REFERENCE MANUAL

ENVIRONMENTAL SAMPLING TRAINING COURSE

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INTRODUCTION

This manual provides an overview of the procedures involved in carrying out various types of environmental sampling projects. Planning methods and quality control are stressed throughout the manual, as well as the selection of proper equipment suitable for each planning method. Field sampling techniques are also emphasised for various media including:

- surface water,
- groundwater,
- soil,
- sediment,
- air,
- biological
- surficial, and
- human habitation.

While this module is comprehensive, it is not to be used as a detailed field guide for sampling procedures. Instead, its purpose is to illuminate the overall process of environmental sampling planning and environmental field sampling so that project personnel are aware of the complexities of their project and can plan accordingly. Readers are directed to other sources of information on environmental sampling such as presented in the reference section of the present manual.

When using this guide it is important to remember that each project is unique. The diversity of environmental conditions can vary immensely even within a small area. Therefore, guidelines or procedures that work well in some situations may not work at all in others. It is the responsibility of the project personnel to recognize these differences and only select sampling methods or procedures that are in line with their project objectives.

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1.0 SECTION 1 – PRE-SAMPLING PLANNING

1.1 INTRODUCTION

Pre-sampling planning is an important component of any environmental sampling project. It requires that a period of time be set aside before the commencement of fieldwork in order to collect background data and develop an organizational framework. Once completed, these tasks will help to ensure the effectiveness, quality and efficiency of the sampling project.

1.2 THE PURPOSE OF SAMPLING

The main purpose of environmental sampling is to acquire a set of samples that are representative of the source that is being sampled and that are appropriate for analysis. Once obtained, these samples can be tested to identify and determine the concentrations of known and unknown contaminants present and the extent to which these contaminants have become integrated into the surrounding environment.

Environmental sampling can be undertaken for a variety of reasons including:

- Routine monitoring,
- Environmental site assessment,
- Research projects,
- Site characterization, and
- Emergency response.

1.3 ESTABLISHING SAMPLING OBJECTIVES

Determining the sampling objectives of a specific project is the first step in pre-sampling planning.

Questions that may help a team establish these objectives are:

- Why is the study being done?
- What is the main goal of the project?
- What future decisions need to be made based upon the results achieved?

It is important to ensure that all members of the project team discuss, understand, and agree upon the project objectives from the start of the project.

1.4 COLLECTING BACKGROUND DATA

Once the sampling objectives have been discussed and agreed upon by team members, the next step is to collect as much background data about the field site as possible.

1.4.1 Purpose

Collecting background data about the site will aid in identifying components of the sampling plan and developing a safety plan. Knowledge of the site's past and present land uses, and the collection of photographs and maps of the area will be useful in making decisions regarding sampling locations, site access, and stakeholders. Information about potential contaminants present at the site and their dispersal pathways will aid in selecting sampling methods. In addition, this information will serve to identify potential hazards in the area and the nearest sources of emergency help so that a safety plan can be developed accordingly.

1.4.2 Important Background Data and Data Sources

The following is a list of pertinent background data and potential data sources:

a. Past Projects

Search for company or government records describing past projects in your study area. Knowledge of the obstacles and constraints faced by other projects in the past will help you to avoid them.

b. Interviews

Interview past and present site personnel and inhabitants of the area. People that have lived and worked in the area will have special knowledge that cannot be found on maps or in reports. Also interview people who have expertise in the project area or in the type of sampling being conducted.

c. Government Regulations

Research the government regulations that apply to the study area. Knowledge of existing regulations will aid in establishing project guidelines and avoiding future litigation.

d. Stakeholders

Identify the site owner and any other groups or individuals who will be affected by the project. It is important to inform these groups of the purpose of the sampling activity, the exact project location, and the tasks that will be performed, in order to avoid future discontent or controversy.

e. Maps

Collect as many different maps and photos of the area as possible.

- Road maps will provide information about accessibility and the methods of transportation needed to access the study area.
- Aerial photos (if available) will provide historical and/or current information on land use, topography, vegetation etc.
- Topography maps will provide information on surface water patterns and general land conditions.
- Geological maps will provide information about the soil and underlying bedrock of the study area.

f. Emergency Help

Locate the nearest centers of emergency help and the best way to access them. If the study area is in a remote location, identify a radio contact that can be used in case of an emergency. This information is necessary to develop a responsible safety plan.

g. Chemical Characteristics

Research the chemicals or materials that are potentially present at the site and their physical and chemical characteristics including flammability, toxicity, volatility, and persistence. These characteristics will determine how a chemical behaves when released into the environment and the potential pathways it may take. This information will aid in selecting a sampling method and developing a safety plan.

h. Land Use

Study the current land use of your project site. Land use can affect the dispersion of materials from the site. For example, urban areas have more possible dispersal pathways then agricultural areas.

i. Physical Environment

Use maps and/or geological and hydrological data to study the physical environment of the site as this will also help to identify the dispersal pathways of the substances of concern. For example:

- Knowledge of soil types at the site provides information about soil porosity and permeability e.g. sandy soil permits faster infiltration than clay.
- Knowledge of rainfall and wind direction provides information about potential erosion of contaminants by water and wind.

j. Decontamination and Waste Disposal

Research the different methods of decontamination and waste disposal that are appropriate for your project

1.5 DEVELOPING AN ORGANIZATIONAL FRAMEWORK

Organization is the key to running a successful sampling project. If project tasks and duties are designated and laid out well in advance of fieldwork, then there is less room for oversight or error.

1.5.1 Personnel Responsibility

Every member of the sampling team must be fully aware of his or her responsibilities from the start of the project. Every sampling project should have a team manager who is responsible for delegating specific tasks to each team member.

Examples of sampling project responsibilities include:

Sampling Manager

The sampling manager must possess experience in managing field activities as well as the technical expertise necessary to head the project. The sampling manager will ensure that the project plan is followed, quality assurance procedures are carried out, and proper safety measures are taken. The selection of sampling location and other important field decisions are also the responsibility of the sampling manager.

Field Technicians

The field technicians perform all of the sampling operations.

Documentation Personnel

Documentation personnel are responsible for taking photographs, making sketches of the study area, and recording data in field notebooks.

Depending on the size of the sampling team, some of these duties may overlap.

Note: When delegating responsibility, the team leader must be sure that the person assigned to each task has the technical expertise and knowledge to complete it.

1.5.2 Project outline

Once the project personnel are aware of their responsibilities, a basic project outline can be developed. A project outline may be broken down into phases such as preplanning, preparation, sampling and demobilization.

A project outline may include:

- The sequence of project activities within each phase.
- A timeframe for each phase that is designed to complete the project in a reasonable time based on limiting factors such as the budget, human resources, and available equipment.
- Personnel responsibilities.
- The equipment needed to complete each task.

When devising a project schedule it is important to remember that plans may change. Time estimates may be inaccurate or unforeseen obstacles may be encountered that prolong the time it takes to complete a task. In an effort to plan for these changes, try to consider each phase of the project separately so that the commencement of one phase is not dependent on the completion of another.

Establishing a project schedule is an important way of setting goals and objectives for the project.

1.5.3 Equipment list

In the early stages of project planning, an equipment checklist should be developed and distributed to all project personnel. Equipment should be assembled and checked against this list well in advance of the commencement of fieldwork. (See Appendix I).

2.0 SECTION 2 - DEVELOPING QUALITY CONTROL PLANS

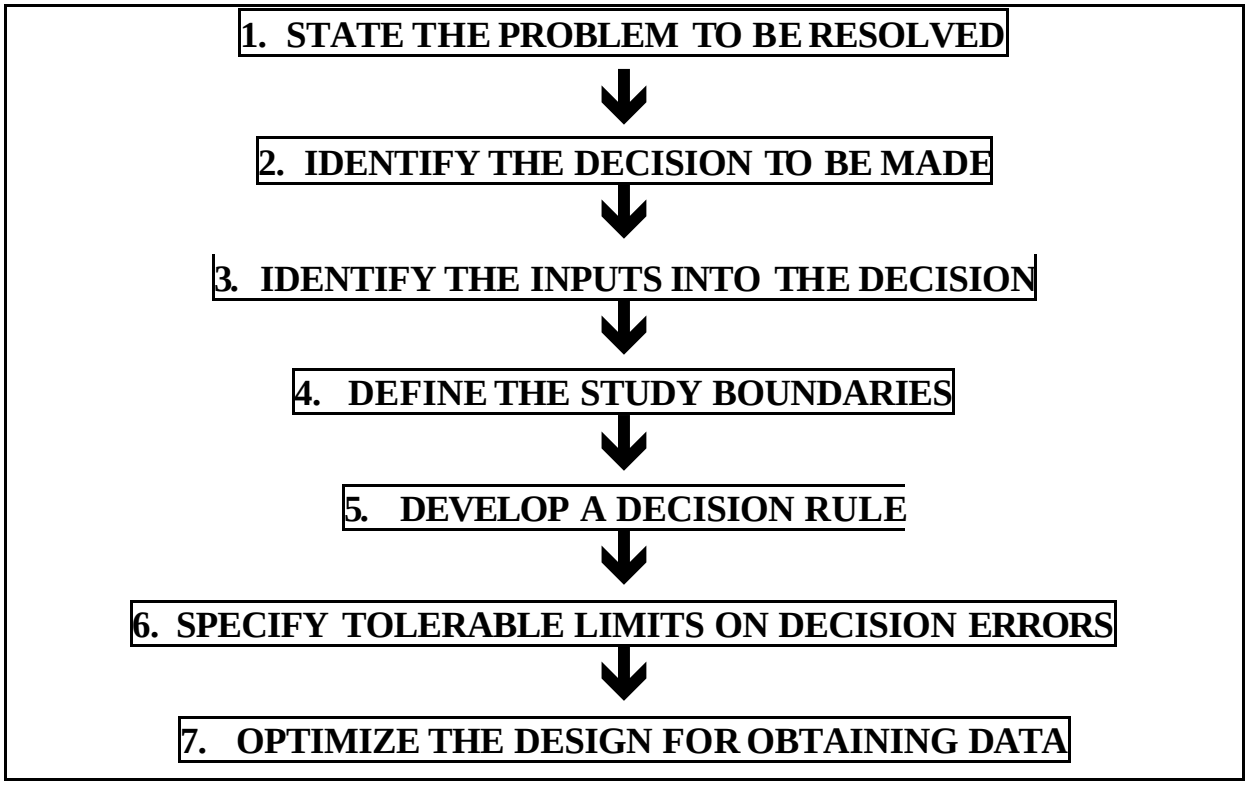
2.1 INTRODUCTION

It is very important that every sampling project establish a set of quality control plans to ensure that sampling procedures are carried out efficiently and effectively. A quality control plan involves the establishment of procedures that must be carried out in the field and laboratory to ensure that the results of the sampling activity meet the projects data quality objectives (DQOs).

2.2 ESTABLISHING DATA QUALITY OBJECTIVES

In order to develop quality control plans, it is necessary to first define the DQOs of the project. DQOs are statements that define the type, quality and quantity of data needed to meet the users needs. They determine the degree of total uncertainty or error that the data user is willing to accept. Figure 2.1 presents the principle steps in the data quality objectives process.

Figure 2.1: The principle steps in the DQO process



Each one of the above stages will produce qualitative and quantitative statements about the need for the data, what the data should represent, and how much uncertainty is tolerable.

As a result of defining data quality objectives:

- Data generated is of known quality
- Data users can plan for uncertainty and have knowledge of the amount of uncertainty that they can tolerate

2.3 QUALITY CONTROL PLANS

Once DQOs have been established, a quality control plan can be written. This plan will specify the activities required to achieve the DQOs, and will describe how data is assessed for precision, accuracy, representativeness, completeness, comparability and compatibility.

A quality control plan requires that all data be documented and may include:

- A project description.
- Project organization and designated responsibilities.
- QC objectives for the data in terms of precision, accuracy, completeness, and comparability.
- Sampling procedures and sample handling.
- Sample transportation, preservation, and storage.

To satisfy the requirements for quality data, a QC project plan must describe the following activities:

- Sampling design and the selection of specific sampling sites.
- Sampling, analytical methodology, calibration, and standard operating procedures (SOPs).
- Sampling devices, storage containers, and preservatives.
- Special operating conditions (e.g., heat, light, reactivity, etc.).
- Reference or alternate test procedures.
- Instrument selection and use.
- Preventive and remedial maintenance.

- Replicate sampling.
- Replicate analyses.
- Blank and spiked samples.
- Laboratory QC procedures.
- Documentation needed.

2.4 QUALITY ASSURANCE PLANS

Quality assurance plans usually involve an active auditing process to ensure that the quality control procedures are being carried out correctly. (Refer to Section 14 on Auditing).

2.5 CONTAMINATION CONTROL PLANS

Sampling projects usually involve the collection of data in less than ideal conditions. In addition, a variety of organizations are often responsible for providing the equipment; and collecting, transporting and storing samples. Prior to laboratory analysis, the integrity of a sample must be maintained throughout the implementation of appropriate quality assurance practices.

Plans to ensure that contamination is minimized throughout the project are essential and may include:

2.5.1 Establishing Qualifications and Documentation

It is important that both the field and laboratory staff are trained in the concepts of quality assurance and possess the technical skills needed to carry out their roles. Problems with techniques and practices can be minimized by ensuring instructions related to collecting, transporting and storing samples are well thought out and clearly documented. These documents need to be controlled so that only the current versions are available and in use by field and laboratory staff.

Instructions are needed for the following:

- Purchasing supplies (sample bottles and caps, filter paper, equipment).
- Purchasing services, including subcontractors.

- Carrying out ongoing quality control of sample bottles, caps and filter paper, including establishing and using acceptance criteria and acting on non-conformances.
- Preparing field supplies, including cleaning equipment and sample bottles (where applicable).
- Preparing and collecting quality control samples such as travel blanks and field blanks.
- Shipping field supplies.
- Labeling sample bottles.
- Collecting samples.
- Maintaining records related to sampling.
- Transporting samples from the field to the laboratory.
- Receiving samples in the laboratory.
- Tracking samples in the laboratory.
- Storing samples in the laboratory.
- Scheduling analyses.
- Reporting and recording non-conformances and taking corrective and preventive action.

Sample collection and handling procedures must be documented and must identify:

- The equipment and materials used, including cleaning procedures.
- The type of material sampled.
- The time and location of sampling.
- The person doing the sampling.
- All steps in the sample collection handling process.

Documented sample collection handling procedures must contain specifications that ensure that valid results are obtained, including specifications to ensure that:

- Samples are not contaminated.
- Samples do not deteriorate.
- There is adequate quality control

2.5.2 Field Equipment

Field equipment that is properly calibrated and maintained is essential to collecting valid, representative samples. The care and maintenance of this equipment should be assigned to a specific, experienced individual or group.

Quality control elements required to avoid potential contamination of field equipment may include but are not limited to:

- Ensuring that field sampling equipment such as pumps, buckets, funnels etc. is made of stainless steel or Teflon.

- Properly maintaining and calibrating scientific field equipment such as conductivity meters, thermometers, pH meters etc.

- Decontaminating field equipment after a location has been sampled, and before it is moved to the next location to avoid cross contamination of samples.

- Washing the equipment with soap and water or a decontamination solution, rinsing with tap water or de-ionized water and triple rinse with de-ionized water.

- Rinsing buckets, funnels, scoops etc. used to collect and transfer the sample with a portion of the actual sample and then discarding the rinse.

2.5.3 Scientific Equipment

Data generated for any sample can only be as good as the sample itself. Quality control and quality assurance procedures must therefore be taken to ensure that once collected, samples do not deteriorate and are not contaminated.

Quality control elements required to avoid potential contamination of scientific sampling equipment include but are not limited to:

- Establishing an ongoing procedure of checking supplier quality control of sampling equipment including bottles, caps and filter papers.

- Ensuring that only sample bottles and caps appropriate for the analyses of interest are used (see Table 2.1).

- Ensuring that sample bottles and caps are new or laboratory cleaned (the cleaning methods should be documented by the person cleaning the containers).

- Storing bottles and caps in such a way so as to minimize exposure to dirt, dust and fumes.

- Capping bottles before they are sent to the field, opening them just before sampling and capping them immediately and tightly following sampling to minimize the time the sample preservative is exposed to the atmosphere.

- Checking equipment such as samplers and filter units for possible sources of contamination before being put into use.

- Washing filter units with acid and soaking them with reagent water before they go to the field. In the field they should be rinsed at least twice with reagent 13 water between samples to prevent carry-over.

- Soaking plastic pipette tips in 2N HCl $HN0_3$ for several days before use and rinsing them with deionized water as they are often contaminated with copper, iron, zinc, and cadmium.

- Taking extreme care to protect container caps from contamination during sampling.

- Ensuring that chemicals used as preservatives are of high purity and their containers are labeled with expiry dates to ensure their integrity.

- Minimizing the exposure of sample bottles to dirt, dust and fumes when chemical preservatives are added (lead contamination from fumes is particularly a problem).

- Packing chemical preservatives in single sample aliquots to minimize contamination from the field environment. It is critical that quantities of chemicals added as preservatives are controlled to obtain reproducible blanks.

- Ensuring that the amount of preservative required to reach a specified pH is determined by titration on water samples collected specifically for that purpose. The amount of preservative needed should never be arrived at by measuring the pH of the actual sample.

- Keeping coolers clean and using ice packs rather than ice because ice can be expected to melt during the transport of samples and the resulting water may contaminate the samples.

- Making sure your hands are clean during sampling and never touching the inside of sample bottles or caps with anything other than the sample itself and the preservative.

- Minimizing the contamination from the surrounding environment by refraining from smoking in the vicinity of the sample collection and handling activities. Smokers should wear unlined latex or polyethylene gloves.

- Potential contamination problems relating to sampling surface water, ground water, air quality, etc. can be found in the respective chapters.

2.5.4 Controlling Preservation and Storage

The objective of preservation is to ensure that samples do not deteriorate or degrade prior to laboratory testing. Chemical preservation, storage temperatures and holding time (e.g. elapsed time between sampling and testing) all play a key role in sample preservation. (See following Table 2.1).

Table 2.1: Sampling Handling Instructions With Preservation Methods and Container Types

Parameter	Matrix	Container	Min Volume or Weight	Preservative	Holding Time	Stora Temp (°C)
Acidity	aqueous	plastic or glass	250 ml	refrigerate	24 h	4
Adsorbable Organic Halides (AOX)	aqueous	amber glass, Teflon® lid liner	1L	0.5% sodium sulphite, 1 ml concentrated nitric acid, no headspace, refrigerate	Final Effluent - 12 wk C and E Stages - 2 d	4
Alkalinity	aqueous	plastic or glass	250 ml	refrigerate	3 d	4
Ammonia	aqueous	plastic	100 or 250 ml	acidify to pH 2 with conc. H_2SO_4, 1.0 ml sodium arsenate/1.0 mg residual chlorine in sample		
Anti-sapstains	aqueous	glass, Teflon® - lined lids	1L	5 ml Rexonic N25-7 + 10 ml 37% formaldehyde/L sample, refrigerate	4 wk	4
Anti-sapstains	solid	glass, Teflon® - lined lids	100 g	2.5 ml Rexonic N25-7 + 5 ml 37% formaldehyde/100g sample, refrigerate	4 wk	4
Bacteria - Fecal Coliform and Steptococci	aqueous, solid	sterile plastic or glass	250 ml	refrigerate sodium thiosulphate	24 h	10
Bioassay or Acute Lethality Testing	aqueous	pail, jerry can, carboy drum	20, 50 or 100L	refrigerate, do not freeze store in dark	5 d	1-8
Carbon	aqueous solid	plastic glass	100 or 250 ml 125 ml	1 ml conc. HCl refrigerate	14 d	4
Dibenzodioxins and Dibenzofurans, Polychlorinated (PCDD/PCDF)	aqueous solid	amber glass	2 - 1L 100 g	refrigerate	N/A	4

Table 2.1: Sampling Handling Instructions With Preservation Methods and Container Types (suite)

Parameter	Matrix	Container	Min Volume or Weight	Preservative	Holding Time	Storage Temp (°C)
Chlorinated Phenols	aqueous	amber glass, Teflon®-lined lid	1L	2 Ml conc. HCl refrigerate	3 wk	4
Chloride, Fluoride, Bromide	aqueous	plastic or glass	100 Ml	refrigerate	consult lab	4
Cyanide	aqueous	plastic	100 or 500 Ml	ascorbic acid, 1.5 Ml 40% NaOH/100 Ml refrigerate	7 d	4
Dibenzofurans and dibenzo-p-dioxins	defoamer surfaces	glass, Teflon®-lined lids amber glass		N/A	consult lab	
Dissolved Oxygen	aqueous	glass or plastic	100 Ml or 1L	no headspace, refrigerate, consult laboratory	varies with type of sample, consult lab	4
Metals	aqueous	plastic	250 or 500 Ml	pH = 2, with nitric acid (filter sample if testing for dissolved metals)	240 d	
Mercury	aqueous	Teflon® or glass, Teflon®-lined lid	100 or 250 Ml	1 ml, 5% potassium dichromate + 1 Ml conc. HNO_3	6 mo	
Nitrate, Nitrite, TKN	aqueous	plastic	100 Ml	refrigerate 2 Ml conc. H_2SO_4 for TKN sample	5 d 7 d for TKN	4
Ozone-Depleting Substances (ODS)	product	1 can of product	N/A	N/A	N/A	N/A
Oxygen Demand (Biochemical OxygenDemand)	aqueous	glass or plastic	300 Ml and 1 L	no headspace, refrigerate	24 h	4
Oxygen Demand (Chemical OxygenDemand)	aqueous	plastic	500 ml	1 ml conc. H_2SO_4/L refrigerate	28 d	4
Pesticides	aqueous solids	amber glass	1L or 4L 100 g	consult laboratory refrigerate	consult lab	4

Table 2.1: Sampling Handling Instructions With Preservation Methods and Container Types (suite)

Parameter	Matrix	Container	Min Volume or Weight	Preservative	Holding Time	Stora Temp (°C)
Petroleum Products	aqueous, solid	glass, Teflon®-lined lids	1 L	refrigerate	ASAP	4
Petroleum Products (Oil and Grease)	aqueous, solid	clear glass, Teflon®-lined lids	1L	2 Ml conc. HCL or H_2SO_4, refrigerate	5 d	4
Phosphorus	aqueous, solid	glass	125 Ml	N/A	N/A	
Phosphates (ortho and total)	aqueous	plastic for effluents, glass for surface waters	125 Ml	refrigerate	14 d	4
Polychlorinated Biphenyls (PCBs)	aqueous solids	glass	1L (oils - 20 Ml) 125 Ml	refrigerate	30 d	4
Polycyclic Aromatic Hydrocarbons (PAHs)	aqueous solid	amber glass, Teflon®-lined lid	1L 100g	refrigerate	30 d	4
Resin Acids	aqueous solid	amber glass, Teflon®-lined lid	1L 100g	0.5 N NaOH or 0.5 N H_2SO_4	14 d	
Sulphate	aqueous	plastic	250 Ml	refrigerate	7 d	4
Sulphides	aqueous	plastic or glass	1L	consult lab	24 to 48 h	
Surfactants (Anionic)	aqueous	glass, Teflon®-lined lid	200 Ml	refrigerate	2 mo	4
Total Suspended Solids (TSS)	aqueous	glass or plastic	200 Ml for turbid sample, 1L for clear sample	refrigerate	24 h - pulp and paper effluents, 7 d for other samples	4
Turbidity	aqueous	plastic or glass	250 or 500 Ml	refrigerate	24 h	4
Volatile Organic Carbon (VOC)	aqueous	amber glass, Teflon® septum cap	40 Ml	no headspace, refrigerate	14 d	4

Source of Information: Environment Canada, The Inspector's Field Sampling Manual, First Edition, 1995.

