. V4G 1A8	(604)940-2313 Fax 940-1626	Martin Provest/ Laurie Davies

D/C - Ability to sample discrete & composite samples
FL - Flow Proportional (impulse)
TM - Time Proportional
E - Event Activation
M - Manual Operation

CSO/UR EQUIPMENT INFORMATION

H:\1043\13\WQ1\LOGGERS2.WQ1

DATA AQUISTION/DATA LOGGERS

#	NAME	TYPE	MANUFACTURER	SUPPLIER	ADDRESS	PHONE #	CONTACT NAME
1	Data loggers	A	Moore Industries	BG Controls	2460 Kingsway Port Coquitlam, B.C.	(604)942-0288	George Balder
2	Telog 2400 series data loggers 4 Channel	P / A / V / R	Levitt-Safety Limited	Levitt-Safety Limited	#106,5855-9 St. SE Calgary, Al T2H 1Z9	(403)253-7767 Fax 253-2935	Jim Broadbent
3	Rustrak Ranger II data logger	E / V / A	Rustrak Instruments	Watt-Pearson Ltd	835 West 15th St North Vancouver, BC	(604)986-3457 Fax 986-3458	John Watt
4	Smart readers	A / V / T	ACR Systems Inc.	ACR Systems Inc.	8561-132nd Street Surrey, BC	(604)591-1128 Fax 591-2252	
5	Fluke data acquistion many models	A / V	John Fluke Mfg. Co. Inc.	John Fluke Mfg. Co. Inc.	400 Britannia Td.E., Unit #1 Mississauga, Ontario L4Z 1X9	(416)890-7600 Fax 890-6866	Dairo DePaolis
6	Ultra Logger	R / A / V	Lakewood Systems	Hoskin Scientific Ltd.	239 East 6th Ave., Vancouver, B.C.	(604)872-7894 Fax 872-0281	Frank Vanderhove
7	5096 "alert" data acquistion		Sierra-Misco Environment Ltd	Sierra-Misco Environment Ltd	830D Pembroke Street Victoria, B.C. V8T 1H9	(604)665-2092	
8	Data logging Module	2-D / 3-A	Badger Meter, Inc.	Badger Meter, Inc.	PO Box 581390 Tulsa, Oklahoma 74158-1390	(918)836-8411	Craig Stewart
9	Data logger - single/multiple inputs	A	Northwest Instrumentation	Terrascience Systems	1574 West 2nd Ave. Vancouver, B.C. V6J 1H2	(604)734-3443	Joe Seraphim
10	DA2500E Data Acquistion Terminal - multiple(30)	V / A / T / P	Johnson Yokogawa	CB Engineering Ltd.	#20,5920-11th St. SE Calgary, AL T2H 2M4	(403)259-6220 Fax 259-3377	Randy Schafer

E - Event ex. pump on/off
A - mA signal
V - voltage signal
R - Raingauge hookup

T - Thermocouple
P - pulse
D - digital

CSO/UR EQUIPMENT INFORMATION

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RAIN GAUGES

#	NAME	MANUFACTURER	SUPPLIER	ADDRESS	PHONE #	CONTACT NAME
1	Rain gauge with Datapod data logger	Omnidata International,Inc.	Electronic Data Solutions	P.O. Box 15 Jerome, Idaho 83338	(208)324-4008	
2	Tipping Bucket Rain gauge with optional internal or external datalogger	Hydrological Services	Hoskin Scientific	239 East 6th Ave Delta, B.C. V4C 3C6	(604)872-7894 FAX 872-0281	Frank VanDerHave
3	Tipping Bucket Rain gauge with optional external datalogger	Rimco	"	"	"	"
4	Tipping Bucket Rain gauge M674 optional data logger	ISCO	Nortech Control Equipment	401 - 11861 88th Ave Delta, B.C. V4C 3C6	(604)596-6510 FAX 596-6512	Jim Cornish
5	Tipping Bucket Rain gauge optional hookup to Flo-Log data logger	Geneq	Watt-Pearson	836 West 15th Street North Vancouver, BC	(604)986-3457 FAX 986-3458	John Watt
6	Tipping Bucket Rain Gauge various models	Sierra-Misco	Sierra-Misco Environment Ltd	830D Pembroke Street Victoria, B.C. V8T 1H9	(604)665-2092	
7	Rain gauge & Rainlogger	Detectronic	Heath Consultants Limited	2085 Piper Lane, London, Ontario	(519)659-1144	Julian Thornton