Potential contamination problems relating to the preservation and storage of surface water, ground water, air samples etc. can be found in the respective chapters.

2.6 MONITORING SAMPLE CONTAMINATION

The use of quality control samples (or blanks) to monitor sample contamination is an important objective of a QC program. Examples of different types of blanks are as follows:

2.6.1 Trip Blanks

Trip blanks are also referred to as travel or transport blanks.

- Trip blanks are used to check for background contamination and contamination from transport and/or handling.
- Trip blanks are transported to the field with the regular sample bottles and submitted to the laboratory unopened in the same shipping container that contains the samples.
- The blanks are opened at the time of analysis and the contents are analyzed in the same manner as the samples.
- At least one trip blank should be submitted with each batch of samples.

2.6.2 Field Blanks

Field blanks are also referred to as site blanks.

- They are samples of analyte-free media similar to the sample.
- Field blanks are used to check contamination from all the potential sources including accidental contamination during sampling, transport, sample preparation, and analysis.
- Reagent water or certified clean soil are transported to the field in clean containers and carried through all sample handling/processing steps that the test samples undergo (e.g., filtration, transfer to a sample container, chemical preservation, exposure to the atmosphere).
- Field blanks are transported, stored and analyzed in the same manner as the samples.
- At least one field blank should be collected per day per collection apparatus.

2.6.3 Equipment Blanks

Equipment blanks are also referred to as rinsate blanks.

- Equipment blanks are samples of analyte-free materials used to check contamination of the sampling equipment
- The equipment is rinsed with reagent water that is then stored in a clean sample bottle.
- Equipment blanks are preserved and analyzed in the same manner as the samples.

2.6.4 Filtration Blanks

Filtration blanks are used to check contamination from the filtering apparatus and filter paper.

- They are collected both at the start and at some point during sample collection.
- Filtration blanks are prepared using reagent water that is filtered in the same manner as the samples.
- Filtration blanks are preserved and analyzed in the same manner as the samples.

Generally, blanks should contain no measurable contamination. Where some contamination is detected, it is possible that the contamination is related to the sampling method, although other possibilities should not be ruled out.

In order to respond to contaminated blanks, acceptance criteria, also called nonconformance criteria, must be established and documented for each type of blank. Analysts use these criteria to identify data that are unreliable because of unacceptable levels of contamination. If a result for a blank is outside the acceptance criteria, the nonconformance must be recorded and reported. If the decision is to continue with the analysis, the data must be flagged as nonconforming in the report to the client. Corrective action should be taken to identify the cause of the problem and to prevent it from recurring. Data for sampling blanks should be reported with the data for the samples.

2.7 DOCUMENTATION

Recording field measurement data and other field information is an important component of any field sampling project. Field notes, collected samples and decontamination procedures all require careful documentation.

2.7.1 Field Notes

Good field notes are essential to all sampling projects as they document the quality assurance and quality control measures taken throughout the project. Every individual sampling project must have its own set of field notes that are recorded by a designated team member. The notes should record all field measurements, observations, calibrations, samples, maps, photographs and correspondence. The pages should be numbered and should not be easy to remove.

The following are important points to keep in mind when making field notes:

- Notes should be recorded by one designated team member.
- They should be neatly printed in waterproof ink.
- Notes should be recorded in a logical order, possibly being divided into sections based on phases of the sampling project or listed in chronological order.
- If mistakes are made they should not be erased but crossed out with a single line through the error. The correct information should be inserted near the mistake and the notekeeper should initial and date the mistake.

Field notes should contain details on:

- The project name and project number.
- The identities of the sampling team.
- The exact site location and site description which can include the name of the stream, lake etc being sampled, the general description of the area including topography, land uses etc, and the sampling points including a site sketch.

- The weather conditions, current and recent.
- Date and time of the site visit and departure.
- Sample numbers and time of collection.
- Sample descriptions.
- Sampling methods.
- Equipment used.
- Calibration data.
- Types of analysis for which samples are collected.
- In-situ measurements, flow volumes, pH etc.
- Photographs of the site.

The notes should be legible, dated and contain only factual information and observations. Entries made by someone other than the official notetaker should be dated and signed by the individual that made the entry. A designated individual to ensure quality control and field note completeness should review all entries.

2.7.2 Sample Documentation

The type of sample documentation used depends on the measurements that are taken. Measurements that are taken in-situ such as pH, conductivity, and temperature are recorded directly into a field notebook. These records should include:

- Project number.
- Sample number.
- Sample type.
- Station Location.

- Date and time.
- Names of samplers.
- General observations.
- Analysis required.
- Preservation methods.

Samples that are taken, removed from the sampling site, and sent to a laboratory require identification by a sample label. The sample label should be attached to the container holding the sample and should include the same information that is recommended for in-situ samples. When there is not enough room on the sample label to record all of this information, the samples number should be recorded in the field book with the rest of the information. (See Figure 2.7).

In order to avoid sample labeling errors the data should be recorded and attached to the sample immediately after the sample is taken. It is also a good idea to have a second person double check the sample label information.

Figure 2.2: A Typical Sample Label

Site Number:	**Date\Time of Collection:**
Site Location:	**Sample Number:**
Sample Type: ☐ **Grab Sample** ☐ **Composite Sample** ☐ **Other**	**Sample Collector:**
Preservation Techniques:	**Analysis Required:**

When a sample requires preservatives it is important to document:

The type of preservative required.

The appropriate preservation holding time (the amount of time allowed between sampling and analyzing the sample).

Preservation techniques.

This information should be included in the project plan to ensure that the correct amount of preservatives are taken to the field and arrangements can be made to transport samples to the lab

within the required holding time. This information should also be documented in the field notebook at the time the preservative is added.

2.7.3 Decontamination Documentation

When moving from one sampling site to another all field equipment must be decontaminated to avoid cross-contamination. All decontamination steps taken should be documented in the field notebook.

3.0 SECTION 3 - SELECTING SAMPLING METHODS

3.1 INTRODUCTION

There are many different sampling methods to choose from regardless of the type of survey being conducted. Every method has its pros and cons and every project has constraints that limit the number of sampling options available.

3.2 METHOD SELECTION CRITERIA

Some criteria that must be considered when selecting a sampling method are:

- Project budget -the financial resources available for equipment, manpower, and maintenance
- Representativeness –the sampling method selected must be able to provide a true representation of the material being sampled
- Practicality –a simple, proven sampling method with easy to follow procedures and equipment that is simple to operate is preferable
- Safety –the potential risks involved in carrying out the sampling method at a specific site must also be considered when selecting a sampling plan
- The above criteria will serve as limiting factors when selecting sampling methods for the project.

3.3 SELECTING A SAMPLING LOCATION

The number of samples that need to be taken and from which locations, are questions that need to be answered before going out into the field.

Several factors that may influence these decisions include:

- The degree of accuracy that is required,
- The variability of the media that is being sampled, and
- The cost of collecting and analyzing the samples.

There are two main types of sampling strategies, non-statistical and statistical.

3.3.1 Non-Statistical Sampling Strategies

Non-statistical sampling strategies may be used to select sampling locations and estimate the number of samples that are needed.

Non-statistical or judgemental sampling involves sampling near the potential source of contamination or along potential pathways of contamination. This method allows the introduction of bias into the survey as it relies on the samplers' expertise in determining contaminant distribution. It is useful when the limitations of the samplers judgement are known and the objective is identification and not quantification of a substance, however, it can lead to inaccurate results if too few samples are taken, or to increased costs if more samples are taken than necessary.

If a judgemental approach is selected, it is up to the sampling team to select the sampling sites. Before sites are selected it is necessary to:

- Review the study work plan, especially the types of measurements and samples needed.
- Make reconnaissance trips to the study area before selecting sampling sites and note any obstacles, manmade structures etc that should be avoided.
- Review site files and folders including the site description, land uses, access, physical, chemical and biological data.

3.3.2 Statistical Sampling Strategies

In order to obtain the most accurate data possible while minimizing costs, a statistical sampling strategy can be used which allows the appropriate sample number to be estimated and the sample locations to be selected without bias.

There are several methods of statistical sampling:

a. Simple Random Sampling

Simple Random Sampling is a statistical sample strategy that involves selecting the sampling point by chance without consideration of the source of contamination. Because each sampling location has an equal chance of being selected, sampling error

can be accurately estimated. This method is unbiased and can often produce higher levels of accuracy. In general, the study area is divided into a grid and sampling is performed at random co-ordinates. Sampling locations should be selected using a random number table (Table 3.3) or a random number generator so that the bias of the sample collector is eliminated.

b. Systematic Sampling

Systematic Sampling can increase efficiency because either the sampling error is reduced while the sample number stays the same, or the number of samples is reduced while the sampling error is maintained. This method also does not require any knowledge of contaminant distribution. Two examples of systematic sampling are:

Pre-selecting a transect and sampling interval but starting the sampling from a randomly selected point or,

Randomly selecting a transect but sampling at a pre-selected interval.

All randomly selected points should be chosen using a random number table or a random number generator so that the bias of the sample collector is eliminated (Table 3.3).

c. Stratified Random Sampling

Stratified Random Sampling requires some knowledge of contaminant distribution. It requires dividing the study area into homogenous strata and then dividing the strata into grids. Simple random sampling techniques are used to select the sampling location randomly.

After analysis has been performed it is necessary to determine whether or not stratification actually existed and thus, whether the use of a stratified random sampling technique was statistically valid.

Table 3.1: Random Numbers Table

03	47	43	73	86	36	96	47	36	61	46	98	63	71	62
97	74	24	67	62	42	81	14	57	20	42	53	32	37	32
16	76	62	27	66	56	50	26	71	07	32	90	79	78	53
12	56	85	99	26	96	96	68	27	31	05	03	72	93	15
55	59	56	35	64	38	54	82	46	22	31	62	43	09	90
16	22	77	94	39	49	54	43	54	82	17	37	93	23	78
84	42	17	53	31	57.	24	55	06	88	77	04	74	47	67
63	07	63	78	59	16	95	55	67	19	98	10	50	71	75
33	21	12	34	29	78	64	56	07	82	52	42	07	44	38
57	60	86	32	44	09	47	27	96	54	49	17	46	09	52
18	18	07	92	46	44	17	16	58	09	79	83	86	19	62
26	62	38	97	75	84	16	07	44	99	83	11	46	32	24
23	42	40	64	74	82	97	77	77	81	07	45	32	14	08
52	36	28	19	95	50	92	26	11	97	00	56	76	31	38
37	85	94	35	12	83	39	50	08	30	42	34	07	96	88
70	29	17	12	13	40	33	20	38	26	13	89	51	03	74
56	62	18	37	35	96	83	50	87	75	97	12	25	93	47
99	49	57	22	77	88	42	95	45	72	16	64	36	16	00
16	08	15	04	72	33	27	14	34	09	45	59	34	68	49
31	16	93	32	43	50	27	89	87	19	20	15	37	00	49

How to use the Random Numbers Table:

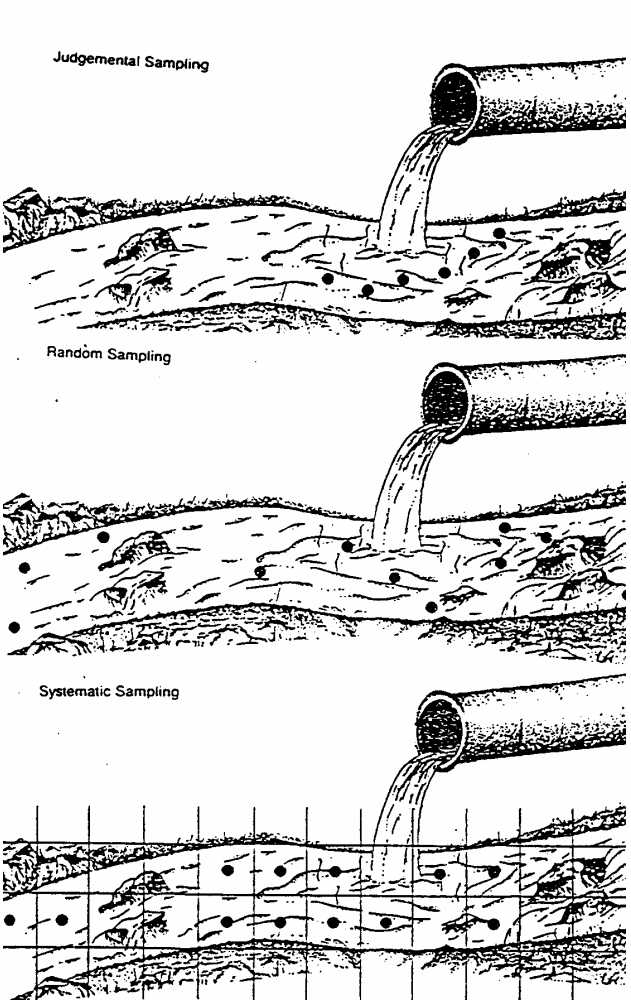
1. If sampling containerized wastes (i.e., drums, sacks, etc.) segregate the containers according to waste type based on available information e.g-container markings, labels. Number containers with the same waste type consecutively, starting from 01. If sampling surface waters. divide the area into a two- or three-dimensional grid and number the grid locations.

2. Determine the number of samples you need to take. For routine surveillance sampling one or two is usually adequate and judgment sampling is suitable. But for regulatory or research purposes, a larger sample size (such as one sample for every group of five. containers) taken at random will generate more statistically valid data.

3. Using the random numbers table, choose any number as a starting point.

4. From this number go in any direction until you have selected the predetermined number of samples with no repetitions. Numbers larger than the population size are ineligible

Figure 3.1: Example of Judgmental Sampling, Systematic Sampling and Random Sampling Approaches



3.4 DETERMINING SAMPLE QUANTITY

The purpose of sampling is to acquire a representative sample from the substance of interest (e.g. groundwater, surface water, air, soil, etc.). One way to achieve this would be to take a large number of samples and average the results, as the mean of any distribution becomes normal as the number of samples becomes larger. But, as taking large numbers of samples can be costly, a method of determining the appropriate sample number needed for a given level of accuracy needs to be used. This can be achieved by using the Simple Random Strategy of determining quantity**.**

The simple random strategy involves establishing confidence limits. Confidence limits can be used to determine with what degree of confidence it can be stated that the sample mean (average) is representative of the true mean. Confidence limits can be derived for any level of statistical probability that is thought to be appropriate, e.g. 80%, 90%, 95%, 99%. 95% confidence limits are used most often, but if only rough estimates are required lower confidence limits can be used.

For example, four samples were taken for PCB concentration and subsequent analysis indicated that contamination was present at 41, 45, 48, and 50ppm with a mean (X) of 46 ppm. The regulatory threshold for PCB concentration is 50 ppm. In order to determine whether a larger sample size is needed to be representative, and if so how many more samples are needed, the following statistical method should be followed.

1. The most appropriate statistic to characterize a set of samples is the mean (X). In this case:

   $$X = \frac{41+45+48+50}{4} = 46$$

2. Any distribution needs to be characterised by variance. Variance (V) is a measure of the variability in a population and can be used to compute confidence intervals about estimates of population averages. It is defined as the arithmetic mean of the squares of all deviations from the mean.

   $$V = \frac{\Sigma (X_i - X)^2}{n - 1}$$

   $$V = 15.33$$

3. The standard deviation (S) which is the square root of the variance is the crucial quantity used in calculating confidence intervals.

   S = square root V = square root 15.33 = 3.92

4. The next step is to calculate the standard error of the mean (S_x). Standard error is inversely proportional to the square root of the number of samples e.g. increasing the number of sample measurements from 4 to 16 reduces S_x by 50%.

$$S_x = \frac{V}{n} = \frac{3.92}{4} = 0.98$$

5. Since the concern is only with whether the upper limit of a confidence interval is below or above the regulatory threshold, the lower confidence limit (LCL) need not be considered. The upper confidence limit (UCL) can thus be calculated using one-sided t values with n-i degrees of freedom derived from a table of the cumulative t distribution (Table 3.4). Where only small-sized statistical samples are involved (i.e. less than 30), the normal or Gaussian distribution is not accurate, and the "t-distribution" must be used. So for this example the t-distribution must be used.

6. The 95% UCL is calculated by using the following formula and substituting previously calculated values plus the appropriate t value obtained from Table 3.4.

   $UCL = X + t_{0.95\,(n-1)}\, S_x$

   $= 46 + (2.353)\,(0.98) = 48.3$ ppm

   Therefore, there is a 95% probability that the true mean is less than 48.3 ppm and also a slightly greater probability that the true mean is less than the RT of 50 ppm. If this degree of accuracy is sufficient for the needs of the sampling program, then no further samples many be needed.

   If a compound does not have a specified RT, then the UCL is compared to whatever concentration is of concern (i.e. cleanup level, action level etc.). This value is then used instead of the RT in all subsequent calculations. If more than one contaminant exists or more than one is of concern, then the UCL is compared to the lowest RT of the compounds of concern.

   If so desired the 99% UCL could be calculated in a similar manner:

   $UCL = X + t_{0.99(n-1)}\, S_x$

   $= 46 + (4.541)\,(0.98) = 50.5$ ppm

   Therefore, there is a 99% probability that the true mean is less than 50.5 ppm. Thus, if this degree of accuracy is desired, the UCL would exceed the RT and the true mean may exceed the RT. In cases such as this, an increased sampling effort may be necessary, and to determine the correct number of samples needed to increase the UCL referred to in the following section.

Table 3.2: Cumulative Distribution Table

		p								
one-tailed		0.55	0.75	0.80	0.90	0.95	0.975	0.99	0.995	0.9995	
two-tailed		0.10	0.50	0.60	0.80	0.90	0.95	0.98	0.99	0.999	
	1	.158	1.000	1.376	3.078	6.314	12.706	31.821	63.657	636.619	1
	2	.142	.816	1.061	1.886	2.920	4.303	6.965	9.925	31.598	2
	3	.137	.765	.978	1.638	2.353	3.182	4.541	5.841	12.924	3
	4	.134	.741	.941	1.533	2.132	2.776	3.747	4.604	8.610	4
	5	.132	.727	.920	1.476	2.015	2.571	3.365	4.032	6.869	5
	6	.131	.718	.906	1.440	1.943	2.447	3.143	3.707	5.959	6
	7	.130	.711	.896	1.415	1.895	2.365	2.998	3.499	5.408	7
	8	.130	.706	.889	1.397	1.860	2.306	2.896	3.355	5.041	8
	9	.129	.703	.883	1.383	1.833	2.262	2.821	3.250	4.781	9
	10	.129	.700	.879	1.372	1.812	2.228	2.764	3.169	4.587	10
	11	.129	.697	.876	1.363	1.796	2.201	2.718	3.106	4.437	11
	12	.128	.695	.873	1.356	1.782	2.179	2.681	3.055	4.318	12
	13	.128	.694	.870	1.350	1.771	2.160	2.650	3.012	4.221	13
	14	.128	.692	.868	1.345	1.761	2.145	2.624	2.977	4.140	14
	15	.128	.691	.866	1.341	1.753	2.131	2.602	2.947	4.073	15
	16	.128	.690	.865	1.337	1.746	2.120	2.583	2.921	4.015	16
df	17	.128	.689	.863	1.333	1.740	2.110	2.567	2.898	3.965	17
	18	.127	.688	.862	1.330	1.734	2.101	2.552	2.878	3.922	18
	19	.127	.688	.861	1.328	1.729	2.093	2.539	2.861	3.883	19
	20	.127	.687	.860	1.325	1.725	2.086	2.528	2.845	3.850	20
	21	.127	.686	.859	1.323	1.721	2.080	2.518	2.831	3.819	21
	22	.127	.686	.858	1.321	1.717	2.074	2.508	2.819	3.792	22
	23	.127	.685	.858	1.319	1.714	2.069	2.500	2.807	3.767	23
	24	.127	.685	.857	1.318	1.711	2.064	2.492	2.797	3.745	24
	25	.127	.684	.856	1.316	1.708	2.060	2.485	2.787	3.725	25
	26	.127	.684	.856	1.315	1.706	2.056	2.479	2.779	3.707	26
	27	.127	.684	.855	1.314	1.703	2.052	2.473	2.771	3.690	27
	28	.127	.683	.855	1.313	1.701	2.048	2.467	2.763	3.674	28
	29	.127	.683	.854	1.311	1.699	2.045	2.462	2.756	3.659	29
	30	.127	.683	.854	1.310	1.697	2.042	2.457	2.750	3.646	30
	40	.126	.681	.851	1.303	1.684	2.021	2.423	2.704	3.551	40
	60	.126	.679	.848	1.296	1.671	2.000	2.390	2.660	3.460	60
	120	.126	.677	.845	1.289	1.658	1.980	2.358	2.617	3.373	120
	∞	.126	.674	.842	1.282	1.645	1.960	2.326	2.576	3.291	∞

NOTE: For one-tailed distributions $\frac{\alpha}{2} = 1-p$

For two-tailed distributions $\alpha = 1-p$

3.5 DETERMINING THE NUMBER OF SAMPLES

A step-by-step approach to calculating an appropriate sample population size based on the analytical data derived from the four preliminary samples follows. To follow the above example and determine the number of samples required achieving an UCL of 99% the following is accomplished.

1. The appropriate number of samples to be collected can be estimated by use of the Lambda (λ) relationship and then consulting a table of λ values (Table 3.4.1) and their corresponding sample size number.

$$\lambda = \frac{RT - X}{S} = \frac{50-46}{3.92} \frac{4.0}{3.92} = 1.02$$

The lower the calculated λ value, the more samples required to maintain a certain level of confidence. Also, as X approaches RT, λ becomes smaller and therefore a greater sample size is indicated for a certain level of confidence.

2. To obtain the appropriate sample size from the table of λ values (Table 3.4.1), use the single- sided value for α to test at the 1% significance level ($\alpha = 0.01$).

   Testing hypothesis (H) of: true mean $\leq$ RT

   α error is the probability of rejecting a true hypothesis. For example in the above hypothesis, if the true mean is $\leq$ RT, then the α error is the probability of concluding that it is not a true hypothesis or a rejected true hypothesis.

   Use a β error of 0.05. β error is the probability of accepting a false hypothesis. For example in the above hypothesis, the true mean is > RT, then the β error is the probability of concluding that the X is $\leq$ RT.

3. Table 3 indicates that 19 additional samples (n_2) should be taken to gain a UCL of 99, If n_2 were not more than 20% > n_1 (4), there would be little chance that collecting additional samples would decrease S_x (and therefore, increase C) and result in the waste being considered hazardous. Therefore, the study would be complete.

4. Since n_2 is more than 20% > n_1, collect an additional $n_2 - n_1$ samples i.e. 19 - 4 =15 samples..

5. Assume the 15 samples were collected and new concentration values were determined.

6. From these concentrations the following values were calculated:

$$X = 47.75 \quad S=3.88 \quad S^2 = 15.07 \quad S_x = 0.26$$

7. If the new X $\geq$ RT, then the contaminant is present above a regulated concentration and the study would be complete

8. If X < RT and X > S^2**,** calculate C (the criterion for determining if contamination is present at hazardous concentrations). If X = S^2 or X < S^2 the data must be transformed prior to calculating C.

   Using the newly derived data, C is calculated by the formula:

$$C = \frac{RT-X}{S_x} = \frac{50 - 47.75}{0.26} = 8.65$$

9. Compare the calculated C value to the two-tailed t value (from Table 3) for the level of significance desired (0.99). The two-tailed t value is used because both the possibility that C is > t or that C is <t must by checked.

   (Use t_{099} and df = n_1-1 = 14) t_{099} (df= 14) = 2.977 (So t = 2.977)

10. Since C > t value, the contaminant is not present at hazardous concentrations, and the study is complete. If C <t value, the total number of additional samples (n_3) required to be collected would be determined by deriving a new λ and employing the newly calculated (not preliminary) values of X and S.

Table 3.3: Lambda (λ) Values (Numbers of Observations for t test of mean)

Level of t Test																					
Single-Sided Test		α=0.005					α=0.01					α=0.025					α=0.05				
Double-Sided Test		α=0.01					α=0.02					α=0.05					α=0.1				
δ=		0.01	0.05	0.1	0.2	0.5	0.01	0.05	0.1	0.2	0.5	0.01	0.05	0.1	0.2	0.5	0.01	0.05	0.1	0.2	0.5	
	0.05																					0.05
	0.10																					0.10
	0.15																				122	0.15
	0.20										139					99					70	0.20
	0.25					110					90				128	64			139	101	45	0.25
	0.30				134	78				115	63			119	90	45		122	97	71	32	0.30
	0.35			125	96	58			109	85	47		109	88	67	34		90	72	52	24	0.35
	0.40		115	97	77	45		101	85	66	37	117	84	68	51	28	101	70	55	40	19	0.40
	0.45		92	77	62	37	110	81	68	53	30	93	67	54	41	21	80	55	44	33	15	0.45
	0.50	100	75	63	51	30	90	66	55	43	25	76	54	44	34	18	65	45	36	27	13	0.50
	0.55	83	63	53	42	26	75	55	46	36	21	63	45	37	28	15	54	38	30	22	11	0.55
	0.60	71	53	45	36	22	63	47	39	31	18	53	38	32	24	13	46	32	26	19	9	0.60
	0.65	61	46	39	31	20	55	41	34	27	16	46	33	27	21	12	39	28	22	17	8	0.65
	0.70	53	40	34	28	17	47	35	30	24	14	40	29	24	19	10	34	24	19	15	8	0.70
	0.75	47	36	30	25	16	42	31	27	21	13	35	25	21	16	9	30	21	17	13	7	0.75
	0.80	41	32	27	22	14	37	28	24	19	12	31	22	19	15	9	27	19	15	12	6	0.80
λ	0.85	37	29	24	20	13	33	25	21	17	11	28	21	17	13	8	24	17	14	11	6	0.85
Value	0.90	34	26	22	18	12	29	23	19	16	10	25	19	16	12	7	21	15	13	10	5	0.90
	0.95	31	24	20	17	11	27	21	18	14	9	23	17	14	11	7	19	14	11	9	5	0.95
	1.00	28	22	19	16	10	25	19	16	13	9	21	16	13	10	6	18	13	11	8	5	1.00
	1.1	24	19	16	14	9	21	16	14	12	8	18	13	11	9	6	15	11	9	7		1.1
	1.2	21	16	14	12	8	18	14	12	10	7	15	12	10	8	5	13	10	8	6		1.2
	1.3	18	15	13	11	8	16	13	11	9	6	14	10	9	7		11	8	7	6		1.3
	1.4	16	13	12	10	7	14	11	10	9	6	12	9	8	7		10	8	7	5		1.4
	1.5	15	12	11	9	7	13	10	9	8	6	11	8	7	6		9	7	6			1.5
	1.6	13	11	10	8	6	12	10	9	7	5	10	8	7	6		8	6	6			1.6
	1.7	12	10	9	8	6	11	9	8	7		9	7	6	5		8	6	5			1.7
	1.8	12	10	9	8	6	10	8	7	7		8	7	6			7	6				1.8
	1.9	11	9	8	7	6	10	8	7	6		8	6	6			7	5				1.9
	2.0	10	8	8	7	5	9	7	7	6		7	6	5			6					2.0
	2.1	10	8	7	7		8	7	6	6		7	6				6					2.1
	2.2	9	8	7	6		8	7	6	5		7	6				6					2.2
	2.3	9	7	7	6		8	6	6			6	5				5					2.3
	2.4	8	7	7	6		7	6	6			6										2.4
	2.5	8	7	6	6		7	6	6			6										2.5
	3.0	7	6	6	5		6	5	5			5										3.0
	3.5	6	5	5			5															3.5
	4.0	6																				4.0

3.6 SAMPLE SIZE

Large samples should be taken in order to account for the different analytical techniques that are needed for the different analytes of interest. Large samples also enable the laboratories to re-analyse samples when data **are suspect.**

3.7 OPTIONS FOR SAMPLE COLLECTION

There are two main methods available for the collection of samples including:

- Grab sampling, which involves collecting a single sample at a specific spot in a short period of time. This type of sampling provides a snapshot. It reveals what is happening in a specific place at a specific time.

- Composite sampling involves collecting and combining multiple grab samples. This type of sampling may be used to reduce the cost of analyzing a large number of samples and to provide a representative sample of heterogeneous matrices in which pollutant concentrations may vary over short periods of time (wfw). Composite samples is not practical, however, when the purpose of the sampling project is for example, to analyze the concentration of a pollutant in a water source.

3.8 CONTROL SITE SELECTION

Control sites are sites that have characteristics similar to those of the sampling site with the exception of being affected by the pollutant in question. Samples should be collected from the control site and analyzed in the same way as the environmental test samples. The results can then be compared to determine whether the site is contaminated and/or different from the surrounding area.

When selecting a control site it is essential to avoid contamination from the main sampling site.

- Control sites should be upwind or downstream from the sampling site.
- Travel between the two sites should be minimized to avoid contamination by humans, equipment or vehicles**.**
- Control site samples should be taken first to avoid contamination from the sampling site.

4.0 SECTION 4 - DEVELOPING SAMPLING PLANS

4.1 INTRODUCTION

Once background data has been collected, an organizational framework has been established, quality control plans have been made, and sampling strategies selected, it is time to develop comprehensive sampling work plans and safety plans.

4.2 WORK PLANS

The work plan will be the major source of reference for the fieldwork component of the project.

A typical work plan will include:

- A summary of the background data collected about the site.
- A statement of the project objectives and secondary objectives.
- The methods that will be used to investigate the site including the type and number of samples to be taken, where they are to be taken, all sampling procedures, and a list of equipment and information needed for sampling.
- All quality control measures.
- Sampling equipment needs and procedures.
- Decontamination equipment and procedures.
- The personnel that are to perform each task.
- Steps to be taken in case of emergency.

Other factors that must be considered are the project time constraints, financial resources, and personnel and equipment availability, hazards that may be encountered, and site access.

4.3 SAFETY PLANS

Before going out into the field to collect samples, it is necessary to be aware of the applicable health and safety requirements. Because sample collection may occur at contaminated sites or in remote, rugged country far from immediate medical attention:

- Receive prior training in personal safety at a level appropriate for the types of chemicals likely to be encountered;
- Consult with your personal safety officer;
- Never go alone into the field;
- Determine the location of the nearest hospital, clinic or physician beforehand.
- Receive the appropriate immunizations. Vaccinations for tetanus, hepatitis B, and typhoid fever are recommended when working near contaminated waters.
- Notify others of your itinerary and whereabouts;
- Take precautions against hunters, poisonous reptiles and sudden floods;
- Carry identification. In addition, if possible, take a two-way telephone or radio with you; and
- When handling sample preservatives such as acid, always wear splash-proof goggles and non-contaminating gloves.

Never underestimate the importance of developing a comprehensive safety plan. A good safety plan can serve to avoid potential accidents or mishaps and can ensure a faster, more efficient response if any problems do occur.

5.0 SECTION 5 - PREPARATION

5.1 INTRODUCTION

In the weeks before samples are collected, preparations must be made to ensure that the sampling team will be ready to commence fieldwork at the time specified in the sampling plan. The following describes the activities that must be performed well in advance of the fieldwork portion of the project.

5.2 OBTAIN CONTAINERS AND PRESERVATIVES

Clean sample containers, preservatives and coolers are generally provided by the laboratory. Contact the laboratory about a month before the sampling date to schedule analyses and container shipment or pickup. Use chain-of-custody procedures when coolers and containers are prepared, sealed and shipped. They will remain sealed until used in the field. When making arrangements with the laboratory, make sure enough containers are requested, including those for blank and duplicate samples. Order extra sample bottles to allow for breakage or contamination in the field.

Some samples require low-temperature storage and/or preservation with chemicals to maintain their integrity during shipment and before analysis in the laboratory. The most common preservatives are hydrochloric, nitric, sulfuric and ascorbic acids, sodium hydroxide, sodium thiosulfate, and biocides. Many laboratories provide pre-preserved bottles filled with measured amounts of preservatives. Although most federal and state agencies allow the use of pre-preserved sample containers, some may require either cool temperatures or added preservatives in the field.

When the containers and preservatives are received from the laboratory, check to see that none have leaked. Be aware that many preservatives can burn eyes and skin, and must be handled carefully. Sampling bottles should be labeled with type of preservative used, type of analysis to be done and be accompanied by A Material Safety Data Sheet (MSDS). Make sure it is known which containers are pre-preserved, because extra care must be taken not to overfill them when collecting samples in the field. Check with the laboratory about quality control procedures when using pre-preserved bottles.

Coolers used for sample shipment must be large enough to store containers, packing materials and ice. Obtain extra coolers, if necessary. Never store coolers and containers near solvents, fuels or other sources of contamination or combustion. In warm weather, keep coolers and samples in the shade.

5.3 ASSEMBLE AND CHECK FIELD SAMPLING EQUIPMENT

As obtaining representative samples commonly requires large amounts of equipment it is necessary to be prepared. This is especially important if the sampling site is far from the office, making it difficult to replenish supplies or pick up forgotten items. Assemble, check and calibrate all equipment within twenty-four hours of the sampling time. In addition, re-calibrate pH and dissolved oxygen meters in the field before use.

Check all electronic equipment and batteries for proper operation. Inspect glass thermometers for column separation. Make sure tubing lengths are sufficient for depths to water. Discard cracked or discolored lengths of tubing or wires. If there are any doubts about the condition of a piece of equipment, bring along a replacement. This will save a long trip back to the office or the possibility of violating QA/QC guidelines.

Obtaining a representative sample also means being careful in the choice of equipment. If you are sampling for the presence of heavy metals, do not use samplers with metal components. When sampling for organics, avoid using samplers with plastic components, as the plastic may adsorb and contaminate the samples. Most importantly, always decontaminate equipment before use. Once the equipment is decontaminated, wrap inorganic equipment in plastic and organic equipment in aluminum foil for transport to the site.

5.4 CLEAN SAMPLING EQUIPMENT

All equipment that makes contact with a sample or station must be carefully cleaned before reuse. Examples are pumps, shovels, tubing, DH-81 samplers, filtration equipment, water-level probes or tapes, interface probes and clear product bailers. Filters, however, are discarded after use.

Procedures for cleaning sampling equipment can be found in Section 2.5.

If several sets of sampling tools are available, such as one for each station, then decontamination can be performed in batches at the beginning or end of a sampling day. This saves time and reduces the number of field blanks necessary.

5.5 CALIBRATE FIELD EQUIPMENT

Field equipment used to monitor physical parameters must be calibrated before samples can be taken. Always read the manufacturer's instructions about equipment operation and calibration. Take copies of all the manufacturers' manuals with you to the site. (Calibration procedures for temperature, pH, electrical conductivity, dissolved oxygen and turbidity meters also can be found in Appendix 2). Document calibration results according to these procedures and record the results in the field notes.

5.6 LOCATE AND DESCRIBE THE SAMPLING STATION

The location and identification number of a sampling station (monitoring point) should be accurately marked on a large-scale map as an X, circle, or dot. This not only enables field personnel to easily find the stations but also allows the data to be digitized into a computer database. In addition, drawing site sketches, which show roads, buildings, trees and other landmarks not shown on topographic quadrangles, helps locate remote stations for others.

If the sampling station is not shown on a map, then determine its location by physical positioning.

5.6.1 Physical Positioning

Positioning is accomplished by measuring in meters or feet the horizontal distance between the station (such as the well casing) and other physical features, measuring that distance on a map, and marking the location with an X, circle, dot or other symbol. Useful features for reference on topographic quadrangles are roads, buildings, power lines, surface waters, or abrupt changes in slope.

Sketch the station and its surroundings in the field log book.

Common devices for measuring distances are listed below, in order of decreasing accuracy:

- Triangulation

- Electronic distance measurer
- Tape measure
- Hip-chain distance measurer
- Distance measuring wheel
- Rangefinder
- Global positioning system
- Pacing
- Vehicle odometer

Other less direct methods such as visually estimating a station's location on low-altitude aerial photographs also may be used if measurement on the ground is impractical.

5.6.2 Determining Stationing Coordinates

Coordinates should be measured in units of degrees, minutes, seconds, and fractions of seconds of latitude and longitude. Location coordinates are usually measured in one of four ways.

- The least expensive is overlaying a scale template on the station location in the topographic quadrangle, using coordinates such as UTM, and reading the degrees, minutes and seconds along the north-south (latitude) and east-west (longitude) axes.
- The second is hiring a professional land surveyor.
- The third is digitizing locations from a map using Geographic Information System (GIS) technology.
- The fourth is using a portable global positioning system (GPS) device.

GIS technology has grown in popularity as a data management and mapping tool. Station coordinates in latitude/longitude or other projection can be obtained with a GIS by digitizing their locations from a paper or mylar map. Digitizing simply means marking that point with a magnetic cursor on a digitizing table. The accuracy of the method is only as good as the accuracy of the map and the mapped location. A large number of points or areas can be digitized with a GIS in a short time.

A global positioning system consists of a portable receiver or transponder that receives coded transmissions from an array of navigational satellites. The accuracy of location coordinates depends on satellite geometry, number and transmission frequencies. Other factors, such as interference from nearby buildings, hills, vegetation and electrical power lines may also affect accuracy. Coordinates may be obtained at a station after about 4 or 5 minutes, and the data can be stored in the unit for retrieval later. Accuracy is improved when satellite transmissions are also monitored by a nearby base station and then relayed to the hand held unit.

5.6.3 Photographing the Station

Photograph fixed station sites on a regular basis for site documentation purposes. Take enough photos on the first visit to the site to establish a complete photo record of the site and its surroundings. (This also will assist a first-time visitor in locating the site.) After the first visit, take photos according to the procedures outlined below.

Take photos at each visit to the site from established and constant photopoints. The preferred photopoint is naturally occurring, such as a large tree or boulder. For example, the photographer can put his or her back against a specific tree trunk to take one of the required photographs at each visit to the site. If naturally occurring landmarks are unavailable at a given site, try to mark the photopoint in some durable yet unobtrusive and temporary way, such as with a pile of rocks. At the first visit to the site describe the photopoints in detail in the field notes. Record field notes in the site files as a permanent part of the file.

Include a person in the photo of the sample point to show scale. For a surface water station, take two photos using Kodachrome slide film (K-64) from 1) upstream of the sample point looking downstream at the sample point; and 2) downstream of the sample point looking upstream at the sample point.

Take additional photos if any significant changes in the site area are noticed, such as severe channel scour, severe deposition, recent construction or other biological or ecological changes that warrant documentation. Emphasize in the photos, those aspects that are likely to impact water quality.

Upon receipt of the processed slides, label them with the following information: site ID, site name, date and time, and the orientation of photo. Put the slides from each particular site into an 8-1/2 by 11 inch (21.6 by 27.9 mm) vinyl chloride slide sleeve and store them in their respective site file.

On the last visit to a site, retake the same photos that were taken on the first visit (from the same photopoints) in order to document the changes that occurred over the lifetime of the site.

6.0 SECTION 6 - SURFACE WATER SAMPLING

6.1 INTRODUCTION

There are two main types of surface water that can be sampled:

- Flowing water which includes perennial and ephemeral streams, and
- Still water which includes ponds, lakes and reservoirs.

Surface water samples must accurately represent the water body being sampled. Project personnel must select a method to locate acceptable sampling site(s) and the method(s) used to make field measurements.

6.2 SURFACE WATER CHARACTERISTICS

The composition and dynamics of surface water can make producing a representative sample difficult. Surface water is often very heterogeneous. In rivers, the chemical composition of the water may vary with depth or depend on flow. The chemical composition of lakes and ponds may also vary significantly depending on the season.

Stratification within water bodies is also common. In shallow ponds and lakes, wind action serves to mix the water so that neither chemical nor thermal stratification is likely, but in deeper water bodies both may occur. Deep rivers can also exhibit chemical and/or thermal stratification, while quickly flowing shallow rivers are usually not stratified.

In addition, the nature of flowing waters is constantly changing. Seasonal variations can cause water levels to rise or fall. During the rainy season small streams can turn into raging torrents and during the dry season some streams may dry up completely.

Humans can also influence the characteristics of a waterbody by:

- Increasing turbidity (usually the result of erosion from improper mining, logging or agricultural practices, and
- Introducing contaminants from industrial operations.

All of the above characteristics of surface water must be considered when selecting the time and location of water sampling.

6.3 SELECTING SAMPLING LOCATIONS

Before sampling collection can begin, sampling sites and conditions must be selected. Each body of water, whether flowing or still, has a unique set of conditions that need to be identified for the site-selection process. Before selecting a site location, review the historical information available about the site, such as flood history, land use, and type, and source of any previous contamination.

Once site locations are selected, it is necessary to select sampling point(s) within the site location. If a water body is well mixed, a single sampling point could be sufficiently representative. In most cases, however, multiple sampling points are needed to truly represent the water body.

The methods that are used to select sampling sites and sampling points differ for flowing water and still water.

6.3.1 Rivers and Streams

a. Selecting Site Locations

As part of the process for selecting site locations on rivers or streams, consider study objectives with respect to:

- The proximity to the sampling site of manmade structures such as bridges, roads, and piers. Selecting sites near such structures can interfere with data-collection objectives and therefore such sites normally are avoided.

- Locating sites near a water discharge-stage gauging station. Such site locations are advantageous for data interpretation.

- Sample perennial flowing streams during low-flow periods. Sample ephemeral and intermittent streams immediately after water recedes, while bottom material is still wet.

- The geomorphology, geology, and geography of the area, such as its size and shape, tributary and runoff patterns, streambank structure and lithology, land use, and climate.

- The chemical,* physical,* and biological* character of the water column above the sample-collection site (for example, water depth and hydraulics, fluvial-sediment transport characteristics, and especially the presence or absence of oxygen).

* **Chemical characteristic**s include geochemistry/mineralogy, oxidation state, colloidal/noncolloidal fractions, inorganic/organic composition, spatial and temporal heterogeneity, bioassay data, and data from reconnaissance sampling.

* **Physical characteristics** include size fraction, texture, structure, thickness, pore-water content, horizontal and vertical spatial heterogeneity, and temporal heterogeneity.

***** **Biological characteristics** include population densities, and community s tructure and diversity of aquatic organisms.

- The chemical, physical, and biological character of the bottom material to be sampled.

- The use of either statistical or deterministic methods to select the location and number of sampling sites.

Flowing water sampling sites are optimally located:

- At or near a stream gauging station.
- In a homogenous, straight reach with uniform flow and with a uniform bottom contour.
- Far enough above or below secondary stream confluences or sources of contamination to avoid sampling where flows are poorly mixed.
- Upstream from bridges or other structures.
- In undirectional flow that does not include eddies.

- At or near a transect in a reach where other data are collected or for which historical data are available.
- At a cross section where samples can be collected at any stage throughout the period of study.
- At the centre of flow for small streams.

b. Selecting Sampling Points

In most cases, a single set of sampling data can be used to represent a cross section of the stream. Depending on the variability of discharge across the stream, the equal-discharge-increment (EDI) or equal-width-increment (EWI) method of locating specific sampling points is used.

The variability of discharge across the stream can be determined by making individual measurements of stream depth and velocities along a cross section.

- If the stream depth and velocities are relatively uniform, use the EWI method.
- If stream depth and velocities are highly variable, use the EDI method.
- If the stream is small and well-mixed, a single point at the centre of flow can be used to represent the cross section.

EDI Method

To divide the cross section into increments of equal discharge:

- Observe the velocity, width, and depth distribution across the stream and identify areas of stagnant water, eddies, reverse flows, etc.
- Make discharge measurements across the selected section of the channel.
- From the measurements, divide the stream into a minimum of four EDI sections.
- In situ measurements should be taken at the center of each equal discharge increment at mid depth and subsamples should be collected at the center of each equal discharge increment.

EDI Methods

To divide the cross section into increments of equal distance:

- Visually inspect the stream and observe the velocity, width, depth distribution across the stream and identify areas of stagnant water, eddies, reverse flows, etc.
- Use a tagline to determine stream width
- Divide the cross section into equal width increments based on flow and stream channel characteristics.
- If the stream is 5 ft wide or greater then use a minimum of 10 increments.
- If the stream is less than 5 ft wide, use as many increments as practical.
- In situ measurements should be taken at the center of each equal width increment at mid depth and subsamples should be collected at the center of each equal width increment and emptied into a compositing device.