CSO/UR EQUIPMENT INFORMATION
PORTABLE FLOW MONITORING SYSTEMS

OC - OPEN CHANNEL FLOW
FL - FLUME, WIER REQUIRED
S - SEWER & STORM WATER FLOW (partially filled pipe)
PI - FULL PIPE
ST - STORM OVERFLOW

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29-Oct-93

#	NAME	PRINCIPAL	TYPE	MANUFACTURER	SUPPLIER	ADDRESS	PHONE #	CONTACT NAME
1	ISCO 3000 Series Flow Transmitters	ultrasonic, bubbler, submerged sensors, no data storage, AC only	OC/FL	ISCO Environmental Division	Nortech Control Equipment Inc.	Suite 401, 11861 - 88th Ave Delta, B.C. V4C 3C6	(604)596-6510 Fax 596-2124	Jim Cornish
2	ISCO Flow Poke	Manometer/V-notch weir, for 6, 8, 10 & 12" pipe, instantaneous readings only	S	"	"	"	"	"
3	ISCO 3200 Series Open Channel Flow Meters	ultrasonic, bubbler, submerged sensors, data storage, AC or DC, display	OC/FL	"	"	"	"	"
4	ISCO 4100 Series Flow Loggers	ultrasonic, submerged, area-vel sensors, data storage, need laptop, no display	OC/FL	"	"	"	"	"
5	Quadrascan 3000 Flow monitor	Ultrasonic Level & Velocity data logger	S	ADS Services Inc	Q Monitoring	122 Saunders Rd, Unit 5, Bldg B Barrie, Ontario	(705)739-0255	David Lee
6	Manning Dipper Model F-3000A	Level chart recorder/totalizer cap. only	FL	TN Manning Products	B.G. Controls	2460 Kingsway Port Coquitlam, B.C.	(604)942-0288	Don Sackle
7	UL-1100 Portable Flow Recorder	ultrasonic transducer, data logger	FL	TN Manning Products	"	"	"	"
8	Data gator	data logger, flow	S	TN Manning Products	"	"	"	"
9	Flow-tote Model 260 Flowmeter System	Electromagnetic Velocity/Depth data logger	OC/S	Marsh-McBirney, Inc.	ESKO Environmental	Suite 220 - 340 Brooksbank Avenue North Vancouver, B.C.	(604)984-4201	Bob Lowden
10	FlowMate Model 2000	port. & manual for velocity profiling	OC/S	Marsh-McBirney, Inc.	"	"	"	"
11	Surveylogger - 3510	Ultrasonic Velocity Transducer temp, battery powered, logger	OC/S FL	Montech	Heigh Consultants	457 E 8th Avenue, North Van, B.C.	(604)980-9552	Jamie Eickenberger
12	DET4CM Flow Measurement System	Ultrasonic Doppler Velocity/ Pressure Transducer Depth	OC/S	Montech	"	"	"	"
13	MONITOR 8	Ultrasonic Velocity Transducer permanent, hardwired, logger	PI/FL	Montech	"	"	"	"
14	Portable Channel Flow Monitor	Level, data logger	OC/FL	Metex Corp. Ltd.	Metex Corp. Ltd.	12 Penn Drive, Unit 1 Weston, Ontario M9L 2A9	(416)749-1210 Fax 740-2839	Andrew Toth
15	OCM II Open Channel Meter	Ultrasonic Level, opt. data logger	FL	Milltronics Ltd	Milltronics Ltd	730 The Kingsway, POBox 4225 Peterborough, Ontario K9J 7B1	(705)745-2431 Fax 745-0414	
16	Flo-Log	Ultrasonic velocity & press. sensor data logger, combines with raingauge	OC/S	Geneq Inc.	Watt-Pearson Ltd.	836 W 15th St. Vancouver, B.C. V7P 1M6	(604)986-3457 Fax 986-3458	John Watt
17	Pressure Transducer Level Sensor	Pressure transducer Level mA output for opt logger	FL	Lakewood Systems	Hoskin Scientific	239 East 6th Ave., Vancouver, B.C.	(604)872-7894	Frank Vanderhave
18	Ultrasonic Level Sensor	Ultrasonic Level mA output for opt logger	FL	Lundahl	"	"	"	"
19	Ultrasonic Level Sensor	Ultrasonic Level, display mA output for opt logger	FL	Fisher & Porter	Fisher & Porter	Suite 240, 4259 Canada Way Burnaby, B.C.	(604)430-0345	Peter Kerevan
20	Sigma Model 950 Open Channel Flowmeter	AC or DC, mA output signal ultrasonic, bubbler, submerged press. transducer	OC/FL	American Sigma	Mackenzie & Feimann Ltd.	7930 Vantage Way Delta, B.C. V4G 1A8	(604)940-2313 Fax 940-1626	Martin Provost/ Laurie Davies
21	SWINGO Storm Flow Data Logging System	Swing Arm/Velocity	ST	SWINGO	Heath Consultants Limited	2085 Piper Lane, London, Ontario Mississauga, Ontario	(519)659-1144 (905)273-3040	Julian Thornton
22	Series 5000 Flow Measurement	Ultrasonic depth X Velocity 12" pipe & greater	OC/S	Badger Meter, Inc.	Badger Meter, Inc.	PO Box 581390 Tulsa, Oklahoma 74158-1390	(918)836-8411	Craig Stewart
23	Pressure Transducer Level Sensor	Pressure transducer Level mA output signal	FL	Northwest Instrumentation	Terrascience Systems	1574 W.2nd Ave. Vancouver, B.C. V6J 1H2	(604)734-3443	Joe Seraphim

APPENDIX B

Local Laboratory Physical/Chemical Analytical Services

Analytical Laboratories

Company	Contacts	
ASL Analytical Service Laboratories 1988 Triumph Street Vancouver, BC V5L 1K5 tel: 253-4188 fax: 253-6700 Manager(s): **Allan Maynard, John Park, Rob Deverall**	Technical Mgr: Project Mgr: Conventionals Metals: Organics: GC/MS:	Rob Deverall (various) Barbara Szczachor James Downie Scott Hannam Scott Hannam
Ayxs Analytical Services Ltd PO Box 2219, 2045 Mills Road Sidney, BC V8L 3S1 tel: 656-0881 fax: 656-4511 Manager(s): **Coreen Hamilton**	Technical Mgr: Project Mgr: Conventionals Metals: Organics: GC/MS:	Coreen Hamilton Laurie Phillips - - Coreen Hamilton Coreen Hamilton
BC Research Corp 3650 Wesbrook Mall Vancouver, BC V6S 2L2 tel: 224-4331 fax: 224-0540 Manager(s): **John Leach**	Technical Mgr: Project Mgr: Conventionals Metals: Organics: GC/MS:	John Leach Herb Lanz, Jim McKinley Herb Lanz Herb Lanz Jim McKinley Jim McKinley
CanTest Ltd Suite 200, 1523 West 3rd Avenue Vancouver, BC V6J 1J8 tel: 734-7276 fax: 731-2386 Manager(s): **Don Enns**	Technical Mgr: Project Mgr: Conventionals Metals: Organics: GC/MS:	Robert Hunter Richard Jornitz Amy Orr David Nadler Don Noot, Anglina Elliot Don Noot
Chemex Labs Ltd 212 Brooksbank Ave North Vancouver, BC V73 2C1 tel: 984-0221 fax: 984-0218 Manager(s): **Glen Scott**	Technical Mgr: Project Mgr: Conventionals Metals: Organics: GC/MS:	Ivonne Mackay Glen Scott Ivonne Mackay Brenda Caughlin - -