6.3.2 Still Water Sites

a. Selecting Site Locations

Factors to consider when selecting still water sampling sites include:

- Water and sediment sampling stations should be located near the center of the water body and at the greatest depth to avoid shoreline effects.
- Avoid areas near structures such as boat ramps, piers, and fuel docks to avoid sources of contamination.
- Select sites with a record of historical data if possible

b. Selecting Sampling Points

Field measurements in still water are usually made in situ at different locations and depths. Conductivity, pH, and turbidity, however, can be measured in a discrete sample or sub sample while alkalinity must be measured in a discrete sample.

The location and number of sampling points is selected according to the specific study objectives.

6.4 SAMPLING EQUIPMENT

Specific considerations for selecting surface water sampling equipment are:

- Use sampling devices constructed of materials that are compatible with the target analyses.
- Use stainless steel hardware.
- Rinse sampling equipment with double or triple distilled water prior to use.
- Samples collected from large bodies of water are usually collected manually while automatic samplers are commonly used for samples of streams.
- Samples taken for volatile organic analysis are always grab samples using glass vials with Teflon lined caps with no headspace allowed.
- Teflon lined caps should be used when organic compounds are being analyzed.
- Plastic or glass containers with added nitric acid (for stability) are usually used when metal species are the analyses of interest.

6.5 OPTIONS FOR WATER SAMPLING COLLECTION

There is a wide variety of sampling devices to choose from. The selection of sampling equipment should be made so that it reflects the goals of the study as much as possible.

Several of the methods available for the collection of water samples, include:

- Discrete grab samplers which take individual samples, at a particular location and time;
- Composite grab samples which are removed from various locations (usually various depths) at a particular time;
- Composite grab samples which are removed from a particular location at various times; and

- Continuous removal of a sample at a particular location over a selected time interval.

The types of samplers may generally be classified as grab samplers, multiple samplers, and continuous samplers.

Figure 6.1: Types of Water Samples

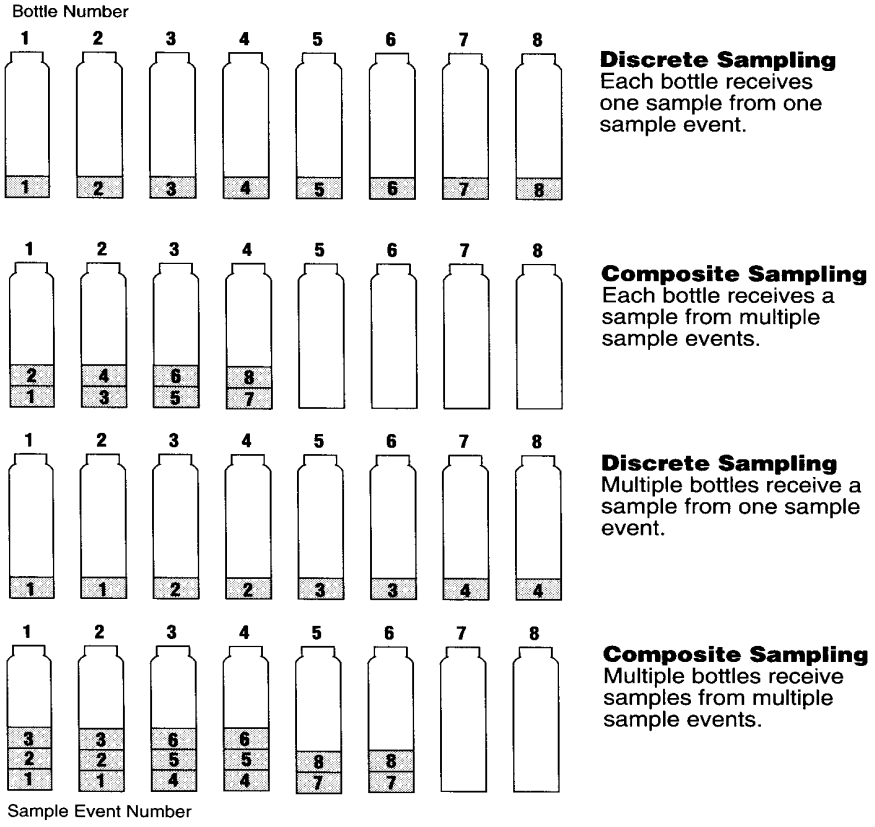


Figure 1. Types of water and wastewater samples.

A brief description of each type of sampler follows:

6.5.1 Grab Samplers

Grab samplers at their most basic level consist of a container that is held just below the surface of the water body being sampled. Other mechanical grab samplers are more sophisticated and provide for sampling at depths of 1 - 2 metres or greater. They include the Van Dorn and Kemmerer samplers. This type of sampler is basically a tube with end seals, a trip mechanism to close these seals and a drain valve. To collect a sample, the tube is lowered, with the end seals raised, by rope to the desired depth. The mechanism that closes the end seals is tripped, the sampler is raised to the surface, and the sample is transferred to a sample bottle.

6.5.2 Multiple Samplers

Multiple samplers are devices that hold more than one bottle. They are used to collect several samples at the same time. The device containing the sample bottles is lowered until all bottle openings are below the surface of the water. The bottles are allowed to fill. The sampler is then pulled out of the water and the bottles are capped**.**

6.5.3 Continuous Samplers

Automatic samplers that sample (for prescribed intervals) at either fixed or proportional flow rates are available. They use either peristaltic or vacuum pumps.

6.6 COMMON SAMPLING PROCEDURES

Collecting water samples, taking in situ measurements and taking measurements from sub samples are the common procedures involved with surface water sampling.

6.6.1 Water Sample Collection

Water sample collection involves the use of a grab sampler, multiple sampler or continuous sampler to collect a representative sample of water from the water body of interest. The sample will then be analyzed in a lab for specific contaminants.

The following general principles apply to the collection of representative water samples:

- Collect a large enough volume of water to permit for quality control testing and replicate analysis.
- Avoid the inclusion of large particles such as leaves in the sample.
- Relate the choice of sampler type to the analyte list to avoid potential sample contamination.

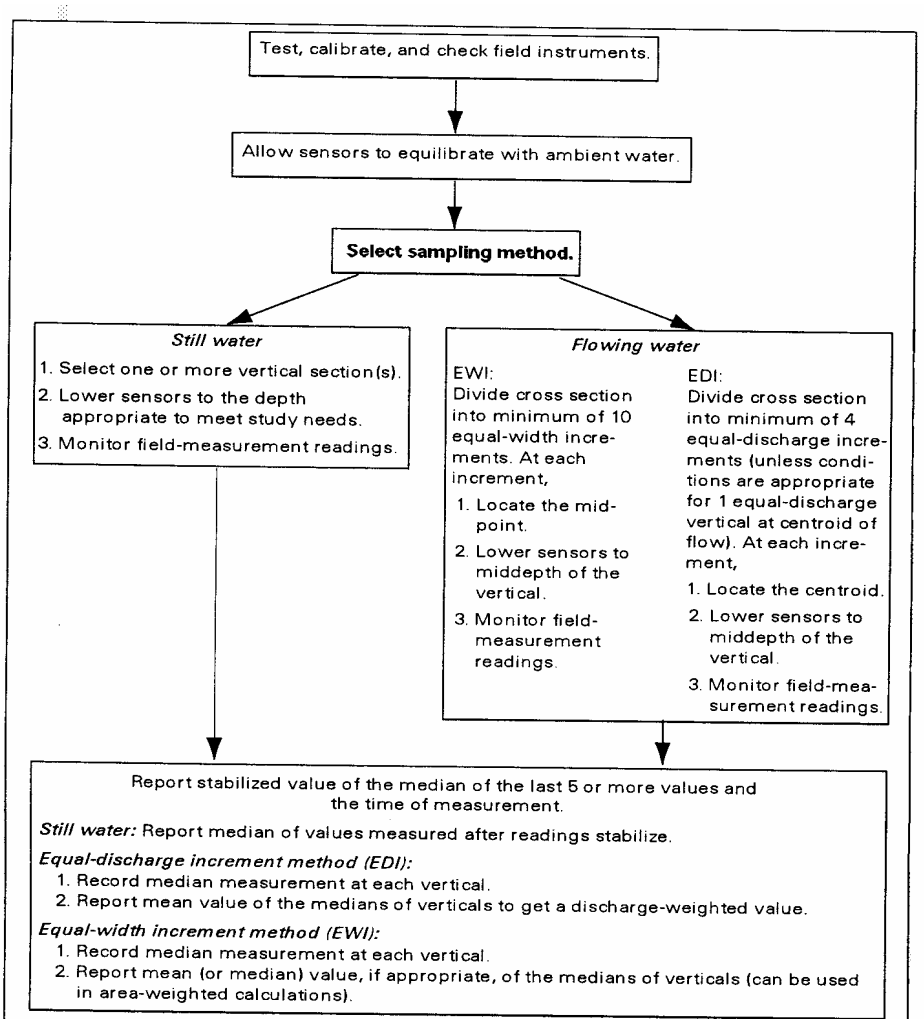
6.6.2 In-Situ Measurements

In situ measurements are made by immersing the sensory component of a field instrument directly into the water body. These measurements are advantageous because they avoid changes in a water sample that may occur when it is removed from its source.

In situ measurements are mandatory for determining temperature, dissolved oxygen concentration and Eh. They can also be used for pH, conductivity, and turbidity, but not for alkalinity.

These measurements are normally made at the locations that water samples are collected. Sampling procedures for in situ water measurements can be found in Appendix II.

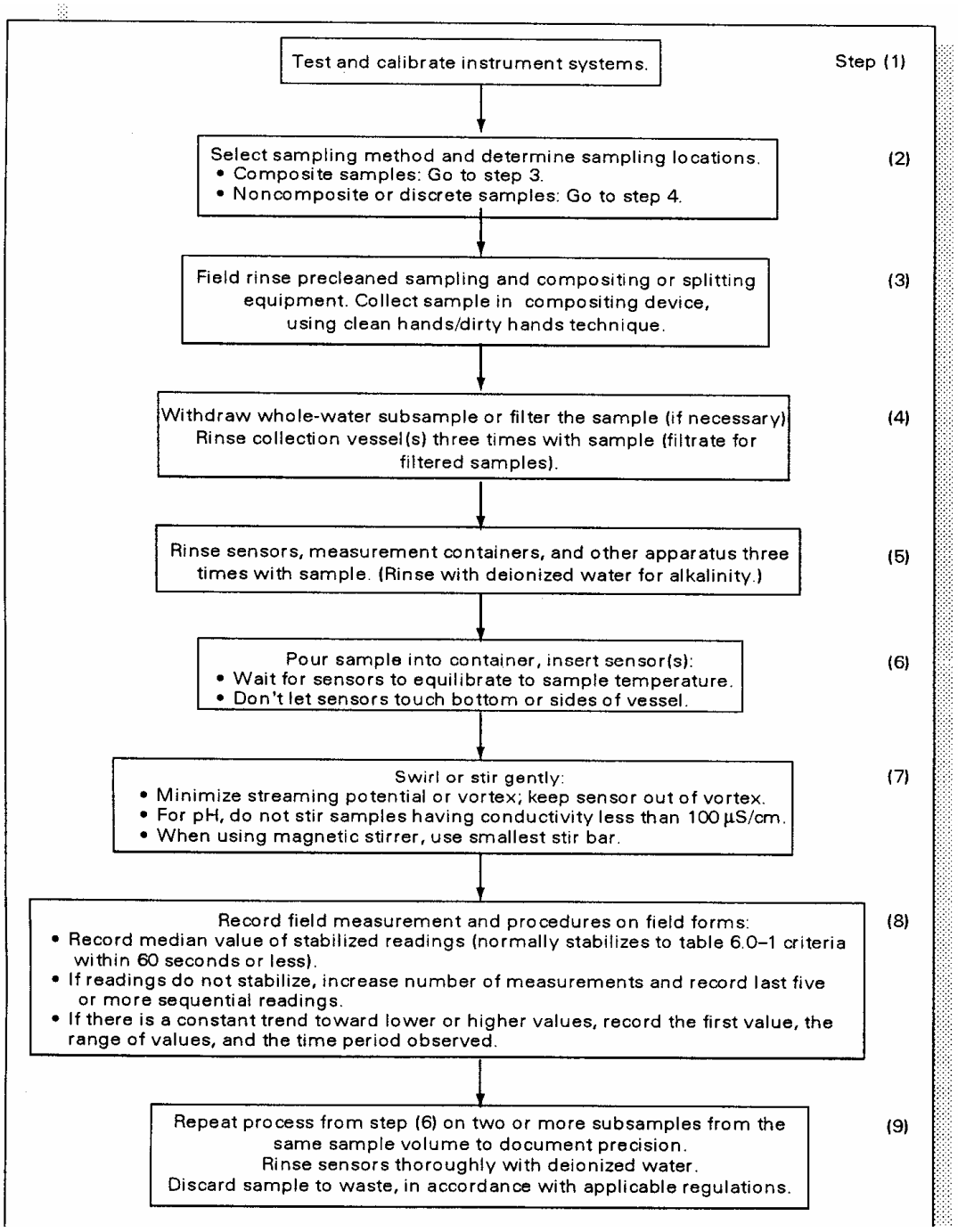
Figure 6.2: In Situ Field Measurement Procedures for Surface Water



6.6.3 Sub-Sample Measurements

Subsample measurements involve taking measurements from water that has been removed from the source either using depth and width integrating sampling methods or discrete samples collected with a bailer or grab sampler. Conductivity, pH, turbidity, and alkalinity can all be measured from subsamples.

Figure 6.3: Subsample Field Measurements Procedures



6.7 FLOW MEASUREMENTS

Flow is defined as the volume of water that passes through the cross section of a stream in some unit of time. Flow measurement procedures must be carefully planned, and implemented by qualified personnel.

Flow measurements are generally made in an open channel and are based on determining cross sectional area and velocity across that area.

- The cross section is best measured directly using a meter or yardstick and weighted chains or lines. A location on the stream where the dimensions will not change during the time in which flow measurements are taken must be found. The width and depth are expressed in meters or feet and cross-sectional area is expressed as square meters or square feet.

- Velocity is commonly determined by using a current meter. Current meters are mechanical devices with a rotating element that rotates at a speed proportional to the velocity of stream flow at that point below the surface. Current meters provide readings at a single point, so multiple readings must be taken along a vertical line across the water body or a single reading can be converted to an estimated mean velocity using standard coefficients. Units are given in meters/sec or feet/sec.

- When the cross sectional area and the flow velocity are multiplied the product is the volumetric flow rate, expressed as cubic meters/sec or cubic feet/sec.

6.7.1 Methods

The typical procedures for measuring flow or discharge follows:

1. Ensure that the current meter is assembled properly.

2. Divide the water body into sections (with tag-line or bridge railing), based on visual observations of the velocity and stream flow. Stations should be established so that no more than 10% of the total discharge passes through any individual section.

3. Record the necessary site information such as: stream stage as indicated by one of the staff gauges, project site, names of study personnel, time at start of measurements, wind direction, stream condition (e.g. turbid, low level, temperature etc.), total stream width, type of current meter.

4. Determine the depth and mean velocity at the first station or "initial point". Measure depth at the second station from initial point and record. Determine whether the velocity should be measured at the 0.6 depth from the surface (six-tenths depth method), or at the 0.2 and 0.8 depths (two-point method). Calculate the depths from the surface, measure the velocity at each point, and record these values.

5. Follow the same procedure at each successive station as rapidly as possible.

6. Record the intervals of time and stage variations during the cross-sectional measurements. Also, enter the date and indicate that a calibration has taken place over this interval.

7. Remove the tag-line (if used) and rinse the current meter in clean water. Allow the current meter to dry before packing it.

6.7.2 Other Points to Consider

Several other points to keep in mind when measuring stream flow are:

- The person sampling should stand down stream and to the side of the meter when making measurements.
- Care should be taken to avoid disturbing or standing along the stream-bed beneath the cross-sectional measuring points.
- Try to use the same cross section throughout the study period and during all of the stream calibrations.
- Always hold the wading rod vertical.
- Recalibrate at regular intervals to account for seasonal changes in streambank vegetation and stream-bed alterations that may affect measurements.

6.8 PROBLEMS UNIQUE TO SAMPLING SURFACE WATER

Like all types of sampling, water sample collection must be carried out so that any impact on the sample from the surrounding environment, is minimized.

The location of sampling must be away from areas of natural disturbances which could increase the amount of sediment in a sample (eg where a wave disturbs a lake bottom)

- Ensure that equipment does not touch the bottom of a sampling site as this can increase the amount of sediment in a sample.
- Take care to avoid contamination from skin contact with the sample. When collecting grab samples in lakes, hold the sample bottle at arms length, plunge it below the surface and slowly force it through the water until it is full.
- When sampling from flowing rivers or streams, wade into the river downstream from the sampling site, then proceed upstream until the site is reached. Face upstream, plunge the sample bottle below the surface with the top facing down and then immediately face the

bottle top into the current. When the bottle is full, remove it by forcing it into the current and upward.

- When sampling from a boat, care must be taken to reduce contamination from the boat and/or the motor. Collect samples at the bow either with the boat facing into the current or with the boat moving slowly forwards. Hold the bottle at arm's length from the boat, plunge it below the surface and move it slowly into the current. When the bottle is full remove it by forcing it into the current and upwards.

- When sampling from a bridge, collect the samples on the upstream side to avoid contamination from the bridge itself or material falling from the bridge. Avoid touching the bridge with any part of the sampling equipment.

6.9 WATER SAMPLE PRESERVATION

The objective of water sample preservation is to ensure that samples do not deteriorate or degrade prior to laboratory testing. Chemical preservation, storage temperatures and holding time (i.e., the elapsed time between sampling and testing) all play a key role in sample preservation. Typical sample preservation and storage information are summarized in Table 6.9 but may vary somewhat for specific methods and jurisdictions.

Table 6.1: Water Sample Preservation and Storage Techniques

Analyze	Container*	Preservation and Storage	Holding Time
Metals, general	P(A); G(A)	For dissolved metals, filter Immediately, add HNO_3 to pH < 2	6 months
Mercury	T(A); G(A)	Add H2SO4 or HNO_3 to pH < 2, plus $K_2Cr_2O_7$. Refrigerate at 4° C. May also use HCl alone.	28 days
Cyanide	P,G	Add NaOH to pH > 12, refrigerate at 4 ° C.	3 to 14 days depending on method. 24 hours if sulphide present.
Ammonia	P,G	None or add H_2SO_4 to pH < 2, Refrigerate at 4° C	28 days, 3 days if no preservation.

(Standards Methods, 19th edition; B.C. Environment 1994)

***Notes:** **P** = plastic (polyethylene or equivalent); **G** = glass; **T** = Teflon; **A** = rinsed with 1+1 HNO_3

A source of sample degradation is the sorption of small amounts of metals onto container walls. When measuring very low concentrations of metals, loss to container walls can be significant. The degree to which this occurs will depend on the metal species, concentration, pH, contact time, sample and container composition, presence of dissolved organic carbon and complexing agents (Keith 1991). The addition of nitric acid (HNO_3) usually prevents this from occurring.

A further source of degradation is the formation of salts that precipitate. The most common occurrence is precipitation of metal oxides and hydroxides due to the reaction of metal ions with oxygen. This precipitation is usually prevented by adding nitric acid: the combination of a low pH (less than 2) and nitrate ions keeps most metal ions in solution. Other acids (especially hydrochloric and sulphuric) may cause precipitation of insoluble salts and/or analytical interferences (Keith 1991).

Water samples containing cyanides may evolve hydrogen cyanide. The addition of sodium hydroxide (NaOH) is used to prevent this. Similarly, water samples containing ammonia may evolve ammonia gas. The addition of sulphuric acid (H_2SO_4) forms stable ammonium sulphate and is used to prevent this.

Storage at 4±2^oC slows changes caused by the growth of microorganisms. For example, microbiological activity may be responsible for changes in the nitrate-nitrite-ammonia content (Standard Methods, 19th edition). Both filtering and the addition of chemical preservatives, where specified, are carried out as soon as possible after samples are collected. Filtering is carried out before adding the chemical preservatives. (See Figure 6.4).

From sampling until analysis, where specified, samples are kept at 4±2^oC. Even when preservation techniques are followed, the shorter the time between sampling and analysis, the more reliable the analytical result. This is particularly true for ultra-low level samples. It is preferable that samples are transported to the laboratory on the day they are collected. Transporting samples in coolers with ice packs is the most common practice for keeping samples at 4±2^oC. For ambient temperatures above freezing, samples most likely to deteriorate should be kept closest to the ice packs and enough ice packs should be used to last the duration of the transport time. Holding time is the maximum time that can elapse from sampling to measurement before significant deterioration can be expected to occur.

Figure 6.4: List of Operating Procedures for Filtration of Environmental Water Sample

List of Good Operating Procedures for Filtration of Environmental Water Samples—*Continued*

- Filter directionality should be observed. Filter performance is in some cases dependent on the direction of flow through the filter. Filter rupture may occur when filter directionality is not observed. Some disk filters differ in color or texture between sides. This difference can be an important consideration for microscopy. Most cartridge filters have a flow direction indicator cast or printed on the body of the cartridge.
- Disk filters should usually not be handled directly so as to avoid contamination and possible physical damage. Some manufacturers recommend the use of flat forceps specifically designed for handling disk filters.
- Disk filter spacer materials must not be confused with filter media. Some disk filters are packaged with spacers between individual filters. There are reports that spacers have mistakenly been used in place of filters, even though the spacers differed in appearance.
- Filters should generally be used for only one sample and not reused for other samples because of the possible carryover of interferences.
- Filters and filtering equipment should be visually inspected prior to each use. Filtration equipment and filters should be inspected for visual signs of contamination and physical damage. Damaged filtration equipment may present a safety hazard to field personnel where pressure and vacuum filtration is performed.
- Filters and filtration equipment should be carefully monitored during use to ensure proper operation, to detect the accumulation of particles and possible clogging of the filter, and to detect possible filter bypass or rupture.
- Filtration should always be performed within pressure/vacuum limitations specified by the filter and filtering equipment manufacturer(s). Failure to operate within pressure/vacuum limitations can affect the particle retention properties of the filter and/or cause rupture of the filter. Excessive pressure can result in filtrate being pulled through the body of the filter. Failure to observe equipment pressure/vacuum limitations can result in injury to personnel.
- Pressure/vacuum limitations for the filtration of aquatic organisms should be carefully considered and followed. Use of excessive pressure/vacuum during filtration may destroy some aquatic organisms.