Company	Contacts	
Econotech Services Ltd 852 Derwent Way, Annacis Island New Westminster, BC V3M 5R1 tel: 526-4221 fax: 526-1898 Manager(s): **Terry E. Peel**	Technical Mgr: Project Mgr: Conventionals Metals: Organics: GC/MS:	Terry E. Peel Donna Johannes Yetunde Bankole Tom Yuen Jennifer Lewis -
Enviro-Test Laboratories # 406, 3700 Gilmore Way Burnaby, BC V5G 4M1 tel: 451-9317 fax: 436-0565 Manager(s): **George W. Ruddock**	Technical Mgr: Project Mgr: Conventionals Metals: Organics: GC/MS:	Jim Haeberle Gordon Nelson Quanta Trace Quanta Trace Gary Bruns Gordon Nelson
JB Laboratories Ltd 827 Fort Street Victoria, BC V8W 1H6 tel: 385-6112 fax: 382-6364 Manager(s): **Barbara Klassen**	Technical Mgr: Project Mgr: Conventionals Metals: Organics: GC/MS:	John Evanoff Barbara Klassen John Evanoff John Evanoff - -
Norwest Labs # 203, 20771 Langley By-pass Langley, BC V3A 5E8 tel: 530-4344 fax: 534-9996 Manager(s): **Tom Guthrie**	Technical Mgr: Project Mgr: Conventionals Metals: Organics: GC/MS:	Tom Guthrie Nicole Ferrel Tom Guthrie Andrew Masters Randy Reicle Randy Reicle
Quanta Trace Laboratories Inc # 401, 3700 Gilmore Way Burnaby, BC V5G 4M1 tel: 438-5226 fax: 436-0565 Manager(s): **Derrel Dixon**	Technical Mgr: Project Mgr: Conventionals Metals: Organics: GC/MS:	John Davidson Walter Brandl/Janet Pel Walter Brandl/Janet Pel Janet Pel Enviro-Test Enviro-Test
Zenon Environmental Laboratories 8577 Commerce Court Burnaby, BC V5A 4N5 tel: 444-4808 fax: 444-4511 Manager(s): **David Hope**	Technical Mgr: Project Mgr: Conventionals Metals: Organics: GC/MS:	Barry Oliver Tracy Sutela, Shawn Heier Rob Gilbert Dorrie Olenigzak Mike Arychuk Dave Hope, Barry Oliver

Laboratory Capabilities

Parameter	ASL	Axys	B.C. Research	CanTest	Chemex	Econotech	Enviro-Test	J.B. Labs	Norwest	Quantra Trace Lab	Zenon
INORGANICS											
Conventionals	X	(*)	X	X	X	X	(*)	X	X	X	X
Metals: ICP scan	X	(*)	X	X	X	(*)	(*)	(*)	X	X	X
Metals: Individual elements	X	(*)	X	X	X	X	(*)	X	X	X	X
ORGANICS											
Acid Extractables (Chlorinated Phenols)	X	X	X	X	(*)	(*)	X	(*)	X	(*)	X
Base-Neutral Extractables (PAHs)	X	X	X	X	(*)	X	X	(*)	X	(*)	X
Chlorinated Extractables (Hydrocarbons)	X	X	X	X	(*)	(*)	X	(*)	X	(*)	X
Chlorinated Pesticides	X	X	X	X	(*)	X	X	(*)	X	(*)	X
PCB's	X	X	X	X	(*)	X	X	(*)	X	(*)	X
Phthalate Esters	X	X	X	X	(*)	(*)	X	(*)	X	(*)	X
Volatiles, Halogenated	X	X	X	X	(*)	X	X	(*)	X	(*)	X
Volatiles, Non-halogenated	X	X	X	X	(*)	(*)	X	(*)	X	(*)	X
Dioxins & Furans	(*)	X	X	(*)	(*)	(*)	X	(*)	(*)	(*)	X

X Indicates in-house capabilities

(*) *Due to the scope of the analytical requirements, labs provide complete services by sub-contracting with other laboratories.*

1043\13\LABTAB/WQ1

Analytical Costs

WATER SAMPLES Parameter	Methodology	ANALYSIS PRICES Minimum	Maximum	Representative Prices	
INORGANICS					
Conventionals					
pH	SM	$3.00	$10.00	$6.00	
Ammonia	SM	$14.00	$28.00	$18.00	
TKN	SM	$21.00	$45.00	$30.00	
Nitrite	SM	$9.00	$25.00	$15.00	
Nitrate	SM	$15.00	$35.00	$22.00	
Total P	SM	$15.00	$40.00	$22.00	
TSS, VSS	SM	$15.00	$32.00	$22.00	
Oil & Grease	SM	$25.00	$45.00	$35.00	
Metals					
ICP scan (includes sample prep)	SM, EPA	$36.00	$75.00	$55.00	
GFAA Al, Cd, Cr, Co, Cu, Pb, Ni, V, Zn	SM, EPA	$6.00	$20.00	$13.00	each
Hydride: Sb, As, Se	SM, EPA	$12.00	$25.00	$15.00	each
Mercury	SM, EPA	$15.00	$40.00	$25.00	
ORGANICS					
Priority Pollutants includes: Acid Extractables (Chlorinated Phenols) Base-Neutral Extractables Organochlorine Pesticides & PCB's Phthalate Esters Polynuclear Aromatic Hydrocarbons (PAH)	GC/MS	$550.00	$950.00	$750.00	
Purgeable Organics includes: Volatiles, Halogenated Volatiles, Non-halogenated	GC/MS	$200.00	$300.00	$250.00	
Chlorinated Extractables (Hydrocarbons)	GC/MS	$200.00	$250.00	$225.00	
Chlorinated Pesticides & PCB's	EPA 608	$135.00	$300.00	$200.00	
Phthalate Esters	GC/MS	$150.00	$250.00	$250.00	
Purgeable Halocarbons	GC/MS	$130.00	$250.00	$200.00	
Dioxins & Furans (low res)	EPA/EC	$800.00	$1,100.00	$900.00	
(high res)		$950.00	$1,100.00	$1,000.00	

Prices indicated are for single sample submissions.
Considerable savings are available through Project pricing for multi-sample / multi-parameter analyses.
EPA - Environmental Protection Agency
EC - Environment Canada
SM - Standard Method for the Examination of Water & Wastewater, AWWA/APHA

APPENDIX C

MISA and EPA Contaminant Detection Limit Requirements

MISA and EPA Minimum Contaminant Detection Limits

Parameter	MISA	EPA 624 (Water)	EPA 8240 (Sediment)
Conventionals (mg/L)			
pH	N/A	N/A	N/A
Ammonia	0.02	N/A	N/A
Total Kjeldahl Nitrogen	0.02	N/A	N/A
Nitrite	0.001	N/A	N/A
Nitrate	0.005	N/A	N/A
Total Phosphorus	0.001	N/A	N/A
Total Suspended Solids	1	N/A	N/A
Volatile Suspended Solids	1	N/A	N/A
Oil & Grease	1	N/A	N/A
Total Metals (ug/L)			
Aluminum	.005	-	-
Antimony	.0001	-	-
Arsenic	0.0001	-	-
Cadmium	0.0002	-	-
Chromium	0.015	-	-
Cobalt	0.015	-	-
Copper	0.01	-	-
Lead	0.001	-	-
Mercury	0.0001	-	-
Molybedenum	0.005	-	-
Nickel	0.02	-	-
Selenium	0.0005	-	-
Titanium	0.03	-	
Vanadium	0.005	-	-
Zinc	0.005	-	-
Halogenated Volatiles (ug/L) (ug/Kg)			
Chlorobenzene	0.7	1	1
Chloroform	0.7	1	1
1,2-Dichlorobenzene	1.4	1	1
1,4-Dichlorobenzene	1.7	1	1
1,2-Dichloroethane	2.8	1	1
Dichloromethane	1.3	1	1
1,1,2,2-Tetrachloroethane	4.3	1	1
Tetrachloroethane	1.1	1	1
1,1,1-Trichloroethane	0.5	1	1
Trichloroethene	1.9	1	1