List of Good Operating Procedures for Filtration of Environmental Water Samples—*Continued*

- Disk filters should be properly supported within filtration equipment in accordance with manufacturer's recommendations for expected pressure differentials. Improperly supported filters can distort or rupture during filtration.
- Particle retention properties of a filter can be a function of controllable factors such as the velocity of water passing through the filter, the pressure differential applied to the filter, and water temperature. It may be advantageous to minimize variation of these factors between samples to reduce variability and possible related bias.
- It may be advantageous to use filters produced within the same manufacturer's quality control/production lot or batch number for each study to reduce possible filter performance variability.
- Filters may require changing during the filtration of turbid samples. Care should be exercised when changing filters, especially disk filters. Improper or careless changeout of disk filters can introduce contaminants into the filtration system or allow particulate bypass. In some cases, the entire filtration apparatus may require cleaning between disk filter changes to prevent contamination of the sample. Filtration systems are sometimes set up in parallel to avoid filter changeout. Prefiltration may also be used to prevent filter clogging and the need for filter changeout.

[1]Discussions on the need for, and practices of, filter preconditioning and filtration equipment cleaning and flushing for various analyses are contained in Shelton (*13*) and referenced technical memoranda by the U.S. Geological Survey that are referenced therein.

6.10 MONITORING WATER SAMPLE PRESERVATION

Preservation should be monitored at several points in the process leading up to the analysis of samples to ensure that the integrity of the samples has not been jeopardized. The following describes actions to be taken at these points. If a nonconformance is identified, it must be recorded and reported. If the decision is to continue with the analysis, the data must be flagged as nonconforming in the report to the client. Corrective action should be taken to identify the cause of the problem and to prevent it from recurring.

Further detail relating to the critical points at which preservation should be monitored appears below.

6.10.1 Collecting Samples

Notes on sample preservation should be recorded on or attached to the chain of custody form so that staff involved in the next steps of the process are aware of what has taken place. To be able to monitor whether the time between sampling and analysis falls within the range specified for the analyte of interest, the date (and time) of sampling must be recorded.

6.10.2 Transporting Samples from the Field to the Laboratory

When temperature control of samples is specified, a bottle of reagent water that will not be analyzed should be transported with the samples from the field to the laboratory so that the temperature can be checked at the laboratory without contaminating a sample.

6.10.3 Receiving Samples in the Laboratory

The date (and time) of arrival at the laboratory should be recorded and compared to the date and time of sampling. If the holding time specified for the analyte of interest has been exceeded, the nonconformance must be acted upon. When temperature control is specified, the temperature of the bottle of reagent water sent with the samples must be checked and recorded. If it is outside the acceptable range for the analyte of interest, the nonconformance must be acted upon.

6.10.4 Storing Samples in the Laboratory Prior to Analysis

Storage temperatures must be monitored and recorded, preferably daily or using a thermometer that records temperatures continuously. If a temperature has gone outside the acceptable range, the nonconformance must be acted upon.

6.10.5 Analyzing the Samples

Just before analysis is carried out, the date (and time) should again be recorded and compared to the date and time of sampling. If the specified sample holding time has been exceeded, the nonconformance must be acted upon.

7.0 SECTION 7 - SOIL SAMPLING

7.1 INTRODUCTION

Soil sampling is conducted in order to obtain a representative sample of the soil at a particular site. The sample can be analyzed in order to determine the specific contaminants and/or the extent of contamination in the soil.

Soil sampling is often an important component of groundwater sampling because contaminants can be detected in the soil horizons before they infiltrate the groundwater.

7.2 IMPORTANT SOIL CHARACTERISTICS TO CONSIDER WHEN SAMPLING

When sampling soil, it is necessary to take into consideration the geological variability of soil, and the variability of pollutants and their concentration variations throughout the site.

Soil is a heterogeneous material. Soil properties may vary from one location to another and also among horizons in a specific profile. In order to obtain a representative sample, the soil of interest should be subdivided horizontally and vertically into strata that are as homogeneous as possible.

The structural properties of soil should also be considered when sampling. Gases and fluids entrapped in the soil may be important components of soil analysis and care must be taken to ensure that aeration or changes in moisture content do not occur during sampling.

The variability of soil types within a contaminated site can affect the migration of contaminants throughout the soil. Therefore, it is essential that a record of location, depth, grain size, color and odor of the soil samples be maintained throughout the sampling period.

7.3 EQUIPMENT AND PROCEDURES

When selecting equipment for soil sampling, it is necessary to take into account soil grain size, cohesiveness, moisture content, and depth to bedrock as these factors will limit the depth from which samples can be collected and the equipment used to collect them.

Considering the above factors, several methods of soil sampling include:

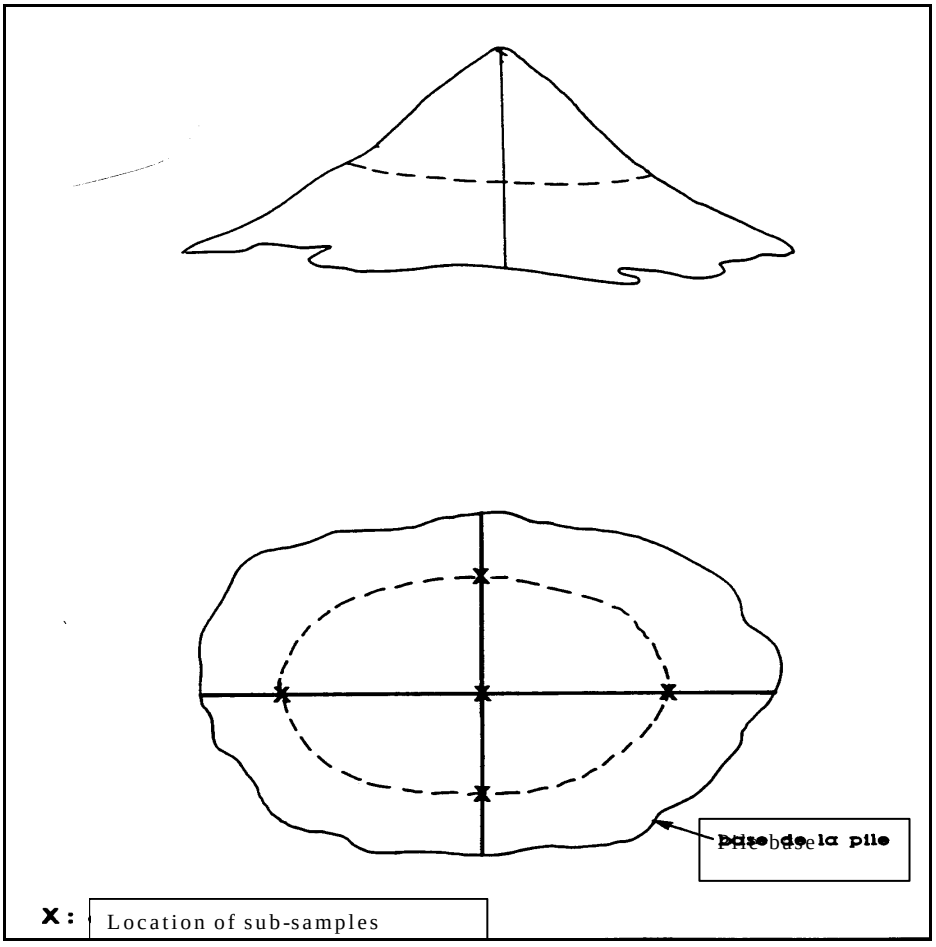
7.3.1 Soil Surface Sampling

Collection of samples near the soil surface can be accomplished using tools such as spades, and scoops.

Methods

- Using a stainless steel spade, carefully remove the top layer of soil to the desired sample depth.
- Collect the desired amount of soil with a stainless steel scoop.
- Transfer the samples into a glass bottle with a stainless steel spoon.
- Seal the bottle tightly with a cap and refrigerate it at 4°C.
- Label the sample bottle and place it in a carrying container maintained at 4°C throughout transportation.

Figure 7.1: Example of sampling points for a soil pile.



7.3.2 Soil Sampling at Greater Depths

Soil sampling at greater depths can be accomplished using several different types of equipment:

a. Using An Auger and a Thin-Wall Tube Sampler

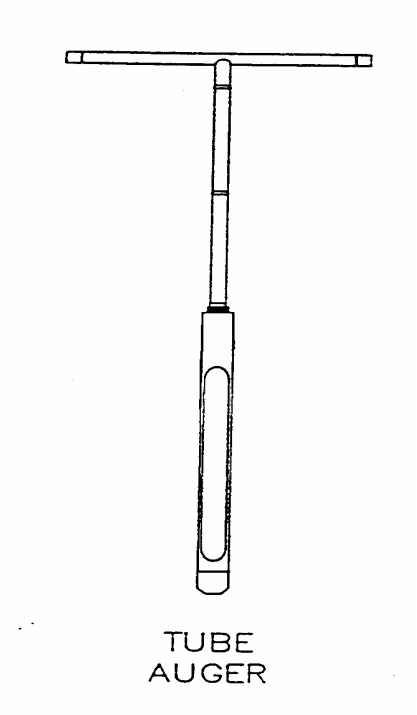
This system can be used in many different soil conditions and can be used to sample near the soil surface or to depths greater than 6 m.

Methods

- Clear away any surface debris such as twigs, rocks etc. from the sampling site.
- Use the auger bit to bore a hole to the desired sampling depth.
- Carefully withdraw the auger.
- Replace the auger tip with the thin walled tube corer and gradually force it into the soil at the required depth.
- Withdraw the core.
- Discard the top 2 cm of the core.
- Place the remaining core in a sample container and secure the cap tightly.
- Label the container with the appropriate information and place it in a carrying container that will maintain a temperature of 4°C throughout transportation.

The Figure 7.2 on the next page presents an example of sampling Auger.

Figure 7.2: Example of a Sampling Auger



b. Other Equipment

Other equipment that can be used to sample soil at greater depths are the:

- Veihmeyer Sampler which can be used to core sample most types of soil to a maximum depth of 4.9 m, and the
- Split Spoon which can be used to collect undisturbed soil samples from a wide variety of soil types at a greater depth than any other equipment.

The Figure 7.3 and 7.4. on the next page presents examples of such instrument.

Figure 7.3: Example of a Veihmeyer Sampler

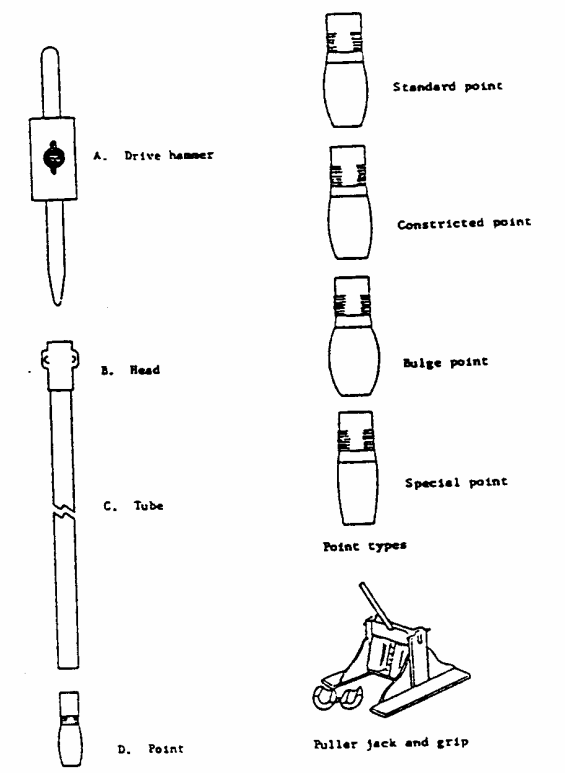
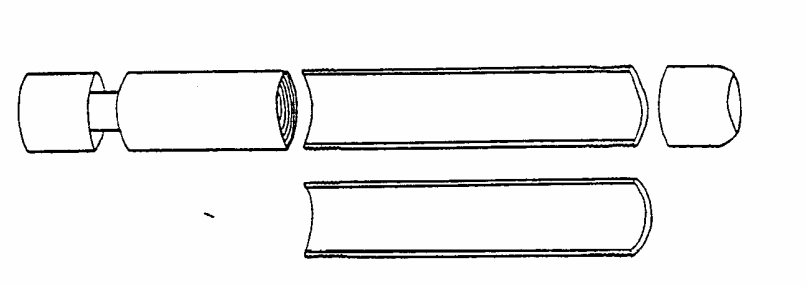


Figure 7.4: Example of a Split Spoon Sampler



7.4 SOIL SAMPLING FOR VOLATILE ORGANIC COMPOUNDS

Volatile organic compounds in soil exist in gaseous, liquid and solid states. The concentration and retention of VOCs in soils is affected by:

- The chemical properties of the VOCs,
- The chemical and physical properties of the soil,

- Environmental factors, and

- Biological factors.

There are no standard procedures for sampling soils for Volatile Organic Compounds (VOCs). Different samplers are available for collecting undisturbed samples and bulk (disturbed) samples. Samples are placed in glass jars and sealed with Teflon-lined caps. These procedures, however, may involve significant VOC losses. Any headspace present in the container may lead to a desorption of VOCs from the soil into the headspace upon which the VOCs will be lost when the container is opened.

Ultimately, the sampling equipment chosen, sampling procedures, containerizing and transport of soil containing VOCs should minimize the loss of VOCs and avoid contamination of the sample.

7.4.1 VOC Sampling Equipment

Soil characteristics, the type of VOC, and the depth of sample collection are all factors that need to be considered when selecting sampling equipment. Table 7.4 lists specific soil characteristics to consider and the corresponding sampling equipment that is appropriate for those characteristics:

Table 7.1: Soil Characteristics and Sampling Equipment

Characteristics	Appropriate Sampling Equipment
Compact, rocky, rubble filled soil	Hollow stem auger or Pit sampling
Fine grained soil	Split spoons, Shelby tubes, liners, hollow stem augers
Flowing sands or water saturated soils	Piston samplers

Several different samplers that cover a broad range of sampling conditions are recommended for obtaining representative samples. (See Table 7.2).

Table 7.2: Criteria for Commercially Available Sampling Devices

Type of sampler	Obtains core samples	Most suitable soil types	Operation in stony soils	Suitable soil moisture conditions	Relative sample size	Labor requirements (no. of persons)	Manual or power operation
A. Mechanical sample recovery							
1. Hand-held Power augers	No	Coh/coh'less	Unfavorable	Intermediate	Large	2+	Power
2. Solid stem flight augers	No	Coh/coh'less	Favorable	Wet to dry	Large	2+	Power
3. Hollow-stem augers	Yes	Coh/coh'less	Fav/unfav	Wet to dry	Large	2+	Power
4. Bucket augers	No	Coh/coh'less	Favorable	Wet to dry	Large	2+	Power
5. Backhoes	No	Coh/coh'less	Favorable	Wet to dry	Large	2+	Power
B. Samplers							
1. Screw-type augers	No	Coh	Unfavorable	Intermediate	Small	Single	Manual
2. Barrel augers							
a. Post-hole augers	No	Coh	Unfavorable	Wet	Large	Single	Manual
b. Dutch augers	No	Coh	Unfavorable	Wet	Large	Single	Manual
c. Regular barrel augers	No	Coh	Unfavorable	Intermediate	Large	Single	Manual
d. Sand augers	No	Coh'less	Unfavorable	Intermediate	Large	Single	Manual
e. Mud augers	No	Coh	Unfavorable	Wet	Large	Single	Manual
3. Tube-type samplers							
a. Soil samplers	Coh	Unfavorable	Wet to dry	Small	Single	Manual	
b. Veihmeyer tubes	Yes	Coh	Unfavorable	Intermediate	Large	Single	Manual
c. Shelby tubes	Yes	Coh	Unfavorable	Intermediate	Large	2+[b]	Both
d. Ring-lined samplers	Yes	Coh'less	Favorable	Wet to intermediate	Large	2+[b]	Both
e. Continuous samplers	Yes	Coh	Unfavorable	Wet to dry	Large	2+	Power
f. Piston samplers	Yes	Coh	Unfavorable	Wet	Large	2+[b]	Both
g. Zero-contamination	Yes	Coh	Unfavorable	Wet to intermediate	Small	2+[b]	Both
h. Split spoon samplers	Yes	Coh	Unfavorable	Intermediate	Large	2+[b]	Both
4. Bulk samplers	No	Coh	Favorable	Wet to dry	Large	Single	Manual

[a] Adapted from U.S. EPA. 1986a.

[b] All hand-operated versions of samplers, except for continuous samplers, can be worked by one person.

Coh = cohesive.

7.4.2 Sampling for VOCs

There is not specific method that is recommended for sampling soils for VOCs. However, experiments have proved that a procedure that collects an undisturbed sample with a device that allows direct transfer to a container is superior to a more disruptive procedure that uses a crude bulk sampler.

When sampling, it is important to avoid interactions between the sample and the liner of the corer and between the sample and the sampler in order to avoid adsorption of VOCs from the sample or release of VOCs to the sample.

7.4.3 Containerising VOCS

When transferring the sample to the container it is very important to minimize the time the sample is exposed to the atmosphere. VOC losses of up to 80% have been observed during this step.

The best method for transferring a sample from a large diameter coring device into a container is by collecting the appropriate size sample for laboratory analysis with a small diameter hand held corer and extruding the sub sample into a 40mL VOA vial.

Soil samples should be stored at 4^{o}C in the dark.

7.4.4 Shipping VOCs

It is important that seals are intact on storage containers and adequate cooling is maintained throughout the shipping process.

For more information on VOC sampling see Section 10 of the Multi-Media Sampling Training Course.

7.5 WASTE PILE SAMPLING

Waste pile sampling requires the collection of representative samples from waste piles, sludge or other solid or liquid waste mixed with soil.

7.5.1 Sampling Methods

Simple random sampling is the method of choice for obtaining representative samples from waste piles.

Stratified sampling should be used, however, if there are known strata within the pile, there is a need to prove or disprove that there are distinct strata, or there is a limit to the number of samples that can be taken and a need to reduce the chance that a “hot spot” could go unsampled.

7.5.2 Equipment and Procedures

The type of waste being sampled should be considered when selecting sampling equipment.

Several common types of equipment used to sample waste piles are:

a. Shovels and Scoops

Shovels and scoops are used to collect samples from surface portions of the pile.

Procedures

- The top layer of material can be removed with a pre-cleaned stainless steel spade to the desired sampling depth.
- With a pre-cleaned stainless steel scoop, remove a thin layer of material that came in contact with the spade
- When analyzing for volatiles, place a portion of the sample into an appropriate container.
- Mix the rest of the sample to assure homogenization.

b. Alternative Waste Pile Sampling Equipment

Other equipment used to sample waste piles are augers and thin-walled tube samplers, triers, and grain samplers. The procedures for these types of equipment can be found in the Multimedia Sampling References Manual…

8.0 SECTION 8 - SEDIMENT SAMPLING

8.1 INTRODUCTION

Sediments are clastic particles of different size, shape, and chemical composition that have been transported by water or air from their source on land, and deposited in a water body.

The purpose of sampling sediments is to collect a representative, undisturbed sample of the sediment that is to be investigated. This sample can be analyzed in order to define the extent of bottom sediment pollution, and to measure the presence and abundance of specific pollutants.

8.2 SEDIMENT DEPOSITION

When particles are transported by water, the location where they are deposited is dependent on their texture. Coarse grained sediment, such as sand and pebbles, are deposited in shallow zones near the shoreline while fine grained particles, such as silt and clay, are deposited in deeper water zones with slower currents.

Humans can also have an impact on the deposition of bottom sediments. Man made compounds (contaminants) can enter streams, lakes and oceans through atmospheric deposition, runoff and direct discharge into the water. These compounds can become associated with the sediment particles and settle at the bottom of the water body where they may eventually be released into the water.

Contaminated sediments can pose a high risk to the environment and may require an approach that includes sampling and analyzing the sediments, interpreting the results and the establishing guidelines and remedial action plans.

8.3 SELECTING A SAMPLING LOCATION

When selecting a sampling site, it is important to maximize the probability of selecting sites with the higher concentrations of pollutants. Persons involved in site selection must consider the principles of sediment transport and the physical size of the project area.

In general, fine-grained sediments (grain size smaller than 63um) have a higher concentration of organic matter and may contain higher levels of many different contaminants. As mentioned

above, fine-grained sediments accumulate in low energy zones, such as outer river estuaries and the outer side of the main channel of a meandering stream.

The physical size of the project area and the location of the sediment of interest will help to determine the number and spacing of sediment sampling stations.

Several approaches to sediment sampling are found in the following Table 8.1:

Table 8.1: Approaches to Sediment Sampling

Approach	Method	Recommendations
Easy Access	Samples are collected from sites that are the easiest to access	Only use this approach when the team can make informed judgments based on an understanding of the dynamics of the project site.
Stratified Random Sampling	Divides an area into a series of blocks or triangles where sampling sites are in the centre of each unit or at the intersections of each unit. The number of sampling points can be selected based on the size of the study area and the potential dispersal patterns of the constituent of interest.	Most suitable for previously mapped project areas with well defined zones of different types of sediment.
Point Source Sampling	Uses a grid that begins with a sample at a fixed distance from the point source, "x" with further samples taken at points of "2x", "4x", etc. until a distance that is equivalent to background (no contamination) is reached. If the point source is within a body of water then the radial sampling pattern is used, with sites located at the intersection of each distance line and at each major point of the compass. (See Figure 8.3)	It is important to take into account the affect that currents and other physical factors can have on the dispersal of materials from the point source.
Sediment Sampling in a River	Sampling stations are usually spaced 500m to 1 km apart throughout the study area. For a more detailed survey, a sector grid with sorter spacing can be used.	Sample upstream of rapids and before eddies.

Figure 8.1: Sampling Grid at a Point Source

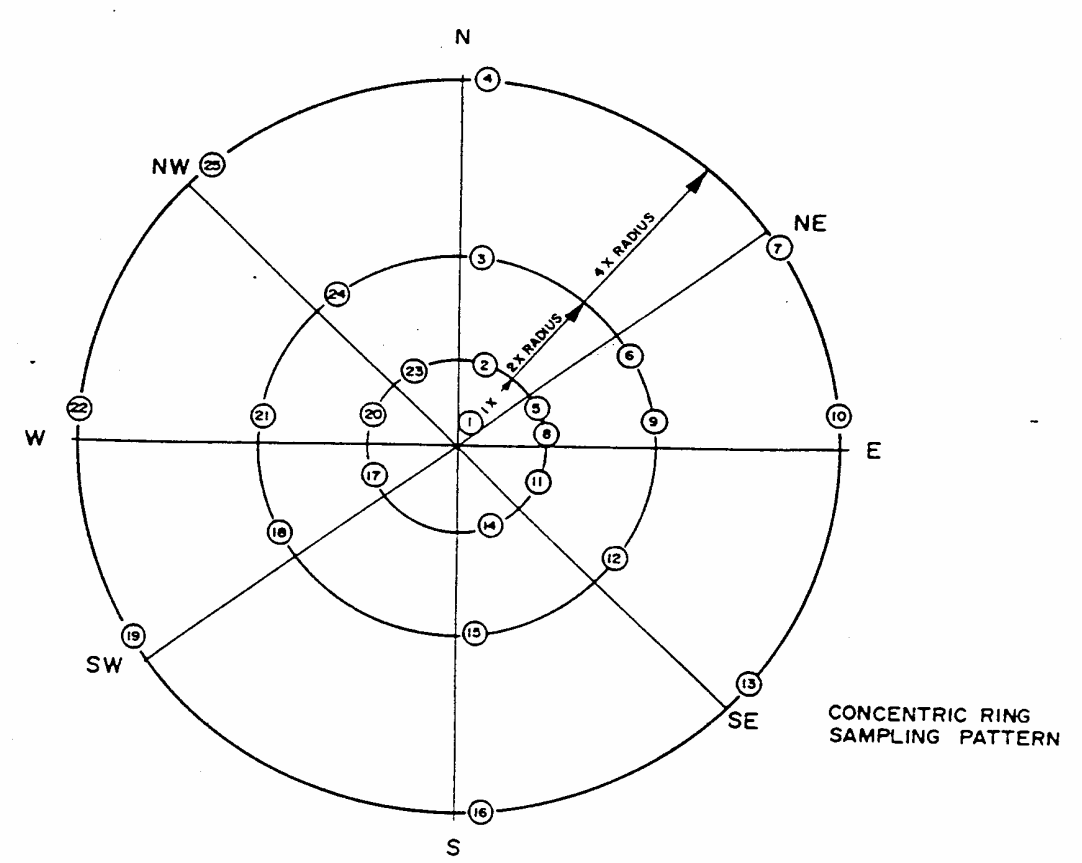


Figure 8.2: Random Selection of Sampling Stations With No Data Available on the Project

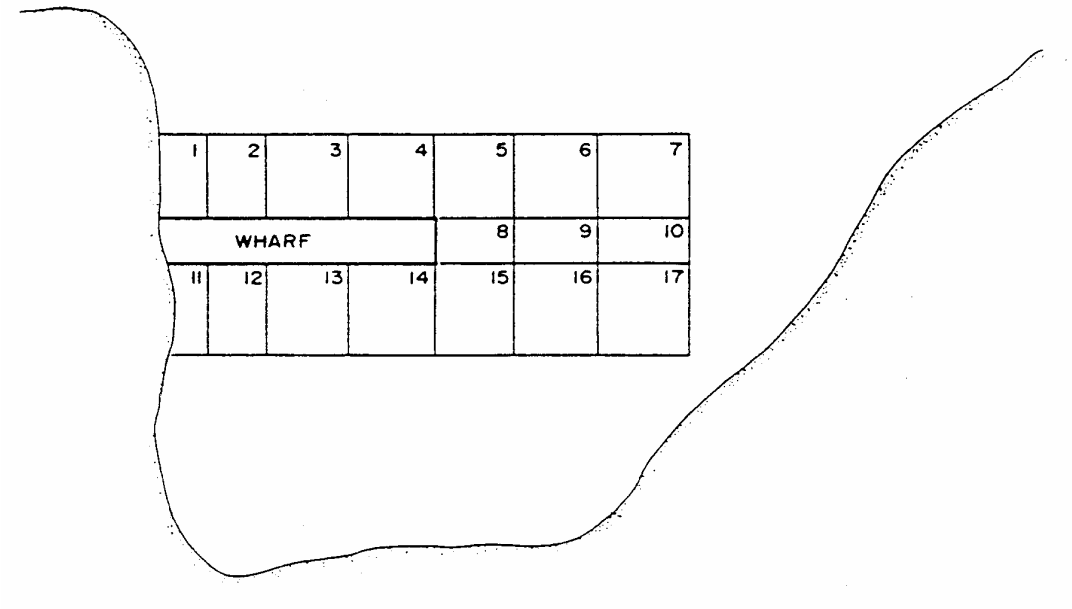
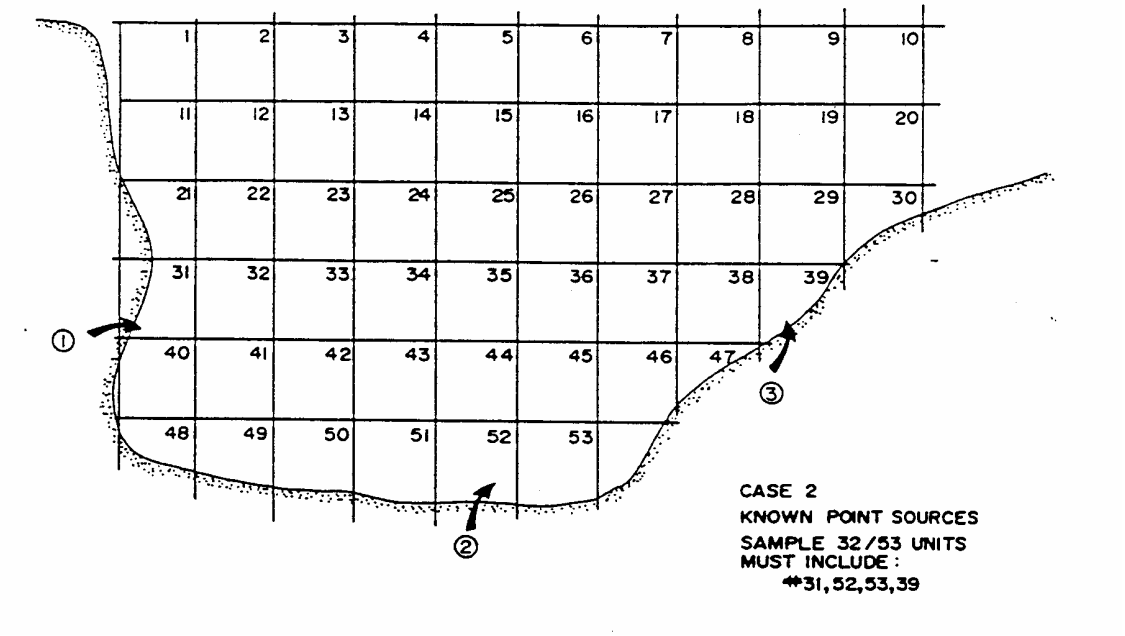


Figure 8.3: Selection of Sampling Stations With Available Information on Point Sources



8.4 SELECTING SAMPLING EQUIPMENT

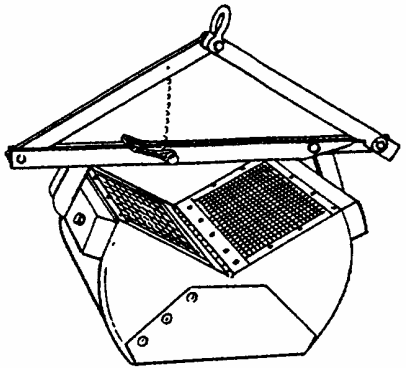
It is important to select sampling equipment that can recover a sample that accurately represents the nature of the bottom sediment in the study area.

There are two main types of samplers used to collect bottom sediments:

8.4.1 Grab Samplers

Grab samplers consist of either a set of jaws that close when lowered to the surface of the bottom sediment, or a bucket that rotates into the sediment upon reaching the bottom. A large screen or opening in the back of the bucket minimizes sediment disturbance caused by the descending sampler. Grab samplers collect surface sediment that can be used to determine the horizontal distribution of parameters. (See Figure 8.4)

Figure 8.4: Ponar Grab Sampler



8.4.2 Corers

Corers are used to obtain sediment samples for geological and geotechnical surveys. They collect a vertical section of sediments that can be used to determine the subsurface distribution of parameters with depth. They consist of a hollow metal or plastic core barrel. The barrel contains an easily removable plastic liner that retains the sediment sample. An open valve or piston mounted on the top of the core barrel allows water to flow through the barrel during descent but shuts when the corer penetrates the sediment. A core cutter and lead weights help to increase the penetration of the corer into the sediment.

Examples of different types of grab samplers and corers and the procedures for their use can be found in Section 11 in the Multi-Media Sampling Training Course manual.

Before selecting sampling equipment there are several factors to consider:

It is important to calculate the depth of the water at each station to ensure that enough cable or rope is available to operate the sampler and control the speed of its entry into the sediment. Knowledge of water depth can also help in selecting the type of sampler to use. (See Table 8.4).
It is also important to consider your sampling options. Two main options for the collection of bottom sediment samples: sampling from a platform and sampling by a diver.

- When sampling from a platform, the method of sampling equipment is important. Small grab samplers and corers can be hand operated from a vessel but large sampling devices may require strong winches or cranes. The vessel must be large enough to accommodate several project personnel, a sediment storage facility e.g. freezers or refrigerators, and all of the required equipment.

- If undisturbed samples are required, the use of diver should be considered. The diver can select a suitable area for sampling, make notes and/or take underwater photographs and control the operation of the sampler.

Table 8.2: Sediment Depth Collected by Different Samplers Under Optimal Conditions

Depth of Sediment Sample	Appropriate Sampling Equipment
0-10 cm	Lightweight, small-volume grabs
0-30 cm	Heavy, large-volume grabs
0-50 cm	Single gravity corers, box corers, multiple corers
0-2 m	Single gravity corers
Deeper than 2 m	Piston corers

8.5 PRESERVATION AND STORAGE OF SEDIMENT SAMPLES

In order to ensure that the integrity of the sediment samples is maintained throughout the preservation and storage process the following steps should be followed**:**

- Sample bottles should be pre-cleaned and dried before being transported to the sampling site.

- After collection, sediment samples should be filtered as soon as possible.

- Preservation should involve refrigeration for organics, and acidification for metals. Bottom sediments for particle size analysis can be transported and stored without refrigeration.

9.0 SECTION 9 - GROUNDWATER SAMPLING

9.1 INTRODUCTION

Groundwater sampling is conducted in order to acquire information on the quality of our subsurface water resources. Groundwater sampling can be a complicated procedure because it requires drilling and constructing a monitoring well at each sampling location. The wells are used to access representative groundwater samples that can be analyzed for contaminants. When sampling groundwater, care must be taken to ensure that proper well design and sampling techniques are selected in order to avoid and prevent contamination of the aquifer being studied.

9.2 WELL DESIGN

Wells must be designed so that groundwater samples can be easily obtained without altering the quality of the water being sampled. Effective well design requires some understanding of the hydrogeology and subsurface geochemistry of the site and should only be carried out by experienced personnel.

Several important components of well design include:

9.2.1 Location and Number of Wells

The main goal of most groundwater sampling surveys is to determine the effect that an above ground activity may be having on the groundwater quality in the vicinity. As water generally descends vertically through the unsaturated zone and then horizontally through the saturated zone, wells are usually completed downgradient in the first permeable water bearing unit encountered.

The number of wells constructed is influenced by the size of the study area, site geology and hydrology, and contaminant characteristics. The larger the study area, and/or the more complex the contaminant and/or the geology and hydrology, the more monitoring wells will be required (Figure 9.1).

9.2.2 Diameter

Small diameter pumps with a less than 5 cm outer diameter, capable of lifting water over 30 m, have become the standard. Therefore, monitoring wells with an inner diameter of 5 cm are commonly used.

When monitoring is required at depths of over 30 m or where a stronger casing is needed, wells of larger diameter may be preferred.

9.2.3 Casing, Screen and Sampling Materials

The material used for a monitoring well must not affect the integrity of the groundwater sample. Materials used should be inert towards the chemical constituents of the samples so as to neither adsorb or contaminate the sample. They should also be durable enough to withstand several decades of use. The following is a list of materials ranked from best to worst:

1. Teflon
2. Stainless Steel 316
3. Stainless Steel 304
4. PVC Type I
5. Low Carbon Steel
6. Galvanized Steel
7. Carbon Steel

Although teflon and stainless steel are expensive, trying to save money by using cheaper materials may also increase the project cost if reanalysis or monitoring well reconstruction is needed.

Well screens should be commercially manufactured and they should be the correct slot size for the well. Screen lengths are dependent on the contaminant in question. If a water supply aquifer is being tested then the entire thickness of the water bearing body could be screened. If the saturated zone is too thick to sample effectively with one long screen then a vertical nesting of wells may be required (diagram). In such situations screen lengths of no more than 1.5 – 3 m are used. If only the first water bearing zone encountered requires monitoring then screen length should be only .25 to .5 m thick to minimize siltation problems from surrounding materials. When monitoring for a low density substance such as gasoline, screens should extend above the zone of saturation to allow for entry of these lighter substances.

9.2.4 Sealing Materials

The screened portion of a monitoring well must be protected from the vertical infiltration of groundwater and leachate that may contaminate samples. Protection is achieved by placing seals within or near the saturated zone to isolate the screened portion and at the ground surface to prevent downward movement of surface contaminants. Seals usually consist of sand and cement, cement grout, dry bentonite or bentonite slurry.

9.2.5 Purging

Proper monitoring wells facilitate the entrance of water into the well and provide water samples free of suspended solids. In order to ensure these requirements, wells must be purged to eliminate stagnant water in the wellbore, break down any mud cake surrounding the well bore and loosen fine particles in the borehole. Purging also serves to rinse and condition sampling equipment with well water. Typical methods of purging include:

- Bailing –which involves rapidly dropping and retrieving a bailer in and out of the water in the well in order to loosen fine-grained materials and move them into the well where they can be removed.

- Surging –uses the up and down motion of a plunger to transfer that energy to an in and out action on the water near the screen.

- Peristaltic pump - used to purge small diameter wells when the water table is less than 25 – 30 ft from land surface.

- Air pumping –involves pumping air into the well to loosen particles. This technique may expose crews to hazardous substances depending on the contamination level of the groundwater.

Electric tapes or water-level sensors should be used to continuously monitor drawdown during purging.

A minimum of three well volumes should be purged. Measurements of pH, conductivity, dissolved-oxygen concentration, and turbidity should be made during each purge. These measurements are used as criteria to aid in determining when water withdrawn from a well is representative of water flowing through the aquifer.

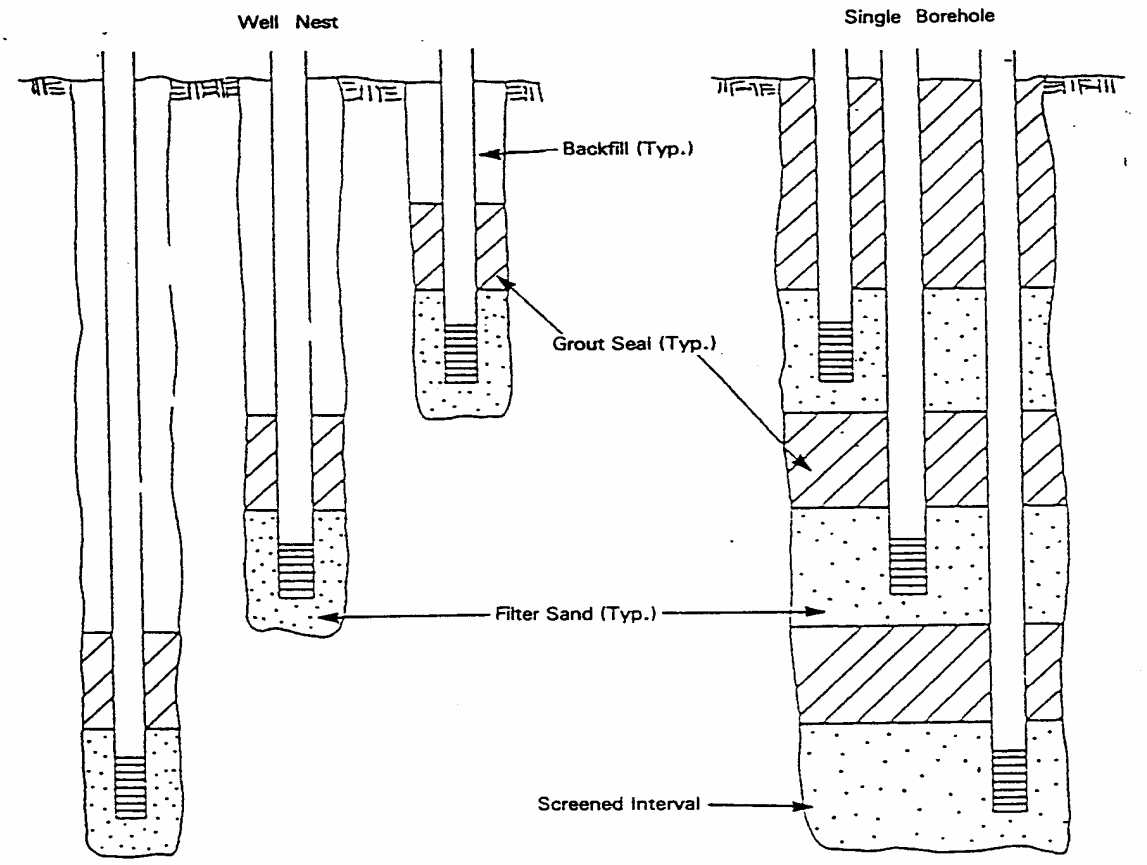
The same pump should be used for purging and sampling.

9.2.6 Security

Well security is an important consideration in well development. Potential security problems include vandalism and vehicle contact. While vandalism is difficult to plan for, vehicle contact is more likely to avoided if the following steps are followed:

- Paint the above ground portion of the well a bright color and reinforce it.
- Inform the owner and users of the site of the exact location of the well.

Figure 9.1: Typical Multiwell Installation



9.3 DRILLING METHODS

The selected drilling method should depend on the geology of the site, the required depth of the well, and the equipment available for drilling. When drilling, subsurface disturbance should be minimized as much as possible and drilling tools should be steam cleaned to minimize the potential for contamination. The drilling method and driller can influence the quality of the

groundwater sample that is produced. Table 7.3 summarizes several drilling methods and their advantages and disadvantages

Table 9.1: Advantages and Disadvantages of Selected Drilling Methods For Monitoring Well Construction

Method	Drilling Principle	Advantages	Disadvantages
Drive Point	1.25 to 2 inch ID casing with pointed screen mechanically depth.	Inexpensive. Easy to install, by hand if necessary. Water samples can be collected as driving proceeds. Depending on overburden, a good seal between casing and formation can be achieved.	Difficult to sample from smaller diameter drive points if water level is below suction lift. Bailing possible. No formation samples can be collected. Limited to fairly soft materials. Hard to penetrate compact, gravelly materials. Hard to develop. Screen may become clogged if thick clays are penetrated. PVC and Teflon® casing and screen are not strong enough to be driven. Must use metal construction materials which may influence some water quality determinations.
Auger, Hollow- and Solid-stem	Successive 5-foot flights of spiral-shaped drill stem are rotated into the ground to create a hole. Cuttings are brought to the surface by the turning action of the auger.	Inexpensive. Fairly simple operation. Small rigs can get to difficult-to-reach areas. Quick set-up time. Can quickly construct shallow wells in firm, noncavey materials. No drilling fluid required. Use of hollow-stem augers greatly facilitates collection of split-spoon samples. Small-diameter wells can be built inside hollow-stem flights when geologic materials are cavey.	Depth of penetration limited, especially in cavey materials. Maximum depths 150 feet. Cannot be used in rock or well-cemented formations. Difficult to drill in cobbles/boulders. Log of well is difficult to interpret without collection of split spoons due to the lag time for cuttings to reach ground surface. Vertical leakage of water through borehole during drilling is likely to occur. Solid-stem limited to fine grained, unconsolidated materials that will not collapse when unsupported. With hollow-stem flights, heaving materials can present a problem. May need to add water down auger to control heaving or wash materials from auger before completing well.
Jetting	Washing action of water forced out of the bottom of the drill rod clears hole to allow penetration. Cuttings brought to surface by water flowing up the outside of the drill rod.	Inexpensive. Driller often not needed for shallow holes. In firm, noncavey deposits where hole will stand open, well construction fairly simple.	Somewhat slow, especially with increasing depth. Extremely difficult to use in very coarse materials, i.e., cobbles/boulders. A water supply is needed that is under enough pressure to penetrate the geologic materials present. Difficult to interpret sequence of geologic materials from cuttings. Maximum depth 150 feet, depending on geology and water pressure capabilities.
Cable-tool (Percussion)	Hole created by dropping a heavy "string" of drill tools into well bore, crusing materials at bottom. Cuttings are removed occasionally by bailer. Generally, casing is driven just ahead of the bottom of the hole; a hole greater than 6 inches in diameter is usually made.	Can be used in rock formations as well as unconsolidated formations. Fairly accurate logs can be prepared from cuttings if collected often enough. Driving a casing ahead of hole minimizes cross-contamination by vertical leakage of formation waters. Core samples can be obtained easily.	Requires an experienced driller. Heavy steel drive pipe used to keep hole open and drilling "tools" can limit accessibility. Cannot run some geophysical logs due to presence of drive pipe. Re atively slow drilling method.

Method	Drilling Principle	Advantages	Disadvantages
Hydraulic Rotary	Rotating bit breaks formation; cuttings are brought to the surface by a circulating fluid (mud). Mud is forced down the interior of the drill stem, out the bit, and up the annulus between the drill stem and hole wall. Cuttings are removed by settling in a "mud pit" at the ground surface and the mud is circulated back down the drill stem.	Drilling is fairly quick in all types of geologic materials. Borehole will stay open from formation of a mud wall on sides of borehole by the circulating drilling mud. Eases geophysical logging and well construction. Geologic cores can be collected. Virtually unlimited depths possible.	Expensive, requires experienced driller and fair amount of peripheral equipment. Completed well may be difficult to develop, especially small-diameter wells, because of mud wall on borehole. Geologic logging by visual inspection of cuttings is fair due to presence of drilling mud. Thin beds of sand, gravel, or clay may be missed. Presence of drilling mud can contaminate water samples, especially the organic, biodegradable muds. Circulation of drilling fluid through a contaminated zone can create a hazard at the ground surface with the mud pit and cross-contaminate clean zones during circulation.
Reverse Rotary	Similar to Hydraulic Rotary method except the drilling fluid is circulated down the borehole outside the drill stem and is pumped up the inside, just the reverse of the normal rotary method. Water is used as the drilling fluid, rather than a mud, and the hole is kept open by the hydrostatic pressure of the water standing in the borehole.	Creates a very "clean" hole, not dirtied with drilling mud. Can be used in all geologic formations. Very deep penetrations possible. Split-spoon sampling possible.	A large water supply is needed to maintain hydrostatic pressure in deep holes and when highly conductive formations are encountered. Expensive—experienced driller and much peripheral equipment required. Hole diameters are usually large, commonly 18 inches or greater. Cross-contamination from circulating water likely. Geologic samples brough to surface are generally poor, circulating water will "wash" finer materials from sample.
Air Rotary	Very similar to Hydraulic Rotary, the main difference being that air is used as the primary drilling fluid as opposed to mud or water.	Can be used in all geologic formations; most successful in highly fractured environments. Useful at any depth. Fairly quick. Drilling mud or water not required.	Relatively expensive. Cross-contamination from vertical communication possible. Air will be mixed with water in the hole and that which is blown from the hole, potentially creating unwanted reactions with contaminants; may affect "representative" samples. Cuttings and water blown from the hole can pose a hazard to crew and surrounding environment if toxic compounds encountered. Organic foam additives to aid cuttings removal may contaminate samples.
Air-Percussion Rotary or Downhole-Hammer	Air Rotary with a reciprocating hammer connected to the bit to fracture rock.	Very fast penetrations. Useful in all geologic formations. Only small amounts of water needed for dust and bit temperature control. Cross-contamination potential can be reduced by driving casing.	Relatively expensive. As with most hydraulic rotary methods, the rig is fairly heavy, limiting accessibility. Vertical mixing of water and air creates cross-contamination potential. Hazard posed to surface environment if toxic compounds encountered. Organic foam additives for cuttings removal may contaminate samples.