MISA and EPA Minimum Contaminant Detection Limits (Cont'd)

Parameter	MISA	EPA 624 (Water)	EPA 8240 (Sediment)
Non-halogenated Volatiles (ug/L) (ug/Kg)			
Benzene	0.5	0.5	1
Ethylbenzene	0.5	0.5	1
Styrene	0.5	0.5	1
Toluene	0.5	0.5	1
meta- & para-xylene	1	0.5	1
ortho-xylene	0.5	0.5	1
Polynuclear Aromatic Hydrocarbons (ug/L) (ug/Kg)			
Acenaphthene	1	1	5
Acenaphthylene	0.7	1	5
Anthracene	0.8	1	5
Benzo(a)anthracene	0.3	1	10
Benzoa1)pyrene	0.6	1	20
Benzo(b)fluoranthene	0.7	1	20
Benzo(ghi)perylene	0.7	1	20
Benzo(k)fluoranthene	0.7	1	20
Chrysene	0.3	1	10
Dibenzo(a,h)anthracene	1.3	1	20
Fluoranthene	0.3	1	10
Fluorene	1.2	1	5
Naphthalene	1.1	1	5
Phenanthrene	0.3	1	5
Pyrene	0.3	1	10
Phthalate Esters (ug/L) (ug/Kg)			
Bis(2-ethylhexyl) Phthalate	1.3	1	50
Butyl Benzyl Phthalate	-	1	50
Diethyl Phthalate	-	1	50
Dimethyl Phthalate	-	1	50
Di-n-butyl Phthalate	1.2	1	50
Di-n-octyl Phthalate	1	1	50
Acid Extractables (ug/L) (ug/Kg) (Chlorinated Phenols)			
2-Chlorophenol	1.8	-	-
2,4-Dichlorophenol	1.7	1	50
2,3,4-Trichlorophenol	0.6	1	20
2,3,5-Trichlorophenol	1.1	1	20
2,4,5-Trichlorophenol	1	1	20
2,4,6-Trichlorophenol	0.9	1	50
2,3,4,5-Tetrachlorophenol	0.4	1	10

MISA and EPA Minimum Contaminant Detection Limits (Cont'd)

Parameter	MISA	EPA 624 (Water)	EPA 8240 (Sediment)
Acid Extractables (ug/L) (ug/Kg) (Chlorinated Phenols) (cont'd)			
2,3,4,6-Tetrachlorophenol	1.1	1	10
2,3,5,6-Tetrachlorophenol	1.1	1	10
Pentachlorophenol	0.5	1	50
4,6-Dinitro-o-cresol	12	5	50
2,4-Dinitrophenol	18	5	50
4-Nitrophenol	1.4	5	50
Phenol	2.4	5	50
Chlorinated Extractables (Hydrocarbons) (ug/L) (ug/Kg)			
Hexachlorobenzene	0.01	1	5
Pentachlorobenzene	0.01	-	-
1,2,3,4-Tetrachlorobenzene	0.01	-	-
1,2,3,5-Tetrachlorobenzene	0.01	-	-
1,2,4,5-Tetrachlorobenzene	0.01	-	-
1,2,4-Trichlorobenzene	0.01	1	20
Polychlorinated Biphenyls (ug/L) (ug/Kg)			
Total Polychlorinated Biphenyls	0.05	10	20
Dioxins and Furans (ug/L)			
Tetra, penta, hexa, hepta & octa dibenzo-p-dioxins	- 0.0003	- -	- -
Tetra, penta, hexa, hepta & octa dibenzofurans	- 0.0003	- -	- -