9.4 DOCUMENTATION

Documentation in the field is essential. In addition to the basic information (location, time, equipment used etc) other elements that should be documented include:

9.4.1 Water Level Measurements

In order to estimate the amount of water that needs to be purged from the well, it is important to record the water level in the well before purging or sampling takes place. These records will also provide information on seasonal variations and changes in flow paths.

9.4.2 Purging

The calculations used for the purging process as well as the purging process itself should be well documented.

9.5 METHODS FOR PURGING AND SAMPLE COLLECTION

If the proper drilling methods, well construction materials, and development techniques are selected then it should be possible to collect a representative groundwater sample from the monitoring well.

9.5.1 Purging

The following are the general procedures for well purging:

- Measure and record the depth to static water level.
- Calculate the well volume (figure..)
- Lower the selected purging device followed by a water-level sensor to the desired location of the pump intake.
- Start the pump and adjust the drawdown rate to between 0.5 and 1.0 ft (0.15 to 0.3 m).
- Measure water level as purging continues.
- If the final intake position is above the screen, the pumping rate should be about 500 to 1,000 milliliters per minute.
- If the final intake position is within the screened section, the rate should be about 200 to 500 milliliters per minute.
- A minimum of three well volumes should be purged and field measurement readings should be recorded about three to five minutes apart.
- As the last well volume is purged, adjust the rate to the pumping rate to be used during sampling.
- Document well purging information (See Figure 9.2)

Figure 9.2: Example of a Field Form to Record Well Purging

RECORD OF WELL PURGING

Date:_____ By:_____

SITE ID _____ STATION NAME _____ OTHER ID _____

WELL PURGING METHOD AND PUMP TYPE (describe):_____

TIME	WATER LEVEL below: MP or LS	DRAW-DOWN	WELL YIELD	TEMPER-ATURE	CON-DUC-TIVITY	pH	DIS-SOLVED OXYGEN	TURBID-ITY	APPROX. PUMPING RATE
HR:MIN	ft or m	ft or m	gpm or cfs	°C	µS/cm	units	mg/L	NTU (or FTU)	gal/min or L/min

Well volume = V = 0.0408 HD^2 = ____ gallons **Purge volume** = (n)(V) = ____ gallons

V = volume of water in well, in gallons; D = inside well diameter, in inches; H = height of water column, in feet; n = number of well volumes to purge. If casing diameter = 2 in., well volume is 0.16 gallons per foot of casing.

FIELD MEASUREMENTS	STABILITY CRITERIA
NTU, Nephelometric Turbidity Units; FTU, Formazin Turbidity Units	Allowable difference in sequential parameter values
pH	± 0.1 standard units
Temperature, in degrees Celsius (°C)	± 0.2°C (thermistor)
Specific electrical conductance (SC), in microsiemens per centimeter at 25°C (µS/cm)	± 5%, for SC ≤ 100 µS/cm ± 3%, for SC > 100 µS/cm
Dissolved-oxygen concentration, in milligrams per liter (mg/L)	± 0.3 mg/L
Turbidity (TBY), in NTU (FTU ≈ NTU)	± 10%, for TBY < 100 NTU; ambient TBY is <5 NTU for most ground-water systems (visible TBY > 5 NTU)

Groundwater samples should be collected after a stable sample chemistry indicated by pH, Eh, Q and To readings has been reached over three successive well volume purges.

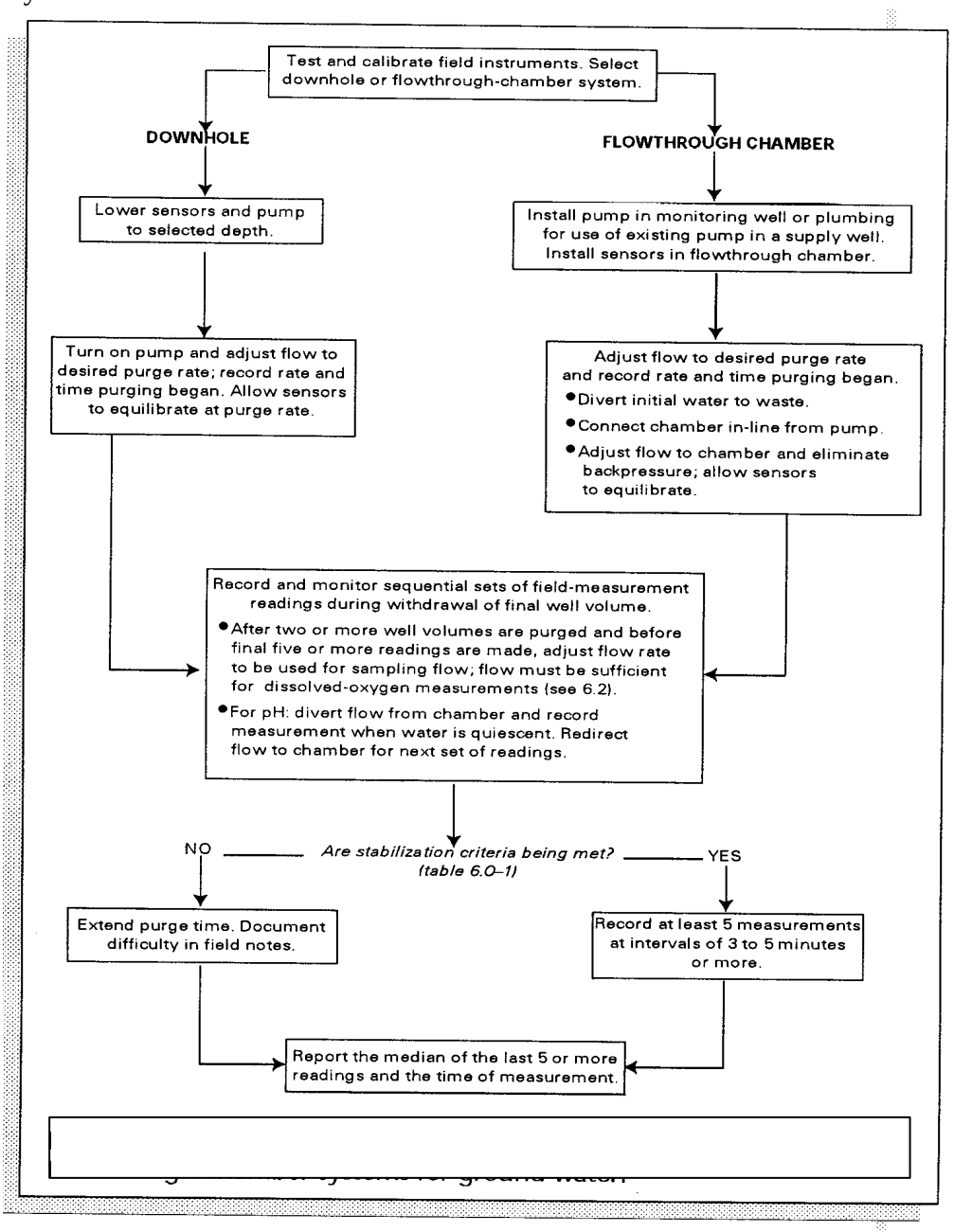
9.5.2 Sample Measurements

There are two different systems that can be used to sample wells, a flowthrough chamber system or a downhole system. The flowthrough chamber system is used for direct field measurements and water samples that are collected for chemical analysis. A downhole system is used if field measurements will be monitored without sampling. Either of these systems are required for

measurements of temperature, dissolved oxygen and Eh as opposed to taking these measurements from a bailed sample.

The field measurement procedures for both types of well sampling are described in figure….

Figure 9.3: Field Measurement Procedures Using Downhole and Flowthrough-Chamber Systems for Groundwater



9.5.3 Sub-Sample Measurements

Subsamples are samples that are not collected directly from the well itself but from devices such as a bailer, or syringe sampler that have been used to remove well water. These samples are more subject to bias from changes in temperature, pressure, turbidity etc. Subsamples can be used for measuring pH and alkalinity but should not be used to measure temperature, dissolved oxygen, Eh, or turbidity. The following Figure 9.4 shows the steps measurement steps for sample collection from a bailed sample.

Figure 9.4: Subsample Field Measurement Procedures for Conductivity, pH, and Alkalinity of Groundwater

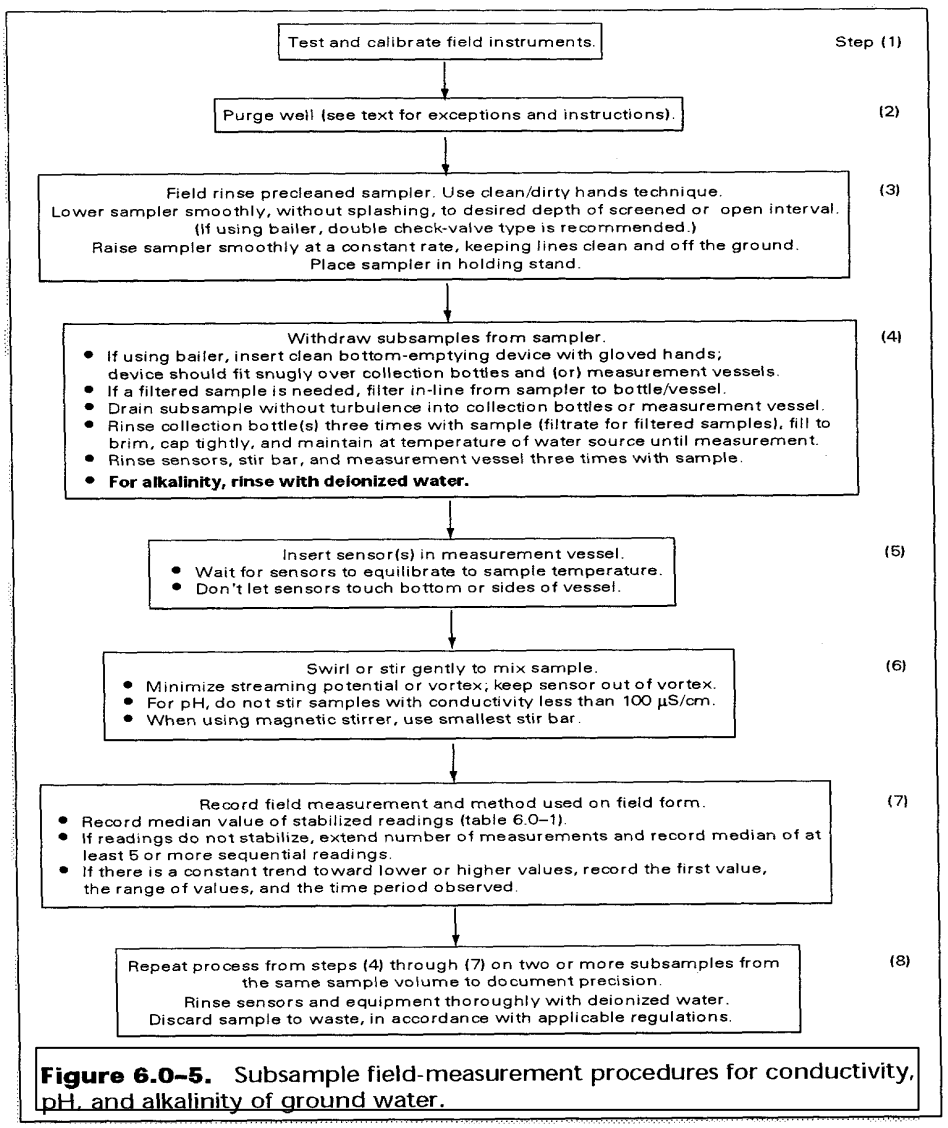


Figure 6.0–5. Subsample field-measurement procedures for conductivity, pH, and alkalinity of ground water.

9.6 GROUNDWATER PRESERVATION

The physical, chemical and biological state of water samples may change during transport and storage. In an effort to avoid such changes, samples are usually refrigerated or preserved by the addition of acid or alkaline solutions. Samples that are not preserved should be placed into a sample container with no headspace.

10.0 SECTION 10 - AIR SAMPLING

10.1 INTRODUCTION

Air sampling is conducted primarily to identify and quantify any gases, vapours, or particulates present in the atmosphere within a certain area.

10.2 AIR SAMPLING METHODS

There are two common methods of sampling air:

- Area sampling, which involves placing collection devices in areas of concern and monitoring them over specific time periods.
- Personal sampling, which involves sampling the air within a humans breathing zone.

Factors that may influence the method selected include project objectives and site characteristics**.**

10.3 TYPES OF AIR SAMPLES

Once air sampling methods have been established, it is necessary to determine the type of air sample that will be collected. Once again, project objectives and site characteristics will help to determine this.

There are two main types of air samples:

10.3.1 Instantaneous Grab Samples

Instantaneous air samples are collected over short time periods. They are used to examine stable contaminant concentrations and may require very sensitive analytical tools because of the small volume of air that they collect.

10.3.2 Integrated Samples

Integrated samples are collected when minimum sample periods or volumes are required, or when samples are to be compared to an established limit or standard. Two systems that are used to collect integrated samples are: active samplers and passive samplers.

1. Active samplers, which move air through a mechanical collection system or into a specific medium. Samples are collected over specific periods of time at fixed flow rates. The medium is then analyzed to identify and quantify contaminants.

Examples of active samplers are:

- Sampling pumps which rely on electrically powered pumps to induce air movement,
- Gas vapour absorbers such as impingers and bubblers which collect gases and vapours by liquid absorption, (See Figure 10.3 and 10.3.1)
- Particulate collectors which use active systems to trap particulates on filters, and
- Sample bags which are useful if instantaneous and integrated samples of gases and vapours are needed.

Figure 10.1: Impinger and Fritted Bubbler

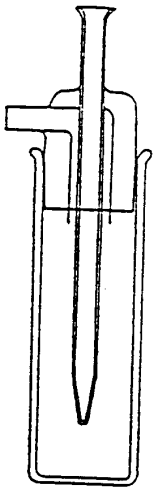
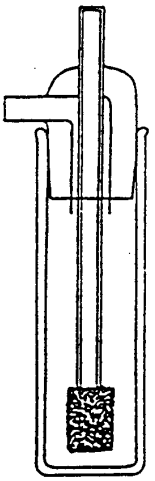


Figure 13.1a: Midget Impinger.



Fritted Bubbler.

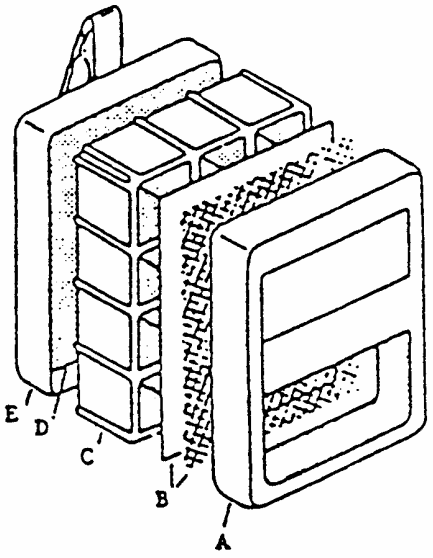
2. Passive samplers use natural forces to collect samples. The most common type of passive samplers are quantitative passive dosimeters which apply to gas and vapour contaminants only. They are small, lightweight and do not require any calibration or maintenance as they are not mechanical.

Examples of passive dosimeters are:

- Diffusion samplers that operate by the passive movement of contaminants through a concentration gradient that is created within a stagnant layer of air between the contaminated atmosphere and the indicator material. (See Figure 10.3.2).

- Permeation samplers which rely on natural permeation of a contaminant through a membrane. They are efficient at picking out single contaminants from a mixture of contaminants.

Figure 10.2: Diffusion Sampler



A - Sampler front
B - Draft shield
C - Grid section
D - Sorbant impregnated pad
E - Sampler back

10.4 SAMPLE LOCATION

Air samplers are usually placed at more than one location throughout the study area. The specific locations they are placed are influenced by the project objectives.

Typical locations for air samplers are:

- Upwind of the site in order to determine background levels of air contamination.

- Near any facilities on site to ensure that they are not in a contaminated area.
- Near the source of contamination.
- Downwind of the site to determine if contaminated air is leaving the site.

Other important factors to consider when selecting a sampling site are:

- Wind speed and direction in order to place samplers upwind and downwind of the source of contamination. If wind direction shifts then samplers must be relocated.
- Temperature and barometric pressure as their values are needed to make corrections in air sampler calibration curves and air volumes.
- Humidity.

10.5 CALIBRATION

Calibration for flow rate is very important when using active air samplers. The most common calibrating device for sampling pumps is the soap bubble flow meter. Active samplers should be calibrated before use and after use. Instructions for calibration can be found in the Multi-Media Sampling Training Course module of the reference page.

11.0 SECTION 11 - BIOLOGICAL SAMPLING

11.1 INTRODUCTION

In depth biological studies are not always essential for identifying or quantifying contaminants, especially if other methods of sampling (e.g. surface water, groundwater, soil etc.) have been successful. However, knowledge of the quantity of specific contaminants present in an area does not always reveal the extent of the impact that the contaminants have on the biological system. Therefore, in some cases a biological sampling program may be necessary.

Several reasons that biological sampling may be conducted are:

- To detect biological contamination,

- To detect differences between biological parameters at the site and at a reference location, or

- To determine if contaminants that have been detected in the air, water, soil, or sediment are affecting or could affect natural systems either directly or through the food chain and, if an impact is possible, what risk it might be to humans.

There are two main types of biological sampling:

1. Ecological surveys – which compare ecological parameters such as species abundance to the same parameters in the affected area and,

2. Individual assays – which examine the levels of contaminants in the tissues of organisms collected near the site. When examining organisms that are consumed by humans, assays can help assist in human health risk assessment.

11.2 DEVELOPING A SAMPLING PLAN

Before going out into the field, it is necessary to develop a sampling plan that defines the overall objectives of the study and steps that will be taken to accomplish the objectives.

The following describes the steps to developing a biological sampling plan:

1. The sampling team should determine the pollutants of concern by reviewing the results of soil, sediment, groundwater and surface water testing.

2. Once a final list of pollutants is established, sampling personnel need to define the overall objectives of the project including:

    - The number of sample collection sites,
    - experimental procedures, and
    - analytical techniques.

3. The next step is to establish the probable transport routes of the pollutants by studying their chemical and physical properties and identifying possible dispersal mechanisms at the site**.**

4. Once the nature of the pollutants is better understood, it is necessary to conduct a background information search. Important information may include**:**

    - Prior uses of the site.
    - Species most likely present at the site.
    - Species present that are used for human consumption.
    - Appropriate sampling methods for species of interest.
    - Research on the known contaminants and how they affect local species.
    - Background levels of contaminants of concern in soils, water, and biota.

5. Next, a preliminary site survey should be conducted which involves identifying habitat types on the site, pollutant transportation routes, and the indicator species to be studied. A site survey may include the following activities:

    - Photographing important ecological features within the site and the surrounding area.
    - Mapping vegetation types.
    - Mapping animal tracks, trails, and burrows.

- Identifying the locations of aquatic or marine habitat.
- Identifying aquatic habitat type.
- Noting the presence of aquatic species.

Once the above information has been obtained, the study team should be able to determine the type of sampling plan that will be most effective in addressing the site-specific issues of concern.

11.3 SAMPLING TECHNIQUES

Biological sampling generally involves sampling vegetation, terrestrial vertebrates, aquatic macroinvertebrates, or fish. The following provides a brief overview of several of the techniques used for each type of sampling. (More information can be found in Section 14.2 in the Multi-Media Sampling Training Course manual).

11.3.1 Vegetation Sampling

Assessing the stress level of plants can aid in determining subtle effects that a pollutant has on the environment.

Several methods used for sampling vegetation include:

a. Visual Observation

Vegetation should be observed by project personnel throughout the study area and in downwind, downstream and downhill areas for signs of stress. Stress indicators may include the size of annual or biennial plants, evidence of changes in levels of disease or insect damage, premature leaf fall, abnormal wilting, and abnormal coloration. It may be valuable to make these observations at different times of the year.

b. Ecological Assessments

The composition, biomass, and productivity of the plant community can be assessed by performing an ecological survey. When ecological surveys are conducted in a potentially contaminated area and then compared with surveys conducted in a reference area, vegetation stress can be determined if exposure to contaminants is the only difference between the two sites.

The most common ecological assessment survey techniques are:

- Plot Sampling – is used to quantify species composition in an area. Plots are laid out randomly or systematically and vary in size depending on the size of the vegetation being sampled (eg. 10 x 10 m for trees or tall shrubs). Once plots are laid out, the sampler estimates the percentage of the plot that is covered by the leaves of each species. Then an average percent cover is calculated for each plant species from several plots.

- plotless sampling –is used in areas where plants to be sampled are widely spaced e.g. Arid regions.

- line-intercept sampling –which is useful for low growing vegetation.

c. Tissue Analysis

Tissue analysis involves collecting plant tissue and analyzing it for metals, organics, and various other elements. Approximately 30 grams of plant tissue are needed for analysis.

Vegetation samples should be placed in a collectors box that is kept moist. After identification, samples may be pressed and mounted.

If tissue analysis is required, samples are placed in 4 litre paper bags and labelled. The bags are stapled shut and placed in a larger plastic bag which is then placed in a cooler with ice, ice packs, or dry ice.

11.3.2 Terrestrial Vertebrate Sampling

The effects of contaminants on terrestrial vertebrates can be determined through tissue analysis and\or an ecological survey.

a. **Tissue Analysis**

Tissue analysis usually involves the collection of small to medium sized animals. The collection of animals can help in identifying species present, estimating the numbers of each species, and securing tissue chemical analysis.

Common terrestrial vertebrate collection techniques include:

- Live traps which completely enclose the captured animal but do not kill the captive.

- Lethal traps that grab and retain the animal once the trap is tripped.

- Hunting which is used for animals that are not easily trapped.