CEPA PARAMETERS

Parameter	MISA	EPA 624 (Water)	EPA 8240 (Sediment)
Group 2 (mg/L)			
Inorganic Fluorides	0.02	-	-
Group 3 (mg/L)			
Benzidine	0.01	-	-
bis(Chloromethy) ether	0.01	-	-
Chloromethyl methyl ether	0.01	-	-
3,3'-Dichlorobenzidine	0.01	-	-

APPENDIX D

B.C. Workers Compensation Board

Confined Space Entry
A Manual of Standard Practices

APPENDIX E

Summary of Confined Space Entry Procedures

SUMMARY OF CONFINED SPACE ENTRY PROCEDURES

GENERAL

There are three steps for safe work procedure:

1. Pre-entry planning
2. Entry procedures
3. Rescue procedures

A written work procedure is required for sewer entry, to be followed whenever a sewer manhole or similar is to be entered. A copy of this must be available to everyone involved in sewer entry. For sewer entry special training, proper equipment including rescue equipment, along with the workers' physical capabilities is required.

PRE-ENTRY PLANNING

The following conditions must be considered before work begins at a confined space work site.

- Is entry absolutely necessary?
- What is the physical layout of the site?
- Will traffic control be a factor and if so what control devices will be needed?
- Any problems with this sewer encountered before?
- What are the most likely hazards to be encountered at this particular site?
- What type of work will be done? Is there any special precautions needed or created by this type of work?
- Is all personnel involved trained and competent in the appropriate procedures and equipment use(including rescue).
- What tests are needed to determine the contaminant levels in the atmosphere?
- If contaminants are found:
  1. what special precautions will be done?
  2. will respiratory protective equipment be needed?
  3. is ventilation required?
- Is any special equipment required? (lights, etc.)
- Do we have enough workers to do the job safely or if rescue is required?

- What rescue equipment is required?
- Will weather interfere and if so check with the weather office?

ENTRY PROCEDURES

1. Secure the site - traffic control, barricades etc.
2. Ensure all equipment is on site and ready for use
   - air testing equipment
   - harness, lifeline
   - lighting
   - rescue equipment
3. Ensure environmental hazards present are identified and controlled
   - monitor air quality for hazards and sufficient oxygen
   - is air environment safe for entry?
   - are explosive gases present?
   - are airborne contaminants below Occupation Exposure Limits?
   - if work is lengthy, tests must be repeated periodically
4. If sewer is found unsafe, ensure worker(s):
   - use proper breathing apparatus
   - is in communication with worker by entrance of confined space
   - know all appropriate procedures, especially rescue
   - protected by appropriate rescue equipment available for immediate use.
   - are physically capable of effecting a rescue
5. Isolate space to protect from harmful substances from entering work space.
6. Check for physical hazards in the sewer.
   - broken access rungs, deep or fast-flowing effluent, cracked walls
7. If any "hot work" such as welding is to be done, confirmation tests for flammable substances must be carried out previously to and during the work.

AIR MONITORING, VENTILATION, AND ISOLATION TECHNIQUES

Air Monitoring

The sewer atmosphere must be tested before a worker enters the confined space and during work to determine safety in the following situations:

- where ventilation is not practical or effective
- after ventilation to ensure removal of a harmful substance
- before and during any "hot work" procedures

Accurate testing requires that the appropriate equipment is calibrated and maintained correctly, and used properly by a competent person trained in its use. The testing must be carried out in the proper locations and at different levels to have an accurate picture of the work environment. Care to detect trapped gases and gases that are lighter or heavier than air must be taken.

Three types of detection tests are required to ensure a safe atmosphere in a confined space:

1. OXYGEN LEVEL - Oxygen content of the air must be above the minimum requirements of 18 kPa.
2. TOXIC GAS DETECTION - There must not be a buildup of harmful substances, poisonous gases, such as hydrogen sulphide (H_2S).
3. COMBUSTIBLE GAS DETECTION - explosive gases, such as methane

There are many types of testing equipment available but all require competent personnel to operate them. The equipment that is selected must be approved for use in explosive atmospheres.

Ventilation

Well-designed efficient ventilation is the best protection against the major hazards in a sewer which can be asphyxiating, toxic or explosive atmospheres. Ventilation also can be used to control extreme temperature conditions and reduce other discomforts such as unpleasant smells. Powered blower equipment must be used. Natural ventilation is not dependable and not recommended. Care must be taken in placing the air intake for fresh clean air. **DO NOT PLACE NEAR VEHICLE EXHAUSTS.**

Proper ventilation requires air to be blown through hoses to the furthest limits of the work area. This reduces the risk of a build-up of hazardous gases. Re-testing the atmosphere will determine the amount or duration of ventilation.
Ventilation will continue until:

- the oxygen content of the air exceed 18 kilopascals (18% @ sea level)
- toxic contaminants are below their OEL(Occupational Exposure Limit)
- flammable contaminants are below the lower explosive limit (LEL)

Isolation

Harmful substances should be prevented to being introduced to the work space particularly for long work periods, pipes should be blocked off if possible. If there are any moving parts, main power switches should be locked out and tagged to prevent accidental re-activation.

PERSONAL PROTECTIVE EQUIPMENT

Respiratory equipment should be used in the few situations where it is the only way to protect workers. It must be carefully selected to meet the requirements of the job, for ease of access and egress. It must be properly maintained and used for adequate protection.

Other protective equipment that may be necessary are:

- coveralls
- hard hats
- gloves
- safety boots
- eye protection
- hearing protection

Cleaning and laundering of personal protective equipment must be done frequently to prevent disease. Protective clothing must never be worn home.

RESCUE PROCEDURES AND EQUIPMENT

Emergency rescue procedures must be planned whenever the sewer contains or may contain, a toxic or explosive atmosphere or oxygen deficiency.

These procedures should include:

- Communication and alert procedures.
- There must always be a worker stationed at or near the entrance to the confined space area who is in direct communication with those inside the sewer.
- Notification to medical support.

- Communication between the attendant and rescue personnel is also necessary, as is a means of immediately notifying medical personnel.
- Rescue personnel assignments
- Workers must be trained and ready to assist in first aid, CPR, traffic control. In a remote field situation extra planning and equipment are required.
- Rescue equipment requirements
- A tripod and harness system, or adequate substitute, to maneuver the victim to the surface is required. Some way to move the victim to emergency transportation should be available.
- Breathing apparatus requirements.
- Sufficient and appropriate breathing apparatus to protect rescue personnel must be at the site if they are required to enter sewer (no ability to move victim out of area without going in).
- First aid equipment and trained personnel available.
- Ambulance directions and access.
- Adequate transportation to nearest medical facility. Receiving facility should be notified by phone with full information on circumstances of injury and/or toxic exposure so appropriate preparations can be made prior to arrival.
- Follow up contact should be handled by a designated person to reduce multiple phone calls.
- Speed is critical. Poorly trained personnel could be life threatening. The more difficult and hazardous the rescue is liable to be, the more detailed the pre-planning should be.

References:

Alberta Community and Occupational Health. 1986. Sewer Entry Guidelines.

The CRC Handbook for Chemistry and Physics. 1991.

Worker's Compensation Board of British Columbia. 1992. Confined Space Entry - A Manual of Standard Practices.

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