If tissue analysis is required, the collected specimens are usually killed. Information such as weight, sex etc. should be recorded and specimens should be photographed. Stainless steel scalpels can be used to remove muscle and fatty deposits, liver, kidneys, and hair and claw samples. Tissues are wrapped in aluminum foil, labelled, and frozen in the field using dry ice.

b. **Ecological Survey**

Ecological surveys involve evaluating the impacts of site contamination on wildlife and developing a mitigation plan to offset those impacts. For information on the methods used for this type of survey, the US Fish and Wildlife ServicesÈ Habitat Evaluation Procedures (HEP) are found in ….the book.

11.3.3 Aquatic Macro invertebrate sampling

As invertebrates live on or in sediments where contaminants accumulate, invertebrates that are collected by sediment sampling devices are often good indicators of contamination. Collected invertebrates can be used in tissue analysis or ecological assessments.

Several different methods of sampling freshwater and marine macroinvertebrates are:

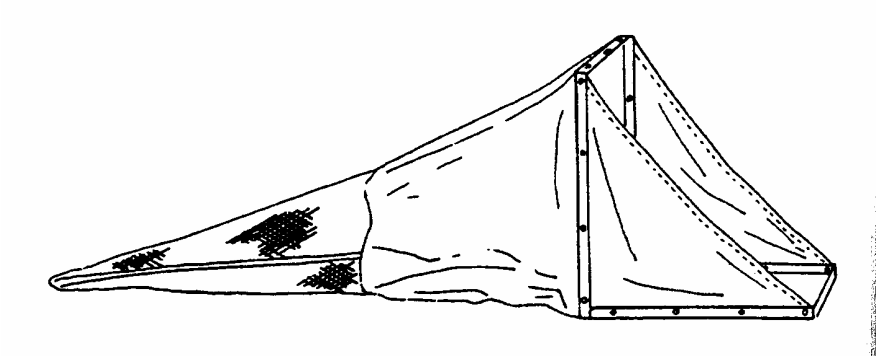
- Bottom grabs, sediment coring devices, and shovels can be used to collect invertebrates inhabiting soft substrate. Once the substrate is collected, it is sieved through one or more screens to extract the organisms.

- Sieving Devices remove aquatic invertebrates from their habitats, either by capturing organisms drifting in the water or capturing organisms that are larger than the sediments in which they live.

- Other methods of collection include the otter trawl, traps, artificial substrate, and in situ bioassays. The techniques for these methods of collection can be found in Section 14.2 of the Multi-Media Sampling Training Course.

If invertebrates are collected for tissue analysis they should be sorted by species, counted, and weighed. Samples should be packed in ice chests and kept frozen until transported to the laboratory.

Figure 11.1: Suber Square Foot Sampler for Macroinvertebrate Sampling in Shallow Streams



11.3.4 Fish Sampling Techniques

Techniques for collecting freshwater and marine fish include:

- Trawling which entails dragging an open net through a water body with a boat.

- Electrofishing which is a freshwater fish sampling method that uses a direct, pulsating current to stun the fish when the current travels through water with a resistance between 300 ohms and 30,000 ohms. It is a good method for collecting specimens for tissue analysis or to obtain population estimates for creeks or small rivers.

- Other methods of collection include seining, and hook and line. The techniques for these methods are found in the reference volume list: U.S. E.P.A., Rapid Bioassessment Protocols for Use in Streams and Rivers.

- In situ bioassay techniques for fish are the same as those for macroinvertebrates

Fish collected for tissue analysis are handled according to the procedures found in Section 14 of the Multi-Media Sampling Training Course Manual.

11.4 BIOASSAYS

Bioassays are used to determine the level of contaminants in organisms collected from the site, or to test toxicity by comparing site media to organisms from unaffected areas near the site.

The most common bioassay is the static acute bioassay using aquatic invertebrates or fish. This procedure involves confining local invertebrates from a clean environment (or laboratory raised) in traps and holding them at the site and at a references site. If testing for toxicity, the test and reference cages are checked and compared on a regular basis for mortality rates. Tests for bioaccumulations involve the sacrifice of several of the specimens from each site at set time intervals throughout the study period.

12.0 SECTION 12 SURFICIAL SAMPLING

12.1 INTRODUCTION

Surficial sampling can be used to assess the extent or existence and/or extent of contamination on various surfaces. For example, the wooden portion of a loading dock may analyzed for PCBs by collecting a chip sample.

12.2 SAMPLING PROCEDURES

Three types of surficial sampling procedures are:

12.2.1 Wipe Samples

Wipe samples are intended for non-volatile species of analytes (e.g. PCB, TCDD, TCDF) on non-porous surfaces (e.g. metal and glass). Examples of sampling points are process vessels, fans, windowpanes, etc. Sample points should be carefully selected based on the site history, potential for contamination, and available surface area.

Procedures

Wearing disposable surgical gloves, soak a piece of 7.6 x 7.6 cm gauze in a pesticide grade hexane solvent (approximately 15 –2 0 ml per 7.6 cm x 7.6 cm pad). This should be done just before sample collection.

The gauze should then be used to wipe a 25 x 25 cm area -once in a horizontal direction and once in a vertical direction.

The gauze should then be placed in a sample bottle

A blank should always be collected for each wipe sample in order to ensure data quality.

12.2.2 Chip Samples

Chip samples are intended for non-volatile species of analytes (e.g. PCB, TCDD, TCDF) on porous surfaces (e.g. cement, brick, wood). Examples of sampling points include storage tanks, loading dock areas etc. Sample points should be carefully selected based on the site history, potential for contamination, and available surface area.

Procedures

Wearing disposable gloves, break up a 25 cm x 25 cm area of the surface to be sampled with a decontaminated chisel and hammer.

The area should be chipped to less than 1 cm.

Collect the pieces using a decontaminated dustpan and natural bristle brush and transfer the sample directly into the bottle.

12.2.3 Sweep Samples

Sweep samples are intended for non-volatile species of analytes (e.g. PCB, TCDD, TCDF) in residue found in porous (e.g. asphalt) or non-porous (e.g. metal) surfaces. Suggested sampling points include floor surfaces near process vessels and storage tanks, street gutters, etc. Sample points should be carefully selected based on the site history, potential for contamination, and available surface area.

Procedures

Wearing disposable gloves, sweep the entire residue in a 25 cm x 25 cm area into a decontaminated dustpan with or without the aid of a decontaminated spatula.

13.0 SECTION 13 - HUMAN HABITATION SAMPLING

13.1 INTRODUCTION

Human habitation sampling is conducted in order to determine the potential for human exposure to contaminants that are present in residential environments. This type of sampling is very sensitive, and involves a high level of communication skills on the part of the sampling personnel.

13.2 COMMUNICATION

The first step in human habitation sampling is to phone public officials, property owners and any other involved persons to receive permission to access the habitation desired for sampling. Permission slips should be collected from property owners prior to entering the property. All telephone conversations, permission slips, and agreements should be documented.

13.3 SAMPLING PROCEDURES

Once access to the habitation has been approved, it is necessary to select the type of samples that will be taken.

Several options for human habitation sampling are:

13.3.1 Vacuum Bag

Materials from the air and home surfaces that may affect humans through ingestion and inhalation pathways can potentially be present within the vacuum bag of the household vacuum cleaner. The vacuum bag should be removed from the vacuum and collected as if it were a soil sample. Information on the period of use of the bag should be recorded

13.3.2 Air Container Filter

Air conditioner filters are another source of representative samples of the residential environment. Filters should be removed and placed in plastic bags for shipment to the laboratory for analysis. Information on the period of use of the filter should be recorded.

13.3.3 Dust Sweep

If significant amounts of dust can be found within the household, dust should be swept into a pile and transferred to sample containers. If only low volumes of dust exist, surface wipe samples may be an alternative.

13.3.4 Sump or Drain Sediment

Sediment that collects in drains over a period of time, or backs up into the sump is collected as a normal soil or sediment sample.

13.3.5 Lint Traps

Lint traps in clothes washers and dryers may contain sufficient material for a representative sample. It must be kept in mind, however, that such material has been subjected to heat, water, and laundry products.

14.0 SECTION 14 - PREPARING SAMPLES FOR SHIPPING

14.1 INTRODUCTION

Once a sample has been collected in the field, it must be transported to a lab for analysis. In order to ensure that the integrity of all samples is maintained throughout the transport process, it is important that specific steps are followed.

14.2 PROCEDURES FOR SAFE SHIPPING

Steps to ensure that samples are shipped safely include:

1) Properly labeling all sample bottles,

2) Sealing sample containers tightly and packing them with appropriate padding to prevent spillage or breakage,

3) Not overloading the sample container,

4) Adding Blue Ice, regular ice or an equivalent cooling media if the sample is to be kept cool. The ice should be kept in plastic bags to prevent it from melting and contaminating the samples,

5) Ensuring that the chain-of-custody for each sample is included within the shipping container and is signed and sealed within the shipping container if the container is shipped by a third party (see Figure 14.2),

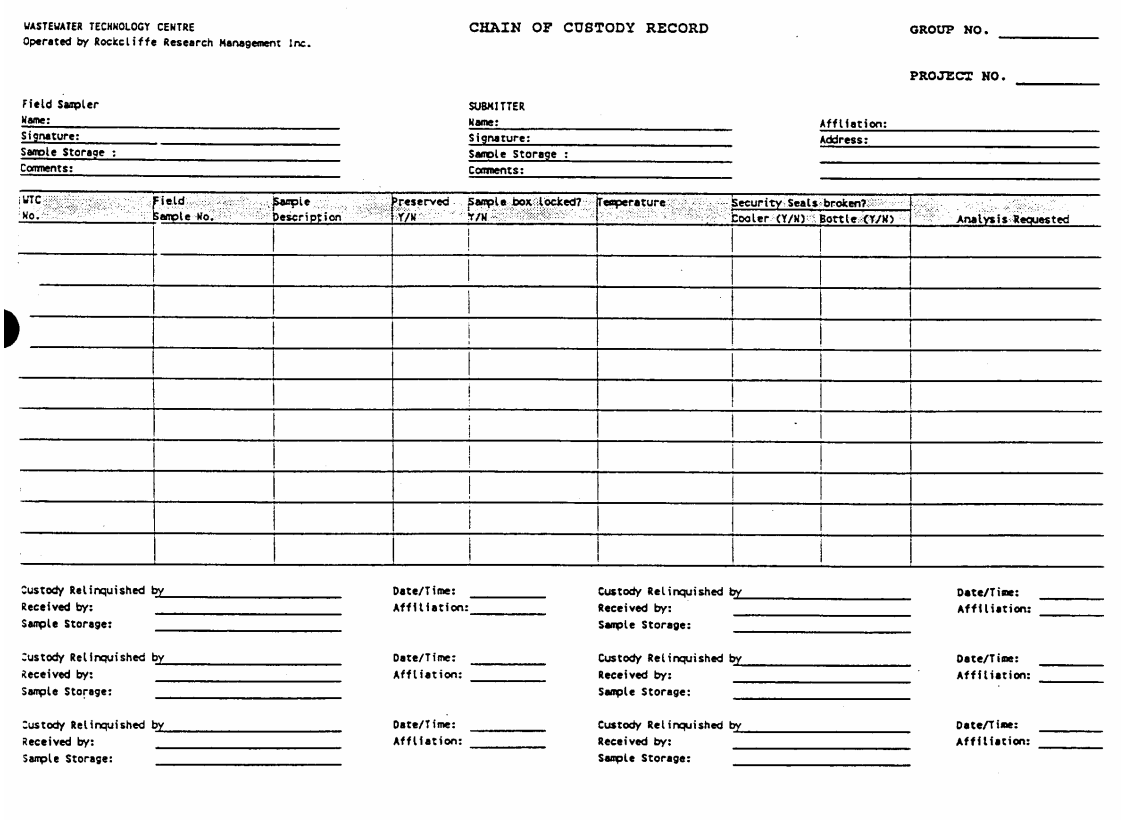
6) Labeling each container with the samples identification, destination, and special instructions such as “THIS END UP”, “FRAGILE”, “KEEP COOL”,

7) Keeping samples from one location together in one container during shipping,

8) Shipping samples in plastic coolers, aluminum boxes, wooden boxes, metal pails or fibre board boxes, and

9) Ensuring that containers have a method of sealing or locking.

Figure 14.1: Chain of Custody Record



WASTEWATER TECHNOLOGY CENTRE
Operated by Rockcliffe Research Management Inc.

CHAIN OF CUSTODY RECORD

GROUP NO. _____

PROJECT NO. _____

Field Sampler
Name:
Signature:
Sample Storage :
Comments:

SUBMITTER
Name:
Signature:
Sample Storage :
Comments:

Affiliation:
Address:

WTC No.	Field Sample No.	Sample Description	Preserved Y/N	Sample box Locked? Y/N	Temperature	Security Seals broken? Cooler (Y/N)	Bottle (Y/N)	Analysis Requested

Custody Relinquished by _____ Date/Time: _____
Received by: _____ Affiliation: _____
Sample Storage: _____

Custody Relinquished by _____ Date/Time: _____
Received by: _____ Affiliation: _____
Sample Storage: _____

Custody Relinquished by _____ Date/Time: _____
Received by: _____ Affiliation: _____
Sample Storage: _____

Custody Relinquished by _____ Date/Time: _____
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Sample Storage: _____

Custody Relinquished by _____ Date/Time: _____
Received by: _____ Affiliation: _____
Sample Storage: _____

Custody Relinquished by _____ Date/Time: _____
Received by: _____ Affiliation: _____
Sample Storage: _____

15.0 SECTION 15 - AUDITING

15.1 INTRODUCTION

Environmental auditing is a method of ensuring that the policies, objectives and responsibilities for achieving data quality goals are being followed. It involves analysis, testing, and confirmation of the procedures and practices involved in the day to day operation of a project or an organisation.

15.2 AUDITING TEAMS AND TRAINING

There are two ways that a project or organisation can be audited. One method is internal auditing whereby specialists from each unit of the organisation are trained in auditing procedures. This method is beneficial in that the skills that are acquired during training and actual auditing procedures stay within the organisation.

It is also possible to have an external audit performed by a qualified organisation or individual(s).

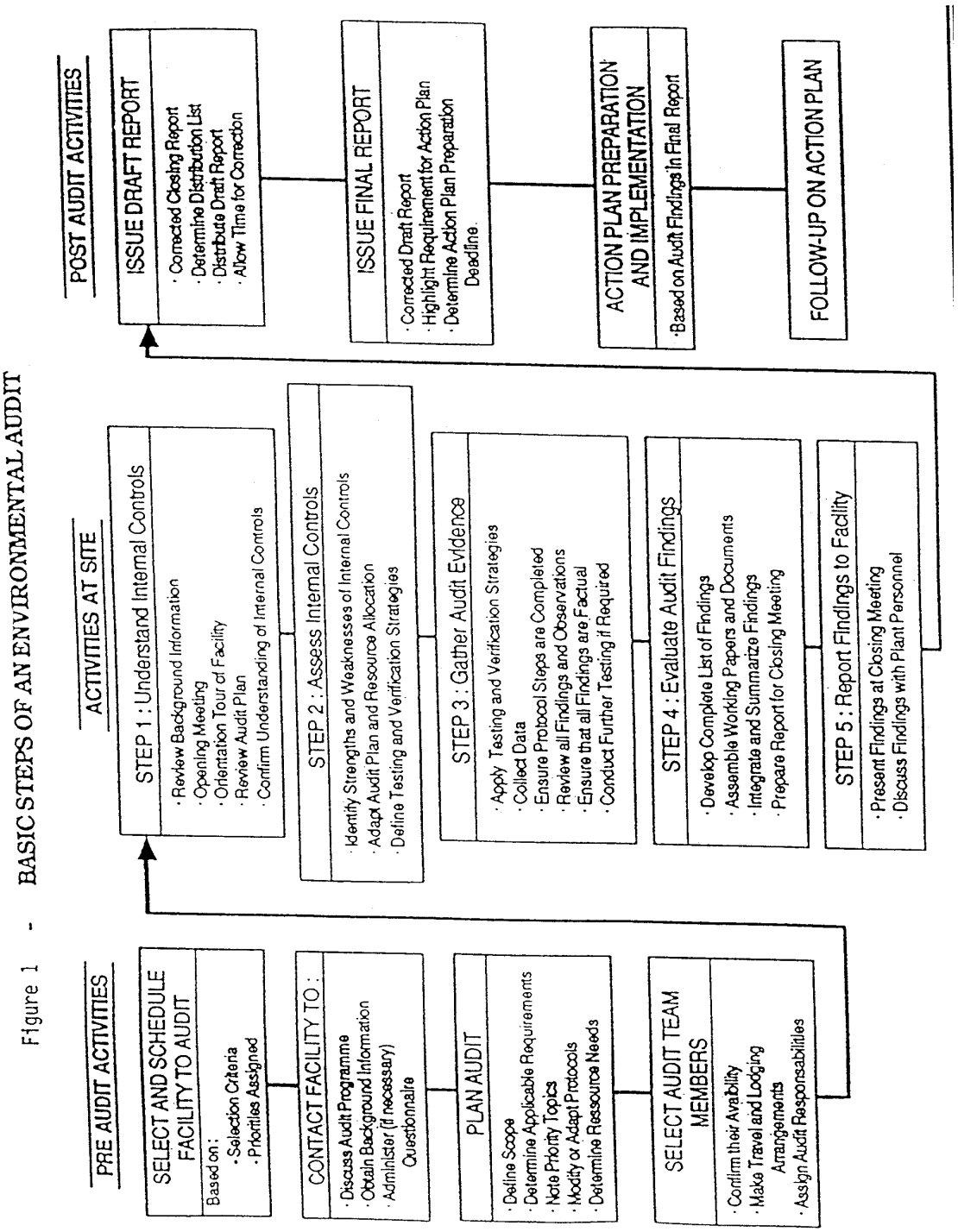
15.3 THE BASIC STEPS OF AN AUDIT

The basic steps of an audit include:

- Studying and understanding the management system of the company or organization.
- Determining the strengths and weaknesses.
- Collecting audit materials through assessment and verification.
- Evaluating the audit findings.
- Meeting with management to discuss the audit findings.
- Preparing a final audit report.
- Preparing an action plan in response to the audit findings.
- Ensuring that the action plan is carried out.

The preparation of an action plan is essential to any auditing procedure. This plan will ensure that all deficiencies discovered during the auditing process will be corrected in a cost efficient and timely manner.

Figure 15.1: The Basic Steps of An Environmental Audit



15.4 AUDIT TYPES

There are many different types of audits that can be carried out. Examples include the external environment, occupational health, industrial hygiene, emergency response, acquisition, divestiture and closure.

Table 15.1 : Different Audit Types

Audit Type	Protocols
• External environment • Safety • Industrial hygiene • Emergency response	The protocols for auditing may involve compliance with government regulations as well as company policies and guidelines.
• Acquisitions, divestitures and closures	Involves identifying the liabilities and costs involved in upgrading facilities, closing facilities or acquiring new facilities or equipment.

Environment, safety, industrial hygiene and emergency response audits are normally conducted with internal personnel. Depending on the scope of the audit and the expertise required a team of three or four auditors may be assigned to carry out a specific task. At small facilities, these audits may be conducted one at a time using personnel with expertise in each area. At larger facilities, an audit may involve one protocol and require three or more experts in that specific field.

Acquisition, divestiture and closure audits are generally performed by an unbiased external auditor.

15.5 DOCUMENTATION AND DISTRIBUTION

The final product of an audit should be a comprehensive document. This document should be distributed to the managers of the project and any relevant government agencies.

15.6 AUDIT SCHEDULING

It is very important to develop a long term auditing schedule. Acquisition, divestiture and closure audits can be scheduled as needed. Environment, occupational health, industrial hygiene,

product safety and emergency preparedness audits should be scheduled approximately every four years depending on the following factors:

- New legislation or changes to existing legislation.
- The size of the facility.
- The volumes of waste, emission, and effluent and their characteristics.
- The sensitivity of the surrounding environment.
- The proximity of public residences to the plant or activity.
- The exposure of employees to chemicals and process by-products.

Facilities which have a higher rating with regards to the above criteria may need to be audited more frequently.

APPENDIX I
EQUIPMENT CHECK LIST

EQUIPMENT CHECK LIST

1**) OAKTON Phmeter**
ð Instrument; ð Spare instrument; ð pH 4 Buffer, ðpH 7 Buffer, ðpH 10 buffer, Distilled water (quantity:_____ L), ð small cup. ð Spare Batteries: 4xGPA-76/303. ð Spare Electrode #35624-29. Small screwdriver for calibration.

2) TDSTestr1-4
ð Instrument; ð Spare instrument; ð higher Range instrument; ð low range Buffer; ð mid range Buffer; Distilled water; ð small cup. ð Spare Batteries: 4xGPA-76/303. ð Spare Electrode #356661-39. Small screwdriver for calibration.

3) ORP Test
ð Instrument; Distilled water; ð small cup. ð Spare Batteries: 4x ??.

4) Electronic Thermometer
ð Instrument; ð Spare Battery: LR-44.

5) WQ700 Turbidity Sensor
ð Instrument; ð Spare Battery: 2 x9V alkaline. (Calibration in lab only). Need to have cleaning accessories with the instrument, must be keep clean.

6) YSI Model 55 Oxygen and Temperature System
ð Instrument; ð Spare Batteries: 6xAA alkaline. ð Calibration kit (ð membrane, ð KCL solution, ðo-ring), ð Deionized Water. ALWAYS KEEP STORAGE CHAMBER SPONGE WET. Need to know: altitude of sampling site and salinity of the measured water.

7) Global Flow Probe FP101-FP201
ð Instrument; ð Spare Battery: 675. Be sure calibration is at 33.31 when in mi mode (1603 in metric).

8) GARMIN GPS 12XL
ð Instrument; ð Spare Batteries: 4xAA alkaline, 1x??? lithium. When necessary: ð External antenna, ð car power-supply cord, ð Computer connector. Always copy on paper at end of the day important coordinates.

9) OTHER FIELD INSTRUMENT:
ð Sechi disk, ð Triton turbidity wedge, ð 1.00-1.20 Hydrometer, ð Sampling tube for Hydrometer, ð Imoph Cone (2), ð Sediments benne, ð Underwater sampler, ð testing tips (Cyanida and Ammonia), ð Camera and box (waterproof), ð accessories (film, flashcard, wire, batteries, charger).

10) OTHER
ð Sampling bottles & cap, ð sampling cup & bag, ð Gloves, ð Pencils and permanent marker, ð Field books, pad and paper, ð Shipping and electric tape, ð Measuring tape, ð Rulers, ð Calculator, ð Area maps (water proof + water soluble pens) ð Compass, ð Tape Recorder, ð Rubber & field boots, ð Insect repellent (body and air), ð First aid kit including Malaria test, ð Tools, ð Emergency contact list (site, code, name, other), ð Washing accessories.

APPENDIX II

FIELD EQUIPMENT INSTRUCTION MANUALS

SEE SEPARATE DOCUMENT